Concrete Aggregates from Ceramic Waste

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INTRODUCTION

Polystyrene wastes are a major environmental concern, due to its large production quantity and non-biodegradable nature. Plastic waste represent 11.1% from all municipal solid waste generated each year in the US alone, not inclusive of a majority of post-industrial plastics waste. In Perlis, Malaysia, for landfills such as in Kuala Perlis, 1/3 of the municipal solid waste is polystyrene foam waste. Most plastic waste go to landfills, as its economic re-use is hindered by two integrated factors. First, it comprises a large number of different resins, and each type has had to be handled or sorted separately, which are expensive, and cause waste to be less attractive as a feedstock for manufacturing. Second, products manufactured from waste plastics have been commodity items so cost of production must be kept low.

Polymer recycling has typically been through reprocessing into other polymeric items, or energy recovery from complete combustion. However, reprocessing is limited in the number of reprocessing cycles, since contamination and thermal degradation result from melting and reshaping. Development of concrete with non-conventional aggregates such as polystyrene foam waste is an alternative, to improve the properties of the concrete and save cost. The concrete properties are modified by substitution of crushed stone coarse aggregate with processed polystyrene foam waste aggregate. This development is to reduce the amount of polymer waste deposited in landfills and help keep natural resources.

Lightweight aggregate is an important material in reducing the unit weight of concrete complying with special concrete structures of large high-rise buildings. Generally, it is from ground granulated blast-furnace slag (GBFS), fly ash, or volcanic ash. However, lightweight aggregate do face some problems, such as high cost of aggregate due to high incineration temperature, shrinkage and resistance to freezing and thawing due to high absorption of lightweight aggregates. Therefore, the improvement on the quality of lightweight aggregate concrete has attracted much attention and is the main objective of this research.

EXPERIMENTAL TARGET

The target of the experiment is to determine the contribution of the waste aggregate type to the strength of the concrete. As such the investigation aims to (i) study the behavior of fresh and hardened concrete with polymer waste coarse aggregates and compare the respective properties with conventional concrete, and (ii) produce light weight concrete from polystyrene waste aggregates for multi purpose use.

RAW MATERIALS

Polystyrene foam wastes are generally too big and not suitable to be fed into a crushing machine. They have to be reduced to about 100mm – 120mm sizes, before being oven shrunk by 65 – 68% to the required size of 15mm – 20mm coarse aggregates.

Sand is a very fine, loose fragment of crushed rock. Sand fine aggregates consist of natural particles ranging in size from 150µm to 4.75µm. In the construction industry, fine aggregate is defined as aggregate with particles predominantly of size smaller than 0.0029 inch and equal to or larger than 4.75µm.

Figure 1: Polystyrene foam waste and aggregate

In conventional concrete, **crushed stone or gravel** is used as coarse aggregate and river sand as fine aggregate. The size ranges from the 1/4 inch up to the maximum size permitted for the job. River sand as fine aggregate consists of particles 1/4 inch or less in size. Both, river sand and gravel provide high volume at low cost. Ordinary Portland cement, locally available river sand and natural crushed stone aggregate of maximum size 20 mm are used in conventional concrete.

Mixing proportions

Several polystyrene waste coarse aggregate mixes are designed by volume and weight to three different water-cement ratios (0.40, 0.50 and 0.60). The proportions for the polystyrene waste concrete are 1:1.39:2.28 and 1:1.75:2.75 of cement, fine aggregate and coarse aggregate, respectively, for all designs. There are 2 mixes of conventional concrete designed for control as well as comparison, and the proportions for these are 1:1.50:3.0. The volume of individual ingredients is the same in both the polystyrene waste coarse aggregate and the conventional concrete mixes. Polystyrene waste coarse aggregate and crushed stone coarse aggregate are of saturated and dry surface condition.

PROCEDURE

After being oven shrunk in the oven, <2 minutes, the polystyrene waste coarse aggregates undergo characterization tests such as morphology, density, mechanical and physical tests. Then it is mixed with the raw materials, consisting of ordinary Portland cement and water. The aggregates are divided into two types - coarse and fine. The coarse aggregate consists of polystyrene foam waste and crushed stone whereas fine aggregate consists of normal sand. The ratio for each mixture is based on volumetric proportions. After mixing, the concrete mixtures are measured using the slump test. Then the concrete mixtures are sampled in the cube mold size 150x150x150 mm and 100x100x100 mm for cross-sectioning. After a day, the samples are opened from the mold and cured in water, since all the desirable properties of concrete are improved by proper curing. The moist concrete is cured for 28 days. After 28 days, cube test is carried out using a universal testing machine (UTM) to measure the strength of the concrete.

RESULT AND DISCUSSION

The properties of the polystyrene waste coarse aggregate and conventional concrete are presented in table 2. Six (6) tests were run for polystyrene waste coarse aggregate concrete and 2 tests for conventional concrete. For comparison purposes, the water-cement ratio for conventional control concrete is 0.5. The compressive strength of polystyrene waste coarse aggregate concrete varies from 17.27 to 13.61 MPa whereas for conventional concrete it varies from 19.20 to 18.73. As far as strength is concerned, the basic trend in the behavior of polystyrene waste coarse aggregate concrete is not significantly different from conventional crushed stone aggregate. The strength properties for polystyrene waste coarse aggregate are comparable with the conventional concrete.

The density of polystyrene waste coarse aggregate concrete varies from 1560 to 1467 kg/m3. These values were less than for conventional concrete. The density for light weight concrete are below 1800 kg/m3, hence the polystyrene waste coarse aggregate are categorized as light weight concrete group. Polystyrene waste aggregate concrete is ~30% lighter compared to conventional concrete.

Concrete Type	Mix	w/c	Cement Content (kg/m^3)	Concrete Properties		
				Slump Test (mm)	Compressive Strength (MPa)	Density (kg/m^3)
Polystyrene waste concrete	1	0.50	606	50	15.14	1521
	2	0.50	516	30	14.12	1467
	3	0.60	464	100	13.70	1511
	4	0.60	395	80	13.61	1467
	5	0.40	696	13	17.27	1560
	6	0.40	592	10	15.04	1477
Conventional concrete	7	0.50	606	60	19.20	2371
	8	0.50	516	90	18.73	2305

Table 1 : Properties of polystyrene wastes coarse aggregate concrete and conventional concrete at day 28.

CONCLUSION

Polystyrene waste can be transformed into useful coarse aggregate and the properties of polystyrene waste coarse aggregate are within the range of values for concrete-making aggregates. The polystyrene waste coarse aggregate concrete compressive strength is comparable to conventional concrete, which is from 17.27 to 13.61 Mpa. The polystyrene waste coarse aggregate has a lower density than conventional concrete and is classified as light weight concrete. The properties of polystyrene waste coarse aggregate are not significantly different from those conventional concrete. This research work is the foundation for further experiments on normal concrete with the use of polystyrene foam waste.

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