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RESEARCH ARTICLE

A STUDY ON SUITABILITY OF GENERAL PURPOSE POLYSTYRENE AS A BINDING MATERIAL IN MORTAR

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ABSTRACT

With large quantities of waste produced on earth, innovative practices to utilize wastes are constantly evolving. Plastic is a major pollutant and its expensive decomposing methods have further encouraged development of alternate solutions. A major form of plastic, Polystyrene, in expanded form is used in an extensive manner to produce lighter weight and environment friendly materials. The study focuses on assessing the suitability of General Purpose Polystyrene (GPPS) as a binding material in mortars with Crushed stone aggregates called Manufactured Sand (M-Sand) instead of cement, so that it satisfies the characteristics of conventional cement mortar used to develop building products. The objective of the study is to obtain a suitable dosage of GPPS as binding material with M-Sand and explore its usability by assessing its compressive strength and durability properties. The trial dosages of GPPS of 10%, 15% and 20% is assumed initially by weight in the mix. A dosage of 15% is chosen as this dosage enables proper mixing to cast test cubes. Tests on compressive strength shows that it varies from 11.16 MPa to 15.82 MPa. It is found that when then the test samples of composite mix of GPPS and M-Sand is heated up to 100±5^{0}C, there was a very slight decrease in its compressive strength. The mean water absorption of the test samples was between 0.1% to 5%. The composite mix thus adopted proves as a strong potential binding agent for producing building products. No usage of cement also proves a novelty considering the environmental concerns.

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INTRODUCTION

Construction industry continues to expand at an exponential rate and as the consumption of materials grow, it is leading to depletion of natural resources while producing high amounts of waste and pollution. Ordinary Portland cement (OPC) is the most widely used construction material, production of 1 metric ton of OPC emits 0.7 metric tons of carbon dioxide and carbon dioxide is the greenhouse gas which has great influence on global warming. As most of the present construction techniques involve usage of cement, cement production continues to grow at the rate of 2.5% annually accounting for major emissions of greenhouse gases both directly and indirectly (Emission Reduction of Greenhouse Gases from the Cement Industry, 2004) [1]. With increasing carbon emissions and its growing percentage, the need to develop alternate building products is imminent. The persistent and extensive extraction of natural resources for construction and its related industries puts the principle of sustainability in question. The unwise mining of sand and continuous depletion of natural sources for aggregates has led to strict implementation of new environmental laws such that procurement is difficult and costly now. The sand pits which are licensed may or may not be near the construction sites thus leading to high transportation costs. Crushed stone aggregates called Manufactured Sand (M-Sand) is able to meet all the challenges associated with naturals and in an efficient way and continues to be the preferred choice for construction practices now a days. M-sand is cost effective and production can be carried out near the construction site, thus bringing transportation costs down by a great margin. M-sand can be used as aggregates in concrete mixes and has good working properties. It has also been approved by Department of Mines and Geology, Government of Karnataka, for usage in mortar and concrete [2]. Studies have also shown that usage of M-Sand as fine aggregates in mortar/concrete exhibits good characteristic properties. The study undertaken aims to develop a building material which does not contribute to the depletion of natural resources and in this regard polystyrene is used as a binding material to replace cement completely with M-Sand. Polystyrene with a chemical formula, $(C_8H_8)_n$ is a cyclic polymer made from styrene monomer. It is one of the most common forms of plastic and abundant quantity of it are recycled every year for different purposes. Plastics break into micro particles that circulate in the environment and decomposing plastic wastes take years. Herki *et al.* [3] studied the properties of lightweight concrete made from waste polystyrene and fly ash. Yi Xu *et al.* [4] studied the mechanical properties of expanded polystyrene lightweight aggregate concrete and brick. From various studies it is observed that polystyrene is used as an extruded form or expanded form for development of materials and not as a binding agent. With stricter environmental regulations at both national and international levels, disposal of plastic waste poses further problems and is costly too. Open dumping of plastic continues to be a challenging issue and studies have shown that consuming plastic could lead to cancer, effect on hormone levels and heart damage. Thus utilizing polystyrene will not only solve the problem associated with disposal but also help in preserving natural resources.

Experimental Study

The materials used in the study and the experimental procedure adopted is discussed below.

MATERIALS

General Purpose Polystyrene (GPPS) and locally available M-Sand is used. Table 1 gives the detail of properties of M-Sand used for experiment. The following observations are made from the grain size distribution curve and properties of M-Sand.

- M-Sand falls within limits of grade zone- II as per IS 383:2016 and S-curve of Particle size distribution indicates that it is well graded. 20% fines which are less than 150 microns (µ) are allowed [5].
- The hydrometer analysis shows that the clay content is 1.28% and 12.5% silt content is present. The values are well within permissible limits [5].
- The specific gravity of M- Sand is found to be 2.61 and bulk density is 1657 kg/m^3.

Table 1. Properties of M-Sand

PROPERTIES	M-SAND VALUES
1. Textural Composition (% by weight)	
Coarse Sand (4.75-2.00 mm)	25.7
Medium Sand (2.00-0.425 mm)	39.4
Fine Sand (0.425- 0.075 mm)	26.6
2. Specific Gravity	2.61
3. Bulk Density (kg/m^3)	1657

General Purpose Polystyrene (GPPS) is obtained from local industry. It is a crystal-clear polystyrene, round granularly shaped, which is transparent and rigid with wide usage in food package applications and cases for storage.

Experimental Procedure

The materials are mixed in the following order: Firstly, GPPS granules are placed in the pan surrounded by M-Sand. Secondly, the mix containing GPPS granules and M-Sand is heated in a pan to 540^{0}C, as the granules start melting, it converts to a liquid state. At this stage M-Sand surrounding the granules is mixed thoroughly with the melted polystyrene and whole mix is transferred to the cube moulds of size (50*50*50) mm immediately [6]. The hot mix is stamped with tamping rod and left to cool at room temperature followed by demoulding.

Dosage of Polystyrene

Adequate information regarding dosage of GPSS is not available. Three dosages of GPSS by trial and error i.e. 10%, 15% and 20% by weight are assumed. The mean compressive strength with 10%,15% and 20% of GPSS dosage are found to be 9.30 MPa, 12.33 MPa and 18.67 MPa respectively and shown in Fig. 1. The cubes don't require any curing since there is no C-S-H gel formation as in case of cement.

Hence, the GPSS content of 15% dosage is chosen among the three assumed dosages for following reasons-

- The mean compressive strength of 12.33 MPa is in line with the compressive strength of masonry bricks. [7]
- Good uniform mix is achieved to enable casting of cubes

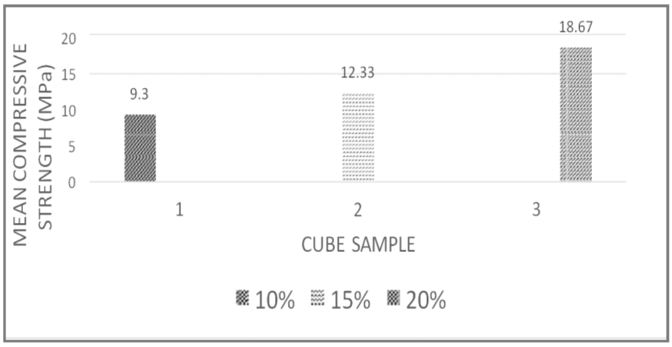

Fig. 1. Compressive Strength for different dosages of GPSS

RESULTS AND DISCUSSION

The mortar of GPSS and M-sand cast in the test cubes of size (50mm*50mm*50mm) are tested to assess its density, compressive strength, temperature resistance, water absorption, durability property by cyclic heating and cooling and its ability for adhesion to cement mortar by triplet shear strength tests. Six cubes were cast for each test. The results of the tests conducted on the test samples at 15% dosage of GPSS and the discussions made are made as under.

Density

GPPS granules when melted and mixed with M-Sand exhibited uniform mix enabling to cast cubes. A sample with good dimensional characteristics is obtained if temperature is maintained while mixing and casting is done immediately. The density of the samples cast using GPPS and M-Sand varied from 1700kg/m^3 to 2100 kg/m^3 and is in line with traditional masonry units [8]. Fig. 2 shows test cube samples of GPSS with M- sand.

Fig. 2. Cube Samples

Compressive strength

The samples at dosage of 15% are tested for compressive strength. With load applied at rate of 0.5 kN/s. Strength of cubes varies from 11.16 MPa to 15.82 MPa with mean value of 13.53 MPa and coefficient of variation is 0.128. The compressive strength is adequate for mortar to be used in various building products

Temperature resistance

The compressive strength of test samples is found after heating them in an oven to a temperature of $(100\pm5)^0$ C for 48 hours. It was observed that after samples are exposed to heat, there is a very small decrease in compressive strength. The mean compressive strength after subjecting to temperature of $(100\pm5)^0$C is 12.87 MPa thus exhibiting that test samples are resistant to temperature up to 100^0.

Water absorption

Water absorption test is carried out on the test samples to check its water absorption capability. The samples after oven drying at a temperature of $(100\pm5)^0$ C are weighed and immersed in water for 24 hours [9]. The samples are weighed again after removing from water and percentage of water absorption is found. It is found that the mean absorption was 0.1%-5%. There is not much change in density of the samples after the water absorption test and it remains fairly constant.

Cyclic heating and cooling of cubes

This test is conducted to assess its durability property. The behavior of cube samples under the repetitive cycles of heating and cooling is studied. The saturated wet test cubes immersed in water after 24 hours is taken and then kept in an oven for 48 hours at a temperature of $(100\pm5)^0$C. The weights of saturated wet cubes and its corresponding oven dry weight are taken. The difference in the weights would give the water absorption capacity of the samples. Four cyclic heating and cooling of the test cubes was conducted. It is found that alternate cycles bring a change of about 5% to 10% in the density of the samples and water absorption is fairly constant throughout the process, in the range of 0.1-5%. It is also observed that there is not much change in the dimensional sizes of the cubes after four cycles and the loss in weight of cubes which suffered edge damages was minimal and less than 5%.

Adhesion to cement mortar

The cube samples are tested to assess their adhesive capability to cement mortar by triplet shear strength test. Test is conducted on three sets and each set consists of three cubes adjoined together by mortar joint (not exceeding 10mm) of cement and sand in proportion of 1:6. [10]. The mortar shear strength is given by the ratio of ultimate load to cross sectional area of the adjacent cubes (2*50mm*50mm). The shear strength of mortar joint samples lies in the range of 0.07 MPa to 0.12 MPa with a mean value of 0.09 MPa. Mortar shear strength results also validate the work by C. Freeda Christy *et al.* [11]. Hence, building products using GPSS and M- sand exhibit good bond with cement mortar justifying its suitability in masonry works.

Conclusion

The following conclusions are drawn based on the results of this study-

- The dosage of GPSS plays the most important role in determining the strength and durability of the cube samples. While lower GPSS dosage provide good compressive strength but an uniform mix with M-Sand is little difficult and thus 15% percent of polystyrene is better.
- The mix of GPSS with M-Sand exhibits a good compressive strength (13.53MPa). However, there is not much variation in compressive strength (12.87MPa) when the mix is heated to 100^0 C and tested at room temperature.
- GPSS acts as a good binder material and the cube samples show less water absorption (0.1- 5%).
- Cement mortar adheres very well with surface of mix of GPSS with M-Sand. The mean shear strength is 0.09 MPa and justifies the building product of GPSS with M-Sand as masonry units.
- The use of GPSS with M-Sand can address many challenges for some of the viable applications. However, the production viability poses as a challenge and mechanized setup for casting the samples as per procedure adopted may be more suitable.

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