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Experimental Study on Thermal Insulation Lightweight Block by using Waste Polyurethane Foam

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Abstract: *This paper represents review on the use of waste polyurethane foam as an aggregate for thermal insulating block for partition wall. The structural, physical and mechanical property of polyurethane is described by different researchers is represented here. Polyurethane (PUR) is one of the larger polymer product groups within the plastics family and it possesses high thermal insulation property.*
Keywords: *Disposal of waste Polyurethane, Lightweight concrete and block, Mechanical properties, Physical properties, Polyurethane foam, Reuse, Thermal properties.*

I. Introduction

The development of lightweight concrete is made with a good achievement of performance in their characteristics. Lightweight concrete and block is needed to reduce the cost of construction attaining an economical construction practice. It is also essential to reduce the consumption of raw materials for the production of concrete. There are many types of lightweight concrete such as foamed concrete, cellular concrete, aerated or gas concrete. Polyurethane foam is one of the larger polymer products within the plastic family.

Polyurethane wastes from end of life scrapped refrigerator, district heating tubes, vehicles and many other sources are receiving increased attention over its rising amounts and its treatment and disposal. However, polyurethane is having properties such as high thermal conductivity, sound insulation, and lightweight so we can use this in construction industry which will add new material for construction and add new method of its disposal which is environmental friendly. This project study aims at the use of Polyurethane Foam in concrete and analyzing its properties such as compressive strength, tensile strength along with its comparative study of strength against conventional concrete. In this project fine and coarse aggregates are replaced by polyurethane foam.

II. Literature Review

Thanapol Tantisattayakul and Premrudee Kanchanapiya et al (2018) [1] assessed the appropriate options for managing rigid polyurethane waste (RPUW) remaining from refrigerator dismantling in Thailand by analyzing the impacts on environment, energy and economic aspects. There are four options for RPUW management option 1 landfill option 2 incineration option 3 hydrolysis landfill and option 4 production of lightweight concrete (LWC) mixed with RPUW (LWC-RPUW). The results showed that option 4 had the lowest human toxicity, followed by option 3, option 1 and option 2, respectively. Option 4 is the only one option that can make a profit, and its net present value (NPV) is positive. Option 1 had the lowest climate change and fossil depletion impacts, followed by option 2, option 3 and option 4, respectively. However, without considering energy consumption during the use phase of LWC as wall material in building, option 4 has the least energy and environmental impact. Option 4 is economical and feasible, while the other options are costly to carry out. Option 4 is more appropriate considering all three kinds of impact studied in their paper, it will be necessary to improve option 4 in terms of the insulation properties of the LWC-RPUW products to reduce the environmental impact from energy consumption during the product use phase.

Xavier Mathew and Binol Varghees (2018**)** [2] concluded that the polyurethane material is the main component of the new material polyurethane– cement composites (PUC) as a new material can be used for different structural purposes. The utilization of PUC material is a repairing material such as strengthening old bridge , The objective of their research was to find the displacement and pressure variation of building frame with and without polyurethane cement composites and compare it with CFRP. The PUC material considered as light weight material with highly strength due to less density comparing with normal concrete. Strengthening with polyurethane cement composite material of building frame was proven by the authors to be an easy to operate and reliable technique. Comparing with normal concrete and CFPR, Polyurethane cement composite is lightweight material, highly deformable, and very good strength. According to the experimental result, PUC can be used for different purpose of construction field, such as repairing deteriorated concrete structural elements, strengthening the structure members (beams, columns, etc.).

Abin Chandy and S.S. Janagan (2018) [3] presented that, at present construction field all around the world is facing a serious problem with price hike of raw materials. So they are very much concerned to reduce the consumption of readily available raw materials. It is also important for engineers to develop ecofriendly material, as environment is getting affected day by day by the increasing construction activities. Foam concrete is an innovative idea to achieve the requirements. The rate of construction is quick and the installation becomes easy Because of its lightweight,. The focus of their project was to study the properties of lightweight foam concrete with addition of various binders /fillers such as Fly ash, Micro silica, Sio2 powder, clay and Rice husk ash. The results are elaborately discussed with respect to split tensile strength, compressive strength, and water absorption. Recently, foamed concrete is being widely used in civil construction and building, because of its high fluidity and settlement, low self-weight and low thermal conductivity. However, it has some major setbacks such as increased shrinkage and low strength at later ages. The gain of strength of concrete depends upon several variables like the curing conditions.

R.B.N. Santhosh and K. Sasidhar (2017)[4] Studied Polyurethane Waste along with cement, sand, and/or admixtures can be used as a construction material and this can be called as "Polyurethane Foam based Cement Mortar" or "PUF Mortar". Their experimentation paves way to turn the prodigious amount of waste into low-cost, high-value sustainable construction material. From this point of view, an experimental study has been carried out in order to determine the influence of Polyurethane foam wastes, considered as lightweight aggregates which can be used as replacement to fine aggregate, on the thermal conductivity and mechanical strength of cement mortar. PUF-Mortar cubes were cast using Polyurethane foam waste, cement, Fly ash, sand and water in different proportions and the physical & mechanical properties of PUF mortar cubes were determined. They concluded that it is technically possible to use polyurethane foams from industrial waste materials in the manufacture of cement based mortars and that these could be of use in the building industry. Also it has less thermal conductivity hence it acts as an insulator, thus using this mix as mortar in the walls makes them passive. Mix proportion and experimental results were as given in table 1 and 2.

Table no 1: Mix proportions of Cement Mortar.

Mix No	Sand replaced by foam in volume (%)	w/c	Mix Proportions (kg/ m3)			
			Cement + Fly Ash	sand	water	foam
1	0	0.6	421.6 + 105.1	1577.2	316	0
2	10	0.6	421.6 + 105.1	1418	316	7.4
3	20	0.7	421.6 + 156.3	1258.9	404.5	14.8
4	30	0.7	421.6 + 176.2	1099.8	418.5	22.2

Table no 2: Experimental Results.

Description	Results (Replacement %)			
	0 %	10%	20%	30%
Cube weight (grams)	770	727.5	702.5	692.5
Volume of the cube (cc)	351.9	351.9	351.9	351.9
Fresh Density of the cube (Kg/m3)	2419.9	2268.1	2256.1	2138.3
Dry Density of the cube (Kg/m3)	2293.3	2066.48	1988.64	1974.43
Occluded air (%)	5.23	8.89	11.85	7.67
Compressive strength (N/mm2) After 3 days	11.67	9.11	7.14	5.9
Compressive strength (N/mm2) After 7 days	17.5	15.23	14.1	11.9

Leon Agavriloaie et al (2012) [5] studied a new type of polymer concrete obtained using epoxy polyurethane acryl and aggregates. Mechanical properties, such as: flexural strength, compressive strength, pullout stress elasticity modulus, and adherence stress between cement concrete and polymer concrete were experimentally determined. Thermo-physical properties, such as: bulk density in natural and dry state, relative and absolute mass humidity, thermal conductivity, linear thermal dilatation, thermal shock strength, chemical resistance, frost-thaw resistance and water adsorption resistance were studied to establish the durability properties of the epoxy polyurethane acryl concrete. The experimental results have shown that epoxy polyurethane acryl concrete is a high performance, lightweight concrete with properties that recommend it as a possible replacement material for classical building materials.

Vojtěch Václavík et al (2012) [6] their contribution describes the use of polyurethane foam after the end of its life cycle as an aggregate both for thermal insulating mortars for various wall surfaces and for lightweight concrete. The structure and the physical and mechanical properties of thermal insulating mortar are described in their paper. The verification of application of thermal insulating polyurethane mortar in the thickness of 50 to 70 mm to a reference building, where external walls were insulated, is provided further. The second important area dealt with in this contribution is that of lightweight concrete, for which polyurethane foam of grain size of 0,125 to 6 mm is used as an aggregate. The physical and mechanical properties of polyurethane concrete of various densities and an example of its prefabrication are presented.

S. Gutiérrez-González et al (2011) [7] published a paper which presents a study of the properties and thermal behavior of plaster with polyurethane foam wastes. Plaster mixtures, prepared using differing volumes of polyurethane foam waste from two different sources, were ground to different granulometric sizes. The characteristics of the specimens were defined and tested by fixing the consistency at a good workability and then studying the mechanical properties, Shore C hardness and adherence to ceramic materials after both 7 and 28 days. The thermal behavior was examined via thermogravimetry and thermal conductivity analysis, correlating the latter with the apparent density values of the plaster polyurethane material. The interface of materials was observed by Scanning Electron Microscopy (SEM). Their experimental results show that when there is the increase in the polyurethane quantity there is decrease in mechanical properties and the density of the plaster while it increases its thermal resistance proportionally to the reduction in density. These results suggest that the use of plaster containing polyurethane foam waste is comparable to that of plaster lightened with conventional materials.

Amor Ben Fraj et al (2010) [8] published a paper in which they examined the mechanical properties and the durability parameters of lightweight aggregate concretes (LWAC) incorporating rigid polyurethane (PUR) foam waste as coarse aggregates (8/20 mm). The effect of both, the increasing incorporation of polyurethane foam waste and the presence of superplasticizer on the bulk density, workability, drying shrinkage, mass loss, dynamic modulus of elasticity, compressive strength, total porosity and gas permeability of the different concretes, has been investigated and analyzed. The results showed that the use of PUR foam waste enabled to reduce by 29–36% the dry density of concrete compared to that of the normal weight concrete (made without foam waste). The reduction of density was due to the increase of total porosity in the lightweight concretes, which also induced higher gas permeability and chloride diffusion coefficient. These negative effects on durability of concrete were lowered by improving the characteristics of the cementitious matrix. The mechanical properties of the lightweight aggregate concrete was ranged between 8 to 16 MPa for the compressive strength and between 10 to 15 GPa for the dynamic modulus of elasticity; the concrete mixture with the higher performances almost satisfied the mechanical and density criteria of structural lightweight concrete. These results consolidate the idea of the use of PUR foam waste for the manufacture of lightweight aggregate concretes.

P. Mounanga et al (2007) [9] published a paper which presents the results of an experimental study concerning the incorporation of polyurethane foam wastes into cementitious mixtures in order to produce lightweight concrete. To predict the density of fresh polyurethane foam based concrete mixtures a semi empirical method was first proposed. Seven concrete mixtures containing various polyurethane foam volume fractions from 13.1% to 33.7%, and two reference concrete mixtures without polyurethane foam were prepared and characterized. In particular, their thermal and mechanical properties were determined. This permitted to quantify the influence of the polyurethane foam volume fraction on these parameters. Some specimens were maintained under water during 28 days, while the others were dried in air. The polyurethane foam concrete's compressive strength and thermal conductivity are, respectively, 2 to 17 times and 2 to 7 times lower than those of the reference mixture, depending on the volume fraction of polyurethane foam and on the curing conditions. Besides, the use of polyurethane foam in concrete implies a strong increase in the the mass loss and drying shrinkage during the first seven days. These results can be related to the weak compressive strength and the high porosity of polyurethane.

III. Conclusion

Everyday thousands of tonnes of polyurethane is being discarded in landfills, Year by year the production of polyurethane is increasing but hardly any of it is being recycled or reused. This is being dumped into the seas or else piled up in the dump yards. The need of the hour is to reuse the waste polyurethane which leads to the invention of light weight cement mortar, which is 20 % lesser in weight than the conventional mortar. The main difficulty to proportion lightweight concrete of plastic consistency using rigid polyurethane (PUR) foam wastes concrete mixtures lies in the estimation of the PUR foam density, which is greatly influenced by both the high compressibility and absorption of the lightweight aggregates. Increasing the amount of PUR foam LWA results in the higher porosity of concrete, which facilitates moisture exchange with the environment, increases drying shrinkage and gas permeability in saturated conditions.

We concluded that waste polyurethane foam (PUF) can be used in manufacturing the lightweight blocks by partial replacement with sand, which can be used in partition walls in framed structures in order to reduce dead load of the overall structure and hence in reducing the sizes of structural elements. These blocks also possess the thermal insulation property. Use of waste polyurethane foam (PUF) helps in reducing the load on solid waste management authorities and provides best disposal method of it.

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