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Studying the effect of partial replacement of coarse aggregates in PCC by waste tire rubber aggregates in the case of rigid pavements

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Abstract: In this research work, ours emphasis is laid on the employment of rubber tyre aggregates(5% min & 15% max) by partially replacing the coarser rock aggregates in plain cement concrete in the case of rigid pavements. To get the maximum possible outcome it is very much advised to treat the rubber tire aggregate surface with NaOH and cement paste, before using them with M20 concrete mix . Using untreated rubber it was noticed that the overall compressive strength of the concrete mix had a rapid dip but when treated rubber was employed the overall 28-day compressive strength of the mix showed more than a 90% increase, which is quite satisfactory, considering the availability of used tire rubber at ease and cheap rates furthermore its employment reducing the amount of hazardous threat it can pose to the environment. Such an amount of compressive strength is accepted as quite satisfactory for treated rubberized tires, e.g. in the case of floor construction and concrete pavements where the compressive strength is not of so much importance. It was found that the flexural and split tensile strength is higher than the normal concrete but only when the rubber was treated with NaOH and cement paste. However, the workability had a certain dip, flexibility shows awesome increment, and the resultant mix is lighter than the concrete mix because of the light weight of rubber particles. Such enhancement in the properties like compressive strength, split and flexural strength, lightweight, high impact, and toughness resistance etc. can be helpful in the employment of this concrete in various civil engineering works.

Keywords: OPC (ordinary Portland cement) UTR(untreated rubber),Ctr(cement treated test) NTR (NAOH treated rubber) workability Test, slump value, flexural test ,tensile split strength test, compressive strength.

1. Introduction

As a result of modernization and industrialization, this issue is now gradually becoming a serious concern and hence is also being felt in many Asian countries, especially India and China. The use of waste tyres or used tyres of automobiles has long been a concern for the environment in western nations. India has started to address this danger slowly but gradually, albeit less successfully than its western competitors.

India is moving swiftly from being a developing to a developed country, which is why there are increasingly more cars and tyres on the road every year. As more tyres are produced or used, more trash tyres are created at the end of the year, which increases the number of environmentally dangerous landfills and seashores. Due to the enormous environmental harm that these tyres' many harmful gases they cause, burning them has also been discouraged. The tyre industry in India has expanded by about 12% during the last five fiscal years, from 2010 to 2015, thanks to increased vehicle production. This growth is seen as highly positive for the nation's economy and from the standpoint of industrialization, but it has been acknowledged as a challenge and a growing threat when considering the environmental component. Numerous studies are being conducted to discover more effective uses for recycled tyre rubber, which can be used in a range of applications. It is difficult to employ rubber exclusively in one region or field, though, due to the peculiar physical and chemical properties of rubber and how much of it is generated. Sports fields, the automotive industry, construction, geotechnical/asphalt applications, adhesives and sealants, and items for shock absorption and safety are just a few examples of the many uses of used tyre rubber that have been successfully put to use.

One industry where old tyre rubber can be used to address environmental problems is construction. It has shown significant potential in the construction industry when used with cement concrete pavements. Numerous research have been conducted with notable results to successfully utilise waste rubber in concrete. Two of rubber's unique qualities are regarded to be the main reasons for its rising use in the construction industry: its high flexibility and light weight. Used rubber has effectively taken the place of the aggregates in cement-based concrete. To lessen our impact on the environment and maintain the natural rock aggregates, we have replaced a portion of the standard coarse aggregates with shredded rubber aggregates made by cutting worn tires.

2. Materials and Methods

The materials used in the project are cement, fine aggregates, coarse aggregates, tyre rubber, and sodium hydroxide. From these sources, waste rubber from tyres is only accessible in a constrained quantity and at a constrained number of sites. For this project, the sodium hydroxide was bought at the market, and the tyre rubber was retrieved from a local garage. Cement is a widely used substance with particle sizes ranging from 0.1 to 250 microns. The rubber that was so obtained was crushed until it resembled coarse gravel. To achieve this, rubber was purchased and mechanically or manually cut into the required size of materials.

Examples of experiments that have been conducted on the materials include the following:-

Consistency of cement, starting and ultimate setting times, compressive strength, fineness (sieve analysis), and soundness tests are all performed on cement.

Materials:

OPC: Ordinary Portland cement , the binding material employed with the aggregates , sand and admixtures to form the concrete mix, is basically developed from hydraulic lime and usually consists of limestone. Generally in the powdered form produced by the heating of limestone and clay materials with addition of gypsum to enhance the initial and final setting time.

Rubber tyre aggregates : Rubber tyre aggregates or rubber chips or shredded rubber used in place of rock aggregates in the percentage of 5 to 15 % in our project , is actually an elastic material produced naturally from various plant sources or being synthesized synthetically through some steps of chemical process.

Aggregates : The rock aggregates or in simple language aggregate is broad category of coarse to medium granular partricles of metamorphic or sedimentary orgin rocks, employed in the construction of various engineering construction works, as they work, serve and act as reinforcement to impart overall strength to the concrete mix of any grade. It must be noted aggregates of different sizes like 10mm 15mm and 20mm etc can be employed and used .

NAOH : Sodium hydroxide or commonly called as Caustic soda is reffered as an inorganic compound which was employed in the treatment of shredded rubber along with opc cement to enhance the overall properties of rubber tyre aggregates when used with common cement concrete in the construction of rigid pavements, is actually the white ionic compound consisting of sodium cations(Na^+) and hydroxide anions oH^-

Methods :

Workablity Test : A slump cone mould with a top diameter of 10 cm, a bottom diameter of 20 cm, and a height of 30 cm is used for this test. In this test, a mould is placed on a level surface, then cement, tiny stones, rubber pieces, and water are added until the mould is filled approximately one-fourth of the way up. Using a tamping rod, the concrete is then evenly compressed 25 times across the surface of the mould. Continue until the mould is full, then use a shovel to clear the top surface before lifting the mould vertically and waiting for the concrete to stop settling to determine the slump value. Plain concrete is made using this method, and it likely adviced to repeat the test for mixtures that have been treated with cement paste or sodium hydroxide or even both.

Test for compressive strength : This test is performed in a compression testing equipment. Cubical moulds of 15 cm x 15 cm x 15 cm are used to conduct this test. To avoid any voids, the concrete is properly tempered and put into the mould for this test. After 24 hours, these moulds are eliminated, and test specimens are subsequently immersed in water to cure. Its top surface need to be uniform and smooth. These specimens are put through compression testing devices after seven or twenty-eight days of curing, which gradually add 140 kg/cm of stress per minute until the specimen fails. The load at failure is divided by the specimen's area to get the compressive strength of rubberized concrete. For mixes that have been treated with cement paste, sodium hydroxide (NaOH), and other chemicals as well as for mixtures that have not been treated, the procedure is repeated.

Flexural strength test : A testing machine, tamping rods, steel moulds, scoops, and troveletc are among the tools used for this test. The mould is filled with three layers of the cement, sand, waste rubber aggregates, and water mixture. Each layer is compressed into a cube form with the use of a tamping rod. Once the excess concrete has been removed, smooth the top of the mould. The samples are kept at room temperature up to the test. After 28 days, the test specimens are mounted on the testing apparatus, and a little force is applied. Measure the cross-section of the tested specimen at both the ends and the centre to calculate the average depth and height. The procedure is repeated for mixes that have not been treated, mixtures that have been treated with cement paste, plain concrete, sodium hydroxide (NaOH), and mixtures that have undergone these treatments.

Test for split tensile strength: The equipment used to assess the split tensile strength of concrete includes steel moulds, testing devices, and tamping rods. Fine sand, cement, rubberized concrete, and water are all blended to make a homogenous slurry.The mixture is then layer-by-layer put to the mould, compressed by a tamping rod after each layer, and the specimen's top surface is well completed. The specimen is cured for 28 days at a steady temperature. The specimen's weight and measurements are checked once it has had time to cure. The breaking load is then calculated when it is put on a testing machine and loaded gradually at a rate of 0.7 to 1.4 MPa/min. The procedure is repeated for mixes that have not been treated, mixtures that have been treated with cement paste, plain concrete, sodium hydroxide (NaOH), and mixtures that have undergone these treatments.

3. Results :

Workablity test result(Slump value): It is demonstrated that rubberized concrete's workability, whether treated or untreated, is inferior to that of regular concrete and that it decreases as the proportion of aggregate replacement increases. With the exception of NTR-5(NAOH treated rubber), which has a little increase of 1mm in slump value over the UTR(untreated rubber)-5, all replacement levels and treatments show a deterioration in workability when the percentage replacement is elevated, as can be seen from the graph in Figure mentioned below. Lackluster bonding and rubber aggregates that impede the flow of concrete paste and natural aggregates are to blame for the low workability of rubberized concrete (untreated). The increase in viscosity that results from NaOH treatment that enhances bonding reduces workability. The amount of water available to give workability is decreased when rubber is treated with cement paste because cement particles adhere to rubber particles, absorbing water from the concrete.

Table 1: Properties

SAMPLE	SLUMP VALUE (mm)	PERCENT REDUCTION OF SLUMP
PC	50	0
UTR-5	47	6
UTR-10	45	10
UTR-15	43	14
NTR-5	48	4
NTR-10	44	12
NTR-15	40	20
CTR-5	45	10
CTR-10	42	16
CTR-15	35	30

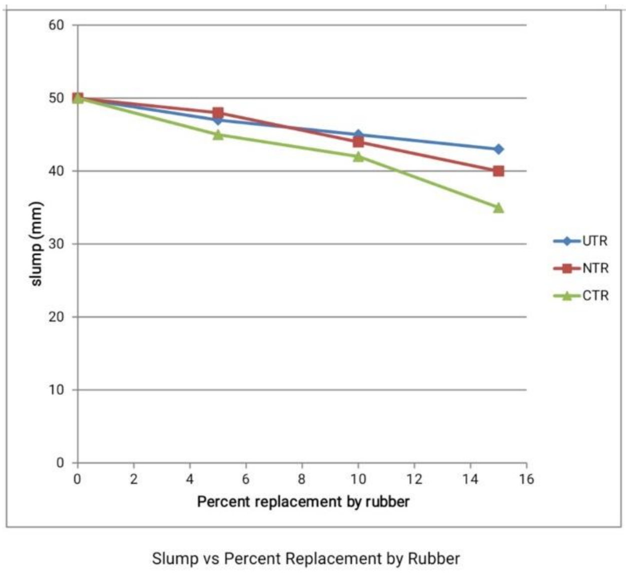


Fig. 1: Slumps vs Rubber

Compressive strength test: The 7-day compressive strength of NTR-10 is found to be the highest of all the substituted mixes, however it is still less than plain concrete. However, in this case, the 92.62% compressive strength of ordinary concrete is retained, which is rather exceptional given the material used. The compressive strength after 28 days is similarly found to be at its maximum for NTR-10, but it is once more less than that of standard concrete. Its compressive strength accounts for 92.57% of that of conventional standard concrete, which is considered adequate. The compressive strengths of untreated and cement-treated rubberized concrete are found to be significantly lower when compared to NTR-10 and plain concrete. Large elastic module variations, poor bonding, and restricted adhesion between concrete materials and untreated rubber particles may be the cause of the lower compressive strength. Moreover, since When force is applied, cracks first appear where the rubber and concrete matrix come into contact as ntities of rubber are weaker than the concrete matrix around them.

Table 2: Compressive strength

SAMPLE	7-DAY COMPRESSIVE STRENGTH-CUBE (N/mm^2)	28-DAY COMPRESSIVE STRENGTH-CUBE (N/mm^2)
PC	19.11	27.33
UTR-5	13.87	19.80
UTR-10	16.44	23.50
UTR-15	15.60	20.40
NTR-5	16.40	23.30
NTR-10	17.70	25.30
NTR-15	11.11	15.60
CTR-5	15.60	22.2
CTR-10	12.11	15.50
CTR-15	17.33	21.70

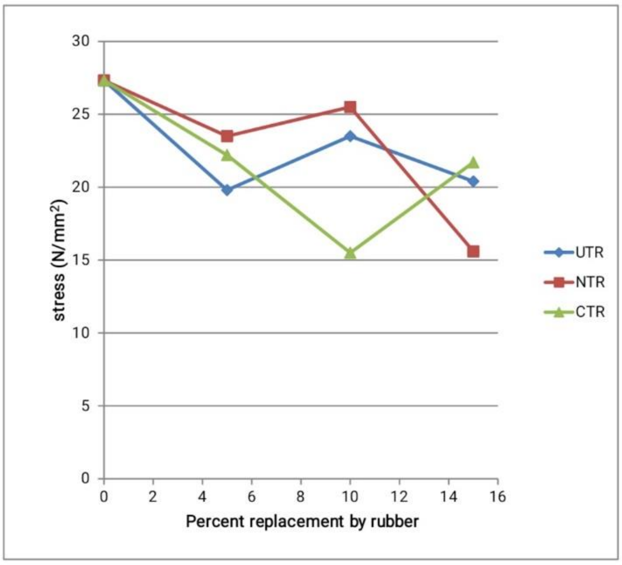
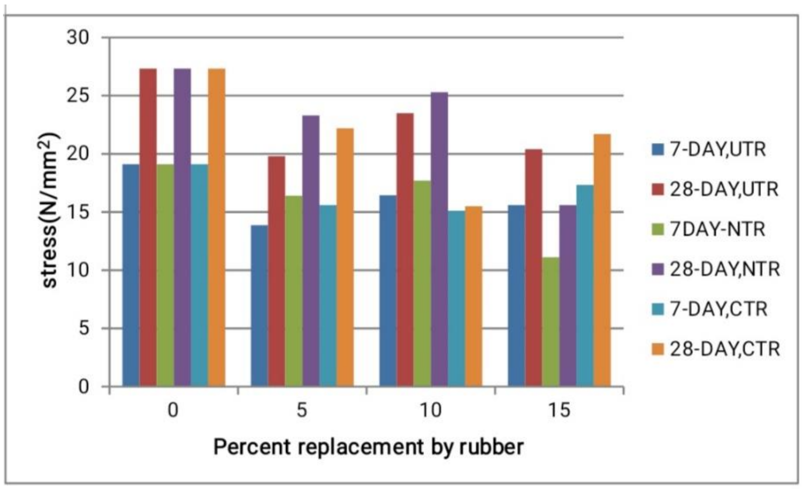


Fig. 2 : Variation of 28 days compressive strength vs percent replacement by rubber



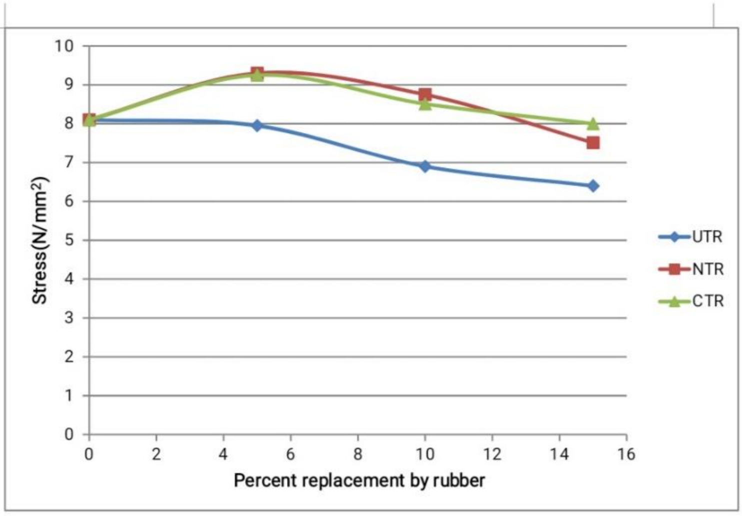
Comparison between 7 and 28 days Compressive Strength on Varying Percentages of Rubber

Fig. 3: Data of rubber.

Flexural Strength : Flexural strength has a varying pattern in the current experiment. In comparison to all replacement mixes and conventional concrete, NTR-5 is found to have the highest 28-day flexural strength. Untreated rubber concrete's flexure strength dropped, but the trend for treated rubber varied. For treated rubberized concretes, the minimum flexural strength is comparable to 15% replacement, while the maximum flexural strength is equivalent to 5% replacement level. The strength gain is estimated to be around 13% when treated rubber replaces 5% of the typical ordinary concrete. Combinations are made less stiff by using less cement. Because the rubber aggregates may bridge fractures caused by flexural strain, less rigid specimens with them can withstand more load after cracking. Thus, the treated rubber aggregate content increases flexural strength, but only up to a replacement range of extent to 5 percent.

Table 3: Test results

SAMPLE	28-DAY FLEXURAL STRENGTH BEAM (N/mm^2)	ULTIMATE LOAD `(KN)	DISPLACEMENT (mm)
PC	8.10	16.20	0.96
UTR-5	7.95	15.90	1.12
UTR-10	6.90	13.80	1.10
UTR-15	6.40	14.80	0.80
NTR-5	9.30	18.60	1.30
NTR-10	8.75	17.50	1.50
NTR-15	7.51	15.02	1.38
CTR-5	9.25	18.50	1.60
CTR-10	8.51	17.02	1.45
CTR-15	8.00	16.00	1.30



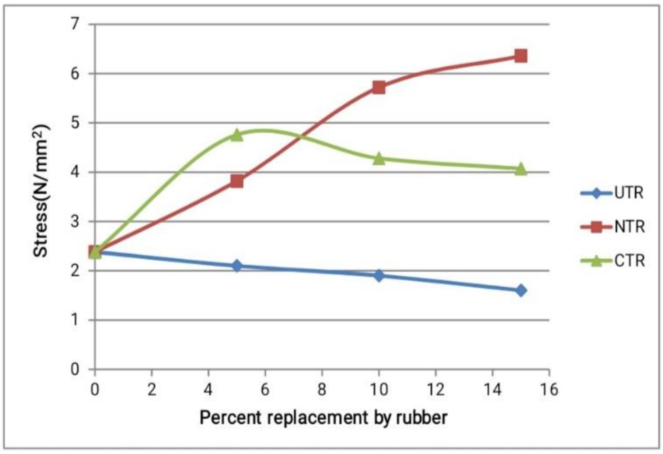
Variation of 28 days Flexural Strength vs Percent Replacement by Rubber

Fig. 4 Replacement of rubber.

Split Tensile Strength Test : Split tensile strength is discovered to be higher after 28 days in every circumstance where treated rubber is used, and it is demonstrated to be maximal at NTR-15 (NAOH treated with 15% replacement). This replacement level's split tensile strength is 2.67 times more than conventional concrete's strength, which is quite important and promising. The increase in split tensile strength following rubber treatment can be attributed to both this treatment-induced improvement in bonding and the more flexible character the rubber particle gave the concrete.

Table 4: Samples

SAMPLE	28-DAY SPLIT TENSILE STRENGTH CYLINDER(N/mm^2)
PC	2.38
UTR-5	2.10
UTR-10	1.90
UTR-15	1.60
NTR-5	3.82
NTR-10	5.72
NTR-15	6.36
CTR-5	4.76
CTR-10	4.28
CTR-15	4.07



Variation of 28 days Split Tensile Strength vs Percent Replacement by Rubber

Fig. 5. Stress results

4. Conclusions

We may sum up the conclusion of our project cum research work within the below mentioned points.

- The recycled tyre material that has undergone NaOH treatment and 5% replacement yields the greatest and most suited results, with a little rise in slump value of 1mm over UTR-5. Given that aggregates were used in place of the waste tyre rubber, the achieved compressive strength is 92.57%, which is thought to be an excellent outcome from a structural perspective.
- Almost all replacement levels of treated rubberized concrete are found to have higher flexural and split tensile strengths than typical conventional concretes. The strongest 28-day flexural and split tensile materials are found to be the NTR-5 and NTR-15, respectively.
- This study sought to determine whether waste materials, such as used tyres, may enhance concrete's basic properties. The data from this study show how effectively employing tyres as aggregates is a substantial possibility. It is believed that because used tyres may be utilised in place of more expensive materials like rock aggregate, they would provide far more opportunities for value addition and cost recovery.

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