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Effects of Elevated Temperature on the Properties of Lightweight Concrete Containing Expanded Polystyrene Beads and Rice Husk Ash

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ABSTRACT
This study investigates the potential of expanded polystyrene (EPS) beads as a lightweight aggregate and rice husk ash (RHA) as a pozzolan in concrete, aimed at reducing both the environmental impact and cost associated with conventional concrete materials. Expanded polystyrene (EPS) is a lightweight, non-biodegradable and incompressible hydrocarbon-based material that is widely used for packaging goods. A large volume of the EPS was dumped in landfills, while some in the water bodies, thereby causing harm to aquatic life. On the other hand, the production of Portland cement (PC) adds to global greenhouse gas emissions which is also harmful to ecosystem. The expanded polystyrene was modified by heating and used to substitute the coarse aggregate, which reduced the concrete deadload significantly. Also used in the concrete formation is the Rice Husk Ash (RHA), which is a known pozzolan, and was used as a partial replacement for Portland cement. By partially replacing coarse aggregate with EPS and cement with RHA, the effects on strength, density, and fire resistance were evaluated. Concrete mixes containing 10%-5%, 20%-10%, and 30%-15% EPS-RHA respectively were produced with a 0.52 water-binder ratio. Concrete samples of (100×100×100 mm cubes) were cast and tested for compressive strength, density, and fire resistance. Results showed that compressive strength at 28 days decreased as EPS and RHA percentages increased. The control mix had an average compressive strength of 30.84 N/mm², with 10%-5%, 20%-10%, and 30%-15% EPS-RHA mixes showing respective reductions of 37.84%, 39.40%, and 51.20%. Density also declined, with the control at 2367 kg/m³, while reductions of 6.89%, 11.24%, and 21.88% were recorded. Only the 30%-15% mix met the lightweight concrete classification under BS EN 206-1 (2013). Additionally, Fire resistance tests revealed that samples remained intact up to 600°C but failed at 800°C. Overall, EPS and RHA substitution reduces compressive strength relative to conventional concrete but offers substantial fire resistance within the 300°C–600°C range, demonstrating potential for lightweight and thermally resilient construction applications.

Keywords: *Expanded Polystyrene Beads, Rice Husk Ash, Lightweight Concrete, Elevated Temperatures and Physical, Mechanical and Durability Properties.*

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I. Introduction

The demand for decent and affordable housing in Nigeria is increasing at an expedited rate due to population growth. This has resulted in increased infrastructural developments in an attempt to meet the existing deficit and the demands of population pressure. Demand for affordable construction materials is thus increasing day by day prompting the need for alternative building materials to reduce the cost of construction, and mitigate the rate of extraction and consumption of constituents of concrete (Mwero & Onchaga, 2020). Therefore, there is need to seek an alternative construction material that will partially or fully replace the conventional concrete materials and cement, as this will help in conserving the environment (Mwero & Onchaga, 2020). In this paper, the normal weight aggregate and Portland cement were partially substituted with Expanded Polystyrene (EPS) beads and Rice Husk Ash (RHA) to produce lightweight concrete of decent compressive strength.

Lightweight concretes have unit weight being less than 1840 kg/m^3. Low unit lightweight concrete which is used for block production typically has a density of 400 – 1200 kg/m^3, while the high unit weights (typically 1300 – 1840 kg/m^3) are used for structural concrete (Posi *et al.*, 2015). Conventional concrete on the other hand has densities that vary between 2240 and 2400 kg/m^3 (Mwero & Onchaga, 2020).

One of the aggregates that are used in lightweight concrete mixture is expanded polystyrene (EPS) beads. Polystyrene is a thermostatic polymeric material that is produced in unexpanded form (UEPS). EPS is produced by heating the UEPS in wet conditions until an ideal volume is achieved (June *et al.,* 2010). The EPS produced contains around 98% air and 2% polystyrene. EPS is light in weight and has fine circular shaped particles. It is formed in a closed cell arrangement, does not absorb water, and has desirable thermal and sound insulation properties, and impact resistance (Bejan *et al.,* 2020).

Polystyrene foam has similar fire-resistant behavior as most organic materials where both are easily combustible. Thus, a small amount (<1%) of fire-retardant material is added to the EPS products to enhance their fire retardance (Shaaban *et al.,* 2020).

Rice Husk Ash (RHA) is one of the supplementary cementitious materials that have been proven to be effective in meeting up most of the requirements of durability in concrete. It is an agricultural by-product that can be used as a good pozzolanic material that can replace Portland cement. The rice husk ash, being an agricultural waste material, is a very reactive pozzolanic material produced by controlled burning of rice husk and providing several advantages, such as improved strength and durability properties, reduced materials cost due to cement savings and environmental benefits (Kawabata *et al.*, 2012).

Salahaldee &Al-Hadithi (2022) the chemical resistance of EPS is affected by the reaction time, temperature, and applied stress. It generally has identical resistance to polystyrene. EPS is sensitive toward solvent attack which causes it to soften and crack due to its thin cell walls and large exposed surface (Ramli Sulong *et al.,* 2019).

There is currently significant exploitation of natural aggregate sources due to the high demand of aggregates in construction works and this may contribute to natural hazards and environmental degradation. The consistent blasting of rocks for aggregate production contributes to the occurrence of earthquakes which in turn affects biodiversity (Awoyera *et al.,* 2016). NWC has a negative impact on the environment as a great quantity of natural resources is required to produce it. To reduce the negative impact of NWC, a study has been undertaken on the use of by-products and recycled materials for construction (Verian *et al.*, 2018).

Washed river sand which is obtained from riverbeds is one of main sources of fine aggregates that are used in concrete production (Ramli-Sulong *et al.,* 2019). The growing demand for concrete has resulted in the significant exploitation of sand from riverbeds, and this has led to a range of environmental problems such as increased riverbed depth and lowering of the water table. A restriction to the extraction of sand from riverbeds will no doubt increase its cost due to limited supply, and this will in turn affect the cost and supply of this construction material. Finding an alternative material to river sand has therefore become imperative (Ganesh Prabhu *et al.,* 2014). It is obvious that the selection of a coarse aggregate type for concrete production is first determined by its demand and production in a specific region. However, the choice of an aggregate should be based on its physical and chemical properties (such as density, compressive strength, abrasion).

A large quantity of EPS and RHA ends up as waste materials that were either sent to landfills or illegally dumped in open areas, especially in developing countries like Nigeria (Gawale *et al.,* 2016). The global overall production of polystyrene is over 14 million tons annually (Awoyera *et al.,* 2016). Western Europe takes about 2.5 million tons while the USA uses about 2.3 million tons annually; most of the EPS ends up in landfills (Abdullahi, *et al.,* 2019). While the current rice production in the world is estimated to be 700 million tons and 20% of such quantity is the rice husk (Wang *et al.*, 2019). Since millions of tons of both waste polystyrene and RH are produced in the world yearly, some of the waste is disposed through incineration, this causes environmental pollution which is harmful to the ecosystem (Awoyera *et al.,* 2016). Both National and International environmental regulations have also become more inflexible, causing these wastes to become increasingly expensive to dispose. Therefore, utilizing waste polystyrene and rice husk ash in concrete production does not only solve the problem of disposal, but also helps to preserve natural resources that would have been exploited and used in concrete production.

The partial replacement of normal weight coarse aggregates and cement with waste EPS beads and RHA in concrete production will reduce the day-to-day damage to the environment that is caused by continuous exploitation of natural aggregates through quarrying of rocks for coarse aggregates.

(Awoyera *et al.,* 2016) investigated that, polystyrene and rice husk are not accepted in curbside collection recycling programs, and are not separated and recycled where they are accepted. Most polystyrene products and rice husk are currently not recycled due to the lack of incentive to invest in the compactors and logistical systems required.

Herki *et al.,* (2019), strength of the EPS concrete can be improved by heating the EPS particles to 130ºC for 15 minutes. The results obtained showed that, the properties of hardened EPS concrete were influenced by the quantity of polystyrene beads incorporated in the concrete mix.

II. Materials and Methods

2.1 Materials

Materials that were used in this work include; cement, fine aggregate, coarse aggregate, waste expanded polystyrene (EPS) material beads, Rice husk ash and water.

2.2 Methods

2.2.1 Concrète Mix Design

The mix design of normal weight and lightweight concrete was carried out in accordance with (ACI 211. 2-98 and ACI 211. 2-87) to design a 25 N/mm^2 lightweight concrete grade. The basic reason in the design for the strength is the physical property of the coarse aggregates or aggregates types to be used, since the strength of hardened concrete mixture cannot significantly exceed that of the coarse aggregates used (Herki *et al.,* 2019). The procedure for mix design begins with selecting the targeted concrete strength, followed by choosing the slump level to ensure appropriate workability for the specific application. Next, the nominal maximum size of coarse aggregate was determined, impacting the mix's density and durability. Cement content is then calculated to achieve the desired strength, followed by estimating the amount of lightweight coarse aggregate for proper density balance. Finally, fine aggregate content is estimated to complete the mix proportions, ensuring a balanced and workable concrete mix.

2.2.2 Production of Concrete Samples

The concrete specimens were cast in 100x100x100 mm cubes for compressive strength, density and fire resistance tests, in accordance with ACI 311.6-09. Number and size of cube specimens: 84 numbers of concrete cubes of 100x100x100 mm cubes were produced and used to test for the concrete compressive strength, density and fire resistance. Percentage replacement of EPS beads used: 0%, 10%, 20%, and 30% by volume of coarse aggregate. Percentage replacement of RHA used: 0%, 5%, 10% and 15% by volume of cement as shown in Table 1.

Table 1: Mix Proportion of ESP and RHA Concrete Mixes

Parameters	0%EPS, 0%RHA	10% EPS, 5%RHA	20% EPS, 10%RHA	30% EPS, 15%RHA
W/C ratio	0.52	0.52	0.52	0.52
Water content (kg/m^3)	193	193	193	193
Cement content (kg/m^3)	371	353	334	315
Fine agg. content (kg/m^3)	600	600	600	600
Coarse agg. content (kg/m^3)	1210	1089	968	847
EPS Foam content (kg/m^3)	0	13.7	27.4	41.1
RHA content (kg/m^3)	0	12.4	24.8	37.2
Total	2374	2261	2147	2033

2.2.2.1 Curing Cubes

As soon as the cubes were de-molded, they were put in a curing tank full of water and cured for 7, 14, and 28 days respectively. At the end of each curing period, three (3) specimens for each mixture and each percentage were tested for compressive strength, density and fire resistance test.

2.2.3 Concrete Samples Preparation

2.2.3.1 Workability

Workability of each concrete mix was assessed using the slump test in accordance with the provisions of BS EN 12350-2:2009.

2.2.3.1.1 Slump Test

Slump test is an empirical test that measures the workability of fresh concrete and was done in accordance with BS EN 12350-2 (2009).

2.2.4 Determination of Density

The concrete materials for the density test were mixed and compacted manually. The hardened concrete specimens were cured by immersion in water (kept at 20ºC) for 28 days. After curing, the specimens were removed from the water and placed outside to surface dry, then weighed using a weigh balance to determine the mass of the samples in accordance with BS EN 12390-7:2019. The density of concrete specimens was calculated, using Equation (1).

$$D = \frac{M}{V} \qquad (1)$$

Where D is the density of the concrete specimen in kg/m³, M is the mass of the specimen and V its volume.

2.2.5 Determination of Compressive Strength of Concrete Cubes

After the cubes were crushed, the maximum load applied by the compressive strength testing machine before the specimen fails was recorded. The compressive strength of the specimens was obtained by computing the ratio of the applied load to the cross-sectional area of the specimen. The apparatus and specimens used were the Compressive strength testing machine and 100 mm concrete cubes, and the procedure include the following. After the specified curing period, the specimens were removed from water and allowed to surface dry briefly. Dimensions were measured, and each specimen was positioned on the test machine base plate with the load applied perpendicularly to the casting face. The load was gradually increased at a rate of 0.6 ± 0.2 N/s until failure occurred, with the maximum load recorded as the specimen's load capacity. The compressive stress was then calculated by dividing this maximum load, averaged across three identical specimens, by the area of one cube face was calculated using Equation (2).

$$\text{Compressive stress (N/mm}^2\text{)} = \frac{Load(N)}{SurfaceArea(mm^2)} \qquad (2)$$

2.2.6 Determination of Fire Resistance Test

The fire resistance test was carried out using 100 mm concrete cubes. The cubes were removed from water after 28 days of curing age, and allowed to air dry for seven days (1 week), and thereafter subjected to different temperatures, ranging from 300ºC, 600ºC, 700ºC and 800ºC, in a kiln. After the heat application to different temperatures, the cubes were observed of any possible defect and their compressive strengths were tested, complying to ASTM E119 and section 4 of BS 8110-2 (1985).

2.2.7 Method of data analysis

The result obtained for different tests carried out in this research work was analyzed using simple statistical tools (mean and percentage). According to Umasabor & Okovido (2018) mean also called arithmetic mean, represented by M or X is the most commonly used measure of central tendency which is the sum of scores divided by the total number of scores, often represented by Equation (3).

$$\bar{X} = \frac{X}{N} \qquad (3)$$

Where: $\bar{X}$ (read as X- bar) is the symbol for the mean, and also a percentage is a proportion multiplied by hundred. It was used in this research to analyze the result of abrasion and a water absorption/sorptivity test is shown in Table 2.

Table 2: Test carried out, Test Duration, Specimen Size and Standards

Standard codes	Number of samples/ Age in days			Shape	Specimen (mm)
	7	14	28		
BS EN12390-7:2000	3	3	3	Cubes	100x100x100
BS EN12390-3:2002.	3	3	3	Cubes	100x100x100
BS 8110-2 (1985)	3	3	3	Cubes	100x100x100

III. Results and Discussion

3.1 Fresh Properties of lightweight Concrete made with EPS/RHA

3.1.1 Workability

The workability of the concrete reduces as the percentage of EPS and RHA increases as shown in Table 3 and Figure 1.

Table 3: Slump Test Results

S/N	% Replacement of EPS	% Replacement of RHA	Slump (mm)
1	0	0	13
2	10	5	10
3	20	10	7
4	30	15	5

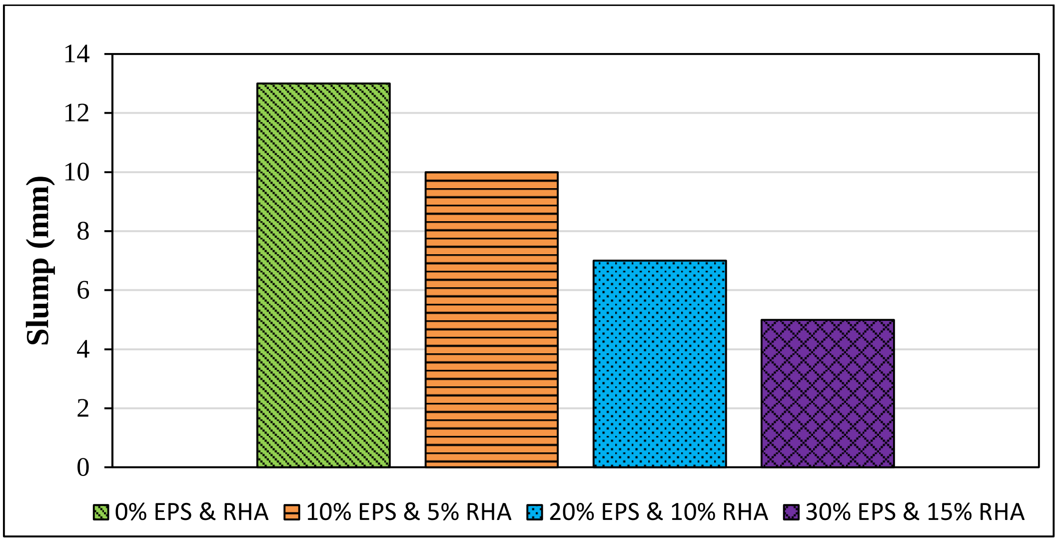

Figure 1: *Slump heights versus percentage replacements*

Table 3 and Figure 1 showed that the workability of the concrete reduces as the percentage of EPS and RHA increases with slump values of 13 mm for 0% EPS/RHA (normal concrete), 10 mm for 10% and 5% EPS/RHA, 7 mm for 20% and 10% EPS/RHA, and 7 mm for 30% and 15% EPS/RHA respectively. However, slump values are still within the medium range degree of workability and which agreed with (Neville, 2015). The workability of concrete decreases with the inclusion of Expanded Polystyrene (EPS) and Rice Husk Ash (RHA). This reduction in workability can be attributed to several factors. The lightweight and low density of EPS beads reduce the overall density and cohesiveness of the concrete mix, leading to diminished workability (Salahaldeen & Al-Hadithi, 2022). Additionally, RHA has a high surface area and is highly porous, which increases the water demand of the mix (Xie, Ozbakkaloglu, Fang, & Huang, 2019).

3.2 Hardened Properties of Lightweight Concrete Made with EPS and RHA

3.2.1 Density of EPS/RHA Concrete at 7, 14 and 28 Days

The average densities of EPS/RHA concrete samples cured in water for 7, 14, and 28 days are shown in Table 4 and Figure 2.

Table 4: Density of EPS/RHA Concrete at 7, 14 and 28 Days

Replacement level	**3 cubes 7 days**			**3 cubes 14 days**			**3 cubes 28 days**		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Control mix	2351	2332	2386	2357	2337	2391	2361	2344	2396
Average		2356			2361			2367	
10% EPS & 5% RHA	2246	2187	2149	2251	2191	2153	2258	2197	2157
Average		2194			2198			2204	
20% EPS &10% RHA	2118	2054	2093	2124	2060	2099	2132	2066	2103
Average		2088			2094			2101	
30% EPS & 15% RHA	1910	1815	1790	1916	1822	1796	1920	1826	1802
Average		1839			1845			1849	

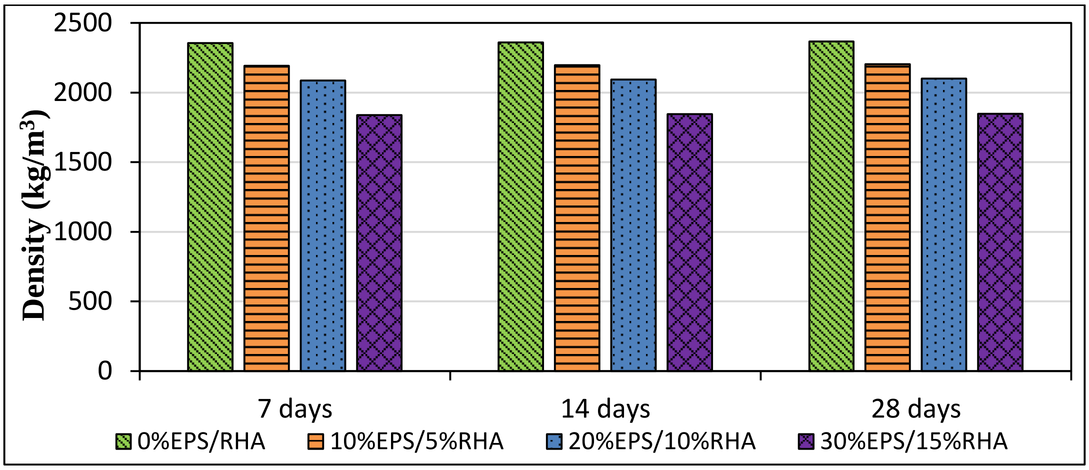

Figure 2: *Density of concrete specimens*

Table 4 and Figure 2 show that concrete density ranges from 1836 to 2361 kg/m³. Density increases with curing time but decreases as EPS and RHA content rise. Since EPS has a much lower bulk density than traditional coarse aggregates (Neville & Brooks, 2019), replacing coarse aggregate with EPS naturally reduces concrete weight (ACI Committee 213, 2014). The 28-day density of the control specimens was 2367 kg/m³, followed by the 10% EPS & 5% RHA, 20% EPS & 10% RHA, and 30% EPS & 15% RHA samples, which had densities of 2204 kg/m³, 2101 kg/m³, and 1849 kg/m³, respectively. This represents approximately a 6.89%, 11.24%, and 21.88% reduction in density compared to the control samples. However, only the 30% EPS & 15% RHA replacements fall within the range of lightweight concrete as specified by BS EN 206-1 (2013).

3.3 Compressive Strength

The average compressive strength of EPS/RHA concrete samples is shown in Table 5 and Figure 3 respectively.

Table 5: Compressive Strength of Cubes Cured at 7, 14 and 28 Days

Replacement level	7 days	14 days	28 days
0% EPF & 0% RHA	21.58	27.5	30.84
10% EPS & 5% RHA	15.6	18.3	19.17
20% EPS & 10% RHA	14.66	15.96	18.69
30% EPS & 15% RHA	14.55	14.95	15.05

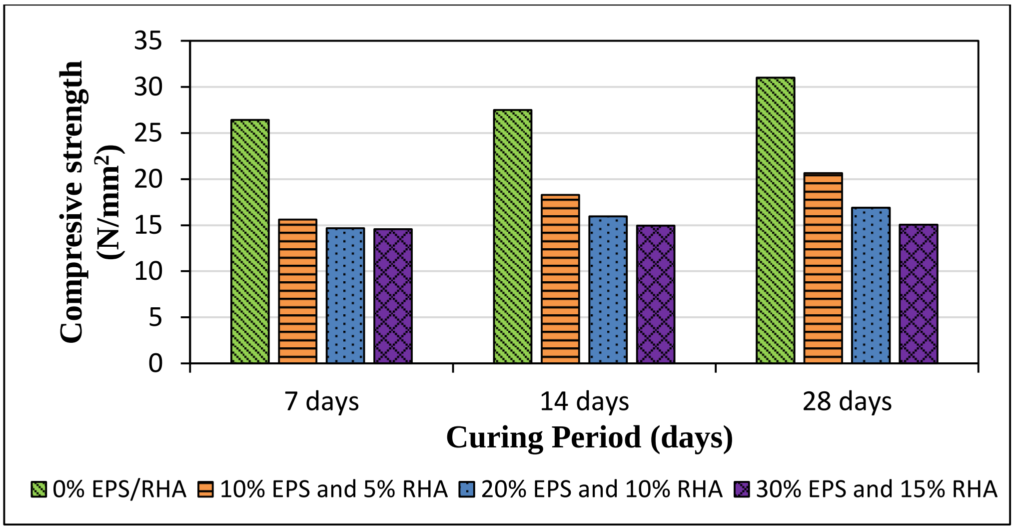

Figure 3*: Average compressive strength of Hardened concrete specimens*

The average compressive strength of EPS/RHA concrete samples cured in water for 7, 14, and 28 days are presented in Table 5 and Figure 3. The average compressive strength of the samples ranged from 30.84 N/mm² to 15.05 N/mm², increasing with longer curing periods but decreasing with higher percentages of EPS and RHA. The average 28-day compressive strength of the control specimen was 30.84 N/mm², followed by samples with 10% EPS & 5% RHA, 20% EPS & 10% RHA, and 30% EPS & 15% RHA respectively, which exhibited compressive strengths of 19.17 N/mm^2, 18.69 N/mm^2, and 15.05 N/mm^2, respectively. This corresponds to reductions of approximately 37.84%, 39.40%, and 51.20% compared to the control sample. The decrease in compressive strength with increasing EPS and RHA content is due to EPS's low mechanical strength and high porosity, which weaken the concrete matrix (Zhou *et al.*, 2019; Mohammed *et al.*, 2021). Additionally, RHA's slow pozzolanic reaction delays strength development (Chindaprasirt *et al.*, 2018). The increased voids from EPS further reduce density and strength (Yassin *et al.*, 2020). These findings are supported by Yassin, Adnan, Shahidan, Ayop, Kamarulzaman, & Osman, (2020), who reported a reduction in compressive strength of about 40% at 20% EPS replacement in their study on the effects of curing conditions on the properties of lightweight concrete brick containing expanded polystyrene and palm oil fuel ash. While these mixtures do not meet structural lightweight concrete strength requirements (BS EN 206-1, 2013), they can still be utilized for non-structural applications.

3.7 Fire Resistance

3.7.1 Density and weight of fired samples

The average densities of fired concrete samples are shown in Tables 6a and 6b respectively.

Table 6a: Percentage Decrease Weight for Fired Cubes at 300 and 600 °C

Replacement level	Temperature (°C)	Mean Weight of fired Cube (W_1)	Mean Weight Of Unfired cube(W_2)	Decrease weight =[(w_2-w_1)	%weight decrease [(w_2-w_1)/w_2]×100
Control mix	300	2250	2367	117	4.94
	600	2200	2367	167	7.06
10% EPS & 5% RHA	300	2150	2204	54	2.45
	600	2100	2204	104	4.72
20% EPS & 10% RHA	300	2100	2101	1	0.05
	600	1980	2101	121	5.76
30% EPS & 15% RHA	300	1800	1849	49	2.65
	600	1750	1849	99	5.35

Table 6b: Percentage Decrease Weight for fired Cubes at 700 And 800 °C

Replacement level	Temperature (°C)	Mean Weight of fired Cube (W_1)	Mean Weight Of Unfired cube(W_2)	Decrease weight =[(w_2-w_1)	%weight decrease [(w_2-w_1)/w_2]×100
Control mix	700	2180	2367	187	7.06
	800	2150	2367	217	9.17
10% EPS & 5% RHA	700	2100	2204	104	4.72
	800	2050	2204	154	6.99
20% EPS & 10% RHA	700	1950	2101	151	7.19
	800	1900	2101	201	9.57
30% EPS & 15% RHA	700	1730	1849	119	6.44
	800	1650	1849	199	10.76

Tables 6a and 6b present the average densities of fired concrete samples. The results show that for control samples, the weight after firing was 2150 grams, while before firing it was 2367 grams. According to studies by Rashwan, Diab, and Gad (2014), the specimen unit weights decrease with increasing temperature. Furthermore, for the control mix, the percentage of weight loss at 300℃, 600℃, 700℃, and 800℃ was 4.94%, 7.06%, 7.90%, and 9.17%, respectively. In comparison, the samples with 10% EPS & 5% RHA, 20% EPS & 10% RHA, and 30% EPS & 15% RHA at 800℃ exhibited weight losses of 4.65%, 11.63%, and 23.26%, respectively, compared to the control samples. The reduction in density after firing is primarily due to moisture loss, decomposition of hydrated cement compounds, and thermal degradation of organic materials such as EPS (Rashwan, Diab, & Gad, 2014). When exposed to high temperatures, free and bound water evaporates, leading to mass loss and increased porosity (Khoury, 2018). Additionally, the decomposition of hydrated cement compounds, such as calcium hydroxide ($Ca(OH)_2$), into calcium oxide (CaO) and water vapor at temperatures above 400°C, leads to structural changes that affect density. At even higher temperatures, the breakdown of calcium silicate hydrate (C-S-H) gel further reduces density and mechanical strength (Phan, 2000). This suggests that lower-density concrete, such as EPS/RHA mixtures, enhances fire resistance due to its lightweight nature.

3.7.2 Compressive strength of fired samples

The average compressive strength of fired concrete samples is presented in Table 7.

Table 7: Compressive Strength of fired Samples Cured for 28 Days

Replacement level	Temperature (°C)	Mean strength of fired cubes (w_1)	Mean strength of unfired cube(W_2)	Decrease in strength =[(w_2-w_1)	%Strength decrease [(w_2-w_1)/w_2]×100
Control mix	300	25.66	30.84	5.18	16.8
	600	24.61	30.84	6.23	20.2
	700	14.5	30.84	16.34	52.98
	800	9.5	30.84	21.34	69.2
10% EPS & 5% RHA	300	32.05	19.17	-12.88	67.19+
	600	25.49	19.17	-6.32	32.97+
	700	17.33	19.17	1.84	9.6
	800	11.5	19.17	7.67	40.01
20% EPS & 10% RHA	300	17.67	18.69	1.02	5.46
	600	17.04	18.69	1.65	8.83
	700	6.9	18.69	11.79	63.08
	800	5.2	18.69	13.49	72.18
30% EPS & 15% RHA	300	12.71	15.05	2.34	15.55
	600	9.55	15.05	5.5	36.54
	700	5.55	15.05	9.5	63.12
	800	3.54	15.05	11.51	76.48

Table 7 presents the average compressive strength of fired concrete samples. The results show that for control samples, the compressive strength after firing was 9.5 N/mm², while before firing it was 30.84 N/mm². Furthermore, for the control mix, the percentage of compressive strength loss at 300℃, 600℃, 700℃, and 800℃ was 16.80%, 20.20%, 52.98%, and 69.20%, respectively. In comparison, the samples with 20% EPS & 10% RHA and 30% EPS & 15% RHA at 800℃ exhibited compressive strength losses of 45.26% and 62.74%, respectively, while for 10% EPS & 5% RHA concrete samples, there was an increase in strength of about 21.05% compared to the control samples. The reduction in compressive strength after firing is due to the decomposition of hydrated cement compounds, increased porosity, and EPS degradation at high temperatures (Zhang *et al.*, 2019; Hager, 2018). EPS melts above 200℃, creating voids that weaken the concrete (Mohammad *et al.*, 2021). However, the slight strength increase in 10% EPS & 5% RHA samples may result from RHA's pozzolanic reaction, which refines the pore structure (Memon *et al.*, 2020). BS EN 1992-1-2 (2004) states that concrete should retain 50% of its strength at 800℃. Lightweight concrete shows better fire resistivity due to reduced thermal stresses (Ali *et al.*, 2019).

3.7.3 Fire resistance observation

The results of fire resistance testing are presents in Table 8 and Figure 7 respectively.

Table 8: Fire Resistance Observation

Time (minute)	Temperature (°C)	Remark Control mix	10% EPS & 5% RHA	20% EPS & 10% RHA	30% EPS & 15% RHA
75	300	no crack	no crack	no crack	no crack
160	600	no visible crack	no visible crack	no visible crack	no visible crack
175	700	single hairy crack	single hairy crack	double hairy crack	double hairy crack

190	800	multiple hairy cracks	multiple hairy cracks	multiple cracks	multiple cracks

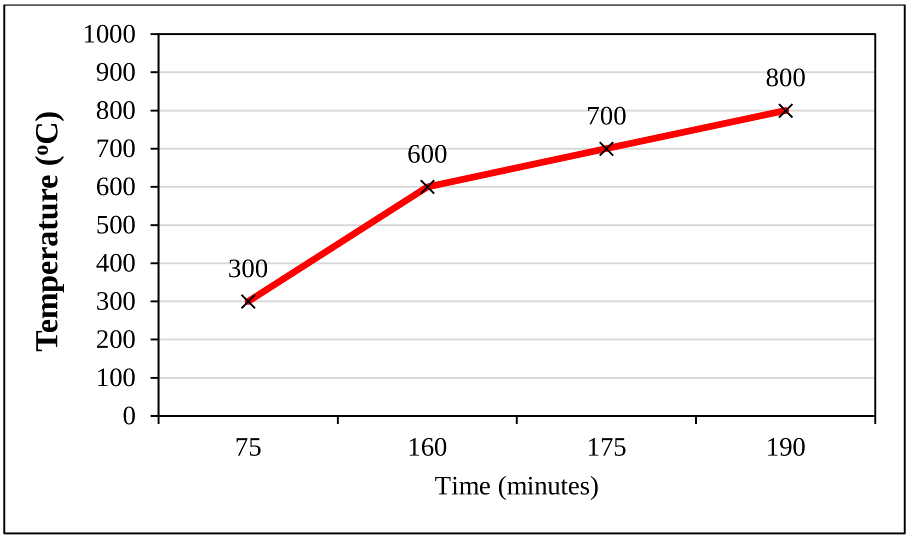

Figure 7: *Fire Resistivity curve*

Table 8 and Figure 7 show the results of fire testing. The cubes placed in the oven were heated from room temperature to 600℃, during which they remained in their original state. However, upon reaching 700℃, the control sample developed a long, thin, hairy crack. The samples with 20% EPS & 10% RHA and 30% EPS & 15% RHA exhibited double hairy cracks, indicating signs of failure, and both samples failed completely at 800℃, by showing multiple hairy cracks. The control sample began to disintegrate due to the effect of fire. For the fire resistance test of the 10% EPS & 5% RHA sample, the temperature started at 30℃ and continued to increase. After 160 minutes of firing, the sample reached 600℃ and remained stable without any signs of failure. At 700℃, single hairy crack was observed on the sample, and double hairy cracks appeared at 800℃. This demonstrates that the 10% EPS & 5% RHA cube sample has better fire resistivity compared to the control samples.

IV. Conclusion

The use of expanded polystyrene (EPS) beads and rice husk ash (RHA) as partial replacements for conventional concrete materials offers a viable approach to producing lightweight, eco-friendly concrete with distinct performance characteristics. The study reveals that increasing EPS and RHA content reduces compressive strength by up to 51.20%**,** decreases density by 21.88%**,** but enhances fire resistance, with strength loss reduced by up to 21.05% at lower replacement levels. Additionally, EPS-RHA concrete exhibited improved thermal resilience between 300°C and 600°C, demonstrating its potential for fire-resistant applications. These findings highlight the potential of EPS and RHA in creating cost-effective, sustainable concrete for lightweight, non-structural use, contributing to environmental sustainability and lower material costs.

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