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Reuse of Hazardous Waste as Alternative Building Materials–A Review

UG Student Harshith. M
Dept. of Civil Engineering
East West Institute of Technology (EWIT)
Bangalore, Karnataka, India
harshith.zigzag@gmail.com

Masters Student Aditi Parmar Chitharanjan
Dept. of Environmental Science
Ca' Foscari University of Venice
Venice, Italy
parmaraditi017@gmail.com

Abstract:-Waste materials are a major environmental problem, among them the most dangerous are hazardous wastes that are substantial or potential threats to public health or the environment. Waste can be used in the construction industry in two ways: by reusing and recycling. This article presents a review of the literature on changes in the composition of traditional building materials with the addition of certain wastes without compromising on its durability and efficiency. This article mainly concentrates on the use of Polystyrene (PS), and formaldehyde resin which are some wastes attained from construction industries and their by-products. Some physical and mechanical properties are studied when these mixtures are partially replaced in cement with sand in experimental ratios to receive efficient ratios and to study its properties. This article is a review of major work done in this field.

Keywords- Waste materials, Waste materials, Reusing, Polystyrene, and Formaldehyde.

I. INTRODUCTION

Cement is a binder, a substance that is used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is rarely used on its own, but rather to bind sand and gravel together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Cement mortar may be a building compound created by mixing sand and different types of aggregates with a specified amount of water. Concrete is essentially a mix of aggregates and paste. The aggregates are sand and gravel or crushed stone; the paste is water and Portland cement .concrete additives are added to the mixture of water cement and aggregate in small quantities to extend the sturdiness of the concrete, to repair concrete behavior and to regulate setting or hardening. They can either be liquid or powdered additives. The aim of the study is to work out the effect of selected additives the physical and mechanical properties of modified cement mortars.

In recent times, the problems associated with waste management have become very predominant within the view of a sustainable model of improvisation and consumption of latest resources and energy. The development industry is one among the best consumers of raw materials along the assembly of huge quantities of waste. Some wastes are often used as additives in cement mixes to scale back the consumption of latest raw materials and also a far better methodology of disposal of a number of the wastes generated. Hazardous wastes create the necessity for immediate reuse, recycle or proper method of disposal as they create a greater threat to mankind. A number of the hazardous wastes like polystyrene and expanded foamed glass granules and formaldehyde resin are often used as additives with the cement. Studies are administered to gauge an equivalent.

II. LITERATURE REVIEW

To protect the environment, many efforts are being made for the recycling of various forms of wastes with a view to using them within the production of various construction materials. Their main objective was to analyze the potential use of different wastes for producing construction materials. The standard methods for producing construction materials are using the available natural resources. Alongside, the industrial and urban management systems are generating solid wastes, and usually dumping them in open fields or landfills. These activities pose serious degrading effects on the environment. (Safiuddin et al., 2010)

Studies have analyzed various properties of concrete containing by-products and waste materials like granulated blast-furnace slag (GBFS), fly ash (FA), bottom ash (BA), and silica fume, waste glass (WG) as admixtures, aggregate replacements or binding materials. Wastes and by-products are often utilized in addition to concrete without the necessity for significant changes in its preparation.

Its granulometric properties indicate that it is often utilized in fine sand in production. (Smita Badur and Rubina Chaudhary, 2008)

Recycled waste glass in concrete is usually utilized in many different methodologies within the building construction industry as quantified substitutions of a minimum of one or more of its constituents. Studies are being done using waste glass as partial substitution for fine or coarse aggregates, combined as fine and coarse aggregates; others used glass powder in partial substitutions of cement due to its pozzolanic nature. Reviews show that in the glass waste in construction has shown that recycled waste glass, when combined with concrete either in powder form or crushed as an aggregate, improved the mechanical strength of the concrete. (Ogundairo et al., 2019)

Lightweight thermo-insulating mixes are often considered environmentally sustainable materials for indoor non-structural artifacts because they're prepared with non-pre-treated secondary raw materials and with an inexpensive route since complex techniques of production aren't required. These treatments and processes would, however, be more effective within the case of production on a bigger scale. (Andrea Petrella et al., 2020)

III. MATERIALS

Formaldehyde is a colorless, pungent gas used in the making of building materials and many household products. It is a highly toxic poison that is absorbed into the body by inhalation. The vapor is a severe respiratory tract and skin irritant and may also cause dizziness or suffocation. Direct contact with formaldehyde solution may cause severe burns to the eyes and skin. It is used in pressed-wood products, such as particleboard, plywood, and fiberboard; glues and adhesives; permanent-press fabrics; paper product coatings; and certain insulation materials which are used to manufacture composite and engineered wood products which are used in cabinets, countertops, moulds, furniture, shelves, stair systems, flooring, and many other household applications. These materials also cause threat to life when one is exposed continuously to it.

Polystyrene is a multifaceted plastic which used to make a wide range of consumer durables. It also is made into a foam material, called expanded polystyrene (EPS) or extruded polystyrene (XPS), which is valued for its insulating and cushioning characteristics. As a hard, solid plastic, it is often used in products that require transparency, such as food packaging and laboratory apparatuses. When combined with different additives, colorants or other different forms of plastics, polystyrene is employed to make different types of appliances, electronics, automobile parts, toys, gardening pots and equipment and much more.

IV. REUSE OF THE MATERIALS

1. Formaldehyde- Few studies have been made on the recycling of thermosetting plastic waste in lightweight concrete. Recycling thermosetting plastic waste to produce cement composites, might be one of the best solutions for disposing of plastic waste of economic advantages and environmentally friendly methods, and hence has been tried. Formaldehyde waste has been incorporated into cement mixes replacing the fine aggregates.

The mixing and moulding of concrete specimens were performed according to standards. The ratio was proportioned by weight 1:1:0.5 as cement: fine aggregate: water. The formaldehyde waste was used to replace 0%, 15%, 25% and 35% by weight of river sand. From each ratio, samples were taken for the compressive strength testing, water absorption testing and thermal conductivity testing. The wet density of the concrete was calculated by measuring the volume and weight of concrete before casting.

The dry density of concrete was measured for the cubes taken from the mould before compressive strength testing was done. Five cubic samples of each ratio were used to find the compressive strength of concrete at the ages of 3, 7, 14, 28, and 60 days. The compressive testing machine was loaded with a loading capacity of 2000 KN. The load was applied gradually at 0.40 MPa/ sec until the specimen failed. Three 28-day cubic samples of each ratio were used for the water absorption test. Two samples, aged 28 and 60 days, of each ratio were used for the determination of thermal conductivity. The dry densities of the different concrete mixes at 28 and 60 days are calculated.

The dry density of all specimens slightly decreased with time due to the evaporation of water. The results indicated that the dry density of the concrete without formaldehyde had little deviation from the design density. On the contrary, values of dry density slightly deviated from the actual design density for mixes containing formaldehyde waste. The formaldehyde waste might yield a decrease of plasticity and compaction when compared with the concrete without formaldehyde.

The compressive strength should be higher than 4.14 MPa and dry density lower than 1, 680 kg/m³ for non-load-bearing lightweight concrete. It was seen that, the compressive strength developed rapidly up to 14 days because of hydration reaction between the cement and water. But, after 14 days the compressive strength increment slowed down due to the decreasing amount of water in concrete. It was also seen that the concrete which contained formaldehyde waste showed the highest compressive strength at 25% formaldehyde waste content, which rendered the compressive strength of 5.65 MPa and dry density of 1,328 kg/m³. These could be compared to the standards for non-load-bearing lightweight concrete. The compressive strength of formaldehyde waste containing lightweight concrete, found in this study, was higher than that of the non-load-bearing lightweight concrete.

The results also showed that the water absorption of concrete containing formaldehyde waste increased with an increase of formaldehyde waste contents. The debris was able to absorb water better than sand because the water absorption of formaldehyde waste (5.51%) was higher than that of sand (0.33%).the results showed that replacing sand with formaldehyde waste significantly affected the thermal conductivity of the concrete when compared with the concrete without formaldehyde. The thermal conductivity of concrete containing formaldehyde waste is slightly higher than that of the concrete without it, which increased with an increase in formaldehyde waste content, although the conductivity of sand is higher than that of formaldehyde. Formaldehyde waste replacement significantly influences the thermal conductivity positively.

2. Expanded glass along with polystyrene

In this test, expanded glass granules with varying fraction size of 0–2 mm, 4–8 mm, 8–16 mm and crushed expanded polystyrene waste fraction of 0–2 were used. Air voids between expanded glass granules are seen. The size of these voids varies from 1 mm to 3 mm. When aggregates are mixed air voids are filled thoroughly by crushed expanded polystyrene waste, in large voids intensive thermal conductivity was seen. In separate zones between crushed expanded polystyrene particles and expanded glass air voids were seen which indicated poor adhesion between crushed expanded polystyrene waste and binding material.

Depending on the quantity of Portland concrete, the density of lightweight aggregate concrete samples only with expanded glass aggregate ranged between 247 and 335 kg/m³. As the amount of Portland concrete increases, w/c increases as well. When the amount of Portland concrete increased, the density of lightweight aggregate concrete samples varied directly by 19% and 36% respectively. Density of lightweight aggregate concrete samples, where a part of expanded glass aggregate was replaced by crushed expanded polystyrene waste, ranged between 225 and 309 kg/m³. In these lightweight aggregate concrete samples, the increase of Portland concrete amount from 70 to 100 or 130 kg/m³ resulted in an increase of the density by 24 and 27%.

In lightweight aggregate concrete samples, only with expanded glass aggregate increased amount of Portland concrete from 70 to 100 or 130 kg/m³, resulted in increased compressive strength after 7 days of curing by 1.96 and 2.25 times respectively and ranged between 0.32 and 0.72 MPa. The compressive strength of lightweight aggregate concrete samples, where a part of expanded glass aggregate was replaced by crushed expanded polystyrene waste, increased two folds with the increase in the amount of Portland concrete and ranged between 0.31 and 0.62 MPa. The values of compressive strength after 28 days of curing of lightweight aggregate concrete samples, where a part of expanded glass aggregate was replaced by crushed expanded polystyrene waste, was 8%, 10% and 14% lower compared to the values of lightweight aggregate concrete samples only with expanded glass aggregate.

In lightweight aggregate concrete samples with only expanded glass aggregate, the thermal conductivity coefficient ranged between 0.073 and 0.097 w/ (m·K).a partial replacement of expanded glass aggregate by crushed expanded polystyrene waste increased the amount of closed voids in lightweight aggregate concrete samples leading to lower thermal conductivity coefficient. Thermal conductivity coefficient of these lightweight aggregate concrete samples ranged between 0.071 and 0.087 w/ (m·K). Research results confirm that expanded polystyrene and crushed expanded polystyrene waste can significantly improve the thermal conductivity coefficient of lightweight aggregate concrete samples of various compositions in a wide range.

It showed that regardless of the aggregate used, as the amount of Portland concrete was increased, higher density and lower water absorption of lightweight aggregate concrete samples was obtained. The water absorption of lightweight aggregate concrete samples with only expanded glass aggregate reduced from 9.9% to 8.4% after the increase of amount of Portland concrete from 70 to 130 kg/m³. In the lightweight aggregate concrete samples where a part of expanded glass aggregate was replaced by crushed expanded polystyrene waste, increased amount of Portland concrete resulted in decreased water absorption from 8.5 to 7.4%, when compared to the lightweight aggregate concrete samples with only expanded glass aggregate.

VI. CONCLUSION

Formaldehyde waste was replaced river sand in lightweight concrete as a fine aggregate in an increasing replacement ratio of the sand by formaldehyde waste. The appropriate sand replacement ratio was found to be 25% by weight. The test results showed that the dry density was slightly varied in comparison with the design density although not beyond the permissible limits of ±90 kg/m³ the appropriate proportions of formaldehyde waste powder was 25%, which yielded the compressive strength of 5.65 MPa and dry density of 1,328 kg/m³ . These stood at par with the standard for non-load-bearing lightweight concrete. It was also seen that the water absorption of concrete containing formaldehyde waste increased with an increase in formaldehyde waste contents the waste was able to absorb water better than sand. The thermal conductivity of concrete containing formaldehyde waste was found to be slightly higher than that of the concrete without any additive. In light weight aggregate concrete samples only with expanded glass aggregate, depending on the amount of Portland cement, the thermal conductivity coefficient ranges between 0.074 and 0.098 w/(m·K).

In the light weight aggregate concrete samples where a part of expanded glass aggregate is replaced by crushed expanded polystyrene waste, depending on the amount of Portland cement, the thermal conductivity coefficient ranges from 0.070 to 0.086 w/ (m·K).in light weight aggregate concrete sample a partial replacement of expanded glass aggregate by crushed expanded polystyrene waste, depending on the amount of Portland cement, reduced the density accordingly by 9–15% and decreased the water absorption due to lower density of samples. Due to low compressive strength, densities and thermal conductivity coefficients, concretes obtained in this work can be classified as thermal insulating light weight aggregate concrete. The wide range of low thermal conductivity coefficients and densities, combined with the ability to cast in any desired shape, enables to create light weight aggregate concrete as a very suitable material for using as flooding insulation in partitions of civil and industrial buildings. It shows that light weight aggregate concrete presented in this study are competitive.

From above experimental results and discussions, it is proved that the replacements made are the good alternatives for materials for reducing cement & fine aggregate consumption, reducing the cost of materials. Hence this waste can be utilized in construction purposes without compromising strength and especially with no secondary pollution while reducing the waste. This method not only reduces the cost of waste disposal but also reduces the use of virgin materials in concrete making thus one of the economical ways for disposing waste in an environment friendly manner.

The positive results obtained in the above tests create a never-ending trial and error method for different materials as replacements or additives to in practice construction materials. A lot of other tests are also to be conducted for the above materials too to ascertain the additive probability. With all of the above being said and done different hazardous and non hazardous wastes can be used as additives or replacements in different fields of construction, after being tested for their physical and mechanical properties.

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AUTHOR PROFILE

Harshith M
UG Student
Dept. of Civil Engineering,
East West Institute of Technology
Bangalore, Karnataka, India
harshith.zigzag@gmail.com

Aditi Parmar Chitharanjan
Masters Student
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Venice, Italy
parmaraditi017@gmail.com