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STRENGTH AND THERMAL CONDUCTION ASSESSMENT OF LIGHTWEIGHT AROMATIC HYDROCARBON WASTE POLYSTYROL GLASS CONCRETE

MUHAMMAD S. KHAN*, MATEEULLAH,
ALI A. J. KHATTAK, MUZAMIL YAQOOB, KASHIF ALAM

Sarhad University of Science and Information Technology,
Landi Akhun Ahmad, Hayatabad Link, Ring Road, Peshawar, Pakistan
*Corresponding Author: siyab.btech@suit.edu.pk

Abstract

Effect of Waste Polystyrol Glass Aggregate (WPGA) on the concrete was investigated in this article mainly regarding the compressive and flexure strength and rate of heat transfer in concrete with the time. Concrete used in this work was made utilizing locally accessible materials. Diverse substitution of Waste (WPGA) was made to research consequences for advancement of thermal conduction. For testing the strengths and thermal resistance assurance, 20 cubes and 10 prisms specimens were utilized. Compressive strength of the WPGA concrete was noted to be decreased by increasing the WPGA contents. As far as flexural capacity is concerned, it is also in the diminishing rate by expanding the WPGA content at the same rate as compressive strength. During exploring the concrete having WPGA in different percentages for thermal conductivity in the oven with thermocouples installed, it was found to be a greater difference of time to reach 60°C temperature between the normal and 40% WPGA concrete, i.e., 5 h 12 m and 9 h 13 m respectively which shows the higher heat insulating property of WPGA.

Keywords: Compressive strength, Flexure strength, Light weight concrete, Thermal conductivity, Waste polystyrol glass.

1. Introduction

Many researchers had been working on the additive called polystyrene to be replaced by aggregates in the concrete, but this research is based on using the waste material of polystyrol glass which is being used in the concrete to fulfil the purpose of making concrete heat resistant. This material polystyrol glass is a different material than the normal polystyrene used by many investigators to amend the concrete properties.

Concrete blocks of WPGA are a light weight and not of high-quality substance. This undertaking negates the consequences of a trial examination into the properties of concrete blocks containing extended WPGA dabs. WPGA is a compelling and moderately cheap protecting and basic material. Works of numerous masters are dedicated to build up the arrangement of WPGA concrete blend and furthermore to think about the physical and mechanical, thermal, and innovative properties [1]. One of the actual issues underway of WPGA concrete mixture and in development of its items is the peeling property because of the distinctive weight of included parts. Concrete blocks of WPGA are light weight and made of inferior quality materials due to replacement of aggregate with WPGA but having great thermal energy resisting attributes. It is outstanding for its great heat shield properties driving for the most part to non-auxiliary application including precast rooftop and partitions and light weight infill panels [2].

It has likewise been affirmed for utilizing as a center material in boards, bars & sections, as a base course material for street asphalts and furthermore in drifting marine structures. In Japan, it has been utilized in the development of ocean quaint little inns wall. WPGA concrete is a lightweight composite material, broadly utilized in development. Contingent upon the piece the WPGA concrete can be utilized as the heat and sound protection or potentially auxiliary material. The principal segments of WPGA concrete are the squashed or extended WPGA, mineral cover and water, and different additives give the extra properties to it [3]. Air-entraining additives and fortifying filaments are consumed to keep the peeling of WPGA concrete mixture because of a notable distinction in thickness of WPGA and mineral fastener. The fortifying filaments add to balance out the blends, as well as decrease the shrinkage disfigurement of WPGA concrete. Basalt filaments, glass fiber, that have great bond to the mineral folio, are utilized as the fortification material. With the end goal to decrease the setting time of mineral fastener and satisfactory restoring process we proposed a creation of WPGA concrete that contains hemihydrate gypsum, cement, water and added materials, and chrysotile asbestos was utilized as the fortifying material. The investigation of physical, mechanical, and thermal characteristics of the proposed WPGA concrete of various densities had been performed [4].

Different added substances and strengthening strands are utilized to make a homogeneous WPGA concrete blend [5-8] uncovered that the thermal conductivity of WPGA concrete is 10-30% lower, yet the compressive capacity is 10-15% higher than the cell concrete. Along these lines, WPGA concrete has great prospects of utilization as the heat and sound protection material. Current innovative arrangement, which incorporates the blending, shaping, and adjusting equipment, and in addition modifiers of WPGA concrete mixture, permits getting the WPGA concrete items with the coveted physical and mechanical and thermal attributes. One of the highlights of WPGA concrete blend is its peeling. It is because of the extraordinary distinction of parts weight and the hydrophobicity of WPGA that *is* utilized as the aggregate [9, 10].

WPGA concrete permits enhancing the thermal protection properties of outside coating for underground concrete dividers. After the extraction of channel shapers, the WPGA concrete mixture is set in the vertical channels of the dividers that permit heat protection efficiency by a normal of 65%. WPGA concrete of thickness review D250 is prescribed to fill the channels [11]. It was set up that the expansion of rice husk and waste propylene strands permit to get a moderate quality review for auxiliary material. Some auxiliary components of building can be affected by the dynamic load [12]. Investigation of the wet blanket conduct of WPGA concrete was completed and was built up that the drag twisting of WPGA concrete increments with the expansion of amount of WPGA in the blend [13]. The utilization of WPGA concrete permits taking care of the issue of vitality sparing in structures by enhancing the warm attributes of outer dividers. As the segments it is practical to utilize waste of different industry exercises, which will decrease the anthropogenic load on nature.

These days extended WPGA is generally utilized for bundling of electrical hardware, household unit machines and others. After utilizing, some portion of this bundling material is sent for reusing; however, part - to the landfill as the long haul natural toxins. The current advances for preparing the extended WPGA permit reusing it as an aggregate in different lightweight concrete composition. The connected smashers permit to keep the circular state of grains with the measure of 0.5 to 4-6 mm. WPGA concrete blends depend on water driven covers, extended or smashed WPGA with added substances to give different properties to the subsequent items [6-8]. Lightweight concretes created with recycled ground distended polystyrene by proprietary technology of the school of Civil Engineering in Subotica [14] are light-weight, highly malleable materials in their fresh state. In hardened state they can have noteworthy plastic deformation while not a classical, brittle failure mechanism that normal weight and different light-weight concretes normally have. Henceforward this type of concrete is stated to as "Poly-styrol light-weight concrete". The density of such concrete can be intended from 350 kg/m3 to 1600 kg/m3 and it can be the function of its physical and mechanical properties. Lower density will result with a lower constant of thermal conduction and lower strength, and vice versa [15].

Following were the objectives of the research.

- Compare the weight of light weight concrete blocks by using WPGA with normal weight concrete blocks.
- Determine and compare the rate of change of temperature of concrete cubes.
- Determine and compare physical and mechanical properties of light weight and weight normal concrete cubes.
- Evaluate the capacity or strength characteristics and thermal insulation of concrete cubes by using WPGA for application in weight of concrete having low strength.

With end objective to minimize the rate of transfer of heat from concrete, WPGA are utilized. In Pakistan, the greater part of the time of the year, weather stays hot. In view of the study work, the venture is started to enhance the nature of concrete with respect to keeping the building cool.

2. Materials and Methods

Light weight concrete block is the one in which some additional lightweight materials are used to replace the aggregate, consequently reducing the weight and thermal conductivity of the resulting buildings.

The materials used are ordinary cement, coarse aggregate, fine aggregate (sand), WPGA, and portable water (Water free from any impurities)'

2.1. Fine aggregates

There was just a single kind of the fine aggregate utilized in this examination including which Chenab waterway sand. Chenab sand is supplanted with various rates of the WPGA, i.e., 10%, 20%, 30% and 40%. Following is the gradation curve attained by sieve analysis of fine aggregates shown in Fig. 1. Water absorption for the fine aggregate was 0.65%.

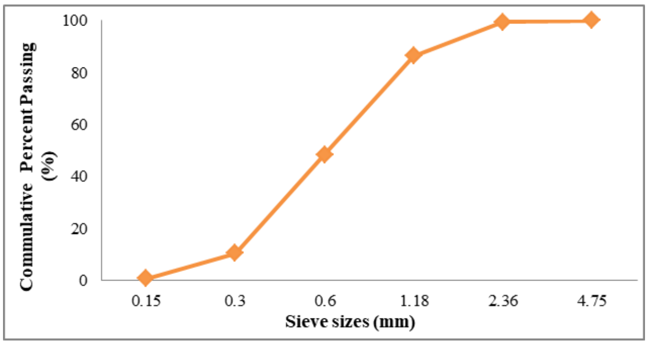

Fig. 1. Gradation curve of fine aggregates.

2.2. Polystyrol glass

The Polystyrol glass is engineered polymer fashioned utilizing the monomer styrene, a fluid petrochemical. Universally polystyrol glass is weak, clear, and hard [16]. Polystyrol glass can be like normal glass; however, can be coloured with pigments. The structure of polystyrol glass shown in Fig. 2, is that it comprises of 9 carbon particles and 12 hydrogen atoms. It is involved ethylene and benzene [17, 18].

Fig. 2. WPGA used in the investigation.

2.3. Cement

The common cement of code ASTM C 150 Type-1 shown in Fig. 3, was utilized all through the examination. Cement utilized in examination was ML brand of Grade 53. Cement utilized in the examination was giving to the accompanying benchmarks: Pakistan PS 232.00-2008 I, Standards of America ASTM C 150.00 Type-1, Standards of British BS 12.00: 1996, and Standards of Europe EN 197.00-1/2000 CEM I 42.50 N/R.

Fig. 3. Cement used in the investigation.

2.4. Coarse aggregate

In such examination, stone which was pulverized taken from Sargodha, Punjab, Pakistan quarries and was utilized as common coarse aggregate. Water absorption for the coarse aggregate was 1.154%. Following is the gradation curve of coarse aggregate as shown in the Fig. 4.

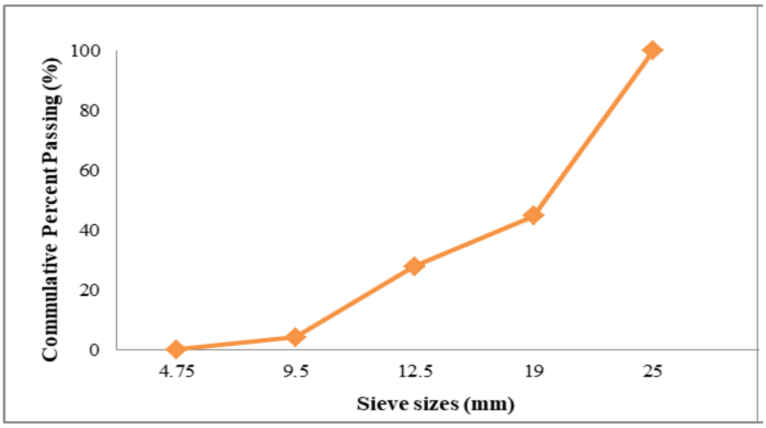

Fig. 4. Gradation curve of coarse aggregates.

3. Experimental Program

The aim of this research is to do examine the strength development for the prior prediction of compressive strength of 28 days of the WPGA and to relate the thermal conductivity of concrete cubes at different replacements. During the work, 20 cubes and 10 prisms were cast with various substitutes of WPGA and explored at dissimilar percentages.

3.1. Mix design

WPGA concrete is made from 3 principal components, i.e., water, cement and aggregate. In this research, mixes of plain cement concrete (PCC) were cast with coarse aggregate. Each batch's mix design was design by the method of absolute volume. The mixing ratio was set in accordance with ACI 211.10. In this study, compressive strength was design for 28 MPa (4000 psi) and 5 different percentages of WPGA are replaced with coarse aggregates, i.e., 0%, 10%, 20%, 30% and 40% and hence used ratio of 1:1.5:2.5.

3.2. Casting and curing of concrete specimens

Standard cube of size 150 × 150 mm and prism of 152.4× 152.4× 457.2 mm were used. Two samples were cast from each batch with overall 20 cubes and 10 prisms. The mixing process of concrete for altogether specimens was done in orthodox tilting mixer of blade type having extreme batching capacity of 0.10 m^3 (2.50 ft^3) as presented in Fig. 5. For concrete mixing, all aggregates are used in SSD (saturated surface dry) condition to withstand the similar water-cement ratio according to mix design. Thermocouples were installed at the time of concrete poured into the moulds. Particulars about the thermocouple is discussed in Section 4.5.

Fig. 5. Moulding of the cubes and prims in the investigation.

3.3. Workability of concrete

The slump test was performed to measure the workability of the fresh concrete according to ASTM C 143. Process was done and value was achieved for all the different mixes of WPGA as shown in the Fig. 6.

Fig. 6. Workability test of concrete.

4. Results and Discussion

Following are the results of the different tests carried out in this investigation.

4.1. Density of concrete

Following are the results of density of normal and WPGA concrete as shown in Table 1 and Fig. 7.

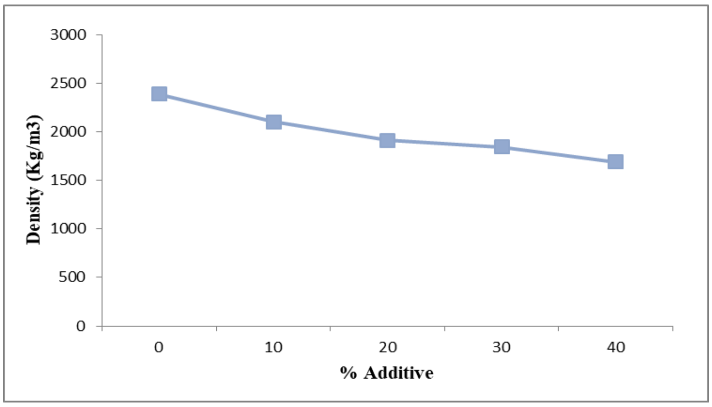

Fig. 7. Density of concrete cubes.

Table 1. Variation of density with increase in WPGA contents.

% Additive	Density (kg/m^3)
0	2387.85
10	2104.32
20	1911.61
30	1844.12
40	1691.95

4.2. Compressive strength

The aim of this experiment is to evaluate the compressive strength of the specimens of concrete casted with WPGA and to make comparison of these values to those obtained for normal weight concrete specimens [19]. This experiment was done succeeding the method explicated in ASTM C39 as shown in Fig. 8.

In this study, two concrete specimens of each 0%, 10%, 20%, 30% and 40% of WPGA were investigated. Outcomes obtained are given in Table 2 and Fig. 9.

Fig. 8. Compressive strength tests on concrete cubes.

Table 2. Variation of compressive strength with increase in WPGA contents.

WPGA %	1stSample (MPa)	2nd Sample (MPa)	Average
0	23.52	22.95	23.235
10	22.45	22.11	22.255
20	20.38	19.61	19.995
30	18.21	18.04	18.121
40	17.24	16.67	16.955

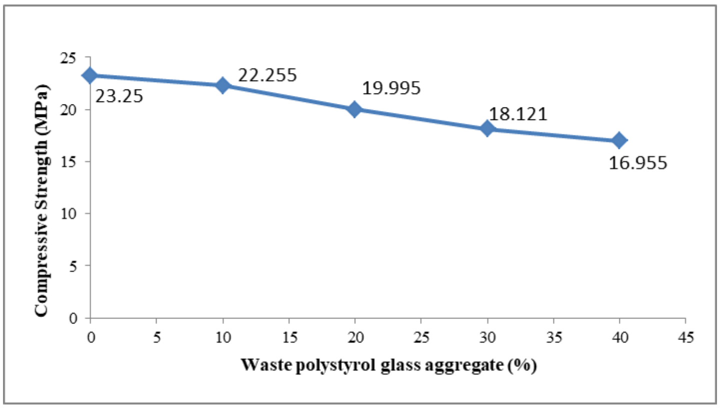

Fig. 9. Variation between compressive strength and different percentage of WPGA.

4.3. Flexure strength

The aim of this experiment is to evaluate the flexural strength of the specimens of concrete casted with WPGA and to compare with normal weight concrete specimens. This test was carried out using the method described in ASTM C348-08 as shown in the Fig. 10. The flexural test is based on applying a two-point loading on specimen up to failure.

Fig. 10. Flexural strength test on prisms.

In this study, flexural test was performed on ten samples after 28 days curing. Two concrete specimens of each 0%, 10%, 20%, 30% and 40% of WPGA were investigated. Outcomes obtained are given in Table 3 and Fig. 11.

Table 3. Variation of flexural strength with the increase in WPGA contents.

WPGA %	1st Sample (MPa)	2nd Sample (MPa)	Average (MPa)
0	5.37	5.44	5.405
10	5.12	5.22	5.17
20	4.83	4.69	4.76
30	4.56	4.35	4.45
40	4.21	4.11	4.16

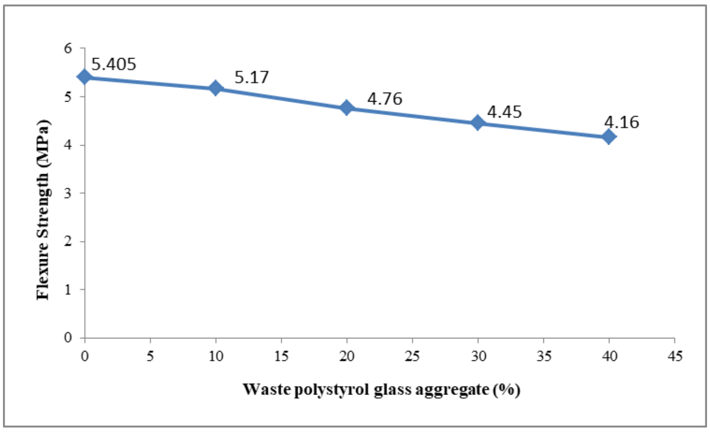

Fig. 11. Variation of flexural strength with different WPGA percentages.

It is clear from Fig. 11 that the increase of the content of WPGA causes a decrease of the strength. For instance, in case of 0%, 10%, 20%, 30% and 40% WPGA replacement, the average flexural strength is 5.40, 5.17, 4.76, 4.45 and 4.16 MPa, respectively. The increasing percentage of the WPGA inversely affects the flexural strength of the concrete cubes.

4.4. Workability

Concrete specimens of each 0%, 10%, 20%, 30% and 40% of WPGA were investigated. Following are the results of the workability of fresh and WPGA concrete as shown in the Table 4 and Fig. 12. It is clear from Fig. 12 that, with the increase of the WPGA content the workability increases.

Table 4. Variation of workability with increase in WPGA contents.

Serial. No.	Waste Polystyrol Glass Aggregate (%)	Slump Value (mm)
1	0	4.41
2	10	4.72
3	20	4.98
4	30	5.11
5	40	5.40

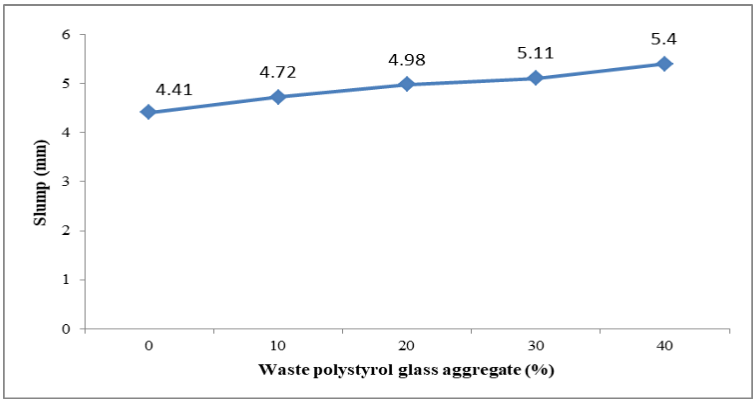

Fig. 12. Variation between workability and different WPGA percentages.

4.5. Thermal conduction

The motivation behind this assessment is to identify the connection of WPGA and heat resistance. The device utilized in this examination for the assurance of the thermal conductivity of concrete cubes is known as Thermo Couple. It comprises of a steel pole, wire, and advanced thermometer. Thermocouple used in the investigation shown in the Fig. 13, was a Type J thermocouple and was designed by combining two different alloys (Iron/Constantan) which worked as a temperature sensor. This was further connected to the digital meter showing the temperature variation in the degree centigrade with respect to time in the oven. It is able to gauge the rate of heat of transfer through diverse concrete samples made out of various arrangements of WPGA as the aggregates.

The motivation behind this experiment was to decide the thermal conductivity of specimens of concrete casted with WPGA and to contrast those qualities with those got for typical specimens of concrete casted without utilizing WPGA, having an equivalent mix design. The warm conductivity test comprised fundamentally in applying heat in oven to a cubical concrete specimen constantly and with no breaking interim. The warm conductivity esteem as far as time was computed as average value of single. Warm conductivity estimation of the 2 samples produced using a similar clump. The individual warm conductivity time is estimated on hourly premise with Thermocouple and specimens were in oven by giving steady warmth of 60 °C as appeared in Fig. 14. Temperature of the specimens is kept an eye on hourly premise. The time interims of achieving the temperature of the samples to 60 °C were noted always. Subsequently, by expanding the contents of WPGA in the cubes, the time was considerably increasing to achieve 60 °C temperature. In this way, it demonstrates that by increasing the measure of WPGA, the thermal conductivity of the samples was decreasing. Consequences of the tests got are as given in Table 5 and Fig. 14.

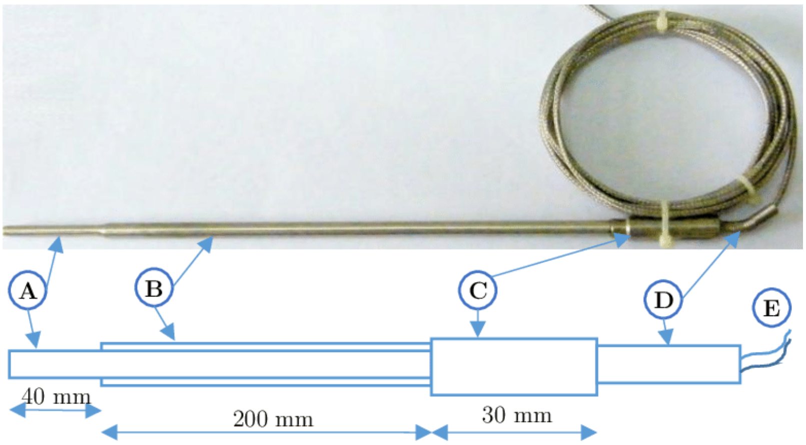

Fig. 13. Type J Thermocouple.

Fig. 14. Performance of the thermal conductivity test on concrete cubes.

Table 5. Thermal conductivity of cubes at different percentages of WPGA

Percentage (%)	Time to reach 60°C (Hours)	Time to reach 60°C (Minutes)	Time Difference (minutes)
0	5 h 12 m = 5.20	312	--
10	6 h 8 m = 6.13	368	(368-312) = 56
20	7 h 10 m = 7.17	430	(430-368) = 62
30	8 h 9m = 8.15	489	(489-430) = 59
40	9 h 13 m = 9.22	553	(553-489) = 64

After comparing the results of thermal conduction test of all the different cubes it was found to be a greater difference of time to reach 60°C temperature between the normal and 40% WPGA concrete, i.e., 5 h 12 m and 9 h 13 m respectively as mentioned in the Table 5 which shows the higher heat insulating property of WPGA.

Figure 15 shows that with rising percentage of the WPGA, the thermal conductivity of the cubes becomes lower and lower. For instance, in case of 0%, 10%, 20%, 30% and 40% of WPGA replacement, the average time to reach is 5.2, 6.13, 7.17 and 9.22 hours, respectively. With increase in the ratio of the WPGA, it is clear that the average value of the time to reach 60 °C temperature is increasing. So, thermal conductivity is inversely proportional to the rising percentage of WPGA contents.

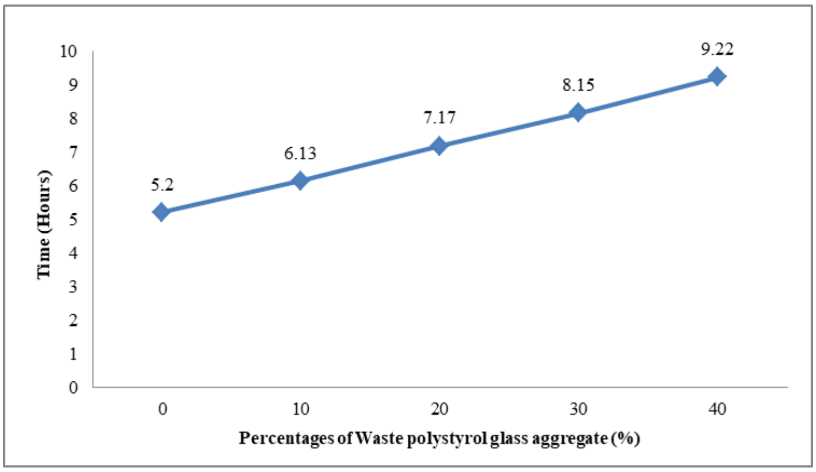

Fig. 15. Graph showing the effective thermal conduction property of WPGA w.r.t time.

5. Graphical Relationship between Compressive Strength, Flexural Strength, Thermal Conduction and Density

Following are the Figs. 16-19, representing the relationship between the above-mentioned properties with respect to the normal (0%) and different percentages (10%, 20%, 30% and 40%) of WPGA added to the concrete.

Figure 16 indicates the relationship of compressive and flexure strength with respect to the different percentages of WPGA used as an additive in the concrete. It is obvious that with increase in contents of WPGA flexure strength property is modified a little as compare to the compressive strength property. This is due to the harder aggregate is being replaced by the softer aggregate.

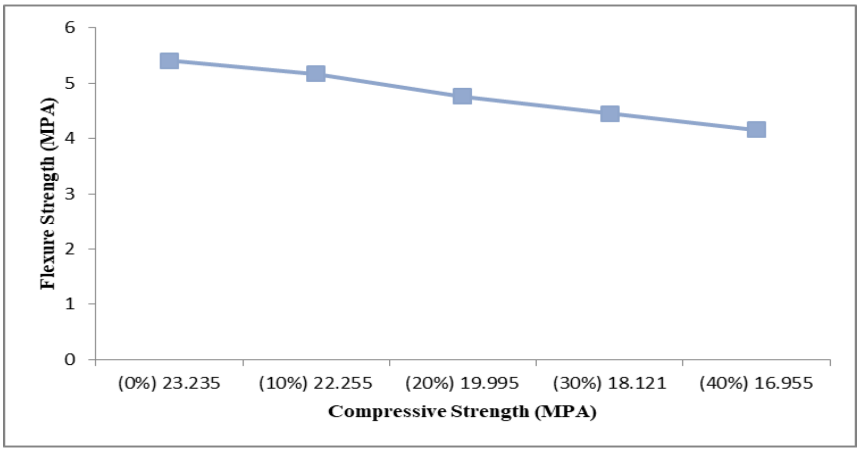

Fig. 16. Relation between compressive and flexural strength.

Figure 17 indicates the relationship of compressive strength and thermal conduction property with respect to the different percentages of WPGA used as an additive in the concrete. It is obvious that with increase in contents of WPGA thermal conduction property is developing in a very positive manner but with the compressive strength in slightly decreasing state.

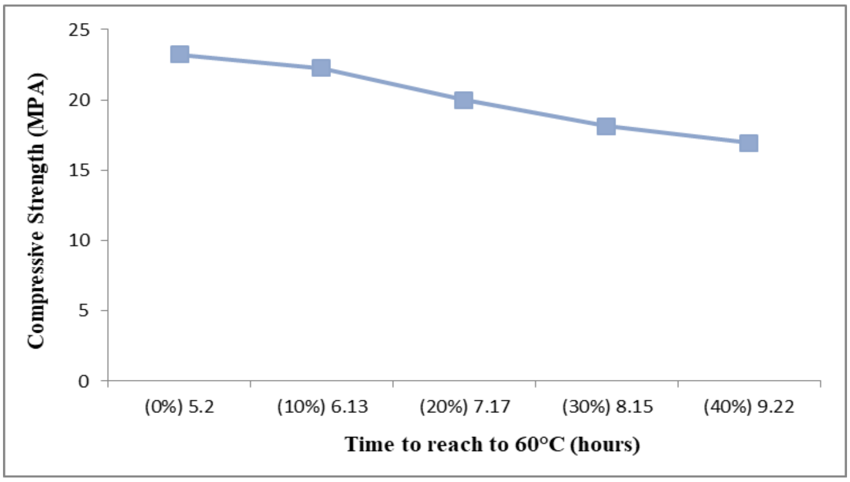

Fig. 17. Relation between compressive and thermal conduction.

Figure 18 indicates the relationship of flexure strength and thermal conduction property with respect to the different percentages of WPGA used as an additive in the concrete. It is obvious that with increase in contents of WPGA thermal conduction property is developing in a very positive manner but with the flexure strength in slightly decreasing state.

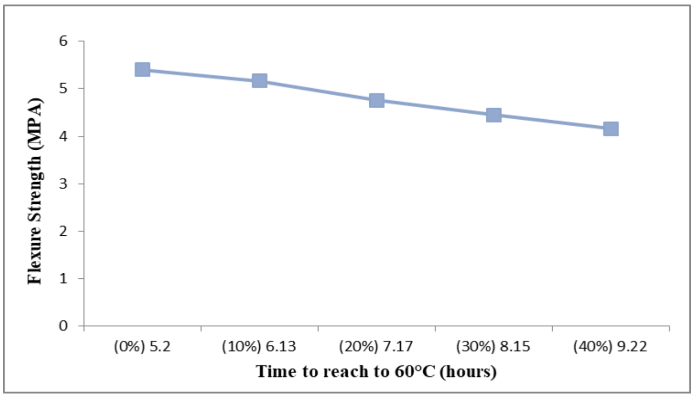

Fig. 18. Relation between flexural strength and thermal conduction.

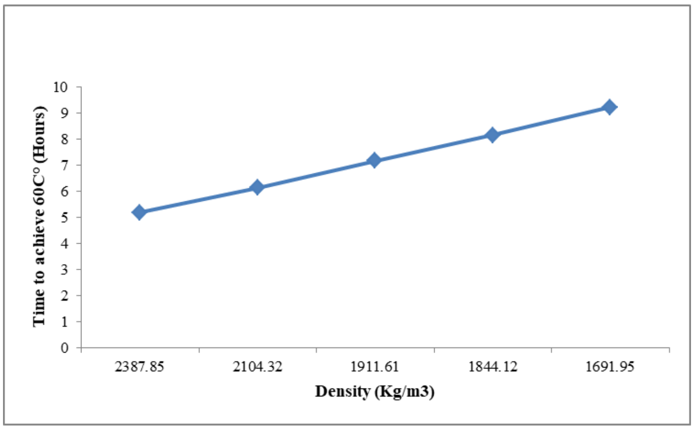

Fig. 19. Relation between thermal conduction and density.

5. Conclusions

From the results of the study of strength and thermal conduction assessments of the light weight WPGA concrete, the following conclusions can be made.

- Very prominent change was noticed in making the concrete heat insulator by adding the WPGA in specific proportions.
- Higher the percentage of replacement of the normal aggregate by the WPGA, maximum will be the thermal insulation property but flexure strength reducing in a constant manner, i.e., 5.405, 5.17, 4.76, 4.45 and 4.16 MPa at 0, 10, 20, 30 and 40% respectively.
- Same is the case with compressive strength which reduces with replacing the normal aggregate by WPGA, i.e., 23.235, 22.255, 19.995, 18.121 and 16.955 MPa at 0, 10, 20, 30 and 40% respectively.
- It has been studied that with increase in contents of WPGA flexure strength property is modified a little as compare to the compressive strength property. This is due to the harder aggregate is being replaced by the softer aggregate and ultimately affected the compression property more.

- After comparing the results of thermal conduction test of all the different cubes it was found to be a greater difference of time to reach 60°C temperature between the normal and 40% WPGA concrete, i.e., 5h 12 m and 9 h 13 m respectively which shows the higher heat insulating property of WPGA.
- It has been verified from the results that WPGA can be used to replace in concrete cubes for normal aggregates within specified limits.
- WPGA results in producing light weight concrete as it causes 22% reduction in weight.
- Using WPGA as an aggregate can be a solution to produce energy efficient buildings.
- Introduction of WPGA in cubes inclines to make concrete somehow ductile, henceforth rising the capability of concrete to meaningfully distort before failure.
- A denser concrete generally provides higher strength and fewer number of voids and porosity. WPGA concrete consistently losing its compressive strength due to the foaming agents added into the concrete resulting in decrease in density.
- By decreasing the water cement ratio up to some extent, higher compressive strength can be achieved but resulting workability will be very low while using the WPGA as aggregate.
- For given water-cement ratio, the use of WPGA in a mix slightly lowers the compressive and flexural strength because of replacing the hard material.
- One of the most environmental responsible ways of meeting the challenges of sustainability in construction is the use of thermally efficient materials such as WPGA in the new construction.

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