COMPARATIVE LOAD RATING STUDY UNDER LRFR AND LFR METHODOLOGIES FOR ALABAMA HIGHWAY BRIDGES

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COMPARATIVE LOAD RATING STUDY UNDER LRFR AND LFR METHODOLOGIES FOR ALABAMA HIGHWAY BRIDGES

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Michael Brawner Murdock, son of Harry Mike and Judy Kay (Moore) Murdock, was born November 21, 1984, in Cornwall, England. He graduated from Apopka High School with honors in May, 2003. In September of 2003, Michael entered Auburn University where he received the Bachelor of Science in Civil Engineering in May, 2007. He married Jennifer Short on December, 16 2006, also a graduate of Auburn University. Michael entered the graduate school of Auburn University in September, 2007 to seek the Masters of Science in Civil Engineering, focusing on structural engineering.

THESIS ABSTRACT

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Currently, the Alabama Department of Transportation (ALDOT) uses the load factor rating (LFR) methodology of the *American Association of State Highway and Transportation Officials* (AASHTO) *Manual for Condition Evaluation* (MCE) *of Bridges* (1994) in load rating of highway bridges across the state. With the introduction of the new *AASHTO MCE and Load and Resistance Factor Rating* (LRFR) *of Highway Bridges* (2003), the need arose to assess the impact of implementing the new manual on ALDOT's current bridge rating practices. To this end, a comparative study was performed between ALDOT's current rating practices utilizing the older LFR methodology, according to the AASHTO MCE (1994), and the new LRFR methodology.

This comparative study was performed on a representative sample of 95 bridges from Alabama's state and county owned bridge inventory at all three primary levels of

LRFR rating: Design, Legal and Permit rating levels. The load models that were utilized in the rating analysis were the AASHTO design load models, AASHTO standard legal loads, ALDOT state legal loads, and a sample of ALDOT overweight loads. The bridges were modeled in AASHTO BridgeWare's Virtis version 5.6 (2007) and analyzed in BRASS-GIRDER LRFR and LFR analysis engines (2007). Rating results were generated for interior and exterior girders of each bridge analyzed as well as for moment and shear load effects.

The rating data at all three primary levels of rating indicated that the LRFR methodology produces lower rating factors than the LFR. It was therefore concluded that adopting the AASHTO MCE LRFR (2003) can have a significant impact on the rating practices of ALDOT.

Comparisons were additionally made between the LRFR and LFR rating data, at the Design rating level, in the context of estimated probability of failure for a bridge based on the Monte Carlo simulation technique. This comparison showed that rating factors produced under the LRFR methodology have strong correlation to a bridge's estimated probability of failure, whereas rating factors under the LFR methodology showed only sporadic correlation to a bridge's estimated probabilities of failure.

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Computer software used Microsoft Word, Microsoft Excel, Adobe Photoshop CE,

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Chapter 1 INTRODUCTION

1.1 Overview

In 1994 the American Association of State Highway and Transportation Officials (AASHTO) *Load and Resistance Factor Design* (LRFD) *Bridge Design Specifications* was introduced (Minervino et al. 2004). The AASHTO LRFD introduced a new limit state design philosophy based on structural reliability. The bridge design philosophy of the time was load factor design (LFD) or allowable stress design (ASD) as found in the AASHTO *Standard Specifications for Highway Bridges* (Sivakumar 2007). The main advantage of the LRFD over ASD and LFD is that it aims to achieve a more uniform level of reliability in bridge design among the various types of materials and systems employed (Minervino et al. 2004).

The AASHTO design specifications are intended to provide guidelines for the design of new bridges. To assist in the evaluation of existing bridges, AASHTO developed guidelines for bridge condition evaluation as well. This evaluation involves a process that is often referred to as bridge rating. The specifications for bridge rating are found in the AASHTO *Manual for Condition Evaluation*. The second edition of the AASHTO *Manual for Condition Evaluation of Bridges*, published in 1994, provides guidelines for evaluating existing bridges according to the allowable stress and load factor methodologies (Sivakumar 2007). With the introduction of the new AASHTO LRFD Bridge Design Specifications, a new methodology of evaluation and rating was needed for consistency with the new limit state design philosophy (Minervino et al. 2004). In March 1997 the National Cooperative Highway Research Program (NCHRP) Project 12-46 was initiated and resulted in a rating manual based on the load and resistance factor approach (Lichtenstein 2001). The end result of NCHRP's Project 12-46 was the AASHTO *Manual for Condition and Evaluation and Load and Resistance Factor Rating* (LRFR) *of Highway Bridges,* hereafter referred to as AASHTO MCE LRFR (Minervino et al. 2004).

Currently, the Alabama's Department of Transportation (ALDOT) uses the AASHTO MCE (1994) for bridge rating. With the introduction of the new AASHTO MCE LRFR (2003) ALDOT expressed concern over how the new bridge rating system would affect state rating practices. In order to address this concern, a comparative bridge rating study between the existing AASHTO MCE (1994) and the new AASHTO MCE LRFR (2003) was conducted on a sample of Alabama's state bridges.

1.2 Motivation

The study described in this thesis is in response to concerns expressed by ALDOT over how adopting the new AASHTO MCE LRFR (2003) would affect their current bridge rating practices in regard to legal load posting and the issuance of overweight permits. For the legal load posting, ALDOT is interested in evaluating how the number of bridges required to be posted and the degree to which they are posted would change under the new rating methodology. For the overweight permits, ALDOT is interested in evaluating how the number of bridges that overweight loads are allowed on will be affected and how the allowances for overweight permits will be affected.

1.3 Research Objectives and Scope

The research described in this thesis compares the two rating methodologies LRFR and LFR on a select sample of Alabama State and County owned and maintained bridges. The research objectives for this study can be broken into primary and secondary objectives

The primary objectives are as follows:

1. Generate and compare LRFR and LFR rating factor results at the Design Inventory level of rating
2. Generate and compare LRFR and LFR rating factor results at the Legal load level of rating for AASHTO and ALDOT legal loads and provide LRFR load postings
3. Generate and compare LRFR and LFR rating factor results at the Permit level of rating for ten ALDOT permit trucks

The secondary objectives are as follows:

1. Compare the effect of ALDOT state legal loads to the effect of AASHTO typical legal loads and design load model on the rating results
2. Compare the rating factor results of the LRFR and LFR in the context of bridge reliability, as discussed in Chapter 6

The research presented within this thesis is limited to the selected sample of Alabama State and County owned and maintained bridges described in Chapter 3. The rating factors used in all comparisons within the study were generated through the use of software and with the assumptions listed in Chapters 2 and 4.

1.4 Approach

The approach taken to accomplish the research objectives outlined above can be broken into the following briefly described tasks:

1. Review previous research comparing the LRFR and LFR methodologies.
2. Select representative bridge samples for use in the rating analysis from Alabama's State and County owned and maintained bridge inventory.
3. Develop experience modeling and rating bridges in AASHTO BridgeWare's Virtis Version 5.6.0.
4. Model the selected bridge samples in Virtis and rate bridges at the Design, Legal, and Permit levels of rating.
5. Review and analyze LRFR and LFR results at the Design, Legal, and Permit levels of rating.
6. Develop LRFR load posting based on Legal level rating results as described in the AASHTO MCE LRFR (2003).
7. Perform a reliability study on the selected bridge sample and compare to LRFR and LFR rating results at the Design Inventory level of rating.
8. Prepare final report on the research findings.

1.5 AASHTO Specifications

Several AASHTO publications are referred to in this study. The AASHTO Bridge Design Specifications used in the study are as follows:

1. AASHTO *Standard Specification for Highway Bridges 17th Edition*, 2002. This document will be referred to as AASHTO Standard Specifications 2002.
2. AASTHO *Load and Resistance Factor Design Bridge Design Specification 4th Edition*, 2007. This document will be referred to as AASHTO LRFD 2007.

The AASHTO Manuals for Condition Evaluation used in the study are as follows:

1. AASHTO Manual *for Condition Evaluation of Bridges Second Edition*, 1994, with revisions and interims through 2003. This document will be referred to as AASHTO MCE 1994.
2. AASTHO *Manual for Condition Evaluation and Load and Resistance Factor Rating of Highway Bridges*, 2003 with 2005 interim. This document will be referred to as AASHTO MCE LRFR 2003.

1.6 Thesis Organization and Presentation

The thesis is organized into seven chapters. Chapter 1 provides an introduction to the research objectives and the research approach used. Chapter 2 provides the background information on the two rating methodologies compared in the research, a listing of the different live load models used at each rating level, and a summary of the previous comparative research done. Chapter 3 details how the bridge samples used in the research were selected as well as descriptions of the bridges included in the samples. Chapter 4 presents an overview of the analysis software used in the study, a detailed rating example, and a description of the in-house tools developed to aid in the research.

Chapter 5 presents the rating results for Design, Legal, and Permit rating levels and the comparisons and trends found between the LRFR and the LFR. Chapter 6 provides an introduction to bridge reliability as well as a comparison between LRFR and LFR factors of reliability at the Design Inventory level of rating. Chapter 7 presents a summary of the research findings as well as conclusions and recommendations based on the comparative study.

Chapter 2 BACKGROUND

2.1 Overview of Bridge Rating

The purpose of bridge rating is to provide a measure of a bridge's ability to carry a given live load in terms of a simple factor, referred to as the rating factor. These bridge rating factors can be used by bridge owners to aid in decisions about the need for load posting, bridge strengthening, overweight load allowances, and bridge closures (AASHTO 2003). The way that these rating factors are calculated depends on the rating methodology used. The AASHTO MCE (1994) provides guidelines as to how to calculate rating factors based upon load factor rating and allowable stress rating methodologies (Minervino et al. 2004). The load factor rating and allowable stress rating methodologies are commonly referred to as LFR and ASR, respectively. With the introduction of the AASHTO LRFD 1994, which was based on structural reliability methods, a new rating methodology was also needed. The AASHTO MCE LRFR was developed based on the same limit state philosophies as the AASHTO LRFD (Minervino et al. 2004). The Load and Resistance Factor Rating methodology is more commonly referred to as the LRFR.

2.2 Rating Methodologies

The basic concept of the load factor rating (LFR) methodology is to analyze a structure at its ultimate load level under multiples of the actual dead and live loads. The load factors used to accomplish this are specified in the AASHTO MCE (1994) and are based on engineering judgment and not on statistical studies or probability of failure (Sivakumar 2007). The factors were developed assuming normal traffic and overload conditions. The AASHTO MCE (1994), however, does not provide any additional guidance as to how to adjust the load factors to more accurately reflect actual conditions. In essence, the load factor methodology represents a “tried and true approach” to the rating problem (Sivakumar 2007).

The load and resistance factor rating methodology, LRFR, was developed under the NCHRP project 12-46 to be a rating methodology consistent in philosophy with the AASHTO LRFD Bridge Design Specifications in its use of reliability-based limit states (Lichtenstein 2001). The goal of the design philosophy in the AASHTO LRFD was to achieve a more uniform level of reliability in bridge design. With the introduction of the AASHTO MCE LRFR (2003), the new methodology of rating provided a systematic and flexible approach to bridge rating based on reliability. The LRFR rating philosophy allows for a realistic assessment of a bridge’s actual safe load capacity as opposed to the “tried and true approach” in the LFR (Sivakumar 2007).

2.3 Rating Equations

The general load rating equations for both the LFR and LRFR are arranged in the same way to provide a ratio of the live load capacity of a member to its live load demand. As shown in Equation 2 - 1.

$$\text{Rating Factor} = \frac{\text{Capacity} - \text{Dead Load Effect}}{\text{Live Load Effect}}$$ *Equation 2 - 1*

The numerator of each equation represents the live load capacity of a member, the difference between the factored capacity and the applied factored dead load effect. The denominator of each equation consists of the factored live load model's effect. For the LFR methodology found the in the AASHTO MCE (1994) the rating factor is given as:

$$RF = \frac{C - A_1 D}{A_2 L(1+I)}$$ *Equation 2 - 2*

where,

RF = Rating factor

C = Factored Capacity

A_1 = Factor for dead loads

D = Dead load effect

A_2 = Factor for live load

L = Live load effect

I = Impact factor

For the LRFR methodology found the in the AASHTO MCE LRFR (2003) the rating factor is given as:

$$RF = \frac{C - (\lambda_{DC})(DC) - (\lambda_{DW})(DW) \pm (\lambda_P)(P)}{(\lambda_L)(LL + IM)}$$ *Equation 2 – 3*

where,

RF = Rating factor

C = Capacity, defined as $\phi_c \phi_s \phi R_n$ for the strength limit state and f_R for the service limit states

λ_{DC} = LRFD load factor for structural components and attachments

DC = Dead-load effect due to structural components and attachments

λ_{DW} = LRFD load factor wearing surface and utilities

DW = Dead-load effect due to wearing surface and utilities

λ_P = LRFD load factor for permanent loads

P = Permanent loads other than dead loads

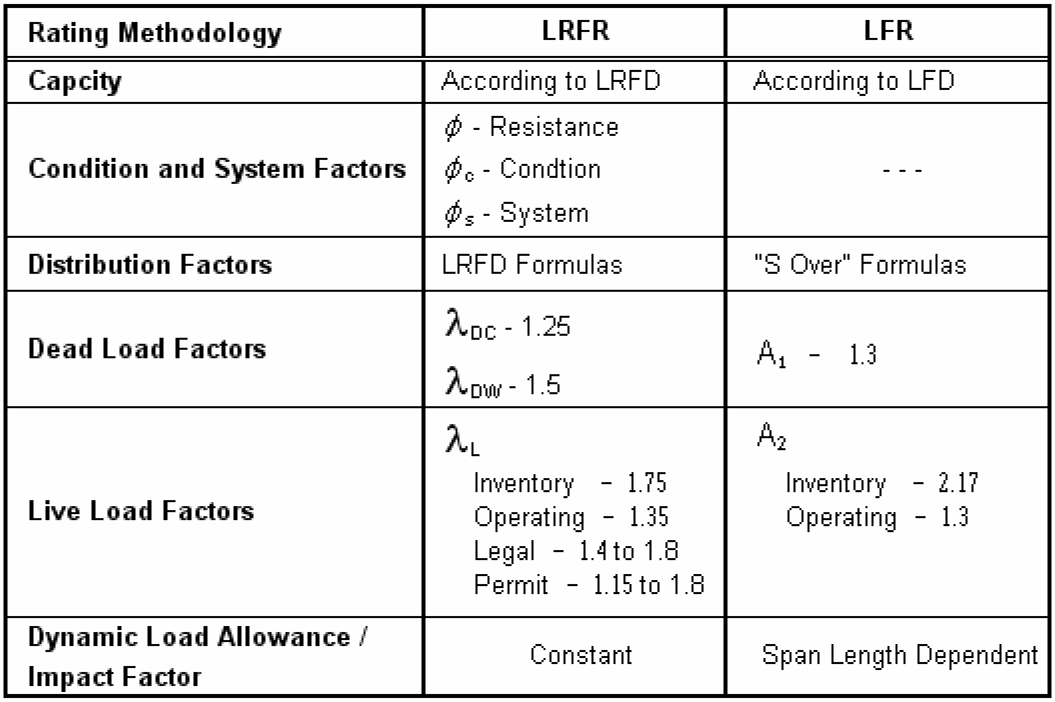
λ_L = Evaluation live-load factor

LL = Live-load effect

IM = Dynamic load allowance

While the general form of both the LRFR and LFR rating equations is the same, there are several distinct differences between the two, as summarized in Table 2 - 1. The first difference is the inclusion of two new resistance factors in the LRFR equations: the condition factor, ϕ_c, which deals with the amount of deterioration a member has experienced, and the system factor, ϕ_s, which deals with the global structural redundancy of the bridge (Lichtenstein 2001). The ± sign associated with the permanent loads in Equation 2 - 3 accounts for the favorable or unfavorable effect that permanent loads can have on the live load capacity. The resistance for both the LRFR and the LFR is calculated differently as well. The resistance for the LRFR capacity is calculated according to the LRFD Bridge Design specifications according to the AASHTO MCE LRFR (2003). The capacity for the LFR is calculated according to the Standard Specification for Highway Bridges based on the LFD principles according to the AASHTO MCE (1994).

Table 2 - 1: Differences Between the LRFR and LFR



Rating Methodology	**LRFR**	**LFR**
Capcity	According to LRFD	According to LFD
Condition and System Factors	ϕ - Resistance ϕ_c - Condtion ϕ_s - System	- - -
Distribution Factors	LRFD Formulas	"S Over" Formulas
Dead Load Factors	λ_{DC} - 1.25 λ_{DW} - 1.5	A_1 - 1.3
Live Load Factors	λ_L Inventory - 1.75 Operating - 1.35 Legal - 1.4 to 1.8 Permit - 1.15 to 1.8	A_2 Inventory - 2.17 Operating - 1.3
Dynamic Load Allowance / Impact Factor	Constant	Span Length Dependent

Another difference between the two equations is that the LRFR equation separates the dead loads into two parts: structural components / attachments and the wearing surface. This allows for unique load factors to be applied to the each of the categories based on their variable statistics (Lichtenstein 2001). Under the LFR load factor, A_1, was specified as 1.3 for all dead loads (AASHTO 1994). In the LRFR the load factor λ_{DC} is specified as 1.25 and λ_{DW} as 1.5 unless the in-place thickness of the wearing surface can be verified by field measurements. Then, the factor λ_{DW} can be reduced to 1.25 (AASHTO 2003).

The live load factors for the two methodologies are also different. The A_2 factor in the LFR is fixed at 2.17 for Inventory rating and 1.3 for Operating rating for all traffic conditions and vehicle loadings. The differences between these rating levels are discussed in a later section. The LRFR, however, uses calibrated live load factors which vary based on the vehicular loadings, bridge ADTT and rating level (Lichtenstein 2001). In addition to differing live load factors, both the LRFR and LFR use different live load distribution factors. The live load distribution factor accounts for how live load effects are passed through the deck to the supporting structural element of a bridge (Lichtenstein 2001). The LFR uses the live load distribution factors from the AASHTO Standard Specification which accounts for the distribution of the live load across the deck using a simplistic “S over” approach, S referring to girder spacing. LRFR uses the reevaluated live load distribution equations found in the AASHTO LRFD, which accounts for additional effects in transverse load distribution such as the deck stiffness. The changes made to the live load distribution equations in AASHTO LRFD result in a more complex but supposedly more accurate live load distribution factor (Lichtenstein 2001).

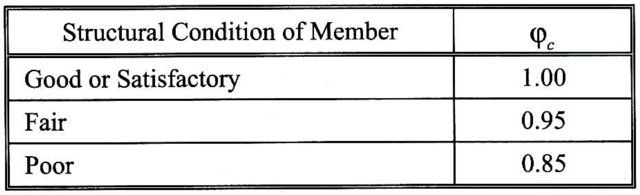
The impact factor is also calculated differently for each of the rating equations. The LFR impact factor is based on a formula where the impact factor increases with a bridge’s span length. The dynamic load allowance, or impact factor, of the LRFR is fixed at 33% for all legal loads; however, the code allows for the factor to be lowered based upon riding surface conditions (Lichtenstein 2001).

2.4 LRFR Condition and System Factors

The resistance factor, ϕ, as defined in the AASHTO LRFD 2007, is usually a reduction factor applied to the nominal resistance of a new member to account for the uncertainties associated with its resistance. As an existing member experiences deterioration, the uncertainties associated with its resistance increase and can no longer be accounted for solely through the use of the design resistance factor. The condition factor, ϕ_c, was introduced to provide an additional estimated reduction to a member's resistance to account for the added uncertainties caused by the deterioration a member has experienced and that it is likely to experience between inspections (Minervino et al. 2004).

The recommended values for the condition factor found in Table 2 - 2, are from the AASHTO MCE LRFR (2003), and are related to the Superstructure Condition Rating number found in the bridge's inspection report. While the condition factor is related to the structural condition of a member, it only accounts for deterioration from natural causes, such as corrosion, and not from incident-oriented damage.

Table 2 - 2: Recommended Condition Factor Values According to AASHTO MCE LRFR (2003)

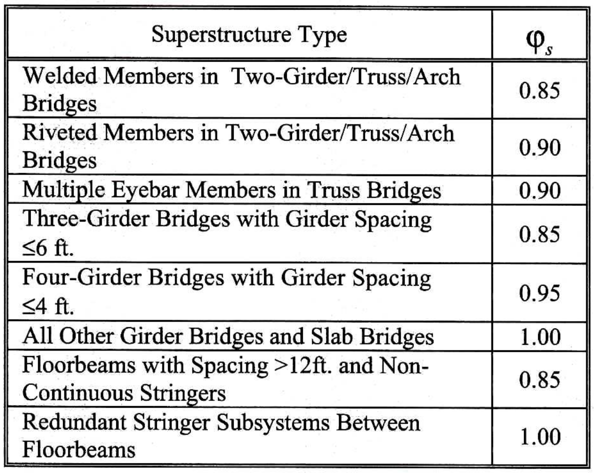


Structural Condition of Member	φ_c
Good or Satisfactory	1.00
Fair	0.95
Poor	0.85

The superstructure of a bridge is composed of multiple structural members interacting with one another to form a single structural system. A bridge's redundancy is the capacity of the structural system to carry loads after one or more of its structural members has been damaged or has failed. The purpose of the system factor, ϕ_s, is to be a multiplier applied to the nominal resistance of a member to account for the redundancy of the full superstructure system. As a result, bridges that are less redundant have a lower system factor, which lowers each individual member's factored capacities and ratings (Minervino et al. 2004).

The recommended values for the system factor according to the AASHTO MCE LRFR (2003) are shown Table 2 - 3. The recommended system factor values are based on a bridge's superstructure type as described in the AASHTO MCE LRFR (2003). The system factor ranges from 1.00 for redundant systems, such as bridges with more than four girders, to 0.85 for non-redundant systems, such as truss bridges, arch bridges, or bridges with two girders or less. If the presence of adequate redundancy can be demonstrated, the system factor can be different from those presented and can exceed 1.0, but is limited to a maximum value of 1.2 according to NCHRP Report 406 (1998). The simplified system factors can only be used when checking the flexural and axial effects under the strength limit states. When checking shear under the strength limit states, a system factor of 1.0 is recommended for all superstructure types according to the AASHTO MCE LRFR (2003).

Table 2 - 3: Recommend System Factor Values According to AASHTO MCE LRFR (2003)



Superstructure Type	φ_s
Welded Members in Two-Girder/Truss/Arch Bridges	0.85
Riveted Members in Two-Girder/Truss/Arch Bridges	0.90
Multiple Eyebar Members in Truss Bridges	0.90
Three-Girder Bridges with Girder Spacing ≤6 ft.	0.85
Four-Girder Bridges with Girder Spacing ≤4 ft.	0.95
All Other Girder Bridges and Slab Bridges	1.00
Floorbeams with Spacing >12ft. and Non-Continuous Stringers	0.85
Redundant Stringer Subsystems Between Floorbeams	1.00

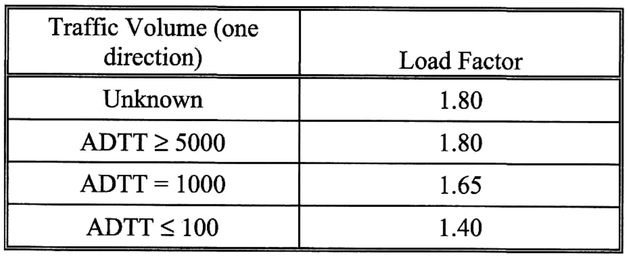
The minimum value of the combined effect of the condition and system factors on an individual member's capacity shall not be made less than 0.85 according to the general load rating procedure provided in the AASHTO MCE LRFR (2003).

2.5 Live Load Factors

The live load factors are unique for each of the two rating methodologies. LFR has fixed factors of 2.17 for Inventory rating and 1.3 for Operating rating (AASHTO 1994), whereas LRFR uses varying calibrated live load factors. The LRFR factors vary not only with rating level, but also with vehicle type and bridge ADTT (Lichtenstein 2001). For design level rating in the LRFR the live load factor, λ_L, is specified as 1.75 for Inventory rating and 1.35 for Operating rating (AASHTO 2003). Live load factors for Legal loads vary based upon a bridge's ADTT, ranging from 1.4 to 1.8 (AASHTO 2003).

Table 2 - 3 from the AASHTO MCE LRFR (2003) shows the specified values for λ_L based on a bridge’s ADTT.

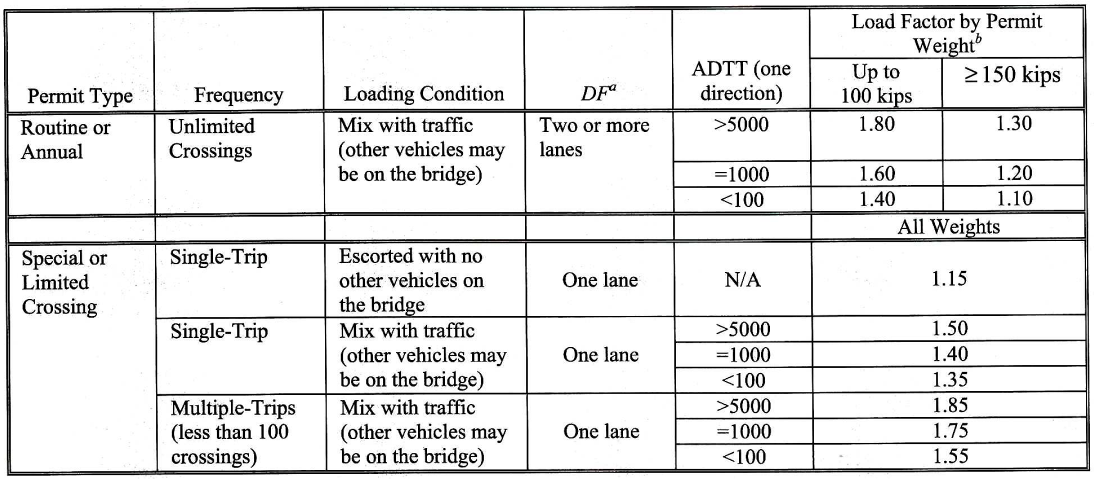
Table 2 - 4: Live Load Factors as a Function of ADTT (AASHTO 2003)



Traffic Volume (one direction)	Load Factor
Unknown	1.80
ADTT ≥ 5000	1.80
ADTT = 1000	1.65
ADTT ≤ 100	1.40

Permit loadings have a λ_L that is based upon several variables, the permit type, number of trips, whether the permit truck is allowed to be mixed with traffic, ADTT of the bridge, and total weight of the permit truck. Table 2 - 4 from the AASHTO MCE LRFR (2003) summarizes these variables and shows the corresponding λ_L for a given permit truck’s situation; this factor can range from 1.15 to 1.85 (AASHTO 2003).

Table 2 - 5: Live Load Factors for Permit Loads Based on Bridge's ADTT (AASHTO 2003)



Permit Type	Frequency	Loading Condition	DF^a	ADTT (one direction)	Load Factor by Permit Weight^b	
					Up to 100 kips	≥ 150 kips
Routine or Annual	Unlimited Crossings	Mix with traffic (other vehicles may be on the bridge)	Two or more lanes	>5000	1.80	1.30
				=1000	1.60	1.20
				<100	1.40	1.10
					All Weights	
Special or Limited Crossing	Single-Trip	Escorted with no other vehicles on the bridge	One lane	N/A	1.15	
	Single-Trip	Mix with traffic (other vehicles may be on the bridge)	One lane	>5000	1.50	
				=1000	1.40	
				<100	1.35	
	Multiple-Trips (less than 100 crossings)	Mix with traffic (other vehicles may be on the bridge)	One lane	>5000	1.85	
				=1000	1.75	
				<100	1.55	

2.6 Load Combinations

The AASHTO Standard Specifications 2002 and the AASHTO LRFD 2007 both specify a series of load combinations that new bridge designs must satisfy. The different load combinations for each specification allow for a structure to be designed for a degree of different loading conditions.

The AASHTO Standard Specifications 2002 specifies load combinations in two main groups: service load combinations and load factor design combinations. Each load combination in the two groups has different loads and load factors that are evaluated against the design capacity of a member. For evaluating existing bridges according to the AASHTO MCE (1994) under the LFR methodology, the terms service load combinations and load factor design combinations are not used. Instead, two load combinations are specified. The first corresponds to the LFR Inventory level of rating, and the second corresponds to the Operating level of rating. Both Inventory and Operating levels of rating are discussed in greater detail in the following Section 2.7. The load factors associated with these load combinations are based on a “tried and true approach” and are not calibrated (Sivakumar 2007).

The AASHTO LRFD (2007) specifies load combinations in four different categories: strength, service, fatigue, and extreme event. Each of the load combinations under the LRFD methodology are calibrated specifically for the loading condition and limit state under evaluation (Minervino et al. 2004). Strength load combinations relate to limit states associated with the strength of a member. Service load combinations relate to operational effects a structure will experience. The fatigue load combinations relate to the effect of repetitive live loads. The extreme event load combinations relate to structural response under extreme loading conditions such as an earthquake loading (AASHTO 2007). The load combinations that are utilized in the LRFR rating methodology are taken from the AASHTO LRFD (2007). However, the LRFR load combinations are limited to the strength, service and fatigue categories, according to the AASHTO MCE LRFR (2003). Within this comparative study all of the LRFR rating analysis is performed using the Strength I load combination at the Design and Legal levels of rating and using the Strength II load combination at the Permit level of rating. These levels of rating are discussed in greater detail in Section 2.7. The Strength I load combination is defined as the “[basic] load combination relating to the normal vehicular use of a bridge without wind” according to the AASHTO LRFD (2007). The Strength II load combination is defined as the “[load] combination relating to the use of the bridge by Owner-Specified special design vehicles, evaluation of permit vehicles, or both without wind" according to the AASHTO LRFD (2007).

2.7 Rating Levels

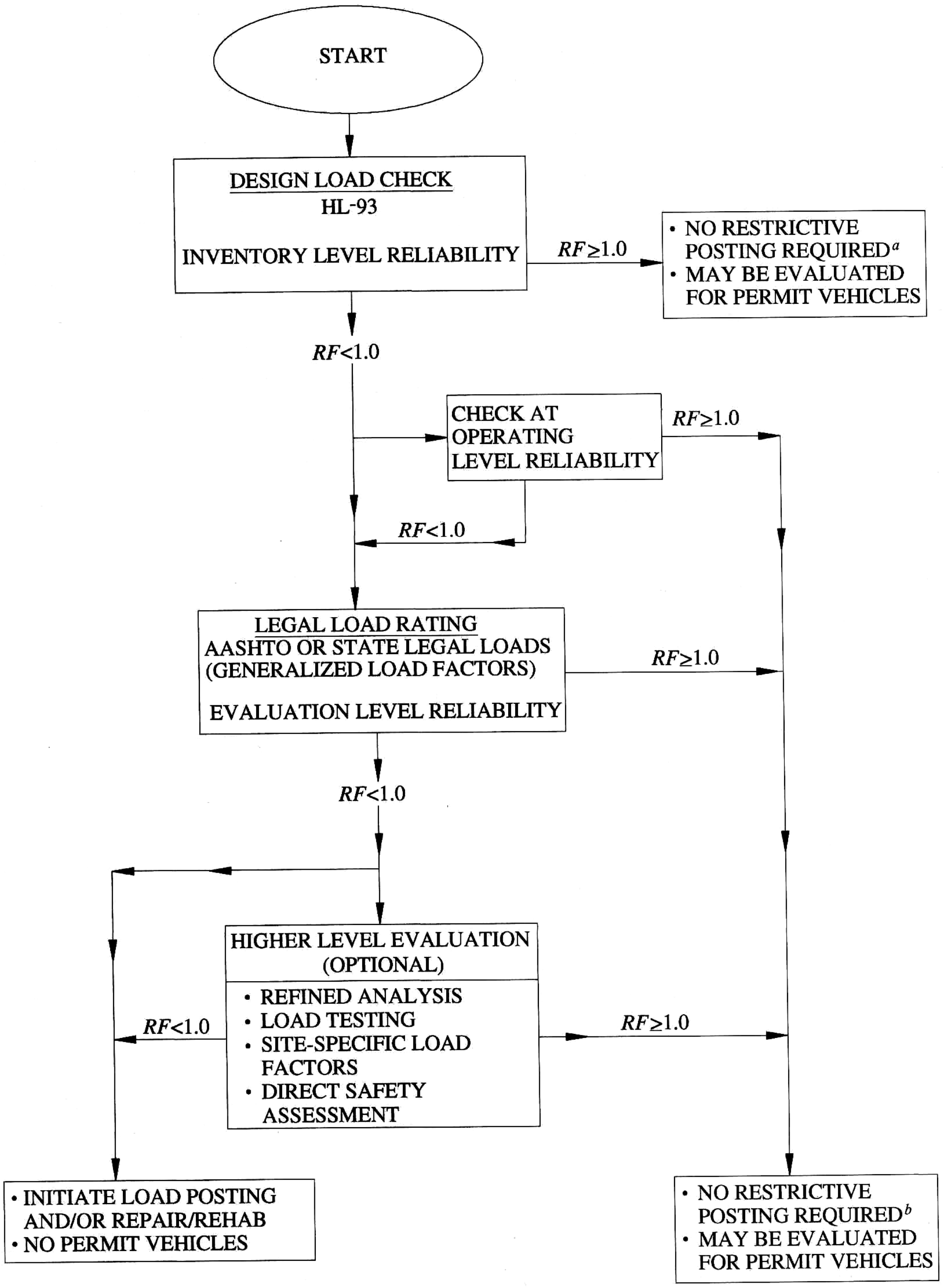
The rating systems for both the LFR and LRFR are broken down into a series of levels that bridges can be evaluated under, each level corresponding to a different level of safety. The LFR has a simple two-level system, where LRFR has a more complex three-level system.

The two levels of the LFR's rating system are the Inventory and Operating levels. The Inventory level of rating is the highest level of safety corresponding to "a live load which can safely utilize an existing structure for an indefinite period of time", according to the AASHTO MCE (1994). Rating results under the HS-20 design truck at this level are used in reporting to the Federal Highway Administration (FHWA) for the National Bridge Inventory, NBI (Lichtenstein 2001). The operating rating level is a secondary lower level of safety corresponding to "the maximum permissible live load to which the structure may be subjected", according to the AASHTO MCE (1994). The results from the Operating level of rating can be used for determinations of load postings, bridge strengthening, and possible closure (AASHTO 1994). Permitting is recommended to only be allowed on bridges that are found to be satisfactory at the operating level of rating under the HS-20 load model (AASHTO 1994).

The three levels that make up the LRFR rating system are the design, legal and permit load rating levels. Each of these three levels of rating are discussed in detail in immediately following sections. The procedure that the LRFR uses in its rating system is shown in the flow chart in Figure 2 – 1 as given in the AASHTO MCE LRFR (2003). The process starts with a bridge first being rated at the design Inventory level under HL-93 load model. If the bridge is found to be satisfactory at this level of rating, it's considered not to require posting for "AASHTO legal loads and state legal loads within the LRFD exclusion limits", according to the AASHTO MCE LRFR (2003), and hence the bridge can be evaluated directly for permit load vehicles.

However if the rating factor at the Design Inventory level is found to be less than 1.0, the bridge must be evaluated under either the Design Operating level or the Legal load level. At these levels of rating if the bridge is found to be satisfactory it is considered not to require posting for "AASHTO legal loads and state legal loads having only minor variations form the AASHTO legal loads", according to the AASHTO MCE LRFR (2003), and the bridge can be evaluated for permit load vehicles. If, however, the bridge is found to be not satisfactory, load posting will be required for legal loads and no permit analysis is allowed. There is however the option for higher forms of evaluation, such as load testing of the bridge or the use of finite element modeling, for when a bridge is found to be unsatisfactory at the Legal load level and the engineer feels the bridge may not require posting.

LOAD AND RESISTANCE FACTOR RATING FLOW CHART



a– For AASHTO legal loads and state legal loads within the LRFD exclusion limits.

b– For AASHTO legal loads and state legal loads having only minor variations from the AASHTO legal loads.

Figure 2 – 1: Load and Resistance Factor Rating Flow Chart From the AASHTO MCE LRFR (2003)

2.7.1 LRFR Design Load Rating

The design load rating is the first level of the LRFR rating system that a bridge undergoes. The design level of rating is intended to measure the performance of an existing bridge relative to the LRFD Bridge Design Specifications. The load model used for this rating level is HL-93 live load model, discussed in Section 2.9.1. Design load analysis can be done at one of two sublevels either the Inventory level, checking design level reliability, or the Operating level, checking a second lower level of reliability (Minervino et al. 2004). The LRFR shares the limit state philosophy of its design counterpart, the LRFD. The design level of rating analysis is primarily checked at the strength limit state (Lichtenstein 2001). The main difference between the two sublevels of the design level rating is a difference in the λ_L factor. The Inventory level uses a λ_L factor of 1.75 calibrated that a passing bridge at this level would correspond to reliability index of 3.5 or greater (Minervino et al. 2004). A reliability index of 3.5 represents a probability of failure of two hundred and thirty three in one million. The Operating level uses a λ_L factor of 1.35, which was calibrated to a reliability index of 2.5 (Minervino et al. 2004). A reliability index of 2.5 corresponds to a probability of failure of six thousand two hundred and ten in one million. The results of an Inventory level of rating under the HL-93 load model are used in the reporting to the NBI (Lichtenstein 2001).

2.7.2 LRFR Legal Load Rating

The second level of rating in the LRFR is legal load rating. At this rating level, live load factors are selected based upon bridge ADTT values and are used in conjunction with AASHTO and state Legal Loads. The legal load's λ_L factors are "calibrated by reliability methods to provide a uniform [level of safety] over varying traffic exposure conditions," according to Lichtenstein Engineers (2001). Rating results at this level can be used for the purpose of load posting and making decisions on potential bridge strengthening needs or closures. The strength limit state is the primary limit state used for evaluation at this level (Lichtenstein 2001).

2.7.3 LRFR Permit Load Rating

The third level of bridge rating in the LRFR system is the permit load rating for overweight vehicles. This level of rating is only available to bridges that have at least the capacity to carry AASHTO or state legal loads. Strength and service limit states are typically used in evaluations at this rating level.

2.8 Posting

When a bridge is found to be unsatisfactory under Legal loads load posting may be required, which restricts the weight of legal loads for the bridge. Posting procedures differ between the LFR and LRFR methodologies. Under the LFR, bridge owners are given a wide range of freedom as to how posting is performed. The AASHTO MCE (1994) recommends that the general procedures outlined for rating in Section 6 of the code should be followed for determination of need for load posting (AASHTO 1994). The AASHTO MCE (1994) provides three typical legal loads: type 3, type 3-3 and type 3S2. These models can be used for posting considerations in addition to state legal loads.

However, the determination of the exact posting loads and procedure to obtain these loads is left up to the Bridge owner's own posting practices.

The LRFR methodology provides a more structured format for load posting than the LFR, however it also allows Bridge Owners to use their own posting polices. The LRFR makes an important distinction between bridge inspections and rating, which are considered "engineering-related activities" and bridge posting, which is a "policy decision made by the Bridge Owner" according to the AASHTO MCE LRFR (2003). The recommended posting procedure outlined in the LRFR calls for bridges to be rated at the legal load level under the legal load truck in question. If the rating factor from the analysis is greater than one, the bridge does not need to be posted for the given truck. If the rating factor is between 0.3 and 1.0, the AASHTO MCE LRFR (2003) recommends the following safe posting load based on the rating factor:

$$\text{Safe Posting Load} = \frac{W}{0.7}[(RF) - 0.3] \qquad \textit{Equation 2 - 5}$$

Where,

W = Weight of rating vehicle

RF = Legal load rating factor

If the rating factor from the legal load analysis is below 0.3, the AASHTO MCE LRFR (2003) recommends that the legal truck used in the analysis not be allowed to cross the bridge. When the rating factors for all three of the AASHTO standard legal loads is below 0.3, the bridge should be considered for closure (AASHTO 2003).

2.9 Live Load Models

The live load models used during rating analysis, for both the LFR or LRFR methodologies, come from two main sources: the AASHTO, and from individual bridge rating agencies. The AASHTO MCE (1994) and the AASHTO MCE LRFR (2003) specify live load models in two categories, design load models and legal load models. The design load model for the LFR is composed of the HS20 load model and a design lane load AASHTO MCE (1994). The AASHTO MCE LRFR (2003) for the LRFR specifies the LRFD’s design load model the HL-93. Each of these design load models is discussed in greater detail in Section 2.1.5.1. Both AASHTO MCE (1994) and the AASHTO MCE LRFR (2003), for the LFR and the LRFR respectively, specify the same three legal load models the Type 3, Type 3-3, Type 3S2, discussed in greater detail in Section 2.1.5.2. Additionally under both rating methodologies individual bridge rating agencies can specify their own alternative live load models that can be used in their own rating practices. The live load models used in this study are those specified in the AASHTO MCE (1994) and the AASHTO MCE LRFR (2003) and those used in ALDOT’s own rating practices. A detailed breakdown of each live load model used in the study is given below. The models are divided into their corresponding rating levels according to the LRFR methodology.

2.9.1 Design

The LFR analysis at the Design Inventory rating level uses the maximum load effect from either the HS20 load model or the lane load as defined in the AASHTO

Standard Specification (2002) according to the AASHTO MCE (1994). The HS20 load model consists of three axles weighing 8 kips, 32 kips and 32 kips spaced at 14 feet and 14 to 30 feet respectively. The variable spacing of the last axle is used to maximize the desired load effect (AASHTO 1994). The lane load according to the AASHTO Standard Specification (2002) is the combination of a uniform load of 640 lb per linear foot and a moving concentrated load of 18,000 lbs for investigation of moment load effects and 26,000 lbs for shear load effects.

The LRFR methodology at the Design Inventory rating level uses the HL-93 live load model as defined in the AASHTO LRFD Specification according to the AASHTO MCE LRFR (2003). The HL-93 load model is composed of three parts: the design truck, the design tandem, and the design lane load. The design truck resembles that of the HS20 load model with three axles weighing 8 kips, 32 kips and 32 kips spaced at 14 feet and 14 to 30 feet, respectively. The variable spacing of the last axle is once again used to maximize the desired load effect. The design tandem is composed of two concentrated loads of 25 kips spaced at 4 feet. The design lane load is composed of a uniform load of 640 pounds per foot. The live load effect used in rating analysis is the combined maximum effect of the design lane load with either the design truck or design tandem. An additional live load model can be considered for negative moment regions in continuous bridges consisting of the design lane load and two design trucks, with fixed axle spacings of 14 ft, spaced at no closer than 50 feet to each other (AASHTO 2003).

2.9.2 Legal

The LRFR Legal rating level is not explicity defined for the LFR methodology, although its counter part would be the Operating level of rating. The AASHTO MCE (1994) does not specify any required load models to be used at the Operating level of rating. However the AASHTO MCE (1994) does suggest three typical legal load models to consider: the Type 3, Type 3-3, and the Type 3S2. Figure 2 - 2, below, provides a depiction of each of these three load models showing their axle weights and configurations. The LFR methodology, under the AASHTO MCE (1994), additionally allows agencies to specify their own unique load models for use at the operating level of rating for posting, strengthening, and closure decisions. The LRFR methodology, under the AASHTO MCE LRFR (2003), also allows for agencies to specify their own unique load models at the legal load level of rating as well as specifying the same three AASHTO standard legal loads found in the AASHTO MCE (1994). The three AASHTO standard legal load models provide a baseline for legal load rating and posting decisions and are intended to envelope unique state legal loads that have only minor variations in axle and weight configurations (Moses 2001).

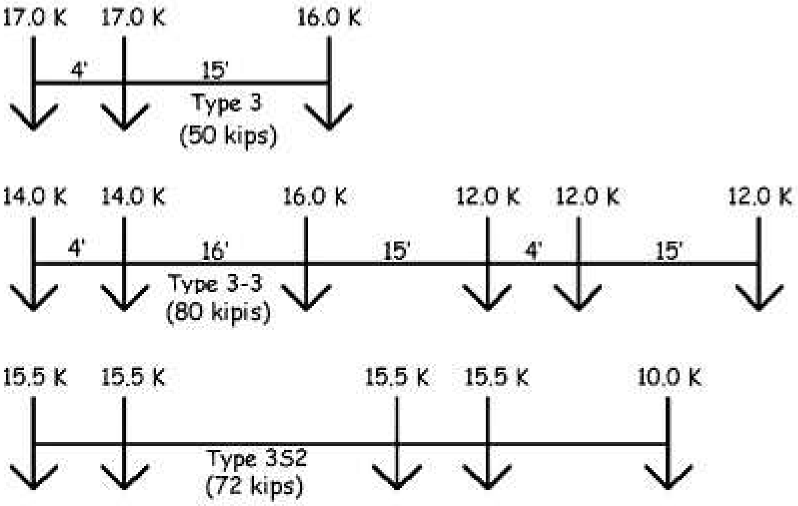


Figure 2 - 2: AASHTO Legal Load Models (AASHTO 1994)

In addition to the three AASHTO standard legal loads ALDOT provided eight legal load models currently being used in their rating practices to be considered at this level of the study. Currently ALDOT bases its posting decisions on rating results from these eight legal load models. This selection of load models consists of the H20, HS20, two axle tuck, three axle dump truck, concrete truck, 18 wheeler (3S2 Alabama), 6 axle truck (3S3 Alabama), and school bus. A depiction of each load model showing its unique axle configuration and weight is shown in Figure 2 – 3.

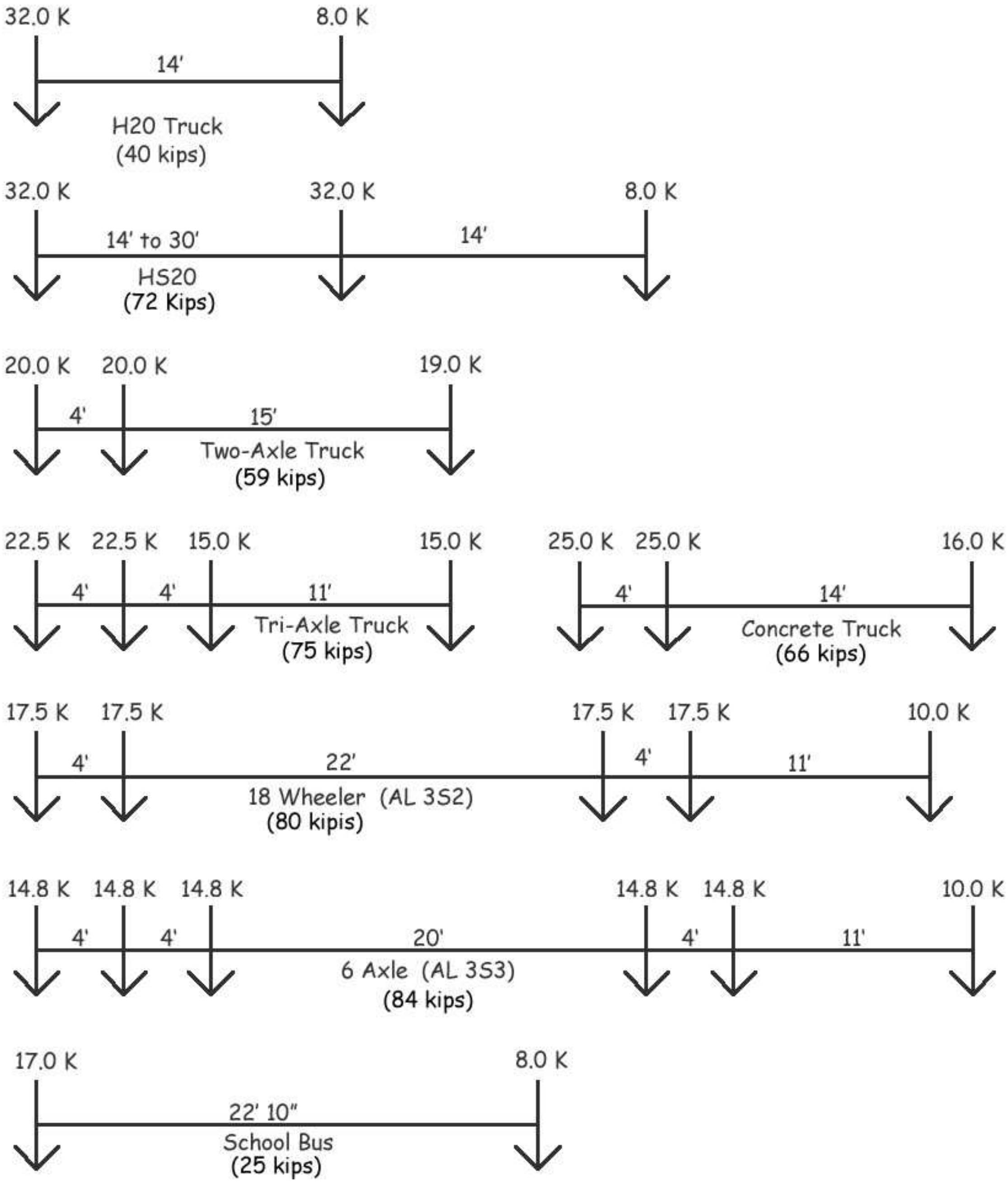


Figure 2 - 3: ALDOT Legal Load Models

2.9.3 Permit

The AASHTO MCE (1994) and the AASHTO MCE LRFR (2003), for the LFR and the LRFR respectively, do not specify any overload permit evaluation load models.

This is due to permit load models consisting of overweight loads that tend to be unique to individual rating agencies according to the AASHTO MCE LRFR (2003). ALDOT provided ten unique overweight load models for uses in the permit rating portion of the study. These load models were selected by ALDOT to be a representative sample of their current overload model inventory. A depiction of each load model's axle weight and configuration is shown below in Figure 2 - 4 and Figure 2 - 5.

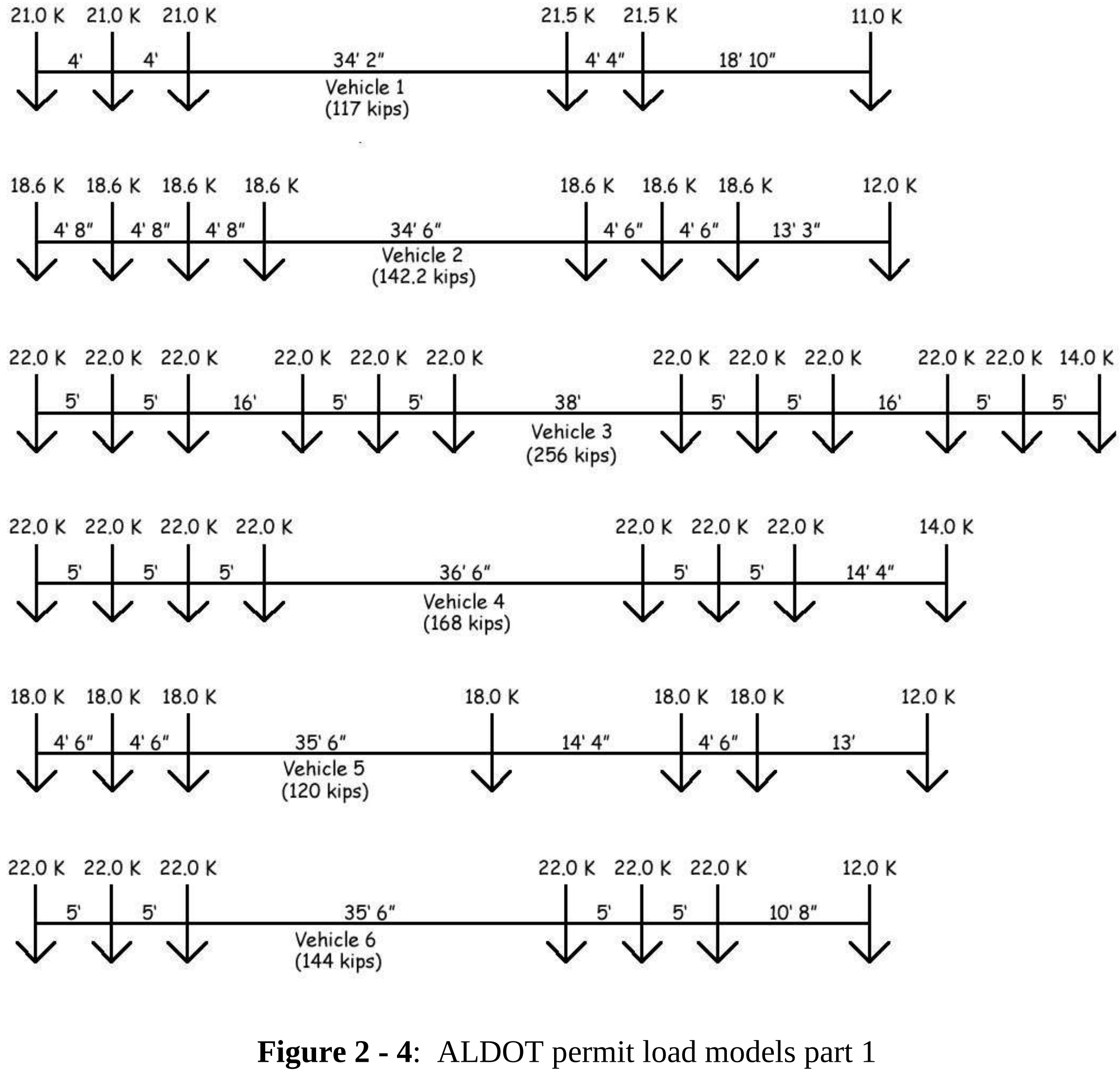


Figure 2 - 4: ALDOT permit load models part 1

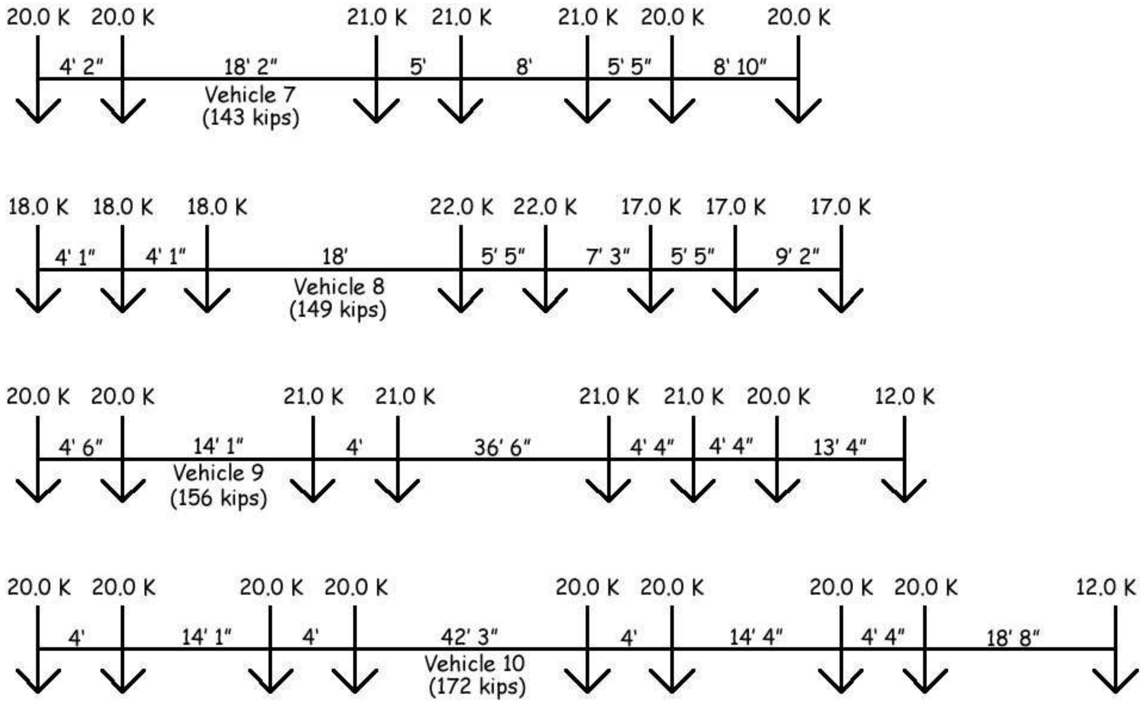


Figure 2 - 5: ALDOT permit load models part 2

2.10 Previous Research

With the introduction of the LRFR a significant amount of research has been conducted with regards to its implementation. Keeping within the scope of this project, only research comparing the LRFR and the LFR is reviewed within this section. The comparative research published to date is limited to three studies. The first comparative study was conducted by Lichtenstein Consulting Engineers as reported in their final NCHRP project C12-46 report, which introduced the new LRFR philosophy and the AASHTO MCE LRFR (Lichtenstein 2001). This research is discussed in detail in Section 2.10.1. The second comparative study was performed by Mertz in his final report on NCHRP project 20-07 Task 122 (Mertz 2005). This research is discussed in detail in Section 2.10.2. The third comparative study, which is more limited in scope than the previous two, was conducted by Rogers and Jáuregui (Rogers and Jáuregui 2005). This research is discussed in detail in Section 2.10.3. In all three comparative studies only the Strength I limit state for Design and Legal levels and Strength II limit state for rating at the Permit level were considered for the LRFR methodology.

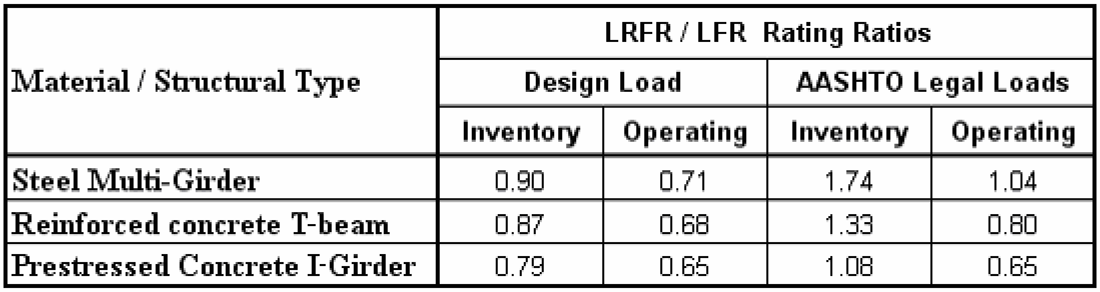
2.10.1 Lichtenstein Consulting Engineers (2001)

The comparative work done by Lichtenstein Consulting Engineers in their project C12-46 report was performed on 37 bridges rated at both the Design and Legal ratings levels. The LRFR analysis was preformed according to the Final Draft Manual of the AASHTO MCE LRFR in March of 2000. The LFR analysis was performed according to the AASHTO MCE (1994). The 37 bridge sample used for the study consisted of 17 Steel multi-girder bridges, 9 reinforced concrete T-beam bridges, and 11 prestressed concrete I-girder bridges. The bridges used in the study were provided by nine different states, including one bridge from Alabama. Each bridge was analyzed at the Design, Inventory and Operating levels of rating under the HL-93 and HS-20 load models for the LRFR and LFR, respectively. A subset of the bridge sample was additionally analyzed under AASHTO Legal loads at the Inventory and Operating level of rating for the LRFR and the LFR (Lichtenstein 2001). The entirety of the rating analysis was performed on interior girders of a bridge with only the flexure data reported and compared. Shear analysis data, although mentioned in the report, was not reported or directly compared. Analysis of exterior girders was not performed for either flexure or shear.

During the comparative study, the following assumptions and factors were used. All LRFR analysis was performed at the Strength I limit state. The system factor, ϕ_s, and condition factor, ϕ_c, for the LRFR were allowed to vary in accordance to the AASHTO MCE LRFR (2003) per bridge. The live load factors used at the Design Inventory level of rating were 1.75 for the LRFR and 2.17 for the LFR. The live load factors used at the Design Operating level of rating were 1.35 for the LRFR and 1.67 for the LFR.

Table 2 - 6 summarizes the rating results of the study. The values displayed here are the mean LRFR to LFR ratios for each type of bridge evaluated for each rating level investigated. If the displayed rating ratio is greater then 1.0 than on average LRFR produced higher rating factors than LFR, and if the ratio is less than 1.0 than LRFR produced lower rating factors than LFR.

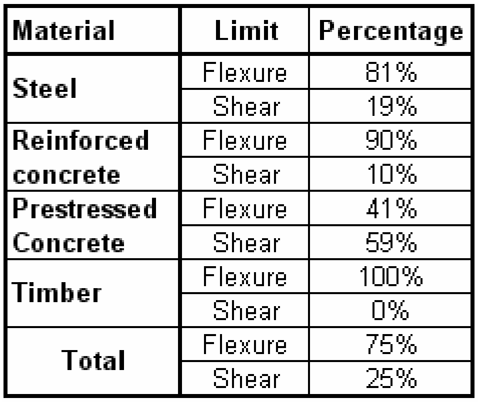
Table 2 - 6: Rating Ratio Results From Lichtenstein Consulting Engineers (2001)



Material / Structural Type	LRFR / LFR Rating Ratios			
	Design Load		AASHTO Legal Loads	
	Inventory	Operating	Inventory	Operating
Steel Multi-Girder	0.90	0.71	1.74	1.04
Reinforced concrete T-beam	0.87	0.68	1.33	0.80
Prestressed Concrete I-Girder	0.79	0.65	1.08	0.65

As can be seen from Table 2 – 6, the LRFR produced lower rating results than the LFR under the design load model at both the Inventory and Operating levels of rating, for all bridge types evaluated. Under AASHTO legal loads, however, this trend did not always hold true. At the Inventory level of rating the LRFR produced larger rating factors than the LFR. However, legal loads rating results at the Inventory level have little meaning under the LRFR or the LFR. The operating level though, is the critical level of rating for legal loads as results here are used by agencies for: posting decisions, availability of the bridge to be evaluated for overweight loads, and decisions on bridge closure. At the Operating level of rating, under the AASHTO legal loads, it was observed that the LRFR produced nearly equal or lower rating results.

Table 2 - 7: Controlling Load Effect Data From Lichtenstein Consulting Engineers (2001)



Material	Limit	Percentage
Steel	Flexure	81%
	Shear	19%
Reinforced concrete	Flexure	90%
	Shear	10%
Prestressed Concrete	Flexure	41%
	Shear	59%
Timber	Flexure	100%
	Shear	0%
Total	Flexure	75%
	Shear	25%

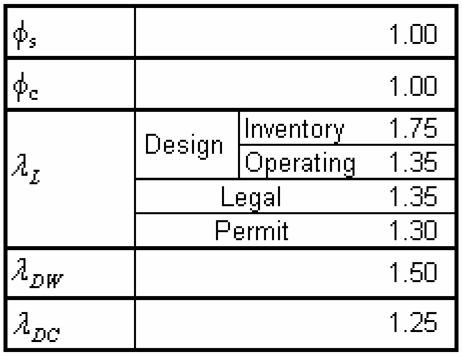
In addition to the rating factor comparisons reported by Lichtenstein Consulting Engineers, observations were made about the controlling load effect for the LRFR. The reported observations were made under the HL93 load model at the Design Inventory level of rating. Table 2 - 7 provides a summary of this controlling load effect data. Primarily, it was observed that the majority of the bridges in the sample, 75%, were controlled by flexure. No comparisons to the controlling load effect for the LFR were reported however.

2.10.2 Mertz (2005)

In June 2005 Mertz's report on the findings from his NCHRP Project 20-07 Task 122 were released. The goal of Task 122 was to conduct a comparative study between the LRFR and LFR bridge rating methodologies. The comparative study by Mertz consisted of 74 different bridges. The bridge sample was composed of reinforced concrete, prestressed concrete, and steel bridges. Each of the bridges used in the study was provided by either the New York Department of Transportation or Wyoming Department of Transportation. Bridges were modeled and analyzed in using AASHTO Bridgeware's Virtis Version 5.1 with analysis engines BRASS-GIRDER^{TM} (version 5, release 08, level 6) and BRASS-GIRDER(LRFD)^{TM} (Version 1, release 5, level 4, beta version). For more information about AASHTO Bridgeware's Virtis and analysis engines BRASS-GIRDER^{TM} see Chapter 4.

The assumptions used in the Task 122 comparative study are summarized in Table 2 - 8. Virtis Version 5.1 uses these summarized values by default. Using these default factors can have a profound impact on the study. One example of this can be seen in the use of 1.35 as the live load factor for legal load rating (Mertz 2005). The AASHTO MCE LRFR (2003) specifies that the minimal value that the live load factor for legal loads should be taken as is 1.4 and can range as high as 1.8 for bridges exposed to large volumes of truck traffic (AASHTO 2003). Therefore, use of a 1.35 factor in the study resulted in higher LRFR rating factors for legal loads than can even be allowed under the current code previsions. Additionally using the default values for system factor, ϕ_s, and condition factor, ϕ_c, results in the highest possible factored resistance under the AASHTO MCE LRFR (2003); see Section 2.1.2.1 and Section 2.1.2.2 for more details.

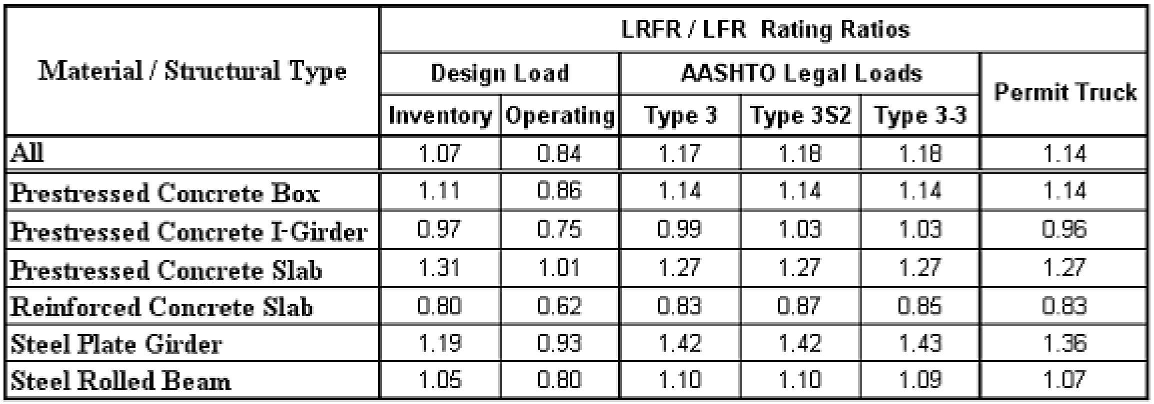
Table 2 - 8: Virtis 5.1 Default LRFR Factors (Mertz 2005)



ϕ_s			1.00
ϕ_c			1.00
λ_I	Design	Inventory	1.75
		Operating	1.35
	Legal		1.35
	Permit		1.30
λ_{DW}			1.50
λ_{DC}			1.25

Similar to Lichtenstein Consulting Engineers comparative study, the rating analysis for Task 122 was performed on interior girders and only for flexure. The entire 74 bridge sample was analyzed at each of the LRFR rating levels and their corresponding LFR counterparts. For the Design Inventory and Operating rating levels the HL93 live load model was used for LRFR and the HS20 for LFR. At the Legal load rating level, the three AASHTO standard legal load models were used for both the LRFR and LFR analysis. For the permit portion of this study a single overload model was used consisting of 8 axles with a combined weight of 175 kips.

Table 2 - 9: Rating Ratio Results Rrom Dennis Mertz (2005)



Material / Structural Type	LRFR / LFR Rating Ratios					
	Design Load		AASHTO Legal Loads			Permit Truck
	Inventory	Operating	Type 3	Type 3S2	Type 3-3	
All	1.07	0.84	1.17	1.18	1.18	1.14
Prestressed Concrete Box	1.11	0.86	1.14	1.14	1.14	1.14
Prestressed Concrete I-Girder	0.97	0.75	0.99	1.03	1.03	0.96
Prestressed Concrete Slab	1.31	1.01	1.27	1.27	1.27	1.27
Reinforced Concrete Slab	0.80	0.62	0.83	0.87	0.85	0.83
Steel Plate Girder	1.19	0.93	1.42	1.42	1.43	1.36
Steel Rolled Beam	1.05	0.80	1.10	1.10	1.09	1.07

A summary of the rating results from Mertz's Task 122 report is given in Table 2 - 9. The data presented as the mean LRFR to LFR ratio for each material and structural bridge type for the different rating levels analyzed. As can be seen from Table 2 - 9, LRFR to LFR ratios in Mertz's report tend to be larger than those presented by Lichtenstein Consulting Engineers. At the Design Inventory level the LRFR tended to produce nearly equal or higher rating factors than the LFR, with the one material and structural bridge type exception, reinforced concrete slab. Additionally, unlike Lichtenstein Consulting Engineers finding, at the Legal rating level the LRFR produced nearly equal or higher rating factors then the LFR. Important to keep in mind while reviewing the results from Task 122 are the assumptions used during its rating analysis which can produce higher LRFR rating factors then would be specified by the AASHTO MCE LRFR. This would tend to bias the LRFR to LFR ratio to be slightly higher than they truly would be.

In addition to LRFR to LFR rating factor comparative study found in the Task 122 report, Mertz also reported the results from a reliability study. This reliability study shows the relationship between the LRFR and LFR rating factors and a bridge's estimated probability of failure. More information about reliability studies in regards to bridge rating and Mertz's reliability study will be discussed in Chapter 6.

2.10.3 Rogers and Jáuregui (2005)

The third comparative study by Rogers and Jáuregui (2005) had a limited scope of only comparing the LRFR to the LFR for five simply supported prestressed concrete I-girder bridges. The five bridges included in the study were provided by the New Mexico Department of Transportation and were selected to provide a range of span lengths from 38 to 107 feet. Analysis of the bridges was performed only for the interior girders of the bridges for both flexure and shear. The bridges were evaluated using both a BRASS rating analysis software and hand calculations. The hand calculations were done to insure the accuracy of the BRASS rating analysis software. The rating analysis for the comparative study was performed using the BRASS software, after it was verified, at the Design Inventory and Operating rating levels. The live load models used in the analysis were the HL-93 load model for the LRFR and the HS-20 load model for the LFR.

The results of the rating analysis revealed that the LRFR produced nearly equal to or lower rating factors when compared to the LFR at the Design Inventory rating level for both flexure and shear. Additionally, at the Design Operating rating level, the LRFR produced significantly lower rating factors than the LFR for flexure and nearly equal to or lower rating factors for shear. However when comparing the load effects it was discovered that the majority of the bridges in the study were controlled by shear load effects. The flexural rating results were found to be in agreement with those presented by

Lichtenstein Consulting Engineers (2001) and are similar to those presented by Mertz (2005). Direct comparison for the shear rating results cannot be made due to the limitations of Lichtenstein Consulting Engineers (2001) and Mertz (2005) studies. To farther understand the source of the disagreement of the LRFR and LFR rating results, Rogers and Jáuregui studied the individual parameters that make up each the rating factor, ie the resistance, dead load and live load components. Through this study, Rogers and Jáuregui found that for prestressed concrete I-girders:

- The critical dead load flexural and shear effects of the LRFR and the LFR showed little disagreement
- The critical flexural resistance of the LRFR and the LFR showed little disagreement
- The critical shear resistance of the LRFR and the LFR showed varying degrees of disagreement due to differences in design philosophy
- The critical live load flexural effect was shown to be nearly equally or higher for the LRFR compared to the LFR
- The critical live load shear effect was shown to be greater for the LRFR compared to the LFR

Chapter 3 BRIDGE SAMPLE

3.1 Determining Bridge Sample

The bridge samples used in the study can be broken into three categories: the standard, unique, and permit bridge samples. The goal in the development of these samples was to insure that they would be representative of the Alabama's state and county owned and maintained bridge inventory. To achieve this two things are required, first an understanding of the Alabama's state and county owned and maintained bridge inventory and second what limitations would be set on the development of each of the bridge samples. To assist with the first requirement, in the understanding of Alabama's bridge inventory, ALDOT provided two main tools. The first was a set of standard bridge plans that are commonly used and appear repeatedly in Alabama's bridge inventory. The second tool provided by ALDOT was a copy of Alabama's state and county owned and maintained bridge database, referred to as the SCOMB database from here on. The combination of these two tools provided an understanding of the ALDOT bridge composition. The second requirement, in development of the bridge samples, was to determine what limitations would be used for the bridge samples. The primary source of these limitations were dictated by the limitations of the principle modeling and rating software used for the study, AASHTO BRIDGEWare's Virtis version 5.6. Virtis version 5.6 was used in this study and is discussed in detail in Chapter 4. A secondary source of limitations came from ALDOTs own modeling and rating practices using Virtis.

Based on the modeling and rating limitations of Virtis version 5.6 and ALDOT's own practices using Virtis, a number of useable bridge type categories were identified and used in selecting the bridge samples. There are two main bridge type categories: the material type and structural system type of the bridge. These two categories are defined based on their usage in the SCOMB database. The material type of a bridge denotes, the material type of the principle structural element of a bridge and the end support conditions of a bridge. An example of a material type in this context would be a reinforced concrete simply supported bridge. The structural system type of a bridge denotes the principle structural element of a bridge. An example of a structural system type in this context would be a T-Beam. Six material types and five structural system types were selected to be included in the bridge sample selection criteria.

The six material types included are as follows, and are defined in accordance with ALDOT's SCOMB database:

- Reinforced Concrete, Simply Supported
- Reinforced Concrete, Continuously Supported
- Steel, Simply Supported
- Steel, Continuously Supported
- Prestressed Concrete, Simply Supported
- Prestressed Concrete, Continuously Supported

The five structural system types included are as follows, and are defined in accordance with ALDOT's SCOMB database; also see Figure 3-1:

- Slab
- Stringer / Multi Beam or Girder

- T-Beam
- Box-Beam
- C-Channel

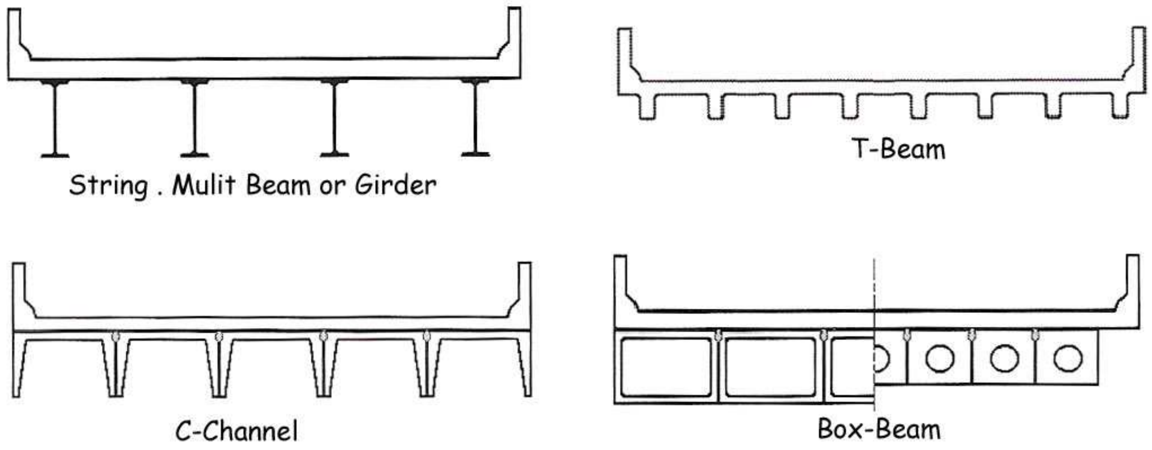


Figure 3 - 1: Structural System Types

Virtis version 5.6 can be used to model all of the material and structural system types listed above straightforwardly with one exception, the structural system type C-Channel. Currently this structural system type is not directly supported in Virtis version 5.6. However ALDOT uses a modeling simplification, which allows the inclusion of this structural system type and has requested this practice to be used within this study.

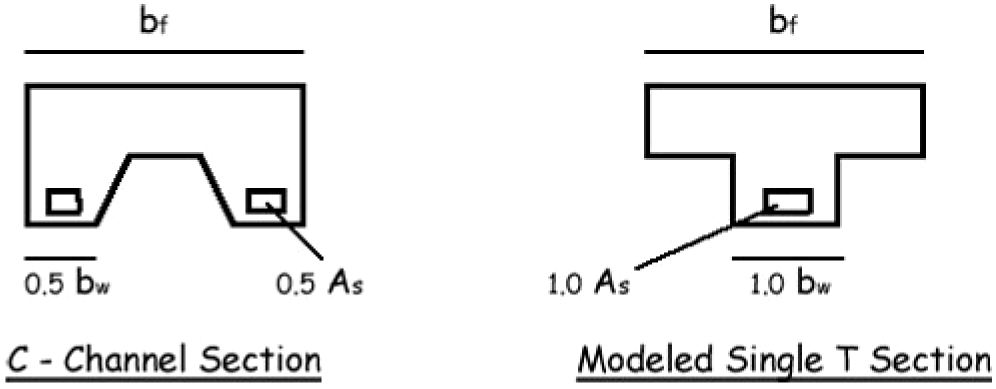


Figure 3 - 2: Virtis C - Channel Cross Section Conversion to T - Section

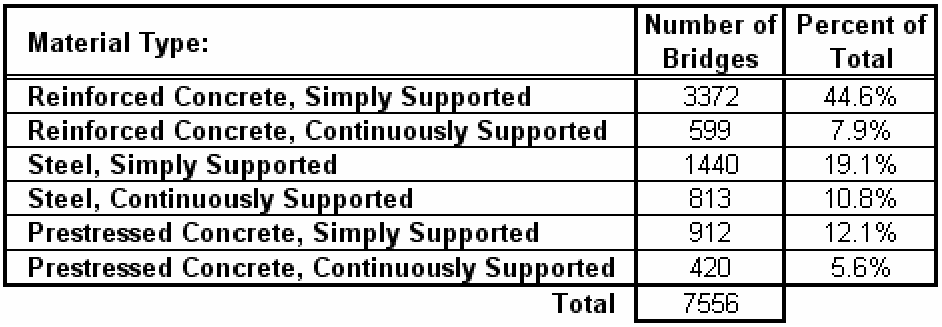
The modeling simplification developed by ALDOT is depicted in the above Figure 3 - 2. Here the two outside webs of the C-Channel cross-section are moved together to form a single web, resulting in a more traditional T-Beam cross-section. Therefore, using this cross-section transformation, C-Channel bridges can be modeled in Virtis version 5.6 as T-Beam bridges. The implications of modeling a C-Channel bridge as a T-Beam bridge were not studied in this research.

With the tools previously described, the standard bridge plans and the SCOMB database, and the usable material and structural system types listed above, the bridge samples were selected. The three bridge samples that were created are: the standard, unique and permit bridge samples. The standard bridge sample is composed of bridges from standard bridge plans, which are repeatedly used in the Alabama's bridge inventory. These standard bridges could have multiple Bridge Identification Numbers, BIN, associated with each standard bridge. A BIN is a unique number given to identify a single existing bridge. Standard bridges, therefore, could have multiple BIN numbers associated with each. The unique bridge sample is composed of bridges that have a single BIN associated with each of them. The permit bridge sample is composed of a mixture of the standard and unique bridge samples based on selection criteria discussed in Section 3.1.3 and Chapter 5.

The standard bridge sample was selected by ALDOT. The sample was composed of the standard bridge plans that ALDOT desired to include in the comparative study. In total the standard bridge sample has 50 standard bridges, which are discussed in greater detail in Section 3.1.2.

The unique bridge sample was selected to be representative of the SCOMB database. The SCOMB database provided a great deal of information about each of the bridges found in Alabama's bridge inventory. The following information for each bridge is included: BIN, material type, structural system type, location, total length, maximum single span length and whether or not a standard drawing was incorporated the bridge's design. The SCOMB database originally contained 15839 bridges however not all the bridges listed meet the previously described selection criteria for the study. Limiting the database to the selected material and structural system types reduces the database to 7556 bridges. Before the sample of bridges was selected the SCOMB database was evaluated with regards to the selected material and structural system types and span length. The breakdown of the material types within the reduced SCOMB database can be found in Table 3 - 1 below. A breakdown of the structural system types and span length ranges for each of the six material types is shown in Tables A - 1 through A - 6, in Appendix A. These distributions are important as they quantify how the SCOMB database is composed and provide a guideline as to how a reflective sample should be composed.

Table 3 - 1: Material Type Distribution of the Reduced SCOMB Database



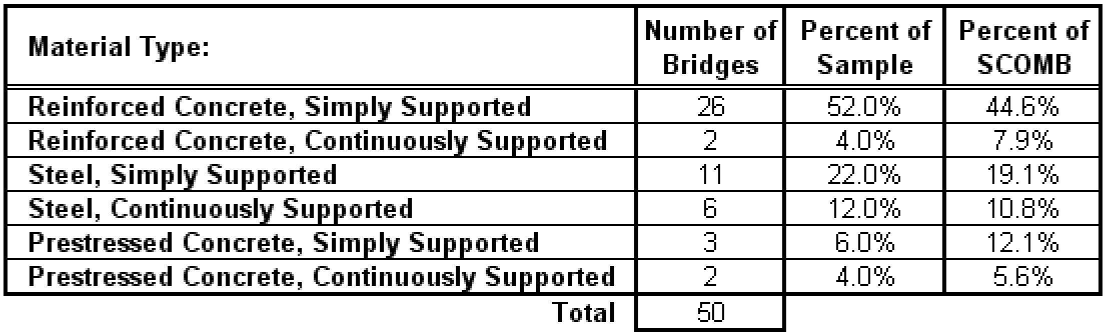
Material Type:	Number of Bridges	Percent of Total
Reinforced Concrete, Simply Supported	3372	44.6%
Reinforced Concrete, Continuously Supported	599	7.9%
Steel, Simply Supported	1440	19.1%
Steel, Continuously Supported	813	10.8%
Prestressed Concrete, Simply Supported	912	12.1%
Prestressed Concrete, Continuously Supported	420	5.6%
Total	7556	

Using the material and structural system type distributions of the SCOMB database, a matrix was formed detailing what bridge categories should be included in the unique bridge sample with regards to material, structural system type and span length. The matrix consists of 78 bridge categories covering the full range of usable bridge types found within the reduced SCOMB database. A copy of this bridge matrix can be seen in Appendix A, Tables A - 7 and A - 8. Initially, the plan was for the unique bridge sample to have at least one bridge from each of the bridge categories listed to insure that the full range of bridge categories would be represented. Then, as time permitted, additional bridges could be added to different bridge categories. However, due to difficulties in locating bridge plans, mislabeled bridges within the SCOMB database and time restrictions, the final unique bridge sample contained only 46 unique bridges spanning 31 bridge categories. A detailed breakdown of the bridges included in the unique bridge sample is provided in Section 3.1.2.

3.1.1 Standard Bridge Sample

The standard bridge sample was extracted from bridge plans that were provided by ALDOT and are used repeatedly throughout the SCOMB database. The sample is composed of 50 standard bridges, from 20 different plans. The material breakdown of the standard bridge sample is presented in Table 3 - 2 and is compared with the material distribution of the SCOMB database. As can be seen the material distribution found in the SCOMB database is well represented in the standard bridge sample. A detailed description of each bridge including its structural system type as well as span length can be found in Appendix A, Table A - 9.

Table 3 - 2: Material Type Distribution of Standard Bridge Sample

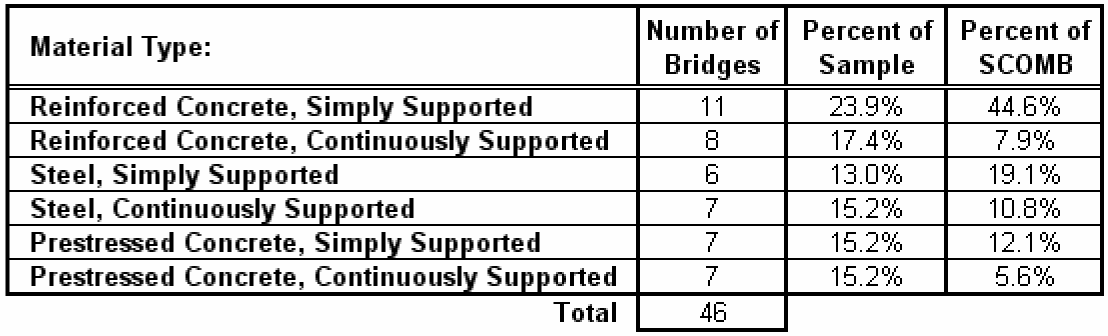


Material Type:	Number of Bridges	Percent of Sample	Percent of SCOMB
Reinforced Concrete, Simply Supported	26	52.0%	44.6%
Reinforced Concrete, Continuously Supported	2	4.0%	7.9%
Steel, Simply Supported	11	22.0%	19.1%
Steel, Continuously Supported	6	12.0%	10.8%
Prestressed Concrete, Simply Supported	3	6.0%	12.1%
Prestressed Concrete, Continuously Supported	2	4.0%	5.6%
Total	50		

3.1.2 Unique Bridge Sample

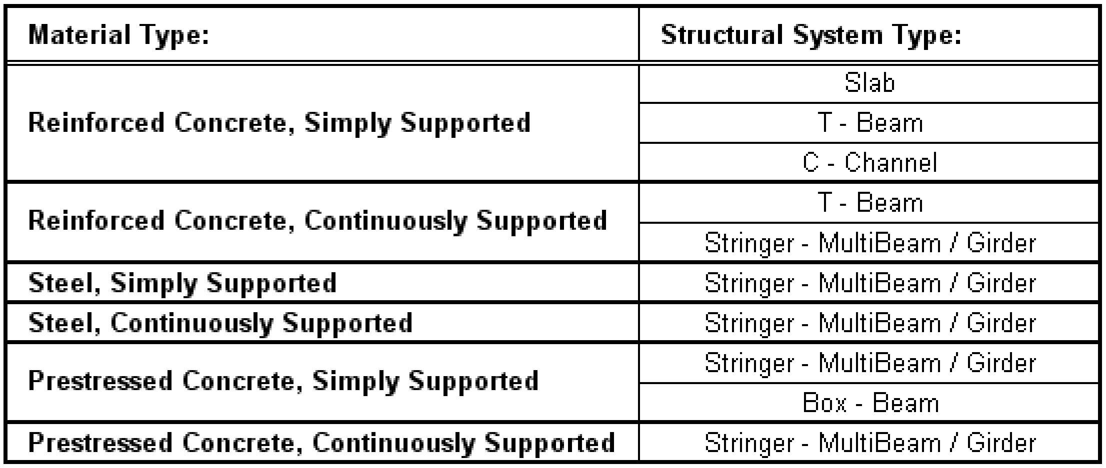
The goal of the unique bridge sample was to reflect the SCOMB database in regards to material type, structural system type, and span length. The sample consists of 46 unique bridges spanning 31 different bridge categories. The material type distribution of the sample is shown in Table 3 – 3. Table 3 - 4 displays which structural system types are found within each material type. While the material type percentages of the unique bridge sample do not directly reflect that of the SCOMB database the goal of the sample was to capture as many of the unique bridge categories found within the database as possible. A matrix showing the material type, structural system type, and span length breakdown of the sample is shown in Table A – 10 of Appendix A.

Table 3 - 3: Material Type Distribution of Unique Bridge Sample



Material Type:	Number of Bridges	Percent of Sample	Percent of SCOMB
Reinforced Concrete, Simply Supported	11	23.9%	44.6%
Reinforced Concrete, Continuously Supported	8	17.4%	7.9%
Steel, Simply Supported	6	13.0%	19.1%
Steel, Continuously Supported	7	15.2%	10.8%
Prestressed Concrete, Simply Supported	7	15.2%	12.1%
Prestressed Concrete, Continuously Supported	7	15.2%	5.6%
Total	46		

Table 3 - 4: Structural System Type Breakdown for each Material Type



Material Type:	Structural System Type:
Reinforced Concrete, Simply Supported	Slab
	T - Beam
	C - Channel
Reinforced Concrete, Continuously Supported	T - Beam
	Stringer - MultiBeam / Girder
Steel, Simply Supported	Stringer - MultiBeam / Girder
Steel, Continuously Supported	Stringer - MultiBeam / Girder
Prestressed Concrete, Simply Supported	Stringer - MultiBeam / Girder
	Box - Beam
Prestressed Concrete, Continuously Supported	Stringer - MultiBeam / Girder

3.1.3 Permit Bridge Sample

The permit bridge sample is composed of bridges form both the standard and unique bridge samples. The bridges that were included within the sample were those that are eligible for overweight load evaluation under either the LFR or LRFR methodologies. A detailed description of bridges comprising this sample is provided in Section 5.4 of Chapter 5.

3.2 Bridge Sample Information

Information about each of the bridges in both the standard and unique bridge samples is provided in Appendix A, Tables A - 11 through A - 14. These tables provide the following additional information for each bridge:

- BIN (bridge identification number)
- Year (fiscal year reported on bridge plans)
- ADTT (average daily truck traffic as reported by ALDOT)
- Live Load Factor, λ_L (based on bridge ADTT)
- Bridge Span Lengths
- Number of Spans
- Girder Spacing
- Condition Factor, ϕ_c, and System Factor, ϕ_s
- Material Type
- Structural System Type
- Deck Concrete Compressive Strength, f_c'
- Girder Concrete Compressive Strength, f_c' / Structural Steel Grade
- Reinforcement Grade
- Prestressing Tendon Grade

In the few cases where the provided plans for a bridge did not specifically report a required material property, the following assumptions were used. For unknown f_c' on bridges constructed prior to 1954, 2.5 ksi was assumed. For bridges constructed post

1954 f_c' was assumed to be 3 ksi. For unknown structural steel grade on bridges constructed between 1936 and 1963, yield strength of 33 ksi was assumed. Bridges constructed after 1963, 36 ksi was assumed. For an unknown steel reinforcement grade, Grade 40 was assumed. These assumptions were provided by ALDOT based on their current bridge rating practices.

Chapter 4 ANALYSIS TOOLS

4.1 Analysis Software

Several computer programs were used for the analysis and rating in the project. AASHTO BridgeWare's Virtis Bridge Load Rating software version 5.6 (2007) was the primary analysis and rating tool for both LRFR and LFR methodologies. Additionally, in-house rating tools were developed in Mathcad version 14 (2007) for several simply supported bridge cases to develop a working understanding of the new LRFR methodology. Two additional programs were developed in Visual Basic to aid in data collection and organization of the Virtis output files.

4.1.1 Virtis

Virtis is a bridge analysis and rating computer program (BridgeWare 2007). The program is composed of two major components: the graphical user interface (GUI) used to model a bridge, and the analysis engines. The modeling of a bridge is done through the use of several input screens where needed pieces of information about each component of the bridge is required, including member dimensions, material properties, member locations, weight, etc. Once a bridge is fully modeled, it can be analyzed under several different rating methodologies and under a variety of different live load models (BridgeWare 2007).

While the actual modeling of a bridge is done within Virtis, the analysis is preformed by a separate analysis engine. During a rating exercise Virtis allows the user to specify what rating methodology to be used as well as what engine to use for the analysis (BridgeWare 2007). In this study version 5.6.0 of Virtis, released in November of 2007, was used. This was the first version to include an analysis engine capable of rating under the LRFR methodology. Version 5.6.0 of Virtis is capable of rating in three methodologies: ASR, LFR and LRFR. To perform the analysis according to these different rating methodologies, six analysis engines are available; BRASS ASD, BRASS LFD, BRASS LRFR, Mandero ASD, Virtis ASD, Virtis, LFD. For this study the BRASS LFD engine was used for the LFR analysis and the BRASS LRFR engine was used for the LRFR analysis. The BRASS LFD engine is based on the AASHTO MCE 1994 with interims up 2003 and the AASHTO Standard Specifications of Highway Bridges 17th edition 2002. The BRASS LRFR Engine is based on the AASHTO MCE LRFR (2003) with the 2005 interim and the AASHTO LRFD (2007) Bridge Design Specification (BridgeWare 2007).

Each of the analysis engines that Virtis uses operates in a similar fashion. First, an influence line analysis is conducted to determine the maximum effect for a given live load model. The influence line approach by default subdivides each span into 100 increments and moves the specified live load model across the span one increment at a time to determine the maximum effect. Next, the analysis engine subdivides each span into 10 equal increments and analyzes the eleven cross section created. For each of the cross-section the dead load, the maximum live load effect, and resistance are determined at that specific location. Rating factors for both moment and shear are then produced at each cross section for the live load model (BridgeWare 2007). The assumption Virtis makes is that the maximum shear and moment effect will occur at one of its eleven predetermined analysis points. This is however not always the case. Additionally, different shear provisions allow for the shear at supports to be taken at a specified distance from the support in reinforced and prestressed concrete members, AASHTO LRFD (2007) Section 5.8.3.2. These provisions when applied would reduce the shear effect at the supports. The BRASS LRFR analysis engine however does not use these provisions by default, and as such all shear rating analysis done at the support uses the non reduced shear effect. The result of this is slightly lower shear rating factors for the support analysis points, for those bridges that can make use of these shear provisions.

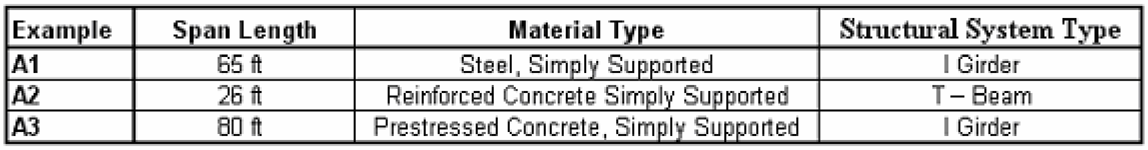
4.1.2 In-House Rating Tools

In-house rating tools were developed for several simply supported bridge cases using Mathcad version 14 (2007). Mathcad is a powerful mathematical program that can be used to develop worksheets that can perform repetitive calculations efficiently. This allows for analysis problems with constrained variables and predefined calculations to be repeated with little difficulty through only the change of predefined variables. An example of this can be seen in the Mathcad worksheet found in Appendix B1 that performs LRFR analysis for slab bridges. Once the worksheet was developed, analyzing different slab bridges could be done simply through manipulation of the variables describing the unique components of a bridge located at the top of the file. In this study, the use of Mathcad served two purposes. First, to develop an understanding of LRFR methodology through developing worksheets to perform the rating analysis for simply supported reinforced concrete, steel, and prestressed bridges. Secondly, to perform the LRFR analysis for the single slab bridge found in the unique bridge sample. A copy of the final Mathcad worksheets for a simply supported reinforced concrete, steel and prestressed bridges can be found in Appendix B2, B3, and B4 respectively.

4.1.2.1 AASHTO Rating Example Comparisons

To develop a working understanding of the LRFR methodology, three Mathcad worksheets were developed to perform Strength I analysis and rating for simply supported reinforced concrete, steel, and prestressed bridges. These worksheets followed the rating procedure outlined in the AASHTO MCE LRFR (2003) and the resistance and load effect calculations as detailed in the AASHTO LRFD (2007) Bridge Design Specification. To assess the accuracy of the developed worksheets, three example problems form the AASHTO MCE LRFR (2003) Appendix A were analyzed and the results were compared. Table 4 – 1 provides a description of the three bridges used in the comparison. The example bridges were also modeled and analyzed in Virtis allowing for an additional point of comparison. The live load model used for the comparison was the HL-93.

Table 4 - 1: Description of AASHTO MCE Example Bridges (AASHTO 2003)



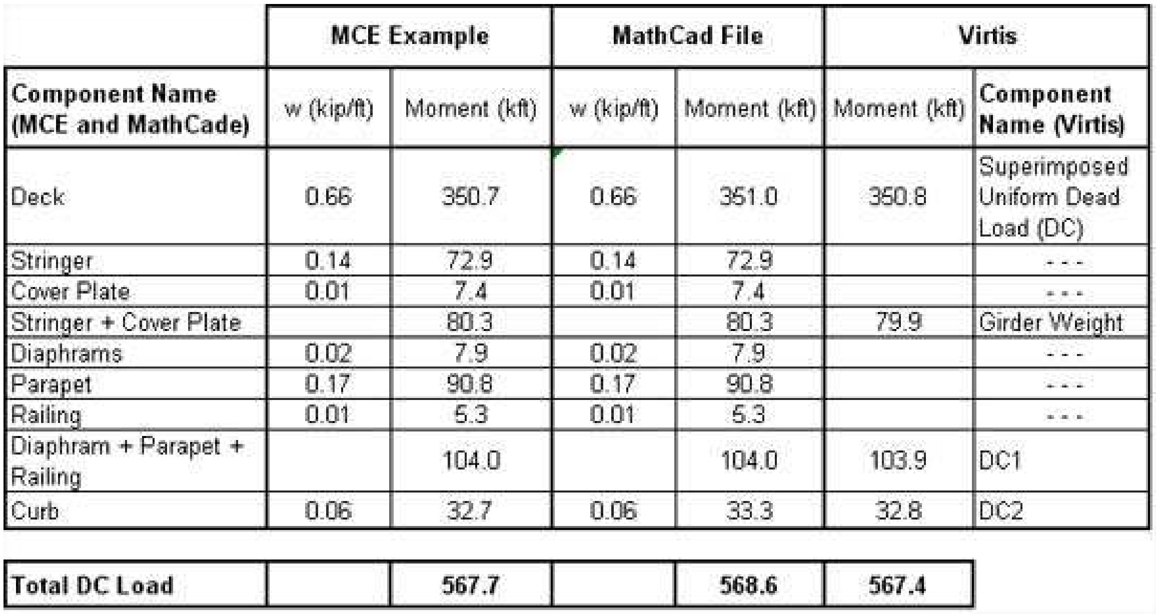
Example	Span Length	Material Type	Structural System Type
A1	65 ft	Steel, Simply Supported	I Girder
A2	26 ft	Reinforced Concrete Simply Supported	T – Beam
A3	80 ft	Prestressed Concrete, Simply Supported	I Girder

Comparing the results from the example problem A1 of the AASHTO MCE LRFR (2003) and the Mathcad file to the results Virtis version 5.6 analysis two discoveries were made. The first discovery was that a factor of 0.8333 or 5 / 6 was being applied by Virtis to live load before it was used in the general rating equation. This factor reduced the actual live load effect causing the rating factor to be greater than anticipated by 1.2 or the reciprocal of the applied factor. Upon further investigation, it was found that this error originated in Virtis from a provision in the AASHTO LRFD (2007) which allows for the multiple-presence factor, for a single-lane loaded condition, 1.2 to be removed from the live load distribution factor through the application of a 5 / 6 factor when analyzing under the fatigue limit state, since multiple presence factors should not be used with the fatigue limit state. However Virtis was using this reduction for all limit states not just for the fatigue limit state as specified in the code. While this error was known by AASHTO's BRIDGEWare and would be corrected in a later release of Virtis, version 6.0, it was not known to ALDOT or to the researcher until this exercise was performed. To compensate for this unwanted reduction factor Virtis's Scale Factor, used to amplify live loads, was set to 1.20. The product of the scale factor set to 1.2 and the applied reduction factor of 5/6 is 1.0, so the actual live load effect used during the rating analysis is correct.

The second discovery that was made dealt with the live load distribution factors, discussed in Section 2.1.2. While the AASHTO MCE LRFR (2003) example problem, the Mathcad worksheet, and Virtis all produced the same live load distribution factors, the factor used in the Virtis analysis was different. Section 4.6.2.2.2 of the AASHTO LRFD (2007) specifies that the controlling, largest, live load distribution factor should be used in the analysis. However while the AASHTO MCE LRFR (2003) example and the worksheet did use the controlling live load distribution factors as specified in the code, Virtis used the smallest of the factors. Due to using the smaller of the factors Virtis was producing lower than anticipated live load effects and higher than anticipated rating factors. This error was also know by AASHTO's Bridge Ware and would be corrected in a later release of Virtis, version 6.0. The error however was not known to ALDOT or to the research until this investigation was performed. To compensate for the error during the research the live load distribution factor was manually set to the controlling factor for each bridge during its modeling process.

With the inclusion of these two corrections Table 4 – 2 shows a comparison of the dead load moment results between the AASHTO MCE LRFR (2003) example problem, the Mathcad worksheet, and Virtis results. As can been seen there is virtually no difference between the calculated total dead load moments from the three different methods.

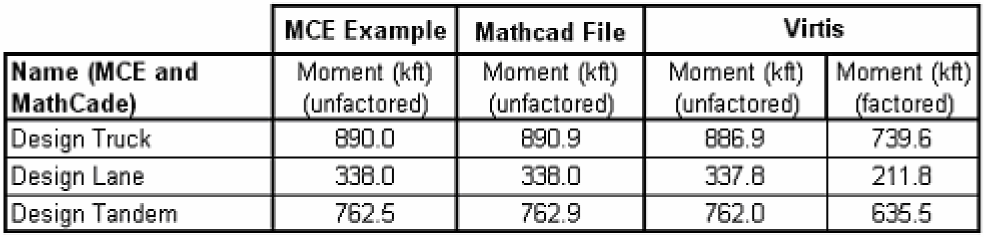
Table 4 - 2: Steel I-Girder Example Eead Load Results



	MCE Example		MathCad File		Virtis	
Component Name (MCE and MathCade)	w (kip/ft)	Moment (kft)	w (kip/ft)	Moment (kft)	Moment (kft)	**Component Name (Virtis)**
Deck	0.66	350.7	0.66	351.0	350.8	Superimposed Uniform Dead Load (DC)
Stringer	0.14	72.9	0.14	72.9		- - -
Cover Plate	0.01	7.4	0.01	7.4		- - -
Stringer + Cover Plate		80.3		80.3	79.9	Girder Weight
Diaphrams	0.02	7.9	0.02	7.9		- - -
Parapet	0.17	90.8	0.17	90.8		- - -
Railing	0.01	5.3	0.01	5.3		- - -
Diaphram + Parapet + Railing		104.0		104.0	103.9	DC1
Curb	0.06	32.7	0.06	33.3	32.8	DC2
Total DC Load		**567.7**		**568.6**	**567.4**	

Table 4 – 3 shows a comparison of the live load moment results for the three different methods for the HL-93 live load model. The moment and shear results presented for the AASHTO MCE LRFR (2003) example and the Mathcad worksheet are un-factored effects. Virtis however only outputs factored live load effects which include the live load distribution factor, the impact factor and the scale factor, where applicable. The un-factored live load effects for Virtis were produced by manually removing those known factors in Microsoft Excel. When comparing the live load moment results from the AASHTO MCE LRFR (2003) example and the Mathcad worksheet, little difference can be seen. The live load moment for Virtis however is slightly lower. This is due to Virtis assuming that the maximum moment effect occurs at one of its eleven predetermined analysis points. The maximum moment for this case then would occur at the mid-span analysis point, due to the bridge’s support conditions. When dealing with a simply supported member and a moving live loads however, the maximum moment typically occurs just off of mid-span, which occurs here. Thus this causes Virtis to slightly underestimate the true maximum live load moment as it does not occur at one of its predefined analysis points.

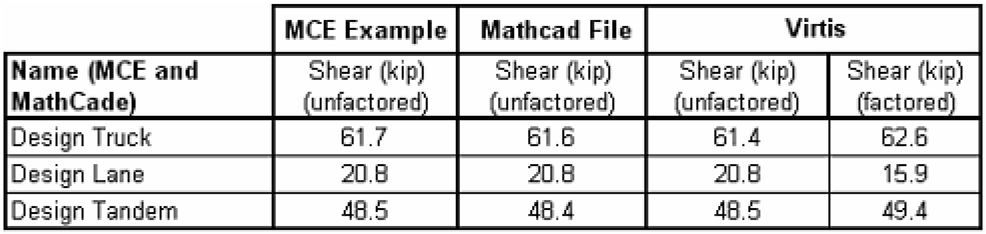
Table 4 - 3: Steel I-Girder Example Live Load Moment Results



	MCE Example	**Mathcad File**	**Virtis**	
Name (MCE and MathCade)	Moment (kft) (unfactored)	Moment (kft) (unfactored)	Moment (kft) (unfactored)	Moment (kft) (factored)
Design Truck	890.0	890.9	886.9	739.6
Design Lane	338.0	338.0	337.8	211.8
Design Tandem	762.5	762.9	762.0	635.5

The shear results however show very little discrepancy between the three different methods, Table 4 – 4. This is due to the maximum shear actually occurring at one of the Virtis eleven predetermined analysis point, the supports.

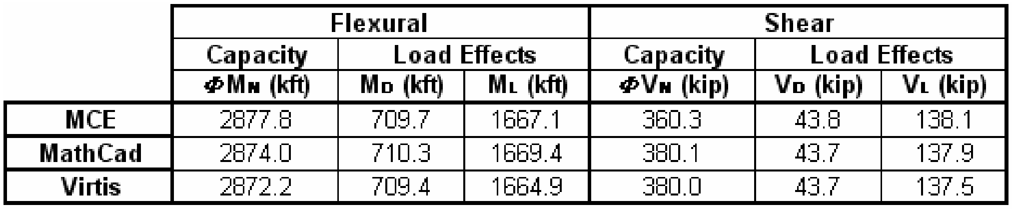
Table 4 - 4: Steel I-Girder Example Live Load Shear Results



	MCE Example	Mathcad File	Virtis	
Name (MCE and MathCade)	Shear (kip) (unfactored)	Shear (kip) (unfactored)	Shear (kip) (unfactored)	Shear (kip) (factored)
Design Truck	61.7	61.6	61.4	62.6
Design Lane	20.8	20.8	20.8	15.9
Design Tandem	48.5	48.4	48.5	49.4

The factored capacities and a summary of the total factored load effects for the steel I-girder example problem are shown in Table 4 – 5. Little disagreement can be found between the three methods with regards to the flexural capacity and load effects. The capacities for shear however are different for the AASHTO MCE LRFR (2003) example compared to the Mathcad worksheet and Virtis. This difference is due to changes in the AASHTO LRFD Bridge Design Specification 2001 code used in the AASHTO MCE LRFR (2003) example and the AASHTO LRFD (2007) code used in the Mathcad worksheet and Virits. In the 2001 code the fillet depth is excluded from the web depth for shear calculations. The 2007 code however does not exclude the fillet depth for shear calculations, thus the full web depth is used yielding a large shear capacity.

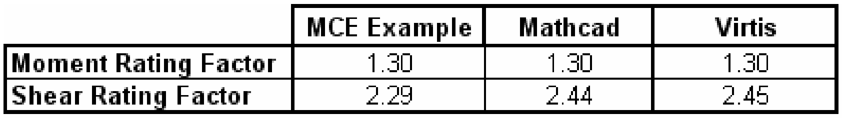
Table 4 - 5: Steel I-Girder Example Capacity Comparison



	Flexural			Shear		
	Capacity	Load Effects		Capacity	Load Effects	
	ΦM_N (kft)	M_D (kft)	M_L (kft)	ΦV_N (kip)	V_D (kip)	V_L (kip)
MCE	2877.8	709.7	1667.1	360.3	43.8	138.1
MathCad	2874.0	710.3	1669.4	380.1	43.7	137.9
Virtis	2872.2	709.4	1664.9	380.0	43.7	137.5

The Strength I rating results for the three different methods for the steel I girder example are compared in Table 4 – 6. The three different methods produce nearly the same moment rating results and similar shear rating results with the exclusion of the AASHTO MCE LRFR (2003) example due to code changes. This affirms that the use of the Mathcad worksheet and Virtis using the two previously noted corrections can produce reliable rating results with regards to the AASHTO MCE LRFR (2003) and the AASHTO LRFD (2007) Bridge Design Specification for steel I-girders.

Table 4 - 6: Steel I-Girder Example Rating Comparison



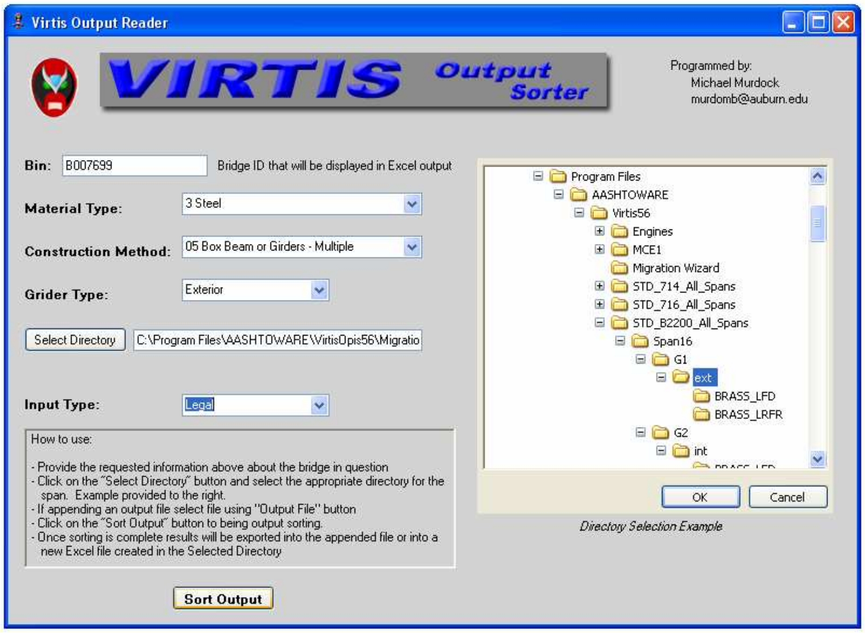
	MCE Example	Mathcad	Virtis
Moment Rating Factor	1.30	1.30	1.30
Shear Rating Factor	2.29	2.44	2.45

Similar results were found when comparing the AASHTO MCE LRFR (2003) example reinforced concrete T-beam and the prestressed concrete I-girder problems to there Mathcad worksheets and Virtis results. Summaries of these comparisons similar to those presented for the steel I-Girder example can be found in Appendix B5 and B6, respectively. One important differences to note in the AASHTO LRFD 2001 Bridge Design code used in the AASHTO MCE LRFR (2003) examples and the AASHTO LRFD (2007) code used in the Mathcad worksheets and Virtis, deals with the way shear capacity is calculated for reinforced and prestressed concrete members. The 2007 code provides a more refined form of analysis in calculating shear capacity allowing for β, a factor relating effect of longitudinal strain on shear capacity, and θ, the angle of inclination of diagonal compressive stresses, to be variable with regards to a calculated longitudinal strain, ε_x, at the cross section under analysis. This is referred to as the general procedure for shear design with tables. A simplified approach still is allowed which assumes a β of 2.0 and θ of 45° which tends to yield lower shear capacities than the general approach. By default Virtis uses the general procedure and the general procedure was used for all concrete analysis in this research.

4.1.2.2 Output Sorting Programs

One of the goals of the research was to be able to compare both moment and shear rating factors for LRFR and LFR for each bridge member under every used live load model. This however created a problem because Virtis only displays the absolute controlling rating factor after each rating analysis. Moreover, in order to be able to perform bounding studies for the rating results due to changes in γ_L, ϕ_c, and ϕ_s, all the components of the rating equations need to be known, such as: the resistance, applied dead and live load, γ factors and ϕ factors. For more information about the bounding studies see Chapter 5. All this information is not readily available from the Virtis output screens; therefore, the data was required to be gathered from Virtis's output files. This presented an additional challenge in that the formatting of Virtis output files is not standard. For example during an LRFR analysis each analysis point generates its own unique file and the structure of that file changes depending on the material and structural system type of the bridge. LFR on the other hand puts all its output for each analysis point into a single file but again the structure of the file changes with each bridge's material and structure type.

To overcome this problem of gathering the required data two options presented themselves. The first was to manually gather the data by hand. This however presented significant problems in locating the controlling data as well as gathering it, this would introduce two possible sources of human error. The second option, was to write a computer program that would be able to read through the various types of Virtis output files and gather the required data. To accomplish this task the Virtis Output Sorter program was written by the author (2008). The Virtis Output Sorter allows its user to specify the bridge type, material type, rating methodology and location of the output file(s) and then using this information the program gathers all the required controlling data for the bridge and exports it into an organized Microsoft Excel file. Figure 4 - 1 shows the graphical user interface of the program.



Virtis Output Reader

Programmed by:
Michael Murdock
murdomb@auburn.edu

Bin: B007699 Bridge ID that will be displayed in Excel output

Material Type: 3 Steel

Construction Method: 05 Box Beam or Girders - Multiple

Grider Type: Exterior

Select Directory C:\Program Files\AASHTOWARE\VirtisOpis56\Migratio

Input Type: Legal

How to use:

- Provide the requested information above about the bridge in question
- Click on the "Select Directory" button and select the appropriate directory for the span. Example provided to the right.
- If appending an output file select file using "Output File" button
- Click on the "Sort Output" button to being output sorting.
- Once sorting is complete results will be exported into the appended file or into a new Excel file created in the Selected Directory

Figure 4 - 1: Virtis Output Sorter User Interface (Murdock© 2008)

The Microsoft Excel file that the Virtis Output Sorter exports the data to is extremely large containing over 450 different pieces of data per bridge. This caused the file to be very cumbersome to work with in regards manipulating the data and graphically presenting it. Therefore, a need arose to be able to break the data down into smaller segments allowing it to be worked with easier. The Data Organizer written by the author (2008) extracts the data from the Microsoft Excel file and splits it into several smaller Excel files, allowing for the large amount of data gathered over the course of the research to be broken down into smaller data files. These smaller files allow for the data to be analyzed more easily and rapidly.

Chapter 5 RATING RESULTS

5.1 Overview

In order to facilitate the presentation of the results, the data gathered from the comparative study has been subdivided into several smaller sections based on the rating level considered. The data from each LRFR rating level is presented in its own separate section. The Design Inventory rating data is presented in Section 5.2. The Legal load rating data is presented in Section 5.3. The Permit load rating data is presented in Section 5.4. Each section will present comparisons between the LRFR and the LFR with regards to flexure and shear rating factors for interior and exterior girders. The data presented in each of the sections follows a similar pattern. The data will be presented in two primary manners, and will be presented in alternate manners when needed. The first manner in which the data will be presented is through the use of LRFR versus LFR rating factor plots, which will be described in the following paragraphs. The second manner in which the data will be presented is through the use of tables providing various statistics of the data.

The LRFR versus LFR rating factor plots, commonly used in the presentation of the data in this thesis, can provide a great deal of information in a concise manner. Examples of this type of plot can be seen in Figures 5 - 1 through 5 - 3. Each of these example plots have been divided into numbered regions. Data falling into each of the shaded regions holds a specific meaning. To help facilitate the discussion of data presented shortly, these regions are first defined.

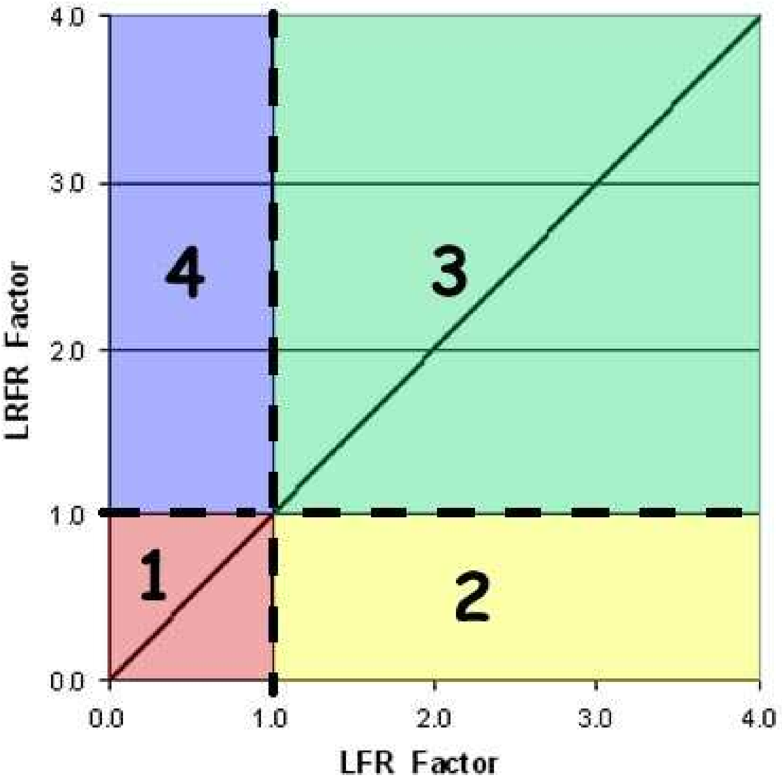


Figure 5 - 1: LFR **Versus** LRFR Region Plot 1

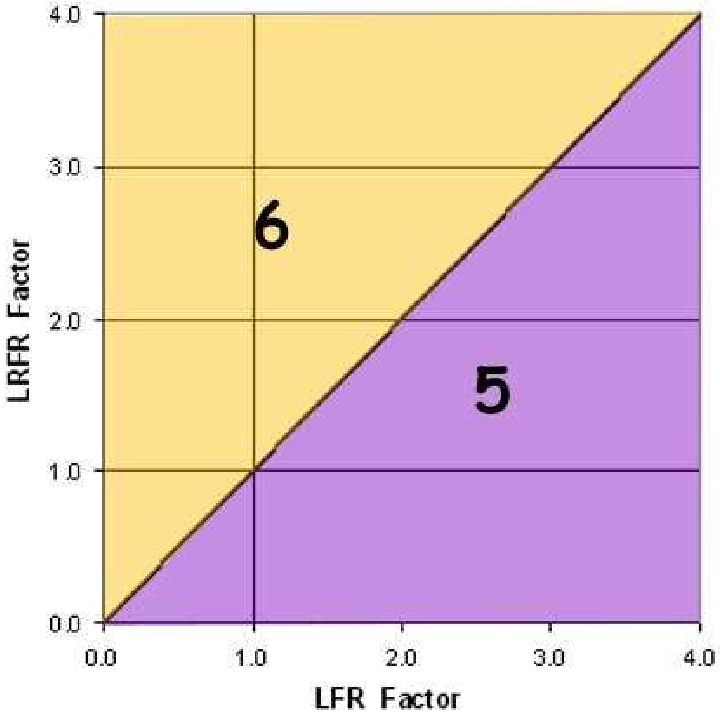


Figure 5 - 2: LFR **Versus** LRFR Region Plot 2

The horizontal and vertical dashed lines shown in Figure 5 - 1 subdivide the plot into four regions. These four regions are labeled 1 through 4. The solid diagonal line further divides the LRFR verses LFR rating factor plot into two more regions as seen in Figure 5 - 2, creating Regions 5 and 6. These two regions are of high importance. Data in Region 5 have lower LRFR rating factors than LFR rating factors. Data in Region 6 have higher LRFR rating factors than LFR rating factors. Overlaying Figures 5 - 1 and 5 - 2 a six-region plot is created as found in Figure 5 - 3.

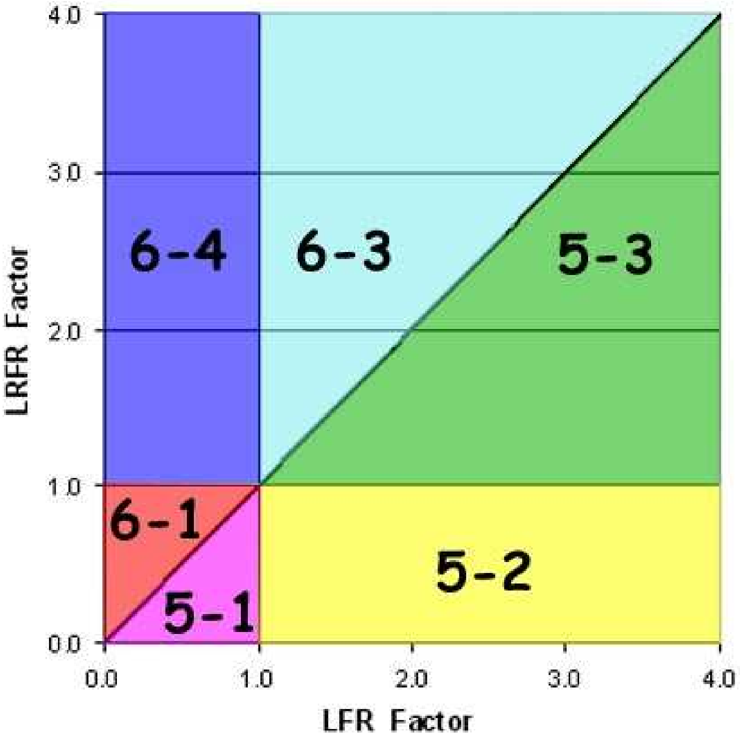


Figure 5 - 3: LFR **Versus** LRFR Region Plot 3

Data found in each of these six regions holds a specific meaning when comparing the rating factors produced by the LRFR to the LFR. Data found in Region 5 - 1 indicates unsatisfactory rating factors for both the LRFR and the LFR, and lower LRFR rating factors than the LFR rating factors. Data found in Region 5 - 2 indicates unsatisfactory rating factors for the LRFR, satisfactory rating factors for the LFR, and lower LRFR rating than the LFR rating factors. Data found in Region 5 - 3 indicates satisfactory rating factors for both the LRFR and the LFR, and lower LRFR rating factors than the LFR rating factors. Data found in Region 6 - 1 indicates unsatisfactory rating factors for both the LRFR and the LFR, and higher LRFR rating factors than the LFR rating factors. Data found in Region 6 - 2 indicates satisfactory rating factors for the LRFR, unsatisfactory rating factors for the LFR, and higher LRFR rating factors than the

LFR rating factors. Data found in Region 6 - 3 consists of satisfactory rating factors for both the LRFR and the LFR, and higher LRFR rating factors than the LFR rating factors.

5.2 Design Level Rating Results

Comparisons at the design level of rating were made between the LRFR's Design Inventory level and the LFR's Inventory level. The live load models used were the HL-93 live load model for the LRFR and the HS-20 Design truck for the LFR. The live load factors used at this level of rating were as specified by the AASHTO MCE LRFR (2003) for the LRFR and the AASHTO MCE (1994) for the LFR, as 1.75 and 2.17, respectively. Data comparisons for the standard bridge sample are given in Section 5.2.1 and for the unique bridge sample in Section 5.2.2. Combined comparisons for both the standard and unique bridge samples are given in Section 5.2.3. A summary of the comparisons for both samples at the design level of rating is provided in Section 5.2.4.

5.2.1 Standard Bridges

The rating data generated for the standard bridge sample (refer to Section 3.1.1), at the Design Inventory rating level, are provided in the tables from Appendix C1, Tables C1 - 1 through C1 - 12. A summary of the rating factors used in the comparisons for this section are provided in Table 5 - 1 and 5 - 2. Table 5 - 1 provides the moment and shear rating factors generated for both the interior and exterior girders for each bridge in the sample, under the LRFR methodology. Additionally, the controlling rating factor for the interior and exterior girders are identified, as well as the controlling rating factor for the bridge. Table 5 - 2 provides the same rating factor information as Table 5 -1 but for the

LFR methodology. The material and structural system type key for this table is as follows.

For material types:

- Reinforced Concrete, Simply Supported - 1
- Reinforced Concrete, Continuously Supported - 2
- Steel, Simply Supported - 3
- Steel, Continuously Supported - 4
- Prestressed Concrete, Simply Supported - 5
- Prestressed Concrete, Continuously Supported - 6

For structural system types:

- Stringer / Multi Beam or Girder - 2
- T-Beam - 4
- Box-Beam - 5
- C-Channel - 22

Table 5 - 1: LRFR Rating Factors Generated for the Standard Bridge Sample at the Design Inventory Rating Level

Bridge Information			LRFR Rating Factors						
Bin	Material Type	Structural System Type	Interior Girder			Exterior Girder			Absolute Controlling
			Moment	Shear	Controlling	Moment	Shear	Controlling	
STD 714 24	1	4	0.49	0.48	0.48	0.44	0.47	0.44	0.44
STD 714 26	1	4	0.45	0.49	0.45	0.39	0.49	0.39	0.39
STD 714 28	1	4	0.50	0.51	0.50	0.44	0.51	0.44	0.44
STD 714 30	1	4	0.53	0.51	0.51	0.47	0.51	0.47	0.47
STD 714 32	1	4	0.52	0.55	0.52	0.47	0.56	0.47	0.47
STD 714 34	1	4	0.52	0.59	0.52	0.47	0.60	0.47	0.47
STD 716 42	1	4	0.45	0.55	0.45	0.45	0.59	0.45	0.45
STD 716 44	1	4	0.41	0.64	0.41	0.49	0.60	0.49	0.41
STD 716 46	1	4	0.39	0.67	0.39	0.47	0.70	0.47	0.39
STD 716 48	1	4	0.38	0.73	0.38	0.47	0.69	0.47	0.38
STD 716 50	1	4	0.41	0.76	0.41	0.45	0.80	0.45	0.41
STD 716 52	1	4	0.38	0.82	0.38	0.45	0.87	0.45	0.38
STD C2401 32	1	4	0.62	0.63	0.62	0.54	0.61	0.54	0.54
STD C2401 34	1	4	0.63	0.70	0.63	0.56	0.68	0.56	0.56
STD C2401 36	1	4	0.62	0.74	0.62	0.60	0.75	0.60	0.60
STD C2401 38	1	4	0.34	0.76	0.34	0.56	0.79	0.56	0.34
STD C2411 32	1	4	0.68	0.74	0.68	0.60	0.72	0.60	0.60
STD C2411 34	1	4	0.69	0.80	0.69	0.61	0.79	0.61	0.61
STD C2411 36	1	4	0.63	0.81	0.63	0.56	0.80	0.56	0.56
STD C2411 38	1	4	0.68	0.91	0.68	0.62	0.91	0.62	0.62
STD C2414 32	1	4	0.85	1.04	0.85	0.81	1.05	0.81	0.81
STD C2414 34	1	4	0.87	1.18	0.87	0.85	1.21	0.85	0.85
STD C2414 36	1	4	0.86	1.25	0.86	0.85	1.28	0.85	0.85
STD C2414 38	1	4	0.83	1.28	0.83	0.82	1.33	0.82	0.82
STD PC34 24R	1	22	1.39	1.71	1.39	1.14	1.61	1.14	1.14
STD PC34 26R	1	22	1.02	1.40	1.02	0.94	1.73	0.94	0.94
STD CS2403	2	2	0.69	0.94	0.69	0.57	0.82	0.57	0.57
STD CS2404	2	2	1.17	0.28	0.28	0.95	0.30	0.30	0.28
STD B2200 16	3	2	1.43	1.19	1.19	1.36	1.13	1.13	1.13
STD B2200 20	3	2	1.30	1.30	1.30	1.47	1.24	1.24	1.24
STD B2200 24	3	2	1.31	1.43	1.31	1.28	1.51	1.28	1.28
STD B2200 28	3	2	1.34	1.64	1.34	1.29	1.74	1.29	1.29
STD B2200 30	3	2	1.23	1.58	1.23	1.16	1.67	1.16	1.16
STD B2200 32	3	2	1.22	1.64	1.22	1.14	1.74	1.14	1.14
STD B2200 34	3	2	1.34	1.88	1.34	1.28	1.99	1.28	1.28
STD B2200 36	3	2	1.24	1.82	1.24	1.16	1.92	1.16	1.16
STD B2800	3	2	1.13	2.81	1.13	0.96	2.93	0.96	0.96
STD BC2402	3	2	1.34	2.93	1.34	1.21	3.14	1.21	1.21
STD BC2801	3	2	1.52	2.75	1.52	1.37	2.98	1.37	1.37
STD B2400	4	2	0.71	2.05	0.71	0.58	2.14	0.58	0.58
STD B2411	4	2	0.92	2.62	0.92	0.70	2.74	0.70	0.70
STD B2809	4	2	1.09	2.49	1.09	0.96	2.68	0.96	0.96
STD CSC2800 3S	4	2	0.59	3.33	0.59	0.52	3.64	0.52	0.52
STD CSC2800 4S	4	2	0.58	3.30	0.58	0.52	3.60	0.52	0.52
STD 632	4	2	0.32	1.80	0.32	0.26	1.76	0.26	0.26
STD S28130	5	2	1.48	1.77	1.48	1.36	1.89	1.36	1.36
STD PC34 24R	5	22	1.29	1.53	1.29	0.64	1.26	0.64	0.64
STD PC34 26R	5	22	1.46	1.71	1.46	0.51	1.10	0.51	0.51
STD PSC4041	6	2	1.20	0.60	0.60	1.71	1.22	1.22	0.60
STD PSC4465	6	2	0.46	1.11	0.46	0.53	1.56	0.53	0.46

Table 5 - 2: LFR Rating Factors Generated for the Standard Bridge Sample at the Design Inventory Rating Level

Bridge Information			LFR Rating Factors						
Bin	Material Type	Structural System Type	Interior Girder			Exterior Girder			Absolute Controlling
			Moment	Shear	Controlling	Moment	Shear	Controlling	
STD 714 24	1	4	0.66	0.45	0.45	0.61	0.42	0.42	0.42
STD 714 26	1	4	0.61	0.43	0.43	0.57	0.41	0.41	0.41
STD 714 28	1	4	0.66	0.46	0.46	0.61	0.44	0.44	0.44
STD 714 30	1	4	0.67	0.46	0.46	0.63	0.44	0.44	0.44
STD 714 32	1	4	0.66	0.54	0.54	0.62	0.52	0.52	0.52
STD 714 34	1	4	0.64	0.56	0.56	0.60	0.54	0.54	0.54
STD 716 42	1	4	0.50	0.53	0.50	0.54	0.54	0.54	0.50
STD 716 44	1	4	0.45	0.60	0.45	0.56	0.59	0.56	0.45
STD 716 46	1	4	0.43	0.63	0.43	0.55	0.62	0.55	0.43
STD 716 48	1	4	0.44	0.68	0.44	0.56	0.67	0.56	0.44
STD 716 50	1	4	0.47	0.70	0.47	0.53	0.69	0.53	0.47
STD 716 52	1	4	0.44	0.74	0.44	0.54	0.74	0.54	0.44
STD C2401 32	1	4	0.78	0.61	0.61	0.73	0.58	0.58	0.58
STD C2401 34	1	4	0.78	0.65	0.65	0.73	0.63	0.63	0.63
STD C2401 36	1	4	0.76	0.70	0.70	0.73	0.67	0.67	0.67
STD C2401 38	1	4	0.41	0.74	0.41	0.71	0.71	0.71	0.41
STD C2411 32	1	4	0.86	0.68	0.68	0.81	0.66	0.66	0.66
STD C2411 34	1	4	0.84	0.73	0.73	0.81	0.70	0.70	0.70
STD C2411 36	1	4	0.77	0.73	0.73	0.74	0.71	0.71	0.71
STD C2411 38	1	4	0.82	0.82	0.82	0.79	0.80	0.79	0.79
STD C2414 32	1	4	1.13	0.89	0.89	1.09	0.86	0.86	0.86
STD C2414 34	1	4	1.15	0.98	0.98	1.12	0.96	0.96	0.96
STD C2414 36	1	4	1.13	1.04	1.04	1.11	1.02	1.02	1.02
STD C2414 38	1	4	1.08	1.07	1.07	1.06	1.05	1.05	1.05
STD PC34 24R	1	22	2.21	1.91	1.91	1.36	1.20	1.20	1.20
STD PC34 26R	1	22	2.51	2.18	2.18	1.12	1.05	1.05	1.05
STD CS2403	2	2	0.91	0.87	0.87	0.86	0.82	0.82	0.82
STD CS2404	2	2	1.34	0.56	0.56	1.36	0.59	0.59	0.56
STD B2200 16	3	2	1.65	1.48	1.48	1.67	1.51	1.51	1.48
STD B2200 20	3	2	1.63	1.43	1.43	1.66	1.46	1.46	1.43
STD B2200 24	3	2	1.79	1.65	1.65	1.81	1.67	1.67	1.65
STD B2200 28	3	2	1.75	1.87	1.75	1.78	1.89	1.78	1.75
STD B2200 30	3	2	1.51	1.80	1.51	1.54	1.82	1.54	1.51
STD B2200 32	3	2	1.45	1.87	1.45	1.48	1.90	1.48	1.45
STD B2200 34	3	2	1.59	2.16	1.59	1.62	2.19	1.62	1.59
STD B2200 36	3	2	1.43	2.09	1.43	1.46	2.12	1.46	1.43
STD B2800	3	2	1.33	3.48	1.33	1.34	3.70	1.34	1.33
STD BC2402	3	2	1.47	3.71	1.47	1.52	3.86	1.52	1.47
STD BC2801	3	2	1.63	3.41	1.63	1.77	3.76	1.77	1.63
STD B2400	4	2	0.87	2.73	0.87	0.84	2.71	0.84	0.84
STD B2411	4	2	1.16	3.72	1.16	1.11	3.71	1.11	1.11
STD B2809	4	2	1.15	3.41	1.15	1.25	3.69	1.25	1.15
STD CSC2800 3S	4	2	0.82	4.18	0.82	0.91	4.58	0.91	0.82
STD CSC2800 4S	4	2	0.82	4.18	0.82	0.91	4.58	0.91	0.82
STD 632	4	2	0.87	2.14	0.87	0.80	2.09	0.80	0.80
STD S28130	5	2	1.99	1.44	1.44	2.33	1.68	1.68	1.44
STD PC34 24R	5	22	1.58	1.71	1.58	1.39	1.54	1.39	1.39
STD PC34 26R	5	22	1.58	1.70	1.58	1.38	1.95	1.38	1.38
STD PSC4041	6	2	1.25	0.44	0.44	2.05	0.76	0.76	0.44
STD PSC4465	6	2	0.54	0.68	0.54	1.05	1.34	1.05	0.54

The first aspect of the data analyzed was the moment rating factor data for the interior and exterior girders. This data is plotted on the previously described LRFR verses LFR rating factor plot and is shown in Figure 5 - 4 for the entire sample. As can be seen from the figure the data points fall in Region 5 of the plot, meaning that the moment rating factor data shows the LRFR methodology producing lower rating factors than the LFR. The data points, however, are scattered over Regions 5 - 1, 5 - 2, and 5 – 3.

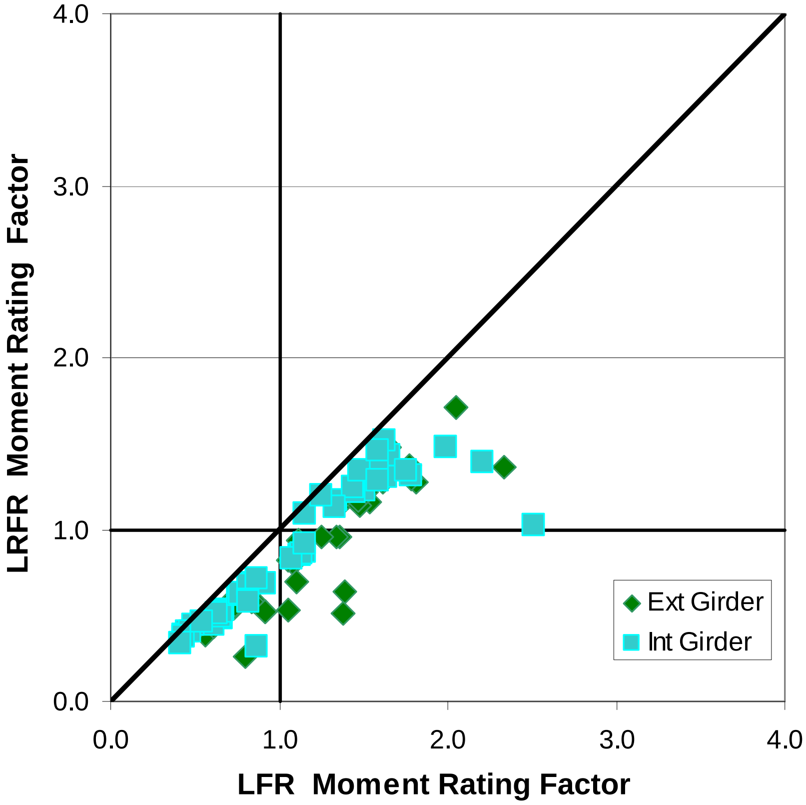


Figure 5 - 4: Moment Rating Factor Comparison at the Design Inventory Level for the Standard Bridge Sample

The shear rating factor data at the Design Inventory level for the standard bridge sample is presented in Figure 5 - 5 for the exterior and interior girders. The shear rating factor data differs from the moment rating data in that parts of the data fall in Regions 5 and 6. Bridges with low shear rating factors, below 1.0, seem to be found primarily in

Region 6 - 1. Bridges with high shear rating factors, above 2.0, are within Region 5 - 3. Bridges with rating factors between 1.0 and 2.0 are scattered over Regions 5 - 3 and 6 - 3. This suggests that LRFR produces higher rating results than LFR for bridges with low shear rating factors and produces lower rating results than LFR for bridges with high shear rating factors.

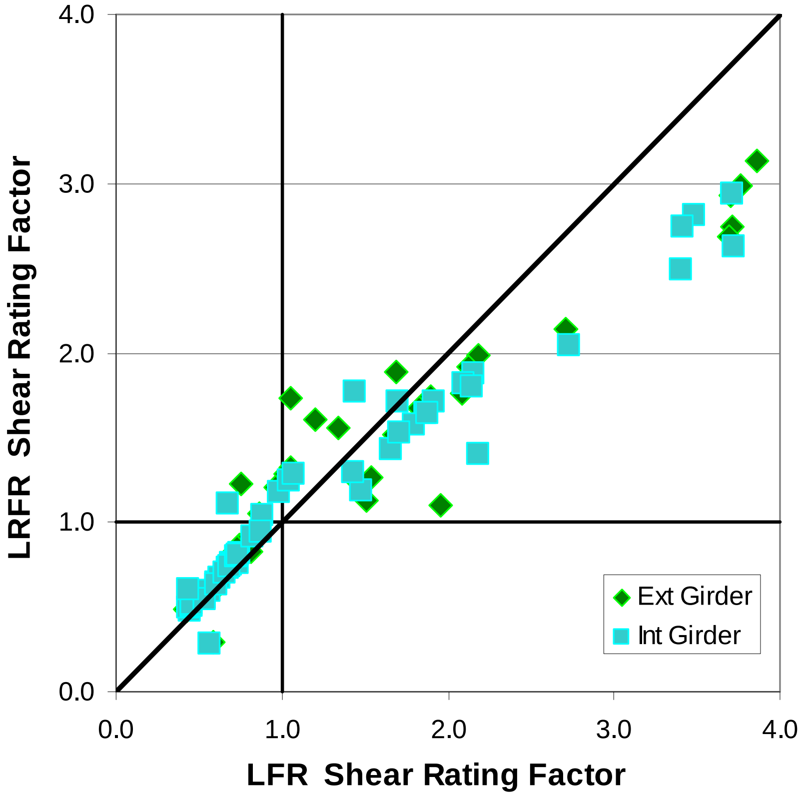
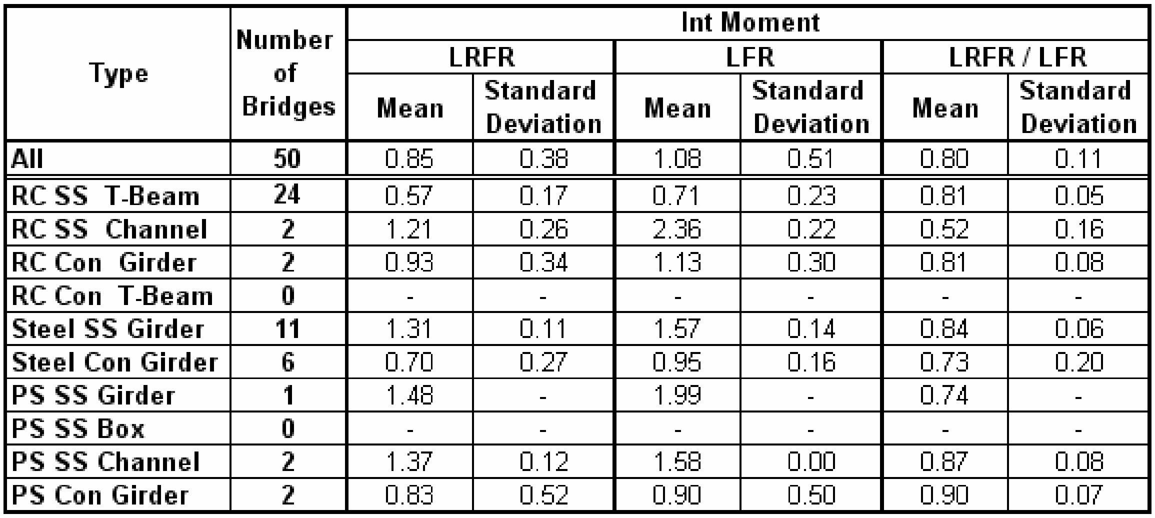


Figure 5 - 5: Shear Rating Factor Comparison at the Design Inventory Level for the Standard Bridge Sample

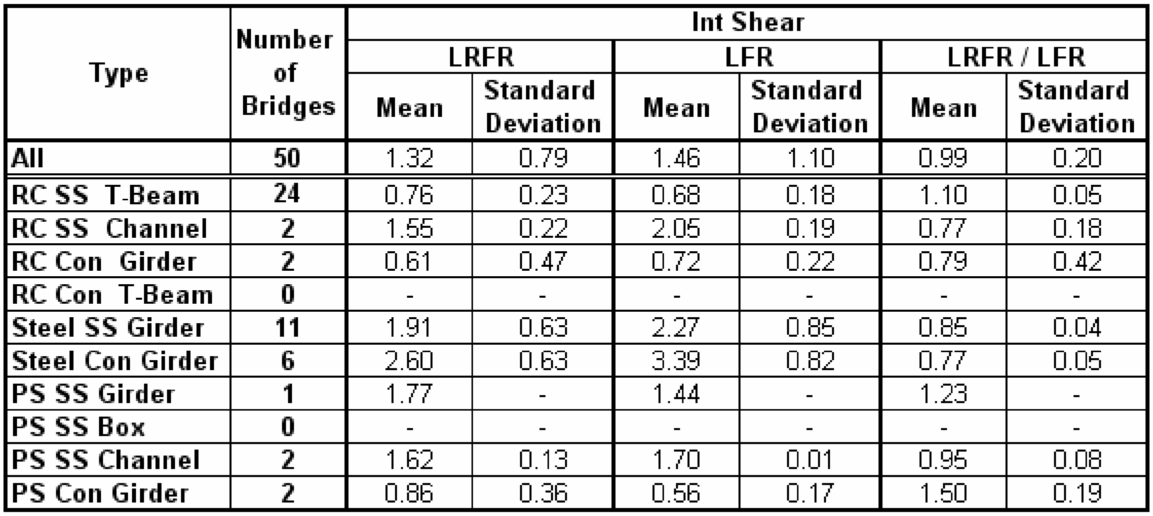
Results from a statistical analysis of the rating factor data are presented in Tables 5 - 1 to 5 - 4 for the standard bridge sample at the Design Inventory level. These Tables provide the mean and standard deviation for the LRFR, LFR, and ratio of LRFR to LFR rating factor data. The tables provide these statistics for the entire standard as well as for the various bridge categories represented within the sample, as shown. Tables 5 - 3 and 5 - 6 provide the results for the interior girders of the sample for moment and shear respectively. For moment rating factors for interior girders, Table 5 - 3, the LRFR always produced lower rating results than LFR. These results are in agreement with those of Lichtenstein Consulting Engineers who found that for this rating level, LRFR produced nearly equal or lower rating factors than LFR (Lichtenstein 2001). The same trend is seen in Table 5 - 5 for the exterior girders. The results form the shear rating factor analysis showed that the LRFR and LFR produced similar results, as shown in Tables 5 - 4 and 5 - 6. However, at the material and structural system level, Table 5 - 4 and 5 - 6 , that for reinforced concrete T-beams, prestressed concrete channel and I-girder bridges, LRFR produced greater or equal rating factors than the LFR, for interior and exterior girders. An interesting observation is seen for the reinforced concrete channel bridges, where for exterior girders the LRFR produce considerably larger rating results than the LFR, Table 5 - 6, but for interior girders the opposite was seen, Table 5 - 4. For all other bridge types the LRFR produces lower rating factors than LFR, for interior and exterior girders.

Table 5 - 3: Mean and Standard Deviation Data at the Design Inventory Level for the Standard Bridge Sample – Interior Girder Moment Rating Data



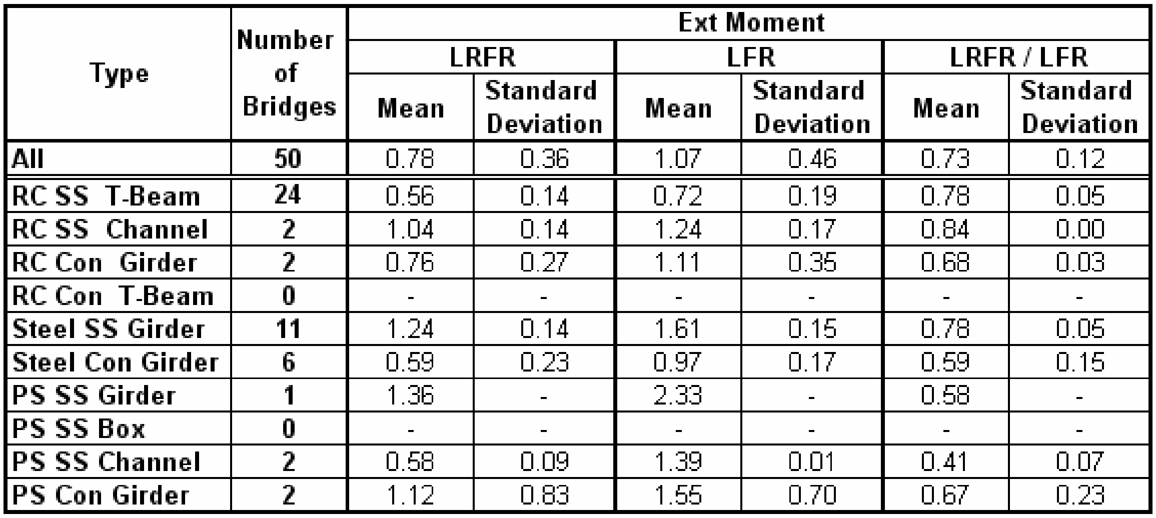
Type	Number of Bridges	Int Moment					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	50	0.85	0.38	1.08	0.51	0.80	0.11
RC SS T-Beam	24	0.57	0.17	0.71	0.23	0.81	0.05
RC SS Channel	2	1.21	0.26	2.36	0.22	0.52	0.16
RC Con Girder	2	0.93	0.34	1.13	0.30	0.81	0.08
RC Con T-Beam	0	-	-	-	-	-	-
Steel SS Girder	11	1.31	0.11	1.57	0.14	0.84	0.06
Steel Con Girder	6	0.70	0.27	0.95	0.16	0.73	0.20
PS SS Girder	1	1.48	-	1.99	-	0.74	-
PS SS Box	0	-	-	-	-	-	-
PS SS Channel	2	1.37	0.12	1.58	0.00	0.87	0.08
PS Con Girder	2	0.83	0.52	0.90	0.50	0.90	0.07

Table 5 - 4: Mean and Standard Deviation Data at the Design Inventory Level for the Standard Bridge Sample – Interior Girder Shear Rating Data



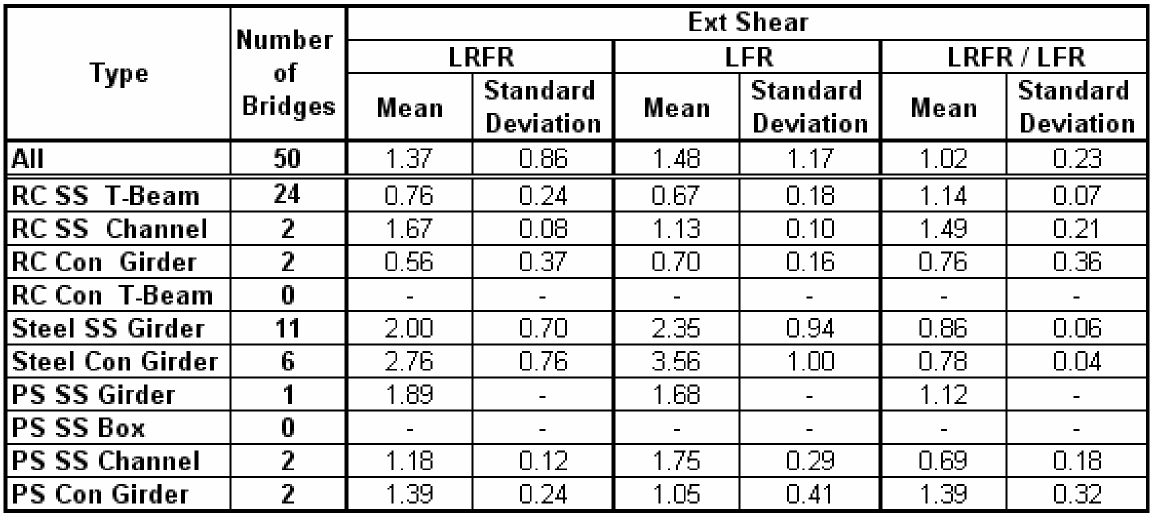
Type	Number of Bridges	Int Shear					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	50	1.32	0.79	1.46	1.10	0.99	0.20
RC SS T-Beam	24	0.76	0.23	0.68	0.18	1.10	0.05
RC SS Channel	2	1.55	0.22	2.05	0.19	0.77	0.18
RC Con Girder	2	0.61	0.47	0.72	0.22	0.79	0.42
RC Con T-Beam	0	-	-	-	-	-	-
Steel SS Girder	11	1.91	0.63	2.27	0.85	0.85	0.04
Steel Con Girder	6	2.60	0.63	3.39	0.82	0.77	0.05
PS SS Girder	1	1.77	-	1.44	-	1.23	-
PS SS Box	0	-	-	-	-	-	-
PS SS Channel	2	1.62	0.13	1.70	0.01	0.95	0.08
PS Con Girder	2	0.86	0.36	0.56	0.17	1.50	0.19

Table 5 - 5: Mean and Standard Deviation Data at the Design Inventory Level for the Standard Bridge Sample – Exterior Girder Moment Rating Data



Type	Number of Bridges	Ext Moment					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	50	0.78	0.36	1.07	0.46	0.73	0.12
RC SS T-Beam	24	0.56	0.14	0.72	0.19	0.78	0.05
RC SS Channel	2	1.04	0.14	1.24	0.17	0.84	0.00
RC Con Girder	2	0.76	0.27	1.11	0.35	0.68	0.03
RC Con T-Beam	0	-	-	-	-	-	-
Steel SS Girder	11	1.24	0.14	1.61	0.15	0.78	0.05
Steel Con Girder	6	0.59	0.23	0.97	0.17	0.59	0.15
PS SS Girder	1	1.36	-	2.33	-	0.58	-
PS SS Box	0	-	-	-	-	-	-
PS SS Channel	2	0.58	0.09	1.39	0.01	0.41	0.07
PS Con Girder	2	1.12	0.83	1.55	0.70	0.67	0.23

Table 5 - 6: Mean and Standard Deviation Data at the Design Inventory Level for the Standard Bridge Sample – Exterior Girder Shear Rating Data



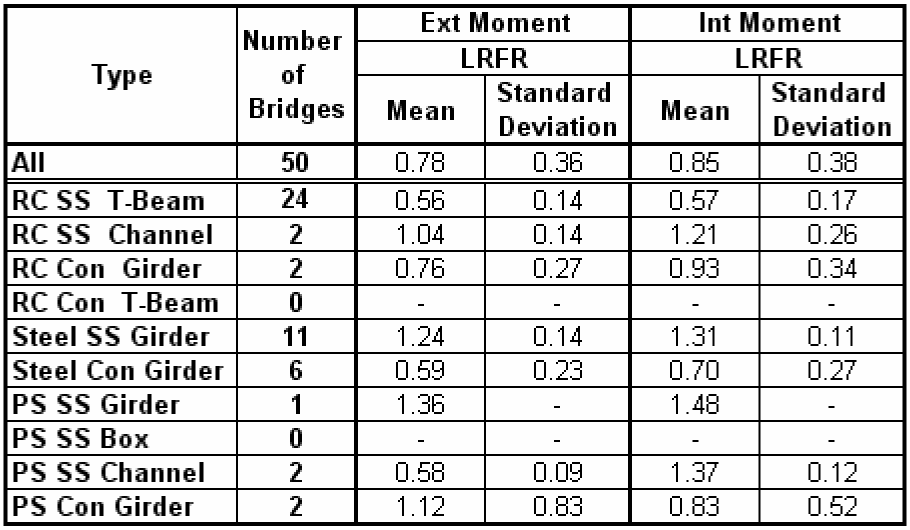
Type	Number of Bridges	Ext Shear					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	50	1.37	0.86	1.48	1.17	1.02	0.23
RC SS T-Beam	24	0.76	0.24	0.67	0.18	1.14	0.07
RC SS Channel	2	1.67	0.08	1.13	0.10	1.49	0.21
RC Con Girder	2	0.56	0.37	0.70	0.16	0.76	0.36
RC Con T-Beam	0	-	-	-	-	-	-
Steel SS Girder	11	2.00	0.70	2.35	0.94	0.86	0.06
Steel Con Girder	6	2.76	0.76	3.56	1.00	0.78	0.04
PS SS Girder	1	1.89	-	1.68	-	1.12	-
PS SS Box	0	-	-	-	-	-	-
PS SS Channel	2	1.18	0.12	1.75	0.29	0.69	0.18
PS Con Girder	2	1.39	0.24	1.05	0.41	1.39	0.32

Based upon material type alone, prestressed bridges are seen to have the highest LRFR to LFR ratio for both moment and shear except for exterior girder moment rating. Reinforced concrete bridges on average tend to have the lowest LRFR to LFR ratio for moment rating factors, with steel bridges having the lowest LRFR to LFR ratio for shear rating factors.

The statistical data also shows that reinforced concrete C – Channel bridges, rating factors for both load effects tend to have a lower than usual LRFR to LFR ratio for interior girders and a higher than usual LRFR to LFR ratio for exterior girders. The reason for these usual ratios was not investigated; however it is believed that this may in part be due to the modeling assumptions made for this bridge type as discussed in Chapter 3. Further investigation however would be required to determine the exact reason for the C – Channel's unusual LRFR to LFR ratios.

Table 5 - 7 compares the interior with exterior girder's LRFR moment rating factor statistical data. The comparison reveals that the exterior girder controls over the interior girder for all material and structural system types with the exception of prestressed concrete continuously supported girder bridges. This trend was not observed for the LFR moment statistical data or the shear statistical data of either methodology, as shown in Tables 5 - 3 to 5 - 6.

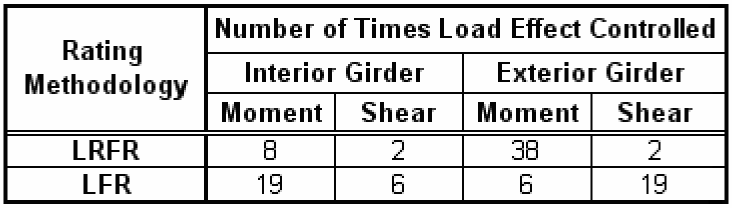
Table 5 - 7: Mean and Standard Deviation Data at the Design Inventory level for the Standard Bridge Sample – Interior to Exterior LRFR Moment Rating Comparison



Type	Number of Bridges	Ext Moment		Int Moment	
		LRFR		LRFR	
		Mean	Standard Deviation	Mean	Standard Deviation
All	**50**	0.78	0.36	0.85	0.38
RC SS T-Beam	**24**	0.56	0.14	0.57	0.17
RC SS Channel	**2**	1.04	0.14	1.21	0.26
RC Con Girder	**2**	0.76	0.27	0.93	0.34
RC Con T-Beam	**0**	-	-	-	-
Steel SS Girder	**11**	1.24	0.14	1.31	0.11
Steel Con Girder	**6**	0.59	0.23	0.70	0.27
PS SS Girder	**1**	1.36	-	1.48	-
PS SS Box	**0**	-	-	-	-
PS SS Channel	**2**	0.58	0.09	1.37	0.12
PS Con Girder	**2**	1.12	0.83	0.83	0.52

The final point of comparison for this sample of bridges was made to determine the controlling load effect for each rating methodology. Table 5 - 8 shows the results of this comparison. The data in this table was constructed by counting the number of times a rating factor for each load effect controlled for a bridge within the sample. The data indicates that for the LRFR methodology exterior girder moment load effects primarily controlled. The controlling load effect for the LFR methodology is seen to be evenly split between the interior girder moment and exterior girder shear load effects.

Table 5 - 8: Controlling Load Effect Comparison, Design Inventory Level for the Standard Bridge Sample



Rating Methodology	Number of Times Load Effect Controlled			
	Interior Girder		Exterior Girder	
	Moment	Shear	Moment	Shear
LRFR	8	2	38	2
LFR	19	6	6	19

Note: The standard bridge sample consists of 50 bridges

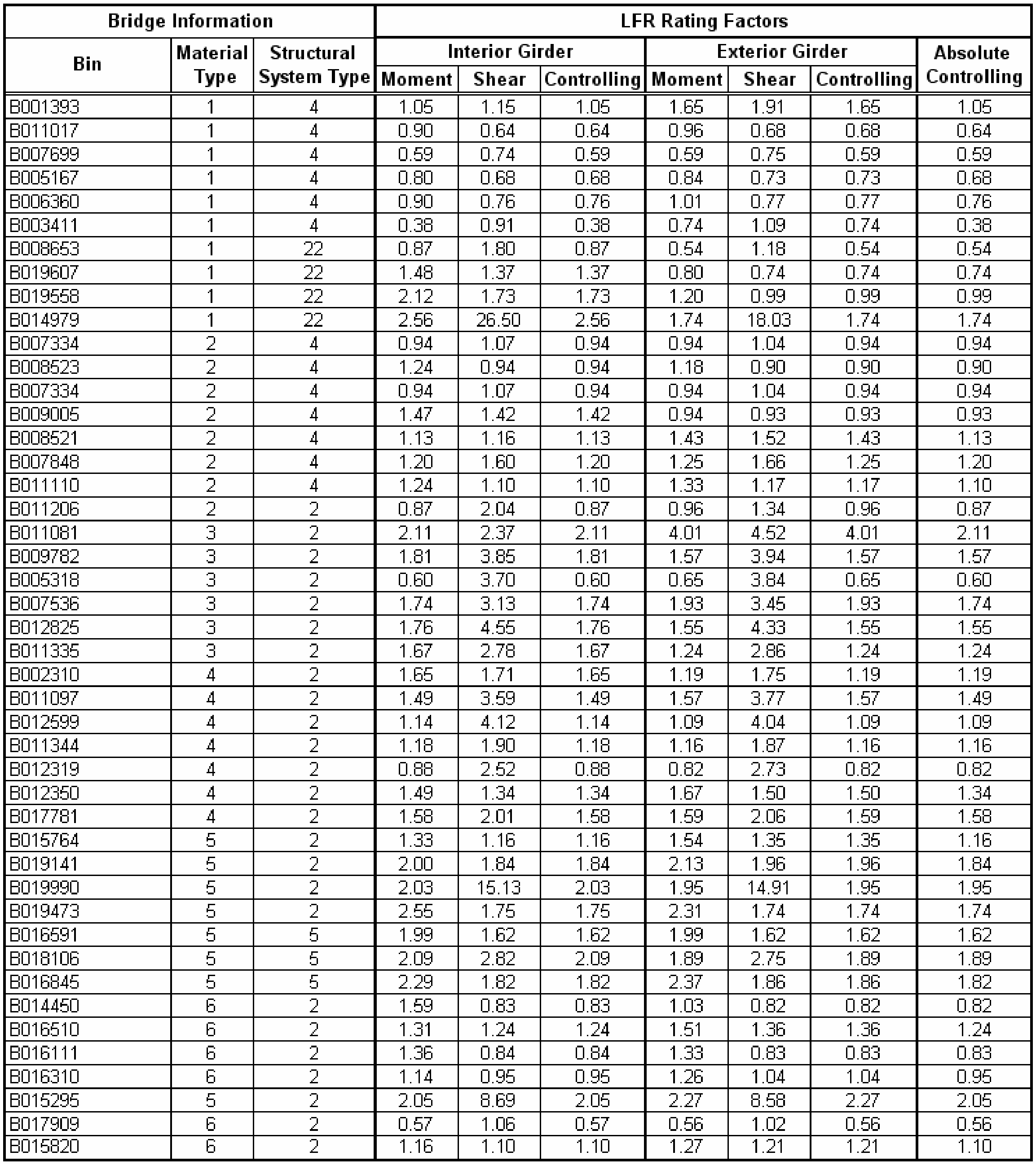
5.2.2 Unique Bridges

The rating data generated for the unique bridge sample (refer to Section 3.1.2) at the Design Inventory rating level are provided in the tables from Appendix C2, Tables C2 - 1 through C2 - 12. A summary of the rating factors used in the comparisons for this section are provided in Table 5 - 9 and 5 - 10. Table 5 - 9 provides the moment and shear rating factors generated for both the interior and exterior girders for each bridge in the sample, under the LRFR methodology. Additionally, the controlling rating factors for the interior and exterior girders are identified, as well as the controlling rating factor for the bridge. Table 5 - 10 provides the same rating factor information as Table 5 - 9 but for the LFR methodology.

Table 5 - 9: LRFR Rating Factors Generated for the Unique Bridge Sample at the Design Inventory Rating Level

Bridge Information			LRFR Rating Factors						
Bin	Material Type	Structural System Type	Interior Girder			Exterior Girder			Absolute Controlling
			Moment	Shear	Controlling	Moment	Shear	Controlling	
B001393	1	4	0.74	1.05	0.74	1.18	1.82	1.18	0.74
B011017	1	4	0.79	0.73	0.73	0.80	0.80	0.80	0.73
B007699	1	4	0.50	0.50	0.50	0.46	0.48	0.46	0.46
B005167	1	4	0.66	0.85	0.66	0.65	0.86	0.65	0.65
B006360	1	4	0.75	0.87	0.75	0.83	0.91	0.83	0.75
B003411	1	4	0.32	0.86	0.32	0.56	1.22	0.56	0.32
B008653	1	22	0.40	1.20	0.40	0.40	1.27	0.40	0.40
B019607	1	22	0.55	0.79	0.55	0.55	0.98	0.55	0.55
B019558	1	22	1.41	1.49	1.41	1.07	1.22	1.07	1.07
B014979	1	22	1.66	23.45	1.66	1.36	21.41	1.36	1.36
B007334	2	4	0.72	0.67	0.67	0.74	0.68	0.68	0.67
B008523	2	4	0.87	0.61	0.61	0.86	0.60	0.60	0.60
B007334	2	4	0.72	0.67	0.67	0.74	0.68	0.68	0.67
B009005	2	4	1.18	0.85	0.85	0.78	0.66	0.66	0.66
B008521	2	4	1.01	0.70	0.70	0.98	0.87	0.87	0.70
B007848	2	4	1.12	1.52	1.12	1.05	1.63	1.05	1.05
B011110	2	4	1.07	0.39	0.39	0.94	0.40	0.40	0.39
B011206	2	2	0.72	1.71	0.72	0.70	1.26	0.70	0.70
B011081	3	2	1.85	2.19	1.85	3.16	4.31	3.16	1.85
B009782	3	2	1.61	2.87	1.61	1.28	2.92	1.28	1.28
B005318	3	2	0.43	2.90	0.43	0.40	3.14	0.40	0.40
B007536	3	2	1.64	2.74	1.64	1.61	3.00	1.61	1.61
B012825	3	2	1.57	3.51	1.57	1.14	3.25	1.14	1.14
B011335	3	2	1.37	1.93	1.37	1.11	1.93	1.11	1.11
B002310	4	2	0.36	1.43	0.36	0.42	1.75	0.42	0.36
B011097	4	2	1.29	2.93	1.29	1.21	3.09	1.21	1.21
B012599	4	2	0.87	3.18	0.87	0.63	3.02	0.63	0.63
B011344	4	2	0.82	1.43	0.82	0.65	1.37	0.65	0.65
B012319	4	2	0.60	1.82	0.60	0.62	2.39	0.62	0.60
B012350	4	2	1.31	0.90	0.90	1.05	0.91	0.91	0.90
B017781	4	2	1.36	1.89	1.36	1.33	1.91	1.33	1.33
B015764	5	2	1.25	1.25	1.25	1.25	1.39	1.25	1.25
B019141	5	2	2.03	1.27	1.27	1.75	1.30	1.30	1.27
B019990	5	2	1.71	7.25	1.71	1.01	6.84	1.01	1.01
B019473	5	2	1.44	1.70	1.44	1.20	1.43	1.20	1.20
B016591	5	5	2.13	1.47	1.47	1.71	2.13	1.71	1.47
B018106	5	5	2.44	3.70	2.44	1.59	2.64	1.59	1.59
B016845	5	5	1.96	1.68	1.68	1.64	1.38	1.38	1.38
B014450	6	2	1.44	0.79	0.79	0.77	0.67	0.67	0.67
B016510	6	2	1.11	1.27	1.11	1.12	1.32	1.12	1.11
B016111	6	2	1.14	0.88	0.88	1.00	0.85	0.85	0.85
B016310	6	2	0.88	1.77	0.88	0.84	1.77	0.84	0.84
B015295	5	2	1.67	14.67	1.67	1.86	15.10	1.86	1.67
B017909	6	2	0.41	1.50	0.41	0.34	1.24	0.34	0.34
B015820	6	2	1.04	1.54	1.04	0.90	1.73	0.90	0.90

Table 5 - 10: LFR Rating Factors Generated for the Unique Bridge Sample at the Design Inventory Rating Level



Bridge Information			LFR Rating Factors						
Bin	Material Type	Structural System Type	Interior Girder			Exterior Girder			Absolute Controlling
			Moment	Shear	Controlling	Moment	Shear	Controlling	
B001393	1	4	1.05	1.15	1.05	1.65	1.91	1.65	1.05
B011017	1	4	0.90	0.64	0.64	0.96	0.68	0.68	0.64
B007699	1	4	0.59	0.74	0.59	0.59	0.75	0.59	0.59
B005167	1	4	0.80	0.68	0.68	0.84	0.73	0.73	0.68
B006360	1	4	0.90	0.76	0.76	1.01	0.77	0.77	0.76
B003411	1	4	0.38	0.91	0.38	0.74	1.09	0.74	0.38
B008653	1	22	0.87	1.80	0.87	0.54	1.18	0.54	0.54
B019607	1	22	1.48	1.37	1.37	0.80	0.74	0.74	0.74
B019558	1	22	2.12	1.73	1.73	1.20	0.99	0.99	0.99
B014979	1	22	2.56	26.50	2.56	1.74	18.03	1.74	1.74
B007334	2	4	0.94	1.07	0.94	0.94	1.04	0.94	0.94
B008523	2	4	1.24	0.94	0.94	1.18	0.90	0.90	0.90
B007334	2	4	0.94	1.07	0.94	0.94	1.04	0.94	0.94
B009005	2	4	1.47	1.42	1.42	0.94	0.93	0.93	0.93
B008521	2	4	1.13	1.16	1.13	1.43	1.52	1.43	1.13
B007848	2	4	1.20	1.60	1.20	1.25	1.66	1.25	1.20
B011110	2	4	1.24	1.10	1.10	1.33	1.17	1.17	1.10
B011206	2	2	0.87	2.04	0.87	0.96	1.34	0.96	0.87
B011081	3	2	2.11	2.37	2.11	4.01	4.52	4.01	2.11
B009782	3	2	1.81	3.85	1.81	1.57	3.94	1.57	1.57
B005318	3	2	0.60	3.70	0.60	0.65	3.84	0.65	0.60
B007536	3	2	1.74	3.13	1.74	1.93	3.45	1.93	1.74
B012825	3	2	1.76	4.55	1.76	1.55	4.33	1.55	1.55
B011335	3	2	1.67	2.78	1.67	1.24	2.86	1.24	1.24
B002310	4	2	1.65	1.71	1.65	1.19	1.75	1.19	1.19
B011097	4	2	1.49	3.59	1.49	1.57	3.77	1.57	1.49
B012599	4	2	1.14	4.12	1.14	1.09	4.04	1.09	1.09
B011344	4	2	1.18	1.90	1.18	1.16	1.87	1.16	1.16
B012319	4	2	0.88	2.52	0.88	0.82	2.73	0.82	0.82
B012350	4	2	1.49	1.34	1.34	1.67	1.50	1.50	1.34
B017781	4	2	1.58	2.01	1.58	1.59	2.06	1.59	1.58
B015764	5	2	1.33	1.16	1.16	1.54	1.35	1.35	1.16
B019141	5	2	2.00	1.84	1.84	2.13	1.96	1.96	1.84
B019990	5	2	2.03	15.13	2.03	1.95	14.91	1.95	1.95
B019473	5	2	2.55	1.75	1.75	2.31	1.74	1.74	1.74
B016591	5	5	1.99	1.62	1.62	1.99	1.62	1.62	1.62
B018106	5	5	2.09	2.82	2.09	1.89	2.75	1.89	1.89
B016845	5	5	2.29	1.82	1.82	2.37	1.86	1.86	1.82
B014450	6	2	1.59	0.83	0.83	1.03	0.82	0.82	0.82
B016510	6	2	1.31	1.24	1.24	1.51	1.36	1.36	1.24
B016111	6	2	1.36	0.84	0.84	1.33	0.83	0.83	0.83
B016310	6	2	1.14	0.95	0.95	1.26	1.04	1.04	0.95
B015295	5	2	2.05	8.69	2.05	2.27	8.58	2.27	2.05
B017909	6	2	0.57	1.06	0.57	0.56	1.02	0.56	0.56
B015820	6	2	1.16	1.10	1.10	1.27	1.21	1.21	1.10

The unique bridge sample yielded similar trends to those of the standard bridge sample at the Design Inventory rating level. Figures 5 - 6 and 5 - 7 present the LRFR verses LFR rating factor data for moment and shear effects, respectively.

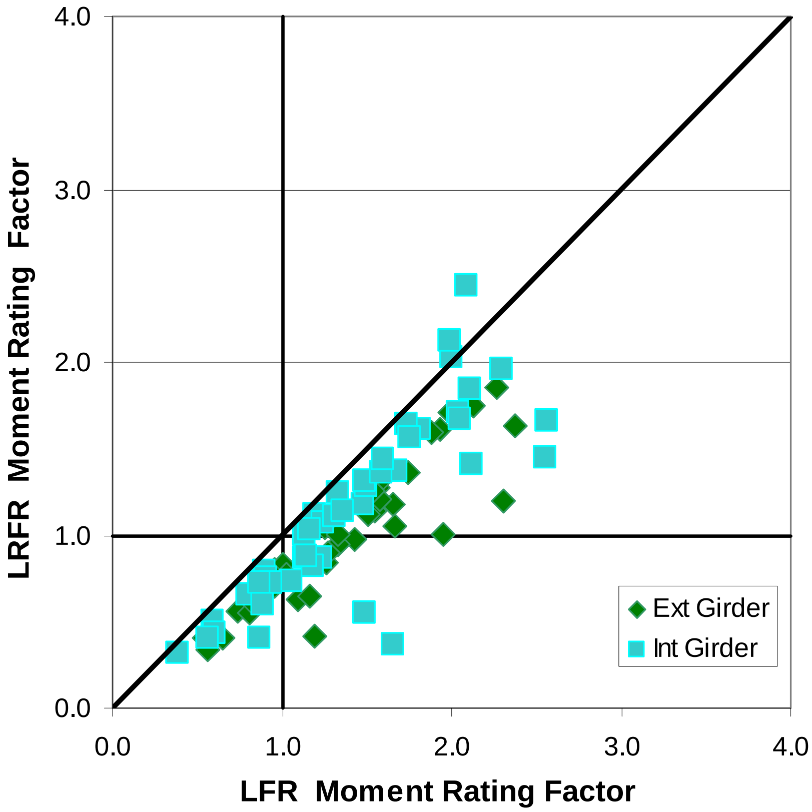


Figure 5 - 6: Moment Rating Factor Comparison at the Design Inventory Level for Unique Bridge Sample

The moment data for both exterior and interior girders falls primarily within Region 5 of the plot, indicating that the LRFR rating factors are lower than their LFR counterparts. Data again is heavily scattered over Regions 5 - 1, 5 - 2 and 5 - 3 as was seen previously for the standard sample. However, a greater number of data points fall within Region 2 of the plots, which signify satisfactory ratings under LFR but unsatisfactory ratings under the LRFR. The potential effect of this would be a greater number of bridges being reported as unsatisfactory to the NBI under the LRFR as opposed to the LFR.

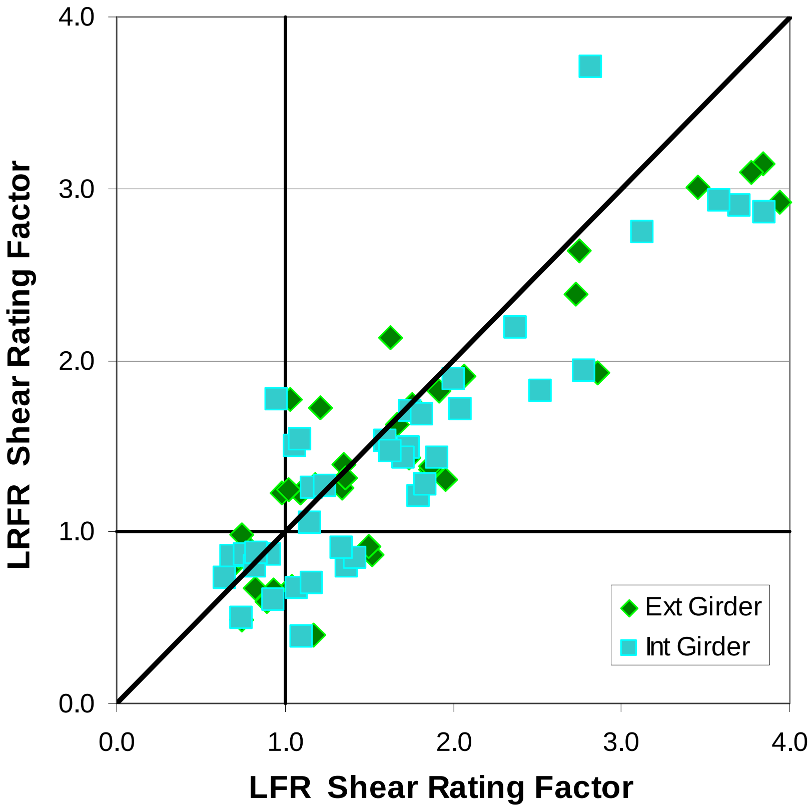
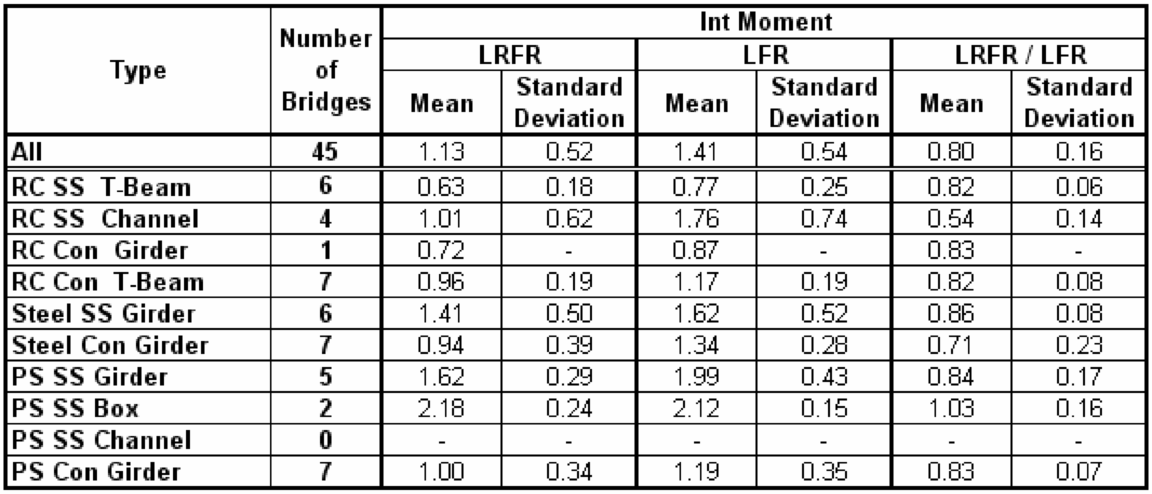


Figure 5 - 7: Shear Rating Factor Comparison at the Design Inventory Level for Unique Bridge Sample

The shear data for the unique bridge sample has a greater degree of scatter than was observed in the standard bridge sample, as shown in Figure 5 - 7. The trend of the LRFR producing higher shear rating results than LFR for bridges with low shear rating factors, seen previously for the standard bridge sample, is not as pronounced for the unique bridge sample. The majority of the data for the unique bridge sample falls within Region 5 with only portions of the data, with rating factors near 1.0 for LFR, falling within Region 6.

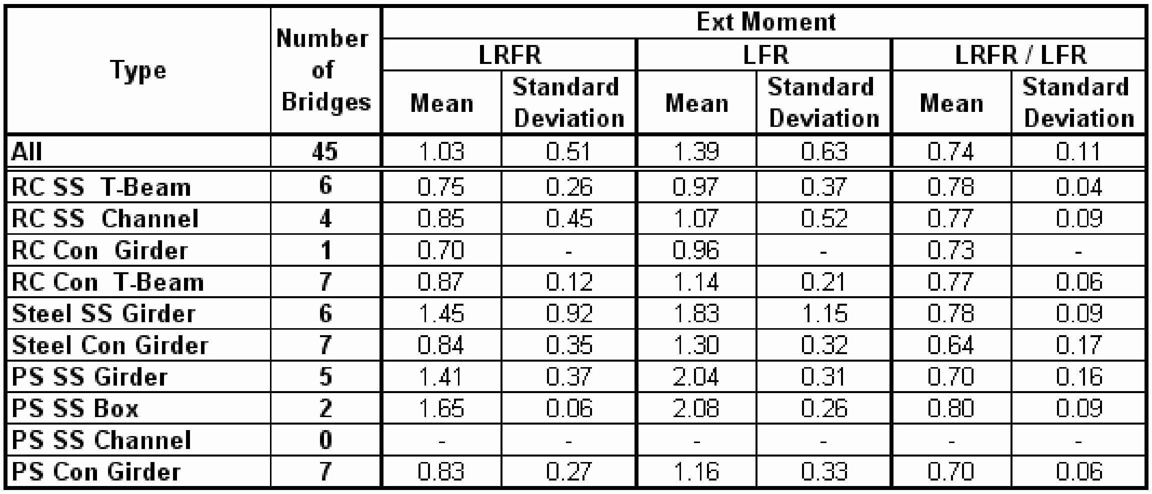
Results from the statistical analysis of the rating data for the unique bridge sample produced similar trends to those of the standard bridge sample. The mean and standard deviations for the moment rating results of the interior and exterior girders are presented in Table 5 - 11 and 5 - 12 respectively. Across all material and structural system types the LRFR method produced nearly equal or lower rating results compared to the LFR for flexure for interior girders, Table 5 - 11. This trend was also seen for the standard bridge sample and concurs with the findings of Lichtenstein Consulting Engineers (Lichtenstein 2001). Similar results can be observed for the exterior girder, Table 5 - 12.

Table 5 - 11: Mean and Standard Deviation Data at the Design Inventory Level for the Unique Bridge Sample – Interior Girder Moment Rating Data



Type	Number of Bridges	Int Moment					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	**45**	1.13	0.52	1.41	0.54	0.80	0.16
RC SS T-Beam	**6**	0.63	0.18	0.77	0.25	0.82	0.06
RC SS Channel	**4**	1.01	0.62	1.76	0.74	0.54	0.14
RC Con Girder	**1**	0.72	-	0.87	-	0.83	-
RC Con T-Beam	**7**	0.96	0.19	1.17	0.19	0.82	0.08
Steel SS Girder	**6**	1.41	0.50	1.62	0.52	0.86	0.08
Steel Con Girder	**7**	0.94	0.39	1.34	0.28	0.71	0.23
PS SS Girder	**5**	1.62	0.29	1.99	0.43	0.84	0.17
PS SS Box	**2**	2.18	0.24	2.12	0.15	1.03	0.16
PS SS Channel	**0**	-	-	-	-	-	-
PS Con Girder	**7**	1.00	0.34	1.19	0.35	0.83	0.07

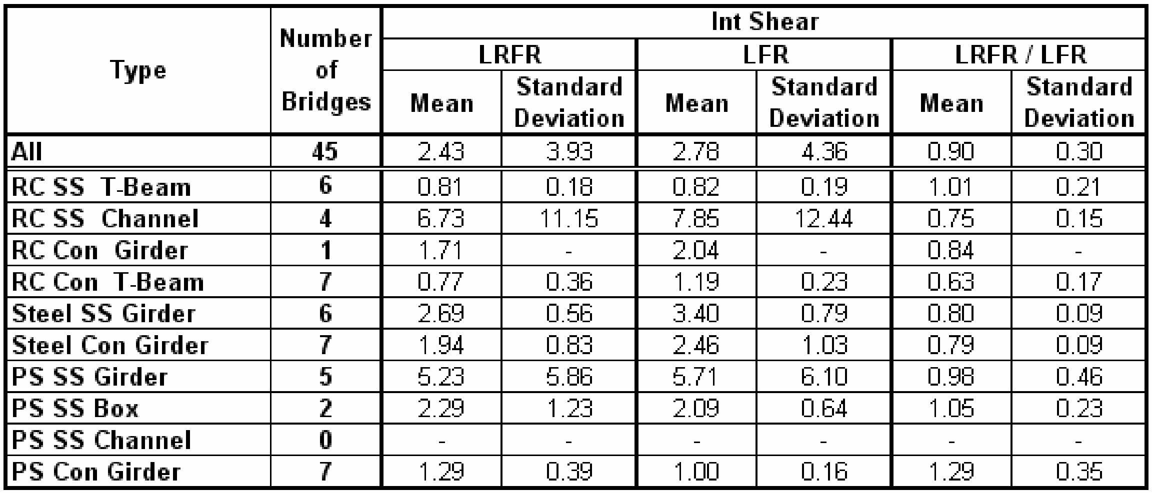
Table 5 - 12: Mean and Standard Deviation Data at the Design Inventory Level for the Unique Bridge Sample – Exterior Girder Moment Rating Data



Type	Number of Bridges	Ext Moment					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	45	1.03	0.51	1.39	0.63	0.74	0.11
RC SS T-Beam	6	0.75	0.26	0.97	0.37	0.78	0.04
RC SS Channel	4	0.85	0.45	1.07	0.52	0.77	0.09
RC Con Girder	1	0.70	-	0.96	-	0.73	-
RC Con T-Beam	7	0.87	0.12	1.14	0.21	0.77	0.06
Steel SS Girder	6	1.45	0.92	1.83	1.15	0.78	0.09
Steel Con Girder	7	0.84	0.35	1.30	0.32	0.64	0.17
PS SS Girder	5	1.41	0.37	2.04	0.31	0.70	0.16
PS SS Box	2	1.65	0.06	2.08	0.26	0.80	0.09
PS SS Channel	0	-	-	-	-	-	-
PS Con Girder	7	0.83	0.27	1.16	0.33	0.70	0.06

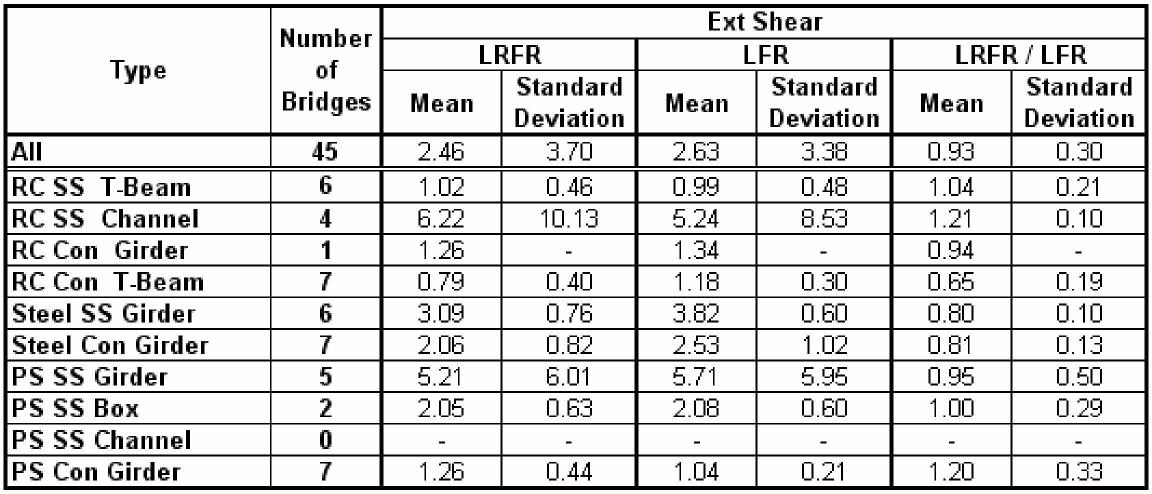
Shear statistics are reported for the interior and exterior girders in Table 5 - 13 and 5 - 14 respectively. For nearly all material and structural system types, for interior girders, the LRFR method produced nearly equal or lower rating results when compared to the LFR for shear. With the exception of prestressed concrete continuously supported girder bridges where the LRFR tended to produce higher rating factors than the LFR. Similar results were found for the exterior girders of the unique bridge sample.

Table 5 - 13: Mean and Standard Deviation Data at the Design Inventory Level for the Unique Bridge Sample – Interior Girder Shear Rating Data



Type	Number of Bridges	Int Shear					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	45	2.43	3.93	2.78	4.36	0.90	0.30
RC SS T-Beam	6	0.81	0.18	0.82	0.19	1.01	0.21
RC SS Channel	4	6.73	11.15	7.85	12.44	0.75	0.15
RC Con Girder	1	1.71	-	2.04	-	0.84	-
RC Con T-Beam	7	0.77	0.36	1.19	0.23	0.63	0.17
Steel SS Girder	6	2.69	0.56	3.40	0.79	0.80	0.09
Steel Con Girder	7	1.94	0.83	2.46	1.03	0.79	0.09
PS SS Girder	5	5.23	5.86	5.71	6.10	0.98	0.46
PS SS Box	2	2.29	1.23	2.09	0.64	1.05	0.23
PS SS Channel	0	-	-	-	-	-	-
PS Con Girder	7	1.29	0.39	1.00	0.16	1.29	0.35

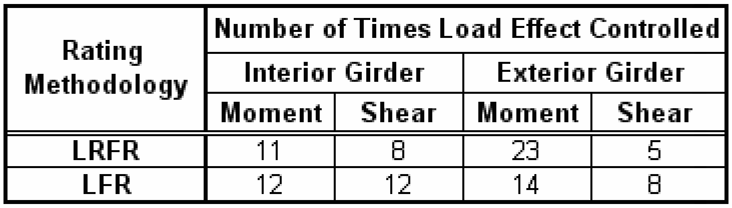
Table 5 - 14: Mean and Standard Deviation Data at the Design Inventory Level for the Unique Bridge Sample – Exterior Girder Shear Rating Data



Type	Number of Bridges	Ext Shear					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	45	2.46	3.70	2.63	3.38	0.93	0.30
RC SS T-Beam	6	1.02	0.46	0.99	0.48	1.04	0.21
RC SS Channel	4	6.22	10.13	5.24	8.53	1.21	0.10
RC Con Girder	1	1.26	-	1.34	-	0.94	-
RC Con T-Beam	7	0.79	0.40	1.18	0.30	0.65	0.19
Steel SS Girder	6	3.09	0.76	3.82	0.60	0.80	0.10
Steel Con Girder	7	2.06	0.82	2.53	1.02	0.81	0.13
PS SS Girder	5	5.21	6.01	5.71	5.95	0.95	0.50
PS SS Box	2	2.05	0.63	2.08	0.60	1.00	0.29
PS SS Channel	0	-	-	-	-	-	-
PS Con Girder	7	1.26	0.44	1.04	0.21	1.20	0.33

The final point of comparison for this sample of bridges was made to determine the controlling load effect for each rating methodology. Table 5 - 15 shows the results of this comparison. The data in this table was constructed by counting the number of times a rating factor for each load effect controlled for a bridge within the sample. The data indicates that for the LRFR methodology exterior girder moment load effect mainly controlled, similar to what was seen with the standard bridge sample. However this trend is less dominant as moment and shear load effects for the interior girder controlled a larger number of bridges for the unique bridge sample. For the LFR methodology however, the trend seen for the standard bridge sample is not seen at all as bridges in this sample were nearly evenly controlled across all load effects.

Table 5 - 15: Controlling Load Effect Comparison, Design Inventory Level for the Unique Bridge Sample



Rating Methodology	Number of Times Load Effect Controlled			
	Interior Girder		Exterior Girder	
	Moment	Shear	Moment	Shear
LRFR	11	8	23	5
LFR	12	12	14	8

Note: The unique bridge sample consists of 45 bridges

5.2.3 Combined Sample Comparison

The final comparison made at the Design Inventory level of rating was in studying the absolute controlling rating factor between the two rating methodologies. For this comparison, rating factor data was used from both the standard and unique bridge samples. The absolute controlling rating data used for these comparisons can be found in the previously shown Tables 5 - 1, 5 - 2, 5 - 9, and 5 - 10. Provided in Figure 5 - 8 is a LRFR versus LFR plot of the controlling rating data. From this plot it is seen that the majority of the data falls into Region 5 with only sporadic data found in Region 6. This indicates that the LRFR produced lower rating results than the LFR in general.

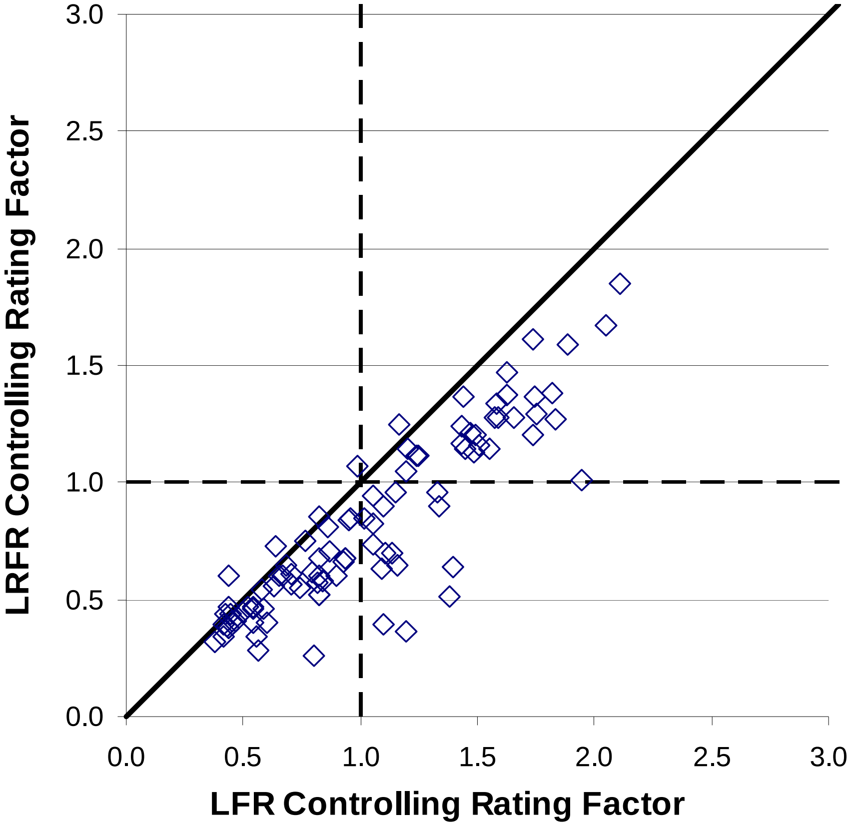
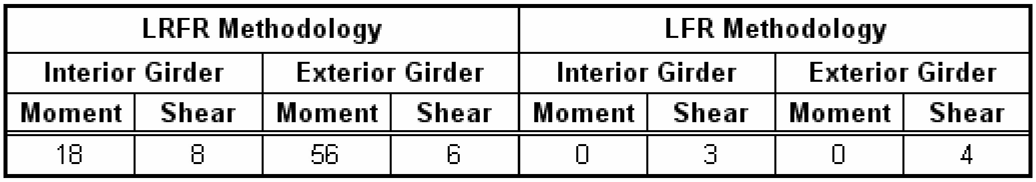


Figure 5 - 8: Controlling Rating Factor Comparisons at the Design Inventory Level

Additionally, the absolute controlling load effect and rating methodology was investigated; Table 5 - 16 shows the results of this investigation. The data provided in Table 5 - 16 is the total number of times each load effect and methodology controlled for the combined bridge samples. This data indicates that the LRFR exterior girder moment load effect primarily controlled. This finding is in agreement with the previously reported results showing the LRFR producing nearly equal or lower rating results than the LFR, in general. An additional point of observation, however, is that for the few occasions where the LFR methodology did control it was only for the shear load effect.

Table 5 - 16: Controlling Load Effect and Rating Methodology at the Design Inventory Level



LRFR Methodology				LFR Methodology			
Interior Girder		Exterior Girder		Interior Girder		Exterior Girder	
Moment	Shear	Moment	Shear	Moment	Shear	Moment	Shear
18	8	56	6	0	3	0	4

<u>Note</u>: The combined bridge sample consists of 95 bridges

5.2.4 Summary

Analysis of the standard and unique bridge samples at the design rating level provided the following general findings:

- LRFR methodology produces predominantly lower moment rating factors than the LFR methodology for exterior and interior girders.
- LRFR methodology produces predominantly lower shear rating factors than the LFR methodology for exterior and interior girders.
- Flexural rating factors predominantly controlled over shear rating factors for the LRFR methodology
- Flexural and shear rating factors nearly evenly controlled for the LFR methodology
- Moment rating factors for the Exterior girders tend to control over moment rating factors for the interior girders under the LRFR
- Prestressed bridges tend to have the highest LRFR to LFR ratio of the different material types

- C – Channel bridges tend to have unusual LRFR to LFR ratio when compared to other structural system types.

5.3 Legal Load Rating Results

The primary objective of this portion of the study is to compare rating factors produced by LRFR and LFR methodologies under ALDOT's own legal loads. Before the results of this primary investigation are presented, the findings of a sub-investigation are given in Section 5.3.1. This sub-investigation examines how the rating results produced under ALDOT's legal loads should be handled in the LRFR procedure; see Section 2.7 for the LRFR procedure description and flowchart. This sub-investigation was performed through a comparison of ALDOT's legal loads and AASHTO load models under the LRFR rating procedure. The rating results of comparisons between the LRFR and LFR methodologies for ALDOT legal loads are then presented in the following sections. Due to the unknown ADTT (Average Daily Truck Traffic) values for the standard bridge sample, a series of bounding studies were performed comparing the LRFR to the LFR. Results of these studies are presented in Section 5.3.2. ADTT information, however, was available for the unique bridge sample allowing for more explicit comparisons to be made for the two rating methodologies under ALDOT's legal loads. These rating results are presented in Section 5.3.3. A summary of the findings for all of the investigations made at the Legal load level of rating are provided in Section 5.3.4.

5.3.1 AASHTO Load Models and ALDOT Legal Loads Comparison

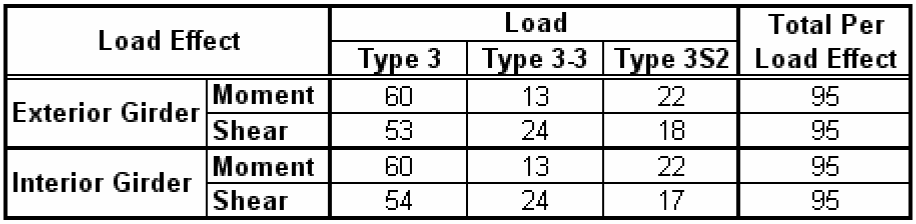
To determine whether or not the provisions for state legal loads can be applied to ALDOT legal loads, as outlined in Section 2.7, a comparison study was performed between ALDOT legal loads and the AASHTO load models. This comparative study is broken into two parts. The first part is a comparison between the controlling rating factors for the AASHTO standard legal loads and ALDOT legal loads at the Legal load level of rating. The second part is a comparison between the controlling rating factors for the HL-93 load model at the Design Inventory level of rating and ALDOT legal loads at the Legal load level of rating. Both parts of this study used the standard and unique bridge samples.

The first part of the study was conducted at the Legal load level of rating and used the following assumptions. The condition factor, ϕ_c, is set to 1.0 and system factor, ϕ_s, was allowed to vary as defined in the AASTHO MCE LRFR (2003). However, for this study, all the bridges included have a system factor, ϕ_s equal to 1.0 according to the specification. For the standard bridge sample, the live load factor, λ_L, was taken as 1.4. For the unique bridge sample, λ_L was determined based on each bridge's unique ADTT as provided by ALDOT. For bridges from the unique bridge sample with unknown ADTT values, λ_L was assumed to be 1.8 according to the AASTHO MCE LRFR (2003).

The first part of the study considered eight ALDOT legal loads and three AASHTO legal loads, at the Legal load level of the LRFR. However for ease of comparison only the controlling load from the ALDOT legal loads, see Section 2.9.2, and AASHTO legal loads, see Section 2.9.2, are compared. The controlling load for a given bridge is defined as the load which produced the lowest rating factor. Tables 5 - 17 and 5

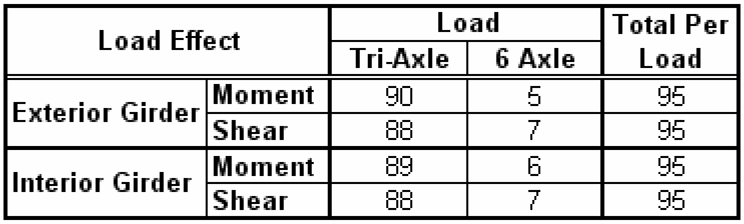
- 18 show the number of times an AASHTO and ALDOT legal load, respectively, controlled for each load effect. Each of the AASHTO legal loads controlled segments of the bridge within the study with the Type 3 load controlling the most. Within the ALDOT legal loads, the Tri-Axle load predominantly controlled across all load effects, with the 6-Axle load occasionally controlling.

Table 5 - 17: Controlling AASHTO Legal Loads



Load Effect		Load			Total Per Load Effect
		Type 3	Type 3-3	Type 3S2	
Exterior Girder	Moment	60	13	22	95
	Shear	53	24	18	95
Interior Girder	Moment	60	13	22	95
	Shear	54	24	17	95

Table 5 - 18: Controlling ALDOT Legal Loads



Load Effect		Load		Total Per Load
		Tri-Axle	6 Axle	
Exterior Girder	Moment	90	5	95
	Shear	88	7	95
Interior Girder	Moment	89	6	95
	Shear	88	7	95

The LRFR rating results from the controlling AASHTO and ALDOT legal loads are compared in Figures 5 - 9 and 5 - 10 for moment and shear, respectively. The plots are set up in an ALDOT controlling rating factor versss AASHTO controlling rating factor fashion. Therefore, data falling above the solid diagonal line would indicate ALDOT legal loads controlled over AASHTO Legal Loads and vice versa for data below the diagonal line.

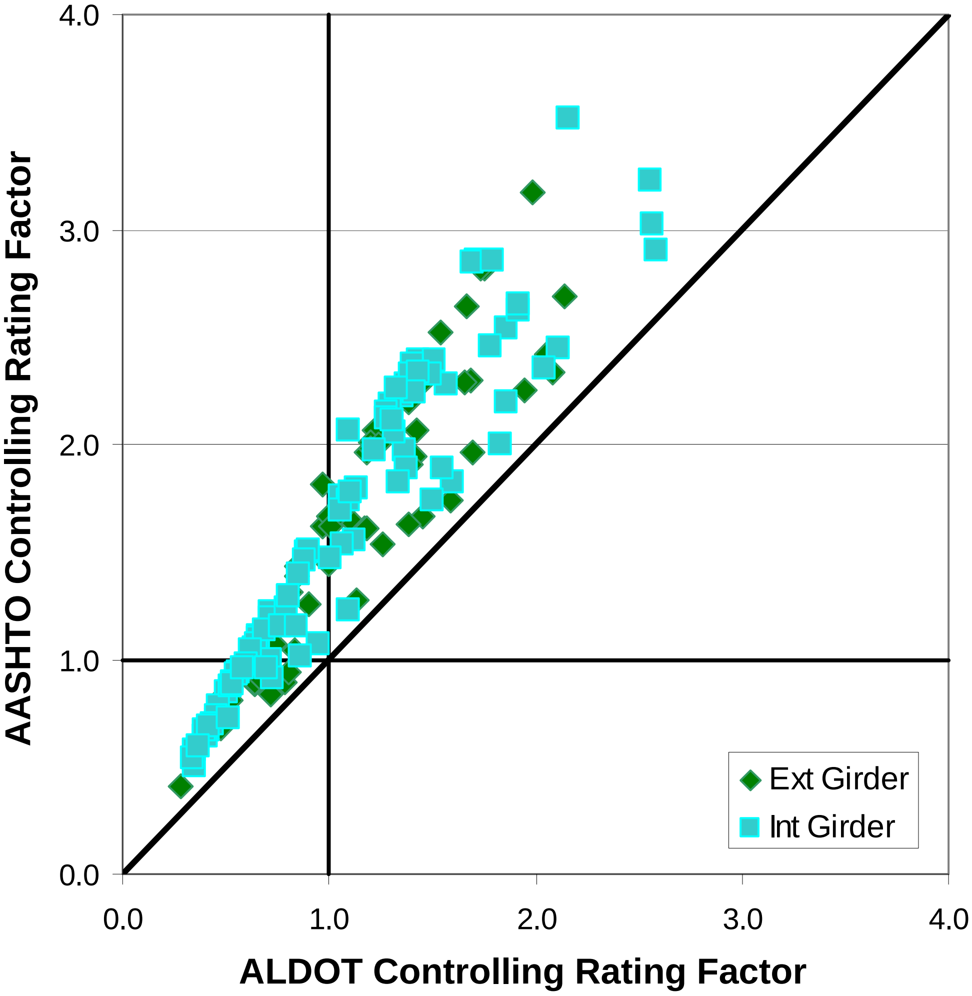


Figure 5 - 9: LRFR Moment Rating Factor under AASHTO and ALDOT Legal Loads

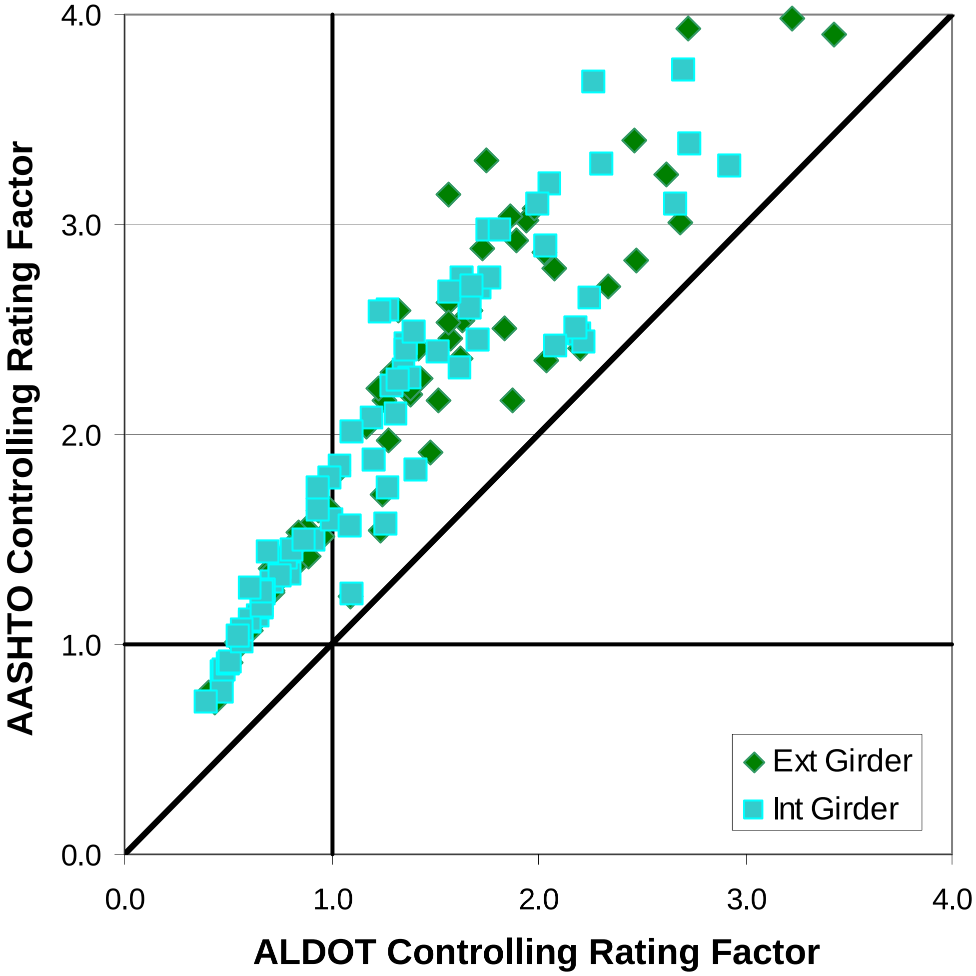


Figure 5 - 10: LRFR Shear Rating Factor under AASHTO and ALDOT Legal Loads

For both load effects, and for exterior and interior girders, all the rating factor data can be found in Region 6 of the plots showing that ALDOT legal loads always produce lower rating factors than AASHTO legal loads. This indicates that ALDOT legal loads are not enveloped by AASHTO legal loads. The current LRFR rating procedure, discussed in Section 2.7, indicates that a bridge may be evaluated for permit loads if it has a satisfactory rating at the Legal load level for either AASHTO or State legal loads (AASHTO 2003). Because ALDOT legal loads are not enveloped by AASHTO Legal loads, it is therefore that ALDOT legal loads be used instead of AASHTO Legal loads for load posting decisions and for determinations on whether a bridge can be evaluated for overweight loads.

The second part of the comparative study was done between the ALDOT legal loads and the AASHTO HL-93 live load model, see Section 2.9.1. In this part of the comparison the same factors as described in first part of the study were used. Rating results for ALDOT legal loads at the Legal load level are compared to the rating results from the HL-93 load model at the Design Inventory level, for which λ_L is equal to 1.75. As stated before, the comparisons presented here are for the controlling rating factor for both the ALDOT legal loads to the HL-93 load model. Figures 5 - 11 and 5 - 12 present the moment and shear rating factor data, respectively.

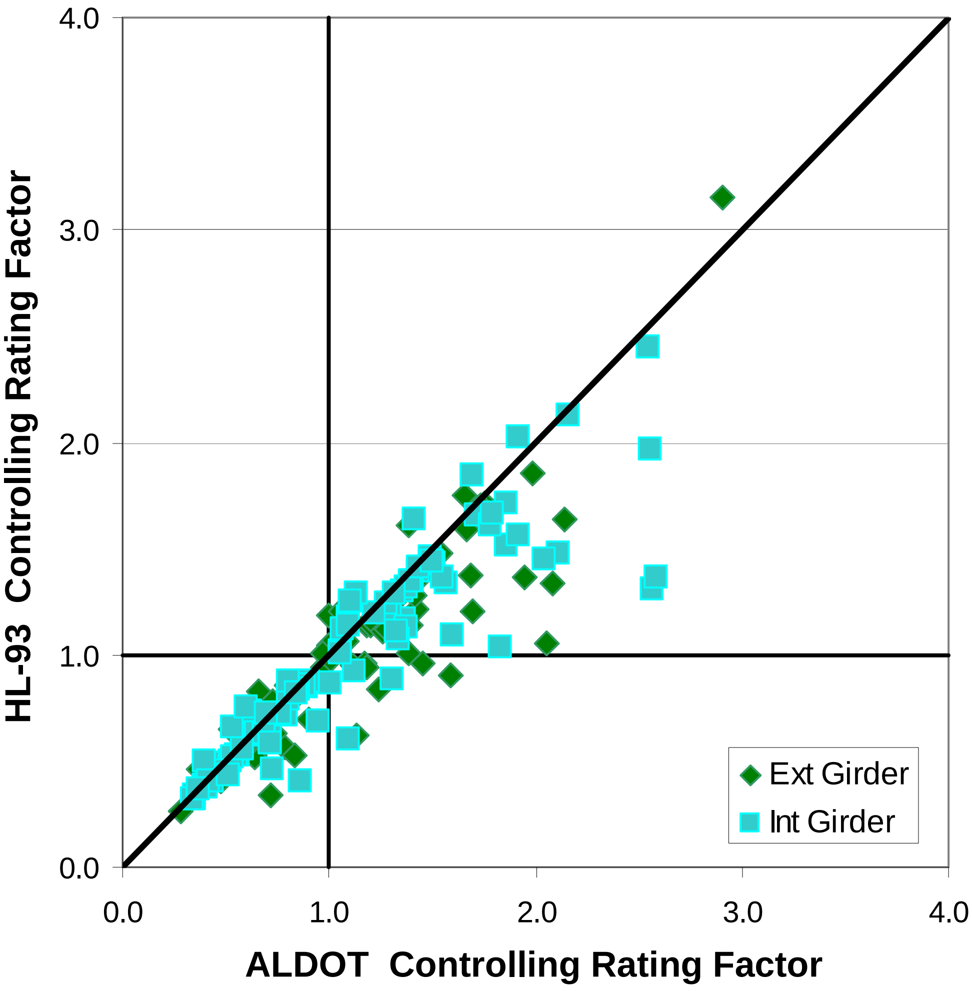


Figure 5 - 11: LRFR Moment Rating Factor under HL-93 Load Model and ALDOT Legal Loads

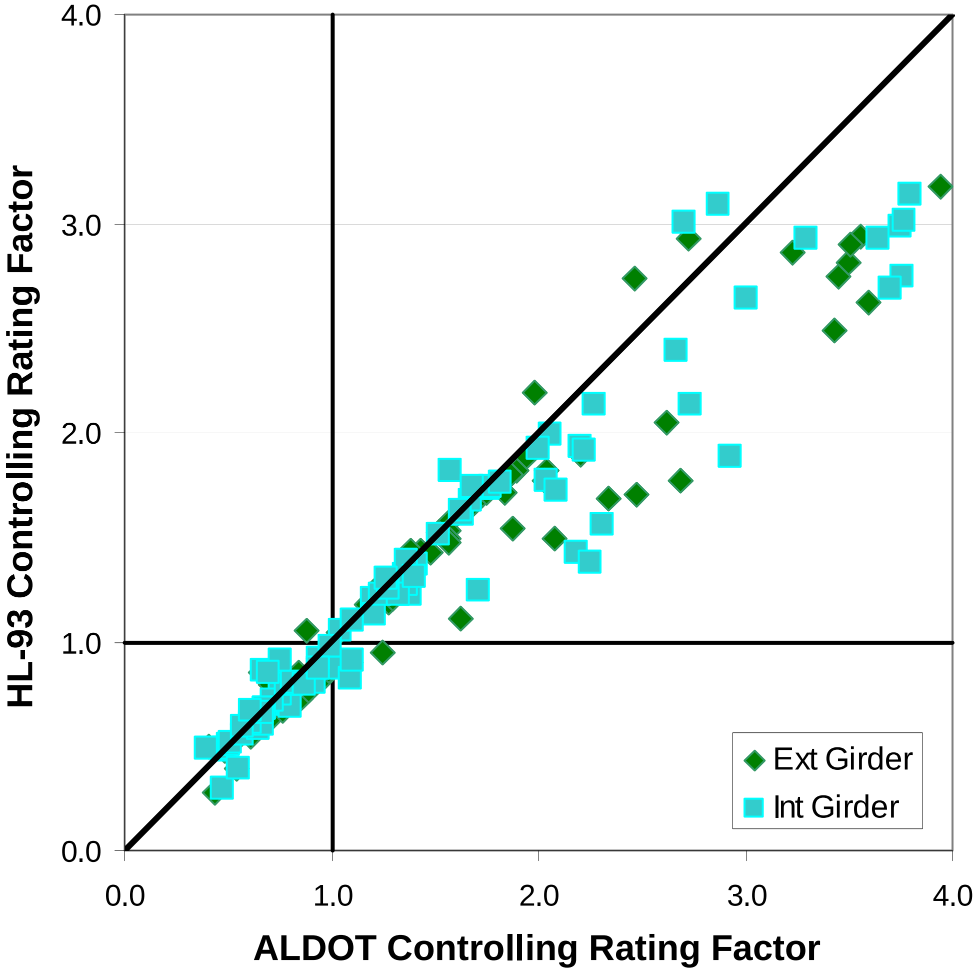


Figure 5 - 12: LRFR Shear Rating Factor under HL-93 Load Model and ALDOT Legal Loads

Data from these plots can be found in both Region 5 and 6 for each load effect and for interior and exterior girders. This shows that the HL-93 load model does not always envelope ALDOT's legal loads. This observation is in agreement with Hayworth's findings in a 2008 study comparing several different states' legal loads to the different AASHTO load models. Hayworth (2008) discovered that state legal loads are not always enveloped by the AASHTO legal load models and the HL-93 load model.

The implication of this for ALDOT is that even for bridges that are found to be satisfactory at the Design Inventory level of rating under the HL-93 load model, posting restrictions for the heavier ALDOT legal loads may still be required. Therefore to insure a bridge does not require posting, rating analysis at the Legal load level under ALDOT legal loads will always be required even if the rating factor under the AASHTO design or legal loads is satisfactory.

5.3.2 Standard Bridge Sample

Comparisons made at the legal load level for the standard bridge sample are broken into three bounding studies. This was necessary because the bridges in the standard bridge sample did not have unique ADTT values; due to this the LRFR rating factor data generated are based on assumed live load factors. However, this allowed for the effects of several different factors in the LRFR methodology to be studied. The rating factor data generated for these studies was gathered from rating analysis performed at the Legal load level of rating for the LRFR and the Operating level of the LFR under ALDOT legal loads. The three bounding studies were performed by varying the live load factor, λ_L, and the product of the condition factor, ϕ_c, and system factor, ϕ_s. The first bounding study shows the effect of varying λ_L from 1.4 and 1.8 while keeping the product of ϕ_c and ϕ_s at 1.0. The second bounding study shows the effect of the product of ϕ_c and ϕ_s varying from 1.0 to 0.85 while keeping λ_L at 1.4. The third bounding study shows the possible effect that actual ADTT values can have on λ_L and the LRFR rating factor. Within this third study, three unique ADTT values were provided for each standard bridge used, bounding the λ_L factors for each bridge; while ϕ_c and ϕ_s were held at 1.0.

5.3.2.1 λ_L Bounding Study Results

The λ_L factor for the LRFR at the Legal rating level can range from 1.4 to 1.8 depending on a bridge’s ADTT (AASHTO 2003). This variation of λ_L can change a bridge’s rating factor by nearly 30% under the LRFR. This bounding study shows how this variation in λ_L can influence LRFR and LFR comparisons. The LRFR and LFR data that are presented in this section are limited to the controlling ALDOT truck for each load effect, for both interior and exterior girders.

Results for the interior girder are shown in Figures 5 - 13 and 5 - 14 for moment and shear load effects, respectively. For moment load effects, the LRFR produced lower rating results than LFR independent of λ_L, with all the data falling within Region 5 of the plot. This trend is similar to what was seen at the Inventory level of rating. The variation of λ_L only served to amplify the degree to which the LRFR rating factors are below the LFR factors. This would be especially important in cases where posting is required (i.e. for bridges with rating factors below 1.0). The shear results for the majority were also found within Region 5. However the possible influence λ_L can have is seen on the few shear rating results found in region 6 for λ_L equal to 1.4. Two of these bridges when λ_L is increased to 1.8 fall into Region 5 changing the rating method that controlled them from LFR to LRFR Similar results were found for the exterior girders for the standard bridge sample as seen in Figures 5 - 15 and 5 - 16 for moment and shear, respectively.

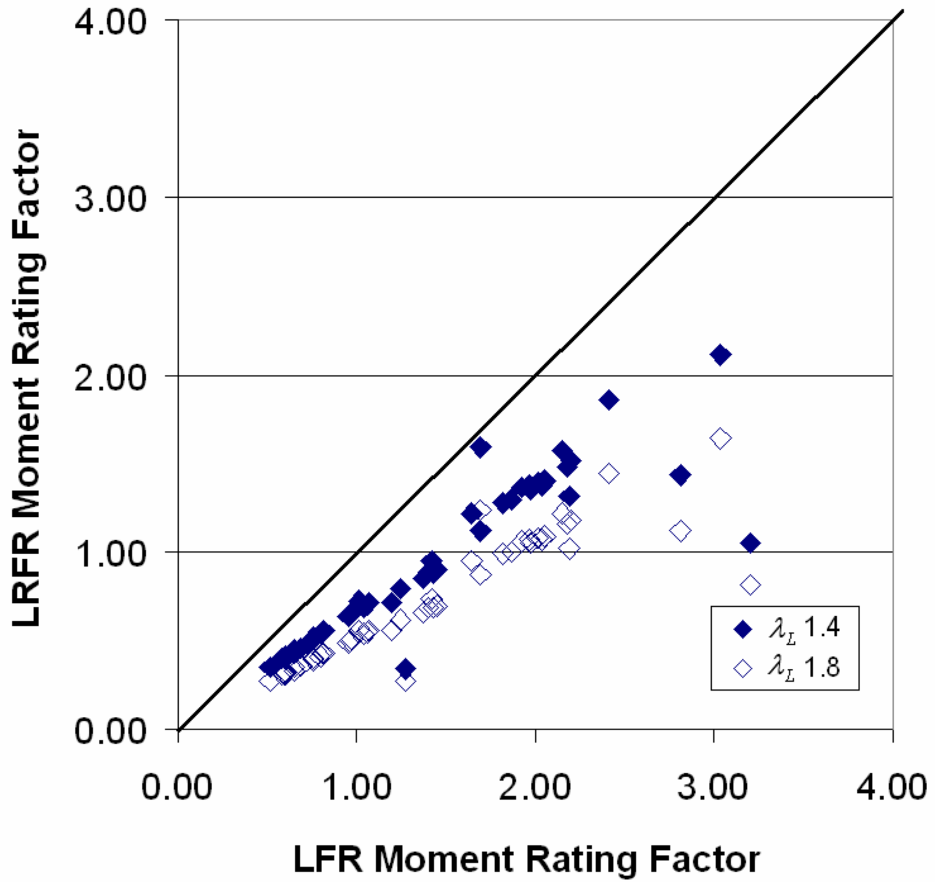


Figure 5 - 13: Effect of varying λ_L on Moment Rating at the Legal Level for Interior Girders

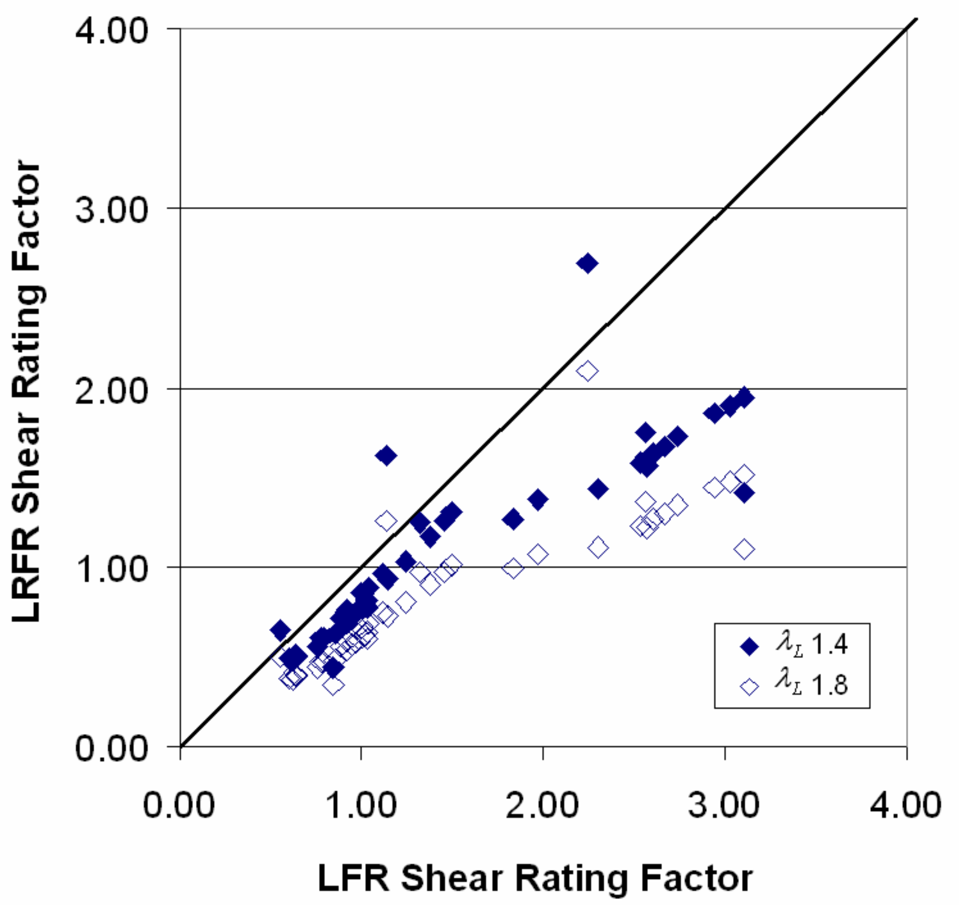


Figure 5 - 14: Effect of varying λ_L on Shear Rating at the Legal Level for Interior Girders

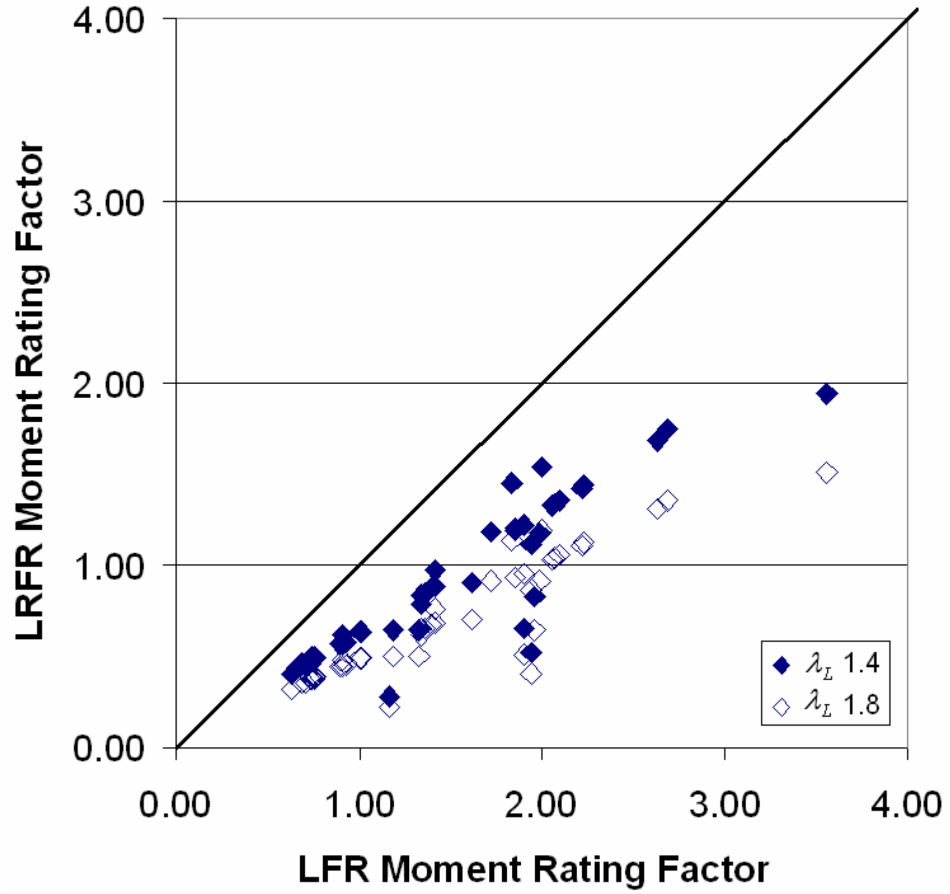


Figure 5 - 15: Effect of varying λ_L on Moment Rating at the Legal Level for Exterior Girders

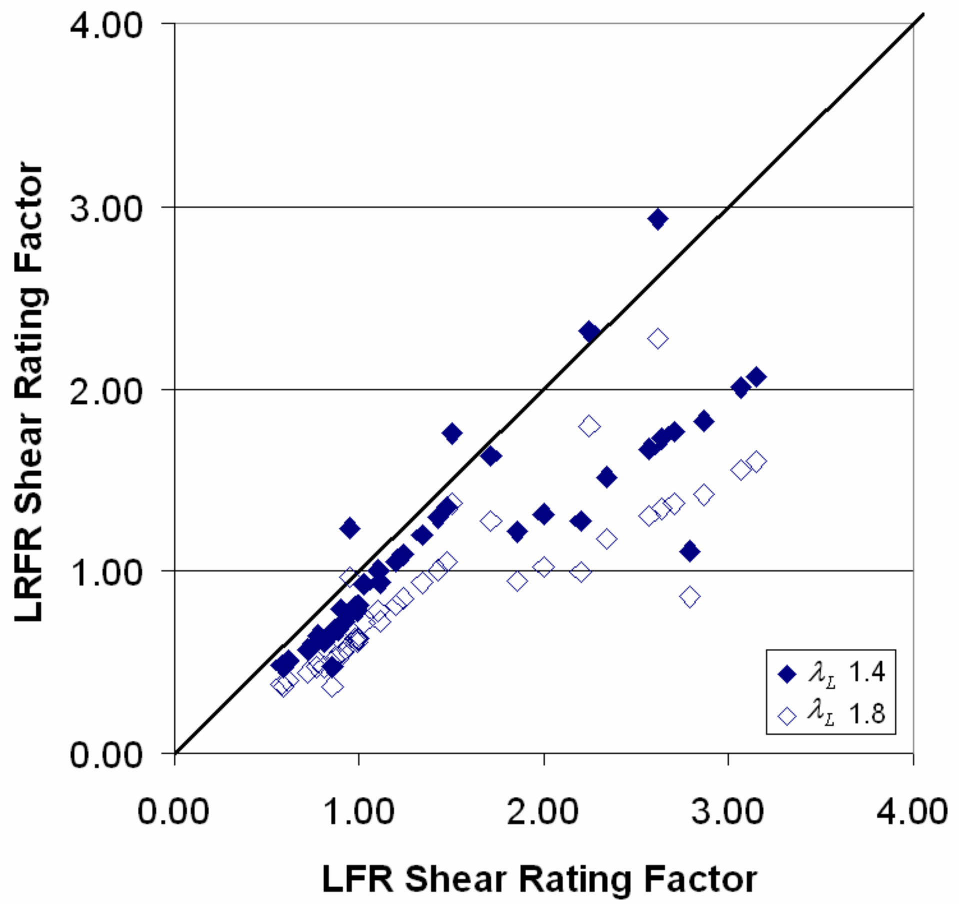


Figure 5 - 16: Effect of varying λ_L on Shear Rating at the Legal Level for Exterior Girders

5.3.2.2 ϕ_c and ϕ_s Bounding Study Results

According to the AASHTO MCE LRFR (2003), the product of the condition factor, ϕ_c, and system factor, ϕ_s cannot be taken less than 0.85. To study the effect that the product of ϕ_c and ϕ_s can have on the rating results for ALDOT's legal loads, a bounding study was performed on the combined effect of the factors. For this study the LFR Operating level rating results, which remain the same, are compared to the bounded results of the LRFR at the Legal load level with the product of ϕ_c and ϕ_s effect ranging from 0.85 to 1.0. The live load factor, λ_L, for this study is fixed at 1.4. The AASHTO MCE 2005 allows ϕ_s to be greater than 1.0, when higher order analysis is performed to determine a member specific structural redundancy; however, this effect was not studied.

Comparisons of the rating results for interior girders of the standard bridge sample are shown in Figures 5 - 17 and 5 - 18 for moment and shear, respectively. The effect of the product of ϕ_c and ϕ_s on the rating comparisons between LRFR and LFR is very similar to what was seen in the bounded study of λ_L. All the moment rating data is once again found in Region 5 of Figure 5 - 17 for the combined $\phi_c\phi_s$ effect equal to 0.85 and 1.0. The only change lowering the combined $\phi_c\phi_s$ effect had, was to increase the degree to which LRFR produced lower factors than LFR. Unlike changes in λ_L, which had a fixed effect on a bridge's rating factor, changes to the product of ϕ_c and ϕ_s have varying impacts on different bridge's rating factors due their effect on the factored resistance of a member. Shear data predominately was found within Region 5 of Figure 5 - 18 with few exceptions in Region 6. Similar to the trend seen for λ_L when $\phi_c\phi_s$ is reduced, the parts of the data found in Region 6 shift to Region 5. Similar trends were seen for exterior girders as seen in Figures 5 - 19 and 5 - 20 for moment and shear, respectively.

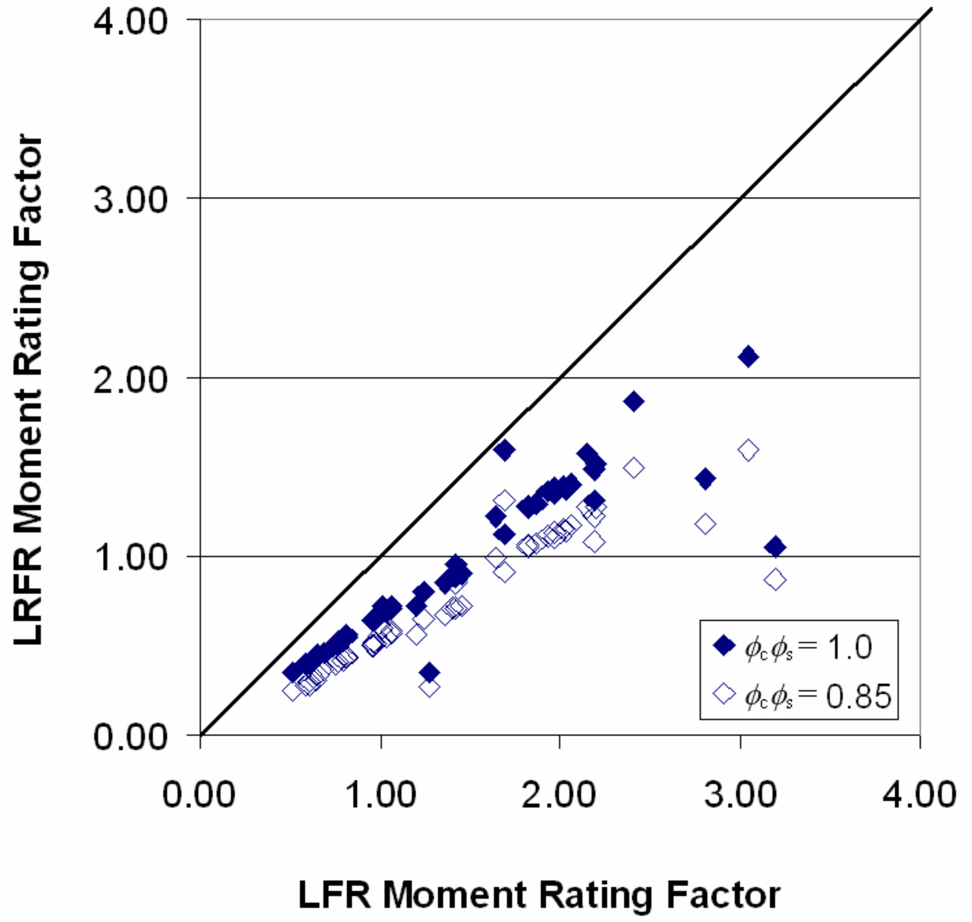


Figure 5 - 17: Effect of varying ϕ_c and ϕ_s, on Moment Rating at the Legal Level for Interior Girders

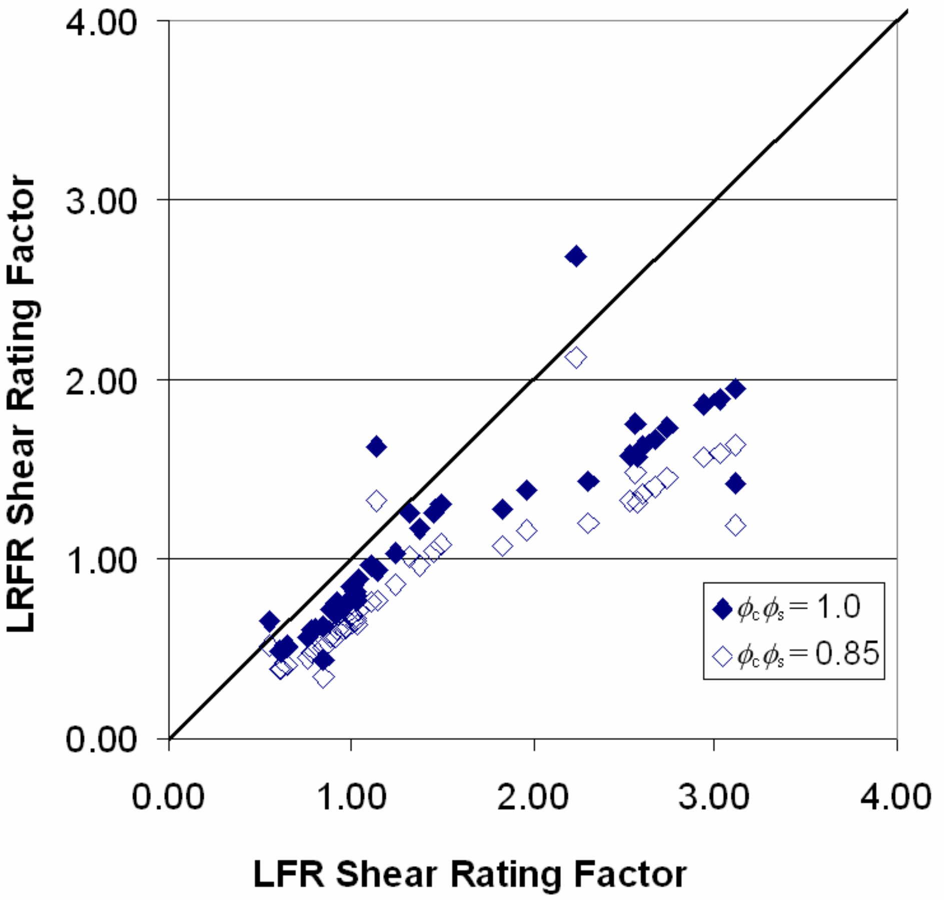


Figure 5 - 18: Effect of varying ϕ_c and ϕ_s, on Shear Rating at the Legal Level for Interior Girders

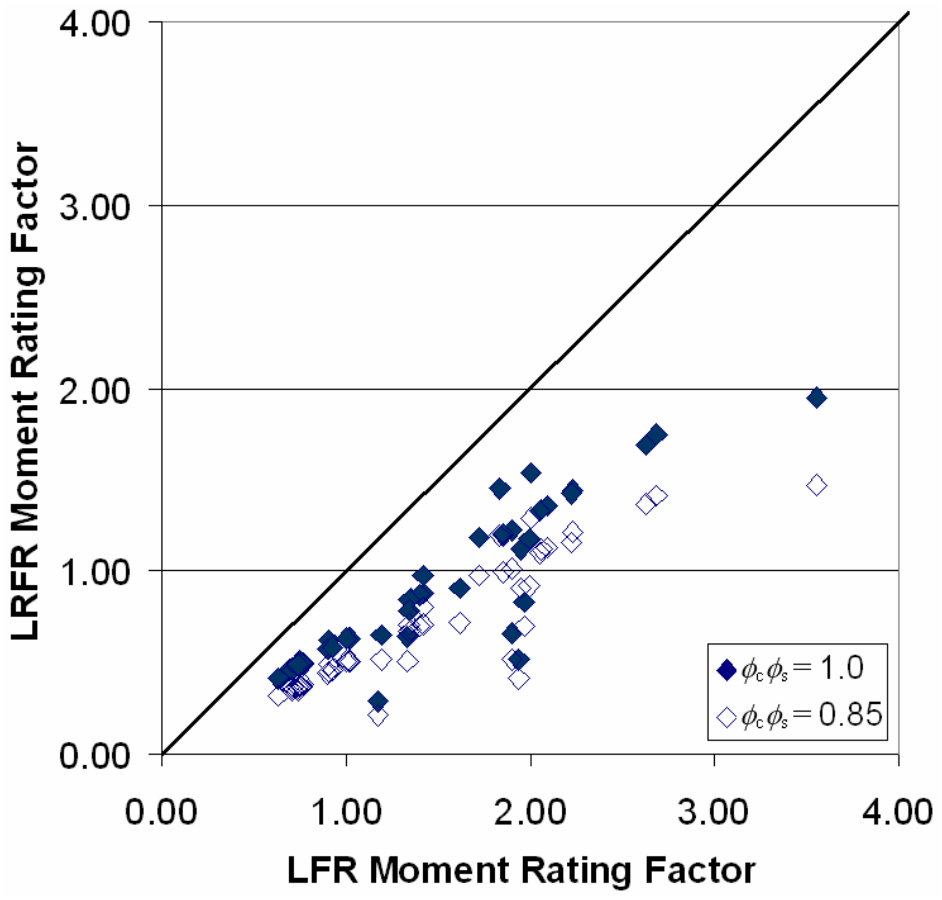


Figure 5 - 19: Effect of varying ϕ_c and ϕ_s, on Moment Rating at the Legal Level for Exterior Girders

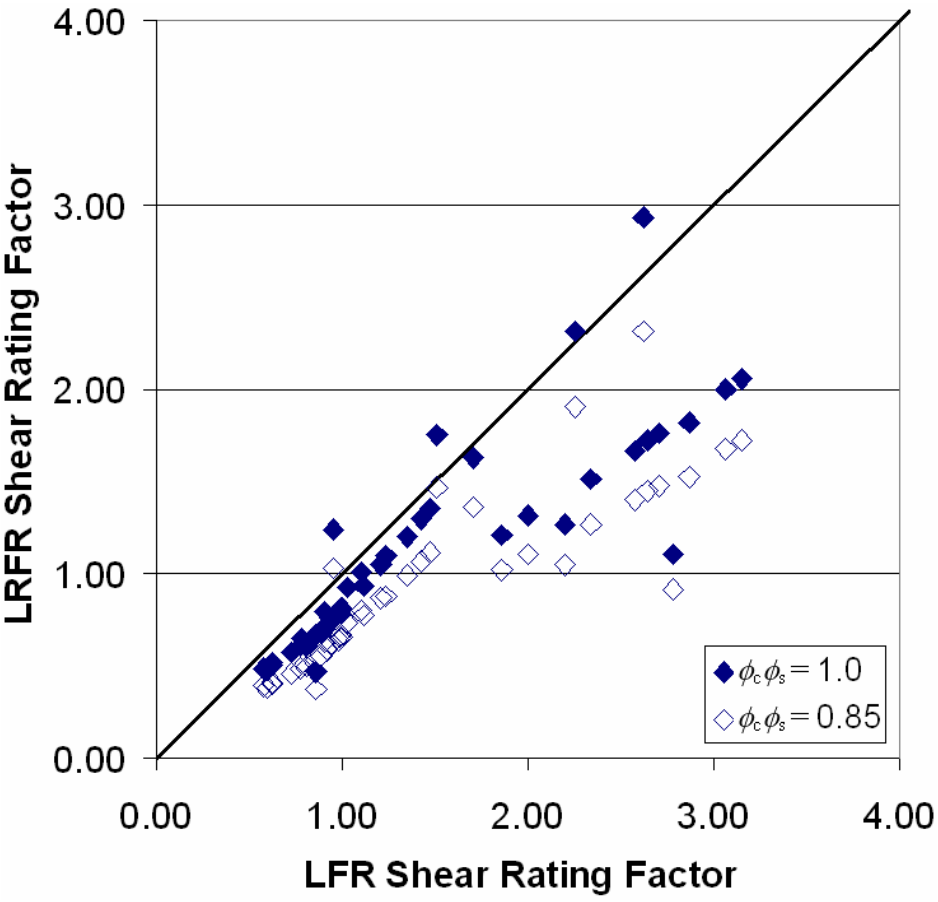
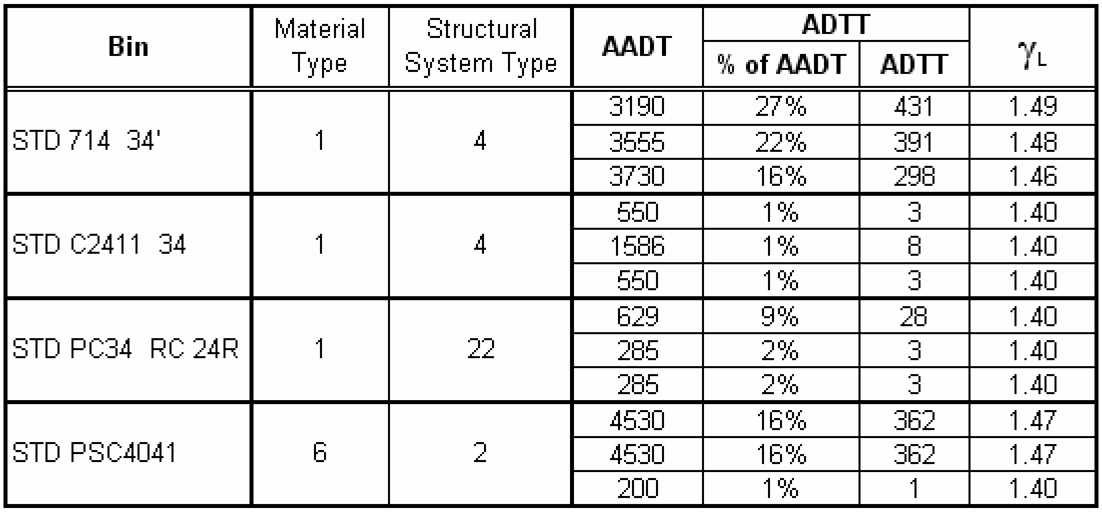


Figure 5 - 20: Effect of varying ϕ_c and ϕ_s, on Shear Rating at the Legal Level for Exterior Girders

5.3.2.3 Varying ADTT Bounding Study Results

The standard bridge sample is composed of bridges that are used repeatedly throughout Alabama's bridge inventory. As a result, each bridge in the sample does not have unique ADTT, average daily truck traffic, data. To provide a reference point as to how actual ADTT values on standard bridges will affect rating results under the LRFR a small sample of bridges were analyzed using multiple ADTT values. ALDOT provided three different ADTT values for four standard bridges for the study, shown in Table 5 – 19. Additionally, in Table 5 – 19 are the corresponding λ_L values for the ADTT data provided by ALDOT. Bridges “STD C2411 34” and “STD PC34 RC 24R” have a the same λ_L due to the relationship between ADTT and λ_L; this relationship is described in Section 2.5.

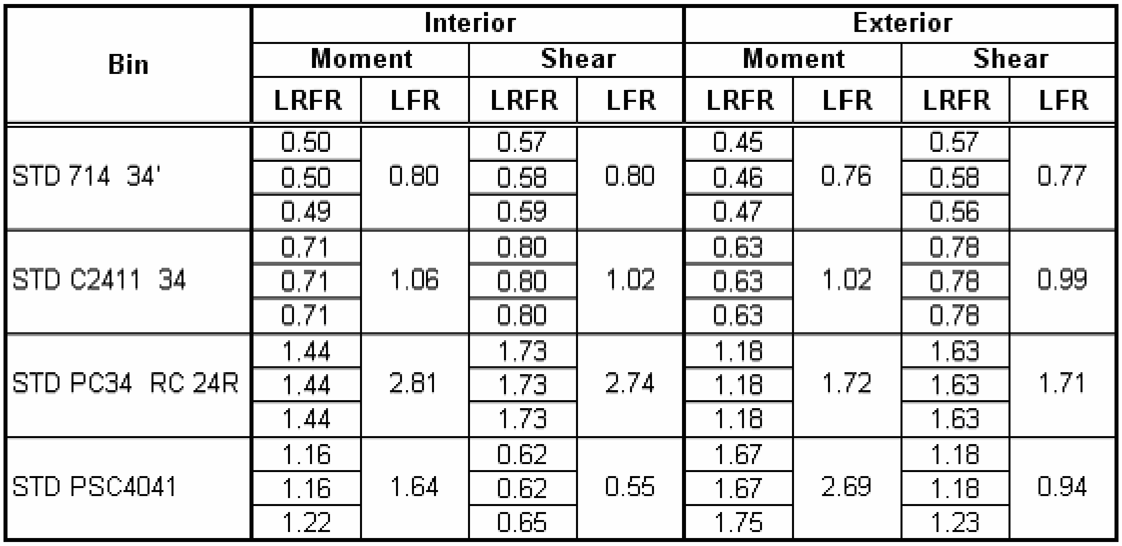
Table 5 - 19: Standard Bridge Varying ADTT Values



Bin	Material Type	Structural System Type	AADT	ADTT		γ_L
				% of AADT	ADTT	
STD 714 34'	1	4	3190	27%	431	1.49
			3555	22%	391	1.48
			3730	16%	298	1.46
STD C2411 34	1	4	550	1%	3	1.40
			1586	1%	8	1.40
			550	1%	3	1.40
STD PC34 RC 24R	1	22	629	9%	28	1.40
			285	2%	3	1.40
			285	2%	3	1.40
STD PSC4041	6	2	4530	16%	362	1.47
			4530	16%	362	1.47
			200	1%	1	1.40

The lack of change in λ_L factors provided in Table 5 - 19 is due to the low ADTT values for the studied bridges. The selected bridges, using their unique λ_L factors, were analyzed under ALDOT’s legal loads for LRFR at the Legal load level of rating. The rating results from the controlling legal load are provided in Table 5 - 20 along with corresponding LFR factors. Similar to what has been seen before, the LRFR produced lower rating factors than the LFR. Additionally, as λ_L increased due to higher ADTT values, the difference between the LRFR and LFR factors increase.

Table 5 - 20: Standard Bridge Sample Rating Results, Legal level, Varying ADTT Structural System Type



Bin	Interior				Exterior			
	Moment		Shear		Moment		Shear	
	LRFR	LFR	LRFR	LFR	LRFR	LFR	LRFR	LFR
STD 714 34'	0.50	0.80	0.57	0.80	0.45	0.76	0.57	0.77
	0.50		0.58		0.46		0.58	
	0.49		0.59		0.47		0.56	
STD C2411 34	0.71	1.06	0.80	1.02	0.63	1.02	0.78	0.99
	0.71		0.80		0.63		0.78	
	0.71		0.80		0.63		0.78	
STD PC34 RC 24R	1.44	2.81	1.73	2.74	1.18	1.72	1.63	1.71
	1.44		1.73		1.18		1.63	
	1.44		1.73		1.18		1.63	
STD PSC4041	1.16	1.64	0.62	0.55	1.67	2.69	1.18	0.94
	1.16		0.62		1.67		1.18	
	1.22		0.65		1.75		1.23	

5.3.3 Unique Bridge Sample

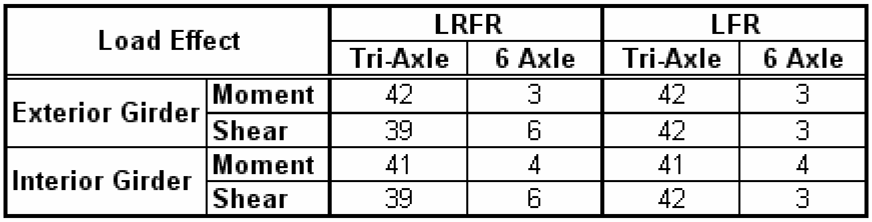
Comparisons made for the unique bridge sample are presented between the LRFR at the Legal Load level and the LFR at the Operating level under ALDOT legal loads. The following assumptions were used for the LRFR analysis:

- ϕ_c set to 1.0
- ϕ_s as specified in the AASHTO MCE LRFR 2003

  (1.0 for every bridge in sample)
- λ_L based on bridge-specific ADTT

The rating comparisons made in this section are for the controlling ALDOT legal load. Similar to the results found for the standard bridge studies, the Tri-Axle and 6-Axle loads produced the lowest rating factor results, or controlling rating factors. Table 5 – 21 provides a summary of the number of times each truck controlled for LRFR and LFR, for each load effect, and for both interior and exterior girders.

Table 5 - 21: Controlling ALDOT Truck Comparison at Legal Level for the Unique Bridge Sample



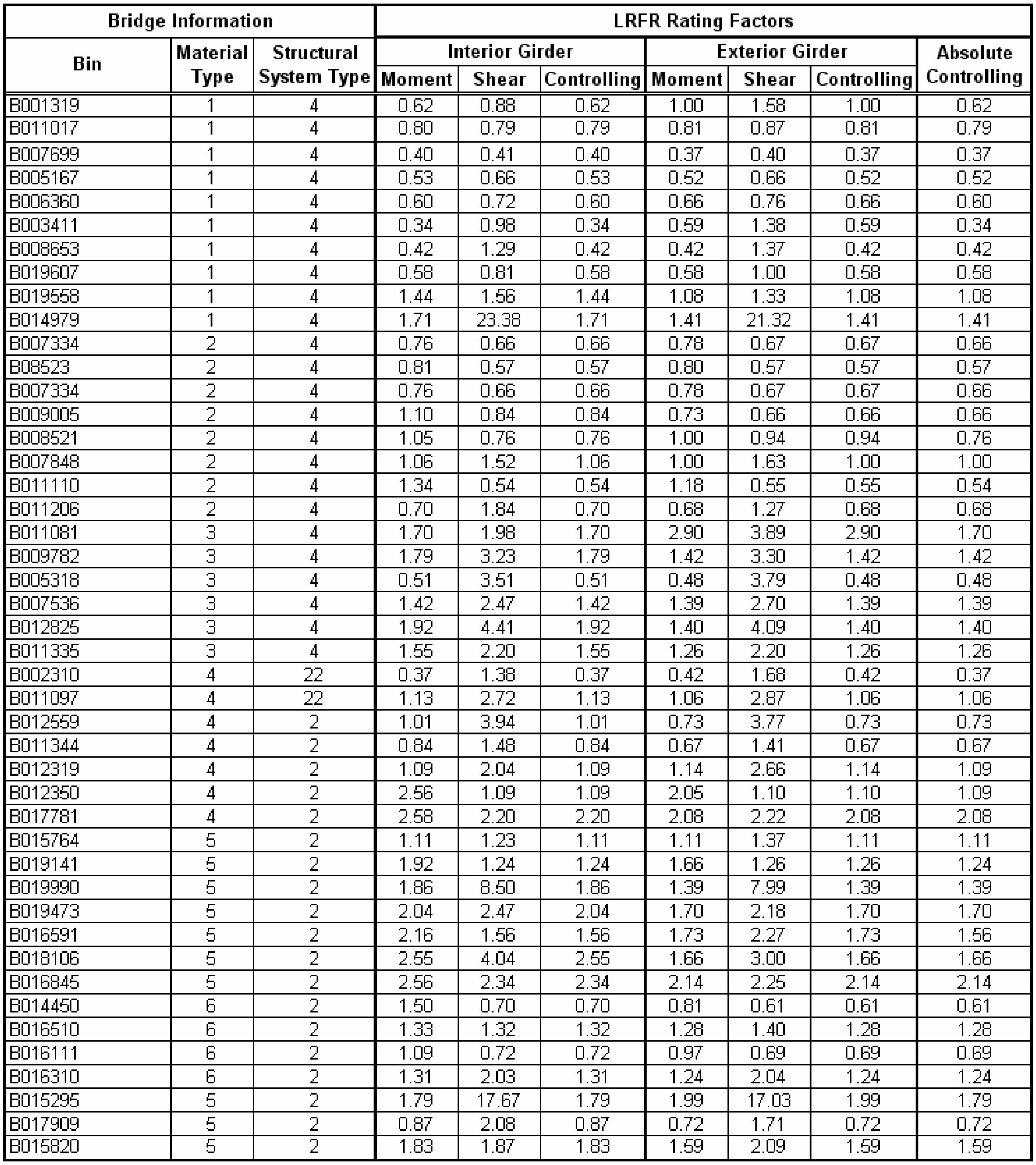
Load Effect		LRFR		LFR	
		Tri-Axle	6 Axle	Tri-Axle	6 Axle
Exterior Girder	Moment	42	3	42	3
	Shear	39	6	42	3
Interior Girder	Moment	41	4	41	4
	Shear	39	6	42	3

The presentation of the data for the unique bridge sample is broken down into the following sections to highlight the different trends that were found. Section 5.3.3.1 provides an overall summary of the LRFR and LFR rating factor data compared at this Legal load level under ALDOT Legal loads. Section 5.3.3.2 looks at how the age of the bridge may influence the rating data. Section 5.3.3.3 briefly discusses the relationships between span length and girder spacing on the rating results. Section 5.3.3.4 presents the suggested load posting for the unique bridge sample based on the AASHTO MCE LRFR (2003) recommendations.

5.3.3.1 Overall Summary

A summary of the rating factors used for the unique bridge sample (refer to Section 3.1.2) comparisons at the Legal load level of rating are provided in Table 5 - 22 and 5 - 23. Table 5 - 22 provides the moment and shear rating factors generated for both the interior and exterior girders for each bridge in the sample, under the LRFR methodology. Additionally, the controlling rating factor for the interior and exterior girders are identified, as well as the controlling rating factor for the bridge. Table 5 - 23 provides the same rating factor information as Table 5 - 22 but for the LFR methodology.

Table 5 - 22: LRFR Rating Factors Generated for the Unique Bridge Sample at the Legal Load Rating Level



Bridge Information			LRFR Rating Factors						
Bin	Material Type	Structural System Type	Interior Girder			Exterior Girder			Absolute Controlling
			Moment	Shear	Controlling	Moment	Shear	Controlling	
B001319	1	4	0.62	0.88	0.62	1.00	1.58	1.00	0.62
B011017	1	4	0.80	0.79	0.79	0.81	0.87	0.81	0.79
B007699	1	4	0.40	0.41	0.40	0.37	0.40	0.37	0.37
B005167	1	4	0.53	0.66	0.53	0.52	0.66	0.52	0.52
B006360	1	4	0.60	0.72	0.60	0.66	0.76	0.66	0.60
B003411	1	4	0.34	0.98	0.34	0.59	1.38	0.59	0.34
B008653	1	4	0.42	1.29	0.42	0.42	1.37	0.42	0.42
B019607	1	4	0.58	0.81	0.58	0.58	1.00	0.58	0.58
B019558	1	4	1.44	1.56	1.44	1.08	1.33	1.08	1.08
B014979	1	4	1.71	23.38	1.71	1.41	21.32	1.41	1.41
B007334	2	4	0.76	0.66	0.66	0.78	0.67	0.67	0.66
B08523	2	4	0.81	0.57	0.57	0.80	0.57	0.57	0.57
B007334	2	4	0.76	0.66	0.66	0.78	0.67	0.67	0.66
B009005	2	4	1.10	0.84	0.84	0.73	0.66	0.66	0.66
B008521	2	4	1.05	0.76	0.76	1.00	0.94	0.94	0.76
B007848	2	4	1.06	1.52	1.06	1.00	1.63	1.00	1.00
B011110	2	4	1.34	0.54	0.54	1.18	0.55	0.55	0.54
B011206	2	4	0.70	1.84	0.70	0.68	1.27	0.68	0.68
B011081	3	4	1.70	1.98	1.70	2.90	3.89	2.90	1.70
B009782	3	4	1.79	3.23	1.79	1.42	3.30	1.42	1.42
B005318	3	4	0.51	3.51	0.51	0.48	3.79	0.48	0.48
B007536	3	4	1.42	2.47	1.42	1.39	2.70	1.39	1.39
B012825	3	4	1.92	4.41	1.92	1.40	4.09	1.40	1.40
B011335	3	4	1.55	2.20	1.55	1.26	2.20	1.26	1.26
B002310	4	22	0.37	1.38	0.37	0.42	1.68	0.42	0.37
B011097	4	22	1.13	2.72	1.13	1.06	2.87	1.06	1.06
B012559	4	2	1.01	3.94	1.01	0.73	3.77	0.73	0.73
B011344	4	2	0.84	1.48	0.84	0.67	1.41	0.67	0.67
B012319	4	2	1.09	2.04	1.09	1.14	2.66	1.14	1.09
B012350	4	2	2.56	1.09	1.09	2.05	1.10	1.10	1.09
B017781	4	2	2.58	2.20	2.20	2.08	2.22	2.08	2.08
B015764	5	2	1.11	1.23	1.11	1.11	1.37	1.11	1.11
B019141	5	2	1.92	1.24	1.24	1.66	1.26	1.26	1.24
B019990	5	2	1.86	8.50	1.86	1.39	7.99	1.39	1.39
B019473	5	2	2.04	2.47	2.04	1.70	2.18	1.70	1.70
B016591	5	2	2.16	1.56	1.56	1.73	2.27	1.73	1.56
B018106	5	2	2.55	4.04	2.55	1.66	3.00	1.66	1.66
B016845	5	2	2.56	2.34	2.34	2.14	2.25	2.14	2.14
B014450	6	2	1.50	0.70	0.70	0.81	0.61	0.61	0.61
B016510	6	2	1.33	1.32	1.32	1.28	1.40	1.28	1.28
B016111	6	2	1.09	0.72	0.72	0.97	0.69	0.69	0.69
B016310	6	2	1.31	2.03	1.31	1.24	2.04	1.24	1.24
B015295	5	2	1.79	17.67	1.79	1.99	17.03	1.99	1.79
B017909	5	2	0.87	2.08	0.87	0.72	1.71	0.72	0.72
B015820	5	2	1.83	1.87	1.83	1.59	2.09	1.59	1.59

Table 5 - 23: LFR Rating Factors Generated for the Unique Bridge Sample at the Legal Load Rating Level

Bridge Information			LFR Rating Factors						
Bin	Material Type	Structural System Type	Interior Girder			Exterior Girder			Absolute Controlling
			Moment	Shear	Controlling	Moment	Shear	Controlling	
B001319	1	4	1.18	1.59	1.18	1.84	2.65	1.84	1.18
B011017	1	4	1.19	0.94	0.94	1.27	1.00	1.00	0.94
B007699	1	4	0.74	1.05	0.74	0.74	1.05	0.74	0.74
B005167	1	4	1.00	0.96	0.96	1.06	1.02	1.02	0.96
B006360	1	4	1.17	1.11	1.11	1.31	1.12	1.12	1.11
B003411	1	4	0.52	1.36	0.52	1.03	1.62	1.03	0.52
B008653	1	4	1.05	2.39	1.05	0.66	1.58	0.66	0.66
B019607	1	4	1.66	1.90	1.66	0.90	1.03	0.90	0.90
B019558	1	4	2.77	2.52	2.52	1.56	1.44	1.44	1.44
B014979	1	4	3.26	27.87	3.26	2.22	27.87	2.22	2.22
B007334	2	4	1.39	1.53	1.39	1.37	1.49	1.37	1.37
B08523	2	4	1.68	1.37	1.37	1.63	1.32	1.32	1.32
B007334	2	4	1.39	1.53	1.39	1.37	1.49	1.37	1.37
B009005	2	4	2.06	2.09	2.06	1.30	1.37	1.30	1.30
B008521	2	4	1.52	1.65	1.52	1.91	2.17	1.91	1.52
B007848	2	4	1.73	2.37	1.73	1.81	2.46	1.81	1.73
B011110	2	4	1.84	1.66	1.66	1.96	1.77	1.77	1.66
B011206	2	4	1.29	2.72	1.29	1.43	2.06	1.43	1.29
B011081	3	4	2.66	3.40	2.66	5.05	6.48	5.05	2.66
B009782	3	4	2.66	5.93	2.66	2.31	6.06	2.31	2.31
B005318	3	4	0.88	5.68	0.88	0.94	5.89	0.94	0.88
B007536	3	4	2.45	4.73	2.45	2.72	5.22	2.72	2.45
B012825	3	4	2.61	7.06	2.61	2.30	6.71	2.30	2.30
B011335	3	4	2.52	4.37	2.52	1.87	4.48	1.87	1.87
B002310	4	22	1.38	2.39	1.38	1.43	2.46	1.43	1.38
B011097	4	22	2.06	5.44	2.06	2.17	5.71	2.17	2.06
B012559	4	2	1.62	6.21	1.62	1.55	6.10	1.55	1.55
B011344	4	2	1.73	2.91	1.73	1.69	2.86	1.69	1.69
B012319	4	2	1.58	3.93	1.58	1.71	4.26	1.71	1.58
B012350	4	2	2.60	2.11	2.11	2.90	2.36	2.36	2.11
B017781	4	2	2.89	3.84	2.89	3.04	4.21	3.04	2.89
B015764	5	2	1.82	1.74	1.74	2.11	2.02	2.02	1.74
B019141	5	2	2.95	2.39	2.39	3.14	2.48	2.48	2.39
B019990	5	2	3.10	23.56	3.10	2.97	23.24	2.97	2.97
B019473	5	2	3.93	2.34	2.34	3.56	2.33	2.33	2.33
B016591	5	2	2.59	1.95	1.95	2.59	1.95	1.95	1.95
B018106	5	2	2.89	3.48	2.89	2.61	3.36	2.61	2.61
B016845	5	2	3.45	2.00	2.00	3.57	2.04	2.04	2.00
B014450	6	2	2.34	1.13	1.13	1.51	1.12	1.12	1.12
B016510	6	2	1.92	1.42	1.42	2.12	1.63	1.63	1.42
B016111	6	2	2.00	1.29	1.29	1.97	1.27	1.27	1.27
B016310	6	2	2.04	1.45	1.45	2.26	1.61	1.61	1.45
B015295	5	2	2.83	12.93	2.83	3.13	12.90	3.13	2.83
B017909	5	2	1.20	1.65	1.20	1.19	1.61	1.19	1.19
B015820	5	2	2.93	1.69	1.69	3.21	1.85	1.85	1.69

Presented in Figure 5 -21 is the LRFR versus LFR moment rating factor data for the controlling ALDOT legal load data for exterior and interior girders. Similar to what has been seen before, the majority of the data is found to be within Region 5 of the plot, indicating that for the unique bridge sample at the legal load level the LRFR produces lower rating results than LFR. Of key interest to ALDOT however would be the portions of the data that fall into Regions 5 - 1 and 5 - 2. Data found in Regions 5 - 1 signify bridges that would require posting in both the LFR and the LRFR; under the LRFR the posting loads are likely to be lower. Data found in Region 5 - 2 corresponds to bridges that are not required to be posted under the LFR but would require posting under the LRFR. Data found in Regions 5 - 3 has no impact on posting under either rating system.

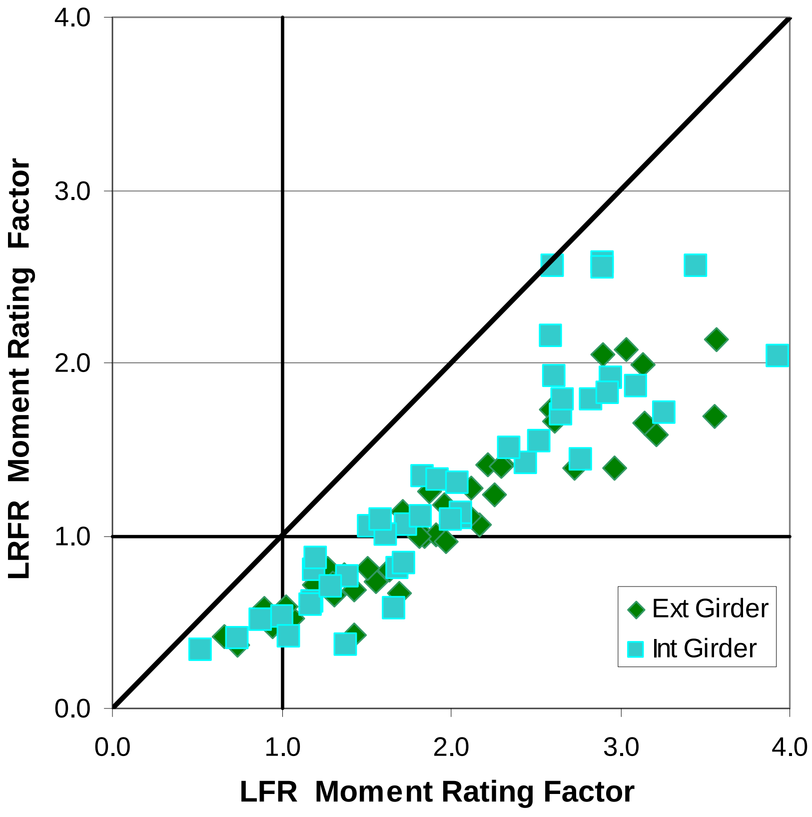


Figure 5 - 21: Moment Rating Factor Comparison at the Legal Load Level for the Unique Bridge Sample

Breaking the information found in Figure 5 - 21 down into material types can reveal which types of bridges may be more prone to be found in Regions 5 - 1 and 5 - 2. A material type plot of the data for the interior girder is shown in Figure 5 - 22. From this we find that the majority of bridges in Regions 5 - 1 and 5 - 2 are simply and continuously supported reinforced concrete bridges. The continuously supported steel bridges appear to be broken into two groups. One group found in Region 5 - 3 and the second primarily in Region 5 - 2. Upon inspection of the two groups, it was discovered that bridges with high rating factor had span lengths over 140 whereas the bridges with lower rating factors had span lengths under 100 feet. The majority of simply and continuously supported prestressed concrete bridges were found to be in Region 5 - 3. Similar trends were found for the exterior girder, see Figure 5 - 23.

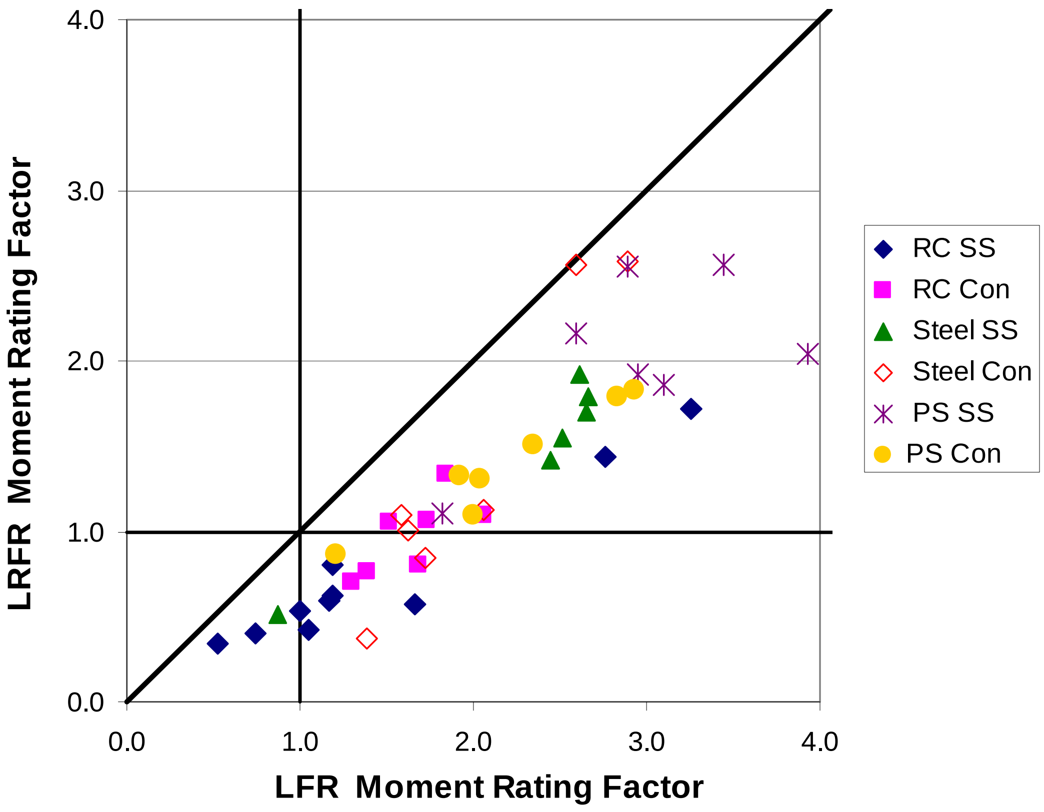


Figure 5 - 22: Moment Rating Factor Material Type Comparison at the Legal Load Level for the Unique Bridge Sample Interior Girders

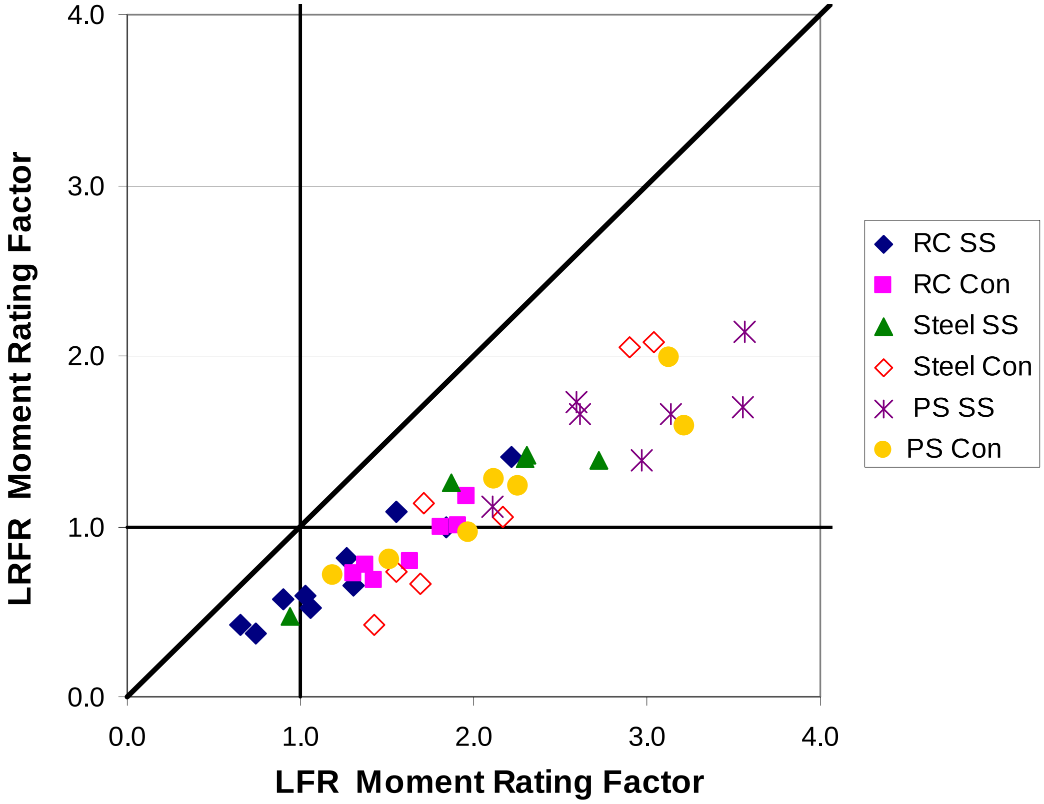


Figure 5 - 23: Moment Rating Factor Material Type Comparison at the Legal Load Level for the Unique Bridge Sample Exterior Girders

Analysis of the shear ratings factor data produced similar trends to moment rating data. An overview of the shear ratings for both interior and exterior girders is presented in Figure 5 - 24. A material breakdown of this shear data for the interior and exterior girders is shown in Figure 5 - 25 and 5 - 26, respectively. Similar trends to what were seen in the moment data are found in the shear data with one exception. Prestressed concrete, simply and continuously supported, bridges tend to transition from Region 5 - 3 into Region 6 - 3 as the rating factors for each method increase. Reinforced concrete, simply and continuously supported, bridges tend to transition from Region 5 - 2 into

Region 5 - 3 as the rating factors for each method increase. Steel simply and continuously supported bridges primarily were found in Region 5 - 3 These trends would indicates that as shear rating factors increase so do the LRFR to LFR ratios.

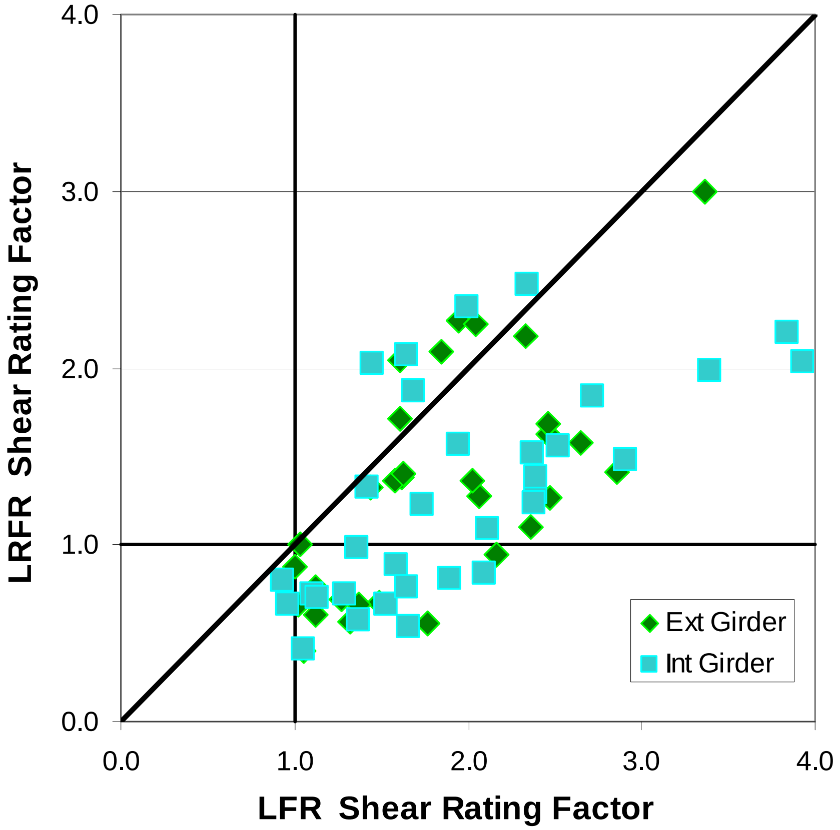


Figure 5 - 24: Shear Rating Factor Comparison at the Legal Load Level for the Unique Bridge Sample

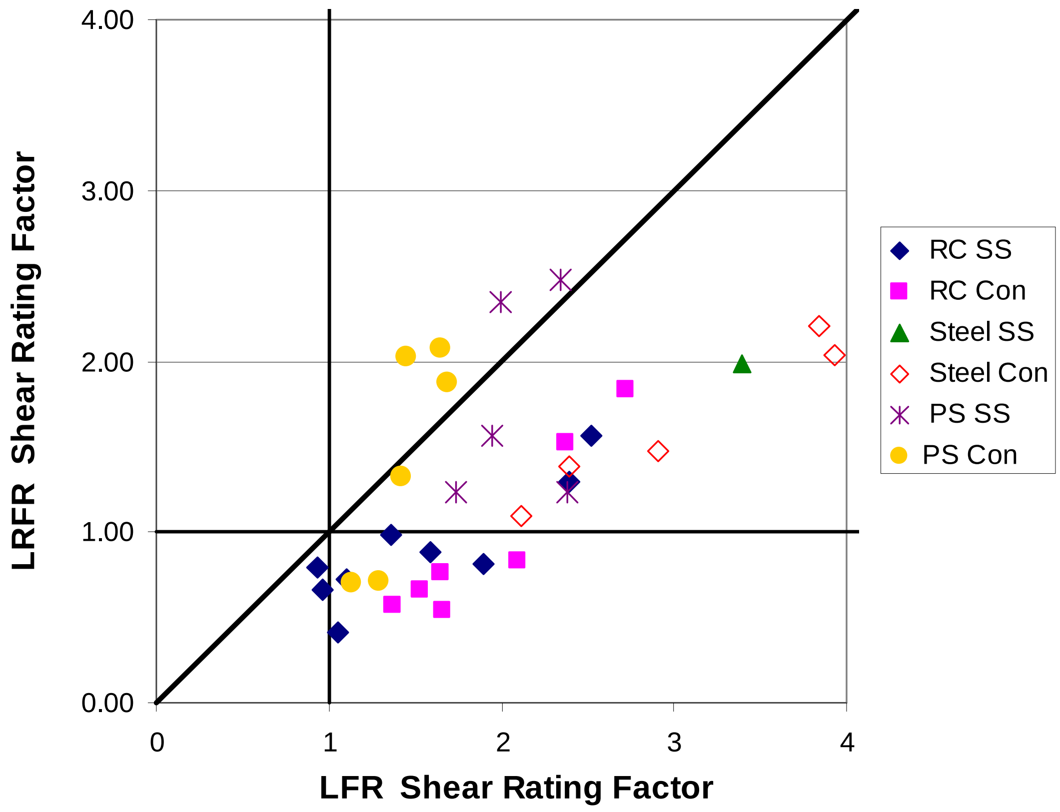


Figure 5 - 25: Shear Rating Factor Material Type Comparison at the Legal Load Level for the Unique Bridge Sample Interior Girders

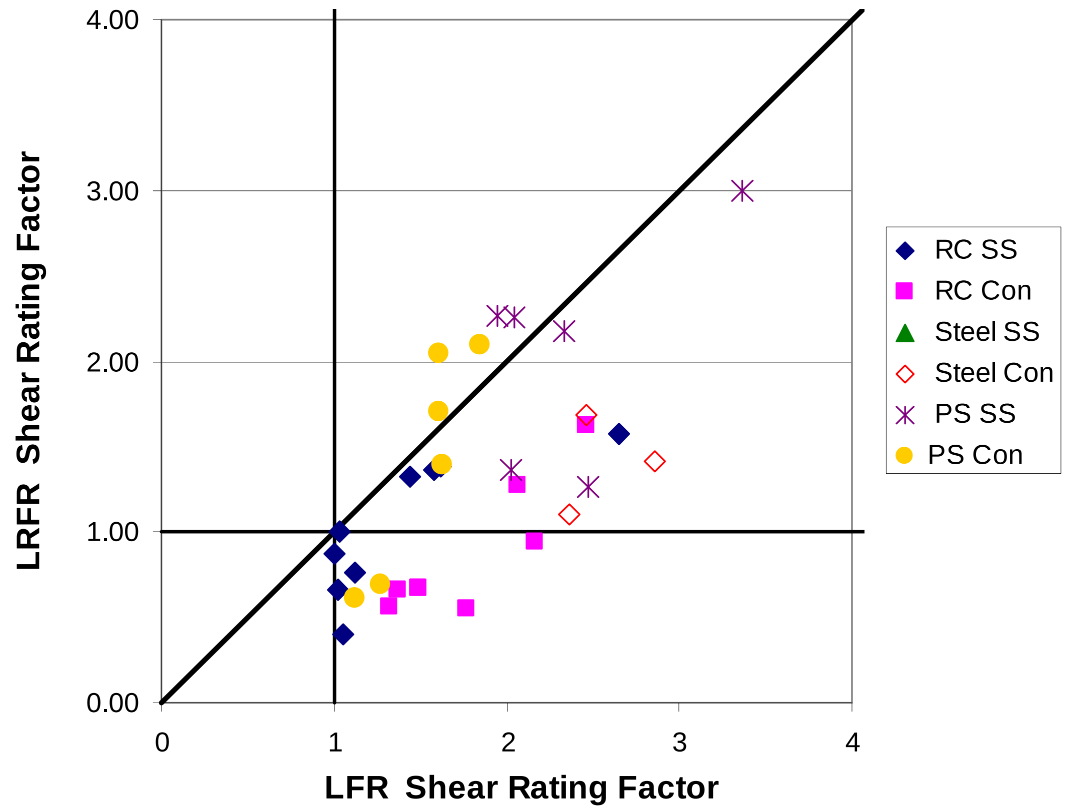
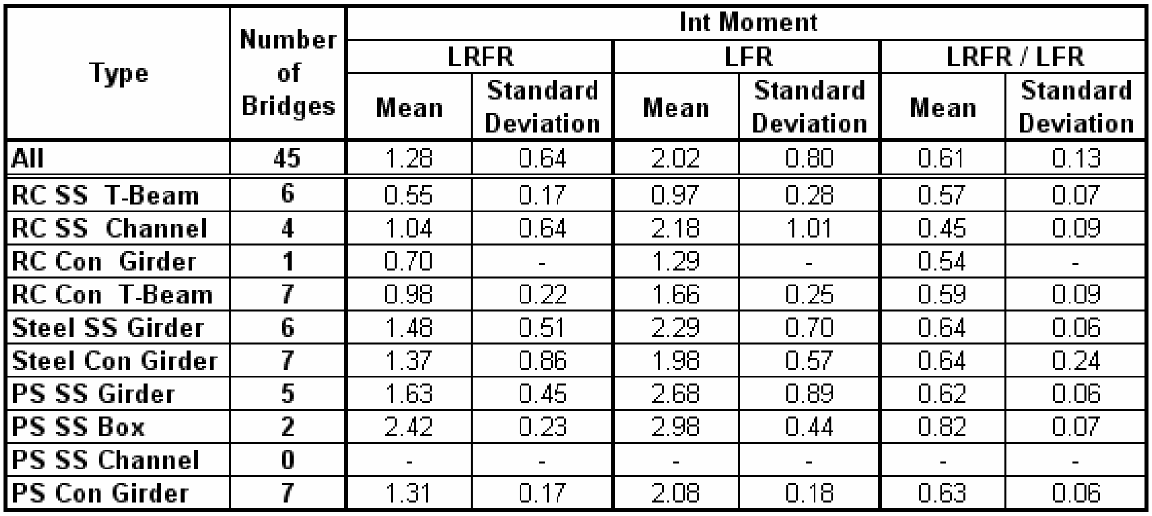


Figure 5 - 26: Shear Rating Factor Material Type Comparison at the Legal Load Level for the Unique Bridge Sample Exterior Girders

In addition to the material level of behavior between the LRFR and the LFR, the structural system type differences were studied. The results are presented in the same form previously discussed. Table 5 - 24 and 5 - 25 summarize the data for the flexural load effects for interior and exterior girders respectively. Similar to what has been seen before, LRFR for all material and structural system types produced lower rating results than the LFR. Prestressed concrete bridges have the highest LRFR to LFR ratio ranging from 0.62 to 0.82 between different structural systems, for interior girders. C – Channel bridges are observed to have the significantly lowest LRFR to LFR ratio for interior girders and the highest LRFR to LFR ratio for exterior girders; similar to the trends previously observed. Table 5 - 26 and 5 - 27 summarizes the data for the shear load effects for interior and exterior girders respectively. Similar to the trends previously stated, the LRFR produced nearly equal or lower rating results than the LFR for the shear load effect.

Table 5 - 24: Mean and Standard Deviation Data at the Legal Load Level for the Unique Bridge Sample – Interior Girder Moment Rating Data



Type	Number of Bridges	Int Moment					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	**45**	1.28	0.64	2.02	0.80	0.61	0.13
RC SS T-Beam	**6**	0.55	0.17	0.97	0.28	0.57	0.07
RC SS Channel	**4**	1.04	0.64	2.18	1.01	0.45	0.09
RC Con Girder	**1**	0.70	-	1.29	-	0.54	-
RC Con T-Beam	**7**	0.98	0.22	1.66	0.25	0.59	0.09
Steel SS Girder	**6**	1.48	0.51	2.29	0.70	0.64	0.06
Steel Con Girder	**7**	1.37	0.86	1.98	0.57	0.64	0.24
PS SS Girder	**5**	1.63	0.45	2.68	0.89	0.62	0.06
PS SS Box	**2**	2.42	0.23	2.98	0.44	0.82	0.07
PS SS Channel	**0**	-	-	-	-	-	-
PS Con Girder	**7**	1.31	0.17	2.08	0.18	0.63	0.06

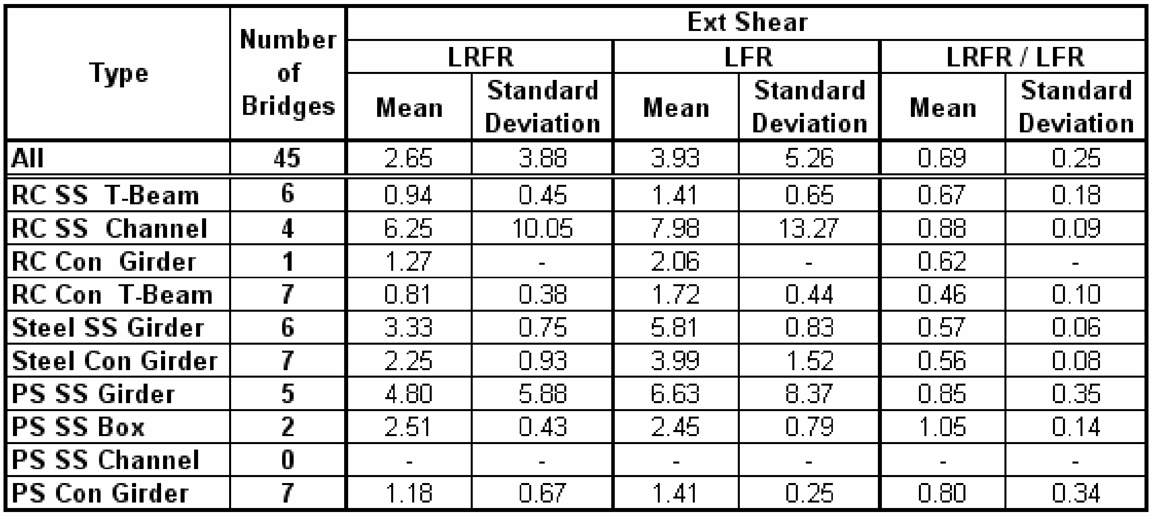
Table 5 - 25: Mean and Standard Deviation Data at the Legal Load Level for the Unique Bridge Sample – Exterior Girder Moment Rating Data

Type	Number of Bridges	Ext Moment					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	**45**	1.14	0.55	2.02	0.89	0.56	0.08
RC SS T-Beam	**6**	0.66	0.22	1.21	0.37	0.54	0.06
RC SS Channel	**4**	0.87	0.46	1.33	0.70	0.65	0.03
RC Con Girder	**1**	0.68	-	1.43	-	0.48	-
RC Con T-Beam	**7**	0.89	0.17	1.62	0.28	0.55	0.04
Steel SS Girder	**6**	1.47	0.79	2.53	1.37	0.58	0.07
Steel Con Girder	**7**	1.16	0.66	2.07	0.66	0.53	0.16
PS SS Girder	**5**	1.45	0.42	2.76	0.82	0.53	0.06
PS SS Box	**2**	1.84	0.26	2.92	0.56	0.63	0.04
PS SS Channel	**0**	-	-	-	-	-	-
PS Con Girder	**7**	1.07	0.22	1.96	0.32	0.54	0.05

Table 5 - 26: Mean and Standard Deviation Data at the Legal Load Level for the Unique Bridge Sample – Interior Girder Shear Rating Data

Type	Number of Bridges	Int Shear					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	**45**	2.65	4.19	3.86	5.26	0.67	0.27
RC SS T-Beam	**6**	0.74	0.20	1.17	0.26	0.64	0.16
RC SS Channel	**4**	6.76	11.09	8.67	12.80	0.61	0.17
RC Con Girder	**1**	1.84	-	2.72	-	0.68	-
RC Con T-Beam	**7**	0.79	0.34	1.74	0.36	0.44	0.10
Steel SS Girder	**6**	2.97	0.92	5.19	1.29	0.57	0.05
Steel Con Girder	**7**	2.12	0.98	3.83	1.53	0.55	0.05
PS SS Girder	**5**	5.01	6.14	6.61	8.52	0.91	0.38
PS SS Box	**2**	2.65	1.27	2.48	0.87	1.04	0.21
PS SS Channel	**0**	-	-	-	-	-	-
PS Con Girder	**7**	1.19	0.63	1.32	0.15	0.88	0.38

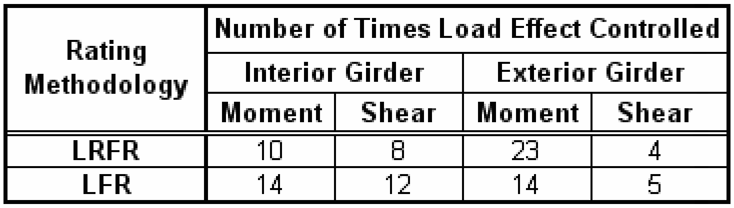
Table 5 - 27: Mean and Standard Deviation Data at the Legal Load Level for the Unique Bridge Sample – Exterior Girder Shear Rating Data



Type	Number of Bridges	Ext Shear					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	**45**	2.65	3.88	3.93	5.26	0.69	0.25
RC SS T-Beam	**6**	0.94	0.45	1.41	0.65	0.67	0.18
RC SS Channel	**4**	6.25	10.05	7.98	13.27	0.88	0.09
RC Con Girder	**1**	1.27	-	2.06	-	0.62	-
RC Con T-Beam	**7**	0.81	0.38	1.72	0.44	0.46	0.10
Steel SS Girder	**6**	3.33	0.75	5.81	0.83	0.57	0.06
Steel Con Girder	**7**	2.25	0.93	3.99	1.52	0.56	0.08
PS SS Girder	**5**	4.80	5.88	6.63	8.37	0.85	0.35
PS SS Box	**2**	2.51	0.43	2.45	0.79	1.05	0.14
PS SS Channel	**0**	-	-	-	-	-	-
PS Con Girder	**7**	1.18	0.67	1.41	0.25	0.80	0.34

An additional point of comparison was made for the controlling load effect for each rating methodology. Table 5 - 28 shows the results of this comparison. The data in this table was constructed by counting the number of times a rating factor for each load effect controlled for a bridge within the sample. The data indicates that for the LRFR methodology exterior girder moment load effect mainly controlled. For the LFR methodology it can be observed that the sample was nearly evenly controlled across all load effects with the exception of the exterior girder shear load effect.

Table 5 - 28: Controlling Load Effect Comparison, Legal Load Level for the Unique Bridge Sample



Rating Methodology	Number of Times Load Effect Controlled			
	Interior Girder		Exterior Girder	
	Moment	Shear	Moment	Shear
LRFR	10	8	23	4
LFR	14	12	14	5

<u>Note</u>: The unique bridge sample consists of 45 bridges

The final point of comparison was on the absolute controlling rating factor between the two rating methodologies. The absolute controlling rating data used for this comparison can be found in the previously shown Tables 5 - 22 and 5 - 23. Provided in Figure 5 - 27 is a LRFR verses LFR plot of the absolute controlling rating data. From this plot it is seen that the majority of the data falls into Region 5 with only a single data point found in Region 6. This indicates that the LRFR produced lower rating results than the LFR in general.

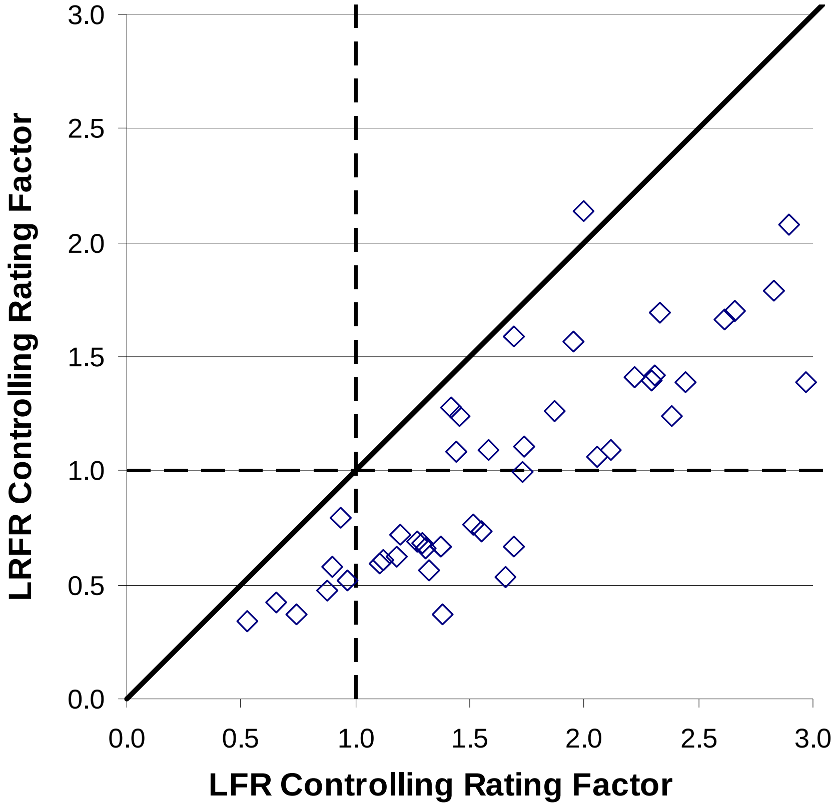
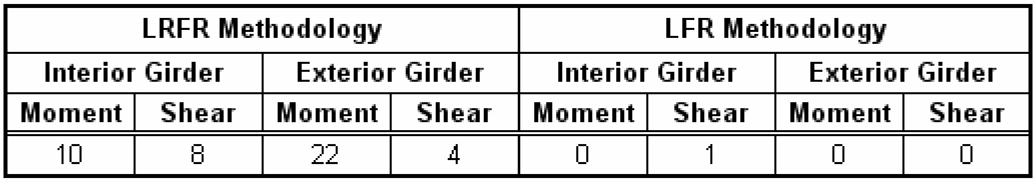


Figure 5 - 27: Controlling Rating Factor Comparisons at the Legal Load Level

Additionally, the absolute controlling load effect and rating methodology was investigated; Table 5 - 29 shows the results of this investigation. The data provided in Table 5 - 29 is the total number of times each load effect and methodology controlled for the bridge sample. This data indicates that the LRFR exterior girder moment load effect primarily controlled. This finding is in agreement with the previously reported results showing the LRFR producing nearly equal or lower rating results than the LFR, in general.

Table 5 - 29: Controlling Load Effect and Rating Methodology at the Legal Load Level



LRFR Methodology				LFR Methodology			
Interior Girder		Exterior Girder		Interior Girder		Exterior Girder	
Moment	Shear	Moment	Shear	Moment	Shear	Moment	Shear
10	8	22	4	0	1	0	0

Note: The unique bridge sample consists of 45 bridges

5.3.3.2 Bridge Age

The potential effect of bridge age on the rating results was also investigated. The age of the bridge used in this portion of the study was assumed to be the fiscal year of the bridge as indicated on each bridge's set of plans. The fiscal year corresponds to the year in which the plans for the bridge were produced. Figure 5 - 28 shows a plot of interior girder moment rating factor, for both the LRFR and LFR, against the bridge's fiscal year. As can be seen, a trend emerges that progressively newer bridges have the tendency to produce a higher rating factor for each methodology. Additionally, only two bridges built after the mid-1980s yielded unsatisfactory rating results for either rating system, for the flexural load effect.

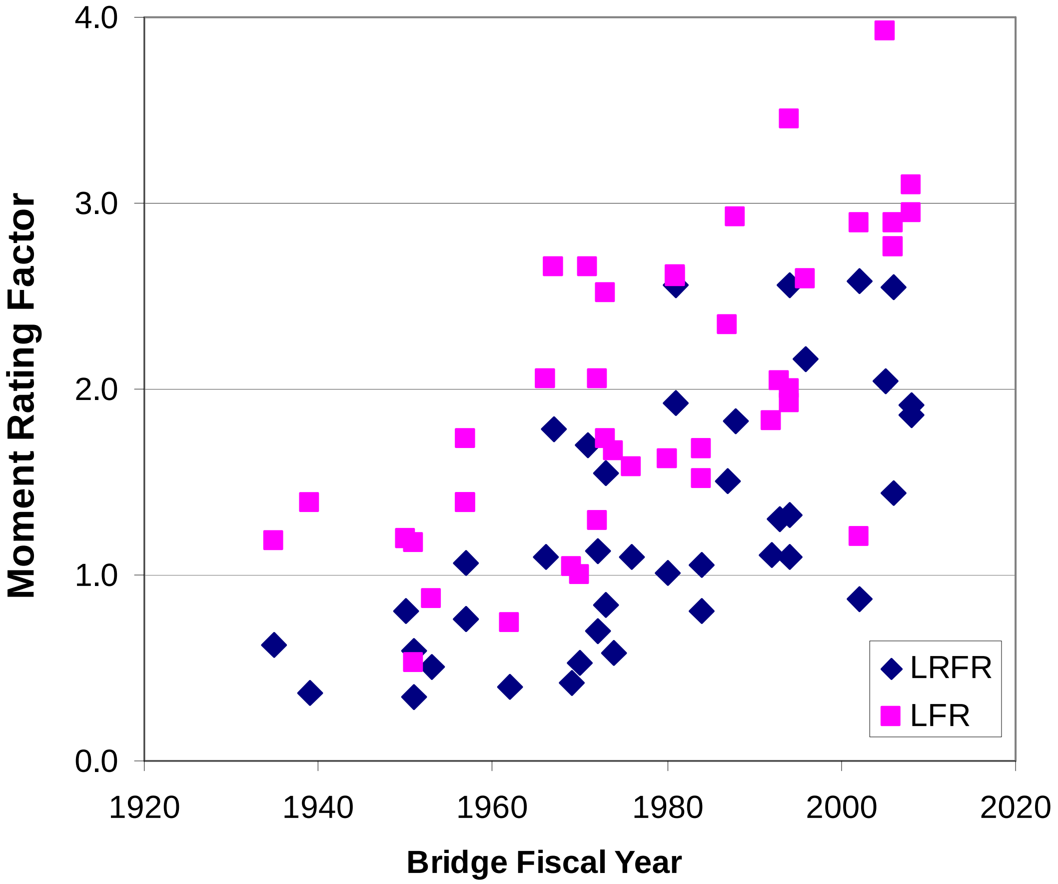


Figure 5 - 28: Bridge Age and Moment Rating Factor Comparison at the Legal Load Level for the Unique Bridge Sample

A material breakdown of just the LRFR data is seen in Figure 5 - 29, which shows additional trends. In general, the trend of the fiscal year of the bridge increasing along with the moment rating factor of a bridge can be seen. On the material level, this trend can be well observed in continuously supported steel bridges. Reinforced concrete simply and continuously supported bridges, however, tend to have similar rating factors under the LRFR independent of their fiscal age. Similar trends were seen for exterior girders. These trends suggest that a correlation between a bridge's moment rating factor and its fiscal age does exist.

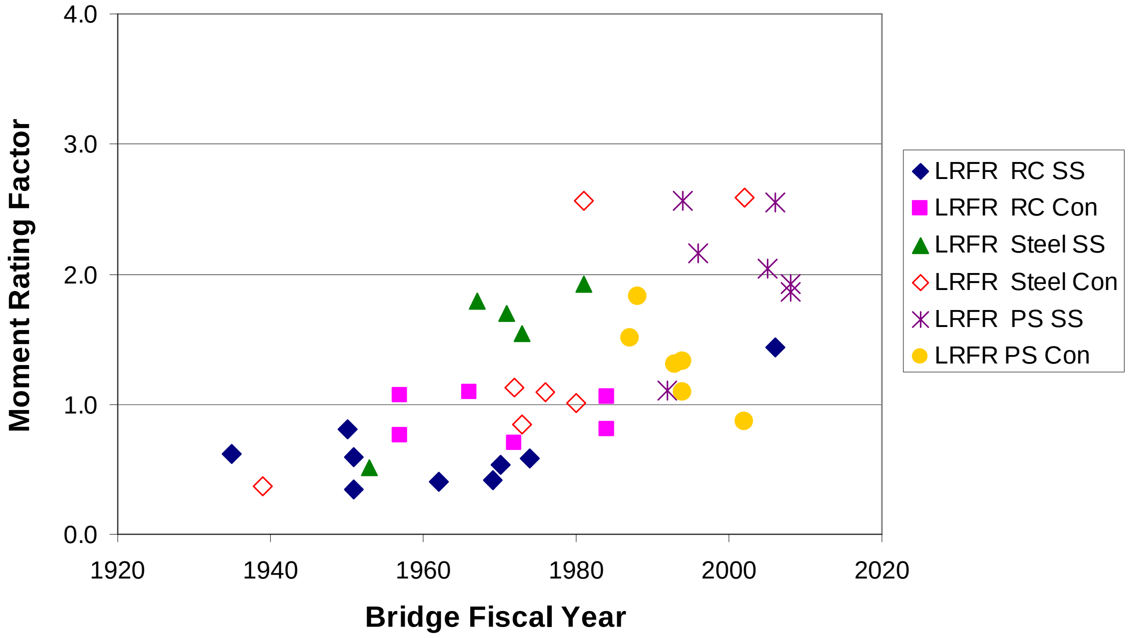


Figure 5 - 29: Bridge Age and Moment Rating Factor Comparison, Material Level, at the Legal Load Level for the Unique Bridge Sample

Analyzing a bridge's fiscal year compared to shear rating data yielded less apparent trends than when compared to the moment rating data, as can be seen in Figure 5 - 30. Comparing the LRFR and LFR factors to a bridge's age produced a large degree of scatter with no apparent trends for the shear rating factor data. Breaking the data down into its material level for the LRFR yielded no additional trends, as shown in Figure 5 – 31 for interior girders. Similar results were found for exterior girders. This suggests that for both LRFR and LFR little correlation exists between a bridge's shear rating factor and its fiscal age.

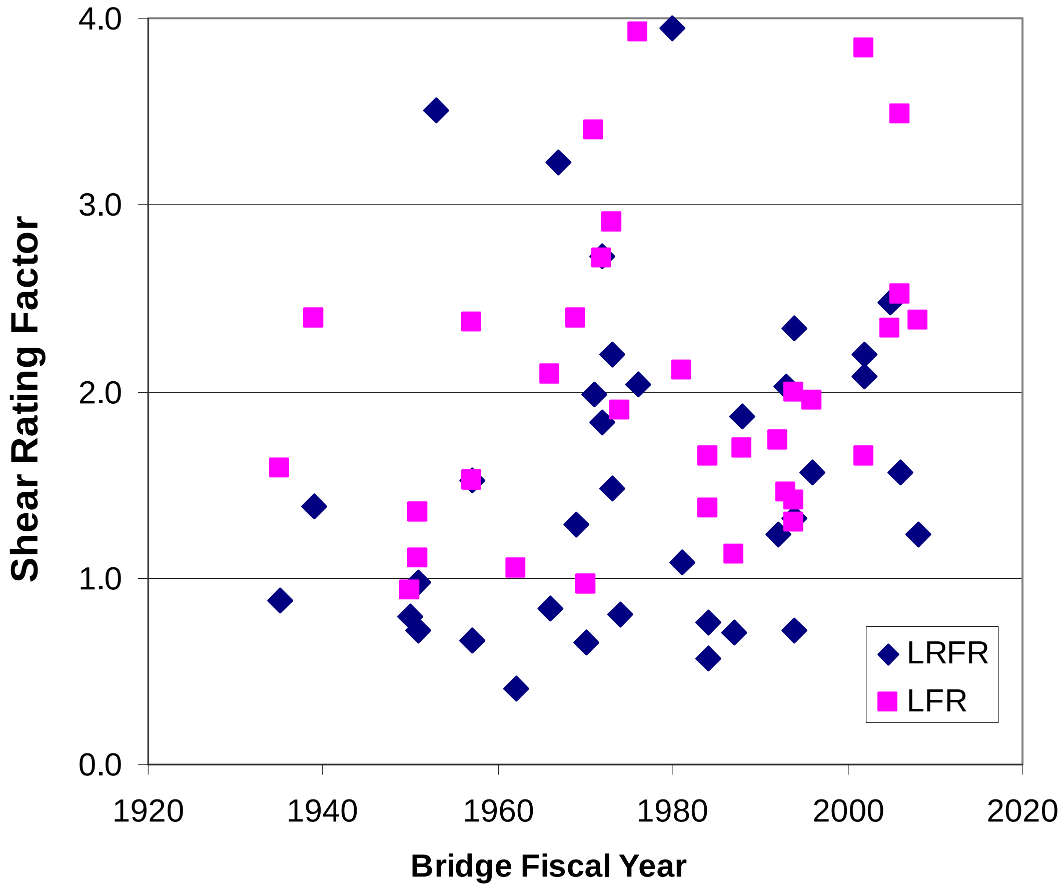


Figure 5 - 30: Bridge Age and Shear Rating Factor Comparison at the Legal Load Level for the Unique Bridge Sample

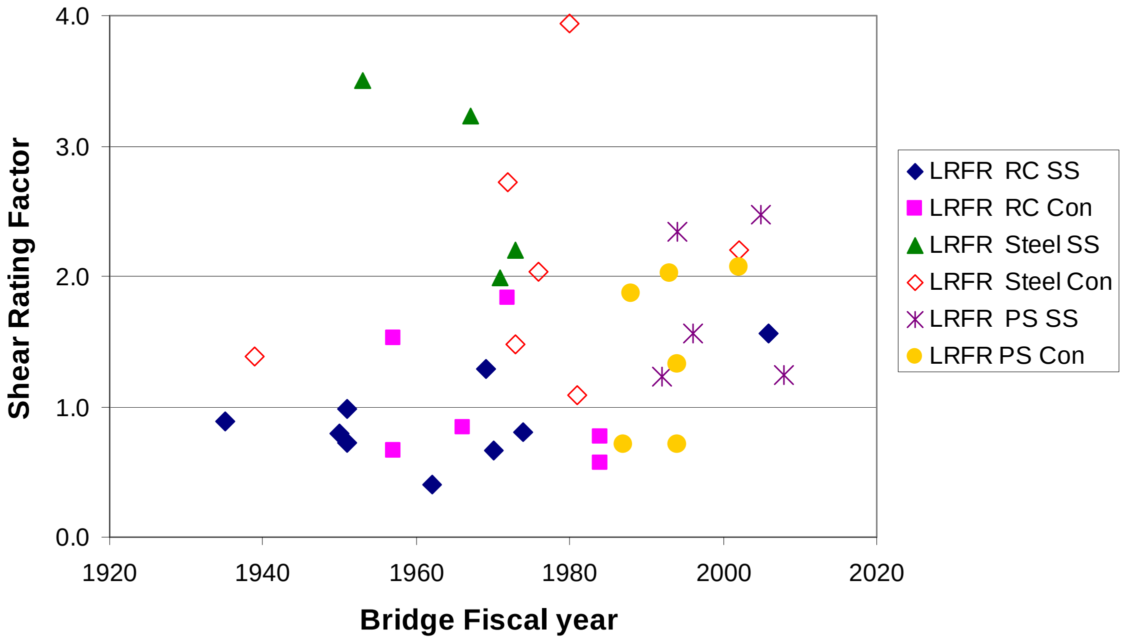


Figure 5 - 31: Bridge Age and Shear Rating Factor Comparison, Material Level, at the Legal Load Level for the Unique Bridge Sample

5.3.3.3 Span Length and Girder Spacing

The potential effect of span length and girder spacing on the rating results was investigated. Figures 5 - 32 and 5 - 33 show the interior girder moment rating factors for LRFR versus span length and girder spacing, respectively. Little correlation between span length and the LRFR moment rating factor can be observed. The one exception however, is for continuously supported steel bridges for which the rating factor is observed to increase with span length.

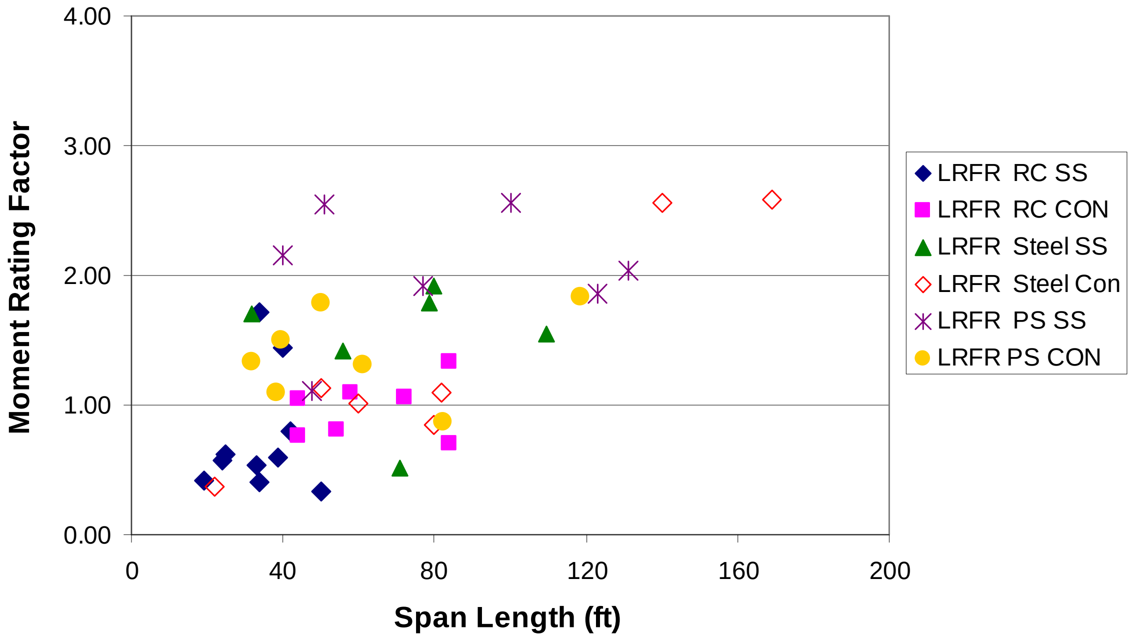


Figure 5 - 32: Span length and Moment Rating Factor Comparison, Material Level, at the Legal Load Level for the Unique Bridge Sample

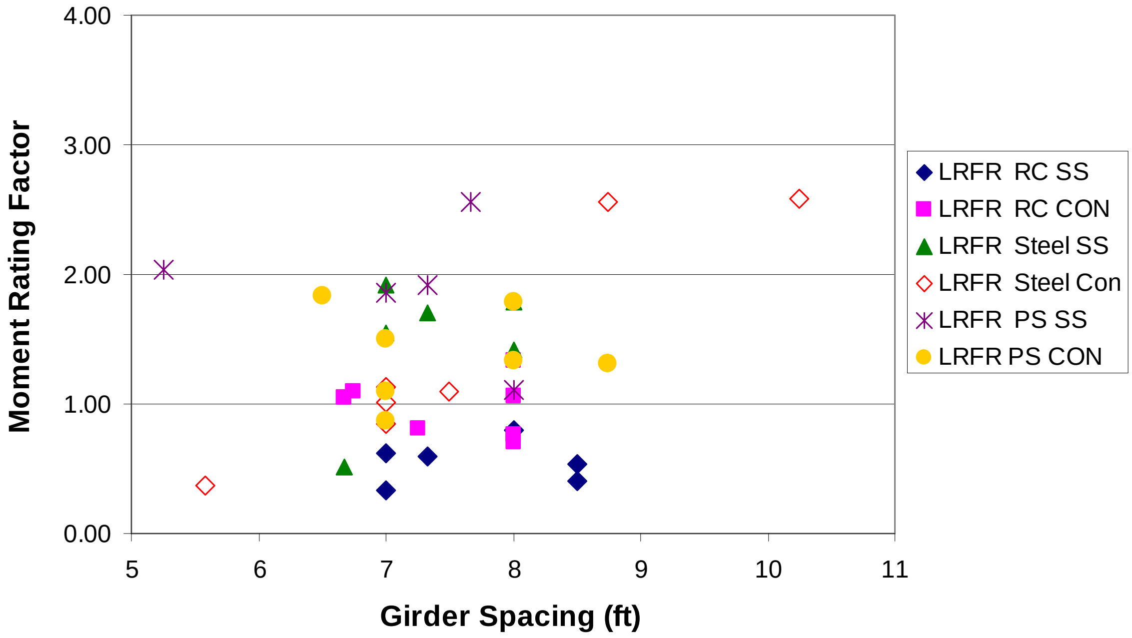


Figure 5 - 33: Girder Spacing and Moment Rating Factor Comparison, Material Level, at the Legal Load Level for the Unique Bridge Sample

Little correlation between girder spacing and LRFR moment rating factors was found with one exception for continuously supported steel bridges, for which the rating factor is observed to increase with girder spacing. For the completeness the same variables, span length and girder spacing, are plotted against the LRFR / LFR in Figures 5 - 34 and 5 - 35; however, little additional information was learned. Similar results were found for both moment and shear for interior and exterior girders.

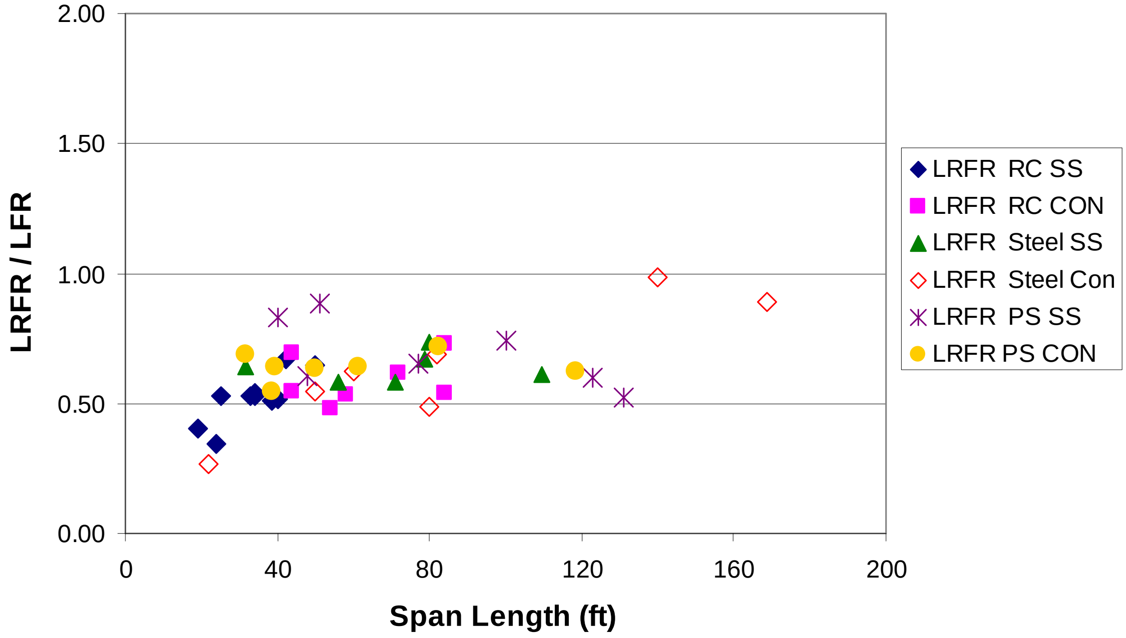


Figure 5 - 34: Span length and LRFR to LFR Ratio Comparison, Material Level, at the Legal Load Level for the Unique Bridge Sample

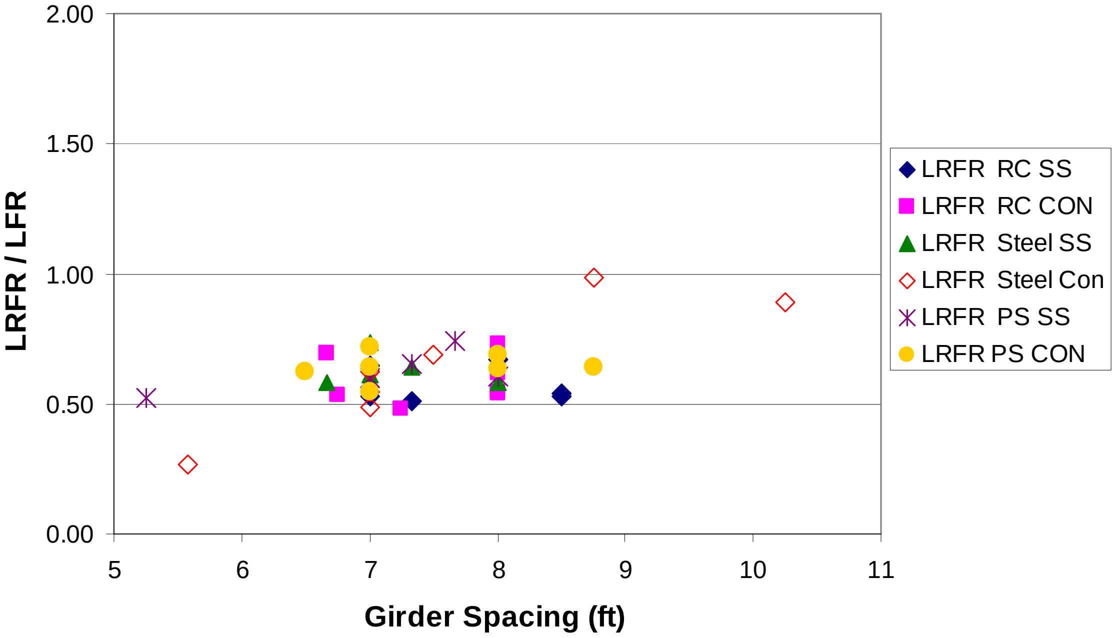


Figure 5 - 35: Girder Spacing and LRFR to LFR Ratio Comparison, Material Level, at the Legal Load Level for the Unique Bridge Sample

5.3.3.4 LRFR Load Posting Recommendations

The load posting recommendations found in the AASHTO MCE LRFR (2003), were applied to the ALDOT legal loads for the unique bridge sample of this study. The recommended posting procedure under the LRFR uses the controlling rating factor for a bridge and a legal load's weight to determine the posting load, as described in Section 2.8. For comparison purposes ALDOT's posting load procedure was used to determine LFR, load posting data. ALDOT's current posting load procedure uses the controlling LFR legal load rating factor and a legal load's weight. The posting load is determined by multiplying a load's controlling rating factor by the weight of the load, in units of tons. Figure 5 - 36 graphically presents the differences in the LRFR posting load equation and

ALDOT's posting load procedure. As Figure 5 - 36 shows, for a given rating factor LRFR load postings will be lower than an LFR load posting, calculated by ALDOT's procedure. Load posting is only required for when loads produce rating factors below 1.0 for both methods.

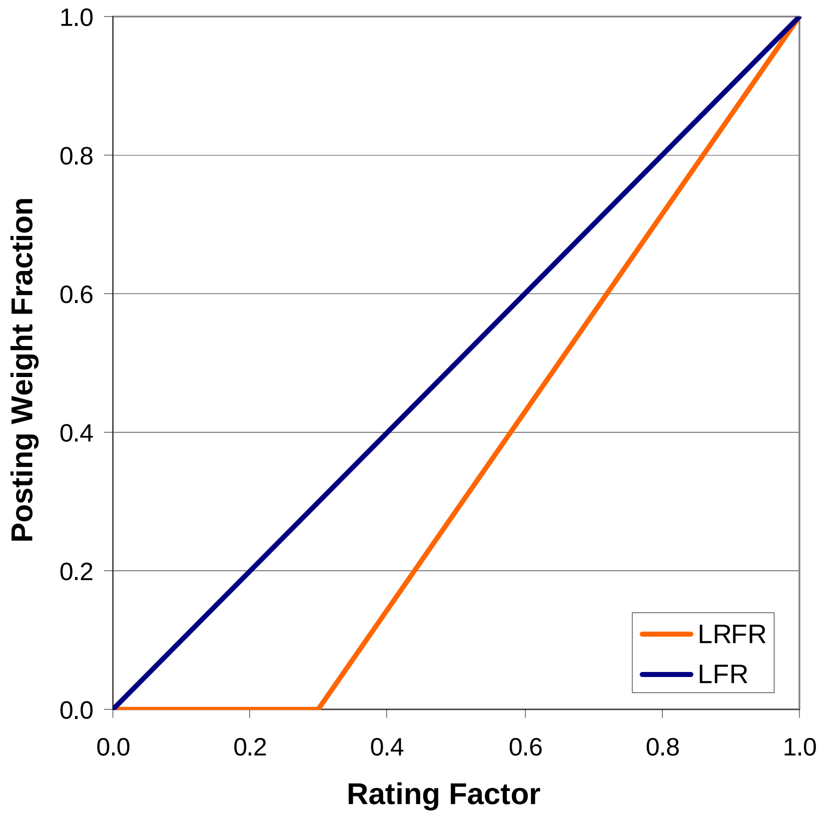
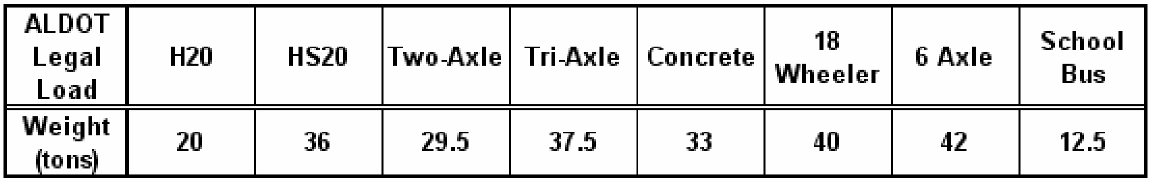


Figure 5 - 36: Posting Weight Fraction Compared to Rating Factor

The ALDOT legal loads weights are summarized in Table 5 - 30. Using this LRFR load posting procedure, the load postings found in Table 5 - 31 were developed. Load posting information for each truck per load effect for interior and exterior girders according to the LRFR procedure can be found in Appendix E Tables E - 1 through E - 4. Using this ALDOT's LFR load posting procedure, the load postings found in Table 5 - 32 were developed. Load posting information for each truck per load effect for interior and exterior girders according to the LFR procedure can be found in Appendix E Tables E - 5 through E - 8. As expected the load posting data generated under the LRFR procedure, Table 5 - 31, is lower than the LFR load posting data, Table 5 - 32. Additionally the differences in the number of bridges requiring load posting under the two methods is seen. From the unique bridge sample 23 bridges, just over half the sample, required load posting under the LRFR methodology. From the unique bridge sample only 8 bridges required load posting under the LFR methodology. Therefore, the number of bridges that require load posting under the LRFR is triple the number that require load posting under the LFR.

Table 5 - 30: Summary ALDOT Legal Loads Weights

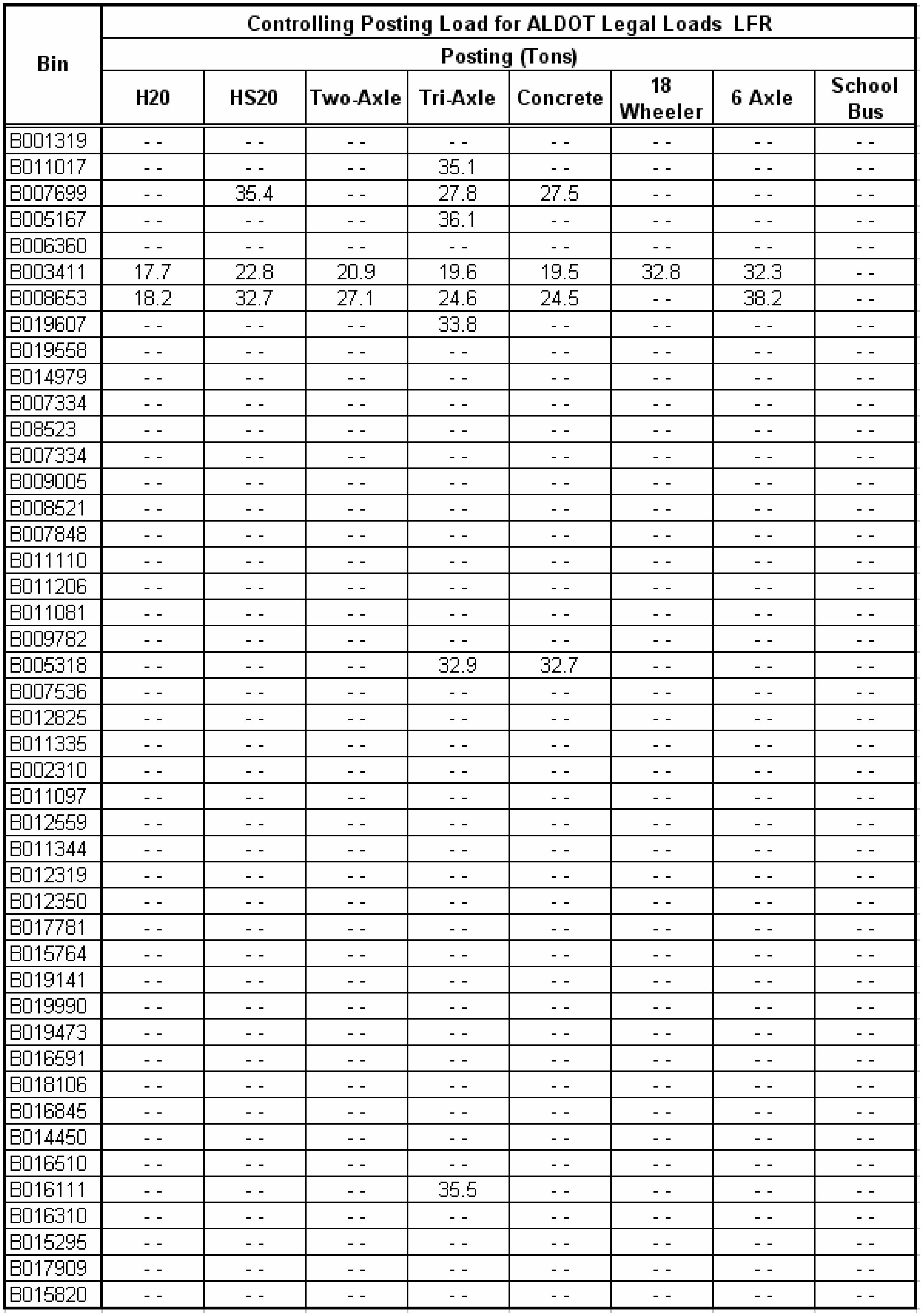


ALDOT Legal Load	H20	HS20	Two-Axle	Tri-Axle	Concrete	18 Wheeler	6 Axle	School Bus
Weight (tons)	20	36	29.5	37.5	33	40	42	12.5

Table 5 - 31: ALDOT Legal Loads LRFR Posting Weights

Bin	ALDOT Legal Load Posting (Tons)							
	H20	HS20	Two-Axle	Tri-Axle	Concrete	18 Wheeler	6 Axle	School Bus
B001319	17.3	30.7	23.3	16.1	18.1	36.8	31.5	- -
B011017	18.3	- -	- -	26.5	28.5	- -	- -	- -
B007699	8.1	10.0	9.4	3.8	5.6	15.4	13.4	- -
B005167	15.0	20.4	18.6	11.9	13.6	28.5	26.0	- -
B006360	16.2	24.1	22.2	15.9	17.6	35.9	33.9	- -
B003411	7.3	4.9	6.0	1.4	3.3	12.1	10.8	- -
B008653	8.1	14.6	12.1	6.4	8.0	21.1	16.9	- -
B019607	15.9	28.6	21.7	14.6	16.6	34.8	29.3	- -
B019558	- -	- -	- -	- -	- -	- -	- -	- -
B014979	- -	- -	- -	- -	- -	- -	- -	- -
B007334	14.0	25.7	26.4	17.2	19.8	37.9	36.0	- -
B08523	11.7	20.6	21.9	13.1	15.6	38.1	33.7	- -
B007334	14.0	25.7	26.4	17.2	19.8	37.9	36.0	- -
B009005	19.0	23.9	26.6	17.8	20.5	35.4	34.4	- -
B008521	19.1	- -	- -	24.8	27.3	- -	- -	- -
B007848	- -	- -	- -	35.7	- -	- -	- -	- -
B011110	9.8	18.2	21.5	12.7	15.8	31.6	28.2	- -
B011206	- -	24.5	25.3	20.5	22.4	30.7	30.6	- -
B011081	- -	- -	- -	- -	- -	- -	- -	- -
B009782	- -	- -	- -	- -	- -	- -	- -	- -
B005318	14.8	12.0	13.3	8.8	10.7	17.0	17.4	- -
B007536	- -	- -	- -	- -	- -	- -	- -	- -
B012825	- -	- -	- -	- -	- -	- -	- -	- -
B011335	- -	- -	- -	- -	- -	- -	- -	- -
B002310	5.4	9.7	7.5	2.6	3.9	14.1	11.2	11.1
B011097	- -	- -	- -	- -	- -	- -	- -	- -
B012559	- -	28.1	28.1	22.8	24.6	37.2	37.7	- -
B011344	- -	22.3	23.1	18.4	20.2	28.2	28.0	- -
B012319	- -	- -	- -	- -	- -	- -	- -	- -
B012350	- -	- -	- -	- -	- -	- -	- -	- -
B017781	- -	- -	- -	- -	- -	- -	- -	- -
B015764	- -	- -	- -	- -	- -	- -	- -	- -
B019141	- -	- -	- -	- -	- -	- -	- -	- -
B019990	- -	- -	- -	- -	- -	- -	- -	- -
B019473	- -	- -	- -	- -	- -	- -	- -	- -
B016591	- -	- -	- -	- -	- -	- -	- -	- -
B018106	- -	- -	- -	- -	- -	- -	- -	- -
B016845	- -	- -	- -	- -	- -	- -	- -	- -
B014450	15.9	27.6	21.9	15.7	19.9	- -	- -	- -
B016510	- -	- -	- -	- -	- -	- -	- -	- -
B016111	17.9	35.3	- -	21.1	26.0	- -	40.1	- -
B016310	- -	- -	- -	- -	- -	- -	- -	- -
B015295	- -	- -	- -	- -	- -	- -	- -	- -
B017909	- -	24.0	26.2	22.3	24.3	26.4	25.7	- -
B015820	- -	- -	- -	- -	- -	- -	- -	- -

Table 5 - 32: ALDOT Legal Loads LFR Posting Weights



Bin	Controlling Posting Load for ALDOT Legal Loads LFR							
	Posting (Tons)							
	H20	HS20	Two-Axle	Tri-Axle	Concrete	18 Wheeler	6 Axle	School Bus
B001319	- -	- -	- -	- -	- -	- -	- -	- -
B011017	- -	- -	- -	35.1	- -	- -	- -	- -
B007699	- -	35.4	- -	27.8	27.5	- -	- -	- -
B005167	- -	- -	- -	36.1	- -	- -	- -	- -
B006360	- -	- -	- -	- -	- -	- -	- -	- -
B003411	17.7	22.8	20.9	19.6	19.5	32.8	32.3	- -
B008653	18.2	32.7	27.1	24.6	24.5	- -	38.2	- -
B019607	- -	- -	- -	33.8	- -	- -	- -	- -
B019558	- -	- -	- -	- -	- -	- -	- -	- -
B014979	- -	- -	- -	- -	- -	- -	- -	- -
B007334	- -	- -	- -	- -	- -	- -	- -	- -
B08523	- -	- -	- -	- -	- -	- -	- -	- -
B007334	- -	- -	- -	- -	- -	- -	- -	- -
B009005	- -	- -	- -	- -	- -	- -	- -	- -
B008521	- -	- -	- -	- -	- -	- -	- -	- -
B007848	- -	- -	- -	- -	- -	- -	- -	- -
B011110	- -	- -	- -	- -	- -	- -	- -	- -
B011206	- -	- -	- -	- -	- -	- -	- -	- -
B011081	- -	- -	- -	- -	- -	- -	- -	- -
B009782	- -	- -	- -	- -	- -	- -	- -	- -
B005318	- -	- -	- -	32.9	32.7	- -	- -	- -
B007536	- -	- -	- -	- -	- -	- -	- -	- -
B012825	- -	- -	- -	- -	- -	- -	- -	- -
B011335	- -	- -	- -	- -	- -	- -	- -	- -
B002310	- -	- -	- -	- -	- -	- -	- -	- -
B011097	- -	- -	- -	- -	- -	- -	- -	- -
B012559	- -	- -	- -	- -	- -	- -	- -	- -
B011344	- -	- -	- -	- -	- -	- -	- -	- -
B012319	- -	- -	- -	- -	- -	- -	- -	- -
B012350	- -	- -	- -	- -	- -	- -	- -	- -
B017781	- -	- -	- -	- -	- -	- -	- -	- -
B015764	- -	- -	- -	- -	- -	- -	- -	- -
B019141	- -	- -	- -	- -	- -	- -	- -	- -
B019990	- -	- -	- -	- -	- -	- -	- -	- -
B019473	- -	- -	- -	- -	- -	- -	- -	- -
B016591	- -	- -	- -	- -	- -	- -	- -	- -
B018106	- -	- -	- -	- -	- -	- -	- -	- -
B016845	- -	- -	- -	- -	- -	- -	- -	- -
B014450	- -	- -	- -	- -	- -	- -	- -	- -
B016510	- -	- -	- -	- -	- -	- -	- -	- -
B016111	- -	- -	- -	35.5	- -	- -	- -	- -
B016310	- -	- -	- -	- -	- -	- -	- -	- -
B015295	- -	- -	- -	- -	- -	- -	- -	- -
B017909	- -	- -	- -	- -	- -	- -	- -	- -
B015820	- -	- -	- -	- -	- -	- -	- -	- -

5.3.4 Summary

Analysis of the standard and unique bridge samples at the Legal Load level of rating led to the following general findings:

- ALDOT legal loads are not enveloped by AASHTO typical legal loads
- ALDOT legal loads are not enveloped by the HL-93 live load model
- Moment rating factors for exterior girders tend to control over interior girders under the LRFR, as opposed to no dominant load effect per girder was observed for the LFR
- For moment load effects the LRFR methodology produces generally lower rating results than the LFR methodology
- For shear load effects the LRFR methodology in general produces equal or lower rating results than the LFR methodology
- Variations in λ_L and $\phi_c\phi_s$ only amplify the degree to which LRFR produces lower rating results than LFR
- Newer bridges tend to have higher LRFR and LFR factors
- Load posting values produced under the LRFR were found to be significantly lower than load postings values under the LFR
- The number of bridges requiring load posting for the unique bridge sample was found to be much larger for the LRFR than the LFR

5.4 Permit Load Rating

Work conducted at the permit load level consisted of two main tasks. The first task was the selection of the permit bridge sample. The second task was a comparison of LRFR and LFR rating factor data. Section 5.4.1 describes the permit bridge sample and its selection. Section 5.4.2 compares the rating factor data of the permit sample.

5.4.1 Permit Bridge Sample

The permit bridge sample is a collection of bridges, from both the unique and standard bridge samples, that are eligible for overweight load evaluation under at least one of the rating methodologies. Initially, all 95 bridges from the unique and standard bridge samples were considered for inclusion in the permit bridge sample. However, as the rating criteria was checked, the sample size decreased. To aid in the discussion of the permit bridge sample, the Venn diagram shown in Figure 5 – 28 is used. Each region of this figure refers to a different set of bridges. Region ‘A’ represents the set of all 95 bridges from the unique and standard bridge samples. Region ‘B’ represents the set of bridges that are allowed to be permitted under the LFR. In the LFR rating methodology, bridges are allowed to be permitted if they are found to be satisfactory at the Operating level under the HS-20 design truck (AASHTO 2003). Of the 95 bridges, 76 were found to be allowed to be permitted under the LFR. Region ‘C’ represents the set of bridges that are allowed to be permitted under the LRFR. Permitting allowance under the LRFR is determined based on whether a bridge is found to be satisfactory at the Legal load level under at least the AASHTO standard legal loads, as shown in Section 2.7. Of the 95 bridges considered, 60 meet the LRFR criteria for permit allowance. Region ‘D’ represents the set of bridges that are allowed to be permitted under both rating methodologies, which consists of 59 bridges. Therefore, the permit bridge sample consists of a total of 77 bridges, which as indicated above, is the number of bridges that are allowed to be permitted under at least one of the rating methodologies.

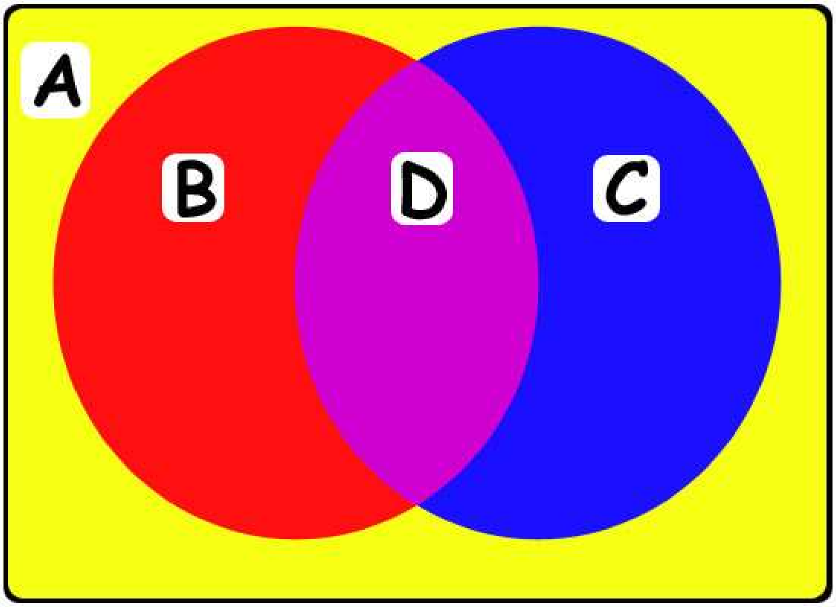
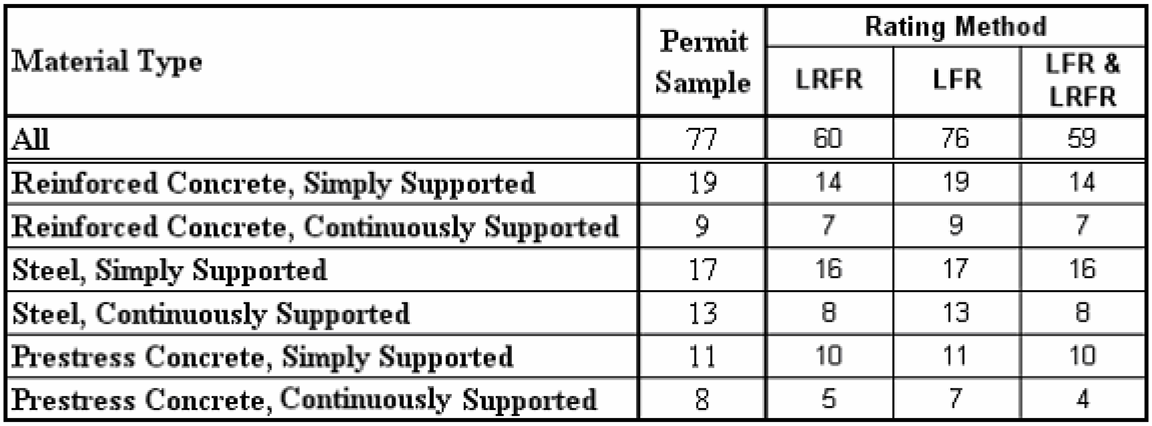


Figure 5 - 37: Permit Bridge Sample Diagram

A material type breakdown of the permit bridge sample is provided in Table 5 - 24 along with material type breakdowns of the B, C, and D regions of the sample. This shows that while the LRFR allows fewer bridges to be permitted than the LFR, there is no material type that is more susceptible to not being allowed under either of the two systems.

Table 5 - 33: Material Type Breakdown of the Permit Bridge Sample



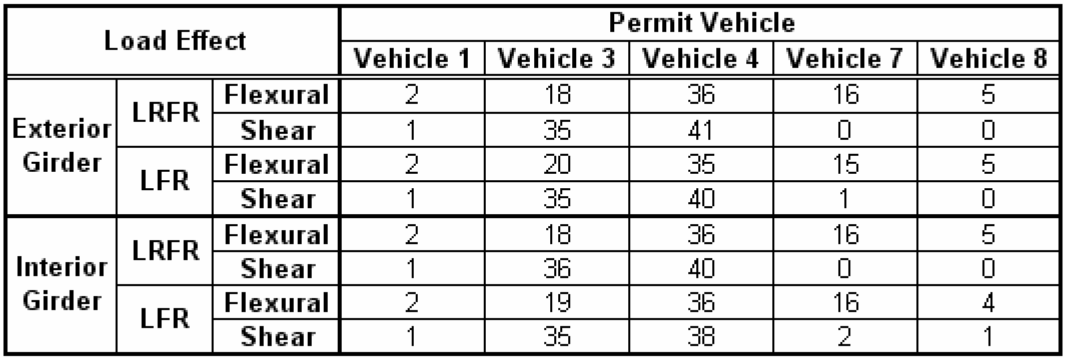
Material Type	Permit Sample	Rating Method		
		LRFR	LFR	LFR & LRFR
All	77	60	76	59
Reinforced Concrete, Simply Supported	19	14	19	14
Reinforced Concrete, Continuously Supported	9	7	9	7
Steel, Simply Supported	17	16	17	16
Steel, Continuously Supported	13	8	13	8
Prestress Concrete, Simply Supported	11	10	11	10
Prestress Concrete, Continuously Supported	8	5	7	4

5.4.2 Permit Rating Results

The permit bridge sample was analyzed under the ten ALDOT permit trucks previously described in Section 2.9.3. The trucks were analyzed at the Operating level of the LFR with a live load factor of 1.3. Analysis under the LRFR was done at the Permit level with a live load factor of 1.15. The LRFR live load factor of 1.15 corresponds to the lower bound of the possible live load factors for permit trucks and assumes a single trip frequency with the permit truck being escorted and no other vehicles on the bridge during crossing.

The comparisons made in this section in regards to the ALDOT permit loads are for the controlling permit vehicle. Table 5 – 34 presents the breakdown of which permit vehicle controlled for each rating method, interior and exterior girder, and load effect. Data is only presented for Vehicles 1, 3, 4, 7, and 8 due to these five vehicles controlling all of the permitting analysis. Vehicle 4 was found to predominately control in moment rating factors with Vehicle 3 and 4 largely controlling in shear rating factors for both methodologies.

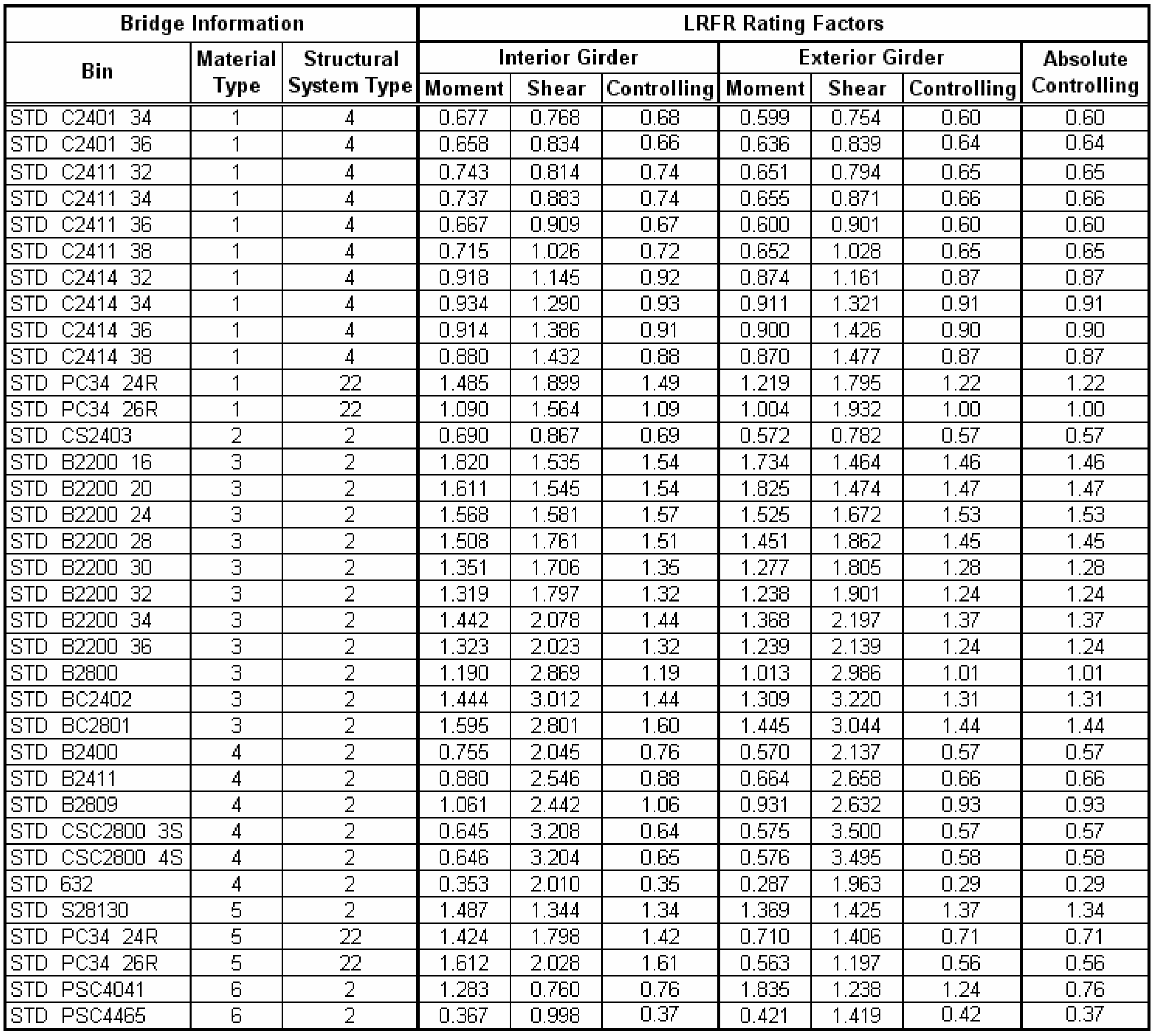
Table 5 - 34: Controlling Permit Vehicles



Load Effect			Permit Vehicle				
			Vehicle 1	Vehicle 3	Vehicle 4	Vehicle 7	Vehicle 8
Exterior Girder	LRFR	Flexural	2	18	36	16	5
		Shear	1	35	41	0	0
	LFR	Flexural	2	20	35	15	5
		Shear	1	35	40	1	0
Interior Girder	LRFR	Flexural	2	18	36	16	5
		Shear	1	36	40	0	0
	LFR	Flexural	2	19	36	16	4
		Shear	1	35	38	2	1

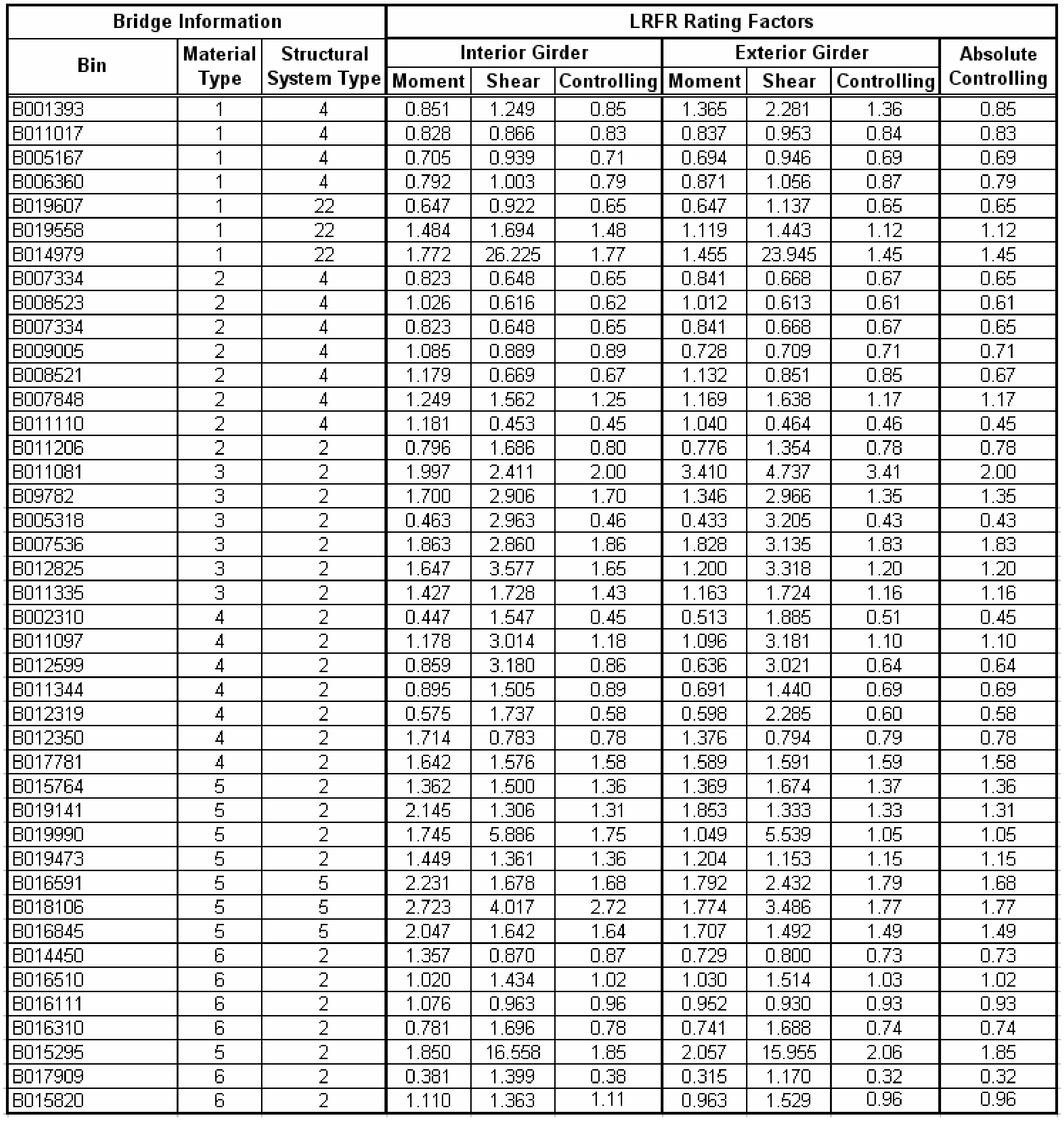
The LRFR to LFR comparisons are presented in a similar format as before. A summary of the controlling rating factors used in the comparisons at the Permit level of rating are provided in Table 5 - 35 through 5 - 38. Table 5 - 35 and 5 - 36 provides the moment and shear rating factors generated for both the interior and exterior girders for each bridge in the sample, under the LRFR methodology. Additionally, the controlling rating factor for the interior and exterior girders are identified, as well as the controlling rating factor for the bridge. Table 5 - 37 and 5 - 38 provides the same rating factor information but for the LFR methodology.

Table 5 - 35: LRFR Rating Factors Generated for the Permit Bridge Sample at the Permit Rating Level, Part 1



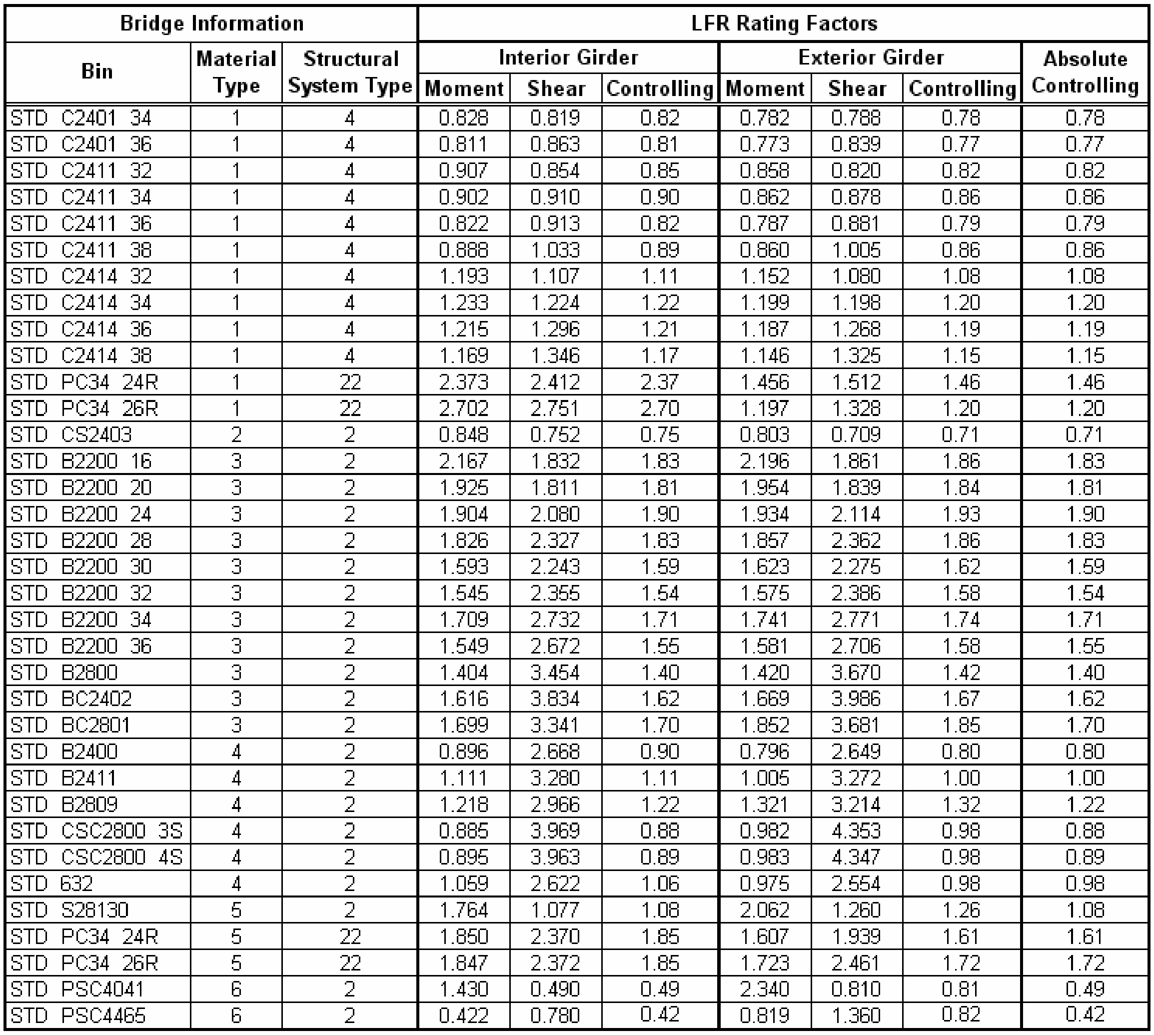
Bridge Information			LRFR Rating Factors						
Bin	Material Type	Structural System Type	Interior Girder			Exterior Girder			Absolute Controlling
			Moment	Shear	Controlling	Moment	Shear	Controlling	
STD C2401 34	1	4	0.677	0.768	0.68	0.599	0.754	0.60	0.60
STD C2401 36	1	4	0.658	0.834	0.66	0.636	0.839	0.64	0.64
STD C2411 32	1	4	0.743	0.814	0.74	0.651	0.794	0.65	0.65
STD C2411 34	1	4	0.737	0.883	0.74	0.655	0.871	0.66	0.66
STD C2411 36	1	4	0.667	0.909	0.67	0.600	0.901	0.60	0.60
STD C2411 38	1	4	0.715	1.026	0.72	0.652	1.028	0.65	0.65
STD C2414 32	1	4	0.918	1.145	0.92	0.874	1.161	0.87	0.87
STD C2414 34	1	4	0.934	1.290	0.93	0.911	1.321	0.91	0.91
STD C2414 36	1	4	0.914	1.386	0.91	0.900	1.426	0.90	0.90
STD C2414 38	1	4	0.880	1.432	0.88	0.870	1.477	0.87	0.87
STD PC34 24R	1	22	1.485	1.899	1.49	1.219	1.795	1.22	1.22
STD PC34 26R	1	22	1.090	1.564	1.09	1.004	1.932	1.00	1.00
STD CS2403	2	2	0.690	0.867	0.69	0.572	0.782	0.57	0.57
STD B2200 16	3	2	1.820	1.535	1.54	1.734	1.464	1.46	1.46
STD B2200 20	3	2	1.611	1.545	1.54	1.825	1.474	1.47	1.47
STD B2200 24	3	2	1.568	1.581	1.57	1.525	1.672	1.53	1.53
STD B2200 28	3	2	1.508	1.761	1.51	1.451	1.862	1.45	1.45
STD B2200 30	3	2	1.351	1.706	1.35	1.277	1.805	1.28	1.28
STD B2200 32	3	2	1.319	1.797	1.32	1.238	1.901	1.24	1.24
STD B2200 34	3	2	1.442	2.078	1.44	1.368	2.197	1.37	1.37
STD B2200 36	3	2	1.323	2.023	1.32	1.239	2.139	1.24	1.24
STD B2800	3	2	1.190	2.869	1.19	1.013	2.986	1.01	1.01
STD BC2402	3	2	1.444	3.012	1.44	1.309	3.220	1.31	1.31
STD BC2801	3	2	1.595	2.801	1.60	1.445	3.044	1.44	1.44
STD B2400	4	2	0.755	2.045	0.76	0.570	2.137	0.57	0.57
STD B2411	4	2	0.880	2.546	0.88	0.664	2.658	0.66	0.66
STD B2809	4	2	1.061	2.442	1.06	0.931	2.632	0.93	0.93
STD CSC2800 3S	4	2	0.645	3.208	0.64	0.575	3.500	0.57	0.57
STD CSC2800 4S	4	2	0.646	3.204	0.65	0.576	3.495	0.58	0.58
STD 632	4	2	0.353	2.010	0.35	0.287	1.963	0.29	0.29
STD S28130	5	2	1.487	1.344	1.34	1.369	1.425	1.37	1.34
STD PC34 24R	5	22	1.424	1.798	1.42	0.710	1.406	0.71	0.71
STD PC34 26R	5	22	1.612	2.028	1.61	0.563	1.197	0.56	0.56
STD PSC4041	6	2	1.283	0.760	0.76	1.835	1.238	1.24	0.76
STD PSC4465	6	2	0.367	0.998	0.37	0.421	1.419	0.42	0.37

Table 5 - 36: LRFR Rating Factors Generated for the Permit Bridge Sample at the Permit Rating Level, Part 2



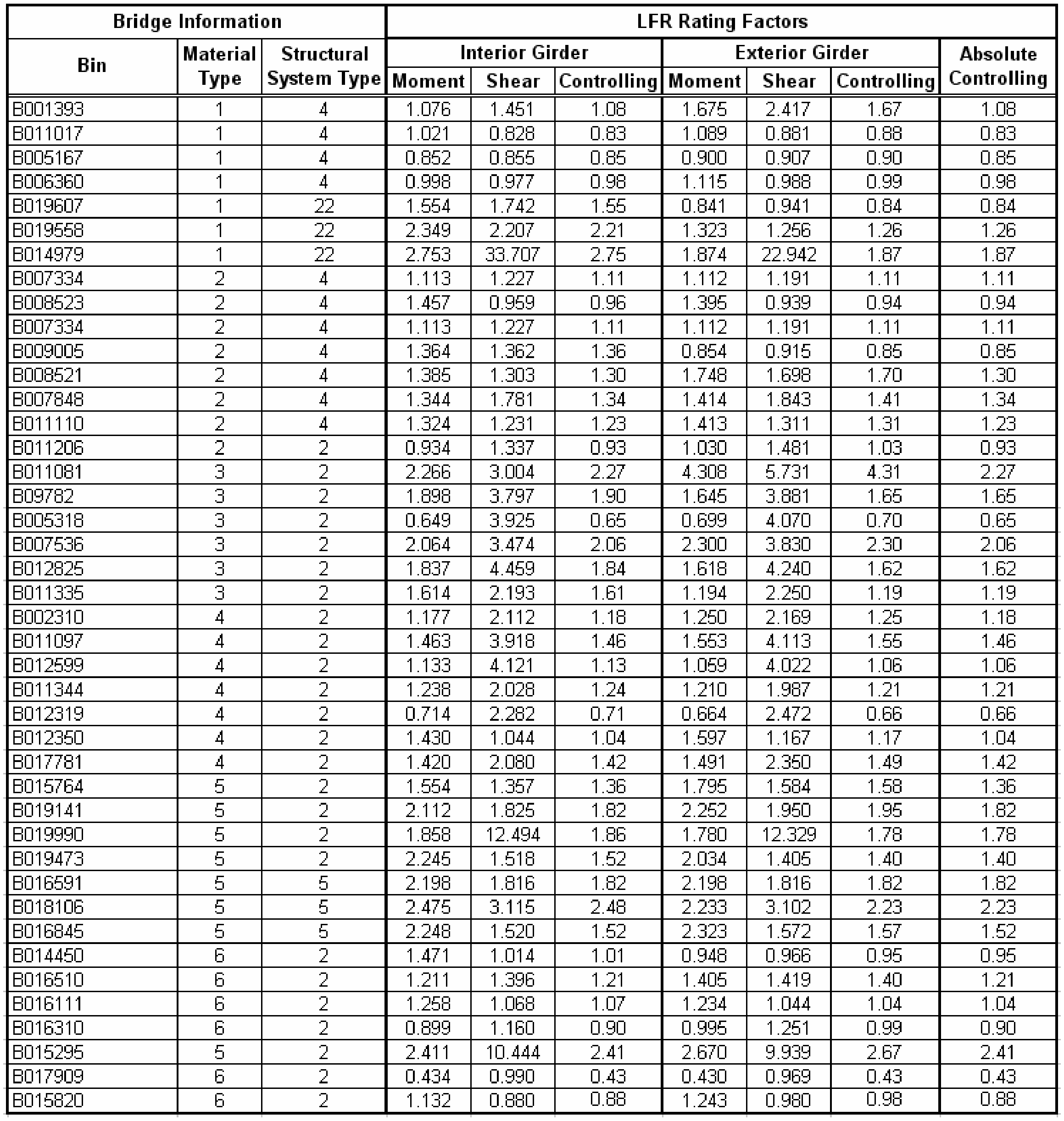
Bridge Information			LRFR Rating Factors						
Bin	Material Type	Structural System Type	Interior Girder			Exterior Girder			Absolute Controlling
			Moment	Shear	Controlling	Moment	Shear	Controlling	
B001393	1	4	0.851	1.249	0.85	1.365	2.281	1.36	0.85
B011017	1	4	0.828	0.866	0.83	0.837	0.953	0.84	0.83
B005167	1	4	0.705	0.939	0.71	0.694	0.946	0.69	0.69
B006360	1	4	0.792	1.003	0.79	0.871	1.056	0.87	0.79
B019607	1	22	0.647	0.922	0.65	0.647	1.137	0.65	0.65
B019558	1	22	1.484	1.694	1.48	1.119	1.443	1.12	1.12
B014979	1	22	1.772	26.225	1.77	1.455	23.945	1.45	1.45
B007334	2	4	0.823	0.648	0.65	0.841	0.668	0.67	0.65
B008523	2	4	1.026	0.616	0.62	1.012	0.613	0.61	0.61
B007334	2	4	0.823	0.648	0.65	0.841	0.668	0.67	0.65
B009005	2	4	1.085	0.889	0.89	0.728	0.709	0.71	0.71
B008521	2	4	1.179	0.669	0.67	1.132	0.851	0.85	0.67
B007848	2	4	1.249	1.562	1.25	1.169	1.638	1.17	1.17
B011110	2	4	1.181	0.453	0.45	1.040	0.464	0.46	0.45
B011206	2	2	0.796	1.686	0.80	0.776	1.354	0.78	0.78
B011081	3	2	1.997	2.411	2.00	3.410	4.737	3.41	2.00
B09782	3	2	1.700	2.906	1.70	1.346	2.966	1.35	1.35
B005318	3	2	0.463	2.963	0.46	0.433	3.205	0.43	0.43
B007536	3	2	1.863	2.860	1.86	1.828	3.135	1.83	1.83
B012825	3	2	1.647	3.577	1.65	1.200	3.318	1.20	1.20
B011335	3	2	1.427	1.728	1.43	1.163	1.724	1.16	1.16
B002310	4	2	0.447	1.547	0.45	0.513	1.885	0.51	0.45
B011097	4	2	1.178	3.014	1.18	1.096	3.181	1.10	1.10
B012599	4	2	0.859	3.180	0.86	0.636	3.021	0.64	0.64
B011344	4	2	0.895	1.505	0.89	0.691	1.440	0.69	0.69
B012319	4	2	0.575	1.737	0.58	0.598	2.285	0.60	0.58
B012350	4	2	1.714	0.783	0.78	1.376	0.794	0.79	0.78
B017781	4	2	1.642	1.576	1.58	1.589	1.591	1.59	1.58
B015764	5	2	1.362	1.500	1.36	1.369	1.674	1.37	1.36
B019141	5	2	2.145	1.306	1.31	1.853	1.333	1.33	1.31
B019990	5	2	1.745	5.886	1.75	1.049	5.539	1.05	1.05
B019473	5	2	1.449	1.361	1.36	1.204	1.153	1.15	1.15
B016591	5	5	2.231	1.678	1.68	1.792	2.432	1.79	1.68
B018106	5	5	2.723	4.017	2.72	1.774	3.486	1.77	1.77
B016845	5	5	2.047	1.642	1.64	1.707	1.492	1.49	1.49
B014450	6	2	1.357	0.870	0.87	0.729	0.800	0.73	0.73
B016510	6	2	1.020	1.434	1.02	1.030	1.514	1.03	1.02
B016111	6	2	1.076	0.963	0.96	0.952	0.930	0.93	0.93
B016310	6	2	0.781	1.696	0.78	0.741	1.688	0.74	0.74
B015295	5	2	1.850	16.558	1.85	2.057	15.955	2.06	1.85
B017909	6	2	0.381	1.399	0.38	0.315	1.170	0.32	0.32
B015820	6	2	1.110	1.363	1.11	0.963	1.529	0.96	0.96

Table 5 - 37: LFR Rating Factors Generated for the Permit Bridge Sample at the Permit Rating Level, Part 1



Bridge Information			LFR Rating Factors						
Bin	Material Type	Structural System Type	Interior Girder			Exterior Girder			Absolute Controlling
			Moment	Shear	Controlling	Moment	Shear	Controlling	
STD C2401 34	1	4	0.828	0.819	0.82	0.782	0.788	0.78	0.78
STD C2401 36	1	4	0.811	0.863	0.81	0.773	0.839	0.77	0.77
STD C2411 32	1	4	0.907	0.854	0.85	0.858	0.820	0.82	0.82
STD C2411 34	1	4	0.902	0.910	0.90	0.862	0.878	0.86	0.86
STD C2411 36	1	4	0.822	0.913	0.82	0.787	0.881	0.79	0.79
STD C2411 38	1	4	0.888	1.033	0.89	0.860	1.005	0.86	0.86
STD C2414 32	1	4	1.193	1.107	1.11	1.152	1.080	1.08	1.08
STD C2414 34	1	4	1.233	1.224	1.22	1.199	1.198	1.20	1.20
STD C2414 36	1	4	1.215	1.296	1.21	1.187	1.268	1.19	1.19
STD C2414 38	1	4	1.169	1.346	1.17	1.146	1.325	1.15	1.15
STD PC34 24R	1	22	2.373	2.412	2.37	1.456	1.512	1.46	1.46
STD PC34 26R	1	22	2.702	2.751	2.70	1.197	1.328	1.20	1.20
STD CS2403	2	2	0.848	0.752	0.75	0.803	0.709	0.71	0.71
STD B2200 16	3	2	2.167	1.832	1.83	2.196	1.861	1.86	1.83
STD B2200 20	3	2	1.925	1.811	1.81	1.954	1.839	1.84	1.81
STD B2200 24	3	2	1.904	2.080	1.90	1.934	2.114	1.93	1.90
STD B2200 28	3	2	1.826	2.327	1.83	1.857	2.362	1.86	1.83
STD B2200 30	3	2	1.593	2.243	1.59	1.623	2.275	1.62	1.59
STD B2200 32	3	2	1.545	2.355	1.54	1.575	2.386	1.58	1.54
STD B2200 34	3	2	1.709	2.732	1.71	1.741	2.771	1.74	1.71
STD B2200 36	3	2	1.549	2.672	1.55	1.581	2.706	1.58	1.55
STD B2800	3	2	1.404	3.454	1.40	1.420	3.670	1.42	1.40
STD BC2402	3	2	1.616	3.834	1.62	1.669	3.986	1.67	1.62
STD BC2801	3	2	1.699	3.341	1.70	1.852	3.681	1.85	1.70
STD B2400	4	2	0.896	2.668	0.90	0.796	2.649	0.80	0.80
STD B2411	4	2	1.111	3.280	1.11	1.005	3.272	1.00	1.00
STD B2809	4	2	1.218	2.966	1.22	1.321	3.214	1.32	1.22
STD CSC2800 3S	4	2	0.885	3.969	0.88	0.982	4.353	0.98	0.88
STD CSC2800 4S	4	2	0.895	3.963	0.89	0.983	4.347	0.98	0.89
STD 632	4	2	1.059	2.622	1.06	0.975	2.554	0.98	0.98
STD S28130	5	2	1.764	1.077	1.08	2.062	1.260	1.26	1.08
STD PC34 24R	5	22	1.850	2.370	1.85	1.607	1.939	1.61	1.61
STD PC34 26R	5	22	1.847	2.372	1.85	1.723	2.461	1.72	1.72
STD PSC4041	6	2	1.430	0.490	0.49	2.340	0.810	0.81	0.49
STD PSC4465	6	2	0.422	0.780	0.42	0.819	1.360	0.82	0.42

Table 5 - 38: LFR Rating Factors Generated for the Permit Bridge Sample at the Permit Rating Level, Part 2



Bridge Information			LFR Rating Factors						
Bin	Material Type	Structural System Type	Interior Girder			Exterior Girder			Absolute Controlling
			Moment	Shear	Controlling	Moment	Shear	Controlling	
B001393	1	4	1.076	1.451	1.08	1.675	2.417	1.67	1.08
B011017	1	4	1.021	0.828	0.83	1.089	0.881	0.88	0.83
B005167	1	4	0.852	0.855	0.85	0.900	0.907	0.90	0.85
B006360	1	4	0.998	0.977	0.98	1.115	0.988	0.99	0.98
B019607	1	22	1.554	1.742	1.55	0.841	0.941	0.84	0.84
B019558	1	22	2.349	2.207	2.21	1.323	1.256	1.26	1.26
B014979	1	22	2.753	33.707	2.75	1.874	22.942	1.87	1.87
B007334	2	4	1.113	1.227	1.11	1.112	1.191	1.11	1.11
B008523	2	4	1.457	0.959	0.96	1.395	0.939	0.94	0.94
B007334	2	4	1.113	1.227	1.11	1.112	1.191	1.11	1.11
B009005	2	4	1.364	1.362	1.36	0.854	0.915	0.85	0.85
B008521	2	4	1.385	1.303	1.30	1.748	1.698	1.70	1.30
B007848	2	4	1.344	1.781	1.34	1.414	1.843	1.41	1.34
B011110	2	4	1.324	1.231	1.23	1.413	1.311	1.31	1.23
B011206	2	2	0.934	1.337	0.93	1.030	1.481	1.03	0.93
B011081	3	2	2.266	3.004	2.27	4.308	5.731	4.31	2.27
B09782	3	2	1.898	3.797	1.90	1.645	3.881	1.65	1.65
B005318	3	2	0.649	3.925	0.65	0.699	4.070	0.70	0.65
B007536	3	2	2.064	3.474	2.06	2.300	3.830	2.30	2.06
B012825	3	2	1.837	4.459	1.84	1.618	4.240	1.62	1.62
B011335	3	2	1.614	2.193	1.61	1.194	2.250	1.19	1.19
B002310	4	2	1.177	2.112	1.18	1.250	2.169	1.25	1.18
B011097	4	2	1.463	3.918	1.46	1.553	4.113	1.55	1.46
B012599	4	2	1.133	4.121	1.13	1.059	4.022	1.06	1.06
B011344	4	2	1.238	2.028	1.24	1.210	1.987	1.21	1.21
B012319	4	2	0.714	2.282	0.71	0.664	2.472	0.66	0.66
B012350	4	2	1.430	1.044	1.04	1.597	1.167	1.17	1.04
B017781	4	2	1.420	2.080	1.42	1.491	2.350	1.49	1.42
B015764	5	2	1.554	1.357	1.36	1.795	1.584	1.58	1.36
B019141	5	2	2.112	1.825	1.82	2.252	1.950	1.95	1.82
B019990	5	2	1.858	12.494	1.86	1.780	12.329	1.78	1.78
B019473	5	2	2.245	1.518	1.52	2.034	1.405	1.40	1.40
B016591	5	5	2.198	1.816	1.82	2.198	1.816	1.82	1.82
B018106	5	5	2.475	3.115	2.48	2.233	3.102	2.23	2.23
B016845	5	5	2.248	1.520	1.52	2.323	1.572	1.57	1.52
B014450	6	2	1.471	1.014	1.01	0.948	0.966	0.95	0.95
B016510	6	2	1.211	1.396	1.21	1.405	1.419	1.40	1.21
B016111	6	2	1.258	1.068	1.07	1.234	1.044	1.04	1.04
B016310	6	2	0.899	1.160	0.90	0.995	1.251	0.99	0.90
B015295	5	2	2.411	10.444	2.41	2.670	9.939	2.67	2.41
B017909	6	2	0.434	0.990	0.43	0.430	0.969	0.43	0.43
B015820	6	2	1.132	0.880	0.88	1.243	0.980	0.98	0.88

Comparisons of the moment rating factors are presented in Figure 5 - 38. Similar to previous results, the majority of data is found within Region 5, with only a few data points found in Region 6, indicating that for the LRFR produces nearly equal or lower rating results when compared to the LFR at the permit level. Bridges found within

Region 5 - 1, while having lower LRFR factors, are found to be unsatisfactory for both LRFR and LFR for the controlling permit truck. This results in the controlling load not being permitted for bridges found within this region. Bridges within Region 5 - 3, while having lower LRFR factors, are found to be satisfactory for both LRFR and LFR for the controlling permit load. This results in permits being granted under LRFR and LFR for all bridges within this region. Data found in Region 5 - 2 are satisfactory under LFR but not under LRFR. These represent bridges where permits would be under LFR, but not LRFR.

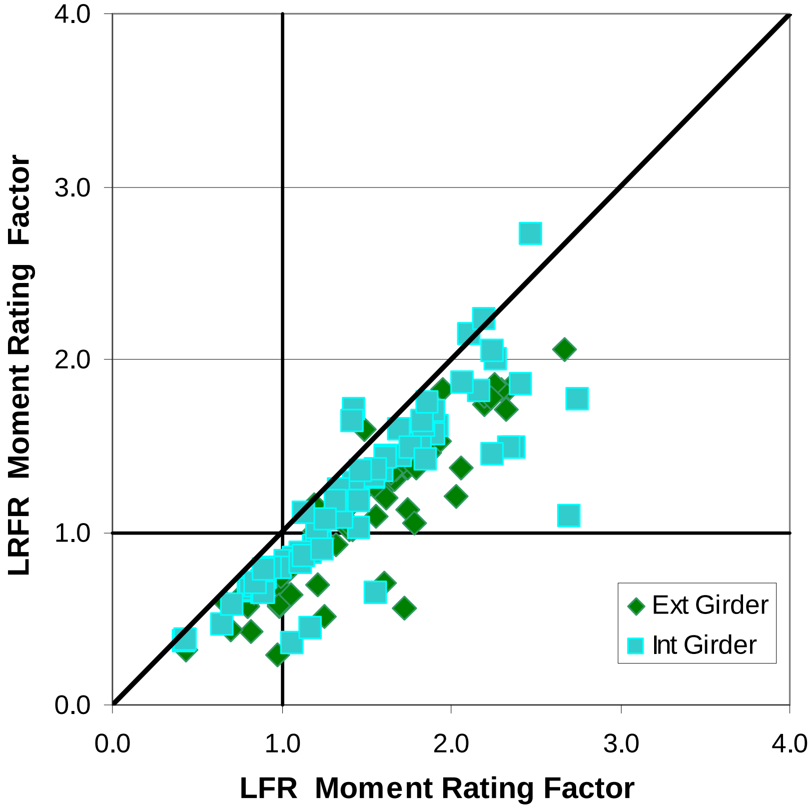


Figure 5 - 38: Moment Rating Factor Comparison at the Permit Level for the Permit Bridge Sample

Breaking down the LRFR interior girder moment rating data into its material types produced little additional information. As Figure 5 - 39 shows, nearly all the material types can be found in Regions 5 - 1, 5 - 2, and 5 - 3. However a large amount of the simply supported steel and presstresed concrete bridges can be found in Region 5 – 3. Additionally only simply supported prestressed concrete bridges and steel continuously supported bridges were found in Region 6 – 3. Similar trends were found for the exterior girders.

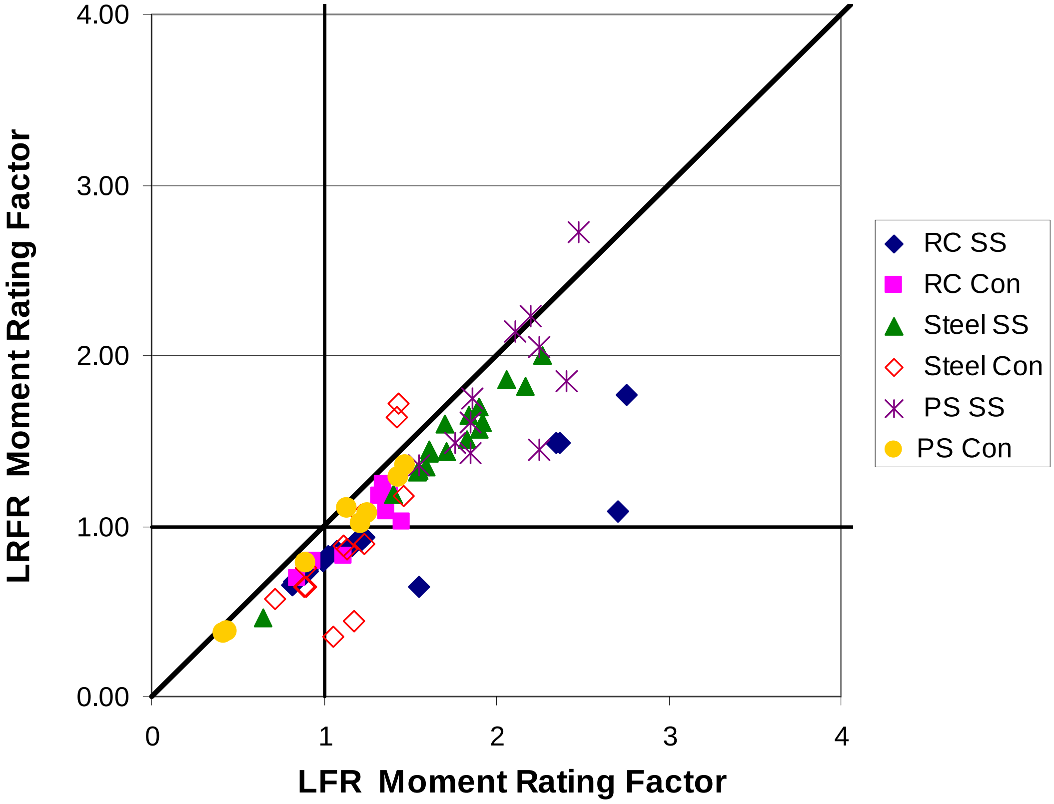


Figure 5 - 39: Moment Rating Factor Material Type Comparison at the Permit Level for the Permit Bridge Sample Interior Girders

Figure 5 - 40 shows the LRFR to LFR shear rating data for the interior and exterior girders. As can be seen there are large portions of the data in both Region 5 and 6 of the plot. Additionally a trend can be seen that as rating factors become greater than 2.0 for either rating methodology the data primarily falls in Region 5. However, for shear rating factors less than 2.0 for either rating methodology, the data falls in both Regions 5 and 6.

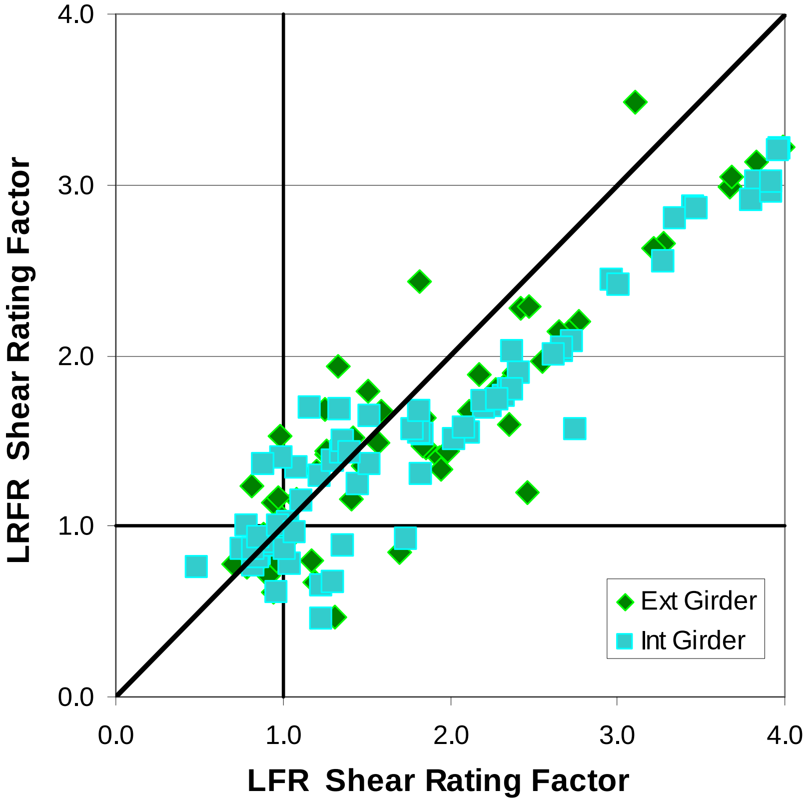


Figure 5 - 40: Shear Rating Factor Comparison at the Permit Level for the Permit Bridge Sample

Breaking down the LRFR interior girder shear rating data into its material types produced some additional information as seen in Figure 5 - 41. From this plot it is shown that all the simply and continuously supported steel bridges can be found in Region 5. Additionally all the reinforced and prestressed concrete bridges tend to be near the border of Region 5 with Region 6.

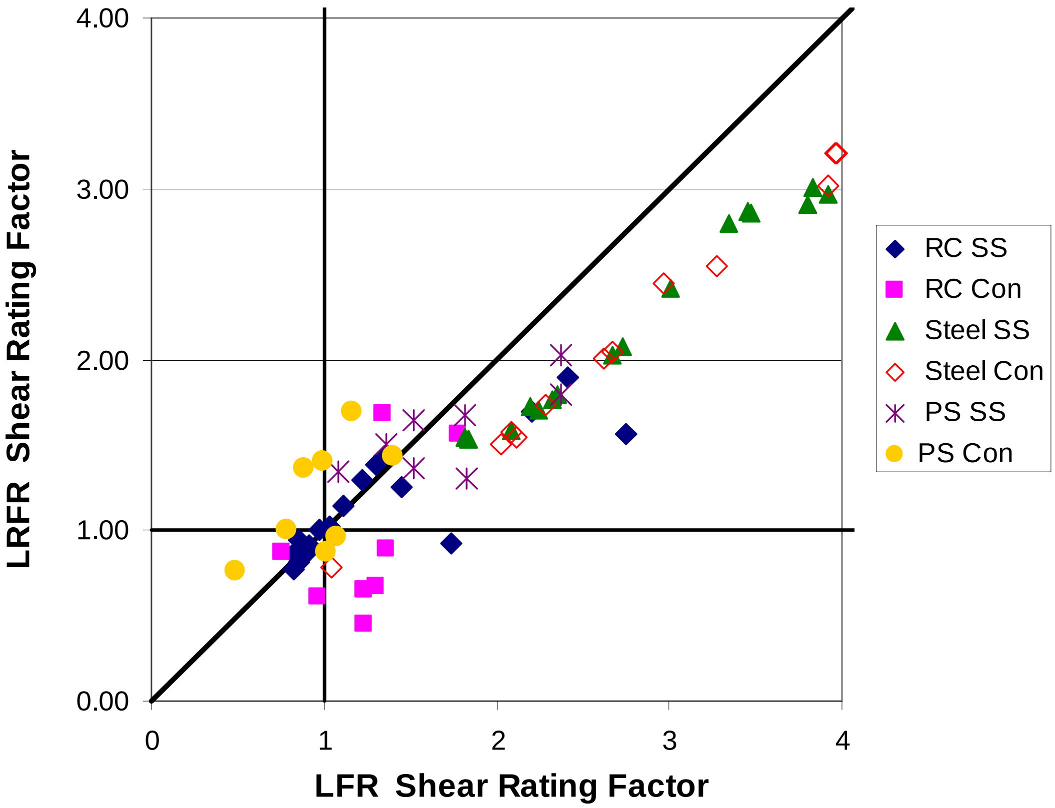
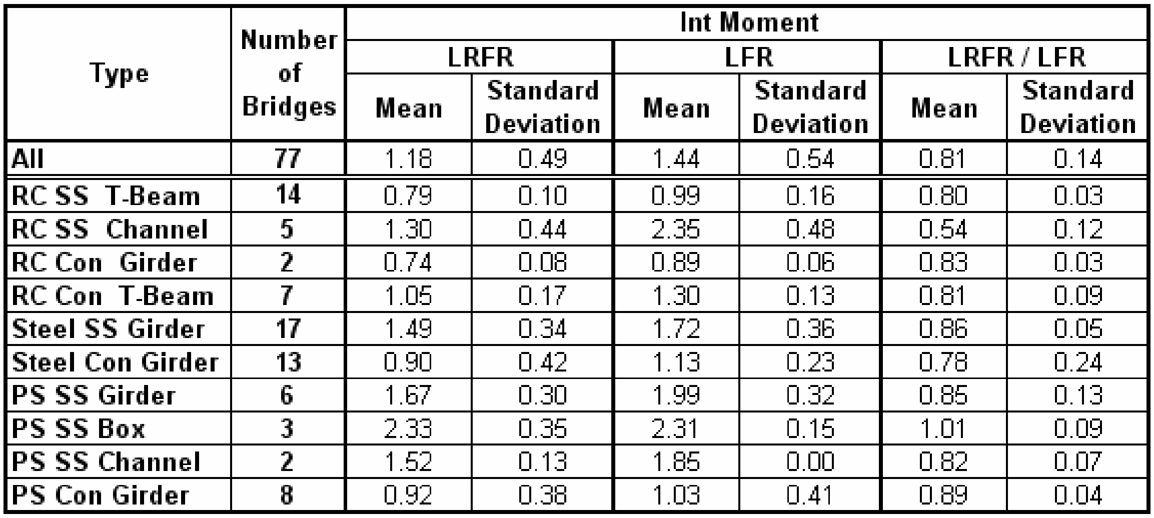


Figure 5 - 41: Moment Rating Factor Material Type Comparison at the Permit Level for the Permit Bridge Sample Interior Girders

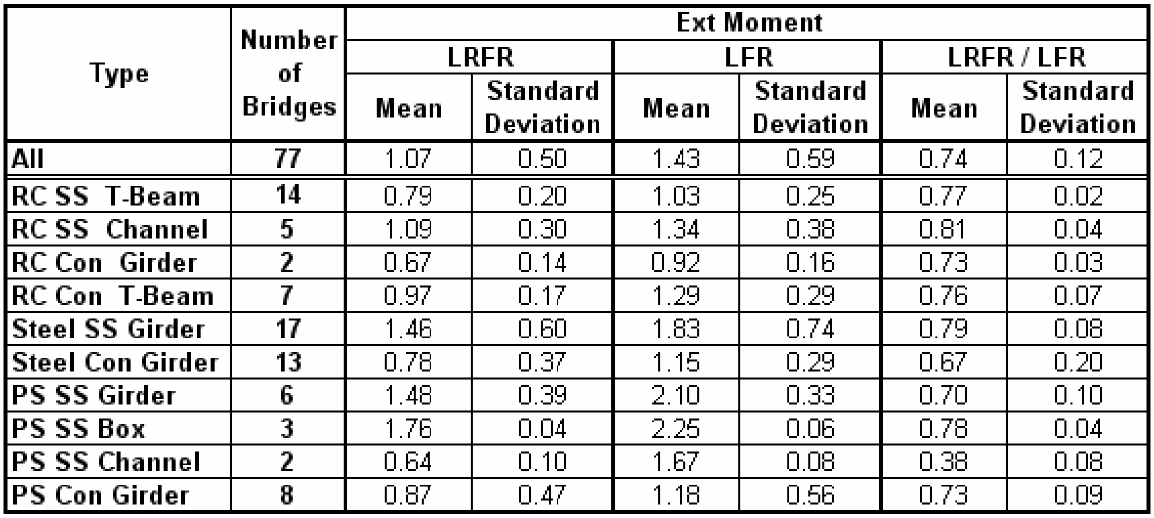
Statistical analysis was performed on the Permit level rating factor data and the results are provided in Tables 5 - 39 through 5 - 42. Tables 5 - 39 and 5 - 40 provide the moment rating factor data analysis for the interior and exterior girders. Similar to previous findings the LRFR is shown to produce nearly equal or lower rating results when compared to the LFR. The C-Channel structural system type produced unusual low and high LRFR to LFR ratios for the interior and exterior girders, respectively, as seen previously.

Table 5 - 39: Mean and Standard Deviation Data at the Permit Level for the Permit Bridge Sample – Interior Girder Moment Rating Data



Type	Number of Bridges	Int Moment					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	**77**	1.18	0.49	1.44	0.54	0.81	0.14
RC SS T-Beam	**14**	0.79	0.10	0.99	0.16	0.80	0.03
RC SS Channel	**5**	1.30	0.44	2.35	0.48	0.54	0.12
RC Con Girder	**2**	0.74	0.08	0.89	0.06	0.83	0.03
RC Con T-Beam	**7**	1.05	0.17	1.30	0.13	0.81	0.09
Steel SS Girder	**17**	1.49	0.34	1.72	0.36	0.86	0.05
Steel Con Girder	**13**	0.90	0.42	1.13	0.23	0.78	0.24
PS SS Girder	**6**	1.67	0.30	1.99	0.32	0.85	0.13
PS SS Box	**3**	2.33	0.35	2.31	0.15	1.01	0.09
PS SS Channel	**2**	1.52	0.13	1.85	0.00	0.82	0.07
PS Con Girder	**8**	0.92	0.38	1.03	0.41	0.89	0.04

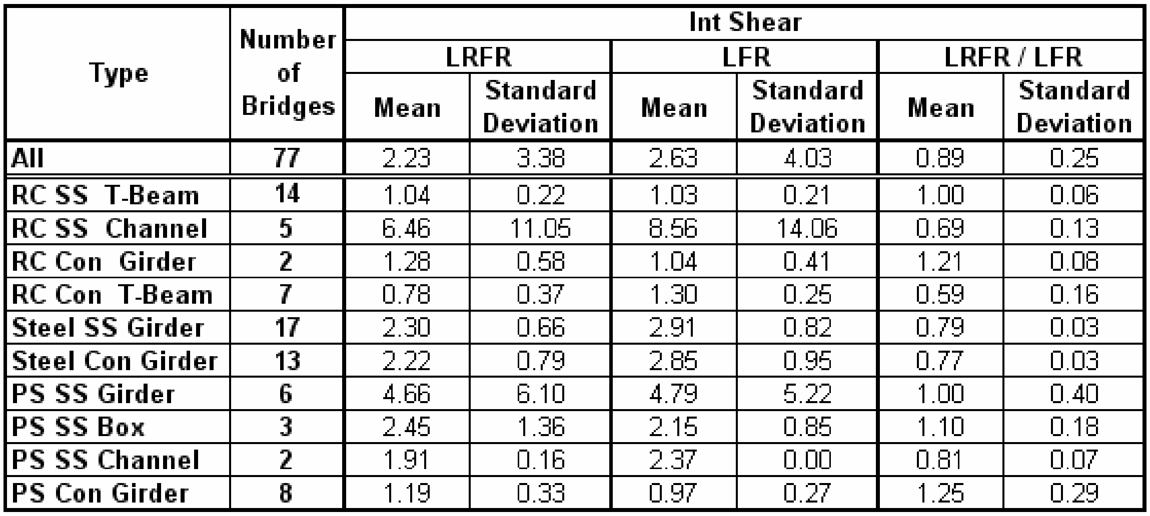
Table 5 - 40: Mean and Standard Deviation Data at the Permit Level for the Permit Bridge Sample – Exterior Girder Moment Rating Data



Type	Number of Bridges	Ext Moment					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	**77**	1.07	0.50	1.43	0.59	0.74	0.12
RC SS T-Beam	**14**	0.79	0.20	1.03	0.25	0.77	0.02
RC SS Channel	**5**	1.09	0.30	1.34	0.38	0.81	0.04
RC Con Girder	**2**	0.67	0.14	0.92	0.16	0.73	0.03
RC Con T-Beam	**7**	0.97	0.17	1.29	0.29	0.76	0.07
Steel SS Girder	**17**	1.46	0.60	1.83	0.74	0.79	0.08
Steel Con Girder	**13**	0.78	0.37	1.15	0.29	0.67	0.20
PS SS Girder	**6**	1.48	0.39	2.10	0.33	0.70	0.10
PS SS Box	**3**	1.76	0.04	2.25	0.06	0.78	0.04
PS SS Channel	**2**	0.64	0.10	1.67	0.08	0.38	0.08
PS Con Girder	**8**	0.87	0.47	1.18	0.56	0.73	0.09

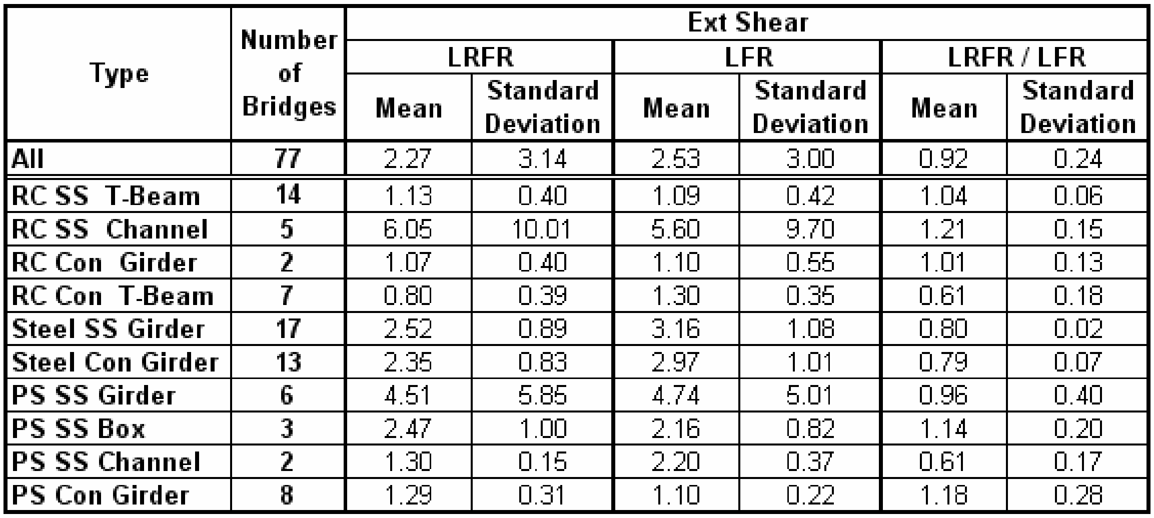
Tables 5 - 41 and 5 - 42 provide the shear data analysis for the interior and exterior girders. Similar to pervious data the LRFR is shown to generally produce nearly equal or lower rating factors when compared to the LFR. There are a few exceptions to this with regards to a few reinforced and prestressed concrete bridge types showing the LRFR produced slightly higher rating factors than the LFR.

Table 5 - 41: Mean and Standard Deviation Data at the Permit Level for the Permit Bridge Sample – Interior Girder Shear Rating Data



Type	Number of Bridges	Int Shear					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	**77**	2.23	3.38	2.63	4.03	0.89	0.25
RC SS T-Beam	**14**	1.04	0.22	1.03	0.21	1.00	0.06
RC SS Channel	**5**	6.46	11.05	8.56	14.06	0.69	0.13
RC Con Girder	**2**	1.28	0.58	1.04	0.41	1.21	0.08
RC Con T-Beam	**7**	0.78	0.37	1.30	0.25	0.59	0.16
Steel SS Girder	**17**	2.30	0.66	2.91	0.82	0.79	0.03
Steel Con Girder	**13**	2.22	0.79	2.85	0.95	0.77	0.03
PS SS Girder	**6**	4.66	6.10	4.79	5.22	1.00	0.40
PS SS Box	**3**	2.45	1.36	2.15	0.85	1.10	0.18
PS SS Channel	**2**	1.91	0.16	2.37	0.00	0.81	0.07
PS Con Girder	**8**	1.19	0.33	0.97	0.27	1.25	0.29

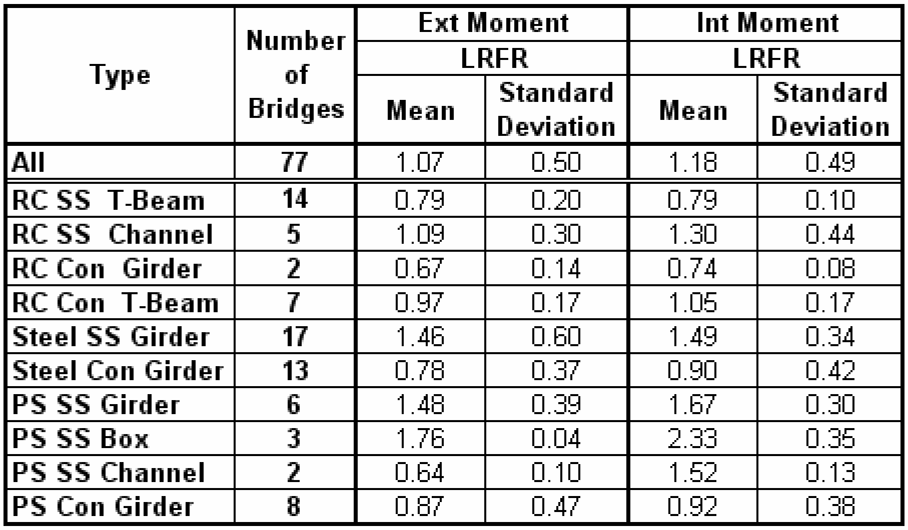
Table 5 - 42: Mean and Standard Deviation Data at the Permit Level for the Permit Bridge Sample – Exterior Girder Shear Rating Data



Type	Number of Bridges	Ext Shear					
		LRFR		LFR		LRFR / LFR	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
All	77	2.27	3.14	2.53	3.00	0.92	0.24
RC SS T-Beam	14	1.13	0.40	1.09	0.42	1.04	0.06
RC SS Channel	5	6.05	10.01	5.60	9.70	1.21	0.15
RC Con Girder	2	1.07	0.40	1.10	0.55	1.01	0.13
RC Con T-Beam	7	0.80	0.39	1.30	0.35	0.61	0.18
Steel SS Girder	17	2.52	0.89	3.16	1.08	0.80	0.02
Steel Con Girder	13	2.35	0.83	2.97	1.01	0.79	0.07
PS SS Girder	6	4.51	5.85	4.74	5.01	0.96	0.40
PS SS Box	3	2.47	1.00	2.16	0.82	1.14	0.20
PS SS Channel	2	1.30	0.15	2.20	0.37	0.61	0.17
PS Con Girder	8	1.29	0.31	1.10	0.22	1.18	0.28

Additionally, as was observed with the Design Inventory level rating data, the Permit level rating data suggests that the exterior girder produces lower flexural rating factors than the interior girder for the LRFR methodology, as shown in Table 5 - 43.

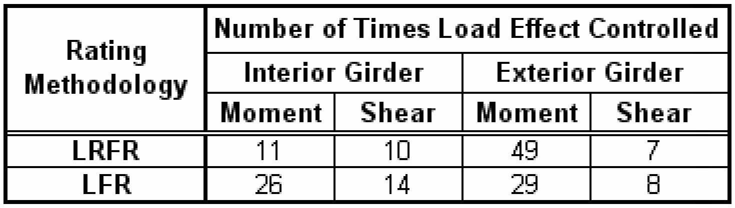
Table 5 - 43: Mean and Standard Deviation Data at the Permit level for the Permit Bridge Sample – Interior to Exterior LRFR Moment Rating Comparison



Type	Number of Bridges	Ext Moment		Int Moment	
		LRFR		LRFR	
		Mean	Standard Deviation	Mean	Standard Deviation
All	77	1.07	0.50	1.18	0.49
RC SS T-Beam	14	0.79	0.20	0.79	0.10
RC SS Channel	5	1.09	0.30	1.30	0.44
RC Con Girder	2	0.67	0.14	0.74	0.08
RC Con T-Beam	7	0.97	0.17	1.05	0.17
Steel SS Girder	17	1.46	0.60	1.49	0.34
Steel Con Girder	13	0.78	0.37	0.90	0.42
PS SS Girder	6	1.48	0.39	1.67	0.30
PS SS Box	3	1.76	0.04	2.33	0.35
PS SS Channel	2	0.64	0.10	1.52	0.13
PS Con Girder	8	0.87	0.47	0.92	0.38

An additional point of comparison was made for the controlling load effect for each rating methodology. Table 5 - 44 shows the results of this comparison. The data in this table was constructed by counting the number of times a rating factor for each load effect controlled for a bridge within the sample. The data indicate that, for the LRFR methodology, exterior girder moment load effects mainly controlled. For the LFR methodology, the sample was more heavily controlled by moment load effects for both exterior and interior girders.

Table 5 - 44: Controlling Load Effect Comparison, Permit Level for the Permit Bridge Sample



Rating Methodology	Number of Times Load Effect Controlled			
	Interior Girder		Exterior Girder	
	Moment	Shear	Moment	Shear
LRFR	11	10	49	7
LFR	26	14	29	8

Note: The permit bridge sample consists of 77 bridges

Additionally, the absolute controlling rating factor between the two rating methodologies was compared. The absolute controlling rating factor data used for this comparison can be found in the previously shown Tables 5 - 35 through 5 - 38. Provided in Figure 5 – 42 is a LRFR verses LFR plot of the absolute controlling rating data. From this plot it is seen that the majority of the data falls into Region 5 with only two data points found in Region 6. This indicates that the LRFR produced lower rating results than the LFR in general.

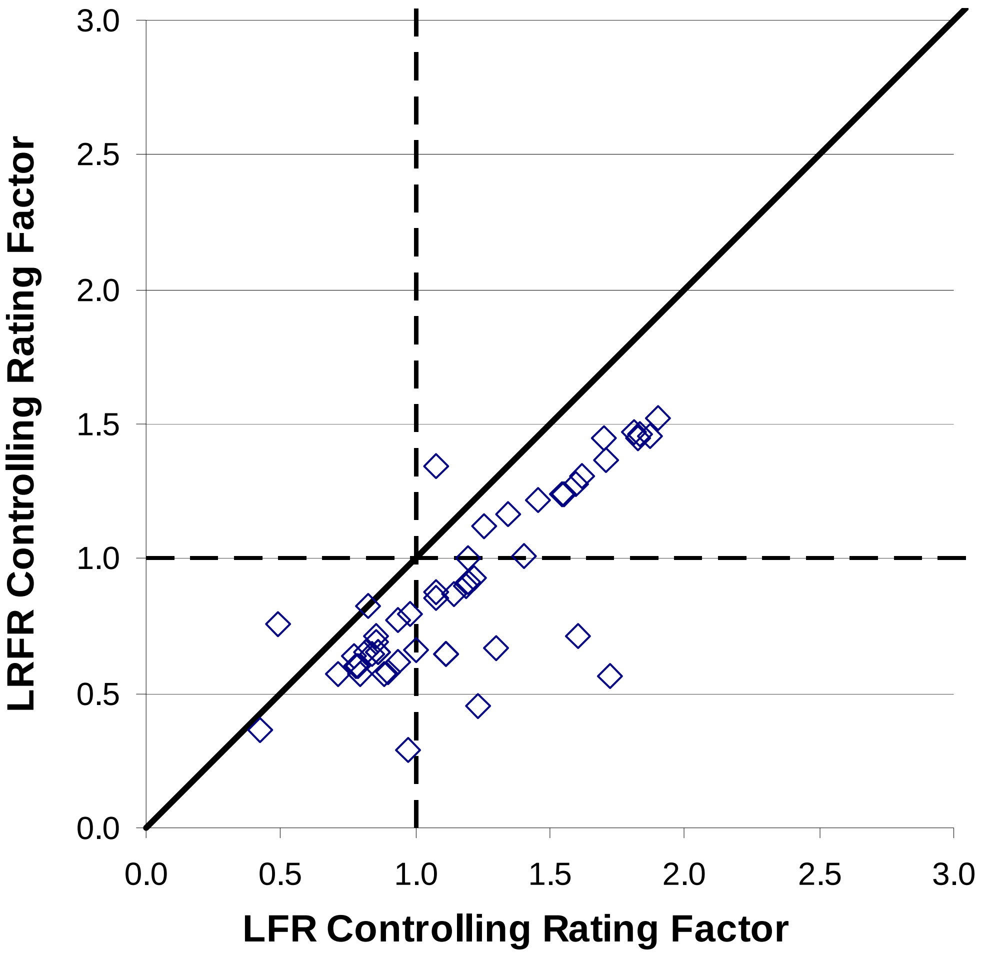
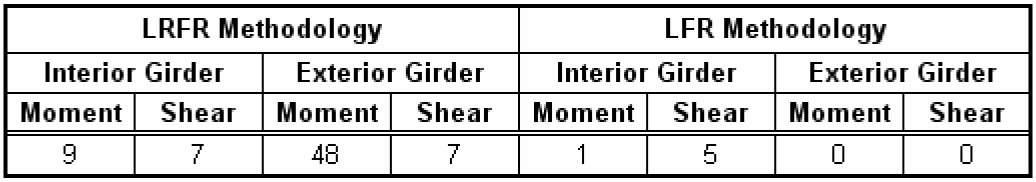


Figure 5 - 42: Controlling Rating Factor Comparisons at the Permit Level for the Permit Bridge Sample

The final point of comparison was on the absolute controlling load effect and rating methodology, Table 5 - 45 shows the results of this comparison. The data provided in Table 5 - 45 is the total number of times each load effect and methodology controlled for the bridge sample. This data indicates that the LRFR exterior girder moment load effect primarily controlled.



LRFR Methodology				LFR Methodology			
Interior Girder		Exterior Girder		Interior Girder		Exterior Girder	
Moment	Shear	Moment	Shear	Moment	Shear	Moment	Shear
9	7	48	7	1	5	0	0

Note: The permit bridge sample consists of 77 bridges

Table 5 - 45: Controlling Load Effect and Rating Methodology at the Permit Level for the Permit Bridge Sample

5.4.3 Summary

Analysis of the Permit bridge samples at the Permit level of rating provided the following general findings:

- The LFR allows a slightly greater number of bridges to be considered for permitting compared to the LRFR
- Permit Vehicle 3 and 4 largely controlled the rating analysis for both LRFR and LFR for both load effects
- LRFR tends to produce nearly equal or lower moment rating factors compared to the LFR
- LRFR tends to produce nearly equal or lower shear rating factors compared to the LFR, with a few exceptions
- Exterior girders tend to control over interior girders for moment load effects under the LRFR

5.5 Analysis of Rating Results

As shown in the previous sections, reviewing the results at each of the LRFR rating levels reveals that on average the LRFR produces nearly equal or lower rating results when compared to the LFR. To gain additional insight into the observed trends, the results at the legal load level were analyzed in greater detail. In particular, the variation of each of the of the components of the fundamental rating equation, Equation 2 - 1, (i.e. the factored capacity, *C*, factored dead load effect, *D*, and factored live load effect, *L*) with the rating factor was investigated. Figure 5 - 43, shows a plot of LRFR to LFR component ratios verses the LRFR to LFR moment rating factor ratio, for the standard and unique bridge samples at the Legal load level of rating. The live load data used in this study was from the ALDOT Tri-Axle load model. Three sets of data are shown on the y-axis. The first set is for the LRFR to LFR capacity ratio, denoted as ratio *C ratio* in the figure. The second set is for the LRFR to LFR dead load effect ratio, denoted as *D ratio* in the figure. The third set is for LRFR to LFR live load effect ratio, denoted as *L ratio* in the figure.

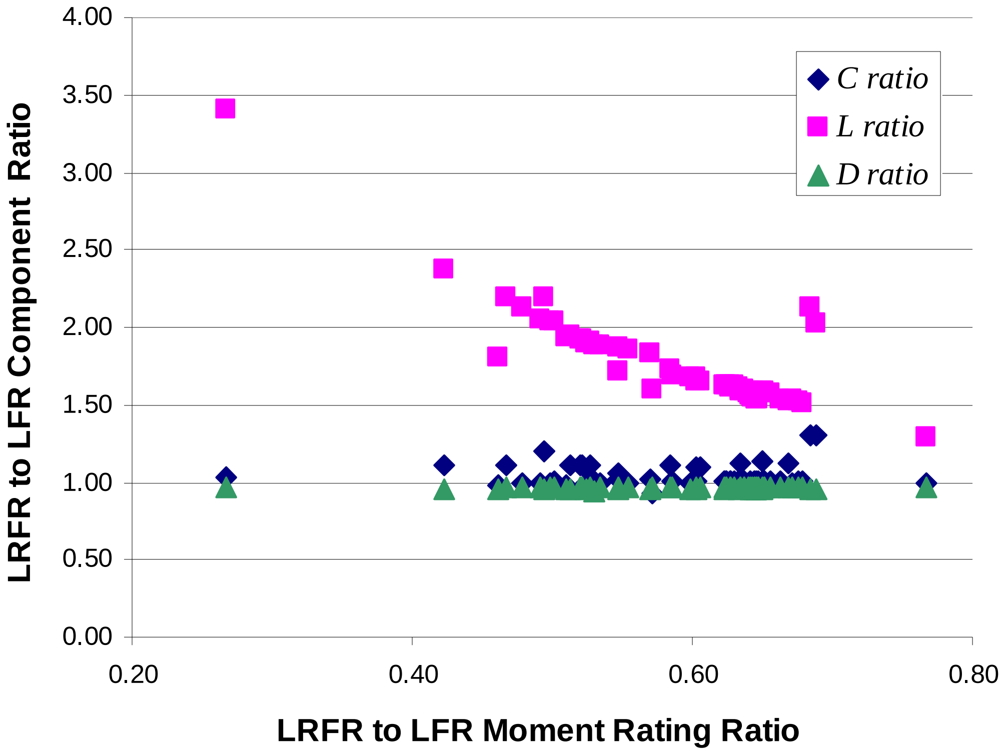


Figure 5 - 43: LRFR to LFR Component Ratio Comparisons for Exterior Girder Moment Rating Factors

Examining Figure 5 - 43 two important observations are made. First, it can be observed that the *D ratio* for the two methodologies is nearly constant for all LRFR to LFR moment rating factor ratios. This is expected because there is be no difference in the way the dead load is calculated between the two methodologies. The observation that the *D ratios* is slightly less than 1.0 is due to the difference in dead load factors for the two methodologies (i.e. dead load factor for LRFR is equal to1.25 and 1.3 for the LFR). The second observation is that the *C ratio* for the two methodologies is relativity constant, being equal to 1.0 or slightly greater; with the exception of two data points, as discussed next.

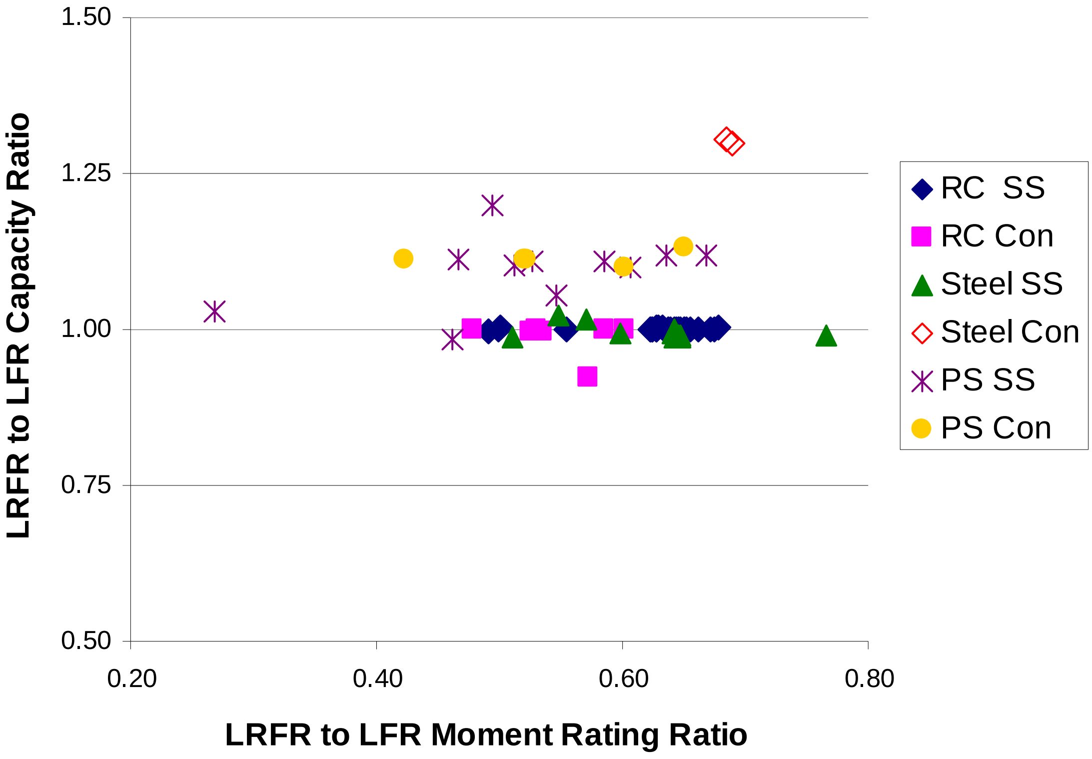


Figure 5 - 44: LRFR to LFR Capacity Ratio Comparisons for Exterior Girder Moment Rating Factors

Breaking the resistance ratios studied previously into their material types, as shown in Figure 5 - 44, reveals additional information about differences between the two rating methodologies. In general, it can been seen that the resistance ratios for reinforced concrete simply and continuously supported bridges and steel simply supported bridges are constant, indicating that little difference in the capacities between the LRFR and the LFR is observed for these material types. Prestressed concrete simply and continuously supported bridges tended to exhibit a *C ratio* of about 1.1 suggesting that LRFR capacities are roughly ten percent higher than the LFR capacities. Steel continuously supported bridges show a *C ratio* closer to 1.3 suggesting that the LRFR capacities are on the order of thirty percent greater than the LFR capacities. The differences in the capacities shown for these material types can be attributed to differences in the capacity calculation guidelines found in the AASTHO LRFD Bridge Design Specification (2007) and the AASTHO Standard Specification for Bridge Design (2002), used for the LRFR and LFR respectively.

Examining the *L ratio* data from Figure 5 - 43 a decaying trend can be observed. To investigate this trend the LRFR to LFR rating factor, *RF*, ratio is examined in greater detail. The LRFR to LFR *RF* ratio can be written in the following form:

$$\frac{RF_{LRFR}}{RF_{LFR}} = \frac{\dfrac{(C-D)_{LRFR}}{L_{LRFR}}}{\dfrac{(C-D)_{LFR}}{L_{LFR}}} \qquad \textit{Equation 5 - 1}$$

Equation 5 - 1 can be written in the following form:

$$\frac{RF_{LRFR}}{RF_{LFR}} = \left(\frac{(C-D)_{LRFR}}{(C-D)_{LFR}}\right)\left(\frac{L_{LFR}}{L_{LRFR}}\right) \qquad \textit{Equation 5 - 2}$$

Since the capacity, *C*, and the dead load effect, *D*, have been shown to be consistent between the rating methodologies, the ratio of the subtraction of the two can be approximated as a constant, so that:

$$\frac{RF_{LRFR}}{RF_{LFR}} \approx (\text{Constant})\left(\frac{1}{\dfrac{L_{LRFR}}{L_{LFR}}}\right) \qquad \textit{Equation 5 – 3}$$

Equation 5 - 3 can be written in the following form:

$$\frac{L_{LRFR}}{L_{LFR}} \approx (\text{Constant})\left(\frac{1}{\dfrac{RF_{LRFR}}{RF_{LFR}}}\right) \qquad \textit{Equation 5 - 4}$$

Examining Equation 5 - 4 reveals that when *C* and *D* are constant the ratio of *L* is related to the ratio of *RF* through a decaying function. Therefore the decaying trend for the *L ratio* data seen in Figure 5 - 43 can be expected when the *C ratio* and *D ratio* are constant. To farther understand the decaying trend observed for the *L ratio* data, the components of the *L* were investigated to determine a possible source for the trend.

For the investigation of the components of the live load effect, *L*, the standard and unique bridge samples are studied separately. The samples are separated to study the effect that the live load factor may have on the observed decaying trend. For this investigation bridges in the standard bridge sample have a fix live load factor of 1.4 and bridges in the unique bridge sample have a varying live load factor based on bridge ADTT. Figure 5 - 45 and 5 - 46, shows the plots of LRFR to LFR live load component ratios verses the LRFR to LFR rating factor ratio for the standard and unique bridge samples, respectively. There are again three sets of data shown on the y-axis for these plots. The first set is for the LRFR to LFR factored live load effect ratio, denoted as *L ratio* in the figure. The second set is for the LRFR to LFR live load factor ratio, denoted as *A ratio* in the figure. For the standard bridge sample, the *A ratio* is constant and is equal to 1.08 as seen in Figure 5 - 45. The third set is for LRFR to LFR unfactored live load effect, without live load factor, ratio, denoted as *B ratio* in the figure.

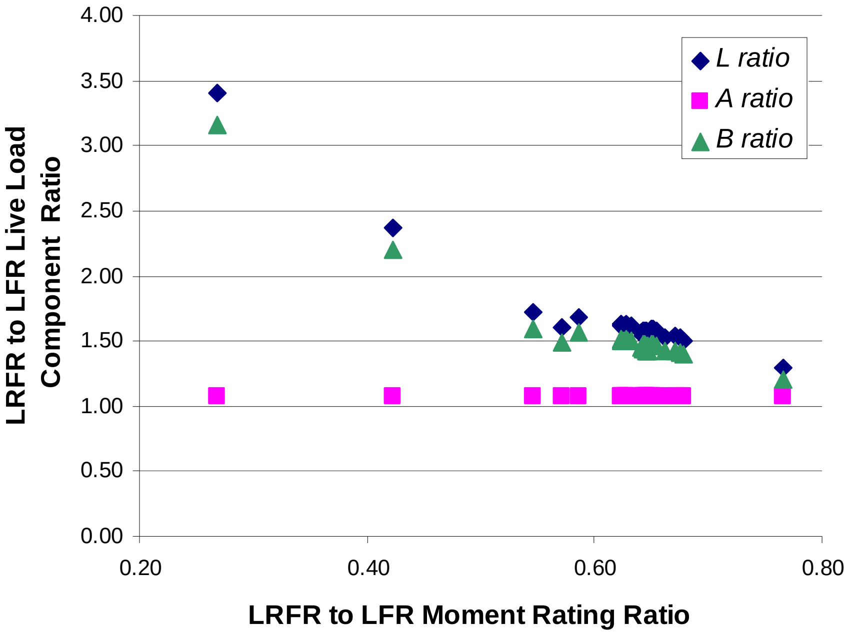


Figure 5 - 45: LRFR to LFR Live Load Component Ratio Comparisons for Standard Bridge Sample Exterior Girder Moment Rating Factors

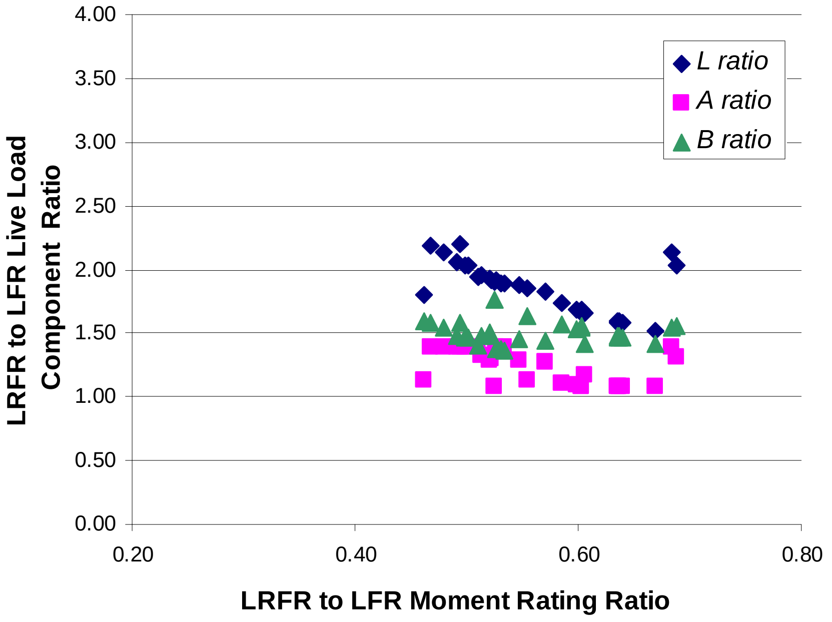


Figure 5 - 46: LRFR to LFR Live Load Component Ratio Comparisons for Unique Bridge Sample Exterior Girder Moment Rating Factors

Examining Figure 4 - 45 reveals that when the live load factor ratio, *A ratio*, is constant the decaying trend is observed to be in the *B ratio*, or the live load effect without live load factor. Examining Figure 5 - 46 reveals that when the live load factor ratio, *A ratio*, is variable the decaying trend is observed is not seen for the *B ratio*, or the live load effect without live load factor. This implies the observed trend in the live load effect ratio, *L ratio*, is due to the combined effects of the components live load effect (i.e. the live load factor, live load distribution factor, and impact factor). This indicates that variations in moment rating factors produced by the LRFR and LFR methodologies can be contributed to the components of the live load effect.

A similar investigation was conducted for the shear load effects at the Legal load level for the ALDOT Tri-Axle load on the unique and standard bridge samples. Figure 5 - 47 shows the plot of LRFR to LFR component ratios versus the LRFR to LFR shear rating factor ratio. Three sets of data are shown on the y-axis. The first set is for the LRFR to LFR capacity ratio, denoted as ratio *C ratio* in the figure. The second set is for the LRFR to LFR dead load effect ratio, denoted as *D ratio* in the figure. The third set is for LRFR to LFR live load effect ratio, denoted as *L ratio* in the figure.

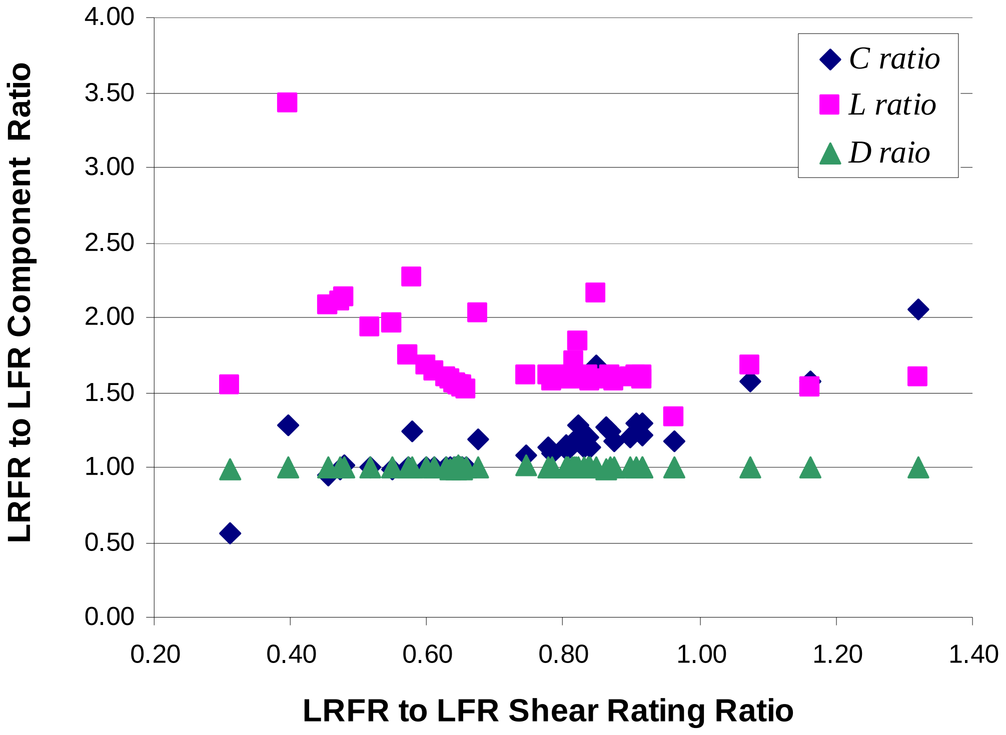


Figure 5 - 47: LRFR to LFR Component Ratio Comparisons for Exterior Girder Shear Rating Factors

Examining Figure 5 - 47 three important observations are made. First, it can be observed that the *D ratio* for the two methodologies is constant for all LRFR to LFR shear rating factor ratios. This is expected because there is be no difference in the way the dead load is calculated between the two systems, and is in agreement with the moment rating factor analysis previously reviewed. The second observation is that the *C ratio* for the two methodologies is no longer constant. The *C ratio* is observed to increase with increasing rating factor ratios. A material type breakdown of the *C ratio* data is provided in Figure 5 - 48. The third observation is that the decaying trend previously observed for the *L ratio* data is no longer seen. This is due to the *C ratio* and *D ratio* no longer being constant; therefore, the decaying trend would not be expected.

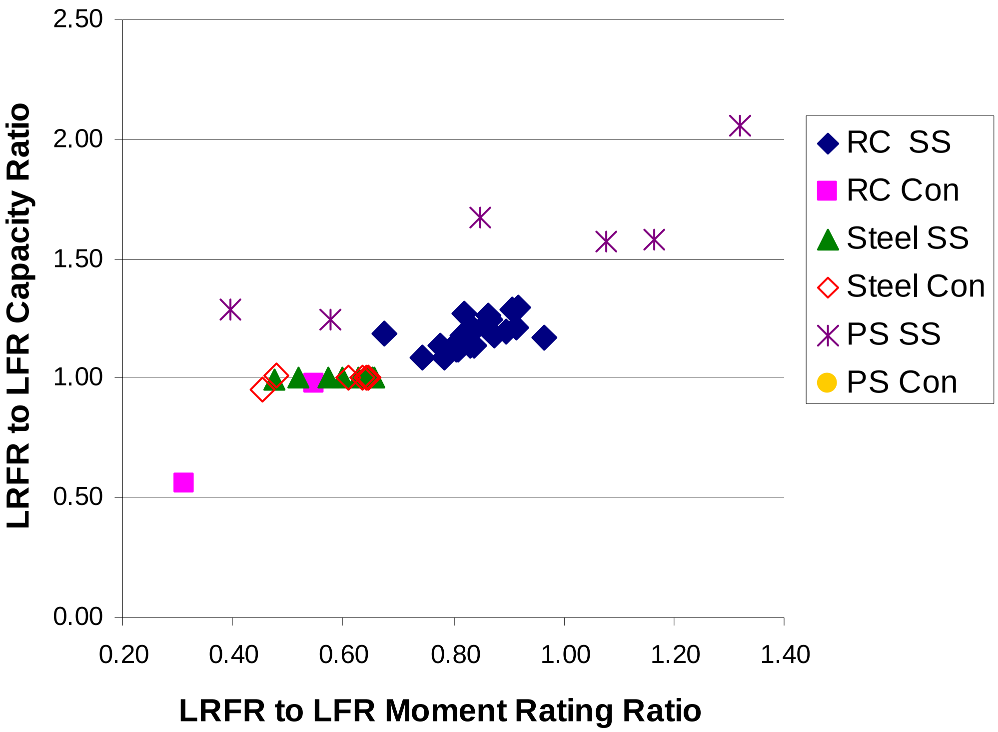


Figure 5 - 48: LRFR to LFR Capacity Ratio Comparisons for Exterior Girder Shear Rating Factors

From Figure 5 - 48 it can be seen that the steel material type bridges had a constant *C ratio* across different rating factor ratios. However the reinforced concrete and prestressed concrete material type bridges showed a varying *C ratio*. This difference in shear capacity for the two methodologies can be attributed to the new shear provisions found in the AASHTO LRFD (2007) relating shear capacity for reinforced concrete and prestressed concrete members. This indicates that variations in shear rating factors produced by the LRFR and LFR methodologies can be contributed to variations in shear capacities and live load effect.

Investigating the effects the components of the fundamental rating equation on the rating factors generated for the Tri-Axle load model at the Legal load level for the standard and unique bridge samples produced the following findings:

- Moment capacities and dead load effects calculated from the LRFR and LFR methodologies are similar
- Variations in moment rating factors produced by the LRFR and LFR methodologies can be contributed to the components of the live load effect (i.e. the live load factor, live load distribution factor, and impact factor)
- Dead load effects calculated from the LRFR and LFR methodologies are similar
- Shear capacities for steel bridges calculated from the LRFR and LFR methodologies are similar
- Shear capacities for reinforced concrete and prestressed concrete bridges calculated from the LRFR and LFR methodologies show significant variation
- Variations in shear rating factors produced by the LRFR and LFR methodologies can be contributed to variations in shear capacities and the live load effect

Chapter 6 BRIDGE RELIABILITY

6.1 Introduction

The goal of the development of the AASHTO MCE LRFR (2003) was to have a bridge rating specification consistent with the philosophy of the AASHTO LRFD (2007) in its use of reliability-based limit states. This allows the LRFR to produce a more rigorous assessment of a bridge's actual safe load capacity when compared to the LFR (Sivakumar 2007). To show how the rating results of the LRFR compare to those of the LFR in the context of a bridge's reliability, reliability analyses were performed on both standard and unique bridge samples. In this analysis a bridge's reliability was assessed through the use of the Monte Carlo simulation technique (Nowak and Collins 2000).

6.2 Background Information

In structural design, the capacity and applied loads for a member are not deterministic in nature. There are varying degrees of uncertainty associated with each. Structures are therefore designed in a manner to fulfill their requirements with an acceptable degree of probability of failure based on these uncertainties. One way to define failure is when the applied load effect exceeds the capacity of the structure. The load effect and capacity can be defined as two continuous random variables Q and R, respectively. Q and R then would have unique probability density functions (PDF) similar to the ones found in Figure 6 - 1. Failure then could be expressed as when $R - Q$

< 0 (Nowak and Collins 2000). Using this terminology, a performance function, g, can be defined for a given structural member as (Nowak and Collins 2000):

$$g(R,Q) = R - Q \qquad \textit{Equation 6 – 1}$$

Where,

g = Performance Function

R = Capacity (Resistance)

Q = Demand (Load Effect)

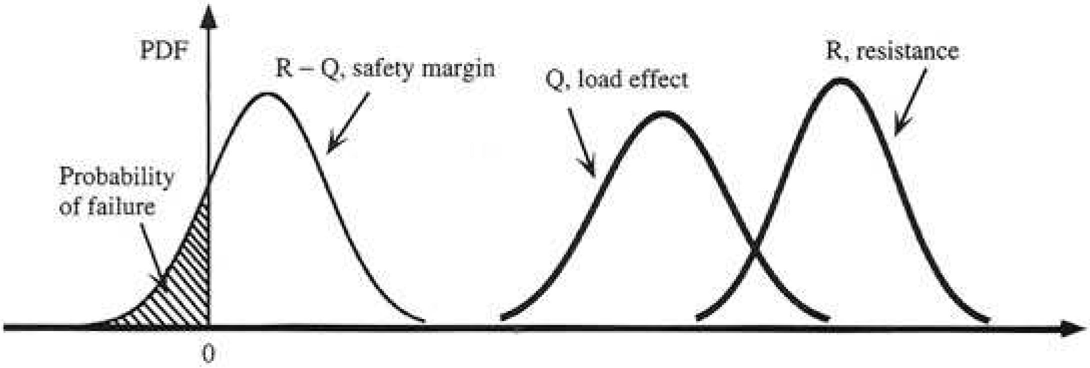


Figure 6 - 1: Probability of Failure Depiction (Nowak and Collins 2000)

When the performance function $g \geq 0$, then the capacity is greater than or equal to the demand and the member is considered safe, having adequate capacity for the demand. When $g < 0$, then the capacity is less than the demand and the member is considered unsafe, not having adequate capacity for the demand. Therefore, the probability of failure of the member would be equal to the probability of $g < 0$ (Nowak and Collins 2000). This can be expressed mathematically as (Nowak and Collins 2000):

$$P_f = P(R - Q < 0) = P(g < 0) \qquad \textit{Equation 6 – 2}$$

Where,

P_f = Probability of Failure

P = Probability

g = Limit State Function

R = Capacity (Resistance)

Q = Demand (Load Effect)

Since R and Q are defined as continuous random variables each having a PDF, g would also be a random variable with is own unique PDF. Moreover, if the PDF for R, f_R, and the PDF for Q, f_Q, are Gaussian (i.e. having a normal distribution) then the PDF for g, f_g, is Gaussian as well. The mean for f_g then could be defined as:

$$g_m = R_m - Q_m \qquad \textit{Equation 6 – 3}$$

Where,

g_m = Mean of f_g

R_m = Mean of f_R

Q_m = Mean of f_Q

The standard deviation for f_g could be defined based on the standard deviations of f_R and f_Q as:

$$\sigma_g^2 = \sigma_R^2 + \sigma_Q^2 \qquad \textit{Equation 6 – 4}$$

Where,

σ_g = Standard Deviation of f_g

σ_R = Standard Deviation of f_R

σ_Q = Standard Deviation of f_Q

Since f_g is Gaussian, it is convenient to use standard normal distribution tables to evaluate P_f. However, these tables are prepared for a PDF having a mean of 0 and a standard deviation of 1.0. However, since f_g does not necessarily have a mean of 0 and a standard deviation of 1.0, the following transformation is used:

$$u = \frac{g - g_m}{\sigma_g} \qquad \text{Equation 6 – 5}$$

Where, *u* is a standard normal variate of the random normal variable *U*, which has a PDF with a mean of 0 and a standard deviation of 1.0. Setting *g* to 0 in Equation 6 - 5, this corresponds to the condition of failure. Then,

$$u = \frac{-g_m}{\sigma_g} = -\beta \qquad \text{Equation 6 – 6}$$

This provides a relationship between the standard normal variate, *u*, and *β*. Where, *β* defined as:

$$\beta = \frac{g_m}{\sigma_g} \qquad \text{Equation 6 – 7}$$

The significance of *β* is graphically represented in Figure 6 - 2, as can be seen, as *β* increases the P_f decreases and vise versa. *β* is commonly referred to as the reliability index or safety index in the literature when in reference to the probability of failure.

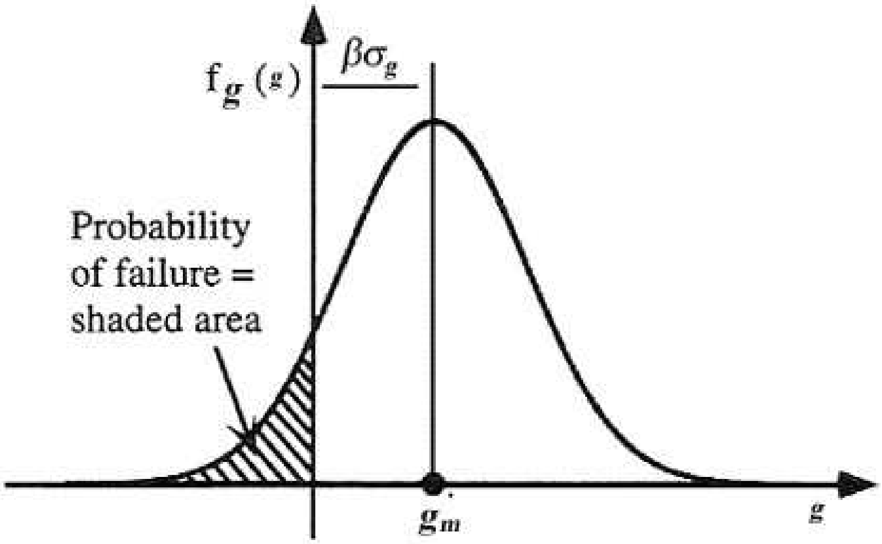


Figure 6 - 2: Graphical Representation of β (Nowak and Collins 2000)

Hence, by using the transformation of Equation 6 - 5, P_f. can be related to β by:

$$P_f = P(U < \frac{-g_m}{\sigma_g} = -\beta) \qquad \textit{Equation 6 – 8}$$

P_f , therefore, can be evaluated using the standard normal distribution tables under this formulation, or alternatively β can be evaluated from P_f using (Nowak and Collins 2000):

$$\beta = -\Phi^{-1}(P_f) = -u \qquad \textit{Equation 6 – 9}$$

where, (Nowak 2000)

β = Reliability Index

Φ^{-1} = Inverse of the Standard Normal Distribution Function

P_f = Probability of Failure

u = Standard Normal Variate

The formulation for β as it relates to the P_f through the inverse of the standard normal distribution function (Equation 6 - 9), is used for the estimated β values presented in the results section of this chapter. A graphical representation of the relationship between β and the P_f can be seen in Figure 6 - 3.

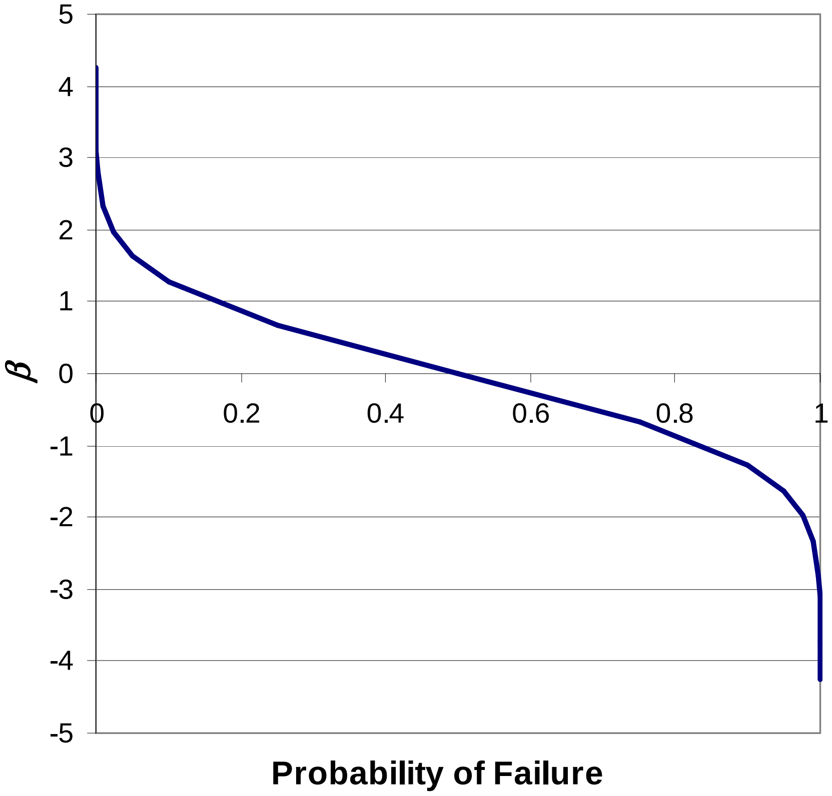


Figure 6 - 3: Relationship Between β and the P_f

Several important pieces of information can be gathered from Figure 6 - 3:

- As the P_f increases β decreases
- β equal to 0 corresponds to a P_f of 0.5 (or 50 percent)
- Positive β corresponds to P_f less than 0.5 (or 50 percent)
- Negative β corresponds to P_f greater than 0.5 (or 50 percent)
- β is more sensitive to changes in very low or high P_f

This formulation for β is dependent on the assumption that both f_R and f_Q are both Gaussian. For cases where f_R and f_Q are of a different type of distribution, different formulations β are required. For additional information on the formulations of β for different distribution types see Nowak and Collins (2000).

6.2.1 Analysis Method

The goal of this analysis is to estimate the probability of failure of an existing bridge and relate it to its rating factor. Since R and Q are not deterministic, there are an infinite number of combinations of R and Q than can arise for any given structural member. Therefore, the performance function, g, can assume an infinite number of values as well. However, with a sufficient number of tests, it is possible to estimate to a certain degree of confidence the probability of failure of a member. However, physical testing would not be feasible due to its destructive nature and the cost involved. Therefore, an artificial simulation technique is needed. One such commonly utilized simulation technique is the Monte Carlo method. The Monte Carlo method can generate results numerically without the need of any physical testing. An example of a basic Monte Carlo procedure is as follows (Nowak and Collins 2000):

1. Randomly generate a value for R (using a the nominal resistance, assumed normal bias factor and coefficient of variation)
2. Randomly generate a value for Q (using a load effect, assumed normal bias factor and coefficient of variation)
3. Calculate $g = R - Q$
4. Store g values (Each simulation will produce a single value for g)

5. Repeat steps 1 – 4 until sufficient number of *g* values has been generated
6. Estimate the probability of failure as the number of times $g < 0$ divided by the total number simulations.

The *g* values generated from a Monte Carlo simulation can be used in ways to calculate the probability of failure. One way, as indicated previously, is to take the number of times $g < 0$ and divide it by the total number of simulations. This will be refered to as Method 1 subsequently. This method works well only when a significant number of $g < 0$ values are produced. The number of $g < 0$ values needed depends upon how precise an estimate of probability of failure is desired. Method 2 requires that a plot of cumulative probability distribution versus *g* be constructed on probability paper, as shown in Figure 6 - 4. Then, a straight line is fitted through the data by linear regression analysis. The probability of failure then would be defined as the probability-axis intercept. Method 3 picks the probability of failure by simply observing where the data crosses the probability-axis, as shown in Figure 6 - 4. Ideally, if the assumptions that the PDF for the *R*, *Q* and *g* are Gaussian (i.e. normally distributed) are true, the probabilities of failure calculated by all three methods for a single data set would be similar (Nowak and Collins 2000).

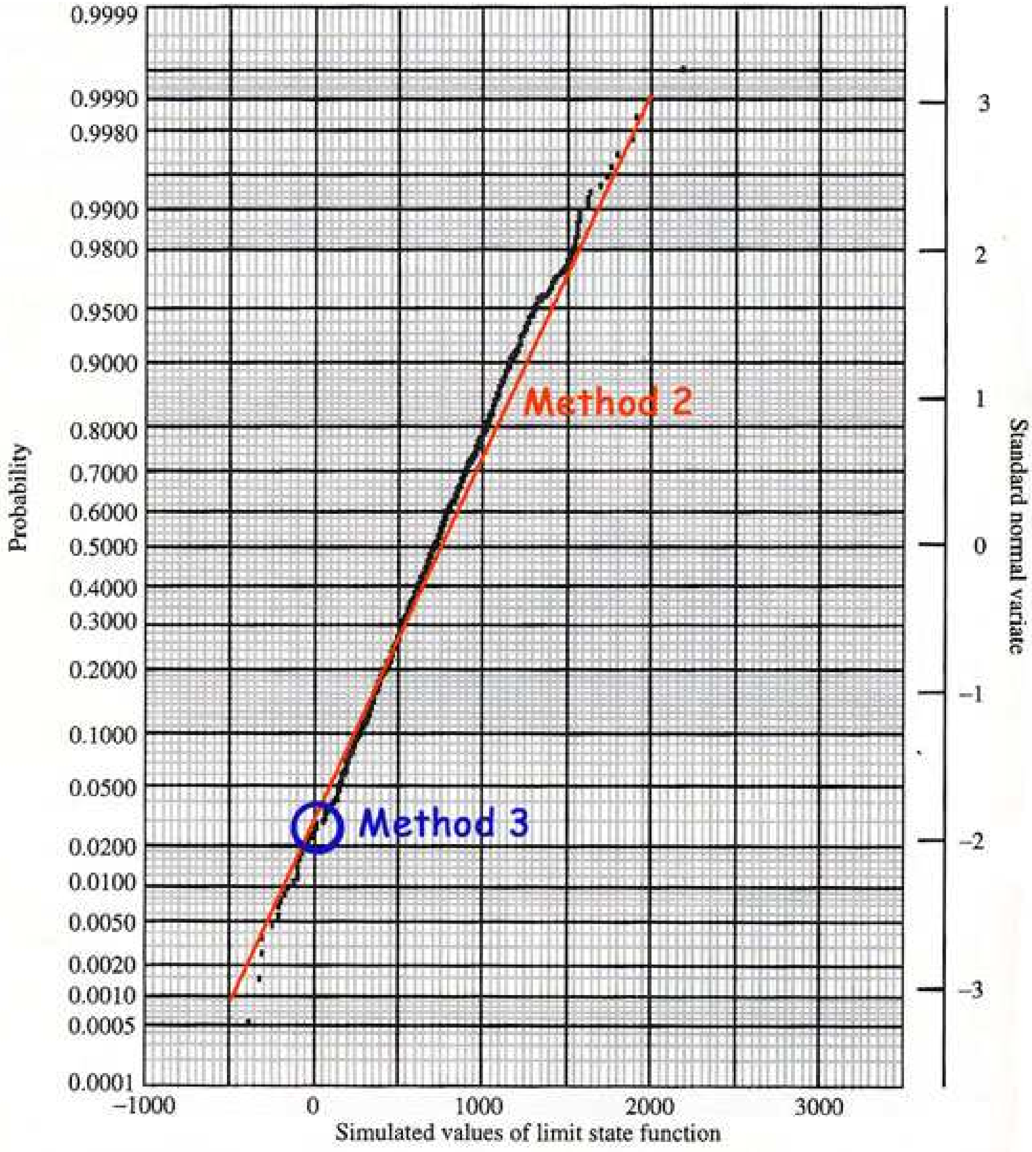


Figure 6 - 4: Methods of Calculating Probability of Failure (Nowak and Collins 2000)

6.2.2 Previous Research

In his Task 122 report, Mertz (2005) presented a limited comparative study between the probability of failure estimated for a bridge and its corresponding LRFR and

LFR factors at the Design Rating level. The approach used to calculate the probability of failure for each bridge was a modified Monte Carlo simulation, performed using Method 1 of estimating the probability of failure, the ratio of the number of $g < 0$ values to the total number of g values. The main modification used in the Monte Carlo procedure outlined previously in the study was to assume a lognormal distribution for the resistance, R, instead of assuming R as being Gaussian (Mertz 2004). Assuming R to be lognormal is believed to accurately describe the PDF of R (Nowak and Collins 2000). However, changing the distribution type of R results in the PDF of g no longer being Gaussian as assumed before. The resulting distribution for g though, is similar enough to Gaussian for the previously described Method 1 of calculating probability of failure to still be valid (Nowak and Collins 2000).

The findings of Mertz's study showed a strong correlation between the rating factors produced by the LRFR method and a bridge's corresponding probability of failure, which seemed to follow a noticeable trend, as shown in Figure 6 - 5. However, this correlation was not seen with the LFR method, where the data seemed to scatter from the trend observed for the LRFR data. Under the LFR method, multiple bridges produced significantly high failure rates, even when their rating factors were found to be above 1.0. Mertz concluded that the rating factors produced under the LFR method are not appropriate and that continued use of the LFR method was irrational (Mertz 2004).

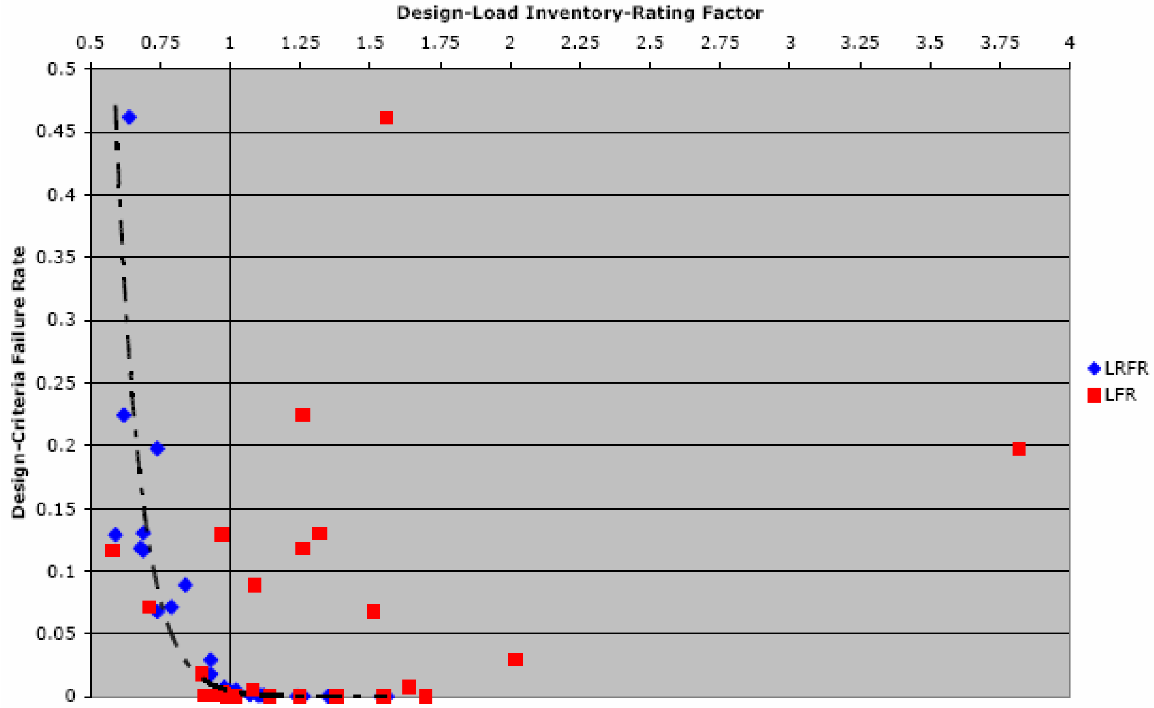


Figure 6 - 5: Reliability analysis results from Mertz Task 122 Report (2005)

In addition, Mertz studied comparisons between the LRFR and the LFR factors and a bridge's corresponding reliability index, as shown in Figure 6 – 6, where β were calculated from Equation 6 - 9. As expected, a strong correlation is seen between the reliability index and corresponding LRFR rating factor. Additionally, the rating factors produced by the LFR were observed to show little correlation when compared to the reliability index of a bridge. Another important observation made by Mertz was that the targeted reliability index of 3.5 at Design level rating for the LRFR was not being reached. The data showed that for rating factors equal to 1.0, a bridge's observed reliability index would be closer to 2.5 (Mertz 2005).

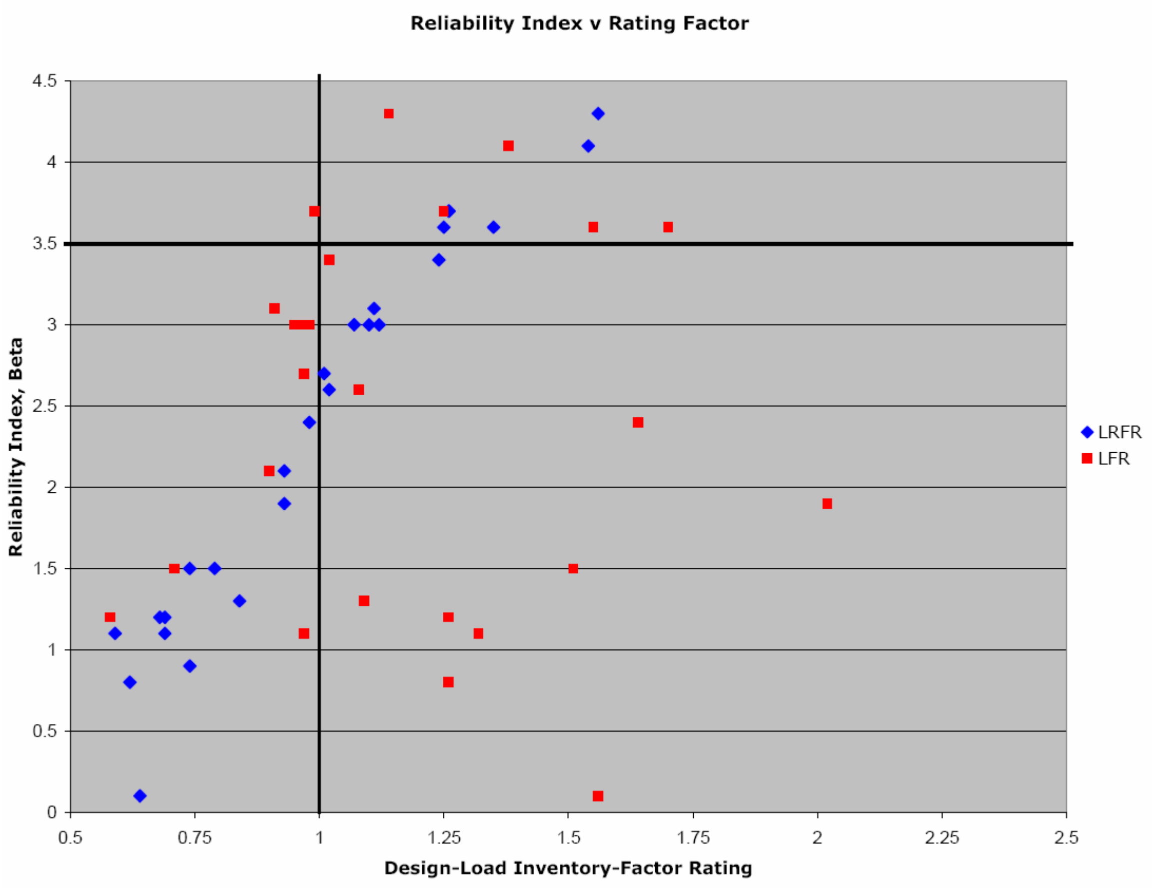


Figure 6 - 6: Reliability Index compared to Rating Factor from Mertz Task 122 Report (2005)

6.3 Analysis Tools

The reliability analysis for this research was performed using two computer programs developed to estimate the probability of failure through the use of the Monte Carlo simulation technique. The first program that was developed to estimate the probability of failure of a bridge by all three methods described above. To do this the $g = Q - R$ data for each simulation were stored and sorted. The need to store and sort the data limited the programming packages available due to the desire for the program to be able to perform at least 1 million simulations per bridge. The ability for the program to perform at least 1 million simulations per bridge was desirable so that the results generated could be directly compared to those presented by Mertz (2005). With this limitation MatLAB (2008) was chosen as the most suited framework for programming. A copy of the MatLAB Reliability Analysis program can be found in Appendix F1. The program works by extracting a bridge's resistance, dead load effect, and live load effect from a Microsoft Excel file and then performs a Monte Carlo Simulation for the data one million times. Using the data gathered during these simulations, the probability of failure is then calculated based on the three methods previously discussed, and exported to a unique file. The second program was designed only to estimate the probability of failure by the Method 1, described above, but for ten million simulations. Since Method 1 does not require the data for *g* to be sorted and stored, a Visual Basic Macro was developed in Microsoft Excel. This macro uses the same Monte Carlo simulation procedure as the MatLAB program but for ten million simulations per bridge. A copy of the Reliability Analysis Macro can be found in Appendix F2.

The reliability of a bridge was determined based on the HL-93 design load model effects and resistances calculated based on the AASHTO LRFD (2007). The Monte Carlo simulation procedure used for the determination of the probability of failure for each program is similar to the Monte Carlo procedure Mertz used in his Task 122 Study (Mertz 2005). The Monte Carlo simulation involves the following ten steps:

1. Gather the nominal dead load, D_n, nominal live load plus impact, L_n, and nominal resistance, R_n, for a bridge according to the AASHTO LRFD Bridge Design Specifications

2. Assume i = 1

3. Generate a uniformly distributed random number μ_{Di}, between 0 and 1

4. Calculate $D_i = \mu_D + \sigma_D \Phi^{-1}(\mu_{Di})$

   Where, Φ^{-1} = is the inverse standard normal distribution function

   μ_D = $\lambda_D D_N$

   σ_D = $V_D \mu_D$

   Where, λ_D is the dead load bias factor and V_D is the dead load coefficient of variation

5. Generate a uniformly distributed random number μ_{Li}, between 0 and 1

6. Calculate $L_i = \mu_L + \sigma_L \Phi^{-1}(\mu_{Li})$

   Where, Φ^{-1} = is the inverse standard normal distribution function

   μ_L = $\lambda_L L_N$

   σ_L = $V_L \mu_L$

   Where, λ_L is the live load bias factor and V_L is the live load coefficient of variation

7. Generate a uniformly distributed random number μ_{Ri}, between 0 and 1

8. Calculate $R_i = \exp(\mu_{\ln R} + \sigma_{\ln R} \Phi^{-1}(\mu_{Ri}))$

   Where, Φ^{-1} = is the inverse standard normal distribution function

   $\mu_{\ln R}$ = $\ln(\mu_R) - 1/2\sigma_{\ln R}{}^2$

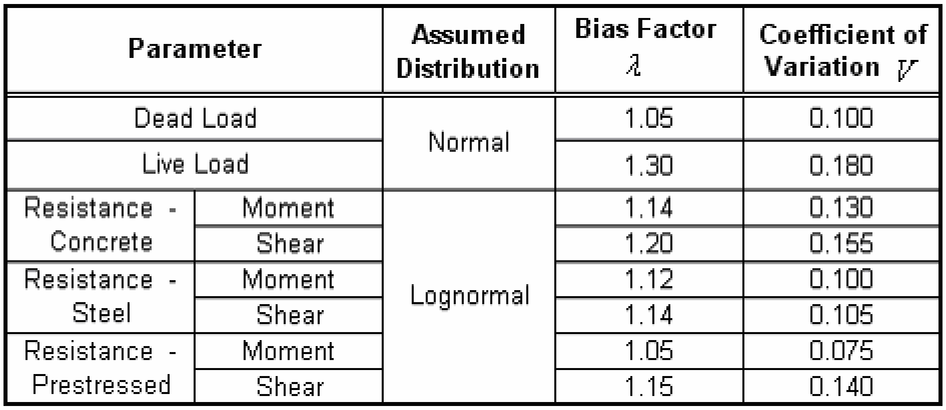
   $\sigma_{\ln R}$ = $(\ln(V_R{}^2 + 1))^{1/2}$

Where, λ_R is the resistance bias factor and V_R is the resistance coefficient of variation

9. Calculate $g_i = R_i – (D_i – L_i)$
10. assume i = i + 1, loop to step 3 until i > number of desired simulations

The results obtained from this procedure will vary with the bias factor and coefficients of variation. In this thesis, the bias factors and coefficients of variation used in both programs for the resistance and load were adopted from Nowak's NCHRP report 368 on Calibration of the LRFD Bridge Design Code and are listed in Table 6 - 1 (Nowak 1999). Note that the dead and live load effects are assumed to be normally distributed whereas the resistance is assumed to follow a lognormal distribution.

Table 6 - 1: Bias Factors and Coefficients of Variation Used in Reliability Analysis (Nowak 1999)



Parameter		Assumed Distribution	Bias Factor λ	Coefficient of Variation V
Dead Load		Normal	1.05	0.100
Live Load			1.30	0.180
Resistance - Concrete	Moment	Lognormal	1.14	0.130
	Shear		1.20	0.155
Resistance - Steel	Moment		1.12	0.100
	Shear		1.14	0.105
Resistance - Prestressed	Moment		1.05	0.075
	Shear		1.15	0.140

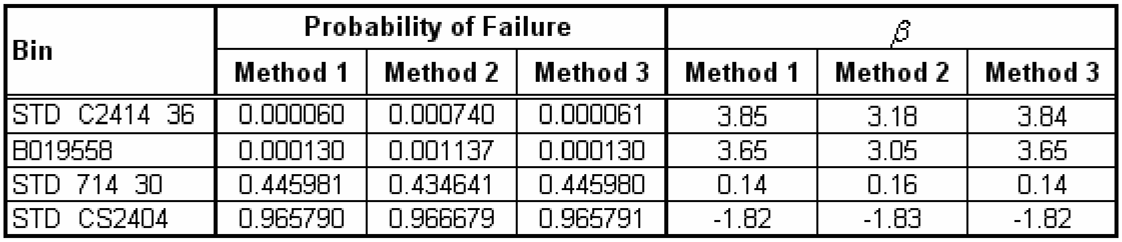
A key component of any Monte Carlo simulation is the generation of uniformly distributed numbers between 0 and 1. These numbers are generated by computer subroutines, which vary between software packages. Nowak warns that the use of such built-in number generators should be done with caution as some tend to work better than others (Nowak 2000).

Comparing the probability of failure estimates between the two computer programs that were developed for the reliability portion of this research, a 5 % difference was found on a series of test bridges. Investigating the source of this difference revealed that the random number generator algorithms for Excel and MatLAB differed enough to produce the 5 % difference. Therefore, it was decided to perform the entire reliability study using a single algorithm. Due to the desire to produce probabilities of failure based on all three methods previously described, the MatLAB program was chosen to perform all the analysis. For the ten million simulations exercise, which was to be performed using the Excel Macro, a modified version of the MatLAB program was used estimating the probability of failure only by Method 1.

6.4 Results

The probability of failure for each bridge was calculated by three different methods for one million simulations and by one method for ten million simulations. Comparing the three different methods used for calculating the probability of failure at one million simulations revealed that Methods 1 and 3 produced very comparable results. The similarity of the results from Method 2 with Methods 1 and 3 was found to be depend on the probability of failure. As the estimated probability of failure increased, the results from Method 2 increasingly matched Methods 1 and 3. This trend can be seen in the data provided in Table 6 - 2. Consequently, the reliability index calculated from each method's probability of failure is presented as well which demonstrates a similar trend. The reason for all three methods not always producing similar probability of failures is due to the PDF of g not truly being Gaussian (i.e. normally distributed). Therefore the data when plotted on probability paper does not form a perfectly linear, straight, line and as such the best-fit linear approach, Method 2, does not always agree with the other approaches. Nowak and Collins (2000) suggest, when a large enough number of simulations are present, to use the Method 1 approach for estimating probability of failure. Consequently Method 1's estimated of probability of failures and β values are therefore used in the comparative portion of the study.

Table 6 - 2: Probability of Failure Methods Comparison

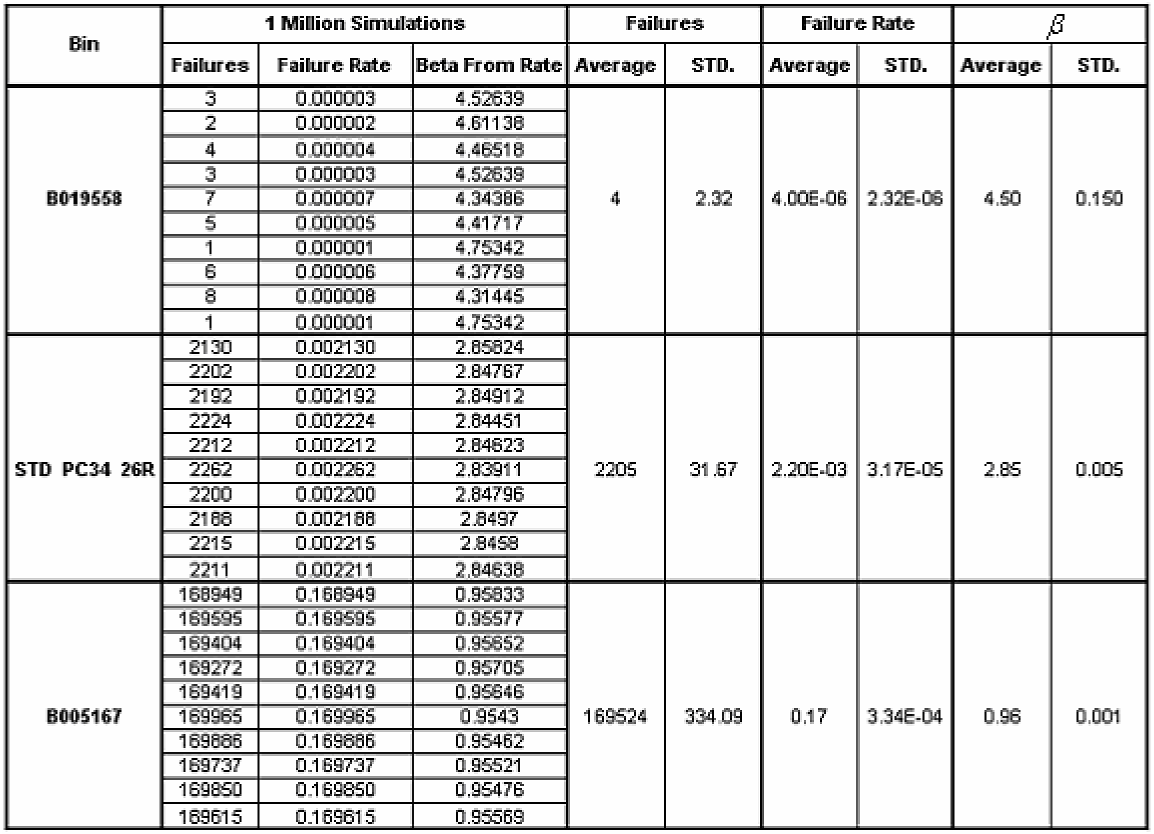


Bin	Probability of Failure			β		
	Method 1	Method 2	Method 3	Method 1	Method 2	Method 3
STD C2414 36	0.000060	0.000740	0.000061	3.85	3.18	3.84
B019558	0.000130	0.001137	0.000130	3.65	3.05	3.65
STD 714 30	0.445981	0.434641	0.445980	0.14	0.16	0.14
STD CS2404	0.965790	0.966679	0.965791	-1.82	-1.83	-1.82

To demonstrate the reproducibility of the results using Method 1 for estimating the probability of failure, three bridges were selected and 10 unique one-million simulations were performed. The results of these 10 simulations were compared with regards to their averages and standard deviations, shown in Table 6 - 3. It was found that for bridges having a significant number of failures, the estimated probability of failure and β were highly reproducible. The cut off point for when the one million run simulation results were no longer reproducible was taken to be 30 failures in 1,000,000. This roughly corresponds to a β of 4.0 which would be considered a relatively safe bridge, targeted β for design when calibrating the AASHTO LRFD (2007) was 3.5

(Nowak 1999). Therefore bridges that produced failure rates lower than 30 in 1,000,000 were considered safe and are not considered in this portion of the study.

Table 6 - 3: Ten Repetitive One-Million-Run Simulations Comparison.



Bin	1 Million Simulations			Failures		Failure Rate		β	
	Failures	Failure Rate	Beta From Rate	Average	STD.	Average	STD.	Average	STD.
B019558	3	0.000003	4.52639	4	2.32	4.00E-06	2.32E-06	4.50	0.150
	2	0.000002	4.61138						
	4	0.000004	4.46518						
	3	0.000003	4.52639						
	7	0.000007	4.34386						
	5	0.000005	4.41717						
	1	0.000001	4.75342						
	6	0.000006	4.37759						
	8	0.000008	4.31445						
	1	0.000001	4.75342						
STD PC34 26R	2130	0.002130	2.85824	2205	31.67	2.20E-03	3.17E-05	2.85	0.005
	2202	0.002202	2.84767						
	2192	0.002192	2.84912						
	2224	0.002224	2.84451						
	2212	0.002212	2.84623						
	2262	0.002262	2.83911						
	2200	0.002200	2.84796						
	2188	0.002188	2.8497						
	2215	0.002215	2.8458						
	2211	0.002211	2.84638						
B005167	168949	0.168949	0.95833	169524	334.09	0.17	3.34E-04	0.96	0.001
	169595	0.169595	0.95577						
	169404	0.169404	0.95652						
	169272	0.169272	0.95705						
	169419	0.169419	0.95646						
	169965	0.169965	0.9543						
	169886	0.169886	0.95462						
	169737	0.169737	0.95521						
	169850	0.169850	0.95476						
	169615	0.169615	0.95569						

To verify the adequacy of the 30 in 1,000,000 breakpoint for reproducing β results of 4.0 or less, a comparison between β values generated from one million simulations and ten million simulations were compared. This was done on both the unique and standard bridge samples. The thought behind this comparison was that if the β values produced by the two simulations were comparable, showing little difference, then the chosen breakpoint would be adequate. To illustrate this comparison the percent difference for β and probability of failure between the one million simulations and ten million simulations is plotted versus the number of failures for the one million simulation analysis, shown in Figure 6 - 7 for interior girders moment load effect. As Figure 6 - 7 shows that even when the probability of failure showed significant percent differences, larger than 50 %, β showed little difference with the increase in number of simulations, less than 3%. This would indicate that the 30 in 1,000,000 breakpoint would adequately capture, allow the reproduction of, β values of 4.0 or less. Tables presenting the percent difference for probability of failure and β between the one million and ten million run simulations are presented in Appendix F3 for both interior and exterior girders in flexure and shear.

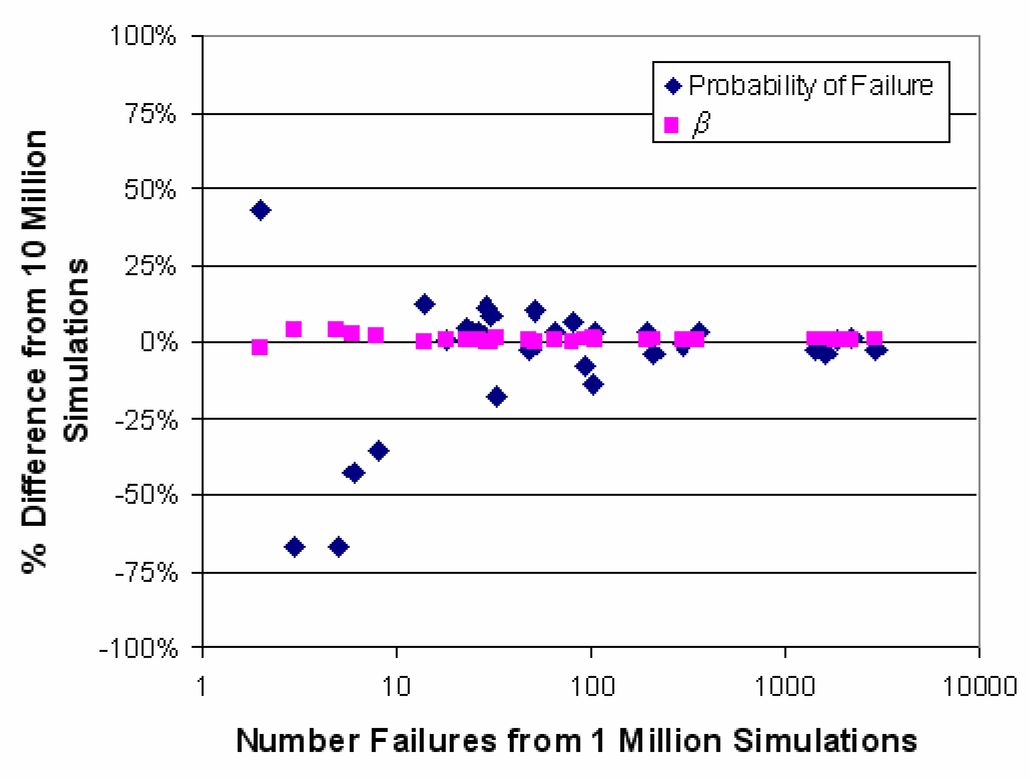


Figure 6 - 7: Percent Difference in Estimated Probability of Failure and Beta Between One Million and Ten Million Run Simulations for Interior Girders in Flexure

The first set of comparisons made between the LRFR and the LFR with regards to probability of failure is shown in Figure 6 - 8. In Figure 6 - 8 the probability of failure is plotted versus moment rating factors produced by both the LRFR and the LFR methodologies for interior girders. Similar to the results presented by Mertz (2004), the rating factors produced by the LRFR have a direct correlation with a bridge's estimated probability of failure. However, rating factors produced under the LFR are shown to not be well correlated to estimated probabilities of failure. Additionally the range of probabilities of failure observed for a given rating factor is greater for the LFR than the LRFR. This suggests that the rating factors produced under the LFR may not be an appropriate representation of a bridges adequacy under a given loading. Bridges with rating factors greater than one are even shown to have probabilities of failure as high as 50% under the LFR. Similar results were found for exterior girders in flexure, as shown in Figure 6 - 9.

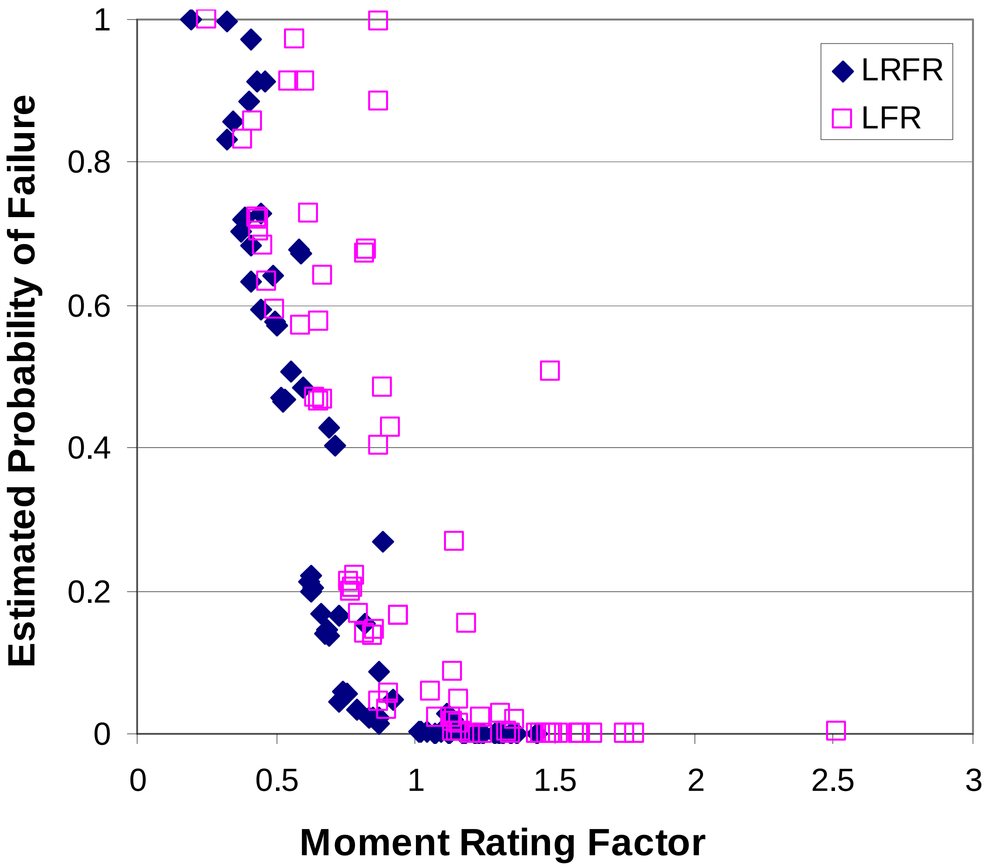


Figure 6 - 8: Probability of Failure and Rating Factor Comparison, Interior Girders Moment Load Effect

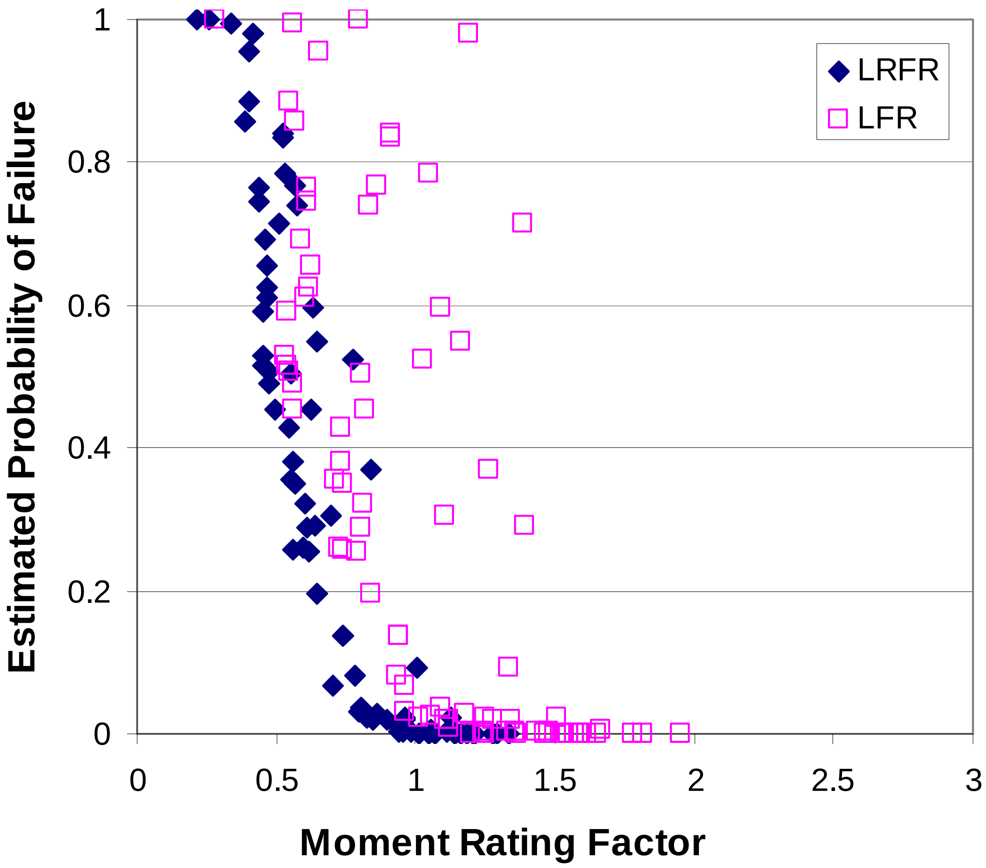


Figure 6 - 9: Probability of Failure and Rating Factor Comparison, Exterior Girders Moment Load Effect

In Figure 6 – 10 the probability of failure is plotted verse shear rating factors produced by both the LRFR and the LFR methodologies for interior girders. Different from the data presented for interior girders for moment load effects, the scatter seen for both the LFR and the LRFR is greatly reduced for interior girder in shear. The correlation between the LRFR and failure rate is strongly shown for interior girders in shear. The LFR however shows only sporadic correlation to a probability of failure. Rating factors less than one are shown to have very low probabilities of failure in some cases, while rating factors greater than one have very high probabilities of failure. Additionally, it is important to note the sharp increase in probability of failure for rating factors less than 0.8 for both the LRFR and LFR methodologies. Similar results were found for exterior girders as seen in Figure 6 - 11.

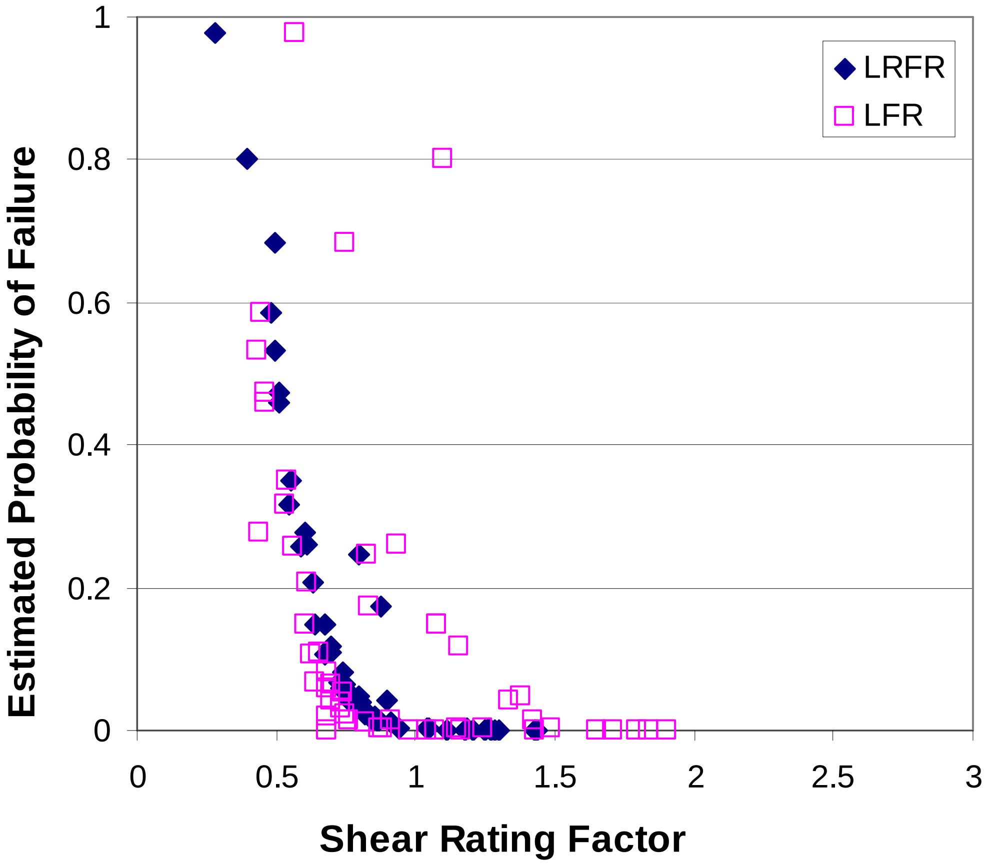


Figure 6 - 10: Probability of Failure and Rating Factor Comparison, Interior Girders Shear Load Effect

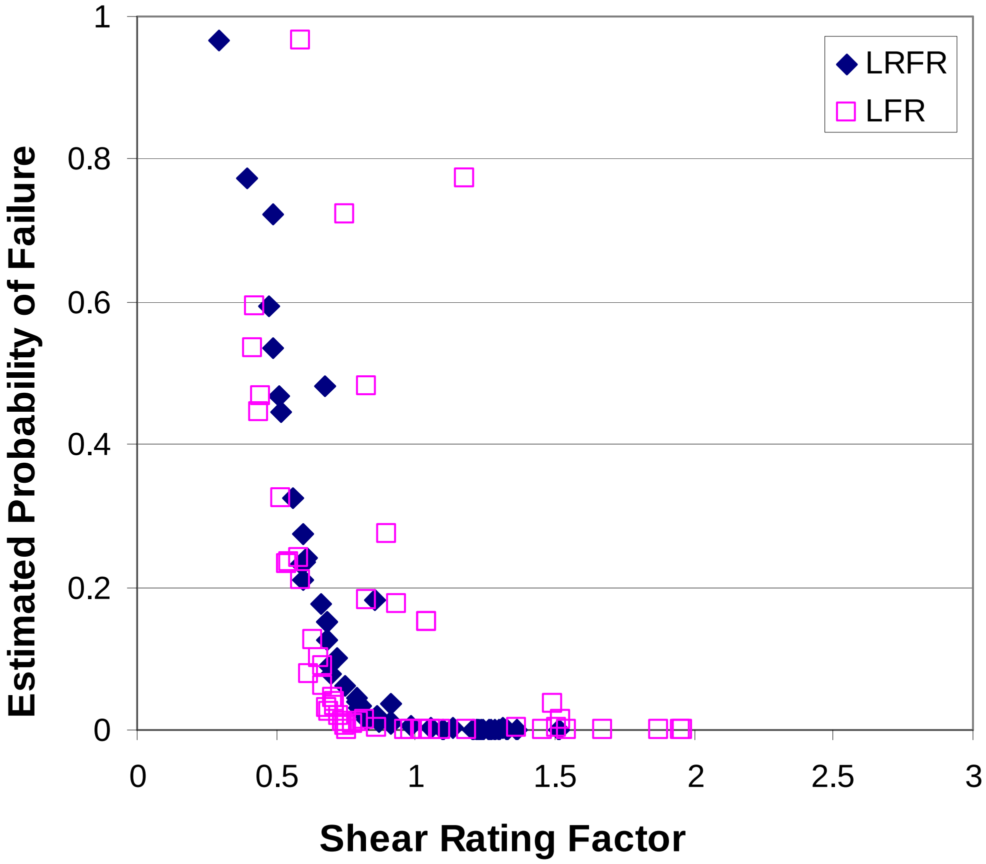


Figure 6 - 11: Probability of Failure and Rating Factor Comparison, Exterior Girders Shear Load Effect

The LRFR and LFR rating factors were also compared to the β values calculated from the estimated probabilities of failure. Figure 6 - 12 presents the data for the interior girders for moment load effect. This comparison demonstrates again the correlation β has with the rating factors produced under the LRFR. Additionally, the LFR is shown to have little to no correlation to β with a large scatter across the plot. It is important to note that rating factors equal to 1.0 appear to correlate with a β of 2.5 instead of the intended targeted β of 3.5 for this level of rating in the LRFR. Similar results were reported by

Mertz in his Task 122 report (2004) as indicated before. Exterior girders produced similar results as shown in Figure 6 - 13.

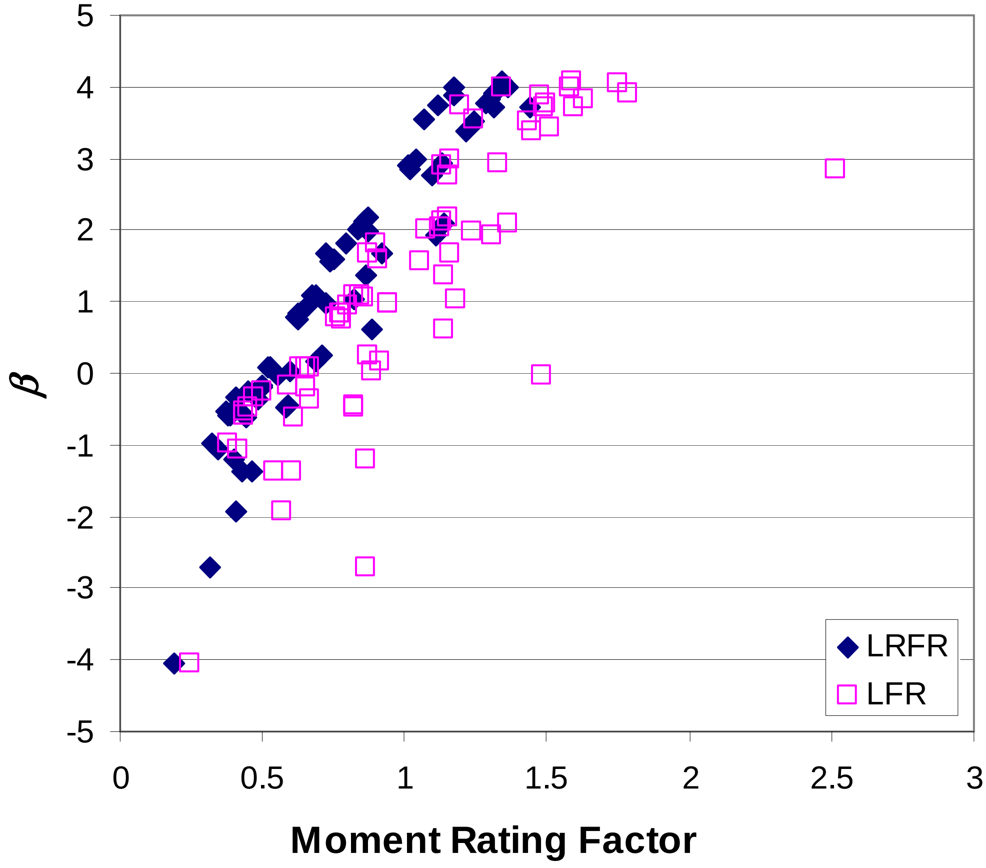


Figure 6 - 12: β and Rating Factor Comparison, Interior Girders Moment Load Effect

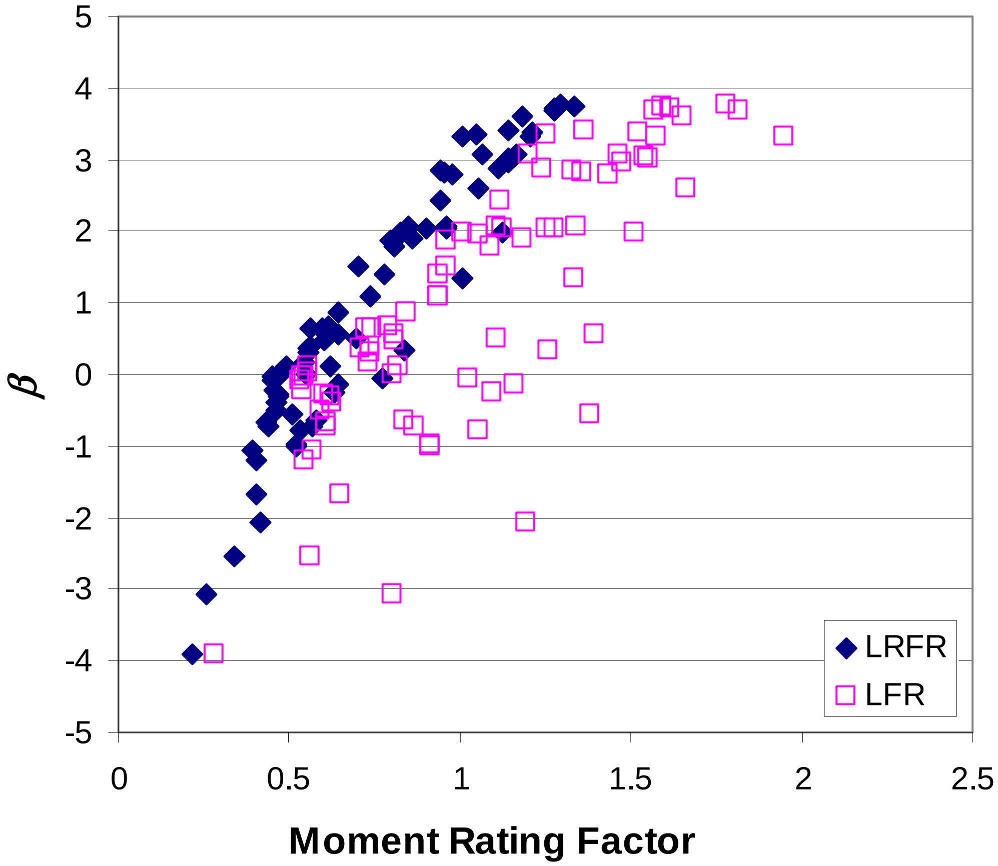


Figure 6 - 13: β and Rating Factor Comparison, Exterior Girders Moment Load Effect

The shear data for the interior girders is presented in Figure 6 - 14. Similar to the flexural results, the LRFR rating factors are seen to have a strong correlation with β while the LFR does not. Additionally, the trend of rating factors of 1.0 correlating to a β of 2.5, instead of the intended targeted β of 3.5 for the design rating level, is seen for the interior girders in shear as well. Similar results are found for the exterior girders in shear as seen in Figure 6 - 15.

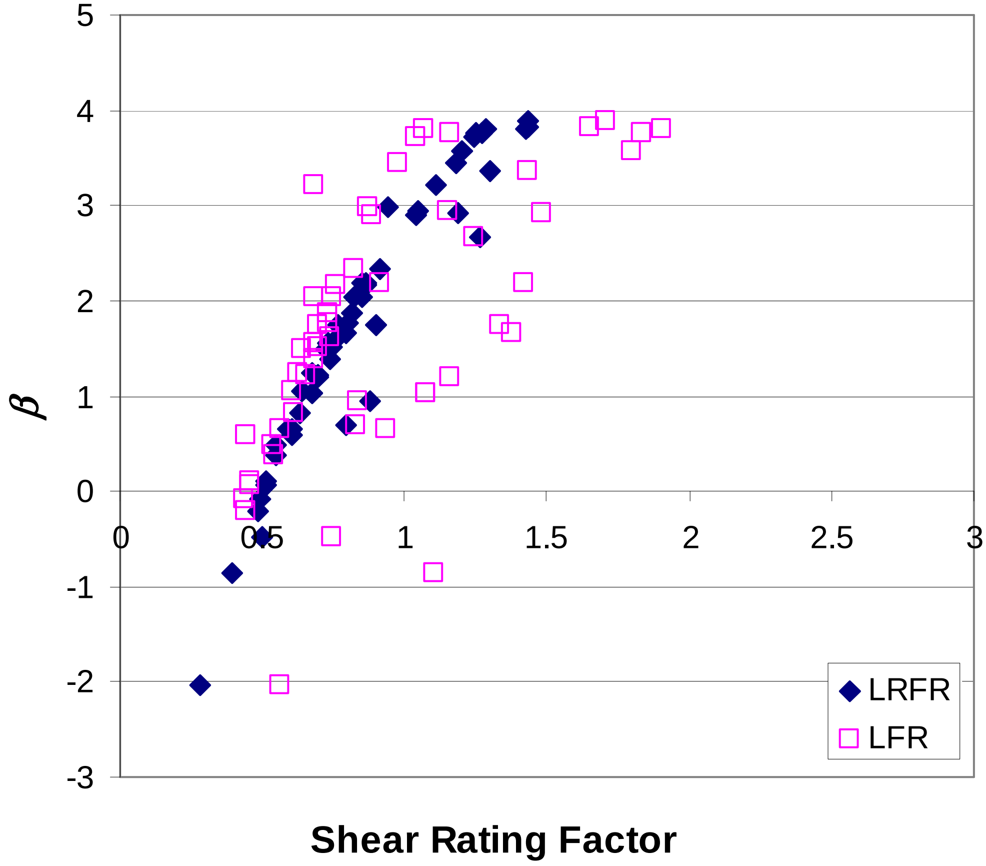


Figure 6 - 14: *β* and Rating Factor Comparison, Interior Girders Shear Load Effect

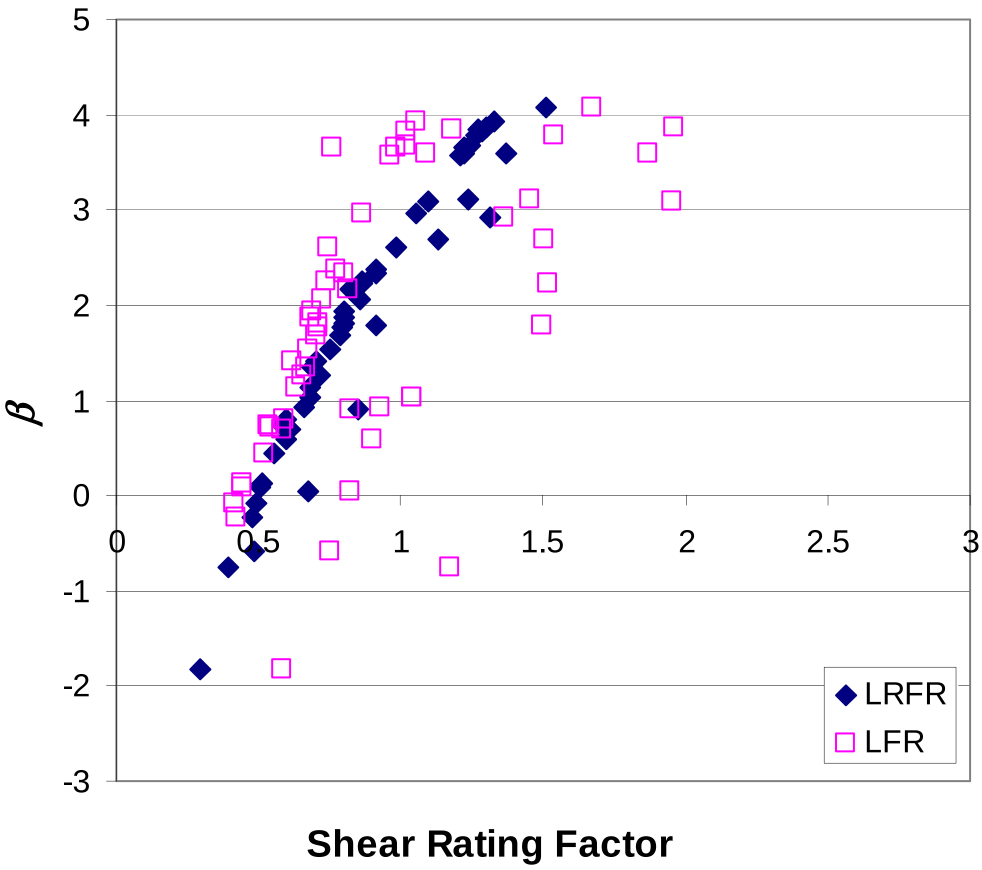


Figure 6 - 15: *β* and Rating Factor Comparison, Exterior Girders Shear Load Effect

6.5 Summary and Conclusion

The reliability analysis of the standard and unique bridge samples at the Design Inventory level of rating provided the following findings:

- Rating factors produced by the LRFR are well correlated to estimated probability of failure for interior and exterior girders in moment and shear
- Rating factors produced by the LFR are not well correlated to estimated probability of failure for interior and exterior girders in moment and shear

- Rating factors equal to 1.0 under the LRFR were shown to correspond to a reliability index of approximately 2.5 which is significantly lower than the targeted reliability index of 3.5 for the Design Inventory rating level

Based on the reliability analysis of the unique and standard bridge samples the LRFR rating methodology is shown to produce a more rigorous assessment of a bridge's level of safety compared to the LFR rating methodology. The LFR rating methodology however showed a poor correlation between estimated probabilities of failure and LFR rating factors. This suggests that the LFR rating methodology produces rating factors that do not consistently reflect a bridge's level of safety.

Chapter 7 Summary, Conclusions and Recommendations

7.1 Summary

Adopting the AASHTO MCE LRFR (2003) can have a profound effect on the rating practices of ALDOT with regards to Alabama’s State and County owned bridges. In order to assess how the new rating methodology would affect Alabama’s bridge inventory, a comparative study was done by the Auburn University Highway Research Center between the LRFR and LFR. This study was conducted on a representative sample of 95 bridges from Alabama’s State and County owned bridge inventory. Rating factors were compared between the two rating methodologies at the Design load level, Legal load level, and Permit load level of rating. AASHTO design and standard legal load models were used in addition to eight Alabama State Legal Loads and ten State permit trucks. In addition to the comparative study of rating methodologies, a reliability study was done to evaluate how rating factors at the Design Inventory level of rating compared to the estimated probability of failure of a bridge.

7.2 Conclusions

The comparative study provided in this thesis showed how the new LRFR rating methodology compares to the LFR rating methodology on a sample of 95 bridges from Alabama State and County owned and maintained bridge inventory. The conclusions from this study are as follows:

- Rating factors produced under the LRFR at all levels of rating were shown to be nearly equal or lower to the LFR rating factors for exterior and interior girders as well as for moment and shear.
- Moment rating factors under the LRFR methodology tend to control over shear rating factors at all levels of rating; for the LFR methodology, moment and shear rating factors were seen to control more or less evenly
- Load rating under the LRFR methodology was predominantly controlled by exterior girder moment rating; for the LFR methodology load rating was not dominated by any particular load effect or girder
- ALDOT legal loads are not enveloped by either the AASHTO legal loads or the HL-93 design load model
- Load rating under ALDOT legal loads for the unique bridge sample, which consisted of 45 bridges, showed that 23 bridges require posting under the LRFR and 8 bridges require posting under the LFR
- Posting loads under the LRFR tend to be significantly lower than posting loads under the LFR
- The LRFR allows a slightly fewer number of bridges to be considered for permitting compared to the LFR
- Differences in moment rating factors produced by the LRFR and the LFR can be attributed to differences in live load distribution factor, live load factor, and dynamic load allowance factor.

- Differences in shear rating factors produced by the LRFR and the LFR can be attributed to differences in live load distribution factor, live load factor, dynamic load allowance factor and capacity.
- The structural system type C – Channel bridges were shown to produce unusual LRFR to LFR rating factor ratios when compared to other structural system types at all levels of rating.
- Moment and shear rating factors produced by the LRFR at the Design Inventory level of rating are well correlated to the estimated probability of failure for interior and exterior girders
- Moment and shear rating factors produced by the LFR at the Inventory level of rating are not well correlated to the estimated probability of failure for interior and exterior girders

7.3 Recommendations

The findings of the comparative study showed that in most cases the LRFR produces lower rating factors than the LFR for Alabama's State and County owned and maintained bridges. However, while the LRFR may produce lower rating factors, the rating factors produced were found to be well correlated to a bridge's estimated probability of failure which adds credence to the LRFR methodology.

Based on this observation the following recommendations are suggested to ALDOT. From an implementation point of view:

- It is recommended that ALDOT uses the LRFR for rating new bridges designed to the AASHTO LRFD (2007) at all rating levels

- It is recommended that ALDOT uses both the LRFR and LFR methodologies for rating existing bridges at all rating levels. When RF > 1.0 for LRFR and for LFR, a bridge can be considered satisfactory. When RF < 1.0 for LRFR and for LFR, a bridge can be considered unsatisfactory. When RF < 1.0 for LRFR and RF > 1.0 for LFR, further investigation of the safety of the bridge is recommended according to ALDOT current policies.

In addition, the following recommendations for further investigations are also made:

- It is recommended that further research be conducted to understand and identify factors affecting the observed differences between the LRFR and the LFR. Factors to investigate may include, but are not limited to: the live load distribution factor and live load factor.
- Based on unusual LRFR to LFR rating factor ratios produced by the C-Channel bridges during the study it is recommend that further research be conducted in regards to the modeling simplifications incorporated within this study, with special attention given to the live load distribution factors used during the rating analysis.

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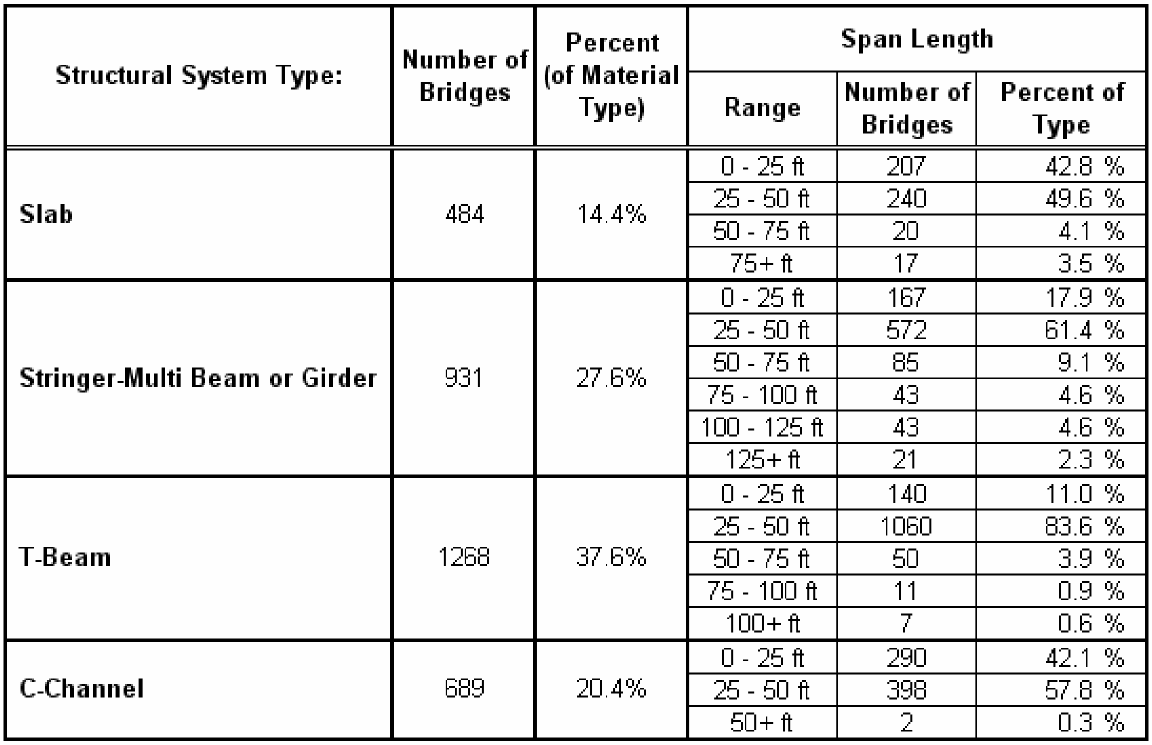
APPENDICES

APPENDIX A: Sample Distributions

Presented in Tables A - 1 through A - 6 is the structural system type breakdown of the SCOMB inventory for each material type. Each table provides a summary of number of bridges in each structural system, and span length ranges included in each structural system type.

Table A - 1: Structural System Type Distribution for Reinforced Concrete Simply Supported Bridges According to SCOMB Distribution



Structural System Type:	Number of Bridges	Percent (of Material Type)	Span Length		
			Range	Number of Bridges	Percent of Type
Slab	484	14.4%	0 - 25 ft	207	42.8 %
			25 - 50 ft	240	49.6 %
			50 - 75 ft	20	4.1 %
			75+ ft	17	3.5 %
Stringer-Multi Beam or Girder	931	27.6%	0 - 25 ft	167	17.9 %
			25 - 50 ft	572	61.4 %
			50 - 75 ft	85	9.1 %
			75 - 100 ft	43	4.6 %
			100 - 125 ft	43	4.6 %
			125+ ft	21	2.3 %
T-Beam	1268	37.6%	0 - 25 ft	140	11.0 %
			25 - 50 ft	1060	83.6 %
			50 - 75 ft	50	3.9 %
			75 - 100 ft	11	0.9 %
			100+ ft	7	0.6 %
C-Channel	689	20.4%	0 - 25 ft	290	42.1 %
			25 - 50 ft	398	57.8 %
			50+ ft	2	0.3 %

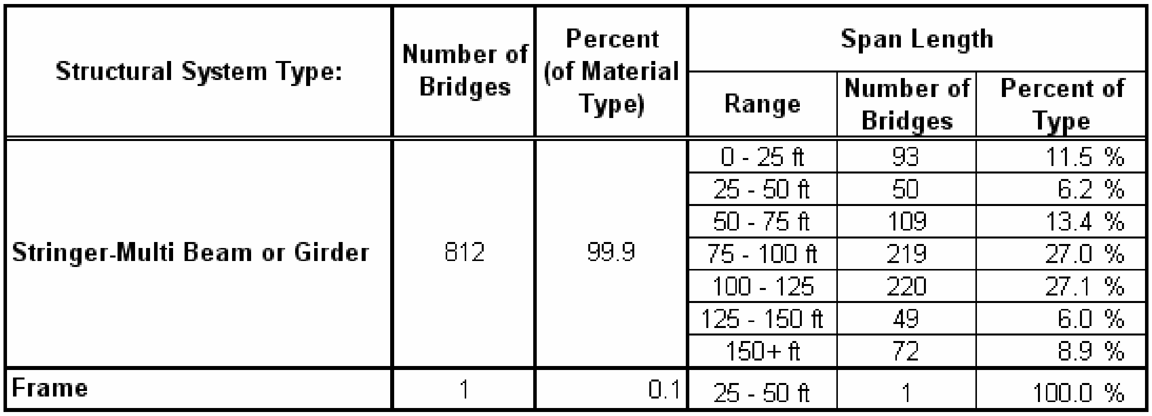
Table A - 2: Structural System Type Distribution for Reinforced Concrete Continuously Supported Bridges According to SCOMB Distribution

Structural System Type:	Number of Bridges	Percent (of Material Type)	Span Length		
			Range	Number of Bridges	Percent of Type
Slab	55	9.2	0 - 25 ft	50	90.9 %
			25 - 50 ft	5	9.1 %
Stringer-Multi Beam or Girder	124	20.7	0 - 25 ft	16	12.9 %
			25 - 50 ft	32	25.8 %
			50 - 75 ft	37	29.8 %
			75 - 100 ft	30	24.2 %
			100+ ft	9	7.3 %
T-Beam	418	69.8	0 - 25 ft	3	0.7 %
			25 - 50 ft	26	6.2 %
			50 - 75 ft	225	53.8 %
			75 - 100 ft	146	34.9 %
			100+ ft	18	4.3 %
C-Channel	2	0.3	0 - 25 ft	1	50.0 %
			25 - 50 ft	1	50.0 %

Table A - 3: Structural System Type Distribution for Steel Simply Supported Bridges According to SCOMB Distribution

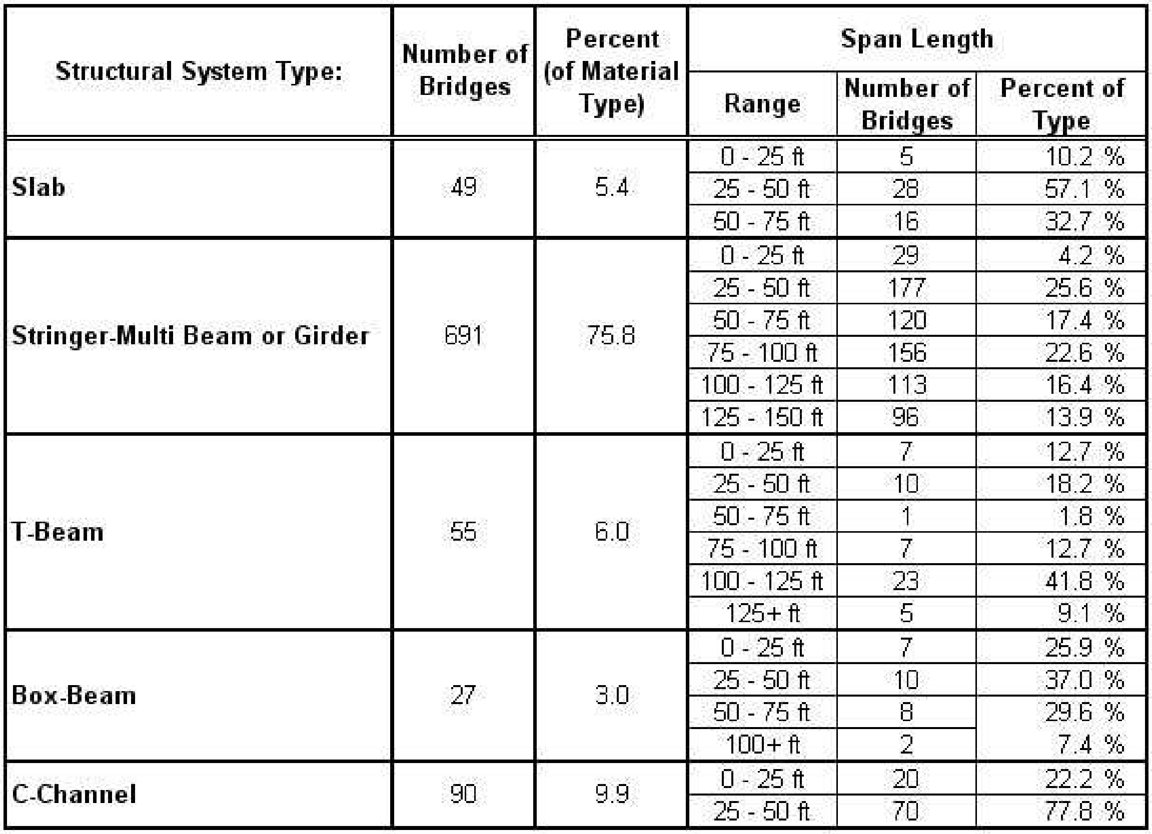
Structural System Type:	Number of Bridges	Percent (of Material Type)	Span Length		
			Range	Number of Bridges	Percent of Type
Stringer-Multi Beam or Girder	1425	99.0	0 - 25 ft	411	28.8 %
			25 - 50 ft	547	38.4 %
			50 - 75 ft	216	15.2 %
			75 - 100 ft	146	10.2 %
			100 - 125	62	4.4 %
			125 - 150 ft	20	1.4 %
			150+ ft	23	1.6 %
T-Beam	1	0.1	0 - 25 ft	1	100.0 %
Frame	14	1.0	0 - 25 ft	8	57.1 %
			25 - 50 ft	5	35.7 %
			50+ ft	1	7.1 %

Table A - 4: Structural System Type Distribution for Steel Continuously Supported Bridges According to SCOMB Distribution



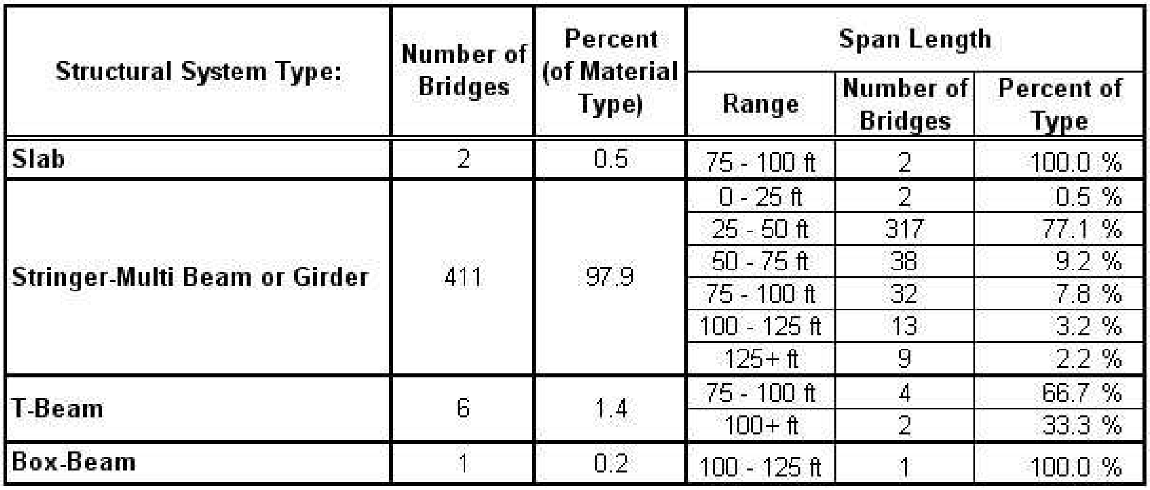
Structural System Type:	Number of Bridges	Percent (of Material Type)	Span Length		
			Range	Number of Bridges	Percent of Type
Stringer-Multi Beam or Girder	812	99.9	0 - 25 ft	93	11.5 %
			25 - 50 ft	50	6.2 %
			50 - 75 ft	109	13.4 %
			75 - 100 ft	219	27.0 %
			100 - 125	220	27.1 %
			125 - 150 ft	49	6.0 %
			150+ ft	72	8.9 %
Frame	1	0.1	25 - 50 ft	1	100.0 %

Table A - 5: Structural System Type Distribution for Prestressed Concrete Simply Supported Bridges According to SCOMB Distribution



Structural System Type:	Number of Bridges	Percent (of Material Type)	Span Length		
			Range	Number of Bridges	Percent of Type
Slab	49	5.4	0 - 25 ft	5	10.2 %
			25 - 50 ft	28	57.1 %
			50 - 75 ft	16	32.7 %
Stringer-Multi Beam or Girder	691	75.8	0 - 25 ft	29	4.2 %
			25 - 50 ft	177	25.6 %
			50 - 75 ft	120	17.4 %
			75 - 100 ft	156	22.6 %
			100 - 125 ft	113	16.4 %
			125 - 150 ft	96	13.9 %
T-Beam	55	6.0	0 - 25 ft	7	12.7 %
			25 - 50 ft	10	18.2 %
			50 - 75 ft	1	1.8 %
			75 - 100 ft	7	12.7 %
			100 - 125 ft	23	41.8 %
			125+ ft	5	9.1 %
Box-Beam	27	3.0	0 - 25 ft	7	25.9 %
			25 - 50 ft	10	37.0 %
			50 - 75 ft	8	29.6 %
			100+ ft	2	7.4 %
C-Channel	90	9.9	0 - 25 ft	20	22.2 %
			25 - 50 ft	70	77.8 %

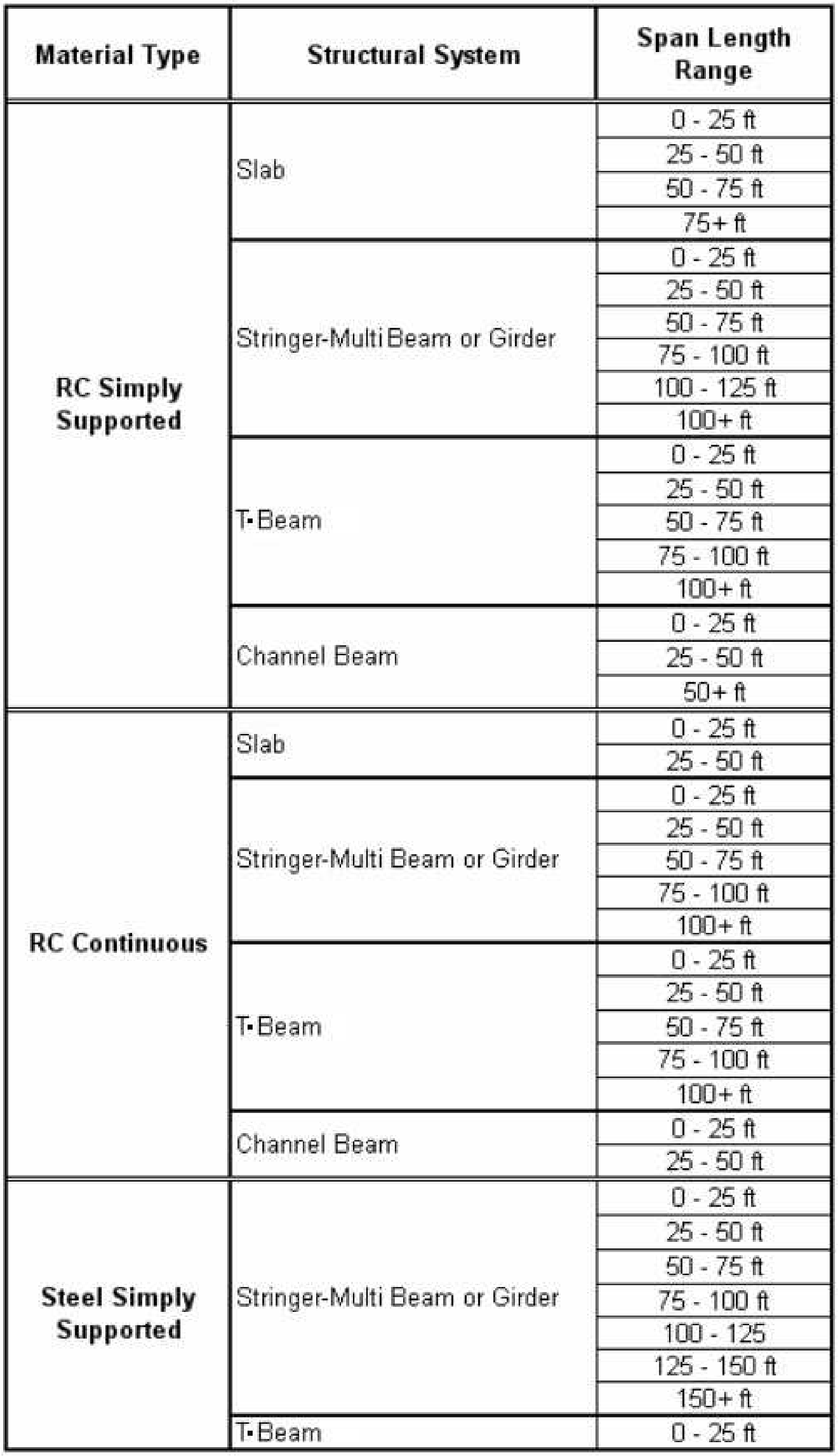
Table A - 6: Structural System Type Distribution for Prestressed Concrete Continuously Supported Bridges According to SCOMB Distribution



Structural System Type:	Number of Bridges	Percent (of Material Type)	Span Length		
			Range	Number of Bridges	Percent of Type
Slab	2	0.5	75 - 100 ft	2	100.0 %
Stringer-Multi Beam or Girder	411	97.9	0 - 25 ft	2	0.5 %
			25 - 50 ft	317	77.1 %
			50 - 75 ft	38	9.2 %
			75 - 100 ft	32	7.8 %
			100 - 125 ft	13	3.2 %
			125+ ft	9	2.2 %
T-Beam	6	1.4	75 - 100 ft	4	66.7 %
			100+ ft	2	33.3 %
Box-Beam	1	0.2	100 - 125 ft	1	100.0 %

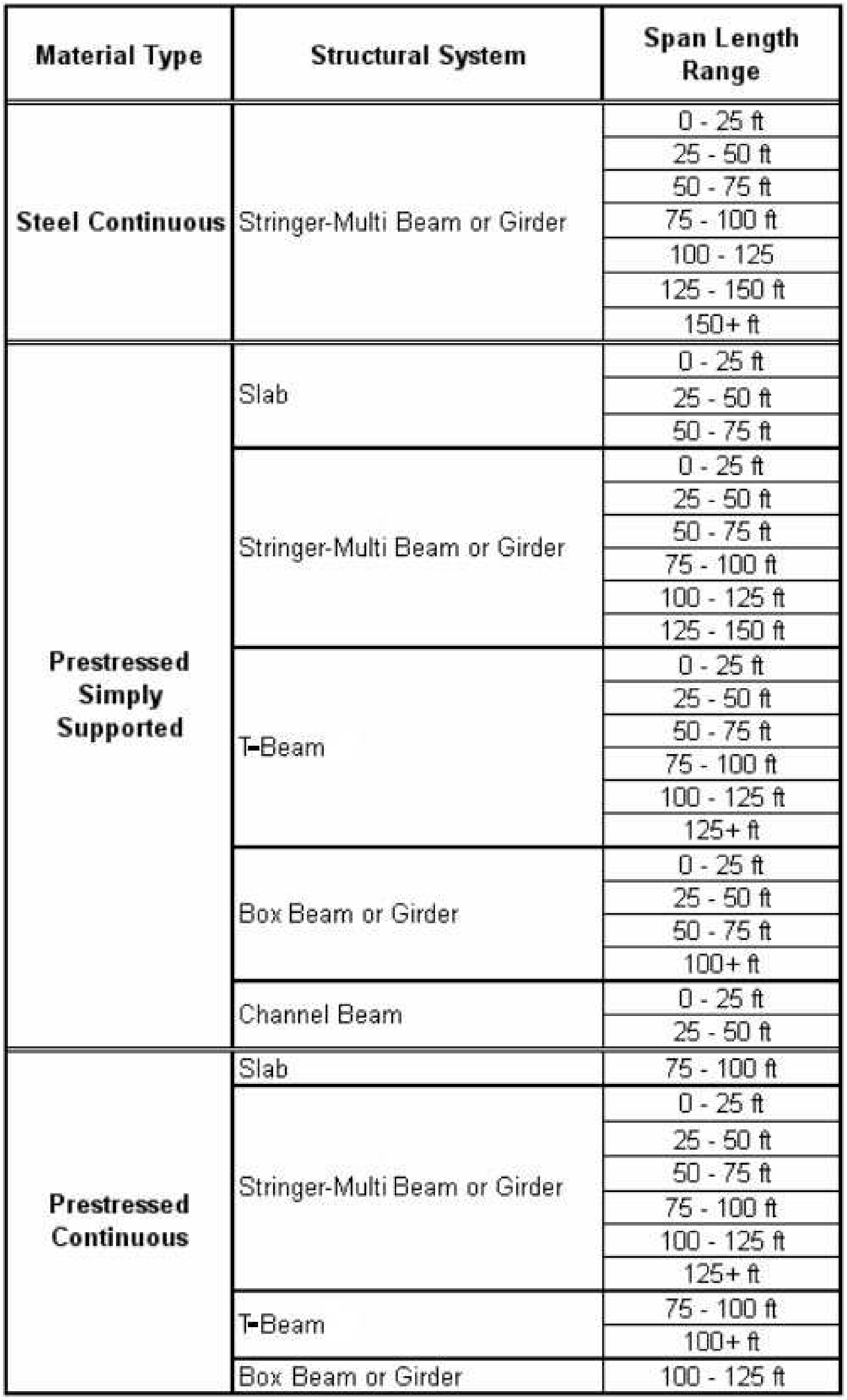
Tables A - 7 and A - 8 present the proposed unique bridge sample's material and structural system types. Table A - 9 presents the final standard bridge sample's material and structural system types and additional sample information. Table A - 10 presents the final unique bridge sample's material and structural system types.

Table A - 7: Proposed Unique Bridge Sample Part 1



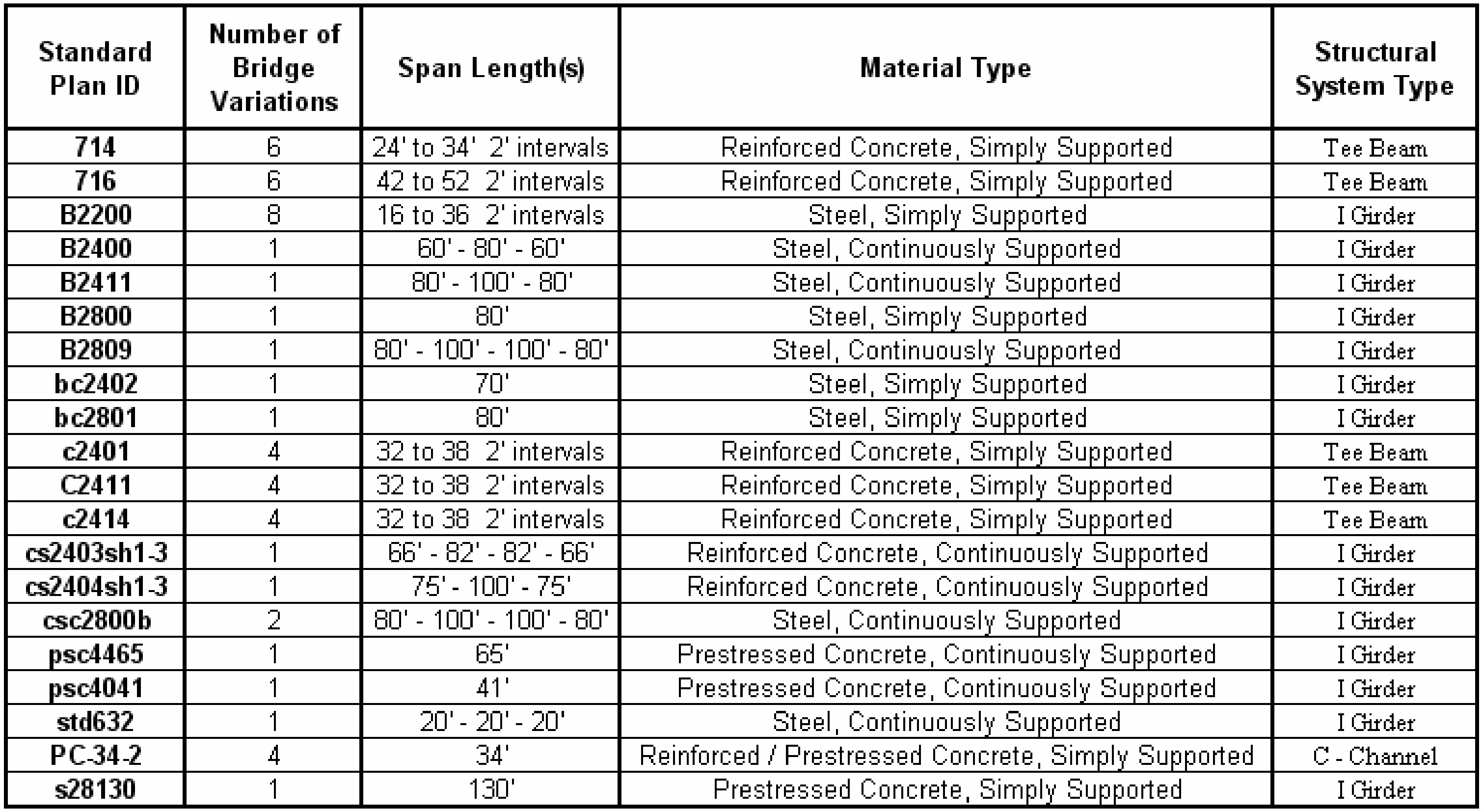
Material Type	Structural System	Span Length Range
RC Simply Supported	Slab	0 - 25 ft
		25 - 50 ft
		50 - 75 ft
		75+ ft
	Stringer-Multi Beam or Girder	0 - 25 ft
		25 - 50 ft
		50 - 75 ft
		75 - 100 ft
		100 - 125 ft
		100+ ft
	T-Beam	0 - 25 ft
		25 - 50 ft
		50 - 75 ft
		75 - 100 ft
		100+ ft
	Channel Beam	0 - 25 ft
		25 - 50 ft
		50+ ft
RC Continuous	Slab	0 - 25 ft
		25 - 50 ft
	Stringer-Multi Beam or Girder	0 - 25 ft
		25 - 50 ft
		50 - 75 ft
		75 - 100 ft
		100+ ft
	T-Beam	0 - 25 ft
		25 - 50 ft
		50 - 75 ft
		75 - 100 ft
		100+ ft
	Channel Beam	0 - 25 ft
		25 - 50 ft
Steel Simply Supported	Stringer-Multi Beam or Girder	0 - 25 ft
		25 - 50 ft
		50 - 75 ft
		75 - 100 ft
		100 - 125
		125 - 150 ft
		150+ ft
	T-Beam	0 - 25 ft

Table A - 8: Proposed Unique Bridge Sample Part 2



Material Type	Structural System	Span Length Range
Steel Continuous	Stringer-Multi Beam or Girder	0 - 25 ft
		25 - 50 ft
		50 - 75 ft
		75 - 100 ft
		100 - 125
		125 - 150 ft
		150+ ft
Prestressed Simply Supported	Slab	0 - 25 ft
		25 - 50 ft
		50 - 75 ft
	Stringer-Multi Beam or Girder	0 - 25 ft
		25 - 50 ft
		50 - 75 ft
		75 - 100 ft
		100 - 125 ft
		125 - 150 ft
	T-Beam	0 - 25 ft
		25 - 50 ft
		50 - 75 ft
		75 - 100 ft
		100 - 125 ft
		125+ ft
	Box Beam or Girder	0 - 25 ft
		25 - 50 ft
		50 - 75 ft
		100+ ft
	Channel Beam	0 - 25 ft
		25 - 50 ft
Prestressed Continuous	Slab	75 - 100 ft
	Stringer-Multi Beam or Girder	0 - 25 ft
		25 - 50 ft
		50 - 75 ft
		75 - 100 ft
		100 - 125 ft
		125+ ft
	T-Beam	75 - 100 ft
		100+ ft
	Box Beam or Girder	100 - 125 ft

Table A - 9: Standard Bridge Sample Bridge Descriptions



Standard Plan ID	Number of Bridge Variations	Span Length(s)	Material Type	Structural System Type
714	6	24' to 34' 2' intervals	Reinforced Concrete, Simply Supported	Tee Beam
716	6	42 to 52 2' intervals	Reinforced Concrete, Simply Supported	Tee Beam
B2200	8	16 to 36 2' intervals	Steel, Simply Supported	I Girder
B2400	1	60' - 80' - 60'	Steel, Continuously Supported	I Girder
B2411	1	80' - 100' - 80'	Steel, Continuously Supported	I Girder
B2800	1	80'	Steel, Simply Supported	I Girder
B2809	1	80' - 100' - 100' - 80'	Steel, Continuously Supported	I Girder
bc2402	1	70'	Steel, Simply Supported	I Girder
bc2801	1	80'	Steel, Simply Supported	I Girder
c2401	4	32 to 38 2' intervals	Reinforced Concrete, Simply Supported	Tee Beam
C2411	4	32 to 38 2' intervals	Reinforced Concrete, Simply Supported	Tee Beam
c2414	4	32 to 38 2' intervals	Reinforced Concrete, Simply Supported	Tee Beam
cs2403sh1-3	1	66' - 82' - 82' - 66'	Reinforced Concrete, Continuously Supported	I Girder
cs2404sh1-3	1	75' - 100' - 75'	Reinforced Concrete, Continuously Supported	I Girder
csc2800b	2	80' - 100' - 100' - 80'	Steel, Continuously Supported	I Girder
psc4465	1	65'	Prestressed Concrete, Continuously Supported	I Girder
psc4041	1	41'	Prestressed Concrete, Continuously Supported	I Girder
std632	1	20' - 20' - 20'	Steel, Continuously Supported	I Girder
PC-34-2	4	34'	Reinforced / Prestressed Concrete, Simply Supported	C - Channel
s28130	1	130'	Prestressed Concrete, Simply Supported	I Girder

Table A - 10: Unique Bridge Sample Matrix

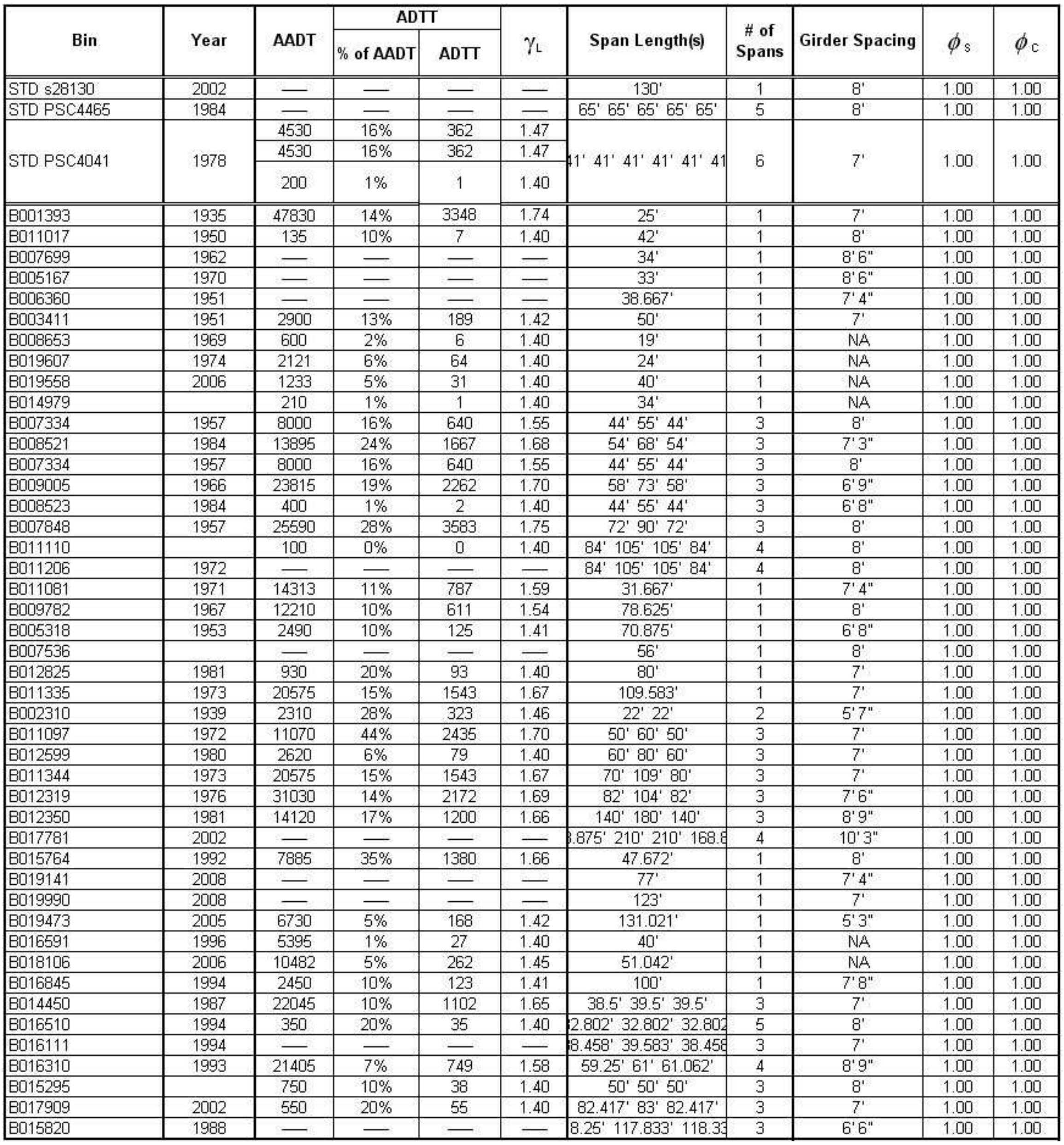
Material Type	Structural System	Span Length Range	BIN
RC Simply Supported	Slab	0 - 25 ft	**1541**
	Tee Beams	0 - 25 ft	**1393**
		25 - 50 ft	**11017**
			7699
			5167
			6360
		50 - 75 ft	**3411**
	PC Channel Beam	0 - 25 ft	**8653**
			19607
		25 - 50 ft	**19558**
			14979
RC Continuous	Tee Beams	25 - 50 ft	**7334**
		50 - 75 ft	**8523**
			7334
			9005
			8521
		75 - 100 ft	**7848**
		100+ ft	**11110**
	Stringer-MultiBeam or Girder	75 - 100 ft	**11206**
Steel Simply Supported	Stringer-MultiBeam or Girder	25 - 50 ft	**11081**
		50 - 75 ft	**9782**
			5318
			7536
		75 - 100 ft	**12825**
		100 - 125	**11335**
Steel Continuous	Stringer-MultiBeam or Girder	0 - 25 ft	**2310**
		50 - 75 ft	**11097**
		75 - 100 ft	**12599**
		100 - 125	**11344**
			12319
		125 - 150 ft	**12350**
		150+ ft	**17781**
Prestressed Simply Supported	Stringer-MultiBeam or Girder	50 - 75 ft	**15764**
		75 - 100 ft	**19141**
		100 - 125 ft	**16845**
			19990
		125 - 150 ft	**19473**
	BoxBeam or Girder	25 - 50 ft	**16591**
		50 - 75 ft	**18106**
Prestressed Continuous	Stringer-MultiBeam or Girder	25 - 50 ft	**14450**
			16510
			16111
		50 - 75 ft	**16310**
			15295
		75 - 100 ft	**17909**
		100 - 125 ft	**15820**

Provided in Tables A – 11 thorugh A – 14 is additional information about each bridge in both the unique and standard bridge samples. Information included about each bridge is the following: BIN, Year, AADT, Live Load Factor, Span Length(s), Girder Spacing, Condition and System Factors, Material Type, Structural System Type, Deck and Girder Concrete Strength, Reinforcement Grade, and Structural Steel Grade.

Table A - 11: Additional Sample Information Table 1

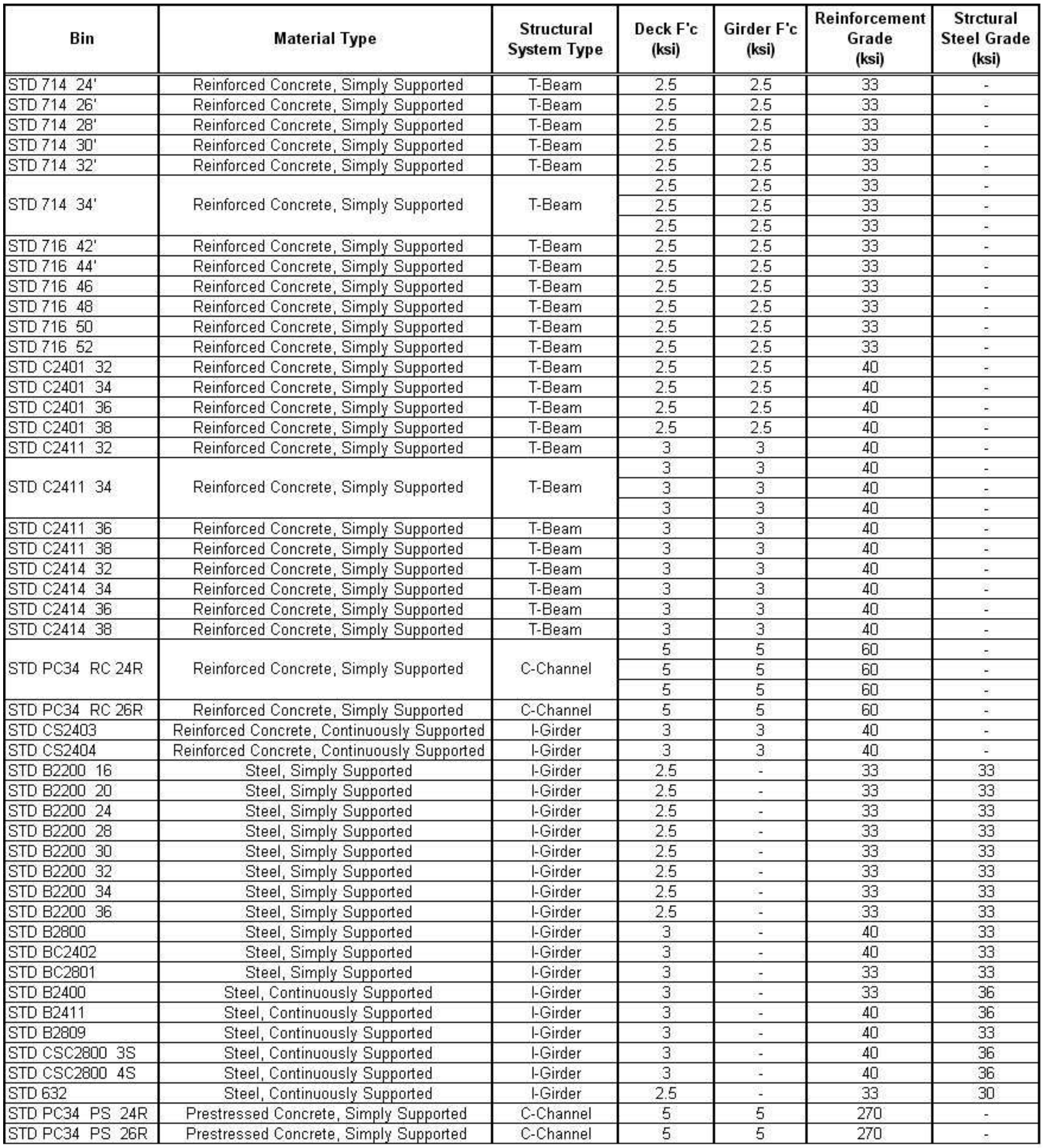
Bin	Year	AADT	ADTT		γ_L	Span Length(s)	# of Spans	Girder Spacing	ϕ_s	ϕ_c
			% of AADT	ADTT						
STD 714 24'	1942	—	—	—	—	23'	1	7' 4"	1.00	1.00
STD 714 26'	1942	—	—	—	—	25'	1	7' 4"	1.00	1.00
STD 714 28'	1942	—	—	—	—	27'	1	7' 4"	1.00	1.00
STD 714 30'	1942	—	—	—	—	29'	1	7' 4"	1.00	1.00
STD 714 32'	1942	—	—	—	—	31'	1	7' 4"	1.00	1.00
STD 714 34'	1942	3190	27%	431	1.49	33'	1	7' 4"	1.00	1.00
		3555	22%	391	1.48					
		3730	16%	298	1.46					
STD 716 42'	1942	—	—	—	—	41'	1	7' 4"	1.00	1.00
STD 716 44'	1942	—	—	—	—	43'	1	7' 4"	1.00	1.00
STD 716 46	1942	—	—	—	—	45'	1	7' 4"	1.00	1.00
STD 716 48	1942	—	—	—	—	47'	1	7' 4"	1.00	1.00
STD 716 50	1942	—	—	—	—	49'	1	7' 4"	1.00	1.00
STD 716 52	1942	—	—	—	—	51'	1	7' 4"	1.00	1.00
STD C2401 32	1952	—	—	—	—	31'	1	6' 8"	1.00	1.00
STD C2401 34	1952	—	—	—	—	33'	1	6' 8"	1.00	1.00
STD C2401 36	1952	—	—	—	—	35'	`	`	1.00	1.00
STD C2401 38	1952	—	—	—	—	37'	1	6' 8"	1.00	1.00
STD C2411 32	1963	—	—	—	—	31'	1	6' 8"	1.00	1.00
STD C2411 34	1963	550	1%	3	1.40	33'	1	6' 8"	1.00	1.00
		1586	1%	8	1.40					
		550	1%	3	1.40					
STD C2411 36	1963	—	—	—	—	35'	1	6' 8"	1.00	1.00
STD C2411 38	1963	—	—	—	—	37'	1	6' 8"	1.00	1.00
STD C2414 32	1966	—	—	—	—	31'	1	6' 8"	1.00	1.00
STD C2414 34	1966	—	—	—	—	33'	1	6' 8"	1.00	1.00
STD C2414 36	1966	—	—	—	—	35'	1	6' 8"	1.00	1.00
STD C2414 38	1966	—	—	—	—	37'	1	6' 8"	1.00	1.00
STD PC34 RC 24R	1978	629	9%	28	1.40	34'	1	NA	1.00	1.00
		285	2%	3	1.40					
		285	2%	3	1.40					
STD PC34 RC 26R	1978	—	—	—	—	34'	1	NA	1.00	1.00
STD CS2403	1963	—	—	—	—	75' 100' 75'	3	9'	1.00	1.00
STD CS2404	1963	—	—	—	—	66' 82' 82' 66'	4	6' 8"	1.00	1.00
STD B2200 16	1950	—	—	—	—	15'	1	6' 2"	1.00	1.00
STD B2200 20	1950	—	—	—	—	19'	1	6' 2"	1.00	1.00
STD B2200 24	1950	—	—	—	—	23'	1	6' 2"	1.00	1.00
STD B2200 28	1950	—	—	—	—	27'	1	6' 2"	1.00	1.00
STD B2200 30	1950	—	—	—	—	29'	1	6' 2"	1.00	1.00
STD B2200 32	1950	—	—	—	—	31'	1	6' 2"	1.00	1.00
STD B2200 34	1950	—	—	—	—	33'	1	6' 2"	1.00	1.00
STD B2200 36	1950	—	—	—	—	35'	1	6' 2"	1.00	1.00
STD B2800	1955	—	—	—	—	78.875'	1	8'	1.00	1.00
STD BC2402	1968	—	—	—	—	68.75'	1	6' 8"	1.00	1.00
STD BC2801	1950	—	—	—	—	80'	1	8'	1.00	1.00
STD B2400	1951	—	—	—	—	60' 80' 60'	3	6' 10"	1.00	1.00
STD B2411	1963	—	—	—	—	80' 100' 80'	3	6' 10"	1.00	1.00
STD B2809	1960	—	—	—	—	80' 100' 100' 80'	4	8'	1.00	1.00
STD CSC2800 3S	1979	—	—	—	—	80' 100' 80'	3	8'	1.00	1.00
STD CSC2800 4S	1979	—	—	—	—	80' 100' 100' 80'	4	8'	1.00	1.00
STD 632	1934	—	—	—	—	20' 20' 20'	3	5' 3"	1.00	1.00
STD PC34 PS 24R	1978	—	—	—	—	34'	1	NA	1.00	1.00
STD PC34 PS 26R	1978	—	—	—	—	34'	1	NA	1.00	1.00

Table A - 12: Additional Sample Information Table 2



Bin	Year	AADT	ADTT		γ_L	Span Length(s)	# of Spans	Girder Spacing	ϕ_s	ϕ_c
			% of AADT	ADTT						
STD s28130	2002	—	—	—	—	130'	1	8'	1.00	1.00
STD PSC4465	1984	—	—	—	—	65' 65' 65' 65' 65'	5	8'	1.00	1.00
STD PSC4041	1978	4530	16%	362	1.47	1' 41' 41' 41' 41' 41	6	7'	1.00	1.00
		4530	16%	362	1.47					
		200	1%	1	1.40					
B001393	1935	47830	14%	3348	1.74	25'	1	7'	1.00	1.00
B011017	1950	135	10%	7	1.40	42'	1	8'	1.00	1.00
B007699	1962	—	—	—	—	34'	1	8' 6"	1.00	1.00
B005167	1970	—	—	—	—	33'	1	8' 6"	1.00	1.00
B006360	1951	—	—	—	—	38.667'	1	7' 4"	1.00	1.00
B003411	1951	2900	13%	189	1.42	50'	1	7'	1.00	1.00
B008653	1969	600	2%	6	1.40	19'	1	NA	1.00	1.00
B019607	1974	2121	6%	64	1.40	24'	1	NA	1.00	1.00
B019558	2006	1233	5%	31	1.40	40'	1	NA	1.00	1.00
B014979		210	1%	1	1.40	34'	1	NA	1.00	1.00
B007334	1957	8000	16%	640	1.55	44' 55' 44'	3	8'	1.00	1.00
B008521	1984	13895	24%	1667	1.68	54' 68' 54'	3	7' 3"	1.00	1.00
B007334	1957	8000	16%	640	1.55	44' 55' 44'	3	8'	1.00	1.00
B009005	1966	23815	19%	2262	1.70	58' 73' 58'	3	6' 9"	1.00	1.00
B008523	1984	400	1%	2	1.40	44' 55' 44'	3	6' 8"	1.00	1.00
B007848	1957	25590	28%	3583	1.75	72' 90' 72'	3	8'	1.00	1.00
B011110		100	0%	0	1.40	84' 105' 105' 84'	4	8'	1.00	1.00
B011206	1972	—	—	—	—	84' 105' 105' 84'	4	8'	1.00	1.00
B011081	1971	14313	11%	787	1.59	31.667'	1	7' 4"	1.00	1.00
B009782	1967	12210	10%	611	1.54	78.625'	1	8'	1.00	1.00
B005318	1953	2490	10%	125	1.41	70.875'	1	6' 8"	1.00	1.00
B007536		—	—	—	—	56'	1	8'	1.00	1.00
B012825	1981	930	20%	93	1.40	80'	1	7'	1.00	1.00
B011335	1973	20575	15%	1543	1.67	109.583'	1	7'	1.00	1.00
B002310	1939	2310	28%	323	1.46	22' 22'	2	5' 7"	1.00	1.00
B011097	1972	11070	44%	2435	1.70	50' 60' 50'	3	7'	1.00	1.00
B012599	1980	2620	6%	79	1.40	60' 80' 60'	3	7'	1.00	1.00
B011344	1973	20575	15%	1543	1.67	70' 109' 80'	3	7'	1.00	1.00
B012319	1976	31030	14%	2172	1.69	82' 104' 82'	3	7' 6"	1.00	1.00
B012350	1981	14120	17%	1200	1.66	140' 180' 140'	3	8' 9"	1.00	1.00
B017781	2002	—	—	—	—	.875' 210' 210' 168.8	4	10' 3"	1.00	1.00
B015764	1992	7885	35%	1380	1.66	47.672'	1	8'	1.00	1.00
B019141	2008	—	—	—	—	77'	1	7' 4"	1.00	1.00
B019990	2008	—	—	—	—	123'	1	7'	1.00	1.00
B019473	2005	6730	5%	168	1.42	131.021'	1	5' 3"	1.00	1.00
B016591	1996	5395	1%	27	1.40	40'	1	NA	1.00	1.00
B018106	2006	10482	5%	262	1.45	51.042'	1	NA	1.00	1.00
B016845	1994	2450	10%	123	1.41	100'	1	7' 8"	1.00	1.00
B014450	1987	22045	10%	1102	1.65	38.5' 39.5' 39.5'	3	7'	1.00	1.00
B016510	1994	350	20%	35	1.40	2.802' 32.802' 32.802	5	8'	1.00	1.00
B016111	1994	—	—	—	—	8.458' 39.583' 38.458	3	7'	1.00	1.00
B016310	1993	21405	7%	749	1.58	59.25' 61' 61.062'	4	8' 9"	1.00	1.00
B015295		750	10%	38	1.40	50' 50' 50'	3	8'	1.00	1.00
B017909	2002	550	20%	55	1.40	82.417' 83' 82.417'	3	7'	1.00	1.00
B015820	1988	—	—	—	—	8.25' 117.833' 118.33	3	6' 6"	1.00	1.00

Table A - 13: Additional Sample Information Table 3



Bin	Material Type	Structural System Type	Deck F'c (ksi)	Girder F'c (ksi)	Reinforcement Grade (ksi)	Strctural Steel Grade (ksi)
STD 714 24'	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	33	-
STD 714 26'	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	33	-
STD 714 28'	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	33	-
STD 714 30'	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	33	-
STD 714 32'	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	33	-
STD 714 34'	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	33	-
			2.5	2.5	33	-
			2.5	2.5	33	-
STD 716 42'	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	33	-
STD 716 44'	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	33	-
STD 716 46	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	33	-
STD 716 48	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	33	-
STD 716 50	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	33	-
STD 716 52	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	33	-
STD C2401 32	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	40	-
STD C2401 34	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	40	-
STD C2401 36	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	40	-
STD C2401 38	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	40	-
STD C2411 32	Reinforced Concrete, Simply Supported	T-Beam	3	3	40	-
STD C2411 34	Reinforced Concrete, Simply Supported	T-Beam	3	3	40	-
			3	3	40	-
			3	3	40	-
STD C2411 36	Reinforced Concrete, Simply Supported	T-Beam	3	3	40	-
STD C2411 38	Reinforced Concrete, Simply Supported	T-Beam	3	3	40	-
STD C2414 32	Reinforced Concrete, Simply Supported	T-Beam	3	3	40	-
STD C2414 34	Reinforced Concrete, Simply Supported	T-Beam	3	3	40	-
STD C2414 36	Reinforced Concrete, Simply Supported	T-Beam	3	3	40	-
STD C2414 38	Reinforced Concrete, Simply Supported	T-Beam	3	3	40	-
STD PC34 RC 24R	Reinforced Concrete, Simply Supported	C-Channel	5	5	60	-
			5	5	60	-
			5	5	60	-
STD PC34 RC 26R	Reinforced Concrete, Simply Supported	C-Channel	5	5	60	-
STD CS2403	Reinforced Concrete, Continuously Supported	I-Girder	3	3	40	-
STD CS2404	Reinforced Concrete, Continuously Supported	I-Girder	3	3	40	-
STD B2200 16	Steel, Simply Supported	I-Girder	2.5	-	33	33
STD B2200 20	Steel, Simply Supported	I-Girder	2.5	-	33	33
STD B2200 24	Steel, Simply Supported	I-Girder	2.5	-	33	33
STD B2200 28	Steel, Simply Supported	I-Girder	2.5	-	33	33
STD B2200 30	Steel, Simply Supported	I-Girder	2.5	-	33	33
STD B2200 32	Steel, Simply Supported	I-Girder	2.5	-	33	33
STD B2200 34	Steel, Simply Supported	I-Girder	2.5	-	33	33
STD B2200 36	Steel, Simply Supported	I-Girder	2.5	-	33	33
STD B2800	Steel, Simply Supported	I-Girder	3	-	40	33
STD BC2402	Steel, Simply Supported	I-Girder	3	-	40	33
STD BC2801	Steel, Simply Supported	I-Girder	3	-	33	33
STD B2400	Steel, Continuously Supported	I-Girder	3	-	33	36
STD B2411	Steel, Continuously Supported	I-Girder	3	-	40	36
STD B2809	Steel, Continuously Supported	I-Girder	3	-	40	33
STD CSC2800 3S	Steel, Continuously Supported	I-Girder	3	-	40	36
STD CSC2800 4S	Steel, Continuously Supported	I-Girder	3	-	40	36
STD 632	Steel, Continuously Supported	I-Girder	2.5	-	33	30
STD PC34 PS 24R	Prestressed Concrete, Simply Supported	C-Channel	5	5	270	-
STD PC34 PS 26R	Prestressed Concrete, Simply Supported	C-Channel	5	5	270	-

Table A - 14: Additional Sample Information Table 4

Bin	Material Type	Structural System Type	Deck F'c (ksi)	Girder F'c (ksi)	Reinforcement Grade (ksi)	Strctural Steel Grade (ksi)
STD s28130	Prestressed Concrete, Simply Supported	I-Girder	3	6.5	270	-
STD PSC4465	Prestressed Concrete, Simply Supported	I-Girder	3	5	250	-
STD PSC4041	Prestressed Concrete, Simply Supported	I-Girder	3	5	250	-
B001393	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	33	-
B011017	Reinforced Concrete, Simply Supported	T-Beam	3	3	40	-
B007699	Reinforced Concrete, Simply Supported	T-Beam	3	3	40	-
B005167	Reinforced Concrete, Simply Supported	T-Beam	3	3	40	-
B006360	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	40	-
B003411	Reinforced Concrete, Simply Supported	T-Beam	2.5	2.5	40	-
B008653	Reinforced Concrete, Simply Supported	C-Channel	3	3	33	-
B019607	Reinforced Concrete, Simply Supported	C-Channel	3	3	40	-
B019558	Reinforced Concrete, Simply Supported	C-Channel	4.5	4.5	60	-
B014979	Reinforced Concrete, Simply Supported	C-Channel	5	5	60	-
B007334	Reinforced Concrete, Continuously Supported	T-Beam	3	3	40	-
B008521	Reinforced Concrete, Continuously Supported	T-Beam	3	3	40	-
B007334	Reinforced Concrete, Continuously Supported	T-Beam	3	3	40	-
B009005	Reinforced Concrete, Continuously Supported	T-Beam	3	3	40	-
B008523	Reinforced Concrete, Continuously Supported	T-Beam	3	3	40	-
B007848	Reinforced Concrete, Continuously Supported	T-Beam	3	3	40	-
B011110	Reinforced Concrete, Continuously Supported	T-Beam	3	3	40	-
B011206	Reinforced Concrete, Continuously Supported	T-Beam	3	3	40	-
B011081	Steel, Simply Supported	I-Girder	3	-	40	36
B009782	Steel, Simply Supported	I-Girder	3	-	40	36
B005318	Steel, Simply Supported	I-Girder	3	-	40	33
B007536	Steel, Simply Supported	I-Girder	3.3	-	40	33
B012825	Steel, Simply Supported	I-Girder	3	-	40	36
B011335	Steel, Simply Supported	I-Girder	3.3	-	40	36
B002310	Steel, Continuously Supported	I-Girder	2.5	-	33	33
B011097	Steel, Continuously Supported	I-Girder	3	-	40	36
B012599	Steel, Continuously Supported	I-Girder	3	-	40	36
B011344	Steel, Continuously Supported	I-Girder	3.3	-	40	36
B012319	Steel, Continuously Supported	I-Girder	3	-	40	36
B012350	Steel, Continuously Supported	I-Girder	3	-	40	50
B017781	Steel, Continuously Supported	I-Girder	4	-	60	36
B015764	Prestressed Concrete, Simply Supported	I-Girder	3	5	270	-
B019141	Prestressed Concrete, Simply Supported	I-Girder	3	5	270	-
B019990	Prestressed Concrete, Simply Supported	I-Girder	3.3	8	270	-
B019473	Prestressed Concrete, Simply Supported	I-Girder	3	7.5	270	-
B016591	Prestressed Concrete, Simply Supported	Box-Beam	4	5	270	-
B018106	Prestressed Concrete, Simply Supported	Box-Beam	4	5	270	-
B016845	Prestressed Concrete, Simply Supported	I-Girder	3.3	6	270	-
B014450	Prestressed Concrete, Continuously Supported	I-Girder	4	5	270	-
B016510	Prestressed Concrete, Continuously Supported	I-Girder	3	6	270	-
B016111	Prestressed Concrete, Continuously Supported	I-Girder	3	5	270	-
B016310	Prestressed Concrete, Continuously Supported	I-Girder	3	6	270	-
B015295	Prestressed Concrete, Continuously Supported	I-Girder	3	6	270	-
B017909	Prestressed Concrete, Continuously Supported	I-Girder	3	6	270	-
B015820	Prestressed Concrete, Continuously Supported	I-Girder	4	5	270	-

APPENDIX B1: Slab Bridges Mathcad File

Presented in this Appendix is the Mathcad file used for slab bridges for rating under the LRFR methodology.

Slab Bridge LRFR File *BIN 001541*

Mike Murdock 12/08

Input

$L := 19$	ft	*slab length, center to center of bearings*
$W := 51.5$	ft	*entire bridge width*
$w := 36$	ft	*roadway width*
$fc := 2.5$	ksi	*compressive strength of concrete, 28 day*
$fy := 40$	ksi	*yield strength of reinforcement*
$h := 15.5$	in	*depth of slab*
$As := 1.44$	in^2	*area of positive flexural reinforcement per-foot*
$d_f := 1.4375$	in	*distance from extreme tension fiber to centriod of flexural reinforce.*
$wb := .61$	kip/ft	*barrier self weight and walkway*
$w_{bear} := 69$	in	*distance from edge to face of barrier*
$\rho c := .15$	kip/ft^3	*weight of concrete*

AASHTO 4.6.2.3

AASHTO 4.6.2.3-1

Live-Load Strip Width

AASHTO 4.6.2.3-2

One Lane Loaded

$L_1 := \min(L, 60) = 19$ ft $\qquad W_1 := \min(W, 30) = 30$ ft

AASHTO 3.6.1.1.1

$E_1 := 10 + 5 \cdot \sqrt{(L_1 \cdot W_1)} = 129.373$ in

Two Lanes Loaded

$L_1 := \min(L, 60) = 19$ ft $\qquad W_1 := \min(W, 60) = 51.5$ ft

$$N_L := \text{trunc}\left(\frac{w}{12}\right) = 3$$

$$E_2 := \min\left(84 + 1.44\sqrt{L_1 \cdot W_1}, 12.0 \cdot \frac{W}{N_L}\right) = 129.045 \quad \text{in}$$

$E := \min(E_1, E_2) = 129.045$ in

in

Dead Load Calculations

Assumptions:
barrier load spread over width of live-load edge strip

$$M_{DCint} := \left[\rho c \cdot \left(\frac{h}{12}\right) \cdot 1\right] \cdot \left(\frac{L^2}{8}\right) \qquad M_{DCext} := \left[\rho c \cdot \left(\frac{h}{12}\right) \cdot 1 + \frac{wb}{\left(\frac{EdgeStrip}{12}\right)}\right] \cdot \left(\frac{L^2}{8}\right)$$

$$V_{DCint} := 0.5 \cdot \left[\rho c \cdot \left(\frac{h}{12}\right)\right] \cdot L \qquad V_{DCext} := 0.5 \cdot \left[\rho c \cdot \left(\frac{h}{12}\right) + \frac{wb}{\left(\frac{EdgeStrip}{12}\right)}\right] \cdot L$$

$M_{DCint} = 8.743$ kip-ft / ft $\qquad$ $M_{DCext} = 13.862$ kip-ft / ft

$V_{DCint} = 1.841$ kip / ft $\qquad$ $V_{DCext} = 2.918$ kip / ft

Live Load Calculations

Assumptions:
in-house MatLab line load analysis use for moment and shear calculations
impact included

$$M_{max} := \begin{pmatrix} 240.14 \\ 240.14 \\ 239.4 \\ 333.83 \\ 299.25 \\ 209.48 \\ 240.98 \\ 122.86 \end{pmatrix} \text{ kip-ft} \qquad V_{max} := \begin{pmatrix} 64.4 \\ 54.4 \\ 57.02 \\ 77.15 \\ 72.52 \\ 52.73 \\ 55.68 \\ 16.17 \end{pmatrix} \text{ kip}$$

HS 20-44
H 20-44
Tandem
Triaxle
Concrete
18 Wheeler
6-Axel
School Bus

$$M_{LL} := \frac{M_{max}}{\left(\frac{E}{12}\right)} \text{ kip-ft / ft} \qquad V_{LL} := \frac{V_{max}}{\left(\frac{E}{12}\right)} \text{ kip / ft}$$

Strength I

Moment Resistance

$$\beta_1 := \begin{cases} 0.85 & \text{if } fc \le 4 \\ [0.85 - .05\cdot(fc - 4)] & \text{otherwise} \end{cases} \qquad \beta_1 = 0.85$$

AASHTO 5.7.2.2
AASHTO 5.7.3.2.2

$$c := \frac{(As\cdot fy)}{0.85\cdot fc\cdot \beta_1\cdot 12} = 2.657 \quad \text{in}$$

AASHTO 5.7.3.2.2

$$a := \beta_1\cdot c = 2.259 \quad \text{in} \qquad ds := h - d_f = 14.063 \quad \text{in}$$

$$M_n := As\cdot fy\cdot\left(ds - \frac{a}{2}\right)\cdot\left(\frac{1}{12}\right) = 62.079 \quad \text{kip-ft / ft}$$

AASHTO 5.5.4.2

$$\varepsilon_T := 0.003\left[\frac{(ds - c)}{c}\right] = 0.013$$

$$\phi := \begin{cases} 0.9 & \text{if } \varepsilon_T > 0.005 \\ \text{otherwise} & \\ \quad \begin{cases} 0.75 & \text{if } \varepsilon_T < .002 \\ 0.65 + 0.15\cdot\left(\dfrac{ds}{c} - 1\right) & \text{otherwise} \end{cases} \end{cases} \qquad \phi = 0.9$$

$$\phi\cdot M_n = 55.871 \quad \text{kip-ft / ft}$$

AASHTO 5.8.4.1

AASHTO 5.8.3.3

Shear Resistance

AASHTO 5.8.3.3

$$\beta := 2 \qquad \theta := 45 \qquad dv := ds \quad \text{in}$$

AASHTO 5.5.4.2

$$V_c := 0.0316\beta\cdot\sqrt{fc}\cdot dv\cdot 12 = 16.863 \quad \text{kip}$$

$$V_n := V_c = 16.863 \quad \text{kip}$$

$$\phi_v := 0.9$$

$$\phi_v\cdot V_n = 15.177 \quad \text{kip}$$

** assumes shear is only resisted by the concrete section*

LRFR Analysis

$\phi_c := 1.0$ *condition factor* *MCE LRFR 6.4.2.3*

$\phi_s := 1.0$ *system factor* *MCE LRFR 6.4.2.4*

$\gamma_{DC} := 1.25$ *load factor for structural components and attachments* *MCE LRFR 6.4.2.2*

$\gamma_L := 1.4$ *evaluation live-load factor* *MCE LRFR 6.4.4.2.3*

$$RF_{EXTmoment} := \frac{\left(\phi_c \cdot \phi_s \cdot \phi \cdot M_n - \gamma_{DC} \cdot M_{DCext}\right)}{\gamma_L \cdot M_{LL}}$$

$$RF_{EXTshear} := \frac{\left(\phi_c \cdot \phi_s \cdot \phi_v \cdot V_n - \gamma_{DC} \cdot V_{DCext}\right)}{\gamma_L \cdot V_{LL}}$$

$$RF_{EXTmoment} = \begin{pmatrix} 1.233 \\ 1.233 \\ 1.237 \\ 0.887 \\ 0.989 \\ 1.413 \\ 1.229 \\ 2.41 \end{pmatrix}$$

HS 20-44
H 20-44
Tandem
Triaxle
Concrete
18 Wheeler
6-Axel
School Bus

$$RF_{EXTshear} = \begin{pmatrix} 1.375 \\ 1.628 \\ 1.553 \\ 1.148 \\ 1.221 \\ 1.679 \\ 1.59 \\ 5.476 \end{pmatrix}$$

HS 20-44
H 20-44
Tandem
Triaxle
Concrete
18 Wheeler
6-Axel
School Bus

$$RF_{INTmoment} := \frac{\left(\phi_c \cdot \phi_s \cdot \phi \cdot M_n - \gamma_{DC} \cdot M_{DCint}\right)}{\gamma_L \cdot M_{LL}}$$

$$RF_{INTshear} := \frac{\left(\phi_c \cdot \phi_s \cdot \phi_v \cdot V_n - \gamma_{DC} \cdot V_{DCint}\right)}{\gamma_L \cdot V_{LL}}$$

Controlling Rating Results

$RF_{EXTmomentMin} := \min(RF_{EXTmoment}) = 0.887$

$RF_{EXTshearMin} := \min(RF_{EXTshear}) = 1.148$

$RF_{INTmomentMin} := \min(RF_{INTmoment}) = 1.034$

$RF_{INTTshearMin} := \min(RF_{INTshear}) = 1.282$

APPENDIX B2: Example Problem A1: Steel I Girder

Presented in this Appendix is the Mathcad file used for slab bridges for rating under the LRFR methodology.

Simple Span Composite Steel Stringer Bridge

$L := 65 \ \text{ft}$

$Fy := 36 \ \text{ksi}$

$fc := 3000 \ \text{psi}$

$ADDT := 1000$

$wc := .145$

$E := 29000$

W33x130 Section Pro.

$Dw := 33.1 \ \text{in}$ $\quad Aw := 38.26 \ \text{in}^2$ $\quad Sweight := 130$

$bf := 11.51 \ \text{in}$ $\quad tf := .855 \ \text{in}$

$Dweb := Dw - 2 \cdot tf$ $\quad tw := .58 \ \text{in}$ $\quad Iw := 6699$

$Dweb = 31.39$

PL 5/8 in x 10 1/2 in

$tpl := \frac{5}{8} \ \text{in}$ $\quad bpl := 10.5 \ \text{in}$ $\quad Apl := tpl \cdot bpl$

Loads:

$DesignLaneLoadMoment := 338 \ \text{kipft}$	$DesignLaneLoadShear := 20.8 \ \text{kip}$
$DesignTruckMoment := 890.9 \ \text{kipft}$	$DesignTruckShear := 61.6 \ \text{kip}$
$TandemAxlesMoment := 726.9 \ \text{kipft}$	$TandemAxlesShear := 48.4 \ \text{kip}$

Section Properties:

$$y1 := \frac{\left[\left(\frac{Dw}{2} + tpl\right) \cdot Aw + \left(\frac{tpl}{2}\right) \cdot (Apl)\right]}{[Aw + (Apl)]}$$

Distance to C.G.

$y1 = 14.706 \ \text{in}$ from bottom of section

$$Ix := Iw + Aw \cdot \left(\frac{Dw}{2} - y1 + tpl\right)^2 + Apl \cdot \left(y1 - \frac{tpl}{2}\right)^2$$

$Ix = 8291.803$

$$Sb := \frac{Ix}{y1} \qquad St := \frac{Ix}{(Dw + tpl - y1)}$$

$Sb = 563.832$

$St = 435.978$

Effective Flange Width min. of: LRFD 4.6.2.6.1

$tdeck := 7.25$ in $\qquad wdeck := 22$ ft $\qquad spans := 3$

$$Efw1 := \frac{1}{4} \cdot L \cdot 12$$

$$Efw2 := tdeck \cdot 12 + \max\left(tw, \frac{1}{2} \cdot bf\right)$$

$$Efw3 := \frac{wdeck}{spans} \cdot 12$$

$$Efwidth := \min(Efw1, Efw2, Efw3)$$

$$Efwidth = 88$$

Modular Ratio (n):

$$n := \mathrm{round}\left[\frac{29000000}{57000\,(fc)^{.5}}, 0\right] \qquad n = 9$$

Short-Term Composite (n)

$$\frac{Efwidth}{n} = 9.778 \ \text{in}$$ Width of concrete transformed section

Long-Term Composite (3n)

$$\frac{Efwidth}{3 \cdot n} = 3.259 \ \text{in}$$ Width of concrete transformed section

Transformed Slab Short-Term Pro.

$$yslabs := \frac{\left[\left(\frac{Dw}{2} + tpl\right) \cdot Aw + \left(\frac{tpl}{2}\right) \cdot (Apl) + \left(\frac{Efwidth}{n}\right) \cdot tdeck \cdot \left(Dw + tpl + \frac{tdeck}{2}\right)\right]}{Aw + Apl + \left(\frac{Efwidth}{n}\right) \cdot tdeck}$$

$yslabs = 28.579$ from bottom of section

$Ixslabs = 22682.186 \ \text{in}^4$

$$Stslabs := \frac{Ixslabs}{(Dw + tpl - yslabs)} \qquad Stslabs = 4407.365$$

$Sbslabs = 793.678 \ \text{in}^3$

$$\mathrm{Sbslabs} := \frac{\mathrm{Ixslabs}}{(\mathrm{yslabs})} \qquad \mathrm{in}^3$$

Transformed Slab Long-Term Pro.

$$\mathrm{yslabl} := \frac{\left[\left(\frac{\mathrm{Dw}}{2} + \mathrm{tpl}\right)\cdot \mathrm{Aw} + \left(\frac{\mathrm{tpl}}{2}\right)\cdot(\mathrm{Apl}) + \left(\frac{\mathrm{Efwidth}}{3\cdot n}\right)\cdot \mathrm{tdeck}\cdot\left(\mathrm{Dw} + \mathrm{tpl} + \frac{\mathrm{tdeck}}{2}\right)\right]}{\mathrm{Aw} + \mathrm{Apl} + \left(\frac{\mathrm{Efwidth}}{3\cdot n}\right)\cdot \mathrm{tdeck}}$$

$\mathrm{yslabl} = 22.523$ from bottom of section

$\mathrm{Ixslabl} = 16328.84$ in^4

$$\mathrm{Stslabl} := \frac{\mathrm{Ixslabl}}{(\mathrm{Dw} + \mathrm{tpl} - \mathrm{yslabl})} \qquad \mathrm{Stslabl} = 1457.645 \ \mathrm{in}^3$$

$$\mathrm{Sbslabl} := \frac{\mathrm{Ixslabl}}{(\mathrm{yslabl})} \qquad \mathrm{Sbslabl} = 724.992 \ \mathrm{in}^3$$

Summary of Section Properties at MidSpan

a. Steel Section Only:

$\mathrm{St} = 435.978$ in^3 at top of Steel section

$\mathrm{Sb} = 563.832$ in^3 at bottom of Steel section

b. Composite Section - Short Term:

$\mathrm{Stslabs} = 4407.365$ in^3 at top of Steel section

$\mathrm{Sbslabs} = 793.678$ in^3 at bottom of Steel section

c. Composite Section - Long Term:

$\mathrm{Stslabl} = 1457.645$ in^3 at top of Steel section

$\mathrm{Sbslabl} = 724.992$ in^3 at bottom of Steel section

Dead Load Analysis - Interior Stringer

1. Components and Attachments *DC*

a. Non-Composite Dead Loads: *DC1*

$$\text{DeckLoad} := \left(\frac{\text{wdeck}}{\text{spans}}\right)\cdot\left(\frac{\text{tdeck}}{12}\right)\cdot .15 = 0.665 \qquad \frac{\text{kip}}{\text{ft}}$$

$$\text{DeckLoad}\cdot\frac{65^2}{8} = 350.983$$

$$\text{StringLoad} := \text{Sweight}\cdot\frac{1.06}{1000} = 0.138 \qquad \frac{\text{kip}}{\text{ft}}$$

$$\text{CPload} := \text{tpl}\cdot\text{bpl}\cdot\left(\frac{.490}{144}\right)\cdot 1.06\cdot\frac{38}{65} = 0.014 \qquad \frac{\text{kip}}{\text{ft}}$$

$$\text{DiaLoad} := 3\cdot .0427\cdot 7.33\cdot\frac{1.06}{65} = 0.015 \qquad \frac{\text{kip}}{\text{ft}}$$

$$\text{TotalDC1} := \text{DeckLoad} + \text{StringLoad} + \text{CPload} + \text{DiaLoad}$$

$$\text{TotalDC1} = 0.832 \qquad \frac{\text{kip}}{\text{ft}}$$

$$\text{Mdc1} := \frac{\text{TotalDC1}\cdot\left(L^2\right)}{8} = 439.154 \qquad \text{kip}\cdot\text{ft}$$

$$\text{Vdc1} := \text{TotalDC1}\cdot\frac{L}{2} = 27.025 \qquad \text{kip}$$

b. Composite Dead Loads: *DC2*

All Permanent loads on the deck are uniformly distributed among the beams.

$$\text{Curbe} := 1\cdot\left(\frac{10}{12}\right)\cdot .15\cdot\left(\frac{2}{4}\right) = 0.063 \qquad \frac{\text{kip}}{\text{ft}}$$

$$\text{Parapet} := \left[\frac{(18\cdot 12)}{144} + \frac{6\cdot 19}{144}\right]\cdot .15\cdot\frac{2}{4} = 0.172 \qquad \frac{\text{kip}}{\text{ft}}$$

Railing : Assume .02 k/f / 2

$$\text{TotalDC2} := \text{Curbe} + \text{Parapet} + .01 = 0.244 \qquad \frac{\text{kip}}{\text{ft}}$$

$$\text{Mdc2} := \frac{\text{TotalDC2}\cdot\left(L^2\right)}{8} = 129.061 \qquad \text{kip}\cdot\text{ft}$$

$$\text{Vdc2} := \text{TotalDC2}\cdot\frac{L}{2} = 7.942 \qquad \text{kip}$$

2. Wearing Surface DW = 0

Live-Load Analysis - Interior String

1. Compute Live-Load Distribution Factors (Type (a) cross section).

Longitudinal Stiffness Parameter Kg

$$Ed := 33000\left(wc^{1.5}\right)\left[\left(\frac{fc}{1000}\right)^{.5}\right] = 3155.924 \qquad ksi$$

$$Eb := 2900(\qquad ksi$$

$$eg := .5\cdot tdeck + Dweb + tpl - y1 = 20.934$$

$$Kg := \left(\frac{Eb}{Ed}\right)\left[Ix + (Apl + Aw)\cdot eg^{2}\right]$$

$$Kg = 2.567\times 10^{5} \qquad in^{4}$$

$$Kg := 29000($$

a) Distribution Factor for Moment gm

$$S := \frac{wdeck}{spans} = 7.333$$

One-Lane Loaded:

$$gm1 := 0.06 + \left(\frac{S}{14}\right)^{.4}\left(\frac{S}{L}\right)^{.3}\left(\frac{Kg}{12\cdot L\cdot tdeck^{3}}\right)^{.1} = 0.46$$

Two or More Lanes Loaded:

$$gm2 := 0.075 + \left(\frac{S}{9.5}\right)^{.6}\left(\frac{S}{L}\right)^{.2}\left(\frac{Kg}{12\cdot L\cdot tdeck^{3}}\right)^{.1} = 0.627$$

Use: $gm := \max(gm1, gm2) = 0.627$

b) Distribution Factor for Shear

One-Lane Loaded:

$$gv1 := 0.36 + \frac{S}{25} = 0.653$$

Two or More Lanes Loaded:

$$gv2 := 0.2 + \left(\frac{S}{12}\right) - \left(\frac{S}{35}\right)^{2.0} = 0.767$$

Use: $gv := \max(gv1, gv2) = 0.767$

2. Compute Maximum Live Load Effects.

a) Maximum Design Live Load (HL-93) Moment at midspan

$IM := 1.33$

$MaxMoment := DesignLaneLoadMoment + max(DesignTruckMoment, TandemAxlesMoment) \cdot IM$

$MaxMoment = 1522.897$ kipft

b) maximum Design Live Load Shear at Beam ends

$MaxShear := DesignLaneLoadShear + max(DesignTruckShear, TandemAxlesShear) \cdot IM$

$MaxShear = 102.728$ kip

<u>Distributed Live-Load Moments and Shears</u>

Design Live-Load (HL-93):

$Mll := MaxMoment \cdot gm = 954.884$ kipft

$Vll := MaxShear \cdot gv = 78.814$ kip $\qquad Mll = 954.884$

<u>Compute Nominal Resistance of Section At Midspan</u>

Plastic Forces:

$Ps := .85 \cdot fc \cdot Efwidth \cdot \frac{tdeck}{1000} = 1626.9$ kips $\qquad$ Force from Deck

$Pc := Fy \cdot bf \cdot tf = 354.278$ kips $\qquad$ Force of top of W steel

$Pw := Fy \cdot Dweb \cdot tw = 655.423$ kips $\qquad$ Force from web of W steel

$Pt := Fy \cdot (bf \cdot tf + Apl) = 590.528$ kips $\qquad$ Force from bottom steel

$Ptr := 0$

$Pbr := 0$

$Crb := 0$

$Crt := 0$

Force from slab reinforcement

(will add later)

Ybar Calcs

This program uses the formulas given in Table 6D.1-1 in the AASHTO LRFD to determine Ybar based different section forces.

Case One Ybar taken from top of web of W section
Case Two Ybar taken from top of Top Flange of W section
Remaining Cases Ybar taken from top of concrete deck

$\text{Ybar} := \text{FindYbar}(\text{Ps}, \text{Pc}, \text{Pw}, \text{Pt}, \text{Ptr}, \text{Pbr}, \text{Dweb}, \text{tf}, \text{tdeck}, \text{Crb}, \text{Crt})$

$\text{Ybar} = 7.131 \quad \text{in}$

Plastic Moment Mp

This program uses the formulas given in Table 6D.1-1 in the AASHTO LRFD to determine Mp based different section forces and Ybar.

Case One Ybar taken from top of web of W section
Case Two Ybar taken from top of Top Flange of W section
Remaining Cases Ybar taken from top of concrete deck

$$\text{Mp} := \frac{\text{FindMp}(\text{Ps}, \text{Pc}, \text{Pw}, \text{Pt}, \text{Ptr}, \text{Pbr}, \text{Dweb}, \text{tf} + \text{tpl}, \text{tf}, \text{tdeck}, \text{Crb}, \text{Crt}, \text{Ybar})}{12} = 3031.1 \qquad \text{kft}$$

Nominal Flexural Resistance Mn 6.10.7.1.

$Dt := tpl + Dw + tdeck = 40.975$

$Dp := Ybar = 7.131$

```
FindMn(Dt, Dp, Mp) :=  if  $Dp \le 0.1 \cdot Dt$
                           Mp
                           break
                       otherwise
                           $Mp \cdot \left[1.07 - .7 \cdot \left(\frac{Dp}{Dt}\right)\right]$  if  $Dp > 0.1 \cdot Dt$
                           break
```

$Mn := FindMn(Dt, Dp, Mp) = 2874.011$

Nominal Shear Resistance Vn 6.10.9.

$Vp := .58 Fy \cdot Dweb \cdot tw = 380.145$ kips

$TranStif := 0$ Stiffeners spacing

```
findK(Dw, TranStif) :=  5  if  $TranStif = 0$
                        $5 + \frac{5}{\left(\frac{TranStif}{Dw}\right)^2}$  otherwise
```

$k := findK(Dw, TranStif) = 5$

```
findc(Dweb, tw, E, k, Fy) :=  1.0  if  $\frac{Dweb}{tw} \le 1.12 \cdot \sqrt{E \cdot \frac{k}{Fy}}$
                              otherwise
                                  $\left[\frac{1.12}{\frac{Dweb}{tw}} \cdot \sqrt{E \cdot \frac{k}{Fy}}\right]$  if  $\frac{Dweb}{tw} \le 1.4 \cdot \sqrt{E \cdot \frac{k}{Fy}}$
                                  $\frac{1.57}{\left(\frac{Dweb}{tw}\right)^2} \cdot \left(E \cdot \frac{k}{Fy}\right)$  otherwise
```

$C := findc(Dweb, tw, E, k, Fy) = 1$

$Vn := Vp \cdot C = 380.145$ kips

Design Load Rating:

$q := 1.0$ $qc := 1.0$ $qs := 1.0$

A) Strength I Limit State

a) Inventory Level

Load	Load Factor
DC	1.25
LL	1.75

Flexure: $$RFif := \frac{[q \cdot qc \cdot qs \cdot Mn - 1.25 \cdot (Mdc1 + Mdc2)]}{1.75 \cdot Mll}$$

$RFif = 1.295$

Shear: $$RFis := \frac{[q \cdot qc \cdot qs \cdot Vn - 1.25 \cdot (Vdc1 + Vdc2)]}{1.75 \cdot Vll}$$

$RFis = 2.439$

b) Operating Level

Load	Load Factor
DC	1.25
LL	1.35

Flexure: $$RFof := RFif \cdot \left(\frac{1.75}{1.35}\right)$$

$RFof = 1.679$

Shear: $$RFos := RFis \cdot \left(\frac{1.75}{1.35}\right)$$

$RFos = 3.162$

APPENDIX B3: Example Problem A2: Reinforced Concrete Tee Beam

Reinforced Concrete T-Beam

$L := 26$ ft

$\phi := .9$ $\phi s := 1.0$ $\phi c := 1.0$

$fc := 3$ ksi

$RoadWay := 22$ ft

$Girders := 4$

$S := 6.52$ ft Girder Spacing

$ta := 5$ in Asphalt thickness

$As := 6.89$ in^2 Area of Reinforcement

$tb := 15$ in Beam thickness

$dr := 26.61$ in

$db := 24$ in Beam depth

$fy := 33$ ksi Reinforcement Yield

$ts := 6$ in Slab thickness

$\beta := .85$

$h := db + ts$

$Mdl := 54.1$ kft $Vdl := 7$ kip

$Mtruck := 208$ kft $Vtruck := 41.4$ kip

$Mtan := 275$ kft $Vtan := 41.9$ kip

$IM := 1.33$

Dead Load Analysis

DC

Structural Concrete:

$$SC := .150\cdot\left[\left(\frac{6}{12}\right)\cdot 6.52 + 1.25\cdot 2 + 2\cdot(.5\cdot .5\cdot .5)\right] = 0.902$$ k/ft

Railing And Curb

$$RC := .2\cdot\frac{1}{2} = 0.1$$ k/ft

DW

$\gamma DW := 1.25$

Asphalt Overlay:

$$AO := \left(\frac{ta}{12}\right)\cdot(RoadWay)\cdot .144\cdot\frac{1}{Girders} = 0.33$$

Live Load Analysis

Distribution Factors

4.6.2.2.

$n := 1.0$

$I := \left(\frac{1}{12}\right)\cdot(tb)\cdot db^3 = 1.728\times 10^4$

in^4

$A := tb\cdot db = 360 \quad in^2$

$eg := .5(db + ts) = 15$

$Kg := n\cdot\left[I + A\cdot(eg)^2\right] = 9.828\times 10^4$

Moment Distribution Factors

One Lane Loaded:

$$gm1 := 0.06 + \left(\frac{S}{14}\right)^{.4}\left(\frac{S}{L}\right)^{.3}\left(\frac{Kg}{12\cdot L\cdot ts^3}\right)^{.1} = 0.565$$

Two or More Lanes Loaded:

$$gm2 := 0.075 + \left(\frac{S}{9.5}\right)^{.6}\left(\frac{S}{L}\right)^{.2}\left(\frac{Kg}{12\cdot L\cdot ts^3}\right)^{.1} = 0.703$$

Use: $gm := \max(gm1, gm2) = 0.703$

Shear Distribution Factors

One-Lane Loaded:

$$gv1 := 0.36 + \frac{S}{25} = 0.621$$

Two or More Lanes Loaded:

$$gv2 := 0.2 + \left(\frac{S}{12}\right) - \left(\frac{S}{35}\right)^{2.0} = 0.709$$

Use: $gv := \max(gv1, gv2) = 0.709$

Maximum Live Load Effects

$MaxMoment := Mdl + \max(Mtruck, Mtan)\cdot IM$

$MaxMoment = 419.85$

$Mll := MaxMoment\cdot gm = 295.273$

$MaxShear := Vdl + \max(Vtruck, Vtan)\cdot IM$

$MaxShear = 62.727$

$Vll := MaxShear\cdot gv = 44.45$

Effective Flange Width

4.6.2.6.

$$Efw1 := \frac{1}{4} \cdot L \cdot 12$$

$$Efw2 := ts \cdot 12 + \max\left(tb, \frac{1}{2} \cdot ts\right)$$

$$Efw3 := S \cdot 12$$

$$Efwidth := \min(Efw1, Efw2, Efw3)$$

$$Efwidth = 78 \quad \text{in}$$

Compute Distance to Neutral Axis c:

5.7.3.

$$c := \frac{(As \cdot fy)}{(.85 \cdot \beta \cdot fc \cdot Efwidth)} = 1.345 \quad \text{in}$$

Need to add option for when c is in web

$$a := c \cdot \beta = 1.143 \quad \text{in}$$

$$Mn := As \cdot fy \cdot \left(dr - \frac{a}{2}\right) \cdot \frac{1}{12} = 493.363 \quad \text{kft}$$

$$Mr := \phi \cdot Mn = 444.027 \quad \text{kft}$$

Compute Nominal Shear Resistance

5.8.2.

Stirrups: #5 bars @9in

$Av := 2 \cdot \left(\frac{3.1416}{4}\right)\left(\frac{5}{8}\right)^2 = 0.614 \quad in^2$ $\qquad s := 9 \quad in$

$dv1 := \frac{Mn \cdot 12}{(As \cdot fy)} = 26.038$

$dv2 := 0.72 \cdot h = 21.6$

$dv3 := 0.9 \cdot dr = 23.949$

$dv := \max(dv1, dv2, dv3) = 26.038 \qquad in$

$bv := tb = 15 \quad in$ $\qquad$ 5.8.2.9

Simple Procedure: 5.8.3.3

$\beta v := 2 \qquad \theta := 45$

$Vc := 0.0316 \beta v \cdot \left(fc^{.5}\right) \cdot bv \cdot dv = 42.755$

$$Vs := Av \cdot fy \cdot dv \cdot \frac{\left(\cot\left(\frac{\theta \cdot 3.1416}{180}\right)\right)}{s} = 58.582$$

$Vn := Vc + Vs = 101.337$

$Vr := \phi \cdot Vn = 91.203$

MCE Procedure: 5.8.3.3

$\beta v := 2 \qquad \theta := 45 \qquad dv := 23.949$ Conservative Assumption

$Vc := 0.0316 \beta v \cdot \left(fc^{.5}\right) \cdot bv \cdot dv = 39.324$

$$Vs := Av \cdot fy \cdot dv \cdot \frac{\left(\cot\left(\frac{\theta \cdot 3.1416}{180}\right)\right)}{s} = 53.881$$

$Vn := Vc + Vs = 93.205$

$Vr2 := \phi \cdot Vn = 83.885$ $\qquad$ Virtis uses more Complex method by default

Ratings

$$Mdc := (SC + RC)\frac{\left(L^2\right)}{8} = 84.627$$

$$Vdc := (SC + RC)\cdot\left[\left(\frac{L}{2}\right) - \frac{26}{12}\right] = 10.85$$

$$Mdw := (AO)\frac{\left(L^2\right)}{8} = 27.885$$

$$Vdw := (AO)\cdot\left[\left(\frac{L}{2}\right) - \frac{26}{12}\right] = 3.575$$

$\gamma DW := 1.25$ $\quad$ $\gamma DC := 1.25$ $\quad$ $\gamma LL := 1.75$

Moment

$$RF := \frac{(\phi s \cdot \phi c \cdot Mr - \gamma DC \cdot Mdc - \gamma DW \cdot Mdw)}{\gamma LL \cdot Mll} = 0.587$$

Shear

$$RF := \frac{(\phi s \cdot \phi c \cdot Vr2 - \gamma DC \cdot Vdc - \gamma DW \cdot Vdw)}{\gamma LL \cdot Vll} = 0.847$$

$\gamma DW := 1.5$ $\quad$ $\gamma DC := 1.25$ $\quad$ $\gamma LL := 1.75$

Moment

$$RF := \frac{(\phi s \cdot \phi c \cdot Mr - \gamma DC \cdot Mdc - \gamma DW \cdot Mdw)}{\gamma LL \cdot Mll} = 0.574$$

APPENDIX B4: Example Problem A3: Prestressed Concrete I Girder

Reinforced Concrete T-Beam

$L := 80$ ft

$fc := 4$ ksi
$fpc := 5$ ksi
$fpci := 4$ ksi

$RoadWay := 27$ ft

$Girders := 4$

$S := 8.5$ ft Girder Spacing

$ts := 8.5$ $ybar := 3.75$
$tb := 8$
$bf := 20$
$db := 54$
$Hun := 1$

$\phi := 1.0$ $\phi s := 1.0$ $\phi c := 1.0$

$fy := 60$ ksi

$fpu := 270$ ksi

$\beta := .85$

$As := 0$

$As1 := .153$ in^2 Area one strand

$NumSR1 := 12$ $dr1 := 61.5$

$NumSR2 := 12$ $dr2 := 59.5$

$NumSR3 := 8$ $dr3 := 57.5$

$Aps := As1 \cdot (NumSR1 + NumSR2 + NumSR3)$

$Mdl := 512$ kft $Vdl := 22.3$ kip

$Mtruck := 1160$ kft $Vtruck := 58.8$ kip

$Mtan := 950$ kft $Vtan := 45.4$ kip

$IM := 1.33$

$K := .28$ Low Relax

$dp := db + Hun + ts - ybar = 59.75$

Dead Load Analysis

DC1

$GirderSW := .822$ k/ft

$DiaphSW := .15$ k/ft

$Slab := .925$ k/ft

$DC1 := GirderSW + DiaphSW + Slab$

$DC1 = 1.897$ k/ft

DC2

$$DC2 := 2 \cdot \frac{.5}{Girders} = 0.25 \quad \text{k/ft}$$

DW

$$DW := \left(\frac{2.5}{12}\right) \cdot 27 \cdot .144 \cdot .25 = 0.203 \quad \text{k/ft}$$

Live Load Analysis

Distribution Factors 4.6.2.2.2

$n := 1.12$

$I := 260741 \quad in^4$

$A := 789 \quad in^2$

$eg := 34.52$

$Kg := n\cdot\left[I + A\cdot(eg)^2\right] = 1.345\times 10^6 \quad in$

Moment Distribution Factors

One Lane Loaded:

$$gm1 := 0.06 + \left(\frac{S}{14}\right)^{.4}\left(\frac{S}{L}\right)^{.3}\left(\frac{Kg}{12\cdot L\cdot ts^3}\right)^{.1} = 0.514$$

Two or More Lanes Loaded:

$$gm2 := 0.075 + \left(\frac{S}{9.5}\right)^{.6}\left(\frac{S}{L}\right)^{.2}\left(\frac{Kg}{12\cdot L\cdot ts^3}\right)^{.1} = 0.724$$

Use: $gm := \max(gm1, gm2) = 0.724$

Shear Distribution Factors

One-Lane Loaded:

$$gv1 := 0.36 + \frac{S}{25} = 0.7$$

Two or More Lanes Loaded:

$$gv2 := 0.2 + \left(\frac{S}{12}\right) - \left(\frac{S}{35}\right)^{2.0} = 0.849$$

Use: $gv := \max(gv1, gv2) = 0.849$

Maximum Live Load Effects

$MaxMoment := Mdl + \max(Mtruck, Mtan)\cdot IM$

$MaxMoment = 2.055\times 10^3$

$Mll := MaxMoment\cdot gm = 1.487\times 10^3$

$MaxShear := Vdl + \max(Vtruck, Vtan)\cdot IM$

$MaxShear = 100.504$

$Vll := MaxShear\cdot gv = 85.363$

Effective Flange Width

4.6.2.6.

$$Efw1 := \frac{1}{4} \cdot L \cdot 12$$

$$Efw2 := ts \cdot 12 + \max\left(tb, \frac{1}{2} \cdot ts\right)$$

$$Efw3 := S \cdot 12$$

$$Efwidth := \min(Efw1, Efw2, Efw3)$$

$$Efwidth = 102 \quad \text{in}$$

Compute Distance to Neutral Axis c:

5.7.3.

$$c := \frac{(Aps \cdot fpu)}{\left(.85 \cdot \beta \cdot fc \cdot Efwidth + K \cdot Aps \cdot \frac{fpu}{dp}\right)} = 4.392 \quad \text{in}$$

$$a := c \cdot \beta = 3.733 \quad \text{in}$$

$$fps := fpu \cdot \left(1 - K \cdot \frac{c}{dp}\right) = 264.443$$

$$Mn := Aps \cdot fps \cdot \left(dp - \frac{a}{2}\right) \cdot \frac{1}{12} = 6.245 \times 10^{3} \quad \text{kft}$$

$$Mr := \phi \cdot Mn = 6.245 \times 10^{3} \quad \text{kft} \qquad \phi = 1$$

5.5.4.2.

Compute Nominal Shear Resistance 5.8.2.9

Stirrups: #4 bars @9in

$Av := 2 \cdot (.2) = 0.4$ in^2 $s := 9$ in

$dv := 58.4$ in

$bv := tb = 8$ in 5.8.2.9

Simple Procedure: 5.8.3.3

$\beta v := 2$ $\theta := 45$

$$Vc := 0.0316 \beta v \cdot \left(fpc^{.5}\right) \cdot bv \cdot dv = 66.024$$

$$Vs := Av \cdot fy \cdot dv \cdot \frac{\left(\cot\left(\frac{\theta \cdot 3.1416}{180}\right)\right)}{s} = 155.733$$

$$Vn := Vc + Vs = 221.757$$

$$Vr2 := \phi \cdot Vn = 221.757$$

Ratings

$$Mdc := (DC1 + DC2)\frac{\left(L^2\right)}{8} = 1.718 \times 10^3$$

$$Vdc := (DC1 + DC2)\cdot\left[\left(\frac{L}{2}\right) - \frac{64.4}{12}\right] = 74.358$$

$$Mdw := (DW)\frac{\left(L^2\right)}{8} = 162$$

$$Vdw := (DW)\cdot\left[\left(\frac{L}{2}\right) - \frac{64.4}{12}\right] = 7.013$$

$\gamma DW := 1.5$ $\gamma DC := 1.25$ $\gamma LL := 1.75$

Moment

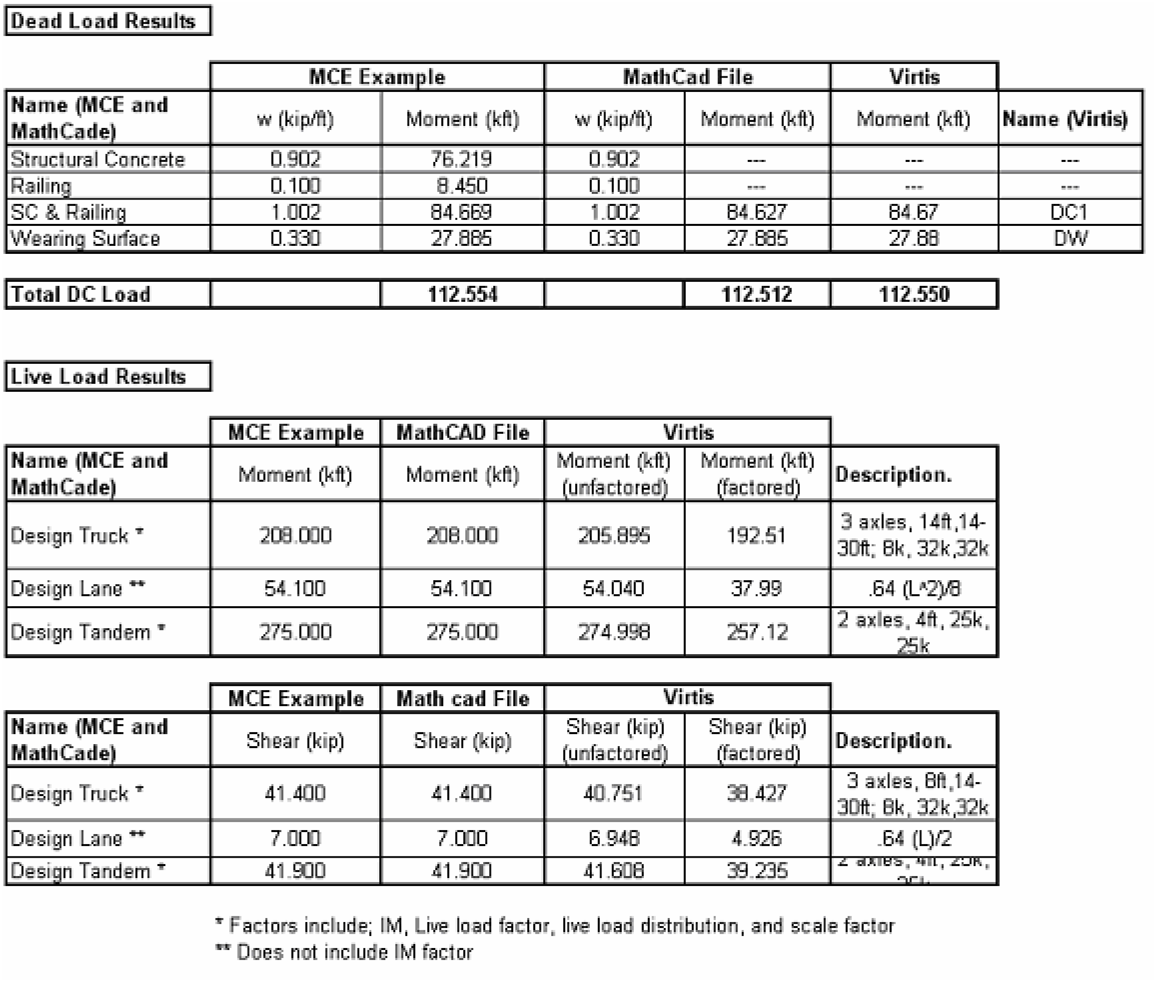
$$RF := \frac{(\phi s \cdot \phi c \cdot Mr - \gamma DC \cdot Mdc - \gamma DW \cdot Mdw)}{\gamma LL \cdot Mll} = 1.481$$

Shear

$$RF := \frac{(\phi s \cdot \phi c \cdot Vr2 - \gamma DC \cdot Vdc - \gamma DW \cdot Vdw)}{\gamma LL \cdot Vll} = 0.792$$

APPENDIX B5: Example Problem A2: Results Summary

Provided in this appendix is a summary of example problem A2 results from the MCE, Mathcad and Virtis.



Dead Load Results

	MCE Example		MathCad File		Virtis	
Name (MCE and MathCade)	w (kip/ft)	Moment (kft)	w (kip/ft)	Moment (kft)	Moment (kft)	**Name (Virtis)**
Structural Concrete	0.902	76.219	0.902	---	---	---
Railing	0.100	8.450	0.100	---	---	---
SC & Railing	1.002	84.669	1.002	84.627	84.67	DC1
Wearing Surface	0.330	27.885	0.330	27.885	27.88	DW
Total DC Load		**112.554**		**112.512**	**112.550**	

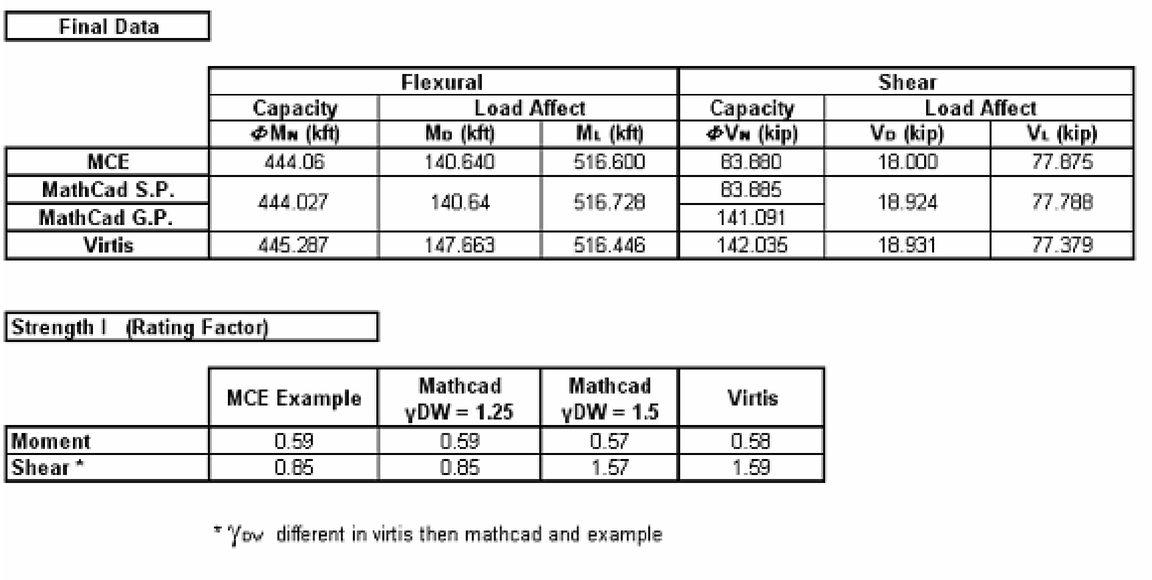
Live Load Results

	MCE Example	MathCAD File	Virtis		
Name (MCE and MathCade)	Moment (kft)	Moment (kft)	Moment (kft) (unfactored)	Moment (kft) (factored)	**Description.**
Design Truck *	208.000	208.000	205.895	192.51	3 axles, 14ft,14-30ft; 8k, 32k,32k
Design Lane **	54.100	54.100	54.040	37.99	.64 (L^2)/8
Design Tandem *	275.000	275.000	274.998	257.12	2 axles, 4ft, 25k, 25k

	MCE Example	Math cad File	Virtis		
Name (MCE and MathCade)	Shear (kip)	Shear (kip)	Shear (kip) (unfactored)	Shear (kip) (factored)	**Description.**
Design Truck *	41.400	41.400	40.751	38.427	3 axles, 8ft,14-30ft; 8k, 32k,32k
Design Lane **	7.000	7.000	6.948	4.926	.64 (L)/2
Design Tandem *	41.900	41.900	41.608	39.235	2 axles, 4ft, 25k,

* Factors include; IM, Live load factor, live load distribution, and scale factor
** Does not include IM factor

Figure B5 - 1: Example A2 Comparisons Part 1



Final Data

	Flexural			Shear		
	Capacity	Load Affect		Capacity	Load Affect	
	ΦM_N (kft)	M_D (kft)	M_L (kft)	ΦV_N (kip)	V_D (kip)	V_L (kip)
MCE	444.06	140.640	516.600	83.880	18.000	77.875
MathCad S.P.	444.027	140.64	516.728	83.885	18.924	77.788
MathCad G.P.				141.091		
Virtis	445.287	147.663	516.446	142.035	18.931	77.379

Strength I (Rating Factor)

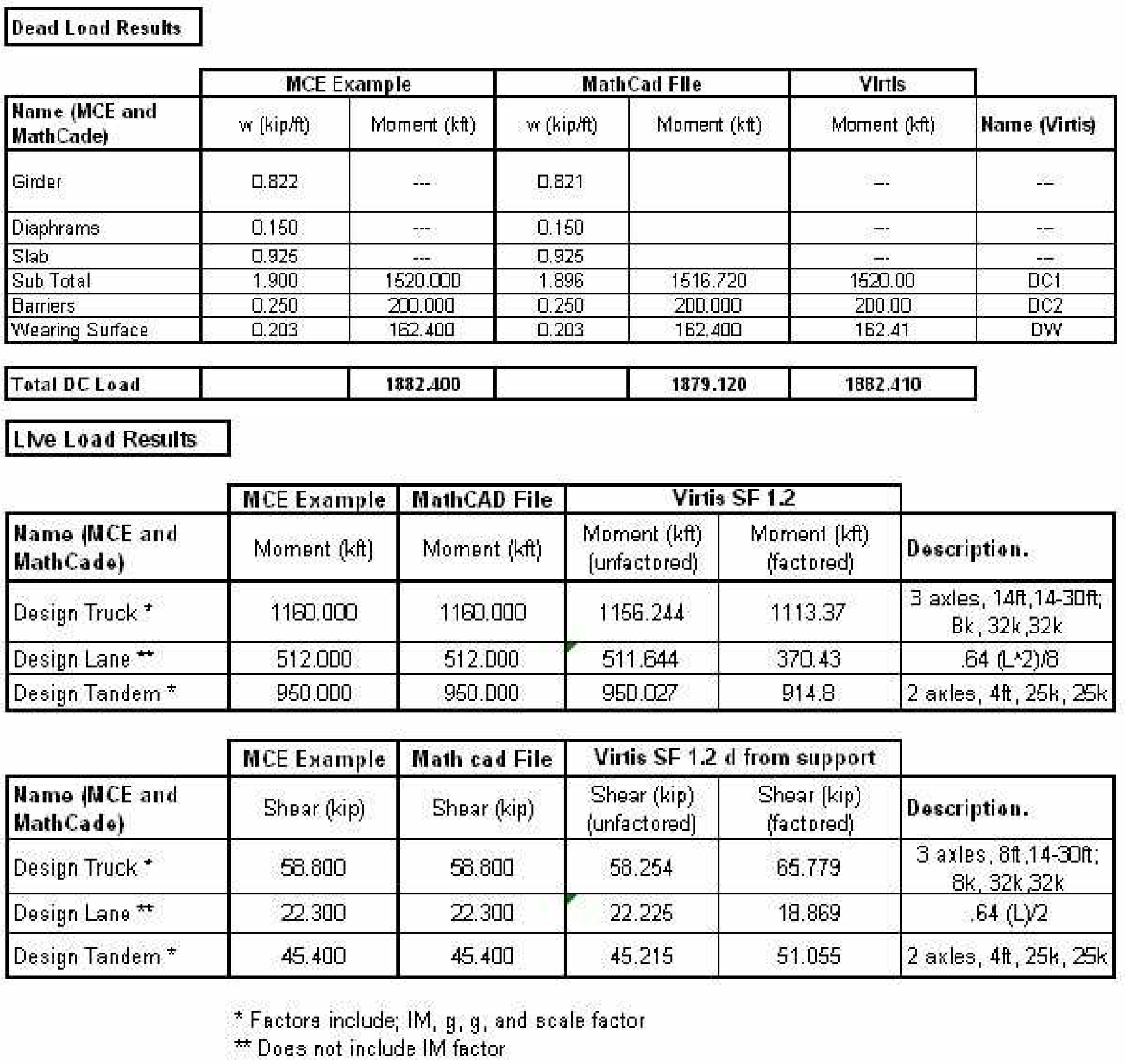
	MCE Example	Mathcad $\gamma DW = 1.25$	Mathcad $\gamma DW = 1.5$	Virtis
Moment	0.59	0.59	0.57	0.58
Shear *	0.85	0.85	1.57	1.59

* γ_{DW} different in virtis then mathcad and example

Figure B5 - 2: Example A2 Comparisons Part 2

APPENDIX B6: Example Problem A3: Results Summary

Provided in this appendix is a summary of example problem A3 results from the MCE, Mathcad and Virtis.



Dead Load Results

	MCE Example		MathCad File		Virtis	
Name (MCE and MathCade)	w (kip/ft)	Moment (kft)	w (kip/ft)	Moment (kft)	Moment (kft)	**Name (Virtis)**
Girder	0.822	---	0.821		---	---
Diaphrams	0.150	---	0.150		---	---
Slab	0.925	---	0.925		---	---
Sub Total	1.900	1520.000	1.896	1516.720	1520.00	DC1
Barriers	0.250	200.000	0.250	200.000	200.00	DC2
Wearing Surface	0.203	162.400	0.203	162.400	162.41	DW

Total DC Load		**1882.400**		**1879.120**	**1882.410**

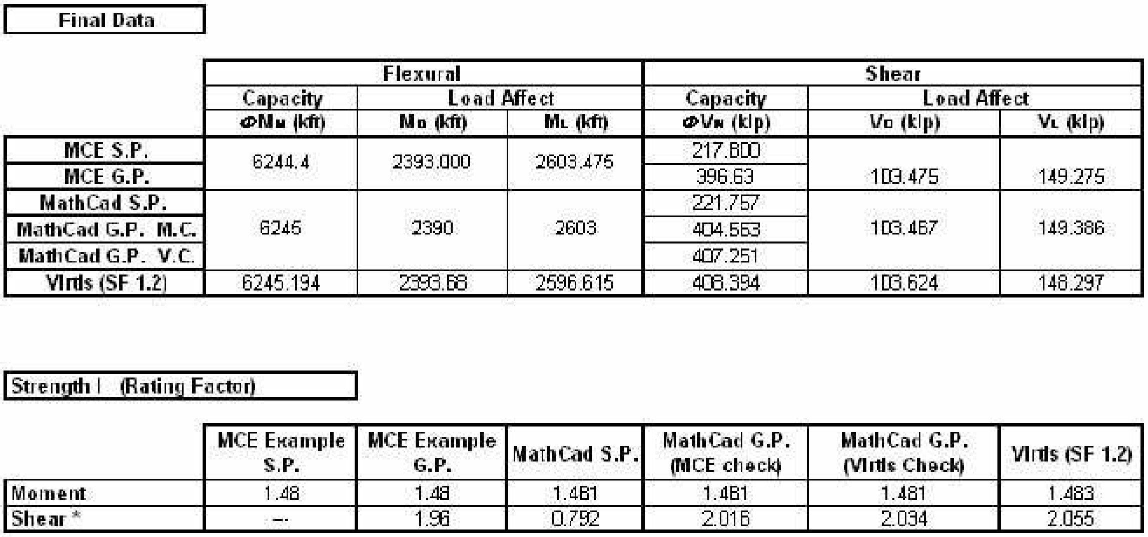
Live Load Results

	MCE Example	MathCAD File	Virtis SF 1.2		
Name (MCE and MathCade)	Moment (kft)	Moment (kft)	Moment (kft) (unfactored)	Moment (kft) (factored)	**Description.**
Design Truck *	1160.000	1160.000	1156.244	1113.37	3 axles, 14ft,14-30ft; 8k, 32k,32k
Design Lane **	512.000	512.000	511.644	370.43	.64 (L^2)/8
Design Tandem *	950.000	950.000	950.027	914.8	2 axles, 4ft, 25k, 25k

	MCE Example	Math cad File	Virtis SF 1.2 d from support		
Name (MCE and MathCade)	Shear (kip)	Shear (kip)	Shear (kip) (unfactored)	Shear (kip) (factored)	**Description.**
Design Truck *	58.800	58.800	58.254	65.779	3 axles, 8ft,14-30ft; 8k, 32k,32k
Design Lane **	22.300	22.300	22.225	18.869	.64 (L)/2
Design Tandem *	45.400	45.400	45.215	51.055	2 axles, 4ft, 25k, 25k

* Factors include; IM, g, g, and scale factor
** Does not include IM factor

Figure B6 - 1: Example A3 Comparisons Part 1



Final Data

	Flexural			Shear		
	Capacity	Load Affect		Capacity	Load Affect	
	ϕM_n (kft)	M_D (kft)	M_L (kft)	ϕV_n (kip)	V_D (kip)	V_L (kip)
MCE S.P.	6244.4	2393.000	2603.475	217.800	103.475	149.275
MCE G.P.				396.63		
MathCad S.P.	6245	2390	2603	221.757	103.467	149.386
MathCad G.P. M.C.				404.563		
MathCad G.P. V.C.				407.251		
VIrtis (SF 1.2)	6245.194	2393.68	2596.615	408.394	103.624	148.297

Strength I (Rating Factor)

	MCE Example S.P.	MCE Example G.P.	MathCad S.P.	MathCad G.P. (MCE check)	MathCad G.P. (VIrtis Check)	VIrtis (SF 1.2)
Moment	1.48	1.48	1.481	1.481	1.481	1.483
Shear *	---	1.96	0.792	2.016	2.034	2.055

Figure B6 - 2: Example A3 Comparisons Part 2

APPENDIX C.1: Design Inventory Standard Bridge Rating Data

Presented in this appendix is the extracted data from Virtis for the standard bridge sample at the Design Inventory level for the LRFR under the HL-93 load model and the Inventory level of the LFR under the HS-20. Tables C.1 - 1 through C.1 - 12 provide the following information: BIN, Material Type, Structural Type, Number of Spans, Span Length, Dead Load Factors, Live Load Factors, Resistance Factors, Condition Factor, System Factor, Controlling Vehicle, Unfactored Capacity, Unfactored Dead Load, Unfactored Live Load, Virtis Rating Factor, and Excel Calculated Rating Factor. The Excel rating factor is calculated using the provided information and the rating methodologies rating equation as provided in Chapter 2.

Table C1 - 1: Design Inventory Standard Bridge Output, Exterior Girder LRFR Part 1

Bin	General Info				LRFR Exterior					
	Material Type	Construction Method	Number of Spans	Span Lengths	γ_D	γ_L	ϕ moment	ϕ shear	ϕ_c	ϕ_s
STD 714 24	1	4	1	23'	1.25	1.75	0.9	0.9	1	1
STD 714 26	1	4	1	25'	1.25	1.75	0.9	0.9	1	1
STD 714 28	1	4	1	27'	1.25	1.75	0.9	0.9	1	1
STD 714 30	1	4	1	29'	1.25	1.75	0.9	0.9	1	1
STD 714 32	1	4	1	31'	1.25	1.75	0.9	0.9	1	1
STD 714 34	1	4	1	33'	1.25	1.75	0.9	0.9	1	1
STD 716 42	1	4	1	41'	1.25	1.75	0.9	0.9	1	1
STD 716 44	1	4	1	43'	1.25	1.75	0.9	0.9	1	1
STD 716 46	1	4	1	45'	1.25	1.75	0.9	0.9	1	1
STD 716 48	1	4	1	47'	1.25	1.75	0.9	0.9	1	1
STD 716 50	1	4	1	49'	1.25	1.75	0.9	0.9	1	1
STD 716 52	1	4	1	51'	1.25	1.75	0.9	0.9	1	1
STD C2401 32	1	4	1	31'	1.25	1.75	0.9	0.9	1	1
STD C2401 34	1	4	1	33'	1.25	1.75	0.9	0.9	1	1
STD C2401 36	1	4	1	35'	1.25	1.75	0.9	0.9	1	1
STD C2401 38	1	4	1	37'	1.25	1.75	0.9	0.9	1	1
STD C2411 32	1	4	1	31'	1.25	1.75	0.9	0.9	1	1
STD C2411 34	1	4	1	33'	1.25	1.75	0.9	0.9	1	1
STD C2411 36	1	4	1	35'	1.25	1.75	0.9	0.9	1	1
STD C2411 38	1	4	1	37'	1.25	1.75	0.9	0.9	1	1
STD C2414 32	1	4	1	31'	1.25	1.75	0.9	0.9	1	1
STD C2414 34	1	4	1	33'	1.25	1.75	0.9	0.9	1	1
STD C2414 36	1	4	1	35'	1.25	1.75	0.9	0.9	1	1
STD C2414 38	1	4	1	37'	1.25	1.75	0.9	0.9	1	1
STD PC34 24R	1	22	1	34'	1.25	1.75	0.9	0.9	1	1
STD PC34 26R	1	22	1	34'	1.25	1.75	0.9	0.9	1	1
STD CS2403	2	2	3	75' 100' 75'	1.25	1.75	0.9	0.9	1	1
STD CS2404	2	2	4	66' 82' 82' 66'	1.25	1.75	0.9	0.9	1	1
STD B2200 16	3	2	1	15'	1.25	1.75	1	1	1	1
STD B2200 20	3	2	1	19'	1.25	1.75	1	1	1	1
STD B2200 24	3	2	1	23'	1.25	1.75	1	1	1	1
STD B2200 28	3	2	1	27'	1.25	1.75	1	1	1	1
STD B2200 30	3	2	1	29'	1.25	1.75	1	1	1	1
STD B2200 32	3	2	1	31'	1.25	1.75	1	1	1	1
STD B2200 34	3	2	1	33'	1.25	1.75	1	1	1	1
STD B2200 36	3	2	1	35'	1.25	1.75	1	1	1	1
STD B2800	3	2	1	78.875'	1.25	1.75	1	1	1	1
STD BC2402	3	2	1	68.75'	1.25	1.75	1	1	1	1
STD BC2801	3	2	1	80'	1.25	1.75	1	1	1	1
STD B2400	4	2	3	60' 80' 60'	1.25	1.75	1	1	1	1
STD B2411	4	2	3	80' 100' 80'	1.25	1.75	1	1	1	1
STD B2809	4	2	4	80' 100' 100' 80'	1.25	1.75	1	1	1	1
STD CSC2800 3S	4	2	3	80' 100' 80'	1.25	1.75	1	1	1	1
STD CSC2800 4S	4	2	4	80' 100' 100' 80'	1.25	1.75	1	1	1	1
STD 632	4	2	3	20' 20' 20'	1.25	1.75	1	1	1	1
STD S28130	5	2	1	130'	1.25	1.75	0.9	0.9	1	1
STD PC34 24R	5	22	1	34'	1.25	1.75	0.9	0.9	1	1
STD PC34 26R	5	22	1	34'	1.25	1.75	0.9	0.9	1	1
STD PSC4041	6	2	6	41' 41' 41' 41' 41' 41'	1.25	1.75	0.9	0.9	1	1
STD PSC4465	6	2	5	65' 65' 65' 65' 65'	1.25	1.75	0.9	0.9	1	1

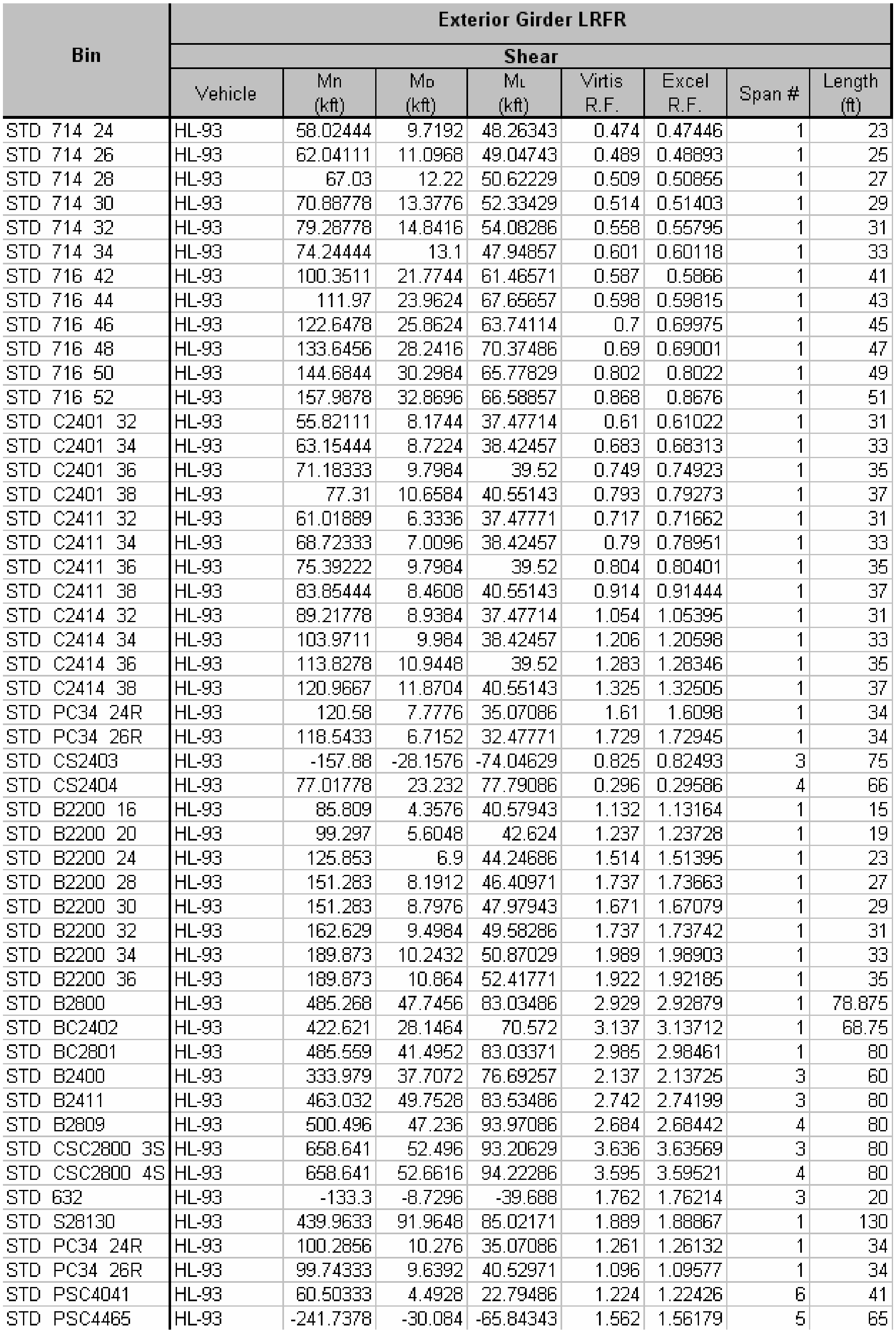
Table C1 - 2: Design Inventory Standard Bridge Output, Exterior Girder LRFR Part 2

Bin	Exterior Girder LRFR							
	Moment							
	Vehicle	M_n (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
STD 714 24	HL-93	287.2944	55.3368	246.4154	0.439	0.4392	1	23
STD 714 26	HL-93	311.02	69.3528	282.9537	0.39	0.39022	1	25
STD 714 28	HL-93	379.5244	82.4832	312.424	0.436	0.43616	1	27
STD 714 30	HL-93	444.3667	96.9904	342.3491	0.465	0.46518	1	29
STD 714 32	HL-93	500.2467	115.0208	372.7223	0.47	0.46982	1	31
STD 714 34	HL-93	556.1267	135.088	403.5429	0.47	0.46963	1	33
STD 716 42	HL-93	779.8889	223.2048	531.4251	0.455	0.45473	1	41
STD 716 44	HL-93	884.6644	257.5968	548.612	0.494	0.49392	1	43
STD 716 46	HL-93	954.5133	290.9528	601.2434	0.471	0.47081	1	45
STD 716 48	HL-93	1059.289	331.8448	652.4891	0.472	0.47165	1	47
STD 716 50	HL-93	1129.139	371.1576	699.512	0.451	0.45115	1	49
STD 716 52	HL-93	1233.913	419.0968	747.0451	0.449	0.44874	1	51
STD C2401 32	HL-93	523.4256	105.5896	356.4257	0.544	0.54365	1	31
STD C2401 34	HL-93	585.8256	119.936	385.9034	0.559	0.55872	1	33
STD C2401 36	HL-93	648.2256	142.8896	386.3817	0.599	0.59865	1	35
STD C2401 38	HL-93	710.6256	164.316	446.1566	0.556	0.55607	1	37
STD C2411 32	HL-93	529.7878	81.804	356.4234	0.6	0.6005	1	31
STD C2411 34	HL-93	592.1878	96.3864	385.9057	0.611	0.61079	1	33
STD C2411 36	HL-93	654.5878	142.8912	415.8246	0.564	0.56413	1	35
STD C2411 38	HL-93	716.9878	130.4384	446.1691	0.618	0.61763	1	37
STD C2414 32	HL-93	718.9378	115.4496	356.4229	0.806	0.806	1	31
STD C2414 34	HL-93	828.1378	137.2792	385.904	0.85	0.84955	1	33
STD C2414 36	HL-93	906.1378	159.6072	415.8189	0.847	0.84654	1	35
STD C2414 38	HL-93	968.5378	183.0056	446.1709	0.823	0.82342	1	37
STD PC34 24R	HL-93	789.5556	82.6368	303.8571	1.142	1.14209	1	34
STD PC34 26R	HL-93	742.3911	71.3456	351.7423	0.941	0.94057	1	34
STD CS2403	HL-93	-589.8567	185.0656	-765.9114	0.569	0.56866	3	75
STD CS2404	HL-93	1799.15	259.5744	775.9691	0.953	0.95347	4	66
STD B2200 16	HL-93	333.822	15.6864	131.8594	1.362	1.36168	1	15
STD B2200 20	HL-93	426.548	26.6232	152.4714	1.474	1.47388	1	19
STD B2200 24	HL-93	570.027	39.6768	232.8069	1.277	1.27741	1	23
STD B2200 28	HL-93	716.683	55.2896	286.4246	1.292	1.29193	1	27
STD B2200 30	HL-93	716.683	63.784	313.8571	1.16	1.15968	1	29
STD B2200 32	HL-93	774.159	73.6152	341.7029	1.141	1.14074	1	31
STD B2200 34	HL-93	931.496	84.5096	369.968	1.276	1.27557	1	33
STD B2200 36	HL-93	931.496	95.0624	398.6429	1.165	1.16491	1	35
STD B2800	HL-93	33	8.3912	13.38457	0.961	0.96106	1	78.875
STD BC2402	HL-93	2979.473	486.2336	1117.154	1.213	1.21312	1	68.75
STD BC2801	HL-93	4774.674	840.3856	1549.348	1.374	1.37355	1	80
STD B2400	HL-93	-36	-7.3784	-26.512	0.577	0.57714	3	60
STD B2411	HL-93	-34.461	-10.8496	-17.1	0.698	0.69838	3	80
STD B2809	HL-93	33	7.94	13.73429	0.96	0.96006	4	80
STD CSC2800 3S	HL-93	-29.181	-7.2664	-21.944	0.523	0.52336	3	80
STD CSC2800 4S	HL-93	-29.181	-7.2376	-22.08629	0.521	0.52092	4	80
STD 632	HL-93	-11.402	-3.9392	-14.228	0.26	0.26017	3	20
STD S28130	HL-93	13306.85	3735.946	3063.703	1.363	1.36273	1	130
STD PC34 24R	HL-93	354.15	69.8784	205.848	0.642	0.64232	1	34
STD PC34 26R	HL-93	326.8611	65.5432	237.8874	0.51	0.50984	1	34
STD PSC4041	HL-93	1181.092	192.1376	274.8926	1.71	1.71041	6	41
STD PSC4465	HL-93	-709.9033	-33.8888	-643.1011	0.53	0.53007	5	65

Table C1 - 3: Design Inventory Standard Bridge Output, Exterior Girder LRFR Part 3

Bin	General Info				Exterior Girder LFR				
	Material Type	Construction	Number of Spans	Span Lengths	γ_{Combo}	γ_D	γ_L	ϕ moment	ϕ shear
STD 714 24	1	4	1	23'	1.3	1.0	1.67	0.9	0.85
STD 714 26	1	4	1	25'	1.3	1.0	1.67	0.9	0.85
STD 714 28	1	4	1	27'	1.3	1.0	1.67	0.9	0.85
STD 714 30	1	4	1	29'	1.3	1.0	1.67	0.9	0.85
STD 714 32	1	4	1	31'	1.3	1.0	1.67	0.9	0.85
STD 714 34	1	4	1	33'	1.3	1.0	1.67	0.9	0.85
STD 716 42	1	4	1	41'	1.3	1.0	1.67	0.9	0.85
STD 716 44	1	4	1	43'	1.3	1.0	1.67	0.9	0.85
STD 716 46	1	4	1	45'	1.3	1.0	1.67	0.9	0.85
STD 716 48	1	4	1	47'	1.3	1.0	1.67	0.9	0.85
STD 716 50	1	4	1	49'	1.3	1.0	1.67	0.9	0.85
STD 716 52	1	4	1	51'	1.3	1.0	1.67	0.9	0.85
STD C2401 32	1	4	1	31'	1.3	1.0	1.67	0.9	0.85
STD C2401 34	1	4	1	33'	1.3	1.0	1.67	0.9	0.85
STD C2401 36	1	4	1	35'	1.3	1.0	1.67	0.9	0.85
STD C2401 38	1	4	1	37'	1.3	1.0	1.67	0.9	0.85
STD C2411 32	1	4	1	31'	1.3	1.0	1.67	0.9	0.85
STD C2411 34	1	4	1	33'	1.3	1.0	1.67	0.9	0.85
STD C2411 36	1	4	1	35'	1.3	1.0	1.67	0.9	0.85
STD C2411 38	1	4	1	37'	1.3	1.0	1.67	0.9	0.85
STD C2414 32	1	4	1	31'	1.3	1.0	1.67	0.9	0.85
STD C2414 34	1	4	1	33'	1.3	1.0	1.67	0.9	0.85
STD C2414 36	1	4	1	35'	1.3	1.0	1.67	0.9	0.85
STD C2414 38	1	4	1	37'	1.3	1.0	1.67	0.9	0.85
STD PC34 24R	1	22	1	34'	1.3	1.0	1.67	0.9	0.85
STD PC34 26R	1	22	1	34'	1.3	1.0	1.67	0.9	0.85
STD CS2403	2	2	3	75' 100' 75'	1.3	1.0	1.67	0.9	0.85
STD CS2404	2	2	4	66' 82' 82' 66'	1.3	1.0	1.67	0.9	0.85
STD B2200 16	3	2	1	15'	1.3	1.0	1.67	1	1
STD B2200 20	3	2	1	19'	1.3	1.0	1.67	1	1
STD B2200 24	3	2	1	23'	1.3	1.0	1.67	1	1
STD B2200 28	3	2	1	27'	1.3	1.0	1.67	1	1
STD B2200 30	3	2	1	29'	1.3	1.0	1.67	1	1
STD B2200 32	3	2	1	31'	1.3	1.0	1.67	1	1
STD B2200 34	3	2	1	33'	1.3	1.0	1.67	1	1
STD B2200 36	3	2	1	35'	1.3	1.0	1.67	1	1
STD B2800	3	2	1	78.875'	1.3	1.0	1.67	1	1
STD BC2402	3	2	1	68.75'	1.3	1.0	1.67	1	1
STD BC2801	3	2	1	80'	1.3	1.0	1.67	1	1
STD B2400	4	2	3	60' 80' 60'	1.3	1.0	1.67	1	1
STD B2411	4	2	3	80' 100' 80'	1.3	1.0	1.67	1	1
STD B2809	4	2	4	80' 100' 100' 80'	1.3	1.0	1.67	1	1
STD CSC2800 3S	4	2	3	80' 100' 80'	1.3	1.0	1.67	1	1
STD CSC2800 4S	4	2	4	80' 100' 100' 80'	1.3	1.0	1.67	1	1
STD 632	4	2	3	20' 20' 20'	1.3	1.0	1.67	1	1
STD S28130	5	2	1	130'	1.3	1.0	1.67	1	0.9
STD PC34 24R	5	22	1	34'	1.3	1.0	1.67	1	0.9
STD PC34 26R	5	22	1	34'	1.3	1.0	1.67	1	0.9
STD PSC4041	6	2	6	41' 41' 41' 41' 41' 41'	1.3	1.0	1.67	1	0.9
STD PSC4465	6	2	5	65' 65' 65' 65' 65'	1.3	1.0	1.67	1	0.9

Table C1 - 4: Design Inventory Standard Bridge Output, Exterior Girder LFR Part 1

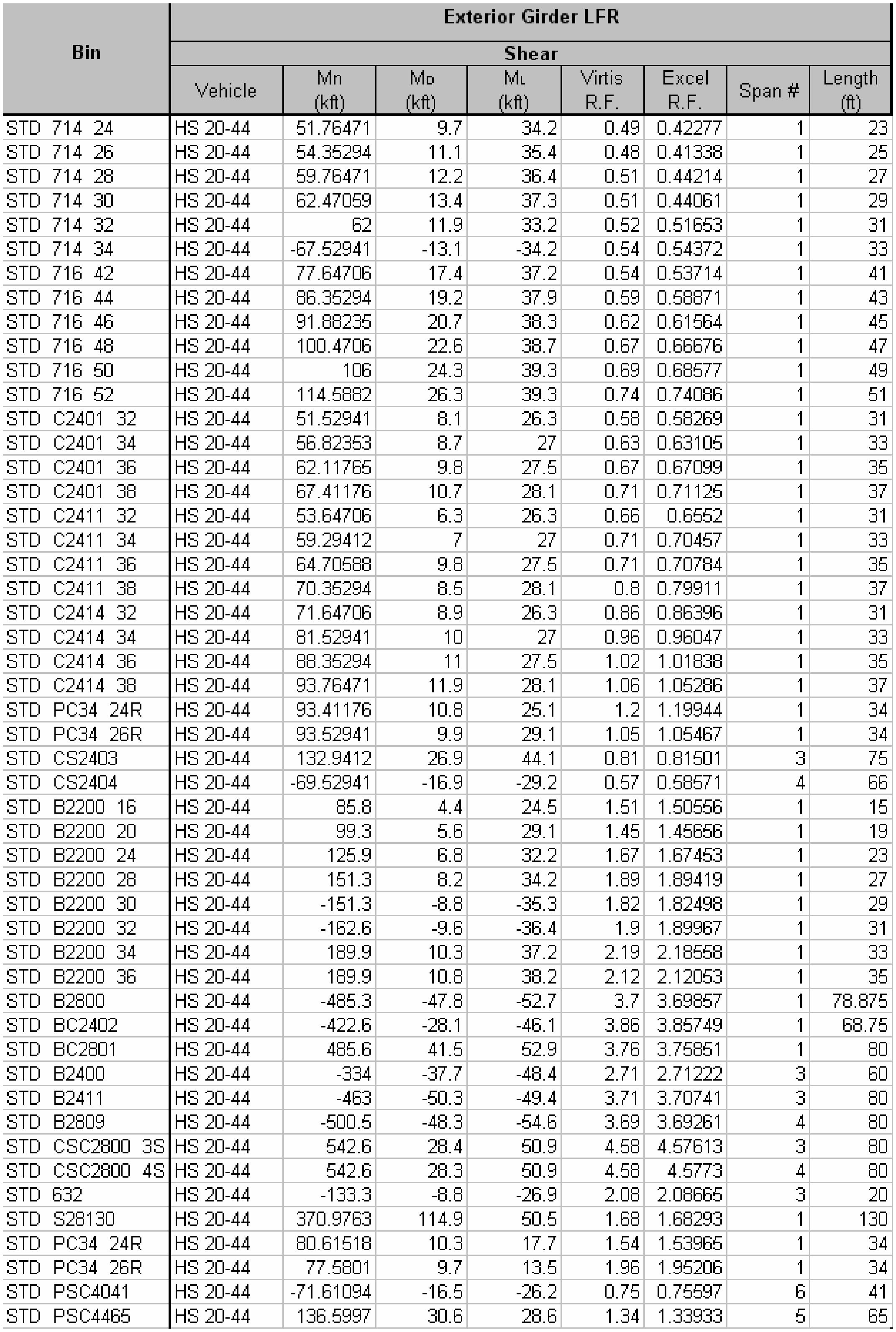


Bin	Exterior Girder LRFR							
	Shear							
	Vehicle	Mn (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
STD 714 24	HL-93	58.02444	9.7192	48.26343	0.474	0.47446	1	23
STD 714 26	HL-93	62.04111	11.0968	49.04743	0.489	0.48893	1	25
STD 714 28	HL-93	67.03	12.22	50.62229	0.509	0.50855	1	27
STD 714 30	HL-93	70.88778	13.3776	52.33429	0.514	0.51403	1	29
STD 714 32	HL-93	79.28778	14.8416	54.08286	0.558	0.55795	1	31
STD 714 34	HL-93	74.24444	13.1	47.94857	0.601	0.60118	1	33
STD 716 42	HL-93	100.3511	21.7744	61.46571	0.587	0.5866	1	41
STD 716 44	HL-93	111.97	23.9624	67.65657	0.598	0.59815	1	43
STD 716 46	HL-93	122.6478	25.8624	63.74114	0.7	0.69975	1	45
STD 716 48	HL-93	133.6456	28.2416	70.37486	0.69	0.69001	1	47
STD 716 50	HL-93	144.6844	30.2984	65.77829	0.802	0.8022	1	49
STD 716 52	HL-93	157.9878	32.8696	66.58857	0.868	0.8676	1	51
STD C2401 32	HL-93	55.82111	8.1744	37.47714	0.61	0.61022	1	31
STD C2401 34	HL-93	63.15444	8.7224	38.42457	0.683	0.68313	1	33
STD C2401 36	HL-93	71.18333	9.7984	39.52	0.749	0.74923	1	35
STD C2401 38	HL-93	77.31	10.6584	40.55143	0.793	0.79273	1	37
STD C2411 32	HL-93	61.01889	6.3336	37.47771	0.717	0.71662	1	31
STD C2411 34	HL-93	68.72333	7.0096	38.42457	0.79	0.78951	1	33
STD C2411 36	HL-93	75.39222	9.7984	39.52	0.804	0.80401	1	35
STD C2411 38	HL-93	83.85444	8.4608	40.55143	0.914	0.91444	1	37
STD C2414 32	HL-93	89.21778	8.9384	37.47714	1.054	1.05395	1	31
STD C2414 34	HL-93	103.9711	9.984	38.42457	1.206	1.20598	1	33
STD C2414 36	HL-93	113.8278	10.9448	39.52	1.283	1.28346	1	35
STD C2414 38	HL-93	120.9667	11.8704	40.55143	1.325	1.32505	1	37
STD PC34 24R	HL-93	120.58	7.7776	35.07086	1.61	1.6098	1	34
STD PC34 26R	HL-93	118.5433	6.7152	32.47771	1.729	1.72945	1	34
STD CS2403	HL-93	-157.88	-28.1576	-74.04629	0.825	0.82493	3	75
STD CS2404	HL-93	77.01778	23.232	77.79086	0.296	0.29586	4	66
STD B2200 16	HL-93	85.809	4.3576	40.57943	1.132	1.13164	1	15
STD B2200 20	HL-93	99.297	5.6048	42.624	1.237	1.23728	1	19
STD B2200 24	HL-93	125.853	6.9	44.24686	1.514	1.51395	1	23
STD B2200 28	HL-93	151.283	8.1912	46.40971	1.737	1.73663	1	27
STD B2200 30	HL-93	151.283	8.7976	47.97943	1.671	1.67079	1	29
STD B2200 32	HL-93	162.629	9.4984	49.58286	1.737	1.73742	1	31
STD B2200 34	HL-93	189.873	10.2432	50.87029	1.989	1.98903	1	33
STD B2200 36	HL-93	189.873	10.864	52.41771	1.922	1.92185	1	35
STD B2800	HL-93	485.268	47.7456	83.03486	2.929	2.92879	1	78.875
STD BC2402	HL-93	422.621	28.1464	70.572	3.137	3.13712	1	68.75
STD BC2801	HL-93	485.559	41.4952	83.03371	2.985	2.98461	1	80
STD B2400	HL-93	333.979	37.7072	76.69257	2.137	2.13725	3	60
STD B2411	HL-93	463.032	49.7528	83.53486	2.742	2.74199	3	80
STD B2809	HL-93	500.496	47.236	93.97086	2.684	2.68442	4	80
STD CSC2800 3S	HL-93	658.641	52.496	93.20629	3.636	3.63569	3	80
STD CSC2800 4S	HL-93	658.641	52.6616	94.22286	3.595	3.59521	4	80
STD 632	HL-93	-133.3	-8.7296	-39.688	1.762	1.76214	3	20
STD S28130	HL-93	439.9633	91.9648	85.02171	1.889	1.88867	1	130
STD PC34 24R	HL-93	100.2856	10.276	35.07086	1.261	1.26132	1	34
STD PC34 26R	HL-93	99.74333	9.6392	40.52971	1.096	1.09577	1	34
STD PSC4041	HL-93	60.50333	4.4928	22.79486	1.224	1.22426	6	41
STD PSC4465	HL-93	-241.7378	-30.084	-65.84343	1.562	1.56179	5	65

Table C1 - 5: Design Inventory Standard Bridge Output, Exterior Girder LFR Part 2

Bin	Exterior Girder LFR							
	Moment							
	Vehicle	M_n (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
STD 714 24	HS 20-44	287.2933	55.3	141.3	0.61	0.60853	1	23
STD 714 26	HS 20-44	311.0189	66.6	157.3	0.57	0.56614	1	25
STD 714 28	HS 20-44	379.5233	79.2	180.5	0.61	0.60891	1	27
STD 714 30	HS 20-44	444.3656	93.1	205.3	0.63	0.62575	1	29
STD 714 32	HS 20-44	500.2456	110.4	228.6	0.62	0.61799	1	31
STD 714 34	HS 20-44	556.1256	129.7	253.1	0.6	0.60403	1	33
STD 716 42	HS 20-44	779.8878	223.2	352.8	0.54	0.53757	1	41
STD 716 44	HS 20-44	884.6633	257.6	381.1	0.56	0.55757	1	43
STD 716 46	HS 20-44	954.5133	290.9	406	0.55	0.54558	1	45
STD 716 48	HS 20-44	1059.288	331.9	430.1	0.56	0.55892	1	47
STD 716 50	HS 20-44	1129.133	371.1	460.7	0.53	0.53369	1	49
STD 716 52	HS 20-44	1233.911	419.1	486.1	0.54	0.53603	1	51
STD C2401 32	HS 20-44	521.5233	101.4	212.9	0.73	0.7303	1	31
STD C2401 34	HS 20-44	583.9233	115.1	235.6	0.73	0.73492	1	33
STD C2401 36	HS 20-44	646.3233	137.1	256.3	0.72	0.72509	1	35
STD C2401 38	HS 20-44	708.38	157.7	280.2	0.71	0.71103	1	37
STD C2411 32	HS 20-44	529.1111	78.6	212.8	0.81	0.80959	1	31
STD C2411 34	HS 20-44	591.5111	92.5	235.6	0.81	0.80571	1	33
STD C2411 36	HS 20-44	653.9111	137.2	256.3	0.74	0.73713	1	35
STD C2411 38	HS 20-44	716.3111	125.2	280.2	0.79	0.79222	1	37
STD C2414 32	HS 20-44	718.2611	110.8	212.8	1.09	1.08746	1	31
STD C2414 34	HS 20-44	827.4611	131.8	235.5	1.12	1.12147	1	33
STD C2414 36	HS 20-44	905.4611	153.2	256.3	1.11	1.10662	1	35
STD C2414 38	HS 20-44	967.8611	175.6	280.2	1.06	1.05668	1	37
STD PC34 24R	HS 20-44	789.5556	111.1	191.5	1.36	1.36182	1	34
STD PC34 26R	HS 20-44	744.7411	101.9	221.6	1.12	1.11786	1	34
STD CS2403	HS 20-44	-589.8555	185	-411.4	0.86	0.86365	3	75
STD CS2404	HS 20-44	1946.756	259.6	480.2	1.36	1.35691	4	66
STD B2200 16	HS 20-44	336.6	16.3	86.8	1.67	1.67377	1	15
STD B2200 20	HS 20-44	430.4	26.6	109.9	1.66	1.65898	1	19
STD B2200 24	HS 20-44	575.9	39.6	133.1	1.81	1.81485	1	23
STD B2200 28	HS 20-44	725.5	53.1	170	1.78	1.77871	1	27
STD B2200 30	HS 20-44	725.5	61.4	193.3	1.54	1.5386	1	29
STD B2200 32	HS 20-44	782.7	70.7	215.3	1.48	1.47789	1	31
STD B2200 34	HS 20-44	942	81.1	238.3	1.62	1.61703	1	33
STD B2200 36	HS 20-44	942	91.3	259.2	1.46	1.46308	1	35
STD B2800	HS 20-44	4028.4	962.8	953.4	1.34	1.34154	1	78.875
STD BC2402	HS 20-44	2979.7	487.1	710.3	1.52	1.52165	1	68.75
STD BC2801	HS 20-44	4811.4	842.1	965.9	1.77	1.7724	1	80
STD B2400	HS 20-44	1134	199.5	482.2	0.84	0.8355	3	60
STD B2411	HS 20-44	2176.7	407.3	685.5	1.11	1.10683	3	80
STD B2809	HS 20-44	2107.9	151.7	636	1.25	1.25	4	80
STD CSC2800 3S	HS 20-44	1989.6	398.5	743.7	0.91	0.91142	3	80
STD CSC2800 4S	HS 20-44	1989.6	396.9	743.8	0.91	0.91258	4	80
STD 632	HS 20-44	-162.6	-29.1	-71.9	0.8	0.79932	3	20
STD S28130	HS 20-44	12624.85	3736.6	1535.4	2.33	2.33017	1	130
STD PC34 24R	HS 20-44	398.624	69.9	101.7	1.39	1.39387	1	34
STD PC34 26R	HS 20-44	317.8418	65.5	77.5	1.38	1.38299	1	34
STD PSC4041	HS 20-44	1045.166	192.5	178.8	2.05	2.04783	6	41
STD PSC4465	HS 20-44	-638.913	-45.3	-254.1	1.05	1.05143	5	65

Table C1 - 6: Design Inventory Standard Bridge Output, Exterior Girder LFR Part 3

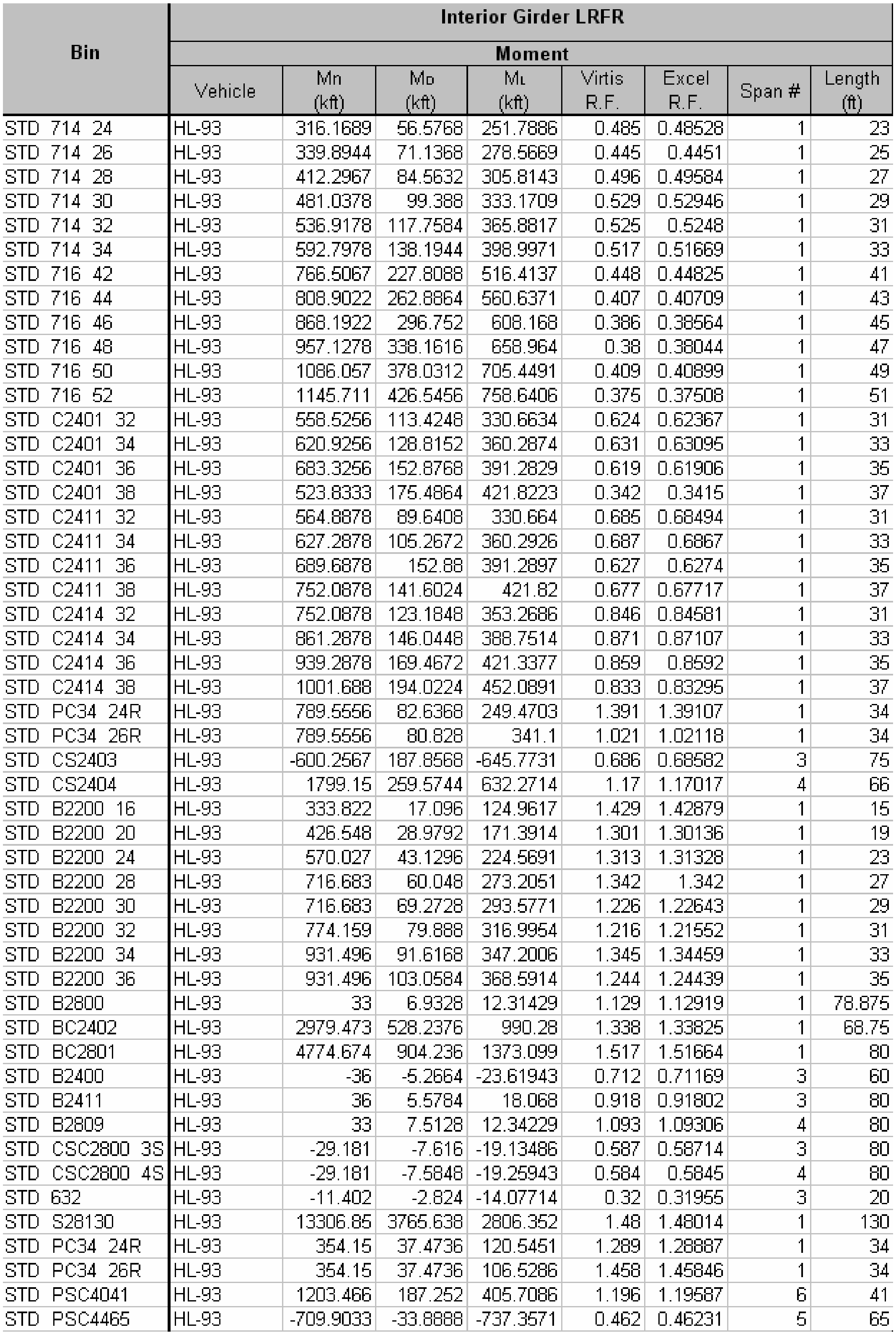


Bin	Exterior Girder LFR							
	Shear							
	Vehicle	Mn (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
STD 714 24	HS 20-44	51.76471	9.7	34.2	0.49	0.42277	1	23
STD 714 26	HS 20-44	54.35294	11.1	35.4	0.48	0.41338	1	25
STD 714 28	HS 20-44	59.76471	12.2	36.4	0.51	0.44214	1	27
STD 714 30	HS 20-44	62.47059	13.4	37.3	0.51	0.44061	1	29
STD 714 32	HS 20-44	62	11.9	33.2	0.52	0.51653	1	31
STD 714 34	HS 20-44	-67.52941	-13.1	-34.2	0.54	0.54372	1	33
STD 716 42	HS 20-44	77.64706	17.4	37.2	0.54	0.53714	1	41
STD 716 44	HS 20-44	86.35294	19.2	37.9	0.59	0.58871	1	43
STD 716 46	HS 20-44	91.88235	20.7	38.3	0.62	0.61564	1	45
STD 716 48	HS 20-44	100.4706	22.6	38.7	0.67	0.66676	1	47
STD 716 50	HS 20-44	106	24.3	39.3	0.69	0.68577	1	49
STD 716 52	HS 20-44	114.5882	26.3	39.3	0.74	0.74086	1	51
STD C2401 32	HS 20-44	51.52941	8.1	26.3	0.58	0.58269	1	31
STD C2401 34	HS 20-44	56.82353	8.7	27	0.63	0.63105	1	33
STD C2401 36	HS 20-44	62.11765	9.8	27.5	0.67	0.67099	1	35
STD C2401 38	HS 20-44	67.41176	10.7	28.1	0.71	0.71125	1	37
STD C2411 32	HS 20-44	53.64706	6.3	26.3	0.66	0.6552	1	31
STD C2411 34	HS 20-44	59.29412	7	27	0.71	0.70457	1	33
STD C2411 36	HS 20-44	64.70588	9.8	27.5	0.71	0.70784	1	35
STD C2411 38	HS 20-44	70.35294	8.5	28.1	0.8	0.79911	1	37
STD C2414 32	HS 20-44	71.64706	8.9	26.3	0.86	0.86396	1	31
STD C2414 34	HS 20-44	81.52941	10	27	0.96	0.96047	1	33
STD C2414 36	HS 20-44	88.35294	11	27.5	1.02	1.01838	1	35
STD C2414 38	HS 20-44	93.76471	11.9	28.1	1.06	1.05286	1	37
STD PC34 24R	HS 20-44	93.41176	10.8	25.1	1.2	1.19944	1	34
STD PC34 26R	HS 20-44	93.52941	9.9	29.1	1.05	1.05467	1	34
STD CS2403	HS 20-44	132.9412	26.9	44.1	0.81	0.81501	3	75
STD CS2404	HS 20-44	-69.52941	-16.9	-29.2	0.57	0.58571	4	66
STD B2200 16	HS 20-44	85.8	4.4	24.5	1.51	1.50556	1	15
STD B2200 20	HS 20-44	99.3	5.6	29.1	1.45	1.45656	1	19
STD B2200 24	HS 20-44	125.9	6.8	32.2	1.67	1.67453	1	23
STD B2200 28	HS 20-44	151.3	8.2	34.2	1.89	1.89419	1	27
STD B2200 30	HS 20-44	-151.3	-8.8	-35.3	1.82	1.82498	1	29
STD B2200 32	HS 20-44	-162.6	-9.6	-36.4	1.9	1.89967	1	31
STD B2200 34	HS 20-44	189.9	10.3	37.2	2.19	2.18558	1	33
STD B2200 36	HS 20-44	189.9	10.8	38.2	2.12	2.12053	1	35
STD B2800	HS 20-44	-485.3	-47.8	-52.7	3.7	3.69857	1	78.875
STD BC2402	HS 20-44	-422.6	-28.1	-46.1	3.86	3.85749	1	68.75
STD BC2801	HS 20-44	485.6	41.5	52.9	3.76	3.75851	1	80
STD B2400	HS 20-44	-334	-37.7	-48.4	2.71	2.71222	3	60
STD B2411	HS 20-44	-463	-50.3	-49.4	3.71	3.70741	3	80
STD B2809	HS 20-44	-500.5	-48.3	-54.6	3.69	3.69261	4	80
STD CSC2800 3S	HS 20-44	542.6	28.4	50.9	4.58	4.57613	3	80
STD CSC2800 4S	HS 20-44	542.6	28.3	50.9	4.58	4.5773	4	80
STD 632	HS 20-44	-133.3	-8.8	-26.9	2.08	2.08665	3	20
STD S28130	HS 20-44	370.9763	114.9	50.5	1.68	1.68293	1	130
STD PC34 24R	HS 20-44	80.61518	10.3	17.7	1.54	1.53965	1	34
STD PC34 26R	HS 20-44	77.5801	9.7	13.5	1.96	1.95206	1	34
STD PSC4041	HS 20-44	-71.61094	-16.5	-26.2	0.75	0.75597	6	41
STD PSC4465	HS 20-44	136.5997	30.6	28.6	1.34	1.33933	5	65

Table C1 - 7: Design Inventory Standard Bridge Output, Interior Girder LRFR Part 1

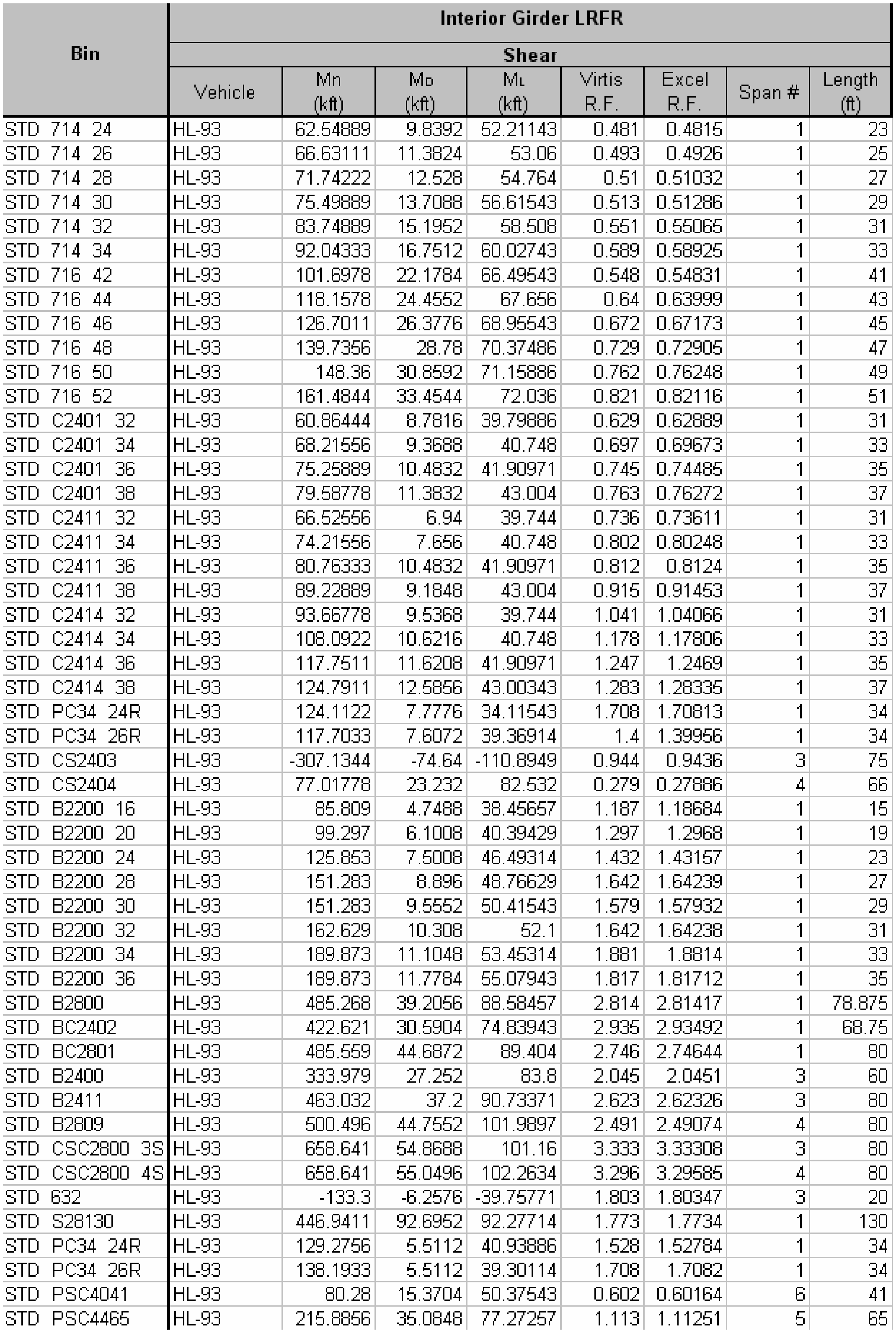
Bin	General Info				Interior Girder LRFR					
	Material Type	Construction	Number of Spans	Span Lengths	γ_D	γ_L	ϕ moment	ϕ shear	ϕ_c	ϕ_s
STD 714 24	1	4	1	23'	1.25	1.75	0.9	0.9	1	1
STD 714 26	1	4	1	25'	1.25	1.75	0.9	0.9	1	1
STD 714 28	1	4	1	27'	1.25	1.75	0.9	0.9	1	1
STD 714 30	1	4	1	29'	1.25	1.75	0.9	0.9	1	1
STD 714 32	1	4	1	31'	1.25	1.75	0.9	0.9	1	1
STD 714 34	1	4	1	33'	1.25	1.75	0.9	0.9	1	1
STD 716 42	1	4	1	41'	1.25	1.75	0.9	0.9	1	1
STD 716 44	1	4	1	43'	1.25	1.75	0.9	0.9	1	1
STD 716 46	1	4	1	45'	1.25	1.75	0.9	0.9	1	1
STD 716 48	1	4	1	47'	1.25	1.75	0.9	0.9	1	1
STD 716 50	1	4	1	49'	1.25	1.75	0.9	0.9	1	1
STD 716 52	1	4	1	51'	1.25	1.75	0.9	0.9	1	1
STD C2401 32	1	4	1	31'	1.25	1.75	0.9	0.9	1	1
STD C2401 34	1	4	1	33'	1.25	1.75	0.9	0.9	1	1
STD C2401 36	1	4	1	35'	1.25	1.75	0.9	0.9	1	1
STD C2401 38	1	4	1	37'	1.25	1.75	0.9	0.9	1	1
STD C2411 32	1	4	1	31'	1.25	1.75	0.9	0.9	1	1
STD C2411 34	1	4	1	33'	1.25	1.75	0.9	0.9	1	1
STD C2411 36	1	4	1	35'	1.25	1.75	0.9	0.9	1	1
STD C2411 38	1	4	1	37'	1.25	1.75	0.9	0.9	1	1
STD C2414 32	1	4	1	31'	1.25	1.75	0.9	0.9	1	1
STD C2414 34	1	4	1	33'	1.25	1.75	0.9	0.9	1	1
STD C2414 36	1	4	1	35'	1.25	1.75	0.9	0.9	1	1
STD C2414 38	1	4	1	37'	1.25	1.75	0.9	0.9	1	1
STD PC34 24R	1	22	1	34'	1.25	1.75	0.9	0.9	1	1
STD PC34 26R	1	22	1	34'	1.25	1.75	0.9	0.9	1	1
STD CS2403	2	2	3	75' 100' 75'	1.25	1.75	0.9	0.9	1	1
STD CS2404	2	2	4	66' 82' 82' 66'	1.25	1.75	0.9	0.9	1	1
STD B2200 16	3	2	1	15'	1.25	1.75	1	1	1	1
STD B2200 20	3	2	1	19'	1.25	1.75	1	1	1	1
STD B2200 24	3	2	1	23'	1.25	1.75	1	1	1	1
STD B2200 28	3	2	1	27'	1.25	1.75	1	1	1	1
STD B2200 30	3	2	1	29'	1.25	1.75	1	1	1	1
STD B2200 32	3	2	1	31'	1.25	1.75	1	1	1	1
STD B2200 34	3	2	1	33'	1.25	1.75	1	1	1	1
STD B2200 36	3	2	1	35'	1.25	1.75	1	1	1	1
STD B2800	3	2	1	78.875'	1.25	1.75	1	1	1	1
STD BC2402	3	2	1	68.75'	1.25	1.75	1	1	1	1
STD BC2801	3	2	1	80'	1.25	1.75	1	1	1	1
STD B2400	4	2	3	60' 80' 60'	1.25	1.75	1	1	1	1
STD B2411	4	2	3	80' 100' 80'	1.25	1.75	1	1	1	1
STD B2809	4	2	4	80' 100' 100' 80'	1.25	1.75	1	1	1	1
STD CSC2800 3S	4	2	3	80' 100' 80'	1.25	1.75	1	1	1	1
STD CSC2800 4S	4	2	4	80' 100' 100' 80'	1.25	1.75	1	1	1	1
STD 632	4	2	3	20' 20' 20'	1.25	1.75	1	1	1	1
STD S28130	5	2	1	130'	1.25	1.75	0.9	0.9	1	1
STD PC34 24R	5	22	1	34'	1.25	1.75	0.9	0.9	1	1
STD PC34 26R	5	22	1	34'	1.25	1.75	0.9	0.9	1	1
STD PSC4041	6	2	6	41' 41' 41' 41' 41' 41'	1.25	1.75	0.9	0.9	1	1
STD PSC4465	6	2	5	65' 65' 65' 65' 65'	1.25	1.75	0.9	0.9	1	1

Table C1 - 8: Design Inventory Standard Bridge Output, Interior Girder LRFR Part 2



Bin	Interior Girder LRFR							
	Moment							
	Vehicle	M_n (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
STD 714 24	HL-93	316.1689	56.5768	251.7886	0.485	0.48528	1	23
STD 714 26	HL-93	339.8944	71.1368	278.5669	0.445	0.4451	1	25
STD 714 28	HL-93	412.2967	84.5632	305.8143	0.496	0.49584	1	27
STD 714 30	HL-93	481.0378	99.388	333.1709	0.529	0.52946	1	29
STD 714 32	HL-93	536.9178	117.7584	365.8817	0.525	0.5248	1	31
STD 714 34	HL-93	592.7978	138.1944	398.9971	0.517	0.51669	1	33
STD 716 42	HL-93	766.5067	227.8088	516.4137	0.448	0.44825	1	41
STD 716 44	HL-93	808.9022	262.8864	560.6371	0.407	0.40709	1	43
STD 716 46	HL-93	868.1922	296.752	608.168	0.386	0.38564	1	45
STD 716 48	HL-93	957.1278	338.1616	658.964	0.38	0.38044	1	47
STD 716 50	HL-93	1086.057	378.0312	705.4491	0.409	0.40899	1	49
STD 716 52	HL-93	1145.711	426.5456	758.6406	0.375	0.37508	1	51
STD C2401 32	HL-93	558.5256	113.4248	330.6634	0.624	0.62367	1	31
STD C2401 34	HL-93	620.9256	128.8152	360.2874	0.631	0.63095	1	33
STD C2401 36	HL-93	683.3256	152.8768	391.2829	0.619	0.61906	1	35
STD C2401 38	HL-93	523.8333	175.4864	421.8223	0.342	0.3415	1	37
STD C2411 32	HL-93	564.8878	89.6408	330.664	0.685	0.68494	1	31
STD C2411 34	HL-93	627.2878	105.2672	360.2926	0.687	0.6867	1	33
STD C2411 36	HL-93	689.6878	152.88	391.2897	0.627	0.6274	1	35
STD C2411 38	HL-93	752.0878	141.6024	421.82	0.677	0.67717	1	37
STD C2414 32	HL-93	752.0878	123.1848	353.2686	0.846	0.84581	1	31
STD C2414 34	HL-93	861.2878	146.0448	388.7514	0.871	0.87107	1	33
STD C2414 36	HL-93	939.2878	169.4672	421.3377	0.859	0.8592	1	35
STD C2414 38	HL-93	1001.688	194.0224	452.0891	0.833	0.83295	1	37
STD PC34 24R	HL-93	789.5556	82.6368	249.4703	1.391	1.39107	1	34
STD PC34 26R	HL-93	789.5556	80.828	341.1	1.021	1.02118	1	34
STD CS2403	HL-93	-600.2567	187.8568	-645.7731	0.686	0.68582	3	75
STD CS2404	HL-93	1799.15	259.5744	632.2714	1.17	1.17017	4	66
STD B2200 16	HL-93	333.822	17.096	124.9617	1.429	1.42879	1	15
STD B2200 20	HL-93	426.548	28.9792	171.3914	1.301	1.30136	1	19
STD B2200 24	HL-93	570.027	43.1296	224.5691	1.313	1.31328	1	23
STD B2200 28	HL-93	716.683	60.048	273.2051	1.342	1.342	1	27
STD B2200 30	HL-93	716.683	69.2728	293.5771	1.226	1.22643	1	29
STD B2200 32	HL-93	774.159	79.888	316.9954	1.216	1.21552	1	31
STD B2200 34	HL-93	931.496	91.6168	347.2006	1.345	1.34459	1	33
STD B2200 36	HL-93	931.496	103.0584	368.5914	1.244	1.24439	1	35
STD B2800	HL-93	33	6.9328	12.31429	1.129	1.12919	1	78.875
STD BC2402	HL-93	2979.473	528.2376	990.28	1.338	1.33825	1	68.75
STD BC2801	HL-93	4774.674	904.236	1373.099	1.517	1.51664	1	80
STD B2400	HL-93	-36	-5.2664	-23.61943	0.712	0.71169	3	60
STD B2411	HL-93	36	5.5784	18.068	0.918	0.91802	3	80
STD B2809	HL-93	33	7.5128	12.34229	1.093	1.09306	4	80
STD CSC2800 3S	HL-93	-29.181	-7.616	-19.13486	0.587	0.58714	3	80
STD CSC2800 4S	HL-93	-29.181	-7.5848	-19.25943	0.584	0.5845	4	80
STD 632	HL-93	-11.402	-2.824	-14.07714	0.32	0.31955	3	20
STD S28130	HL-93	13306.85	3765.638	2806.352	1.48	1.48014	1	130
STD PC34 24R	HL-93	354.15	37.4736	120.5451	1.289	1.28887	1	34
STD PC34 26R	HL-93	354.15	37.4736	106.5286	1.458	1.45846	1	34
STD PSC4041	HL-93	1203.466	187.252	405.7086	1.196	1.19587	6	41
STD PSC4465	HL-93	-709.9033	-33.8888	-737.3571	0.462	0.46231	5	65

Table C1 - 9: Design Inventory Standard Bridge Output, Interior Girder LRFR Part 3



Bin	Interior Girder LRFR							
	Shear							
	Vehicle	M_n (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
STD 714 24	HL-93	62.54889	9.8392	52.21143	0.481	0.4815	1	23
STD 714 26	HL-93	66.63111	11.3824	53.06	0.493	0.4926	1	25
STD 714 28	HL-93	71.74222	12.528	54.764	0.51	0.51032	1	27
STD 714 30	HL-93	75.49889	13.7088	56.61543	0.513	0.51286	1	29
STD 714 32	HL-93	83.74889	15.1952	58.508	0.551	0.55065	1	31
STD 714 34	HL-93	92.04333	16.7512	60.02743	0.589	0.58925	1	33
STD 716 42	HL-93	101.6978	22.1784	66.49543	0.548	0.54831	1	41
STD 716 44	HL-93	118.1578	24.4552	67.656	0.64	0.63999	1	43
STD 716 46	HL-93	126.7011	26.3776	68.95543	0.672	0.67173	1	45
STD 716 48	HL-93	139.7356	28.78	70.37486	0.729	0.72905	1	47
STD 716 50	HL-93	148.36	30.8592	71.15886	0.762	0.76248	1	49
STD 716 52	HL-93	161.4844	33.4544	72.036	0.821	0.82116	1	51
STD C2401 32	HL-93	60.86444	8.7816	39.79886	0.629	0.62889	1	31
STD C2401 34	HL-93	68.21556	9.3688	40.748	0.697	0.69673	1	33
STD C2401 36	HL-93	75.25889	10.4832	41.90971	0.745	0.74485	1	35
STD C2401 38	HL-93	79.58778	11.3832	43.004	0.763	0.76272	1	37
STD C2411 32	HL-93	66.52556	6.94	39.744	0.736	0.73611	1	31
STD C2411 34	HL-93	74.21556	7.656	40.748	0.802	0.80248	1	33
STD C2411 36	HL-93	80.76333	10.4832	41.90971	0.812	0.8124	1	35
STD C2411 38	HL-93	89.22889	9.1848	43.004	0.915	0.91453	1	37
STD C2414 32	HL-93	93.66778	9.5368	39.744	1.041	1.04066	1	31
STD C2414 34	HL-93	108.0922	10.6216	40.748	1.178	1.17806	1	33
STD C2414 36	HL-93	117.7511	11.6208	41.90971	1.247	1.2469	1	35
STD C2414 38	HL-93	124.7911	12.5856	43.00343	1.283	1.28335	1	37
STD PC34 24R	HL-93	124.1122	7.7776	34.11543	1.708	1.70813	1	34
STD PC34 26R	HL-93	117.7033	7.6072	39.36914	1.4	1.39956	1	34
STD CS2403	HL-93	-307.1344	-74.64	-110.8949	0.944	0.9436	3	75
STD CS2404	HL-93	77.01778	23.232	82.532	0.279	0.27886	4	66
STD B2200 16	HL-93	85.809	4.7488	38.45657	1.187	1.18684	1	15
STD B2200 20	HL-93	99.297	6.1008	40.39429	1.297	1.2968	1	19
STD B2200 24	HL-93	125.853	7.5008	46.49314	1.432	1.43157	1	23
STD B2200 28	HL-93	151.283	8.896	48.76629	1.642	1.64239	1	27
STD B2200 30	HL-93	151.283	9.5552	50.41543	1.579	1.57932	1	29
STD B2200 32	HL-93	162.629	10.308	52.1	1.642	1.64238	1	31
STD B2200 34	HL-93	189.873	11.1048	53.45314	1.881	1.8814	1	33
STD B2200 36	HL-93	189.873	11.7784	55.07943	1.817	1.81712	1	35
STD B2800	HL-93	485.268	39.2056	88.58457	2.814	2.81417	1	78.875
STD BC2402	HL-93	422.621	30.5904	74.83943	2.935	2.93492	1	68.75
STD BC2801	HL-93	485.559	44.6872	89.404	2.746	2.74644	1	80
STD B2400	HL-93	333.979	27.252	83.8	2.045	2.0451	3	60
STD B2411	HL-93	463.032	37.2	90.73371	2.623	2.62326	3	80
STD B2809	HL-93	500.496	44.7552	101.9897	2.491	2.49074	4	80
STD CSC2800 3S	HL-93	658.641	54.8688	101.16	3.333	3.33308	3	80
STD CSC2800 4S	HL-93	658.641	55.0496	102.2634	3.296	3.29585	4	80
STD 632	HL-93	-133.3	-6.2576	-39.75771	1.803	1.80347	3	20
STD S28130	HL-93	446.9411	92.6952	92.27714	1.773	1.7734	1	130
STD PC34 24R	HL-93	129.2756	5.5112	40.93886	1.528	1.52784	1	34
STD PC34 26R	HL-93	138.1933	5.5112	39.30114	1.708	1.7082	1	34
STD PSC4041	HL-93	80.28	15.3704	50.37543	0.602	0.60164	6	41
STD PSC4465	HL-93	215.8856	35.0848	77.27257	1.113	1.11251	5	65

Table C1 - 10: Design Inventory Standard Bridge Output, Interior Girder LFR Part 1

Bin	General Info				Interior Girder LFR				
	Material Type	Construction	Number of Spans	Span Lengths	γ_{Combo}	γ_D	γ_L	ϕ moment	ϕ shear
STD 714 24	1	4	1	23'	1.3	1.0	1.67	0.9	0.85
STD 714 26	1	4	1	25'	1.3	1.0	1.67	0.9	0.85
STD 714 28	1	4	1	27'	1.3	1.0	1.67	0.9	0.85
STD 714 30	1	4	1	29'	1.3	1.0	1.67	0.9	0.85
STD 714 32	1	4	1	31'	1.3	1.0	1.67	0.9	0.85
STD 714 34	1	4	1	33'	1.3	1.0	1.67	0.9	0.85
STD 716 42	1	4	1	41'	1.3	1.0	1.67	0.9	0.85
STD 716 44	1	4	1	43'	1.3	1.0	1.67	0.9	0.85
STD 716 46	1	4	1	45'	1.3	1.0	1.67	0.9	0.85
STD 716 48	1	4	1	47'	1.3	1.0	1.67	0.9	0.85
STD 716 50	1	4	1	49'	1.3	1.0	1.67	0.9	0.85
STD 716 52	1	4	1	51'	1.3	1.0	1.67	0.9	0.85
STD C2401 32	1	4	1	31'	1.3	1.0	1.67	0.9	0.85
STD C2401 34	1	4	1	33'	1.3	1.0	1.67	0.9	0.85
STD C2401 36	1	4	1	35'	1.3	1.0	1.67	0.9	0.85
STD C2401 38	1	4	1	37'	1.3	1.0	1.67	0.9	0.85
STD C2411 32	1	4	1	31'	1.3	1.0	1.67	0.9	0.85
STD C2411 34	1	4	1	33'	1.3	1.0	1.67	0.9	0.85
STD C2411 36	1	4	1	35'	1.3	1.0	1.67	0.9	0.85
STD C2411 38	1	4	1	37'	1.3	1.0	1.67	0.9	0.85
STD C2414 32	1	4	1	31'	1.3	1.0	1.67	0.9	0.85
STD C2414 34	1	4	1	33'	1.3	1.0	1.67	0.9	0.85
STD C2414 36	1	4	1	35'	1.3	1.0	1.67	0.9	0.85
STD C2414 38	1	4	1	37'	1.3	1.0	1.67	0.9	0.85
STD PC34 24R	1	22	1	34'	1.3	1.0	1.67	0.9	0.85
STD PC34 26R	1	22	1	34'	1.3	1.0	1.67	0.9	0.85
STD CS2403	2	2	3	75' 100' 75'	1.3	1.0	1.67	0.9	0.85
STD CS2404	2	2	4	66' 82' 82' 66'	1.3	1.0	1.67	0.9	0.85
STD B2200 16	3	2	1	15'	1.3	1.0	1.67	1	1
STD B2200 20	3	2	1	19'	1.3	1.0	1.67	1	1
STD B2200 24	3	2	1	23'	1.3	1.0	1.67	1	1
STD B2200 28	3	2	1	27'	1.3	1.0	1.67	1	1
STD B2200 30	3	2	1	29'	1.3	1.0	1.67	1	1
STD B2200 32	3	2	1	31'	1.3	1.0	1.67	1	1
STD B2200 34	3	2	1	33'	1.3	1.0	1.67	1	1
STD B2200 36	3	2	1	35'	1.3	1.0	1.67	1	1
STD B2800	3	2	1	78.875'	1.3	1.0	1.67	1	1
STD BC2402	3	2	1	68.75'	1.3	1.0	1.67	1	1
STD BC2801	3	2	1	80'	1.3	1.0	1.67	1	1
STD B2400	4	2	3	60' 80' 60'	1.3	1.0	1.67	1	1
STD B2411	4	2	3	80' 100' 80'	1.3	1.0	1.67	1	1
STD B2809	4	2	4	80' 100' 100' 80'	1.3	1.0	1.67	1	1
STD CSC2800 3S	4	2	3	80' 100' 80'	1.3	1.0	1.67	1	1
STD CSC2800 4S	4	2	4	80' 100' 100' 80'	1.3	1.0	1.67	1	1
STD 632	4	2	3	20' 20' 20'	1.3	1.0	1.67	1	1
STD S28130	5	2	1	130'	1.3	1.0	1.67	1	0.9
STD PC34 24R	5	22	1	34'	1.3	1.0	1.67	1	0.9
STD PC34 26R	5	22	1	34'	1.3	1.0	1.67	1	0.9
STD PSC4041	6	2	6	41' 41' 41' 41' 41' 41'	1.3	1.0	1.67	1	0.9
STD PSC4465	6	2	5	65' 65' 65' 65' 65'	1.3	1.0	1.67	1	0.9

Table C1 - 11: Design Inventory Standard Bridge Output, Interior Girder LFR Part 2

Bin	Interior Girder LFR							
	Moment							
	Vehicle	M_n (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
STD 714 24	HS 20-44	316.1689	56.6	146.2	0.66	0.66469	1	23
STD 714 26	HS 20-44	339.8944	68.3	162.7	0.61	0.61467	1	25
STD 714 28	HS 20-44	412.2967	81.2	186.7	0.66	0.65505	1	27
STD 714 30	HS 20-44	481.0367	95.4	212.3	0.67	0.67023	1	29
STD 714 32	HS 20-44	536.9167	113	236.4	0.66	0.65532	1	31
STD 714 34	HS 20-44	592.7967	132.7	261.7	0.64	0.63541	1	33
STD 716 42	HS 20-44	766.5067	227.8	364.8	0.5	0.49713	1	41
STD 716 44	HS 20-44	808.9022	262.9	394.2	0.45	0.45132	1	43
STD 716 46	HS 20-44	868.1922	296.7	419.9	0.43	0.43403	1	45
STD 716 48	HS 20-44	957.1267	338.2	444.9	0.44	0.43665	1	47
STD 716 50	HS 20-44	1086.057	378	476.5	0.47	0.46985	1	49
STD 716 52	HS 20-44	1145.7	426.6	502.6	0.44	0.43674	1	51
STD C2401 32	HS 20-44	562.3422	108.9	215	0.78	0.78099	1	31
STD C2401 34	HS 20-44	624.7422	123.7	238	0.78	0.77697	1	33
STD C2401 36	HS 20-44	687.1422	146.8	259	0.76	0.76044	1	35
STD C2401 38	HS 20-44	525.53	168.4	283	0.41	0.41351	1	37
STD C2411 32	HS 20-44	568.0689	86.1	214.9	0.86	0.85593	1	31
STD C2411 34	HS 20-44	630.4689	101.1	238	0.84	0.8438	1	33
STD C2411 36	HS 20-44	692.8689	146.8	258.8	0.77	0.7702	1	35
STD C2411 38	HS 20-44	755.2689	135.9	283	0.82	0.81881	1	37
STD C2414 32	HS 20-44	755.2689	118.2	214.9	1.13	1.12761	1	31
STD C2414 34	HS 20-44	864.4689	140.2	238	1.15	1.15302	1	33
STD C2414 36	HS 20-44	942.4689	162.7	258.8	1.13	1.13323	1	35
STD C2414 38	HS 20-44	1004.869	186.2	283	1.08	1.07801	1	37
STD PC34 24R	HS 20-44	789.5556	66	130.4	2.21	2.20701	1	34
STD PC34 26R	HS 20-44	789.5556	65.9	114.5	2.51	2.514	1	34
STD CS2403	HS 20-44	-600.2556	187.9	-396.1	0.91	0.91228	3	75
STD CS2404	HS 20-44	1946.756	259.6	485	1.34	1.34348	4	66
STD B2200 16	HS 20-44	336.6	17.7	87.5	1.65	1.6508	1	15
STD B2200 20	HS 20-44	430.4	28.9	110.8	1.63	1.63307	1	19
STD B2200 24	HS 20-44	575.9	43.1	134.1	1.79	1.78569	1	23
STD B2200 28	HS 20-44	725.5	57.6	171.3	1.75	1.74948	1	27
STD B2200 30	HS 20-44	725.5	66.6	194.8	1.51	1.51077	1	29
STD B2200 32	HS 20-44	782.7	76.8	216.9	1.45	1.45015	1	31
STD B2200 34	HS 20-44	942	88	240.1	1.59	1.5877	1	33
STD B2200 36	HS 20-44	942	99	261.2	1.43	1.43423	1	35
STD B2800	HS 20-44	4028.4	796.4	1040	1.33	1.32564	1	78.875
STD BC2402	HS 20-44	3028.9	529.2	731.8	1.47	1.47346	1	68.75
STD BC2801	HS 20-44	4897.3	905.9	1053.7	1.63	1.62601	1	80
STD B2400	HS 20-44	985.7	142.6	500.5	0.87	0.87	3	60
STD B2411	HS 20-44	2176.7	300.4	711.5	1.16	1.15635	3	80
STD B2809	HS 20-44	1920	143.8	693.8	1.15	1.15059	4	80
STD CSC2800 3S	HS 20-44	1989.6	417.7	811.3	0.82	0.8213	3	80
STD CSC2800 4S	HS 20-44	1989.6	415.8	811.4	0.82	0.82261	4	80
STD 632	HS 20-44	-162.6	-20.9	-71.9	0.87	0.86761	3	20
STD S28130	HS 20-44	12624.85	3766.2	1786.6	1.99	1.99262	1	130
STD PC34 24R	HS 20-44	398.624	37.5	101.7	1.59	1.58464	1	34
STD PC34 26R	HS 20-44	398.624	37.5	101.9	1.58	1.58153	1	34
STD PSC4041	HS 20-44	1065.356	186.2	303.4	1.25	1.24992	6	41
STD PSC4465	HS 20-44	-638.913	-45.3	-492.8	0.54	0.54214	5	65

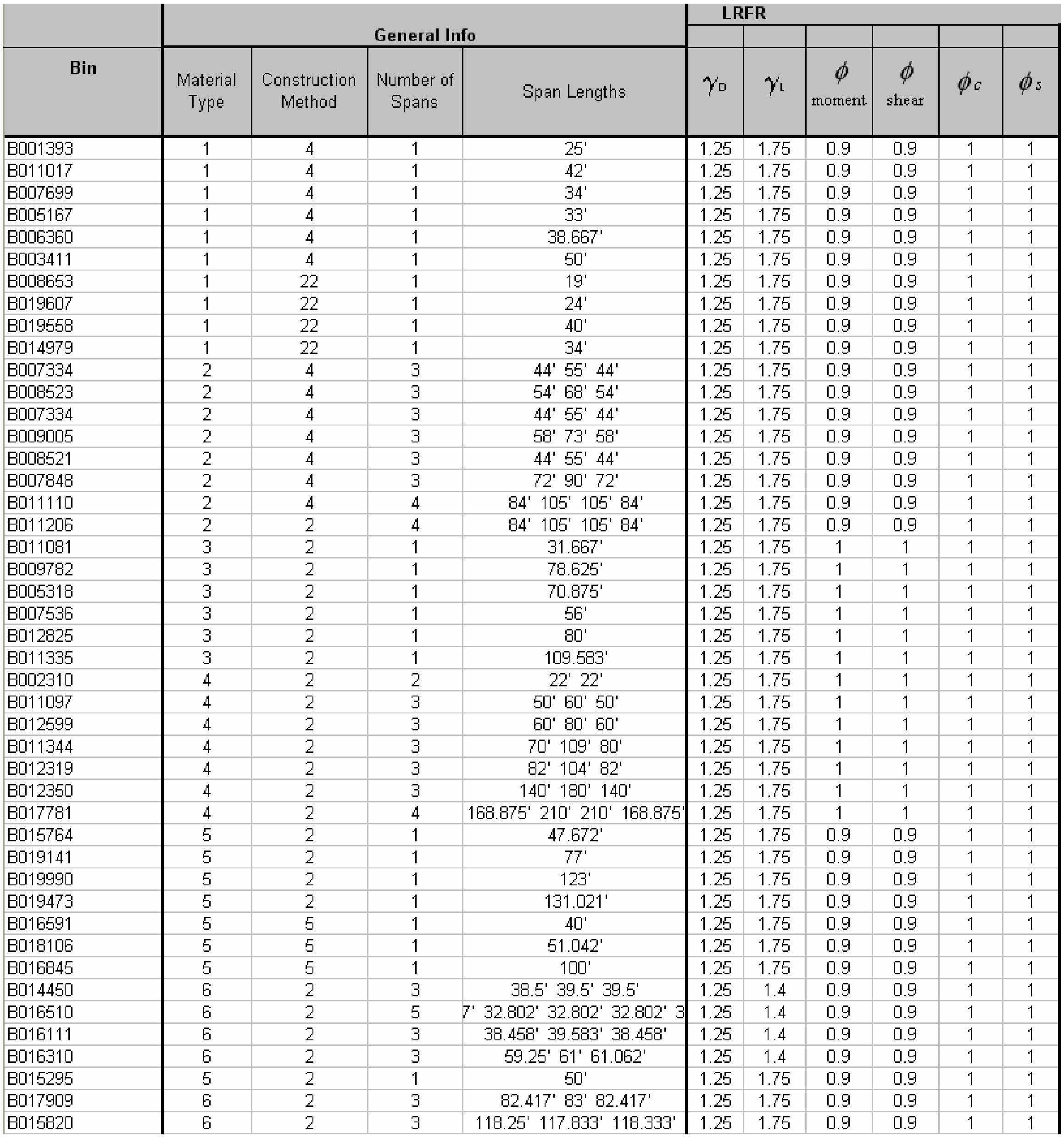
Table C1 - 12: Design Inventory Standard Bridge Output, Interior Girder LFR Part 3

Bin	Interior Girder LFR							
	Shear							
	Vehicle	Mn (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
STD 714 24	HS 20-44	55.29412	9.9	35.3	0.52	0.44535	1	23
STD 714 26	HS 20-44	57.88235	11.4	36.6	0.51	0.43268	1	25
STD 714 28	HS 20-44	63.29412	12.6	37.6	0.54	0.45841	1	27
STD 714 30	HS 20-44	66	13.7	38.6	0.53	0.45692	1	29
STD 714 32	HS 20-44	65.88235	12.2	34.3	0.54	0.53904	1	31
STD 714 34	HS 20-44	-71.41176	-13.4	-35.4	0.56	0.56315	1	33
STD 716 42	HS 20-44	79.64706	17.7	38.5	0.54	0.53467	1	41
STD 716 44	HS 20-44	90.35294	19.6	39.2	0.6	0.60303	1	43
STD 716 46	HS 20-44	95.88235	21.1	39.7	0.63	0.62734	1	45
STD 716 48	HS 20-44	104.4706	23	40	0.68	0.67826	1	47
STD 716 50	HS 20-44	110	24.7	40.6	0.7	0.69649	1	49
STD 716 52	HS 20-44	-118.4706	-26.7	-40.9	0.74	0.74318	1	51
STD C2401 32	HS 20-44	54.70588	8.7	26.6	0.61	0.60937	1	31
STD C2401 34	HS 20-44	60	9.4	27.3	0.66	0.65431	1	33
STD C2401 36	HS 20-44	65.29412	10.5	27.7	0.7	0.69591	1	35
STD C2401 38	HS 20-44	70.94118	11.4	28.4	0.74	0.73764	1	37
STD C2411 32	HS 20-44	57.05882	6.9	26.6	0.69	0.68452	1	31
STD C2411 34	HS 20-44	62.58824	7.7	27.3	0.73	0.72872	1	33
STD C2411 36	HS 20-44	68	10.5	27.7	0.74	0.73416	1	35
STD C2411 38	HS 20-44	73.64706	9.2	28.4	0.82	0.82133	1	37
STD C2414 32	HS 20-44	74.70588	9.5	26.6	0.89	0.88574	1	31
STD C2414 34	HS 20-44	84.58824	10.7	27.3	0.98	0.97843	1	33
STD C2414 36	HS 20-44	91.52941	11.6	27.7	1.04	1.04296	1	35
STD C2414 38	HS 20-44	96.94118	12.6	28.4	1.07	1.07077	1	37
STD PC34 24R	HS 20-44	93.41176	6.4	17.1	1.92	1.91466	1	34
STD PC34 26R	HS 20-44	93.41176	6.4	15	2.18	2.18271	1	34
STD CS2403	HS 20-44	135.8824	27.1	42.5	0.86	0.86997	3	75
STD CS2404	HS 20-44	76.11765	16.6	35.2	0.57	0.56426	4	66
STD B2200 16	HS 20-44	85.8	4.8	24.7	1.48	1.48367	1	15
STD B2200 20	HS 20-44	99.3	6.1	29.4	1.43	1.43152	1	19
STD B2200 24	HS 20-44	125.9	7.4	32.4	1.65	1.6531	1	23
STD B2200 28	HS 20-44	151.3	8.9	34.5	1.87	1.86557	1	27
STD B2200 30	HS 20-44	151.3	-9.6	-35.6	1.8	1.79615	1	29
STD B2200 32	HS 20-44	162.6	-10.4	-36.7	1.87	1.87108	1	31
STD B2200 34	HS 20-44	189.9	11.1	37.5	2.16	2.15532	1	33
STD B2200 36	HS 20-44	189.9	11.7	38.5	2.09	2.09001	1	35
STD B2800	HS 20-44	485.3	-39.3	-57.4	3.48	3.4844	1	78.875
STD BC2402	HS 20-44	422.6	-30.6	-47.5	3.71	3.71228	1	68.75
STD BC2801	HS 20-44	485.6	44.8	57.7	3.41	3.4116	1	80
STD B2400	HS 20-44	334	-27.3	-50.3	2.73	2.73358	3	60
STD B2411	HS 20-44	463	-37.4	-51.3	3.72	3.72067	3	80
STD B2809	HS 20-44	500.5	-45.8	-59.6	3.41	3.40795	4	80
STD CSC2800 3S	HS 20-44	542.6	29.7	55.5	4.18	4.18282	3	80
STD CSC2800 4S	HS 20-44	542.6	29.6	55.6	4.18	4.17637	4	80
STD 632	HS 20-44	133.3	-6.3	-26.9	2.14	2.1423	3	20
STD S28130	HS 20-44	371.1271	115.8	58.8	1.44	1.43727	1	130
STD PC34 24R	HS 20-44	80.87587	5.5	17.7	2.07	1.70814	1	34
STD PC34 26R	HS 20-44	80.92162	5.5	17.8	2.06	1.69961	1	34
STD PSC4041	HS 20-44	-71.3654	-16.8	-44.4	0.44	0.43975	6	41
STD PSC4465	HS 20-44	-142.9808	-36.2	-55.3	0.68	0.67987	5	65

APPENDIX C.2: Design Inventory Unique Bridge Rating Data

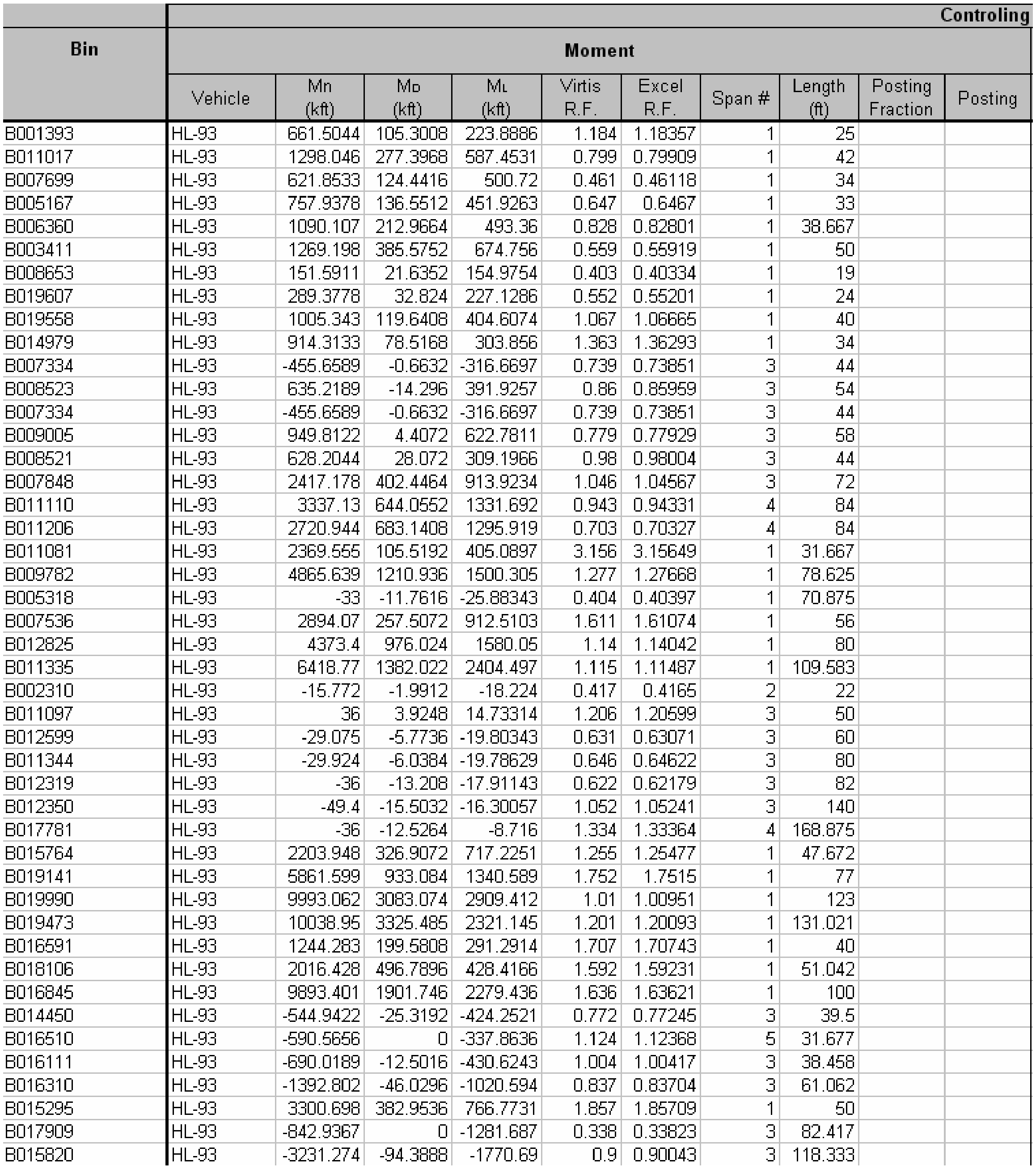
Presented in this appendix is the extracted data from Virtis for the unique bridge sample at the Design Inventory level for the LRFR under the HL-93 load model and the Inventory level of the LFR under the HS-20. Tables C.1 - 1 through C.1 - 12 provide the following information: BIN, Material Type, Structural Type, Number of Spans, Span Length, Dead Load Factors, Live Load Factors, Resistance Factors, Condition Factor, System Factor, Controlling Vehicle, Unfactored Capacity, Unfactored Dead Load, Unfactored Live Load, Virtis Rating Factor, and Excel Calculated Rating Factor. The Excel rating factor is calculated using the provided information and the rating methodologies rating equation as provided in Chapter 2.

Table C2 - 1: Design Inventory Unique Bridge Output, Exterior Girder LRFR Part 1



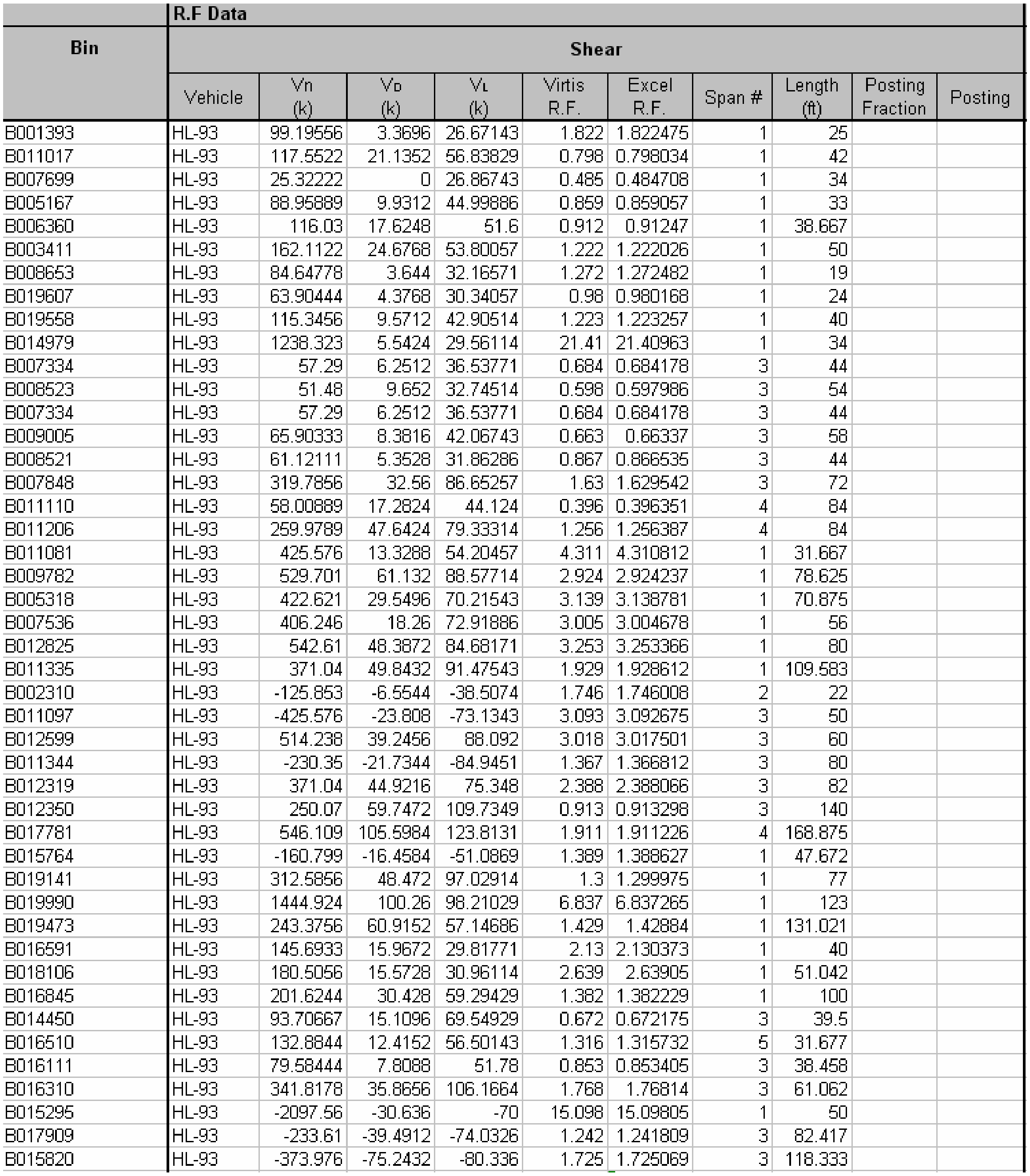
	General Info				LRFR					
Bin	Material Type	Construction Method	Number of Spans	Span Lengths	γ_D	γ_L	ϕ moment	ϕ shear	ϕ_c	ϕ_s
B001393	1	4	1	25'	1.25	1.75	0.9	0.9	1	1
B011017	1	4	1	42'	1.25	1.75	0.9	0.9	1	1
B007699	1	4	1	34'	1.25	1.75	0.9	0.9	1	1
B005167	1	4	1	33'	1.25	1.75	0.9	0.9	1	1
B006360	1	4	1	38.667'	1.25	1.75	0.9	0.9	1	1
B003411	1	4	1	50'	1.25	1.75	0.9	0.9	1	1
B008653	1	22	1	19'	1.25	1.75	0.9	0.9	1	1
B019607	1	22	1	24'	1.25	1.75	0.9	0.9	1	1
B019558	1	22	1	40'	1.25	1.75	0.9	0.9	1	1
B014979	1	22	1	34'	1.25	1.75	0.9	0.9	1	1
B007334	2	4	3	44' 55' 44'	1.25	1.75	0.9	0.9	1	1
B008523	2	4	3	54' 68' 54'	1.25	1.75	0.9	0.9	1	1
B007334	2	4	3	44' 55' 44'	1.25	1.75	0.9	0.9	1	1
B009005	2	4	3	58' 73' 58'	1.25	1.75	0.9	0.9	1	1
B008521	2	4	3	44' 55' 44'	1.25	1.75	0.9	0.9	1	1
B007848	2	4	3	72' 90' 72'	1.25	1.75	0.9	0.9	1	1
B011110	2	4	4	84' 105' 105' 84'	1.25	1.75	0.9	0.9	1	1
B011206	2	2	4	84' 105' 105' 84'	1.25	1.75	0.9	0.9	1	1
B011081	3	2	1	31.667'	1.25	1.75	1	1	1	1
B009782	3	2	1	78.625'	1.25	1.75	1	1	1	1
B005318	3	2	1	70.875'	1.25	1.75	1	1	1	1
B007536	3	2	1	56'	1.25	1.75	1	1	1	1
B012825	3	2	1	80'	1.25	1.75	1	1	1	1
B011335	3	2	1	109.583'	1.25	1.75	1	1	1	1
B002310	4	2	2	22' 22'	1.25	1.75	1	1	1	1
B011097	4	2	3	50' 60' 50'	1.25	1.75	1	1	1	1
B012599	4	2	3	60' 80' 60'	1.25	1.75	1	1	1	1
B011344	4	2	3	70' 109' 80'	1.25	1.75	1	1	1	1
B012319	4	2	3	82' 104' 82'	1.25	1.75	1	1	1	1
B012350	4	2	3	140' 180' 140'	1.25	1.75	1	1	1	1
B017781	4	2	4	168.875' 210' 210' 168.875'	1.25	1.75	1	1	1	1
B015764	5	2	1	47.672'	1.25	1.75	0.9	0.9	1	1
B019141	5	2	1	77'	1.25	1.75	0.9	0.9	1	1
B019990	5	2	1	123'	1.25	1.75	0.9	0.9	1	1
B019473	5	2	1	131.021'	1.25	1.75	0.9	0.9	1	1
B016591	5	5	1	40'	1.25	1.75	0.9	0.9	1	1
B018106	5	5	1	51.042'	1.25	1.75	0.9	0.9	1	1
B016845	5	5	1	100'	1.25	1.75	0.9	0.9	1	1
B014450	6	2	3	38.5' 39.5' 39.5'	1.25	1.4	0.9	0.9	1	1
B016510	6	2	5	7' 32.802' 32.802' 32.802' 3	1.25	1.4	0.9	0.9	1	1
B016111	6	2	3	38.458' 39.583' 38.458'	1.25	1.4	0.9	0.9	1	1
B016310	6	2	3	59.25' 61' 61.062'	1.25	1.4	0.9	0.9	1	1
B015295	5	2	1	50'	1.25	1.75	0.9	0.9	1	1
B017909	6	2	3	82.417' 83' 82.417'	1.25	1.75	0.9	0.9	1	1
B015820	6	2	3	118.25' 117.833' 118.333'	1.25	1.75	0.9	0.9	1	1

Table C2 - 2: Design Inventory Unique Bridge Output, Exterior Girder LRFR Part 2



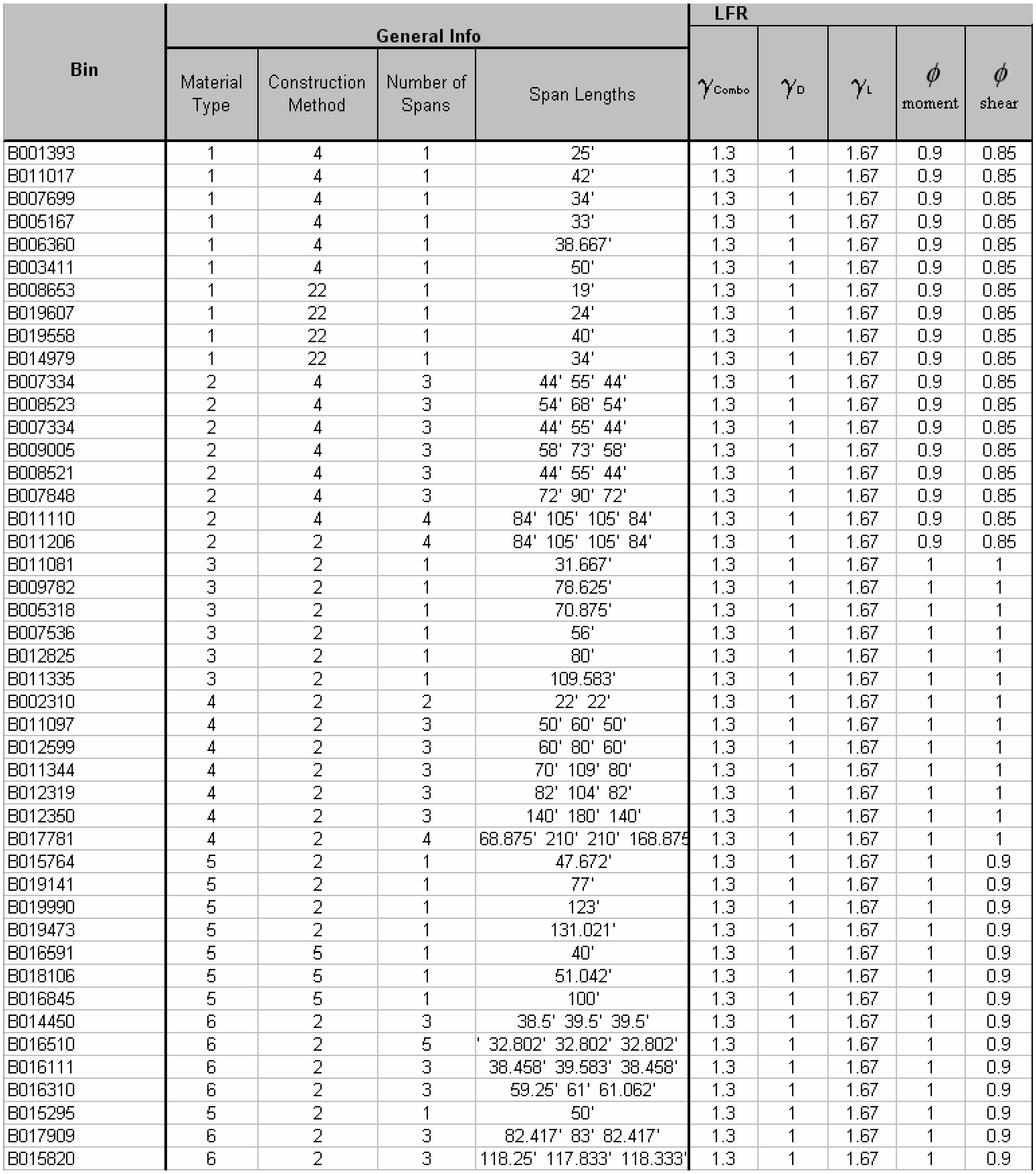
Bin										Controling
	Moment									
	Vehicle	M_n (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)	Posting Fraction	Posting
B001393	HL-93	661.5044	105.3008	223.8886	1.184	1.18357	1	25		
B011017	HL-93	1298.046	277.3968	587.4531	0.799	0.79909	1	42		
B007699	HL-93	621.8533	124.4416	500.72	0.461	0.46118	1	34		
B005167	HL-93	757.9378	136.5512	451.9263	0.647	0.6467	1	33		
B006360	HL-93	1090.107	212.9664	493.36	0.828	0.82801	1	38.667		
B003411	HL-93	1269.198	385.5752	674.756	0.559	0.55919	1	50		
B008653	HL-93	151.5911	21.6352	154.9754	0.403	0.40334	1	19		
B019607	HL-93	289.3778	32.824	227.1286	0.552	0.55201	1	24		
B019558	HL-93	1005.343	119.6408	404.6074	1.067	1.06665	1	40		
B014979	HL-93	914.3133	78.5168	303.856	1.363	1.36293	1	34		
B007334	HL-93	-455.6589	-0.6632	-316.6697	0.739	0.73851	3	44		
B008523	HL-93	635.2189	-14.296	391.9257	0.86	0.85959	3	54		
B007334	HL-93	-455.6589	-0.6632	-316.6697	0.739	0.73851	3	44		
B009005	HL-93	949.8122	4.4072	622.7811	0.779	0.77929	3	58		
B008521	HL-93	628.2044	28.072	309.1966	0.98	0.98004	3	44		
B007848	HL-93	2417.178	402.4464	913.9234	1.046	1.04567	3	72		
B011110	HL-93	3337.13	644.0552	1331.692	0.943	0.94331	4	84		
B011206	HL-93	2720.944	683.1408	1295.919	0.703	0.70327	4	84		
B011081	HL-93	2369.555	105.5192	405.0897	3.156	3.15649	1	31.667		
B009782	HL-93	4865.639	1210.936	1500.305	1.277	1.27668	1	78.625		
B005318	HL-93	-33	-11.7616	-25.88343	0.404	0.40397	1	70.875		
B007536	HL-93	2894.07	257.5072	912.5103	1.611	1.61074	1	56		
B012825	HL-93	4373.4	976.024	1580.05	1.14	1.14042	1	80		
B011335	HL-93	6418.77	1382.022	2404.497	1.115	1.11487	1	109.583		
B002310	HL-93	-15.772	-1.9912	-18.224	0.417	0.4165	2	22		
B011097	HL-93	36	3.9248	14.73314	1.206	1.20599	3	50		
B012599	HL-93	-29.075	-5.7736	-19.80343	0.631	0.63071	3	60		
B011344	HL-93	-29.924	-6.0384	-19.78629	0.646	0.64622	3	80		
B012319	HL-93	-36	-13.208	-17.91143	0.622	0.62179	3	82		
B012350	HL-93	-49.4	-15.5032	-16.30057	1.052	1.05241	3	140		
B017781	HL-93	-36	-12.5264	-8.716	1.334	1.33364	4	168.875		
B015764	HL-93	2203.948	326.9072	717.2251	1.255	1.25477	1	47.672		
B019141	HL-93	5861.599	933.084	1340.589	1.752	1.7515	1	77		
B019990	HL-93	9993.062	3083.074	2909.412	1.01	1.00951	1	123		
B019473	HL-93	10038.95	3325.485	2321.145	1.201	1.20093	1	131.021		
B016591	HL-93	1244.283	199.5808	291.2914	1.707	1.70743	1	40		
B018106	HL-93	2016.428	496.7896	428.4166	1.592	1.59231	1	51.042		
B016845	HL-93	9893.401	1901.746	2279.436	1.636	1.63621	1	100		
B014450	HL-93	-544.9422	-25.3192	-424.2521	0.772	0.77245	3	39.5		
B016510	HL-93	-590.5656	0	-337.8636	1.124	1.12368	5	31.677		
B016111	HL-93	-690.0189	-12.5016	-430.6243	1.004	1.00417	3	38.458		
B016310	HL-93	-1392.802	-46.0296	-1020.594	0.837	0.83704	3	61.062		
B015295	HL-93	3300.698	382.9536	766.7731	1.857	1.85709	1	50		
B017909	HL-93	-842.9367	0	-1281.687	0.338	0.33823	3	82.417		
B015820	HL-93	-3231.274	-94.3888	-1770.69	0.9	0.90043	3	118.333		

Table C2 - 3: Design Inventory Unique Bridge Output, Exterior Girder LRFR Part 3



	R.F Data									
Bin	Shear									
	Vehicle	V_n (k)	V_D (k)	V_L (k)	Virtis R.F.	Excel R.F.	Span #	Length (ft)	Posting Fraction	Posting
B001393	HL-93	99.19556	3.3696	26.67143	1.822	1.822475	1	25		
B011017	HL-93	117.5522	21.1352	56.83829	0.798	0.798034	1	42		
B007699	HL-93	25.32222	0	26.86743	0.485	0.484708	1	34		
B005167	HL-93	88.95889	9.9312	44.99886	0.859	0.859057	1	33		
B006360	HL-93	116.03	17.6248	51.6	0.912	0.91247	1	38.667		
B003411	HL-93	162.1122	24.6768	53.80057	1.222	1.222026	1	50		
B008653	HL-93	84.64778	3.644	32.16571	1.272	1.272482	1	19		
B019607	HL-93	63.90444	4.3768	30.34057	0.98	0.980168	1	24		
B019558	HL-93	115.3456	9.5712	42.90514	1.223	1.223257	1	40		
B014979	HL-93	1238.323	5.5424	29.56114	21.41	21.40963	1	34		
B007334	HL-93	57.29	6.2512	36.53771	0.684	0.684178	3	44		
B008523	HL-93	51.48	9.652	32.74514	0.598	0.597986	3	54		
B007334	HL-93	57.29	6.2512	36.53771	0.684	0.684178	3	44		
B009005	HL-93	65.90333	8.3816	42.06743	0.663	0.66337	3	58		
B008521	HL-93	61.12111	5.3528	31.86286	0.867	0.866535	3	44		
B007848	HL-93	319.7856	32.56	86.65257	1.63	1.629542	3	72		
B011110	HL-93	58.00889	17.2824	44.124	0.396	0.396351	4	84		
B011206	HL-93	259.9789	47.6424	79.33314	1.256	1.256387	4	84		
B011081	HL-93	425.576	13.3288	54.20457	4.311	4.310812	1	31.667		
B009782	HL-93	529.701	61.132	88.57714	2.924	2.924237	1	78.625		
B005318	HL-93	422.621	29.5496	70.21543	3.139	3.138781	1	70.875		
B007536	HL-93	406.246	18.26	72.91886	3.005	3.004678	1	56		
B012825	HL-93	542.61	48.3872	84.68171	3.253	3.253366	1	80		
B011335	HL-93	371.04	49.8432	91.47543	1.929	1.928612	1	109.583		
B002310	HL-93	-125.853	-6.5544	-38.5074	1.746	1.746008	2	22		
B011097	HL-93	-425.576	-23.808	-73.1343	3.093	3.092675	3	50		
B012599	HL-93	514.238	39.2456	88.092	3.018	3.017501	3	60		
B011344	HL-93	-230.35	-21.7344	-84.9451	1.367	1.366812	3	80		
B012319	HL-93	371.04	44.9216	75.348	2.388	2.388066	3	82		
B012350	HL-93	250.07	59.7472	109.7349	0.913	0.913298	3	140		
B017781	HL-93	546.109	105.5984	123.8131	1.911	1.911226	4	168.875		
B015764	HL-93	-160.799	-16.4584	-51.0869	1.389	1.388627	1	47.672		
B019141	HL-93	312.5856	48.472	97.02914	1.3	1.299975	1	77		
B019990	HL-93	1444.924	100.26	98.21029	6.837	6.837265	1	123		
B019473	HL-93	243.3756	60.9152	57.14686	1.429	1.42884	1	131.021		
B016591	HL-93	145.6933	15.9672	29.81771	2.13	2.130373	1	40		
B018106	HL-93	180.5056	15.5728	30.96114	2.639	2.63905	1	51.042		
B016845	HL-93	201.6244	30.428	59.29429	1.382	1.382229	1	100		
B014450	HL-93	93.70667	15.1096	69.54929	0.672	0.672175	3	39.5		
B016510	HL-93	132.8844	12.4152	56.50143	1.316	1.315732	5	31.677		
B016111	HL-93	79.58444	7.8088	51.78	0.853	0.853405	3	38.458		
B016310	HL-93	341.8178	35.8656	106.1664	1.768	1.76814	3	61.062		
B015295	HL-93	-2097.56	-30.636	-70	15.098	15.09805	1	50		
B017909	HL-93	-233.61	-39.4912	-74.0326	1.242	1.241809	3	82.417		
B015820	HL-93	-373.976	-75.2432	-80.336	1.725	1.725069	3	118.333		

Table C2 - 4: Design Inventory Unique Bridge Output, Exterior Girder LFR Part 1

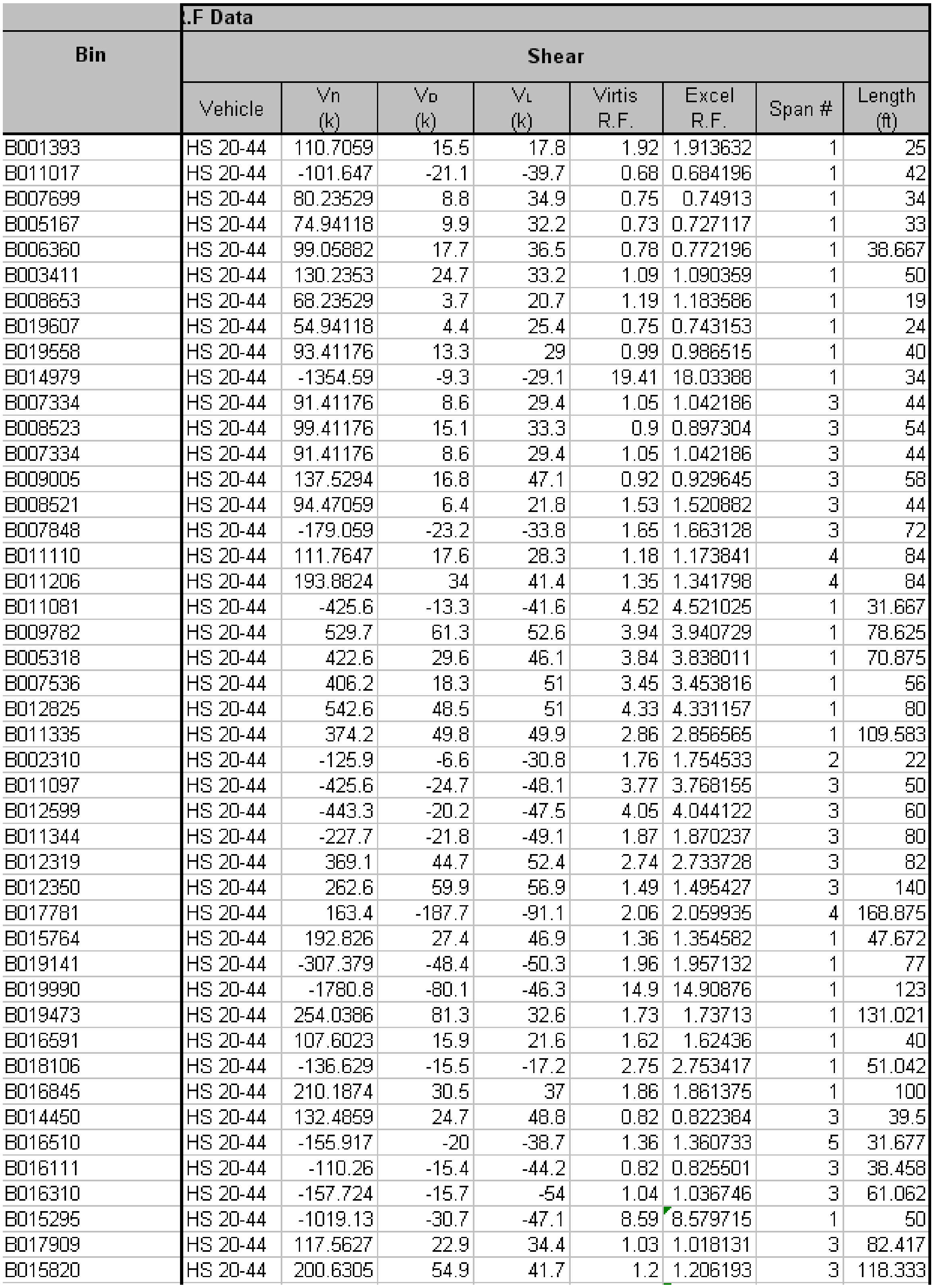


Bin	General Info				LFR				
	Material Type	Construction Method	Number of Spans	Span Lengths	γ_{Combo}	γ_D	γ_L	ϕ moment	ϕ shear
B001393	1	4	1	25'	1.3	1	1.67	0.9	0.85
B011017	1	4	1	42'	1.3	1	1.67	0.9	0.85
B007699	1	4	1	34'	1.3	1	1.67	0.9	0.85
B005167	1	4	1	33'	1.3	1	1.67	0.9	0.85
B006360	1	4	1	38.667'	1.3	1	1.67	0.9	0.85
B003411	1	4	1	50'	1.3	1	1.67	0.9	0.85
B008653	1	22	1	19'	1.3	1	1.67	0.9	0.85
B019607	1	22	1	24'	1.3	1	1.67	0.9	0.85
B019558	1	22	1	40'	1.3	1	1.67	0.9	0.85
B014979	1	22	1	34'	1.3	1	1.67	0.9	0.85
B007334	2	4	3	44' 55' 44'	1.3	1	1.67	0.9	0.85
B008523	2	4	3	54' 68' 54'	1.3	1	1.67	0.9	0.85
B007334	2	4	3	44' 55' 44'	1.3	1	1.67	0.9	0.85
B009005	2	4	3	58' 73' 58'	1.3	1	1.67	0.9	0.85
B008521	2	4	3	44' 55' 44'	1.3	1	1.67	0.9	0.85
B007848	2	4	3	72' 90' 72'	1.3	1	1.67	0.9	0.85
B011110	2	4	4	84' 105' 105' 84'	1.3	1	1.67	0.9	0.85
B011206	2	2	4	84' 105' 105' 84'	1.3	1	1.67	0.9	0.85
B011081	3	2	1	31.667'	1.3	1	1.67	1	1
B009782	3	2	1	78.625'	1.3	1	1.67	1	1
B005318	3	2	1	70.875'	1.3	1	1.67	1	1
B007536	3	2	1	56'	1.3	1	1.67	1	1
B012825	3	2	1	80'	1.3	1	1.67	1	1
B011335	3	2	1	109.583'	1.3	1	1.67	1	1
B002310	4	2	2	22' 22'	1.3	1	1.67	1	1
B011097	4	2	3	50' 60' 50'	1.3	1	1.67	1	1
B012599	4	2	3	60' 80' 60'	1.3	1	1.67	1	1
B011344	4	2	3	70' 109' 80'	1.3	1	1.67	1	1
B012319	4	2	3	82' 104' 82'	1.3	1	1.67	1	1
B012350	4	2	3	140' 180' 140'	1.3	1	1.67	1	1
B017781	4	2	4	68.875' 210' 210' 168.875	1.3	1	1.67	1	1
B015764	5	2	1	47.672'	1.3	1	1.67	1	0.9
B019141	5	2	1	77'	1.3	1	1.67	1	0.9
B019990	5	2	1	123'	1.3	1	1.67	1	0.9
B019473	5	2	1	131.021'	1.3	1	1.67	1	0.9
B016591	5	5	1	40'	1.3	1	1.67	1	0.9
B018106	5	5	1	51.042'	1.3	1	1.67	1	0.9
B016845	5	5	1	100'	1.3	1	1.67	1	0.9
B014450	6	2	3	38.5' 39.5' 39.5'	1.3	1	1.67	1	0.9
B016510	6	2	5	' 32.802' 32.802' 32.802'	1.3	1	1.67	1	0.9
B016111	6	2	3	38.458' 39.583' 38.458'	1.3	1	1.67	1	0.9
B016310	6	2	3	59.25' 61' 61.062'	1.3	1	1.67	1	0.9
B015295	5	2	1	50'	1.3	1	1.67	1	0.9
B017909	6	2	3	82.417' 83' 82.417'	1.3	1	1.67	1	0.9
B015820	6	2	3	118.25' 117.833' 118.333'	1.3	1	1.67	1	0.9

Table C2 - 5: Design Inventory Unique Bridge Output, Exterior Girder LFR Part 2

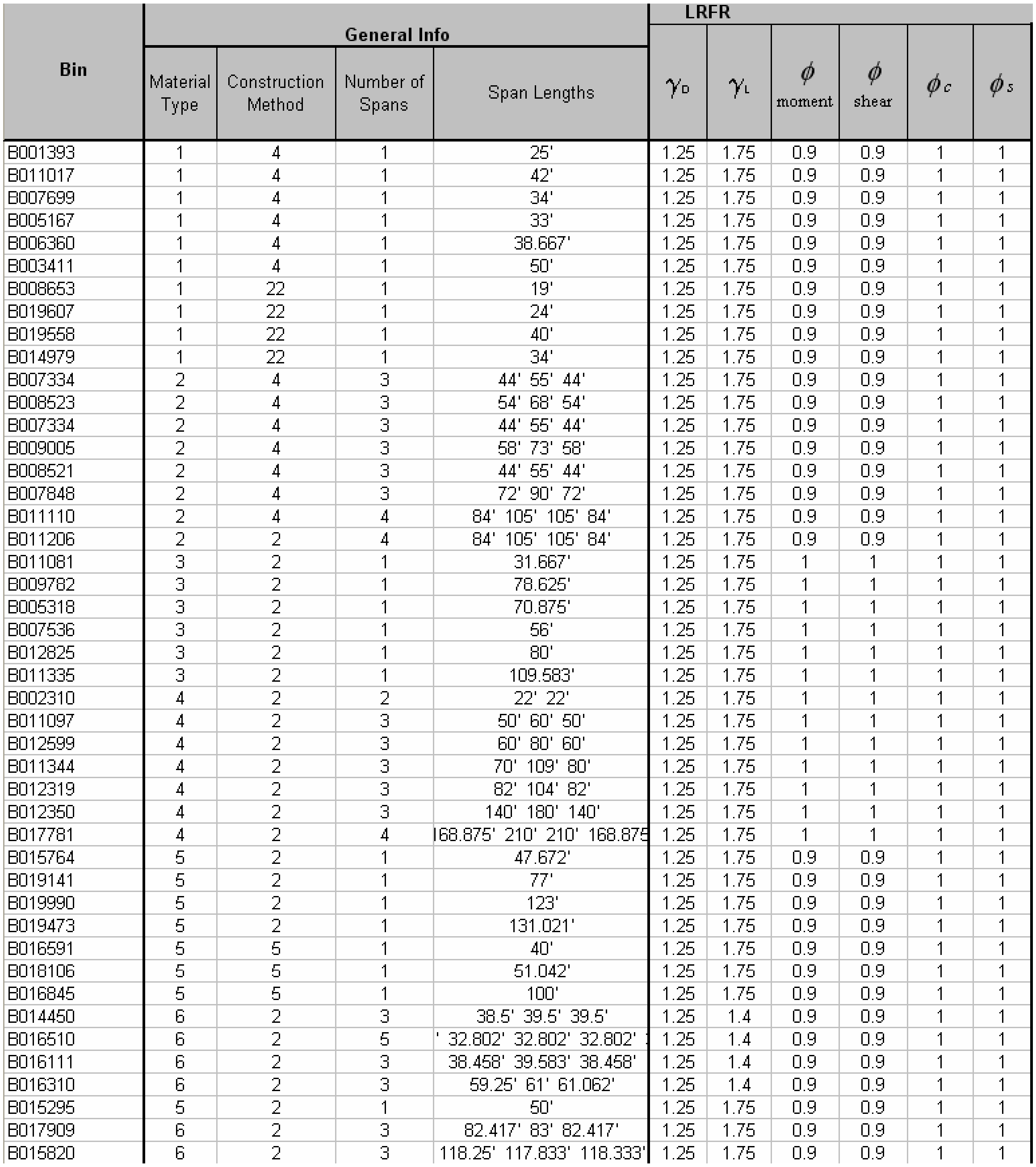
Bin								
	Controling R							
	Moment							
	Vehicle	M_n (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
B001393	HS 20-44	661.6389	155.8	109.6	1.65	1.65139261	1	25
B011017	HS 20-44	1298.044	277.4	387.5	0.96	0.96000951	1	42
B007699	HS 20-44	621.8533	119.4	315.5	0.59	0.59047771	1	34
B005167	HS 20-44	761.1189	131.1	281.3	0.84	0.84259876	1	33
B006360	HS 20-44	1086.534	204.4	325.1	1.01	1.00902376	1	38.667
B003411	HS 20-44	1271.056	385.6	398.6	0.74	0.7426615	1	50
B008653	HS 20-44	151.5911	21.6	91.7	0.54	0.5442617	1	19
B019607	HS 20-44	289.3778	32.8	124.8	0.8	0.80386564	1	24
B019558	HS 20-44	1005.342	158.8	268.5	1.2	1.19806455	1	40
B014979	HS 20-44	914.3122	75.4	191.5	1.74	1.74351678	1	34
B007334	HS 20-44	-455.658	-0.8	-200.9	0.94	0.93786207	3	44
B008523	HS 20-44	1317.256	192.2	365.1	1.18	1.18045938	3	54
B007334	HS 20-44	-455.658	-0.8	-200.9	0.94	0.93786207	3	44
B009005	HS 20-44	949.8111	4.5	418.1	0.94	0.93531407	3	58
B008521	HS 20-44	630.5333	28.1	170.8	1.43	1.43187773	3	44
B007848	HS 20-44	2425.444	402.3	611	1.25	1.25136357	3	72
B011110	HS 20-44	3337.122	641.7	752.7	1.33	1.32744904	4	84
B011206	HS 20-44	2722.556	683.1	749.4	0.96	0.96024616	4	84
B011081	HS 20-44	2321	101.5	251.7	4.01	4.00601566	1	31.667
B009782	HS 20-44	4782.8	1212	940.1	1.57	1.57141961	1	78.625
B005318	HS 20-44	1716	524.5	732.7	0.65	0.65012598	1	70.875
B007536	HS 20-44	2936.4	258	619.4	1.93	1.9342354	1	56
B012825	HS 20-44	4402.5	977.7	931.4	1.55	1.54865605	1	80
B011335	HS 20-44	5251.4	1381.7	1279.5	1.24	1.24386091	1	109.583
B002310	HS 20-44	270.1	16.2	96.2	1.19	1.19243362	2	22
B011097	HS 20-44	1527	140.7	393.4	1.57	1.5737443	3	50
B012599	HS 20-44	1513	210	523	1.09	1.09209438	3	60
B011344	HS 20-44	2212.8	284.8	732	1.16	1.15944655	3	80
B012319	HS 20-44	-2079.1	-755.8	-615.1	0.82	0.82115823	3	82
B012350	HS 20-44	-11864.2	-3618.9	-1980.6	1.67	1.66507569	3	140
B017781	HS 20-44	-19796.5	-6890.6	-3137.4	1.59	1.59128615	4	168.875
B015764	HS 20-44	1996.465	327	471.1	1.54	1.53639908	1	47.672
B019141	HS 20-44	5287.595	933.2	880.3	2.13	2.13194912	1	77
B019990	HS 20-44	10344.17	3083.3	1497.3	1.95	1.9491175	1	123
B019473	HS 20-44	10191.95	3326.8	1171	2.31	2.30784926	1	131.021
B016591	HS 20-44	1112.73	191.3	200	1.99	1.98995785	1	40
B018106	HS 20-44	1834.846	496.3	290.7	1.89	1.88502237	1	51.042
B016845	HS 20-44	8914.598	1902.1	1252	2.37	2.3699962	1	100
B014450	HS 20-44	-490.4478	-25.3	-205.5	1.03	1.02559122	3	39.5
B016510	HS 20-44	-531.5088	0	-162.3	1.51	1.50845413	5	31.677
B016111	HS 20-44	-621.0163	-15.5	-207.5	1.33	1.33382828	3	38.458
B016310	HS 20-44	-1253.521	-46	-436.5	1.26	1.25967615	3	61.062
B015295	HS 20-44	2952.362	383	498.2	2.27	2.26930427	1	50
B017909	HS 20-44	-758.6428	0	-623.6	0.56	0.5603655	3	82.417
B015820	HS 20-44	-2692.068	-94.7	-928.7	1.27	1.2741535	3	118.333

Table C2 - 6: Design Inventory Unique Bridge Output, Exterior Girder LFR Part 3



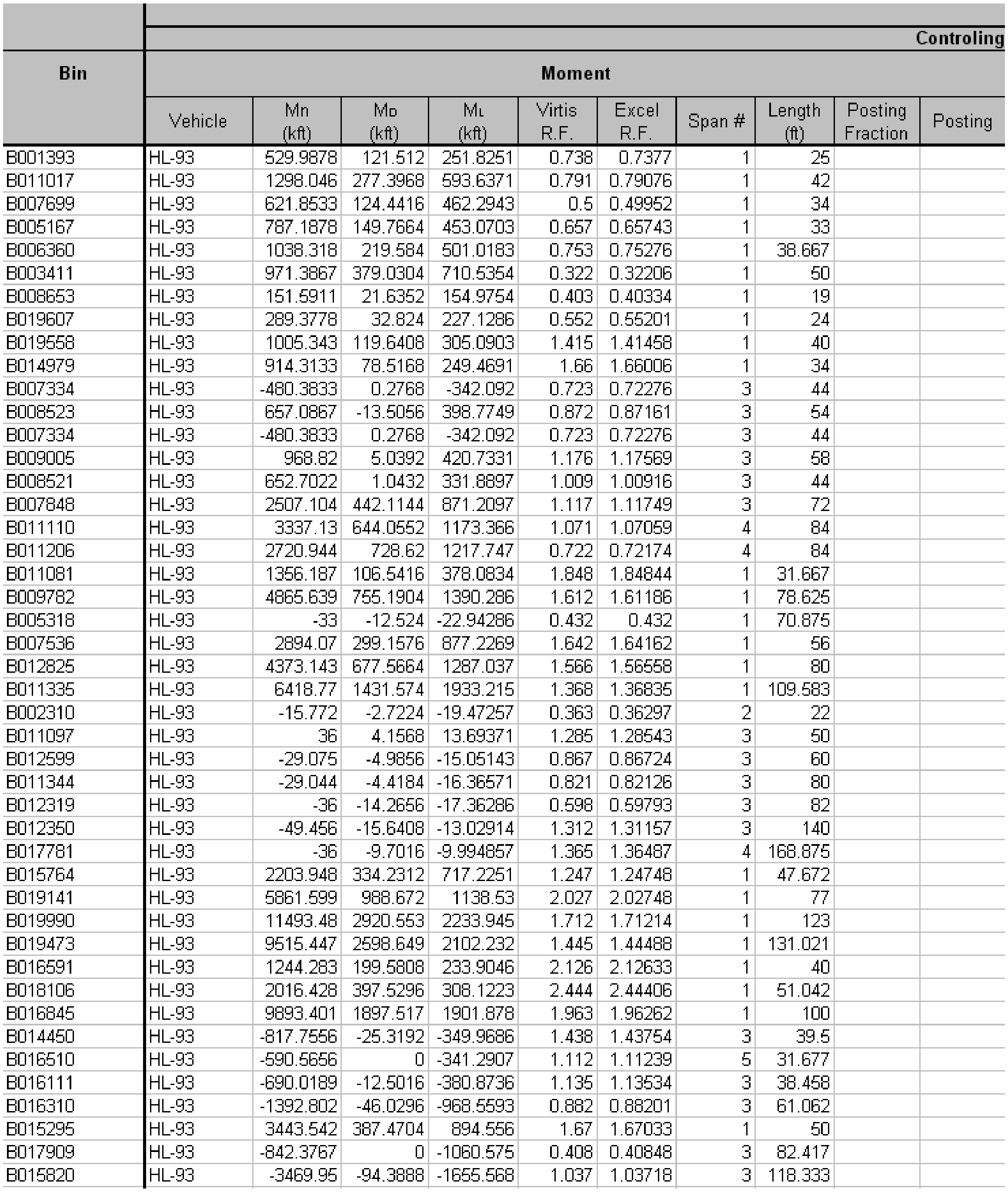
Bin	.F Data							
	Shear							
	Vehicle	V_n (k)	V_D (k)	V_L (k)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
B001393	HS 20-44	110.7059	15.5	17.8	1.92	1.913632	1	25
B011017	HS 20-44	-101.647	-21.1	-39.7	0.68	0.684196	1	42
B007699	HS 20-44	80.23529	8.8	34.9	0.75	0.74913	1	34
B005167	HS 20-44	74.94118	9.9	32.2	0.73	0.727117	1	33
B006360	HS 20-44	99.05882	17.7	36.5	0.78	0.772196	1	38.667
B003411	HS 20-44	130.2353	24.7	33.2	1.09	1.090359	1	50
B008653	HS 20-44	68.23529	3.7	20.7	1.19	1.183586	1	19
B019607	HS 20-44	54.94118	4.4	25.4	0.75	0.743153	1	24
B019558	HS 20-44	93.41176	13.3	29	0.99	0.986515	1	40
B014979	HS 20-44	-1354.59	-9.3	-29.1	19.41	18.03388	1	34
B007334	HS 20-44	91.41176	8.6	29.4	1.05	1.042186	3	44
B008523	HS 20-44	99.41176	15.1	33.3	0.9	0.897304	3	54
B007334	HS 20-44	91.41176	8.6	29.4	1.05	1.042186	3	44
B009005	HS 20-44	137.5294	16.8	47.1	0.92	0.929645	3	58
B008521	HS 20-44	94.47059	6.4	21.8	1.53	1.520882	3	44
B007848	HS 20-44	-179.059	-23.2	-33.8	1.65	1.663128	3	72
B011110	HS 20-44	111.7647	17.6	28.3	1.18	1.173841	4	84
B011206	HS 20-44	193.8824	34	41.4	1.35	1.341798	4	84
B011081	HS 20-44	-425.6	-13.3	-41.6	4.52	4.521025	1	31.667
B009782	HS 20-44	529.7	61.3	52.6	3.94	3.940729	1	78.625
B005318	HS 20-44	422.6	29.6	46.1	3.84	3.838011	1	70.875
B007536	HS 20-44	406.2	18.3	51	3.45	3.453816	1	56
B012825	HS 20-44	542.6	48.5	51	4.33	4.331157	1	80
B011335	HS 20-44	374.2	49.8	49.9	2.86	2.856565	1	109.583
B002310	HS 20-44	-125.9	-6.6	-30.8	1.76	1.754533	2	22
B011097	HS 20-44	-425.6	-24.7	-48.1	3.77	3.768155	3	50
B012599	HS 20-44	-443.3	-20.2	-47.5	4.05	4.044122	3	60
B011344	HS 20-44	-227.7	-21.8	-49.1	1.87	1.870237	3	80
B012319	HS 20-44	369.1	44.7	52.4	2.74	2.733728	3	82
B012350	HS 20-44	262.6	59.9	56.9	1.49	1.495427	3	140
B017781	HS 20-44	163.4	-187.7	-91.1	2.06	2.059935	4	168.875
B015764	HS 20-44	192.826	27.4	46.9	1.36	1.354582	1	47.672
B019141	HS 20-44	-307.379	-48.4	-50.3	1.96	1.957132	1	77
B019990	HS 20-44	-1780.8	-80.1	-46.3	14.9	14.90876	1	123
B019473	HS 20-44	254.0386	81.3	32.6	1.73	1.73713	1	131.021
B016591	HS 20-44	107.6023	15.9	21.6	1.62	1.62436	1	40
B018106	HS 20-44	-136.629	-15.5	-17.2	2.75	2.753417	1	51.042
B016845	HS 20-44	210.1874	30.5	37	1.86	1.861375	1	100
B014450	HS 20-44	132.4859	24.7	48.8	0.82	0.822384	3	39.5
B016510	HS 20-44	-155.917	-20	-38.7	1.36	1.360733	5	31.677
B016111	HS 20-44	-110.26	-15.4	-44.2	0.82	0.825501	3	38.458
B016310	HS 20-44	-157.724	-15.7	-54	1.04	1.036746	3	61.062
B015295	HS 20-44	-1019.13	-30.7	-47.1	8.59	8.579715	1	50
B017909	HS 20-44	117.5627	22.9	34.4	1.03	1.018131	3	82.417
B015820	HS 20-44	200.6305	54.9	41.7	1.2	1.206193	3	118.333

Table C2 - 7: Design Inventory Unique Bridge Output, Interior Girder LRFR Part 1



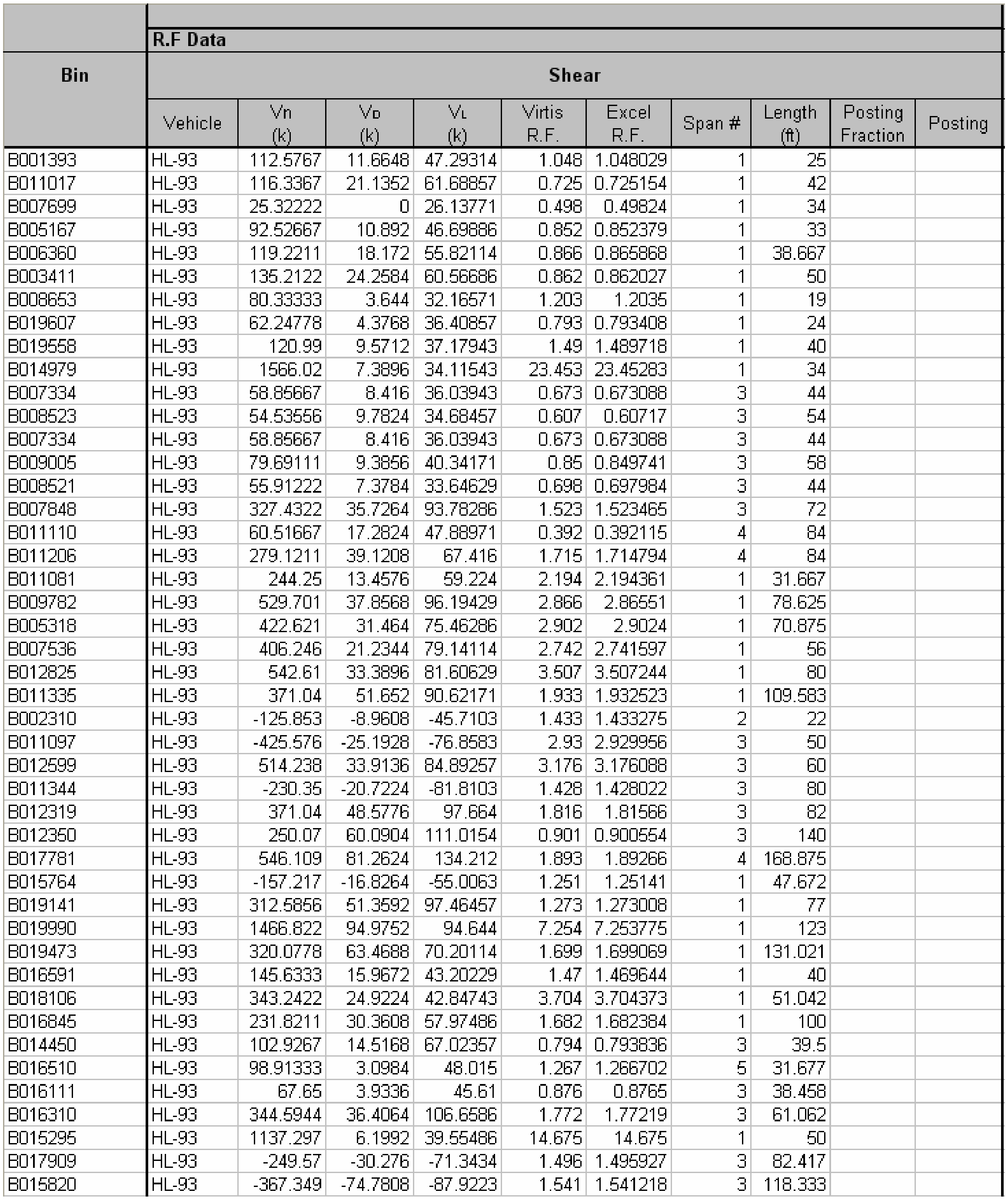
Bin	General Info				LRFR					
	Material Type	Construction Method	Number of Spans	Span Lengths	γ_D	γ_L	ϕ moment	ϕ shear	ϕ_c	ϕ_s
B001393	1	4	1	25'	1.25	1.75	0.9	0.9	1	1
B011017	1	4	1	42'	1.25	1.75	0.9	0.9	1	1
B007699	1	4	1	34'	1.25	1.75	0.9	0.9	1	1
B005167	1	4	1	33'	1.25	1.75	0.9	0.9	1	1
B006360	1	4	1	38.667'	1.25	1.75	0.9	0.9	1	1
B003411	1	4	1	50'	1.25	1.75	0.9	0.9	1	1
B008653	1	22	1	19'	1.25	1.75	0.9	0.9	1	1
B019607	1	22	1	24'	1.25	1.75	0.9	0.9	1	1
B019558	1	22	1	40'	1.25	1.75	0.9	0.9	1	1
B014979	1	22	1	34'	1.25	1.75	0.9	0.9	1	1
B007334	2	4	3	44' 55' 44'	1.25	1.75	0.9	0.9	1	1
B008523	2	4	3	54' 68' 54'	1.25	1.75	0.9	0.9	1	1
B007334	2	4	3	44' 55' 44'	1.25	1.75	0.9	0.9	1	1
B009005	2	4	3	58' 73' 58'	1.25	1.75	0.9	0.9	1	1
B008521	2	4	3	44' 55' 44'	1.25	1.75	0.9	0.9	1	1
B007848	2	4	3	72' 90' 72'	1.25	1.75	0.9	0.9	1	1
B011110	2	4	4	84' 105' 105' 84'	1.25	1.75	0.9	0.9	1	1
B011206	2	2	4	84' 105' 105' 84'	1.25	1.75	0.9	0.9	1	1
B011081	3	2	1	31.667'	1.25	1.75	1	1	1	1
B009782	3	2	1	78.625'	1.25	1.75	1	1	1	1
B005318	3	2	1	70.875'	1.25	1.75	1	1	1	1
B007536	3	2	1	56'	1.25	1.75	1	1	1	1
B012825	3	2	1	80'	1.25	1.75	1	1	1	1
B011335	3	2	1	109.583'	1.25	1.75	1	1	1	1
B002310	4	2	2	22' 22'	1.25	1.75	1	1	1	1
B011097	4	2	3	50' 60' 50'	1.25	1.75	1	1	1	1
B012599	4	2	3	60' 80' 60'	1.25	1.75	1	1	1	1
B011344	4	2	3	70' 109' 80'	1.25	1.75	1	1	1	1
B012319	4	2	3	82' 104' 82'	1.25	1.75	1	1	1	1
B012350	4	2	3	140' 180' 140'	1.25	1.75	1	1	1	1
B017781	4	2	4	168.875' 210' 210' 168.875	1.25	1.75	1	1	1	1
B015764	5	2	1	47.672'	1.25	1.75	0.9	0.9	1	1
B019141	5	2	1	77'	1.25	1.75	0.9	0.9	1	1
B019990	5	2	1	123'	1.25	1.75	0.9	0.9	1	1
B019473	5	2	1	131.021'	1.25	1.75	0.9	0.9	1	1
B016591	5	5	1	40'	1.25	1.75	0.9	0.9	1	1
B018106	5	5	1	51.042'	1.25	1.75	0.9	0.9	1	1
B016845	5	5	1	100'	1.25	1.75	0.9	0.9	1	1
B014450	6	2	3	38.5' 39.5' 39.5'	1.25	1.4	0.9	0.9	1	1
B016510	6	2	5	' 32.802' 32.802' 32.802'	1.25	1.4	0.9	0.9	1	1
B016111	6	2	3	38.458' 39.583' 38.458'	1.25	1.4	0.9	0.9	1	1
B016310	6	2	3	59.25' 61' 61.062'	1.25	1.4	0.9	0.9	1	1
B015295	5	2	1	50'	1.25	1.75	0.9	0.9	1	1
B017909	6	2	3	82.417' 83' 82.417'	1.25	1.75	0.9	0.9	1	1
B015820	6	2	3	118.25' 117.833' 118.333'	1.25	1.75	0.9	0.9	1	1

Table C2 - 8: Design Inventory Unique Bridge Output, Interior Girder LRFR Part 2



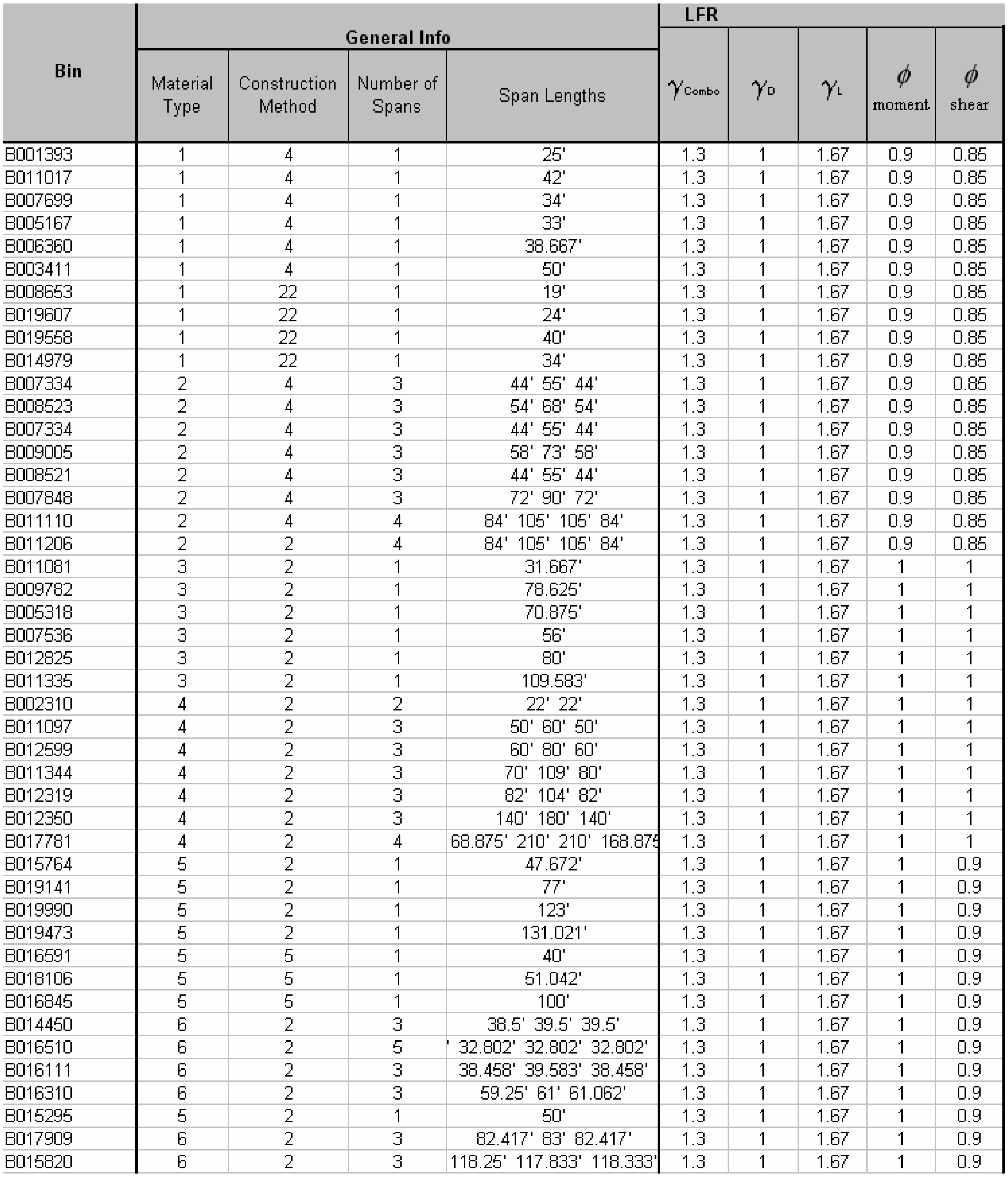
Bin										Controling
	Moment									
	Vehicle	M_n (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)	Posting Fraction	Posting
B001393	HL-93	529.9878	121.512	251.8251	0.738	0.7377	1	25		
B011017	HL-93	1298.046	277.3968	593.6371	0.791	0.79076	1	42		
B007699	HL-93	621.8533	124.4416	462.2943	0.5	0.49952	1	34		
B005167	HL-93	787.1878	149.7664	453.0703	0.657	0.65743	1	33		
B006360	HL-93	1038.318	219.584	501.0183	0.753	0.75276	1	38.667		
B003411	HL-93	971.3867	379.0304	710.5354	0.322	0.32206	1	50		
B008653	HL-93	151.5911	21.6352	154.9754	0.403	0.40334	1	19		
B019607	HL-93	289.3778	32.824	227.1286	0.552	0.55201	1	24		
B019558	HL-93	1005.343	119.6408	305.0903	1.415	1.41458	1	40		
B014979	HL-93	914.3133	78.5168	249.4691	1.66	1.66006	1	34		
B007334	HL-93	-480.3833	0.2768	-342.092	0.723	0.72276	3	44		
B008523	HL-93	657.0867	-13.5056	398.7749	0.872	0.87161	3	54		
B007334	HL-93	-480.3833	0.2768	-342.092	0.723	0.72276	3	44		
B009005	HL-93	968.82	5.0392	420.7331	1.176	1.17569	3	58		
B008521	HL-93	652.7022	1.0432	331.8897	1.009	1.00916	3	44		
B007848	HL-93	2507.104	442.1144	871.2097	1.117	1.11749	3	72		
B011110	HL-93	3337.13	644.0552	1173.366	1.071	1.07059	4	84		
B011206	HL-93	2720.944	728.62	1217.747	0.722	0.72174	4	84		
B011081	HL-93	1356.187	106.5416	378.0834	1.848	1.84844	1	31.667		
B009782	HL-93	4865.639	755.1904	1390.286	1.612	1.61186	1	78.625		
B005318	HL-93	-33	-12.524	-22.94286	0.432	0.432	1	70.875		
B007536	HL-93	2894.07	299.1576	877.2269	1.642	1.64162	1	56		
B012825	HL-93	4373.143	677.5664	1287.037	1.566	1.56558	1	80		
B011335	HL-93	6418.77	1431.574	1933.215	1.368	1.36835	1	109.583		
B002310	HL-93	-15.772	-2.7224	-19.47257	0.363	0.36297	2	22		
B011097	HL-93	36	4.1568	13.69371	1.285	1.28543	3	50		
B012599	HL-93	-29.075	-4.9856	-15.05143	0.867	0.86724	3	60		
B011344	HL-93	-29.044	-4.4184	-16.36571	0.821	0.82126	3	80		
B012319	HL-93	-36	-14.2656	-17.36286	0.598	0.59793	3	82		
B012350	HL-93	-49.456	-15.6408	-13.02914	1.312	1.31157	3	140		
B017781	HL-93	-36	-9.7016	-9.994857	1.365	1.36487	4	168.875		
B015764	HL-93	2203.948	334.2312	717.2251	1.247	1.24748	1	47.672		
B019141	HL-93	5861.599	988.672	1138.53	2.027	2.02748	1	77		
B019990	HL-93	11493.48	2920.553	2233.945	1.712	1.71214	1	123		
B019473	HL-93	9515.447	2598.649	2102.232	1.445	1.44488	1	131.021		
B016591	HL-93	1244.283	199.5808	233.9046	2.126	2.12633	1	40		
B018106	HL-93	2016.428	397.5296	308.1223	2.444	2.44406	1	51.042		
B016845	HL-93	9893.401	1897.517	1901.878	1.963	1.96262	1	100		
B014450	HL-93	-817.7556	-25.3192	-349.9686	1.438	1.43754	3	39.5		
B016510	HL-93	-590.5656	0	-341.2907	1.112	1.11239	5	31.677		
B016111	HL-93	-690.0189	-12.5016	-380.8736	1.135	1.13534	3	38.458		
B016310	HL-93	-1392.802	-46.0296	-968.5593	0.882	0.88201	3	61.062		
B015295	HL-93	3443.542	387.4704	894.556	1.67	1.67033	1	50		
B017909	HL-93	-842.3767	0	-1060.575	0.408	0.40848	3	82.417		
B015820	HL-93	-3469.95	-94.3888	-1655.568	1.037	1.03718	3	118.333		

Table C2 - 9: Design Inventory Unique Bridge Output, Interior Girder LRFR Part 3



Bin	R.F Data									
	Shear									
	Vehicle	V_n (k)	V_D (k)	V_L (k)	Virtis R.F.	Excel R.F.	Span #	Length (ft)	Posting Fraction	Posting
B001393	HL-93	112.5767	11.6648	47.29314	1.048	1.048029	1	25		
B011017	HL-93	116.3367	21.1352	61.68857	0.725	0.725154	1	42		
B007699	HL-93	25.32222	0	26.13771	0.498	0.49824	1	34		
B005167	HL-93	92.52667	10.892	46.69886	0.852	0.852379	1	33		
B006360	HL-93	119.2211	18.172	55.82114	0.866	0.865868	1	38.667		
B003411	HL-93	135.2122	24.2584	60.56686	0.862	0.862027	1	50		
B008653	HL-93	80.33333	3.644	32.16571	1.203	1.2035	1	19		
B019607	HL-93	62.24778	4.3768	36.40857	0.793	0.793408	1	24		
B019558	HL-93	120.99	9.5712	37.17943	1.49	1.489718	1	40		
B014979	HL-93	1566.02	7.3896	34.11543	23.453	23.45283	1	34		
B007334	HL-93	58.85667	8.416	36.03943	0.673	0.673088	3	44		
B008523	HL-93	54.53556	9.7824	34.68457	0.607	0.60717	3	54		
B007334	HL-93	58.85667	8.416	36.03943	0.673	0.673088	3	44		
B009005	HL-93	79.69111	9.3856	40.34171	0.85	0.849741	3	58		
B008521	HL-93	55.91222	7.3784	33.64629	0.698	0.697984	3	44		
B007848	HL-93	327.4322	35.7264	93.78286	1.523	1.523465	3	72		
B011110	HL-93	60.51667	17.2824	47.88971	0.392	0.392115	4	84		
B011206	HL-93	279.1211	39.1208	67.416	1.715	1.714794	4	84		
B011081	HL-93	244.25	13.4576	59.224	2.194	2.194361	1	31.667		
B009782	HL-93	529.701	37.8568	96.19429	2.866	2.86551	1	78.625		
B005318	HL-93	422.621	31.464	75.46286	2.902	2.9024	1	70.875		
B007536	HL-93	406.246	21.2344	79.14114	2.742	2.741597	1	56		
B012825	HL-93	542.61	33.3896	81.60629	3.507	3.507244	1	80		
B011335	HL-93	371.04	51.652	90.62171	1.933	1.932523	1	109.583		
B002310	HL-93	-125.853	-8.9608	-45.7103	1.433	1.433275	2	22		
B011097	HL-93	-425.576	-25.1928	-76.8583	2.93	2.929956	3	50		
B012599	HL-93	514.238	33.9136	84.89257	3.176	3.176088	3	60		
B011344	HL-93	-230.35	-20.7224	-81.8103	1.428	1.428022	3	80		
B012319	HL-93	371.04	48.5776	97.664	1.816	1.81566	3	82		
B012350	HL-93	250.07	60.0904	111.0154	0.901	0.900554	3	140		
B017781	HL-93	546.109	81.2624	134.212	1.893	1.89266	4	168.875		
B015764	HL-93	-157.217	-16.8264	-55.0063	1.251	1.25141	1	47.672		
B019141	HL-93	312.5856	51.3592	97.46457	1.273	1.273008	1	77		
B019990	HL-93	1466.822	94.9752	94.644	7.254	7.253775	1	123		
B019473	HL-93	320.0778	63.4688	70.20114	1.699	1.699069	1	131.021		
B016591	HL-93	145.6333	15.9672	43.20229	1.47	1.469644	1	40		
B018106	HL-93	343.2422	24.9224	42.84743	3.704	3.704373	1	51.042		
B016845	HL-93	231.8211	30.3608	57.97486	1.682	1.682384	1	100		
B014450	HL-93	102.9267	14.5168	67.02357	0.794	0.793836	3	39.5		
B016510	HL-93	98.91333	3.0984	48.015	1.267	1.266702	5	31.677		
B016111	HL-93	67.65	3.9336	45.61	0.876	0.8765	3	38.458		
B016310	HL-93	344.5944	36.4064	106.6586	1.772	1.77219	3	61.062		
B015295	HL-93	1137.297	6.1992	39.55486	14.675	14.675	1	50		
B017909	HL-93	-249.57	-30.276	-71.3434	1.496	1.495927	3	82.417		
B015820	HL-93	-367.349	-74.7808	-87.9223	1.541	1.541218	3	118.333		

Table C2 - 10: Design Inventory Unique Bridge Output, Interior Girder LFR Part 1

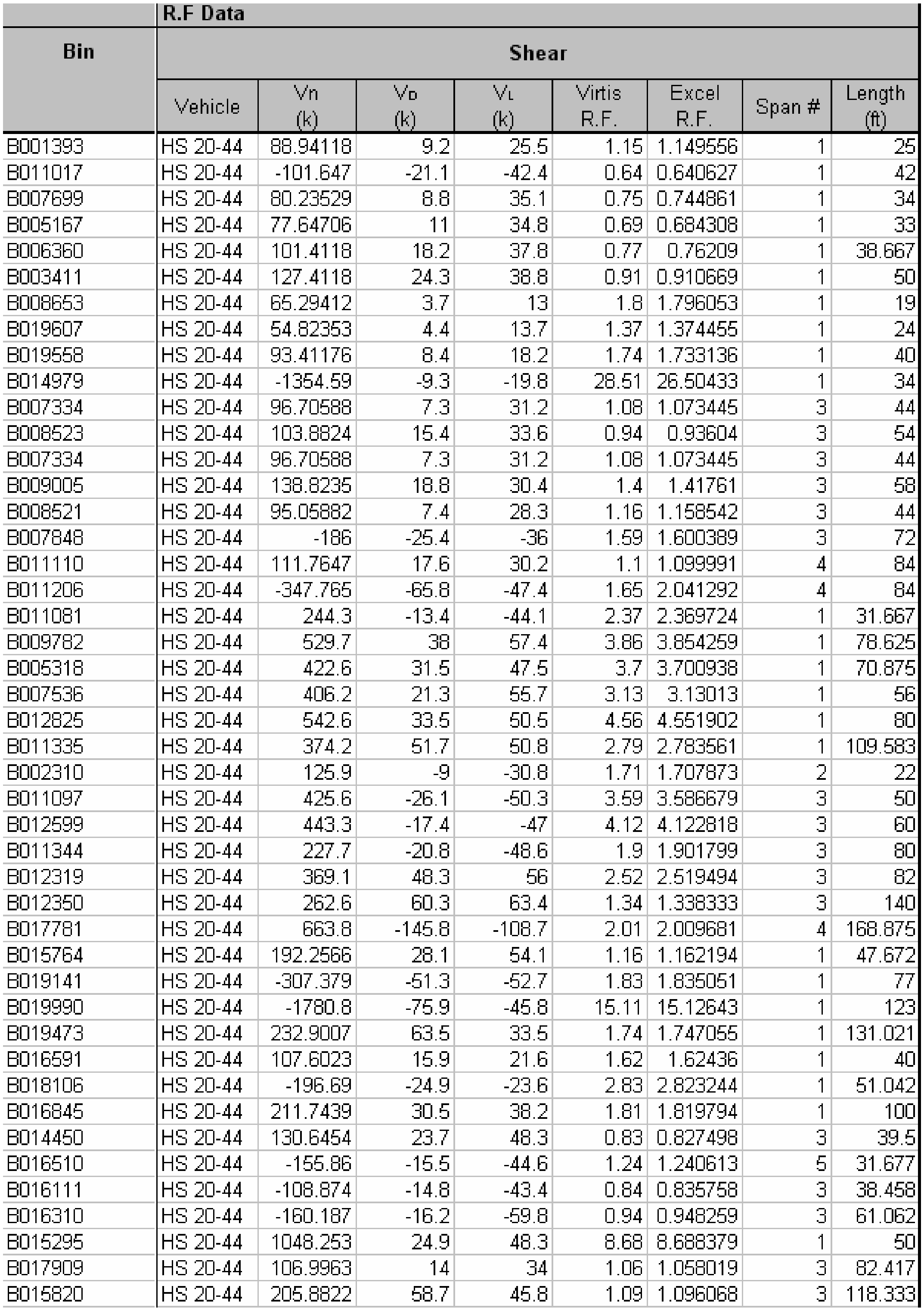


Bin	General Info				LFR				
	Material Type	Construction Method	Number of Spans	Span Lengths	γ_{Combo}	γ_D	γ_L	ϕ moment	ϕ shear
B001393	1	4	1	25'	1.3	1	1.67	0.9	0.85
B011017	1	4	1	42'	1.3	1	1.67	0.9	0.85
B007699	1	4	1	34'	1.3	1	1.67	0.9	0.85
B005167	1	4	1	33'	1.3	1	1.67	0.9	0.85
B006360	1	4	1	38.667'	1.3	1	1.67	0.9	0.85
B003411	1	4	1	50'	1.3	1	1.67	0.9	0.85
B008653	1	22	1	19'	1.3	1	1.67	0.9	0.85
B019607	1	22	1	24'	1.3	1	1.67	0.9	0.85
B019558	1	22	1	40'	1.3	1	1.67	0.9	0.85
B014979	1	22	1	34'	1.3	1	1.67	0.9	0.85
B007334	2	4	3	44' 55' 44'	1.3	1	1.67	0.9	0.85
B008523	2	4	3	54' 68' 54'	1.3	1	1.67	0.9	0.85
B007334	2	4	3	44' 55' 44'	1.3	1	1.67	0.9	0.85
B009005	2	4	3	58' 73' 58'	1.3	1	1.67	0.9	0.85
B008521	2	4	3	44' 55' 44'	1.3	1	1.67	0.9	0.85
B007848	2	4	3	72' 90' 72'	1.3	1	1.67	0.9	0.85
B011110	2	4	4	84' 105' 105' 84'	1.3	1	1.67	0.9	0.85
B011206	2	2	4	84' 105' 105' 84'	1.3	1	1.67	0.9	0.85
B011081	3	2	1	31.667'	1.3	1	1.67	1	1
B009782	3	2	1	78.625'	1.3	1	1.67	1	1
B005318	3	2	1	70.875'	1.3	1	1.67	1	1
B007536	3	2	1	56'	1.3	1	1.67	1	1
B012825	3	2	1	80'	1.3	1	1.67	1	1
B011335	3	2	1	109.583'	1.3	1	1.67	1	1
B002310	4	2	2	22' 22'	1.3	1	1.67	1	1
B011097	4	2	3	50' 60' 50'	1.3	1	1.67	1	1
B012599	4	2	3	60' 80' 60'	1.3	1	1.67	1	1
B011344	4	2	3	70' 109' 80'	1.3	1	1.67	1	1
B012319	4	2	3	82' 104' 82'	1.3	1	1.67	1	1
B012350	4	2	3	140' 180' 140'	1.3	1	1.67	1	1
B017781	4	2	4	68.875' 210' 210' 168.875	1.3	1	1.67	1	1
B015764	5	2	1	47.672'	1.3	1	1.67	1	0.9
B019141	5	2	1	77'	1.3	1	1.67	1	0.9
B019990	5	2	1	123'	1.3	1	1.67	1	0.9
B019473	5	2	1	131.021'	1.3	1	1.67	1	0.9
B016591	5	5	1	40'	1.3	1	1.67	1	0.9
B018106	5	5	1	51.042'	1.3	1	1.67	1	0.9
B016845	5	5	1	100'	1.3	1	1.67	1	0.9
B014450	6	2	3	38.5' 39.5' 39.5'	1.3	1	1.67	1	0.9
B016510	6	2	5	' 32.802' 32.802' 32.802'	1.3	1	1.67	1	0.9
B016111	6	2	3	38.458' 39.583' 38.458'	1.3	1	1.67	1	0.9
B016310	6	2	3	59.25' 61' 61.062'	1.3	1	1.67	1	0.9
B015295	5	2	1	50'	1.3	1	1.67	1	0.9
B017909	6	2	3	82.417' 83' 82.417'	1.3	1	1.67	1	0.9
B015820	6	2	3	118.25' 117.833' 118.333'	1.3	1	1.67	1	0.9

Table C2 - 11: Design Inventory Unique Bridge Output, Interior Girder LFR Part 2

Bin	Controling							
	Moment							
	Vehicle	Mn (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
B001393	HS 20-44	531.3522	91.6	157.2	1.05	1.05232	1	25
B011017	HS 20-44	1298.044	277.4	413.3	0.9	0.90008	1	42
B007699	HS 20-44	621.8533	119.4	316.6	0.59	0.58843	1	34
B005167	HS 20-44	792.0533	143.8	303.4	0.8	0.79843	1	33
B006360	HS 20-44	1038.318	210.8	336.2	0.9	0.90486	1	38.667
B003411	HS 20-44	973.0556	379.1	465	0.38	0.37931	1	50
B008653	HS 20-44	151.5911	21.6	57.6	0.87	0.86647	1	19
B019607	HS 20-44	289.3778	32.8	67.6	1.48	1.48406	1	24
B019558	HS 20-44	1005.342	100.2	168.6	2.12	2.11607	1	40
B014979	HS 20-44	914.3122	75.4	130.4	2.56	2.56046	1	34
B007334	HS 20-44	-480.3778	0.1	-212.2	0.94	0.93875	3	44
B008523	HS 20-44	1383.033	195.8	369.3	1.23	1.23504	3	54
B007334	HS 20-44	-480.3778	0.1	-212.2	0.94	0.93875	3	44
B009005	HS 20-44	968.8189	5.1	270.4	1.47	1.47402	3	58
B008521	HS 20-44	652.7011	32.2	221.5	1.13	1.13453	3	44
B007848	HS 20-44	2520.844	441.8	652.4	1.2	1.19632	3	72
B011110	HS 20-44	3337.122	641.7	802.9	1.24	1.24445	4	84
B011206	HS 20-44	2730.322	728.1	799.2	0.87	0.87072	4	84
B011081	HS 20-44	1357	102.4	267	2.11	2.11139	1	31.667
B009782	HS 20-44	5020	757.1	1025.6	1.81	1.81254	1	78.625
B005318	HS 20-44	1716	558.4	754.9	0.6	0.60412	1	70.875
B007536	HS 20-44	2936.4	299.7	675.7	1.74	1.73612	1	56
B012825	HS 20-44	4402.5	678.9	922	1.76	1.7585	1	80
B011335	HS 20-44	6597.9	1431.3	1302.8	1.67	1.67489	1	109.583
B002310	HS 20-44	270.1	-39.4	-89.6	1.12	1.65185	2	22
B011097	HS 20-44	1527	149.1	411.3	1.49	1.49302	3	50
B012599	HS 20-44	1513	182	517.7	1.14	1.13566	3	60
B011344	HS 20-44	2212.8	271.6	724.3	1.18	1.18269	3	80
B012319	HS 20-44	-2322	-817.6	-657.1	0.88	0.88262	3	82
B012350	HS 20-44	-11863.2	-3651.1	-2205.7	1.49	1.4862	3	140
B017781	HS 20-44	-19796.5	-5333.7	-3743.5	1.58	1.58268	4	168.875
B015764	HS 20-44	2003.721	334.2	543.7	1.33	1.32946	1	47.672
B019141	HS 20-44	5287.595	988.7	922.2	2	1.99905	1	77
B019990	HS 20-44	10344.17	2920.8	1482.2	2.03	2.03462	1	123
B019473	HS 20-44	10028.35	2598.7	1202.4	2.55	2.54751	1	131.021
B016591	HS 20-44	1112.73	191.3	200	1.99	1.98996	1	40
B018106	HS 20-44	1834.846	396.9	290.7	2.09	2.08977	1	51.042
B016845	HS 20-44	8914.598	1897.9	1294.8	2.29	2.2936	1	100
B014450	HS 20-44	-735.9802	-25.3	-203.5	1.59	1.59143	3	39.5
B016510	HS 20-44	-531.5088	0	-187.3	1.31	1.30711	5	31.677
B016111	HS 20-44	-621.0163	-15.5	-203.5	1.36	1.36005	3	38.458
B016310	HS 20-44	-1253.521	-46	-482.9	1.14	1.13864	3	61.062
B015295	HS 20-44	3082.667	387.5	579.7	2.05	2.04915	1	50
B017909	HS 20-44	-758.1387	0	-617.2	0.57	0.5658	3	82.417
B015820	HS 20-44	-2692.068	-94.5	-1018.5	1.16	1.16193	3	118.333

Table C2 - 12: Design Inventory Unique Bridge Output, Interior Girder LFR Part 3



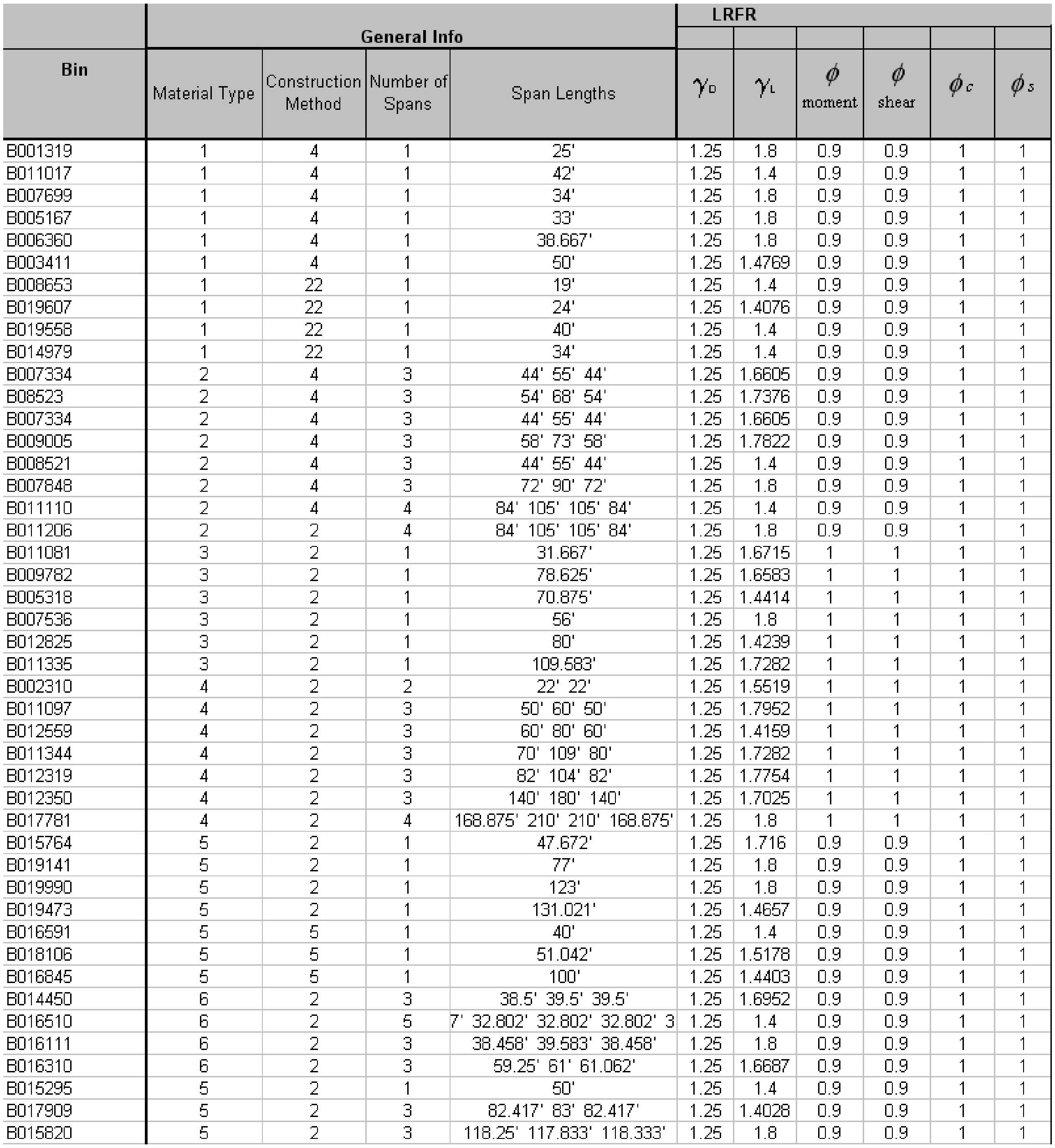
Bin	R.F Data							
	Shear							
	Vehicle	V_n (k)	V_D (k)	V_L (k)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
B001393	HS 20-44	88.94118	9.2	25.5	1.15	1.149556	1	25
B011017	HS 20-44	-101.647	-21.1	-42.4	0.64	0.640627	1	42
B007699	HS 20-44	80.23529	8.8	35.1	0.75	0.744861	1	34
B005167	HS 20-44	77.64706	11	34.8	0.69	0.684308	1	33
B006360	HS 20-44	101.4118	18.2	37.8	0.77	0.76209	1	38.667
B003411	HS 20-44	127.4118	24.3	38.8	0.91	0.910669	1	50
B008653	HS 20-44	65.29412	3.7	13	1.8	1.796053	1	19
B019607	HS 20-44	54.82353	4.4	13.7	1.37	1.374455	1	24
B019558	HS 20-44	93.41176	8.4	18.2	1.74	1.733136	1	40
B014979	HS 20-44	-1354.59	-9.3	-19.8	28.51	26.50433	1	34
B007334	HS 20-44	96.70588	7.3	31.2	1.08	1.073445	3	44
B008523	HS 20-44	103.8824	15.4	33.6	0.94	0.93604	3	54
B007334	HS 20-44	96.70588	7.3	31.2	1.08	1.073445	3	44
B009005	HS 20-44	138.8235	18.8	30.4	1.4	1.41761	3	58
B008521	HS 20-44	95.05882	7.4	28.3	1.16	1.158542	3	44
B007848	HS 20-44	-186	-25.4	-36	1.59	1.600389	3	72
B011110	HS 20-44	111.7647	17.6	30.2	1.1	1.099991	4	84
B011206	HS 20-44	-347.765	-65.8	-47.4	1.65	2.041292	4	84
B011081	HS 20-44	244.3	-13.4	-44.1	2.37	2.369724	1	31.667
B009782	HS 20-44	529.7	38	57.4	3.86	3.854259	1	78.625
B005318	HS 20-44	422.6	31.5	47.5	3.7	3.700938	1	70.875
B007536	HS 20-44	406.2	21.3	55.7	3.13	3.13013	1	56
B012825	HS 20-44	542.6	33.5	50.5	4.56	4.551902	1	80
B011335	HS 20-44	374.2	51.7	50.8	2.79	2.783561	1	109.583
B002310	HS 20-44	125.9	-9	-30.8	1.71	1.707873	2	22
B011097	HS 20-44	425.6	-26.1	-50.3	3.59	3.586679	3	50
B012599	HS 20-44	443.3	-17.4	-47	4.12	4.122818	3	60
B011344	HS 20-44	227.7	-20.8	-48.6	1.9	1.901799	3	80
B012319	HS 20-44	369.1	48.3	56	2.52	2.519494	3	82
B012350	HS 20-44	262.6	60.3	63.4	1.34	1.338333	3	140
B017781	HS 20-44	663.8	-145.8	-108.7	2.01	2.009681	4	168.875
B015764	HS 20-44	192.2566	28.1	54.1	1.16	1.162194	1	47.672
B019141	HS 20-44	-307.379	-51.3	-52.7	1.83	1.835051	1	77
B019990	HS 20-44	-1780.8	-75.9	-45.8	15.11	15.12643	1	123
B019473	HS 20-44	232.9007	63.5	33.5	1.74	1.747055	1	131.021
B016591	HS 20-44	107.6023	15.9	21.6	1.62	1.62436	1	40
B018106	HS 20-44	-196.69	-24.9	-23.6	2.83	2.823244	1	51.042
B016845	HS 20-44	211.7439	30.5	38.2	1.81	1.819794	1	100
B014450	HS 20-44	130.6454	23.7	48.3	0.83	0.827498	3	39.5
B016510	HS 20-44	-155.86	-15.5	-44.6	1.24	1.240613	5	31.677
B016111	HS 20-44	-108.874	-14.8	-43.4	0.84	0.835758	3	38.458
B016310	HS 20-44	-160.187	-16.2	-59.8	0.94	0.948259	3	61.062
B015295	HS 20-44	1048.253	24.9	48.3	8.68	8.688379	1	50
B017909	HS 20-44	106.9963	14	34	1.06	1.058019	3	82.417
B015820	HS 20-44	205.8822	58.7	45.8	1.09	1.096068	3	118.333

APPENDIX D: ALDOT Legal Load Rating Data

Presented in this appendix is the extracted data from Virtis for the unique bridge sample at the Legal load level for the LRFR under the controlling ALDOT legal load and the Operating level of the LFR under the controlling ALDOT legal load. Tables C.1 - 1 through C.1 - 12 provide the following information: BIN, Material Type, Structural Type, Number of Spans, Span Length, Dead Load Factors, Live Load Factors, Resistance Factors, Condition Factor, System Factor, Controlling Vehicle, Unfactored Capacity, Unfactored Dead Load, Unfactored Live Load, Virtis Rating Factor, and Excel Calculated Rating Factor. The Excel rating factor is calculated using the provided information and the rating methodologies rating equation as provided in Chapter 2.

Table D - 1: Legal Load Level Unique Bridge Output, Exterior Girder Flexure, LRFR

Part 1



	General Info				LRFR					
Bin	Material Type	Construction Method	Number of Spans	Span Lengths	γ_D	γ_L	ϕ moment	ϕ shear	ϕ_c	ϕ_s
B001319	1	4	1	25'	1.25	1.8	0.9	0.9	1	1
B011017	1	4	1	42'	1.25	1.4	0.9	0.9	1	1
B007699	1	4	1	34'	1.25	1.8	0.9	0.9	1	1
B005167	1	4	1	33'	1.25	1.8	0.9	0.9	1	1
B006360	1	4	1	38.667'	1.25	1.8	0.9	0.9	1	1
B003411	1	4	1	50'	1.25	1.4769	0.9	0.9	1	1
B008653	1	22	1	19'	1.25	1.4	0.9	0.9	1	1
B019607	1	22	1	24'	1.25	1.4076	0.9	0.9	1	1
B019558	1	22	1	40'	1.25	1.4	0.9	0.9	1	1
B014979	1	22	1	34'	1.25	1.4	0.9	0.9	1	1
B007334	2	4	3	44' 55' 44'	1.25	1.6605	0.9	0.9	1	1
B08523	2	4	3	54' 68' 54'	1.25	1.7376	0.9	0.9	1	1
B007334	2	4	3	44' 55' 44'	1.25	1.6605	0.9	0.9	1	1
B009005	2	4	3	58' 73' 58'	1.25	1.7822	0.9	0.9	1	1
B008521	2	4	3	44' 55' 44'	1.25	1.4	0.9	0.9	1	1
B007848	2	4	3	72' 90' 72'	1.25	1.8	0.9	0.9	1	1
B011110	2	4	4	84' 105' 105' 84'	1.25	1.4	0.9	0.9	1	1
B011206	2	2	4	84' 105' 105' 84'	1.25	1.8	0.9	0.9	1	1
B011081	3	2	1	31.667'	1.25	1.6715	1	1	1	1
B009782	3	2	1	78.625'	1.25	1.6583	1	1	1	1
B005318	3	2	1	70.875'	1.25	1.4414	1	1	1	1
B007536	3	2	1	56'	1.25	1.8	1	1	1	1
B012825	3	2	1	80'	1.25	1.4239	1	1	1	1
B011335	3	2	1	109.583'	1.25	1.7282	1	1	1	1
B002310	4	2	2	22' 22'	1.25	1.5519	1	1	1	1
B011097	4	2	3	50' 60' 50'	1.25	1.7952	1	1	1	1
B012559	4	2	3	60' 80' 60'	1.25	1.4159	1	1	1	1
B011344	4	2	3	70' 109' 80'	1.25	1.7282	1	1	1	1
B012319	4	2	3	82' 104' 82'	1.25	1.7754	1	1	1	1
B012350	4	2	3	140' 180' 140'	1.25	1.7025	1	1	1	1
B017781	4	2	4	168.875' 210' 210' 168.875'	1.25	1.8	1	1	1	1
B015764	5	2	1	47.672'	1.25	1.716	0.9	0.9	1	1
B019141	5	2	1	77'	1.25	1.8	0.9	0.9	1	1
B019990	5	2	1	123'	1.25	1.8	0.9	0.9	1	1
B019473	5	2	1	131.021'	1.25	1.4657	0.9	0.9	1	1
B016591	5	5	1	40'	1.25	1.4	0.9	0.9	1	1
B018106	5	5	1	51.042'	1.25	1.5178	0.9	0.9	1	1
B016845	5	5	1	100'	1.25	1.4403	0.9	0.9	1	1
B014450	6	2	3	38.5' 39.5' 39.5'	1.25	1.6952	0.9	0.9	1	1
B016510	6	2	5	7' 32.802' 32.802' 32.802' 3	1.25	1.4	0.9	0.9	1	1
B016111	6	2	3	38.458' 39.583' 38.458'	1.25	1.8	0.9	0.9	1	1
B016310	6	2	3	59.25' 61' 61.062'	1.25	1.6687	0.9	0.9	1	1
B015295	5	2	1	50'	1.25	1.4	0.9	0.9	1	1
B017909	5	2	3	82.417' 83' 82.417'	1.25	1.4028	0.9	0.9	1	1
B015820	5	2	3	118.25' 117.833' 118.333'	1.25	1.8	0.9	0.9	1	1

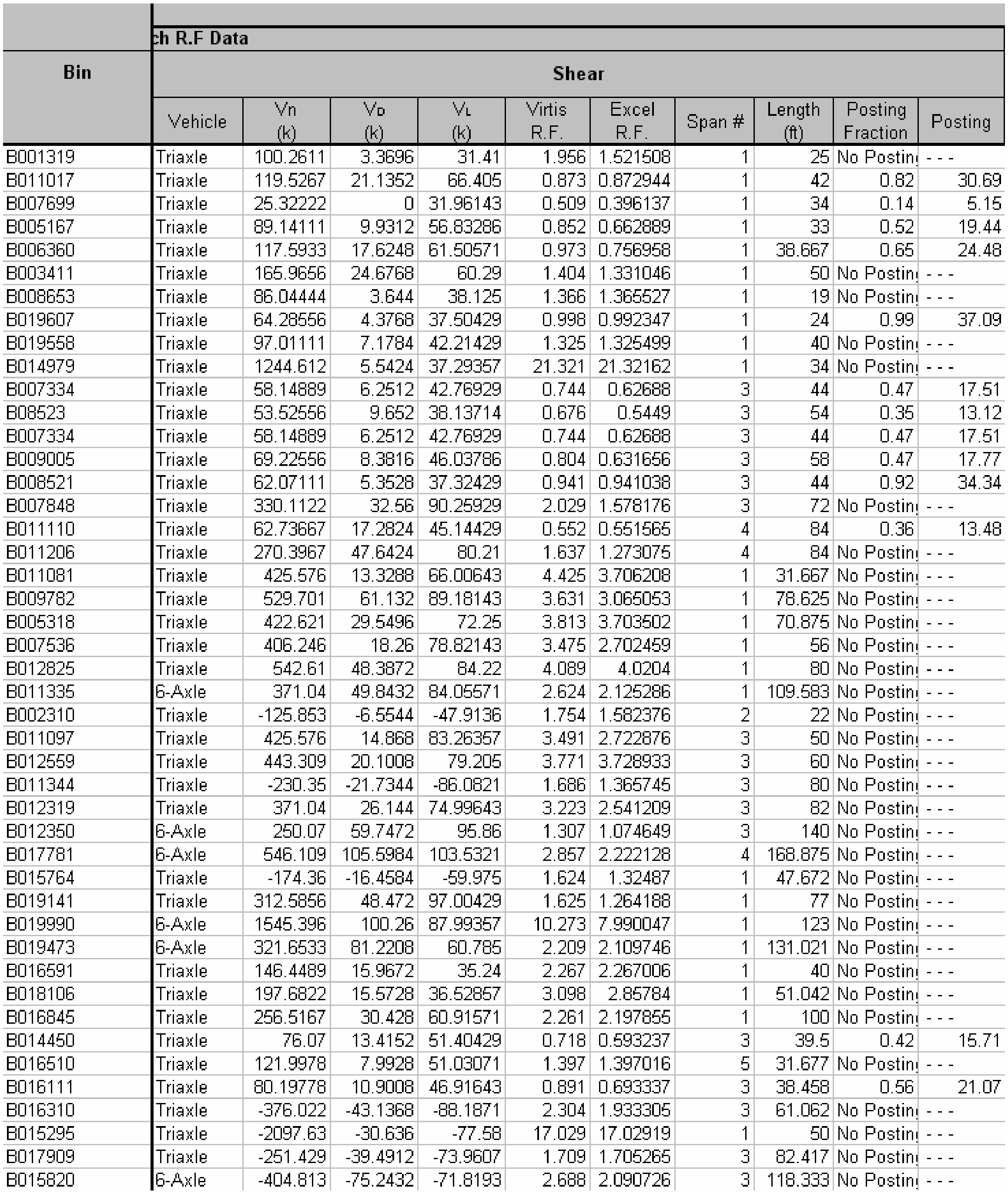
Table D - 2: Legal Load Level Unique Bridge Output, Exterior Girder Flexure, LRFR

Part 2

Bin	Controling Ve									
	Moment									
	Vehicle	M_n (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)	Posting Fraction	Posting (Tons)
B001319	Triaxle	661.5044	105.3008	267.4193	1.239	0.96338	1	25	0.95	35.54
B011017	Triaxle	1298.046	277.3968	724.6029	0.81	0.8098	1	42	0.73	27.31
B007699	Triaxle	621.8533	124.4416	606.0179	0.476	0.37047	1	34	0.10	3.77
B005167	Triaxle	757.9378	136.5512	544.9014	0.67	0.52146	1	33	0.32	11.86
B006360	Triaxle	1090.107	212.9664	605.5714	0.843	0.65584	1	38.667	0.51	19.06
B003411	Triaxle	1269.198	385.5752	787.4257	0.599	0.56777	1	50	0.38	14.34
B008653	Triaxle	151.5911	21.6352	185.9421	0.42	0.42021	1	19	0.17	6.44
B019607	Triaxle	289.3778	32.824	271.83	0.577	0.57344	1	24	0.39	14.65
B019558	Triaxle	1005.343	119.6408	498.3614	1.082	1.08249	1	40	No Posting	- - -
B014979	Triaxle	914.3133	78.5168	367.755	1.408	1.40765	1	34	No Posting	- - -
B007334	Triaxle	616.4856	30.4264	428.8107	0.861	0.72581	3	44	0.61	22.81
B08523	Triaxle	635.2189	-14.296	441.345	0.954	0.76881	3	54	0.67	25.11
B007334	Triaxle	616.4856	30.4264	428.8107	0.861	0.72581	3	44	0.61	22.81
B009005	Triaxle	949.8122	4.4072	688.3707	0.881	0.69231	3	58	0.56	21.02
B008521	Triaxle	628.2044	28.072	376.9193	1.005	1.00494	3	44	No Posting	- - -
B007848	Triaxle	2417.178	402.4464	960.8364	1.243	0.96698	3	72	0.95	35.73
B011110	Triaxle	3337.13	644.0552	1330.708	1.18	1.18001	4	84	No Posting	- - -
B011206	Triaxle	2720.944	683.1408	1297.037	0.878	0.68315	4	84	0.55	20.53
B011081	Triaxle	2369.555	105.5192	484.6921	3.298	2.76191	1	31.667	No Posting	- - -
B009782	Triaxle	4865.639	1210.936	1536.247	1.559	1.31577	1	78.625	No Posting	- - -
B005318	Triaxle	-33	-11.7616	-27.30929	0.479	0.46485	1	70.875	0.24	8.83
B007536	Triaxle	2894.07	257.5072	1028.649	1.786	1.38919	1	56	No Posting	- - -
B012825	Triaxle	4373.4	976.024	1609.674	1.399	1.37582	1	80	No Posting	- - -
B011335	Triaxle	6418.77	1382.022	2227.83	1.504	1.21844	1	109.583	No Posting	- - -
B002310	Triaxle	-15.772	-1.9912	-21.41286	0.443	0.39972	2	22	0.14	5.34
B011097	Triaxle	36	3.9248	17.245	1.288	1.00441	3	50	No Posting	- - -
B012559	Triaxle	-29.075	-5.7736	-21.26857	0.734	0.72584	3	60	0.61	22.81
B011344	Triaxle	-29.044	-4.6344	-20.89714	0.795	0.6438	3	80	0.49	18.42
B012319	6-Axle	-36	-13.208	-10.12	1.376	1.08476	3	82	No Posting	- - -
B012350	Triaxle	10839.76	1446.001	2655.87	2.429	1.99755	3	140	No Posting	- - -
B017781	Triaxle	17141.84	3154.178	3528.418	2.672	2.07822	4	168.875	No Posting	- - -
B015764	Triaxle	2203.948	326.9072	849.4429	1.324	1.08046	1	47.672	No Posting	- - -
B019141	Triaxle	5861.599	933.084	1378.384	2.129	1.65616	1	77	No Posting	- - -
B019990	Triaxle	11493.48	3083.074	2600.607	1.783	1.38649	1	123	No Posting	- - -
B019473	Triaxle	10038.95	3325.485	2027.931	1.718	1.64121	1	131.021	No Posting	- - -
B016591	Triaxle	1244.283	199.5808	358.7886	1.733	1.73277	1	40	No Posting	- - -
B018106	Triaxle	2016.428	496.7896	497.1714	1.715	1.58201	1	51.042	No Posting	- - -
B016845	Triaxle	9893.401	1901.746	2173.228	2.145	2.08523	1	100	No Posting	- - -
B014450	Triaxle	-544.9422	-25.3192	-343.5279	0.954	0.78786	3	39.5	0.70	26.14
B016510	Triaxle	1033.63	151.9248	414.0821	1.277	1.27711	5	31.677	No Posting	- - -
B016111	6-Axle	-690.0189	-12.5016	-347.3843	1.245	0.96817	3	38.458	0.95	40.09
B016310	Triaxle	-1392.802	-46.0296	-610.6243	1.399	1.17375	3	61.062	No Posting	- - -
B015295	Triaxle	3300.698	382.9536	894.8071	1.989	1.9892	1	50	No Posting	- - -
B017909	Triaxle	-842.9367	0	-755.5914	0.717	0.71575	3	82.417	0.59	22.27
B015820	6-Axle	-3231.274	-94.5112	-976.5479	2.041	1.58723	3	118.333	No Posting	- - -

Table D - 3: Legal Load Level Unique Bridge Output, Exterior Girder Flexure, LRFR

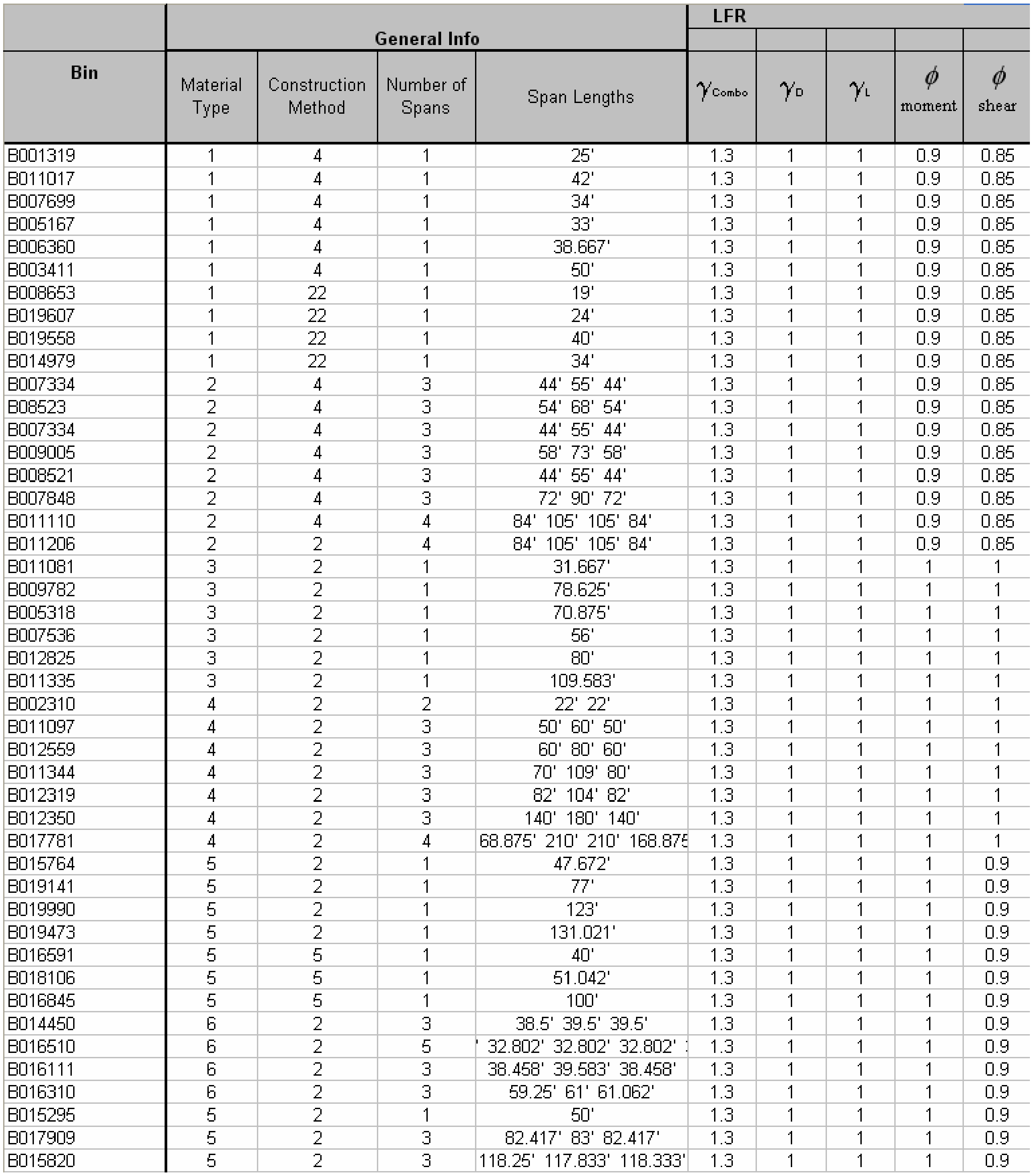
Part 3



Bin	ch R.F Data									
	Shear									
	Vehicle	V_n (k)	V_D (k)	V_L (k)	Virtis R.F.	Excel R.F.	Span #	Length (ft)	Posting Fraction	Posting
B001319	Triaxle	100.2611	3.3696	31.41	1.956	1.521508	1	25	No Postin	- - -
B011017	Triaxle	119.5267	21.1352	66.405	0.873	0.872944	1	42	0.82	30.69
B007699	Triaxle	25.32222	0	31.96143	0.509	0.396137	1	34	0.14	5.15
B005167	Triaxle	89.14111	9.9312	56.83286	0.852	0.662889	1	33	0.52	19.44
B006360	Triaxle	117.5933	17.6248	61.50571	0.973	0.756958	1	38.667	0.65	24.48
B003411	Triaxle	165.9656	24.6768	60.29	1.404	1.331046	1	50	No Postin	- - -
B008653	Triaxle	86.04444	3.644	38.125	1.366	1.365527	1	19	No Postin	- - -
B019607	Triaxle	64.28556	4.3768	37.50429	0.998	0.992347	1	24	0.99	37.09
B019558	Triaxle	97.01111	7.1784	42.21429	1.325	1.325499	1	40	No Postin	- - -
B014979	Triaxle	1244.612	5.5424	37.29357	21.321	21.32162	1	34	No Postin	- - -
B007334	Triaxle	58.14889	6.2512	42.76929	0.744	0.62688	3	44	0.47	17.51
B08523	Triaxle	53.52556	9.652	38.13714	0.676	0.5449	3	54	0.35	13.12
B007334	Triaxle	58.14889	6.2512	42.76929	0.744	0.62688	3	44	0.47	17.51
B009005	Triaxle	69.22556	8.3816	46.03786	0.804	0.631656	3	58	0.47	17.77
B008521	Triaxle	62.07111	5.3528	37.32429	0.941	0.941038	3	44	0.92	34.34
B007848	Triaxle	330.1122	32.56	90.25929	2.029	1.578176	3	72	No Postin	- - -
B011110	Triaxle	62.73667	17.2824	45.14429	0.552	0.551565	4	84	0.36	13.48
B011206	Triaxle	270.3967	47.6424	80.21	1.637	1.273075	4	84	No Postin	- - -
B011081	Triaxle	425.576	13.3288	66.00643	4.425	3.706208	1	31.667	No Postin	- - -
B009782	Triaxle	529.701	61.132	89.18143	3.631	3.065053	1	78.625	No Postin	- - -
B005318	Triaxle	422.621	29.5496	72.25	3.813	3.703502	1	70.875	No Postin	- - -
B007536	Triaxle	406.246	18.26	78.82143	3.475	2.702459	1	56	No Postin	- - -
B012825	Triaxle	542.61	48.3872	84.22	4.089	4.0204	1	80	No Postin	- - -
B011335	6-Axle	371.04	49.8432	84.05571	2.624	2.125286	1	109.583	No Postin	- - -
B002310	Triaxle	-125.853	-6.5544	-47.9136	1.754	1.582376	2	22	No Postin	- - -
B011097	Triaxle	425.576	14.868	83.26357	3.491	2.722876	3	50	No Postin	- - -
B012559	Triaxle	443.309	20.1008	79.205	3.771	3.728933	3	60	No Postin	- - -
B011344	Triaxle	-230.35	-21.7344	-86.0821	1.686	1.365745	3	80	No Postin	- - -
B012319	Triaxle	371.04	26.144	74.99643	3.223	2.541209	3	82	No Postin	- - -
B012350	6-Axle	250.07	59.7472	95.86	1.307	1.074649	3	140	No Postin	- - -
B017781	6-Axle	546.109	105.5984	103.5321	2.857	2.222128	4	168.875	No Postin	- - -
B015764	Triaxle	-174.36	-16.4584	-59.975	1.624	1.32487	1	47.672	No Postin	- - -
B019141	Triaxle	312.5856	48.472	97.00429	1.625	1.264188	1	77	No Postin	- - -
B019990	6-Axle	1545.396	100.26	87.99357	10.273	7.990047	1	123	No Postin	- - -
B019473	6-Axle	321.6533	81.2208	60.785	2.209	2.109746	1	131.021	No Postin	- - -
B016591	Triaxle	146.4489	15.9672	35.24	2.267	2.267006	1	40	No Postin	- - -
B018106	Triaxle	197.6822	15.5728	36.52857	3.098	2.85784	1	51.042	No Postin	- - -
B016845	Triaxle	256.5167	30.428	60.91571	2.261	2.197855	1	100	No Postin	- - -
B014450	Triaxle	76.07	13.4152	51.40429	0.718	0.593237	3	39.5	0.42	15.71
B016510	Triaxle	121.9978	7.9928	51.03071	1.397	1.397016	5	31.677	No Postin	- - -
B016111	Triaxle	80.19778	10.9008	46.91643	0.891	0.693337	3	38.458	0.56	21.07
B016310	Triaxle	-376.022	-43.1368	-88.1871	2.304	1.933305	3	61.062	No Postin	- - -
B015295	Triaxle	-2097.63	-30.636	-77.58	17.029	17.02919	1	50	No Postin	- - -
B017909	Triaxle	-251.429	-39.4912	-73.9607	1.709	1.705265	3	82.417	No Postin	- - -
B015820	6-Axle	-404.813	-75.2432	-71.8193	2.688	2.090726	3	118.333	No Postin	- - -

Table D - 4: Legal Load Level Unique Bridge Output, Exterior Girder Flexure, LFR

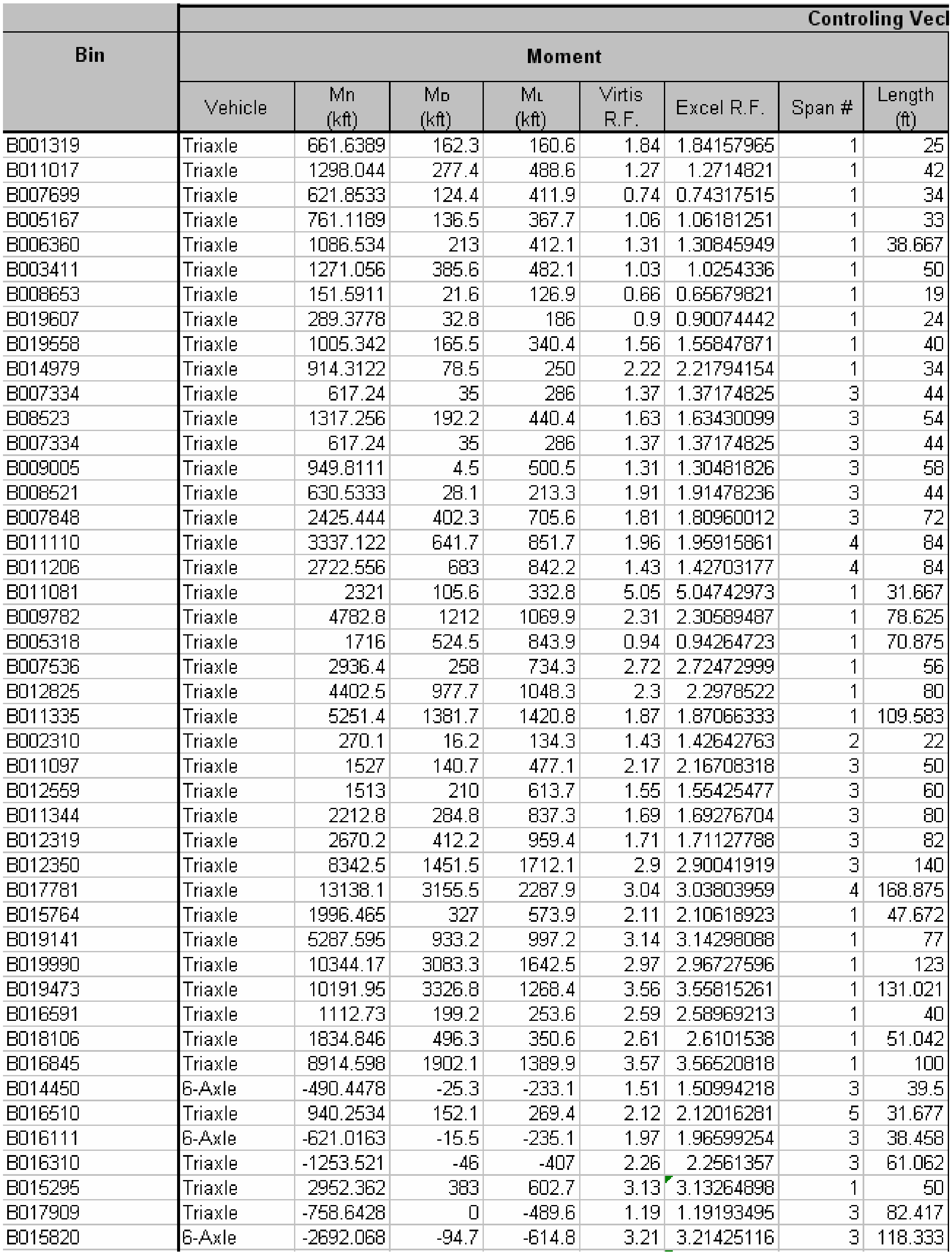
Part 1



Bin	General Info				LFR				
	Material Type	Construction Method	Number of Spans	Span Lengths	γ_{Combo}	γ_D	γ_L	ϕ moment	ϕ shear
B001319	1	4	1	25'	1.3	1	1	0.9	0.85
B011017	1	4	1	42'	1.3	1	1	0.9	0.85
B007699	1	4	1	34'	1.3	1	1	0.9	0.85
B005167	1	4	1	33'	1.3	1	1	0.9	0.85
B006360	1	4	1	38.667'	1.3	1	1	0.9	0.85
B003411	1	4	1	50'	1.3	1	1	0.9	0.85
B008653	1	22	1	19'	1.3	1	1	0.9	0.85
B019607	1	22	1	24'	1.3	1	1	0.9	0.85
B019558	1	22	1	40'	1.3	1	1	0.9	0.85
B014979	1	22	1	34'	1.3	1	1	0.9	0.85
B007334	2	4	3	44' 55' 44'	1.3	1	1	0.9	0.85
B08523	2	4	3	54' 68' 54'	1.3	1	1	0.9	0.85
B007334	2	4	3	44' 55' 44'	1.3	1	1	0.9	0.85
B009005	2	4	3	58' 73' 58'	1.3	1	1	0.9	0.85
B008521	2	4	3	44' 55' 44'	1.3	1	1	0.9	0.85
B007848	2	4	3	72' 90' 72'	1.3	1	1	0.9	0.85
B011110	2	4	4	84' 105' 105' 84'	1.3	1	1	0.9	0.85
B011206	2	2	4	84' 105' 105' 84'	1.3	1	1	0.9	0.85
B011081	3	2	1	31.667'	1.3	1	1	1	1
B009782	3	2	1	78.625'	1.3	1	1	1	1
B005318	3	2	1	70.875'	1.3	1	1	1	1
B007536	3	2	1	56'	1.3	1	1	1	1
B012825	3	2	1	80'	1.3	1	1	1	1
B011335	3	2	1	109.583'	1.3	1	1	1	1
B002310	4	2	2	22' 22'	1.3	1	1	1	1
B011097	4	2	3	50' 60' 50'	1.3	1	1	1	1
B012559	4	2	3	60' 80' 60'	1.3	1	1	1	1
B011344	4	2	3	70' 109' 80'	1.3	1	1	1	1
B012319	4	2	3	82' 104' 82'	1.3	1	1	1	1
B012350	4	2	3	140' 180' 140'	1.3	1	1	1	1
B017781	4	2	4	68.875' 210' 210' 168.875	1.3	1	1	1	1
B015764	5	2	1	47.672'	1.3	1	1	1	0.9
B019141	5	2	1	77'	1.3	1	1	1	0.9
B019990	5	2	1	123'	1.3	1	1	1	0.9
B019473	5	2	1	131.021'	1.3	1	1	1	0.9
B016591	5	5	1	40'	1.3	1	1	1	0.9
B018106	5	5	1	51.042'	1.3	1	1	1	0.9
B016845	5	5	1	100'	1.3	1	1	1	0.9
B014450	6	2	3	38.5' 39.5' 39.5'	1.3	1	1	1	0.9
B016510	6	2	5	' 32.802' 32.802' 32.802'	1.3	1	1	1	0.9
B016111	6	2	3	38.458' 39.583' 38.458'	1.3	1	1	1	0.9
B016310	6	2	3	59.25' 61' 61.062'	1.3	1	1	1	0.9
B015295	5	2	1	50'	1.3	1	1	1	0.9
B017909	5	2	3	82.417' 83' 82.417'	1.3	1	1	1	0.9
B015820	5	2	3	118.25' 117.833' 118.333'	1.3	1	1	1	0.9

Table D - 5: Legal Load Level Unique Bridge Output, Exterior Girder Flexure, LFR

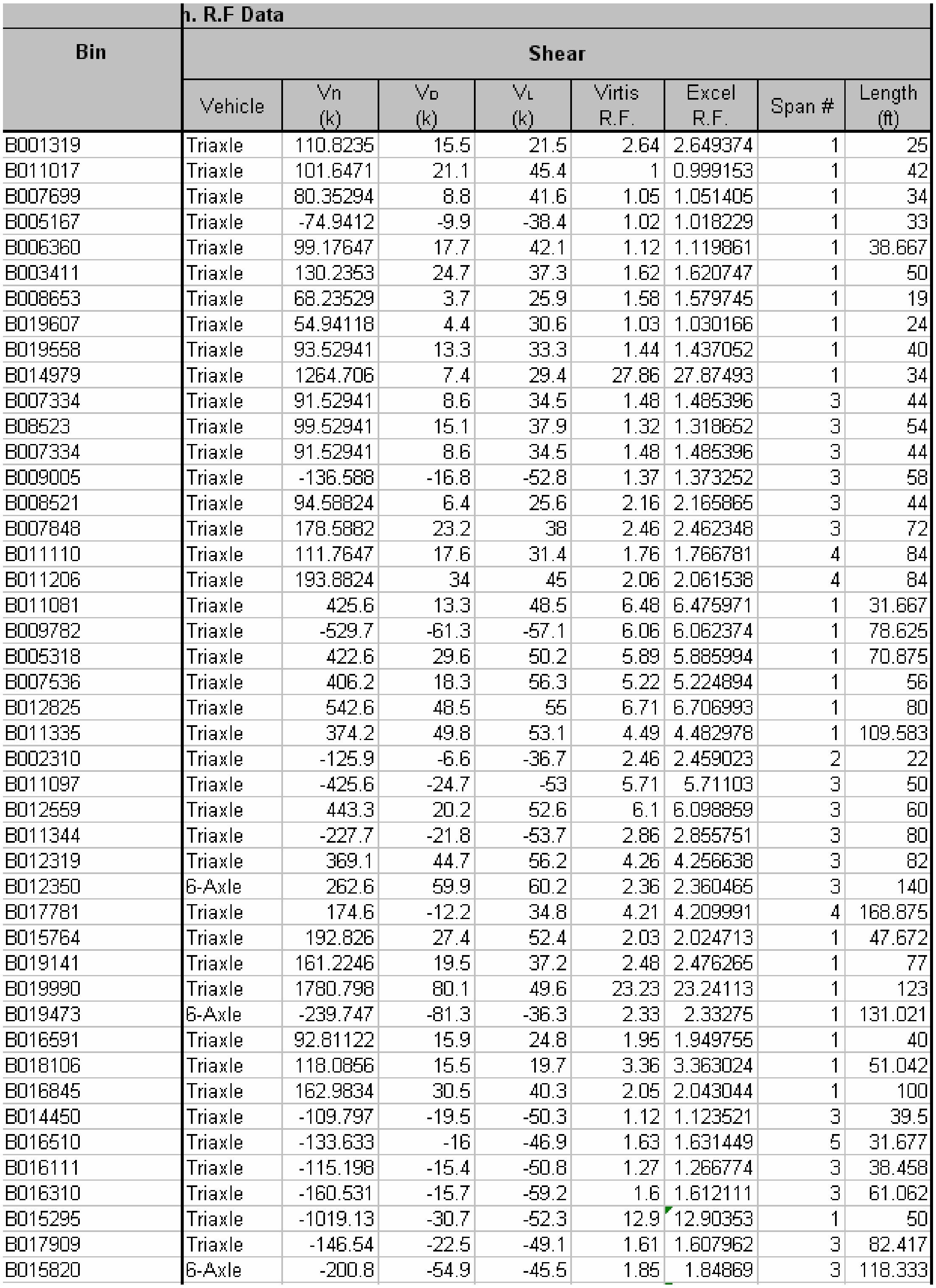
Part 2



Bin	Controling Vecl							
	Moment							
	Vehicle	M_n (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
B001319	Triaxle	661.6389	162.3	160.6	1.84	1.84157965	1	25
B011017	Triaxle	1298.044	277.4	488.6	1.27	1.2714821	1	42
B007699	Triaxle	621.8533	124.4	411.9	0.74	0.74317515	1	34
B005167	Triaxle	761.1189	136.5	367.7	1.06	1.06181251	1	33
B006360	Triaxle	1086.534	213	412.1	1.31	1.30845949	1	38.667
B003411	Triaxle	1271.056	385.6	482.1	1.03	1.0254336	1	50
B008653	Triaxle	151.5911	21.6	126.9	0.66	0.65679821	1	19
B019607	Triaxle	289.3778	32.8	186	0.9	0.90074442	1	24
B019558	Triaxle	1005.342	165.5	340.4	1.56	1.55847871	1	40
B014979	Triaxle	914.3122	78.5	250	2.22	2.21794154	1	34
B007334	Triaxle	617.24	35	286	1.37	1.37174825	3	44
B08523	Triaxle	1317.256	192.2	440.4	1.63	1.63430099	3	54
B007334	Triaxle	617.24	35	286	1.37	1.37174825	3	44
B009005	Triaxle	949.8111	4.5	500.5	1.31	1.30481826	3	58
B008521	Triaxle	630.5333	28.1	213.3	1.91	1.91478236	3	44
B007848	Triaxle	2425.444	402.3	705.6	1.81	1.80960012	3	72
B011110	Triaxle	3337.122	641.7	851.7	1.96	1.95915861	4	84
B011206	Triaxle	2722.556	683	842.2	1.43	1.42703177	4	84
B011081	Triaxle	2321	105.6	332.8	5.05	5.04742973	1	31.667
B009782	Triaxle	4782.8	1212	1069.9	2.31	2.30589487	1	78.625
B005318	Triaxle	1716	524.5	843.9	0.94	0.94264723	1	70.875
B007536	Triaxle	2936.4	258	734.3	2.72	2.72472999	1	56
B012825	Triaxle	4402.5	977.7	1048.3	2.3	2.2978522	1	80
B011335	Triaxle	5251.4	1381.7	1420.8	1.87	1.87066333	1	109.583
B002310	Triaxle	270.1	16.2	134.3	1.43	1.42642763	2	22
B011097	Triaxle	1527	140.7	477.1	2.17	2.16708318	3	50
B012559	Triaxle	1513	210	613.7	1.55	1.55425477	3	60
B011344	Triaxle	2212.8	284.8	837.3	1.69	1.69276704	3	80
B012319	Triaxle	2670.2	412.2	959.4	1.71	1.71127788	3	82
B012350	Triaxle	8342.5	1451.5	1712.1	2.9	2.90041919	3	140
B017781	Triaxle	13138.1	3155.5	2287.9	3.04	3.03803959	4	168.875
B015764	Triaxle	1996.465	327	573.9	2.11	2.10618923	1	47.672
B019141	Triaxle	5287.595	933.2	997.2	3.14	3.14298088	1	77
B019990	Triaxle	10344.17	3083.3	1642.5	2.97	2.96727596	1	123
B019473	Triaxle	10191.95	3326.8	1268.4	3.56	3.55815261	1	131.021
B016591	Triaxle	1112.73	199.2	253.6	2.59	2.58969213	1	40
B018106	Triaxle	1834.846	496.3	350.6	2.61	2.6101538	1	51.042
B016845	Triaxle	8914.598	1902.1	1389.9	3.57	3.56520818	1	100
B014450	6-Axle	-490.4478	-25.3	-233.1	1.51	1.50994218	3	39.5
B016510	Triaxle	940.2534	152.1	269.4	2.12	2.12016281	5	31.677
B016111	6-Axle	-621.0163	-15.5	-235.1	1.97	1.96599254	3	38.458
B016310	Triaxle	-1253.521	-46	-407	2.26	2.2561357	3	61.062
B015295	Triaxle	2952.362	383	602.7	3.13	3.13264898	1	50
B017909	Triaxle	-758.6428	0	-489.6	1.19	1.19193495	3	82.417
B015820	6-Axle	-2692.068	-94.7	-614.8	3.21	3.21425116	3	118.333

Table D - 6: Legal Load Level Unique Bridge Output, Exterior Girder Flexure, LFR

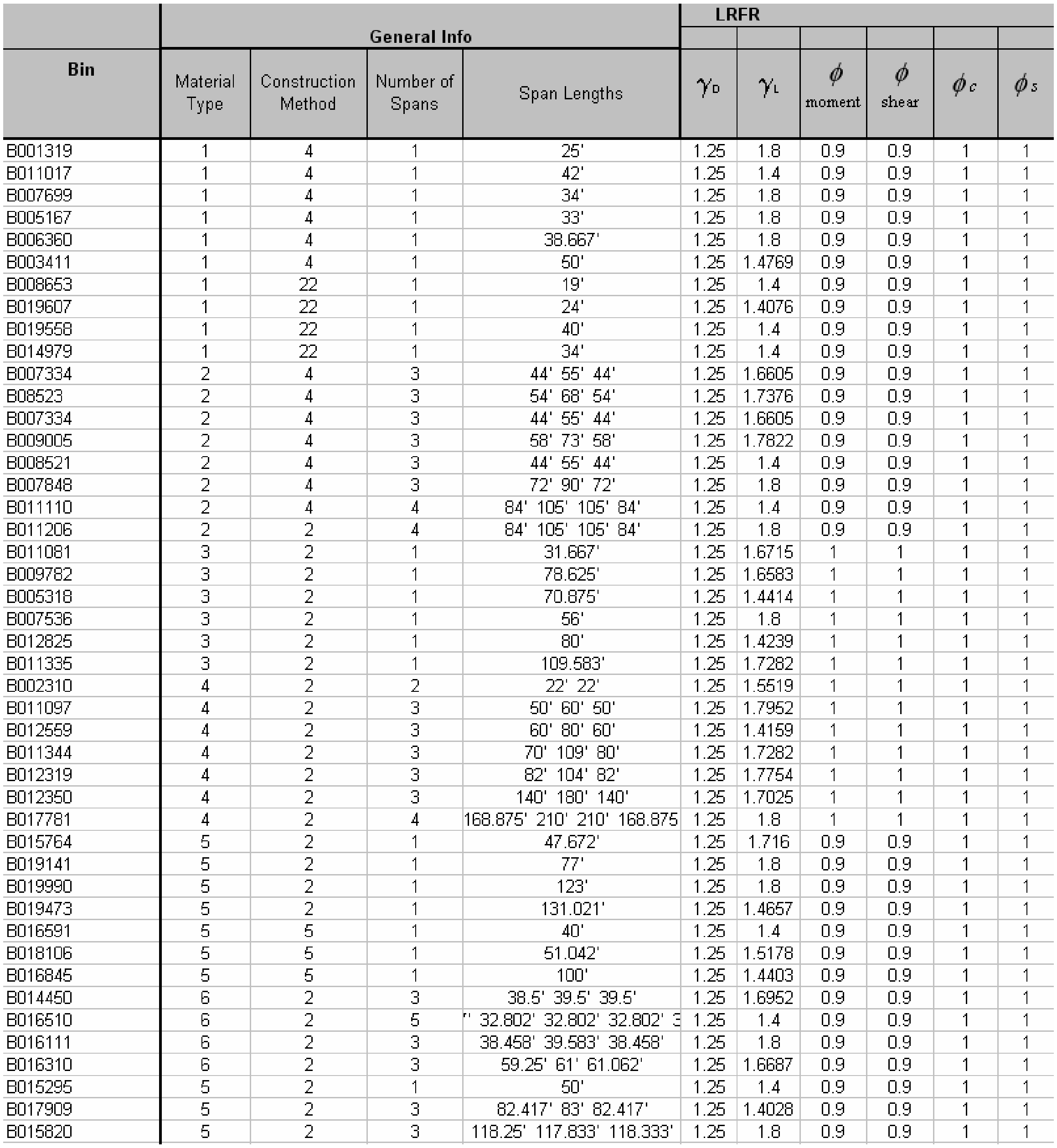
Part 3



Bin	h. R.F Data							
	Shear							
	Vehicle	V_n (k)	V_D (k)	V_L (k)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
B001319	Triaxle	110.8235	15.5	21.5	2.64	2.649374	1	25
B011017	Triaxle	101.6471	21.1	45.4	1	0.999153	1	42
B007699	Triaxle	80.35294	8.8	41.6	1.05	1.051405	1	34
B005167	Triaxle	-74.9412	-9.9	-38.4	1.02	1.018229	1	33
B006360	Triaxle	99.17647	17.7	42.1	1.12	1.119861	1	38.667
B003411	Triaxle	130.2353	24.7	37.3	1.62	1.620747	1	50
B008653	Triaxle	68.23529	3.7	25.9	1.58	1.579745	1	19
B019607	Triaxle	54.94118	4.4	30.6	1.03	1.030166	1	24
B019558	Triaxle	93.52941	13.3	33.3	1.44	1.437052	1	40
B014979	Triaxle	1264.706	7.4	29.4	27.86	27.87493	1	34
B007334	Triaxle	91.52941	8.6	34.5	1.48	1.485396	3	44
B08523	Triaxle	99.52941	15.1	37.9	1.32	1.318652	3	54
B007334	Triaxle	91.52941	8.6	34.5	1.48	1.485396	3	44
B009005	Triaxle	-136.588	-16.8	-52.8	1.37	1.373252	3	58
B008521	Triaxle	94.58824	6.4	25.6	2.16	2.165865	3	44
B007848	Triaxle	178.5882	23.2	38	2.46	2.462348	3	72
B011110	Triaxle	111.7647	17.6	31.4	1.76	1.766781	4	84
B011206	Triaxle	193.8824	34	45	2.06	2.061538	4	84
B011081	Triaxle	425.6	13.3	48.5	6.48	6.475971	1	31.667
B009782	Triaxle	-529.7	-61.3	-57.1	6.06	6.062374	1	78.625
B005318	Triaxle	422.6	29.6	50.2	5.89	5.885994	1	70.875
B007536	Triaxle	406.2	18.3	56.3	5.22	5.224894	1	56
B012825	Triaxle	542.6	48.5	55	6.71	6.706993	1	80
B011335	Triaxle	374.2	49.8	53.1	4.49	4.482978	1	109.583
B002310	Triaxle	-125.9	-6.6	-36.7	2.46	2.459023	2	22
B011097	Triaxle	-425.6	-24.7	-53	5.71	5.71103	3	50
B012559	Triaxle	443.3	20.2	52.6	6.1	6.098859	3	60
B011344	Triaxle	-227.7	-21.8	-53.7	2.86	2.855751	3	80
B012319	Triaxle	369.1	44.7	56.2	4.26	4.256638	3	82
B012350	6-Axle	262.6	59.9	60.2	2.36	2.360465	3	140
B017781	Triaxle	174.6	-12.2	34.8	4.21	4.209991	4	168.875
B015764	Triaxle	192.826	27.4	52.4	2.03	2.024713	1	47.672
B019141	Triaxle	161.2246	19.5	37.2	2.48	2.476265	1	77
B019990	Triaxle	1780.798	80.1	49.6	23.23	23.24113	1	123
B019473	6-Axle	-239.747	-81.3	-36.3	2.33	2.33275	1	131.021
B016591	Triaxle	92.81122	15.9	24.8	1.95	1.949755	1	40
B018106	Triaxle	118.0856	15.5	19.7	3.36	3.363024	1	51.042
B016845	Triaxle	162.9834	30.5	40.3	2.05	2.043044	1	100
B014450	Triaxle	-109.797	-19.5	-50.3	1.12	1.123521	3	39.5
B016510	Triaxle	-133.633	-16	-46.9	1.63	1.631449	5	31.677
B016111	Triaxle	-115.198	-15.4	-50.8	1.27	1.266774	3	38.458
B016310	Triaxle	-160.531	-15.7	-59.2	1.6	1.612111	3	61.062
B015295	Triaxle	-1019.13	-30.7	-52.3	12.9	12.90353	1	50
B017909	Triaxle	-146.54	-22.5	-49.1	1.61	1.607962	3	82.417
B015820	6-Axle	-200.8	-54.9	-45.5	1.85	1.84869	3	118.333

Table D - 7: Legal Load Level Unique Bridge Output, Interior Girder Flexure, LRFR

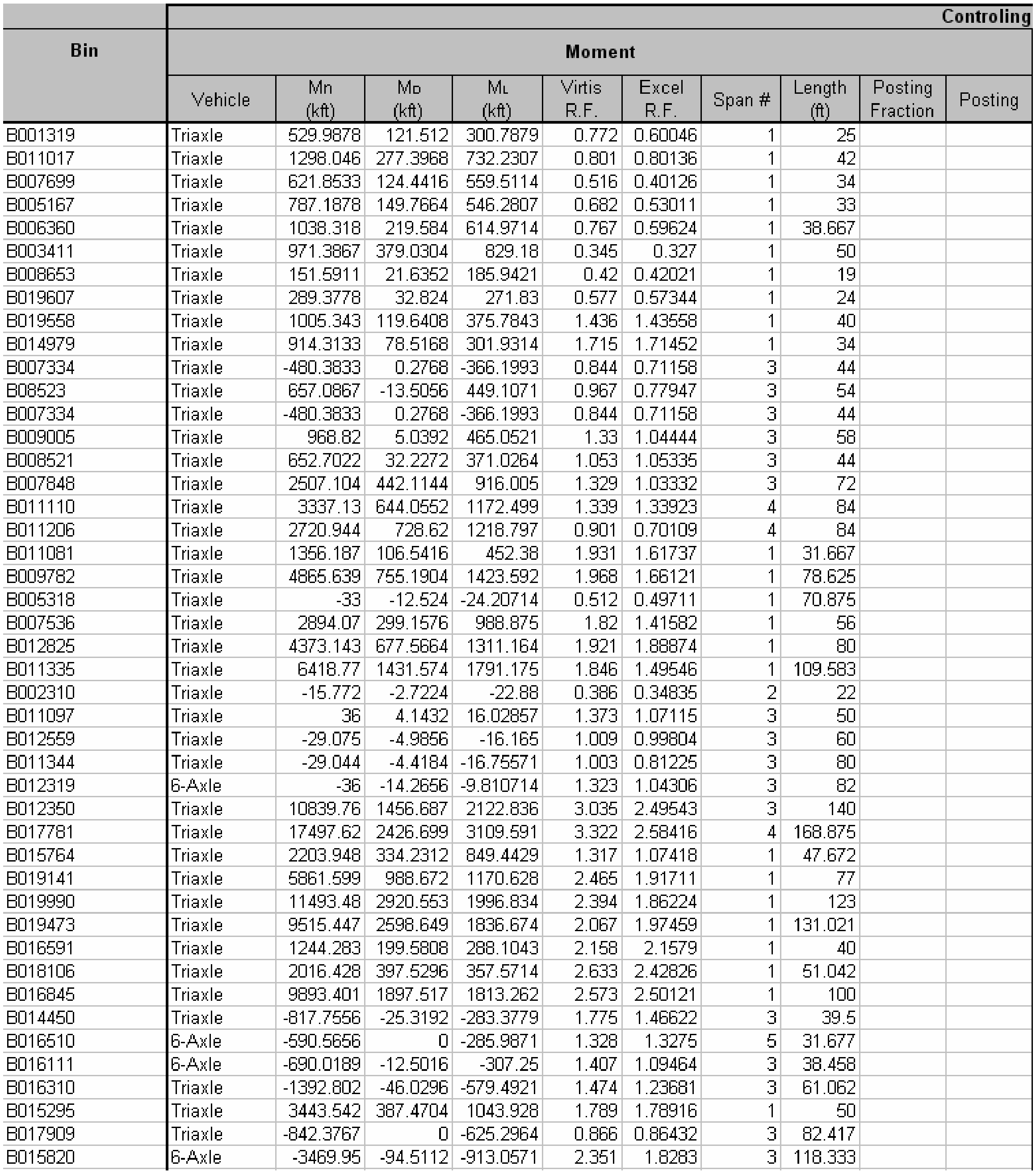
Part 1



Bin	General Info				LRFR					
	Material Type	Construction Method	Number of Spans	Span Lengths	γ_D	γ_L	ϕ moment	ϕ shear	ϕ_c	ϕ_s
B001319	1	4	1	25'	1.25	1.8	0.9	0.9	1	1
B011017	1	4	1	42'	1.25	1.4	0.9	0.9	1	1
B007699	1	4	1	34'	1.25	1.8	0.9	0.9	1	1
B005167	1	4	1	33'	1.25	1.8	0.9	0.9	1	1
B006360	1	4	1	38.667'	1.25	1.8	0.9	0.9	1	1
B003411	1	4	1	50'	1.25	1.4769	0.9	0.9	1	1
B008653	1	22	1	19'	1.25	1.4	0.9	0.9	1	1
B019607	1	22	1	24'	1.25	1.4076	0.9	0.9	1	1
B019558	1	22	1	40'	1.25	1.4	0.9	0.9	1	1
B014979	1	22	1	34'	1.25	1.4	0.9	0.9	1	1
B007334	2	4	3	44' 55' 44'	1.25	1.6605	0.9	0.9	1	1
B08523	2	4	3	54' 68' 54'	1.25	1.7376	0.9	0.9	1	1
B007334	2	4	3	44' 55' 44'	1.25	1.6605	0.9	0.9	1	1
B009005	2	4	3	58' 73' 58'	1.25	1.7822	0.9	0.9	1	1
B008521	2	4	3	44' 55' 44'	1.25	1.4	0.9	0.9	1	1
B007848	2	4	3	72' 90' 72'	1.25	1.8	0.9	0.9	1	1
B011110	2	4	4	84' 105' 105' 84'	1.25	1.4	0.9	0.9	1	1
B011206	2	2	4	84' 105' 105' 84'	1.25	1.8	0.9	0.9	1	1
B011081	3	2	1	31.667'	1.25	1.6715	1	1	1	1
B009782	3	2	1	78.625'	1.25	1.6583	1	1	1	1
B005318	3	2	1	70.875'	1.25	1.4414	1	1	1	1
B007536	3	2	1	56'	1.25	1.8	1	1	1	1
B012825	3	2	1	80'	1.25	1.4239	1	1	1	1
B011335	3	2	1	109.583'	1.25	1.7282	1	1	1	1
B002310	4	2	2	22' 22'	1.25	1.5519	1	1	1	1
B011097	4	2	3	50' 60' 50'	1.25	1.7952	1	1	1	1
B012559	4	2	3	60' 80' 60'	1.25	1.4159	1	1	1	1
B011344	4	2	3	70' 109' 80'	1.25	1.7282	1	1	1	1
B012319	4	2	3	82' 104' 82'	1.25	1.7754	1	1	1	1
B012350	4	2	3	140' 180' 140'	1.25	1.7025	1	1	1	1
B017781	4	2	4	168.875' 210' 210' 168.875	1.25	1.8	1	1	1	1
B015764	5	2	1	47.672'	1.25	1.716	0.9	0.9	1	1
B019141	5	2	1	77'	1.25	1.8	0.9	0.9	1	1
B019990	5	2	1	123'	1.25	1.8	0.9	0.9	1	1
B019473	5	2	1	131.021'	1.25	1.4657	0.9	0.9	1	1
B016591	5	5	1	40'	1.25	1.4	0.9	0.9	1	1
B018106	5	5	1	51.042'	1.25	1.5178	0.9	0.9	1	1
B016845	5	5	1	100'	1.25	1.4403	0.9	0.9	1	1
B014450	6	2	3	38.5' 39.5' 39.5'	1.25	1.6952	0.9	0.9	1	1
B016510	6	2	5	' 32.802' 32.802' 32.802'	1.25	1.4	0.9	0.9	1	1
B016111	6	2	3	38.458' 39.583' 38.458'	1.25	1.8	0.9	0.9	1	1
B016310	6	2	3	59.25' 61' 61.062'	1.25	1.6687	0.9	0.9	1	1
B015295	5	2	1	50'	1.25	1.4	0.9	0.9	1	1
B017909	5	2	3	82.417' 83' 82.417'	1.25	1.4028	0.9	0.9	1	1
B015820	5	2	3	118.25' 117.833' 118.333'	1.25	1.8	0.9	0.9	1	1

Table D - 8: Legal Load Level Unique Bridge Output, Interior Girder Flexure, LRFR

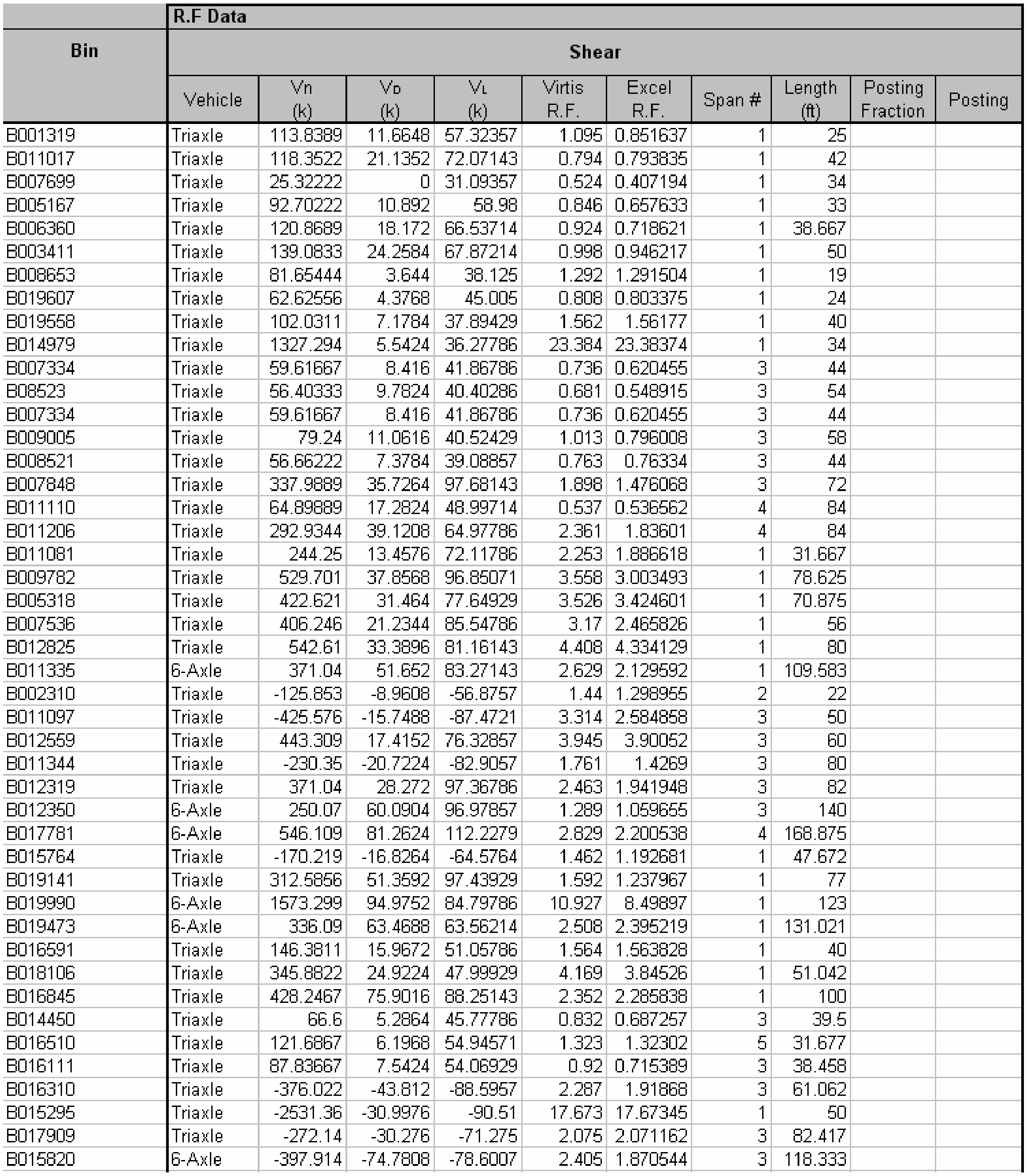
Part 2



Bin	Controling									
	Moment									
	Vehicle	M_n (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)	Posting Fraction	Posting
B001319	Triaxle	529.9878	121.512	300.7879	0.772	0.60046	1	25		
B011017	Triaxle	1298.046	277.3968	732.2307	0.801	0.80136	1	42		
B007699	Triaxle	621.8533	124.4416	559.5114	0.516	0.40126	1	34		
B005167	Triaxle	787.1878	149.7664	546.2807	0.682	0.53011	1	33		
B006360	Triaxle	1038.318	219.584	614.9714	0.767	0.59624	1	38.667		
B003411	Triaxle	971.3867	379.0304	829.18	0.345	0.327	1	50		
B008653	Triaxle	151.5911	21.6352	185.9421	0.42	0.42021	1	19		
B019607	Triaxle	289.3778	32.824	271.83	0.577	0.57344	1	24		
B019558	Triaxle	1005.343	119.6408	375.7843	1.436	1.43558	1	40		
B014979	Triaxle	914.3133	78.5168	301.9314	1.715	1.71452	1	34		
B007334	Triaxle	-480.3833	0.2768	-366.1993	0.844	0.71158	3	44		
B08523	Triaxle	657.0867	-13.5056	449.1071	0.967	0.77947	3	54		
B007334	Triaxle	-480.3833	0.2768	-366.1993	0.844	0.71158	3	44		
B009005	Triaxle	968.82	5.0392	465.0521	1.33	1.04444	3	58		
B008521	Triaxle	652.7022	32.2272	371.0264	1.053	1.05335	3	44		
B007848	Triaxle	2507.104	442.1144	916.005	1.329	1.03332	3	72		
B011110	Triaxle	3337.13	644.0552	1172.499	1.339	1.33923	4	84		
B011206	Triaxle	2720.944	728.62	1218.797	0.901	0.70109	4	84		
B011081	Triaxle	1356.187	106.5416	452.38	1.931	1.61737	1	31.667		
B009782	Triaxle	4865.639	755.1904	1423.592	1.968	1.66121	1	78.625		
B005318	Triaxle	-33	-12.524	-24.20714	0.512	0.49711	1	70.875		
B007536	Triaxle	2894.07	299.1576	988.875	1.82	1.41582	1	56		
B012825	Triaxle	4373.143	677.5664	1311.164	1.921	1.88874	1	80		
B011335	Triaxle	6418.77	1431.574	1791.175	1.846	1.49546	1	109.583		
B002310	Triaxle	-15.772	-2.7224	-22.88	0.386	0.34835	2	22		
B011097	Triaxle	36	4.1432	16.02857	1.373	1.07115	3	50		
B012559	Triaxle	-29.075	-4.9856	-16.165	1.009	0.99804	3	60		
B011344	Triaxle	-29.044	-4.4184	-16.75571	1.003	0.81225	3	80		
B012319	6-Axle	-36	-14.2656	-9.810714	1.323	1.04306	3	82		
B012350	Triaxle	10839.76	1456.687	2122.836	3.035	2.49543	3	140		
B017781	Triaxle	17497.62	2426.699	3109.591	3.322	2.58416	4	168.875		
B015764	Triaxle	2203.948	334.2312	849.4429	1.317	1.07418	1	47.672		
B019141	Triaxle	5861.599	988.672	1170.628	2.465	1.91711	1	77		
B019990	Triaxle	11493.48	2920.553	1996.834	2.394	1.86224	1	123		
B019473	Triaxle	9515.447	2598.649	1836.674	2.067	1.97459	1	131.021		
B016591	Triaxle	1244.283	199.5808	288.1043	2.158	2.1579	1	40		
B018106	Triaxle	2016.428	397.5296	357.5714	2.633	2.42826	1	51.042		
B016845	Triaxle	9893.401	1897.517	1813.262	2.573	2.50121	1	100		
B014450	Triaxle	-817.7556	-25.3192	-283.3779	1.775	1.46622	3	39.5		
B016510	6-Axle	-590.5656	0	-285.9871	1.328	1.3275	5	31.677		
B016111	6-Axle	-690.0189	-12.5016	-307.25	1.407	1.09464	3	38.458		
B016310	Triaxle	-1392.802	-46.0296	-579.4921	1.474	1.23681	3	61.062		
B015295	Triaxle	3443.542	387.4704	1043.928	1.789	1.78916	1	50		
B017909	Triaxle	-842.3767	0	-625.2964	0.866	0.86432	3	82.417		
B015820	6-Axle	-3469.95	-94.5112	-913.0571	2.351	1.8283	3	118.333		

Table D - 9: Legal Load Level Unique Bridge Output, Interior Girder Flexure, LRFR

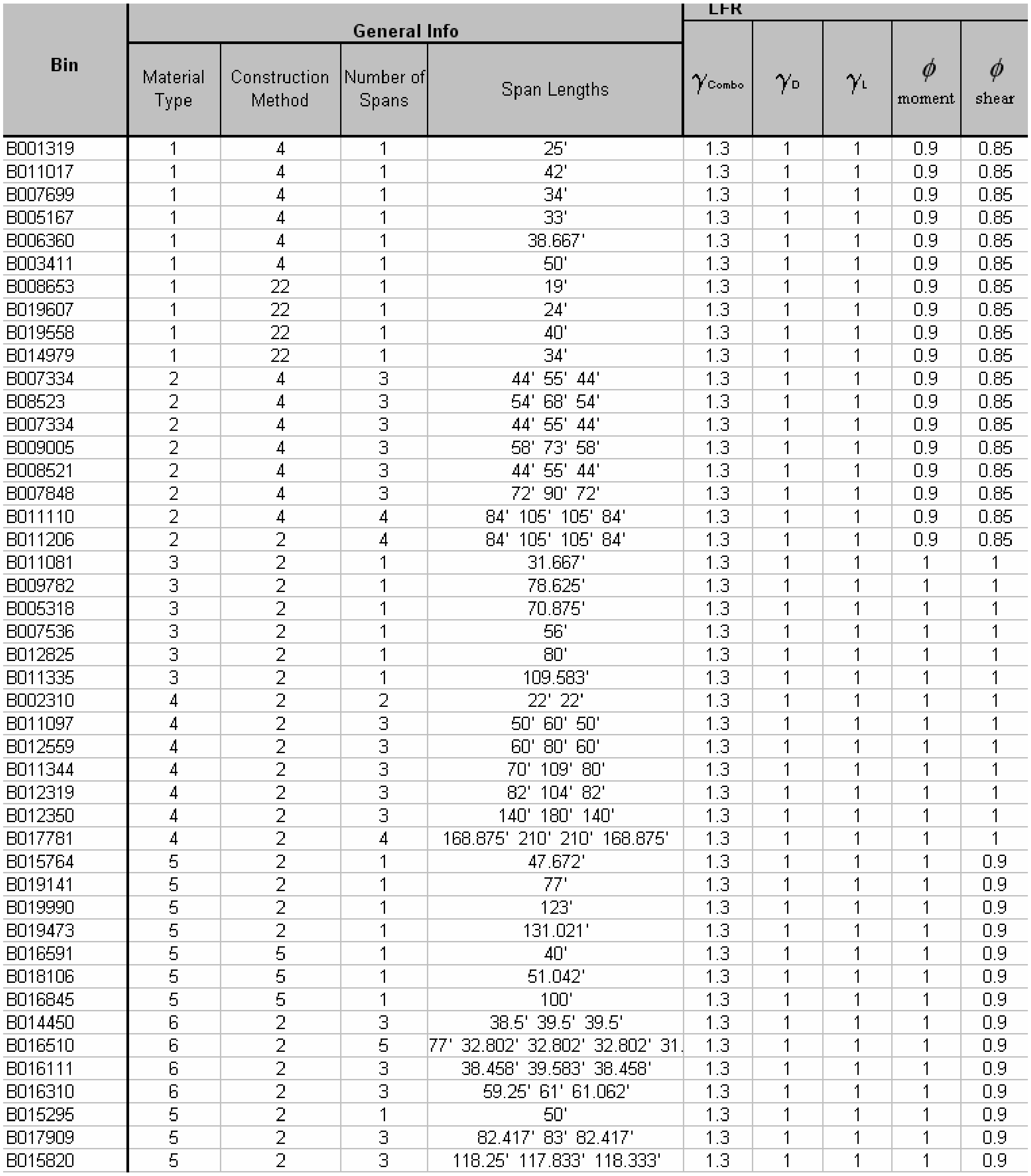
Part 3



	R.F Data									
Bin	Shear									
	Vehicle	V_n (k)	V_D (k)	V_L (k)	Virtis R.F.	Excel R.F.	Span #	Length (ft)	Posting Fraction	Posting
B001319	Triaxle	113.8389	11.6648	57.32357	1.095	0.851637	1	25		
B011017	Triaxle	118.3522	21.1352	72.07143	0.794	0.793835	1	42		
B007699	Triaxle	25.32222	0	31.09357	0.524	0.407194	1	34		
B005167	Triaxle	92.70222	10.892	58.98	0.846	0.657633	1	33		
B006360	Triaxle	120.8689	18.172	66.53714	0.924	0.718621	1	38.667		
B003411	Triaxle	139.0833	24.2584	67.87214	0.998	0.946217	1	50		
B008653	Triaxle	81.65444	3.644	38.125	1.292	1.291504	1	19		
B019607	Triaxle	62.62556	4.3768	45.005	0.808	0.803375	1	24		
B019558	Triaxle	102.0311	7.1784	37.89429	1.562	1.56177	1	40		
B014979	Triaxle	1327.294	5.5424	36.27786	23.384	23.38374	1	34		
B007334	Triaxle	59.61667	8.416	41.86786	0.736	0.620455	3	44		
B08523	Triaxle	56.40333	9.7824	40.40286	0.681	0.548915	3	54		
B007334	Triaxle	59.61667	8.416	41.86786	0.736	0.620455	3	44		
B009005	Triaxle	79.24	11.0616	40.52429	1.013	0.796008	3	58		
B008521	Triaxle	56.66222	7.3784	39.08857	0.763	0.76334	3	44		
B007848	Triaxle	337.9889	35.7264	97.68143	1.898	1.476068	3	72		
B011110	Triaxle	64.89889	17.2824	48.99714	0.537	0.536562	4	84		
B011206	Triaxle	292.9344	39.1208	64.97786	2.361	1.83601	4	84		
B011081	Triaxle	244.25	13.4576	72.11786	2.253	1.886618	1	31.667		
B009782	Triaxle	529.701	37.8568	96.85071	3.558	3.003493	1	78.625		
B005318	Triaxle	422.621	31.464	77.64929	3.526	3.424601	1	70.875		
B007536	Triaxle	406.246	21.2344	85.54786	3.17	2.465826	1	56		
B012825	Triaxle	542.61	33.3896	81.16143	4.408	4.334129	1	80		
B011335	6-Axle	371.04	51.652	83.27143	2.629	2.129592	1	109.583		
B002310	Triaxle	-125.853	-8.9608	-56.8757	1.44	1.298955	2	22		
B011097	Triaxle	-425.576	-15.7488	-87.4721	3.314	2.584858	3	50		
B012559	Triaxle	443.309	17.4152	76.32857	3.945	3.90052	3	60		
B011344	Triaxle	-230.35	-20.7224	-82.9057	1.761	1.4269	3	80		
B012319	Triaxle	371.04	28.272	97.36786	2.463	1.941948	3	82		
B012350	6-Axle	250.07	60.0904	96.97857	1.289	1.059655	3	140		
B017781	6-Axle	546.109	81.2624	112.2279	2.829	2.200538	4	168.875		
B015764	Triaxle	-170.219	-16.8264	-64.5764	1.462	1.192681	1	47.672		
B019141	Triaxle	312.5856	51.3592	97.43929	1.592	1.237967	1	77		
B019990	6-Axle	1573.299	94.9752	84.79786	10.927	8.49897	1	123		
B019473	6-Axle	336.09	63.4688	63.56214	2.508	2.395219	1	131.021		
B016591	Triaxle	146.3811	15.9672	51.05786	1.564	1.563828	1	40		
B018106	Triaxle	345.8822	24.9224	47.99929	4.169	3.84526	1	51.042		
B016845	Triaxle	428.2467	75.9016	88.25143	2.352	2.285838	1	100		
B014450	Triaxle	66.6	5.2864	45.77786	0.832	0.687257	3	39.5		
B016510	Triaxle	121.6867	6.1968	54.94571	1.323	1.32302	5	31.677		
B016111	Triaxle	87.83667	7.5424	54.06929	0.92	0.715389	3	38.458		
B016310	Triaxle	-376.022	-43.812	-88.5957	2.287	1.91868	3	61.062		
B015295	Triaxle	-2531.36	-30.9976	-90.51	17.673	17.67345	1	50		
B017909	Triaxle	-272.14	-30.276	-71.275	2.075	2.071162	3	82.417		
B015820	6-Axle	-397.914	-74.7808	-78.6007	2.405	1.870544	3	118.333		

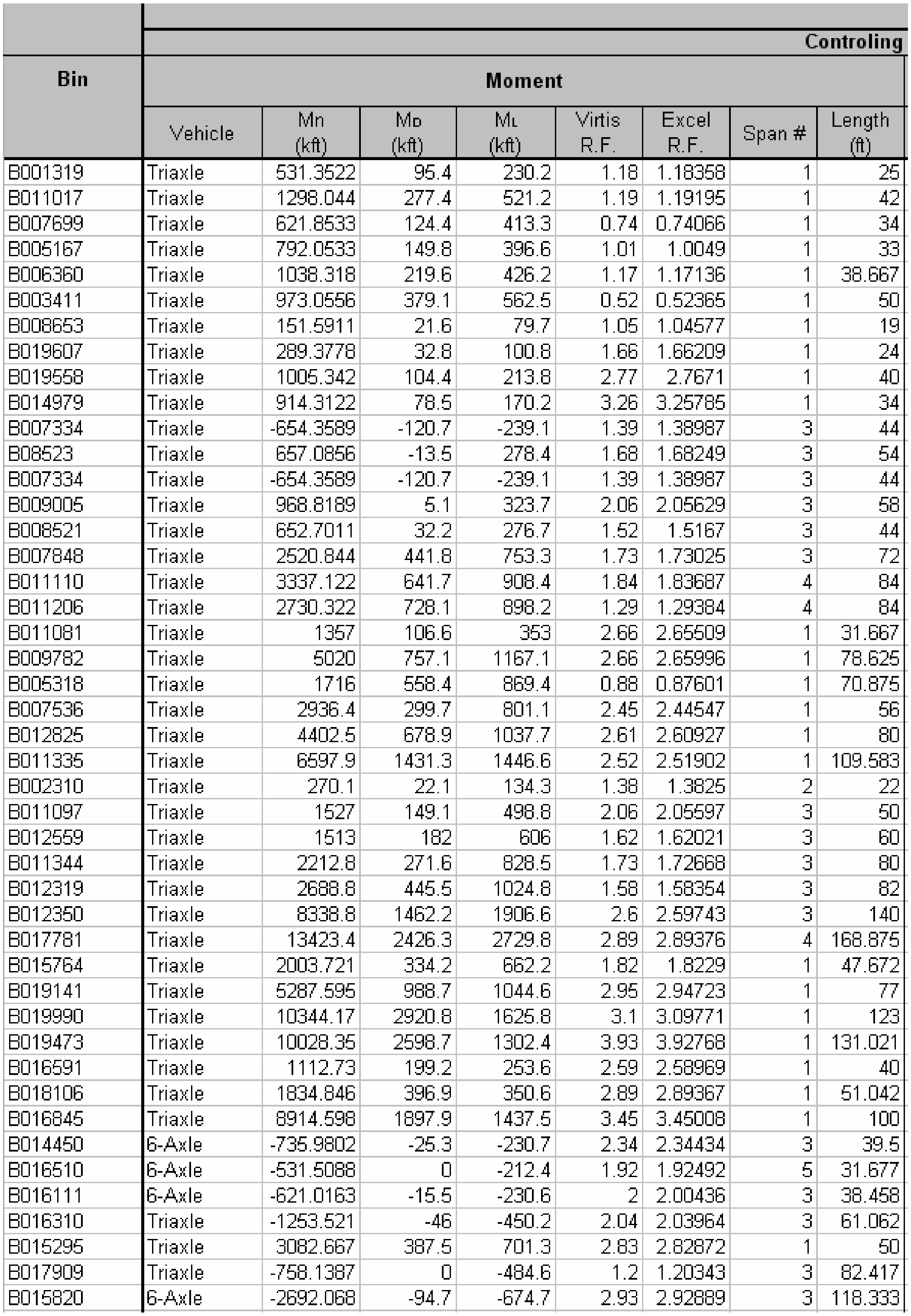
Table D - 10: Legal Load Level Unique Bridge Output, Interior Girder Flexure, LFR

Part 1



Bin	General Info				LFR				
	Material Type	Construction Method	Number of Spans	Span Lengths	γ_{Combo}	γ_D	γ_L	ϕ moment	ϕ shear
B001319	1	4	1	25'	1.3	1	1	0.9	0.85
B011017	1	4	1	42'	1.3	1	1	0.9	0.85
B007699	1	4	1	34'	1.3	1	1	0.9	0.85
B005167	1	4	1	33'	1.3	1	1	0.9	0.85
B006360	1	4	1	38.667'	1.3	1	1	0.9	0.85
B003411	1	4	1	50'	1.3	1	1	0.9	0.85
B008653	1	22	1	19'	1.3	1	1	0.9	0.85
B019607	1	22	1	24'	1.3	1	1	0.9	0.85
B019558	1	22	1	40'	1.3	1	1	0.9	0.85
B014979	1	22	1	34'	1.3	1	1	0.9	0.85
B007334	2	4	3	44' 55' 44'	1.3	1	1	0.9	0.85
B08523	2	4	3	54' 68' 54'	1.3	1	1	0.9	0.85
B007334	2	4	3	44' 55' 44'	1.3	1	1	0.9	0.85
B009005	2	4	3	58' 73' 58'	1.3	1	1	0.9	0.85
B008521	2	4	3	44' 55' 44'	1.3	1	1	0.9	0.85
B007848	2	4	3	72' 90' 72'	1.3	1	1	0.9	0.85
B011110	2	4	4	84' 105' 105' 84'	1.3	1	1	0.9	0.85
B011206	2	2	4	84' 105' 105' 84'	1.3	1	1	0.9	0.85
B011081	3	2	1	31.667'	1.3	1	1	1	1
B009782	3	2	1	78.625'	1.3	1	1	1	1
B005318	3	2	1	70.875'	1.3	1	1	1	1
B007536	3	2	1	56'	1.3	1	1	1	1
B012825	3	2	1	80'	1.3	1	1	1	1
B011335	3	2	1	109.583'	1.3	1	1	1	1
B002310	4	2	2	22' 22'	1.3	1	1	1	1
B011097	4	2	3	50' 60' 50'	1.3	1	1	1	1
B012559	4	2	3	60' 80' 60'	1.3	1	1	1	1
B011344	4	2	3	70' 109' 80'	1.3	1	1	1	1
B012319	4	2	3	82' 104' 82'	1.3	1	1	1	1
B012350	4	2	3	140' 180' 140'	1.3	1	1	1	1
B017781	4	2	4	168.875' 210' 210' 168.875'	1.3	1	1	1	1
B015764	5	2	1	47.672'	1.3	1	1	1	0.9
B019141	5	2	1	77'	1.3	1	1	1	0.9
B019990	5	2	1	123'	1.3	1	1	1	0.9
B019473	5	2	1	131.021'	1.3	1	1	1	0.9
B016591	5	5	1	40'	1.3	1	1	1	0.9
B018106	5	5	1	51.042'	1.3	1	1	1	0.9
B016845	5	5	1	100'	1.3	1	1	1	0.9
B014450	6	2	3	38.5' 39.5' 39.5'	1.3	1	1	1	0.9
B016510	6	2	5	77' 32.802' 32.802' 32.802' 31.	1.3	1	1	1	0.9
B016111	6	2	3	38.458' 39.583' 38.458'	1.3	1	1	1	0.9
B016310	6	2	3	59.25' 61' 61.062'	1.3	1	1	1	0.9
B015295	5	2	1	50'	1.3	1	1	1	0.9
B017909	5	2	3	82.417' 83' 82.417'	1.3	1	1	1	0.9
B015820	5	2	3	118.25' 117.833' 118.333'	1.3	1	1	1	0.9

Table D - 11: Legal Load Level Unique Bridge Output, Interior Girder Flexure, LFR Part 2



Bin	Controling						
	Moment						
	Vehicle	M_n (kft)	M_D (kft)	M_L (kft)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
B001319	Triaxle	531.3522	95.4	230.2	1.18	1.18358	1	25
B011017	Triaxle	1298.044	277.4	521.2	1.19	1.19195	1	42
B007699	Triaxle	621.8533	124.4	413.3	0.74	0.74066	1	34
B005167	Triaxle	792.0533	149.8	396.6	1.01	1.0049	1	33
B006360	Triaxle	1038.318	219.6	426.2	1.17	1.17136	1	38.667
B003411	Triaxle	973.0556	379.1	562.5	0.52	0.52365	1	50
B008653	Triaxle	151.5911	21.6	79.7	1.05	1.04577	1	19
B019607	Triaxle	289.3778	32.8	100.8	1.66	1.66209	1	24
B019558	Triaxle	1005.342	104.4	213.8	2.77	2.7671	1	40
B014979	Triaxle	914.3122	78.5	170.2	3.26	3.25785	1	34
B007334	Triaxle	-654.3589	-120.7	-239.1	1.39	1.38987	3	44
B08523	Triaxle	657.0856	-13.5	278.4	1.68	1.68249	3	54
B007334	Triaxle	-654.3589	-120.7	-239.1	1.39	1.38987	3	44
B009005	Triaxle	968.8189	5.1	323.7	2.06	2.05629	3	58
B008521	Triaxle	652.7011	32.2	276.7	1.52	1.5167	3	44
B007848	Triaxle	2520.844	441.8	753.3	1.73	1.73025	3	72
B011110	Triaxle	3337.122	641.7	908.4	1.84	1.83687	4	84
B011206	Triaxle	2730.322	728.1	898.2	1.29	1.29384	4	84
B011081	Triaxle	1357	106.6	353	2.66	2.65509	1	31.667
B009782	Triaxle	5020	757.1	1167.1	2.66	2.65996	1	78.625
B005318	Triaxle	1716	558.4	869.4	0.88	0.87601	1	70.875
B007536	Triaxle	2936.4	299.7	801.1	2.45	2.44547	1	56
B012825	Triaxle	4402.5	678.9	1037.7	2.61	2.60927	1	80
B011335	Triaxle	6597.9	1431.3	1446.6	2.52	2.51902	1	109.583
B002310	Triaxle	270.1	22.1	134.3	1.38	1.3825	2	22
B011097	Triaxle	1527	149.1	498.8	2.06	2.05597	3	50
B012559	Triaxle	1513	182	606	1.62	1.62021	3	60
B011344	Triaxle	2212.8	271.6	828.5	1.73	1.72668	3	80
B012319	Triaxle	2688.8	445.5	1024.8	1.58	1.58354	3	82
B012350	Triaxle	8338.8	1462.2	1906.6	2.6	2.59743	3	140
B017781	Triaxle	13423.4	2426.3	2729.8	2.89	2.89376	4	168.875
B015764	Triaxle	2003.721	334.2	662.2	1.82	1.8229	1	47.672
B019141	Triaxle	5287.595	988.7	1044.6	2.95	2.94723	1	77
B019990	Triaxle	10344.17	2920.8	1625.8	3.1	3.09771	1	123
B019473	Triaxle	10028.35	2598.7	1302.4	3.93	3.92768	1	131.021
B016591	Triaxle	1112.73	199.2	253.6	2.59	2.58969	1	40
B018106	Triaxle	1834.846	396.9	350.6	2.89	2.89367	1	51.042
B016845	Triaxle	8914.598	1897.9	1437.5	3.45	3.45008	1	100
B014450	6-Axle	-735.9802	-25.3	-230.7	2.34	2.34434	3	39.5
B016510	6-Axle	-531.5088	0	-212.4	1.92	1.92492	5	31.677
B016111	6-Axle	-621.0163	-15.5	-230.6	2	2.00436	3	38.458
B016310	Triaxle	-1253.521	-46	-450.2	2.04	2.03964	3	61.062
B015295	Triaxle	3082.667	387.5	701.3	2.83	2.82872	1	50
B017909	Triaxle	-758.1387	0	-484.6	1.2	1.20343	3	82.417
B015820	6-Axle	-2692.068	-94.7	-674.7	2.93	2.92889	3	118.333

Table D - 12: Legal Load Level Unique Bridge Output, Interior Girder Flexure, LFR

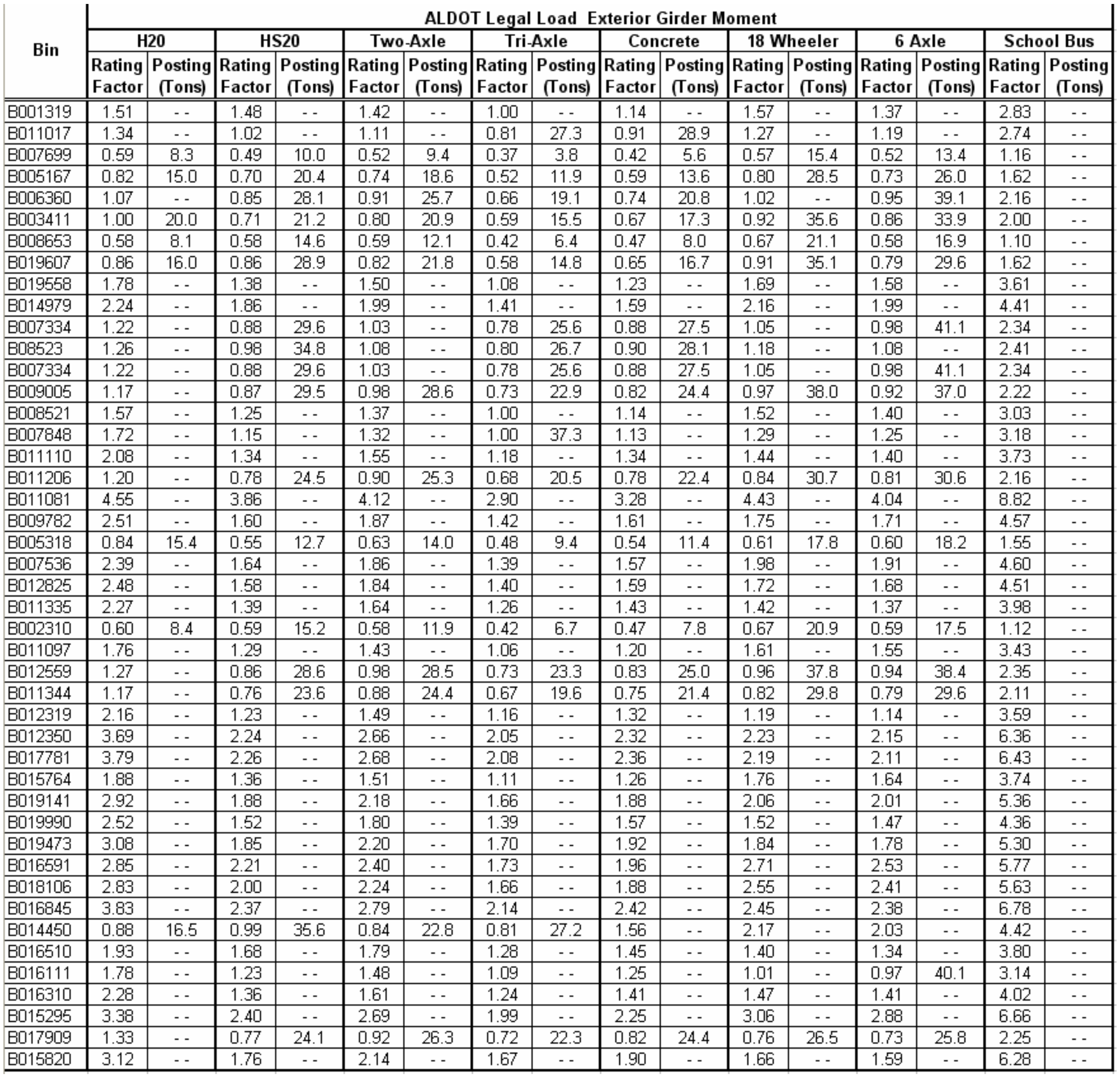
Part 3

	R.F Data							
Bin	Shear							
	Vehicle	V_n (k)	V_D (k)	V_L (k)	Virtis R.F.	Excel R.F.	Span #	Length (ft)
B001319	Triaxle	89.05882	9.2	30.8	1.59	1.591908	1	25
B011017	Triaxle	101.6471	21.1	48.4	0.94	0.937222	1	42
B007699	Triaxle	80.35294	8.8	41.7	1.05	1.048884	1	34
B005167	Triaxle	-77.7647	-11	-41.4	0.96	0.962467	1	33
B006360	Triaxle	101.4118	18.2	43.5	1.11	1.105924	1	38.667
B003411	Triaxle	127.4118	24.3	43.5	1.36	1.356499	1	50
B008653	Triaxle	65.29412	3.7	16.3	2.4	2.392166	1	19
B019607	Triaxle	54.94118	4.4	16.6	1.9	1.898981	1	24
B019558	Triaxle	93.52941	8.4	20.9	2.52	2.524107	1	40
B014979	Triaxle	1264.706	7.4	29.4	27.86	27.87493	1	34
B007334	Triaxle	96.82353	7.3	36.7	1.53	1.526095	3	44
B08523	Triaxle	104	15.4	38.3	1.37	1.373368	3	54
B007334	Triaxle	96.82353	7.3	36.7	1.53	1.526095	3	44
B009005	Triaxle	-137.882	-18.8	-34.1	2.09	2.092488	3	58
B008521	Triaxle	95.29412	7.4	33.3	1.65	1.64888	3	44
B007848	Triaxle	185.5294	25.4	40.5	2.37	2.368091	3	72
B011110	Triaxle	111.7647	17.6	33.5	1.65	1.656028	4	84
B011206	Triaxle	234.2353	39.1	42	2.71	2.715568	4	84
B011081	Triaxle	244.3	13.4	51.4	3.39	3.395391	1	31.667
B009782	Triaxle	430.9	-38	-62.3	5.93	5.930362	1	78.625
B005318	Triaxle	422.6	31.5	51.7	5.68	5.67847	1	70.875
B007536	Triaxle	406.2	21.3	61.5	4.74	4.734334	1	56
B012825	Triaxle	542.6	33.5	54.4	7.05	7.056702	1	80
B011335	Triaxle	374.2	51.7	54	4.37	4.373077	1	109.583
B002310	Triaxle	-125.9	-9	-36.7	2.39	2.393628	2	22
B011097	Triaxle	-425.6	-26.1	-55.4	5.44	5.43835	3	50
B012559	Triaxle	443.3	17.4	52.1	6.21	6.211132	3	60
B011344	Triaxle	-227.7	-20.8	-53.1	2.91	2.906852	3	80
B012319	Triaxle	369.1	48.3	60	3.93	3.927051	3	82
B012350	6-Axle	262.6	60.3	67	2.12	2.114925	3	140
B017781	Triaxle	195.5	-9.4	41.6	3.84	3.840976	4	168.875
B015764	Triaxle	192.2566	28.1	60.4	1.74	1.738422	1	47.672
B019141	Triaxle	164.1241	20.6	39	2.39	2.38524	1	77
B019990	Triaxle	1780.798	75.9	49.1	23.55	23.56334	1	123
B019473	6-Axle	-217.896	-63.5	-37.3	2.34	2.341857	1	131.021
B016591	Triaxle	92.81122	15.9	24.8	1.95	1.949755	1	40
B018106	Triaxle	117.0468	12.4	19.7	3.48	3.483879	1	51.042
B016845	Triaxle	163.9515	30.5	41.6	2	1.995309	1	100
B014450	Triaxle	109.5938	19.1	50.2	1.13	1.130929	3	39.5
B016510	Triaxle	-128.933	-12.4	-54.1	1.42	1.420729	5	31.677
B016111	Triaxle	-114.449	-14.8	-49.8	1.29	1.293857	3	38.458
B016310	Triaxle	-160.973	-16.2	-65.5	1.45	1.454093	3	61.062
B015295	Triaxle	1048.253	24.9	54.2	12.93	12.93014	1	50
B017909	Triaxle	-135.106	-13.5	-48.6	1.64	1.646815	3	82.417
B015820	6-Axle	-206.628	-58.7	-49.9	1.69	1.690378	3	118.333

APPENDIX E: ALDOT Legal Load Posting Data

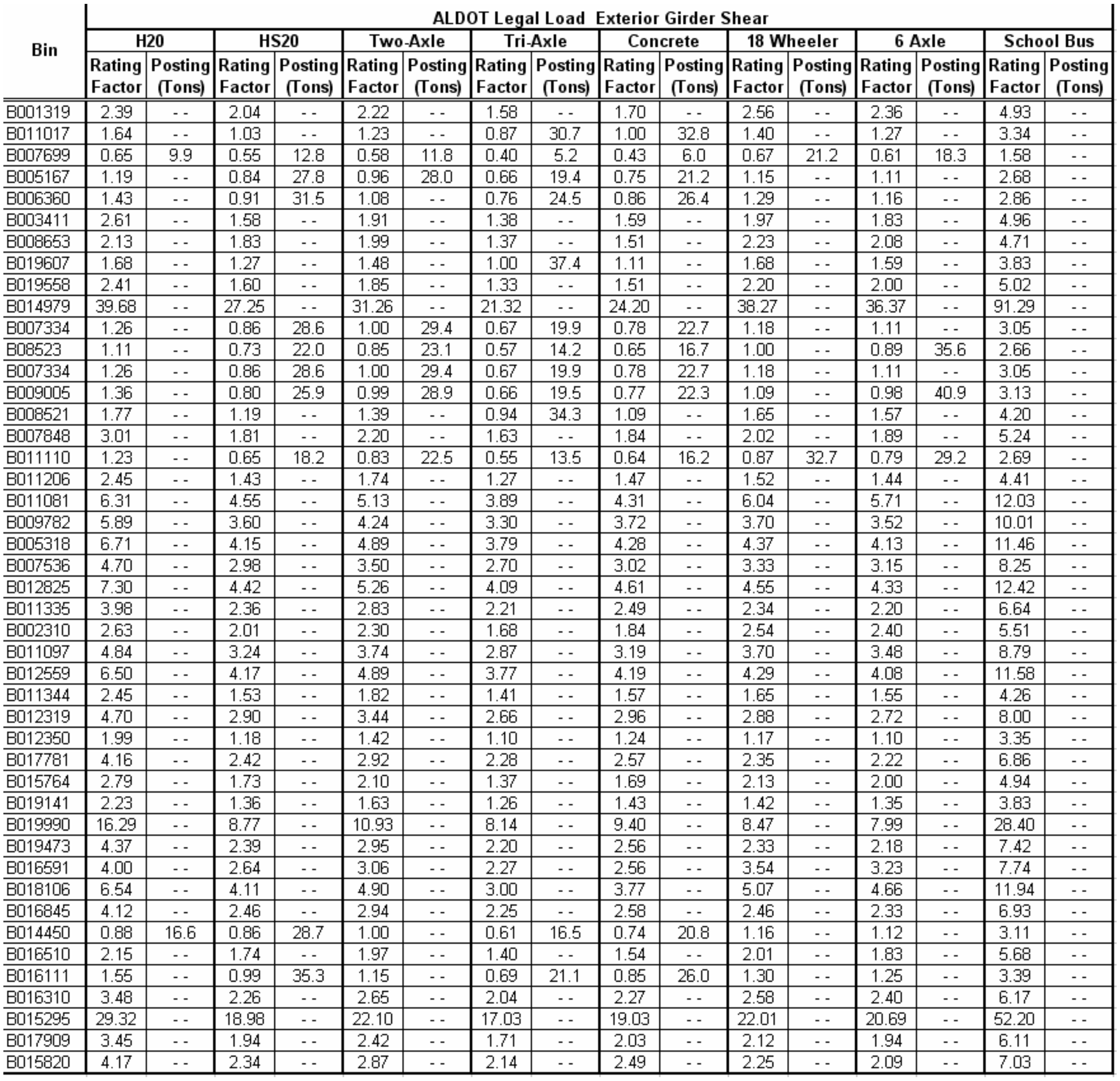
Presented in this appendix is the legal load posting data for the moment and shear rating factors, for interior and exterior girders, for each rating methodology. For more information on posting see Chapter 2 and Chapter 5.

Table E - 1: Legal Load Posting Data for Exterior Girders, LRFR Moment Data



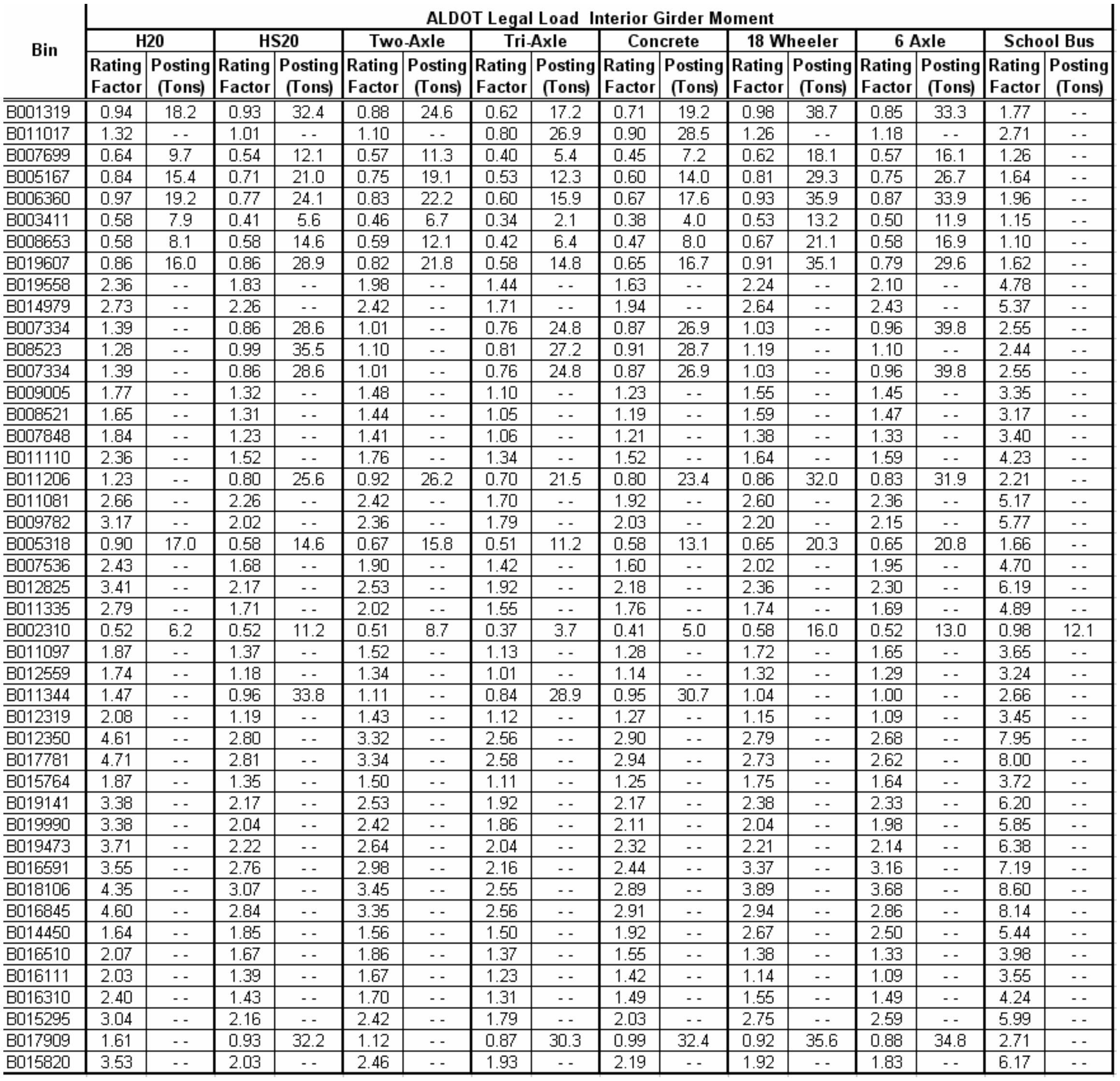
Bin	ALDOT Legal Load Exterior Girder Moment															
	H20		HS20		Two-Axle		Tri-Axle		Concrete		18 Wheeler		6 Axle		School Bus	
	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)
B001319	1.51	- -	1.48	- -	1.42	- -	1.00	- -	1.14	- -	1.57	- -	1.37	- -	2.83	- -
B011017	1.34	- -	1.02	- -	1.11	- -	0.81	27.3	0.91	28.9	1.27	- -	1.19	- -	2.74	- -
B007699	0.59	8.3	0.49	10.0	0.52	9.4	0.37	3.8	0.42	5.6	0.57	15.4	0.52	13.4	1.16	- -
B005167	0.82	15.0	0.70	20.4	0.74	18.6	0.52	11.9	0.59	13.6	0.80	28.5	0.73	26.0	1.62	- -
B006360	1.07	- -	0.85	28.1	0.91	25.7	0.66	19.1	0.74	20.8	1.02	- -	0.95	39.1	2.16	- -
B003411	1.00	20.0	0.71	21.2	0.80	20.9	0.59	15.5	0.67	17.3	0.92	35.6	0.86	33.9	2.00	- -
B008653	0.58	8.1	0.58	14.6	0.59	12.1	0.42	6.4	0.47	8.0	0.67	21.1	0.58	16.9	1.10	- -
B019607	0.86	16.0	0.86	28.9	0.82	21.8	0.58	14.8	0.65	16.7	0.91	35.1	0.79	29.6	1.62	- -
B019558	1.78	- -	1.38	- -	1.50	- -	1.08	- -	1.23	- -	1.69	- -	1.58	- -	3.61	- -
B014979	2.24	- -	1.86	- -	1.99	- -	1.41	- -	1.59	- -	2.16	- -	1.99	- -	4.41	- -
B007334	1.22	- -	0.88	29.6	1.03	- -	0.78	25.6	0.88	27.5	1.05	- -	0.98	41.1	2.34	- -
B08523	1.26	- -	0.98	34.8	1.08	- -	0.80	26.7	0.90	28.1	1.18	- -	1.08	- -	2.41	- -
B007334	1.22	- -	0.88	29.6	1.03	- -	0.78	25.6	0.88	27.5	1.05	- -	0.98	41.1	2.34	- -
B009005	1.17	- -	0.87	29.5	0.98	28.6	0.73	22.9	0.82	24.4	0.97	38.0	0.92	37.0	2.22	- -
B008521	1.57	- -	1.25	- -	1.37	- -	1.00	- -	1.14	- -	1.52	- -	1.40	- -	3.03	- -
B007848	1.72	- -	1.15	- -	1.32	- -	1.00	37.3	1.13	- -	1.29	- -	1.25	- -	3.18	- -
B011110	2.08	- -	1.34	- -	1.55	- -	1.18	- -	1.34	- -	1.44	- -	1.40	- -	3.73	- -
B011206	1.20	- -	0.78	24.5	0.90	25.3	0.68	20.5	0.78	22.4	0.84	30.7	0.81	30.6	2.16	- -
B011081	4.55	- -	3.86	- -	4.12	- -	2.90	- -	3.28	- -	4.43	- -	4.04	- -	8.82	- -
B009782	2.51	- -	1.60	- -	1.87	- -	1.42	- -	1.61	- -	1.75	- -	1.71	- -	4.57	- -
B005318	0.84	15.4	0.55	12.7	0.63	14.0	0.48	9.4	0.54	11.4	0.61	17.8	0.60	18.2	1.55	- -
B007536	2.39	- -	1.64	- -	1.86	- -	1.39	- -	1.57	- -	1.98	- -	1.91	- -	4.60	- -
B012825	2.48	- -	1.58	- -	1.84	- -	1.40	- -	1.59	- -	1.72	- -	1.68	- -	4.51	- -
B011335	2.27	- -	1.39	- -	1.64	- -	1.26	- -	1.43	- -	1.42	- -	1.37	- -	3.98	- -
B002310	0.60	8.4	0.59	15.2	0.58	11.9	0.42	6.7	0.47	7.8	0.67	20.9	0.59	17.5	1.12	- -
B011097	1.76	- -	1.29	- -	1.43	- -	1.06	- -	1.20	- -	1.61	- -	1.55	- -	3.43	- -
B012559	1.27	- -	0.86	28.6	0.98	28.5	0.73	23.3	0.83	25.0	0.96	37.8	0.94	38.4	2.35	- -
B011344	1.17	- -	0.76	23.6	0.88	24.4	0.67	19.6	0.75	21.4	0.82	29.8	0.79	29.6	2.11	- -
B012319	2.16	- -	1.23	- -	1.49	- -	1.16	- -	1.32	- -	1.19	- -	1.14	- -	3.59	- -
B012350	3.69	- -	2.24	- -	2.66	- -	2.05	- -	2.32	- -	2.23	- -	2.15	- -	6.36	- -
B017781	3.79	- -	2.26	- -	2.68	- -	2.08	- -	2.36	- -	2.19	- -	2.11	- -	6.43	- -
B015764	1.88	- -	1.36	- -	1.51	- -	1.11	- -	1.26	- -	1.76	- -	1.64	- -	3.74	- -
B019141	2.92	- -	1.88	- -	2.18	- -	1.66	- -	1.88	- -	2.06	- -	2.01	- -	5.36	- -
B019990	2.52	- -	1.52	- -	1.80	- -	1.39	- -	1.57	- -	1.52	- -	1.47	- -	4.36	- -
B019473	3.08	- -	1.85	- -	2.20	- -	1.70	- -	1.92	- -	1.84	- -	1.78	- -	5.30	- -
B016591	2.85	- -	2.21	- -	2.40	- -	1.73	- -	1.96	- -	2.71	- -	2.53	- -	5.77	- -
B018106	2.83	- -	2.00	- -	2.24	- -	1.66	- -	1.88	- -	2.55	- -	2.41	- -	5.63	- -
B016845	3.83	- -	2.37	- -	2.79	- -	2.14	- -	2.42	- -	2.45	- -	2.38	- -	6.78	- -
B014450	0.88	16.5	0.99	35.6	0.84	22.8	0.81	27.2	1.56	- -	2.17	- -	2.03	- -	4.42	- -
B016510	1.93	- -	1.68	- -	1.79	- -	1.28	- -	1.45	- -	1.40	- -	1.34	- -	3.80	- -
B016111	1.78	- -	1.23	- -	1.48	- -	1.09	- -	1.25	- -	1.01	- -	0.97	40.1	3.14	- -
B016310	2.28	- -	1.36	- -	1.61	- -	1.24	- -	1.41	- -	1.47	- -	1.41	- -	4.02	- -
B015295	3.38	- -	2.40	- -	2.69	- -	1.99	- -	2.25	- -	3.06	- -	2.88	- -	6.66	- -
B017909	1.33	- -	0.77	24.1	0.92	26.3	0.72	22.3	0.82	24.4	0.76	26.5	0.73	25.8	2.25	- -
B015820	3.12	- -	1.76	- -	2.14	- -	1.67	- -	1.90	- -	1.66	- -	1.59	- -	6.28	- -

Table E - 2: Legal Load Posting Data for Exterior Girders, LRFR Shear Data



Bin	ALDOT Legal Load Exterior Girder Shear															
	H20		HS20		Two-Axle		Tri-Axle		Concrete		18 Wheeler		6 Axle		School Bus	
	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)
B001319	2.39	- -	2.04	- -	2.22	- -	1.58	- -	1.70	- -	2.56	- -	2.36	- -	4.93	- -
B011017	1.64	- -	1.03	- -	1.23	- -	0.87	30.7	1.00	32.8	1.40	- -	1.27	- -	3.34	- -
B007699	0.65	9.9	0.55	12.8	0.58	11.8	0.40	5.2	0.43	6.0	0.67	21.2	0.61	18.3	1.58	- -
B005167	1.19	- -	0.84	27.8	0.96	28.0	0.66	19.4	0.75	21.2	1.15	- -	1.11	- -	2.68	- -
B006360	1.43	- -	0.91	31.5	1.08	- -	0.76	24.5	0.86	26.4	1.29	- -	1.16	- -	2.86	- -
B003411	2.61	- -	1.58	- -	1.91	- -	1.38	- -	1.59	- -	1.97	- -	1.83	- -	4.96	- -
B008653	2.13	- -	1.83	- -	1.99	- -	1.37	- -	1.51	- -	2.23	- -	2.08	- -	4.71	- -
B019607	1.68	- -	1.27	- -	1.48	- -	1.00	37.4	1.11	- -	1.68	- -	1.59	- -	3.83	- -
B019558	2.41	- -	1.60	- -	1.85	- -	1.33	- -	1.51	- -	2.20	- -	2.00	- -	5.02	- -
B014979	39.68	- -	27.25	- -	31.26	- -	21.32	- -	24.20	- -	38.27	- -	36.37	- -	91.29	- -
B007334	1.26	- -	0.86	28.6	1.00	29.4	0.67	19.9	0.78	22.7	1.18	- -	1.11	- -	3.05	- -
B08523	1.11	- -	0.73	22.0	0.85	23.1	0.57	14.2	0.65	16.7	1.00	- -	0.89	35.6	2.66	- -
B007334	1.26	- -	0.86	28.6	1.00	29.4	0.67	19.9	0.78	22.7	1.18	- -	1.11	- -	3.05	- -
B009005	1.36	- -	0.80	25.9	0.99	28.9	0.66	19.5	0.77	22.3	1.09	- -	0.98	40.9	3.13	- -
B008521	1.77	- -	1.19	- -	1.39	- -	0.94	34.3	1.09	- -	1.65	- -	1.57	- -	4.20	- -
B007848	3.01	- -	1.81	- -	2.20	- -	1.63	- -	1.84	- -	2.02	- -	1.89	- -	5.24	- -
B011110	1.23	- -	0.65	18.2	0.83	22.5	0.55	13.5	0.64	16.2	0.87	32.7	0.79	29.2	2.69	- -
B011206	2.45	- -	1.43	- -	1.74	- -	1.27	- -	1.47	- -	1.52	- -	1.44	- -	4.41	- -
B011081	6.31	- -	4.55	- -	5.13	- -	3.89	- -	4.31	- -	6.04	- -	5.71	- -	12.03	- -
B009782	5.89	- -	3.60	- -	4.24	- -	3.30	- -	3.72	- -	3.70	- -	3.52	- -	10.01	- -
B005318	6.71	- -	4.15	- -	4.89	- -	3.79	- -	4.28	- -	4.37	- -	4.13	- -	11.46	- -
B007536	4.70	- -	2.98	- -	3.50	- -	2.70	- -	3.02	- -	3.33	- -	3.15	- -	8.25	- -
B012825	7.30	- -	4.42	- -	5.26	- -	4.09	- -	4.61	- -	4.55	- -	4.33	- -	12.42	- -
B011335	3.98	- -	2.36	- -	2.83	- -	2.21	- -	2.49	- -	2.34	- -	2.20	- -	6.64	- -
B002310	2.63	- -	2.01	- -	2.30	- -	1.68	- -	1.84	- -	2.54	- -	2.40	- -	5.51	- -
B011097	4.84	- -	3.24	- -	3.74	- -	2.87	- -	3.19	- -	3.70	- -	3.48	- -	8.79	- -
B012559	6.50	- -	4.17	- -	4.89	- -	3.77	- -	4.19	- -	4.29	- -	4.08	- -	11.58	- -
B011344	2.45	- -	1.53	- -	1.82	- -	1.41	- -	1.57	- -	1.65	- -	1.55	- -	4.26	- -
B012319	4.70	- -	2.90	- -	3.44	- -	2.66	- -	2.96	- -	2.88	- -	2.72	- -	8.00	- -
B012350	1.99	- -	1.18	- -	1.42	- -	1.10	- -	1.24	- -	1.17	- -	1.10	- -	3.35	- -
B017781	4.16	- -	2.42	- -	2.92	- -	2.28	- -	2.57	- -	2.35	- -	2.22	- -	6.86	- -
B015764	2.79	- -	1.73	- -	2.10	- -	1.37	- -	1.69	- -	2.13	- -	2.00	- -	4.94	- -
B019141	2.23	- -	1.36	- -	1.63	- -	1.26	- -	1.43	- -	1.42	- -	1.35	- -	3.83	- -
B019990	16.29	- -	8.77	- -	10.93	- -	8.14	- -	9.40	- -	8.47	- -	7.99	- -	28.40	- -
B019473	4.37	- -	2.39	- -	2.95	- -	2.20	- -	2.56	- -	2.33	- -	2.18	- -	7.42	- -
B016591	4.00	- -	2.64	- -	3.06	- -	2.27	- -	2.56	- -	3.54	- -	3.23	- -	7.74	- -
B018106	6.54	- -	4.11	- -	4.90	- -	3.00	- -	3.77	- -	5.07	- -	4.66	- -	11.94	- -
B016845	4.12	- -	2.46	- -	2.94	- -	2.25	- -	2.58	- -	2.46	- -	2.33	- -	6.93	- -
B014450	0.88	16.6	0.86	28.7	1.00	- -	0.61	16.5	0.74	20.8	1.16	- -	1.12	- -	3.11	- -
B016510	2.15	- -	1.74	- -	1.97	- -	1.40	- -	1.54	- -	2.01	- -	1.83	- -	5.68	- -
B016111	1.55	- -	0.99	35.3	1.15	- -	0.69	21.1	0.85	26.0	1.30	- -	1.25	- -	3.39	- -
B016310	3.48	- -	2.26	- -	2.65	- -	2.04	- -	2.27	- -	2.58	- -	2.40	- -	6.17	- -
B015295	29.32	- -	18.98	- -	22.10	- -	17.03	- -	19.03	- -	22.01	- -	20.69	- -	52.20	- -
B017909	3.45	- -	1.94	- -	2.42	- -	1.71	- -	2.03	- -	2.12	- -	1.94	- -	6.11	- -
B015820	4.17	- -	2.34	- -	2.87	- -	2.14	- -	2.49	- -	2.25	- -	2.09	- -	7.03	- -

Table E - 3: Legal Load Posting Data for Interior Girders, LRFR Moment Data

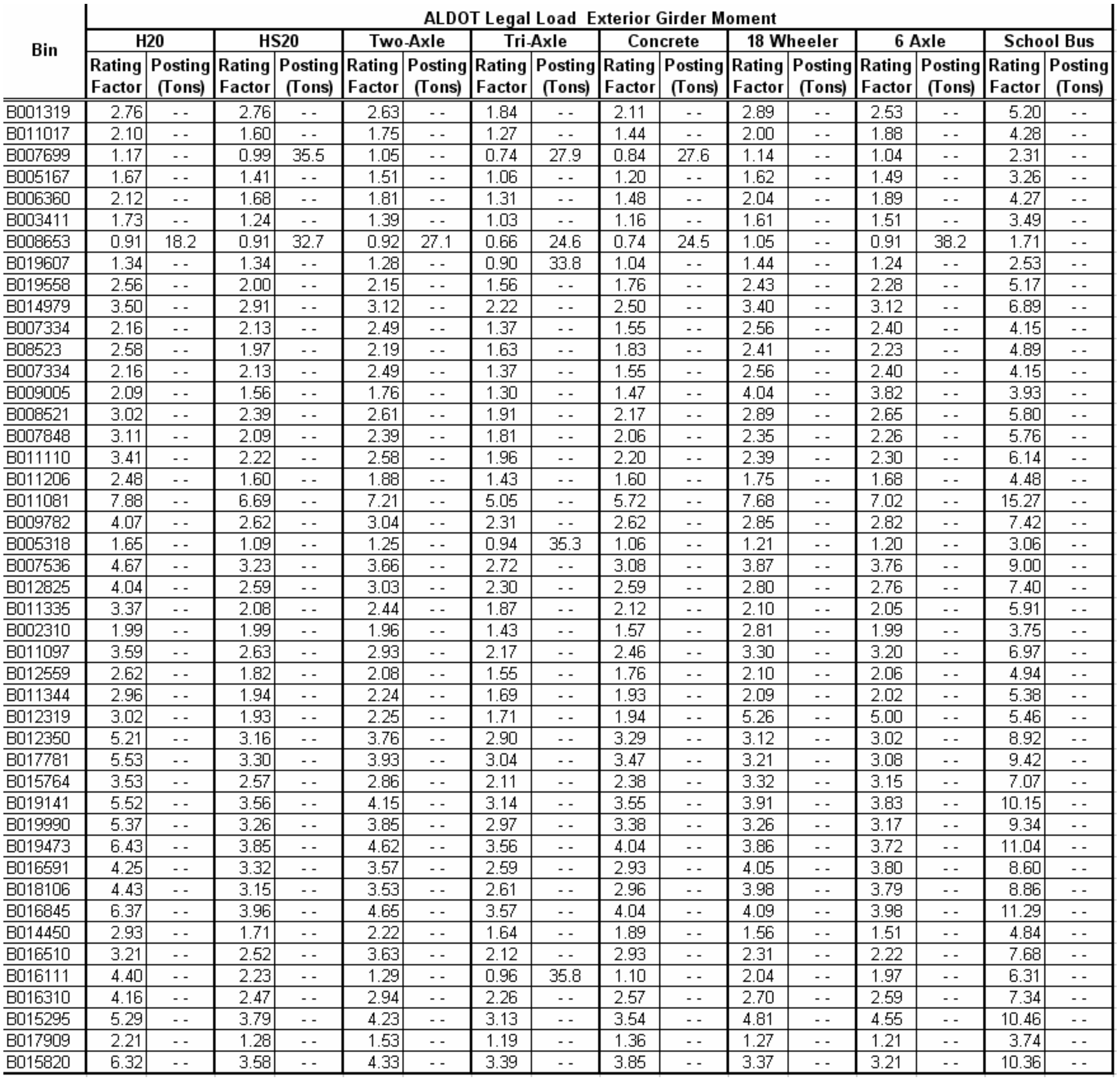


Bin	ALDOT Legal Load Interior Girder Moment															
	H20		HS20		Two-Axle		Tri-Axle		Concrete		18 Wheeler		6 Axle		School Bus	
	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)
B001319	0.94	18.2	0.93	32.4	0.88	24.6	0.62	17.2	0.71	19.2	0.98	38.7	0.85	33.3	1.77	- -
B011017	1.32	- -	1.01	- -	1.10	- -	0.80	26.9	0.90	28.5	1.26	- -	1.18	- -	2.71	- -
B007699	0.64	9.7	0.54	12.1	0.57	11.3	0.40	5.4	0.45	7.2	0.62	18.1	0.57	16.1	1.26	- -
B005167	0.84	15.4	0.71	21.0	0.75	19.1	0.53	12.3	0.60	14.0	0.81	29.3	0.75	26.7	1.64	- -
B006360	0.97	19.2	0.77	24.1	0.83	22.2	0.60	15.9	0.67	17.6	0.93	35.9	0.87	33.9	1.96	- -
B003411	0.58	7.9	0.41	5.6	0.46	6.7	0.34	2.1	0.38	4.0	0.53	13.2	0.50	11.9	1.15	- -
B008653	0.58	8.1	0.58	14.6	0.59	12.1	0.42	6.4	0.47	8.0	0.67	21.1	0.58	16.9	1.10	- -
B019607	0.86	16.0	0.86	28.9	0.82	21.8	0.58	14.8	0.65	16.7	0.91	35.1	0.79	29.6	1.62	- -
B019558	2.36	- -	1.83	- -	1.98	- -	1.44	- -	1.63	- -	2.24	- -	2.10	- -	4.78	- -
B014979	2.73	- -	2.26	- -	2.42	- -	1.71	- -	1.94	- -	2.64	- -	2.43	- -	5.37	- -
B007334	1.39	- -	0.86	28.6	1.01	- -	0.76	24.8	0.87	26.9	1.03	- -	0.96	39.8	2.55	- -
B08523	1.28	- -	0.99	35.5	1.10	- -	0.81	27.2	0.91	28.7	1.19	- -	1.10	- -	2.44	- -
B007334	1.39	- -	0.86	28.6	1.01	- -	0.76	24.8	0.87	26.9	1.03	- -	0.96	39.8	2.55	- -
B009005	1.77	- -	1.32	- -	1.48	- -	1.10	- -	1.23	- -	1.55	- -	1.45	- -	3.35	- -
B008521	1.65	- -	1.31	- -	1.44	- -	1.05	- -	1.19	- -	1.59	- -	1.47	- -	3.17	- -
B007848	1.84	- -	1.23	- -	1.41	- -	1.06	- -	1.21	- -	1.38	- -	1.33	- -	3.40	- -
B011110	2.36	- -	1.52	- -	1.76	- -	1.34	- -	1.52	- -	1.64	- -	1.59	- -	4.23	- -
B011206	1.23	- -	0.80	25.6	0.92	26.2	0.70	21.5	0.80	23.4	0.86	32.0	0.83	31.9	2.21	- -
B011081	2.66	- -	2.26	- -	2.42	- -	1.70	- -	1.92	- -	2.60	- -	2.36	- -	5.17	- -
B009782	3.17	- -	2.02	- -	2.36	- -	1.79	- -	2.03	- -	2.20	- -	2.15	- -	5.77	- -
B005318	0.90	17.0	0.58	14.6	0.67	15.8	0.51	11.2	0.58	13.1	0.65	20.3	0.65	20.8	1.66	- -
B007536	2.43	- -	1.68	- -	1.90	- -	1.42	- -	1.60	- -	2.02	- -	1.95	- -	4.70	- -
B012825	3.41	- -	2.17	- -	2.53	- -	1.92	- -	2.18	- -	2.36	- -	2.30	- -	6.19	- -
B011335	2.79	- -	1.71	- -	2.02	- -	1.55	- -	1.76	- -	1.74	- -	1.69	- -	4.89	- -
B002310	0.52	6.2	0.52	11.2	0.51	8.7	0.37	3.7	0.41	5.0	0.58	16.0	0.52	13.0	0.98	12.1
B011097	1.87	- -	1.37	- -	1.52	- -	1.13	- -	1.28	- -	1.72	- -	1.65	- -	3.65	- -
B012559	1.74	- -	1.18	- -	1.34	- -	1.01	- -	1.14	- -	1.32	- -	1.29	- -	3.24	- -
B011344	1.47	- -	0.96	33.8	1.11	- -	0.84	28.9	0.95	30.7	1.04	- -	1.00	- -	2.66	- -
B012319	2.08	- -	1.19	- -	1.43	- -	1.12	- -	1.27	- -	1.15	- -	1.09	- -	3.45	- -
B012350	4.61	- -	2.80	- -	3.32	- -	2.56	- -	2.90	- -	2.79	- -	2.68	- -	7.95	- -
B017781	4.71	- -	2.81	- -	3.34	- -	2.58	- -	2.94	- -	2.73	- -	2.62	- -	8.00	- -
B015764	1.87	- -	1.35	- -	1.50	- -	1.11	- -	1.25	- -	1.75	- -	1.64	- -	3.72	- -
B019141	3.38	- -	2.17	- -	2.53	- -	1.92	- -	2.17	- -	2.38	- -	2.33	- -	6.20	- -
B019990	3.38	- -	2.04	- -	2.42	- -	1.86	- -	2.11	- -	2.04	- -	1.98	- -	5.85	- -
B019473	3.71	- -	2.22	- -	2.64	- -	2.04	- -	2.32	- -	2.21	- -	2.14	- -	6.38	- -
B016591	3.55	- -	2.76	- -	2.98	- -	2.16	- -	2.44	- -	3.37	- -	3.16	- -	7.19	- -
B018106	4.35	- -	3.07	- -	3.45	- -	2.55	- -	2.89	- -	3.89	- -	3.68	- -	8.60	- -
B016845	4.60	- -	2.84	- -	3.35	- -	2.56	- -	2.91	- -	2.94	- -	2.86	- -	8.14	- -
B014450	1.64	- -	1.85	- -	1.56	- -	1.50	- -	1.92	- -	2.67	- -	2.50	- -	5.44	- -
B016510	2.07	- -	1.67	- -	1.86	- -	1.37	- -	1.55	- -	1.38	- -	1.33	- -	3.98	- -
B016111	2.03	- -	1.39	- -	1.67	- -	1.23	- -	1.42	- -	1.14	- -	1.09	- -	3.55	- -
B016310	2.40	- -	1.43	- -	1.70	- -	1.31	- -	1.49	- -	1.55	- -	1.49	- -	4.24	- -
B015295	3.04	- -	2.16	- -	2.42	- -	1.79	- -	2.03	- -	2.75	- -	2.59	- -	5.99	- -
B017909	1.61	- -	0.93	32.2	1.12	- -	0.87	30.3	0.99	32.4	0.92	35.6	0.88	34.8	2.71	- -
B015820	3.53	- -	2.03	- -	2.46	- -	1.93	- -	2.19	- -	1.92	- -	1.83	- -	6.17	- -

Table E - 4: Legal Load Posting Data for Interior Girders, LRFR Shear Data

Bin	ALDOT Legal Load Interior Girder Shear															
	H20		HS20		Two-Axle		Tri-Axle		Concrete		18 Wheeler		6 Axle		School Bus	
	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)
B001319	1.39	20.0	1.12	- -	1.29	- -	0.88	31.2	0.97	31.7	1.45	- -	1.37	- -	2.93	- -
B011017	1.50	- -	0.94	33.0	1.12	- -	0.79	26.5	0.90	28.5	1.28	- -	1.16	- -	3.06	- -
B007699	0.68	10.9	0.58	14.5	0.61	13.2	0.41	5.7	0.45	6.9	0.71	23.3	0.64	20.4	1.66	- -
B005167	1.18	- -	0.83	27.4	0.96	27.6	0.66	19.2	0.74	20.9	1.14	- -	1.10	- -	2.66	- -
B006360	1.36	- -	0.87	29.1	1.02	- -	0.72	22.4	0.82	24.4	1.23	- -	1.10	- -	2.73	- -
B003411	1.90	- -	1.13	- -	1.38	- -	0.98	36.5	1.13	- -	1.42	- -	1.31	- -	3.72	- -
B008653	2.01	- -	1.73	- -	1.88	- -	1.29	- -	1.43	- -	2.11	- -	1.97	- -	4.45	- -
B019607	1.38	- -	1.03	- -	1.20	- -	0.81	27.2	0.90	28.3	1.38	- -	1.30	- -	3.16	- -
B019558	2.82	- -	1.87	- -	2.17	- -	1.56	- -	1.77	- -	2.53	- -	2.30	- -	5.72	- -
B014979	43.26	- -	29.56	- -	34.01	- -	23.38	- -	26.48	- -	41.80	- -	39.46	- -	95.96	- -
B007334	1.23	- -	0.85	28.1	0.99	29.2	0.66	19.5	0.77	22.2	1.16	- -	1.08	- -	2.98	- -
B08523	1.10	- -	0.74	22.5	0.86	23.4	0.57	14.4	0.65	16.7	1.02	- -	0.91	36.6	2.64	- -
B007334	1.23	- -	0.85	28.1	0.99	29.2	0.66	19.5	0.77	22.2	1.16	- -	1.08	- -	2.98	- -
B009005	1.63	- -	1.01	- -	1.23	- -	0.84	28.7	0.96	31.2	1.36	- -	1.23	- -	3.67	- -
B008521	1.40	- -	0.97	34.4	1.13	- -	0.76	24.8	0.88	27.3	1.32	- -	1.23	- -	3.41	- -
B007848	2.86	- -	1.69	- -	2.06	- -	1.52	- -	1.72	- -	1.89	- -	1.77	- -	4.97	- -
B011110	1.19	- -	0.64	17.7	0.81	21.5	0.54	12.7	0.63	15.8	0.85	31.6	0.77	28.2	2.54	- -
B011206	3.57	- -	2.04	- -	2.49	- -	1.84	- -	2.10	- -	2.19	- -	2.06	- -	6.44	- -
B011081	3.21	- -	2.32	- -	2.61	- -	1.98	- -	2.19	- -	3.07	- -	2.91	- -	6.12	- -
B009782	5.77	- -	3.52	- -	4.16	- -	3.23	- -	3.64	- -	3.63	- -	3.45	- -	9.81	- -
B005318	6.21	- -	3.84	- -	4.52	- -	3.51	- -	3.96	- -	4.04	- -	3.82	- -	10.60	- -
B007536	4.28	- -	2.72	- -	3.19	- -	2.47	- -	2.75	- -	3.03	- -	2.88	- -	7.52	- -
B012825	7.87	- -	4.76	- -	5.67	- -	4.41	- -	4.97	- -	4.90	- -	4.67	- -	13.39	- -
B011335	3.98	- -	2.37	- -	2.84	- -	2.22	- -	2.50	- -	2.35	- -	2.20	- -	6.66	- -
B002310	2.16	- -	1.65	- -	1.88	- -	1.38	- -	1.51	- -	2.09	- -	1.97	- -	4.52	- -
B011097	4.59	- -	3.07	- -	3.55	- -	2.72	- -	3.03	- -	3.51	- -	3.30	- -	8.34	- -
B012559	6.80	- -	4.39	- -	5.12	- -	3.94	- -	4.38	- -	4.51	- -	4.29	- -	12.11	- -
B011344	2.56	- -	1.60	- -	1.91	- -	1.48	- -	1.64	- -	1.72	- -	1.62	- -	4.45	- -
B012319	3.59	- -	2.21	- -	2.63	- -	2.04	- -	2.26	- -	2.19	- -	2.07	- -	6.12	- -
B012350	1.96	- -	1.16	- -	1.40	- -	1.09	- -	1.22	- -	1.16	- -	1.09	- -	3.30	- -
B017781	4.12	- -	2.39	- -	2.89	- -	2.26	- -	2.54	- -	2.33	- -	2.20	- -	6.79	- -
B015764	2.58	- -	1.55	- -	1.95	- -	1.23	- -	1.52	- -	1.98	- -	1.85	- -	4.58	- -
B019141	2.19	- -	1.33	- -	1.59	- -	1.24	- -	1.40	- -	1.39	- -	1.32	- -	3.75	- -
B019990	17.26	- -	9.33	- -	11.60	- -	8.66	- -	9.98	- -	9.01	- -	8.50	- -	30.09	- -
B019473	4.80	- -	2.70	- -	3.29	- -	2.50	- -	2.89	- -	2.65	- -	2.47	- -	8.12	- -
B016591	2.76	- -	1.82	- -	2.11	- -	1.56	- -	1.76	- -	2.44	- -	2.22	- -	5.34	- -
B018106	7.09	- -	4.54	- -	5.34	- -	4.04	- -	4.54	- -	5.52	- -	5.08	- -	12.90	- -
B016845	4.22	- -	2.51	- -	3.00	- -	2.34	- -	2.64	- -	2.52	- -	2.38	- -	7.09	- -
B014450	1.05	- -	0.92	32.1	1.08	- -	0.70	21.7	0.86	26.3	1.25	- -	1.21	- -	3.30	- -
B016510	2.19	- -	1.67	- -	1.94	- -	1.32	- -	1.46	- -	2.06	- -	1.81	- -	5.44	- -
B016111	1.47	- -	0.93	32.3	1.08	- -	0.72	22.3	0.85	26.0	1.22	- -	1.18	- -	3.23	- -
B016310	3.46	- -	2.25	- -	2.63	- -	2.03	- -	2.25	- -	2.56	- -	2.38	- -	6.12	- -
B015295	30.43	- -	19.70	- -	22.93	- -	17.67	- -	19.75	- -	22.85	- -	21.47	- -	54.17	- -
B017909	3.91	- -	2.32	- -	2.78	- -	2.08	- -	2.40	- -	2.48	- -	2.32	- -	6.84	- -
B015820	3.80	- -	2.09	- -	2.62	- -	1.92	- -	2.24	- -	2.01	- -	1.87	- -	6.42	- -

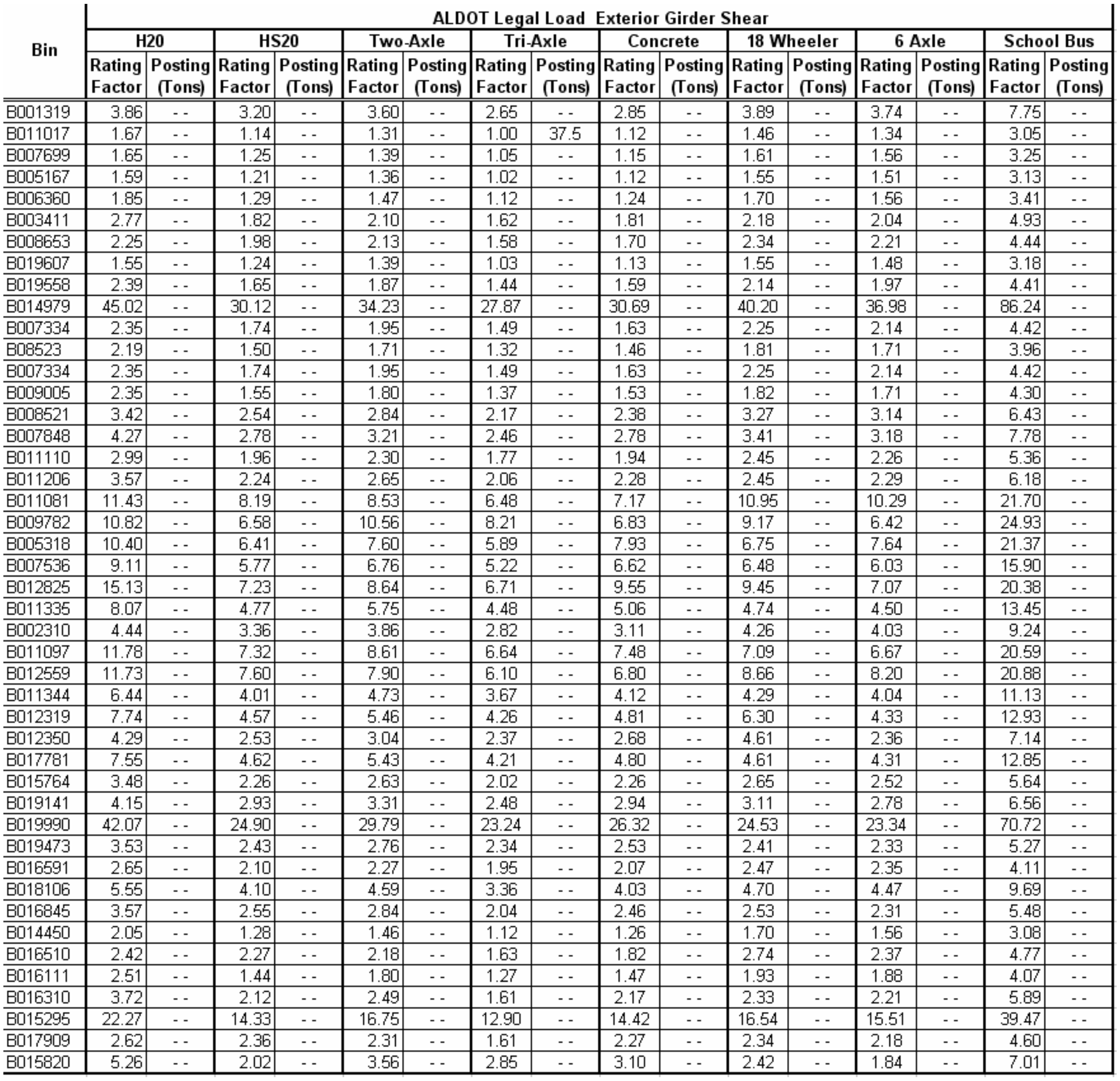
Table E - 5: Legal Load Posting Data for Exterior Girders, LFR Moment Data



ALDOT Legal Load Exterior Girder Moment

Bin	H20		HS20		Two-Axle		Tri-Axle		Concrete		18 Wheeler		6 Axle		School Bus	
	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)
B001319	2.76	- -	2.76	- -	2.63	- -	1.84	- -	2.11	- -	2.89	- -	2.53	- -	5.20	- -
B011017	2.10	- -	1.60	- -	1.75	- -	1.27	- -	1.44	- -	2.00	- -	1.88	- -	4.28	- -
B007699	1.17	- -	0.99	35.5	1.05	- -	0.74	27.9	0.84	27.6	1.14	- -	1.04	- -	2.31	- -
B005167	1.67	- -	1.41	- -	1.51	- -	1.06	- -	1.20	- -	1.62	- -	1.49	- -	3.26	- -
B006360	2.12	- -	1.68	- -	1.81	- -	1.31	- -	1.48	- -	2.04	- -	1.89	- -	4.27	- -
B003411	1.73	- -	1.24	- -	1.39	- -	1.03	- -	1.16	- -	1.61	- -	1.51	- -	3.49	- -
B008653	0.91	18.2	0.91	32.7	0.92	27.1	0.66	24.6	0.74	24.5	1.05	- -	0.91	38.2	1.71	- -
B019607	1.34	- -	1.34	- -	1.28	- -	0.90	33.8	1.04	- -	1.44	- -	1.24	- -	2.53	- -
B019558	2.56	- -	2.00	- -	2.15	- -	1.56	- -	1.76	- -	2.43	- -	2.28	- -	5.17	- -
B014979	3.50	- -	2.91	- -	3.12	- -	2.22	- -	2.50	- -	3.40	- -	3.12	- -	6.89	- -
B007334	2.16	- -	2.13	- -	2.49	- -	1.37	- -	1.55	- -	2.56	- -	2.40	- -	4.15	- -
B08523	2.58	- -	1.97	- -	2.19	- -	1.63	- -	1.83	- -	2.41	- -	2.23	- -	4.89	- -
B007334	2.16	- -	2.13	- -	2.49	- -	1.37	- -	1.55	- -	2.56	- -	2.40	- -	4.15	- -
B009005	2.09	- -	1.56	- -	1.76	- -	1.30	- -	1.47	- -	4.04	- -	3.82	- -	3.93	- -
B008521	3.02	- -	2.39	- -	2.61	- -	1.91	- -	2.17	- -	2.89	- -	2.65	- -	5.80	- -
B007848	3.11	- -	2.09	- -	2.39	- -	1.81	- -	2.06	- -	2.35	- -	2.26	- -	5.76	- -
B011110	3.41	- -	2.22	- -	2.58	- -	1.96	- -	2.20	- -	2.39	- -	2.30	- -	6.14	- -
B011206	2.48	- -	1.60	- -	1.88	- -	1.43	- -	1.60	- -	1.75	- -	1.68	- -	4.48	- -
B011081	7.88	- -	6.69	- -	7.21	- -	5.05	- -	5.72	- -	7.68	- -	7.02	- -	15.27	- -
B009782	4.07	- -	2.62	- -	3.04	- -	2.31	- -	2.62	- -	2.85	- -	2.82	- -	7.42	- -
B005318	1.65	- -	1.09	- -	1.25	- -	0.94	35.3	1.06	- -	1.21	- -	1.20	- -	3.06	- -
B007536	4.67	- -	3.23	- -	3.66	- -	2.72	- -	3.08	- -	3.87	- -	3.76	- -	9.00	- -
B012825	4.04	- -	2.59	- -	3.03	- -	2.30	- -	2.59	- -	2.80	- -	2.76	- -	7.40	- -
B011335	3.37	- -	2.08	- -	2.44	- -	1.87	- -	2.12	- -	2.10	- -	2.05	- -	5.91	- -
B002310	1.99	- -	1.99	- -	1.96	- -	1.43	- -	1.57	- -	2.81	- -	1.99	- -	3.75	- -
B011097	3.59	- -	2.63	- -	2.93	- -	2.17	- -	2.46	- -	3.30	- -	3.20	- -	6.97	- -
B012559	2.62	- -	1.82	- -	2.08	- -	1.55	- -	1.76	- -	2.10	- -	2.06	- -	4.94	- -
B011344	2.96	- -	1.94	- -	2.24	- -	1.69	- -	1.93	- -	2.09	- -	2.02	- -	5.38	- -
B012319	3.02	- -	1.93	- -	2.25	- -	1.71	- -	1.94	- -	5.26	- -	5.00	- -	5.46	- -
B012350	5.21	- -	3.16	- -	3.76	- -	2.90	- -	3.29	- -	3.12	- -	3.02	- -	8.92	- -
B017781	5.53	- -	3.30	- -	3.93	- -	3.04	- -	3.47	- -	3.21	- -	3.08	- -	9.42	- -
B015764	3.53	- -	2.57	- -	2.86	- -	2.11	- -	2.38	- -	3.32	- -	3.15	- -	7.07	- -
B019141	5.52	- -	3.56	- -	4.15	- -	3.14	- -	3.55	- -	3.91	- -	3.83	- -	10.15	- -
B019990	5.37	- -	3.26	- -	3.85	- -	2.97	- -	3.38	- -	3.26	- -	3.17	- -	9.34	- -
B019473	6.43	- -	3.85	- -	4.62	- -	3.56	- -	4.04	- -	3.86	- -	3.72	- -	11.04	- -
B016591	4.25	- -	3.32	- -	3.57	- -	2.59	- -	2.93	- -	4.05	- -	3.80	- -	8.60	- -
B018106	4.43	- -	3.15	- -	3.53	- -	2.61	- -	2.96	- -	3.98	- -	3.79	- -	8.86	- -
B016845	6.37	- -	3.96	- -	4.65	- -	3.57	- -	4.04	- -	4.09	- -	3.98	- -	11.29	- -
B014450	2.93	- -	1.71	- -	2.22	- -	1.64	- -	1.89	- -	1.56	- -	1.51	- -	4.84	- -
B016510	3.21	- -	2.52	- -	3.63	- -	2.12	- -	2.93	- -	2.31	- -	2.22	- -	7.68	- -
B016111	4.40	- -	2.23	- -	1.29	- -	0.96	35.8	1.10	- -	2.04	- -	1.97	- -	6.31	- -
B016310	4.16	- -	2.47	- -	2.94	- -	2.26	- -	2.57	- -	2.70	- -	2.59	- -	7.34	- -
B015295	5.29	- -	3.79	- -	4.23	- -	3.13	- -	3.54	- -	4.81	- -	4.55	- -	10.46	- -
B017909	2.21	- -	1.28	- -	1.53	- -	1.19	- -	1.36	- -	1.27	- -	1.21	- -	3.74	- -
B015820	6.32	- -	3.58	- -	4.33	- -	3.39	- -	3.85	- -	3.37	- -	3.21	- -	10.36	- -

Table E - 6: Legal Load Posting Data for Exterior Girders, LFR Shear Data



Bin	ALDOT Legal Load Exterior Girder Shear															
	H20		HS20		Two-Axle		Tri-Axle		Concrete		18 Wheeler		6 Axle		School Bus	
	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)
B001319	3.86	- -	3.20	- -	3.60	- -	2.65	- -	2.85	- -	3.89	- -	3.74	- -	7.75	- -
B011017	1.67	- -	1.14	- -	1.31	- -	1.00	37.5	1.12	- -	1.46	- -	1.34	- -	3.05	- -
B007699	1.65	- -	1.25	- -	1.39	- -	1.05	- -	1.15	- -	1.61	- -	1.56	- -	3.25	- -
B005167	1.59	- -	1.21	- -	1.36	- -	1.02	- -	1.12	- -	1.55	- -	1.51	- -	3.13	- -
B006360	1.85	- -	1.29	- -	1.47	- -	1.12	- -	1.24	- -	1.70	- -	1.56	- -	3.41	- -
B003411	2.77	- -	1.82	- -	2.10	- -	1.62	- -	1.81	- -	2.18	- -	2.04	- -	4.93	- -
B008653	2.25	- -	1.98	- -	2.13	- -	1.58	- -	1.70	- -	2.34	- -	2.21	- -	4.44	- -
B019607	1.55	- -	1.24	- -	1.39	- -	1.03	- -	1.13	- -	1.55	- -	1.48	- -	3.18	- -
B019558	2.39	- -	1.65	- -	1.87	- -	1.44	- -	1.59	- -	2.14	- -	1.97	- -	4.41	- -
B014979	45.02	- -	30.12	- -	34.23	- -	27.87	- -	30.69	- -	40.20	- -	36.98	- -	86.24	- -
B007334	2.35	- -	1.74	- -	1.95	- -	1.49	- -	1.63	- -	2.25	- -	2.14	- -	4.42	- -
B08523	2.19	- -	1.50	- -	1.71	- -	1.32	- -	1.46	- -	1.81	- -	1.71	- -	3.96	- -
B007334	2.35	- -	1.74	- -	1.95	- -	1.49	- -	1.63	- -	2.25	- -	2.14	- -	4.42	- -
B009005	2.35	- -	1.55	- -	1.80	- -	1.37	- -	1.53	- -	1.82	- -	1.71	- -	4.30	- -
B008521	3.42	- -	2.54	- -	2.84	- -	2.17	- -	2.38	- -	3.27	- -	3.14	- -	6.43	- -
B007848	4.27	- -	2.78	- -	3.21	- -	2.46	- -	2.78	- -	3.41	- -	3.18	- -	7.78	- -
B011110	2.99	- -	1.96	- -	2.30	- -	1.77	- -	1.94	- -	2.45	- -	2.26	- -	5.36	- -
B011206	3.57	- -	2.24	- -	2.65	- -	2.06	- -	2.28	- -	2.45	- -	2.29	- -	6.18	- -
B011081	11.43	- -	8.19	- -	8.53	- -	6.48	- -	7.17	- -	10.95	- -	10.29	- -	21.70	- -
B009782	10.82	- -	6.58	- -	10.56	- -	8.21	- -	6.83	- -	9.17	- -	6.42	- -	24.93	- -
B005318	10.40	- -	6.41	- -	7.60	- -	5.89	- -	7.93	- -	6.75	- -	7.64	- -	21.37	- -
B007536	9.11	- -	5.77	- -	6.76	- -	5.22	- -	6.62	- -	6.48	- -	6.03	- -	15.90	- -
B012825	15.13	- -	7.23	- -	8.64	- -	6.71	- -	9.55	- -	9.45	- -	7.07	- -	20.38	- -
B011335	8.07	- -	4.77	- -	5.75	- -	4.48	- -	5.06	- -	4.74	- -	4.50	- -	13.45	- -
B002310	4.44	- -	3.36	- -	3.86	- -	2.82	- -	3.11	- -	4.26	- -	4.03	- -	9.24	- -
B011097	11.78	- -	7.32	- -	8.61	- -	6.64	- -	7.48	- -	7.09	- -	6.67	- -	20.59	- -
B012559	11.73	- -	7.60	- -	7.90	- -	6.10	- -	6.80	- -	8.66	- -	8.20	- -	20.88	- -
B011344	6.44	- -	4.01	- -	4.73	- -	3.67	- -	4.12	- -	4.29	- -	4.04	- -	11.13	- -
B012319	7.74	- -	4.57	- -	5.46	- -	4.26	- -	4.81	- -	6.30	- -	4.33	- -	12.93	- -
B012350	4.29	- -	2.53	- -	3.04	- -	2.37	- -	2.68	- -	4.61	- -	2.36	- -	7.14	- -
B017781	7.55	- -	4.62	- -	5.43	- -	4.21	- -	4.80	- -	4.61	- -	4.31	- -	12.85	- -
B015764	3.48	- -	2.26	- -	2.63	- -	2.02	- -	2.26	- -	2.65	- -	2.52	- -	5.64	- -
B019141	4.15	- -	2.93	- -	3.31	- -	2.48	- -	2.94	- -	3.11	- -	2.78	- -	6.56	- -
B019990	42.07	- -	24.90	- -	29.79	- -	23.24	- -	26.32	- -	24.53	- -	23.34	- -	70.72	- -
B019473	3.53	- -	2.43	- -	2.76	- -	2.34	- -	2.53	- -	2.41	- -	2.33	- -	5.27	- -
B016591	2.65	- -	2.10	- -	2.27	- -	1.95	- -	2.07	- -	2.47	- -	2.35	- -	4.11	- -
B018106	5.55	- -	4.10	- -	4.59	- -	3.36	- -	4.03	- -	4.70	- -	4.47	- -	9.69	- -
B016845	3.57	- -	2.55	- -	2.84	- -	2.04	- -	2.46	- -	2.53	- -	2.31	- -	5.48	- -
B014450	2.05	- -	1.28	- -	1.46	- -	1.12	- -	1.26	- -	1.70	- -	1.56	- -	3.08	- -
B016510	2.42	- -	2.27	- -	2.18	- -	1.63	- -	1.82	- -	2.74	- -	2.37	- -	4.77	- -
B016111	2.51	- -	1.44	- -	1.80	- -	1.27	- -	1.47	- -	1.93	- -	1.88	- -	4.07	- -
B016310	3.72	- -	2.12	- -	2.49	- -	1.61	- -	2.17	- -	2.33	- -	2.21	- -	5.89	- -
B015295	22.27	- -	14.33	- -	16.75	- -	12.90	- -	14.42	- -	16.54	- -	15.51	- -	39.47	- -
B017909	2.62	- -	2.36	- -	2.31	- -	1.61	- -	2.27	- -	2.34	- -	2.18	- -	4.60	- -
B015820	5.26	- -	2.02	- -	3.56	- -	2.85	- -	3.10	- -	2.42	- -	1.84	- -	7.01	- -

Table E - 7: Legal Load Posting Data for Interior Girders, LFR Moment Data

Bin	ALDOT Legal Load Interior Girder Moment															
	H20		HS20		Two-Axle		Tri-Axle		Concrete		18 Wheeler		6 Axle		School Bus	
	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)
B001319	1.77	- -	1.76	- -	1.69	- -	1.18	- -	1.35	- -	1.86	- -	1.63	- -	3.34	- -
B011017	1.97	- -	1.50	- -	1.64	- -	1.19	- -	1.35	- -	1.87	- -	1.76	- -	4.02	- -
B007699	1.17	- -	0.98	35.4	1.04	- -	0.74	27.8	0.83	27.5	1.14	- -	1.04	- -	2.30	- -
B005167	1.58	- -	1.33	- -	1.43	- -	1.00	- -	1.13	- -	1.53	- -	1.41	- -	3.08	- -
B006360	1.90	- -	1.50	- -	1.62	- -	1.17	- -	1.32	- -	1.83	- -	1.69	- -	3.82	- -
B003411	0.88	17.7	0.63	22.8	0.71	20.9	0.52	19.6	0.59	19.5	0.82	32.8	0.77	32.3	1.78	- -
B008653	1.45	- -	1.45	- -	1.46	- -	1.05	- -	1.17	- -	1.67	- -	1.45	- -	2.72	- -
B019607	2.48	- -	2.48	- -	2.36	- -	1.66	- -	1.91	- -	2.66	- -	2.29	- -	4.67	- -
B019558	4.54	- -	3.53	- -	3.81	- -	2.77	- -	3.13	- -	4.32	- -	4.05	- -	9.17	- -
B014979	5.14	- -	4.28	- -	4.59	- -	3.26	- -	3.67	- -	5.00	- -	4.58	- -	10.12	- -
B007334	2.18	- -	2.13	- -	2.50	- -	1.89	- -	1.57	- -	2.56	- -	2.41	- -	4.20	- -
B08523	2.65	- -	2.06	- -	2.27	- -	1.68	- -	1.89	- -	2.50	- -	2.30	- -	5.04	- -
B007334	2.18	- -	2.13	- -	2.50	- -	1.89	- -	1.57	- -	2.56	- -	2.41	- -	4.20	- -
B009005	3.30	- -	2.46	- -	2.77	- -	2.06	- -	2.32	- -	2.93	- -	2.72	- -	6.20	- -
B008521	2.39	- -	1.89	- -	2.06	- -	1.52	- -	1.72	- -	2.29	- -	2.10	- -	4.60	- -
B007848	2.98	- -	2.00	- -	2.29	- -	1.73	- -	1.97	- -	2.24	- -	2.16	- -	5.51	- -
B011110	3.20	- -	2.08	- -	2.42	- -	1.84	- -	2.06	- -	2.24	- -	2.15	- -	5.76	- -
B011206	2.25	- -	1.45	- -	1.70	- -	1.29	- -	1.45	- -	1.58	- -	1.52	- -	4.06	- -
B011081	4.15	- -	3.53	- -	3.80	- -	2.66	- -	3.01	- -	4.04	- -	3.69	- -	8.04	- -
B009782	4.70	- -	3.03	- -	3.50	- -	2.66	- -	3.02	- -	3.28	- -	3.22	- -	8.56	- -
B005318	1.54	- -	1.01	- -	1.16	- -	0.88	32.9	0.99	32.7	1.12	- -	1.11	- -	2.84	- -
B007536	4.19	- -	2.90	- -	3.28	- -	2.45	- -	2.77	- -	3.48	- -	3.38	- -	8.09	- -
B012825	4.59	- -	2.94	- -	3.44	- -	2.61	- -	2.95	- -	3.18	- -	3.13	- -	8.40	- -
B011335	4.54	- -	2.80	- -	3.28	- -	2.52	- -	2.86	- -	2.83	- -	2.76	- -	7.96	- -
B002310	1.93	- -	2.76	- -	1.90	- -	1.38	- -	1.52	- -	2.93	- -	1.93	- -	3.63	- -
B011097	3.40	- -	2.49	- -	2.77	- -	2.06	- -	2.33	- -	3.13	- -	3.04	- -	6.61	- -
B012559	2.73	- -	1.90	- -	2.16	- -	1.62	- -	1.83	- -	2.20	- -	2.15	- -	5.14	- -
B011344	3.02	- -	1.98	- -	2.28	- -	1.73	- -	1.97	- -	2.13	- -	2.06	- -	5.48	- -
B012319	2.80	- -	1.79	- -	2.08	- -	1.58	- -	1.80	- -	1.92	- -	1.85	- -	5.05	- -
B012350	4.66	- -	2.83	- -	3.37	- -	2.60	- -	2.95	- -	2.79	- -	2.70	- -	7.99	- -
B017781	5.27	- -	3.14	- -	3.74	- -	2.89	- -	3.31	- -	3.06	- -	2.93	- -	8.97	- -
B015764	3.05	- -	2.22	- -	2.48	- -	1.82	- -	2.06	- -	2.87	- -	2.73	- -	6.11	- -
B019141	5.18	- -	3.34	- -	3.89	- -	2.95	- -	3.33	- -	3.67	- -	3.59	- -	9.52	- -
B019990	5.60	- -	3.40	- -	4.02	- -	3.10	- -	3.53	- -	3.41	- -	3.31	- -	9.75	- -
B019473	7.10	- -	4.25	- -	5.10	- -	3.93	- -	4.45	- -	4.26	- -	4.10	- -	12.19	- -
B016591	4.25	- -	3.32	- -	3.57	- -	2.59	- -	2.93	- -	4.05	- -	3.80	- -	8.60	- -
B018106	4.91	- -	3.49	- -	3.92	- -	2.89	- -	3.29	- -	4.39	- -	4.18	- -	9.77	- -
B016845	6.17	- -	3.83	- -	4.50	- -	3.45	- -	3.91	- -	3.96	- -	3.85	- -	10.92	- -
B014450	4.78	- -	2.66	- -	3.44	- -	2.55	- -	2.93	- -	2.43	- -	2.34	- -	7.51	- -
B016510	3.54	- -	2.18	- -	2.70	- -	2.34	- -	2.66	- -	2.00	- -	1.92	- -	5.77	- -
B016111	4.51	- -	2.27	- -	1.28	- -	0.95	35.5	1.09	- -	2.08	- -	2.00	- -	6.43	- -
B016310	3.76	- -	2.23	- -	2.66	- -	2.04	- -	2.33	- -	2.44	- -	2.34	- -	6.63	- -
B015295	4.78	- -	3.42	- -	3.82	- -	2.83	- -	3.20	- -	4.35	- -		0.0	9.44	- -
B017909	2.23	- -	1.29	- -	1.55	- -	1.20	- -	1.37	- -	1.28	- -	1.22	- -	3.77	- -
B015820	5.76	- -	3.26	- -	3.95	- -	3.09	- -	3.51	- -	3.07	- -	2.93	- -	9.44	- -

Table E - 8: Legal Load Posting Data for Interior Girders, LFR Shear Data

Bin	ALDOT Legal Load Interior Girder Shear															
	H20		HS20		Two-Axle		Tri-Axle		Concrete		18 Wheeler		6 Axle		School Bus	
	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)	Rating Factor	Posting (Tons)
B001319	2.32	- -	1.92	- -	2.16	- -	1.59	- -	1.71	- -	2.34	- -	2.24	- -	4.53	- -
B011017	1.57	- -	1.07	- -	1.23	- -	0.94	35.1	1.05	- -	1.36	- -	1.26	- -	2.86	- -
B007699	1.65	- -	1.24	- -	1.39	- -	1.05	- -	1.15	- -	1.61	- -	1.55	- -	3.22	- -
B005167	1.50	- -	1.14	- -	1.28	- -	0.96	36.1	1.06	- -	1.47	- -	1.43	- -	2.97	- -
B006360	1.82	- -	1.27	- -	1.45	- -	1.11	- -	1.23	- -	1.69	- -	1.54	- -	3.39	- -
B003411	2.31	- -	1.52	- -	1.76	- -	1.36	- -	1.51	- -	1.82	- -	1.71	- -	4.13	- -
B008653	3.41	- -	3.00	- -	3.22	- -	2.39	- -	2.58	- -	3.54	- -	3.36	- -	6.71	- -
B019607	2.86	- -	2.30	- -	2.56	- -	1.90	- -	2.07	- -	2.86	- -	2.73	- -	5.81	- -
B019558	4.17	- -	2.89	- -	3.29	- -	2.52	- -	2.80	- -	3.76	- -	3.47	- -	7.72	- -
B014979	66.08	- -	44.26	- -	50.37	- -	40.97	- -	45.02	- -	58.82	- -	54.10	- -	118.43	- -
B007334	2.42	- -	1.79	- -	2.01	- -	1.53	- -	1.67	- -	2.31	- -	2.22	- -	4.56	- -
B08523	2.29	- -	1.56	- -	1.78	- -	1.37	- -	1.52	- -	1.85	- -	1.75	- -	4.13	- -
B007334	2.42	- -	1.79	- -	2.01	- -	1.53	- -	1.67	- -	2.31	- -	2.22	- -	4.56	- -
B009005	3.58	- -	2.35	- -	2.75	- -	2.09	- -	2.34	- -	2.64	- -	2.48	- -	6.57	- -
B008521	2.61	- -	1.93	- -	2.16	- -	1.65	- -	1.81	- -	2.49	- -	2.39	- -	4.91	- -
B007848	4.12	- -	2.67	- -	3.10	- -	2.37	- -	2.68	- -	3.28	- -	3.06	- -	7.43	- -
B011110	2.81	- -	1.84	- -	2.16	- -	1.66	- -	1.82	- -	2.30	- -	2.11	- -	5.02	- -
B011206	4.84	- -	2.95	- -	3.52	- -	2.72	- -	3.03	- -	3.16	- -	2.97	- -	7.02	- -
B011081	6.37	- -	4.57	- -	4.47	- -	3.40	- -	3.75	- -	6.12	- -	5.74	- -	12.06	- -
B009782	10.59	- -	6.44	- -	9.20	- -	7.15	- -	6.68	- -	8.00	- -	6.28	- -	21.73	- -
B005318	10.05	- -	6.18	- -	7.32	- -	5.68	- -	7.75	- -	6.51	- -	7.46	- -	20.85	- -
B007536	8.25	- -	5.23	- -	6.13	- -	4.73	- -	6.12	- -	5.88	- -	5.47	- -	14.41	- -
B012825	14.78	- -	7.60	- -	9.08	- -	7.06	- -	9.34	- -	9.24	- -	7.43	- -	21.33	- -
B011335	7.85	- -	4.65	- -	5.61	- -	4.37	- -	4.93	- -	4.62	- -	4.38	- -	13.12	- -
B002310	4.54	- -	3.44	- -	3.95	- -	2.88	- -	3.18	- -	4.36	- -	4.12	- -	9.45	- -
B011097	11.29	- -	7.03	- -	8.28	- -	6.38	- -	7.18	- -	6.76	- -	6.35	- -	19.75	- -
B012559	11.79	- -	7.63	- -	8.05	- -	6.21	- -	6.93	- -	8.64	- -	8.18	- -	20.84	- -
B011344	6.49	- -	4.03	- -	4.77	- -	3.69	- -	4.14	- -	4.32	- -	4.06	- -	11.20	- -
B012319	7.12	- -	4.21	- -	5.05	- -	3.93	- -	4.44	- -	5.97	- -	3.99	- -	11.96	- -
B012350	3.84	- -	2.27	- -	2.73	- -	2.12	- -	2.40	- -	4.15	- -	2.11	- -	11.87	- -
B017781	6.89	- -	4.22	- -	4.96	- -	3.84	- -	4.39	- -	4.23	- -	3.97	- -	11.75	- -
B015764	3.00	- -	1.94	- -	2.26	- -	1.74	- -	1.94	- -	2.27	- -	2.16	- -	4.99	- -
B019141	4.01	- -	2.83	- -	3.19	- -	2.39	- -	2.81	- -	3.00	- -	2.68	- -	6.27	- -
B019990	42.69	- -	25.26	- -	30.21	- -	23.56	- -	26.66	- -	24.88	- -	23.66	- -	71.42	- -
B019473	3.54	- -	2.44	- -	2.77	- -	2.36	- -	2.55	- -	2.42	- -	2.34	- -	5.27	- -
B016591	2.65	- -	2.10	- -	2.27	- -	1.95	- -	2.07	- -	2.47	- -	2.35	- -	4.11	- -
B018106	5.77	- -	4.13	- -	4.61	- -	3.48	- -	4.04	- -	4.73	- -	4.49	- -	9.76	- -
B016845	3.49	- -	2.50	- -	2.76	- -	2.00	- -	2.39	- -	2.47	- -	2.25	- -	5.35	- -
B014450	2.07	- -	1.29	- -	1.47	- -	1.13	- -	1.27	- -	1.71	- -	1.58	- -	3.12	- -
B016510	2.20	- -	2.07	- -	1.89	- -	1.42	- -	1.58	- -	2.42	- -	2.27	- -	4.32	- -
B016111	2.54	- -	1.47	- -	1.84	- -	1.29	- -	1.50	- -	1.97	- -	1.95	- -	4.20	- -
B016310	3.45	- -	1.91	- -	2.26	- -	1.45	- -	1.96	- -	2.11	- -	2.00	- -	5.40	- -
B015295	22.04	- -	14.51	- -	16.81	- -	12.93	- -	14.42	- -	17.39	- -	16.30	- -	39.59	- -
B017909	2.66	- -	2.39	- -	2.34	- -	1.65	- -	2.29	- -	2.38	- -	2.21	- -	4.70	- -
B015820	4.66	- -	2.19	- -	3.12	- -	2.46	- -	2.72	- -	2.12	- -	2.01	- -	7.41	- -

APPENDIX F1: MatLAB Beta Analysis Program

Presented in this appendix is the MatLab beta analysis program. For more information on its use and construction see Chapter 6.

```
% Beta Analysis Program
% Mike Murdock
% 1-29-08

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Cal. Beta
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

function beta()     %function name
   gD = 1.05;
   gL = 1.3;
   gRS = 1.12;
   gRC = 1.12;
   gRP = 1.05;

   vD = 0.1;
   vL = 0.18;
   vRS = 0.1;
   vRC = 0.13;
   vRP = 0.075;

   Fail = 0;

   NumberOfRuns = 1000;

   i = 1
   ii=1;
   iii = 0;

   clc;    %clears the screen of any random text
```

```
fprintf('\n');
fprintf('\n');

[Numbers] = xlsread('testing.xls');

NumberOfBridges = size(Numbers);

while ii <= NumberOfBridges(1)

   inputBin = num2str(Numbers(ii, 1));
   Mat = Numbers(ii, 2);
   Mr = Numbers(ii, 3);
   DC = Numbers(ii, 4);
   DW = Numbers(ii,5);
   Ml = Numbers(ii,6);



   if Mat < 2
      gR = gRC;
      vR = vRC;
   else
      if Mat < 3
         gR = gRS;
         vR = vRS;
      else
         gR = gRP;
         vR = vRP;
      end
   end

   ud = gD * (DC + DW);
   ul = gL * Ml;
   ur = gR * Mr;
   qr = (log(vR ^ 2 + 1)) ^ 0.5;

   while i < NumberOfRuns
      Di = ud + vD * ud * NormSInv(rand(1));

      Li = ul + vL * ul * NormSInv(rand(1));

      Ri = exp((log(ur) - 0.5 * (qr ^ 2)) + qr * NormSInv(rand(1)));

      Ya(i) = Ri - (Di + Li);
```

```
    if Ya(i) < 0
        Fail = Fail + 1;
    end

    i = i + 1;
end

YaSorted = sort(Ya);

i = 1;
V1 = 0;
V2 = 0;
V3 = 0;
V4 = 0;
PaB = 0;
YaB = 0;


while i < NumberOfRuns
    Pa(i) = NormSInv(i / NumberOfRuns);

    V1 = V1 + YaSorted(i) * Pa(i);
    V2 = V2 + YaSorted(i);
    V3 = V3 + Pa(i);
    V4 = V4 + (YaSorted(i)) ^ 2;

    i = i + 1;
end

PaB = V3 / (NumberOfRuns - 1);
YaB = V2 / (NumberOfRuns - 1);

slope = (NumberOfRuns * V1 - V2 * V3) / (NumberOfRuns * V4 - (V2 ^ 2));
betaLine = -(PaB - slope * YaB);


i =1;
while YaSorted(i) < 0
    i=i+1;
end

if i < 3
    NearZero(1) = 0;
    NearZero(2) = 0;
    NearZero(3) = 0;
```

```
            NearZero(4) = 0;
        else
            NearZero(1) = Pa(i-2);
            NearZero(2) = Pa(i-1);
            NearZero(3) = Pa(i);
            NearZero(4) = Pa(i+1);
        end


        FailRate = Fail / NumberOfRuns;

        if Fail > 0
            Beta1 = -1 * NormSInv(FailRate);
        else
            Beta1 = 0;
        end


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Results
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% Displaying Max Momment and Max Shear values found
fprintf('\n');
fprintf('\n');
fprintf('\n');
fprintf('\n');
fprintf('\n');
fprintf('\n');
fprintf('Matlab Beta Analysis for Bin:   %s \n',inputBin);
fprintf('\n');
fprintf('Slope:    %1.5f      \n',slope);
fprintf('Beta from line:    %1.3f       \n',betaLine);
fprintf('\n');
if NearZero(1) == 0
    fprintf('Betas around Y = 0:    ---      \n');
    fprintf('Betas around Y = 0:    ---      \n');
    fprintf('Betas around Y = 0:    ---      \n');
    fprintf('Betas around Y = 0:    ---      \n');
else
    fprintf('Betas around Y = 0:    %1.3f       \n',NearZero(1));
    fprintf('Betas around Y = 0:    %1.3f       \n',NearZero(2));
    fprintf('Betas around Y = 0:    %1.3f       \n',NearZero(3));
    fprintf('Betas around Y = 0:    %1.3f       \n',NearZero(4));
end
```

```
fprintf('\n');
fprintf('Failures:    %d      \n',Fail);
fprintf('Failure Rate:    %1.5f      \n',FailRate);
if Beta1 > 0
   fprintf('Beta:    %1.3f      \n',Beta1);
else
   fprintf('Beta:    ---      \n');
end

filename = strcat(inputBin,'.txt');

file_1 = fopen(filename,'w');
file_2 = fopen('resultsfull.txt','a');

fprintf(file_1,'Matlab Beta Analysis for Bin:   %s \n\n',inputBin);
fprintf(file_1,'Slope:    %1.5f      \n',slope);
fprintf(file_1,'Beta from line:    %1.3f       \n',betaLine);
fprintf(file_1,'\n');
if NearZero(1) == 0
   fprintf(file_1,'Betas around Y = 0:    ---       \n');
   fprintf(file_1,'Betas around Y = 0:    ---       \n');
   fprintf(file_1,'Betas around Y = 0:    ---       \n');
   fprintf(file_1,'Betas around Y = 0:    ---       \n');
else
   fprintf(file_1,'Betas around Y = 0:    %1.3f       \n',NearZero(1));
   fprintf(file_1,'Betas around Y = 0:    %1.3f       \n',NearZero(2));
   fprintf(file_1,'Betas around Y = 0:    %1.3f       \n',NearZero(3));
   fprintf(file_1,'Betas around Y = 0:    %1.3f       \n',NearZero(4));
end
fprintf(file_1,'\n');
fprintf(file_1,'Failures:    %d      \n',Fail);
fprintf(file_1,'Failure Rate:    %1.5f      \n',FailRate);
if Beta1 > 0
   fprintf(file_1,'Beta:    %1.3f      \n',Beta1);
else
   fprintf(file_1,'Beta:    ---      \n');
end
fprintf(file_1,'\n');
fprintf(file_1,'\n');

fprintf(file_1,'  Y = R - Q          Standard Normal Variate \n\n');
i=1;

while i < NumberOfRuns
   temp = [YaSorted(i), Pa(i)];
```

```
    fprintf(file_1,'    %5.2f                %1.5f\n',temp);
    i=i+1;
end

fprintf(file_2,'%s',inputBin);
fprintf(file_2,'         %5.5f',slope);
fprintf(file_2,'             %5.5f',betaLine);
fprintf(file_2,'               %i',Fail);
fprintf(file_2,'                   %5.5f',FailRate);
fprintf(file_2,'                 %5.5f\n',Beta1);


fclose(file_1);

ii=ii+1;
i=1;
iii=0;
Fail = 0;
FailRate=0;
end

fclose(file_2);
```

APPENDIX F2: Excel Beta Analysis Program

Presented in this appendix is the Excel beta analysis program. For more information on its use and construction see Chapter 6.

```
' Beta Analysis Program
' By Mike Murdock   8 / 25 / 08

   Dim gD As Double
   Dim gL As Double
   Dim gRS As Double
   Dim gRC As Double
   Dim gRP As Double

   Dim vD As Double
   Dim vL As Double
   Dim vRS As Double
   Dim vRC As Double
   Dim vRP As Double

   Dim Di As Double
   Dim Li As Double
   Dim Ri As Double

   Dim Yi As Double
   Dim Fail As Double
   Fail = 0

   Dim Mr As Double
   Dim DC As Double
   Dim DW As Double
   Dim Ml As Double

   Dim gR As Double
   Dim vR As Double
```

```
Dim NumberOfRuns As Double
NumberOfRuns = 10000000

Dim Mat As Integer
Dim Ya As Double
Dim Pa As Double
Dim V1 As Double
Dim V2 As Double
Dim V3 As Double
Dim V4 As Double
Dim PaB As Double
Dim VaB As Double
Dim Slop As Double


Dim i As Double
Dim ii As Integer
Dim iii As Integer
iii = 0

Dim Rand As String
Rand = "=RAND()"
Dim Blank As String
Blank = ""

rowNum = 3
i = 1
ii = Cells(rowNum, 1).Value

Do While ii > 0

   If (Cells(rowNum, 7).Value > 1) Then
      gD = 1.05
      gL = 1.3
      gRS = 1.14
      gRC = 1.2
      gRP = 1.15

      vD = 0.1
      vL = 0.18
      vRS = 0.105
      vRC = 0.155
      vRP = 0.14
   Else
      gD = 1.05
```

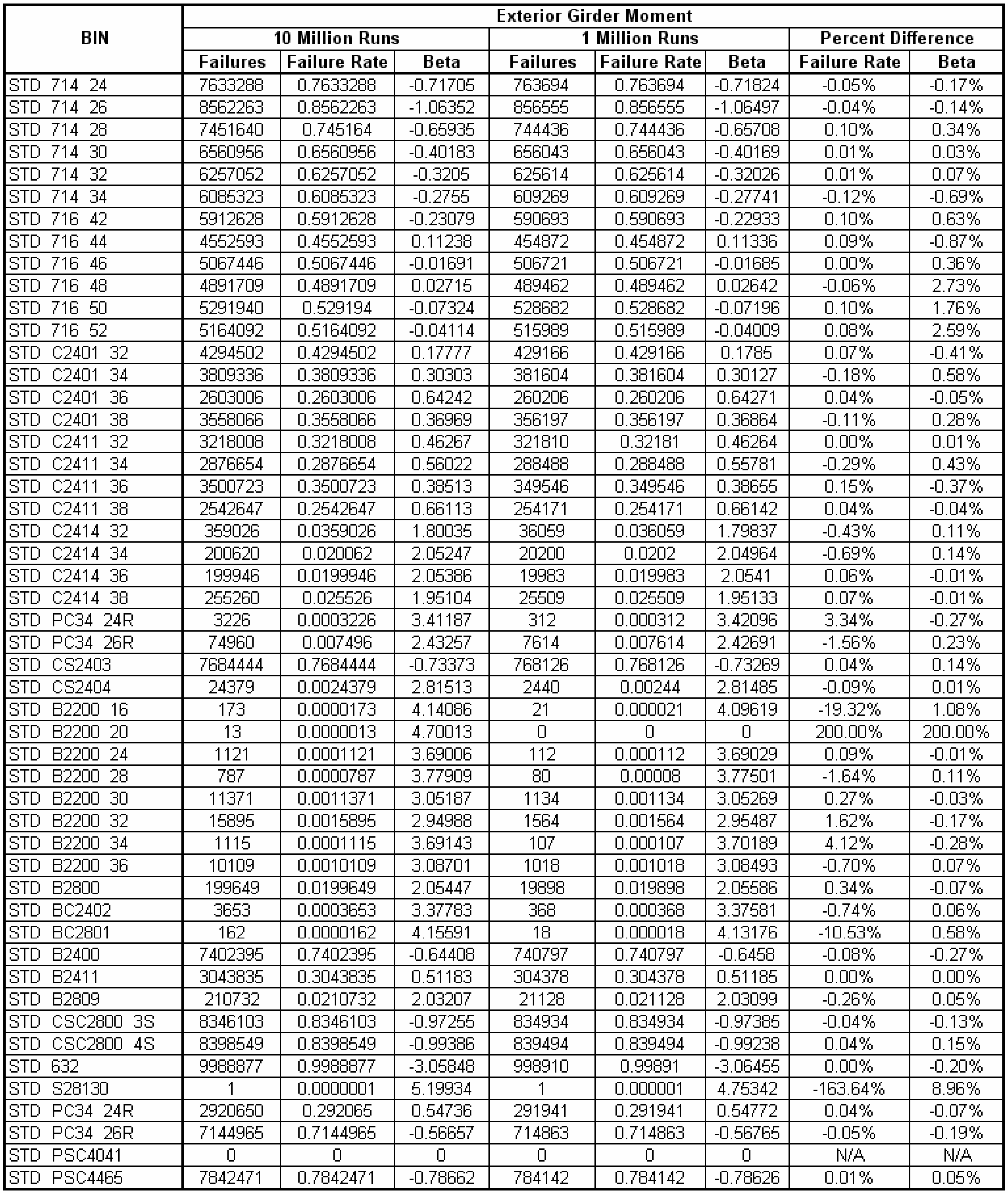
```
   gL = 1.3
   gRS = 1.12
   gRC = 1.14
   gRP = 1.05

   vD = 0.1
   vL = 0.18
   vRS = 0.1
   vRC = 0.13
   vRP = 0.075
End If



Mr = Cells(rowNum, 7).Value
DC = Cells(rowNum, 8).Value
DW = Cells(rowNum, 9).Value
Ml = Cells(rowNum, 10).Value

Mat = Cells(rowNum, 2).Value

If Mat < 3 Then
   gR = gRC
   vR = vRC
Else
   If Mat < 5 Then
      gR = gRS
      vR = vRS
   Else
      gR = gRP
      vR = vRP
   End If
End If

ud = gD * (DC + DW)
ul = gL * Ml
ur = gR * Mr
qr = (Log(vR ^ 2 + 1)) ^ 0.5

Do While i < NumberOfRuns
   Cells(rowNum, 17).Value = Rand
   Di = ud + vD * ud * NormSInv(Cells(rowNum, 17).Value)

   Cells(rowNum, 17).Value = Rand
   Li = ul + vL * ul * NormSInv(Cells(rowNum, 17).Value)
```

```
            Cells(rowNum, 17).Value = Rand
            Ri = Exp((Log(ur) - 0.5 * (qr ^ 2)) + qr * NormSInv(Cells(rowNum, 17).Value))


            Ya = Ri - (Di + Li)

            If Ya < 0 Then
                Fail = Fail + 1
            End If



            i = i + 1
        Loop

        Cells(rowNum, 17).Value = Blank
        Cells(rowNum, 11).Value = Fail
        Cells(rowNum, 12).Value = Fail / NumberOfRuns
        If Fail > 0 Then
            Cells(rowNum, 15).Value = -1 * NormSInv(Cells(rowNum, 12).Value)
        Else
            Cells(rowNum, 15).Value = " --- "
        End If

        iii = iii + 2
        Fail = 0
        i = 1
        rowNum = rowNum + 1
        ii = Cells(rowNum, 1).Value
    Loop

End Sub
```

APPENDIX F3: Percent Difference Between 1 Million and 10 Million Simulations

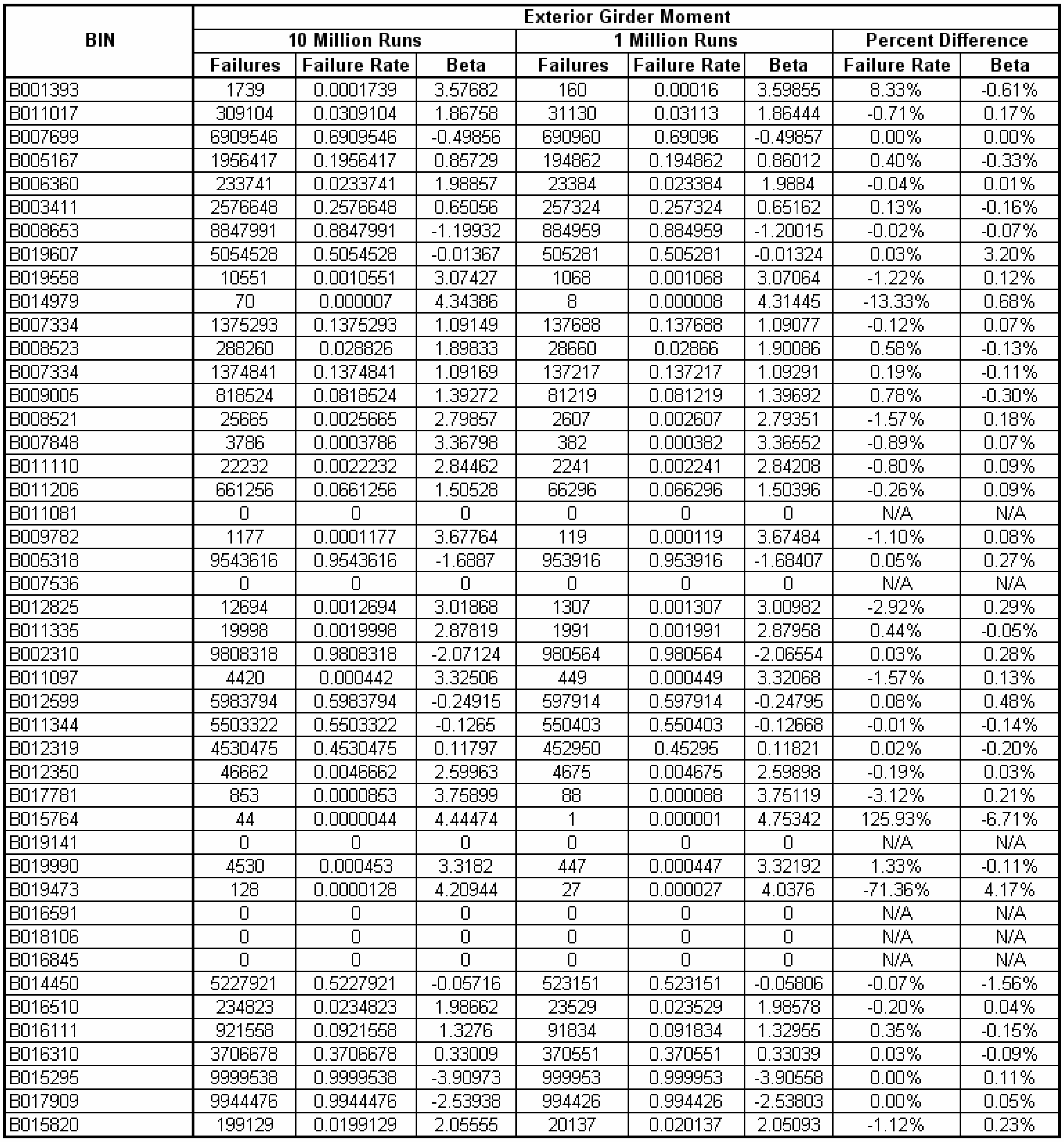
Presented in this section are table summaries of the precent difference from 1 million and 10 million run probability of failure simulations. The data is divided in-between load effect, girder and sample.

Table F3 - 1: Exterior Girder Moment Standard Bridge Sample



BIN	Exterior Girder Moment							
	10 Million Runs			1 Million Runs			Percent Difference	
	Failures	Failure Rate	Beta	Failures	Failure Rate	Beta	Failure Rate	Beta
STD 714 24	7633288	0.7633288	-0.71705	763694	0.763694	-0.71824	-0.05%	-0.17%
STD 714 26	8562263	0.8562263	-1.06352	856555	0.856555	-1.06497	-0.04%	-0.14%
STD 714 28	7451640	0.745164	-0.65935	744436	0.744436	-0.65708	0.10%	0.34%
STD 714 30	6560956	0.6560956	-0.40183	656043	0.656043	-0.40169	0.01%	0.03%
STD 714 32	6257052	0.6257052	-0.3205	625614	0.625614	-0.32026	0.01%	0.07%
STD 714 34	6085323	0.6085323	-0.2755	609269	0.609269	-0.27741	-0.12%	-0.69%
STD 716 42	5912628	0.5912628	-0.23079	590693	0.590693	-0.22933	0.10%	0.63%
STD 716 44	4552593	0.4552593	0.11238	454872	0.454872	0.11336	0.09%	-0.87%
STD 716 46	5067446	0.5067446	-0.01691	506721	0.506721	-0.01685	0.00%	0.36%
STD 716 48	4891709	0.4891709	0.02715	489462	0.489462	0.02642	-0.06%	2.73%
STD 716 50	5291940	0.529194	-0.07324	528682	0.528682	-0.07196	0.10%	1.76%
STD 716 52	5164092	0.5164092	-0.04114	515989	0.515989	-0.04009	0.08%	2.59%
STD C2401 32	4294502	0.4294502	0.17777	429166	0.429166	0.1785	0.07%	-0.41%
STD C2401 34	3809336	0.3809336	0.30303	381604	0.381604	0.30127	-0.18%	0.58%
STD C2401 36	2603006	0.2603006	0.64242	260206	0.260206	0.64271	0.04%	-0.05%
STD C2401 38	3558066	0.3558066	0.36969	356197	0.356197	0.36864	-0.11%	0.28%
STD C2411 32	3218008	0.3218008	0.46267	321810	0.32181	0.46264	0.00%	0.01%
STD C2411 34	2876654	0.2876654	0.56022	288488	0.288488	0.55781	-0.29%	0.43%
STD C2411 36	3500723	0.3500723	0.38513	349546	0.349546	0.38655	0.15%	-0.37%
STD C2411 38	2542647	0.2542647	0.66113	254171	0.254171	0.66142	0.04%	-0.04%
STD C2414 32	359026	0.0359026	1.80035	36059	0.036059	1.79837	-0.43%	0.11%
STD C2414 34	200620	0.020062	2.05247	20200	0.0202	2.04964	-0.69%	0.14%
STD C2414 36	199946	0.0199946	2.05386	19983	0.019983	2.0541	0.06%	-0.01%
STD C2414 38	255260	0.025526	1.95104	25509	0.025509	1.95133	0.07%	-0.01%
STD PC34 24R	3226	0.0003226	3.41187	312	0.000312	3.42096	3.34%	-0.27%
STD PC34 26R	74960	0.007496	2.43257	7614	0.007614	2.42691	-1.56%	0.23%
STD CS2403	7684444	0.7684444	-0.73373	768126	0.768126	-0.73269	0.04%	0.14%
STD CS2404	24379	0.0024379	2.81513	2440	0.00244	2.81485	-0.09%	0.01%
STD B2200 16	173	0.0000173	4.14086	21	0.000021	4.09619	-19.32%	1.08%
STD B2200 20	13	0.0000013	4.70013	0	0	0	200.00%	200.00%
STD B2200 24	1121	0.0001121	3.69006	112	0.000112	3.69029	0.09%	-0.01%
STD B2200 28	787	0.0000787	3.77909	80	0.00008	3.77501	-1.64%	0.11%
STD B2200 30	11371	0.0011371	3.05187	1134	0.001134	3.05269	0.27%	-0.03%
STD B2200 32	15895	0.0015895	2.94988	1564	0.001564	2.95487	1.62%	-0.17%
STD B2200 34	1115	0.0001115	3.69143	107	0.000107	3.70189	4.12%	-0.28%
STD B2200 36	10109	0.0010109	3.08701	1018	0.001018	3.08493	-0.70%	0.07%
STD B2800	199649	0.0199649	2.05447	19898	0.019898	2.05586	0.34%	-0.07%
STD BC2402	3653	0.0003653	3.37783	368	0.000368	3.37581	-0.74%	0.06%
STD BC2801	162	0.0000162	4.15591	18	0.000018	4.13176	-10.53%	0.58%
STD B2400	7402395	0.7402395	-0.64408	740797	0.740797	-0.6458	-0.08%	-0.27%
STD B2411	3043835	0.3043835	0.51183	304378	0.304378	0.51185	0.00%	0.00%
STD B2809	210732	0.0210732	2.03207	21128	0.021128	2.03099	-0.26%	0.05%
STD CSC2800 3S	8346103	0.8346103	-0.97255	834934	0.834934	-0.97385	-0.04%	-0.13%
STD CSC2800 4S	8398549	0.8398549	-0.99386	839494	0.839494	-0.99238	0.04%	0.15%
STD 632	9988877	0.9988877	-3.05848	998910	0.99891	-3.06455	0.00%	-0.20%
STD S28130	1	0.0000001	5.19934	1	0.000001	4.75342	-163.64%	8.96%
STD PC34 24R	2920650	0.292065	0.54736	291941	0.291941	0.54772	0.04%	-0.07%
STD PC34 26R	7144965	0.7144965	-0.56657	714863	0.714863	-0.56765	-0.05%	-0.19%
STD PSC4041	0	0	0	0	0	0	N/A	N/A
STD PSC4465	7842471	0.7842471	-0.78662	784142	0.784142	-0.78626	0.01%	0.05%

Table F3 - 2: Exterior Girder Moment Unique Bridge Sample

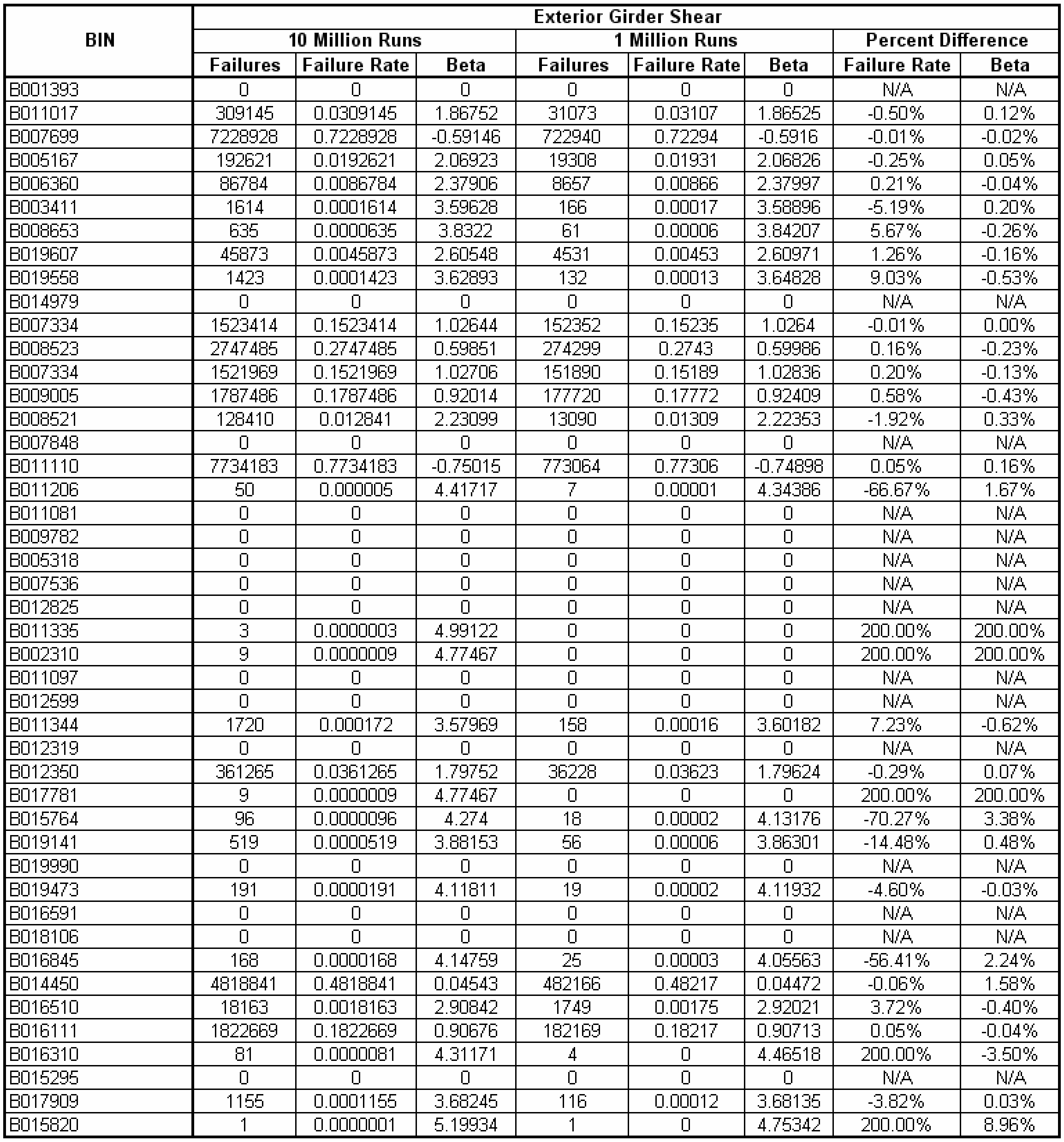


BIN	Exterior Girder Moment							
	10 Million Runs			1 Million Runs			Percent Difference	
	Failures	Failure Rate	Beta	Failures	Failure Rate	Beta	Failure Rate	Beta
B001393	1739	0.0001739	3.57682	160	0.00016	3.59855	8.33%	-0.61%
B011017	309104	0.0309104	1.86758	31130	0.03113	1.86444	-0.71%	0.17%
B007699	6909546	0.6909546	-0.49856	690960	0.69096	-0.49857	0.00%	0.00%
B005167	1956417	0.1956417	0.85729	194862	0.194862	0.86012	0.40%	-0.33%
B006360	233741	0.0233741	1.98857	23384	0.023384	1.9884	-0.04%	0.01%
B003411	2576648	0.2576648	0.65056	257324	0.257324	0.65162	0.13%	-0.16%
B008653	8847991	0.8847991	-1.19932	884959	0.884959	-1.20015	-0.02%	-0.07%
B019607	5054528	0.5054528	-0.01367	505281	0.505281	-0.01324	0.03%	3.20%
B019558	10551	0.0010551	3.07427	1068	0.001068	3.07064	-1.22%	0.12%
B014979	70	0.000007	4.34386	8	0.000008	4.31445	-13.33%	0.68%
B007334	1375293	0.1375293	1.09149	137688	0.137688	1.09077	-0.12%	0.07%
B008523	288260	0.028826	1.89833	28660	0.02866	1.90086	0.58%	-0.13%
B007334	1374841	0.1374841	1.09169	137217	0.137217	1.09291	0.19%	-0.11%
B009005	818524	0.0818524	1.39272	81219	0.081219	1.39692	0.78%	-0.30%
B008521	25665	0.0025665	2.79857	2607	0.002607	2.79351	-1.57%	0.18%
B007848	3786	0.0003786	3.36798	382	0.000382	3.36552	-0.89%	0.07%
B011110	22232	0.0022232	2.84462	2241	0.002241	2.84208	-0.80%	0.09%
B011206	661256	0.0661256	1.50528	66296	0.066296	1.50396	-0.26%	0.09%
B011081	0	0	0	0	0	0	N/A	N/A
B009782	1177	0.0001177	3.67764	119	0.000119	3.67484	-1.10%	0.08%
B005318	9543616	0.9543616	-1.6887	953916	0.953916	-1.68407	0.05%	0.27%
B007536	0	0	0	0	0	0	N/A	N/A
B012825	12694	0.0012694	3.01868	1307	0.001307	3.00982	-2.92%	0.29%
B011335	19998	0.0019998	2.87819	1991	0.001991	2.87958	0.44%	-0.05%
B002310	9808318	0.9808318	-2.07124	980564	0.980564	-2.06554	0.03%	0.28%
B011097	4420	0.000442	3.32506	449	0.000449	3.32068	-1.57%	0.13%
B012599	5983794	0.5983794	-0.24915	597914	0.597914	-0.24795	0.08%	0.48%
B011344	5503322	0.5503322	-0.1265	550403	0.550403	-0.12668	-0.01%	-0.14%
B012319	4530475	0.4530475	0.11797	452950	0.45295	0.11821	0.02%	-0.20%
B012350	46662	0.0046662	2.59963	4675	0.004675	2.59898	-0.19%	0.03%
B017781	853	0.0000853	3.75899	88	0.000088	3.75119	-3.12%	0.21%
B015764	44	0.0000044	4.44474	1	0.000001	4.75342	125.93%	-6.71%
B019141	0	0	0	0	0	0	N/A	N/A
B019990	4530	0.000453	3.3182	447	0.000447	3.32192	1.33%	-0.11%
B019473	128	0.0000128	4.20944	27	0.000027	4.0376	-71.36%	4.17%
B016591	0	0	0	0	0	0	N/A	N/A
B018106	0	0	0	0	0	0	N/A	N/A
B016845	0	0	0	0	0	0	N/A	N/A
B014450	5227921	0.5227921	-0.05716	523151	0.523151	-0.05806	-0.07%	-1.56%
B016510	234823	0.0234823	1.98662	23529	0.023529	1.98578	-0.20%	0.04%
B016111	921558	0.0921558	1.3276	91834	0.091834	1.32955	0.35%	-0.15%
B016310	3706678	0.3706678	0.33009	370551	0.370551	0.33039	0.03%	-0.09%
B015295	9999538	0.9999538	-3.90973	999953	0.999953	-3.90558	0.00%	0.11%
B017909	9944476	0.9944476	-2.53938	994426	0.994426	-2.53803	0.00%	0.05%
B015820	199129	0.0199129	2.05555	20137	0.020137	2.05093	-1.12%	0.23%

Table F3 - 3: Exterior Girder Shear Standard Bridge Sample

BIN	Exterior Girder Shear							
	10 Million Runs			1 Million Runs			Percent Difference	
	Failures	Failure Rate	Beta	Failures	Failure Rate	Beta	Failure Rate	Beta
STD 714 24	5932508	0.5932508	-0.23592	593878	0.59388	-0.23753	-0.11%	-0.68%
STD 714 26	5341139	0.5341139	-0.08562	534830	0.53483	-0.08742	-0.13%	-2.08%
STD 714 28	4694021	0.4694021	0.07677	468738	0.46874	0.07844	0.14%	-2.15%
STD 714 30	4452578	0.4452578	0.13765	445982	0.44598	0.13582	-0.16%	1.34%
STD 714 32	3253431	0.3253431	0.45281	325199	0.3252	0.45321	0.04%	-0.09%
STD 714 34	2364789	0.2364789	0.71767	236415	0.23641	0.71788	0.03%	-0.03%
STD 716 42	2311070	0.231107	0.73521	231145	0.23114	0.73508	-0.01%	0.02%
STD 716 44	2112488	0.2112488	0.8021	210808	0.21081	0.80362	0.21%	-0.19%
STD 716 46	797842	0.0797842	1.40652	79761	0.07976	1.40668	0.03%	-0.01%
STD 716 48	881138	0.0881138	1.35246	88420	0.08842	1.35055	-0.35%	0.14%
STD 716 50	261390	0.026139	1.94084	26542	0.02654	1.93424	-1.52%	0.34%
STD 716 52	123064	0.0123064	2.24743	12313	0.01231	2.24722	-0.03%	0.01%
STD C2401 32	2420991	0.2420991	0.69957	241432	0.24143	0.7017	0.28%	-0.30%
STD C2401 34	1262046	0.1262046	1.14452	126395	0.1264	1.1436	-0.15%	0.08%
STD C2401 36	631199	0.0631199	1.5291	63005	0.06301	1.53003	0.17%	-0.06%
STD C2401 38	387200	0.03872	1.76574	38537	0.03854	1.76792	0.47%	-0.12%
STD C2411 32	1013833	0.1013833	1.27371	101523	0.10152	1.27292	-0.13%	0.06%
STD C2411 34	456977	0.0456977	1.68808	45895	0.04589	1.68603	-0.42%	0.12%
STD C2411 36	348418	0.0348418	1.81396	34675	0.03467	1.81613	0.49%	-0.12%
STD C2411 38	98633	0.0098633	2.33151	9986	0.00999	2.32687	-1.28%	0.20%
STD C2414 32	15248	0.0015248	2.96269	1568	0.00157	2.95408	-2.92%	0.29%
STD C2414 34	1879	0.0001879	3.55652	176	0.00018	3.57368	4.29%	-0.48%
STD C2414 36	617	0.0000617	3.83927	63	0.00006	3.83415	2.79%	0.13%
STD C2414 38	324	0.0000324	3.99461	44	0.00004	3.9215	-20.99%	1.85%
STD PC34 24R	6	0.0000006	4.85564	0	0	0	200.00%	200.00%
STD PC34 26R	2	0.0000002	5.06896	0	0	0	200.00%	200.00%
STD CS2403	148487	0.0148487	2.1741	14965	0.01496	2.17102	-0.75%	0.14%
STD CS2404	9659521	0.9659521	-1.82437	965791	0.96579	-1.82224	0.02%	0.12%
STD B2200 16	36832	0.0036832	2.67981	3683	0.00368	2.67983	0.09%	0.00%
STD B2200 20	8991	0.0008991	3.12168	904	0.0009	3.12008	-0.10%	0.05%
STD B2200 24	191	0.0000191	4.11811	23	0.00002	4.07507	-4.60%	1.05%
STD B2200 28	2	0.0000002	5.06896	1	0	4.75342	200.00%	6.42%
STD B2200 30	19	0.0000019	4.62203	0	0	0	200.00%	200.00%
STD B2200 32	5	0.0000005	4.89164	0	0	0	200.00%	200.00%
STD B2200 34	0	0	0	0	0	0	N/A	N/A
STD B2200 36	0	0	0	0	0	0	N/A	N/A
STD B2800	0	0	0	0	0	0	N/A	N/A
STD BC2402	0	0	0	0	0	0	N/A	N/A
STD BC2801	0	0	0	0	0	0	N/A	N/A
STD B2400	0	0	0	0	0	0	N/A	N/A
STD B2411	0	0	0	0	0	0	N/A	N/A
STD B2809	0	0	0	0	0	0	N/A	N/A
STD CSC2800 3S	0	0	0	0	0	0	N/A	N/A
STD CSC2800 4S	0	0	0	0	0	0	N/A	N/A
STD 632	5	0.0000005	4.89164	1	0	4.75342	200.00%	2.87%
STD S28130	0	0	0	0	0	0	N/A	N/A
STD PC34 24R	755	0.0000755	3.78942	77	0.00008	3.78453	-5.79%	0.13%
STD PC34 26R	9630	0.000963	3.10141	980	0.00098	3.09623	-1.75%	0.17%
STD PSC4041	1293	0.0001293	3.65359	128	0.00013	3.65618	-0.54%	-0.07%
STD PSC4465	2	0.0000002	5.06896	2	0	4.61138	200.00%	9.45%

Table F3 - 4: Exterior Girder Shear Unique Bridge Sample

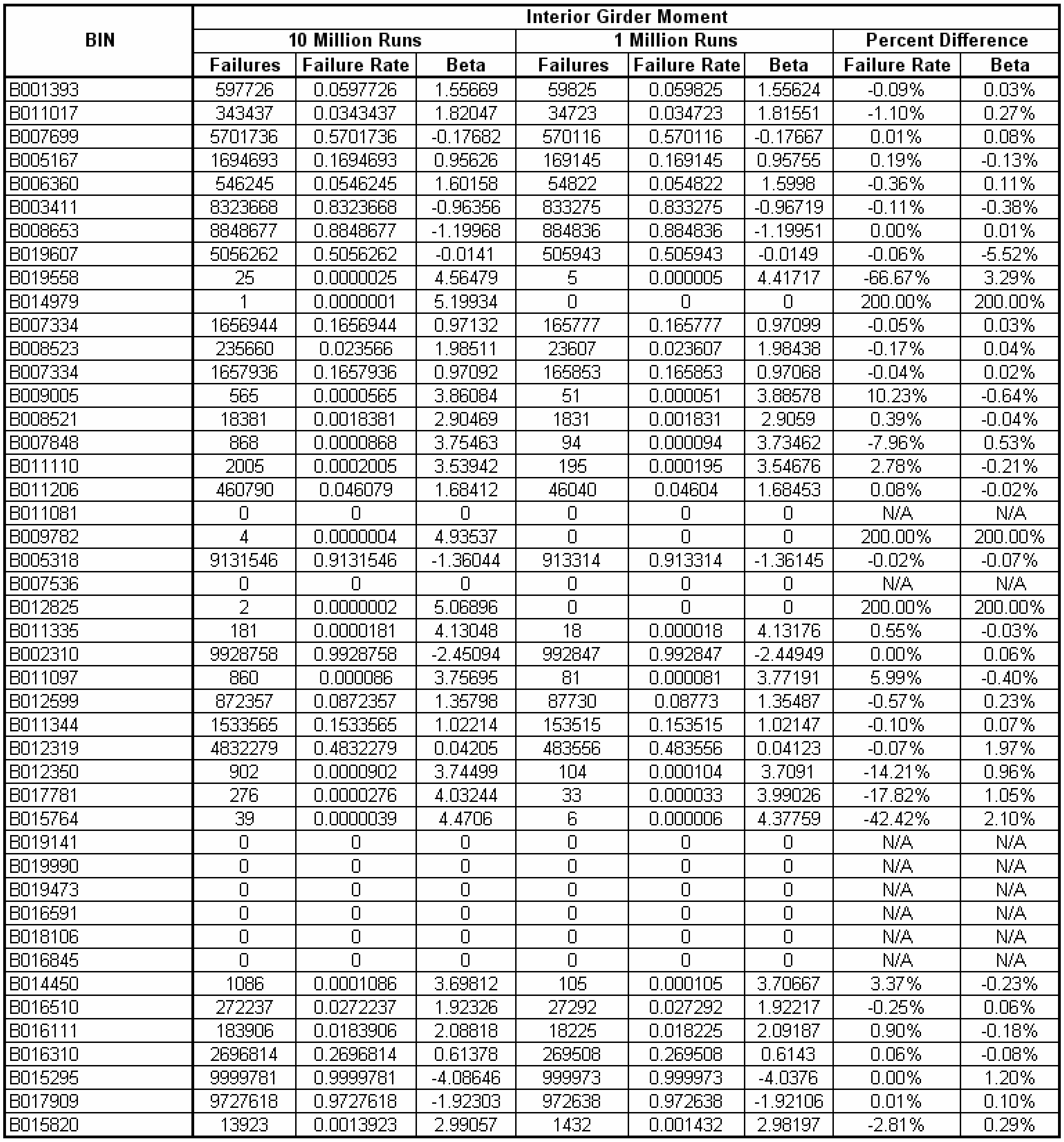


BIN	Exterior Girder Shear							
	10 Million Runs			1 Million Runs			Percent Difference	
	Failures	Failure Rate	Beta	Failures	Failure Rate	Beta	Failure Rate	Beta
B001393	0	0	0	0	0	0	N/A	N/A
B011017	309145	0.0309145	1.86752	31073	0.03107	1.86525	-0.50%	0.12%
B007699	7228928	0.7228928	-0.59146	722940	0.72294	-0.5916	-0.01%	-0.02%
B005167	192621	0.0192621	2.06923	19308	0.01931	2.06826	-0.25%	0.05%
B006360	86784	0.0086784	2.37906	8657	0.00866	2.37997	0.21%	-0.04%
B003411	1614	0.0001614	3.59628	166	0.00017	3.58896	-5.19%	0.20%
B008653	635	0.0000635	3.8322	61	0.00006	3.84207	5.67%	-0.26%
B019607	45873	0.0045873	2.60548	4531	0.00453	2.60971	1.26%	-0.16%
B019558	1423	0.0001423	3.62893	132	0.00013	3.64828	9.03%	-0.53%
B014979	0	0	0	0	0	0	N/A	N/A
B007334	1523414	0.1523414	1.02644	152352	0.15235	1.0264	-0.01%	0.00%
B008523	2747485	0.2747485	0.59851	274299	0.2743	0.59986	0.16%	-0.23%
B007334	1521969	0.1521969	1.02706	151890	0.15189	1.02836	0.20%	-0.13%
B009005	1787486	0.1787486	0.92014	177720	0.17772	0.92409	0.58%	-0.43%
B008521	128410	0.012841	2.23099	13090	0.01309	2.22353	-1.92%	0.33%
B007848	0	0	0	0	0	0	N/A	N/A
B011110	7734183	0.7734183	-0.75015	773064	0.77306	-0.74898	0.05%	0.16%
B011206	50	0.000005	4.41717	7	0.00001	4.34386	-66.67%	1.67%
B011081	0	0	0	0	0	0	N/A	N/A
B009782	0	0	0	0	0	0	N/A	N/A
B005318	0	0	0	0	0	0	N/A	N/A
B007536	0	0	0	0	0	0	N/A	N/A
B012825	0	0	0	0	0	0	N/A	N/A
B011335	3	0.0000003	4.99122	0	0	0	200.00%	200.00%
B002310	9	0.0000009	4.77467	0	0	0	200.00%	200.00%
B011097	0	0	0	0	0	0	N/A	N/A
B012599	0	0	0	0	0	0	N/A	N/A
B011344	1720	0.000172	3.57969	158	0.00016	3.60182	7.23%	-0.62%
B012319	0	0	0	0	0	0	N/A	N/A
B012350	361265	0.0361265	1.79752	36228	0.03623	1.79624	-0.29%	0.07%
B017781	9	0.0000009	4.77467	0	0	0	200.00%	200.00%
B015764	96	0.0000096	4.274	18	0.00002	4.13176	-70.27%	3.38%
B019141	519	0.0000519	3.88153	56	0.00006	3.86301	-14.48%	0.48%
B019990	0	0	0	0	0	0	N/A	N/A
B019473	191	0.0000191	4.11811	19	0.00002	4.11932	-4.60%	-0.03%
B016591	0	0	0	0	0	0	N/A	N/A
B018106	0	0	0	0	0	0	N/A	N/A
B016845	168	0.0000168	4.14759	25	0.00003	4.05563	-56.41%	2.24%
B014450	4818841	0.4818841	0.04543	482166	0.48217	0.04472	-0.06%	1.58%
B016510	18163	0.0018163	2.90842	1749	0.00175	2.92021	3.72%	-0.40%
B016111	1822669	0.1822669	0.90676	182169	0.18217	0.90713	0.05%	-0.04%
B016310	81	0.0000081	4.31171	4	0	4.46518	200.00%	-3.50%
B015295	0	0	0	0	0	0	N/A	N/A
B017909	1155	0.0001155	3.68245	116	0.00012	3.68135	-3.82%	0.03%
B015820	1	0.0000001	5.19934	1	0	4.75342	200.00%	8.96%

Table F3 - 5: Interior Girder Moment Standard Bridge Sample

BIN	Interior Girder Moment							
	10 Million Runs			1 Million Runs			Percent Difference	
	Failures	Failure Rate	Beta	Failures	Failure Rate	Beta	Failure Rate	Beta
STD 714 24	6417354	0.6417354	-0.3631	641748	0.641748	-0.36314	0.00%	-0.01%
STD 714 26	7282598	0.7282598	-0.60756	728453	0.728453	-0.60814	-0.03%	-0.10%
STD 714 28	5756125	0.5756125	-0.19068	575678	0.575678	-0.19085	-0.01%	-0.09%
STD 714 30	4666315	0.4666315	0.08374	467344	0.467344	0.08195	-0.15%	2.16%
STD 714 32	4642368	0.4642368	0.08977	464130	0.46413	0.09003	0.02%	-0.29%
STD 714 34	4710147	0.4710147	0.07272	470550	0.47055	0.07389	0.10%	-1.60%
STD 716 42	5943598	0.5943598	-0.23877	593901	0.593901	-0.23759	0.08%	0.50%
STD 716 44	6830276	0.6830276	-0.47618	682702	0.682702	-0.47527	0.05%	0.19%
STD 716 46	7235988	0.7235988	-0.59357	722987	0.722987	-0.59174	0.08%	0.31%
STD 716 48	7197914	0.7197914	-0.58222	720320	0.72032	-0.58379	-0.07%	-0.27%
STD 716 50	6349438	0.6349438	-0.34498	634287	0.634287	-0.34323	0.10%	0.51%
STD 716 52	7018553	0.7018553	-0.52974	702485	0.702485	-0.53156	-0.09%	-0.34%
STD C2401 32	2227247	0.2227247	0.76302	222575	0.222575	0.76353	0.07%	-0.07%
STD C2401 34	2042816	0.2042816	0.82642	203241	0.203241	0.8301	0.51%	-0.44%
STD C2401 36	2138059	0.2138059	0.79328	213926	0.213926	0.79287	-0.06%	0.05%
STD C2401 38	8571615	0.8571615	-1.06765	856235	0.856235	-1.06356	0.11%	0.38%
STD C2411 32	1456037	0.1456037	1.05548	145985	0.145985	1.05381	-0.26%	0.16%
STD C2411 34	1378096	0.1378096	1.09021	138246	0.138246	1.08823	-0.32%	0.18%
STD C2411 36	1993515	0.1993515	0.84394	199053	0.199053	0.84501	0.15%	-0.13%
STD C2411 38	1399185	0.1399185	1.08069	139848	0.139848	1.081	0.05%	-0.03%
STD C2414 32	213687	0.0213687	2.02627	21220	0.02122	2.02918	0.70%	-0.14%
STD C2414 34	148909	0.0148909	2.17298	14849	0.014849	2.1741	0.28%	-0.05%
STD C2414 36	166349	0.0166349	2.12881	16570	0.01657	2.13038	0.39%	-0.07%
STD C2414 38	221854	0.0221854	2.01057	22090	0.02209	2.01238	0.43%	-0.09%
STD PC34 24R	56	0.0000056	4.39261	8	0.000008	4.31445	-35.29%	1.80%
STD PC34 26R	22198	0.0022198	2.84511	2195	0.002195	2.84869	1.12%	-0.13%
STD CS2403	4294563	0.4294563	0.17776	429652	0.429652	0.17726	-0.05%	0.28%
STD CS2404	337	0.0000337	3.98528	31	0.000031	4.00507	8.35%	-0.50%
STD B2200 16	31	0.0000031	4.51945	2	0.000002	4.61138	43.14%	-2.01%
STD B2200 20	681	0.0000681	3.81497	66	0.000066	3.8227	3.13%	-0.20%
STD B2200 24	466	0.0000466	3.90765	48	0.000048	3.90049	-2.96%	0.18%
STD B2200 28	278	0.0000278	4.03075	27	0.000027	4.0376	2.92%	-0.17%
STD B2200 30	2940	0.000294	3.43709	297	0.000297	3.43434	-1.02%	0.08%
STD B2200 32	3727	0.0003727	3.37231	362	0.000362	3.38033	2.91%	-0.24%
STD B2200 34	240	0.000024	4.06516	23	0.000023	4.07507	4.26%	-0.24%
STD B2200 36	2012	0.0002012	3.5385	209	0.000209	3.52845	-3.80%	0.28%
STD B2800	15590	0.001559	2.95586	1625	0.001625	2.94305	-4.15%	0.43%
STD BC2402	324	0.0000324	3.99461	29	0.000029	4.0208	11.07%	-0.65%
STD BC2801	3	0.0000003	4.99122	0	0	0	200.00%	200.00%
STD B2400	4024368	0.4024368	0.24704	402248	0.402248	0.24753	0.05%	-0.20%
STD B2411	483875	0.0483875	1.66069	47913	0.047913	1.66544	0.99%	-0.29%
STD B2809	28254	0.0028254	2.76738	2912	0.002912	2.75753	-3.02%	0.36%
STD CSC2800 3S	6702679	0.6702679	-0.44065	670939	0.670939	-0.44251	-0.10%	-0.42%
STD CSC2800 4S	6785839	0.6785839	-0.46374	679082	0.679082	-0.46513	-0.07%	-0.30%
STD 632	9966190	0.996619	-2.70834	996731	0.996731	-2.7195	-0.01%	-0.41%
STD S28130	0	0	0	0	0	0	N/A	N/A
STD PC34 24R	15	0.0000015	4.67082	3	0.000003	4.52639	-66.67%	3.14%
STD PC34 26R	0	0	0	0	0	0	N/A	N/A
STD PSC4041	158	0.0000158	4.16162	14	0.000014	4.18915	12.08%	-0.66%
STD PSC4465	9147748	0.9147748	-1.37076	914341	0.914341	-1.36798	0.05%	0.20%

Table F3 - 6: Interior Girder Moment Unique Bridge Sample



BIN	Interior Girder Moment							
	10 Million Runs			1 Million Runs			Percent Difference	
	Failures	Failure Rate	Beta	Failures	Failure Rate	Beta	Failure Rate	Beta
B001393	597726	0.0597726	1.55669	59825	0.059825	1.55624	-0.09%	0.03%
B011017	343437	0.0343437	1.82047	34723	0.034723	1.81551	-1.10%	0.27%
B007699	5701736	0.5701736	-0.17682	570116	0.570116	-0.17667	0.01%	0.08%
B005167	1694693	0.1694693	0.95626	169145	0.169145	0.95755	0.19%	-0.13%
B006360	546245	0.0546245	1.60158	54822	0.054822	1.5998	-0.36%	0.11%
B003411	8323668	0.8323668	-0.96356	833275	0.833275	-0.96719	-0.11%	-0.38%
B008653	8848677	0.8848677	-1.19968	884836	0.884836	-1.19951	0.00%	0.01%
B019607	5056262	0.5056262	-0.0141	505943	0.505943	-0.0149	-0.06%	-5.52%
B019558	25	0.0000025	4.56479	5	0.000005	4.41717	-66.67%	3.29%
B014979	1	0.0000001	5.19934	0	0	0	200.00%	200.00%
B007334	1656944	0.1656944	0.97132	165777	0.165777	0.97099	-0.05%	0.03%
B008523	235660	0.023566	1.98511	23607	0.023607	1.98438	-0.17%	0.04%
B007334	1657936	0.1657936	0.97092	165853	0.165853	0.97068	-0.04%	0.02%
B009005	565	0.0000565	3.86084	51	0.000051	3.88578	10.23%	-0.64%
B008521	18381	0.0018381	2.90469	1831	0.001831	2.9059	0.39%	-0.04%
B007848	868	0.0000868	3.75463	94	0.000094	3.73462	-7.96%	0.53%
B011110	2005	0.0002005	3.53942	195	0.000195	3.54676	2.78%	-0.21%
B011206	460790	0.046079	1.68412	46040	0.04604	1.68453	0.08%	-0.02%
B011081	0	0	0	0	0	0	N/A	N/A
B009782	4	0.0000004	4.93537	0	0	0	200.00%	200.00%
B005318	9131546	0.9131546	-1.36044	913314	0.913314	-1.36145	-0.02%	-0.07%
B007536	0	0	0	0	0	0	N/A	N/A
B012825	2	0.0000002	5.06896	0	0	0	200.00%	200.00%
B011335	181	0.0000181	4.13048	18	0.000018	4.13176	0.55%	-0.03%
B002310	9928758	0.9928758	-2.45094	992847	0.992847	-2.44949	0.00%	0.06%
B011097	860	0.000086	3.75695	81	0.000081	3.77191	5.99%	-0.40%
B012599	872357	0.0872357	1.35798	87730	0.08773	1.35487	-0.57%	0.23%
B011344	1533565	0.1533565	1.02214	153515	0.153515	1.02147	-0.10%	0.07%
B012319	4832279	0.4832279	0.04205	483556	0.483556	0.04123	-0.07%	1.97%
B012350	902	0.0000902	3.74499	104	0.000104	3.7091	-14.21%	0.96%
B017781	276	0.0000276	4.03244	33	0.000033	3.99026	-17.82%	1.05%
B015764	39	0.0000039	4.4706	6	0.000006	4.37759	-42.42%	2.10%
B019141	0	0	0	0	0	0	N/A	N/A
B019990	0	0	0	0	0	0	N/A	N/A
B019473	0	0	0	0	0	0	N/A	N/A
B016591	0	0	0	0	0	0	N/A	N/A
B018106	0	0	0	0	0	0	N/A	N/A
B016845	0	0	0	0	0	0	N/A	N/A
B014450	1086	0.0001086	3.69812	105	0.000105	3.70667	3.37%	-0.23%
B016510	272237	0.0272237	1.92326	27292	0.027292	1.92217	-0.25%	0.06%
B016111	183906	0.0183906	2.08818	18225	0.018225	2.09187	0.90%	-0.18%
B016310	2696814	0.2696814	0.61378	269508	0.269508	0.6143	0.06%	-0.08%
B015295	9999781	0.9999781	-4.08646	999973	0.999973	-4.0376	0.00%	1.20%
B017909	9727618	0.9727618	-1.92303	972638	0.972638	-1.92106	0.01%	0.10%
B015820	13923	0.0013923	2.99057	1432	0.001432	2.98197	-2.81%	0.29%

Table F3 - 7: Interior Girder Shear Standard Bridge Sample

BIN	Interior Girder Shear							
	10 Million Runs			1 Million Runs			Percent Difference	
	Failures	Failure Rate	Beta	Failures	Failure Rate	Beta	Failure Rate	Beta
STD 714 24	5834871	0.5834871	-0.21082	584036	0.584036	-0.21223	-0.09%	-0.67%
STD 714 26	5326629	0.5326629	-0.08197	533215	0.533215	-0.08335	-0.10%	-1.67%
STD 714 28	4733505	0.4733505	0.06685	472740	0.47274	0.06838	0.13%	-2.26%
STD 714 30	4575278	0.4575278	0.10666	458142	0.458142	0.10512	-0.13%	1.45%
STD 714 32	3503508	0.3503508	0.38437	350072	0.350072	0.38513	0.08%	-0.20%
STD 714 34	2568226	0.2568226	0.65317	256941	0.256941	0.6528	-0.05%	0.06%
STD 716 42	3164012	0.3164012	0.47779	316595	0.316595	0.47724	-0.06%	0.12%
STD 716 44	1476443	0.1476443	1.04659	147693	0.147693	1.04638	-0.03%	0.02%
STD 716 46	1076010	0.107601	1.23939	107477	0.107477	1.24006	0.11%	-0.05%
STD 716 48	596916	0.0596916	1.55737	59964	0.059964	1.55508	-0.45%	0.15%
STD 716 50	411551	0.0411551	1.73744	41305	0.041305	1.73574	-0.38%	0.10%
STD 716 52	212331	0.0212331	2.02892	21170	0.02117	2.03016	0.30%	-0.06%
STD C2401 32	2069365	0.2069365	0.8171	206544	0.206544	0.81847	0.19%	-0.17%
STD C2401 34	1102668	0.1102668	1.22511	110540	0.11054	1.22366	-0.25%	0.12%
STD C2401 36	655950	0.065595	1.50943	65782	0.065782	1.50796	-0.28%	0.10%
STD C2401 38	532774	0.0532774	1.61387	52822	0.052822	1.61809	0.86%	-0.26%
STD C2411 32	821748	0.0821748	1.39059	82291	0.082291	1.38983	-0.14%	0.05%
STD C2411 34	391337	0.0391337	1.76083	39354	0.039354	1.75823	-0.55%	0.15%
STD C2411 36	315958	0.0315958	1.85784	31314	0.031314	1.86182	0.91%	-0.21%
STD C2411 38	98881	0.0098881	2.33057	9916	0.009916	2.32951	-0.32%	0.05%
STD C2414 32	18483	0.0018483	2.90295	1845	0.001845	2.90351	-0.09%	-0.02%
STD C2414 34	2728	0.0002728	3.45731	276	0.000276	3.45416	-2.60%	0.09%
STD C2414 36	989	0.0000989	3.72181	97	0.000097	3.7267	-1.11%	-0.13%
STD C2414 38	632	0.0000632	3.83337	72	0.000072	3.80119	-10.21%	0.84%
STD PC34 24R	1	0.0000001	5.19934	0	0	0	200.00%	200.00%
STD PC34 26R	96	0.0000096	4.274	9	0.000009	4.28836	-4.08%	-0.34%
STD CS2403	14147	0.0014147	2.98569	1444	0.001444	2.97941	-1.77%	0.21%
STD CS2404	9785409	0.9785409	-2.02451	978601	0.978601	-2.02568	-0.01%	-0.06%
STD B2200 16	17861	0.0017861	2.91366	1726	0.001726	2.92433	3.19%	-0.37%
STD B2200 20	3892	0.0003892	3.36036	386	0.000386	3.36264	-0.21%	-0.07%
STD B2200 24	599	0.0000599	3.84654	68	0.000068	3.81533	-15.55%	0.81%
STD B2200 28	31	0.0000031	4.51945	5	0.000005	4.41717	-105.34%	2.29%
STD B2200 30	72	0.0000072	4.33767	5	0.000005	4.41717	-32.56%	-1.82%
STD B2200 32	32	0.0000032	4.51272	2	0.000002	4.61138	200.00%	-2.16%
STD B2200 34	1	0.0000001	5.19934	0	0	0	200.00%	200.00%
STD B2200 36	2	0.0000002	5.06896	0	0	0	200.00%	200.00%
STD B2800	0	0	0	0	0	0	N/A	N/A
STD BC2402	0	0	0	0	0	0	N/A	N/A
STD BC2801	0	0	0	0	0	0	N/A	N/A
STD B2400	0	0	0	0	0	0	N/A	N/A
STD B2411	0	0	0	0	0	0	N/A	N/A
STD B2809	0	0	0	0	0	0	N/A	N/A
STD CSC2800 3S	0	0	0	0	0	0	N/A	N/A
STD CSC2800 4S	0	0	0	0	0	0	N/A	N/A
STD 632	1	0.0000001	5.19934	0	0	0	200.00%	200.00%
STD S28130	2	0.0000002	5.06896	0	0	0	200.00%	200.00%
STD PC34 24R	7	0.0000007	4.825	1	0.000001	4.75342	200.00%	1.49%
STD PC34 26R	0	0	0	0	0	0	N/A	N/A
STD PSC4041	2759264	0.2759264	0.59499	276170	0.27617	0.59426	-0.09%	0.12%
STD PSC4465	6926	0.0006926	3.19772	651	0.000651	3.21554	6.35%	-0.56%

Table F3 - 8: Interior Girder Shear Unique Bridge Sample

BIN	Interior Girder Shear							
	10 Million Runs			1 Million Runs			Percent Difference	
	Failures	Failure Rate	Beta	Failures	Failure Rate	Beta	Failure Rate	Beta
B001393	16542	0.0016542	2.93753	1660	0.00166	2.93644	-0.35%	0.04%
B011017	689235	0.0689235	1.48386	68558	0.068558	1.48662	0.53%	-0.19%
B007699	6844904	0.6844904	-0.48029	684585	0.684585	-0.48056	-0.01%	-0.06%
B005167	204367	0.0204367	2.04481	20445	0.020445	2.04464	-0.07%	0.01%
B006360	153866	0.0153866	2.15999	15314	0.015314	2.16187	0.50%	-0.09%
B003411	146109	0.0146109	2.18048	14761	0.014761	2.17645	-1.02%	0.18%
B008653	1830	0.000183	3.56346	180	0.00018	3.56779	1.65%	-0.12%
B019607	488328	0.0488328	1.65628	48746	0.048746	1.65714	0.17%	-0.05%
B019558	27	0.0000027	4.54862	4	0.000004	4.46518	200.00%	1.85%
B014979	0	0	0	0	0	0	N/A	N/A
B007334	1495417	0.1495417	1.0384	149749	0.149749	1.03751	-0.14%	0.09%
B008523	2594951	0.2594951	0.6449	259137	0.259137	0.64601	0.14%	-0.17%
B007334	1496524	0.1496524	1.03793	149385	0.149385	1.03907	0.18%	-0.11%
B009005	143511	0.0143511	2.18755	14258	0.014258	2.19011	0.64%	-0.12%
B008521	1169050	0.116905	1.1906	117170	0.11717	1.18925	-0.23%	0.11%
B007848	0	0	0	0	0	0	N/A	N/A
B011110	8025268	0.8025268	-0.85068	802192	0.802192	-0.84948	0.04%	0.14%
B011206	0	0	0	0	0	0	N/A	N/A
B011081	0	0	0	0	0	0	N/A	N/A
B009782	0	0	0	0	0	0	N/A	N/A
B005318	0	0	0	0	0	0	N/A	N/A
B007536	0	0	0	0	0	0	N/A	N/A
B012825	0	0	0	0	0	0	N/A	N/A
B011335	1	0.0000001	5.19934	0	0	0	200.00%	200.00%
B002310	605	0.0000605	3.84409	51	0.000051	3.88578	19.00%	-1.08%
B011097	0	0	0	0	0	0	N/A	N/A
B012599	0	0	0	0	0	0	N/A	N/A
B011344	669	0.0000669	3.81936	69	0.000069	3.81173	-4.53%	0.20%
B012319	3	0.0000003	4.99122	0	0	0	200.00%	200.00%
B012350	407620	0.040762	1.74191	40859	0.040859	1.7408	-0.24%	0.06%
B017781	4	0.0000004	4.93537	0	0	0	200.00%	200.00%
B015764	968	0.0000968	3.72722	82	0.000082	3.76885	19.00%	-1.11%
B019141	724	0.0000724	3.79982	87	0.000087	3.75405	-21.67%	1.21%
B019990	0	0	0	0	0	0	N/A	N/A
B019473	9	0.0000009	4.77467	0	0	0	200.00%	200.00%
B016591	42	0.0000042	4.45473	2	0.000002	4.61138	200.00%	-3.46%
B018106	0	0	0	0	0	0	N/A	N/A
B016845	1	0.0000001	5.19934	0	0	0	200.00%	200.00%
B014450	2451389	0.2451389	0.68987	245484	0.245484	0.68877	-0.14%	0.16%
B016510	37518	0.0037518	2.67363	3712	0.003712	2.6772	1.12%	-0.13%
B016111	1726399	0.1726399	0.94378	172627	0.172627	0.94383	0.01%	-0.01%
B016310	66	0.0000066	4.35676	4	0.000004	4.46518	200.00%	-2.46%
B015295	0	0	0	0	0	0	N/A	N/A
B017909	20	0.000002	4.61138	1	0.000001	4.75342	200.00%	-3.03%
B015820	29	0.0000029	4.53355	3	0.000003	4.52639	200.00%	0.16%