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A Comparative Study on The Mechanical Properties of High Strength Concrete Made with Basalt and Granite as Coarse Aggregate

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ABSTRACT

High strength concrete (HSC) of grade M60 was prepared and cast in cubes of 100 mm x 100 mm x 100 mm and beams of 100 mm x 100 mm x 500 mm to compare the mechanical properties of the concrete with regards to basalt and granite as coarse aggregate. The aim of this research is to compare the mechanical properties of high-strength concrete made with basalt and granite as coarse aggregates as well as the effects of mild temperature on the strength of the concrete. Compressive strength tests, flexural strength tests, density tests were conducted as well as effects of heat-treatment of 200°C for 24, 48 and 72 hours on the cubes to observe its effect on the concrete. With regard to the compressive strength tests, cubes made with granite posed to have a higher compressive strength (52 N/mm^2 at 28 days of curing) as compared with cubes made with basalt (achieving a strength of 50 N/mm^2 at 28 days of curing). For the flexural strength tests, the beams made with basalt developed a strength of at 28 days while beams of basalt developed which is lesser compared with the strength of beam made with granite. The heat-treatment of the concrete resulted in developing the compressive strength of the concrete to 53.5 N/mm^2 for granite while for basalt resulted in 52 N/mm^2. From the results obtained from this study, it can be deduced further that, HSC made with basalt has poor thermal conductivity as compared with HSC made with granite and hence, could be used for constructing areas which might be exposed to high temperature. Also, with regards to areas of high magnitude of loading, impact or wear such as, pavements, HSC made with granite would be most appropriate as compared to HSC made with basalt.

Keywords: High Strength Concrete, Mechanical Properties, Basalt, Granite and Coarse aggregates.

INTRODUCTION

The versatility, durability, sustainability, and economy of concrete have made it the world's most widely used construction material. The oldest concrete discovered dates from around 7,000 BC. It was found in 1985 when a concrete floor was uncovered during the construction of a road at Yiftah El in Galilee, Israel. It consisted of a lime concrete, made from burning limestone to produce quicklime, which when mixed with water and stone, hardened to form concrete (Brown. 1996 and Auburn, 2000). Examples of early Roman concrete have been found dating back to 300 BC. The very word concrete is derived from a Latin word, "concretus" meaning grown together or compounded. Concrete, a composite consisting of aggregates enclosed in a matrix of cement paste including possible pozzolans, has two major components – cement paste and aggregates. The strength of concrete depends upon the strength of these components, their deformation properties, and the adhesion between the paste and aggregate surface (Berntsson et al., 1990). Not until the 1900's did engineers and materials technologists become involved in optimizing the strength of concrete, though concrete has been used throughout history as a building material. (Portland, 1994) With each successive development and corresponding strength increase, the definition of "high strength" was revised. Of course, there is no exact point of separation between "normal-strength" and "high-strength" concrete. According to the American Concrete Institute, high strength is defined as that over $41N/mm^2$ (6000 psi) compressive strength. (1) This value was adopted by ACI in 1984, but is not yet hard and fast, because ACI recognizes that the definition of high-strength varies on a geographical basis. HSC is still produced using the same materials as when making normal strength concrete (NSC), both concretes obey the same law of physics, chemistry, thermodynamics and of course the law of the market.

However, it has been observed that the HSC can behave differently than NSC because some phenomena that influence very little some NSC practical properties can influence significantly the same properties of HSC (Aitcin, 2011). The essential difference is the w/c:

1. In a NSC, the w/c usually varies from 0.42 to 0.60 (or even more) so that NSC contains more water than necessary to fully hydrate all its cement particles;
2. In a HPC, the w/c is smaller than 0.42 so that usually HPC does not contain enough water to hydrate all its cement particles.

The w/c is not a theoretical number without any physical meaning. Using Dale Bentz mathematical model of cement hydration (Figure 1) it has been possible to demonstrate that the w/c is directly proportional to the distance of cement particles in the paste (Bentz and Aïtcin 2008). The smaller the w/c, the closer the cement particles within the paste, the stronger the bonds generated during hydration.

HSC offers many advantages over conventional concrete. The high compressive strength can be advantageously used in compression members like columns and piles. Higher compressive strength of concrete results in a reduction in column size and increases available floor space. HSC can also be effectively used in structures such as domes, folded plates, shells and arches where large in-plane compressive stresses exist (Mohammad & Mohammad, 2009).The relatively higher compressive strength per unit volume, per unit weight will also reduce the overall dead load on foundation of a structure with HSC. Also, the inherent techniques of producing HSC generate a dense microstructure making ingress of deleterious chemicals from the environment into the concrete core difficult, thus enhancing the long-term durability and performance of the structure.

However, with the recent advancement in concrete technology and the availability of various types of mineral and chemical admixtures, and special superplasticizer, concrete with a compressive strength of up to 100 N/mm^2 can now be produced commercially with an acceptable level of variability using ordinary aggregates. These developments have led to increased applications of high-strength concrete (HSC) all around the globe (Mohammad & Mohammad, 2009). With most natural aggregates, it is possible to make concretes up to 120 N/mm^2, compressive strength by improving the strength of the cement paste, which can be controlled through the choice of water-content ratio and type and dosage of admixtures (Mehta and Aitcin, 1990).

Basalt is a common gray to black volcanic rock. It's usually fine grained due to rapid cooling of lava on the earth's surface. It may be porphyritic containing larger crystals in a fine matrix or vesicular or frothy scoria. Un-weathered basalt is black to gray. The mineralogy of basalt is characterized by a presence mainly of calcic plagioclase feldspar and pyroxene. Olivine can also be a significant constituent. Accessory minerals present in relatively minor amounts include iron oxides such as magnetite, ilmenite and iron-titanium oxides (Titanium-augite, sphene) and spinel (Marwan & Mehyar, 2015).

According to Ramteja (2016), basalt aggregate is a natural aggregate also available in plenty at low cost. He produced an economical and relatively high strength concrete by using basalt aggregate as coarse aggregate. He also concluded that, from laboratory test results of compressive strength, it seemed to indicate that the increase in basalt percentage enhances the mix strength. This is due to the fact that basalt is denser and more durable and less water absorbing than limestone. Also, higher workability was obtained for more basalt aggregate content mix which reduces the cost of labour (Ramteja, 2016). In recent years, several researchers have examined the mechanical properties of materials at elevated temperatures and its effects. Specimen of the materials were collected and subjected to different tests at high temperatures to estimate the changes in elasticity, young's modulus, permeability, tensile strength and compressive strength. When the specimens are subjected to elevated temperatures, thermal stress occur leading to the formation of microcracks. Construed the thermo-physical characteristics of granite, basalt and sandstone at 25 – 100°C to highlight that the presence of quartz plays a vital role on the thermal behavior of the mentioned materials. By this investigation, it was concluded that when granite and sandstone are heated up to 573°C, morphological changes occur and heating above 870°C leads to the production of tridymite (Diaz, 2017). Subsequently after the experimentation, these materials can be used for several engineering and commercial applications such as,

i. Granite rocks/stones are generally utilized in interior and exterior constructional purposes.
ii. Clay finds application in pottery industry, constructional projects, etc.
iii. Basalt is used as fundamental material in the construction of roads and pavements.
iv. Argillite is normally used in exterior decorations.

v. In packaging industry and decorative, tableware components, glass is used.

In general, material strength depends upon mineral composition, grain magnitude, density, porosity, shape, temperature, loading effect, etc. Of all these parameters, the most crucial one is the temperature. Steep increase in temperature causes permanent changes in the characteristics of rocks and materials which include cracking, destruction of the materials, declination in strength, etc. generally, materials like granite, clay, basalt, argillite and glass are composed of numerous minerals. When these materials are heated, they get transformed into ductile material (Diaz, 2017). However, the hard rocks rich in quartz and feldspar are not resistant to high temperatures due to their low levels of melting temperature. It is therefore advisable to build with dark hard rocks or aggregates from the dark rocks such as basalt, gneiss rich in amphibole or pyroxene (Luc-Leroy, Ndop & Ndaka, 2017). The Jos plateau, geo-morphologically consists of gently undulating plains of low relative relief to hill ranges on the plains. Jos, being a location with abundance of Precambrian basement complex rocks: gmeiss, migmatites, granites and the tertiary quartenary volcanic rocks: pumic and basalt (Hassan, Raji, Malgwi, & Agbenin, 2015) initiates the idea of maximizing the benefit of basalt as it possesses a greater thermal property (includes specific heat capacity of 0.84kJ/KgK), also identified to be heat resistant and wear resistant as compared to granite (with a specific heat capacity of 0.79 kJ/KgK) to produce high strength concrete.

MATERIALS AND METHODS

High strength concrete can be produced with a variety of materials and mix designs which eventually produce slightly differing properties. In principle, typical materials that are used for high strength concrete production are fine aggregates, water, ordinary Portland cement, coarse aggregate and admixtures. In this study, due to the unavailability of the mineral admixture, the concrete was produced without the mineral admixture.

Cement

Ordinary Portland cement of grade 42.5N meeting the requirements of BS12:1996 with specific gravity of 3.15, initial setting and final setting times were 110 and 323 minutes respectively, was adopted in this study based on its track record and satisfactory results in concrete works. The material also complies with American Concrete Institute (ACI) compilation 17, 90 high strength concrete. The cement used was free of lumps. Cement content was varies from 300 - 640 kg/m3 as required for high strength. Cement is one of basic component of concrete. For high strength concrete, most available Portland cement can be suitable based on their properties, and comply to national and international standard requirements. For high strength concrete, it is important to select a cement type that will give the best performance. Good workability will depend on cement composition, its fineness and influence of admixtures (Makenya & John-Paul, 2017).

Aggregates

Aggregates are important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. The mere fact that the aggregates occupy 70-80% of the volume of concrete, their impact on various characteristics and properties of concrete is undoubtedly considerable.

Fine aggregate

The fine aggregate used in this study was a natural river sand sourced from a stream in Jos North Local Government area. The specific gravity of the fine aggregate is 2.59. the preliminary sieving on the sand was conduct to remove the debris and larger particle using 4.75mm sieve.

Coarse aggregate

The coarse aggregate generally ranged between 10mm - 20mm diameter (both for the granite and basalt aggregate). The granite coarse aggregate was sourced from Jos North LGA while the Basalt aggregate was obtained from Bassa LGA, Plateau State Nigeria. These two coarse aggregate types were hand crushed

Admixture

The chemical admixture that was used for this study was a Superplasticiser. It is labelled Conplast SP430. It was obtained in Jos South LGA at a company, PW. It was prescribed to be used in relation to its weight and the weight of cement: 0.7kg – 2kg of the superplasticizer to 100kg of cement. Table 1 below shows the descriptions on properties of the superplasticiser as supplied by the manufacturer.

Table 1: Properties of Superplasticizer Used

Property	Description
Physical state	Liquid
Colour	Brown
Freezing temperature	-3.0°C
Boiling point	>100°C
Melting point	Not determined
Flash point	Non aqueous
Solubility	Soluble
pH Value	7.0

Water

Cement and or dry mix concrete will remain inert except mix with water which then starts up the hydration process. The water was clean and free from impurities which are likely to affect the quality or strength of the resulting concrete and also the water was fit for drinking attained from tap and bore-hole water was used in carrying out all the test conducted.

EXPERIMENTAL DESIGN

High strength concrete of grade C60 was prepared and cast into moulds of cubes and beams. After 24 hour of casting of the concrete, specimens were demoulded, weighed and put into curing tank for 28 days and tested at 7 days, 14 days and 28days. Before testing, specimens are weighed immediately they are pulled out of the tank and allowed to dry by air under room temperature for 30 minutes to allow surface water to drain off. Some specimen were used for high temperature test. These specimens of both basalt cubes and granite cubes were placed in the oven for 24 hours, 48 hours and 72 hours at 200°C after achieving a 28 day strength. The remaining samples that were not heated were used as comparative samples with regard to the heated samples.

Table 2 shows the concrete mix proportions used for this study. For a volume of 0.248 m^3 which is the actual mix proportion for the production of concrete samples used for the study, the w/c ratio was 0.35 and the weight of cement used was 120.53 kg, fine aggregate of 120.53 kg and coarse aggregate (both for granite and for basalt) was 317.17 and finally, a weight of superplasticiser of 0.84 kg. For the trial mix, a volume of 0.05 m^3 was produced for w/c ratios of 0.30, 0.35 and 0.40, weight of cement 24.3 kg, weight of fine aggregate 24. 3 kg, weight of coarse aggregate (both granite and basalt) was 63.9 kg and a weight of 0.17 of superplasticiser.

For a volume of a cubic metre concrete, the weight of cement and fine aggregate are 486 kg each, weight of coarse aggregate is 1278.9 kg with a weight of superplasticiser 3.40 kg.

Table 2: Concrete Mix Proportions (kg)

Quantity (m^3)	Water/Cement Ratio	Cement	Fine Aggregate	Coarse Aggregate	Superplasticiser
0.248 (actual)	0.35	120.53	120.53	317.17	0.84
0.05 (trial mix)	0.30, 0.35, 0.4	24.3	24.3	63.9	0.17
1.00	-	486	486	1278.9	3.40

RESULTS, ANALYSIS AND DISCUSSION

The aim of this study is to compare the strength properties of HSC made with basalt and granite, and evaluate their performance when exposed to mild temperatures. An M60 grade concrete was produced for this study. Specimens were produced at certain sizes (100mm x 100mm x 100mm cubes and 100mm x 100mm x 500mm beams) basically of the two different types of rocks as aggregate to be compared; basalt and granite. Admixtures were also used in the preparation of the specimens. The chemical admixture (superplasticiser) was used in a proportion of 0.7 kg to 100kg mass of cement for the mix. The specimens produced were cured for 28 days and tested at 7 days, 14 days and 28 days of age. The mix ratio used to produce the specimens were 1:1:2.63. The results of this study are discussed within the context of physical and mechanical properties.

Properties of fresh concrete

Workability test was carried out to determine the mobility and stability of fresh concrete as seen in tables 2 and 3. Slump test was performed in accordance with the provision of BS 1881, Part 102 (1983). This test was carried out on basalt coarse aggregate for three w/c at 0.30, 0.35 and 0.40 using the same weight of superplasticiser of 0.17 and mix ratio of 1:1:2.63 for each test. For w/c of 0.30, the slump resulted as 12 mm. For 0.35 w/c, the slump obtained was 21 mm and for w/c of 0.40, the slump obtained was 30 mm. The water/cement ratio that gave the predetermined slump was the 0.35 w/c. The w/c gave a slump of 21mm for the mix with regard to basalt coarse aggregate. Hence, the w/c used for all samples of basalt coarse aggregate conformed to the w/c of 0.35, maintaining the same quantity of superplasticiser and same mix ratio of 1:1:2.63. From table 3, results obtained for the test carried out on granite coarse aggregate for three w/c at 0.30, 0.35 and 0.40 using the same weight of superplasticiser of 0.17 and mix ratio of 1:1:2.63 for each test are discussed as follow; for w/c of 0.30, the slump resulted as 14 mm. For 0.35 w/c, the slump obtained was 23 mm and for w/c of 0.40, the slump obtained was 31 mm. The water/cement ratio that gave the predetermined slump was the 0.35 w/c. The w/c gave a slump of 23 mm for the mix with regard to granite coarse aggregate. Hence, the w/c used for all samples of granite coarse aggregate conformed to the w/c of 0.35, maintaining the same quantity of superplasticiser and same mix ratio of 1:1:2.63.

Table 3: Slump test for basalt

Water/Cement Ratio	Superplasticiser (kg)	Mix Ratio	Slump (mm)
0.30	0.17	1:1:2.63	12

0.35	0.17	1:1:2.63	21
0.40	0.17	1:1:2.63	30

Table 4: Slump test for granite

Water/Cement Ratio	Superplasticiser (kg)	Mix Ratio	Slump (mm)
0.30	0.17	1:1:2.63	14
0.35	0.17	1:1:2.63	23
0.40	0.17	1:1:2.63	31

Mechanical properties

The tests carried out with regard to the mechanical properties of the high strength concrete were destructive tests of compressive strength and flexural strength tests. Also, the density of the concrete samples was determined. From table 5, basalt aggregates produced and cast in cubes of were weighed after a curing period of 7 days, the weight determined averagely was 2.36 kg, and the calculated density was 2360 kg/m^3. At 14 days of curing, the average weight of cubes was 2. 54 kg and the density calculated was 2540 kg/m^3. And for a curing day of 28 days, the average weight of the cubes was 2.61 kg and the density calculated was 2610 kg/m^3.

Density Test

Table 5: Density Test of cubes for Basalt Aggregates

Curing Period (Days)	Weight of Cubes (kg)	Density of Cubes (kg/m^3)
7	2.36	2360
14	2.54	2540
28	2.61	2610

From table 6, basalt aggregates produced and cast in cubes of 100 mm x 100 mm x 100 mm were weighed after a curing period of 7 days and the weight determined averagely was 2.43 kg and the calculated density was 2430 kg/m^3. At 14 days of curing, the average weight of cubes was 2. 57 kg and the density calculated was 2570 kg/m^3. And for a curing day of 28 days, the average weight of the cubes was 2.64 kg and the density calculated was 2640 kg/m^3.

Table 6: Density Test of Cubes for Granite Aggregates

Curing Period (Days)	Weight of Cubes (kg)	Density of Cubes (kg/m^3)
7	2.43	2430
14	2.57	2570
28	2.64	2640

From table 7, basalt aggregates produced and cast in cubes of 100 mm x 100 mm x 500 mm were weighed after a curing period of 7 days and the weight determined averagely was 12.26 kg and the calculated density was 2452 kg/m^3. At 14 days of curing, the average weight of cubes was 12.59 kg and the density calculated was 2518 kg/m^3. And for a curing day of 28 days, the average weight of the cubes was 12.88 kg and the density calculated was 2576 kg/m^3.

Table 7: Density of Beams for Basalt Aggregates

Curing Period (Days)	Weight of Cubes (kg)	Density of Cubes (kg/m^3)
7	12.26	2452
14	12.59	2518
28	12.88	2576

From table 8, basalt aggregates produced and cast in cubes of 100 mm x 100 mm x 500 mm were weighed after a curing period of 7 days and the weight determined averagely was 12.54 kg and the calculated density was 2508 kg/m^3. At 14 days of curing, the average weight of cubes was 12.86 kg and the density calculated was 2572 kg/m^3. And for a curing day of 28 days, the average weight of the cubes was 13.04 kg and the density calculated was 2608 kg/m^3.

Table 8: Density of Beams for Granite Aggregates

Curing Period (Days)	Weight of Cubes (kg)	Density of Cubes (kg/m^3)
7	12.54	2508
14	12.86	2572
28	13.04	2608

Compressive Strength Test

Table 8 shows the compressive strength of the high strength concrete made with basalt ranged between 41N/mm^2 to 50 N/mm^2 within a hydration period of 7 days to 28 days. At 7 days, the average density was 2567 kg/m^3, average crushing load of 410 KN, average weight of 2.36 kg resulting to a compressive strength of 41N/mm^2. At 14 days, the average density was 2650 kg/m^3, average crushing load of 470 KN, average weight of 2.54 kg resulting to a compressive strength of 47N/mm^2. At 28 days, the average density was 2700 kg/m^3, average crushing load of 500 KN, average weight of 2.61 kg resulting to a compressive strength of 50 N/mm^2.

Table 8: Compressive strength of basalt aggregate

Curing Period (days)	Average density (kg/m^3)	Average Crushing Load (KN)	Average Weight (kg)	Strength (N/mm^2)
7	2567	410	2.36	41
14	2650	470	2.54	47
28	2760	500	2.61	50

The following results were observed after the exposing samples to a temperature of 200°C for 24 hours (after being open-air dried at room temperature for 24 hours) as seen in table 9. For the samples made with basalt, the compressive strength ranged between 41.5 N/mm^2 to 52 N/mm^2 within 7 days and 28 days. At an elevated temperature of 200°C for a period of 24 hours, the average crushing load applied was 513 KN, with an average weight of cubes of 2.59 resulting to a compressive strength of 51.30 N/mm^2. At a temperature of 200°C for a period of 48 hours, the average crushing load applied was 518 KN, with an average weight of cubes of 2.51 resulting to a compressive strength of 51.80 N/mm^2. At a temperature of 200°C for a period of 72 hours, the average crushing load applied was 520 KN, with an average weight of cubes of 2.32 resulting to a compressive strength of 52.00 N/mm^2. This indicates that there is a progressive increase in strength achieved at mild temperature exposure which might be as a result of an increase in reaction within the matrix which enhances CSH gel formation.

Table 9: Compressive strength of basalt aggregate exposed to mild temperature

Exposure of Temperature Period (hrs)	Mild Temperature exposure (°C)	Average Crushing Load (KN)	Average Weight (kg)	Strength (N/mm²)
24	200	513	2.59	51.30
48	200	518	2.51	51.80
72	200	520	2.32	52.00

The result obtained from compressive strength test on samples of high strength concrete produced with granite coarse aggregates as seen in table 10 are discussed as follows; the compressive strength of the high strength concrete made with granite ranged between 42.5 N/mm^2 to 52 N/mm^2 within a hydration period of 7 days to 28 days. At 7 days, the average density was 2570 kg/m^3, average crushing load of 425 KN, average weight of 2.43 kg resulting to a compressive strength of 42.5 N/mm^2. At 14 days, the average density was 2658 kg/m^3, average crushing load of 480 KN, average weight of 2.57 kg resulting to a compressive strength of 48N/mm^2. At 28 days, the average density was 2762 kg/m^3, average crushing load of 520 KN, average weight of 2.64 kg resulting to a compressive strength of 52 N/mm^2.

Table 10: Compressive strength for Granite aggregate

Curing Period (days)	Average density (kg/m³)	Average Crushing Load (KN)	Average Weight (kg)	Strength (N/mm²)
7	2570	425	2.43	42.5
14	2658	480	2.57	48
28	2762	520	2.64	52

The following results as seen in table 11 were observed after the exposure of samples to a temperature to 200°C for 24 hours (after being open-air dried at room temperature for 24 hours). For the samples made with granite, the compressive strength ranged between 52.10 N/mm^2 to 53.50 N/mm^2 within 7 days and 28 days. At an exposed temperature of 200°C for a period of 24 hours, the average crushing load applied was

521 KN, with an average weight of cubes of 2.54 resulting to a compressive strength of 52.10 N/mm^2. At a temperature of 200°C for a period of 48 hours, the average crushing load applied was 527 KN, with an average weight of cubes of 2.53 resulting to a compressive strength of 52.70 N/mm^2. At a temperature of 200°C for a period of 72 hours, the average crushing load applied was 535 KN, with an average weight of cubes of 2.41 resulting to a compressive strength of 53.50 N/mm^2. This indicates that there is a progressive increase in strength achieved at elevated temperature.

Table 11: Compressive strength for granite aggregate exposed to mild Temperature

Exposure Temperature Period (hrs)	Mild Temperature exposure (°C)	Average Crushing Load (KN)	Average Weight (kg)	Strength (N/mm^2)
24	200	521	2.54	52.10
48	200	527	2.53	52.70
72	200	535	2.41	53.50

Flexural Strength Test

The flexural strength obtained for the high strength concrete beams produced with basalt within the hydration period of 28 days, and tested within 7 days and 28 days ranged between 5.24 N/mm^2 to 6.53 N/mm^2 at room temperature as seen in table12. At 7 days, the average density was 2587 kg/m^3, an average crushing load of 10.48 KN and an average weight of 12.26 kg resulting in a flexural strength of 5.24 N/mm^2. At 14 days, the average density was 2570 kg/m^3, an average crushing load of 11.92 KN and an average weight of 12.59 kg resulting in a flexural strength of 5.96 N/mm^2. At 28 days, the average density was 2603.3 kg/m^3, an average crushing load of 13.06 KN and an average weight of 12.88 kg resulting in a flexural strength of 6.53 N/mm^2.

Table 12: Flexural strength for Basalt Aggregate

Curing Period (days)	Average density (kg/m^3)	Average Crushing Load (KN)	Average Weight (kg)	Strength (N/mm^2)
7	2587	10.48	12.26	5.24
14	2570	11.92	12.59	5.96
28	2603.3	13.06	12.88	6.53

The flexural strength obtained for the high strength concrete beams produced with granite within the hydration period of 28 days, tested within 7 days, 14 days and 28 days ranged between 5.52 N/mm^2 to 6.69 N/mm^2 at room temperature. At 7 days, the average density was 2520 kg/m^3, an average crushing load of 11.04 KN and an average weight of 12.54 kg resulting in a flexural strength of 5.52 N/mm^2. At 14 days, the average density was 2560 kg/m^3, an average crushing load of 12.30 KN and an average weight of 12.86 kg resulting in a flexural strength of 6.15 N/mm^2. At 28 days, the average density was 2629 kg/m^3, an average crushing load of 13.38 KN and an average weight of 13.04 kg resulting in a flexural strength of 6.69 N/mm^2 as seen in table 13.

Table 13: Flexural strength for Granite Aggregate

Curing Period (days)	Average density (kg/m^3)	Average Crushing Load (KN)	Average Weight (kg)	Strength (N/mm^2)
7	2520	11.04	12.54	5.52
14	2560	12.30	12.86	6.15
28	2629	13.38	13.04	6.69

Mild temperature exposure

Table 14: Effect of high temperature on cubes

Property	Period of heat-treatment (hours)	Temperature (°C)	Observation BEFORE elevating temperature	Observation AFTER elevated temperature
Colour	24	200	dark grey	light grey
Cracks	24	200	no cracks	no cracks

From visual observation, it was clear that the samples made of both granite and basalt had undergone changes in appearance during the exposure to mild temperatures. Samples changed from being dark grey in colour to light grey. It was observed that before the samples were placed in the oven, no cracks were visible and after they had been brought out of the oven, no visible cracks were visible. Identifying the behaviour of materials used in the preparation of the samples at mild temperatures for this study is considerably important as they determine the how the variables (High strength concrete made with basalt and granite) behave. According to Pierre, P. et al (2017), there is no standardised test method for determination of high temperature thermal conductivity of concrete.

SUMMARY OF FINDING

a. The compressive strength of high strength concrete made with granite superseded that which was made with basalt. When the concrete made with basalt was reading a compressive strength of 41 N/mm^2 at 7 days concrete made with granite was reading 42.5 N/mm^2 at 7 days and when compared at 28 days, basalt achieved an average strength of 50 N/mm^2 while granite achieved 52 N/mm^2. In percentage, the compressive strength of granite was 3.53% greater than HSC of basalt. The same was proven in the flexural test. When the concrete made with basalt was reading a flexural strength of 5.24 N/mm^2 at 7 days concrete made with granite was reading 5.52 N/mm^2 at 7 days and when compared at 28 days, basalt achieved an average strength of 6.53 N/mm^2 while granite achieved 6.69 N/mm^2. This implies that the granite has higher mechanical properties compared to basalt.

b. After exposure to mild temperatures, both samples (HSC made with basalt and granite) proved to increase their compressive strength with about 1.9 % (from 50 N/mm^2 – 52 N/mm^2) for basalt and 2.88 % (from 52 N/mm^2 – 53.50 N/mm^2) for granite as compared to when they are crushed at room temperature.

c. Increase in compressive strength of both samples of the concrete in comparison are as a result of escape of water within the samples as the temperature was elevated to 200°C. The weight of the concrete samples decreased while there is an increase in compressive strength. Decrease in weight of basalt HSC is 0.77 % and 3.78 % for granite HSC as compared with the weight of samples at room temperature after 28 days of curing.

d. The specific heat capacity of basalt being 0.84kJ/KgK compared to 0.79kJ/KgK that of granite explains the low thermal conductivity in basalt samples as there is less loss of water within the concrete made with basalt as compared to concrete made with granite as basalt requires higher temperature to heat up its entire system unlike granite which resulted in greater loss of water in granite concrete than that of the basalt.

CONCLUSION

From the results obtained from this study, it can be deduced further that, HSC made with basalt has poor thermal conductivity as compared with HSC made with granite and hence, could be used for construction in areas which might be exposed to high temperatures. Also, with regards to areas of high magnitude of loading, impact or wear such as, pavements, HSC made with granite would be most appropriate as compared to HSC made with basalt as seen from the compressive strength. Further studies on the microstructure and durability of these samples are recommended.

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