Impact Performance of Polyurea-coated Cementitious Composite Tiles

by

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Abstract

In this research, I tried to investigate the effect of polyurea coating on improving the impact resistance of concrete. As a synthetic high strength elastomeric coating material, polyurea performed well to protect concrete structures against different loads. Because of its chemical nature, polyurea also offers excellent chemical resistance and moisture protection. In this paper, the relationship between the efficacy of polyurea and impact strength is demonstrated. Additionally, various structure designs are tested during the experiment, including polyurea coated on the blast-receiving face, the back side face, and the interior face between concrete tiles to form a sandwich structure. Those samples were subjected to impact loads while conducting a drop tower experiment where the objective was to study the mechanism behind the improvement of impact resistance.

Acknowledgments

First, I would like to thank my advisor, Dr. Bryan Chin, for his patient guidance and assistance on my research. I learned a lot during studying in his group. I would also like to thank my group members Songtao Du, Yuzhe Liu and Kai Roebbecke, for their help with my research.

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I would like to thank Steven Moore and all other staff in Material Engineering Department for their support.

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1. Introduction

Blast terrorism and explosions have become a significant threat to many nations around the world[1]. Explosives were used in more than half the terroristic attacks since the 20th century [2 3]. Unfortunately, the number of terroristic incidents, around the world is rising sharply in modern times[4]. Additionally, children are the most vulnerable population, and the mortality is still on the rise[5 6]. Since these terrorist activities like explosions are typically directed to infrastructure construction[7 8], there is an increasing interest in developing new technologies against the vulnerability of buildings to explosions[9].

An explosion is a phenomenon caused by rapid physical changes and chemical reaction, usually come with the extreme release of heat, light and sound. Energy comes out while the unstable chemical matter is transferred to a stable state with lower energy within milliseconds. This kind of energy release in a very short time can do a large amount of damage to an ordinary reinforced concrete building. The mechanism of structural failure caused by blast load has been analyzed by many researchers around the world[10]. They reproduced all the processes of blast explosion including the detonation of explosives, spreading of the extreme shock wave and most of all, the interaction between blast and building structures. Numerical results come from ANSYS AUTODYN software. The numerical simulations and real instances are combined to make a structure vulnerability assessment, and then we can design structure configurations that have better resistance against blast impact. Most of the existing concrete structures and buildings were constructed against static loads in the first place. But with the increasing threats of terroristic activities, it is imperative that we should develop new materials to withstand dynamic loads from blast explosion[11].

Polyurea is a synthetic polymerization material with good strength[12 13]. It was first invented to protect table edges and soon developed to spray elastomers along with polyurethane due to their fast kinetics associated with the polyreaction[14 15]. Spray coating yields structures with better physical and chemical resistance because of the continuous membrane. Furthermore, the polyurea coating was chosen to enhance the performance of cement construction and reduce the total weight of steel structure while retaining the same strength[16 17]. Different coating designs were studied[18 19 20 21], and polyurea coating on the interior face between walls was found more advantageous while the coating on the exterior surface shows less economic friendly behavior[22]. When instantaneous dynamic loads were applied on polyurea coated masonry structure, the coating layer underwent large deformation and increased the whole ductility of masonry walls, which is important during failure of masonry walls[23 24]. Meanwhile, polyurea coating was reported to be useful for increasing the survivability of substrate materials in concrete including steel-fiber and micro-fiber[25 26].

2. Literature Review

As mentioned before, the polyurea coating will increase the performance of concrete structures against blast impact from an explosion. Many people have researched the effects of different materials when coated with this kind of polymer.

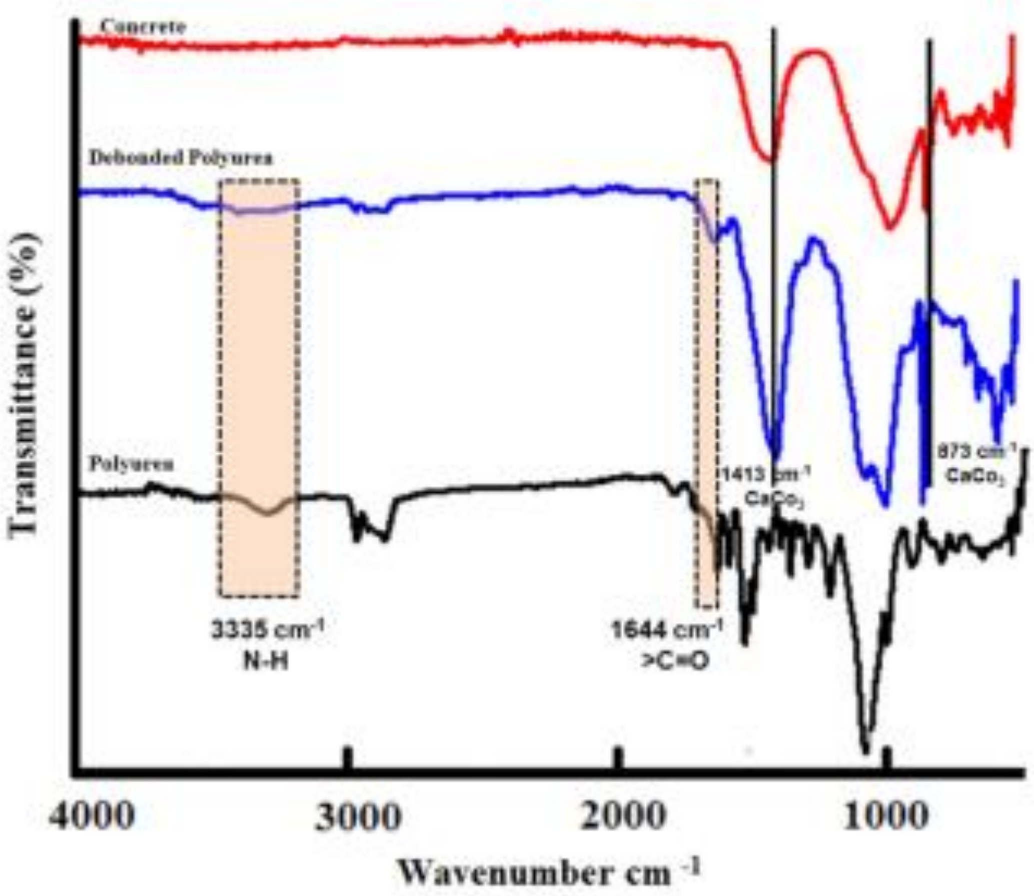

Figure 1 FTIR spectra of polyurea, concrete and debonded polyurea

N. Iqbal[27] studied the enhancement of blast resistance after coating. He used concrete tiles following IS 8112-1989, and polyurea was processed using commercial isocyanate Surprasec 2054 and poly-based amines. Varying thickness (1-6 mm) of samples was tested in a shock loading system, and an improvement of mechanical properties was detected during the blast test. In conclusion, the flexible nature of polyurea allows it to restrict the fracture of concrete tiles. Finally, the dynamic mechanical studies showed that hard domain ordering and

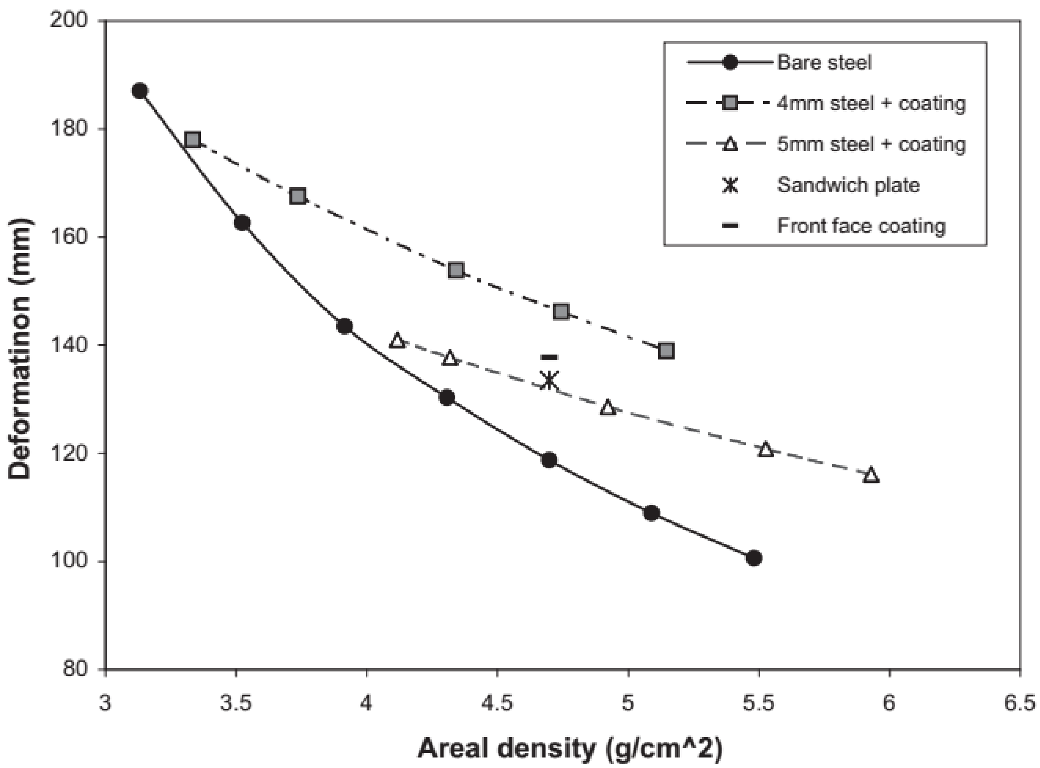

Figure 2 Results from parametric modelling study, showing the effect of various coating and plate configurations of final plate deformation

crystallization caused by shock waves, realignment of the H-bonds in the polymer and shock wave absorption should be the primary mechanisms leading to the improved performance observed during blast loading.

Other researchers studied polyurea on the influence of steel plates[28 29 30]. Kathryn Ackland used a blast test designed by the Defense Science and Technology

Organization. The blast load was generated by pentolite spheres. The sample plates were 4-6 mm in thickness with 15.7 mm and 7.7 mm thick polyurea coating. Experimental and numerical results show that coated samples suffer larger residual deformation with increasing polyurea coating thickness. Ahsan Samiee[31] presented some numerical simulation of dynamic response and deformation of steel plates with or without polyurea coating to investigate the effect of polyurea on the steel plates under blast loads. Results suggested that central plastic strain when samples coated on the back side is less than when polyurea is cast on the front side which receiving the blast load. As the thickness of polyurea is increased, the beneficial effect of polyurea becomes more apparent.

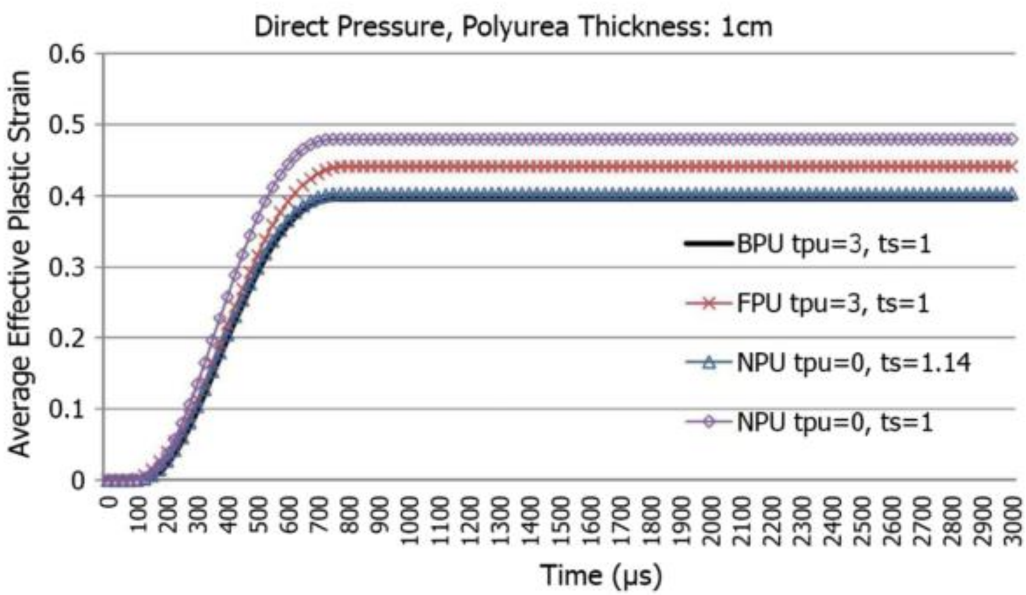

Figure 3 Time-history of average effective plastic strain at a circle of diameter 10 cm within the center of the steel plate for polyurea thickness of 1 cm. There is a negligible difference in performance between BPU and NPU cases.

Ahsan Samiee also studied the ballistic performance of polyurea coated ceramic plates[32]. 1/2” thick Al_2O_3 ceramic tiles with 1/4” thick polyurea and E-Glass/Epoxy were tested with a 10.6g cylindrical projectile made from tungsten heavy alloy. Results show a 10% mass increase of tested samples results in a 8% energy reduction. In this case, polyurea coating is less efficient than other covering methods such as E-Glass/epoxy, carbon-fiber/epoxy, and TiAlV alloy.

By reviewing these papers, we know that the polyurea coating does have a significant influence on impact resistance, due to its flexible nature and deformation mechanism, of materials subjected to blast loads. However, results vary a lot when coated on different materials. Significant beneficial effects are observed on concrete structures. But for other cases, such as coated steel or ceramic plates, the polyurea coating layer has less effect on blast resistance. Furthermore, the thickness of the coating and the relation between the spray surface and the blast-receiving surface also play a role in research.

3. Experimental

Experiments were performed at Wilmore Laboratories, Auburn University. The instrument set-up is shown in figure 4. An accelerometer was mounted on the drop tower to capture velocity during the impact test. The energy absorbed was calculated and compared to investigate the effect of polyurea coating.

3.1 Instrument

The Instron Dynatup 8250 Drop Weight Impact Tester and the PCB 350C03 accelerometer are used in the drop tower test[33]. With the help of oscilloscope and amplifier, we can capture and record the waveform of acceleration versus time.

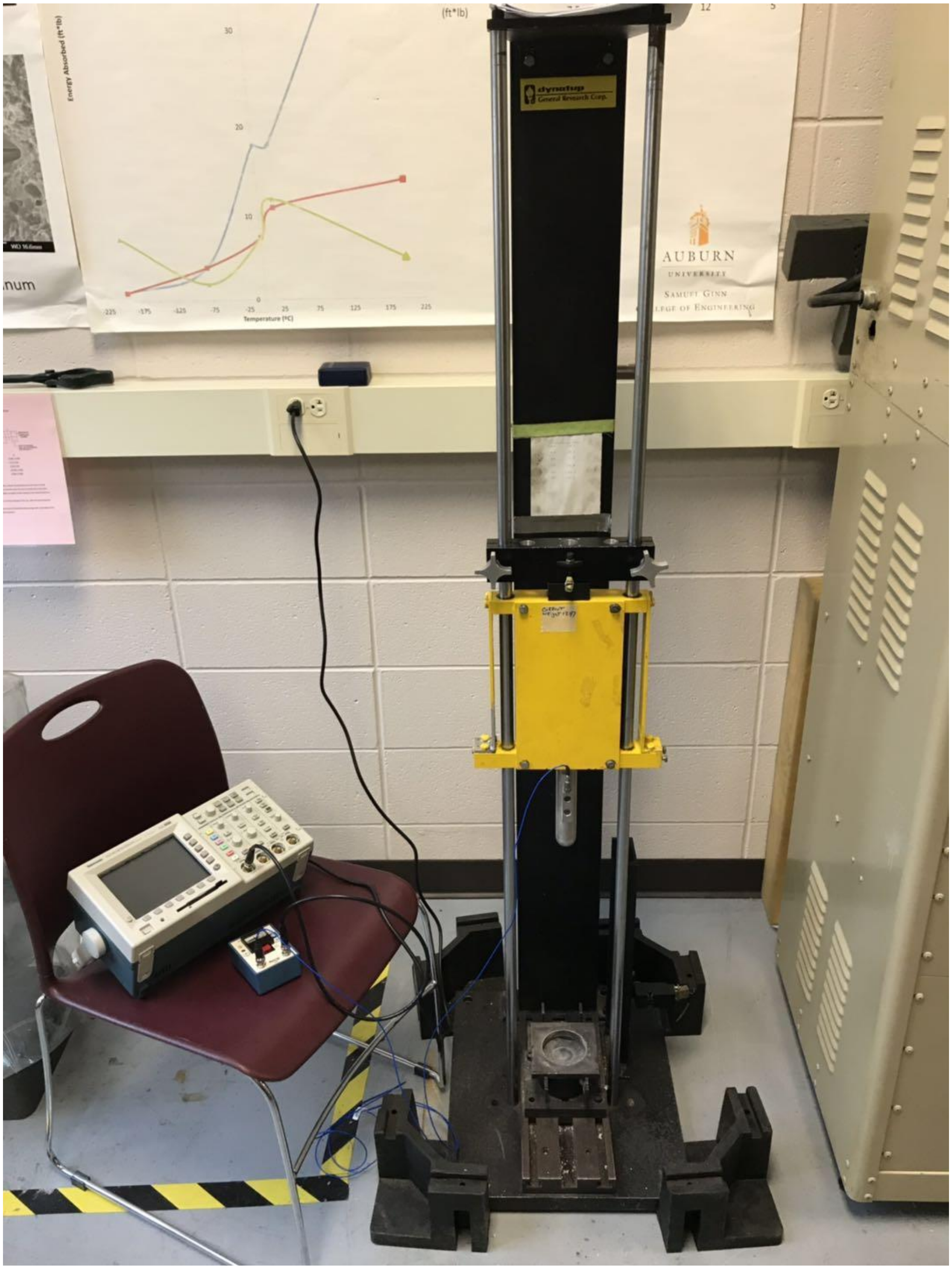

Figure 4 Testing system including drop tower, oscilloscope, amplifier and sensor

The whole testing system includes the drop tower, Tektronix TDS 3014B digital phosphor oscilloscope, PCB 350C03 shock sensor, and ICP sensor signal conditioner.

3.1.1 Data Analyze

After testing, we have the original data with signal versus time, as shown on figure 5.

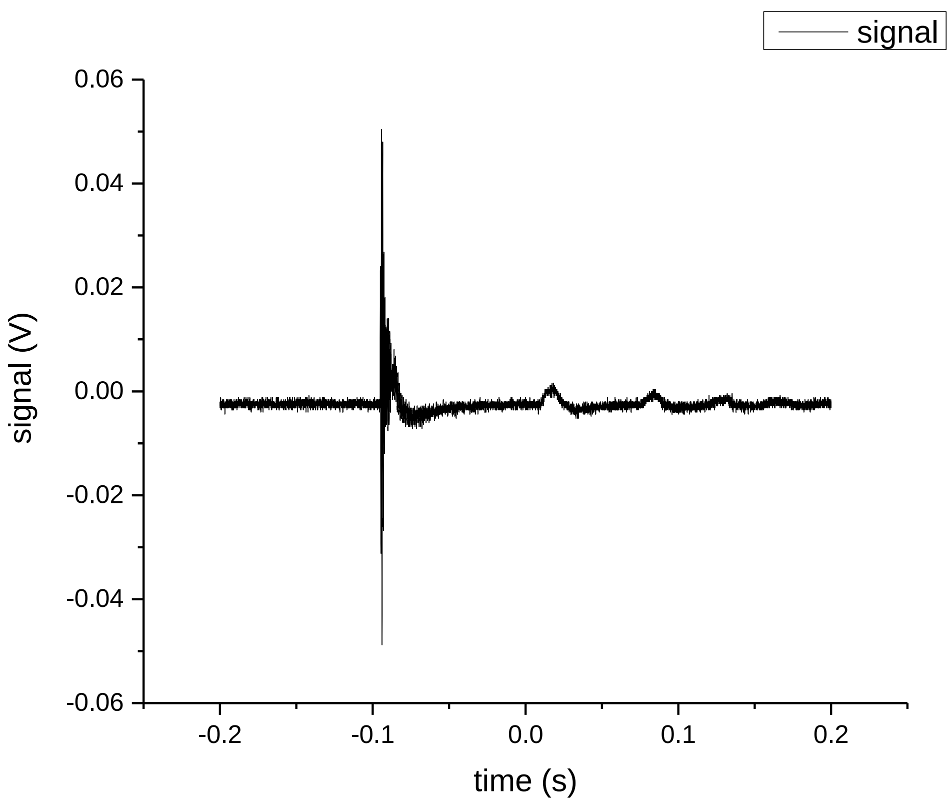

Figure 5 Original data from scope

Then we convert this signal curve into acceleration curve using sensitivity, which is 0.517mV/g (gravitational acceleration). In addition, we set the point where the impact occurred to be original point (0,0).

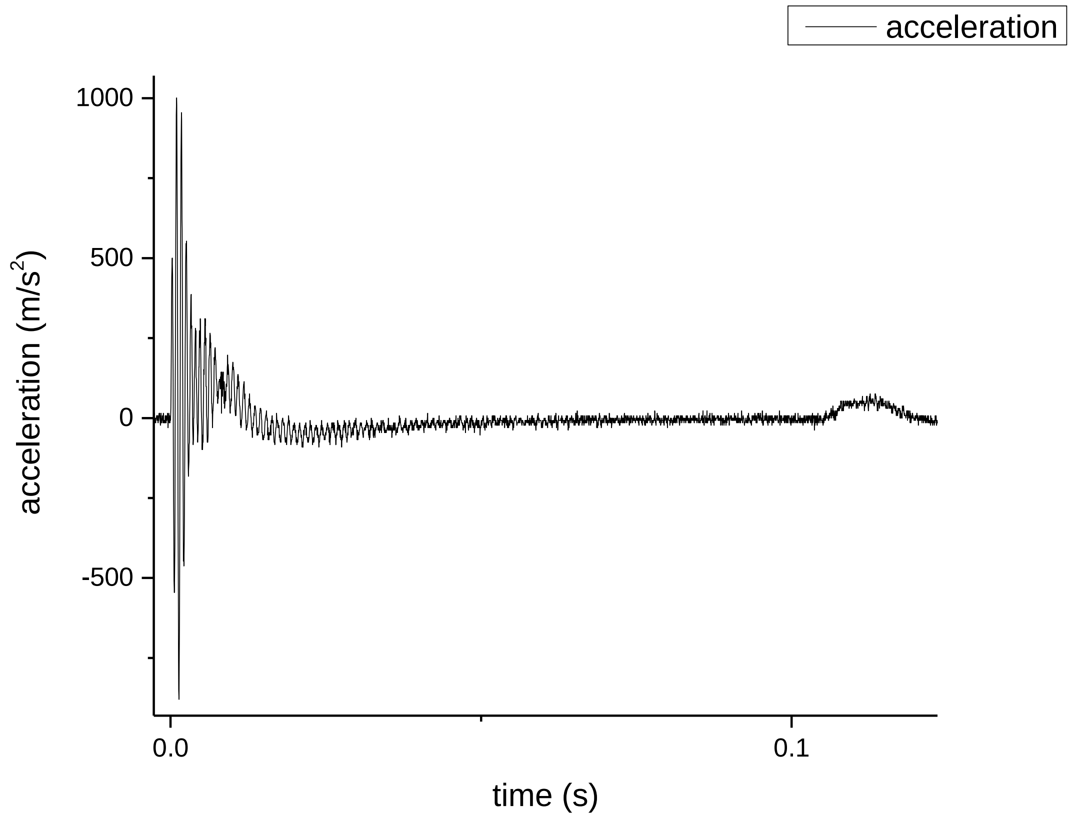

Figure 6 Acceleration versus time

After the integration we get the velocity versus time curve, in which the Y axis refers to the velocity decrease start from impact and X axis refers to the time.

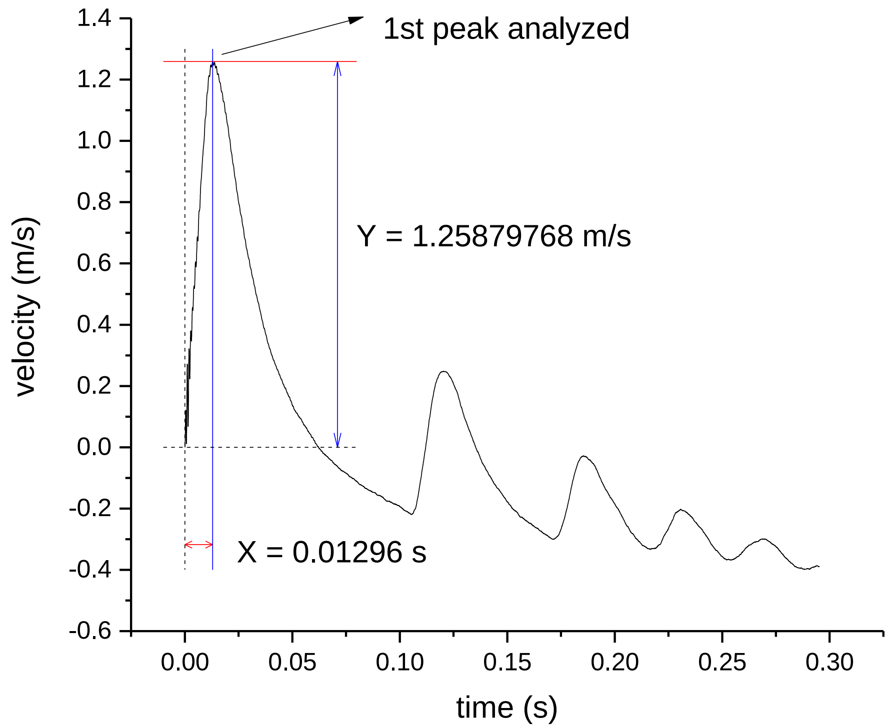

Figure 7 Velocity versus time

We consider the first peak is where the impact between the concrete tiles and the hammer happened. The Y value of peak point is the velocity decrease during the impact.

3.2 Concrete Tiles

Concrete tiles are made of Secutec S9 from CONTEC APS. It's a special cementitious industrial compound of Secutec Binder and selected Secutec aggregates. This type of concrete has an extremely high resistance to mechanical impact and mainly used in security safes and bank vault panels. Its lower water ratio provides a higher density than traditional cementitious composites.

Table 1 Technical data of Secutec S9

Compressive strength	**220-260 N/mm^2**
Flexural	25 – 35 N/mm^2
Modulus of elasticity	80.000 N/mm^2
Density	2850 – 2950 kg/m^3

3.2.1 Mixing

The secutec binder and aggregates are mixed in a plastic container 4 minutes before adding microfibers. After adding microfibers, another 3 minutes of mixing is needed. The composition ratio followed recipes shown in figure 5.

Recipes Secutec		
	S 6	S 9
Materials	Recipe kg for 1 m^3 (ncl. 2 % air)	Recipe kg for 1 m^3 (ncl. 2 % air)
Secutec Binder	780	1056
Bauxite 0.0 -1.0 mm	700	624
Bauxite 3.0 - 6.0 mm	1023	580
Water *	147	192
Steelfibres (0.4 x 12.5 mm)	141	
Microfibres (0.2 x 6 mm)		345
Total	2791	2797
Price index		
* Water can be increased up to + 10 % of described volume. Adding water will influence final strength.		

Figure 8 Recipes for Secutec S6 and S9

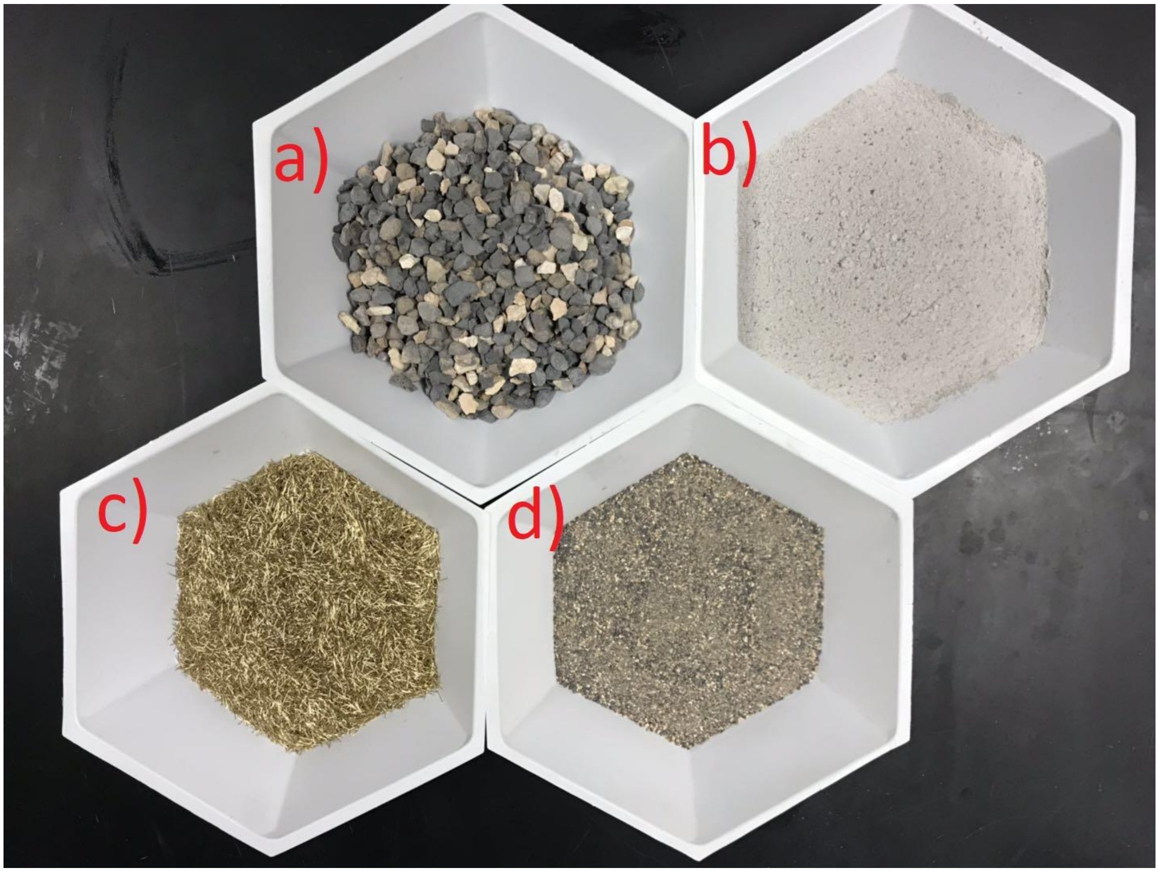

Figure 9 Raw materials of concrete before mixing a) bauxite 3.0-6.0 mm b) secutec binder c) microfibers d) bauxite 0.0-1.0 mm

All materials are mixed with a KHM72 hand mixer from KitchenAid following the instructions provided by Secutec company.

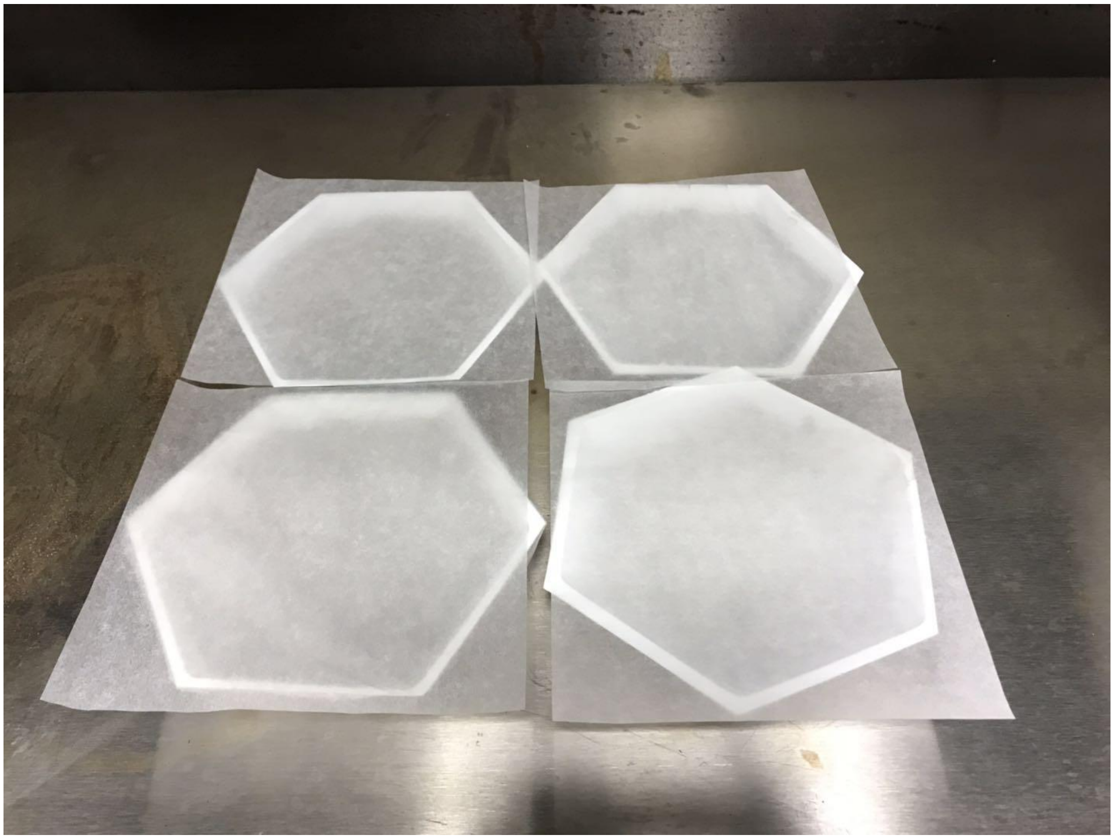

Figure 10 Concrete tiles curing in a chemical fume hood

3.2.2 Influence of water volume

The amount of water added to the mixture plays an essential role on properties of the final product[34]. So, samples with different water ratios are tested in this research. All samples are processed in the same container and cured in a regular hexagon plastic container for the same period of time. A 12oz total mass was chosen to fit the container, and the composition follows the recipes on table 2.

Table 2 Composition of a 12oz concrete sample

materials	**S9(kg/m3)**	**oz**	**g**
secutec binder	1056	4.53	128.44
bauxite 0.0-1.0 mm	624	2.68	75.99
bauxite 3.0-6.0 mm	580	2.49	70.6
water	192	0.82	23.25
steelfibers	0	0	0
microfibers	345	1.48	41.96
total	2797	12	340.23

Concretes made with different amounts of water (20, 23, 40, 42, 50, 55, 63, 84g separately) were tested. Drop tower test result are shown below. It’s worth mentioning that 20g sample failed to form a castable mixture, so it also failed the impact test.

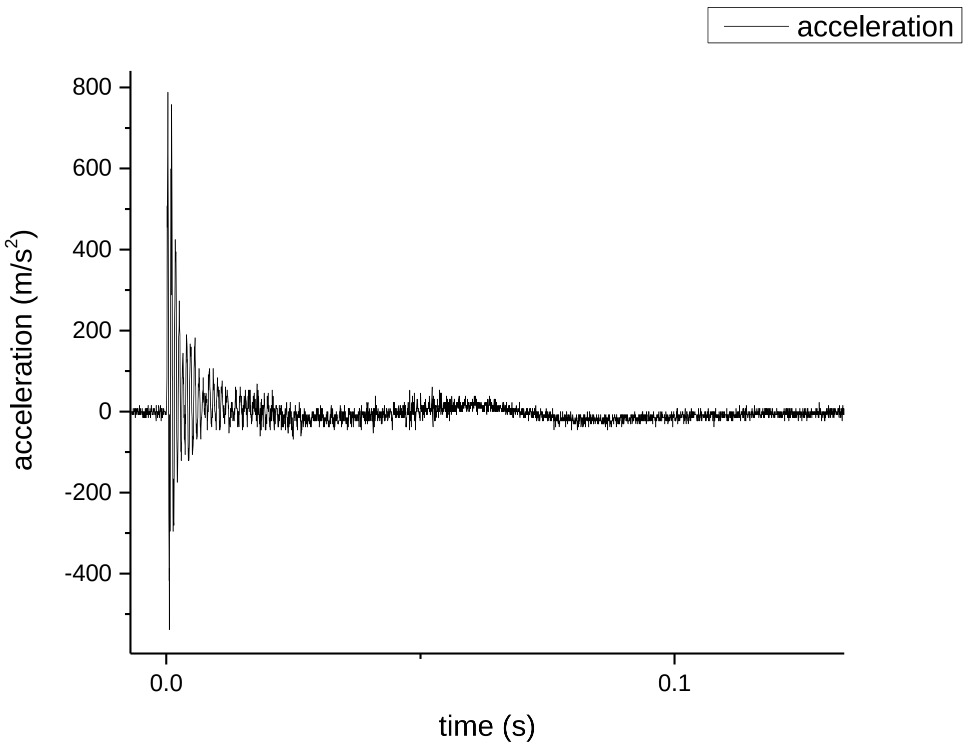

Figure 11 Impact test result for 12oz sample with 23g water

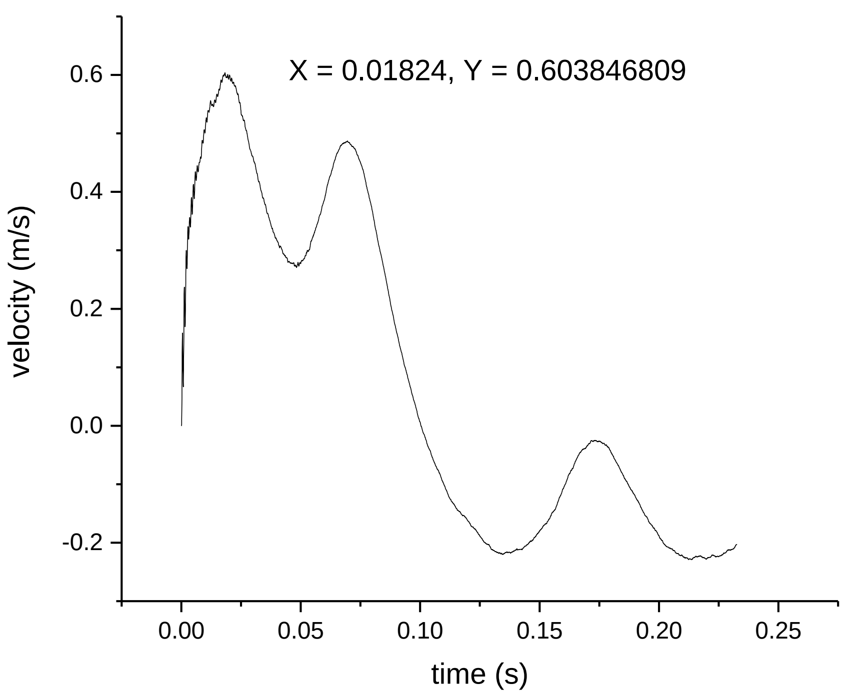

Figure 12 Velocity result of 12oz sample with 23g water

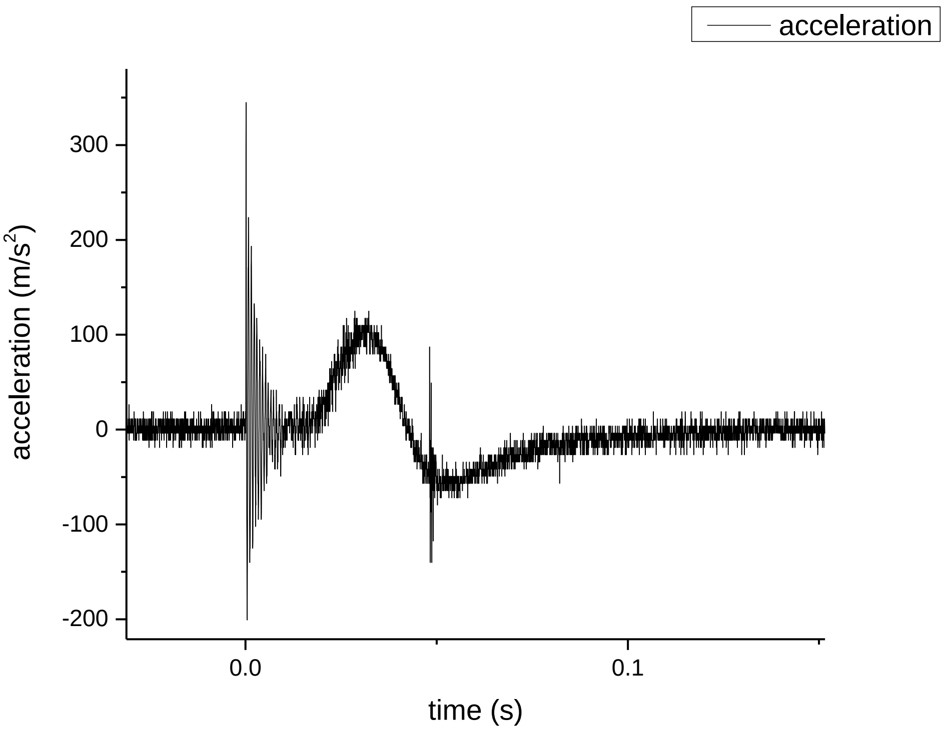

Figure 13 Impact test result for 12oz sample with 40g water

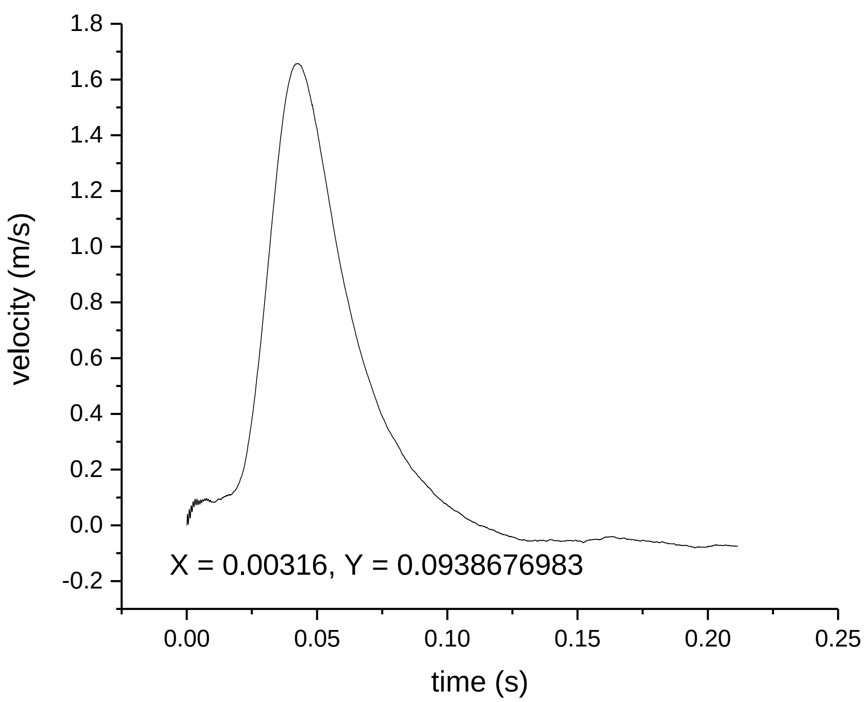

Figure 14 Velocity result of 12oz sample with 40g water

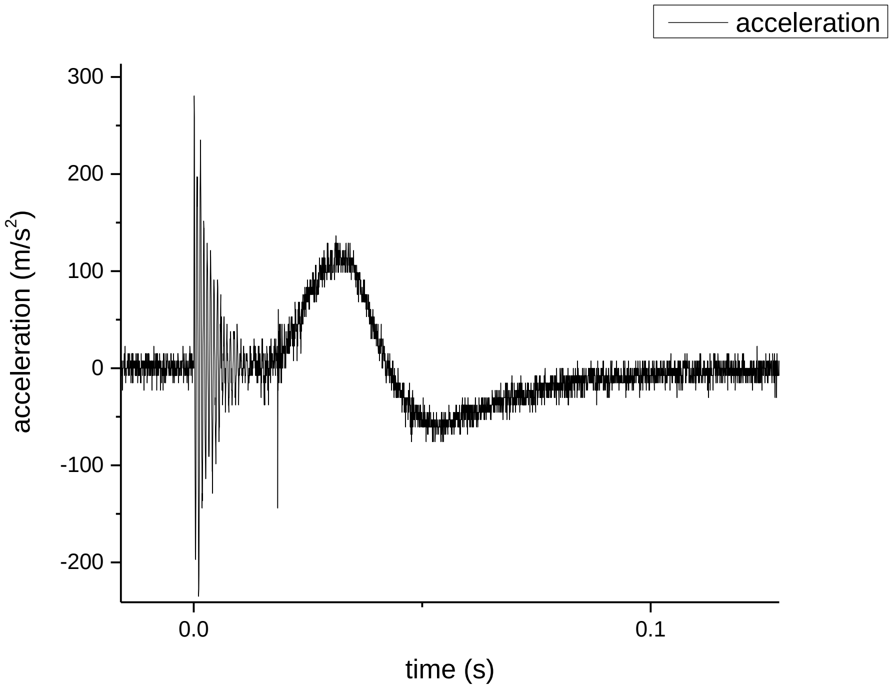

Figure 15 Impact test result for 12oz sample with 42g water

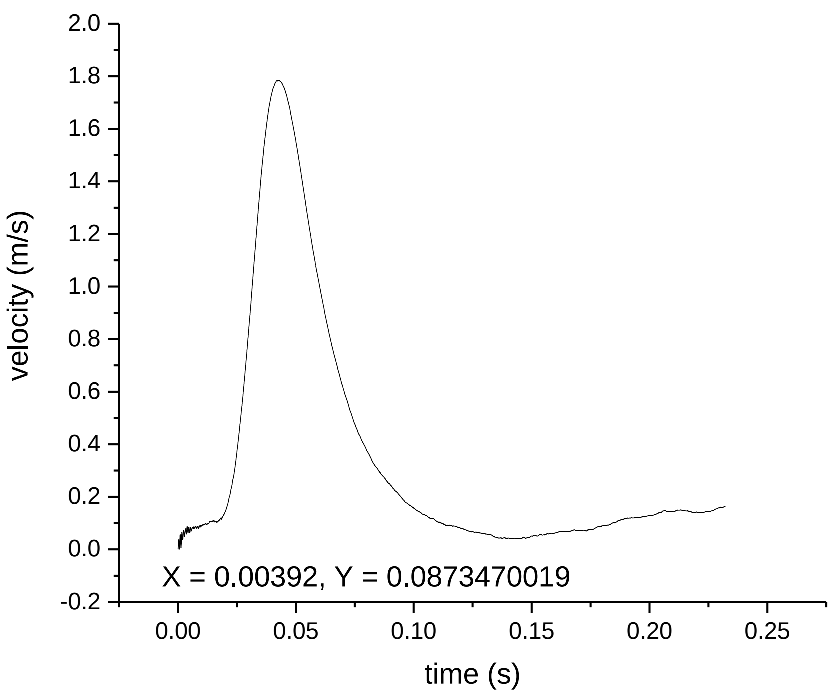

Figure 16 Velocity result of 12oz sample with 42g water

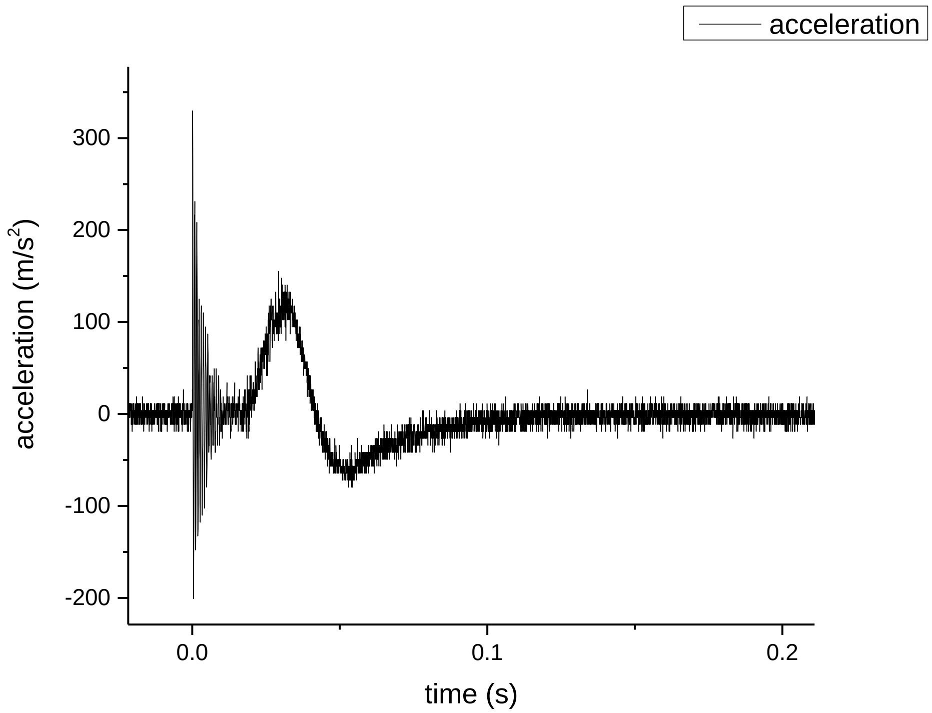

Figure 17 Impact test result for 12oz sample with 50g water

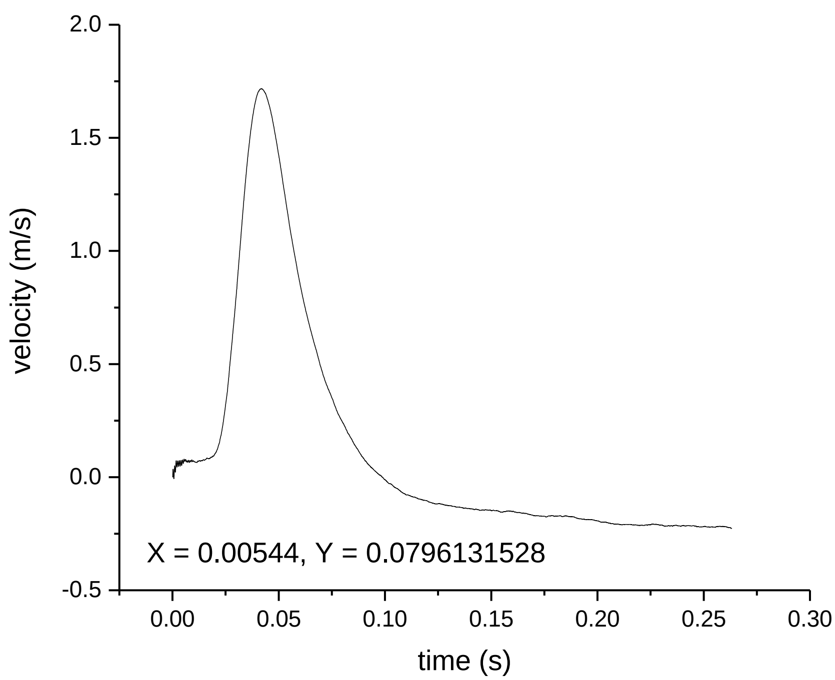

Figure 18 Velocity result of 12oz sample with 50g water

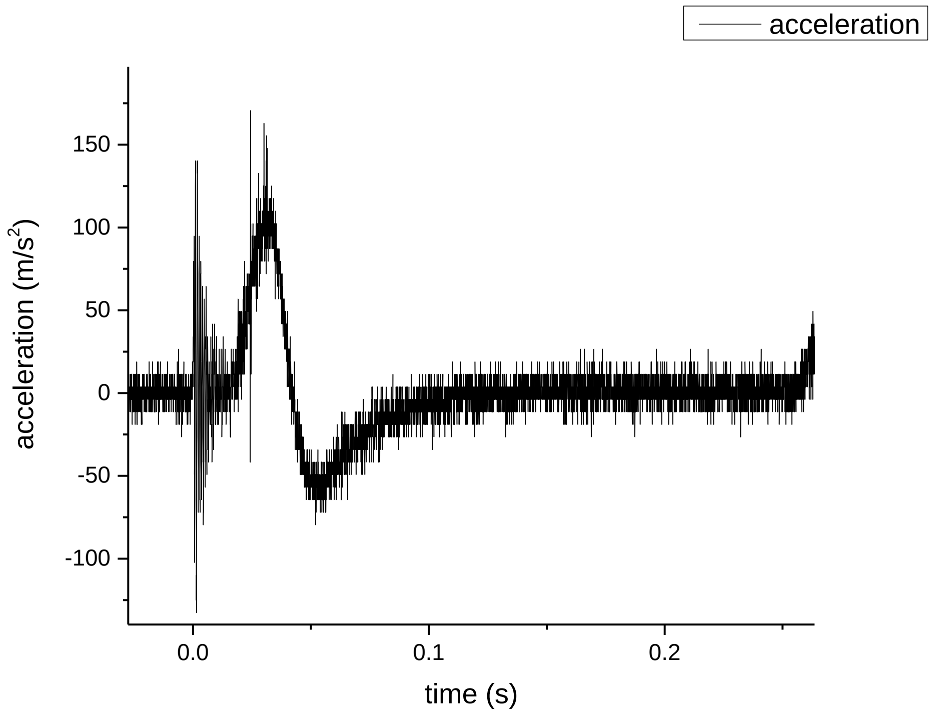

Figure 19 Impact test result for 12oz sample with 55g water

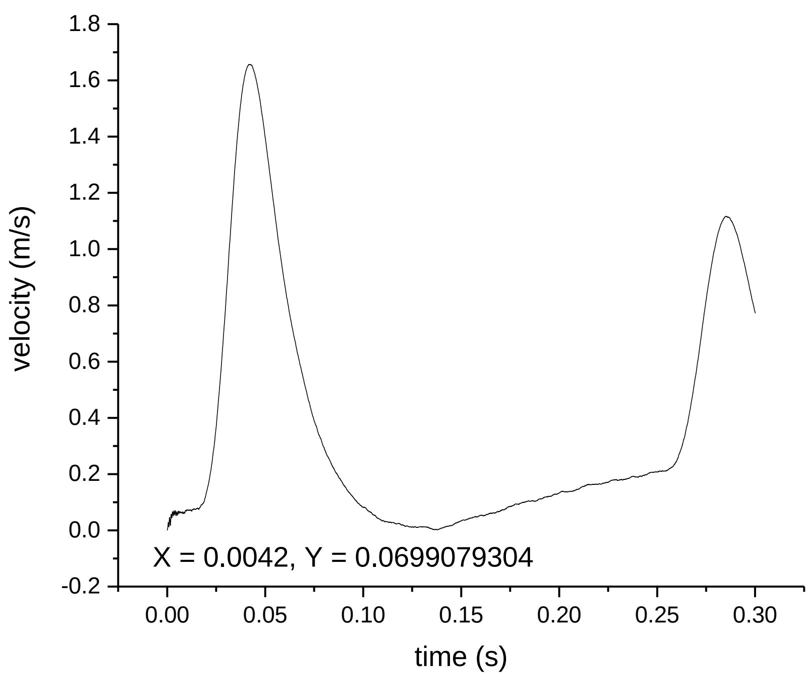

Figure 20 Velocity result of 12oz sample with 55g water

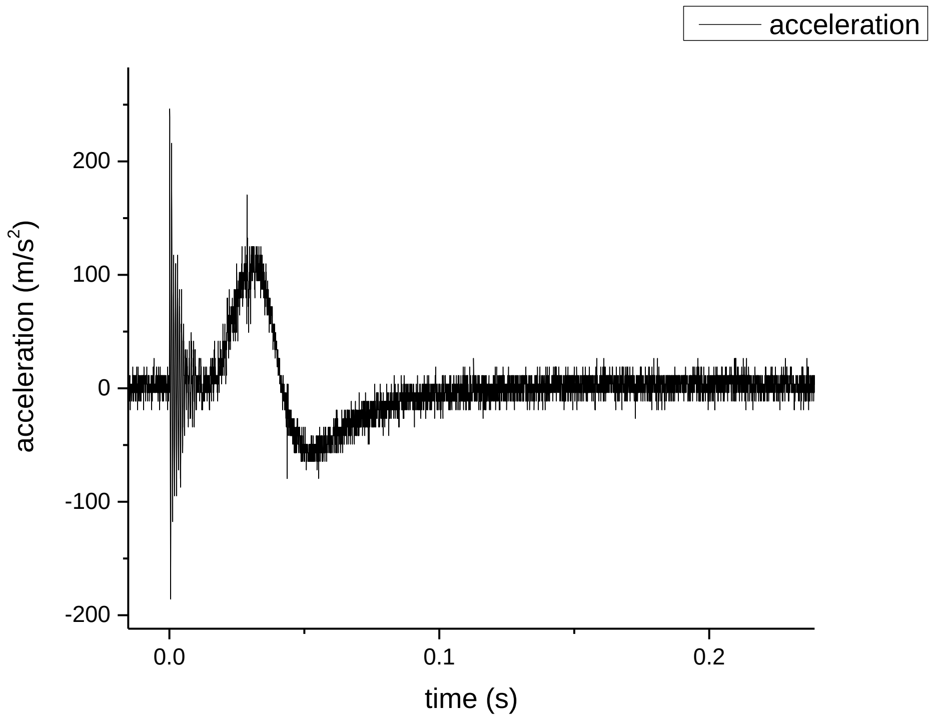

Figure 21 Impact test result for 12oz sample with 63g water

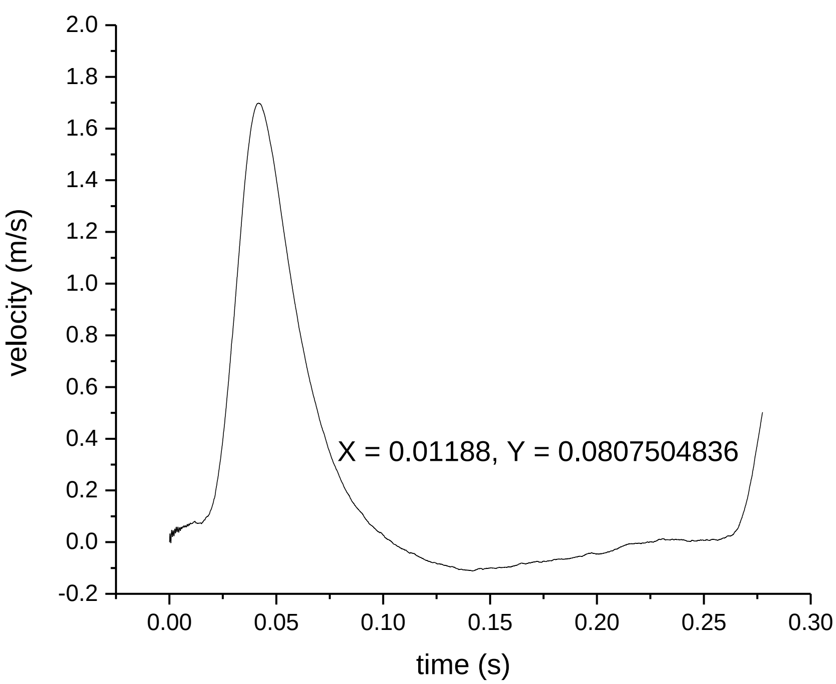

Figure 22 Velocity result of 12oz sample with 63g water

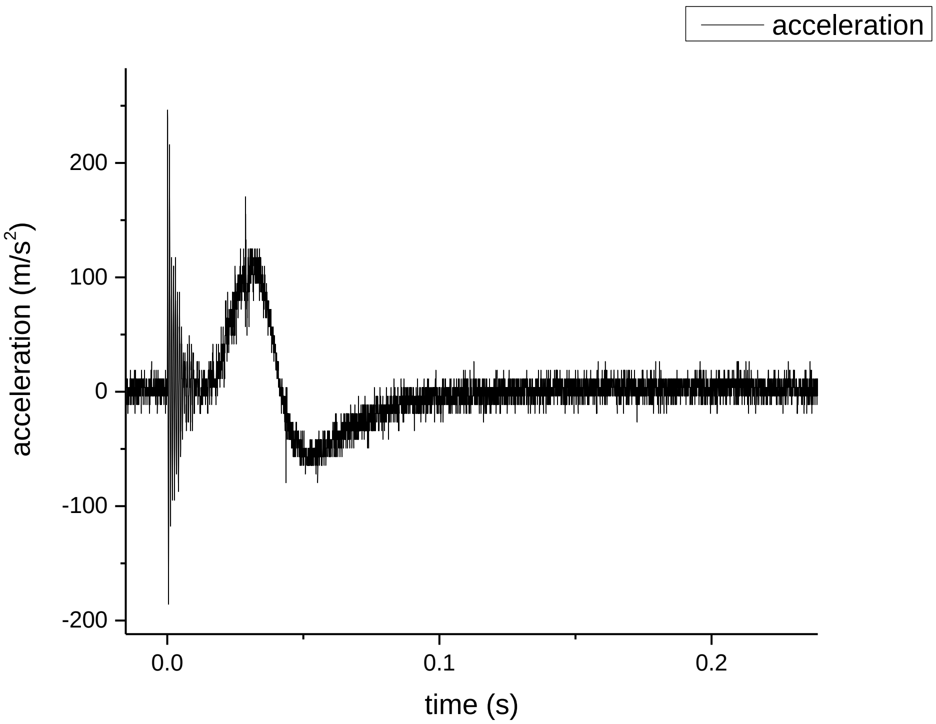

Figure 23 Impact test result for 12oz sample with 84g water

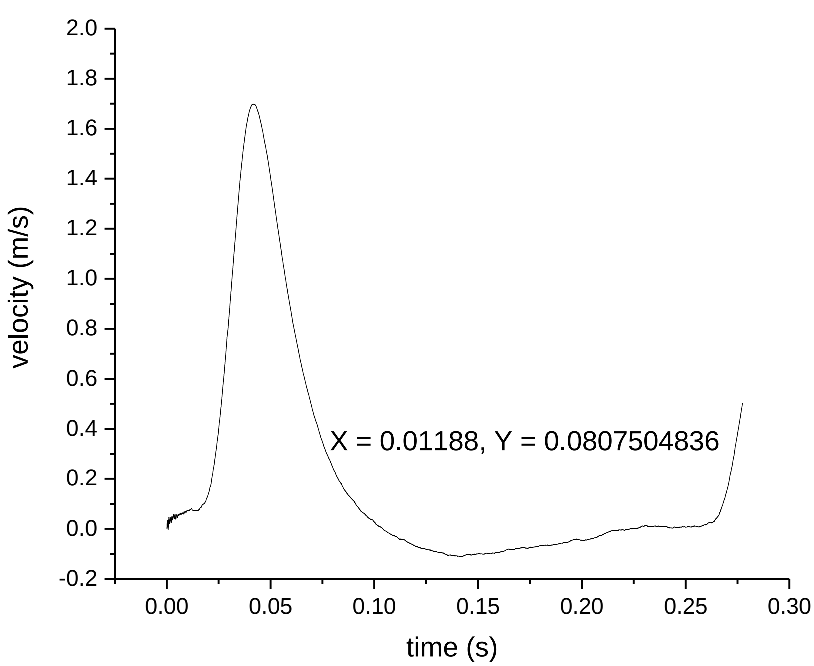

Figure 24 Velocity result of 12oz sample with 84g water

The impact energy was calculated using

$$E = \frac{1}{2} m v_{final}^2 - \frac{1}{2} m v_{initial}^2$$

In which $v_{initial}$ refers to the initial speed before impact occurs, v_{final} refers to the final speed after the impact period, m refers to the total mass of the drop tube. We assume the impact occurs at the first peak and all the bouncing afterward is ignored. All samples are tested for a drop hammer free fall height of 8-inchs. After calculating the impact energy, we determine the relationship between water volumes and impact resistance.

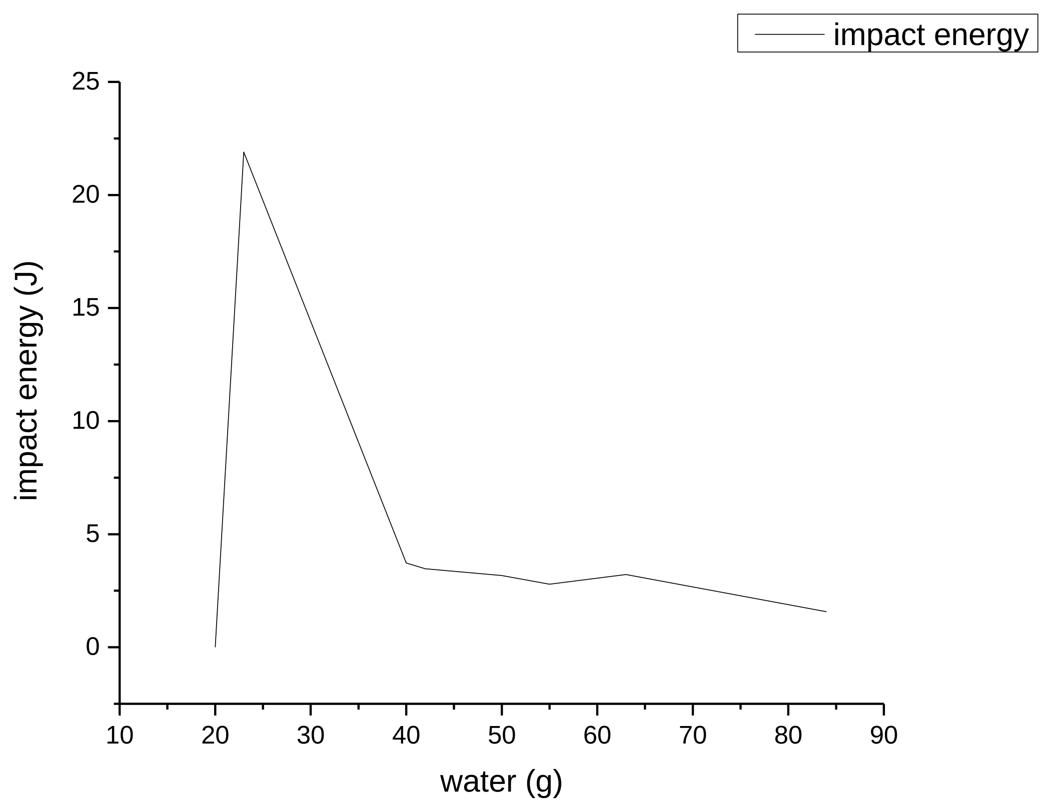

Figure 25 Relationship between water volume and impact energy

In this case, 23g water in a 12oz cementitious composite mixture shows the best mechanical property. So, the rest of concrete samples that were processed all used this ratio composition.

3.3 Calibration and Dimension

First of all, we need to find out the sensitivity of the accelerometer.

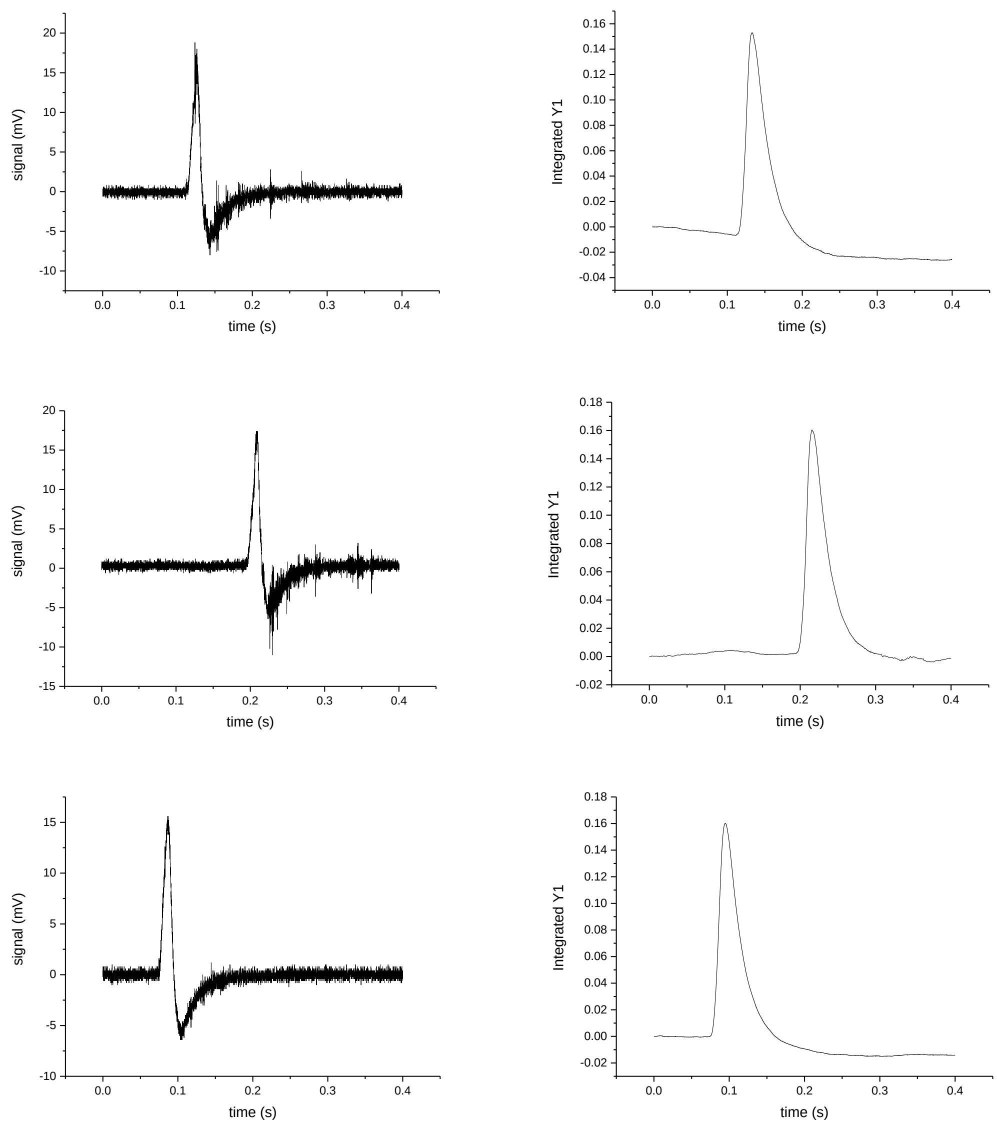

Figure 26 Calibration data

We let the hammer free fall from 18-inch (0.4572m) height, measure the signal waveform, then calculate the sensitivity by $v^2=2gh$.

$$\text{sensitivity}=5.28*10^{-4}\ \text{mV}/(\text{m/s}^2)=0.517\ \text{mV/g}$$

In order to find a better sample size for the drop tower experiment, we produced a number of structure steel plates with different dimensions. Because of the limitation of drop tower instrument, we choose sample sizes from 3”x3” to 8”x6”. Thickness of all steel samples are the same, 1/4”.

Impact test results are shown below.

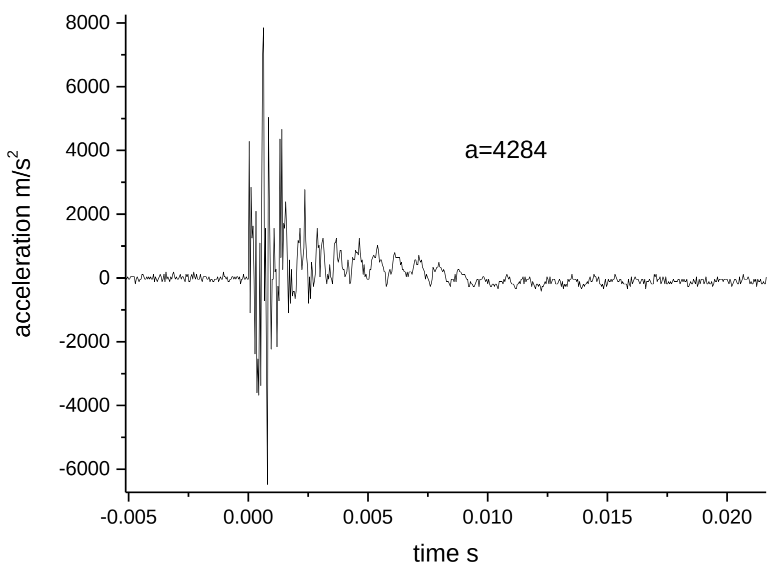

Figure 27 Impact test results of 8''x3'' steel plates #1

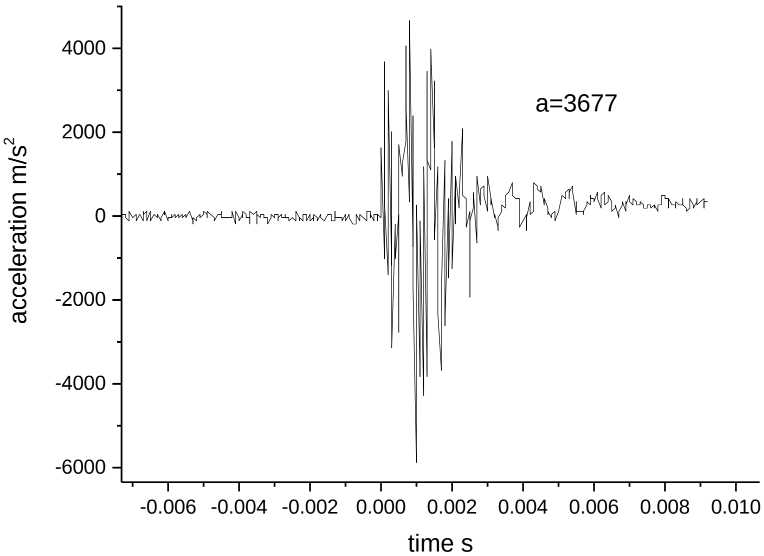

Figure 28 Impact test results of 8"x3" steel plates #2

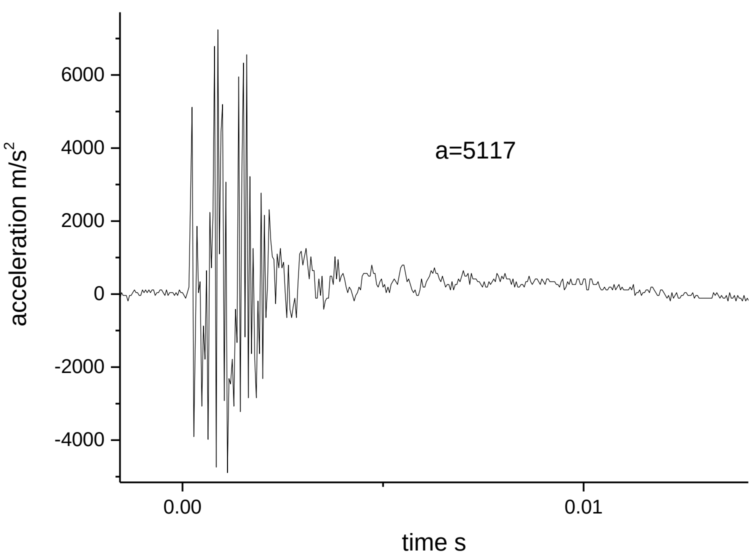

Figure 29 Impact test results of 8"x3" steel plates #3

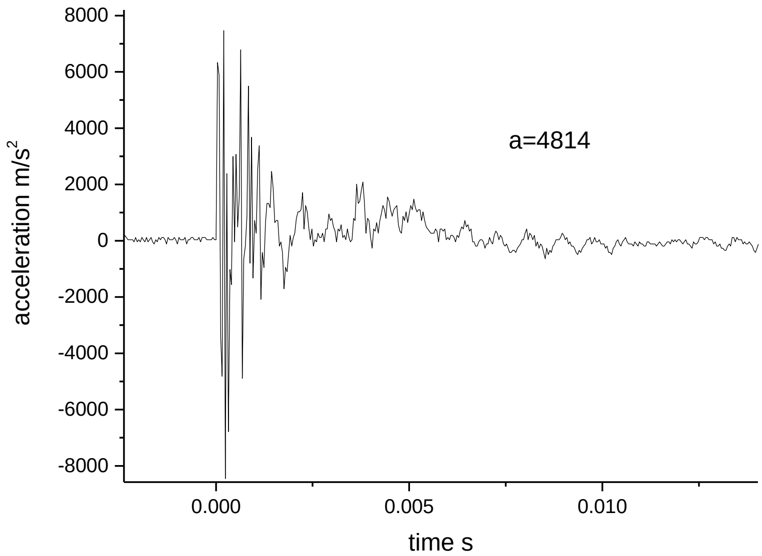

Figure 30 Impact test results of 8"x3" steel plates #4

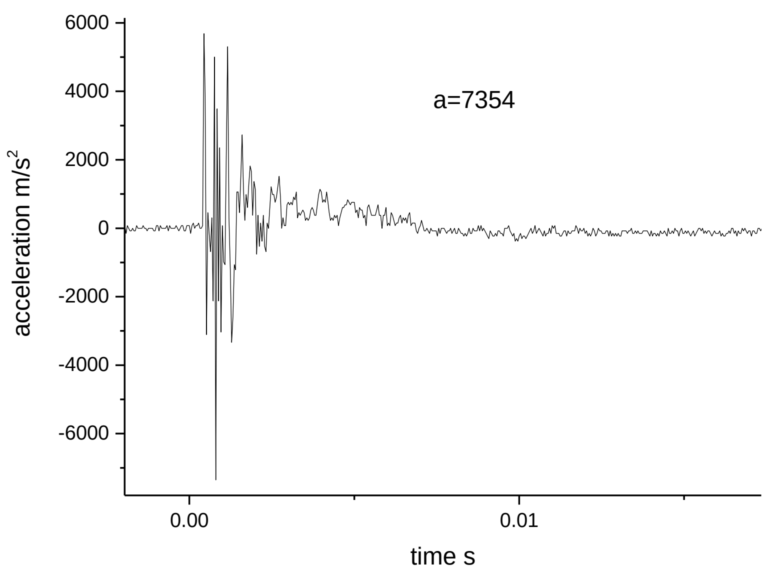

Figure 31 Impact test results of 8"x6" steel plates #1

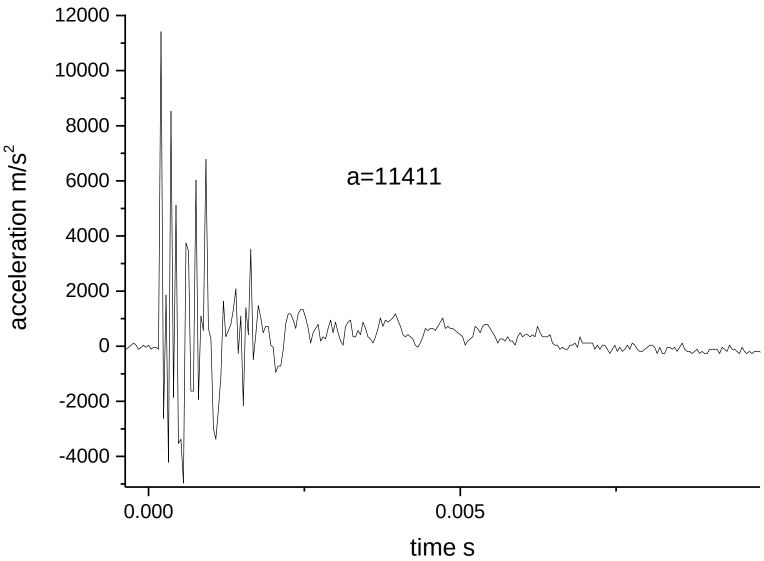

Figure 32 Impact test results of 8"x6" steel plates #2

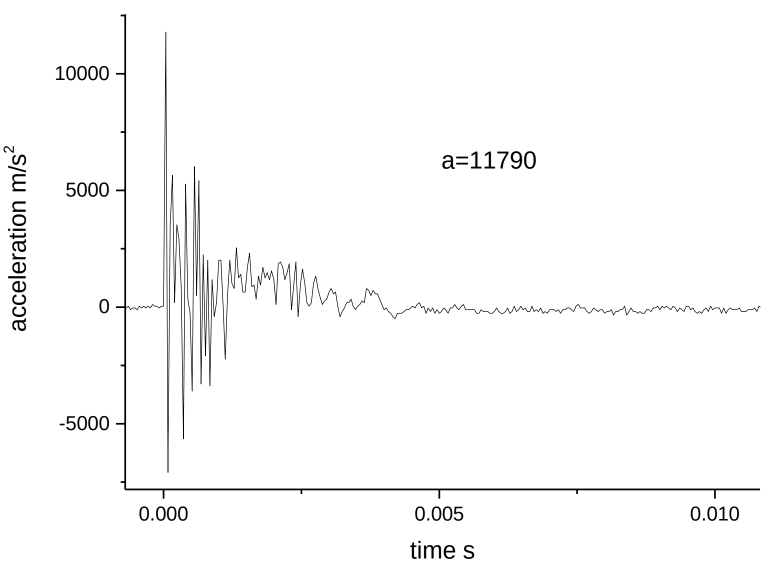

Figure 33 Impact test results of 3"x3" steel plates #1

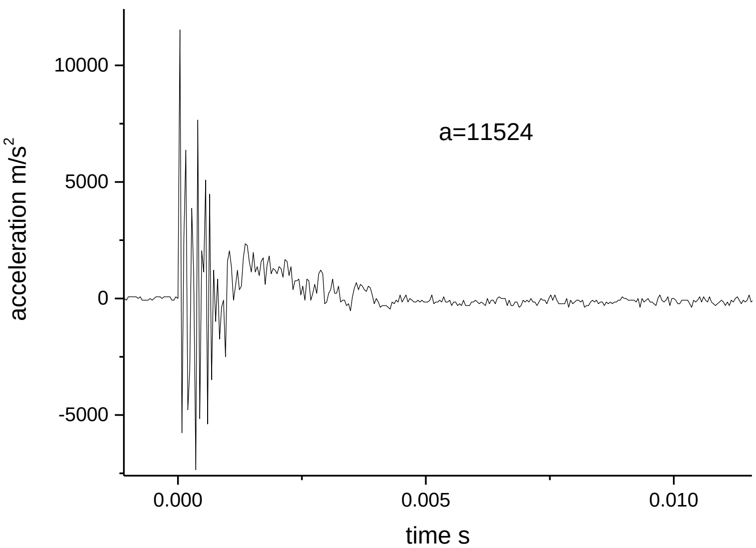

Figure 34 Impact test results of 3"x3" steel plates #2

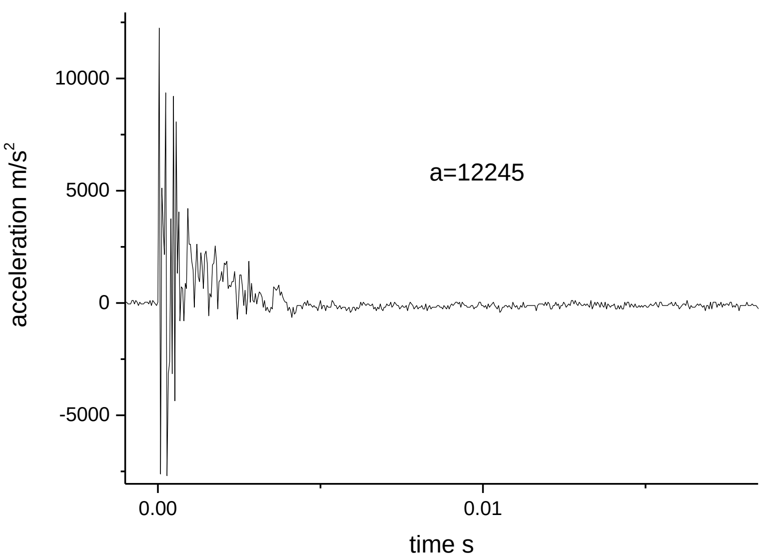

Figure 35 Impact test results of 3"x3" steel plates #3

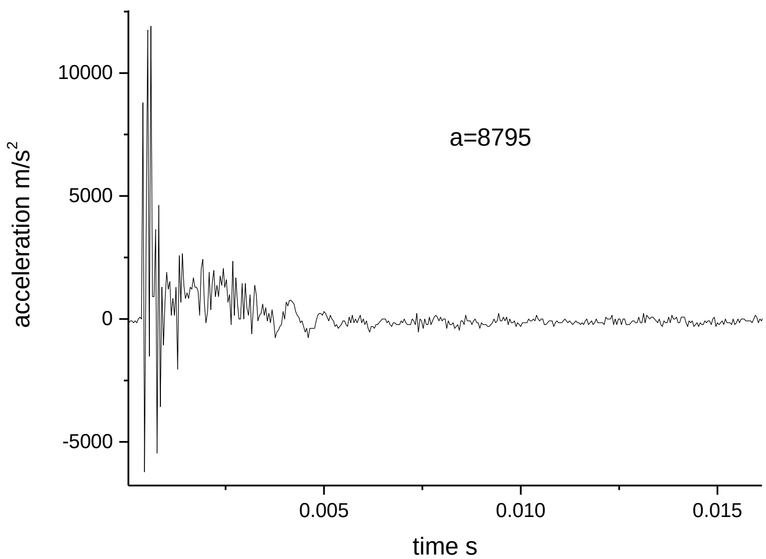

Figure 36 Impact test results of 3"x3" steel plates #4

Based on data that was captured and evaluated, the 3”x3” and 4”x4” square samples have the better performance since the instantaneous acceleration at the first impact is higher than the others. Considering the size of the holder on the bottom of drop tower, a 4”x4” common size is chosen for all the test afterward.

3.4 Polyurea coating

The polyurea coating material is from LINE-X LLC, the product No. is XS-350. This product is a two-component polyurea spray elastomer that offers outstanding performance as a protective coating for different materials. Its polyurea chemistry nature also gives excellent chemical resistance and moisture protection.

Basic physical properties are shown below.

Table 3 Physical properties of LINE-X XS350 polyurea coating

Test name	Test method	Value
Coefficient of friction Static Kinetic	ASTM D1894	 0.305 0.127
Dielectric const.	ASTM D150	3.6
Dissipation factor	ASTM D150	0.031
Volume resistance	ASTM D257	2.3×10^{14} ohm cm
DMA test	ASTM D4065	-48C
Elongation	ASTM D412	162%
Flexural strength	ASTM D790	2630 psi
Flexural modulus	ASTM D790	0.056 msi
Fungus resistance	MIL-STD 810F	pass
Hardness shore D	ASTM D2240	60 ± 1
impact	ASTM D2794	208 in-lbs
Pull-off test-adhesion	ASTM C297	1800 psi
Taber abrasion	ASTM D4060	69.8
Tear strength	ASTM D624	783 pli
Tensile strength	ASTM D412	3432 psi
TMA test	ASTM E2347	188C
Water vaper trans.	ASTM E96	0.499 grains/ft^2/hr

This two component polyurea requires precondition between 70°F to 90°F for both iso and resin parts. The spray application must use a high-pressure, heated, 1:1 composition by volume spray instrument with at least 2000 psi pressure capacity. In this case, Reactor spray equipment from Graco company is used to apply the coating.

Figure 37 Reactor E-XP2 from Graco

Materials coated with polyurea on 1 side, 2 sides and sandwiched were evaluated.

3.5 testing

The shape of the concrete samples is a 4”x4”x1/2” cuboid. All samples are tested with the drop hammer free fall from a 5-inch height. The cross section of coated samples is shown below.

Figure 38 Polyurea coated on one side of concrete

Figure 39 Polyurea coated on two sides of concrete

Figure 40 Two tiles with polyurea in between

The thickness of polyurea coating are measured to be 6.45(±0.5) mm for single tile samples, and 3.85(±0.1) mm for two sides of double tiles samples and 10.21 (±0.1) mm for the center of double tiles samples.

3.6 results

Cuboidal 4”x4” samples were placed into the drop tower and drops were conducted from a 5'' height. The signal from the accelerometer were captured by the oscilloscope and recorded for evaluation and comparison. The acceleration data were integrated to obtain the velocity change during the impact process, and the impact energy was calculated from the kinetic energy equation.

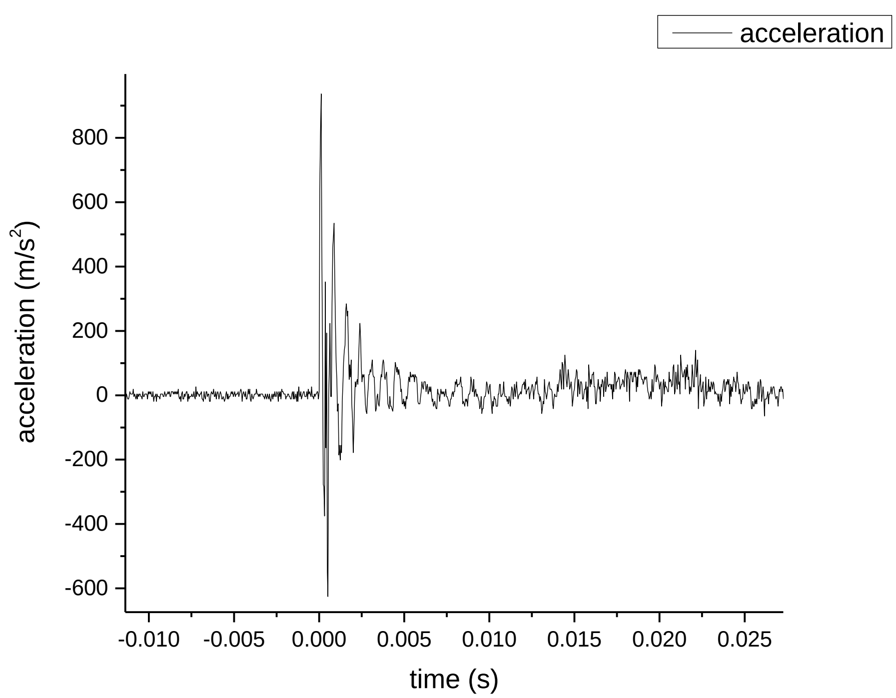

Figure 41 Impact test result of uncoated concrete tile #1

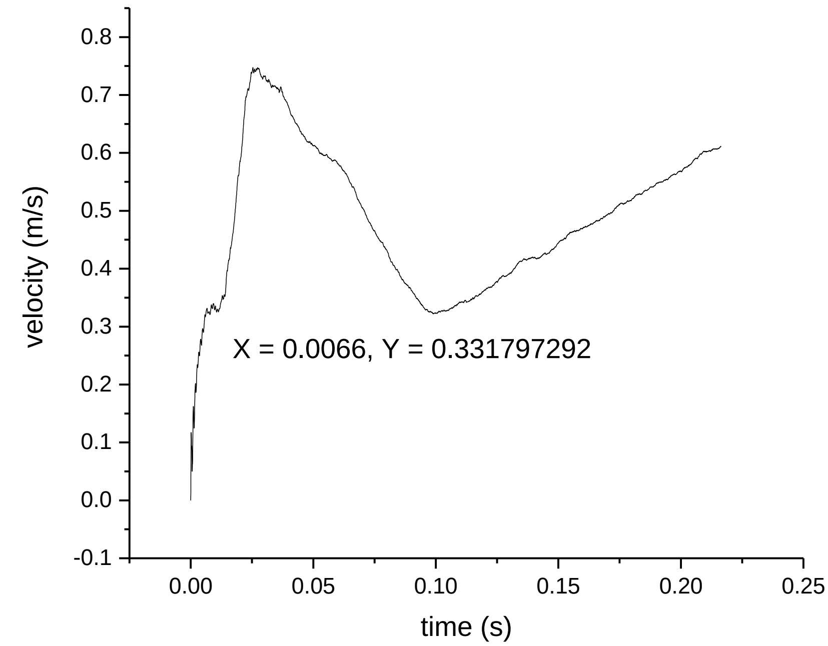

Figure 42 Velocity result of uncoated concrete tile #1

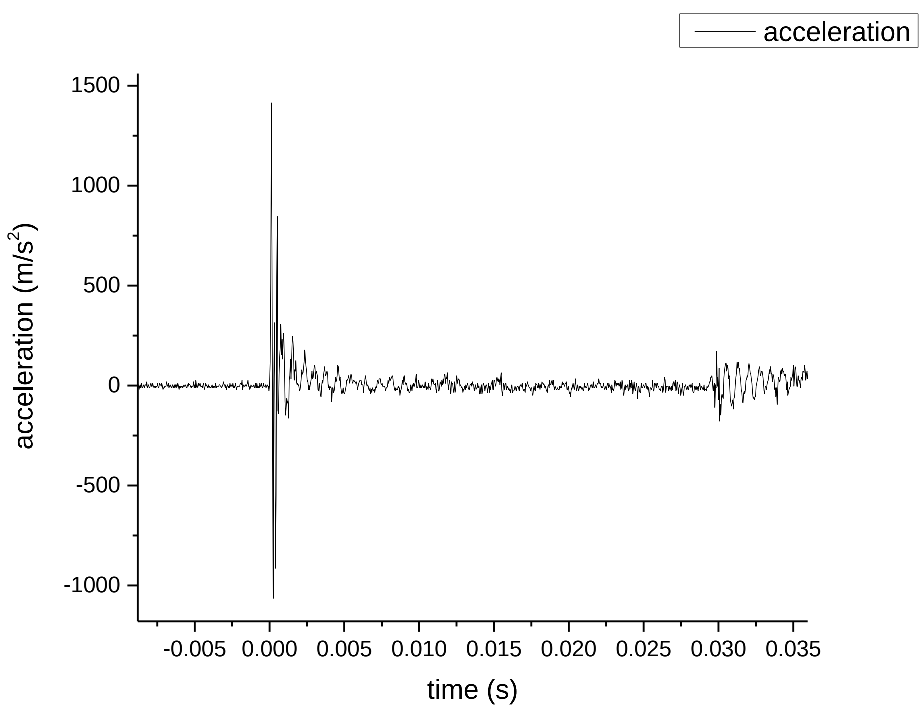

Figure 43 Impact test result of uncoated concrete tile #2

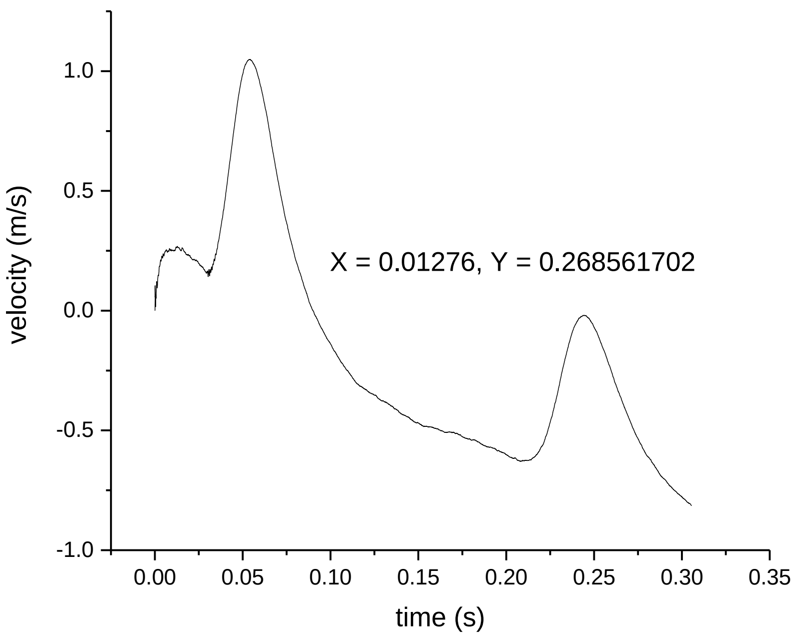

Figure 44 Velocity result of uncoated concrete tile #2

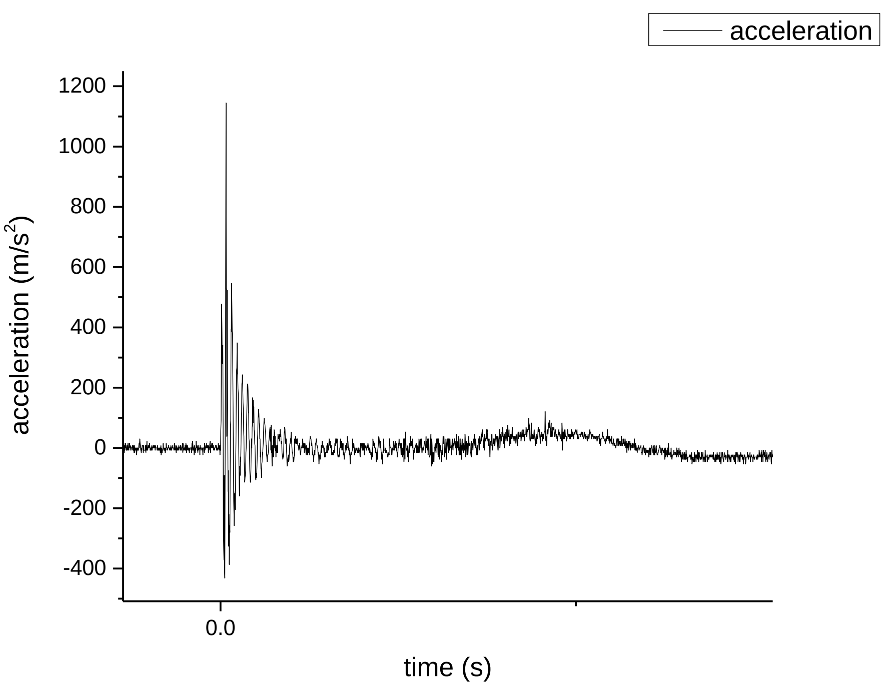

Figure 45 Impact test result of uncoated concrete tile #3

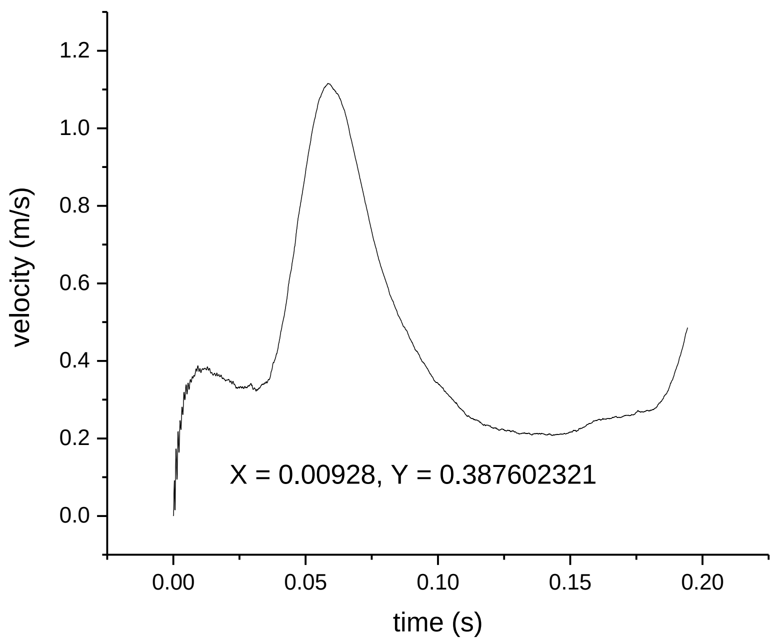

Figure 46 Velocity result of uncoated concrete tile #3

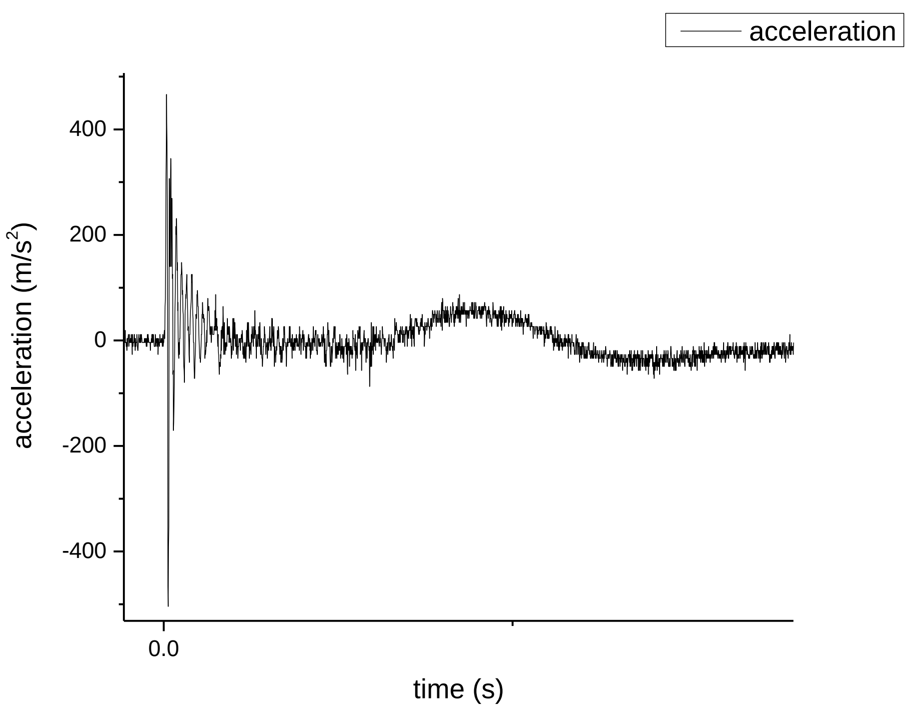

Figure 47 Impact test result of uncoated concrete tile #4

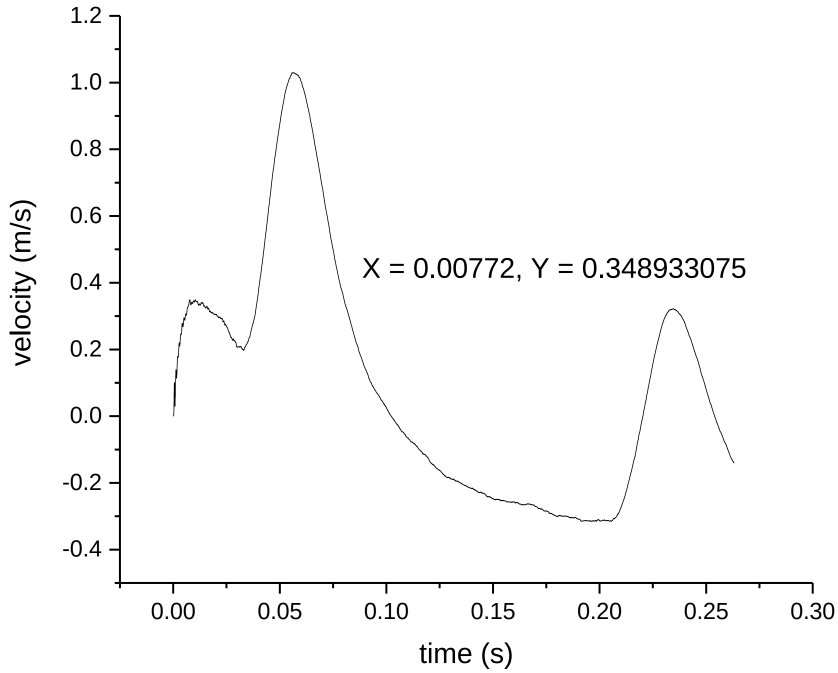

Figure 48 Velocity result of uncoated concrete tile #4

The coordinate of the top point of first peak, where the first impact occurs, is shown on the figure 45. The energy is calculated from Y value which is the velocity decrease.

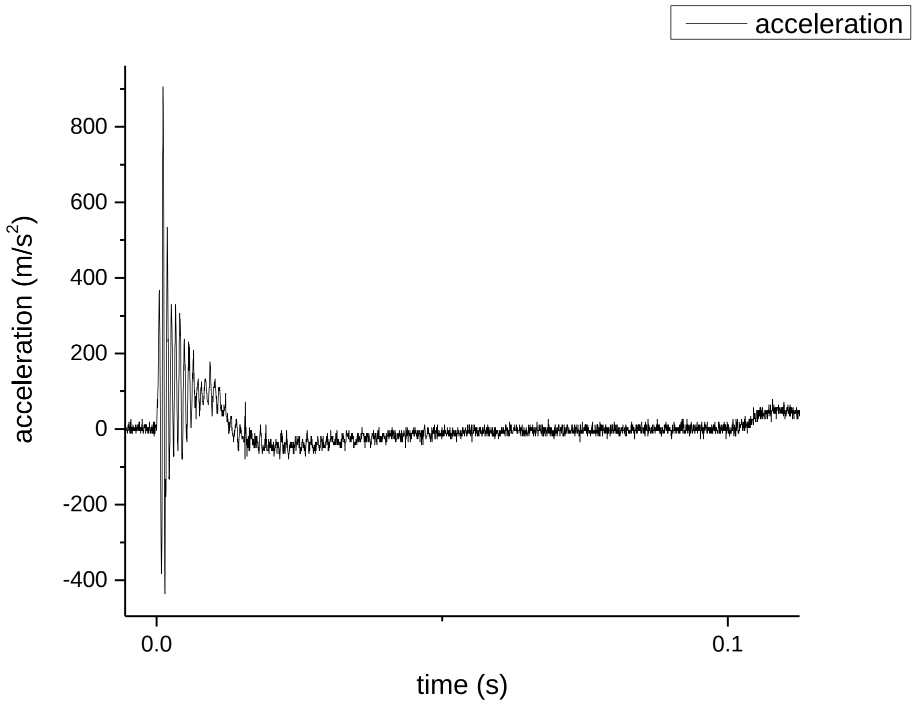

Figure 49 Impact test result of concrete tile coated on top side #1

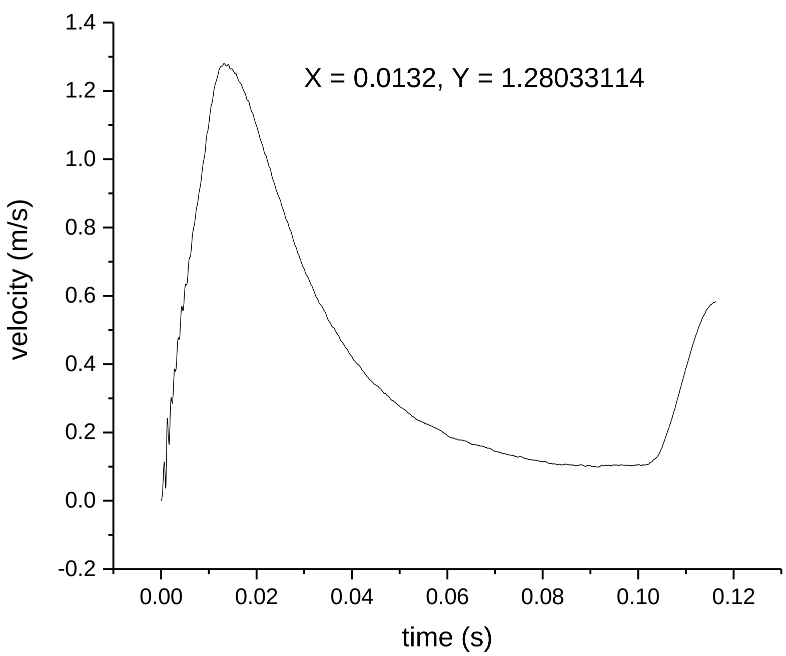

Figure 50 Velocity result of concrete tile coated on top side #1

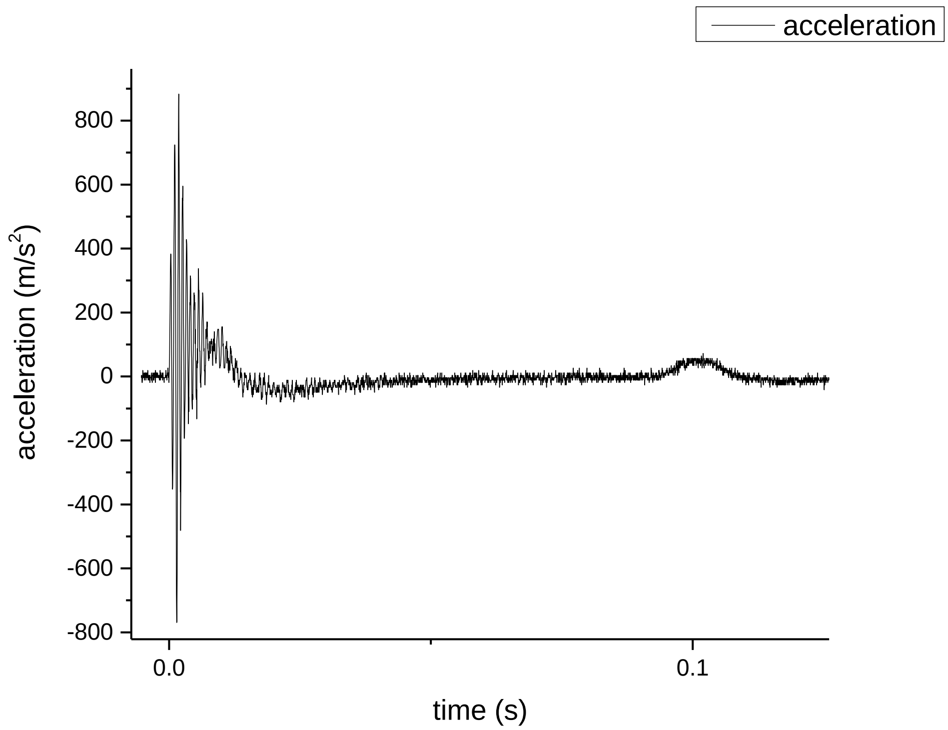

Figure 51 Impact test result of concrete tile coated on top side #2

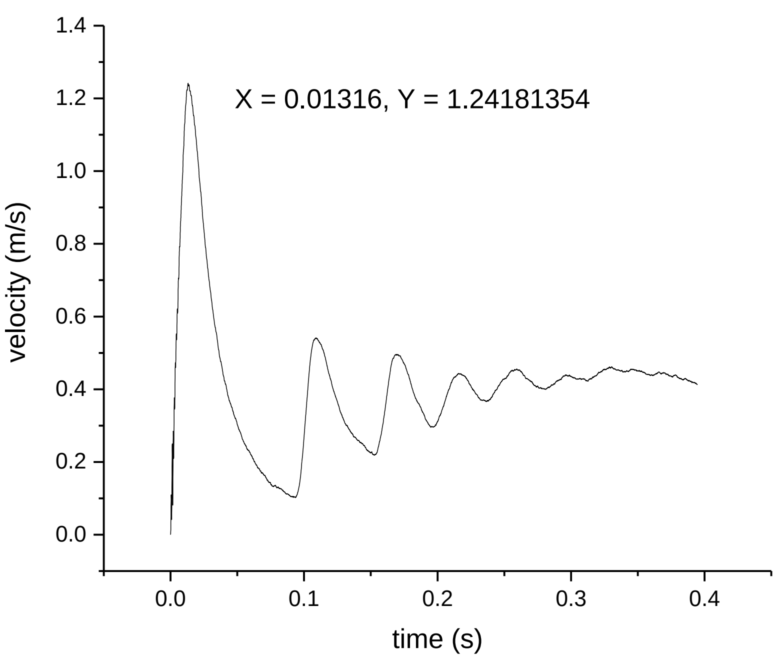

Figure 52 Velocity result of concrete tile coated on top side #2

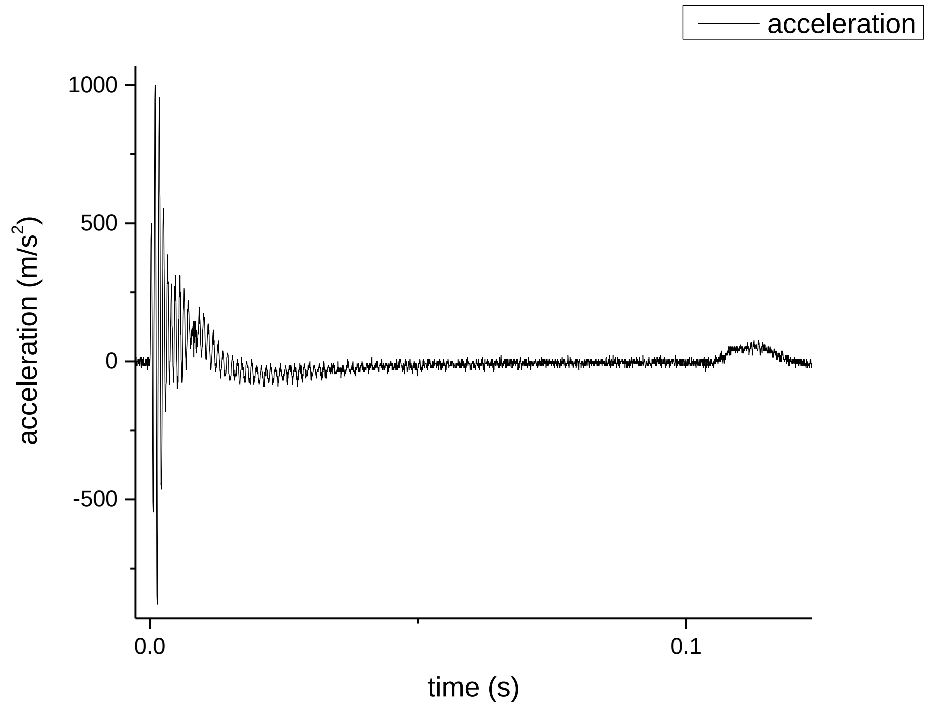

Figure 53 Impact test result of concrete tile coated on top side #3

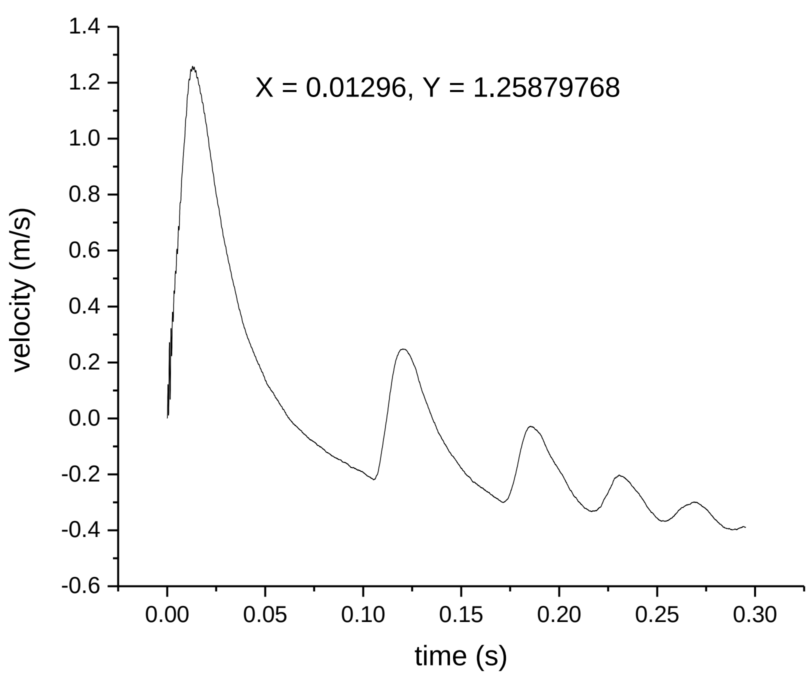

Figure 54 Velocity result of concrete tile coated on top side #3

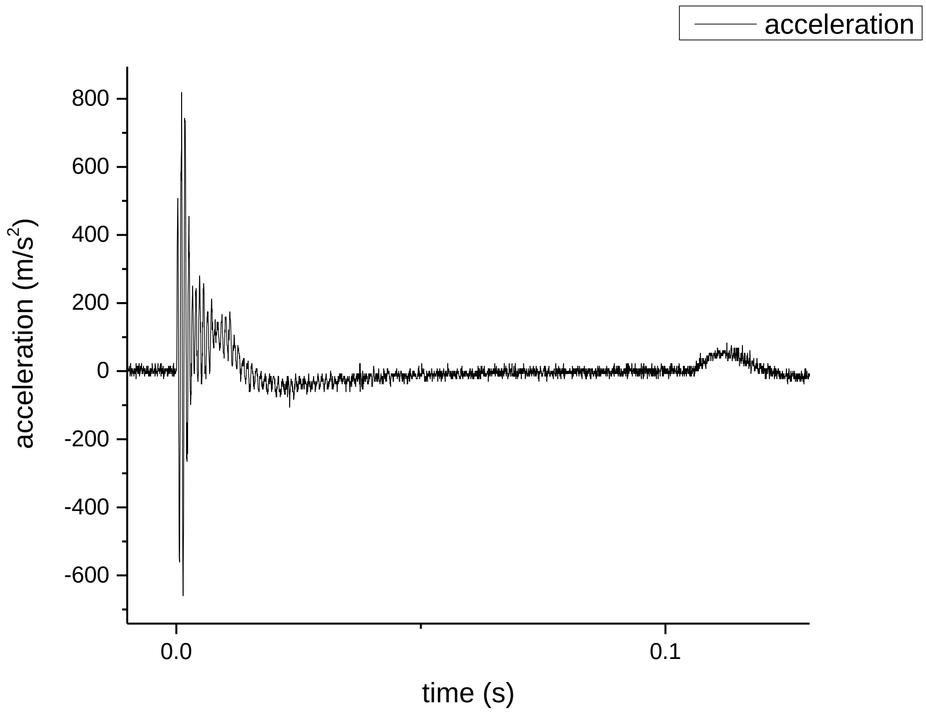

Figure 55 Impact test result of concrete tile coated on top side #4

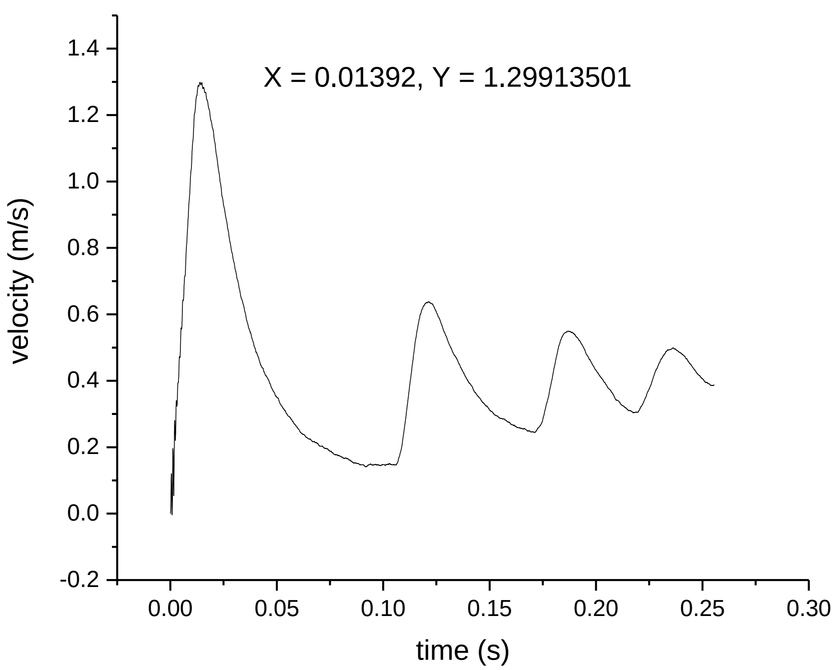

Figure 56 Velocity result of concrete tile coated on top side #4

The test result of all top coated result is shown, we can observe a significant increase in velocity change, which means this kind of coating yields improvement in the impact resistance of concrete tiles.

Figures 47, 49, 51, 53 shows that the samples coated with polyurea on the impact side have a significant change velocity. This yields a dramatic improvement in impact resistance as shown.

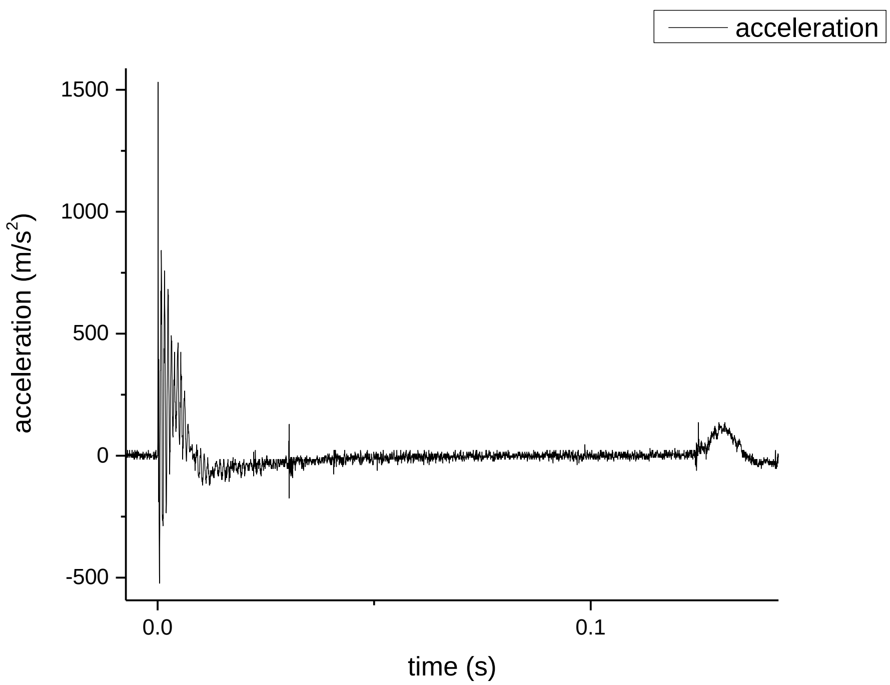

Figure 57 Impact test result of concrete tile coated on bottom side #1

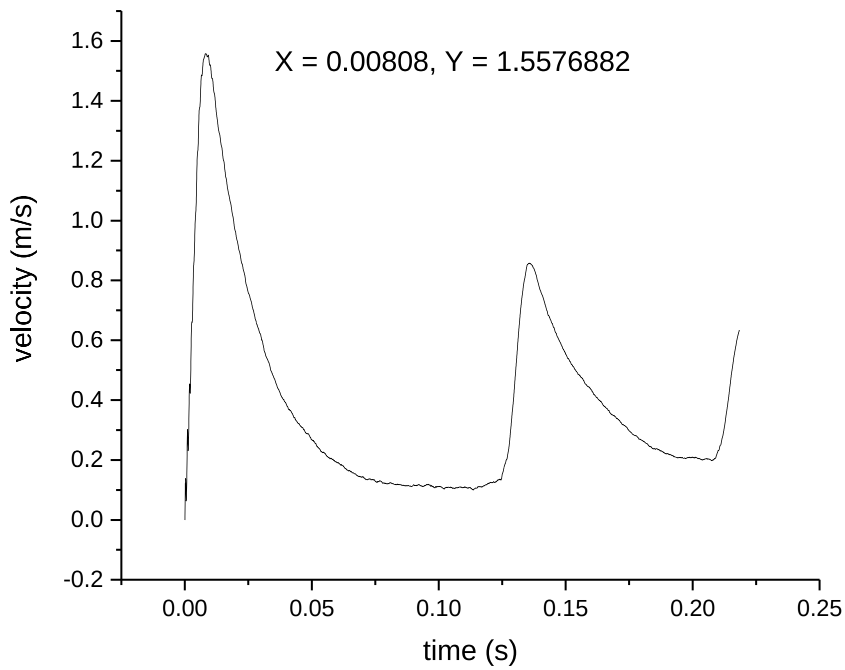

Figure 58 Velocity result of concrete tile coated on bottom side #1

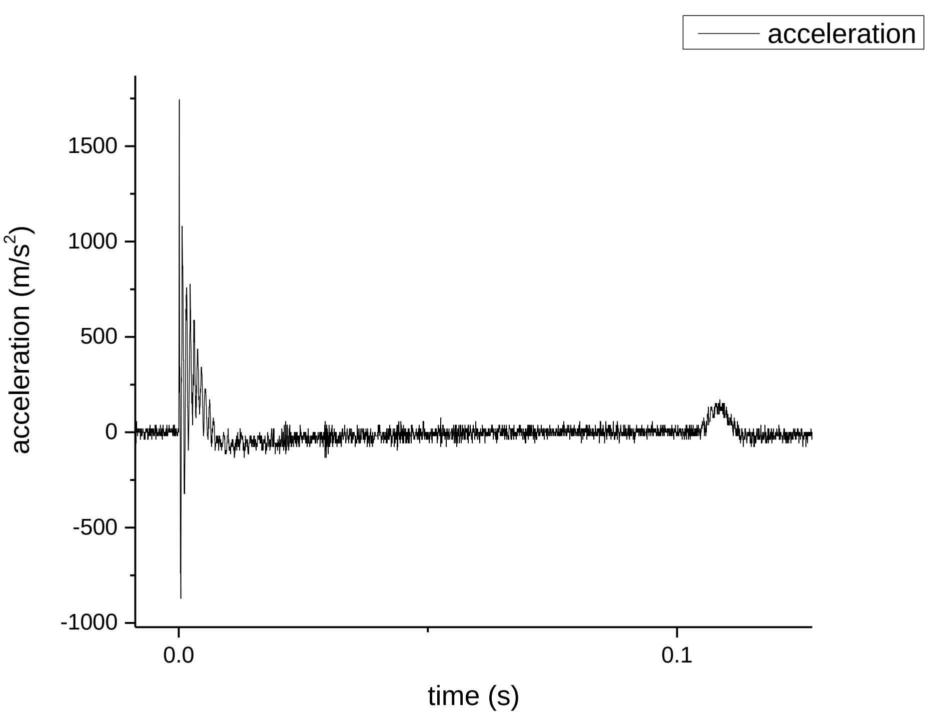

Figure 59 Impact test result of concrete tile coated on bottom side #2

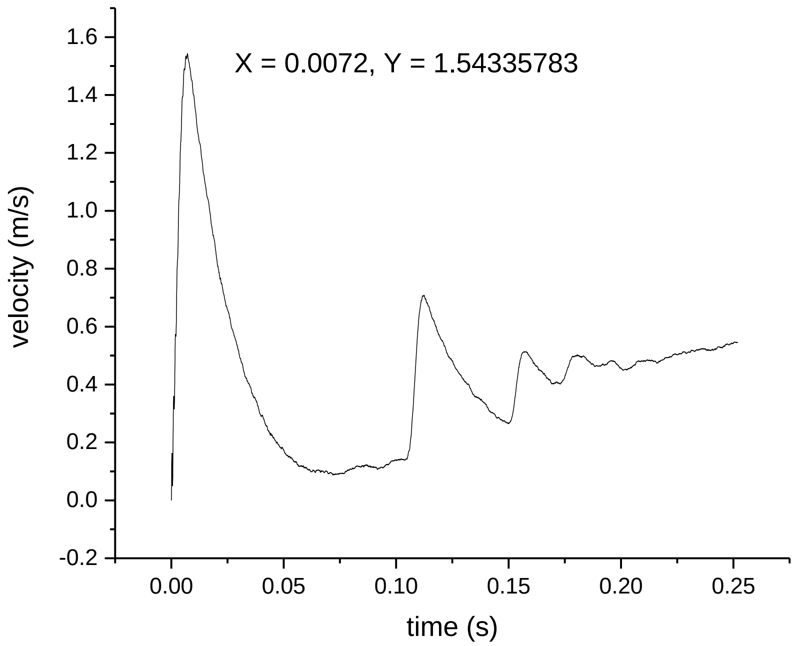

Figure 60 Velocity result of concrete tile coated on bottom side #2

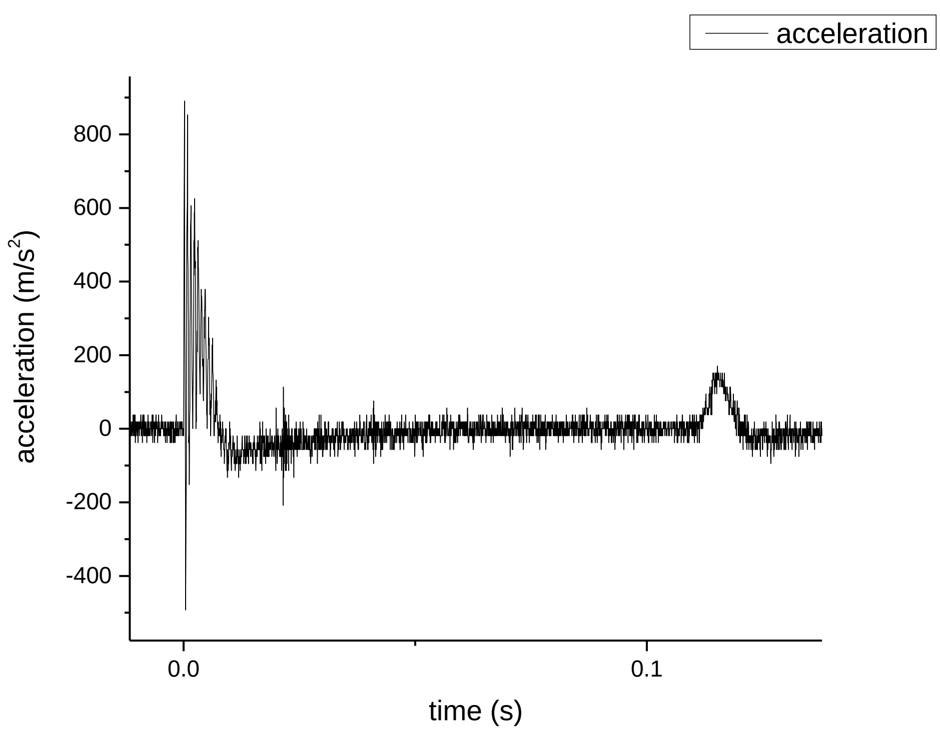

Figure 61 Impact test result of concrete tile coated on bottom side #3

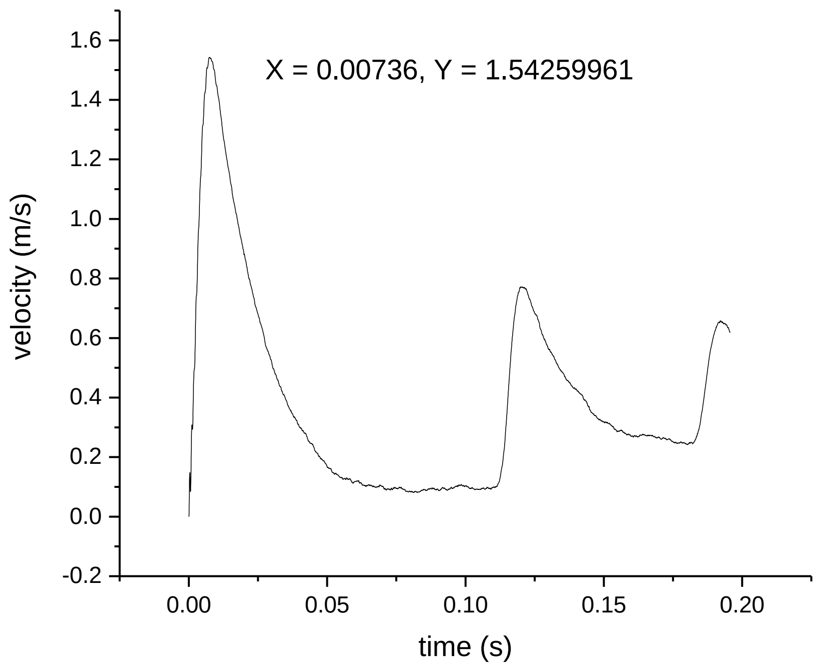

Figure 62 Velocity result of concrete tile coated on bottom side #3

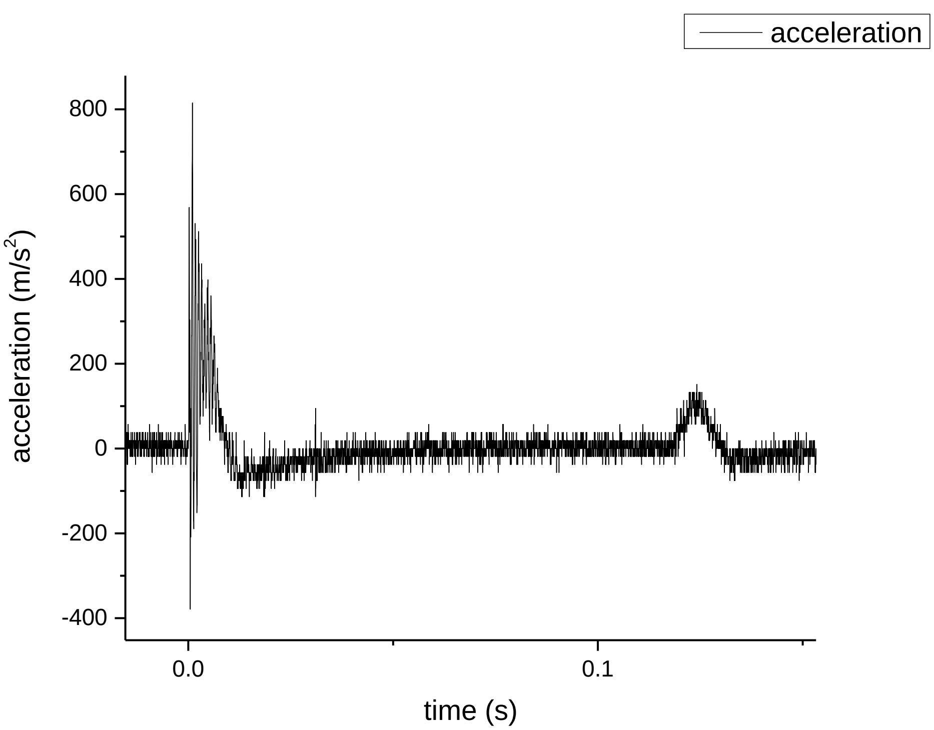

Figure 63 Impact test result of concrete tile coated on bottom side #4

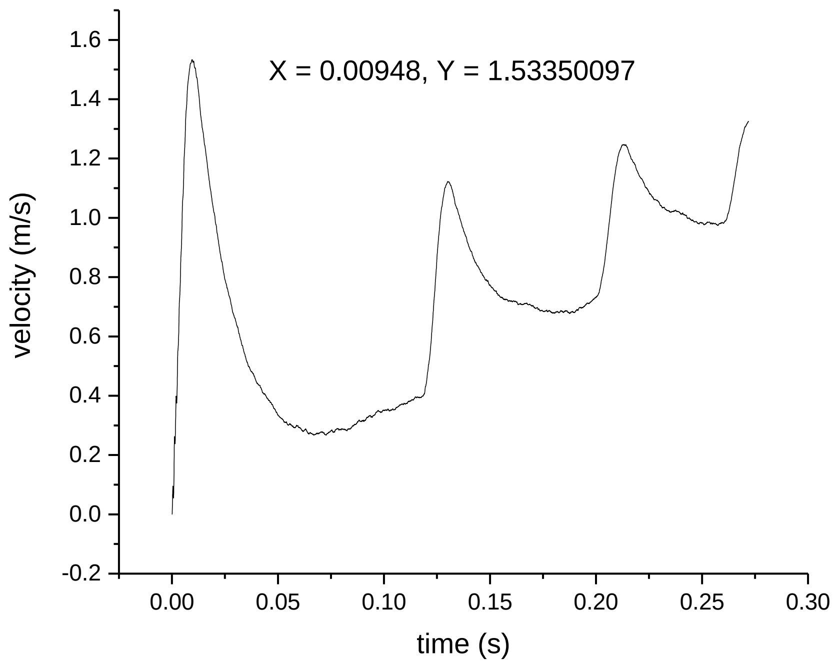

Figure 64 Velocity result of concrete tile coated on bottom side #4

By comparing the experimental results of concrete tiles coated on different surfaces, we notice that there is a difference in impact resistance, which means the impact direction can affect the final fracture form.

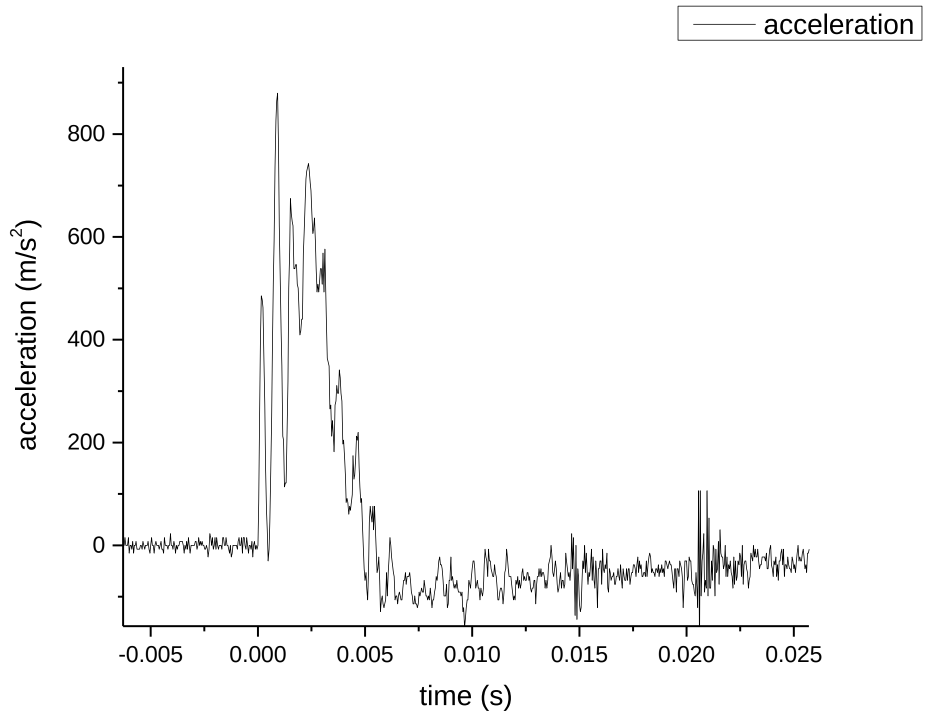

Figure 65 Impact test result of concrete tiles coated on both sides #1

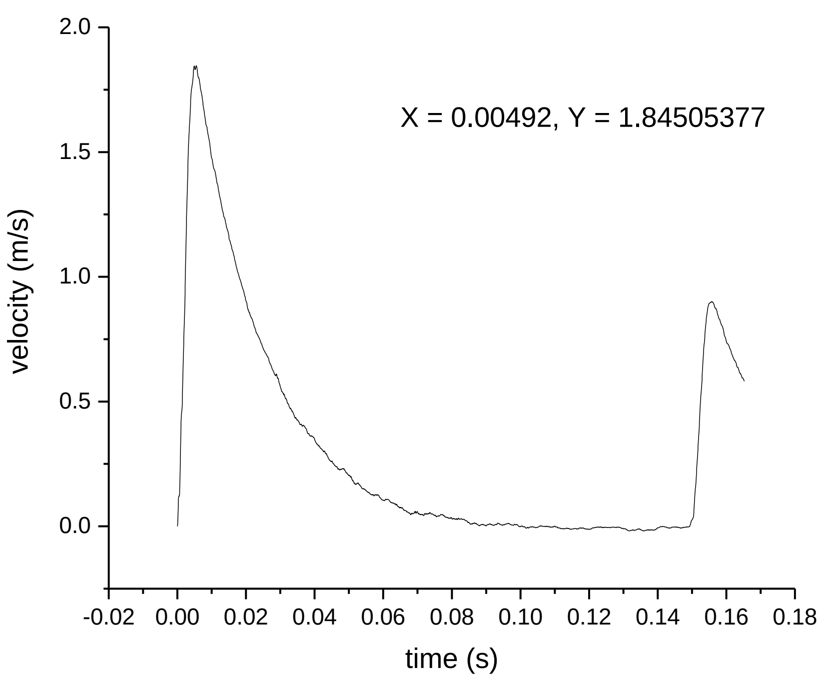

Figure 66 Velocity result of concrete tiles coated on both sides #1

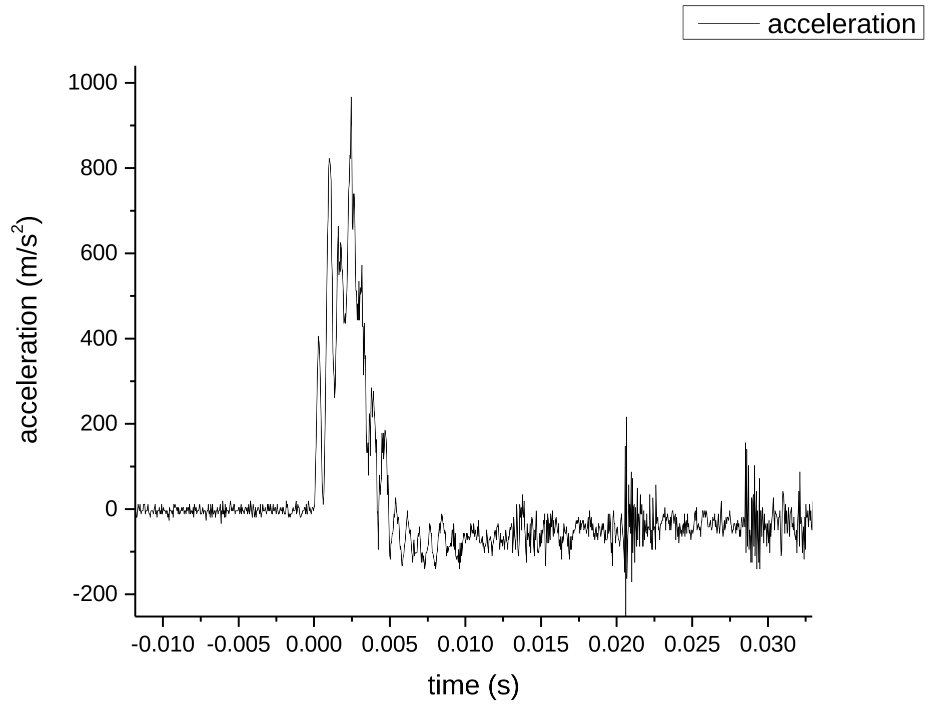

Figure 67 Impact test result of concrete tiles coated on both sides #2

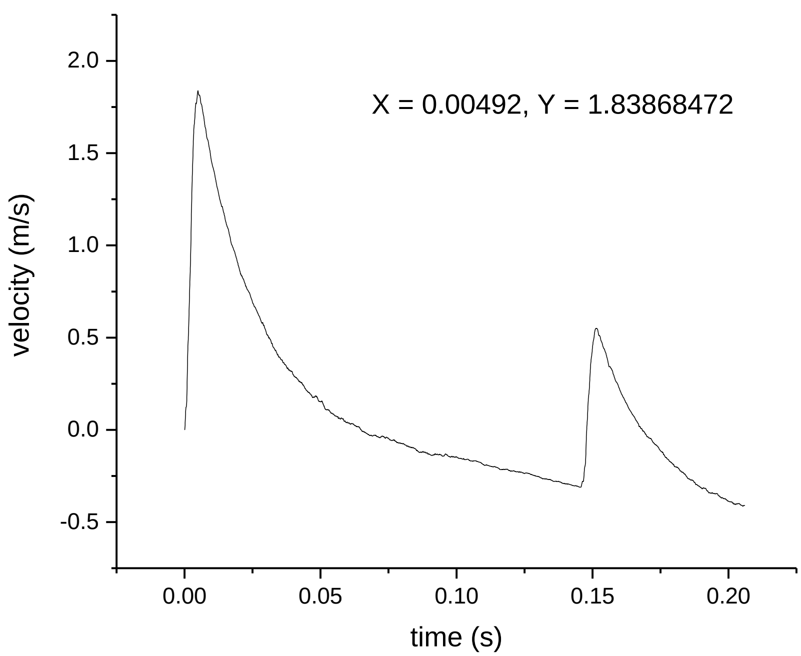

Figure 68 Velocity result of concrete tiles coated on both sides #2

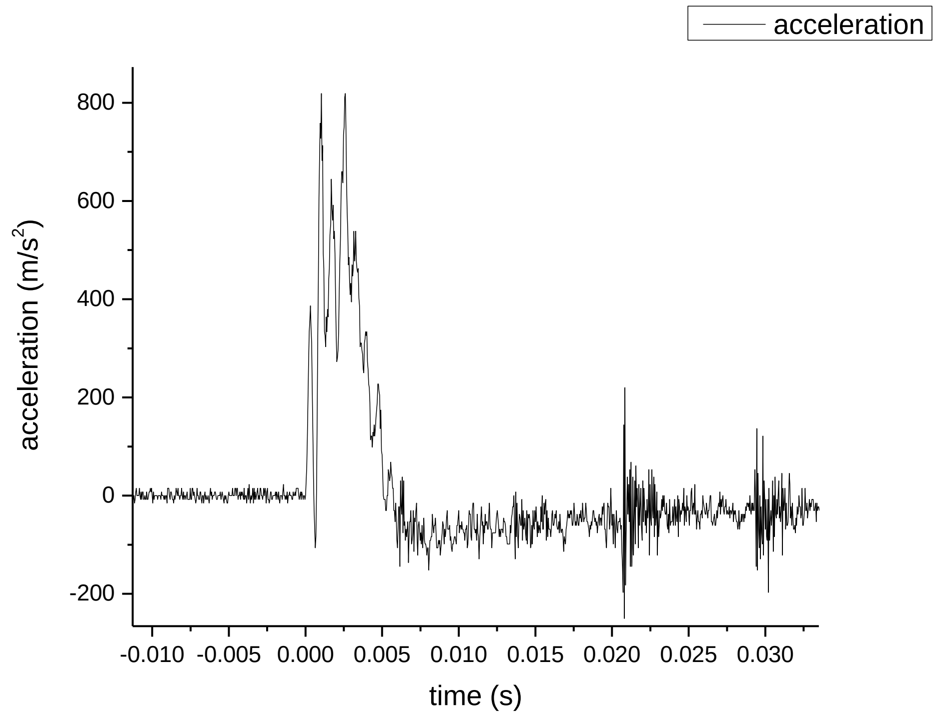

Figure 69 Impact test result of concrete tiles coated on both sides #3

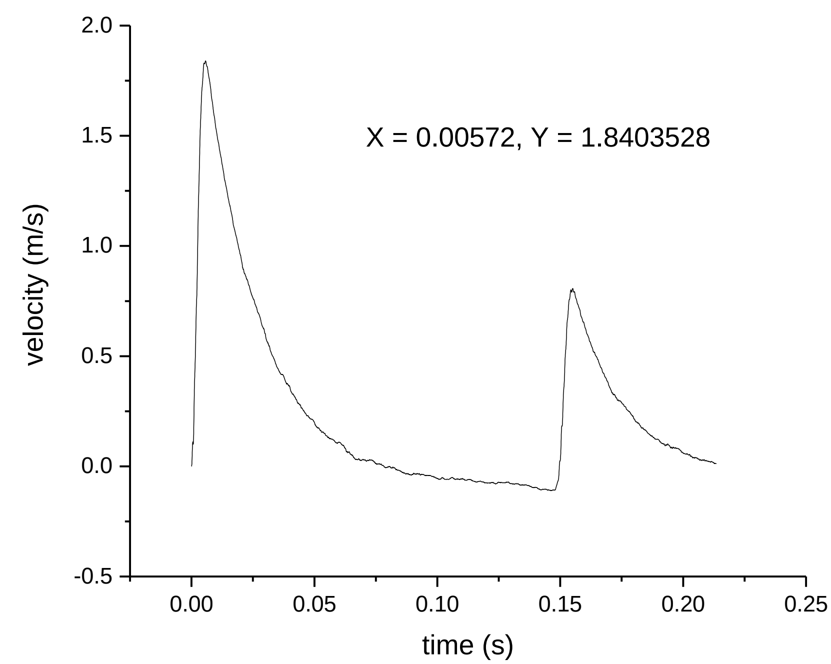

Figure 70 Velocity result of concrete tiles coated on both sides #3

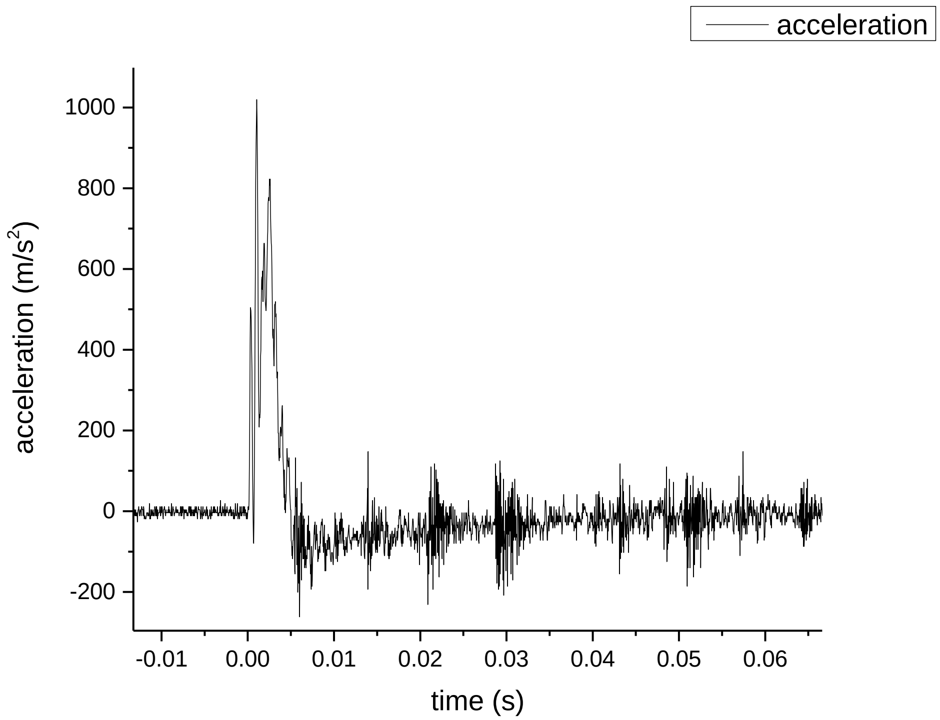

Figure 71 Impact test result of concrete tiles coated on both sides #4

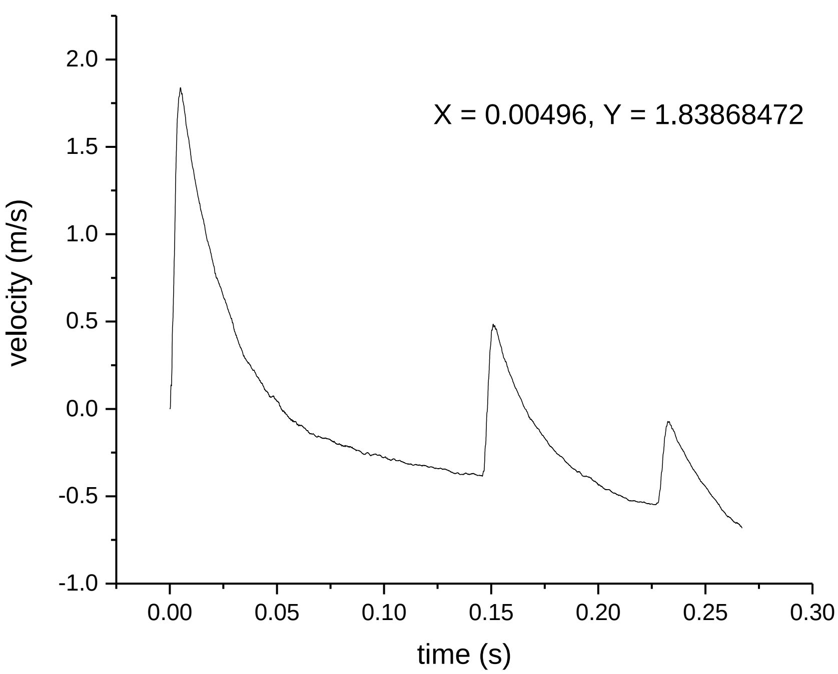

Figure 72 Velocity result of concrete tiles coated on both sides #4

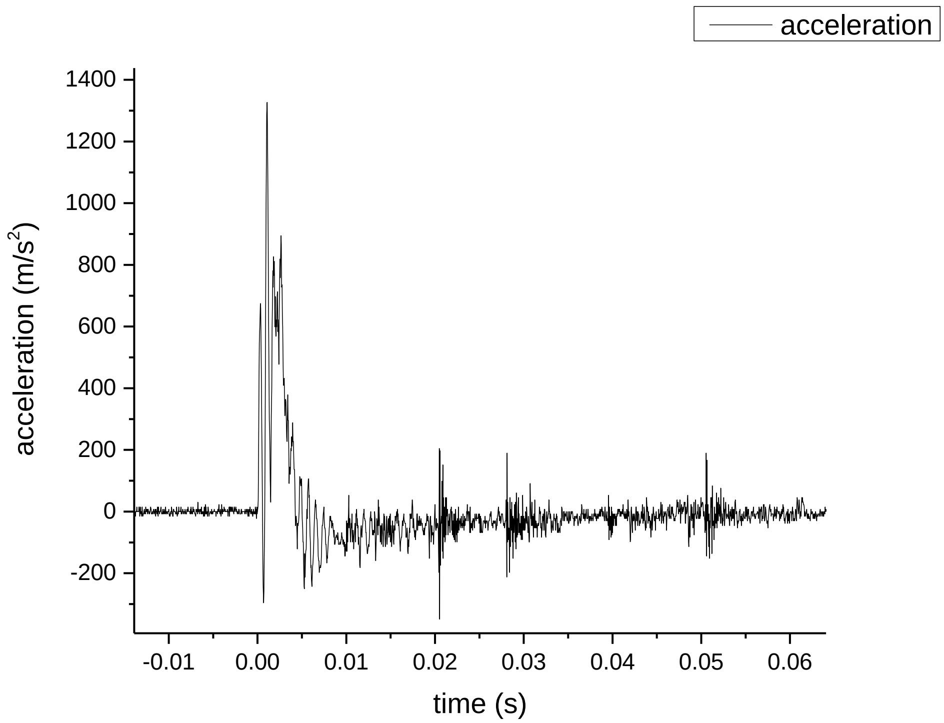

Figure 73 Impact test result of multiple layer coated concrete tiles #1

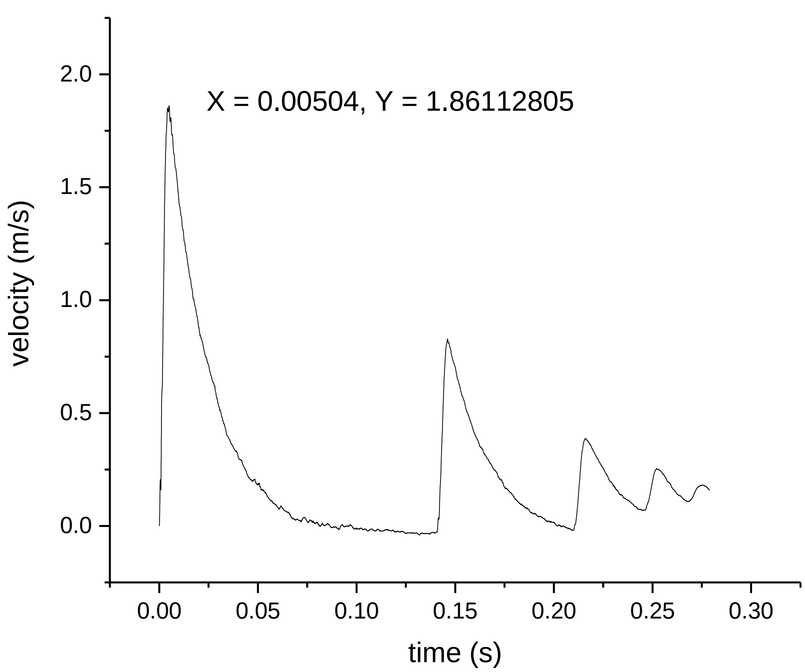

Figure 74 Velocity result of multiple layer coated concrete tiles #1

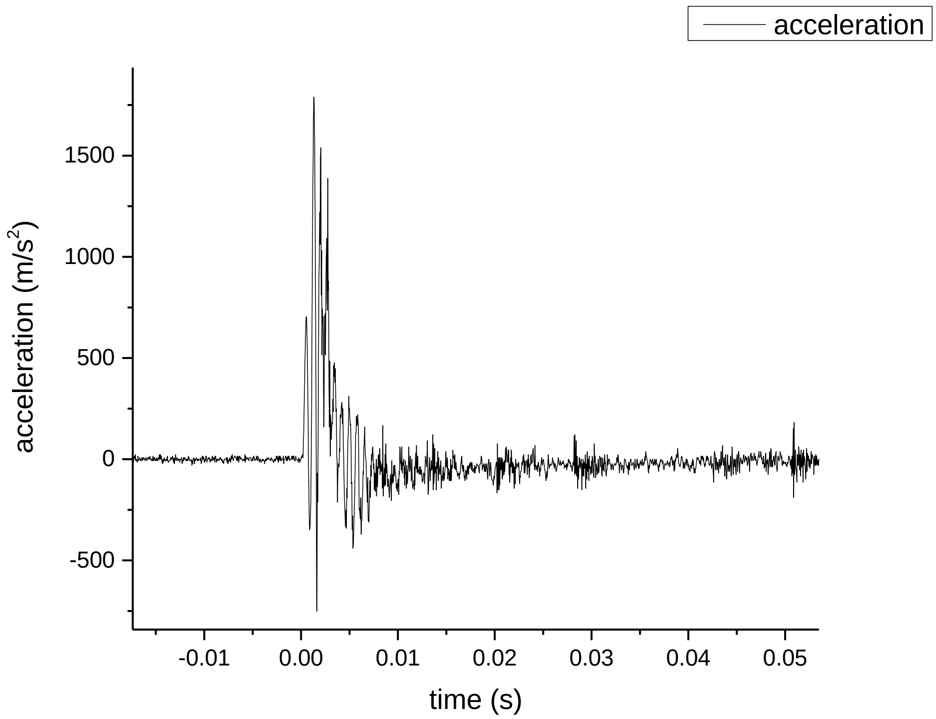

Figure 75 Impact test result of multiple layer coated concrete tiles #2

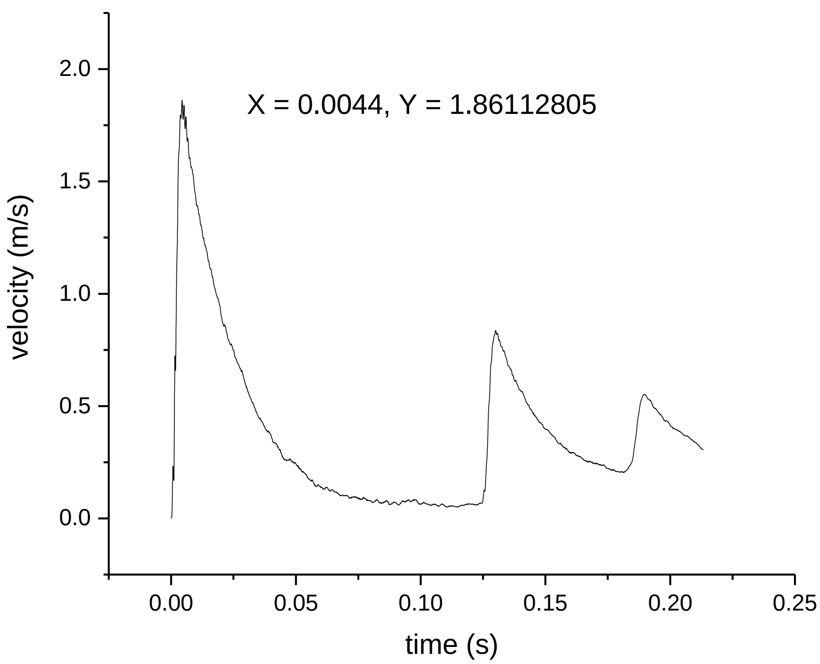

Figure 76 Velocity result of multiple layer coated concrete tiles #2

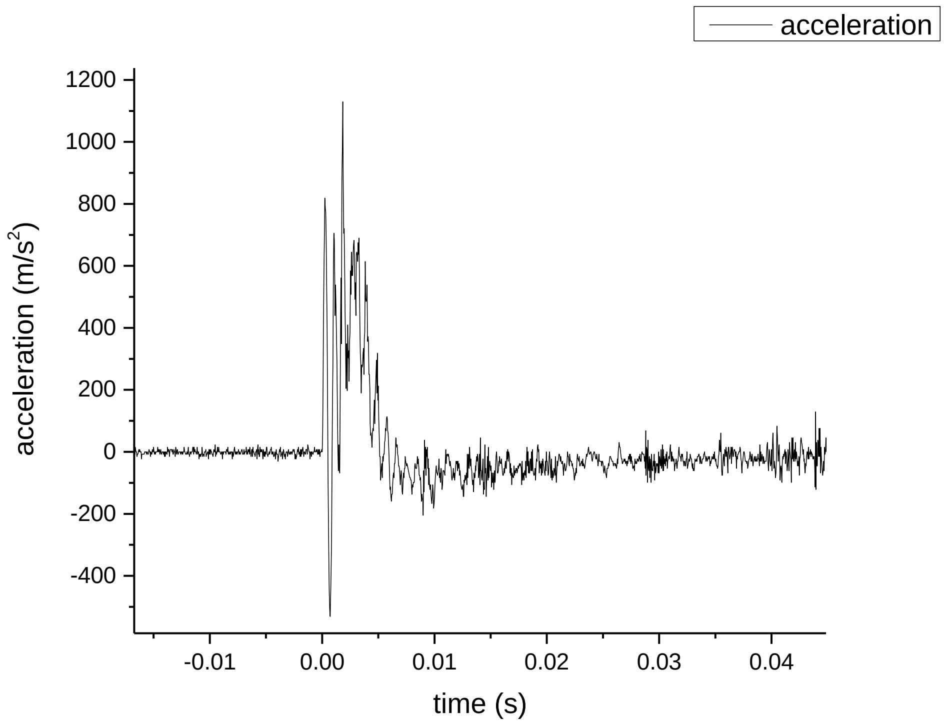

Figure 77 Impact test result of multiple layer coated concrete tiles #3

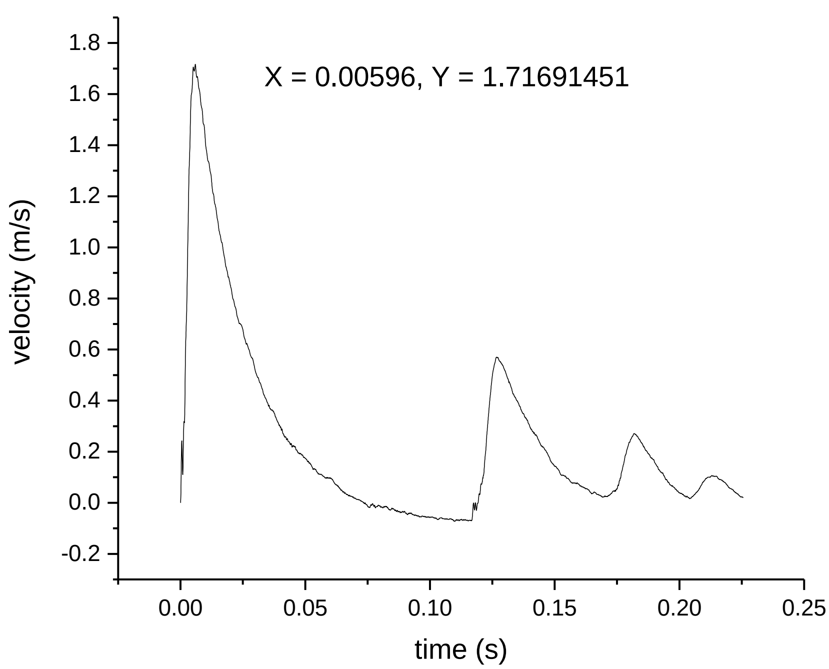

Figure 78 Velocity result of multiple layer coated concrete tiles #3

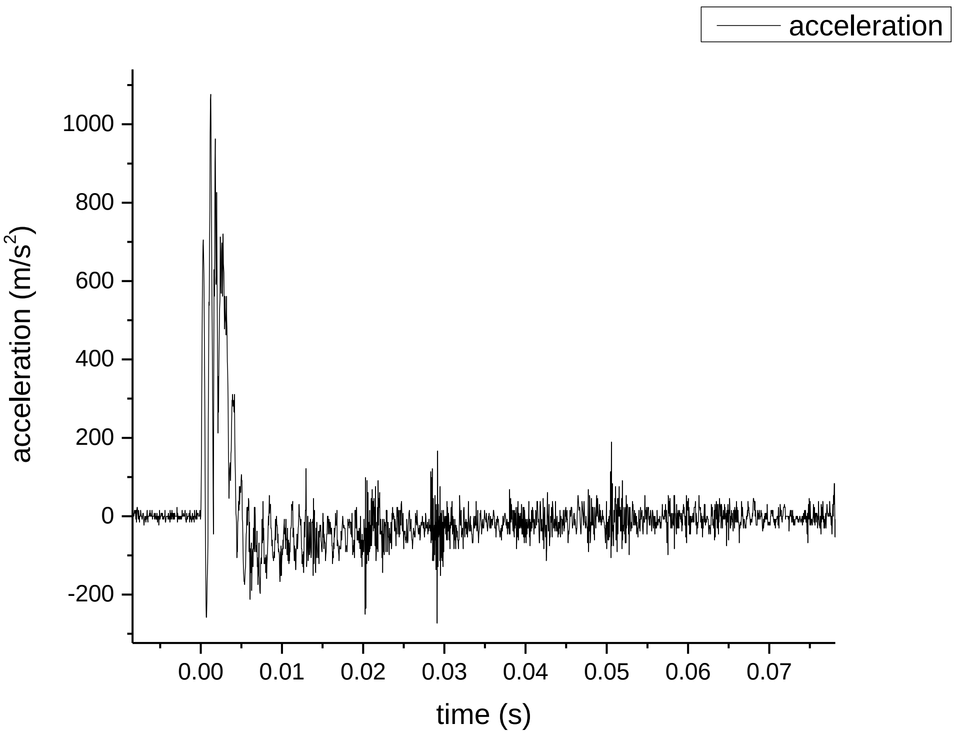

Figure 79 Impact test result of multiple layer coated concrete tiles #4

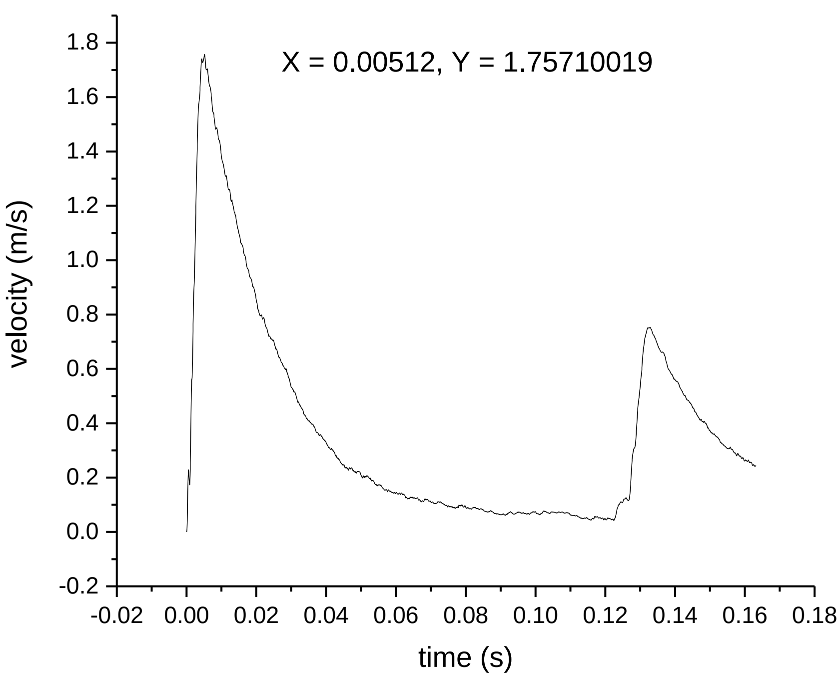

Figure 80 Velocity result of multiple layer coated concrete tiles #4

Finally, we tested the concrete tiles coated on both sides and multiple layered samples with polyurea between, and the results show a small increase in impact energy when comparing to those concrete tiles coated on the bottom side. We hypothesize that their fracture mechanisms are similar with each other.

Figure 81 Image of concrete tiles after testing on the coated side

Figure 82 Image of concrete tiles after testing on the uncoated side

Figure 83 Image of all samples after testing on the coated side

Table 4 Test results of all coated concrete samples

Polyurea coating	Sample #	Max decelleration m/s^2	Velocity decrease m/s	Energy absorbed J	Fracture and # of radial fracture lines
Top	1	906	1.2803	23.4515	Yes 6 lines
	2	883	1.2418	23.0683	Yes 6 lines
	3	1000	1.2588	23.2399	Yes 5 lines
	4	818	1.2991	23.6314	Yes 4 lines
Bottom	1	1531	1.5577	25.6224	No
	2	1743	1.5434	25.5359	No
	3	890	1.5426	25.5309	No
	4	815	1.5335	25.4743	No
Two sides	1	879	1.8451	26.7784	No
	2	966	1.8387	26.7648	No
	3	818	1.8403	26.7682	No
	4	1019	1.8387	26.7648	No
Sandwich	1	1326	1.8611	26.8101	No
	2	1789	1.8611	26.8101	No
	3	1129	1.7169	26.4002	No
	4	1076	1.7571	26.5426	No

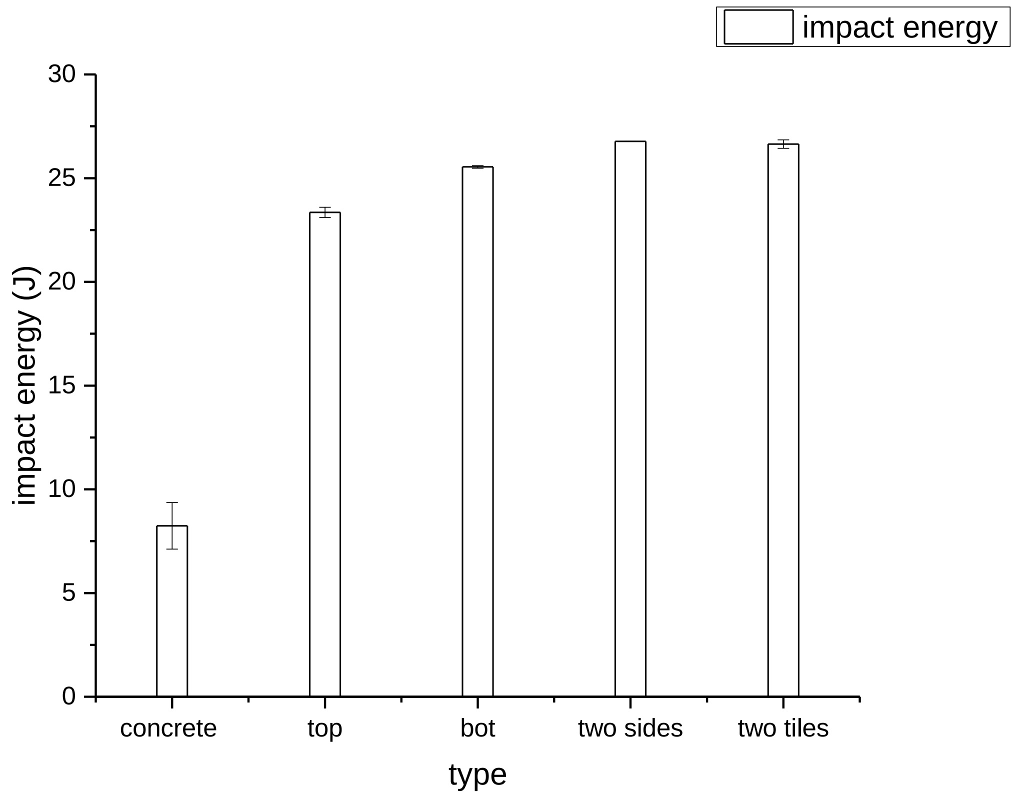

Figure 84 Calculated impact energy of different types of coating

4. Numerical

The numerical simulation was conducted using ANSYS 18.1 Workbench. The figure below shows the setup during simulation. The dimension of the sample concrete is 4”x4”x0.5” (101.6mm x 101.6mm x 12.7mm), and all polyurea coating thickness are set to be 0.25” (6.35mm). The hammer and base plate holder are set to be structural steel, and the mechanical properties of all materials are taken from the ANSYS database.

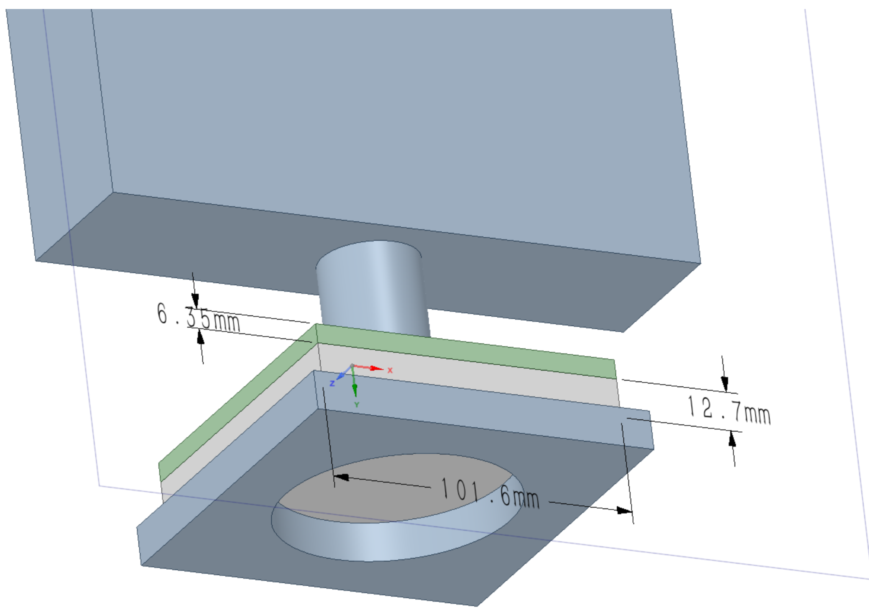

Figure 85 Numerical simulation setup

Furthermore, the bottom surface of base plate was set to be a fixed support, and the x and z axis displacement of the hammer were controlled to be zero, in order to keep it on the same direction. The concrete tile was meshed into small elements with 2.0e-003 m size.

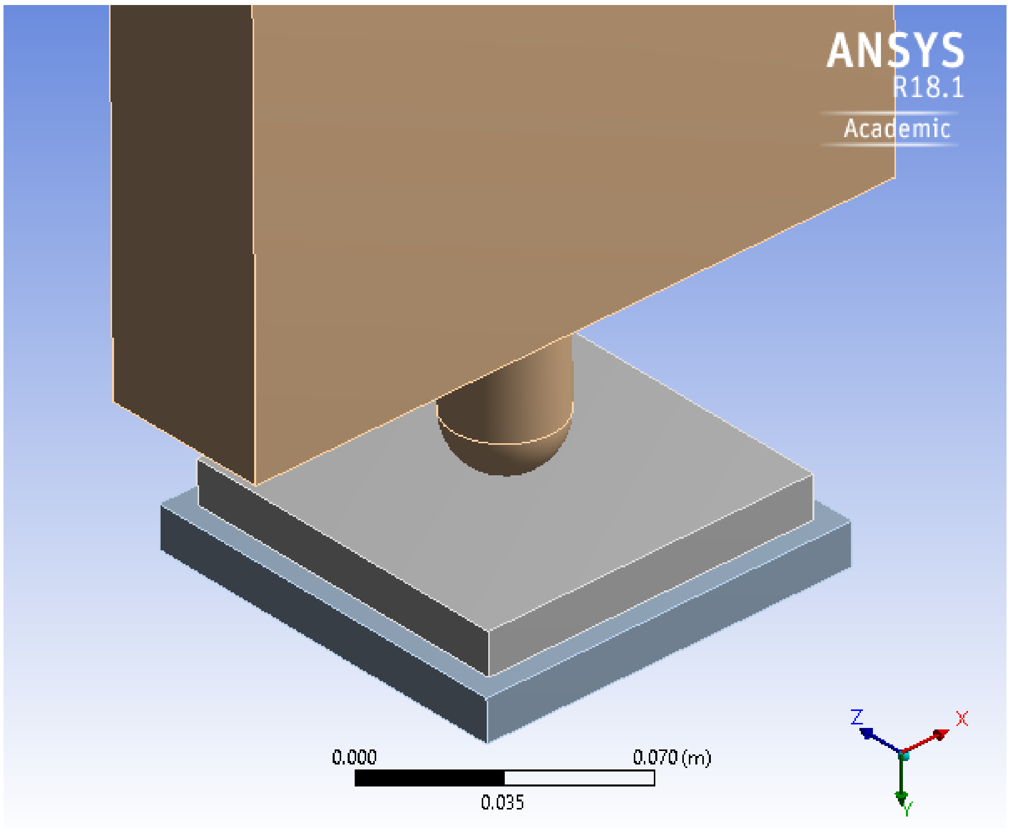

Figure 86 Simulation setup of uncoated concrete tile

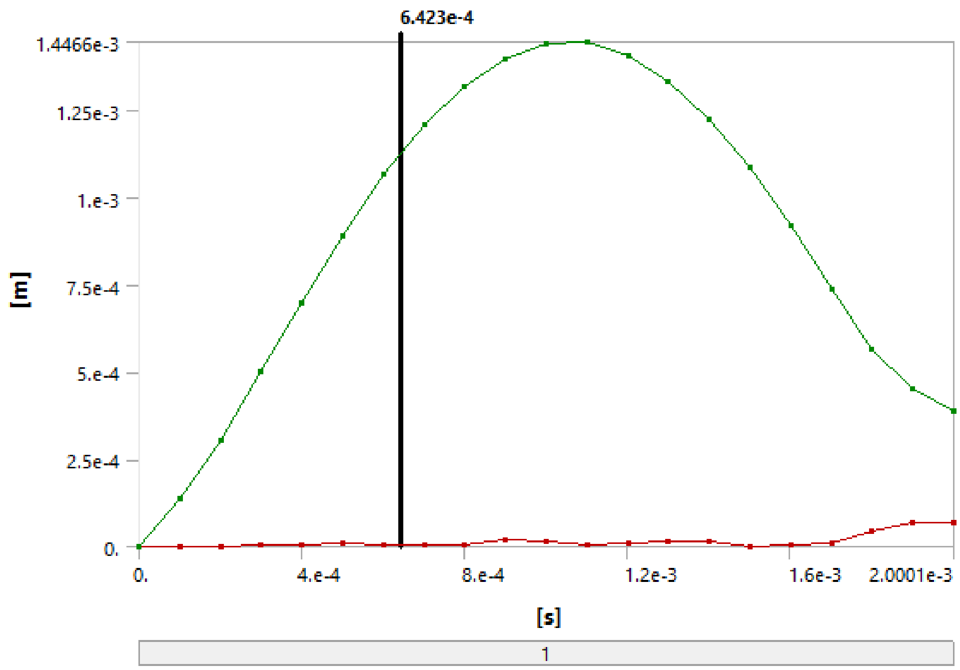

Figure 87 Total deformation of uncoated concrete tile

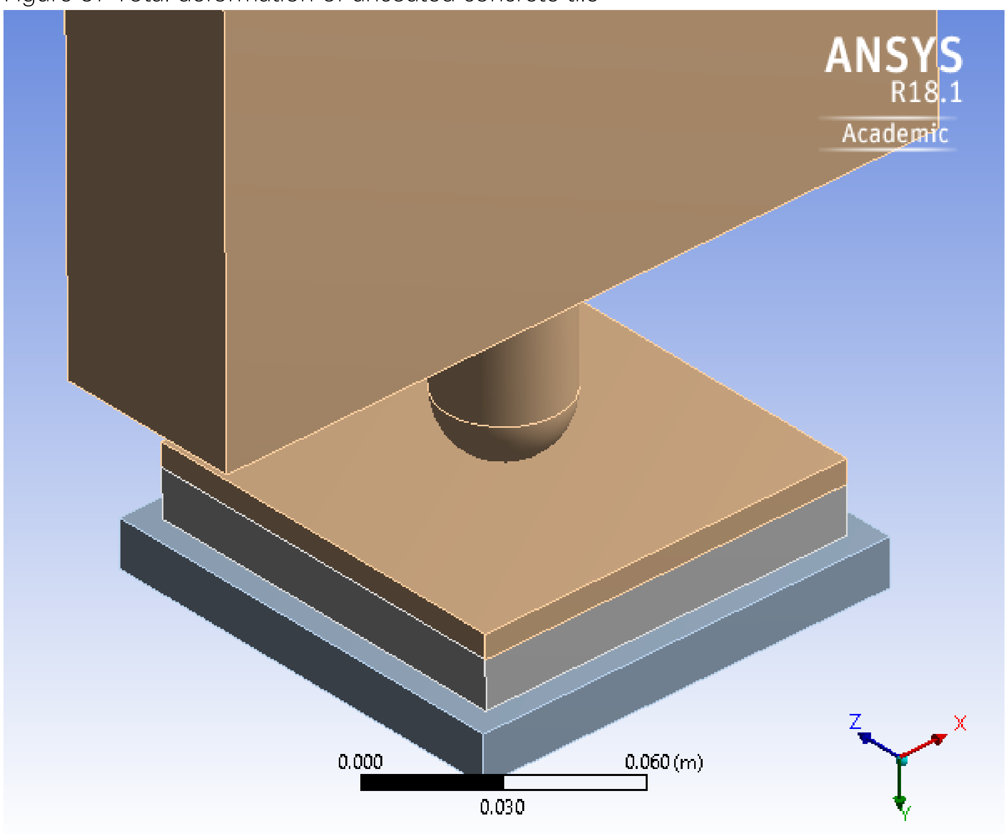

Figure 88 Simulation setup of top coated concrete tile

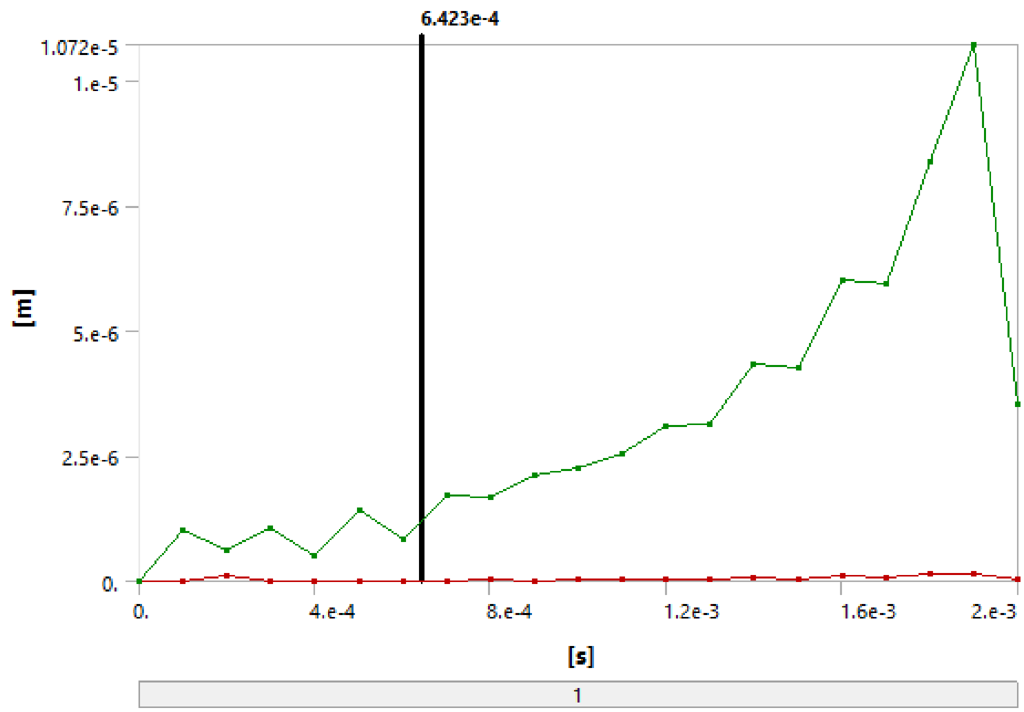

Figure 89 Total deformation of top coated concrete tile

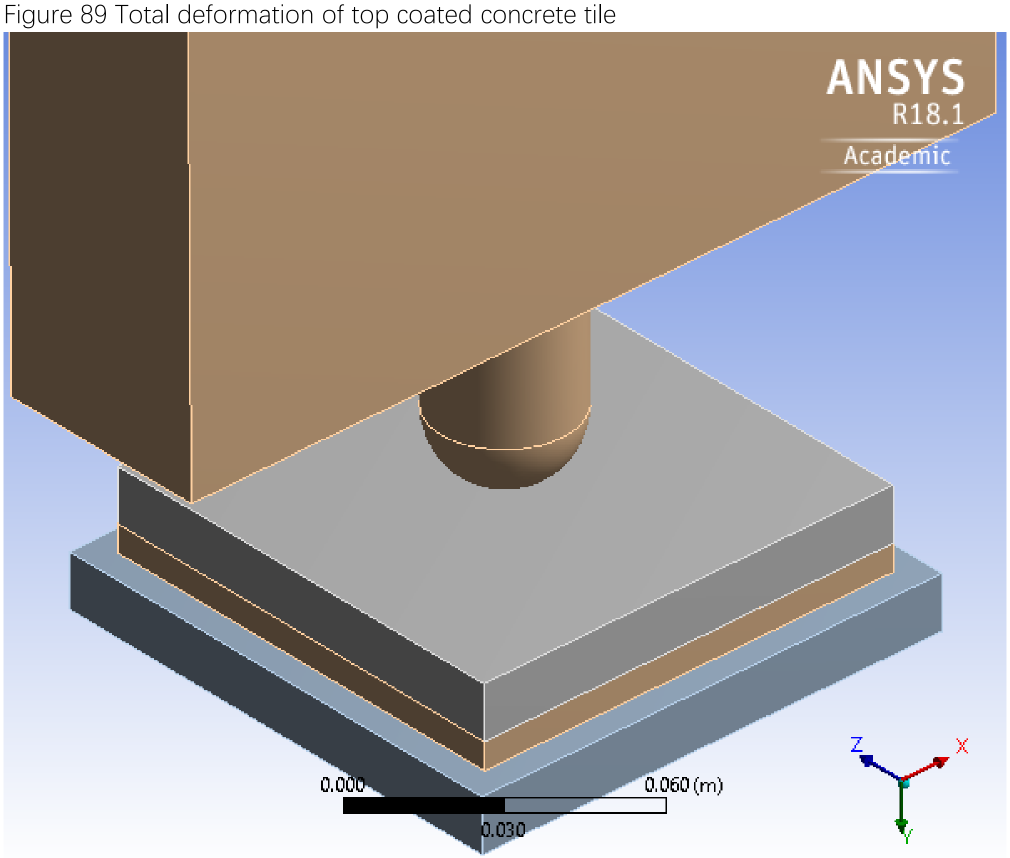

Figure 90 Simulation setup of bot coated concrete tile

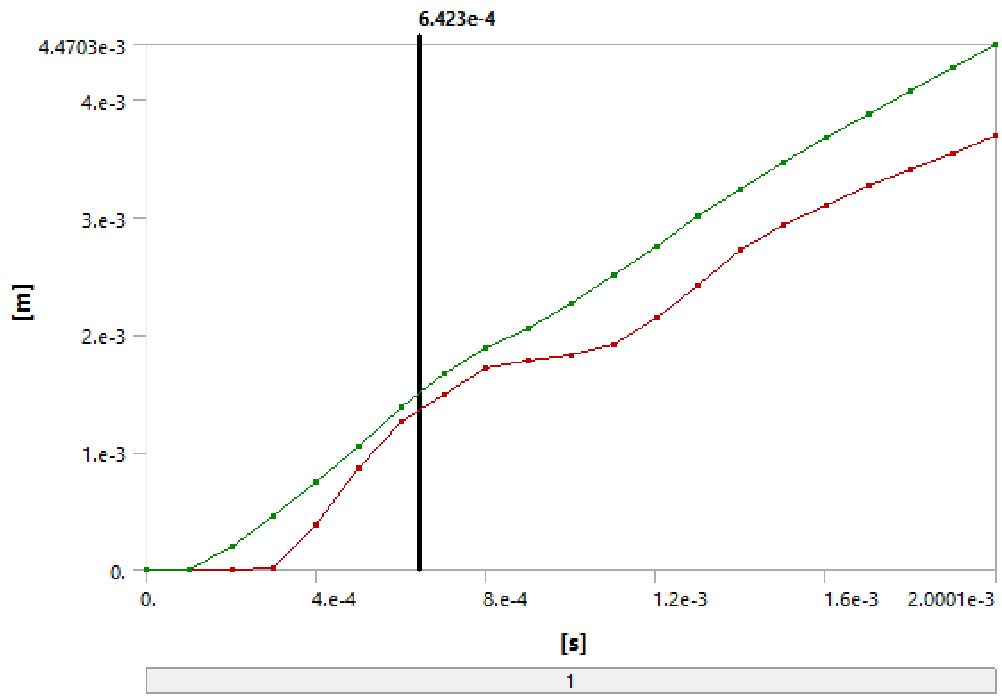

Figure 91 Total deformation of bot coated concrete tile

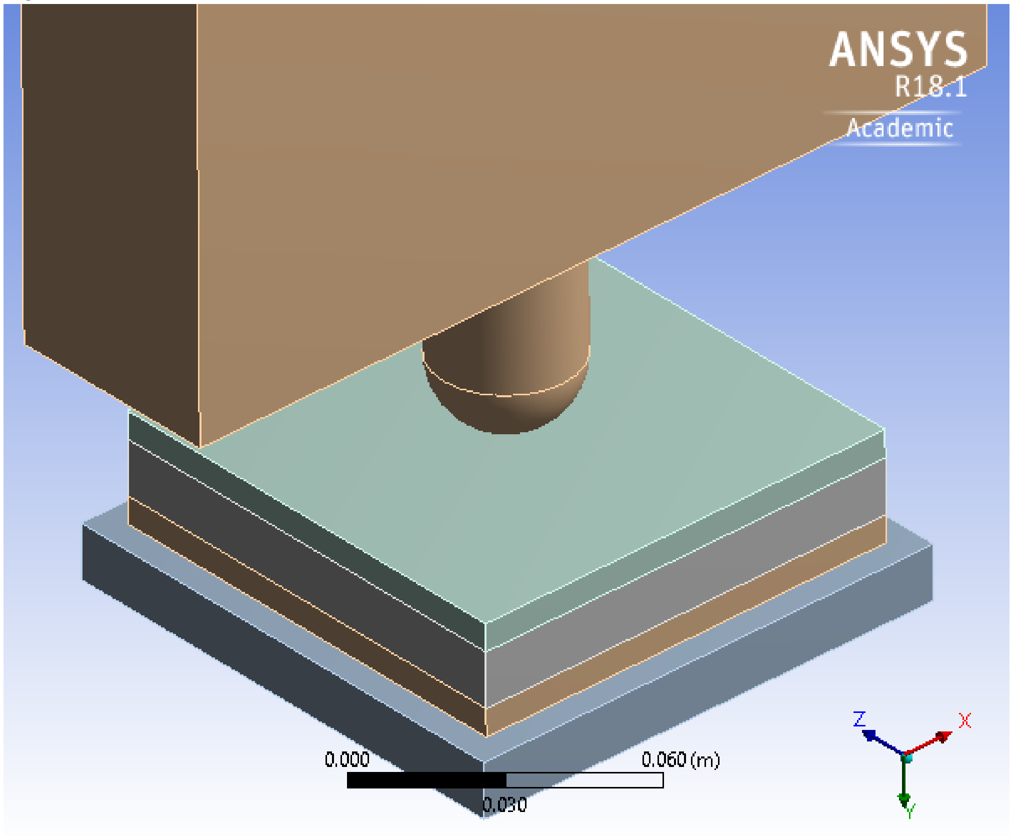

Figure 92 Simulation setup of concrete tile coated on two sides

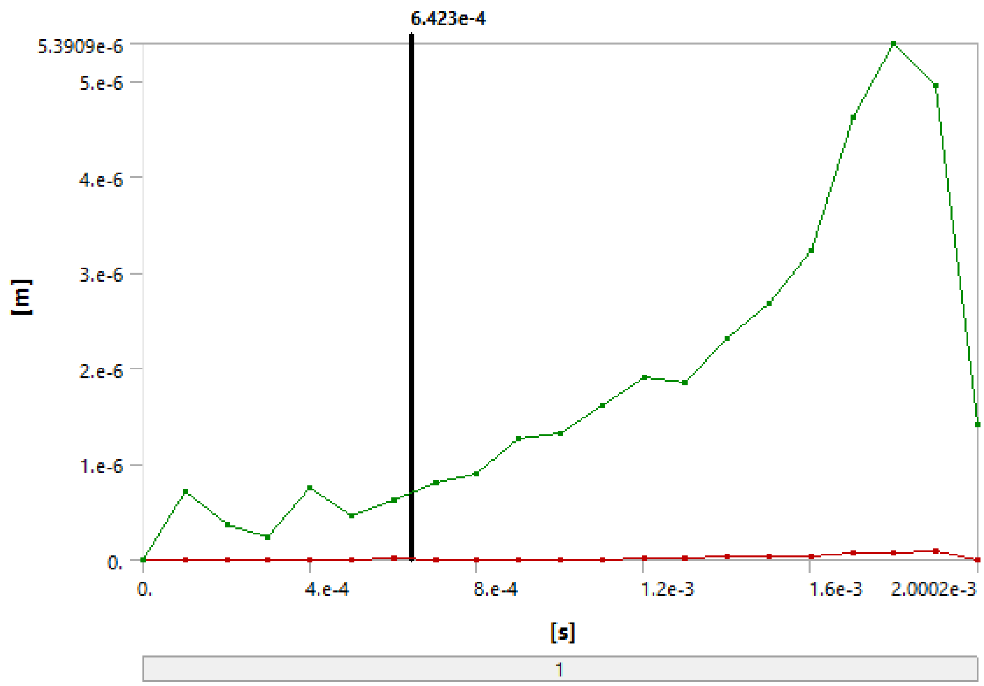

Figure 93 Total deformation of concrete tile coated on two sides

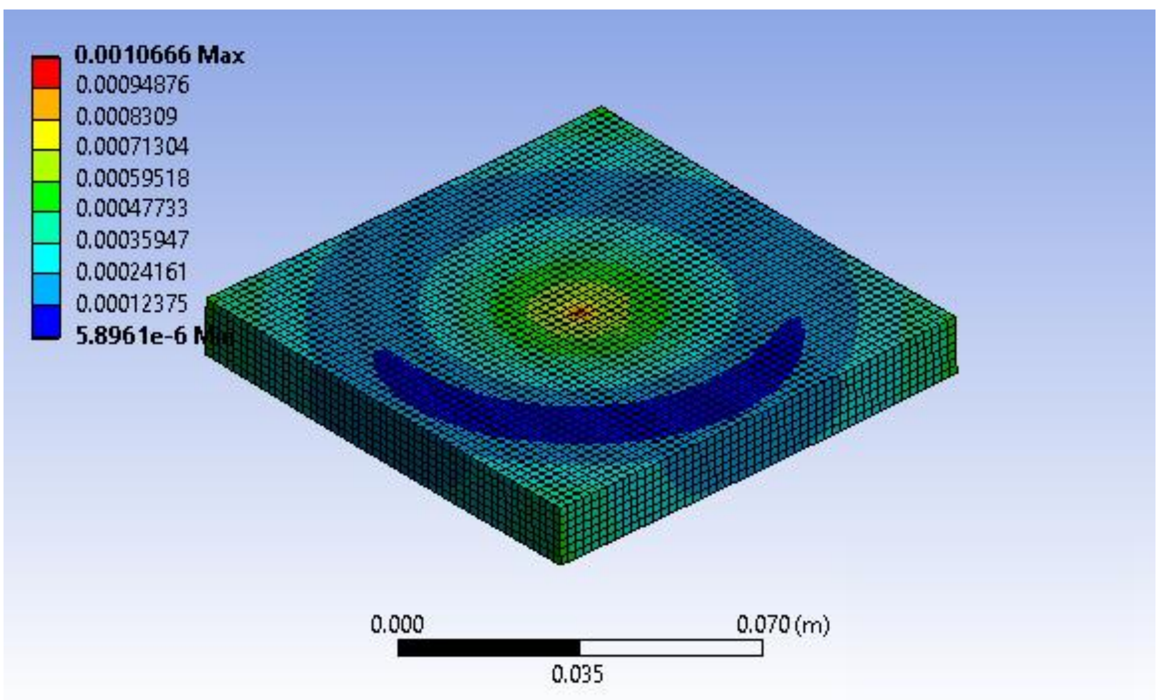

Figure 94 Deformation geometry of uncoated concrete tile

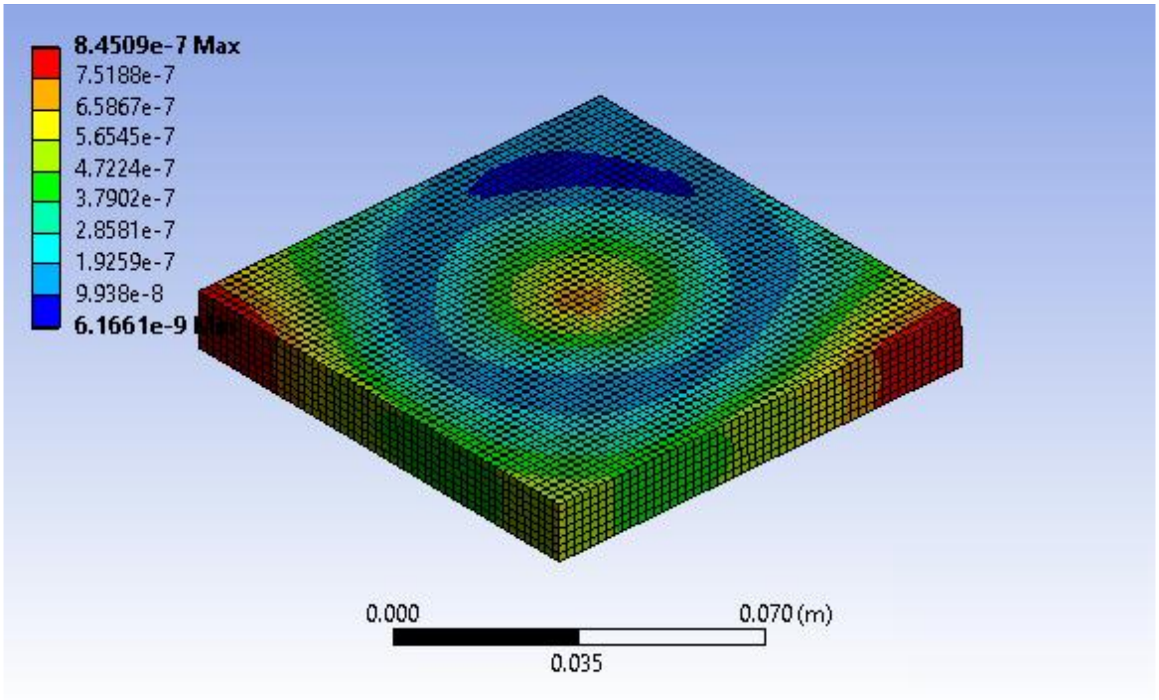

Figure 95 Deformation geometry of top coated concrete tile

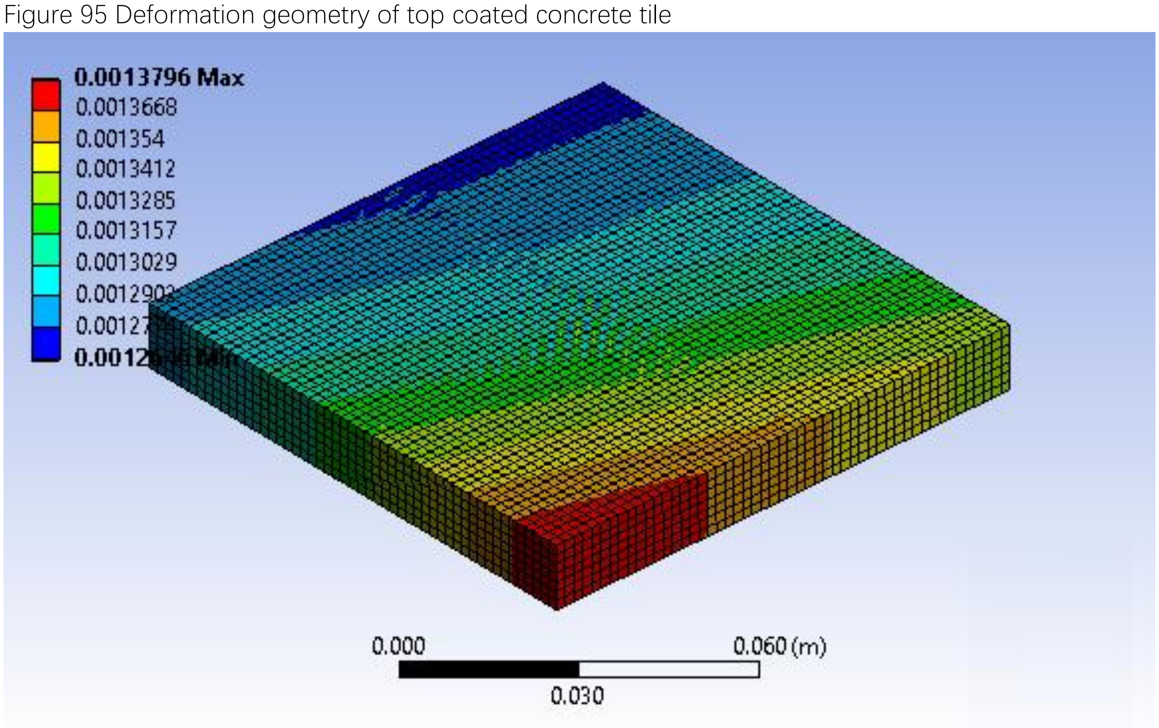

Figure 96 Deformation geometry of bot coated concrete tile

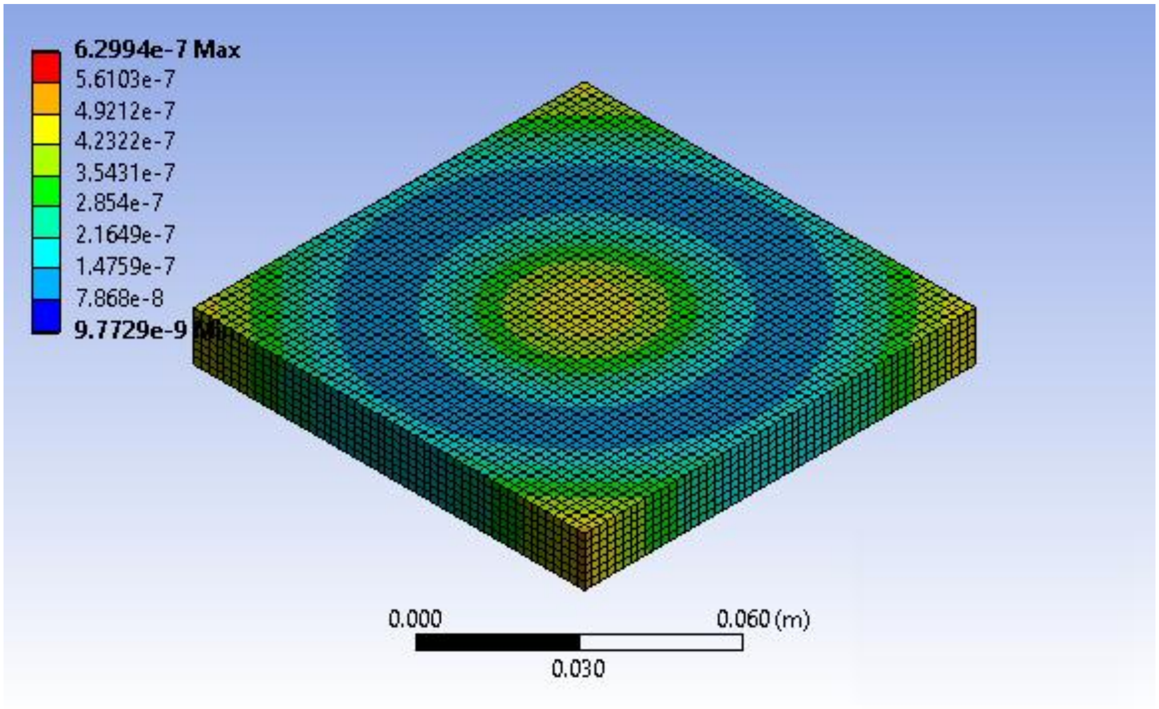

Figure 97 Deformation geometry of concrete tile coated on two sides

The results of simulation tell us that the deformation decreases significantly when the concrete tiles under impact were coated with polyurea, its average value goes from 1e-3 m down to about 1e-6 m. Moreover, the deformation concentrates on the center point when the concrete tile was not coated or coated on the top side. That stress concentration makes concrete much easier to fracture, which agrees with the experimental results of drop tower tests. But when the polyurea is coated on two sides or bottom side, the deformation spreads across the surface, with less relative displacement on the impact surface[35]. An interesting thing is that the deformation of bottom coated concrete tile is relatively larger than others, that's because the deformation of polyurea on the bottom allows the whole sample to flex. The parallel shape on that figure indicates that the impact energy was absorbed by the coating layer on the bottom.

5. Summary and Conclusion

The experimental and numerical research were designed to investigate the impact resistance difference among concrete tiles with or without polyurea coating. Different orientations of the polyurea coating including coating on the impact facing surface, the bottom surface and both sides were also tested during the experiment. The concrete without coating shows very little impact resistance against impact. By coating the polyurea on the impact facing surface the impact properties are improved, but the backside of the concrete sample still fractured. However, when both the impact side and backside are coated with polyurea, good impact resistance is obtained.

With the help of ANSYS software, the numerical simulation of concrete tiles that coated on different sides were conducted. The same size of sample was simulated using a similar environment and drop tower setup. The simulation results agree with the experimental results in the deformation/fracture of concrete tile sample. It also shows that polyurea coated concrete tiles perform better than concrete tiles without coating for the same areal density.

In conclusion, polyurea-coating is a promising method of improving resistance of concrete structures.

6. Future work

This research only studied a small size of concrete structure with the same given polyurea coating thickness. For the commercial construction industry, larger volumes of concrete samples should be considered. Also, different thickness of polyurea coating needed to be compared.

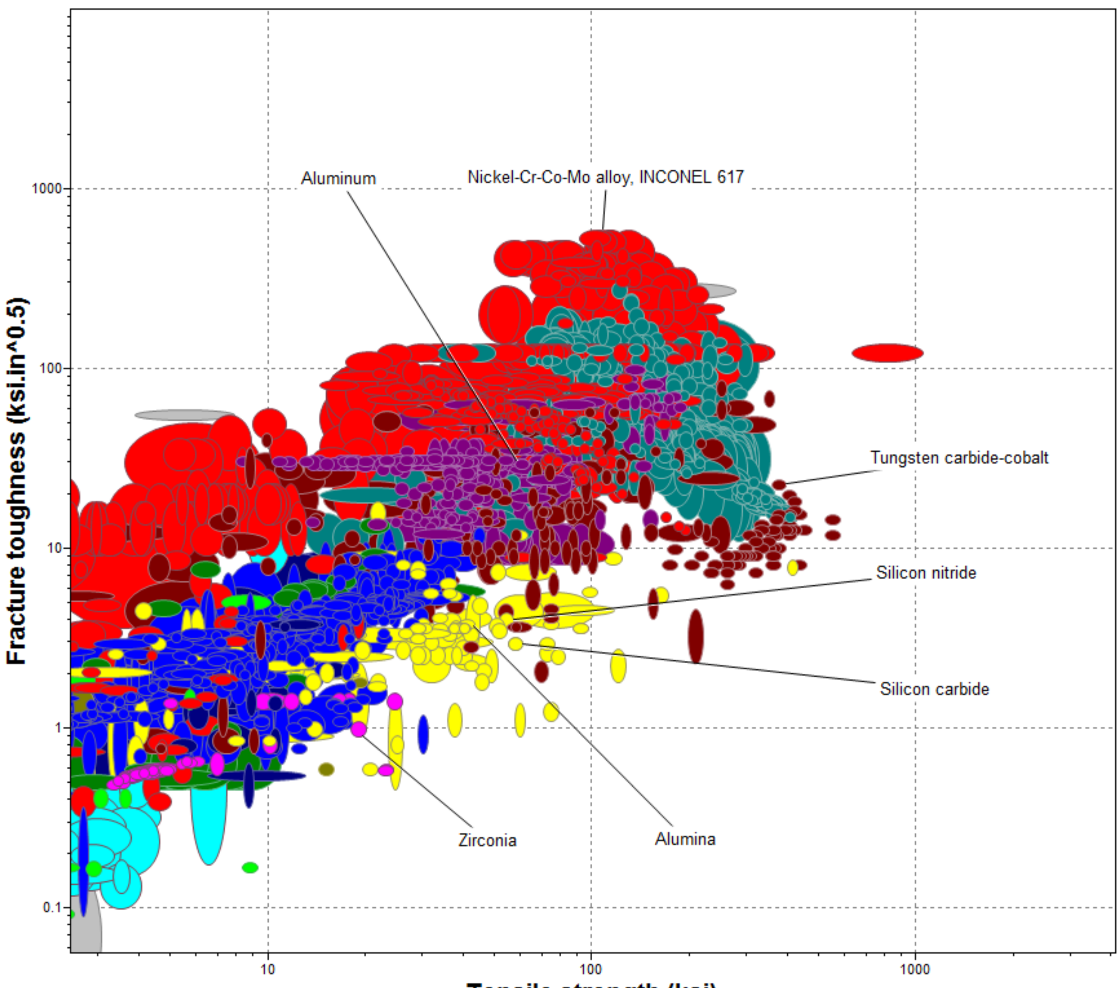

Figure 98 Fracture toughness versus tensile strength

We can also find other materials that can be used to withstand impact. Using the database from CES EduPack to generate figure 95, the ranges of mechanical properties including fracture toughness and tensile strength of different materials is shown.

Nickel-Cr-Co-Mo alloy INCONEL 617 can be selected due to its extremely good mechanical property.

In addition, other different design of sandwich structure with multiple layers of concrete and polyurea should be considered.

References

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