A Comparative Study between the Usages of Differently Sized Waste Rubber Obtained From Tires over the Strength Performance of Rigid Road Pavements

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ABSTRACT

In this research work, waste rubber obtained from tires is mainly used as a fractional substitution of natural coarse aggregate to improve the strength aspects of the concrete. 3 dissimilar sizes of waste rubber obtained from tires aggregates were used that is of 4mm, 10 mm and 16 mm. Depending upon all three sizes all the waste rubber obtained from tires aggregate were used at 3 different percentages that are at 10 percent, 20 percent and 30 percent. Then several concrete samples were prepared depending upon the shape and percentage of the waste rubber obtained from tires aggregate. Then all these samples were cured and tested after 7 days and 28 days. Depending upon the results obtained after these above-discussed test various conclusions has been drawn which are as follows. It was found that the maximum strength was obtained at 20 percent usage of 4mm sized waste rubber obtained from tires aggregate, the strength obtained at 20 percentage with 4mm size was maximum as compared to all other concrete samples, so it can be concluded that the compressive strength depends upon both the size as well as on the percentage of waste rubber obtained from tires aggregate and with the decrease in size of the waste rubber obtained from tires aggregate the strength was increasing. From the test results of the split tensile strength test and flexural strength test, it was found that the maximum strength was obtained at 20 percent usage of 4mm sized waste rubber obtained from tires aggregate and with the increase in size and percentage the strength was declining. So therefore it can be concluded that both split tensile strength and flexural strength depends upon the size of waste rubber obtained from tires aggregate and the percentage of waste rubber obtained from tires aggregate. From the obtained test results it can be concluded that with the addition of the waste tire rubber the overall internal micro-structure of the concrete improves which further leads to enhanced mechanical strength of the concrete. This was due to the physical properties and the chemical composition of the waste tire rubber particles which fills the internal pores in a broader way and lead to improved mechanical strength.
Keywords: compressive Strength, Flexural Strength, Waste Rubber, Waste tire rubber, Split Tensile Strength

1. INTRODUCTION

1.1 General

As compared to the flexible pavement the flexible rigidity of the top slab in the case of rigid pavement is very high due to the usage of plain cement concrete. It consists of 3 to 4 layers depending upon the type and usage of the pavement. At the top of concrete pavement or concrete slab was constructed to increase the flexural rigidity of the pavement, then comes the base course for the rigid pavement. After the base course sub base course is constructed and then comes the subgrade that is the existing soil over which the pavement is to be formed. The top slab of the rigid pavement is made up of plain cement concrete so therefore it has a very high capacity to resist and distribute a large traffic load in a uniform manner and it can resist very heavy loads due to the higher value of modulus of elasticity and this higher value of modulus of elasticity can lead to resistance against the extreme heavy kinds of loads over the pavement[1][2][3][4][5].

1.2 Waste Rubber Obtained From Tires

Day by day the usage of tires in cars, bikes, trucks, dumpers and other vehicles is increasing rapidly due to the economic development of the world and due to this the waste generated from the tire industry is also increasing rapidly in recent times [6][7][8][9]. It has been observed that this waste is dumped in the open or these tires are used again with the help of the scrambling process. But after this usage also a huge amount of tire waste generation is problematic for the upcoming future generation, see figure 1. This can be done by determining an alternative to the process of dumping that can be the usage of this waste to fulfil some other kind of purpose where it is reliable to use and is eco-friendly from the environmental point of view. An alternative to dumping these waste rubber tires can be their usage in the civil engineering sector where they can be used as a constructional material, see Table 1 and 2
2. LITERATURE REVIEW

2.1 Road Pavements

In this research work, rice husk ash and micro silica were used to enhance the strength parameters of rigid road pavement [10][11]. For achieving this goal first rice husks were obtained from the rice mills or rice processing mills and then burnt at extremely high temperature to convert it into the form of ash. Afterwards, micro silica was obtained as waste from the silica processing industry. Both the materials were used separately and in combination with each other [12][13][14]. After preparing the proper specimen all the specimen were cured for twenty-eight days. Afterwards, proper testing was done using...
the compressive strength test and flexural strength test. Test results revealed that in separate form maximum strength was obtained at 15 percent usage of rice husk ash and 10 percent usage of micro silica. In the combined form the compressive strength test results revealed that maximum strength was observed at 10 percent usage of rice husk ash and 7.5 percent usage of micro silica [15][16].

In this research work, various strength aspects of rigid road pavement were discussed in detail. This study deals with the usage of kaolinite clay in a dehydrated form to enhance and increase the strength aspects of rigid road pavement made up of concrete. Kaolinite clay was first dehydrated in controlled temperature conditions to convert it into the form of powder. Then this dehydrated kaolinite clay was used as a partial replacement for cement to predict the strength aspects and engineering properties of concrete. In other words, it was used from 0 to 25 percent at an increment of 5 percent in each case. It was concluded that the maximum strength was obtained at 15 percent usage of dehydrated kaolinite clay [17][18].

2.2 Waste Rubber

In this research work, waste rubber was used to enhance the properties of concrete. Waste rubber was used as a partial replacement of natural fine aggregate to predict the behaviour of concrete after the addition. Firstly waste rubber was collected from the locally available tires shops as waste and then converted into powder form through mechanical crushing and grinding process [19][20]. Then this waste rubber aggregate was tested for its physical and chemical properties to predict its behavioural aspects over the concrete. After this, the process of replacement was initiated and waste rubber was used at different percentages of 0 percent, 2.5 percent, 5 percent, 7.5 percent and 10 percent. In all the mixes M30 grade of concrete was used and waste rubber obtained from tires aggregate was used as partial substitution of natural fine aggregate that is sand. It was found that for the usage of waste rubber as partial replacement of natural fine aggregate the most optimum percentage was 5 percent replacement as the maximum compressive strength was obtained at 5 percent replacement percentage [21].

In this type of research work, waste rubber fibre was used as a partial replacement of natural fine aggregate for enhancing the strength parameters of conventional concrete [22]. Waste rubber fibre was used in combination with high range water reducing admixture to enhance the strength parameters to a greater extent. Waste rubber was collected from locally available sources and then converted into fibre with the help of proper processing techniques. From the test results related to the addition of rubber fibre as partial replacement of natural fine aggregate with high range water reducing admixture, it was concluded that the maximum strength was observed at 5 percent usage of waste rubber fibre and afterwards the strength starts declining up to a greater extent [23][24].

3. RESEARCH OBJECTIVES & METHODOLOGY
3.1 Objectives

The main objective of the current research is to perform “a comparative study between the usages of differently sized waste rubber obtained from tires over the strong performance of rigid road pavements” [25][26].

To achieve this goal certain sub-objectives have been considered which are as follows:
To study the influence of different sized waste rubber obtained from tires in different percentages over the compressive strength of rigid road pavement using compressive strength test.

To study the influence of different sized waste rubber obtained from tires in different percentages over the flexural strength of rigid road pavement using flexural strength test.

To study the influence of different sized waste rubber obtained from tires in different percentages over the split tensile strength of rigid road pavement using split tensile strength test.

To compare the results obtained for waste rubber obtained from tires concrete pavement and the normal conventional concrete pavement.

To identify the optimum percentage as well as the optimum size for the usage of tire rubber waste over rigid road pavement.

3.2 Methodology
The methodology of the research work includes:

- Collection of the material from the various available sources.
- Testing of materials including physical properties and chemical composition.
- Mixing of materials depending upon the percentage and proportions.
- Casting of samples including casting of cubes, casting of cylinders and casting of beams.
- Curing of the casted samples depending upon the duration of curing and climatic conditions.
- Testing of the cured samples so as to determine the mechanical strength of the samples.
- Summarization of the test results depending upon the type of test and testing equipment.
- Final conclusion depending upon the test results.

4. RESULTS AND DISCUSSIONS

4.1 General
In this research work basically, a single material that is waste rubber obtained from tires is used to predict the strength aspects of normal concrete pavement [27][28][29][30]. To achieve this goal various sizes of waste rubber obtained from tires aggregate was used as partial replacement of natural coarse aggregate to determine the optimum size of waste rubber aggregate to be used for the strength enhancement of concrete pavement. Different sizes of waste rubber obtained from tires aggregate are 4 mm, 10 mm and 16 mm, while the different percentages of these 3 different sizes were usage at 10 percent, 20 percent and usage at 30 percent [31][32][33]. All these details are summarized in the given table 3.

| Mix  | Grading Of Waste Rubber Obtained From Tires(Mm) | Percentage Of Waste Rubber Obtained From Tires (%) |
|------|-----------------------------------------------|-----------------------------------------------|
| M1   | 0                                             | 0                                             |
| M2   | 4                                             | 10                                            |
| M3   | 4                                             | 20                                            |
| M4   | 4                                             | 30                                            |
| M5   | 10                                            | 10                                            |
| M6   | 10                                            | 20                                            |
| M7   | 10                                            | 30                                            |
| M8   | 16                                            | 10                                            |
4.2 Compressive Strength Test Results
Several cubes were cast depending upon the ten mixes and then cured for seven days and twenty-eight days. After proper curing samples were oven-dried properly to perform a compressive strength test over it. After this cubes were tested properly under a universal testing machine to determine the required value of compressive strength. Test results revealed that the maximum strength was obtained at 20 percent usage of 4mm waste rubber obtained from tires aggregate as compared to all other mix combinations [34], see Table 4 and figure 2.

Table 4 Compressive Strength Test Results

| Mix  | Compressive Strength Test Results MPA (7 Days) | Compressive Strength Test Results MPA (28 Days) |
|------|---------------------------------------------|---------------------------------------------|
| M1   | 21.54                                       | 32.67                                       |
| M2   | 23.21                                       | 34.23                                       |
| M3   | 24.63                                       | 35.12                                       |
| M4   | 24.23                                       | 34.89                                       |
| M5   | 23.12                                       | 33.88                                       |
| M6   | 23.01                                       | 33.64                                       |
| M7   | 22.56                                       | 33.32                                       |
| M8   | 21.63                                       | 32.86                                       |
| M9   | 21.12                                       | 32.12                                       |
| M10  | 20.55                                       | 31.14                                       |

Figure 2: Compressive Strength Test Results

4.3 Flexural Strength Test Results
The flexural strength test was mainly used as per the Indian standard code for determining the flexural strength of the concrete samples. Flexural strength is the resistance of concrete against flexural forces. For performing this test several beams of size 500mm x 100mm x100mm were cast and then cured for seven days and twenty-eight days. Then after curing, all the samples were properly oven-dried to remove all moisture content from it. After this, this beam was tested for its flexural strength with the help of a flexural strength testing machine. The test results showed that the maximum flexural strength was occurring at 20 percent usage of 4 mm sized waste rubber obtained from tires aggregates, see Table 5 and figure 3.

| Mix | Flexural Strength Test Results MPA (7 Days) | Flexural Strength Test Results MPA (28 Days) |
|-----|-------------------------------------------|-------------------------------------------|
| M1  | 4.37                                      | 5.63                                      |
| M2  | 4.81                                      | 5.94                                      |
| M3  | 4.89                                      | 6.21                                      |
| M4  | 4.76                                      | 6.03                                      |
| M5  | 4.71                                      | 5.84                                      |
| M6  | 4.67                                      | 5.72                                      |
| M7  | 4.63                                      | 5.51                                      |
| M8  | 4.39                                      | 5.44                                      |
| M9  | 4.28                                      | 5.27                                      |
| M10 | 4.21                                      | 5.11                                      |

Figure 3 : Flexural Strength Test Results

4.4 Split Tensile Strength Test Results
For performing this test several beams of cylinders of diameter 150mm and height 300mm were cast and then cured for seven days and twenty-eight days. Then after curing, all the samples were properly oven-dried to remove all moisture content from it [35]. After this, all these cylinders were tested with the help
of a universal testing machine to obtain the results of the split tensile strength test. From the test results, it was found that 20 percent usage of 4mm waste rubber obtained from tires aggregate is the most optimum percentage and size respectively and after these, the split tensile strength was decreasing rapidly, see Table 6 and figure 4.

### Table. 6 Split Tensile Strength Test Results

| Mix | Split Tensile Strength Test Results MPA (7 Days) | Split Tensile Strength Test Results MPA (28 Days) |
|-----|-----------------------------------------------|-----------------------------------------------|
| M1  | 2.72                                          | 4.17                                          |
| M2  | 2.89                                          | 4.27                                          |
| M3  | 3.01                                          | 4.32                                          |
| M4  | 2.97                                          | 4.26                                          |
| M5  | 2.88                                          | 4.21                                          |
| M6  | 2.75                                          | 4.19                                          |
| M7  | 2.68                                          | 4.11                                          |
| M8  | 2.66                                          | 4.08                                          |
| M9  | 2.59                                          | 4.05                                          |
| M10 | 2.53                                          | 3.99                                          |

**Figure 4:** Split Tensile Strength Test Results

**5. CONCLUSION & FUTURE SCOPE**

5.1 General

In this research work, three different sizes of waste rubber obtained from tires aggregates were used that is of 4mm, 10 mm and 16 mm. depending upon all three sizes all the waste rubber obtained from tires aggregate were used at 3 different percentages that are at 10 percent, 20 percent and 30 percent. Then
several concrete samples were prepared depending upon the shape and percentage of the waste rubber obtained from tires aggregate. Then all these samples were cured and tested after 7 days and 28 days. Depending upon the results obtained after these above-discussed test various conclusions has been drawn which are as follows.

5.2 Conclusions

- From the test results of the compressive strength test, it was found that the maximum strength was obtained at 20 percent usage of 4mm sized waste rubber obtained from tires aggregate, the strength obtained at 20 percentage with 4mm size was maximum as compared to all other concrete samples, so it can be concluded that the compressive strength depends upon both the size as well as on the percentage of waste rubber obtained from tires aggregate and with the decrease in size of the waste rubber obtained from tires aggregate the strength was increasing.

- From the test results of the split tensile strength test and flexural strength test, it was found that the maximum strength was obtained at 20 percent usage of 4mm sized waste rubber obtained from tires aggregate and with the increase in size and percentage the strength was declining. So therefore it can be concluded that both split tensile strength and flexural strength depends upon the size of waste rubber obtained from tires aggregate and the percentage of waste rubber obtained from tires aggregate.

- From the test results it can be concluded that the most optimum usage percentage of waste tyre rubber is 20 percent usage, as with the increase in the percentage of the waste tire rubber the mechanical strength of the concrete decreases and the most optimum size for usage of waste tire rubber was found to be 4mm, as with the increase in the size of the waste tire rubber the strength of the concrete decrease.

- The mechanical strength of the concrete was found maximum at 4 mm size as smaller the size of the filler higher will be the fulfilment of the internal pores and internal microstructure of the concrete.

5.3 Limitations

- Limited previous research work is available on the research topic as the topic is completely related to the study of the waste rubber usage and its effect over the strength aspects of the concrete.

- Further implementation of the SEM and the XRD analysis would be difficult task from the practical time of concern.

- The samples and the percentages of the material should be considered in a detailed manner so as to have better result outcomes.

5.4 Future Scope

- In this research work, only a single kind of material was mainly used for the stabilization process of the concrete, further research work can also be done using some other similar kinds of materials to enhance the quality aspects of the concrete.

- Further research work can also be done using different other percentages and sizes of the waste tire rubber to study the effect of the waste tire rubber in a detailed manner.
Futuristic work can also be done using certain other waste materials such as biomass ashes, non-degradable material and other environmentally hazardous materials to get better outcomes from the environmental point of view.

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