

Impact Resisting Concrete

Bassam Z. Mahasneh[1]*, Nafeth Abdel Hadi[2], Amjad A. Yasin[3], Rayeh N. Dala'ien[4]

1Department of Civil and Environmental Engineering, Mutah University; bassam67@mutah.edu.jo

2 Nafeth Abdel Hadi, Department of Civil Engineering, Al-Balqa Applied University; nafeth22@yahoo.com
3 Amjad A. Yasin, Department of Civil Engineering, Al-Balqa Applied University; dr_ayasin@yahoo.com
4Rayeh N. Dala'ien, 1Department of Civil and Environmental Engineering, Mutah University;
raya_nasser@hotmail.com

Abstract
Different percentages of polymers have been added to concrete, to evaluate its impact resistance. Mixes have been made for plain concrete with crushed stone, also plain concrete mixes with round gravel, Concrete mixes with (0.2, 0.85, 1.5 and 2.0) % of Melment to 100 Kg of binder, Concrete mixes with (0.2, 0.5, 0.75 and 1.5) liter of Glenium to 100 Kg of cement and concrete mixes with three sheets of polystyrene and concrete mixes made using polystyrene sheets with 0.85% by weight of Melment.
Concrete with polystyrene sheets and Melment gives average compressive strength of 59.3Mpa, tensile strength of 5.8 Mpa and impact strength when the first crack appears was 1486 blows at 28 days.
Using 0.85 % of Melment per 100Kg of binder enhance the concrete resistance to Impact. Using 0.5 Liter of Glenium per 100Kg of cement shows good performance of concrete to Impact. Using three layers of Polystyrene sheets with 0.85% of Melment gives high compressive strength and improve the Impact capacity of concrete.
Polystyrene sheets increases the adhesive forces between materials in the mix and superplasticizers increases the workability so as to produce self compacting concrete.
Keywords: Polystyrene, Melment, Glenium, Impact Strength. Self Compacting Concrete.

1. Introduction

Efforts have been made during the past three decades to develop methods of structural analysis and design to resist Impact load. The use of vehicle for Impact and Arms Gun to attack city centers has been a feature of campaigns by terrorist organizations around the world. vehicle Impact within or immediately nearby a building can cause catastrophic damage on the building's external and internal structural frames, collapsing of walls, blowing out of large expanses of windows, and shutting down of critical life-safety systems and Loss of life can result from many causes, including structural collapse, debris impact, fire, and smoke.(T. Ngo, et all, 2007).
Impact resistance and progressive collapse-resistant design mitigate disproportionately large failures following the loss of one or more structural elements. Progressive collapse-resistant design is system-focused, and is often divided into two approaches, direct and indirect. The direct method designs the structural system to respond to a specific threat either by providing an alternate load path in the event of failure of one or more members, or by specific local-resistance improvements of key elements (R. Sri Ravindrarajah and M. C., 2007).
The indirect method provides general systemic improvements to toughness, continuity and redundancy; tension ties are an example of an indirect detailing technique.
The use of rubber aggregate in making concrete mix was discussed for impact resisting concrete. Results show a decrease in the unit weigh of the concrete mix as the rubber content increases. The effect on the impact resisting concrete was positively clear. (Kaloush K. E., et al 2004) and (Rui Li 2013).
This research aims to apply using different materials in making concrete mix that could enhance the concrete capacity against; impact load resistant activity. Also, this research aims to test a new form of composite concrete designed by using different materials to reduce the load impact effect on concrete constructions. A possible solution to enhance the ability of concrete to absorb energy resulting from impact load is to add different admixture to concrete mix and to test their effect on concrete impact potential. This work is devoted to Impact-resistant design. The impact resistance of a part is, in many applications, a critical measure of service life. More importantly these days, it involves the perplexing problem of product safety and liability (T. Seshadrisekhara and Srinviv Asarao, 2008) and (Boris Shteinman and David Wynne, 2004).
Road pavements subjected to loads deriving from the vehicles movement amongst the different kinds of pavements normally used to withstand such loads, rigid elements are supposed to be the most suitable for those conditions where severe stresses are experienced (Michele Agostinacchio, Gianluca Cuomo, 2004). This research has been made based on ACI 544 and its different modifications (1990 and 1993), and the ASTM and its different modifications (1997 and 2001).

This research involve a comparison between plain concrete, concrete made with different percentage of admixtures and concrete made with certain percentages with respect to cement weight and composite material weight to figure out the enhancement of concrete physical properties against impact.
Impact resistance tests were performed both at 7 and 28 days, so that all the aspects connected with the rupture of the element (first crack (distress), number and width of cracks at different stages) were perfectly studied. Moreover, some Impact Resistance Indices were defined, in order to correctly characterize the elements during the three following stages of cracking: initial, intermediate and final, corresponding to collapse.

2. Materials

The main mixing materials that a concrete mix requires are: Natural lime Aggregate, Ordinary Portland Cement, Water, Admixture; Polystyrene, Melment and Glenium.

Figure 1. The materials and the admixtures in making the concrete mix.

3. Mix Design:

The mix proportions have been used in this research were; (Coarse, medium and fine respectively are (2.1: 1.2: 1.3) with water/cement of 0.5. Admixtures been added to the mix based on certain dose. The normal dosage for the Melment F10 is between 0.2 and 2 kg per 100 kg of binder. The normal dosage for the GLENIUM 51 is between 0.5 and 1.6 liter per 100 kg of cement. Polystyrene sheets are in different shapes and sizes, in this research it has been used in both circular and square shape to fit into the moulds up to three sheets.

4. **Samples:**

Samples has been used in this work are cubes and cylinders. The cubes samples were with dimensions of (15X15X15) cm for casting concrete to perform the compressive strength test and the impact test as well. Cylinders with dimensions of (15X30) cm have been used for casting concrete to perform the splitting strength test and the impact test. Figure 2 present.

Figure 2. Types of samples

5. Compressive and Tensile Splitting strength test

Compressive strength is considered as an index to assess the overall quality of concrete. It is generally assumed that an improvement in the compressive strength results in improvement of all other physical properties. Hence strength investigations are generally centered on compressive strengths. Figure 3 presents.

Tensile strength of concrete is of prime importance in case of water retaining structures, runway slabs, pre-stressed concrete members, bond and shear failure of reinforced concrete members and cracking of mass Concrete works. So far much of the work is made upon the evaluation of tensile strength of concrete by indirect methods and comparatively fewer efforts have been made for its determination by direct methods. Figure 3 presents.

Figure 3. Compression and Tensile machine

6. Impact Test

Impact is testing an object's ability to resist high-rate of loading. It is a test for determining the Impact energy absorbed in fracturing a test specimen at high velocity. Impact resistance is one of the most important properties for a part designer to consider. The impact resistance of a part is, in many applications, a critical measure of service life. More importantly these days, it involves the perplexing problem of product safety and liability.

The ACI 544 (American Concrete Institute) procedure was followed for this purpose, measuring the number of impacts needed for the material to get to first crack (distress) and to collapse. The Marshall hammer, normally used for bituminous binder specimens, was used for the execution of the impact test [4]. All Marshall Compaction hammers shall meet the following requirements: as calibration requirements, which are: Weight of the falling hammer = 4536 ± 9g (10 ± 0.02 lbs). Height of hammer drop = 457.2 ± 1.524 mm (18 ± 0.06"). Diameter of the foot = 98.4mm ± 400µm (3.875 ± 0.016"). Figure 4 presents.

Figure 4. Impact test apparatus

7. Modification to Marshall Hammer

In the original marshal hummer there is no enough distance between the lower plate and the hummer head, so the arm of the Marshal should be extended in order to hold assembled specimens. For the purpose to perform testing in this research; a steel plate has been made so as to extend the arm of the machine and a suitable calibration has been made to make the measurement accurate. Figure (5a, 5b and 5c) illustrates. A pointed impact load by using a steel ball constrained with a wooden frame has been applied over the samples that have been fixed to the marshal hummer test.

Figure 5a. Added steel plates

Figure 5b. Marshal Device before Modification

Figure 5c. Marshal hammer with the plate from both sides

7. Results and Data analysis

7.1 Compression Test

Three specimens have been tested at each time interval for each type of aggregate (River gravel, limestone**),** as shown in figure 6. The compressive strength of both types are very close but the limestone concrete mix gives a higher values; although river gravel is rounded and have more surface area that's mean more adhesive with cement paste and supposed to achieve higher compressive strength than limestone but; Practically, river gravel is rare to have it pure from salt and sand lumps and that affect the compressive strength adversely.

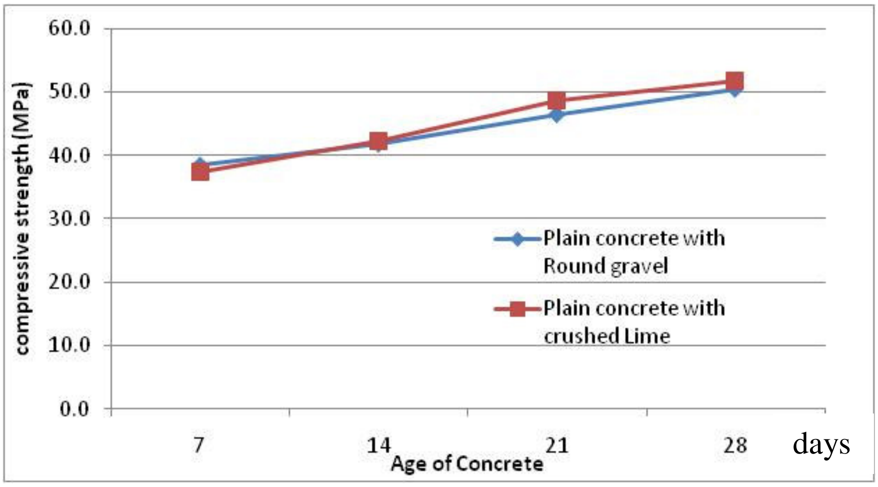

Figure 6. Compressive strength for Plain concrete

Figure 7 present a flow chart for concrete made by using different percentages of Melment, Glenium and Polystyrene sheets. It is clear that the preferred percentage to be added to concrete of both Melment and Glenium is 0.2%; that could enhance the concrete capacity to resist compression. While using three sheets of polystyrene with 0.85% of Melment to make the concrete mix shows how the two materials are matching in bringing up good result.

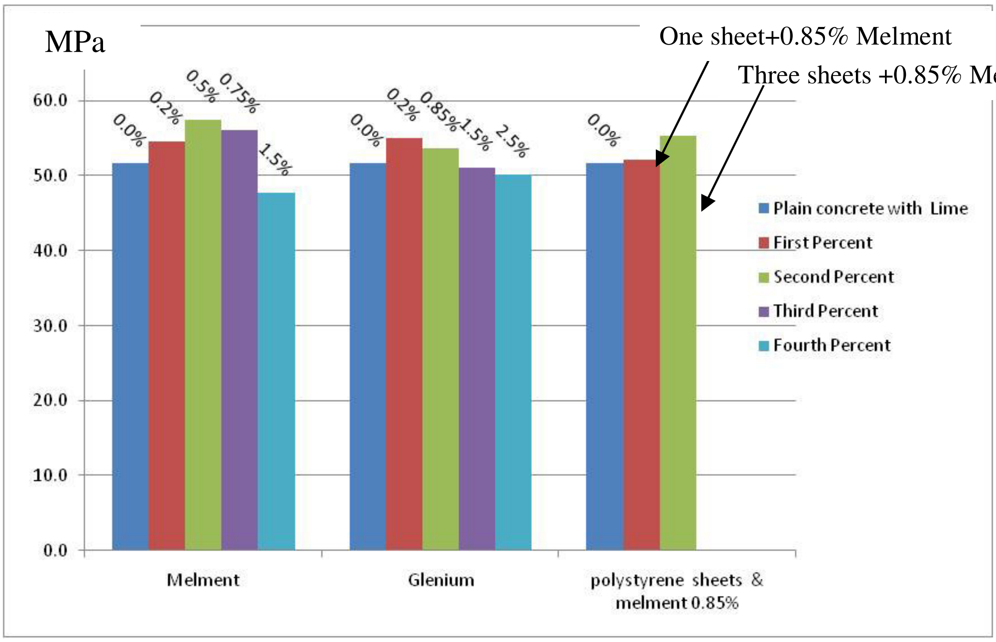

Figure 7. Relationship between compressive strength and time for different percentages of the added materials.

Figures 8 present the impact resistance of concrete made by limestone aggregate and with different percentages of Melment. It is clear that, increasing the percentage of Melment from 0% to 1.5% to the concrete mix will increase the concrete impact resistance as a result of good interaction between the cement and the added Melment; this will enhance the capacity of concrete as a result of good bond between the binder and the aggregate by adding the Melment. Increasing the added percentage of Melment to reach 2.0% will decrease the impact resistance of concrete as a result of decreasing the efficiency of cement in making the required bond between the mix materials.

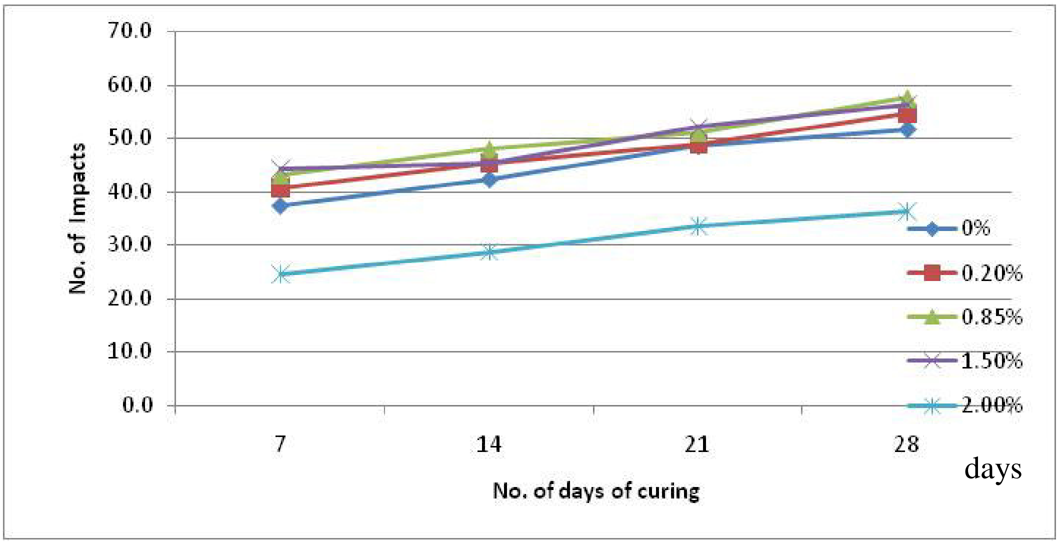

Figure 8. Relationship between No. of impacts versus curing time for concrete made with different Melment percentages.

Figure 9 present the relationship between concrete age and compressive strength for different percentages of Glenium that have been added to the mix. It is clear that the 0.2% of Glenium added to the concrete mix will enhance its capacity against strength; this will present how efficient Glenium in increasing the concrete compressive strength regard the bond that he makes with cement and due to the composition of such good material. Increasing the Glenium percentages to more than 0.2% will not increase the compressive strength but it will increase the cost of the mix.

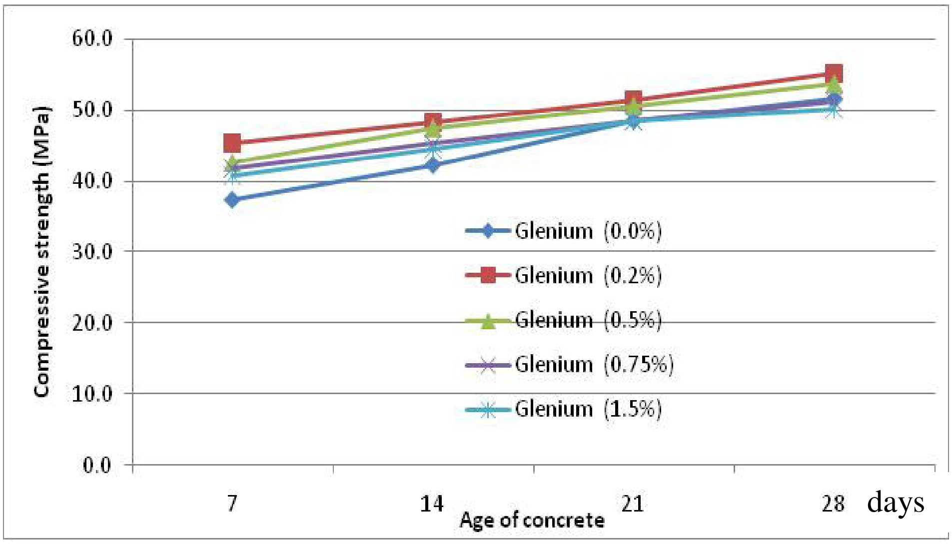

Figure 9. Compressive strength for concrete with different percentage of Glenium.

Figure 10 present the relationship between concrete age and compressive strength for plain concrete and that made by adding three layers of polystyrene sheets to the concrete mix. It is clear that adding polystyrene sheets to the concrete mix will increase bonds between the binder and the aggregate particles due to the mish structure of the sheets that will enhance the capacity of concrete to compression since there is good bond between the binder and the mish structure.

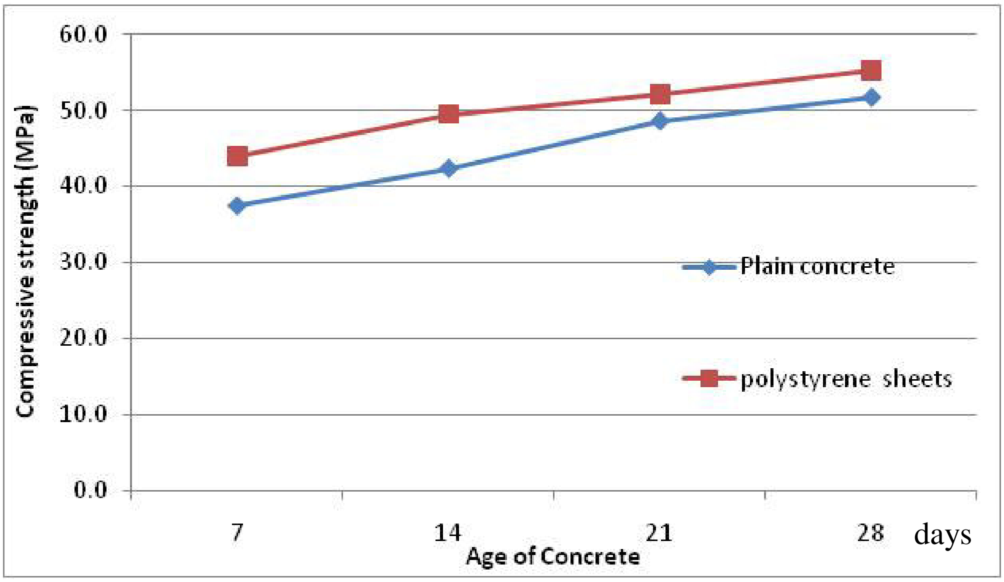

Figure 10. Relationship between Compressive strength versus age for plain concrete and that made with polystyrene sheet.

Figure 11 present relationships between concrete age and compressive strength for plain concrete, concrete made with 0.85% of Melment and for concrete made with polystyrene sheets and 0.85% of Melment. It is clear that adding 0.85% of Melment to the concrete mix will enhance its capacity against compression due to the bond that Melment strengthen between cement and the aggregate particle. Also adding three sheets of polystyrene to the mix with 0.85% of Melment will strengthen the interlocking between cement and the added materials that will enhance the strength of concrete as a result.

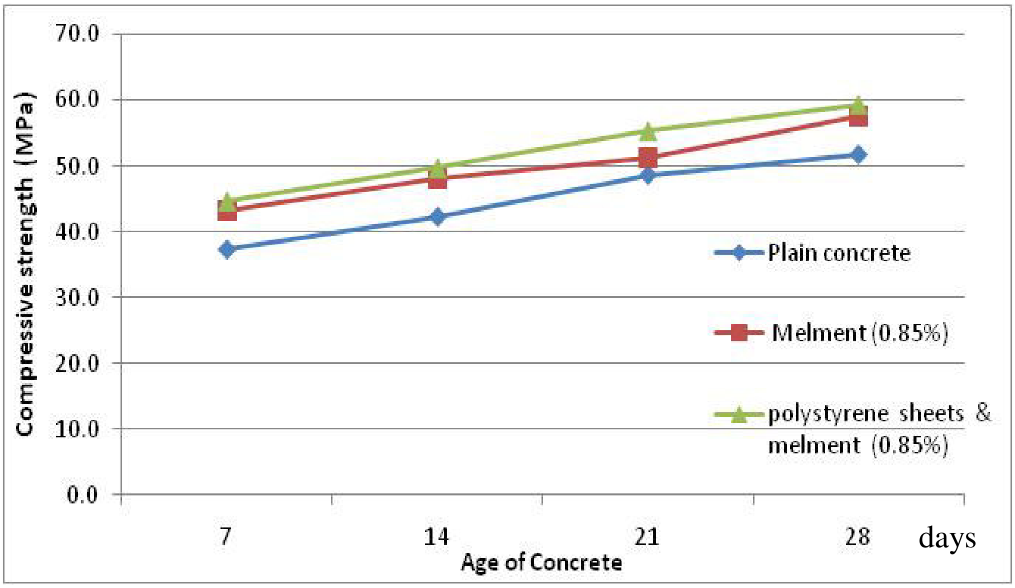

Figure 11. Relationship between compressive strength versus age for plain concrete and that with polystyrene sheet and Melment

7.2 Splitting Tensile Test

7.2.1 Splitting tensile test results

Three specimens for each testing time interval and for each type of aggregate have been tested as shown in figure 12. The tensile results generally are very compatible with compressive strength results. It is clear that concrete made by crushed lime gives higher strength than that made by rounded aggregate due to the purity from chemicals that exist in lime stone but doesn't exist in rounded aggregate that will lead to good bonding between the binder and the aggregate particles in case of using lime stone.

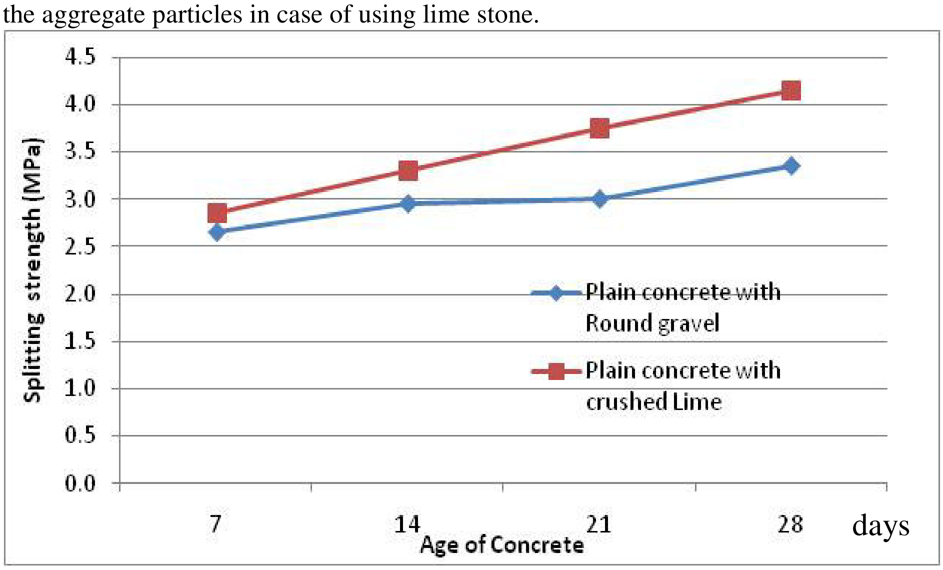

Figure 12. Relationship between Splitting strength versus age for Plain concrete made by rounded aggregate and that made by crushed lime

Figure 13 present relationships between number of impact and curing days for different percentages of Melment testing cylinders with 15X30 cm dimension. It is clear that; increasing Melment percentages up to 0.85% will increase the capacity of concrete cylinders against impact. This is due to the interaction between the Melment and the cement that will lead to good bond between both of them. Increasing the Melment percentage to more than 0.85% will not increase the impact resistance but will increase the cost.

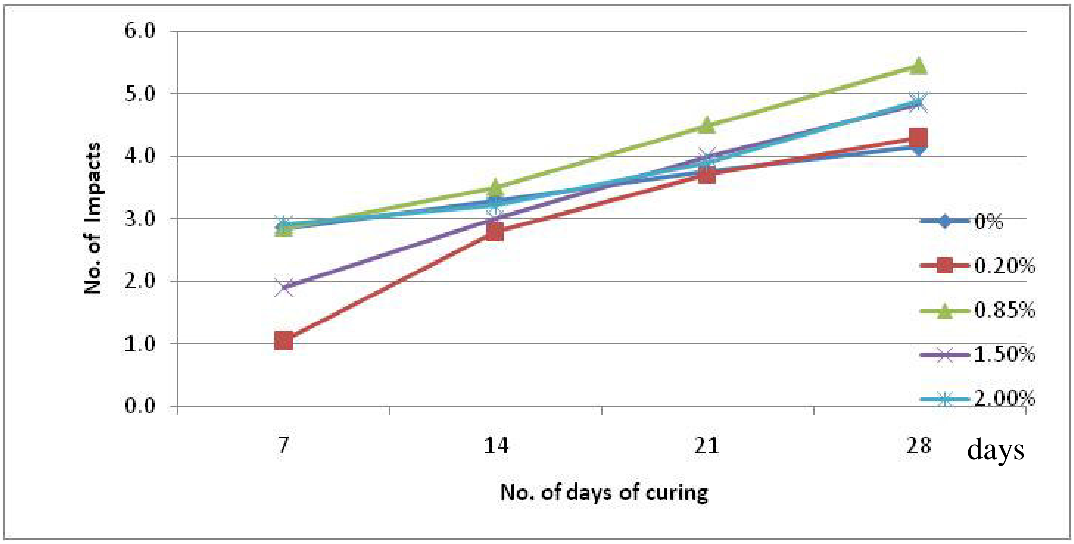

Figure 13. Cylinders tested for impact resistance for concrete made with Melment

Figure 14 present relationships between concrete age and splitting tensile strength for concrete made with different percentages of Glenium. It is clear that; using 0.2% and 0.5% of Glenium will give the same result of increasing the tensile capacity of concrete cylinder. Increasing the Glenium percentage more than 0.5% will not increase the tensile strength but it will increase the cost of the concrete mix. This is due to the good bond that Glenium made with cement to increase the concrete capacity against tensile strength.

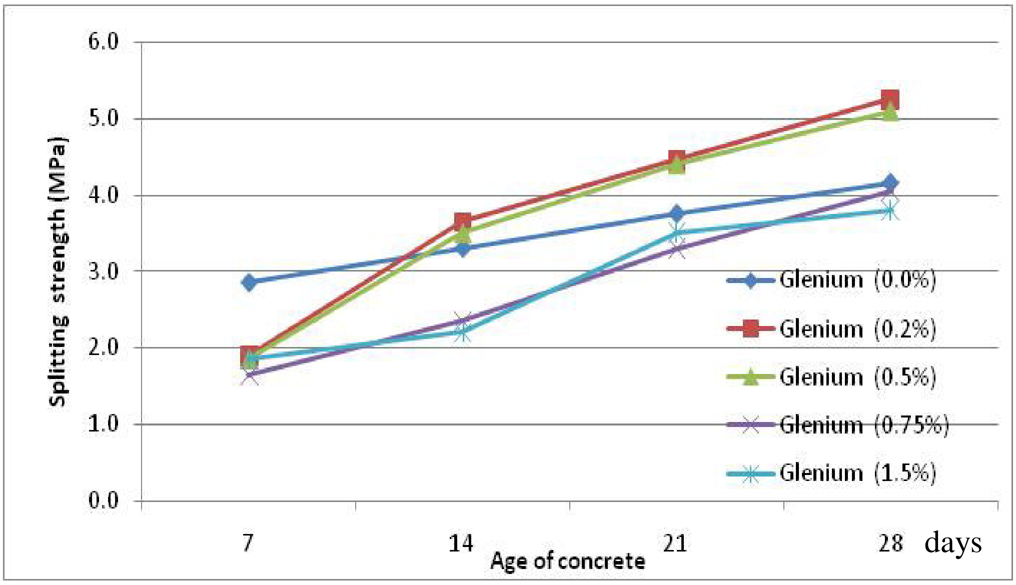

Figure 14. Splitting strength versus age for concrete made with different percentages of Glenium.

Figure 15 present relationship between concrete age and splitting strength for both; plain concrete and that made by adding three polystyrene sheets to the mix. It is clear that adding three polystyrene sheets to the cylinder while casting will enhance the capacity of the cylinder in resisting the tensile strength. This is due to the interaction between the binder and the sheets that encounter good bonds to resist tensile.

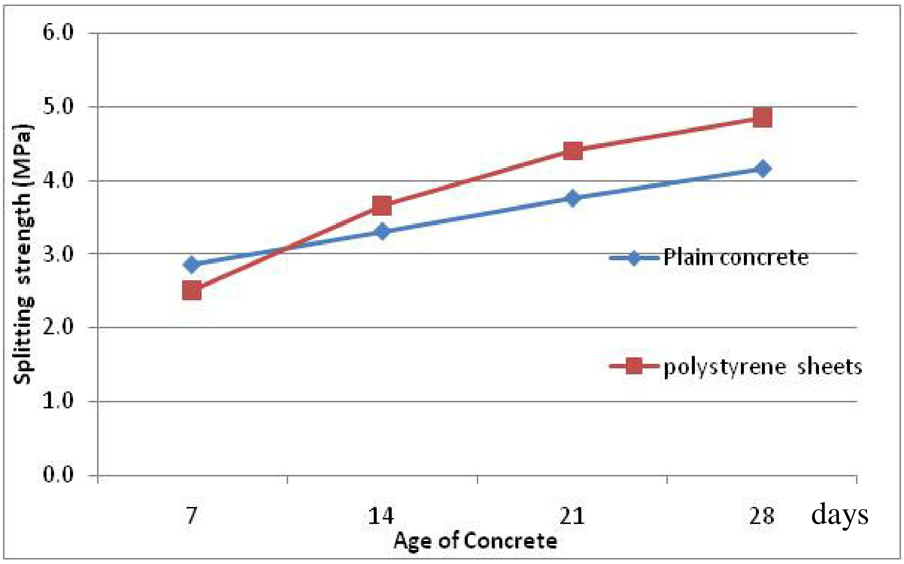

Figure 15. Splitting strength versus age for plain concrete and that made with the polystyrene sheet.

Figure 16 present relationships between concrete age and splitting tensile strength for plain concrete, concrete made with 0.85% Melment and concrete made with three polystyrene sheets and 0.85% of Melment. It is clear that the performance of concrete made with polystyrene sheets and 0.85% is much better than that for plain concrete and that made with only 0.85% of Melment. This is due to the good bonding and interaction between the concrete, the Melment and the polystyrene sheets which let them work together to enhance the splitting tensile strength.

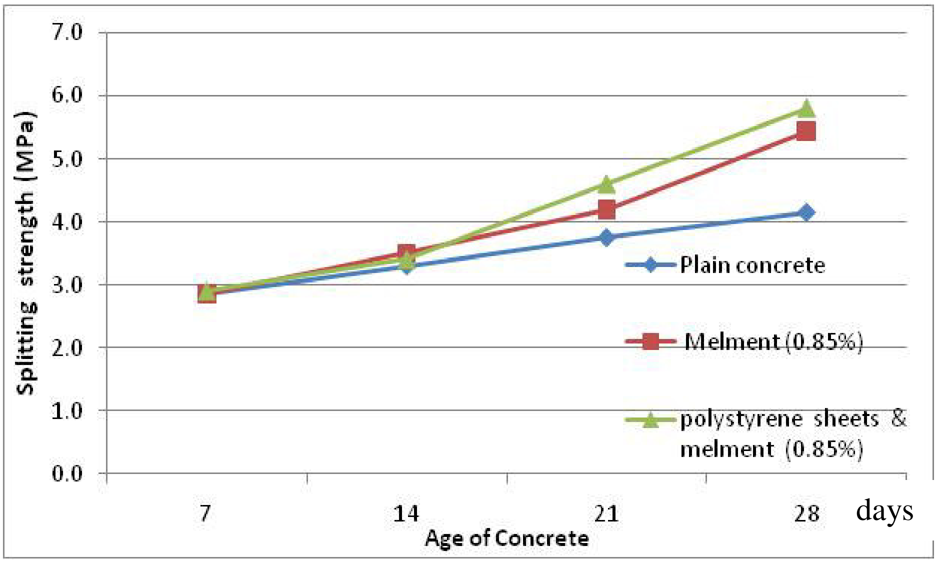

Figure 16. Relationships between Splitting strength and age for concrete made with Polystyrene sheet and Melment.

7.3 Impact test results

The First crack width for Concrete: It's the maximum first crack appears at the concrete mold before collapse as shown in the table 1 below. The maximum crack width appears at concrete mix with Melment as well as the minimum cracks are compatible with both compressive strength and splitting tensile strength. The maximum crack width is related to the depth of penetration of the steel ball into the concrete body; wider crack has less penetration. Table 1 present relationship between the concrete making materials and the range of the first crack. It is clear that the existence of polystyrene sheets affect the crack with, that encounter the least crack in compare with that for plain concrete as well as for plain concrete with some percentages of Melment. This is due to the good interaction that the polystyrene sheets made side by side with the Melment to encounter resisting the Impact energy. Figure 17 illustrates the same results regard crack width for the designed added materials.

Table 1 First crack width of concrete.

Type of admixture	The range of first crack width (cm)
Concrete with Melment	0.8 – 0.14
Concrete with Glenium	0.8 – 0.13
Concrete with the polystyrene sheet	0.06 – 0.11
Concrete with the polystyrene sheet and Melment	0.06 – 0.09

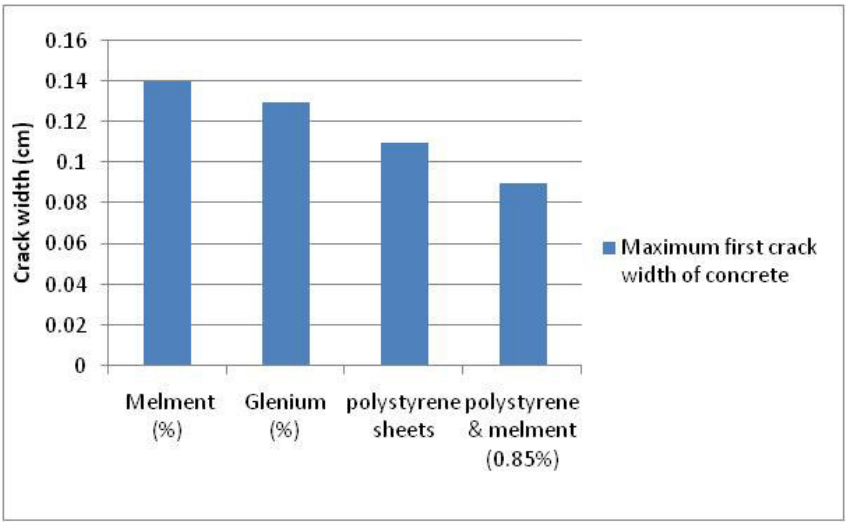

Figure 17. Relationships between Maximum first crack width and the added materials

The First crack Strength for Concrete: The first crack strength presents number of blows for the first crack to show up for cubes and cylinders molds, figure 18 present. This first crack is highly depending on concrete mix with exact W/C ratio as well as the amount of the added materials to the mix. For concrete made with different percentages of Melment. Figures (19 & 20) present the first crack strength for both cubes and cylinders specimens with 0.85% Melment. This percentage will give the maximum resistance to the first crack strength and this is compatible for both compressive and tensile strength, since Melment is good in controlling the first crack due to the chemical composition and due to the bond he makes with cement to overcome the whole mix bonds and manage to resist the Impact energy.

Figure 18. Cube and Cylinder specimens after the first crack to show up.

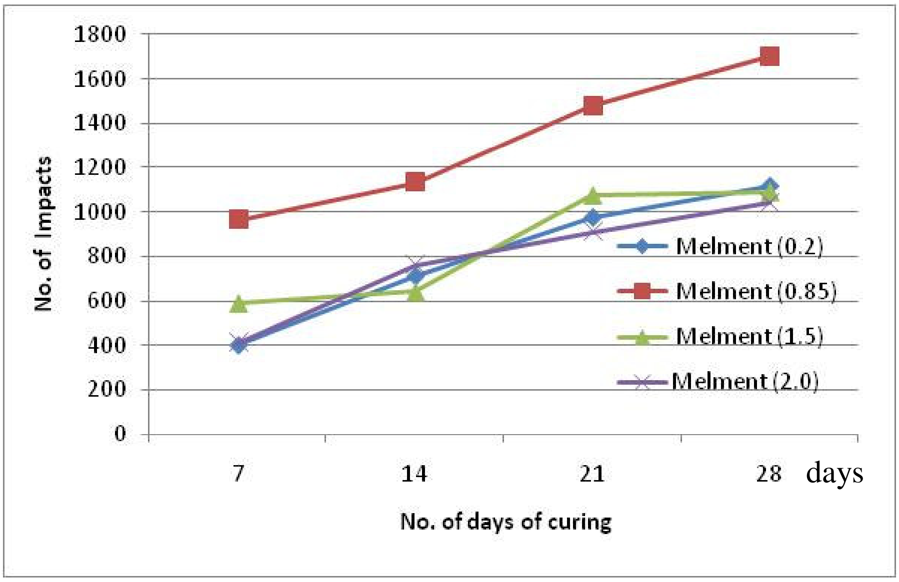

Figure 19. First crack strength with Melment for Cubes samples.

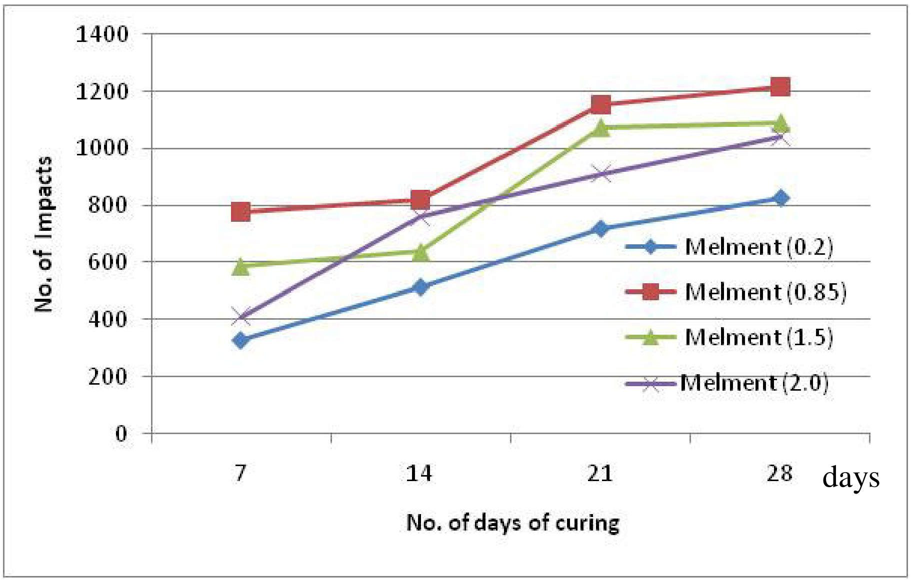

Figure 20. First crack strength with Melment for cylinder samples.

For concrete made with different percentages of Glenium. Figures (21 & 22) present for both cubes and cylinders with 0.5% of Glenium gives the maximum first crack strength and this is compatible for both compressive and tensile strength. Glenium is good in controlling the first crack strength due to the chemical composition and due to the interaction between cement and Glenium that will enhance the Impact energy resistance of concrete.

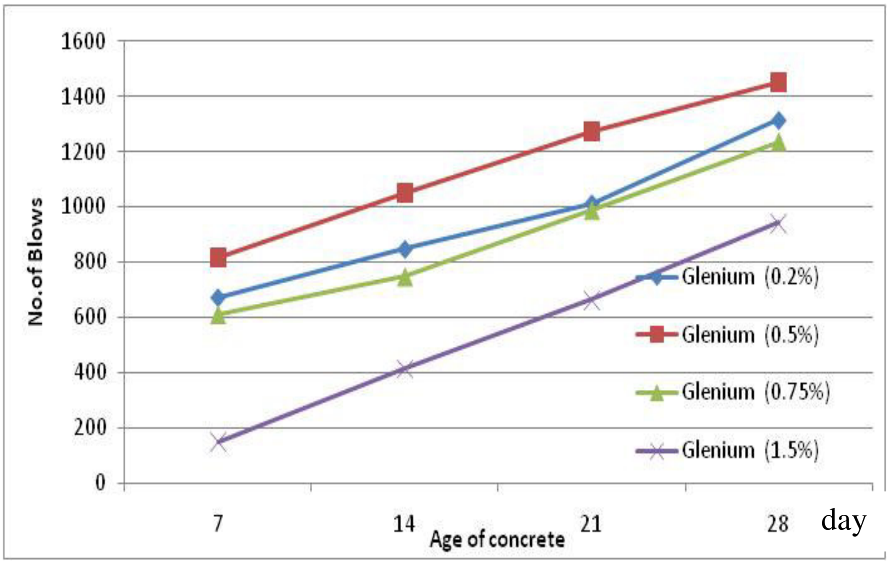

Figure 21. First crack strength with Glenium for cube samples.

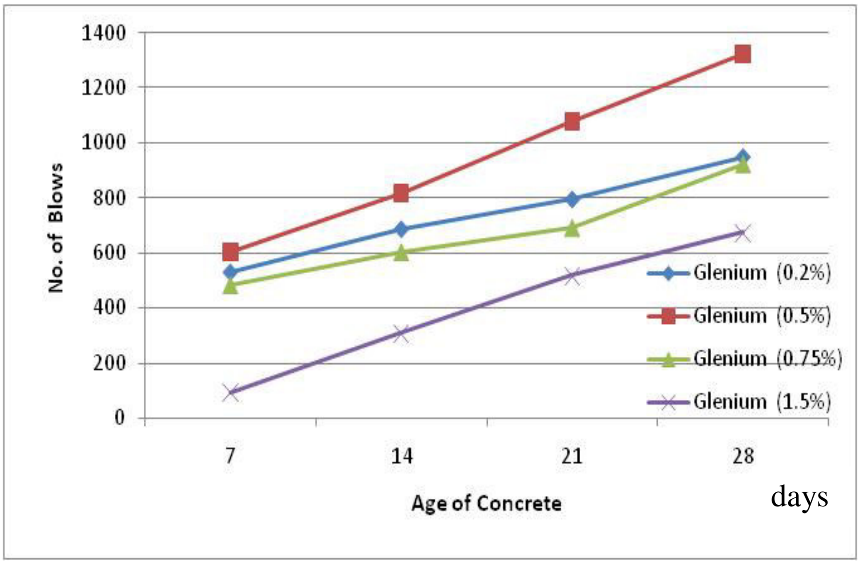

Figure 22. First crack strength with Glenium for cylinder samples.

For concrete made with only polystyrene and that made by polystyrene with Melment. Figures (23 & 24) present; for both cubes and cylinders, Polystyrene concrete with 0.85% of Melment gives the maximum first crack strength resistance. This is compatible for both compressive and tensile strength. It is due to the composition of the added materials and its capacity in enhancing the crack strength of the concrete as a result of good bonds.

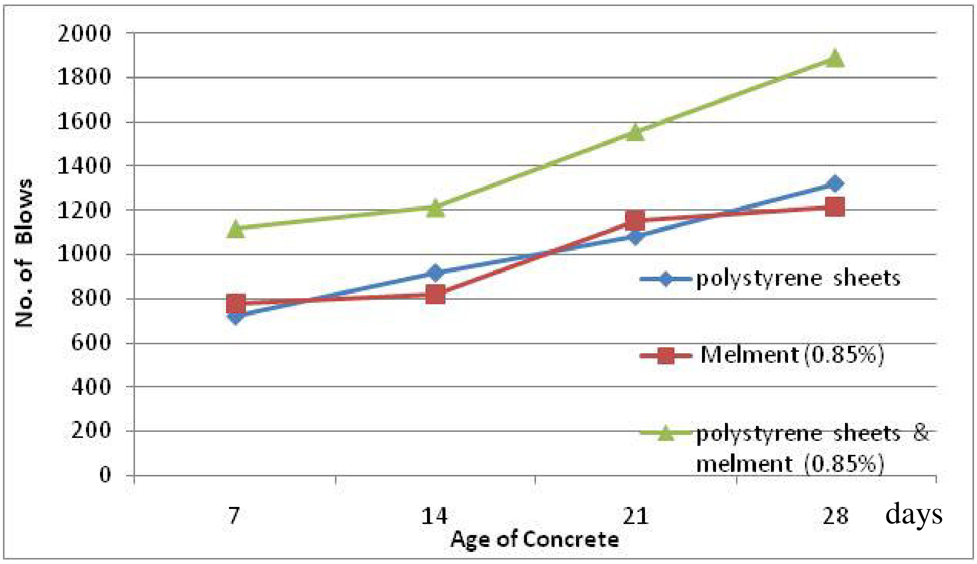

Figure 23. First crack strength with polystyrene for cube samples.

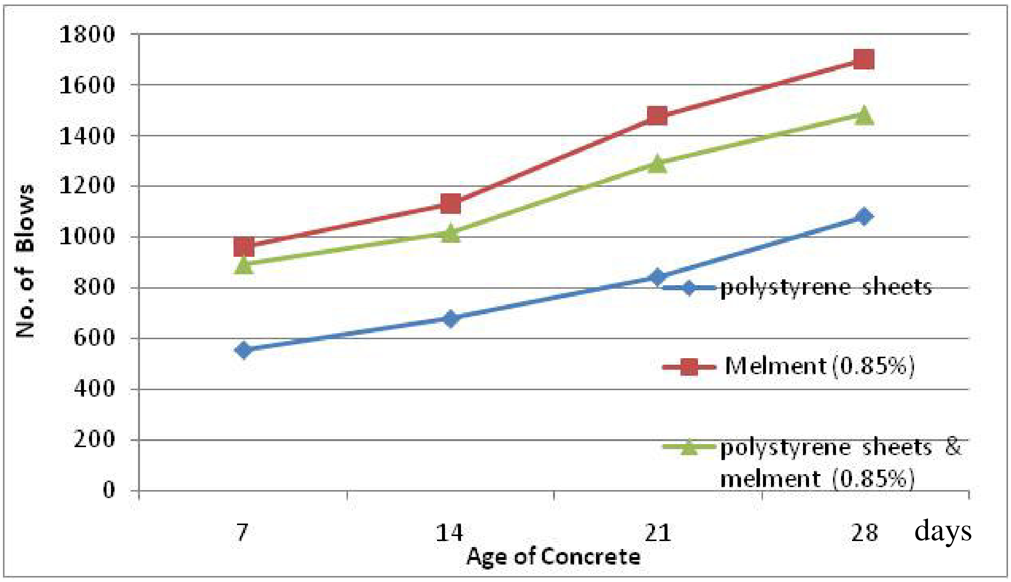

Figure 24. First crack strength with polystyrene for cylinder samples.

The use of Polystyrene sheets in concrete mix can give fewer cracks in compare with that for Melment, and Glenium separately. But when Melment has been added to the mix with polystyrene it gives the best results of all of them, and that's also compatible with other tests.

8. Conclusion

Many concrete samples with the following dimensions; (15X15X15) cm cubes and (15X30) cm cylinders were prepared with different proportions of admixtures and tested to evaluate their resistance to impact energy.

Tests have shown that polystyrene sheets in general increases the impact resistance; were 0.85 of Melment per 100kg of binder was added to the concrete mix which gives higher results than that for the other admixtures. This is due to the chemical composition and physical shape of polystyrene sheets and the chemical properties of Melment. A polystyrene sheet is flexible, capable to absorb Impact energy and its fibers adhere to the cement paste and aggregate and it improves bonds in concrete.

The main role of super plasticizers is to increase the workability without adding more water, i.e. **w/c** will remain fixed. More workability is needed to produce compact homogeneous concrete and later stronger hardened concrete. Adding Melment to the concrete mix will increase the strength of concrete cubes as well as the impact energy resistance.

Using polystyrene alone was not adequate due to difficulties in handling concrete in the presence of polystyrene sheets. When adding superplasticizers and polystyrene together, workability and compaction will be increased and thus will affect the strength as well as the impact resistance.

It's concluded that the impact energy resistance of concrete can be improved by adding proper percentages of superplasticizers and polystyrene sheets.

Results indicated that adding super plasticizers is limited to certain percentages and excess of these materials will have negative effect.

References

T. Ngo, P. Mendis, A. Gupta & J. Ramsay, 2007, Blast Loading and Blast Effects on Structures , The University of Melbourne, EJSE International 2007. Australia .

R. Sri Ravindrarajah and M. C. Lyte ,Senior Lecturer, Centre for Built Infrastructure Research. Energy Absorbing Concrete for Impact Loading , University of Technology, Sydney, NSW 2007, Australia

Kaloush, K. E., Way, G. B., and Han Zhu, 2004; Properties of Crumb Rubber Concrete, Annual Meeting of the Transportation Research Board, Washington DC. http://www.trb.org/AnnualMeeting 2004.aspx.

Rui Li 2013, Recycled Tires as Coarse Aggregate in Concrete pavement mixture, Colorado Department of Transportation Research 2013.

T. Seshadrisekhara and Srinviv Asarao, Relationship between Compressive, Split Tensile, Flexural Strength of Self Compacted Concrete, International Journal of Mechanics and Solids, November (2008).

Boris Shteinman and David Wynne , Study of sediment dynamics in the Jordan River Lake Kinneret contact zone using tracer methods 2004,.

Michele Agostinacchio, Gianluca Cuomo 2004, Assessment of the Impact Resistance in Concrete Pavement Reinforced with Various Kind of Fibers: A Comparison between Common Steel Fibers and New Polymer Modified Fibers. University of Basilicata – Potenza – Italy.

ACI Committee 544, "State of the Art Report on Fiber Reinforced Concrete", ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, 1990.

ACI Committee 544, "Guide for Specifying, Proportioning, Mixing, Placing and Finishing Steel Fiber Reinforced Concrete", ACI Materials Journal, Vol. 90, N. 1, Detroit, 1993.

ASTM 1997, American Society for Testing and Materials, "C1018-97 Standard Test Method for Flexural Toughness and First Crack Strength of Fiber Reinforced Concrete", West Conshohocken, PA, 2001.

ASTM 2001, American Society for Testing and Materials, "C39/C39M-01 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens", West Conshohocken, PA, 2001.

ASTM 2001, American Society for Testing and Materials, "C78-02 Standard Test Method for Flexural Strength of Concrete", West Conshohocken, PA, 2001.

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