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# Study on Possibility of Utilisation of Waste Rubber Tyre as a Constituent of Low Grade Concrete

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***Abstract*— Waste rubber tyres have become a significant cause of environmental distress, due to increasing production of automobiles, leading to an exponential increase in the quantity of waste tyres. They have however, been found to be successfully utilisable for different types of work. One such probable use could be as a constituent of concrete, which may result in reduction in use of natural resources. This project therefore attempts to use these materials as a constituent of low grade concrete and to determine its feasibility at any proportion for M-25 concrete. The method involved partial replacement of coarse aggregates by used rubber tyres, at 10%, 20% and 30% by weight of coarse aggregates. This study shows a decreasing pattern in strength of concrete with addition of rubber as constituent. Target strength was achieved in the design mix M-25 at 10% of rubber constituent. This shows possibility of utilisation of waste rubber tyre as a constituent of low grade of concrete.**

***Keywords*— *Compressive Strength, Waste Rubber tyres, Concrete, Partial Replacement***

## I. INTRODUCTION

Wastes are produced by every organism, and the volume of waste generated depends on the biological characteristics of organisms. Before the coming of industrialisation, waste management generally dealt with the wastes produced by living organisms. The major focus during that time was on physiological wastes such as those generated from burning of wood, or agricultural wastes buried under the ground. However, with the advent of industrialisation, the standard of living of human beings has enhanced, and simultaneously, there has been introduction of several new forms of wastes, many of which are found to be harmful for the planet. One such detrimental material is the waste rubber tyres. Waste tyres are defined as those tyres that are bald and worn down to the tread belt or have bulges or sidewall damage, and are not suitable to be retreated as a result of long usage. In the current scenario, any motor vehicle utilises a series of tyres during its entire lifetime, and the used tyres become waste materials when they get worn out in due course of time, and as the number of automobiles continue to rise, the volume of waste tyres generated increases manifold, and their disposal is now a serious challenge to the society. Along with this, the other major issue that we face is the depletion of the good quality aggregates. Aggregates are a prime constituent of concrete, and in India, most constructions are of concrete structures. This has led us to a realisation that the exploitation of natural aggregates has led to shrinkage in the availability of aggregates. Restrictions have been imposed on mining and quarrying activities, which has led us to look at alternate aggregates to be utilised as construction materials. The objective of the study is to analyse the compressive strength of concrete made by partial replacement of coarse aggregates with rubber. The work involved testing of concrete made with 10%, 20% and 30% replacement of coarse aggregates with rubber tyres of 20 mm down size. The aim was to determine whether the partial replacement of aggregates by rubber would be suitable for low grade of concrete. This has been done to attempt to put to use waste rubber tyres rather than disposing them in landfills or burning them. The other target for attempting this project was to reduce the burden on the existing natural resources, especially the sources of coarse aggregates, in order to provide them time for replenishment and to therefore play a role in sustainable development. The two images below indicate how serious the issue of waste rubber tyres is. Figure 1 is a satellite image of the Sulaibiya tyre dump at Kuwait, which is estimated to be the biggest tyre landfill of the world, so large that it is visible from space. Figure 2 is an image of the Heyote tyre dump, which caught fire and continued to burn for fifteen years, and this illustrates the possible consequence of setting waste rubber tyres on fire, and depicts why burning of tyres is not to be considered a feasible disposal method.

Fig 1 Satellite image of Sulaibiya tyre dump, Kuwait

Fig 2 The Heyote Tyre Dump on fire

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## II. EASE OF USE

Rather than being piled in landfills, waste tyres can be used for other alternative purposes. A number of fields have been ascertained where waste tyres can be used such as for the production of cement, for obtaining several tyre-derived products which may be of immense importance in the coming times or simple re-use without any recycling means. This has been done to attempt to put to use waste rubber tyres rather than disposing them in landfills or burning them.

### *A. Manufacture of Cement*

Here, tyres are basically 3used as a fuel. This is done by introducing the tyres into kilns, where temperatures are between 1000ºC-1200ºC. The high temperature leads to the combustion of tyre. The steel and zinc present in tyres becomes a component of cement.

### *B. Tyre derived products*

A number of tyre-derived products can be obtained with the recent technology. The products may be major or minor ones. Tyres are currently used in embankments, backfill for walls or bridge abutments and as barriers to control soil erosion and runoff of rainwater. They are used in manufacturing of steel, as an alternate source of carbon. They are also recycled for use, as new shoe products and sandals. As per 2003 market records, 130 million tyres were used for tyre derived fuel, 56 million for civil engineering projects while 6.5 million tyres were used for agricultural purposes and 3 million for other miscellaneous purposes.

### *C. Direct Re-use*

Tyres can be directly reused for certain purposes. One of the most common examples is the use of tyres as swings in parks and playgrounds. Tyres are also used as barriers in car racing circuits, mainly to reduce the level of injury in case of a crash.

## III. EFFECT OF CHIPPED RUBBER ON PROPERTIES OF CONCRETE

1) Slump: The slump of concrete reduces, such that it no longer remains workable by hand, and mechanical vibrators are required.

2) Density: The density of concrete reduces on using rubber as a constituent material. This is evident due to the fact that the specific gravity of rubber is less than the specific gravity of coarse aggregates.

3) Air Content: The air content in concrete increases with increase in the quantity of good quality rubber.

4) Bonding with the materials: This depends on the roughness of the rubber. More the roughness better is the bond developed with the other constituents. The roughness of rubber can be improved by pretreatment, most commonly with carbon tetrachloride.

5) Toughness: Concrete made with rubber as a constituent does not undergo brittle failure. This is because rubber can undergo large tensile deformations. This type of concrete is very useful when vibration damping of building is required, as in case of earthquakes when the structure is subjected to lateral seismic forces and vibrations.

6) Impact resistance: The impact resistance of concrete increases on using rubber as a constituent material.

7) Fire resistance: It has been found that when rubber is mixed with cement and aggregates, its flammability in the mixture reduces. This has led to the conclusion that such concrete shows satisfactory fire resistance.

## IV. EXPERIMENTAL DETAILS

### *A. Materials*

Cement of grade OPC-43
Fine aggregates
10 mm down and 20 mm down coarse aggregates
Chipped rubber tyres of 20 mm down size

### *B. Methodology*

The compressive strength was performed as per the specifications of IS 516:1959. For this test, the mix calculations were performed as per the guidelines of IS 10262:2009. Rubber was used as partial replacement of coarse aggregates at 10%, 20% and 30% by weight. The water cement ratios adopted were 0.5, 0.48 and 0.46. At every percentage use of rubber, three trials were carried out, with each trial consisting of a total of six cubes, three for testing after 7 days of curing and three for testing after 28 days of curing. Three trials were also carried out without any replacement of coarse aggregates. Therefore, casting of 72 cubes was done in total. Blending of aggregates was performed before calculation of mix proportions.

### *C. Procedure*

1) Gradation of aggregates is carried out as per the provisions of IS 383:1970. This helps to determine the zone of fine aggregates. Gradation of coarse aggregates helps in carrying out the process of blending of 10 mm and 20 mm aggregates.
2) After performing the blending of aggregates and obtaining the mix requirements, the constituents, along with the required quantity of water was mixed in the batch mixer.
2) The mix was then required to be poured out into the cube moulds of sides 150 mm. The cube moulds were cleaned, and the inside was oiled. Oiling reduces the adhesion between the concrete mix and the surface of the mould. The mix was filled in the mould and was compacted by the vibrating machine and by tamping with tamping rods.
3) The top surface was levelled with a trowel.
4) The mix was allowed to harden in the mould for a period of 24 hours.
5) After 24 hours, the mould was removed and the cubes were placed in water for curing for the required duration of either 7 days or 28 days.
6) The cubes were taken out after the desired curing period. Excess water from the surface of cubes was removed. The weight of the cubes was taken for each trial, under different percentages of rubber to obtain the weight of 7 day and 28 day hardened concrete.

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7) The cubes were then placed in the compression testing machine, and properly alighned centrally on the base place. The upper movable portion was made to the top surface of the specimen.
8) Compressive load was gradually applied, and the load at failure was obtained in each case from which the compressive strength of individual cubes was obtained.

## V. ACCEPTANCE CRITERIA

The test results must conform to the specifications of the Acceptance Criteria provided as per IS 456:2000. The target strength to be achieved is given as:
$f_m = f_{ck}+1.65s$
Also, the mean of group of four non-overlapping consecutive samples is given by:
$f_m \geq f_{ck}+0.825s$ or $f_{ck}+3$, whichever is greater, for M15 and lower.
$f_m \geq f_{ck}+0.825s$ or $f_{ck}+4$, whichever is greater, for M20 and above.
Individual cube results must conform to the following recommendations:
$f_c \geq f_{ck}-3$ MPa for M15 grade.
$f_c \geq f_{ck}-4$ MPa for M20 grade and higher

## VI. RESULTS

TABLE I. SLUMP AND WEIGHT OF CONCRETE CUBES

| PERCENT AGE OF RUBBER | TRIAL MIX | SLUMP (MM) | MEAN WEIGHT OF CUBES | |
|---|---|---|---|---|
| | | | BEFORE CURING (KG) | AFTER CURING (KG) |
| 0 | 1 | NIL | 8.618 | 8.707 |
| | 2 | 2 | 8.581 | 8.563 |
| | 3 | 3 | 8.528 | 8.511 |
| 10 | 1 | NIL | 7.524 | 7.839 |
| | 2 | NIL | 7.595 | 7.874 |
| | 3 | NIL | 7.572 | 7.798 |
| 20 | 1 | NIL | 7.484 | 7.608 |
| | 2 | NIL | 7.400 | 7.737 |
| | 3 | NIL | 7.484 | 7.564 |
| 30 | 1 | NIL | 7.215 | 7.432 |
| | 2 | NIL | 7.274 | 7.400 |
| | 3 | NIL | 7.259 | 7.489 |

TABLE II. MIX RESULTS WITHOUT USE OF RUBBER

| Trial Mix No. | Cube No. | 7 days Compressive Strength ($N/mm^2$) | 28 days Compressive Strength ($N/mm^2$) | 28 days Avg. Compressive Strength ($N/mm^2$) | Remarks |
|---|---|---|---|---|---|
| TM-1 | 1 | 34.88 | 37.33 | 40.89 | Target Strength Achieved |
| | 2 | 36.67 | 44.44 | | |
| | 3 | 37.78 | 40.89 | | |
| TM-2 | 1 | 31.55 | 32.89 | 37.78 | Target Strength Achieved |
| | 2 | 36.89 | 43.11 | | |
| | 3 | 28.44 | 37.33 | | |
| TM-3 | 1 | 36.00 | 36.44 | 37.48 | Target Strength Achieved |
| | 2 | 33.33 | 35.11 | | |
| | 3 | 34.67 | 40.89 | | |

TABLE III. TRIAL MIX AT 10% REPLACEMENT BY RUBBER

| Trial Mix No. | Cube No. | 7 days Compressive Strength ($N/mm^2$) | 28 days Compressive Strength ($N/mm^2$) | 28 days Avg. Compressive Strength ($N/mm^2$) | Remarks |
|---|---|---|---|---|---|
| TM-1 | 1 | 21.24 | 32.89 | 32.23 | Target Strength Achieved |
| | 2 | 20.44 | 32.23 | | |
| | 3 | 19.82 | 31.56 | | |
| TM-2 | 1 | 25.11 | 33.56 | 33.44 | Target Strength Achieved |
| | 2 | 24.89 | 34.53 | | |
| | 3 | 24.44 | 32.22 | | |
| TM-3 | 1 | 28.44 | 38.36 | 37.53 | Target Strength Achieved |
| | 2 | 26.22 | 36.67 | | |
| | 3 | 27.28 | 37.56 | | |

TABLE IV. TRIAL MIX ST 20% REPLACEMENT BY RUBBER

| Trial Mix No. | Cube No. | 7 days Compressive Strength ($N/mm^2$) | 28 days Compressive Strength (N/mm2) | 28 days Avg. Compressive Strength (N/mm2) | Remarks |
|---|---|---|---|---|---|
| TM -1 | 1<br>1 | 18.67 | 20.00 | 18.81 | Failed to achieve target strength |
| | 2<br>2 | 14.67 | 18.22 | | |
| | 4<br>3 | 13.33 | 18.22 | | |
| TM -2 | 2<br>1 | 19.11 | 20.00 | 20.30 | Failed to achieve target strength |
| | 2<br>2 | 22.67 | 21.33 | | |
| | 3<br>3 | 19.11 | 19.56 | | |
| TM -3 | 1<br>1 | 14.22 | 18.67 | 20.00 | Failed to achieve target strength |
| | 2<br>2 | 14.67 | 23.55 | | |
| | 3<br>3 | 16.00 | 17.78 | | |

TABLE V. TRIAL MIX AT 30% REPLACEMENT OF RUBBER

| Trial Mix No. | Cube No. | 7 days Compressive Strength (N/mm$^2$) | 28 days Compressive Strength (N/mm$^2$) | 28 days Avg. Compressive Strength (N/mm$^2$) | Remarks |
|---|---|---|---|---|---|
| TM-1 | 1 | 2.45 | 3.82 | 3.72 | Target Strength not Achieved |
| | 2 | 2.89 | 3.85 | | |
| | 3 | 2.22 | 3.50 | | |
| TM-2 | 1 | 3.78 | 5.23 | 5.81 | Target Strength not Achieved |
| | 2 | 4.22 | 6.12 | | |
| | 3 | 4.22 | 6.07 | | |
| TM-3 | 1 | 3.67 | 5.18 | 6.34 | Target Strength not Achieved |
| | 2 | 4.78 | 7.00 | | |
| | 3 | 4.69 | 6.89 | | |

## VI. CONCLUSION AND INFERENCE

### *7.1 Inference*

From the analysis of mix results, it was observed that in absence of rubber all the trial mixes achieved the target strength. Any of the trials can therefore be recommended for this case.

When 10% of coarse aggregates were replaced by rubber, all the trial mixes achieved the target strength with the third trial showing the maximum value. Any of the trials can be considered but from economic consideration, trial mix 1 can be recommended, that is, corresponding to a water-cement ratio of 0.50 and mix proportion of 1:1.80:2.83.

When 20% of coarse aggregates were replaced by rubber, none of the trial mixes achieve the target strength. Hence, partial replacement of coarse aggregates by utilising 20% of rubber by weight of aggregates is not feasible for M25 grade of concrete.

Similarly, when 30% of the total amount of coarse aggregates was replaced by rubber, none of the trial mixes achieve the target strength. Hence, partial replacement of coarse aggregates by 30% of rubber is not suitable for M25 grade of concrete.

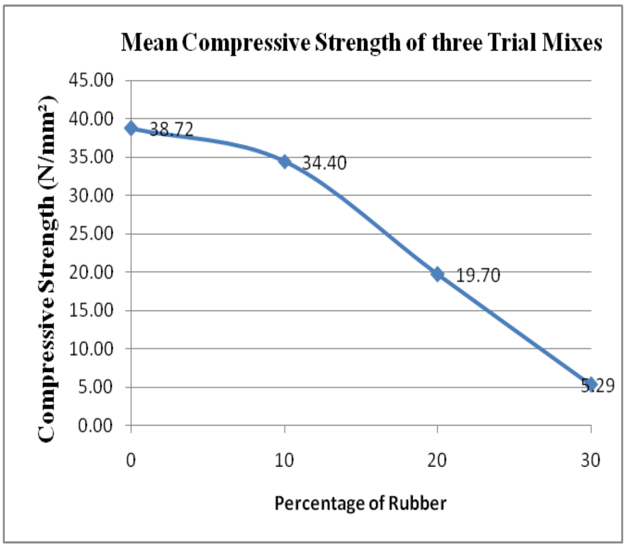


Fig 3 Variation in Mean Compressive Strength with Percentage of Rubber

Along with the compressive strength, the slump and the weight of the cubes were also measured. Very low slump was obtained when rubber was not used, and slump obtained was zero on partial replacement by rubber. The weight of concrete cubes constituting rubber was observed to reduce with the increase in percentage of rubber constituting the concrete.

### *7.2 Recommendations*

From this project study, following recommendations can be made:

1) Waste rubber tyres, chipped to 20 mm down size, has a possibility of being utilised as a constituent of low grade concrete.

2) It can be recommended to use rubber upto a maximum of 10% replacement of total weight of coarse aggregates.

3) The low slump value indicates the recommendation of use of rubber for the purpose of road construction, as it ensures reduced friction and wear and tear of tyres.

### *7.3 Scope for Future Work*

This project provides a scope for future research work and study on the effect of rubber at percentages less than 10%. The study can be extended to higher grade of concrete. Tests can also be conducted for different sizes of rubber. Experimentation can also be performed to study the use of waste rubber in powdered form, especially for road construction. Studies can also be made on the feasibility of use of waste rubber in presence of admixtures for attaining the required workability. Research study can also be conducted on the use of rubber for the construction of earthquake resistant concrete structures due to the fact that rubber increases the toughness of concrete, because it can undergo large deformations and becomes necessary for the vibration damping of structures, especially during earthquakes.

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