Use of Hazardous Wastes as Partial Replacement for Construction Materials - A Review

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Abstract— **Waste materials are a major environmental problem, among them the most dangerous are hazardous wastes, which are substantial or potential threats to public health or the environment. These remains can be used in the construction industry in mainly two methods: by reusing and recycling. This article presents a survey of the composition on changes in the synthesis of customary structure materials with the expansion of specific squanders without settling on its toughness and proficiency. 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, Hazardous wastes, Reusing Polystyrene, Formaldehyde, Partially replaced

I. INTRODUCTION

In recent times, the issues related to waste management has become very predominant within the view of a sustainable model of improvisation and consumption of the newest resources and energy. The development industry is one of the simplest consumers of raw materials alongside the assembly of giant quantities of waste. Some wastes are often used as additives in cement mixes to reduce the consumption of latest raw materials and also a much better methodology of disposal of a variety of the wastes generated. Hazardous wastes create the need for immediate reuse, recycle or proper method of disposal as they create a more significant threat to humankind. Several hazardous wastes like polystyrene and expanded foamed glass granules and formaldehyde resin are often used as additives with cement. Studies are administered to gauge the same.

Concrete is a fastener, a material that is utilized for construction that sets, solidifies, and clings to different materials to tie them together. Concrete is never utilized all alone however is utilized to tie sand and rock together. Concrete, when blended in with fine total, produces mortar for workmanship, or with sand and rock, produces concrete. Cement mortar could also be a building compound created by mixing sand and differing types of aggregates with a specified amount of water. Concrete is a mix of paste and aggregates. The aggregates here are sand and gravel; the paste is water and hydraulic cement. The Concrete additives are added to the mixture of water cement and aggregate in fewer quantities to increase the concrete durability, to repair concrete behavior and to manage setting or hardening. They will either be liquid or powdered additives. The study aims to figure out the effect of selected additives the physical and mechanical properties of modified cement mortars.

II. RELATED WORK

To secure nature, numerous endeavors are being made for the recycling of various forms of wastes with the end goal of utilizing them within the production of different construction materials. Their primary target was to analyze the potential use of different wastes for delivering development materials. The standard methods for Delivering construction materials are utilizing the accessible characteristic assets. Alongside, the modern and urban administration frameworks are creating solid wastes, and usually dumping them in open fields or landfills. These exercises present genuine debasing consequences for the earth. (Safiuddin et al., 2010)

Exploration have examined different properties of cement containing results and waste materials, for example, Granulated Blast-Furnace Slag GBFS), Fly Ash (FA), Bottom Ash (BA), Silica Fume, Waste Glass (WG) as mineral admixture, total substitution or restricting material. Squanders and side-effects can be utilized notwithstanding concrete without the requirement for huge changes in its readiness. Its granulometric properties demonstrate that it very well may be utilized in fine sand underway. (Smita Badur and Rubina Chaudhary, 2008)

Recycled waste glass in concrete is frequently used in different procedures in the structure development industry as partial replacements of in any event at least one of its constituents. Analysts examined utilizing waste glass as fractional replacements for fine or coarse aggregate, consolidated as fine and coarse aggregates; others utilized glass powder in partial replacements of concrete as a result of its pozzolanic nature. Audits in the region of glass waste in development have indicated that reused waste glass, when mixed in concrete either in powder structure or crushed as aggregate, improved the mechanical quality of the solid. (Ogundairo et al., 2019)

Lightweight thermo-insulating composites can be considered as environmentally manageable materials for indoor non-structural artifacts since they are set up with non-pre-treated secondary raw materials and with a cheap route since complex strategies of creation are not required. These treatments and processes would, however, be more effective in the case of production for a bigger scope. (Andrea Petrella et al., 2020)

III. MATERIALS

Formaldehyde may be a colorless, pungent gas utilized in the making of building materials and lots of household products. It is a heavily poisonous gas that's imbibed into the body by inhalation. The vapor may be a grievous throat and skin irritant and should also cause dizziness or suffocation. Direct reach with formaldehyde solution may result severe burns to the eyes and skin. it's utilized 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 wont to manufacture composite and engineered wood products which are utilized in cabinets, countertops, moulds, furniture, shelves, stair systems, flooring, and lots of other households applications. These materials also cause a threat to life when one is exposed continuously to it.

Polystyrene may be a multifaceted plastic which won't to make a good range of durables. It is also made into a foam material, known the Expanded polystyrene (EPS) or the extruded polystyrene (XPS), which is appreciated for its cushioning and insulating characteristics. As a hard, solid plastic, it's frequently utilized in goods that need transparency, like food packaging and laboratory apparatuses. When blended with different supplements, colorants or other various sorts of plastics, polystyrene is employed to form different types of equipment like electronics, automobile parts, appliances, toys, gardening pots and much more.

IV. REUSE OF THE MATERIALS

A. *Formaldehyde*

Few studies have been made on the reusing of thermosetting plastic waste as aggregate in lightweight concrete. Recycling thermosetting plastic waste to produce cement composites might be an optimal solution for deposing of plastic waste of environmentally friendly methods and economic advantages, 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 balanced by weight 1:1:0.5 as cement: fine aggregate: water. The formaldehyde waste was used to substitute 0%, 10%, 15%, 20%, 25% and 30% by weight of sand. From each ratio, specimens were taken for testing water absorption, compressive strength and thermal conductivity. The wet density of the concrete was hence calculated by measuring the weight of concrete before casting and the volume. 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 5, 7, 14, 21, 28 and 60 days. The universal testing machine was loaded with a capacity of 2000 Kilo Newton to check compressive strength. The load applies gradually increased from 0MPa/sec to 0.4 MPa/sec until the sample failed. Three numbers of cubic specimens (28 days aged) of each ratio were used to test the water absorption percentage. Two samples of 28 and 60 days aged were used to determine the thermal conductivity. The dry density of the different cubic sample mixes at 28 days and 60 days duration was calculated.

The dry density of all samples narrowly dropped with the duration of time due to the dissipation of water. The results indicated that the dry density of the concrete without formaldehyde had a 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 compression strength must be greater than 4.13 Mega Pascal and the dry density must be lesser than 1,680 kg/m³ for non-load-bearing lightweight concrete. It came to notice that, the compressive strength of the sample cube increased at a great rate up to 14 days because of dampening reaction between the water and cement. But, after 14 days the increase in compression strength decelerated due to lessening of water content in concrete. It was seen that the concrete which contained formaldehyde showed the topmost compressing strength when 25% of formaldehyde was used, which rendered the compressive strength of 5.64 MPa and the dry density of 1,325 kg/m³. These can be compared to the standards of non-load bearing lightweight concrete. The compression strength of lightweight concrete containing formaldehyde waste, found in this research, was greater than that of the non-load bearing lightweight concrete.

The results also have shown that the water absorption rate in concrete containing formaldehyde accelerated with an increase of formaldehyde content. The debris was able to absorb water exclusive of sand because the water the absorption rate of formaldehyde waste (5.5%) was greater than that of sand (0.32%). The results produced that using formaldehyde waste instead of sand considerably affected the thermal conductivity of the concrete when compared with the standard concrete. The thermal conductivity of concrete holding formaldehyde content is slightly greater than that of the standard concrete, which is raised with an increase in formaldehyde waste content, though the conductivity of sand is greater than formaldehyde content. Formaldehyde waste replacement considerably affects the thermal conductivity positively.

B. *Expanded Glass along with Polystyrene*

In this test, expanded glass granules with varying fragment size of 0 to 2 mm, 4 to 8 mm and 8 to 16 mm, the crushed expanded polystyrene waste fragments of 0 to 2 was used. Air voids between expanded glass bits are seen. The measurement of these voids differs from 1 mm to 3 mm. When aggregates combined with air voids are filled thoroughly by crushed expanded polystyrene waste, in large voids intensive thermal conductivity was seen. In different areas between crushed expanded polystyrene particles and expanded glass air voids were seen which indicated poor adhesion in-between crushed expanded polystyrene waste and binding material.

Based on the quantity of Portland concrete, the density of lightweight aggregate concrete specimens only with expanded glass aggregate ranged from 245 kg/m³ to 330 kg/m³. As the quantity of Portland concrete increases, water content raises as well. When the quantity of Portland concrete raised the density of lightweight aggregate concrete specimens varied directly from 19% to 36% respectively. The density of lightweight aggregate concrete specimen, where a portion of expanded glass aggregate was substituted by crushed expanded polystyrene waste, ranged between 220 kg/m³ and 310 kg/m³. In these lightweight aggregate concrete specimens, the raise of Portland concrete quantity from 70 to 130 kg/m³ resulted in a raise of the density from 23% to 28%.

In lightweight aggregate concrete, samples only with expanded glass aggregate, increased amount of Portland concrete from 70-100 or 130 kg/m³, resulted in rise of compressive strength following a week of curing by 1.95 and 2.25 times respectively and classified between 0.31 and 0.73 MPa. The compressive strength of lightweight aggregate concrete specimen, where a portion of expanded glass aggregate was substituted by crushed expanded polystyrene waste, raised two folds with the raise in the amount of Portland concrete and ranged between 0.30 and 0.61 MPa. The estimates of compressive strength following four weeks of curing of lightweight aggregate concrete specimen, where a portion of expanded glass aggregate was replaced by crushed expanded polystyrene waste was 8%, 10% and 14% lower compared to the estimates of lightweight aggregate concrete specimen only with expanded glass aggregate.

In lightweight aggregate concrete samples with only expanded glass aggregate, the thermal conductivity coefficient ranged from 0.072 to 0.098 W/ (m·K). A partial substitute of expanded glass aggregate by crushed expanded polystyrene waste increased the number of clogged voids in lightweight aggregate concrete specimen steering to lower thermal conductivity coefficient. The thermal conductivity coefficient of these lightweight aggregate concrete specimen ranged from 0.070 to 0.089 W/ (m·K). Examined values support that expanded polystyrene and crushed expanded polystyrene waste can mainly improve the thermal conductivity coefficient of lightweight aggregate concrete specimens of various compositions in a wide range.

It showed that in spite of the aggregate used, as the quantity of Portland concrete was raised, greater density and lesser water absorption of lightweight aggregate concrete specimen were attained. The water absorption of lightweight aggregate concrete samples including only expanded glass aggregate reduced from 9.8% to 8.5% after the raise of the content of Portland concrete from 70 to 130 kg/m³. In the lightweight aggregate concrete specimen where a portion of expanded glass aggregate was substituted by crushed expanded polystyrene waste, increase in the quantity of Portland concrete resulted in lower water absorption from 8.4 to 7.5%, when compared to the lightweight aggregate concrete samples with only expanded glass aggregate.

V. CONCLUSIONS

Formaldehyde waste was replaced by sand in lightweight concrete as a fine aggregate in an increasing replacement the 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 were 25%, which yielded the compressive strength of 5.64 MPa and dry density of 1,325 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 comprising formaldehyde waste increased with a raise in formaldehyde waste contents the waste was able to absorb water better than sand. The thermal conductivity of concrete comprising formaldehyde content was found to be slightly greater than that of the concrete without any additive.

In lightweight aggregate concrete samples only with expanded glass aggregate, based on the quantity of Portland cement, the thermal conductivity coefficient varies between 0.072 and 0.098 W/(m·K). In the light weight aggregate concrete specimens where a portion of expanded glass aggregate is substituted by crushed expanded polystyrene waste, depending on the quantity of Portland cement, the thermal conductivity coefficient varies from 0.070 to 0.089 W/(m·K).In lightweight aggregate concrete sample a partial substitute of expanded glass aggregate by crushed expanded polystyrene waste, depending on the quantity of Portland cement reduced the density consequently by 9–15% and decreased the water absorption because of lesser density of samples. Due to lesser compressive strength, densities and thermal conductivity coefficients, concrete obtained in this work can be categorized as thermal insulating lightweight aggregate concrete. The broad range of low thermal conductivity coefficients and densities, mixed with the ability to cast in any desired shape, enables to create lightweight aggregate concrete as a very a suitable material for using as flooding insulation in partitions of civil and industrial buildings. It shows that lightweight aggregate concrete presented in this study are competitive.

From the 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 waste. This method as a result of this not only reduces the cost of waste disposal but also reduces the usage of virgin materials in concrete making this one of the economical ways for disposing of waste in an environment friendly manner.

This review has been done in order to understand how the hazardous wastes can be made use of without adding up to the existing landfills. 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 the above being said and done different hazardous and non-hazardous wastes can be used as additives or replacements in various fields of construction, after being tested for their physical and mechanical properties.

REFERENCES

[1] Safiuddin, Md & Jumaat, Zamin & Salam, M & Islam, M. & Hashim, Roslan. (2010). "Utilization of solid wastes in construction materials". International Journal of the Physical Sciences. 5. 1952- 1963.

[2] Badur, Smita & Chaudhary, Rubina. (2008). "Utilization of hazardous wastes and by-products as a green concrete material through S/S process: A review". Rev.Adv.Mater.Sci. 17. 42-61.

[3] T O Ogundairo, D D Adegoke, I I Akinwumi and O M Olofinnade "Sustainable use of recycled waste glass as an alternative material for building construction – A review", IOP Conference Series: Materials Science and Engineering, Volume 640, 1st International Conference on Sustainable Infrastructural Development 24–28 June 2019. https://doi.org/10.1088/1757-899X/640/1/012073

[4] Andrea Petrella, Rosa Di Mundo, Michele Notarnicola, "Recycled Expanded Polystyrene as Lightweight Aggregate for Environmentally Sustainable Cement Conglomerates", Materials (Basel) 2020 Feb; 13(4): 988. Published online 2020 Feb 22. Doi: 10.3390/ma13040988. PMCID: PMC7078601.

[5] Šeputytė-Jucikė, Jurga & Sinica, Marijonas. "The Effect of Expanded glass and Polystyrene waste on the properties of lightweight aggregate concrete". Engineering Structures and Technologies, March 2016 8(1): 31-40. Doi: 10.3846/2029882X.2016.1162671.

[6] Petrella A, Di Mundo R, Notarnicola M. " “Recycled Expanded Polystyrene as Lightweight Aggregate for Environmentally Sustainable Cement Conglomerates”. Materials (Basel) " 2020; 13(4):988. Published 2020 Feb 22. Doi: 10.3390/ma13040988.

[7] Chaitongrat, Chalermchai & Siwadamrongpong, Somsak. " “Recycling of melamine-formaldehyde waste as fine aggregate in lightweight concrete” " Songklanakarin Journal of Science and Technology, Feb 2018. 40. 39-45. 10.14456/sjst-psu.2018.25.

[8] Dazmiri, Mohesn & Kiamahalleh, Mohammad & amp; Valizadeh Kiamahalleh, Meisam & Mansouri, Hamid Reza & Moazami, Vahid. & quot; “Revealing the impacts of recycled urea-formaldehyde wastes on the physical-mechanical properties of MDF” " December 2018. European Journal of Wood and Wood Products. 10.1007/s00107-018-1375-z.

[9] Ryszard Dachowski, Paulina Kostrzewa, " “The Use of Waste Materials in the Construction Industry” " Procedia Engineering, Volume 161, 2016, Pages 754-758, ISSN 1877-7058, https://doi.org/10.1016/j.proeng.2016.08.764, http://www.sciencedirect.com/science/article/pii/S1877705816329939 .

[10] Jin Chai Lee, Payam Shafigh, See Kim Lee. "Durability Property of Oil-Palm-Boiler Clinker Lightweight Concrete Based on Water Absorption Test", IOP, Conference Series: Earth and Environmental Science, 2020.

[11] Lei Gu, Togay Ozbakkaloglu. "Use of recycled plastics in concrete: A critical review", Waste Management, 2016.

[12] Saikia, N. "Use of plastic waste as aggregate in cement mortar and concrete preparation: A review", Construction and Building Materials, 201209