"Feasibility Study of Using Waste Tyres in Rigid Pavement"

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Abstract: This paper endeavors to explore the use of tyre waste as a constituent in concrete for rigid pavement construction. The paper presents the study of the variation of the compressive strength of concrete when tyre waste in the form of chipped rubber is being added as a constituent in concrete. The properties within the scope of the investigation are chiefly the compressive strength. The chief constituent materials include PPC 53 cement, fine aggregate, 10mm-20mm coarse aggregate and chipped rubber from tyre waste. The material tests on these constituents were conducted and it was ensured that they fell in the prescribed limits of the various codes and were suitable for the mix design of the specimen concrete. The control specimen adopted was that of M40 grade concrete and the chipped rubber was added to this mix in the percentages of 0%, 5%, 10% and 15% by weight of cube. The study found that the optimal addition was 10% of chipped rubber by weight of cube giving similar strength as the control specimen.

Keywords: PPC 53, tyre waste, compressive strength, rigid pavement, M40.

Introduction

With the rapid growth of population and urbanization, accumulation of waste due to improper disposal has become one of the serious problems that most of the countries around the world are facing. Solid wastes have serious environmental and health impacts. So, the use of environment-friendly materials and industrial wastes in the construction industry would be of great importance. Research studies have been conducted relating to the protection of natural environment incorporating waste material. A very common innovative approach has been to incorporate waste as a constituent in concrete. Among the different choices of waste materials, tyre waste in the form of chipped rubber is a viable choice to study on. Dogan & Çelebi, 2008, explored that presence of rubber in concrete helps improve crack resistance and the ability to absorb shocks from impacts; hence, it is more tough and durable. The decreased brittleness prevents concrete from disintegrating under compressive or flexural loads. Since construction requires very large amounts of sand and aggregates the efficient use of rubber in concrete will minimize the effect on environment but also minimize construction costs (Khatib & Bayomy, 1999). Tao et al., n.d. rubber powder particles are a new type of impact-resistant toughened functional materials produced from cement-based composites in recent years. Due to its existing large strain, impact resistance and low modulus, it has good mechanical performance and decrease of noise reduction. Therefore, as a part of the municipal noise insulation materials and impact resistant bumper isolation, it will have wide application prospects in the municipal engineering district. In this study, tyre waste is added as a constituent to M40 grade concrete by weight in the percentages of 0%, 5%,10% and 15% in the rigid pavement to obtain the required strength and to determine the most suitable mix.

Problem Statement

In Bhutan, according to the survey conducted, Druk tyre services in Phuntsholing produces around 960 to 1200 tyres per year which are exported to India for recycling. After two to three times of recycling tyres, its useful life comes to an end and consequently about 50% to 60% of the total tyres are being dumped as waste in an open space according to the surveys conducted in the automobile workshops. In Bhutan, situations like excessive dumping and piling of waste tyres in the USA does not exist in the present day but it might come into picture in the future. According to the Road Safety and Transport Authority, the total number of vehicles registered is 103814 as of June 30, 2019. With enormous pressure on the environment to reduce solid waste and to recycle as much as possible, our project aims to examine the possibility of incorporating waste tyre in a concrete mix design and feasibility of its application in rigid road construction.

Concrete is a very ancient and common building material. It is becoming more difficult to find suitable alternatives to natural aggregates for the concrete production. Therefore, the usage of alternative sources, like waste materials for natural aggregates is becoming increasingly important. The most promising use of waste tyres in the concrete has great potential to reduce the waste tyres generated in Bhutan.

Aim

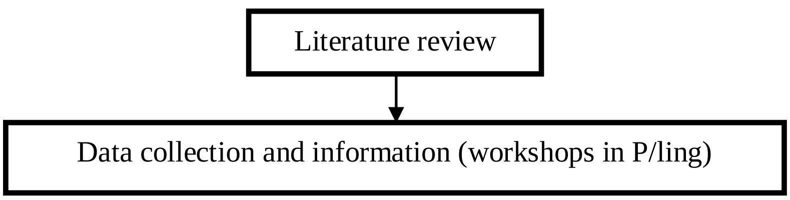
To study the feasibility of using waste tyres in rigid pavement

Objectives:

- Study the waste tyre problem in Phuentsholing, Bhutan
- To explore the possibility of using waste tires in the rigid pavement as an additive.
- Suggest an appropriate mix design for the pavement.

Methodology

The proposed project will follow the following methodology as shown in **Figure 1** below. Literature review will be conducted prior to the research activity and details on waste tyre will be collected from possible sources. The waste tyres are shredded. Materials tests are conducted for other materials to confirm their suitability as per IS standard. Mix design is performed using the test results and a mix ratio is obtained. The cubes are cased as per the mix determined and tested for compressive strength. As per the result of compressive strength test, recommendation to use waste tyre as a component on rigid pavement and its suitable mix proportion are recommended.



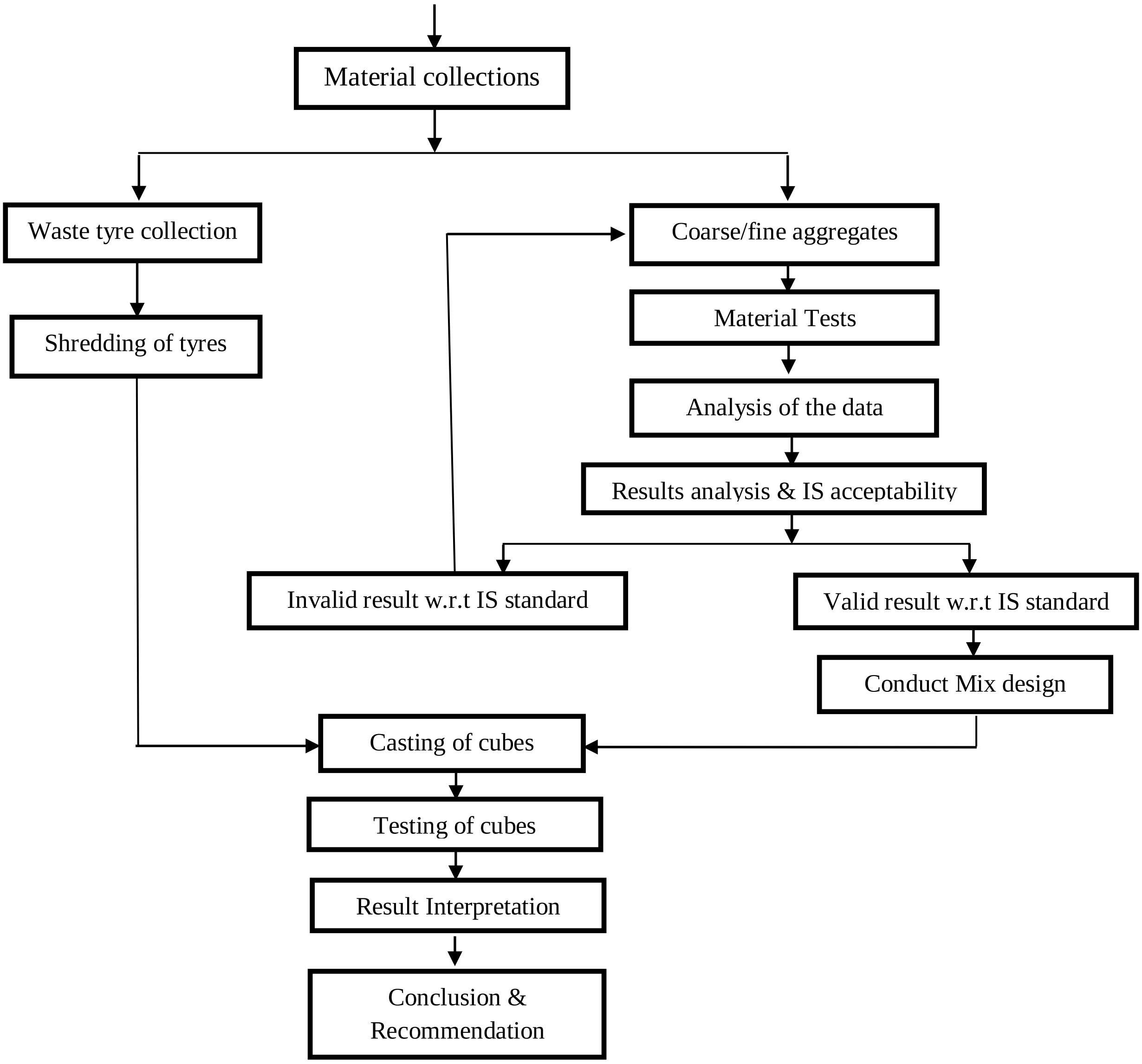


Figure 1. Research Methodology

Literature review

When the quantity of chip tyre in concrete increased, compressive strength along with split tensile strength and elasticity modulus decreased. The decrease in compressive strength was 26% with 20% chip rubber substitution, while the strength of split tensile decreased by 10%. For all specimens, the rupture modulus above 4 Mpa indicates high bending capability. Overall, chip rubber can be developed especially for flexible loads with an aggregate volume replacement of 20%(Science, 2020).

It has also been found that concrete with rubber has better plasticity than plain concrete because of higher strain levels which allow for larger plastic yielding before the failure of the structure. Utilizing chipped rubber as an aggregate can also significantly improve impact resistance in both the initial crack and failure stages (Ansari, 2019)

The compressive strength increases by up to 10% and then gradually decreases. Workability of chipped rubber concrete also decreased when increasing amount of rubber content was used which could be compensated by increasing the dosage of chemical admixtures(Raju & Kumar, 2020).

Concrete appears to shrink and crack throughout the process of hardening and curing. Such shortcomings are continually being challenged with the introduction of new admixtures and aggregates used in the mix, with expectations of progress. One of those approaches could be to adding waste tyre into the concrete. It is one way to modify the characteristics of concrete in addition to recycling waste tyres (Sibiyone & Sundar, 2017).

Presence of rubber improves crack resistance in concrete and the ability to absorb shocks from impacts; hence, it is more tough and durable. The decreased brittleness prevents concrete from disintegrating under compressive or flexural loads(Dogan & Çelebi, 2008).

Tao et al., 2017, explored the feasibility of recycling waste tyres by incorporating and intensify the characteristics of concrete by fractional substitution with fine aggregate to create a better concrete mix. The percentage of waste tyres replaced by weight in the concrete mix was 0%, 10%, 15% and 20 % respectively. The test results indicated a deterioration in the concrete's compression strength, whereas toughness was increased.

Material used

Cement:

The cement used for the study was Portland Pozzolana Cement (PPC), grade 53.

Fine Aggregate

Natural riverbank sand was used as the fine aggregate.

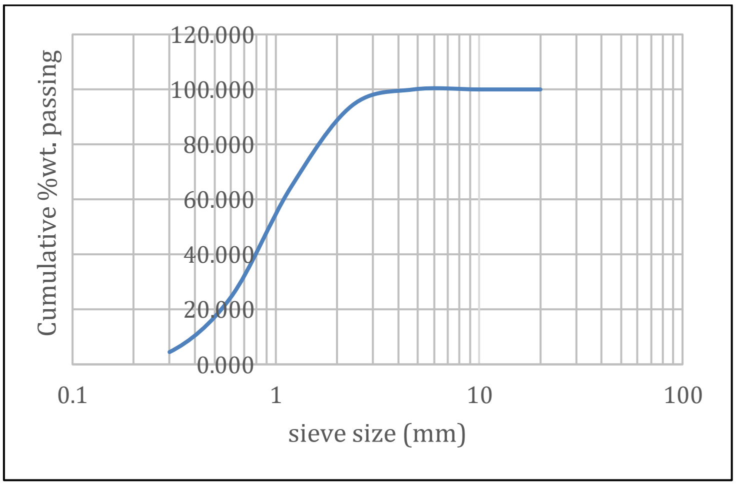


Figure 2. Particle size distribution of fine aggregate

Table 1. Properties of fine aggregate

Sl. No.	Property	Value
1	Silt content	4.25%
2	Specific gravity	2.6
3	Fineness modulus	3.13%

The specific gravity of fine aggregate is 2.6 with a fineness modulus of 3.13%. The sand is well graded coarse sand and falls under zone-I as per IS: 383. The silt content value implies no flushing of silt content is required.

Coarse Aggregate

The laboratory tests done on coarse aggregate were for specific gravity, water absorption, shape, abrasion, impact and crushing. The coarse aggregate satisfies the IS requirements to be used for concrete mix design. These values are used for the mix design calculation of the M40 grade concrete.

Table 2. Properties of coarse aggregate

Sl. No.	Property	Value
1	Fineness modulus	6.96%
2	Specific gravity	2.6
3	Water absorption	0.065%
4	Shape i. Elongation ii. Flakiness	 19.01% 8.76%
5	Abrasion	25.75%
6	Impact	8.03%
7	Crushing	16.44%

Chipped rubber

The rubber added to concrete is wholly a waste tyre rubber. The waste tyre was cut into aggregates size of 10mm- 20 mm to be used in concrete mix.

Casting of concrete cubes

There were 4 sets of specimens corresponding to a control of normal M40 concrete specimen and 3 sets for the 5 %, 10 %, and 15 % partially added by chipped rubber. The compressive strength of these sets was tested in a UTM (universal testing machine) with a cube specimen of 150 mm × 150 mm × 150 mm dimensions. In each set, there were 3 specimens for 7, 14 and 28 days. 36 specimens in total were cast in the laboratory. The following table represents the number of specimens cast.

Table 3. Number of specimens

	Cubes		
Days	7	14	28
M40 with 0% rubber chip	3	3	3
M40 with 5% rubber chip	3	3	3
M40 with 10% rubber chip	3	3	3
M40 with 15% rubber chip	3	3	3

Mix design

The mix design was conducted as per IS 10262: 2009. Different trials were casted with reference to the mix proportions were obtained from manual calculation.

Table 4. M40 concrete mix ratio

Cement	Sand	Coarse	W/c ratio
1	2	3	0.45

Table 5. Compressive strength results in N/mm2

	Trial I				Trial 2				Trial 3			
DAYS	Nominal Concrete	5% rubber by vol. of concrete	10% rubber by vol. of concrete	15% rubber by vol. of concrete	Nominal Concrete	5% rubber by vol. of concrete	10% rubber by vol. of concrete	15% rubber by vol. of concrete	Nominal Concrete	5% rubber by vol. of concrete	10% rubber by vol. of concrete	15% rubber by vol. of concrete
7	31.8	30.2	29.1	26.56	30.8	30.4	28.5	27.2	31.5	30.6	29.8	27.7
14	42.1	40.33	38.8	34.48	41.5	39.8	38.3	33.89	42.2	37.6	35.55	29.98
28	47.3	45.43	43.89	36.5	48.5	43.44	41.12	35.67	45.39	44.78	42.57	35.65

Result and Interpretation

Compressive strength test

The compressive strength tests on cubes, each for 7 days, 14 days and 28 days for different mix concerning Trials 3 are as below. The results are portrayed by the following graphs.

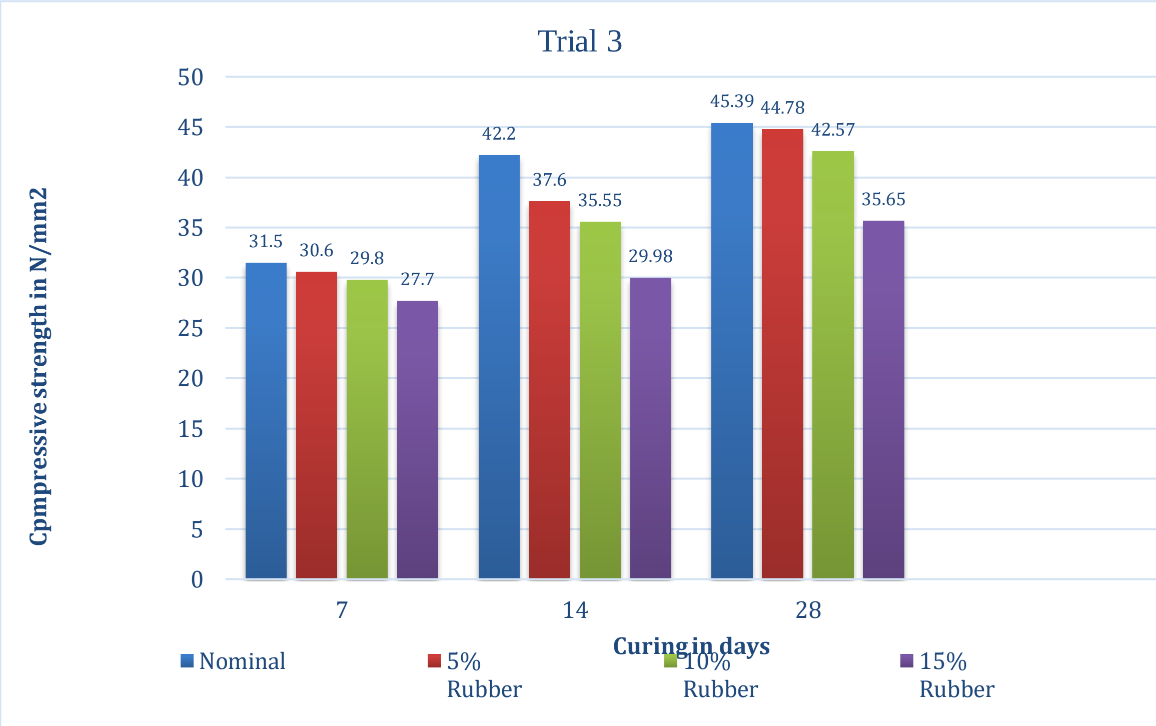


Figure 3. Average compressive strength for Trial-3 mix

The strength values of three cubes were taken for every 7, 14 and 28 days. It was observed that when chipped rubber from the waste tyre was added, the compressive strength decreased gradually. However, the decrease in strength is not very significant for 10% addition of rubber. Hence, from the test result of compressive strength, it can be concluded that 10% addition of rubber of Trial 3 can be used without much alteration of the structural strength. Also Trial 3 showed least variation between the strengths for different days.

Weight difference

When the weight of the nominal cube and cube mixed with the chipped tyre is compared (5%, 10% and 15% of rubber with respect to weight of concrete) it is found that the weight of cube is decreasing with the increasing percentage of the chipped tyre. So, 10% of the chipped tyre in the cube was used as its compressive strength is closer to the nominal strength of compression. The weight of the cube is measured at 7, 14 and 28 days where the weight reduction with respect to the nominal concrete weight was found to be 7.342%, 5.493 % and 5% respectively.

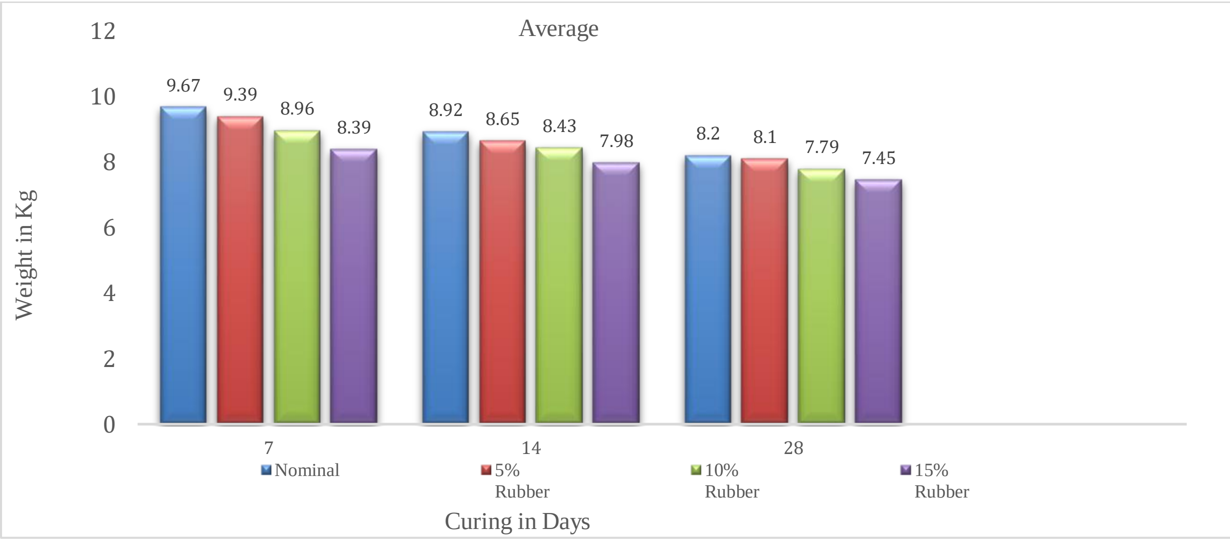


Figure 4. Average weight

Conclusion

The finding and test result from the study concludes that 10% addition of chipped rubber by weight of the concrete of trial III has a less deviation of compressive strength from the nominal concrete mix of M40 and is the most suitable compared to 5% and 15%. The further addition of chipped rubber (above 10%) decreases the compressive strength. The application of 10% chipped rubber in concrete resulted in a 5% reduction in total concrete weight. Therefore, it can be used in the construction of the bridge deck slab. Also, the weight of the cube is measured at 7, 14 and 28 days where the weight reduction with respect to the nominal concrete weight was found to be 7.34%, 5.49 % and 5% respectively.

On an average, the weight reduction is 5%. When making a rigid pavement slab, the pressure on the subbase will be decreased so therefore, it can also be used for huge structure like bridges and deck slabs. The research findings stipulate that for Class AA loading (IRC:6) confirming to minimum M40 concrete for rigid pavement can be achieved by mixing 10% rubber shreds with a mix proportion of 1:2:3.5.

Waste tyres can be used as a material in the construction of rigid pavement. This will minimize the adverse effect on the environment in the future.

Recommendation

- The design mix obtained from the project can be used to cast rigid pavement by the future researchers.
- Noise test and friction test could be performed in the future for the rigid pavement.
- The findings of the project can be applied in places where traffic is heavy and noise production is high especially in Industrial-urban areas.
- Different design mix can be taken by the future researchers incorporating rubber as an additive.

- The possibility of incorporating chipped tyres in the concrete for the construction of light weight concretes that can be utilized in various concrete construction works can be researched in the future.

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