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Utilization of Waste Rubber Tyres as an Ingredient in Concrete Mixes.

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Abstract: Improvements in materials used for construction have an important impact on the Construction industry. Therefore many efforts have been made in the construction industry to put to use waste material products, e.g., worn-out tyres, into useful and Economical items. If this is achieved successfully it will contribute to the reduced quantity of waste material dumping problems by effective use of these waste materials in the building sector. The present research will concentrate on how to effectively put to use the rubber waste tyres in construction industry so as to reduce their impact on our precious environment and also using them effectively in the construction process. It will involve comprehensive laboratory tests on fresh and hardened rubberized concrete in order to study its strength behavior i.e. compressive and flexure strength, and its impact resistance with different volume of rubber in crumb state (fine aggregate).

Volume variation of crumb rubber. The proposed research work will study the effect of volume variation of crumb rubber on the compressive strength, flexural strength, split tensile strength & workability in terms of Slump in mm of the concrete.

Keywords: Construction industry, crumb rubber, rubberized concrete.

I. INTRODUCTION

The total number of registered motor vehicles in India was 210024201 as on 02.05. 2015. About Eleven lakh new vehicles are added to Indian roads each passing year which results in increase of about three crore discarded tyres each year, since these tires are made of non-decaying rubber material its accumulation with time poses a great threat to the environment. Hazardous materials can be classified as chemical, toxic or non-decaying material accumulating with time. The accumulation of non-decaying materials like rubber and plastic is a serious issue because it renders the soil useless for cultivation and results in soil pollution. However, if a positive method is devised for reusing this non-decaying material its accumulation can be very much reduced such as reuse of rubber tyres in concrete mixes which will also have a beneficial effect. Disposal of worn out tires is a major challenge to the world communities nowadays which has to be considered on priority bases by the municipalities around the world in order to save our environment. Burying of discarded automobile tyres render the soil unfit for cultivation and result in soil pollution however fewer are used as raw material for manufacture of rubber goods or fuel.

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. The disposal of waste tyres as shown above accumulates huge stretches of land and renders the land useless and polluted as such it is a major challenge for the world today to device a method to reuse the waste tyres and hence reduce its dangerous environmental hazards.

Therefore it can be concluded that reusing wasted out tires as an ingredient in concrete mixes is a necessity than a desire. 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, and it should be noted here that burning tyres also causes air pollution and release of toxic smoke. Tyre fires are difficult to extinguish - they produce a lot of smoke, which often carries toxic chemicals from the breakdown of rubber compounds while burning.

The use of scrap tyre 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 fine aggregate in cement concrete.

II. METHODOLOGY

The methodology used in the fallowing work is described as below

Total Number of concrete specimens = No.of samples for each percentage x 4 x no. of Tests

Total Number of concrete specimens = 3 x 4 x 3

Total Number of concrete specimens = 36 specimens for 7 days curing tests

Same number of specimens will be needed after 28 days of curing.

A total of 36 x 2 =72 specimens will be needed for this experimental work.

This research aims at utilizing the waste rubber tyres in concrete mixes in an effective way. Waste rubber tyres are shredded and converted into crumb form using suitable means and used in concrete mixes as a partial replacement for fine aggregates. The percentage of crumb rubber is varied from 0 to 18 percent by weight/volume of fine aggregates required for the particular mix and tests are carried out in the laboratory in order to evaluate its strength parameters.

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Concrete specimens are casted in the laboratory in M30 grade using 0, 6, 12, & 18% of crumb rubber by weight/volume of fine aggregate required for M30 design mix.
The main parameters of this investigation include the compressive strength of concrete specimen. The strength performance of concrete specimen is evaluated.
Ultra tech cement of 43 N/mm2 minimum 28 days compressive strength has been used in the research.

Basic materials required

1. OPC 43 grade cement (ultra tech).
2. Natural crushed coarse aggregates locally available.
3. Natural fine aggregate (naturally occurring river sand).
4. Water (fresh drinkable water)
5. **Fine crumb Rubber.**

Engineering properties of crumb Rubber

(A) Specific Gravity

Ratio of unit weight of tyre shreds to the unit weight of water is its specific gravity; this will depend on the amount of steel wire in the tyre it varies from 1.02 to 1.27. For comparison soil weights twice than rubber shreds because specific gravity of soil ranges from 2.6 to 2.8.

(B) Water absorption

Expressed as percentage water absorption is the amount of water absorbed by the tyre shreds, water absorption will depend on the dry weight of crumb rubber. Water absorption of rubber varies from 2 to 4.3 %.

(C) **Compressibility**

Vertical strains of about 25% may occur in tyre shreds under low vertical stress of approximately 48kpa and vertical strains of about 40% may occur under high stress of about 414kpa.

Cement.

Cement is a material that has cohesive and adhesive properties in the presence of water. Such cements are called hydraulic cements. These consist primarily of silicates and aluminates of lime obtained from limestone and clay. There are different types of cement as classified by the Bureau of Indian standards (BIS).

1. 33 grade opc.
2. 43 grade opc.
3. 53 grade opc.
4. Portland cement.
5. High Alumina cement.
6. Super sulphate cement.
7. Spacial cements.

Cement used in this research is OPC of 43 grade ultra tech brand.

Water.

Important properties of water to be used for cement concrete are:

1. Content of organic solids not more than 0.02%.
2. Content of inorganic solids not more than 0.30%.
3. Content of sulphates not less than 0.05%.
4. Content of sulphate Alkali chlorides not more than 10%.
5. Turbidity not more than 2000ppm.
6. Acid not more than 10000ppm.
7. PH should be between 4.5 to 8.5.

Water in concrete has to perform two functions:

1. Water enters into chemical action with cement and this action causes setting and hardening of concrete.
2. Water lubricates the aggregates and it facilitates the passage of cement through voids of aggregates. This means that water makes the concrete workable. Water required for chemical reaction is about 25% by weight of cement i.e. 36% by volume.

Aggregates & aggregate size

Aggregates occupy the bulk quantity of volume in concrete, these are of two types depending on their size which are coarse aggregates & fine aggregates. Coarse aggregates are larger in size than fine aggregates. For RCC work the maximum size of aggregates is limited to 20mm to 25mm. For a concrete of given workability rounded aggregates require least water cement ratio. Particle shape is very important since the water cement ratio governs greatly the strength of concrete. In general aggregate size greater than 4.75mm is considered as coarse aggregate and aggregates size less than 4.75mm is considered as fine aggregate.
Here it is concluded that in order to add tyre rubber as a fine aggregate in concrete mixes its size has to be less than 4.75mm.

Concrete mix design.

The main parameter which decides the strength of the resulting concrete mix is the proportioning of the constituents of concrete. When the proportioning of constituent materials of concrete is done by arbitrary standards the concrete hence produced is termed as nominal mix concrete, but when the proportioning of its constituents is done by use of certain established relationships which are based on inferences drawn from large number of experiments the concrete thus produced is termed as design mix concrete. The basic assumption in design mix concrete produced is that of water cement ratio.
Several methods of mix design have evolved over the years in different countries and have become confident. In India recommendations for mix design are given in IS 10262: 2009 and SP 23: 1982 however these are only recommendations in practice any proven design may be adopted. All that matters finally is that the designed mix must meet **the specified** requirements **within the** fresh and hardened states.
In this investigation the Indian standard recommendations were fallowed for M30 design mix and adopted for proportioning of constituent materials for concrete. Concrete has to be of satisfactory quality in both fresh and hardened states which is best achieved by trial mixes arrived at by the use of certain established relationships among different parameters and by analysis **of knowledge** already generated thereby providing a basis for judicious combination of all the ingredients involved.
The results for trial mixes in tabular form for 1 cum of concrete is given as as fallows

Trial Mix No.	Mass of cement in kgs	Mass of coarse aggregate in kgs.	Mass of Fine aggregate in kgs.	Water / cement ratio	Mix ratio
1.	413.3	1157.52	744.12	0.45	1:1.8:2.8
2	400.93	1164.24	748.44	0.45	1:1.87:2.9
3.	445.48	1161.44	716.04	0.405	1:1.6:2.6
4.	364.48	1163.008	779.328	0.495	1:2.14:3.19

Slump values in mm and 28 day target compressive strength of the concrete specimens came out to be as fallows

Trial Mix No.	Slump in mm	Compressive strength in N/mm^2.
1	80	37.3
2	65	36.9
3	48	38.6
4	75	36.3

Table 1(a) Final Mix proportion

Water (kg/cum)	**Cement (kg/cum)**	**Fine aggregate (kg/cum)**	**Coarse aggregate (kg/cum)**
180.42	445.48	716.04	1161.44
Mix ratio			
0.405	1	1.6	2.6

III. RESULTS & DISCUSSIONS.

This part of this investigation deals with the result output of the experiments and deductions made on the basis of these results which will show how the concrete behavior will change on changing the volume of fine aggregates and replacing it partially with crumb rubber. Hence from this part of the research the viability of using crumb rubber as a constituent in concrete mixes will be studied and discussed.

Test results for compressive strength test.

Table 1: 28 day's compressive strength results.

Size of cube 150mm x150mmx150mm, concrete mix M30

S No.	**%age of crumb rubber used as partial replacement for fine aggregates by weight.**	**Load at failure in KN**	**28 days Compressive strength in N/mm^2**
1.	0%	868.5	38.6
2.	6%	705.9	31.37
3.	12%	601.9	26.75
4.	18%	520.6	23.11

Table 2, 7 day compressive strength

S No.	**Percentage of crumb rubber used as partial replacement for fine aggregates by weight.**	**Load at failure in KN**	**7 days Compressive strength in N/mm^2**
1.	0%	560.47	24.91
2.	6%	446.85	19.86
3.	12%	385.2	17.12
4.	18%	335.7	14.92

Variation of compressive strength with percentage of crumb rubber used after 7 days of curing

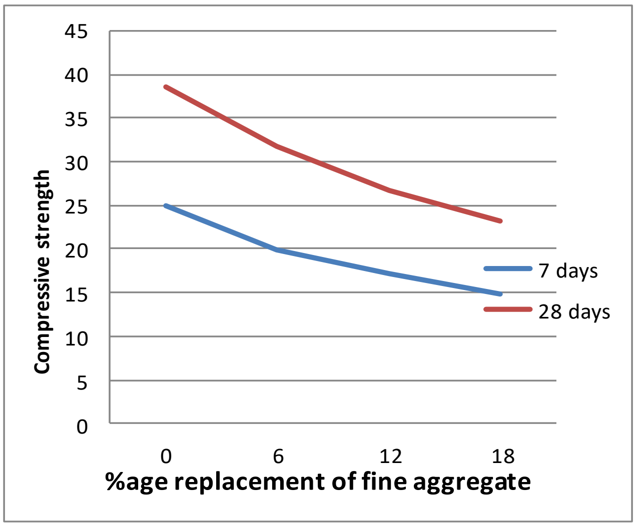

Figure 1, variation of compressive strength with percentage of crumb rubber used

IV. DISCUSSION

As indicated by table 1 & table 2 and illustrated in figure 1 by drawing a curve for compressive strength behavior with increase in the percentage of crumb rubber from 0 to 18 percent, the compressive strength of the concrete decreases with increase in the percentage of rubber used. The decrease in the compressive strength fallows a non-linear path from 0 to 18 percent of crumb rubber used. It clearly shows that if we further increase the percentage of crumb rubber in the concrete mix beyond 18% the compressive strength will decrease considerably. There is a 35.8 percent decrease in the compressive strength by partially replacing fine aggregate by 18% of crumb rubber. Hence it should be taken into consideration while using the rubberized concrete in any construction project. However this concrete mix can be readily used in the projects where strength is not a primary requirement.

Flexure strength test results.

Table 3: Variation of flexure strength at 7 days.

S No.	Percentage of crumb rubber used as partial replacement for fine aggregates by weight.	Load at failure in KN	Flexural strength in N/mm^2
1.	0%	6.9	3.45
2.	6%	6.02	3.01
3.	12%	4.98	2.49
4.	18%	2.84	1.42

Size of cube 500mm x100mmx100mm, concrete mix M30

Table 4: Variation of flexure strength after 28 days of curing

S No.	Percentage of crumb rubber used as partial replacement for fine aggregates by weight.	Load at failure in KN	Flexural strength in N/mm^2
1.	0%	10.8	5.4
2.	6%	9.7	4.8
3.	12%	7.7	3.85
4.	18%	4.5	2.25

Size of cube 500mm x100mmx100mm, concrete mix M30

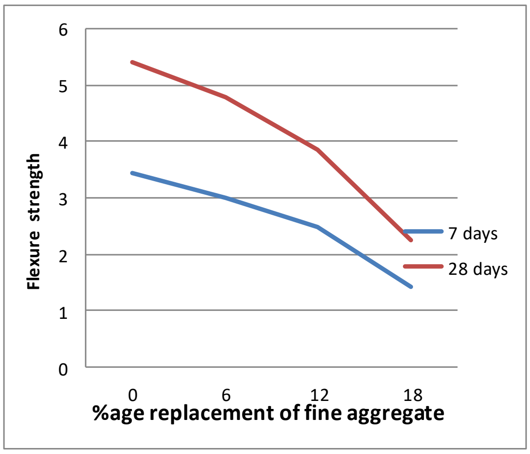

Figure 2. variation of flexure strength

Discussion.

It is clear from the test results of the experiment indicated in table 3, & table 4, figure 2, that the flexural strength of the concrete specimen with crumb rubber as partial replacement of fine aggregate is less than that of concrete specimen having zero percentage of crumb rubber. The flexural strength further gets decreased with increase in the percentage of crumb rubber as partial replacement of fine aggregate. Flexural strength will drastically get reduced if we increase the percentage of crumb rubber more than 18%, and use of the concrete will not suffice the project if strength of concrete is the main requirement needed in the project however rubberized concrete may be readily used in concreting processes where strength is not the primary requirement. The decrease in the flexural strength may be due to weaker bonding of rubber with concrete and increase in the void ratio of concrete specimen. It may however be noted that the specimen with replaced fine aggregate by tire rubber showed enormous amount of distortion than normal concrete before failure which shows that it has high toughness value than normal concrete.

Split tensile strength test results.

Table 5 split tensile strength test after 7 days of curing Size of cylinder 300mm x 150mm concrete mix M30

S No.	Percentage of crumb rubber used as partial replacement for fine aggregates by weight.	Load at failure in KN	Flexural strength in N/mm^2
1.	0%	154.72	2.19
2.	6%	139.8	1.98
3.	12%	87.6	1.24
4.	18%	79.12	1.12

Table 6.Test results for split tensile strength test after 28 days

Size of cylinder 300mm x 150mm concrete mix M30

S No.	Percentage of crumb rubber used as partial replacement for fine aggregates by weight.	Load at failure in KN	Flexural strength in N/mm^2
1.	0%	245.15	3.47
2.	6%	146.7	3.19
3.	12%	137.2	1.94
4.	18%	123.3	1.74

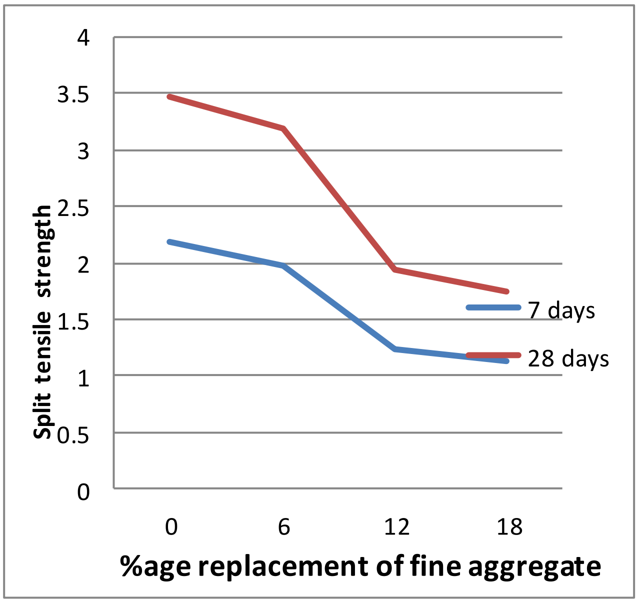

Figure 3. Variation of flexure strength

Discussion

It can be concluded from this experiment that split tensile strength gets decreased with increase in the use of crumb rubber as partial replacement of fine aggregates and fallows a non-linear relationship. There is about 25 to 30 percent decrease in the split tensile strength of concrete with 18 percent introduction of crumb rubber in it. If we go on further increasing the percentage of crumb rubber beyond 18 percent the split tensile strength will get decreased considerably. However it may be noted that concrete with crumb rubber has higher toughness than the specimens without crumb rubber. Hence if used wisely crumb rubber can be used in concrete very effectively for particular projects utilizing its higher toughness behavior. Concrete with higher proportions of crumb rubber up to 18% behaves like a sponge with elastic character which has high toughness than usual concrete specimens.

Workability in terms of slump results.

The slump values at various percentages of crumb rubber are Depicted in a tabular form as fallows.

Table 7

S. No.	Percentage of crumb rubber	Slump value in mm
1.	0	48
2.	6	50
3.	12	54
4.	18	36

This behavior is depicted in a graphical representation as shown in figure 4

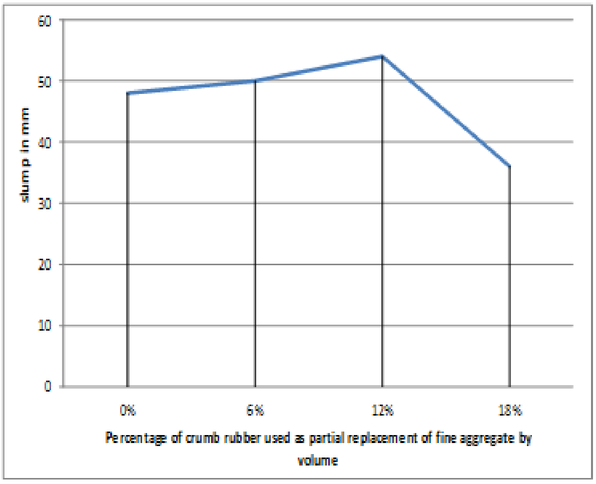

Figure 4

Discussion.

The slump behavior of the concrete with and without inclusion of crumb rubber is shown above in table 7 and figure 4. As depicted by the results the slump of the concrete specimen tends to increase in an almost linear behavior up to 12% inclusion of crumb rubber but after further increase of the percentage of crumb rubber the slump decreases gradually. This means that there is a particular value of percentage of crumb rubber at which the slump or workability of the concrete will be maximum and after further increase in the percentage of the crumb rubber the workability will tend to decrease. However it may be noted that despite the decrease in the slump value the concrete with crumb rubber is found to be workable than the normal concrete specimen without inclusion of crumb rubber this may be attributed to elastic behavior of rubber particles in the concrete mix and their slippery characteristics that renders the concrete mix more workable.

V. CONCLUSION

The conclusions from the work already done based on the experimental results and discussions will be dealt with in this chapter. It may be noted that there is a great possibility and scope of using rubber waste tyres as an ingredient in concrete mixes; it is rather a need of the hour to utilize rubber in this manner because of great environmental threat. The fallowing conclusions can be made from the above experimental work.

1. The target compressive strength of the concrete decreases from 38.6N/mm^2 to 23.11 N/mm^2 at 0% and 18 % replacement of fine aggregates by crumb rubber respectively.
2. On replacing fine aggregate by tyre rubber in fine state in the range of 0 to 6 percent for M30 grade, strength pertaining to a lower grade concrete M25 is obtained which could be used as an alternative to M25 mix.
3. The decrease in the target compressive strength fallows a non- linear path which will further get decreased as we go on increasing the percentage of crumb rubber.

4. The tensile strength of the concrete on introduction of crumb rubber decreases from 5.4N/mm^2 at 0% of crumb rubber to 2.25 N/mm^2 at 18 % replacement of fine aggregates by crumb rubber.
5. The decrease of tensile strength fallows a nonlinear path and there is considerable reduction in tensile strength after introduction of crumb rubber in the concrete.
6. There is also a reduction in the split tensile strength of concrete from 2.277 N/mm^2 at 0% replacement of fine aggregates by crumb rubber to 1.74 N/mm^2 at 18% replacement.
7. The reduction in split tensile strength of concrete on partial replacement of fine aggregates by crumb rubber fallows a non- linear path.
8. Concrete with partially replaced aggregate with crumb rubber from 0 to 10% possesses higher value of toughness than normal concrete.
9. There is a large effect on workability of the concrete when fine aggregate is partially replaced with crumb rubber, as depicted in the test results the slump of the concrete increases from 44mm at 0% crumb rubber to a maximum value of 50mm at 12% partial replacement of fine aggregate with crumb rubber, after further increase in the percentage of crumb rubber the slump decreases to 36mm at 18% partial replacement.
10. This could refer that there is some critical value for percentage of crumb rubber at which the slump value comes out to be maximum after further increase in the percentage of crumb rubber the slump decreases.
11. Usually a lower slump will refer to a concrete with higher compressive strength but it must be noted here that after increasing the percentage of crumb rubber in the concrete the slump decreases but also the compressive strength decreases considerably.
12. At lower slump value normal concrete is less workable but after partially replacing fine aggregate by crumb rubber by more than 12% the slump value decreases however the concrete is more workable than normal concrete

FUTURE SCOPE

The availability of waste rubber tyres in bulk quantities and their disposal scenario imposes a duty on every sane person to find an alternative process of using them in an efficient and useful way. This research is a small attempt to use them in construction processes so as to reduce their quantity in the environment. The concrete so formed by using waste rubber tyres can successfully be used as a light weight concrete. The density of light weight concrete varies from 300 to 1850 kg/m^3 with a varying compressive strength from 0.3 to 40 MPa. The lower range of light weight concrete do not require large values of compressive strength, therefore rubberized concrete can be efficiently used in this range. For using rubberized concrete as high strength light weight concrete more research is needed to be done with efficient admixtures like silica fume, fly ash etc.

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