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An Experimental Study on Rubberized Concrete

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***Abstract*— Modifications of construction materials have an important bearing on the building sector. Several attempts have been therefore made in the building material industry to put to use waste material products, e.g., worn-out tyres, into useful and cost effective items. Success in this regard will contribute to the reduction of waste material dumping problems by utilizing the waste materials as raw material for other products. The present proposal involves a comprehensive laboratory study for the newer application of this waste material in the preparation of fibrous concrete. The primary objective of investigation is to study the strength behaviour i.e. compressive and flexural strength, and impact resistance of rubberized concrete with different volume of crumb rubber. Parameter to be varied in Investigation: I. Volume variation of crumb rubber. The proposed work is aimed to study the effect of volume variation of crumb rubber on the compressive strength, flexural strength, split tensile strength Slump test & The relationship between stress and strain of the concrete.**

***Keywords*— Crumb rubber, rubberized concrete, compressive strength, flexural strength, split tensile strength, Slump test**

I. INTRODUCTION

About one crore 10 lakhs all types of new vehicles are added each year to the Indian roads. The increase of about three crores discarded tyres each year pose a potential threat to the environment. Hazardous materials can be classified as chemical, toxic or non-decaying material accumulating with time. The accumulation of rubber and plastic can be considered non-decaying materials that disturb the surrounding environment. However, a positive method for disposing of this non-decaying material, such as reuse in concrete mixes, would have a beneficial effect. One of the major environmental challenges facing municipalities around the world is the disposal of worn out automobile tyres. Most discarded tyres are buried in the landfills. Only fewer are used as fuel or as raw materials for the manufacture of rubber goods. Burying scrap tyres in landfills is both wasteful and costly. Disposal of whole tyres has been banned in the most landfills because they are bulky and tend to flow to the surface with time, so tyres are often shredded.

If tyres are reused as a construction material instead of being burnt, the unique properties of tyres can once again be exploited in a beneficial manner. In this context, the use of tyre chips in lightweight concrete is considered a potentially significant avenue. Thus, the use of scrap tyres in concrete manufacturing is a necessity than a desire. The use of scrap tyres in concrete is a concept applied extensively over the world. The use of scrap tyres rubber in normal strength concrete is a new dimension in concrete mix design and if applied on a large scale would revolutionize the construction industry, by economizing the construction cost and increasing the worn out tyre disposal. It is with this intension, an experimental study is proposed to be conducted by using crumb rubber as sand in cement concrete.

Crumb rubber (fig. 1)

Engineering Properties Of Crumb Rubber Specific gravity:-The specific gravity of tyre shreds is the ratio of unit weight of solids of the shreds divided by the unit weight of water. The apparent specific gravities of tyre shreds depend on the amount of glass belting or steel wire in the tyre, and range from 1.02 to 1.27. For comparison, the specific gravity for soil typically ranges between 2.6 to 2.8, which are more than twice as heavy as tyre shreds.

Water absorption:-Absorption capacity is the amount of water absorbed onto the surface of the crumb rubber and is expressed as the percent (%) water (based on the dry weight of the crumb rubber). Water absorption capacity of crumb rubber generally ranges from 2% to 4.3%.

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Compressibility:- The compressibility of tyre shreds is applicable in evaluating landfill airspace. Tyre shreds less than 3-in. (75-mm) in size indicate that vertical strains of up to approximately 25% may occur in the tyre shreds under low vertical stress of up to approximately 48 kpa and that vertical strains of up to approximately 40% may occur under high vertical stress of up to 414 kpa .

Shear strength:- Tyre shreds placed as distinctive layers within a municipal solid waste(MSW) landfill could influence the internal stability of the landfill. The shear strengths of tyre shreds and tyre shred/concrete mixtures are variable. However, it appears that they have shear strength properties' such that no detrimental effect on landfill stability should occur.

II. EXPERIMENTAL PROGRAM

This paper aims at utilizing rubber waste tyres as a constituent in concrete mixes and its products as a partial replacement of natural and artificial fine aggregate components

Work Procedure: The following represents the methodology by which to study the effect of utilizing waste crumb tyres in concrete mixes were done.

No. of samples = no. of sample for each percentage x total no. of percentage x 2

No. of cubes = 5 x 5 x 2 = 50.

No. of beams = 5 x 5 x 2 = 50.

No. of cylinders = 5 x 5 x 2 = 50.

Mould- A hollow frustum of a cone made from galvanized steel sheet with thickness of between 1.5mm to 2.0mm. The bottom and the top of the mould are open and at a right angles to the axis of the cone. Internal surface must be smooth. Dimensions of the mould were as below.

Bottom diameter =200mm

Top diameter =100mm Vertical height = 300 mm

Rod - A metal rod of 16 mm in diameter, approximately 600 mm long and having at least one end tapered for a distance of approximately 25 mm (a spherical shape) having diameter of 10mm.

Base plate -A smooth rigid and non-absorbent material of base metal plate with minimum 3.0 mm thickness.

Ruler - Appropriate steel ruler is required for measurement of slump height.

Materials: The basic ingredients of rubberised concrete and its products, which were used in this research work are:

1- OPC 43 grade ultra tech cement.
2- Natural Coarse aggregate (sedimentary rock source).
3- Natural Fine aggregate (sand).
4- Water (fresh drinkable water)
5- Fine crumb rubber

Concrete mix design In the present investigation the existing method as per IS: 10262-2009 has been used for selecting the reference mix (M30), however new information given in IS 456 -2000 have been incorporated, procedure is modified to the extent. In order to get the final mix proportion for the reference mix design, three trial mixes had been prepared earlier and tested at 28 days. The mix proportion of trial mixes are given below in table.

Table 1
Therefore designed ratio for M30 is

Water (kg/m3)	Cement (kg/m3	Fine aggregate (kg/m3)	Coarse aggregate (kg/m3)
15.96	50	54.46	122.57
0.319	1	1.08	2.45

Table 2
Trial mixes: Quantities of materials per cubic meter of concrete

Water (kg/m3)	Cement (kg/m3)	Fine aggregate (kg/m3)	Coarse aggregate (kg/m3)
191.58	478.95	520.41	1175.88
191.58	445.534	556.81	1197.94
191.58	425.733	574.51	1202.55

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Table 3
Final mix design adopted

Mix	Water (kg/m3)	Cement (kg/m3)	Fine aggregate (kg/m3)	Coarse aggregate (kg/m3)
M30	191.58	425.733	574.51	1202.55
	0.45	1	1.34	2.82

III. Results And Discussion

This part aims at analyzing the tests results to show how concrete behaviour will change as a result of the volumetric replacement of sand with crumb waste tyres.

Test results for compressive strength at 7 days

Size of cubes 150mm X 150mm X 150mm Concrete mix used M30 grade.

Table 4

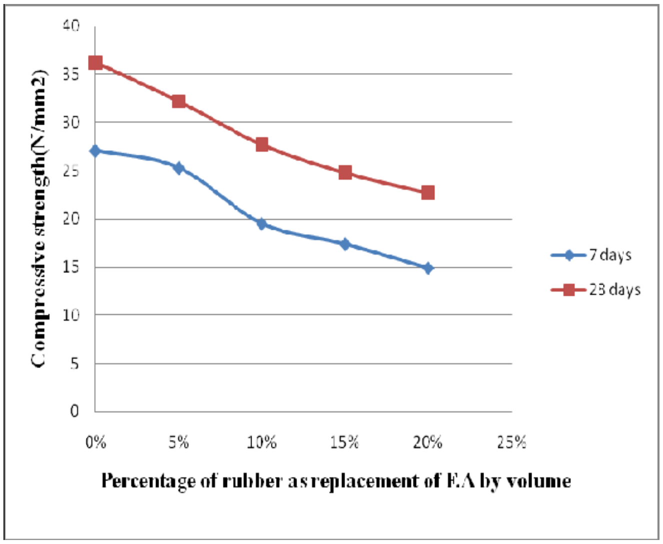
S. No.	Percentage of crumb rubber	Load at failure (KN)	Compressive strength(N/mm2)
1	0%	609.7	27.1
2	5%	569.2	25.3
3	10%	438.7	19.5
4	15%	391.5	17.4
5	20%	335.2	14.9

Test results for compressive strength at 28 days

Size of cubes 150mm X 150mm X 150mm Concrete mix used M30 grade

Table 5

S. No.	Percentage of crumb rubber	Load at failure (KN)	Compressive strength(N/mm2)
1	0%	814.5	36.2
2	5%	724.5	32.2
3	10%	623.2	27.7
4	15%	558.0	24.8
5	20%	510.7	22.7



Variation of compressive strength at 7 and 28 days v/s percentage of crumb rubber as replacement for FA (fig.2)

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1) Compressive strength behaviour of rubberized concrete

The effect of crumb rubber on concrete compressive strength is given in Table 4 , 5 and is demonstrated in Figure 2. It is observed that the use of crumb rubber reduced compressive strength. As expected, the higher the rubber content in the mix, the higher the reduction in compressive (fc) strength. Detailed examination of the Figure shows that increasing the crumb rubber up to 10% exhibited a linear relationship between the increase of crumb rubber and the compressive strength, showing a loss of about 24% of the compressive strength at 10% rubber content. Therefore, this result limits the use of the modified concrete when strength is the prime requirement.

2) Test results for flexural strength at 7 days

Size of beams 100mm X 100mm X 500mm Concrete mix used M30 grade

Table 6

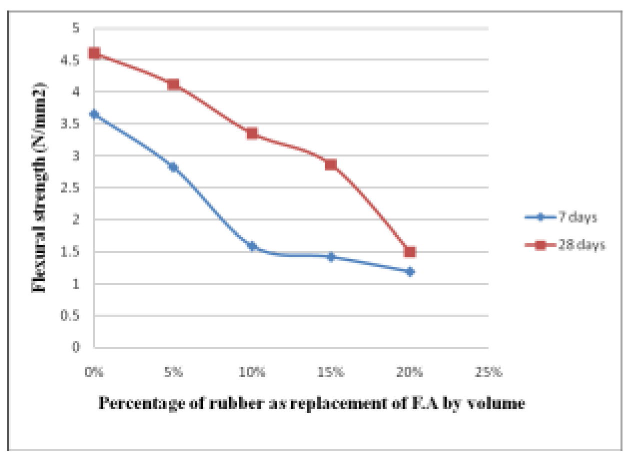
S. No.	Percentage of crumb rubber	Load at failure (KN)	Flexural strength(N/mm2)
1	0%	9.1	3.6
2	5%	7.0	2.8
3	10%	3.7	1.5
4	15%	3.5	1.4
5	20%	2.9	1.1

Test results for flexural strength at 28 days

Size of beams 100mm X 100mm X 500mm Concrete mix used M30 grade

Table 7

S. No	Percentage of crumb rubber	Load at failure (KN)	Flexural strength(N/mm2)
1	0%	11.5	4.6
2	5%	10.3	4.1
3	10%	8.3	3.3
4	15%	7.1	2.8
5	20%	3.5	1.4



Variation of flexural strength at 7 and 28 days v/s percentage of crumb rubber as replacement for FA (fig. 3)

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Flexural strength behaviour of rubberized concrete

The flexural strength or the modulus of rupture of concrete is an indirect measure of the tensile strength. The value of modulus of rupture depends upon the dimensions of the beam and above all on the arrangement of the loading. The maximum load that the rubberized concrete can sustain is lower than the non rubberized concrete. The results of the flexural strength of concrete with and without inclusion of crumb rubber are shown in Tables 6 & 7 and curves in fig.3.The Figure showing the effect of partial replacement of sand with crumb rubber on the flexural strength of concrete. It is observed that with the increase in the crumb rubber, the flexural strength decreases. From figure no 3 it can be concluded that, with the large percentage replacement of fine aggregates, flexural strength decreases drastically. This is due to increase in voids and weaker bonding, as rubber contents increases.

3)Test results for split tensile strength at 7 days

Size of cylinders 150mm X 300mm Concrete mix used M30 grade

Table 8

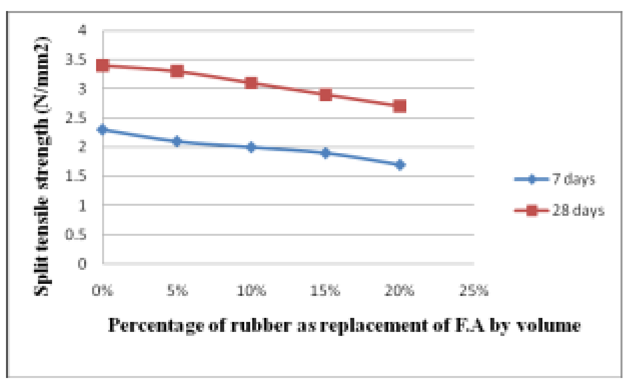
S. No.	Percentage of crumb rubber	Load at failure (KN)	**Split tensile strength(N/mm2)**
1	0%	162.4	2.3
2	5%	148.3	2.1
3	10%	141.3	2.0
4	15%	134.2	1.9
5	20%	120.1	1.7

Test results for split tensile strength at 28 days

Size of cylinders 150mm X 300mm Concrete mix used M30 grade

Table 9

S. No	Percentage of crumb rubber	Load at failure (KN)	**Split tensile strength(N/mm2)**
1	0%	240.2	3.4
2	5%	233.1	3.3
3	10%	219.0	3.1
4	15%	204.8	2.9
5	20%	190.7	2.7



Variation of split tensile strength at 7 and 28 days v/s percentage of crumb rubber as replacement for FA (fig.4)

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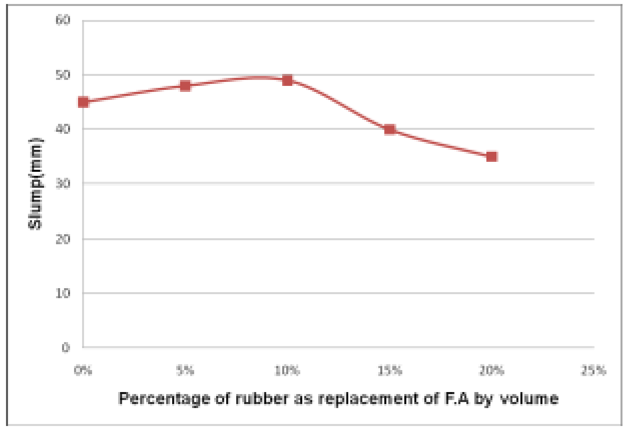
Split tensile strength behaviour of rubberized concrete

The results of the split tensile strength of concrete with and without inclusion of crumb rubber are shown in Table 8 and 9 and Fig no 4. The Figure shows the effect of partial replacement of sand with crumb rubber on the split tensile strength of concrete. It can be noted that with increase in the crumb rubber the tensile strength decreases. The decrease in the strength is due to non polar action of the rubber particles which attract air and repels water. The split tensile strength of the concrete decreases about 30% when 20% sand is replaced by crumb rubber .Failure of plain and rubberized concrete in compression and split tension shows that rubberized concrete has higher toughness. The failed samples containing 15% and 20% fine aggregate substitution with rubber appeared like a true crushing resulting in a post failure material that was sponge-like and elastic in nature

4) Test results for slump value Cone size – 10cm X 20cm X 30cm Concrete mix M30 grade Slump behaviour of rubberized concrete

Table 10

S. No.	Percentage of crumb rubber	Slump value (mm)
1	0%	45
2	5%	48
3	10%	49
4	15%	40
5	20%	35



Variation of slump v/s percentage of crumb rubber as replacement for FA (fig.5)

Slump behaviour of rubberized concrete

The results of the slump of concrete with and without inclusion of crumb rubber are shown in Table 10 .The Figure shows the effect of partial replacement of sand with crumb rubber on the slump value of concrete. It can be noted that with increase in the crumb rubber up to 10%, the slump value increases after that it started decreasing .As seen in Table 10, the increase of the crumb rubber content in the mix resulted in an increase in the slump. At rubber contents of higher than 10% (10% by fine aggregate volume), the slump decreases. However despite the decrease in measured slump, observation during mixing and casting showed that increasing the crumb content in the mix still produced a workable mix in comparison with the control mix. Effect of rubber particles on the workability of concrete is attributed to a reduction in the density of concrete or to actual changes in the yield value and plastic viscosity of the mixture.

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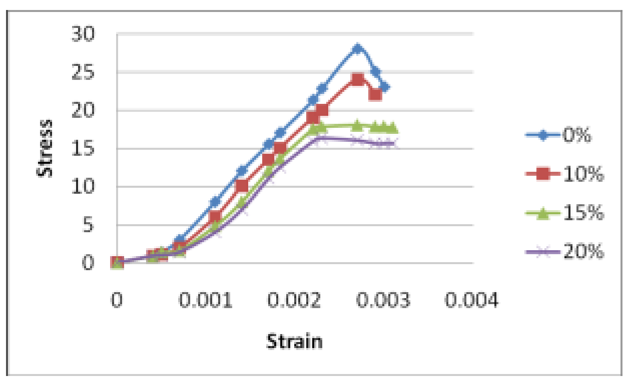
5) Test results for stress and strain

Table 11

Strain(mm)	Stress(MPa)			
	0 percent rubber	10 percent rubber	15 percent rubber	20 percent rubber
0	0	0	0	0
.0004	0.9	0.9	0.9	0.9
.0005	1.4	1.1	1.4	1.0
.0007	3.0	2.0	1.6	1.4
.0011	8.0	6.0	4.8	4.0
.0014	12.0	10.0	8.0	7.0
.0017	15.5	13.5	12.0	11.0
.00183	17.0	15.0	13.6	12.5
.0022	21.3	19.0	17.5	15.9
.0023	22.8	20.0	17.8	16.3
.0027	28.0	24.0	18.0	16.0
.0029	25.0	22.0	17.8	15.6
.003	23.0		17.8	15.6
.0031			17.7	15.6

Stress–strain relationship

The relationship between stress and strain is shown in Fig. 6 for the different rubber contents in the concrete mix. Two different behaviour patterns are shown for the stress–strain curves. The stress–strain behaviours of the specimens containing rubber of up to 10% behave in a similar trend to the control specimen, but having a smaller peak. From the figure, it can be observed that there is linear increase of stresses until it reaches its peak before energy is release specimen's fracture. For this case, the specimens behaved like a brittle material of which the total energy generated upon fracture is elastic energy. However, nonlinear behaviour is seen for the other two specimens containing 15% and 20% rubber. Here, once the peak stress is reached, the specimen continues to yield, as represented by the branch-line. This behaviour is similar to the behaviour of the tough materials having most of its energy generated upon fracture as plastic energy. Plastic energy is defined as the amount of energy required to produce a specified deformation after the elastic range, which increased the ability of the material to support loads even after the formation of cracks. Therefore, it can be stated that concrete with a higher percentage of crumb rubber possess high toughness, since the generated energy is mainly plastic.



Relationship between stress and strain for different rubber contents (fig.6)

IV. CONCLUSION

The test results of this study indicate that there is great potential for the utilization of waste tyres in concrete mixes in several percentages, ranging from 5% to 20%. Based on present study, the following can be concluded:

1) The strength of modified concrete is reduced with an increase in the rubber content; however lower unit weight meets the criteria of light weight concrete that fulfill the strength requirements as per given in table 5.9 by Neville in 1995.

2) Concrete with higher percentage of crumb rubber possess high toughness The slump of the modified concrete increases about 1.08%, with the use of 1 to 10% of crumb rubber.

3)Stress strain shows that concrete with a higher percentage of crumb rubber possess high toughness, since the generated energy is mainly plastic.

4) Failure of plain and rubberized concrete in compression and split tension shows that rubberized concrete has higher toughness.

5) The split tensile strength of the concrete decreases about 30% when 20% sand is replaced by crumb rubber.

6) The flexural strength of the concrete decreases about 69% when 20% sand is replaced by crumb rubber.

7) The compressive strength of the concrete decreases about 37% when 20% sand is replaced by crumb rubber.

8) For large percentage of crumb rubber the compressive strength gain rate is lower than that of plain concrete.

REFERENCES

[1] Al-Akhras NM, Smadi MM (2002) Properties of tyre rubber ash mortar. Dhir RK et al. (Eds.), Proceedings of the International Conference on Sustainable Concrete Construction. University of Dundee, Scotland, UK pp. 805–814.

[2] Albano C, Camacho N, Reyes J, Feliu JL, Hernandez M (2005) Influence of scrap rubber addition to Portland Concrete Composites: Destructive and non-destructive testing. Composite Structures 71: 439–446.

[3] Ali NA, Amos AD, Roberts M (1993) Use of ground rubber tyres in Portland cement concrete.

[4] Al-Tabbaa A, Aravinthan A (1998) Natural clay-shredded tyremixtures as landfill barrier materials.Waste Management 18 (1): 9–16.

[5] Benazzouk A, Queneudec M (2002) Durability of cement rubber-composites under freeze thaw cycles. Dhir RK et al. (Eds.), Proceedings of the International Conference on Sustainable Concrete Construction. University of Dundee, Scotland, UK, pp. 356–362.

[6] Biel TD, Lee H (1996) Magnesium oxychloride cement concrete with recycled tyre rubber. Transportation Research Record No. 1561, Transportation Research Board, Washington, DC,pp. 6–12.

[7] Dhir RK (Ed.), Proceedings of the International Conference on Concrete 2000, University of Dundee, Scotland, UK pp. 379–390

[8] Downs LA, Humphrey DN, Katz LE, Blumenthal(1997)Water quality effects of using tyre chips below the groundwater table. Report Prepared by the Department of Civil and Environmental Engineering, University of Maine, Maine for the Maine Department of Transportation, Orono.

[9] Edil TB, Bosscher PJ (1992) Development of engineering criteria for shredded or whole tyres in highway applications. Report No.WI 14-92, Department of Civil and Environmental Engineering, University of Wisconsin, Madison, WI.

[10] Eldin NN, Senouci AB (1993) Rubber-tyre particles as concrete aggregates. ASCE Journal of Materials in Civil Engineering 5 (4): 478–496.

[11] Fattuhi NI, Clark NA (1996) Cement-based materials containing tyre rubber. Journal of Construction and Building Materials 10 (4): 229–236.

[12] Hernandez-Olivares F, Barluenga G (2004) Fire Performance of recycled rubber-filled highstrength concrete. Cement and Concrete Research 34 (10): 109–117.

[13] Khatib ZK, Bayomy FM (1999) Rubberized Portland cement concrete. ASCE Journal of Materials in Civil Engineering 11 (3): 206–213.

[14] Topcu IB, Avcular N (1997a) Collision behaviors of rubberized concrete. Cement and Concrete Research 27 (12): 1893–1898.

[15] Concrete Aggregates From Discarded Tyre RubberBy Kaushal kishore

[16] IS : 383 - 1970, "Coarse and Fine• aggregate from natural sources for concrete," Indian Standard Institution, New Delhi.

[17] IS : 8112 - 1976, "High Strength ordinary Portland cement," Indian Standard Institution, New Delhi.

[18] IS : 2430 - 1969, "Methods for sampling of aggregates for concrete," Indian Standard Institution, New Delhi.

[19] IS : 2386 - 1963, "Methods of tests for aggregates for concrete," Indian Standard Institution, New Delhi.

[20] IS : 516 - 1959, "Method of test for strength of concrete," Indian Standard Institution, New Delhi.

[21] IS : 10262 - 2009, "Recommended guidelines for concrete mix design," Indian Standard Institution, New Delhi.