International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 6, Issue 9, September 2016)

Development of Rubberised Concrete Using Waste Rubber Tyre as Coarse Aggregate

Ankit Sethi[1], Som Dutta Thanvi[2]

[1]*Assistant professor, Department of Civil Engineering, World College of Technology &n Management ,MDU, Gurgaon, India*
[2]*Assistant professor, Department of Civil Engineering, Kautilya Institute of Technology & Engineering, RTU, Jaipur, India*

Abstract- **Recycled waste tyre rubber is a promising material in the construction industry due to its lightweight, elasticity, energy absorption, sound and heat insulating properties. The Literature available reveals that used rubber tyre can be effectively used in concrete to enhance the various properties of concrete and to protect environment. A mixture composed of ordinary concrete and rubber from the recycled tyres has been presented in technical literature under the name of "Rubber Concrete" or "Rubber Modified Concrete" (Sara Sgobba, 2010).**

In the present experimental study the experimental program was carried out for the partial replacement of natural coarse aggregate by using waste rubber tyre aggregates (hand chopped) of maximum size 20 mm. In this study the natural coarse aggregates were replaced by rubber tyre aggregates by 5%, 7.5% & 10% by weight of coarse aggregate. The compressive & flexural strength were determined at 7 days and 28 days and the results were compared with ordinary concrete of same grade (Controlled mix). A normal concrete (controlled mix) of natural aggregate without any replacement with rubber particles (0%) is used for the purpose of reference. The concrete of M20 grade has been used.

The Compressive strength of rubberised concrete is less than the compressive strength of normal/controlled mix. The decrement in compressive strength at 5%, 7.5%, 10% was found to be 18.21%, 32.25%, 40.55% respectively of compressive strength of controlled mix. The flexural strength of rubberised concrete at 5%, 7.5%, 10% was respectively found to be increased by 27.78%, 81.39%, 61.94% of the flexural strength of controlled mix.

Keywords- **Rubberised concrete, controlled mix, compressive strength, flexural strength, controlled mix, energy absorption, water absorption, interfacial transition zone, surface treatment**

I. INTRODUCTION

Millions of rubber tubes & tyres are generated every year in our country. This is one of the major environmental challenges faced by various agencies all around the world because waste rubber tyre is non-biodegradable, even after a long period of landfill treatment. Hence various efforts have been made to dispose-off this waste rubber tyre.

One of the solutions is found in the construction industry by using this rubber tyre in various forms in the concrete so that the wastage can be reduce and recycling of such material may be minimize which will lead to elimination of various harmful by-products (gases, leachate). Attempts have been made in this direction to use the rubber tyre in various forms in the field of construction. Several studies performed recently have shown that concrete modified with the incorporation of used rubber tyre aggregates improves some of the weak characteristics of conventional concrete such as low tensile strength, low ductility, low energy absorption, shrinkage & cracking (El-Gammal, et al., 2010).

Over the past few years, a number of researches have focused on the use of different shapes and size of waste tires in concrete. A mixture composed of ordinary concrete and rubber from the recycled tires has been presented in technical literature under the name of "Rubber Concrete" or "Rubber Modified Concrete" [1] (Sara Sgobba et al, 2010).

In the present study we are using used rubber tyre in the form of aggregate at varying percentage along with admixtures (mineral, chemical or both at the same time). Used rubber tyre from the same origin has been used in this study to check the behavior of concrete & to find the solution of above mentioned problem. Using discarded rubber tyre in the form of aggregate has recently been the subject of a number of studies throughout the world but the area is still relatively less researched in our country. The literature review available in this area of research shows limited amount of information on the behavior and properties of concrete incorporated with rubber in various forms. From the literature available it is observed that recycled waste tire rubber is a promising material in the construction industry due to its lightweight, elasticity, energy absorption, sound and heat insulating properties.

Objective Of The Study

The main focus of this study is

1) To check the behavior of concrete incorporated with scrap rubber tyre as an aggregate.

2) To find the optimum quantity of used rubber tyre aggregate in concrete mixtures for engineering applications.
3) To find an effective & inexpensive way of recycling the discarded tires.
4) To provide a solution which contribute towards the disposal related problem of non-decaying scrap tyres.
5) To reduce the recycling of such material (which leads to evaluation of various harmful gases). This in turn helps in reducing environmental pollution up to a certain level. Developing such construction materials could have both environmental and economical advantages.

II. Literature Review

Recycled waste tyre rubber is a promising material in the construction industry due to its lightweight, elasticity, energy absorption, sound and heat insulating properties. The Literature available reveals that used rubber tyre can be effectively used in concrete to enhance the various properties of concrete and to protect environment. A mixture composed of ordinary concrete and rubber from the recycled tires has been presented in technical literature under the name of "Rubber Concrete" or "Rubber Modified Concrete". The literature available also shows that workable rubberised concrete can be made with appropriate percentage of rubber tyre aggregates.

Classification Of Scrap Rubber Tire

Siddique & Naik (2004)

Four type of scrap tire particles have been classified by the study carried out by Siddique & Naik (2004), which were graded according to particle size as follows:-

i) Slit tires
ii) Shredded/ chipped tires (particle size is 30-40cm long by 10-22 mm wide)
iii) Ground rubber (19-0.15mm)
iv) Crumb rubber (4.75- 0.075mm)

Strength Studies

1. Sara Sgobba et al, (2010)

The study explores the ameliorative effects of rubber particles on some properties of concrete. The result presented shows that the incorporation of rubber aggregates in concrete, obtained from waste tires, is a suitable solution to decrease the weight in some engineering manufactures.

Some drawbacks were also reported by her such as the large decrease in compressive strengths, and the increase of water request and air content, the test result demonstrated that rubberised concrete mix possesses interesting properties that can be useful in structural and non-structural applications. The test result also shows that the performance of concrete is significantly affected by the type and content of the rubber particles as well as by cement type and admixture properties.

2. El-Gammalet al, (2010)

The application of recycled waste tire rubber by replacing fine and coarse aggregate in concrete has been performed at different percentages to study the change in compressive strength & density of concrete. Two different forms of waste rubber tier (i.e chipped & crumb) have been used in the study. The result for the concrete casted using chipped rubber as a full replacement to coarse aggregate shows a significant reduction in the density (about 30% reduction) & compressive strength (about 90% reduction) compared to controlled specimen. However significant ductility was observed before failure. The result obtained for the concrete casted using crumb rubber as a full replacement to sand shows significant reduction in compressive strength compared to controlled specimen but shows significant increase in compressive strength compared to the concrete casted using chipped rubber as a full replacement to coarse aggregate.

3. Malek K. Batayneh et al, (2008)

A research was carried out to find a positive method for disposing non-decaying materials, such as reuse in concrete mixes. Crumb rubber was used in the concrete mix to partially substitute for fine aggregate (sand) in various percentages of 20%, 40%, 60%, 80%, 100%. For each mix, cubes of 100x100x100 mm, cylinders of 150mm diameter by 300mm height, and small beams of 100x100x400 mm were prepared. All specimens were fabricated and then cured in water for 28 days in accordance with ASTM/C192M-06 Standard practices.

For each concrete mix, slump test were performed and recorded at the casting time of the specimens. After curing, specimens were tested for compressive strength, split tensile strength & flexural strength in accordance with ASTM specified procedures. In his analysis he found that crumb rubber content in mix resulted in a decrease in both the slump & unit weight of the mixtures. However mix still produced a workable mix in comparison with the control mix.

He also reported the reduction in compressive strength, tensile strength & flexural strength (i.e. crumb rubber reduces all types of tested strength). On the basis of his analysis he concluded that higher the rubber content in the mix, the higher the reduction in compressive, tensile & flexural strengths hence it is not recommended to use this modified concrete in structural elements where higher strength is required but it can be used in many other construction elements like partition walls, road barriers, pavements sidewalks, etc.

Static & Dynamic Behaviour Of Rubberised Concrete

F. Hernadez-Olivares et al, (2002)

According to his analysis the addition of crumb rubber tyre rubber volume fractions up to 5% in a cement matrix does not imply a significant variation on the concrete mechanical features, either maximum stresses or elastic modulus.

The mechanical static test result for compressive, indirect tension (Brazilian method) & four point bending strength on standard specimen with fibre reinforcement concrete at 7 & 28 days showed an admissible dispersion as compared to controlled mix. According to F. Hernadez-Olivares rubber fibre-filled specimens show larger result dispersions than sets without fibre, and Gauss distribution is wider in the first case than in the second. It means that Fibre-filled concrete is less reliable than controlled mix (without any fibre) and maximum compressive strength decreases slightly.

In dynamic compression test when a periodic compressive load was applied on the material, shows relaxation on rubber filled concrete. The strain effect appears delayed with regard to the moment when the load is applied. This delay on the deformation is a direct consequence of the internal nature of the material. Specimens with higher fibre volumetric fraction (5%) dissipated more energy than lower contents of fibre (3.5%). The high percentage of the specific energy dissipated (between 23% & 30%), which makes this material with high contents of recycled tyre rubber an optimal candidate for absorbing and dissipating energy under dynamic actions without damage.

It was observed that the variations under static or dynamic load increases with age and decrease as the fibre content or with the increase in temperature.

In fact, the inclusion of fibre implies defects in the internal structure of the composite material (concrete), producing a reduction in strength and decrease in the stiffness, but when maximum strength is overcome, fibre collaborates with concrete, avoiding the openings of the cracks and therefore increasing the energy absorbed by strain (toughness) and the breaking of concrete.

III. EXPERIMENTAL WORK

The study carried out is totally concerned with the partial replacement of natural coarse aggregate by used rubber tyre aggregates of maximum size 20 mm. In this study the natural coarse aggregates were replaced by rubber tyre aggregates by 5%, 7.5% & 10% by weight of coarse aggregate. The *compressive & flexural strength* were determined at 7 days and 28 days and the result was compared with ordinary concrete of same grade. A normal concrete of natural aggregate without any replacement (0%) is used for the purpose of reference. The concrete of M20 grade has been used.

Rubber Aggregates

Tire aggregates used in this study were made by cutting the scrap tires into maximum sizes of 16mm & 20mm. They were used by mixing them in proportion of 2:3. The cutting of tire was done by labor with chisels & hand cutters. The maximum and minimum size of rubber aggregate used is 20mm and 16mm respectively. The tyres used in the analysis are from the same origin (scrap of APPLO tyre were used).

Chemical For Surface Treatment

During the initial stage of the study it was observed that the bonding between the rubber particles in concrete was very week. To enhance the bonding between the rubber particle with rest of the materials, surface treatment becomes necessary. For the purpose of surface treatment we have used NaOH solution. NaOH is a powerful cleansing agent removes the dirt and cleans the surface of rubber which enhances the bonding between the rubber aggregate with the other materials in concrete. The rubber particles were first soaked in the NaOH solution for 24 hours before using. After Subjected to NaOH solution the aggregate were washed with water and cleaned. After the completion of the surface treatment of the rubber aggregates they were allowed to use in the concrete.

IJETAE
EXPLORING RESEARCH AND INNOVATIONS

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 6, Issue 9, September 2016)

IV. RESULTS

Compressive Strength After 7 & 28 Days Days

Table 1
Table showing compressive strength of concrete at different age

S.No.	Sample	Percentage of rubber aggregate	7 days Compressive strength (N/mm^2) (Average)	28 days Compressive strength (N/mm^2) (Average)
1	S_1	0	17.33	25.92
2	S_2	5	16.30	21.20
3	S_3	7.5	13.63	17.56
4	S_4	10	12.22	15.41

Comparative analysis of the compressive strength for at different stages:-

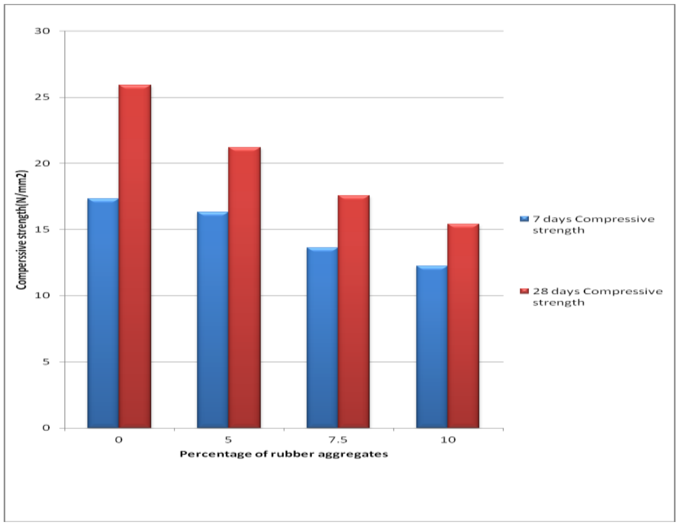

Figure 1-Graph showing variation of compressive strength for the rubberised concrete at different ages

Comparative graphs can be plotted to understand variation (decrement) in the Compressive strength of the rubberised concrete at different ages of concrete with respect to controlled mix as shown below:-

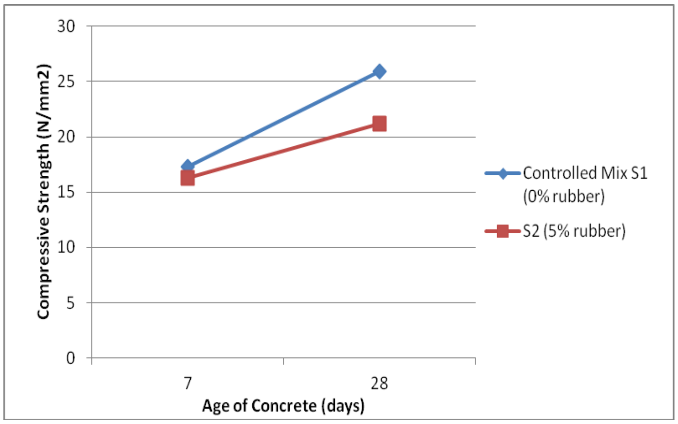

Figure 2- Graph showing decrement in the compressive strength of rubberised concrete (S2) with respect to Controlled mix (S1)

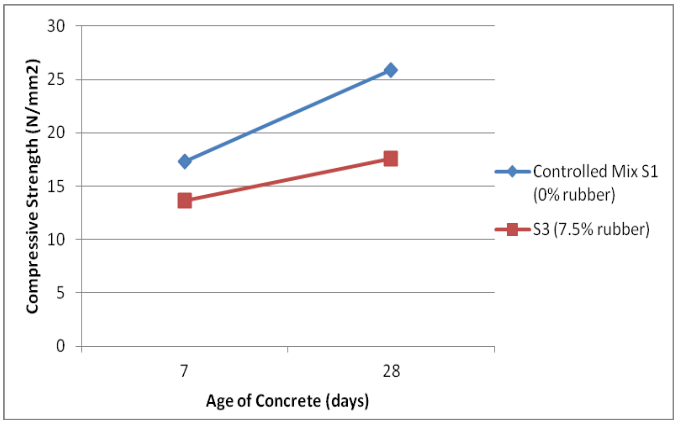

Figure 3-Graph showing decrement in the compressive strength of rubberised concrete (S3) with respect to Controlled mix (S1)

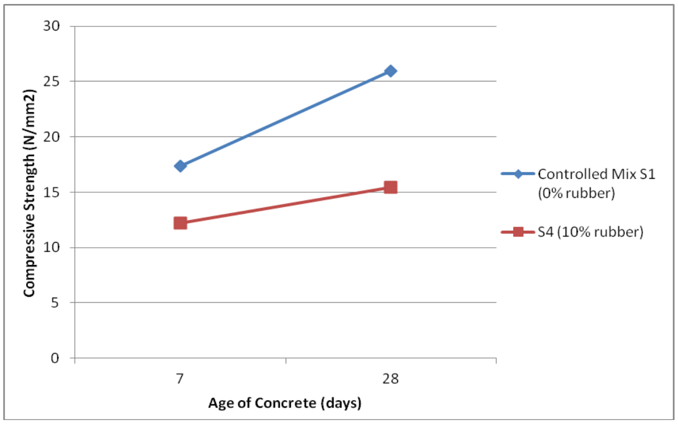

Figure 4- Graph showing decrement in the compressive strength of rubberised concrete (S4) with respect to Controlled mix (S1)

IJETAE
EXPLORING RESEARCH AND INNOVATIONS

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 6, Issue 9, September 2016)

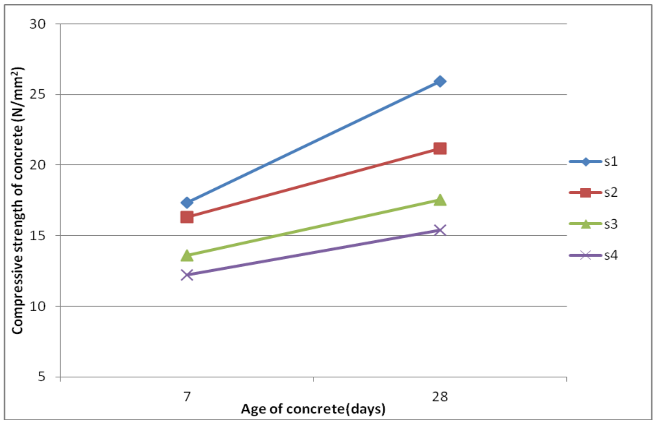

Figure 5- Graph showing decrement in compressive strength of various rubberised concrete with respect to Controlled mix (S1)

Flexural Strength After 28 Days

The results obtained for flexural strength after 28 days are tabulates as follows:-

Table 2-
28 Days Flexural Strength of Rubberised Concrete

S.No.	Sample	Percentage of rubber aggregate	Average load (kN)	Flexural strength (N/mm^2)
1	S_1	0	9.0	3.6
2	S_2	5	11.5	4.6
3	S_3	7.5	16.33	6.53
4	S_4	10	14.66	5.87

Comparative analysis on flexural behaviour of Rubberised Concrete

A comparative graph can be drawn between the variations in flexural strength of rubberised concrete at varying composition of tyre aggregates with the flexural strength requirement of the ordinary concrete of same grade as per Indian Standards.

The graph shows increase in the flexural strength of rubberised concrete.

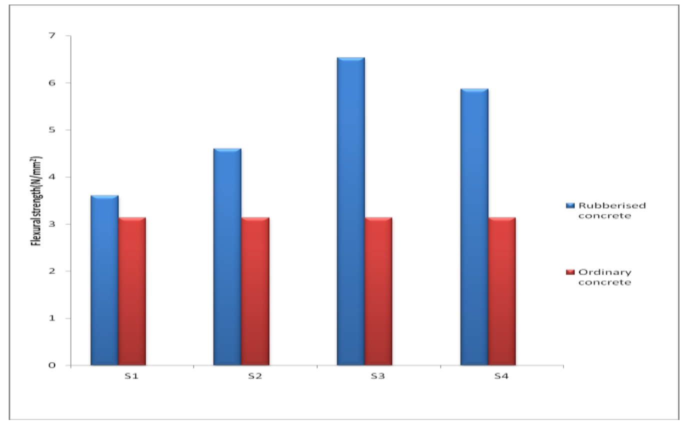

Figure 6- Graph showing increase in flexural strength of rubberised concrete

Comparative analysis on compressive & flexural strength of rubberised concrete

Table 3-
Table showing flexural & compressive strength of rubberised concrete

S.No.	Sample	Percentage of rubber aggregate	Flexural strength at 28 days (N/mm^2)	Compressive strengthat 28 days (N/mm^2)
1	S_1	0	3.6	25.92
2	S_2	5	4.6	21.20
3	S_3	7.5	6.53	17.56
4	S_4	10	5.87	15.41

The graphical representation of above results is as follows:

IJETAE
EXPLORING RESEARCH AND INNOVATIONS

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 6, Issue 9, September 2016)

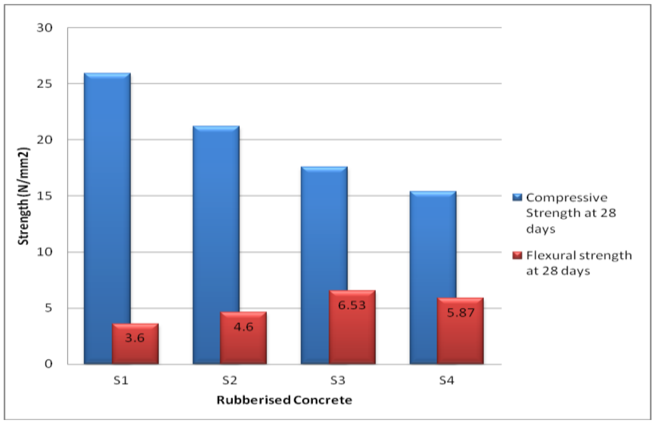

Figure 7- Graph showing Compressive strength v/s flexural strength of Rubberised concrete

Water Absorption

The water absorption of the concrete cube specimen containing used rubber tyre aggregates was determined by placing the cube specimen in the water for 24 hrs just after the removal from the casting mould, wiped with the dry cloth and then weighed in the surface saturated dry condition (W_{ssd}). The cube specimen was then placed in hot oven for 24 hrs maintaining the temperature of 105±5° C. The cube specimen was then weighed (W_{od}). The water absorption of the concrete was determined by using following formula:-

$$\text{Water Absorption} = \frac{W_{ssd} - W_{od}}{W_{od}} \times 100$$

Table 4
Water absorption of rubberized concrete

S.No.	SAMPLE	WEIGHT (SSD) (in Kg)	WEIGHT (Oven Dry) (in Kg)	Water Absorption (%)
1	S_1	7.700	7.447	3.4
2	S_2	7.635	7.412	3.00
3	S_3	7.455	7.300	2.12
4	S_4	7.575	7.307	3.7

The result can be represented graphically as follows:

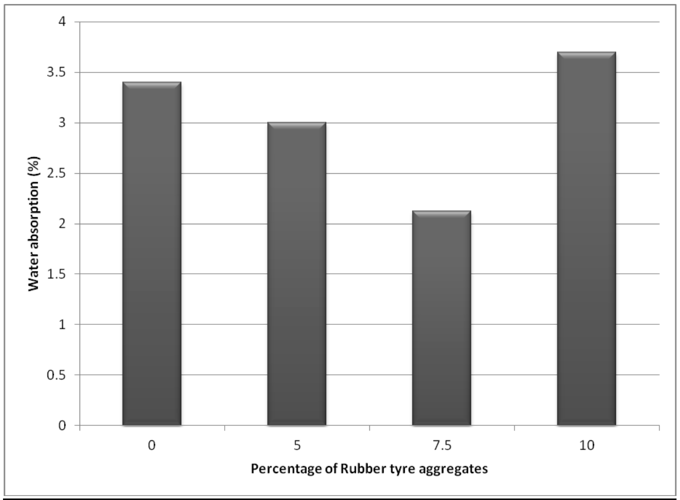

Figure 8-Graph showing water absorption variation in tyre rubberised concrete

Workability Of Concrete

The workability of concrete was determined using Slump Test of freshly prepared concrete mix. The results observed for the slum test are tabulated below:

Table 5
Slump for rubberised concrete

S.No.	Sample	Percentage of Rubber Aggregate	Slump (in mm)
1	S_1	0	82
2	S_2	5	32
3	S_3	7.5	18
4	S_4	10	07

V. Interpretations & Discussions

The results for the test conducted in the present study and the variation observed in compressive strength, flexural strength & Water absorption of the Rubberised concrete are as follows:-

It is evident from the graphical analysis (fig. 1) that the compressive strength decreases with the increase in rubber content.

It is also observed from the comparative analysis of the compressive strength obtained, that the compressive strength of rubberised concrete is less than the compressive strength of controlled mix (fig. 5). The decrement in compressive strength at 5%, 7.5%, 10% of rubber content was found to be 18.21%, 32.25%, 40.55% respectively of controlled mix.

The flexural strength of rubberised concrete at 28 days first showed increment up to 7.5% rubber content and then slight decrease in flexural strength was observed with increase in rubber content for 10%. The decrement in flexural strength is still greater than the required flexural strength.

It was observed that the flexural strength of rubberised concrete at 5%, 7.5%, and 10% of rubber tyre aggregate by weight of total aggregate was respectively found to be increased by 27.78%, 81.39%, and 61.94% of the flexural strength of controlled mix (Table 2).

It was observed that the water absorption of rubberised concrete decreases up to 7.5% rubber content and then increases suddenly at 10% rubber content (Fig 8).

The workability of rubberised concrete decreases with the increase in rubber content (Table 5)

VI. Conclusions

After the complete analysis of the experimental study following points may be concluded:

1. With the increase in rubber aggregates content in rubberised concrete the compressive strength decreases significantly & the flexural strength first increases (up to 7.5%) and then decreases.
2. The decrease in compressive strength might be due to weak bonding between rubber particles & cement paste i.e. weak interfacial transition zone.
3. The water absorption of the rubberised concrete first decreases (up to 7.5%) with the increase in rubber aggregates, and with the further increase in rubber content water absorption increases. This increase in water absorption might be due to increase in voids in the rubberised concrete.
4. From the above discussions of results obtained it may be concluded that the rubberised concrete has limited application in the load bearing structure due to reduction in compressive strength but it can be used in non structural (non load bearing) structure.
5. The workability of rubberised concrete decreases with the increase in rubber content which could be compensated by increasing the dosage of chemical admixtures.

VII. Future Scope Of Work

1) Studies related to the dynamic & static behavior on Rubberised concrete is required to be observed.
2) Studies on freezing & thawing resistance of rubberise concrete need to be conducted.
3) Microscopic study of concrete microstructure is also required for better observations & conclusions.
4) Use of mineral admixtures such as Silica flumes & Alco fines may also need to be study.
5) Behavior of rubberised concrete at varying dosage of chemical admixtures is required.
6) Other properties of concrete should also be part of study.

REFERENCES

[1] http://www.tfhrc.gov/hnr20/recycle/waste/. [Online] [Cited: 15th march 2004.] http://www.tfhrc.gov/hnr20/recycle/waste/.

[2] Freeze/Thaw performance of concrete of concrete using granulated rubber crumb . A. Richardson, K. Coventry, U. Dave, and J. Pienaar. 1, 2010, Journal of green buildings, Vol. 6.

[3] Innovative application of Screp- tire Steel Chords in Concrete mixes. Ahmed N. Bdour, Al-Khalayleh, Yahia A. 1, 15 October 2010, Jordan Journal of Civil Engineering, Vol. 4.

[4] Youjiang Wang, H. C. Wu and Victor C. Li. s.l. : Journal of materials in civil engineering, November 2000, Concrete Reinforcement with Recycled fibres, Vol. 12, p. 6.

[5] Tyre Aassociation. [Online] 2011. http://www.atmaindia.org/Overview.htm.

[6] Tarun R. Naik, Rafat Siddique. Properties of concrete containing scrap tire rubber. 2002. Report No. CBU-2002-06, REP-459.

[7] Shetty, M.S. Concrete mix design. Concrete Technology Theory & practices. s.l. : S. Chand & company ltd, 2011, p. 624.

[8] Sara Sgobba, Giuseppe Carlo Marano, Massimo Borsa & Marcello Molfetta.

[9] RubberBoard. Indian Rubber Statistic. Rubber board. Kottayam : Ministry of commerse and industry, Government of India, 2013.

[10] Use of recycled tyre as partial replacement of Coarse aggregate in the production of concrete. Michelle Danko, Edgar Cano, Jose A. Pena. s.l. : Purdue University Calumet, 2006, p. 14.

[11] Promoting the use of crumb rubber concrete in developing countries. Malel K. Batayneh, Iqbal Marie, Ibrahim Asi. 2008, Science direct-waste management, pp. 2171-2176.

[12] LANXESS, Automative sector. LANXESS rubber day. mumbai : s.n., 2013.

[13] Study on Waste tyre rubber as concrete aggregates. Kotresh K.M, Mesfin Getahun Belachew. 4, 1 april 2014, International Journal of Scientific Engineering and technology, Vol. 3, pp. 433-436.

[14] IS:9103-1999. "Code for practice for Concrete Admixtures-specification". s.l. : BIS New Delhi, (April 1999).

[15] IS:8112-1989. "Ordinary Portland Cement- Specification". s.l. : BIS New Delhi, (Reaffirmed July 1999).

[16] IS:516-1999. "Method of Test of Strength of Concrete". s.l. : BIS New Delhi.

[17] IS:456-2000. "Code for Practice for Plain and reinforced concrete". s.l. : BIS New Delhi, 2000.

[18] IS:383-1970. "Indian Standards Specification for Coarse Aggregate from Natural Sources for Concrete". s.l. : BIS New Delhi.

[19] IS:3812-1981. "Specification For Fly Ash For Use As Pozzolana & Admixture. s.l. : BIS New Delhi, Reaffirmed 1999.

[20] IS:2386-1963. "Methods of testing of Aggregate for Concrete". s.l. : BIS New Delhi, (Part I & II).

[21] IS:1489-1991. "Portland Pozzolana Cement Specificatioms". s.l. : BIS New Delhi, (part-I).

[22] A review on construction technologies that enables environmental protectionL Rubberized concrete. G. Senthil Kumaran, Nurdin Mushule and M., Lakshmipathy. 1, 2008, American Journal of Engineering and applied science, Vol. 1, pp. 40-44.

[23] Static & dynamic Behaviour of recycled tyre rubber filled concrete. F.Hernandez-Olivares, G. Barluenga, M. Bollati, B. Witoszek. Spain : Pergamon, 16 April 2002, Cement & Concrete research, Vol. 32, p. 10.

[24] Compressive Strength of Concrete Utilizing Waste Tire Rubber. El-Gammal, A., Abdel-Gawad, A. K. and Y. El-Sherbini, and A. Shalaby. 2010, Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS).