Experimental Investigation on Partial Replacement of Coarse Aggregate Using Polystyrene Beads in Concrete

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Abstract: With the development of modern construction techniques, the demand for construction materials increases day by day. There is a strong need to utilize alternative materials for sustainable development. The usage of partial replacement of coarse aggregate using polystyrene beads in concrete gives prospective solution to building construction industry. Polystyrene beads are the waste material obtained from packaging industries. This paper handles comparison of concrete which partially replaces coarse aggregate by polystyrene beads with conventional concrete blocks. The result shows that amount of the polystyrene beads incorporated in concrete influences the properties of hardened concrete. Also, the compressive strength and split tensile strength of 5%, 10%, 15%, 20% replacement of coarse aggregate for M25 mix shown. The workability of mix is very high at a low water/cement ratio.

Index Terms- Polystyrene , slump value, compaction factor, compressive strength, split tensile strength, strength to weight ratio,

1. INTRODUCTION

The environment is facing rapid urbanization and industrialization that may change the quantity of municipal solid waste generated. Plastic waste is considered as a serious problem to the environment due to inability of plastic to degrade naturally. Polystyrene is the plastic category that is widely being used as food containers and packaging. It is normally thrown into the waste stream directly without treatment due to higher cost of recycling in comparison to manufacturing of the construction materials. Polystyrene waste is generated from both industrial and municipal solid waste. It has become a major environmental concern due to large waste quantities being disposed to landfills and it is non-biodegradable in nature.

Polystyrene is a light weight cellular plastic material consisting of fine spherical shaped particles which are comprised of 99% air and 2% polystyrene. It has a closed cell structure and cannot absorb water. It has good sound and thermal insulation characteristics as well as impact resistance.

There are many advantages to be gained from the use of light weight concrete. These includes lighter load during construction, reduced self-weight in structures and increased thermal resistance. Light weight concrete is generally accepted as concrete having a density of about 1800kg/m3 or less. The present investigation was taken up keeping two targets in view, disposal of polystyrene waste from the point of view of environment and for the replacement of aggregate from the point of view of construction industry. The present study is aimed at analyzing the suitability of polystyrene beads as partial replacement of coarse aggregate.

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Table 1: Properties of polystyrene beads

Specific gravity	0.011
Bulkdensity(kg/m^3)	6.86
Particle size (mm)	6-9(spherical)

Fig. 1: Polystyrene beads

2. MIX PROPORTION

The physical properties of individual ingredients were determined. After the testing of material used for the experiment, mix proportioning of the materials was carried out. According to IS 383:1970 mix proportioning was done. The mix proportions for M25 conventional concrete mix was arrived as per IS: 10262-2009.Adopting w/c = 0.45, the proportion of concrete mix

Table 2: Weight of materials used in the mix

Water	Cement	Fine aggregate	Coarse aggregate
208 litres	426.22kg	807.5kg	888.25kg

By the mix proportioning conducted mix ratio obtained as 1: 1.75: 1.92.This concrete mix proportion is taken as the reference or control mix in the present study. The mix proportion for beads based concrete is obtained by partially replacing coarse aggregate with different dosages of polystyrene beads volumetrically. The quantities of materials for various mixes are obtained by partial replacement (by volume) of coarse aggregates by beads. Mixture Composition

In this study the partial replacement of coarse aggregate by 5%, 10%, 15% and 20% polystyrene beads were done by volumetric percentage with cement, sand and remaining percentage of crushed gravel. Water to cement ratio (W/C) used in this study was 0.45 which were constant for all proportions of polystyrene. The standard concrete mixed without polystyrene that used as control concrete mix. Three cube and two cylinder samples were made for each age 28 days.

3. TEST ON SPECIMENS

3.1. Test on fresh concrete

3.1.1. Slump test

In general, it was observed that workability of a concrete mix increased on addition of polystyrene. Workability of the mixes was observed to increase with increase in percentage replacement of coarse aggregate with polystyrene (as a partial replacement of aggregate) i.e., higher the polystyrene replacement, higher was the workability.

Table 3: Slump value for different percentage of polystyrene beads

Concrete mix	Slump value(mm)
Control mix(M25 grade concrete)	60
5% Replacement of coarse aggregate	65
10% Replacement of coarse aggregate	68
15%Replacement of coarse aggregate	70
20%Replacement of coarse aggregate	75

3.1.2. Compaction factor test

Compaction factor test is another method used for find out the workability of the fresh concrete. It is more accurate than slump test.From the values obtained it is clear that workability of concrete increases with percentage of polystyrene increases.

Fig. 2: Compaction factor test

Table 4: Compaction factor values for different percentage of polystyrene beads

Concrete mix	Compaction factor
Control mix(M25 grade concrete)	0.876
5% Replacement of coarse aggregate	0.899
10% Replacement of coarse aggregate	0.91
15% Replacement of	0.925

coarse aggregate	
20% Replacement of coarse aggregate	0.943

3.2. Test on hardened concrete

3.2.1 Compressive strength test

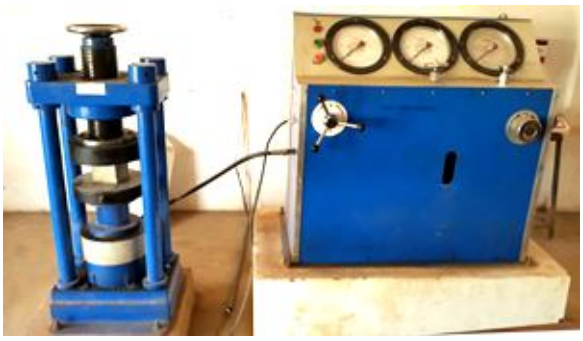

Fig. 3: Compressive strength testing machine

Compression testing of the cube specimens was carried out in Universal Testing Machine of capacity 2000 KN, as per IS: 516-1959. A set of three cubes were tested for each of the mix for their compressive strengths at 28 days of curing.

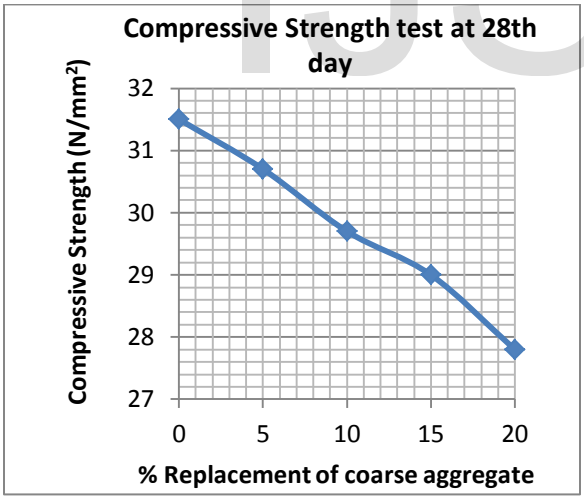

Fig. 4: Test results of compression strength test

3.2.2. Split tensile strength

Fig. 5: Split tensile strength testing machine

Split tensile tests were carried out, on standard cylindrical specimens of all the polystyrene based concrete mixes. This is an indirect method of applying tension in the form of splitting. The test was performed on the cylinders of 150 mm diameter and 300 mm height, as per I.S. specifications. The specimen is placed with its axis horizontal between the platens of testing machine. Thin strips of 12 mm wide and 3mm thick were inserted between the cylinder and the platens of testing machine.

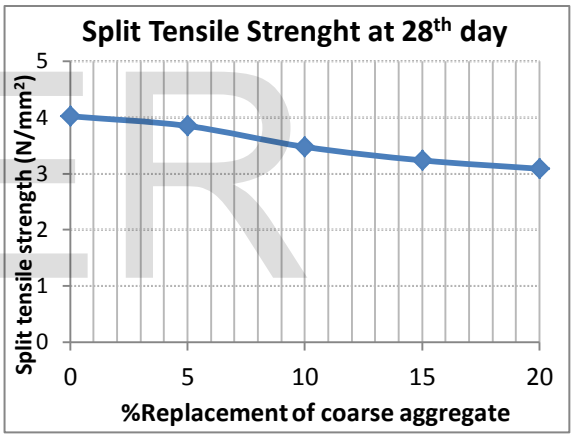

Fig. 6: Test results of split tensile strength test

3.2.3. Strength to weight ratio

Most significant property is reduced weight at no sacrifice in strength. This enables reduction of dead load. Weight reduction becomes highly beneficial for structural reasons, for reduced dimensions and substantial saving of steel reinforcement in the foundation.

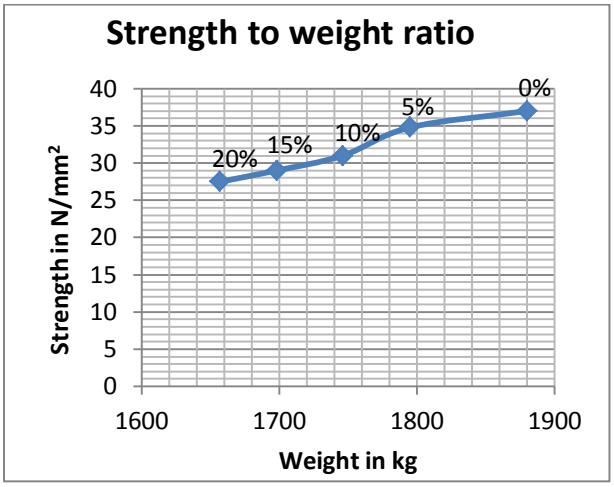

Fig. 7: Strength to weight ratio of specimens tested

4. CONCLUSION

1. Increase in the polystyrene beads content in concrete mixes reduces the compressive and tensile strength of concrete.
2. All the polystyrene concrete without any special bonding agent show good workability and could easily be compacted and finished.
3. Workability increases with increase in polystyrene beads content.
4. The replacement of conventional aggregate materials by using polystyrene showed a positive application as an alternative material in concrete mix for lightweight concrete. Thus, this application in construction industry may provide a solution to reduce polystyrene waste to be disposed in landfills.
5. This work can be considered a new line of research for lightweight concrete as the mixing method is very simple, relatively inexpensive and does not need complex machinery systems.
6. It is recommended that further work should. be done to cover; permeability, structural behavior, absorption, freeze and thaw durability, abrasion, and corrosion of steel reinforcements. The mentioned tests are essential to be carried out before the use of Polystyrene concrete in structural members.

5. REFERENCES

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