Effectiveness of Polystyrene Beads as Aggregate Replacement Material to Recycle Solid Waste: A Study on Workability and Absorption results of Concrete

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Abstract The objective of this study is to determine the maximum usage of polystyrene beads from solid waste as aggregate replacement material in concrete for the purpose to recycle solid waste, and thus diverting waste from being disposed in landfills. Different ratios of polystyrene were used; 25%, 50%, 75%, and 100% were mixed with gravel and sand of the same cement content and water cement ratio. A standard concrete mixture was provided for control concrete standard. Concrete cubes with dimensions of 100 mm x100 mm x100 mm were cast according to British Standard (BS 1881 part 116:1983). The engineering parameters studied were slump test and absorption test in comparison to the control concrete. The results showed that the absorption of concrete with different ratios of polystyrene in comparison to the control mixture reduced up to 82.05 % for 100% replacement of polystyrene. While the workability of the concrete mixtures was increased with the increasing of polystyrene beads with average of (medium).

Keywords ***solid waste, polystyrene beads (PS), concrete, aggregate replacement, workability, slump test, absorption test.***

1. Introduction

The environment is facing rapid urbanization and industrialization that many changes in the quantity of municipal solid waste (MSW) generated [1]. Solid waste was and still one of the major environmental problems in Malaysia and most of other countries worldwide. It plays a significant role in the ability of nature to sustain life within its capacity. Plastic waste is considered a serious problem to the environment due to inability of plastics to degrade naturally. Polystyrene is a 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 virgin material. Polystyrene waste is generated from both industrial and municipal solid wastes sources. It has becoming a major environmental concern due to large waste quantities being disposed to landfills and its non-biodegradable in nature. Thus, the purpose of this study is to assess the effectiveness of polystyrene waste being used as material replacement for aggregate to produce concrete, with a target as an option to minimize the amount and volume of solid waste to be disposed to landfills.

2. Experimental Set-Up

2.1. Materials

Standard Portland cement ASTM TYPE I was used in all mixtures for this study, which met the requirement of ASTM C151 [2] for Portland cement. Fine and coarse aggregate used were according to ASTM C 33 (AASHTO M 6/M 80) [3] that had been analyzed with sieve analysis. The coarse aggregate passed sieve 9.5 mm and stopped at sieve 5mm. The polystyrene used for the study (Figure 1) was in granular form, white in color, solid surface with diameter range between 2-2.5 mm, very light in weight with densities between 15 kg/m^3-20 kg/m^3. Mixing was done by using tap water.

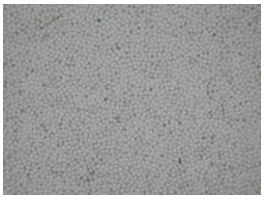

Figure 1 Polystyrene beads

2.2. Mixture Composition

In this study percentage by volume of polystyrene used were 0%, 25%, 50%, 75%, and 100%, which were mixed with sand and crushed gravel. Water to cement ratio (W/C) used in this study was 0.45 which were constant for all proportions of polystyrene. (PS-0) symbolized to the standard concrete mixed without polystyrene that used as control concrete. The other proportions (25%, 50%, 75%, 100%) were named as (PS-S-25), (PS-S-50), (PS-S-75), (PS-100) for sand and (PS-G-25), (PS-G-50), (PS-G-75), (PS-100) for gravel. The mixture proportions are shown in Table (1) for sand and Table (2) for gravel. Three cube samples were made for each age 7, 14, 28 days.

Table 1: Mixed proportions for the concrete mixtures for 9 cubes (10x10x10) cm (Sand proportions)

Mixed design	Fine aggregate (kg) Sand	Polystyrene	Coarse aggregate (kg) Gravel	polystyrene	Cement content (kg)
PS-0	6.12	0	12.24	-	3.06
PS-S-25	4.68	0.009	12.24	-	3.06
PS-S-50	3.12	0.018	12.24	-	3.06
PS-S-75	1.56	0.027	12.24	-	3.06
PS-100	0	0.071	0	0.036	3.06

Table 2: Mixed proportions for the concrete mixtures for 9 cubes (10x10x10) cm (Gravel proportions)

Mixed design	Fine aggregate (kg) Sand	Polystyrene	Coarse aggregate (kg) Gravel	polystyrene	Cement content (kg)
PS-0	6.12	0	12.24	-	3.06
PS-S-25	6.12	-	9.1	0.018	3.06
PS-S-50	6.12	-	6.11	0.04	3.06
PS-S-75	6.12	-	3.04	0.05	3.06
PS-100	0	-	0	0.036	3.06

2.2.1. Workability of fresh concrete

The slump test is the most well-known and widely used test method to characterize the workability of fresh concrete. The test method is widely standardized throughout the world, including in ASTM C143-90a [4] and BS 1881: part 102:1983[5].

2.2.2. Absorption of harden concrete

There are a lot of procedures can be used to measure the absorption and for this study the method which has been used is according to the BS1881: Part 122:1983 [6].

3. Results and Discussion

3.1. Slump Test

3.2. The workability of the concrete mixtures was increased with the increasing of (PS-S) proportions .And that refers to absent of the fines and coarse aggregate and also to the shape of spherical (PS-S) beads which increase the slipping between the mixture particles. Table (3) describes the slump type for the different proportions of sand and table (4) for gravel proportions.

Table 3: Description of concretes based on measured slump (Sand Replacements Proportions)

Mix Designation	Measured Slump ,mm	Description of Slump
PS-0	40	Medium
PS-S-25	42	Medium
PS-S-50	45	Medium
PS-S-75	50	Medium
PS -100	58	Medium

Table 4: Description of concretes based on measured slump (Gravel Replacements Proportions)

Mix Designation	Measured Slump ,mm	Description of Slump
PS-0	40	Medium
PS-S-25	42	Medium
PS-S-50	49	Medium
PS-S-75	53	Medium
PS -100	58	Medium

3.3. Absorption Test

The Absorption test were conducted on the concrete samples for 3 cubes with sizes 100x100x100 mm for each age 7, 14, 28 day and then take the average . The results of this test are shown in table(5) and figure (2) for the mixtures and as shown in the results the less value indicate to the 100 %PS because the solid texture for the polystyrene beads that resist to the absorption of water.

Table 5: Results for Water Absorption Test

Mix ID	Water absorption (Kg/m^2)
Control mix	1.02
PS-S 25 %	0.988
PS-S 50 %	0.8
PS-S 75 %	0.678
PS-G 25 %	0.88
PS-G 50 %	0.76
PS-G 75 %	0.561
PS -100 %	0.183

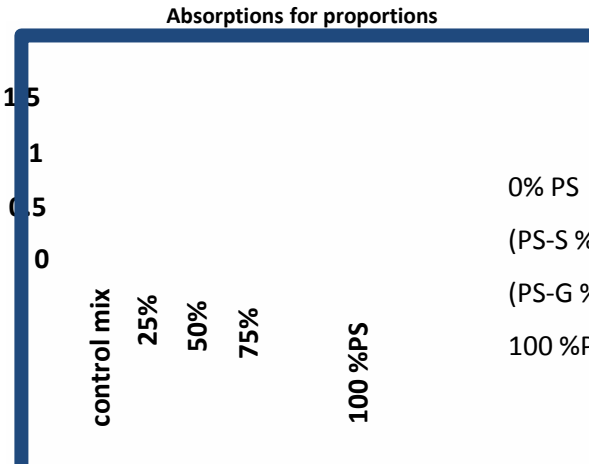

Figure 2 Results of Water Absorption Test for the Concrete Mixtures Used

4. Conclusions

From the results of the study, the following conclusions can be made:

- The fully replacement of the normal aggregate by the polystyrene give maximum usage of the polystyrene that has been extruded as solid waste.
- In comparison to the control mixture absorption has been reduced up to 82.05 % for 100% replacement of polystyrene.
- No segregation was observed in any concrete mixes.
- Lower absorption rating less than 1.1 %.
- 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.

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