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Combined Effect of Ambo Stone as Coarse Aggregate and Fly Ash as Cement on Mechanical Properties of Concrete

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Key words: Ambo stone, fly ash, coarse aggregate, flexural strength, split tensile strength

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Abstract: Concrete is the most popular construction material worldwide. In Ethiopia, concrete productions with conventional building materials are widely used. Conventional concrete is one of the main reason in increasing the weight of the buildings, larger volume comprises of coarse aggregates conventional aggregate is heavy and costly, seeking alternative sustainable aggregate. Lightweight aggregate is receiving more attention now, since, it offers the required concrete density, cost-saving and increase the thermal insulation. In addition to that the manufacturing of cement leads to the release of a significant amount of carbon dioxide, high power consumption and health effects. In order to address all effects associated with cement production, there is a need to develop an alternative way of replacing cement by utilizing industrial waste. Since, Ethiopia is one of the countries that have large coal reserves which is about 500 million tons at different categories, its byproduct fly ash looks to be a promising supplementary cementitious material for cement concrete. Fly ash used as Portland cement that helps in more sustainable cement production by lowering energy and raw material consumption. Also, large area of land required for disposal and toxicity associated with heavy metal led to increased environmental concern of fly ash. Combined effect of ambo stone as coarse aggregate and fly ash as cement on mechanical properties of concrete are experimentally investigated for replacement ratios of 25, 50, 75 and 100% ambo stone by weight of Coarse aggregate with 15% fly ash by weight of cement were used. The physical and chemical properties of fly ash were characterized. The mechanical properties of the concrete are investigated through a compressive strength test, splitting tensile strength test and flexural strength test. The research result revealed that the work ability of concrete has increased in the addition of fly ash. From XRD and SEM result the fly ash is mainly amorphous material and spherical in shape, respectively. Compressive strength of concrete has shown an increment at 25% replacement by 9.59 and 50% replacement by 7.47% of ambo stone with 15% of fly ash on 28th day also splitting tensile strength and flexural strength has shown an increment at 25 and 50% replacement on 28th day. The optimum cement replacement level for fly ash and ambo stone was 15 and 25% by weight of cement and coarse aggregate, respectively. The utilization of fly ash in the construction industry can compensate for environmental, technical and economic issues caused by cement production.

INTRODUCTION

Concrete is a composite material whose behavior depends on the behavior of its constituent materials. The major components of concrete are cement, water and aggregates (fines and coarse aggregate). Depending on the mix proportion of concrete 60-75% by volume and 70-85% by weight is an aggregate[1]. The dominant rock for coarse aggregate production in Ethiopia is generally basalt while ignimbrite is most commonly used for masonry stone. Basically, three classes of aggregates are identified depending on their weight: lightweight, normal weight and heavyweight. In Ethiopia, the thickest developments of red bed sandstones are within the Triassic successions; it is called the Adigrat sandstone. These are found predominantly in the Northern part of the country but also in central parts such as the ambo (i.e., study area), debrelibanos, Bure (Gojam) and Abay area. The Adigrat sandstone varies in thickness from a few to 800 m and consists essentially of red to yellow, well-sorted quartz sandstone. Consolidated sandstone may be used for aggregate when it crushed it is the source of SiO_2[2]. Moreover, in Ethiopian cases aggregate are from natural sources quarry sites, their quality and composition vary from time to time. These types of material are costly which is seeking alternative sustainable aggregate. In addition, fly ash is introduced as a replacement for Cement. The most effective way to decrease the CO_2 emission of the cement industry is to substitute a proportion of cement with other materials. These materials called supplementary cementing materials. With the present practice of fly ash disposal in ash ponds, the total land required for ash disposal would be about 82,200 ha by the year 2020[3]. The large volumetric by-product materials from industry are going to landfills and have been increasing with time. Recycling of construction waste is a viable option in construction waste management. Thus, this study tries to investigate the combined effect of ambo stone and fly ash on the mechanical properties of concrete.

Objective: The general objective of this study was to investigate the combined effect of ambo stone as coarse aggregate and fly ash as cement on mechanical properties of concrete. The specific objectives of this study were to characterize the physical properties and chemical composition of fly ash to investigate fresh properties and hardened properties of concrete at different replacement levels of ambo stone and fly ash and to determine the optimum replacement level of ambo stone and fly ash for 25°C concrete.

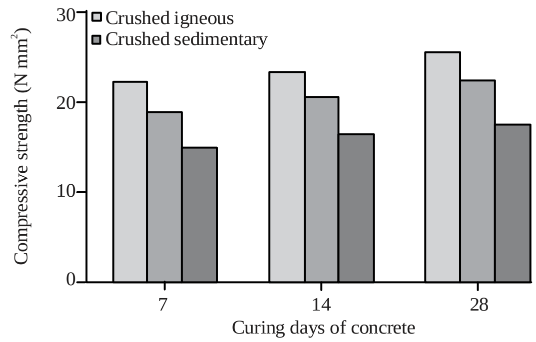

Fig. 1: Compressive strength and types of aggregate; Compressive strength of various days

Literature review: An experimental investigation was conducted on the effect of the physio-mechanical properties of three rock types (quartz, sandstone and quartzite) on the compressive strength of the constituent concrete product with a maximum rock size of 25 mm. The concrete mix design of C-25 was used. Cube test results show that concrete produced from quartz aggregates produced the highest at all-time strength of 25.6 kN, 0.2% above the expected strength at the end of the 28 day period as noticed in Fig. 1. Thus, concrete produced from quartz rocks revealed a superior strength of 13 and 31% above that of crushed sandstone and quartzite, respectively. Again crush quartz (igneous) rock revealed the highest workability in concrete[4].

An experimental investigation carried out on the suitability of using Volcanic Pumice (VP) as cement replacement material and as coarse aggregate in lightweight concrete production. Tests were conducted on cement by replacing 0-25% of cement by weight and on concrete by replacing 0-100% of coarse aggregate by volume. The properties of Volcanic Pumice Concrete (VPC) using different percentages of Volcanic Pumice Aggregate (VPA) were evaluated by conducting comprehensive series of tests on workability, strength, drying shrinkage, surface absorption and water permeability. The results showed that the VPC has sufficient strength and adequate density to be accepted as

Table 1: Properties of hardened concretes produced from different sandstones

Sandstone type and concrete code	Compressive strength (days) 7	28	Splitting tensile strength (28 days)
Subrkos/Arkose (KM1)	15.2	20.4	1.4
Sublitharenite-litharenite (KM4)	17.8	21.9	2.0
Arkose (Rock Fragement, KM5)	9.1	12.1	1.0
Arkose (K3)	24.2	30.3	2.9
Quartz sandstone (K4)	26.4	32.7	3.2
Subrkos-Arkose (AKT)	20.6	40.4	3.5
Subrkos-Arkose (Rock Fragement, CBKT)	21.5	37.0	3.2

structural lightweight concrete. However, compared to control concrete, the VPC has lower modulus of elasticity and has more permeability and initial surface absorption. Addition of fly ash enhances the compressive strength and splitting tensile strength of HSSLC when FA was >20% in cementitious materials, it's 28 days compressive strength and splitting tensile strengths are less than those of the concrete without FA. The addition of silica fume enhances the compressive strength about 25%[5].

Sandstone is a widespread aggregate resource and is increasingly being used in concrete construction around the world the geological properties of this sedimentary rock are fairly diverse such as quantize, Arkose, subarkose and greywacke aggregate that may produce arrange of hardened concrete properties. Therefore, it is important that aggregate can be easily characterized to obtain predictable concrete properties The compressive and splitting tensile strength of concretes produced from different sandstones are shown in Table 1[6].

MATERIALS AND METHODS

Material

Cement: Used for this experimental study is Dangote Ordinary Portland Cement (CEM I\42.5R) compatible with (CES-28 2013).

Fly ash: The fly ash in this research was taken from Ayka Addis Textile industry. It is a by-product of the electric power generation plant. Ayka Addis Textile factory uses local coal which is extracted and supplied from the Achebo area.

Fine aggregate: The type of fine aggregate used for experimentation is natural sand.

Coarse aggregate: The aggregate used for this research is the basaltic crushed rock.

Ambo stone: Used as coarse aggregate for this research is mined from senkele site.

Water: The water used for this study is from the Construction Material Laboratory water supply pipe.

Methods: In order to see the effect of percentage replacement of ambo stone and fly ash on mechanical properties of concrete 25, 50, 75 and 100% for ambo stone and 15% for fly ash replacement by weight was adopted. Mold sizing 150 by 150 mm by 150 mm were used for compression test and cylinder of 150 mm dia. 300 mm long is used for splitting tensile test and flexural strength on prismatic samples of 100×100×500 mm sizes. After casting, the cubes are cured at ambient temperature for 7 days and 28 days.

RESULTS AND DISCUSSION

Physical and chemical property of fly ash

Specific gravity test of fly ash: This test is performed to determine the specific gravity of Fly ash by using a Le Chatelier flask based on ASTM C-188-95 and the physical properties of fly ash is presented in Table 2.

Consistency and setting time: A consistency test was done before slump test to predict the work ability of concrete. Normal consistency of cement was done according to the procedures of ASTM C 187-04 standard test methods for normal consistency of hydraulic cement. The consistency of 15% fly ash blende were good as observed in Table 3 and Fig. 2.

To determine the setting time of cement ASTM C 191-08 standard test methods for a time of setting of hydraulic cement by Vicat needle were used.

The normal consistency and setting time of Hydraulic cement, observed Dangote ordinary cement from experimental work for normal consistency is 32% and the initial setting time is 78 min and the final setting is 255 min then the laboratory result is compared to ES and ASTM the result was with the specified range. As we can observe from Table 4 fly ash results in longer setting times compared to normal concrete.

As we can see from Table 3 the consistency increases for the fly ash blended cement. The range of water to cement ratio for normal consistency lies between 26% up to 33%. The test result for the normal consistency of the blended paste is also far that much within the specification. The setting time results show that the fly ash blended cement paste takes longer to set. The ordinary cement paste took less time to set than the FA mixes as

Table 2: Physical properties of fly ash

Properties	Results
Color	Black
Odor	None
Specific gravity	2.13 g cm^{-3}
Fineness	3788.9 cm^{-2} gm
Form	Powder

Table 3: Consistency for cement and FA blended paste

	Result obtained		
Test description	Cement	15% fly ash	Values specified by ASTM
Normal consistency (%)	32	34	26-33%

Table 4: Setting time for cement and FA blended paste

	Result obtained		
Test description	Cement	15% fly ash	Values specified by ASTM
Initial setting Time (min)	90	138	45 min (minimum)
Final setting time (min)	255	305	10 h (maximum)

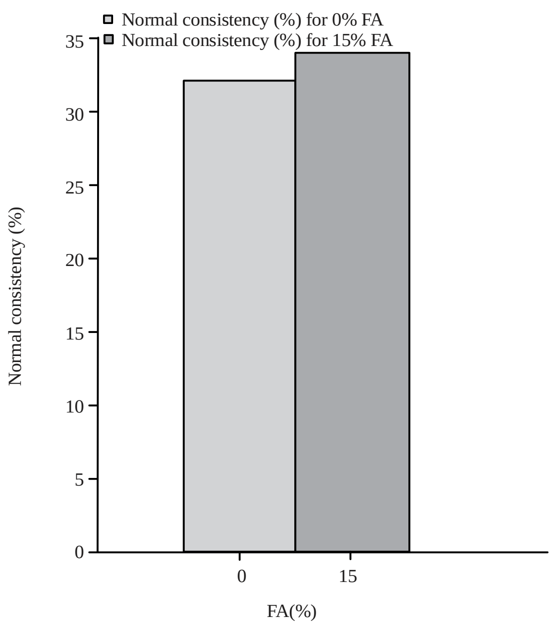

Fig. 2: Consistency of cement paste with FA test result

the hydration process is slower when the cement content is decreased, thus making the concrete set slower than ordinary concrete. It is observed that from Fig. 3 the addition of FA prolongs the setting time of concrete as the hydration process is slower due to reduced generated heat.

Fineness of fly ash: The Blaine test is used for measuring fineness of particles. The time interval for the samples was obtained as 38.15, 38.2, 38.25, sec. The average time interval of the three samples is therefore, 38.2 sec. The

Table 5: The properties of cement and fly ash

Parameters	Cement	Fly ash
Time interval of manometer drop, T (seconds)	49.300	38.200
Specific surface area (cm^{-2} g)	4304.33	3788.9
Volume of bed (cm^3)	1.85200	1.8520
Density (g cm^{-3})	3.15000	2.1300
Mass of bed (g)	2.91700	1.9720
Mean particle diameter (μm)	4.50000	7.2500

Table 6: Complete silicate analysis result of ayka addis fly ash

Oxides	Fly ash (%)
SiO_2	49.34
Al_2O_3	30.52
Fe_2O_3	3.02
CaO	0.14
MgO	0.24
Na_2O	<0.01
K_2O	0.62
MnO	<0.01
P_2O_5	0.17
TiO_2	0.67
H_2O	1.32
LOI	15.14
SiO_2+ Al_2O_3+Fe_2O_3	82.88>70

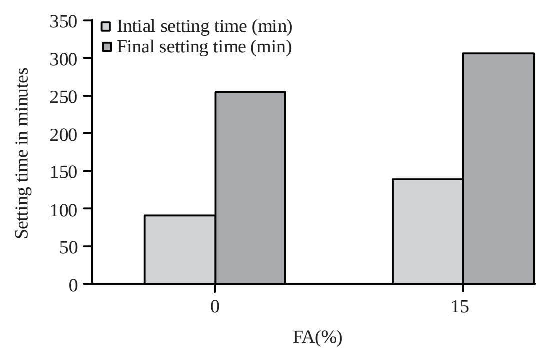

Fig. 3: Setting time of cement paste with FA test result; Setting time of OPC-FA blended paste

properties of cement and fly ash were presented in Table 5 and the specific surface was calculated as follows:

$$S = \frac{SS\sqrt{T}}{\sqrt{TS}} = \frac{3774\sqrt{38.2}}{\sqrt{37.9}} = 3788.9.cm^2 g$$

Chemical property test of fly ash: Complete silicate analysis of fly ashes was conducted in the Geological Survey center of Ethiopia. The sum of the first three chemical constituents (SiO_2, Al_2O_3 and Fe_2O_3) of fly ash is >70% as noticed in Table 6 which indicates that the sample fly ash classified as an ASTM class F fly ash.

XRD analysis: XRD test was conducted to assess the mineralogical contents of the material and to identify the phase of the fly ash. The phases could be crystalline or amorphous.

The characteristic peak of the mineral composition of fly ash is shown below in Fig. 4 X-ray examination has

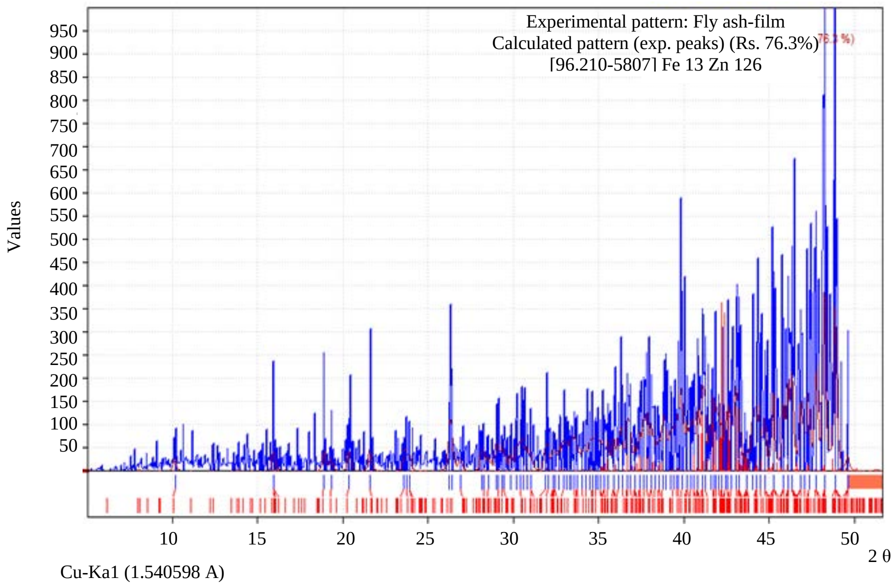

Fig. 4: XRD analysis of fly ash sample

Table 7: Crystalline phases of fly ash

Name of mineral	Label of mineral	Chemical formula	Amount (%)
Quartz	Qz	SiO_2	48.5
Feldspar	F	$Al_{1.9}O_8Si_{2.1}Si_4$	25.5
Melilite	M	$Al_{0.09}\ Ca_{1.87}\ K_{0.02}\ Mg_{0.96}\ Na_{0.1}\ O_7\ Si_{1.98}\ Sr_{0.02}$	9.20
Anhydrite	An	$CaSO_4$	8.70
Iron (III) oxide Hematite	He	Fe_2O_3	5.60
Periclase	Pc	MgO	2.60
Unidentified peak area			24.7

Table 8: Slump values of C-25 OPC-FA blended concrete

Mix notation	Slump (mm)
AS-0-FA0	85
AS-0-FA15	89
AS-25-FA15	84
AS-50-FA15	81
AS-75-FA15	76
AS-100-FA15	70

shown that the fly ash is mainly amorphous but there are also present crystal phases feldspar, melilite, hematite, very little anhydrite and quartz. As observed in Table 7 the most common minerals of fly ash are constituents of quartz. Moreover, about 8.7% of the sample is Anhydrite. It plays a significant role in fly ash hydration behavior because it participates along with tricalcium aluminate and other soluble aluminates[7].

Fresh and harden property of OPC-FA blended concrete

Fresh property of OPC-FA blended concrete slump test: The workability of the concrete was checked by the slump test just before casting freshly made concretes into the mold.

The main point noted in this experiment is: The results indicate as the replacement percentage of ambo stone increased the workability of the mixes decreased as observed in Table 8 and Fig. 5. This may due to the absorption capacity and rough surface texture of ambo stone coarse aggregates.

Partial replacement of portland cement by fly ash in concrete reduces the water required to obtain a given consistency or increases the workability and slump for a given water content compared to that of concrete without fly ash. This phenomenon is generally attributed to the spherical particle shape of fly ash assists in improving workability.

Hardened property of OPC-FA blended concrete: In order to investigate the mechanical property of concrete containing ambo stone at different replacement levels for 25°C of concrete, compressive strength, splitting tensile strength and flexural test at 7 and 28th were tested.

Compressive strength of OPC-FA blended concrete: The compressive strength of concrete with OPC-FA was tested and analyzed. The average results are as shown in Table 9.

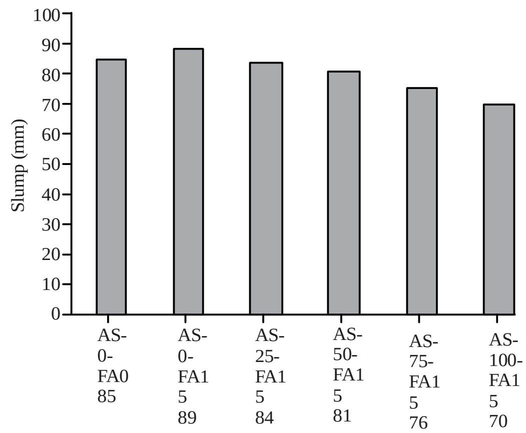

Fig. 5: The observed slump for C-25 OPC-FA blended concrete; Observed slump for different replacement

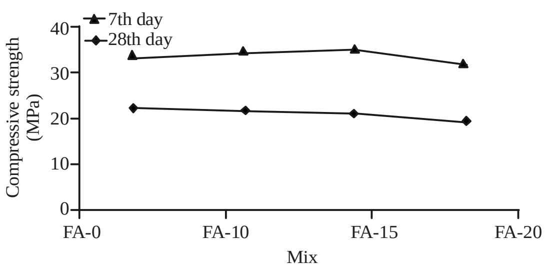

Fig. 6: Compressive strength development of concrete using fly ash; Compressive strength development

The average compressive strength result for a 15% replacement ratio shows that the 28th-day strength of concrete has an increment of 3.74% over the control mix. Although the increment of strength is minor, Fig. 6 clearly shows that the strength at later ages has a larger strength increment than strength at an early age. The strength of concrete with pozzolanic materials is typically lower at early ages and higher at later ages, than are obtained with Portland cement alone[8]. As indicated in the chemical analysis of FA its silica content is relatively high. So, it requires less time to undergo secondary hydration reactions. The compressive strength of concrete is enhanced up to 15% fly ash as cement replacement regardless of the curing ages. Therefore, 15% fly ash is the optimum replacement. The compressive strength of concrete is enhanced by the incorporation of fly ash. This is due to filler effect, acceleration of OPC hydration and pozzolanic reaction.

It can be seen from Table 10 and Fig. 7 the average compressive strength decreased with the increasing percentage of AS. The 7th day average compressive strength of concrete containing 25, 50, 75 and 100% AS declined by 8.63, 12.85, 16.27 and 22.19%, respectively,

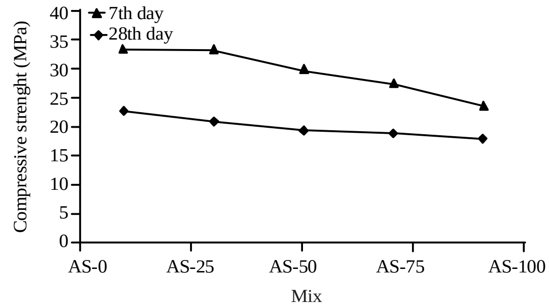

Fig. 7: Compressive strength development of concrete using ambo stone; Compressive strength development

Table 9: Compressive strength development of concrete using fly ash

	Average compressive strength (MPa)	
Mix notation	7th day	28th day
FA-0	22.49	33.46
FA-10	21.45	33.97
FA-15	20.79	34.71
FA-20	19.06	31.58

Table 10: Compressive strength development of concrete using ambo stone

	Average compressive strength (MPa)	
Mix notation	7th day	28th day
AS-0	22.49	33.46
AS-25	20.55	32.82
AS-50	19.60	29.54
AS-75	18.83	27.18
AS-100	17.50	23.91

Table 11: Average compressive strength of OPC-FA blended concrete

	Average compressive strength (MPa)	
Mix notation	7th day	28th day
AS-0-FA0	22.49	33.46
AS-0-FA15	20.79	34.71
AS-25-FA15	20.21	36.67
AS-50-FA15	19.19	35.96
AS-75-FA15	18.75	32.61
AS-100-FA15	17.47	29.76

while the 28th day declined by 1.91, 11.72, 18.77 and 28.54%, respectively. Incorporation of ambo stone decreases the compressive strength of concrete as much as 28.54% for 100% replacement of Coarse aggregate. This is due to the water absorption capacity of ambo stone coarse aggregate. It forms a weak link in AS coarse aggregate which contains many cracks and pores. Consequently, these cracks and pores increase water consumption.

From Table 11 and Fig. 8, it can be show that the 7th-day compressive strength of the control mix is higher than that of the replaced samples. But when we see the 28th-day compressive strength we can observe 25 and 50% replaced samples have shown an improvement of strength. The 25 and 50%, the replaced sample shows an

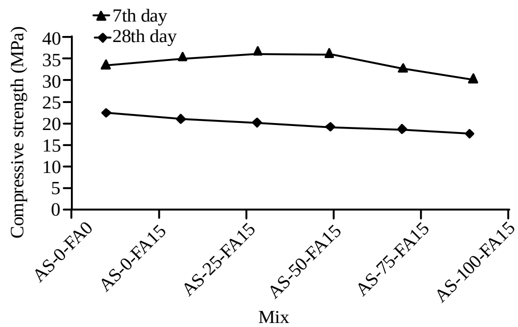

Fig. 8: Compressive strength development of FA blended concrete; Compressive strength development

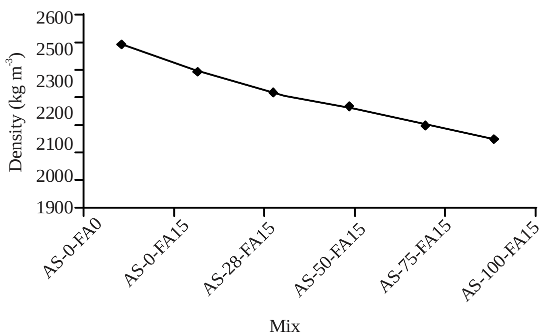

Fig. 9: Average density of concrete; Average density of concrete

improvement of strength by about 9.59 and 7.47% on 28th day, respectively. This implies as OPC contains a smaller amount of silica by itself. The addition of fly ash in this cement had resulted in a higher compressive strength for 25 and 50% of replacement. Generally, increasing the amount of pozzolan in the cement increases the strength development in the long term. This is because of the increase in C-S-H and other hydration products at the expense of calcium hydroxide and the pore refinement which depends on the pozzolanic reaction[9]. The short-term activity of a pozzolan is related to its specific surface area and the long term activity of a pozzolan is related to the chemical and mineralogical compositions of this pozzolan[10]. The probable reason for strength increment would be a denser cement paste matrix produced at the interfacial transition zone. Moreover, fly ash reacts with lime produced from a hydration reaction of the binder. The additional binder resulting from its pozzolanic reaction provides a high strength matrix. Furthermore, lime accumulates at the interface between the matrix and the aggregate, reacts with pozzolanic material in these regions and creates dense transition zones with enhanced properties. Interfacial Transition Zone (ITZ) of a coarse aggregate cement matrix is commonly regarded as the weakest

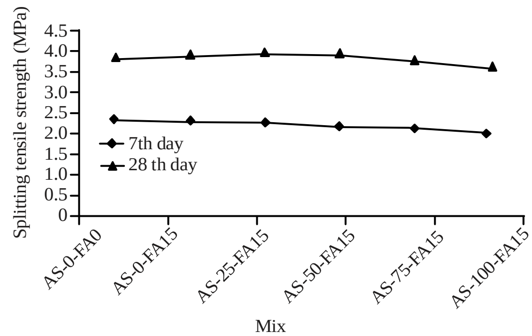

Fig. 10: Splitting tensile strength development of OPC-FA blended concrete; Splitting tensile strength development

element of concrete. In this phase, the first cracks in the material are initiated and the process of destruction of the composite begins. An improvement of the ITZ properties is positively influenced by the mineral additives used for the composite. One of such a substitute for a binder is potentially hazardous industrial waste, siliceous fly ash[11]. Even after 25% replacing natural aggregates the compressive strength is higher than the Control mix. Reduction in compressive strength by 11.06% is observed due to the full replacement of natural aggregate and 15% cement by weight.

Density and specific gravity: Density and specific gravity were obtained from the mass of the cubes at the end of 28 days.

With the increase in the proportion of ambo stone in the mix, mass of the specimen decreases as shown in Table 12 and Fig. 9. Reduction in mass of concrete by 8.48% by 50% replacement of coarse aggregates. The weight of concrete decreases as the percentage of replacement increases. This is due to the low unit weight (1103.6 kg m^{-3}) of ambo stone.

Splitting tensile strength of concrete: The split-tension test (ASTM C496) measures the tensile strength of concrete[12]. This test is an indirect way of determining the tensile strength of concrete using a cylinder.

From Table 13 and Fig. 10 the 28th-day splitting tensile strength, we can observe 25 and 50% replaced samples have shown an improvement of strength. The 25 and 50%, the replaced sample shows an improvement of strength by about 3.94 and 3.41% on 28th day, respectively. Mineral admixtures on the hydration of cement and do not possess self-hardening behavior. Therefore, it could be a major reason for reducing in early age splitting strength of concrete.

Table 12: Average density and specific gravity of OPC-FA blended concrete

Mix notation	Average mass (kg)	Average density (kg m^{-3})	Average specific gravity
AS-0-FA0	8368.33	2479.51	2.479
AS-0-FA15	8091.00	2397.33	2.397
AS-25-FA15	7838.67	2322.57	2.323
AS-50-FA15	7658.67	2269.23	2.269
AS-75-FA15	7448.67	2207.01	2.207
AS-100-FA15	7237.33	2144.40	2.144

Table 13: Average splitting tensile strength of OPC-FA blended concrete

	Average splitting tensile strength (MPa)	
Mix notation	7th day	28th day
AS-0-FA0	2.37	3.81
AS-0-FA15	2.31	3.91
AS-25-FA15	2.28	3.96
AS-50-FA15	2.22	3.94
AS-75-FA15	2.11	3.76
AS-100-FA15	2.03	3.60

Table 14: Average flexural strength of OPC- FA blended concrete

	Average flexural strength(MPa)	
Mix notation	7th day	28th day
AS-0-FA0	3.10	3.94
AS-0-FA15	2.99	4.00
AS-25-FA15	2.86	4.13
AS-50-FA15	2.70	4.05
AS-75-FA15	2.65	3.88
AS-100-FA15	2.52	3.72

The study was made previously on the effect of FA on the split tensile strength of the concrete. Up to 15% replacement of FA, splitting tensile strength value was more compared to the control concrete. But for 20 and 25% of cement replacement the split tensile strength value rapidly decreased. So, 15% of FA was the optimal replacement level of cement[13].

Fly ash mixed in the concrete produced a micro aggregate effect, namely the fly ash of glass beads have the effect of the “ball bearing lubrication” and it improved the density of concrete and reduced the internal porosity. With the increase of the content of fly ash, the matrix is more uniform and the structure of the differences between each section is relatively narrow, so, the tensile strength and cracking strength showed a trend of increase first. As the continued increase of fly ash content, the cement content is reduced, thus reducing the hydration speed of cement, resulting in the weakening of matrix strength. It shows that there is a critical value of matrix strength with fly ash content when more than the critical value, the fly ash micro aggregate effect is not obvious[14].

Flexural strength of concrete: ASTM C-78 recommends that the results of this test method may be used to determine compliance with specifications or as a basis for proportioning, mixing and placement operations. It is used in testing concrete for the construction of slabs and pavements. The flexural strength of concrete with OPC -FA was tested and analyzed. The average results are as shown in Table 14.

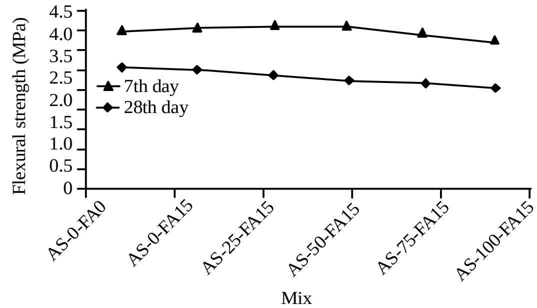

Fig. 11: Flexural strength development of OPC-FA blended concrete; Flexural strength development

From Table 14 and Fig. 11 the 28th-day Flexural strength, we can observe 25 and 50% replaced samples have shown an improvement of strength. The 25 and 50%, the replaced sample shows improvement of strength by about 4.82 and 2.79% on 28th day, respectively.

Although, ambo stone content 50% results lower flexural strength than ambo stone content 25% when it is compared with the control mix, the resulted flexural strength is better. Therefore, up to 50%, ambo stone replacement is possible without degrading the tensile properties of the control mix.

An experiment was conducted on the effect of FA on the flexural performance of concrete at the age of 7th days and 28th days. They replaced 5, 10, 15, 20 and 25% of cement by the weight of the FA. It was observed that at an early age, i.e., 7th days flexural strength has decreased as the percentage of cement replacement increased. A slight increase in strengh at the age of 28 days was observed in 10 and 15% of cement replacement[13].

Scanning electron microscopy: SEM analysis was carried out to examine the characteristics of hardened concrete produced from fly ash blended cement. For SEM

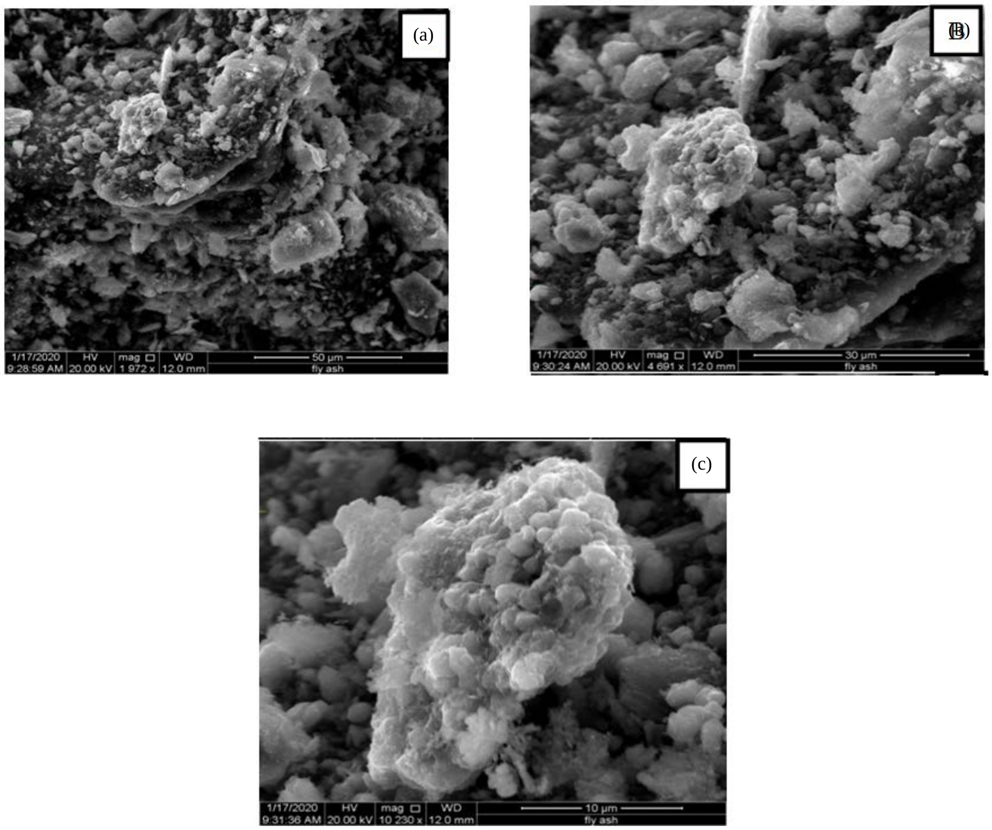

Fig. 12(a-c): SEM image of raw fly ash at 50 μm, (a) 30 μm (b) and 10 μm and (c)

analysis dried paste from the tested sample was taken, broken carefully and sieved through No. 32 sieve to determine morphological and microstructure of concrete. The SEM analysis was done for the raw cement, raw fly ash and for each percentage replacement of 0,10, 15 and 20%.

Figure 12 shows the SEM image of raw fly ash at different magnification. At 50 μm the sample shows agglomerated structure but as the magnification increases, it was observed that the material is spherical in shape. The spherical shape is clearly shown at 10 μm magnification scale. From the result we can observe that most of the material is spherical in shape. The microstructure of the control mix with 0% fly ash is presented in Fig. 13. From the SEM result at different magnification, it shows no additional material in the mix.

Figure 14 reveled that at 10% replacement of cement with fly ash, the microstructure of the binder shows some how spherical material. Its compressive strength test results shows increment in strength. This is due to the fly ash added has fill the pores left out during hydration process to some extent.

The results of compressive strength tests, the 15% addition of fly ash has increased significantly from the control concrete. The microstructure of the OPC-15% fly ash blended concrete is shown in Fig. 15. The effect of the fly ash was not clear at 100 μm magnification. But when we see clearly in Fig. 15. (b, c) we can observe spherical shape between the cement grains.

From the test results of compressive strength test at 20% replacement of cement with fly ash it has observed decrease in strength. For this study it was supposed that even if the fly ash is mainly amorphous but there are also present crystal phases feldspar, melilite, hematite, very little anhydrite and quartz as the fly ash content increase the crystalline is also increasing in which crystalline is inactive and does not have cementitious property. As the necessary amount of amorphous used to fill the pourous once gain the crystalline would not be active which decrease the strength. This is due to the fly ash added is not enough to fill the pores left out during hydration process subjected to excess crystal as observed from Fig. 16. From Fig. 17, we can clearly see how the fly ash and cement blended together in the concrete. And by filling the voids of pores the resultant, strength of the 15% OPC-fly ash concrete has increased significantly.

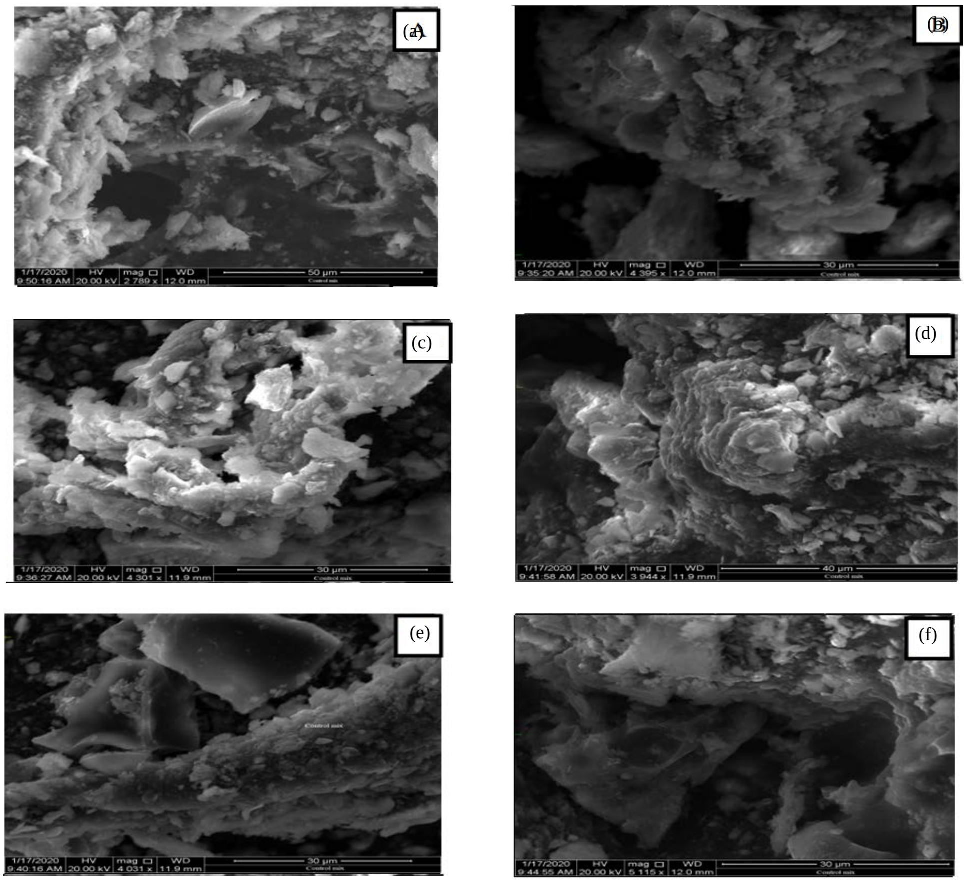

Fig. 13(a-f): SEM image of control mix

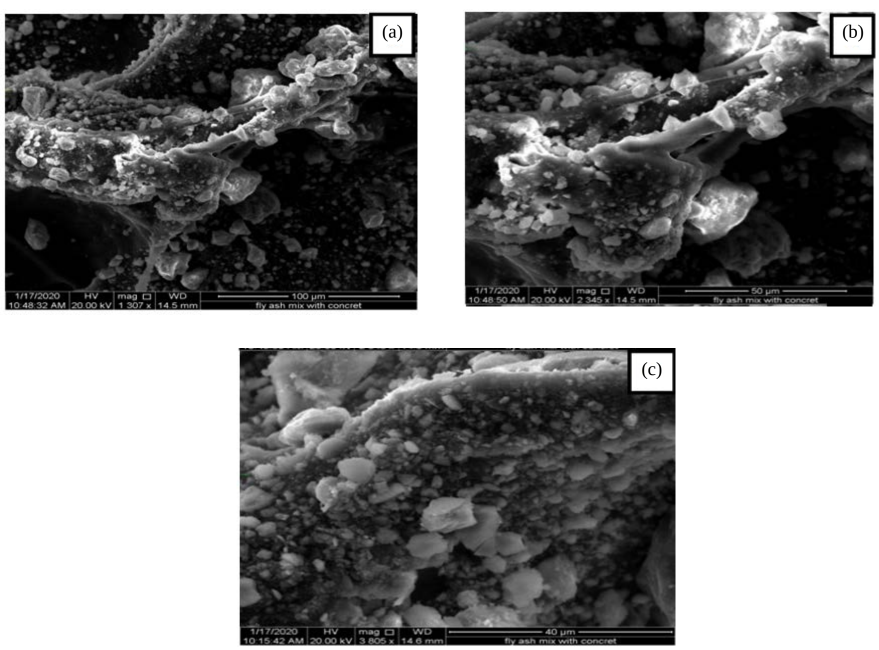

Fig. 14(a-c): SEM image of 10% fly ash blended concrete

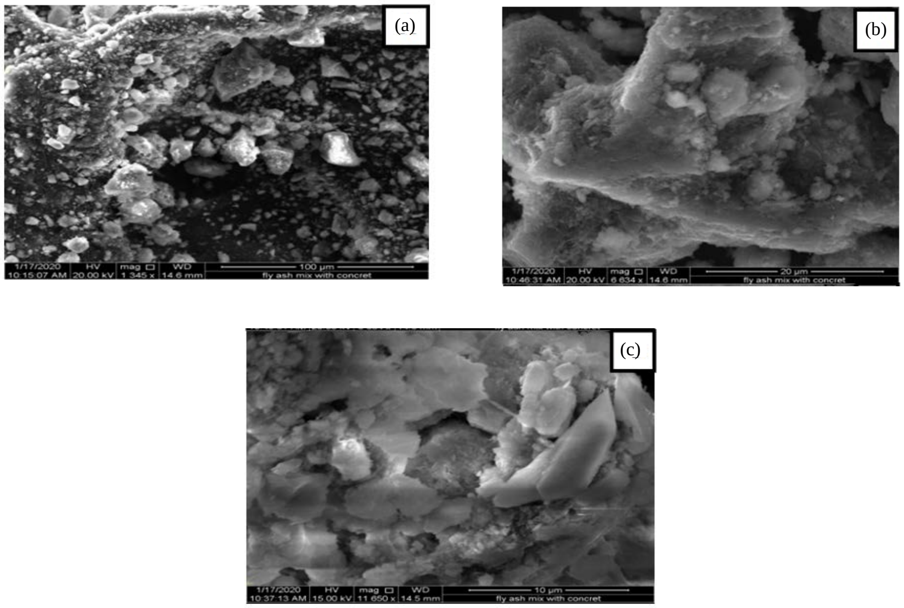

Fig. 15(a-c): SEM image of OPC-15% fly ash blended concrete

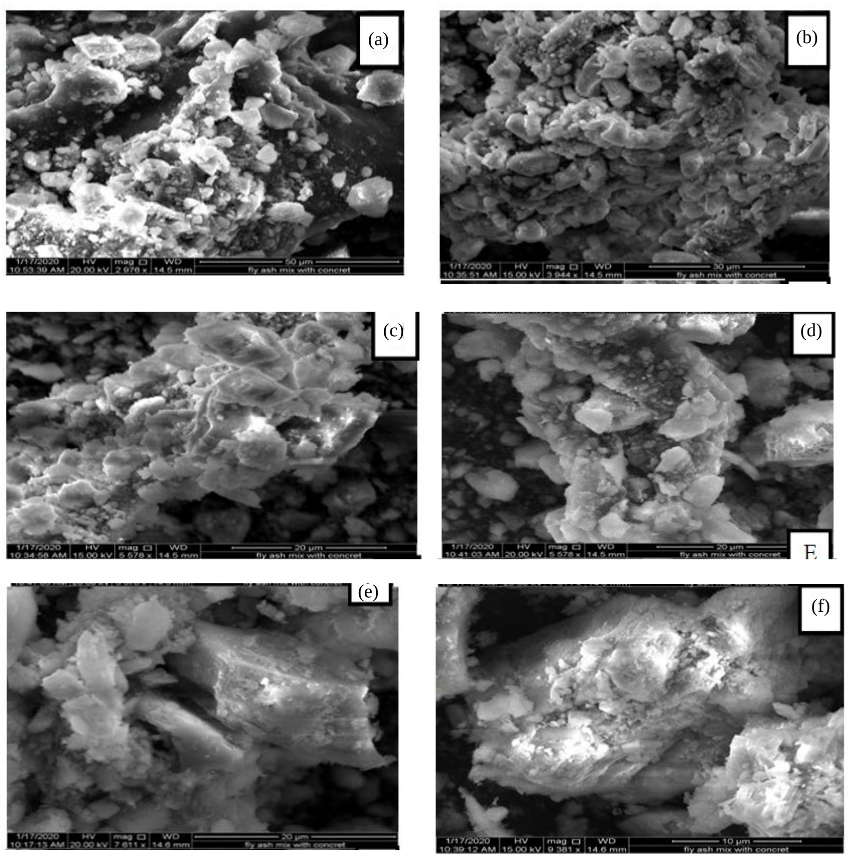

Fig. 16(a-f): SEM image of OPC-20% fly ash blended concrete at 50 μm (a), 30 μm (b), 20 μm (c-e) and 10 μm and (f)

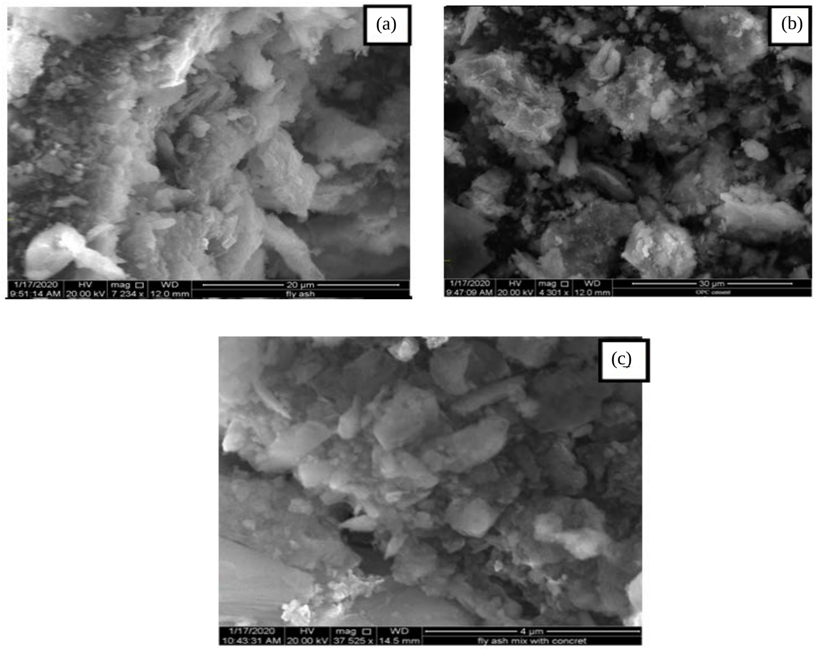

Fig. 17(a-c): Micro structure of OPC (a), fly ash (b) and OPC-15% fly ash blended cement and (c)

CONCLUSION

From the experimental work carried out and the analysis of the results, the following conclusions are drawn: The chemical and physical properties of the fly ash collected from the Ayka Addis Textile factory were suitable to use as pozzolanic material in cement concrete production based on ASTM C 618. The sum of the first three chemical constituents (SiO_2, Al_2O_3 and Fe_2O_3) of fly ash is >70% which indicates that the sample fly ash classified as an ASTM Class F fly ash.

Replacement of cement with FA has a significant effect on setting time. For FA blended cement, both initial and final setting times increase. The normal consistency of replaced cement is higher than the normal consistency of un-replaced cement, it is 34% for 15% replacement. Setting time of 15% fly ash replacement is 138 and 305 min of initial and final setting time, respectively.

The workability of concrete was increased in addition to fly ash. This phenomenon is generally attributed to the spherical shape and smooth surface of fly ash particles. The compressive strength, splitting tensile strength and flexural strength of concrete have shown improvement at 25 and 50% replacement of ambo stone coarse aggregate with a 15% fly ash by weight. Decreases the mechanical properties at an early age and typically superior to those of portland cement concrete of similar at 28-day compressive strength. The results showed that the activity of the ash was directly related to the number of curing days: the longer the curing days, the better the strength development. The optimum replacement level of cement by FA and Coarse aggregate by AS Coarse aggregate is 15 and 25%, respectively.

RECOMMENDATIONS

The following recommendations are given based on the findings of the research, since, Ethiopia is one of the countries that have large coal reserves which is about 500 million tons at different categories, its potential utilization should be realized by all levels of society, so that, optimal management of coal for the benefit of the nation. If that so, its by-product fly ash looks to be a promising supplementary cementitious material for cement concrete. As per this study, ambo stone and fly ash can replaces coarse aggregate and cement 25 and 15% with an improved concrete property. The utilization of FA in the construction industry can compensate for environmental, technical and economic issues caused by cement production.

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