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The Effects of using Plastic waste (Polystyrene) as Course Aggregate in Concrete Mixes

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Abstract*: The use of plastic is increasing day by day, although steps were taken to reduce its consumption. This creates substantial garbage every day which is much unhealthy. A healthy and sustainable reuse of plastics offers a host of advantages. The main aim of this investigation is to evaluate the possibility of using plastic aggregate as coarse aggregate in concrete. In this study concrete mixes were tested to investigate the effect of Plastic waste (polystyrene waste) and evaluate the efficiency on fresh and hardened concrete for trying to produce a concrete with high strength and light weight concrete. An experimental study is made on the utilization of polystyrene waste as coarse aggregates in concrete with a percentage replacement ranging from 1.5 % to 6% on the strength criteria of M25 Concrete. Compressive strength and workability*

Keywords: Concrete, polystyrene foam, Compressive strength.

1. INTRODUCTION

Currently millions of tons of waste polystyrene are produced in the world. This will ultimately cause pollution and is harmful to the ecosystem. National and international environmental regulations have also become more inflexible, causing this waste to become increasingly expensive to dispose. Therefore, utilizing waste polystyrene in concrete production not only solves the problem of disposing this ultra-light (up to 95% air) solid waste but also helps preserve natural resources. [1]

Anju Ramesan [2] conducted that for solving the disposal of large amount of plastic materials and to meet the increasing need for aggregates, reuse of plastic in concrete is considered as the most feasible application. Plastic aggregates will not be crushed as easily as natural aggregate since plastic are polymers made up of long string molecules consisting of carbon atoms bonded with other atoms such as hydrogen, nitrogen, oxygen, fluorine. They develop a crystalline structure which is strong, hard and more resistant to chemical penetration and degradation. Hence it will be a boon to the construction industry if plastic is utilized to prepare aggregates rather than recycling it repeatedly. The present work is aimed at studying the strength of concrete with partial replacement of natural aggregate by plastic aggregate.

Many researches were conducted to use industry by products such as fly ash, silica of concrete. R.Lakshmi and S. Nagan [3] suggested the use of EP lastic particles along with fly ash to improve the properties of concrete.

Hamdan [4] reports that the use of polystyrene beads as lightweight aggregates shows lightweight property that highlights the use of polystyrene aggregate concrete in non-structural applications.

Mohd Hilton et al [5] presented the styrofoam is popular to be used as a good thermal insulation material in building construction. Besides, it widely produced as food packaging especially in storing hot servings and also as protective devices for securing goods and materials from vibration and damage during delivering and transporting process. Commonly, Styrofoam for delivering process was shaped according to the delivering item's shape. Normally after delivering process, it commonly treated as waste product and it seldom to be recycled as a new Styrofoam as it is not economical to be reproduced. Styrofoam aggregate has a closed cell structure consisting essentially of 98% air. Styrofoam concrete is made from a mixture of cement, sand and Styrofoam aggregate. By using different volumes of waste styrofoam incorporated with fly ash, a range of densities and also compressive strength can be obtained.

Abhijit [6] out lined the expanded polystyrene (EPS) geofoam is a lightweight material that has been used in engineering applications since at least the 1950s. Its density is about a hundredth of that of soil. It has good thermal insulation properties with stiffness and compression strength comparable to medium clay. It is utilized in reducing settlement below embankments, sound and vibration damping, reducing lateral pressure on sub-structures, reducing stresses on rigid buried conduits and related applications. Expanded polystyrene waste in a granular form is used as lightweight aggregate to produce lightweight structural concrete with the unit weight varying from 1200 to 2000 kg/m³. The polystyrene aggregate concrete was produced by partially replacing coarse aggregate in the reference (normal weight) concrete mixtures with equal volume of the chemically coated crushed polystyrene granules.

2. METHODOLOGY

The following steps done to complete the study:

- Collection of polyethylene foam (HDPE) materials.
- Preparation of recycled plastic aggregate.

- Various tests were conducted on cement, fine aggregate and coarse aggregate to determine its physical properties
- Mix design of M25 grade concrete.
- Cubes, were casted with control mix using natural aggregate
- Cubes were casted for varying percentage replacement (1.5-6.0%) of natural aggregate by plastic aggregate.
- Workability, compressive strength tests of concrete was conducted.
- Optimum percentage of plastic aggregate that can be replaced in concrete was determined.

3. MATERIALS

3.1 Constituent Materials of Concrete:

Cement: The cement used was Ordinary Portland cement (OPC) conforming to British Standards No. 12 of 1996 with a specific gravity of 3.15. Initial and final setting times of the cement were 160 min and 245 min, respectively.

Fine Aggregate: The sand used for experimental program was locally procured. The fine aggregates were tested as per British Standard Specification BSI: 882-1997. The specific gravity of sand was found out to be 2.71.

Coarse Aggregate: The natural broken stone (coarse aggregate) used for the study was of 20 mm size maximum. It is conforming BSI: 882-1997. It was retrieved from a local quarry .The shape and quality of aggregate was uniform throughout the project work and the specific gravity was found to be 2.6. Table 1 shows the results of tests of impurities, specific gravity and water absorption of coarse and fine aggregates

Table 1: Properties of aggregates

Experiment name	Fine aggregate	Coarse aggregate
Impurities	3%	-
Specific gravity	2.71	2.6
Water Absorption	%0.752	0.45%

Water: The used water from Khartoum city water distribution system.

Polystyrene: Used Styrofoam was used in this research as showed in *fig*1. The Styrofoam that protects equipment during delivering process normally come in a big size and need to be cut into desired size suitable to be used as coarse aggregates. The big size of Styrofoam was cut into 150-160 *square mm* range of size and put inside the oven to allow them shrink into our desired shape for about 10 *minutes*. The Styrofoam obtained will be in the range of 10-20 *mm* size. This size will be sieve and divided into 2 major sizes, i.e., maximum size of 20 *square mm* and 10 square mm respectively. The shrinking Styrofoam will be stored in a barrel until its casting day.

Fig.1.*Plastic aggregate (polystyrene)*

3.2 Mix Design Method

BSI curing method of mix design was used for mix design for concrete cubes test .concrete specimens with various percentages of fiber and fiber waste were prepared .the details of various mix proportions for different replacement levels of cement by fiber and fiber waste at 7 and 28 days.

The aggregate dry density used was 1600 kg/m3 ,and the maximum aggregate size use in all mixes was 20 mm .using standard cubes moulds (150*150*150) mm,6 cubes representing each ratio, were casted and tested at age 7 and 28 days.

3.2 Components of mix materials:

Concrete Mixes Design: The concrete mix to resist compression design (25 N/mm^2) The quantities of materials for all the mixtures as illustrated table3: Mix design: (density of 2375 kg/m^3).

Table 2: The amounts of the mixture of design

Mix Materials	Weight(kg/m^3)
Cement content	370
Fine aggregate content	660
Coarse aggregate content	1125
Water content	220

4.RESULTS OF EXPERIMENTS

Results of Hardened and fresh Concrete

The results of hardened concrete tests conducted by adding different ratios of the fiber glass, examples of this result for 0.0 %, 1.5%, 3%, 4.5% and 6% of polystyrene are shown in tables 3 to 9 and depicted graphically in Figures

Table 3: Results of Compressive Strength Tests at age 7 and 28 days

% of polystyrene aggregate (%)	Average strength at 7days (N/mm^2)	Average strength at 28days (N/mm^2)
0	21	32
1.5	19	25
3	12	17
4.5	9	13
6	5	7

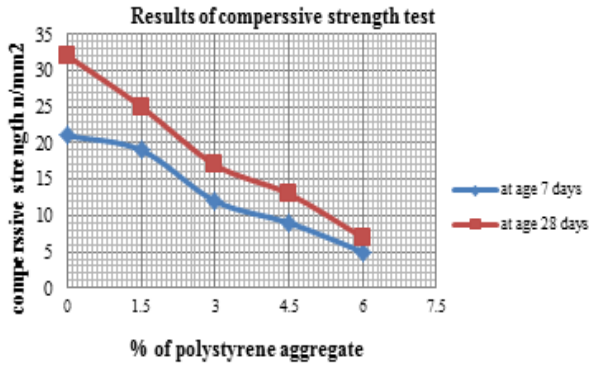

Fig.2. *Results of compressive strength test*

Table 4: Results of slump test

% of polystyrene aggregate (%)	Slump (*mm*)
0	25
1.5	21
3	19
4.5	16
6	12

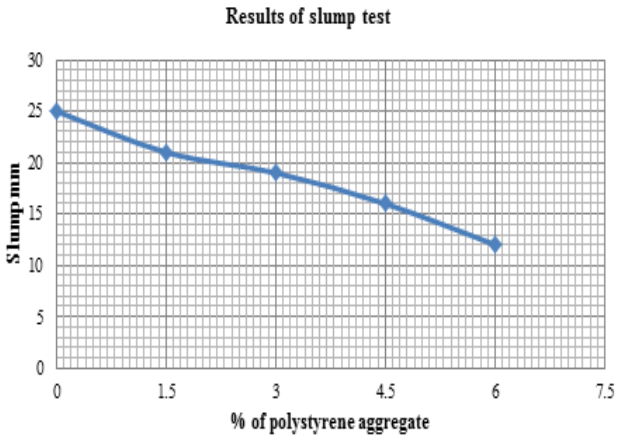

Fig.3. *Results of slump test*

Table 5: Results of slump test

% of polystyrene aggregate (%)	weight (*g*)
0	2589.5
1.5	2326
3	2221
4.5	2065
6	1830

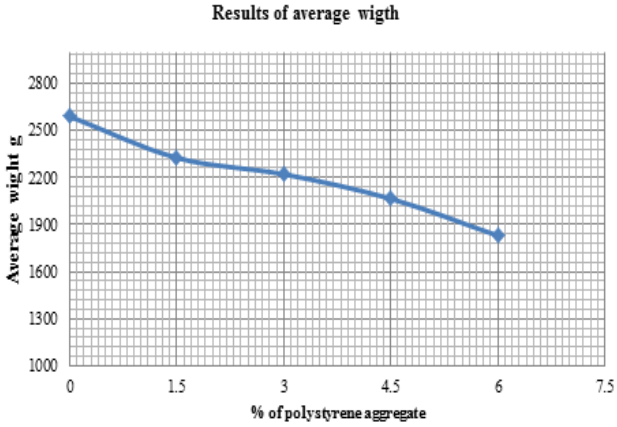

Fig.4. *Results of average weigth of concrete mixes*

5. DISCUSSION OF THE RESULTS

The results obtained from the different tests are summarized and discussed as following:

1. Average Compressive strength of concrete in control mix and without aggregate replacement
2. Average Compressive strength of concrete decreased with increasing amounts polystyrene aggregate as shown in *table* 3 and *Fig*. 2
3. The slump values decreased with increasing amounts polystyrene aggregate as shown in *table* 4 and *Fig*. 3
4. The average weight of concrete mixes decreased with increasing amounts polystyrene aggregate as shown in table 5 and Fig. 4

From the previous indicators it has been obtained that the optimum ratio of the fibers can be added to concrete to improve the compressive strength of it is 1.5 %, and also show's beyond these mention proportioned that the compressive strength decreases as shown in *Fig* 2.

6. CONCLUSIONS

This study intended to find the effective ways to reutilize the polystyrene waste particles as concrete aggregate.
Analysis of the strength characteristics of concrete containing recycled waste plastic have the following results.

- Increase in the polystyrene content in concrete mixes reduces the compressive strength of concrete.
- The replacement by using polystyrene has shown a positive application as an alternate material in

building nonstructural members or on tiles and blocks

- Obtained results suggest that expanded polystyrene concrete has scope for nonstructural applications, like wall panels, partition walls.

7. RECOMMENDATIONS

Based on the result of the study performed in this research, the following recommendations can be drawn:

1) 1.5% of polystyrene aggregate replacement could be used to obtain concrete mixtures with reasonable strength.
2) Study the effect of polystyrene aggregate on the sound and temperature isolation.

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