MECHANICAL AND DURABILITY PROPERTIES OF CONCRETE WITH GRANITE POWDER AS PARTIAL REPLACEMENT OF CEMENT

Asnake Kefelegn[1], Binaya Patnaik [2] and Issayas Kebede [3*]
[1] Department of Civil Engineering, Hawassa University, Hawassa, Ethiopia
[2] Department of Civil Engineering, Gambella University, Gambella, Ethiopia
[3] Construction Supervision Team in SNNPR's Construction Authority, Hawassa, Ethiopia
[*] Corresponding author. E-mail address: issayasworku@gmail.com

ABSTRACT

This experimental investigation was performed to evaluate the strength and durability properties of concrete, in which cement was partially replaced with granite powder at 5%, 10%, 15%, and 20% by volume. A total of five concrete mix proportions were developed for control and concrete with granite powder. The fresh property test, strength, and durability tests were done for normal strength concrete (NSC) as well as high strength concrete (HSC). The fresh property of concrete was evaluated using slump test, and the strength of concrete was evaluated using compressive strength and splitting tensile strength test. Durability properties were evaluated using water absorption test, sorptivity test, and chloride and sulphate attack test for all concrete mixes. From the investigation, the compressive strength was enhanced up to 10% replacement in NSC and at 5% replacement in HSC. The tensile strength was improved up to 10% replacement in the both types of the concrete. Denser concrete against water absorption was made at 5% & 10% in NSC and 5% in HSC. The initial rate of water absorption (sorptivity) was increased at 5% in NSC and 10% in HSC concrete. The resistance to chloride and sulphate attack was enhanced at all replacement percentages for NSC as well as HSC.

Keywords: Cement replacement, durability properties, Granite powder, Mechanical properties

INTRODUCTION

Portland cement is hydraulic cement mainly composed of hydraulic calcium silicates. Hydraulic cement is set and hardened by reacting chemically with water. During this reaction, called hydration, cement combines with water to form a stone-like mass, called paste. When the paste (cement and water) is added to aggregates, it acts as an adhesive and binds the aggregates together to form concrete, the world's most versatile and most widely used construction material [1].

The following are the four primary compounds in Portland cement, their approximate chemical formulas, and abbreviations: Tricalcium silicate $3CaO{\bullet}SiO_2 = C_3S$, Dicalcium silicate $2CaO{\bullet}SiO_2 = C_2S$, Tricalcium aluminate $3CaO{\bullet}Al_2O_3 = C_3A$, Tetra calcium aluminoferrite $4CaO{\bullet}Al_2O_3{\bullet}Fe_2O_3 = C_4AF$[1, 2]. In addition to the four major compounds, there are many minor compounds formed in the cement. The influence of these minor compounds on the properties of cement or hydrated compounds is not significant [2].

The following are the approximate equations of the reactions of C_3S and C_2S with water.
$2\,(3\,CaO.SiO_2) + 6H_2O \rightarrow 3CaO.2SiO_2.3H_2O + 3\,Ca\,(OH)_2$. Similarly, $2(2CaO.SiO_2) + 4H_2O \rightarrow 3CaO.2SiO_2.3H_2O + Ca\,(OH)_2$. $Ca\,(OH)_2$ is not a desirable product in the concrete mass.

It is soluble in water and gets leached out making the concrete porous, particularly in hydraulic structures. And, the lack of durability of concrete is on account of the presence of calcium hydroxide. The calcium hydroxide also reacts with sulphates present in soils or water to form calcium sulphate which further reacts with C_3A and causes deterioration of concrete. This is known as sulphate attack. To reduce the quantity of $Ca(OH)_2$ in concrete and to overcome its bad effects by converting it to cementitious products is the advancement in concrete technology. The use of blending materials such as fly ash, silica fume, and other pozzolanic materials are the steps to overcome the bad effect of $Ca(OH)_2$ in concrete [2].

For reinforced concrete structures, especially for water retaining structures, the limiting of crack width as a result of shrinkage is important. Thermal shrinkage can be reduced by restricting the temperature rise during hydration, which can be achieved by the mix proportions with low cement content or suitable cement replacement e.g. fly ash (pulverized fuel ash) or ground granulated blast furnace slag. Cement containing ground granulated blast furnace slag or fly ash will not only help to reduce temperature rises due to hydration but will also increase durability [3].

Granite powder is a by-product produced in granite factories while cutting huge granite rock to the desired shapes. This granite powder has a chemical composition like the raw materials used for manufacturing cement [4]. Based on ASTM C618, if the sum of the percentage composition of silica, alumina, and ferric oxide is over 70%, the material can be introduced to concrete as a pozzolanic material [5]. The effect of replacing granite fines as the sand on vibrated structural concrete has been studied by different researchers [6, 7, 8, 9, 10].

Divakar Y., et al. used a concrete which was prepared with granite fines as a replacement of fine aggregate in 5 different proportions namely 5%, 15%, 25%, 35%, and 50%, and various tests such as compressive strength, split tensile strength and flexural strength were conducted and these test values were compared with the conventional concrete without granite fines. In this investigation, the compressive strength was increased by 22% with 35% replacement of fine aggregate with granite fines, and the compressive strength was still higher than the control's samples strength for up to 50% replacement. At 50% replacement of granite fines, the compressive strength was 38.5 MPa whereas the control was 37 MPa. The splitting tensile strength was not significantly affected up to 50% replacement. The flexural strength of 10cm x 10cm x 50cm prism without reinforcement increased at 5% replacement by 5.41%, but its value decreased with the replacement beyond 5% even if the reduction was insignificant. The flexural strength of 15 cm x 15 cm x 70 cm beam with reinforcement was checked at 25% and 50% replacements, and the result showed that at 25% replacement a 2% increment was observed and at 50% replacement the strength was increased by 32.7% [6].

Raja G. & Ramalingam K. investigated the mechanical properties of normal-strength concrete by replacing sand with granite fines. The percentage replacement of granite fines used were 10, 20, 30, 40, 50 & 100 for concrete cube strength of 20 MPa mix proportions. Specimens were tested after 28 days of curing for compression strength, flexural strength, and tensile splitting test. From the study, the spacemen with 40% replacement of granite fines achieved higher strength compared to the control specimen [7]. Allam M., et al. investigated the effect of replacing the sand with granite waste in the concrete mix at the values of 10%, 17.5%, and 25%.

In this study, splitting tensile strength after 28 days of curing was increased by 12%, 15%, and 21% respectively as compared to the control mix. By replacing the sand with 10% granite granules by weight, the value of the flexural strength was increased by 34% and at 17.5% replacement, the value dropped back to the same as that of thecontrol**.** At the highest — 25% percentage of replacement, the value of flexural strength was 15% lower than the control mix. By replacing the 10% sand with granite powder, the value of bond strength increased by 1%—further increase decreases the bond strength [8].

Shehdeh G., et al. investigated the effect of replacing granite powder and iron powder as sand at 5%, 10%, 15%, and 20% by weight. From the investigation, it was observed that substitution of the 10% of sand by weight with granite powder in concrete was the most effective in increasing the compressive and flexural strength compared to other replacement percentages. The test result showed that for a 10% ratio of granite powder in concrete, the increase in the compressive strength was about 30% compared tothe control samples. Similar results were observed for the flexural strength. It was also observed that substitution of up to 20% of sand by weight with iron powder in concrete resulted in an increase in compressive and flexural strength of the concrete [9].

Shinde S., et al investigated the effect of sand replacement with granite powder at 10%, 20%, 30%, 40%, 50% & 100%. In this study, the effect on the compressive and tensile strength was examined.The result from the study showed that the maximum compressive and tensile strength was attained at 20% replacement of granite powder. Up to 50% replacement**,** the compressive strength was higher than the compressive strength of the control samples. And up to 40% replacement, the tensile strength was also higher than the controls [10]. A review on partial replacement of cement material in Ethiopia has been carried out in Makebo G., et al. [11]. In this review work, it was stated that the waste materials like coffee husk ash, banana leaf ash, bagasse ash, bone powder, corncobs ash, municipal waste, coal mine, lime sludge, groundnut shell ash, quarry dust, and iron tailing have pozzolanic properties and can partially replace cement in the range of 10% – 15% in medium strength concrete production. The optimum percentage replacement of the materials was 10%. And, if the percentage replacement of the materials increases, the compressive strength starts decreasing.

The effect of replacing cement with granite powder on vibrated structural concrete was investigated by different researchers [8, 12, 13, 14].

The splitting tensile test on the concrete cylinders with different proportions of granite waste as partial replacement ofcement was studied in Allam M., et al. (2016) [8]. In this study, it was shown that at 5% of granite fines waste as a partial replacement of cement, the strength was 20% higher than the control mix, but at 10% replacement, the strength dropped to the value equal to the control. In contrast, the flexural strength of the mixes containing 5%, 10%, and 15% of fine granite waste as a partial replacement of cement was 19%, 30%, and 37% lower than the control mix respectively. The bond strength of mix containing 5% of fines as replacement of cement was slightly higher by 1% [8].

Koneti V., et al. used granite slurry and sawdust to partially substitute cement and sand respectively. Sawdust replaced the fine aggregate at 3%, 5%, and 7% whereas granite slurry replaced the cement by 10%, 20%, and 30%. At 10% of cement replacement with the granite slurry, the corresponding saw dust replacement was 3%. Similarly, at 20% replacement of cement with granite slurry, the corresponding saw dust replacement was 5% and for 30% cement replacement by granite slurry, sawdust replaced sand at 7%. The result from the investigation showed that the compressive strength on the seventh day was almost two times greater than the control mix in all replacement of granite and sawdust which indicates improved early strength gain. The maximum compressive strength was attained at 10% replacement of granite slurry and at 3% replacement of sawdust. Similarly, at 10% replacement of cement with granite slurry and 3% replacement of sand with sawdust, the maximum tensile strength value was attained [12].

Chiranjeevi R., et al studied the strength properties of concrete by using granite powder as an admixture. Concrete with cubic compressive strength of 25 MPa was prepared with the granite fines as a replacement of cement in concrete at different proportions namely 2.5%, 5%, 7.5%, 10%. From the investigation, at the optimum 7.5% replacement of cement by granite waste, the maximum compressive strength with a percentage increment of 42.47% was attained. The splitting tensile strength and the flexural strength were also maximum at 7.5% replacement of cement with granite powder [13].

The investigation of the fresh and hardened properties of ready mix concrete by partial replacement of cement with granite powder, and using manufactured sand and super plasticizer was carried out bySrinivasa C., et al. (2009)[14]. In this investigation, the partial replacement of ordinary portland cement with granite powder by 10%, 15%, 20%, 25%, 30%, 35%, and 40% was carried out. From the investigation, it was observed that the workability and compaction factor were acceptable for all mix batches which satisfy the requirements of ready-mix pumpable concrete. The compressive strength at 28 days with 20% replacement was the maximum one from which the optimum percentage was established for the target mean strength value.

The durability of concrete made with granite powder replacing cement was studied in Allam M., et al in this study, the Scanning Electron Microscope (SEM) of concrete images for 5% granite waste powder as a partial replacement of cement indicates a denser concrete mix with the lowest number of pores. Additionally, Bakhoum E., et al. found the durability improvement of a mortar. In this study, the SEM images of the mix containing replacement of 5% cement and 10% sand with nano-granite waste showed maximum density and minimum micro-cracks and number of pores [16].

As it is observed from different investigations reviewed above, the optimum cement replacement percentage with granite powder for normal strength concrete varies from 5% to 20%. Moreover, in the review part of this article, almost all of the studies were on strength properties and durability cases were not investigated in detail. Furthermore, lots of effort has been done on investigating the strength properties of concrete using granite waste as a partial replacement of fine aggregate. And a few researches were performed on the strength properties of medium-strength concrete by replacing cement partially with granite slurry.

In this study, the granite powder used was finer than the powder used by other researchers, and the cement replacement by volume was also adopted. The investigation also included the granite powder's replacement effect on high strength concrete and durability in addition to the investigation of its effect on medium strength concrete.

MATERIALS

In this experimental study, the medium strength concrete, C20/25 (NSC,) and high strength concrete, C55/67 (HSC) were used [17]. The concrete test specimens were cast by replacing cement with granite powder at 5%, 10%, 15%, and 20% by volume and cured for strength and durability property investigations. The cement used was Dangote Ordinary Portland Cement (OPC) with a 42.5R grade. The fine and coarse aggregates used were locally available materials that were collected from Dimtu and Monopole around Hawassa city respectively. The physical properties of used sand and coarse aggregates which were determined as per the manual [18] are put in Table 1 and 2 respectively. The maximum coarse aggregate size used for medium and high-strength concrete was 25mm and 19mm respectively. The bulk unit weights were also 1372 kg/m^3 and 1360kg/m^3 respectively.

Table 1. Physical properties of aggregates

Fineness modules, FM	2.81
Silt Content, %	3.57
Specific Gravity (OD)	2.33
Absorption, %	2.04
Moisture content, %	2.04

Table 2. Physical properties of coarse aggregates

Specific gravity (OD)	2.55
Absorption,%	1.42
Moisture content, %	0.50

The granite powder used (shown in Figure 1), which was collected from COA General Trading PLC’s workshop in Addis Ababa around Balderas signal,was finer than 45µm (No 325) sieve and its chemical composition, which was tested in the Geological Survey of Ethiopia laboratory, is shown in Table 3.

The properties of the super plasticizer used in this investigation, which was taken from SAS Construction Chemicals Ltd’s profile, are shown in Table 4.

Figure 1. Granite powde

Table 3 Chemical composition of granite powder

Chemical oxides composition	Percentage by weight
Silica (SiO_2)	69.12
Alumina (Al_2O_3)	17.77
Iron (Fe_2O_3)	2.17
Calcium oxide (CaO)	1.54
Magnesia (MgO)	0.46
Soda (Na_2O)	2.22
Potassium Oxide (K_2O)	3.86
Manganosite (MnO)	0.04
Potassium oxide (P_2O_5)	0.05
Titanium dioxide (TiO_2)	0.14
Water (H_2O)	0.1

Table 4. Properties of super plasticizer

Properties	Observations
Colour	Dark brown liquid
Specific gravity	1.22 ± 0.03 at 25°c
Chemical base	Naphthalene sulphonate
Air entrainment	1-2 % depending on dosage
Chloride content	Nil

1. EXPERIMENTAL METHODS

1.1. Mix design, mixing, and curing procedures

The mix proportions for medium and high strength concrete which was designed as per ACI 211.1-91 [19]and ACI 211.4R -93[20] respectively are summarized in Table 5. Hand mixing and tamping of the fresh concrete in the standard mold were carried out as per ASTM C 192 M-02 standards [21]. All specimens were moist cured at room temperature from the time of molding till the moment of the test as per ASTM C 192M-02 standard[21].

Table 5. Mix proportions of medium and high strength concrete

Materials	C20/25	C55/67
	kg/m^3	kg/m^3
Water	201.52	217.88
Cement	327.81	733.18
Coarse aggregates	937.34	984.17
Fine aggregates	774.22	382.34
Super plasticizer	0	11

1.2.Tests carried out

The slump test for workability was carried out as per ASTM C 143/C 143M - 00 standard [22] for each case specimen both for medium and high strength concrete. The compressive strength of cube 15cm-size concrete specimens was tested as per ASTM C 39/C 39M standard [23] for each granite powder replacement case and both for medium and high-strength concrete. Three test specimens were tested for selected curing ages, 7th and 28th days, of concrete. Each compressive strength specimen was subjected to a 0.4 MPa/sec loading rate.

The flexural strength of 15x15cm cross-section size with 50cm span length plain concrete specimens was tested as per ASTM C 293 - 02 standard [24] for each granite powder replacement case and both for medium and high strength concrete. In this test, two test specimens were tested for the only 28th day of concrete. The flexural strength specimens were subjected to a 0.02 MPa/sec loading rate.

The water absorption by immersion test was done based on ASTM C 642 - 97 standard [25]. The water absorption of three cubes of 15 cm size was tested for each granite powder replacement case and both for medium and high 28th-day strength of concrete.

Sorptivity measures the rate of water absorption of hydraulic cement concrete by measuring the increase in the mass of a specimen resulting from absorption of water as a function of time when only one surface of the specimen is exposed to water. The initial rate of water absorption (sorptivity) is the absorption from one minute to six hours. In this study, the sorptivity test was carried out as per ASTM C 1585 – 04 standard [26]. Two-disc slices of the concrete cylinder for each granite powder replacement case were used in this study. The slices used for this testwere the middle two slices after rejecting the top and bottom disc slices. Slice specimens of 5 cm depth were prepared by cutting a cylinder concrete specimen with the size of 5 cm diameter and with a depth of 20 cm into four equal parts as shown in Figure 2.

Figure 2. Sorptivity test specimens after cutting cylinder.

The test method for the chemical resistance of concrete is specified in the ASTM C 1012[27]. However, this method is for mortar, and the behavior of mortar and concrete under chemical attack might not be the same. One of the ways of knowing the deterioration mechanism of concrete under the exposed chemical solution is the mass loss method as shown by equation 1 [28].

In order to get the accelerated degradation process and to shorten the test duration, changing the concentration of the sulfate solution in a way that simulates the highest sulfate concentrations can be done [29]. The lower limit of the exposure proposed by the ASTM C1012 [27] test method is the use of 50,000 mg/L Na_2SO_4 concentration in water solution.

In this sulfate and chloride chemical attack experimental study, JSTM C7401 [30] testing method is used. This test method assesses the chemical resistance of concrete by immersing test specimens into acid or alkaline solutions for a prescribed period and by comparing changes in the measurements against control specimens. The sulfate resistance of concrete can be quantified by measuring changes in weight occurring in specimens stored in chemical solutions [31].

In this experimental investigation, cubes of concrete of 15cm, which were cured for 28 days for both normal and high strength concrete, were used. After the final day of curing, the specimens were removed from the water, and the excess film of water on the surface was cleaned using a standard preliminary surface cleaning process and weighed as initial mass. Then the identified specimens were immersed in the 5% sulfateand chloride chemical solutions for another 28 days. After the prescribed duration, the specimens were removed from the solution and their final weight was recorded. Then, sulfate and chloride resistance of the specimens in terms of weight loss was determined using equation

$$\text{Mass change (\%)} = \frac{w_o - w_f}{w_o} x100\% \qquad (1)$$

Where W_f is the mass of concrete immersed in a test solution on the 28th day (g), and W_o is the mass of concrete before immersion in a test solution (g).

2. RESULTS AND DISCUSSION

In this section, the results from the experiment and discussion are presented. The test result for the slump value is shown in Figure 3.

As observed from Figure 3, the slump value for both types of concrete decreased, which may happen from the higher surface area of granite powder which can increase the surface of hydration leading to higher water absorption. The addition of powder was also observed to result in loss of slump as reported in [32] for medium-strength concrete.

The test result for average compressive strengths is shown in Figure 4. From the test results, for NSC concrete, the 7th-day strength test result for 5% and 10% replacement of cement with granite powder increased by 13% and 9% respectively. Whereas for HSC concrete, the 7th-day strength test result increased at 5% replacement by 5.86%. However, it decreased for 10%, 15%, & 20% replacement compared the control strength.

For NSC concrete, the 28th-day compressive strength test result showed that the average compressive strength at 5% and 10% replacement was higher by 3.36% and 1% respectively. However, relative to the 7th-day strength result, the 28th-day strength increment is lower. This indicates that partial replacement of cement with granite powder improved an early strength gain.

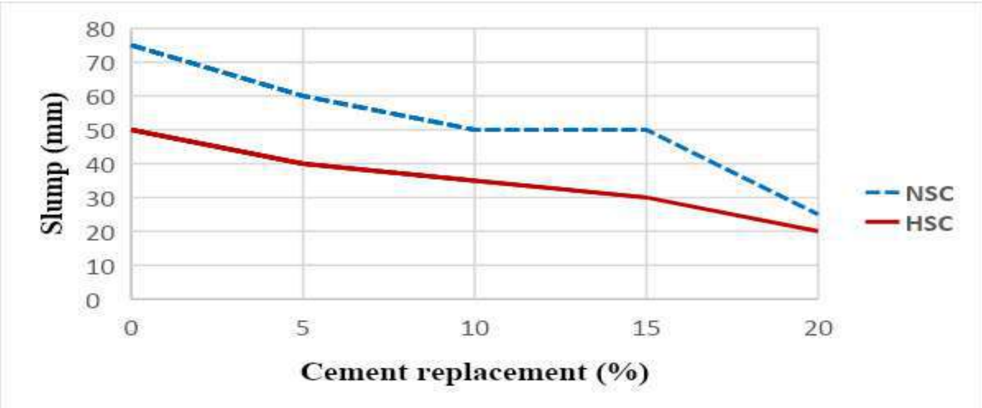

Figure 3. Slump value for each replacement

The strength result for HSC concrete showed that concrete cubes containing 5% granite powder are higher than the control strength both on the 7th and 28th days. Its strength is increased by 5.86% and 6.78% on the 7th and 28th day respectively. For the other replacements, the strength is decreased. The reason for the enhancement of the strength may be fine powders chemically react with calcium hydroxide at ordinary temperatures to form compounds having cementitious properties. When using these materials in concrete, the concrete will make efficient use of the hydration products of Portland cement and consume calcium hydroxide to produce additional cementing compounds.

The test result for average flexural strengths is shown in Figure 5. From the result for NSC concrete, it is observed that concrete beams containing 5% and 10% granite powder attained greater flexural strength compared to the control by 6.34% and 7.94% respectively. However, it decreased by 1% and 1.12% at 15% and 20% replacement respectively. For HSC concrete, the flexural strength is also enhanced up to 10% replacement of cement with granite powder. At 5%

replacement, the flexural strength increased by 6.24%, and at 10% replacement, the strength increased by 4.90% compared to the control beams. But, for 15 & 20% replacement, the strength decreased by 1.32% & 10.52% respectively.

Theaverage water absorption by weight is shown in Figure 6. From this figure, for the NSC concrete, the percentage of water absorption by weight decreased for 5% and 10% replacement. For HSC concrete, the water absorption performance was improved for concrete containing 5% granite powder. This is probably due to the filling effect of granite micro-sized particles which reduced the volume and conductivity of capillary pores which in turn creates fewer voids to permit water to go through.

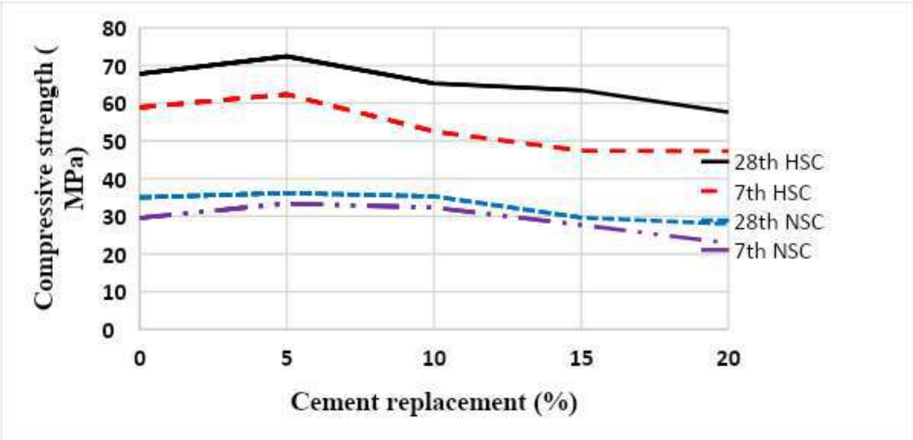

Figure 4. Compressive strength of concrete for each replacement

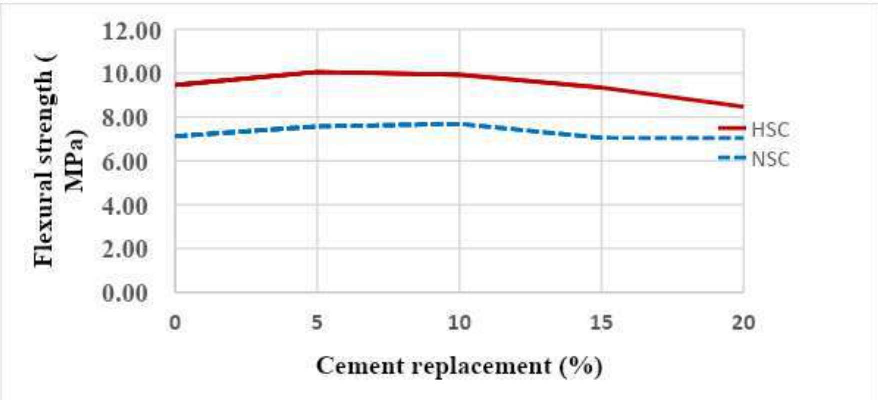

Figure 5. Flexural strength of concrete for each replacement

The absorption (I) is the change in mass divided by the product of the cross-sectional area of the test specimen and the density of water. The initial rate of water absorption (sorptivity) is defined as the slope of the line that best fits to I plotted against the square root of time ($s^{1/2}$) between one minute and six hours. Moreover, according to the ASTM C 1585 – 04[26] standard, the result is valid only for a correlation coefficient greater than 0.98. Otherwise, the result is no longer representative, and hence, the rate of water absorption cannot be determined. The result for the initial rate of water absorption test is shown in Figure 7. From this figure, for NSC concrete, it is observed that the initial rate of water absorption enhanced at 5% replacement. For HSC concrete, the enhancement was observed at 10% replacement. And, the observed water absorption rate behavior follows a contrasting pattern i.e. when the NSC's absorption rate decreases, HSC's absorption rate increases. .

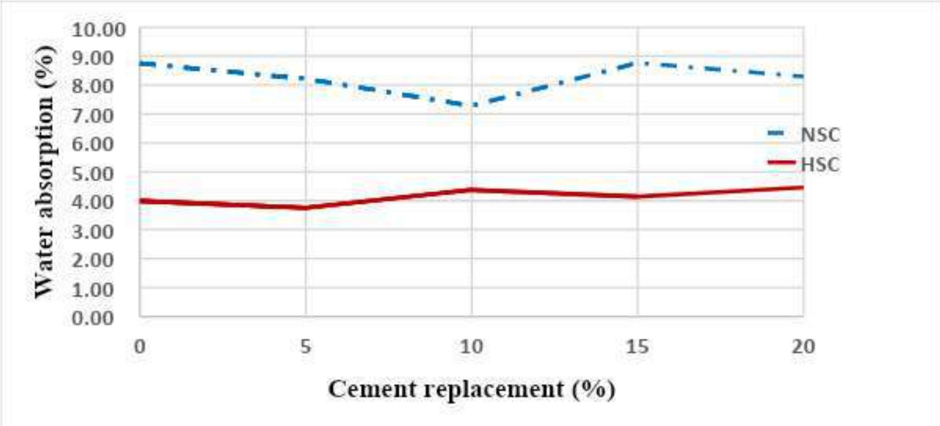

Figure 6. Water absorption of concrete for each replacement

The result for the sulphate and chloride attack test is shown in Figure 8. An "S" and "C" letters are added to the acronym NSC and HSC to show the test result for sulfate and chloride chemical solutions respectively. From Figure 8, it is observed that for all replacements of granite powder, the resistance of concrete was improved under all chemical solutions. The optimum percentage of replacement against sulfate and chloride attack resistance was attained at 5% and 10% replacement for NSC concrete and 5% replacement for chloride attack and 5% and 10% replacement for sulfate attack for HSC concrete.

The reason behind the improvement against sulphate attack might be sulphate salt attacks either C_3A, calcium hydroxide (CH), or mono sulfoalmunate (AFm). Then it forms ettringite which is expansive and causes a crack. Once the salt has consumed all the CH, then it starts to decalcify calcium silicate hydrate (CSH) which is the backbone of concrete strength.

Chloride dissolved in waters tends to increase the rate of leaching of port landite ($Ca(OH)_2$), thus it increases the porosity of concrete and loses weight. [31]. The rate of ingress of chlorides and penetrability of concrete depends on the pore structure of the concrete, which is affected by materials used in the concrete. This will be influenced by the water to cement (w/c) ratio of the pozzolanic materials which serve to subdivide the pore structure [33].

As a result, the improvement against chloride attack is observed for all replacement of granite powder in both NSC and HSC concrete (Figure 8). Moreover, the weight loss observed in HSC concrete was lower than NSC concrete, which may happen due to the presence of denser structure or lower voids in HSC concrete than NSC as a result of the lower water to cement (w/c) ratio used in HSC.

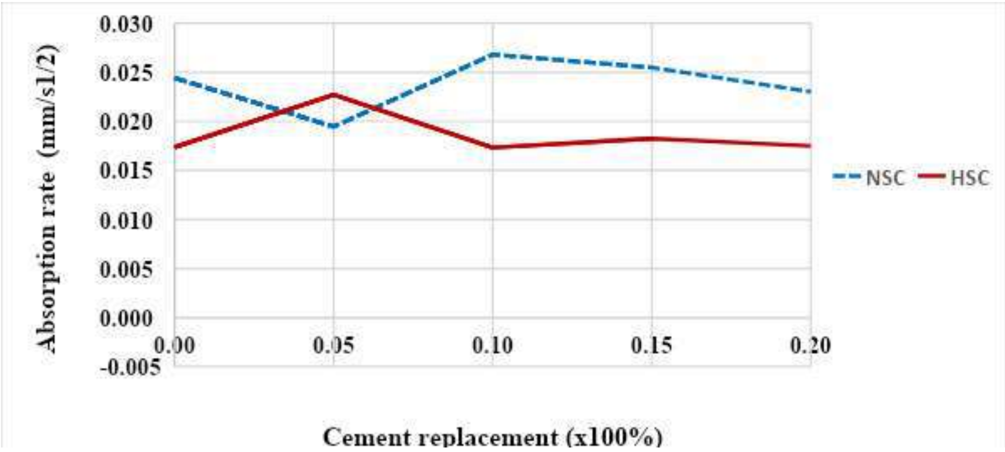

Figure 7. Initial rate of water absorption

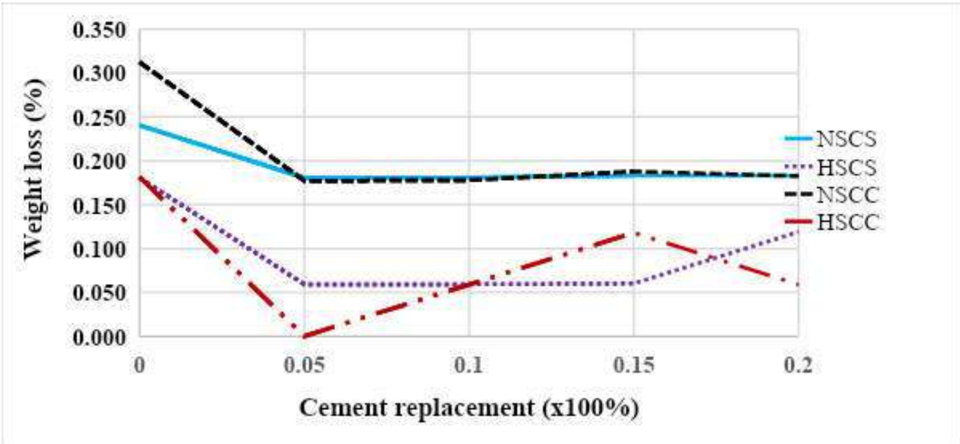

Figure 8. Sulphate and chloride attack (weight loss).

CONCLUSIONS

In this study, the effect of replacing cement partially with granite powder at 5%, 10%, 15%, and 20% were investigated experimentally. The investigation included workability of fresh concrete using slump value, the strength of concrete using compressive and flexural tensile strength, and durability using water absorption test, sorptivity test, and chloride and sulphate attack test for both NSC and HSC concrete specimens and for each granite powder replacement. From the results of the investigation, the following conclusions are drawn.

1. The workability of both NSC and HSC concrete decreased in a linear manner as the percentage replacement increased. This may happen as a result of the higher surface area of granite powder which increased the surface of hydration leading to higher water absorption.

2. Granite powder enhanced the NSC concrete compressive strength of the 7th dayby 13 % and 9 % and the 28th day by 3.36 % and 1 % at 5 % and 10 % replacements respectively. Moreover, the 5% granite powder replacement enhanced the compressive strength of HSC concrete by 5.86 % and 6.78 % on the 7th and 28th day respectively. For the other replacements, the strength is decreased.

The reason for the enhancement may be granite powder chemically react with calcium hydroxide at ordinary temperatures to form compounds having cementitious properties which give additional strength to the concrete.

3. Similarly, the flexural tensile strength was enhanced at 5 % and 10 % replacements for both NSC and HSC concrete. For NSC concrete, it is observed that concrete beams containing 5% and 10% granite powder attained greater flexural strength compared to the control by 6.34% and 7.94% respectively. Similarly, for HSC concrete, the flexural strength increased by 6.24% at 5% replacement and by 4.90% at 10% replacement compared to the control beams. For the other replacements, the strength is decreased.
4. A denser and least permeable concrete with the least water absorption is made at 5% and 10% replacement for NSC and 5% replacement for HSC. This happened might be due to the filling effect of granite powder in which fewer conductivity voids are made at these percentages of the replacements.
5. The least initial rate of absorption is observed at the 5% replacement for NSC concrete and 10% replacement for HSC concrete. Hence, it can be concluded that granite powder had a significant effect in reducing the water absorption by capillary suction.
6. The weight loss resistance of concrete to chloride and sulphate attack was enhanced in all replacements relative to the control specimen for both NSC and HSC concrete. The optimum percentage of replacement against sulfate and chloride attack was attained at the 5% and 10% replacement in NSC concrete and 5% replacement for chloride attack and 5% and 10% replacement for sulfate attack in HSC concrete.

ACKNOWLEDGMENTS

This study was done at Hawassa University Institute of Technology collaborating with Ethiopia Roads Authority. Hence, the authors need to acknowledge these institutions for their backing.

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