Imperial Journal of Interdisciplinary Research (IJIR)
Vol-2, Issue-6, 2016
ISSN: 2454-1362, http://www.onlinejournal.in

Partial Replacement of Coarse Aggregate by Waste Tyre Rubber and Fine Aggregate by Waste Glass

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Abstract: *Disposal of waste glass and worn out tires has become measure issue in India in the past few years as it has very few uses, and if new tires are to be produced from waste rubber then it has to be melted and remolded. This process intern increases pollution and releases toxic gases in the air, which are harmful to the environment as well as living creatures. The main constituent of glass is silica; hence it can be helpful in AAR which take place in all types of concrete.*
Natural coarse aggregate are extracted from quarries and a result this quarries will soon be depleted in few decade if the rate of their uses continuous at this pace .As a result there was a need of permanent solution to this perpetual problem. Keeping this view the feasibility of use of waste tires as replacement of coarse aggregate and waste glass replacement of fine aggregate in road construction has been experimentally assessed in this project. Basic mechanical and physical test have been carried out on aggregates. Whereas in case of fine aggregates, blocks were casted and tested compressive strength.
The experimental results by replacement of coarse aggregate up to 15% by waste tire have shown remarkable improvement in the physical properties of coarse aggregate. The experimental results also stated that fine aggregate can be replaced up to 10% by waste glass.

Keywords- *Aggregate, Durability, Road construction, Replacement, Strength testing, Waste tyre.*

1. Introduction

India is a developing country, it proposes development projects. Every budget proposal involves large construction of roads, bridges, dams, irrigation schemes, public health engineering schemes, educational buildings and residential buildings etc. all these construction schemes demand optimum and efficient use of construction resources. Most of the modern heavy constructions require huge quantity of cement concrete incurs depletion of natural resources, resources such as river sand and rock strata. Cost of river sand and crushed rock particles is rapidly increasing because of inadequate raw materials and rise of transport cost due to hike of fuel price and of other inputs. Further mining of river sand causes severe environmental damage by lowering ground water table and disintegration of rock strata causes landslide and earthquake. This emerging problem obliges contemporary material usage to balance the ecology.

India has taken major initiative on developing the infrastructure such as construction of roads, but the construction of roads involves extensive use of sand and aggregates which contributes to the problems mentioned above, hence it is becoming necessary to use the alternative material to the sand and aggregates. In this research study the assessment will be done on replacement of coarse aggregate and fine aggregate i.e. sand by waste materials such as tyre rubber and glass respectively, in the road construction.

2. Tyre wastage and problems

Now-a-days disposal of different wastes produced from different industries is a great problem. With the development of modern society’s aftermath of industrial revolution, the mobility within automobile sector got momentum. The offshoot of this pragmatic revolution gave rise to new dimensions of problems in the form of rubber garbage. Millions of waste tyres are generated and stock piled every year, often in an uncontrolled manner, causing a major environmental problem. These tyres are often deposited in an uncontrolled manner, because of the noticeable rapid depletion in sites available for waste disposal, causing major environmental problems. Water accumulation inside the tyres provides ideal temperature and moisture conditions for the spread of mosquitoes, mice, rats and vermin at the same time, the quantity of oxygen that exists in the interior of the tyres is enough to cause fire in appropriate conditions, with resulting negative impacts on the atmosphere and human health.

Traditionally soil, stone, bitumen, cement etc. are used for road construction. Natural materials being exhaustible in nature, its quantity is declining gradually. Also, cost of extracting good quality of natural material is increasing. Concerned about this, the scientists are looking for alternative materials for highway construction, by which the pollution and disposal problems may be partly reduced. In India more than 3 million waste tyres are produced every year because of increasing population and increasing demand for vehicles. Hence, it is becoming necessary to dispose the waste tyres in a proper way.

In this research project to overcome the problem of tyre wastage, the aggregates used in the road construction were partially replaced by rubber and the experimental assessments were done, following are the benefits of using waste tyre rubber as a replacement:

- It will help clear valuable land of huge dumps of wastes.
- It will also help to preserve the natural reserves of aggregates, thus protecting the environment.

3. Glass wastage and problems

Glass is a transparent material produced by melting a mixture of materials such as silica, soda ash and CaCO3 at high temperature followed by cooling where solidification occurs without crystallization. Glass is widely used in our lives through manufactured products such as sheet glass, bottles, glassware and vacuum tubing. Waste glass is a major component of solid waste stream in many countries. It can be found in many countries, including container glass, flat glass such as windows, bulb glass and cathode ray tube glass. It has been recognized that glass waste is of large volume and is increasing year by year in the shops, construction areas and shops. The waste glass is one of the most important issues around the world to the increase of solid wastes in the landfill and non-degradable nature of its disposal. The use of recycled glass in concrete has attracted much interest worldwide and numerous researches have been carried out showing the possibility of use of waste glass as a building material by partially replacing concrete mixtures.The use of recycled glass saves lot of energy and the increasing awareness of glass recycling speeds up focus on the use of waste glass with different forms in various fields. One of its significant contributions is the construction field where the waste glass was reused for concrete production. The application of glass in architectural concrete still needs improvement. Several study have shown that waste glass that is crushed and screened is strong, safe and economical alternative to sand used in concrete**.** Using waste glass in the concrete construction sector is advantageous, as the production cost of concrete will go down. The most widely used fine aggregate for the making of concrete is the natural sand mined from the riverbeds. However, the availability of river sand for the preparation of concrete is becoming scarce due to the excessive non scientific methods of mining from the riverbeds, lowering of water table, sinking of the bridge piers, etc. are becoming common treats. The present scenario demands identification of substitute materials for the river sand for making concrete. To overcome such problems an experimental study were carried out to replace the fine aggregate i.e. sand by glass powder and the analysis and assessments were done.

4. Methodology

- Sustainable use of natural aggregates, both coarse and fine.
- Proper disposal of waste tyre rubber and glass.
- Reduce the cost of construction of road by using coarse aggregate.
- Reduce the adverse impact of waste like rubber and glass on environment.

4.1. Replacements

4.1.1. Partial replacement of coarse aggregate by rubber

The waste tyre rubber obtained from the source was cut into the required sizes of aggregates. Cut rubber was then replaced in the total weight of aggregate with varying percentages. The standard aggregate tests were performed on these aggregates, following tests were conducted,

- Aggregate impact test
- Water absorption test
- Specific gravity test
- Los-Angeles abrasion test
- Crushing test
- Shape test
- The above tests were performed with 5%. 10%, 15% replacements and results obtained from these tests were analyzed and the conclusions were made.

4.1.2. Partial replacement of fine aggregate by glass

The waste glass obtained from the source was converted into powdered form. This powder passing

1.7 mm sieve and retained on 150 micron sieve was used.The fine aggregate i.e. sand in the mix was replaced by this glass powder with 0%, 10%, 20%, 30% and 40%. Standard size concrete cubes (150x150x150mm) were made with these varying percentages of glass powder and are placed for curing. The concrete blocks were placed in the curing tank for 7, 14 and 28 days. After curing period is over the compressive strength of the blocks were checked under Uniform Testing Machine. For each percentage of replacement and curing three blocks were made and average of these three blocks were taken as final compressive strength of the block. In this project work 45 concrete blocks were tested and after getting all the results, the proper analysis and the graphs were made. Following are the properties of glass,

- Softening temperature is approx. 600 ^{0}C
- Density 2500 kg/m^3
- Perfectly elastic material, it does not exhibit permanent deformation until breakage
- High compressive strength

5. RESULTS AND DISCUSSION

The aggregates used in the experimentation showed the following physical properties which gives an idea about their strength. The properties of fine and coarse aggregate varies because the coarse aggregates used are naturally crushed aggregates while the fine aggregates are obtained from river sand by the action of attrition and erosion.
The results obtained by partial replacement of coarse aggregates by tire rubber are satisfactory up to certain limit but after that it becomes uneconomical. Glass could also be a better option for sand as both the elements have adequate silica content, but replacement is beneficial only up to 10%.

5.1. For Coarse Aggregates

The coarse aggregates were tested according to the conventional tests of aggregates to determine their physical properties, so that

the aggregates could be used in road construction depending on the properties of aggregates after the replacement of coarse aggregates by tire rubber in varying percentage.

SNO	PROPERTY	VALUE
1.	Dry Loose Bulk Density	1.748
2.	Zone	I
3.	Bulkage	5%
4.	Silt Content	3%
5.	Specific Gravity	2.80

Table 5.1 Physical Properties of Coarse Aggregates

A] For Impact Value test

Impact value gives an idea about the toughness of aggregates. The impact value decreases with the increase in replacement of coarse aggregates by tire rubber according to the weight basis.

Table 5.2 Impact Value

TIRE RUBBER REPLACEMENT	IMPACT VALUE
0%	11.63
5%	9.46
10%	9.39
15%	5.82

The standard value of impact for the aggregates used in road construction varies according to the layer in cross section of the road. The maximum permissible impact value for the coarse aggregates is 50% for dry impact and 60% for wet impact test.

B] For Abrasion Test

Abrasion test gives the percentage wear resistance i.e. the hardness of the aggregates.
The experimental investigation is carried out by considering the' Grading B' of the aggregates i.e. by considering20-12.5mm and 12.5-10mmm aggregate size and 11 metallic spheres. Due to the presence of abrasive charge, this experiment gives an idea about resistance to abrasion as well as impact.

Table 5.3. Los Angeles Abrasion Test

TIRE RUBBER REPLACEMENT	ABRASION VALUE / % WEAR
0%	14.06
5%	11.67
10%	10.66
15%	10.00

The maximum allowable Los Angeles Abrasion Value is 40% for WBM sub base and 30% for bituminous concrete.

C] For Crushing Value test

The increase in tire rubber content by weight leads to the decreases in crushing value of aggregates. The waste tire rubber used as a replacement of aggregate is Tough enough and so it does not undergo crushing.

Table 5.4 Crushing Value Test

TIRE RUBBER REPLACEMENT	CRUSHING VALUE
0%	12.7
5%	12.83
10%	10.66
15%	8.73

The maximum permissible crushing value of aggregates is 45% and depending on the crushing percentage its suitability in various layers of road can be identified.

D] For Specific gravity and water absorption test

Specific gravity gives an idea about the void content and is used for weight-volume conversions. Water absorption percentage is helpful to calculate the strength of aggregates. The specific gravity decreases with increase in water content. Water absorption is directly related to the porosity of aggregates, more porous present,more water absorption.

Table 5.5 Specific gravity and water absorption test

TIRE RUBBER REPLACEMENT	WATER ABSORPTION	SPECIFIC GRAVI-TY
0%	2.62	2.83
5%	2.66	2.24
10%	2.68	2.45
15%	3.26	2.33

Permissible water absorption value changes with the layer, in the drainage layer aggregates absorbing about 4% of water are permissible while the base course can use the aggregates with only 1% water absorption value.

E] For Shape Test: Flakiness & Elongation Index

Maximum permissible flakiness and elongation index is up to 30%. Flaky and elongated materials have the highest possibility of breaking down even under small loads ,therefore, such material should be avoided .The flakiness and elongated index of the tested sample was found out to be 11.82% and 10.81% respectively, the value lies within the permissible limit, therefore, the given sample can be used in road construction.

5.2. For Fine Aggregates

The fine aggregate used in concrete is replaced by the fine glass powder. The main constituent of glass and sand is silica, therefore, the chemical reaction of alkali and aggregate will take place in similar manner even if sand is replaced by glass powder. The compressive strength of the concrete blocks, by replacement of fine aggregate i.e. sand by glass powder, is determined.

A For Slump test of Glass Concrete

The slump of normal concrete was found to be 80mm while that of glass concrete was found 70mm. The workability of normal concrete and glass concrete varies by a small range due to the change in slump.

5.3. COMPRESSIVE STRENGTH OF BLOCKS

The compressive strength of blocks with M40 design, increases with curing up to 10% replacement and then the strength decreases gradually with the increase in glass content or replacement of fine aggregates by glass powder.

Table 5.6. Compressive Strength of blocks

GLASS CONTENT (in %)	CS AFTER 7 DAYS (in MPa)	CS AFTER 14 DAYS (in MPa)	CS AFTER 28 DAYS (in MPa)
0	24.86	32.46	42.38
10	39.26	43.24	45.88
20	35.40	40.36	43.38
30	31.38	38.29	43.05
40	23.25	31.26	38.46

The compressive strength after 28 days curing is more than 7 days curing for 0% replacement of fine aggregate by glass powder. The compressive strength increases up to 10% replacement of fine aggregate by glass powder and for 28 days curing. Beyond 10% replacement, the compressive strength reduces gradually but with increase in curing the CS increases for the replaced % only, which means that for 20 % replacement the CS for 7 day curing is 35.40 and it increases up to 43.48 for 28 day curing, but it is less than CS of 10% replaced glass concrete for 28 days curing. The CS at 40% replacement lowers for 7 day curing as well as 28 days curing, as compared to the replaced lower percentages.

It is observed that when fine aggregate is replaced by 10% glass powder, the compressive strength after 7 days is found to increase by about 57.9% on average (fig. and table) However, it is found that increase in compressive strength after 28 days is only 8.25% , after 14 days curing increase in strength is 33.21% at same replacement level. It is observed that on replacing fine aggregate by 20% glass powder on average there is an increase in compressive strength after 7 days curing by 42.4% however, after 14 days and 28 days curing; increase in compressive strength is 24.33% and 2.36% respectively. Therefore, we can say that with the increase in curing for a replaced %, there is decrease in strength rate. It is seen that there is increase in compressive strength after 7 days curing by about 26.21% for 30% replacement, after 14 days curing strength increases by 17.9% and after 28 days it increases by only 1.6%. Whereas at 40% replacement by glass powder, the compressive strength after 7, 14, 28 days curing decreases marginally.

6. Conclusion

Large volumes of waste products like rubber and glass are generated, because of stricter environmental regulations, landfill disposal has become difficult and therefore disposal cost is escalating. Recycling is the best option over disposal; it helps in reducing disposal costs, conserves natural resources. Substitution of conventional materials by recycled waste materials helps in efficient use of waste material and sustainable use of natural resources; in this case both coarse and fine aggregates.

Replacement of coarse aggregates by tire rubber leads to decrease the aggregate impact value. The present tests are not completely adequate for higher percentages of replacement of rubber. The replacement of coarse aggregate by rubber has shown remarkable improvement in the physical properties, therefore the above method can be used in the actual road construction and the problem of rubber disposal can be solved up to certain extent. Thus rubber can be a partial substitute for coarse aggregate.

Waste glass can effectively be used as fine aggregate replacement. The workability of green concrete i.e. replaced glass concrete is same as that of conventional concrete, therefore, green concrete can be a substitute. Marginal decrease in strength is observed at 40% replacement level of glass powder with fine aggregate. For a constant replaced percentage of glass, the strength increases with curing but the rate of increase in strength is gradual. Beyond 10% the compressive strength reduces as compared to the 0% replacement of fine aggregate by glass powder .Glass powder can be used to manufacture “Green Concrete” but only up to 10% replacement of sand.

The problem that can occurs for replacement is cutting the tyre rubber to the required sizes and crushing of glass up to the size of fine aggregate. It leads to less exploitation of nature, disposal as well as proper use of the waste tire rubber.

7. Acknowledgement

Our thanks to G.S.M.C.O.E. and department of Civil Engineering which has provided us support and equipment which we needed to complete our work. We extend my heartfelt gratitude to our guide Prof. Shweta Patil who has supported us throughout our research with their patience and knowledge.

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