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Effects of Varying Dosage Replacement of Cement Content by Animal Bone Powder in Normal Concrete Mix Production

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Abstract Cement being the main constituent of concrete plays a vital role in concrete production. In Ethiopia, the cement consumption has grown well with a growth rate of about 16.1% per year. Hence, an alternative material to partially replace cement was initiated to reflect the needs of local community in the study area. The waste quantity of animal bones has impacted the environment which are unusual to see in other Non-African countries. The primary aim of the research is to investigate the effects of varying dosage replacement of cement by animal bone powder (ABP) in the normal concrete production. The bone samples collected from Seka Waste Disposal Site of Jimma town, approximately 10km from the bus station where a quantity of waste animal bones can be found. After cleaning and drying, the bone samples burned in the Furnace. The average required energy to burn the animal bone obtained at a temperature of 340°C. The burnt bone was allowed to cool before grinding in a hammer mill and sieving. There were six proportions prepared to start from 0% (as control specimen), 5%, 10%, 15%, 20% and 25% dosage increment by weight of bone powder, and evaluated the normal concrete strengths of C-25 grade concrete. The laboratory test results indicated the chemical analyses of bone powder composed similar compounds of oxide in cement but slightly lesser in content based on ASTM C-150. Likewise, the effects of replacing animal bone on the properties of cement such as consistency and setting time remained within the acceptable limits of the Standard Specifications. On the other hand, the results of compressive, flexural tensile, and the split tensile strengths significantly declined from the control specimen during the dosage increment of the replacement made. Therefore, the optimum dosage of bone powder indicated 10% by weight to replace cement content in normal concrete mix production.

Keywords: *animal bone powder, cement, concrete strengths, optimum dosage, partial replacement*

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1. Introduction

Concrete is a mixture of two components: aggregates and paste. The paste, comprised of Portland cement and water, binds the aggregates (usually sand and gravel or crushed stone) into a rocklike mass as the paste hardens because of the chemical reaction of the cement and water. Supplementary cementitious materials and chemical admixtures may also be included in the adhesive [1]. Concrete is made to possess different properties by adjusting the proportions and varying the properties of the concrete making materials. Cement being the main constituent of concrete, its properties affect the properties of concrete the most it is well recognized that cement plays an essential role in concrete [2].

The cost of cement represents more than 45% of the concrete value. The two primary construction materials, sand and aggregates (fine and coarse aggregates) which are supposed to be cheap because of their availability, are capital intensive both on purchase and transportation [3]. Today's annual global cement production has reached 2.8 billion tons and is expected to increase to some 4 billion tons per year. Cement consumption in Ethiopia during the period 1997-2007 has grown well, with a cumulative annual growth rate of around 10% per annum. In the last five years, the growth rate was approximately 16.1% per annum [4].

The production of cement involves the consumption of large quantities of raw materials, energy, and heat. An output from the cement industry is directly related to the state of the construction business in general and therefore tracks the overall economic situation closely. The cement industry is an energy-intensive industry with energy typically accounting for about 40% of operational costs, i.e., excluding capital costs but including electricity costs [5].

The sustainable development for construction involves the use of nonconventional and innovative materials, and recycling of waste materials to compensate the lack of natural resources and to find alternative ways conserving the environment. Hence, currently, the entire construction industry is in search of a suitable and adequate waste product that would considerably minimize the use of cement and ultimately reduce the construction cost.

Animal bone serves as an essential reservoir for calcium, which can be drawn upon when required for special metabolic activities. 97% of the total calcium in body accumulates in the skeleton [6]. On the other hand, anticipated half of the Portland cement weight has calcium oxide (CaO), the primary raw material in the production of cement [7]. Therefore, this indicates that cement and bone have the same fundamental composition of calcium compounds.

According to the FAO 2015 report, the world has 1.468 billion head of cattle population. Ethiopia has the fifth and the first most significant cattle population in the world and Africa respectively. The total cattle population for the country is estimated about 53.4 million the annual growth rate of cattle population estimated 3.4% [8]. The livestock sector in Ethiopia contributes 12 and 33% of the total and agricultural Gross Domestic Product respectively and provides the livelihood for 65% of the population [9].

On the other hand, the quantity of animal bone waste has highly increased over time to time due to the dynamic population growth of cattle animals. It causes severe disposal problem and continues to accumulate at rising rates, which if not adequately managed, the bone will create increasing environmental issues.

For that reason, utilization of the bone as a sustainable material in concrete production would help to preserve natural resources and maintain ecological balance. The waste production of animal bone in Ethiopia accounted of 10% population of cattle's are slaughtered per year, and the average weight of cow and ox's 300kg plus out of this mass from 20% to 30% are the weight of bone, we can get the average of 400.5 million Kgs animal bone generates annually as waste [10].

In Ethiopia, the cost of cement and cement-based construction materials are getting higher from time to time, and there is the gap between demand and supply of cement throughout the country. This rise in cost and demand of cement is mainly due to the production of cement requires huge energy [11]. Trials to solve cement shortage only by increasing cement factories have another negative environmental impact due to the emission of CO2 from the factories. Hence, the key advantages of using such waste materials as alternatives to construction materials are cost reduction of cement-based materials, cost reduction for landfill, saving in energy, and protecting the environment form possible pollution effects. Besides, the cost of cement represents more than 45% of the actual cost.

Hence, the aim of this research was to analyze the effects of varying dosage replacement of cement by animal bone powder in the normal concrete strength properties. To achieve the major objective of the research, the specific objectives are organized as follows:

1) To determine the properties of the animal bone powder and bone blended cement at different percent dosage of replacement and to compare with the standard specifications.

2) To determine and analyze the workability, compressive strength, flexural strength and tensile strength of the concrete by partial replacement of cement with animal bone powder at different percent dosage replacement.

3) To determine the optimum percent dosage of animal bone powder as a partial replacement in cement of concrete mixture.

2. Materials and Methodology

2.1. Materials

Ejected animal bone as a solid waste was collected from Seka waste disposal site of Jimma town which served as the samples of the study. The animal bone washed with tap water to remove dirty inert material from its surface and dried under the sun. The bone sample burned in the furnace at a temperature of 340°C. After which, grinding the bone into powder and passing 150µm sieve size.

The concrete making materials used in this research are cement, fine aggregates, coarse aggregates, and water. The type of cement was 42.5R Ordinary Portland Cement (OPC) satisfying the AASHTO M-85 Grade, manufactured by Dangote Cement Factory. Gambela sand was used in this research study. While, the coarse aggregates extracted from the quarry site of Varnero aggregate crushing site with the maximum size of 20mm. The water utilized in the concrete mix was drinkable water supplied by the Jimma City Water and Sewerage Authority found in the laboratory area.

2.2. Concrete Mix Design Method and Materials Proportion

The ACI 211.1 Method of concrete mix design used to develop C-25 grade concrete for non-air-entrained normal strength to obtain the target mean strength of 33.5MPa. The target mean strength is determined by considering the ACI 211.1 recommended standard deviation of 8.5MPa in the absence of sufficient data. The slump, considered 20mm to 100 mm for the C-25 grade concrete, while the maximum size of coarse aggregate fixed at 20mm and the water-cement ratio of 0.49.

The volume of concrete materials calculated by using the physical properties of the elements. Table 1 shows some materials for one cubic meter for the C-25 grade concrete. Standard cast iron molds of size 15cm x 15cm x 15cm used in the preparation of Concrete cubes for compressive strength tests. While, for flexural strength test used a standard cast iron mold of size 50cm x 10cm x 10cm, and a standard cast iron mold of size 10cm diameter x 20cm height for split tensile strength.

Table 1. Quantity of materials in kg for 1m^3 C-25 grade concrete production

For C-25 grade concrete; W/C = 0.59				
Materials	Cement (Kg)	Water (Lt)	Fine Aggregates (Kg)	Coarse Aggregates (Kg)
Quantities per (m^3)	378	236.71	720.53	1018.76

2.3. Study Design

The first experiment conducted to determine the properties and characteristics of concrete making materials which are cement, sand, and gravel. The tests were carried out by the appropriate ASTM, ES and AASHTO standards were applicable. The second experiment was undertaken to determine to test the chemical and physical properties of animal bone powder based on silicate analyses and specific gravity testing methods.

There were six different percent dosage of replacement of cement by animal bone powder for 0% (control), 5%, 10%, 15%, 20% and 25% mixes. The normal consistency and setting time of the cement paste and the samples were tested for workability, compressive strength, flexural strength and split tensile strength of the concrete at the ages of the 7th day, 14th day and 28th day.

3. Results and Discussion

3.1. Properties of Animal Bone Powder (ABP) and Bone Powder Blended with Cement Paste

Laboratory test results indicated that animal bone powder composed of a calcium oxide (CaO) contents of 48.40%. While, the Ordinary Portland cement(OPC) has a content of calcium oxide (CaO) ranges from 60.6%-66.3% based on ASTM C 150. On the other hand, based on ASTM 618-00, the classifications of pozzolanic and cementitious proprieties described under Class F, customarily produced from burning anthracite or bituminous coal that meets the applicable requirements for this class Silicon dioxide (SiO_2) plus aluminum oxide (Al_2O_3) plus iron oxide (Fe_2O_3), min, of 70% has pozzolanic properties.

While, the ABP total percentage composition of Silicon dioxide (SiO_2) at 0.01%, aluminum oxide (Al_2O_3) at 0.01% and iron oxide (Fe_2O_3) at 0.01%, found to be 0.03% for ABP percentages are far less than 70% minimum required for pozzolana.

Hence, according to the code, ABP is not a pozzolanic material. Likewise, Class C typically produced from lignite or subbituminous coal that meets the applicable requirements. The Silicon dioxide (SiO_2) plus aluminum oxide (Al_2O_3) plus iron oxide (Fe_2O_3), have at least 50% cementitious proprieties. Whereas, the bone powder found to be 0.03% which is beyond 50% minimum required for cementitious proprieties.

Table 2. Chemical Analysis of ABP and OPC

S/No	chemical oxides	ABP (%)	OPC (%)
1	CaO	48.40	60.6-66.3
2	P_2O_5	33.85	-
3	LOI	5.89	3
4	H_2O	1.62	-
5	Na_2O	0.60	1.67
6	MgO	0.36	0.7-4.2
7	SiO_2	0.01	18.7-22.0
8	Fe_2O_3	0.01	1.6-4.4
9	Al_2O_3	0.01	4.7-6.3
10	MnO	0.01	0.03
11	TiO_2	0.01	-
12	K_2O	0.01	0.51
13	SO_3	--	1.8-4.6

The test of specific gravity of ABP performed by using a Pycnometer, and it showed a specific gravity of 2.9 gm./cm^3. It measured as the ratio of the mass of a unit volume of bone powder at a temperature to the mass of the same amount of gas-free distilled testing solution. The result of ABP specific gravity achieved 92% of the cement. The cement is known to have a specific gravity of 3.15gm./cm^3.

The consistency of ABP blended Cement Paste tests conducted by Vicat apparatus, to observe the relative mobility of a freshly mixed cement paste and its ability to flow when the changes in water requirement of pastes occur due to the ABP replacements. During cement testing, pastes are mixed to normal consistency as manifested by penetration of 10 ± 1 mm of the Vicat plunger.

Table 3. Normal consistency of fresh concrete with varying dosage of ABP

Mix Code	ABP-0%	ABP-5%	ABP-10%	ABP-15%	ABP-20%	ABP-25%
Consistency	27.0	27.5	28.35	28.75	29	29.5

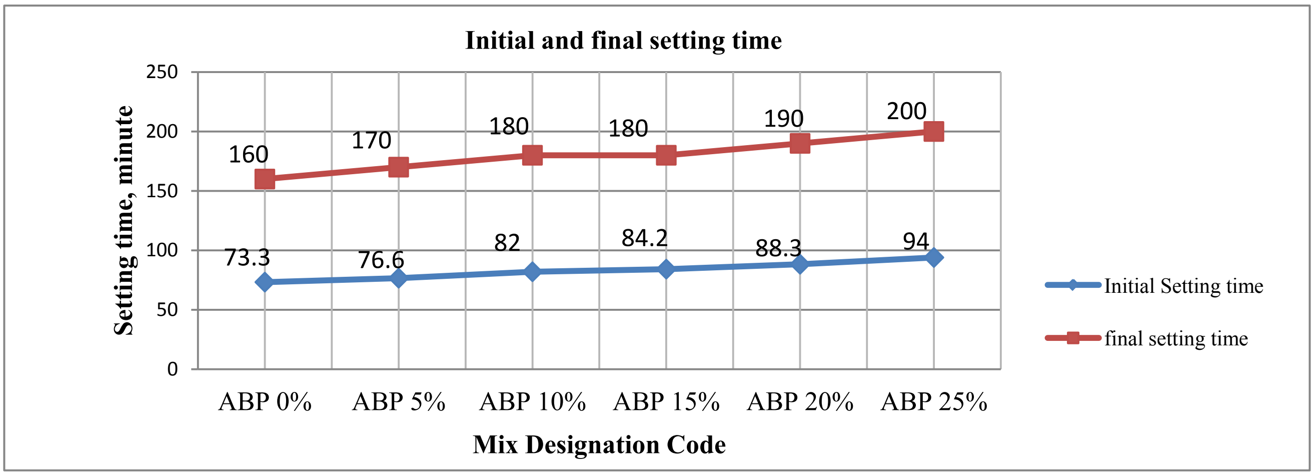

Figure 1. Setting time of Concrete mix with varying dosage of ABP

In general, the normal consistency of the replacement of cement by ABP, indicated water dosage requirement increases when the replacement percentage of animal bone powder also increased. It implies that the bone powder requires more water content than cement. In all cases of blending, the normal consistencies of the paste are within the standard ranges based on ASTM C-187-86 specification. The normal consistency of hydraulic cement which is between 26%-33%.

On the other hand, the test results of ABP blended cement setting time performed based on the normal consistency of each dosage replacement is shown in Figure 1. The result showed that the initial and final setting time increased as the percentage dosage replacement of cement with Bone powder increased. This indicates that the hydration process of cement was slowed down because of increment percentage dosage of bone powder.

According to the Ethiopian standard, it suggested that initial setting time of cement should not to be less than 45min, and the final setting time not to exceed 10hrs. While ASTM C 191-01 limits, setting time to be between 45 to 375min. Comparing the test results with standards, blended cement by different dosage replacement of cement by ABP satisfied the requirement as per the initial and final setting time limits of ASTM and Ethiopian standards.

3.2. Concrete Strengths in Varying Dosage Replacement of Cement by Animal Bone Powder

The test results on fresh and hardened concrete performance relative to compressive strength, flexural strength and split tensile strength with partially replaced cement by ABP are discussed. The performance changes due to the replacement of cement by ABP in concrete production, with the target mean strength of 33.5MPa were prepared and tested the concrete strengths at 7th day, 14th day and 28th day.

3.2.1. Workability of ABP Blended Cement Concrete Mix

The slump tests performed to study the effects of cement replaced by a dosage of ABP on workability. All concrete mixes used with a constant water to cementitious material (W/C) ratio of 0.49. From the varying dosage of bone powder, it was measured the slump to get the workability changes.

The ACI code suggested to obtain more reliable measures of workability by inverted slump cone test. Concrete mixes with cement replaced by varying dosage of ABP indicated a slump reduction than the control mix as shown in Table 4. The results showed that ABP requires more water than the cement in equal quantity. However, at varying dosage of replacement of cement, there is a strong indication that bone powder absorbed more water content which reduces the slump.

3.2.2. Effects of ABP on the Concrete Compressive Strength

From Table 5, it showed the 7th day compressive strength with varying dosage of ABP declined from the control specimen. The compressive strength recorded without bone powder was 23.47MPa (ABP 0% replacement). The test revealed that the reduction of the compressive strength is directly proportional with an increasing percentage dosage of ABP. Considering the 7th day average strength, the different dosage of replacement of cement by ABP can be achieved of about 64.94 % of the 28th day target strength.

The 14th day average compressive strength for the control mixed, was 29.57MPa (i.e. ABP 0% replacement). There was a significant reduction of 4.47MPa strength in ABP 5% dosage replacement from the control value. Also, a decreased in compressive strength noticed in mix ABP 10% dosage by 7.4MPa, in ABP 15% dosage by 9.86MPa in ABP 20% dosage by 11.23MPa and in ABP 25% dosage by 12.88MPa, relatively from the control value. The age of the sample at 14th day achieved an average strength of about 82.7% of the 28th day target strength.

At the age of 28th day, the compressive strength test result indicated the highest compressive strength value of 34.93MPa without bone powder (i.e. ABP 0%, control specimen). By the addition of percent dosage of ABP replacement, it showed that the rate of compressive strength development at 5%, 10%, 15%, 20% and 25% composed of 31.89MPa, 28.77MPa, 23.48MPa, 21.19MPa and 18.84MPa, respectively. It means the rate of compressive strength development of ABP 5% replaced concrete was decreased by 3.04MPa or 8.7% from ABP 0%. For ABP 10% replaced concrete the rate of compressive strength reduced by 6.16MPa or 17.63%, 3.12MPa or 9.78% from ABP 0% and ABP 5%. Similarly, for ABP 15% mix bone powder concrete the amount of compressive strength declined by 11.45MPa or 32.77%, 5.29MPa or 18.38% from ABP 0% and ABP 10%. While, in place of ABP 20% mix concrete, the total of compressive strength reduced by 13.74MPa or 39.33%, 2.29MPa or 9.75% from ABP 0% and ABP 15%. More so, increasing the dosage of ABP by 25%, the value of compressive strength dropped by 16.09MPa or 46.06%, 2.35MPa or 11.09% from ABP 0% and ABP 20% respectively.

Table 4. Workability results of fresh concrete with varying dosage of ABP

Mix Code	ABP-0%	ABP-5%	ABP-10%	ABP-15%	ABP-20%	ABP-25%
W/C ratio	0.49	0.49	0.49	0.49	0.49	0.49
slump (mm)	85	81	73	66	54	48

Table 5. Average Concrete Compressive Strength Results with varying dosage of ABP

Mix Code	ABP-0%	ABP-5%	ABP-10%	ABP-15%	ABP-20%	ABP-25%
Age (days)	Mean Compressive strength (MPa.)					
7th	23.47	19.48	17.86	16.15	14.26	12.11
14th	29.57	25.10	22.17	19.71	18.34	16.69
28th	34.93	31.89	28.77	23.48	21.19	18.84

Based on the compressive strength results at 28th day, the ABP 5% dosage replacement was comparable value with the control specimen. It achieved 91.29% strength out of the control specimen. Likewise, the ABP 10% dosage replacement the compressive strength gained above the required target mix design value of normal C-25 grade concrete. The results of other concrete mixed samples showed a significant influence of varying ABP percent dosage on the strength properties. The decreased in strength mainly attributed to the effect of percent dosage replacement of cement with ABP causing weak properties of mixed concrete due to increasing contents of tri-calcium Silicate (C_3S) and Di-calcium silicate (C_2S).

However, ABP found to have rich content in calcium oxide (CaO), but contains few silicate oxides (SiO_2). It means, there would be less formation of di-calcium silicate ($2CaO.SiO_2$) and tri-calcium Silicate ($3CaO.2SiO_2$) during the hydration process. Because of this process, there was losing reaction when the ABP replaced cement with varying dosage. During the process, the concrete mixed at different curing period, missed to increase its strength in the hardening stage that accounts for early strength development of the concrete as shown in Figure 2.

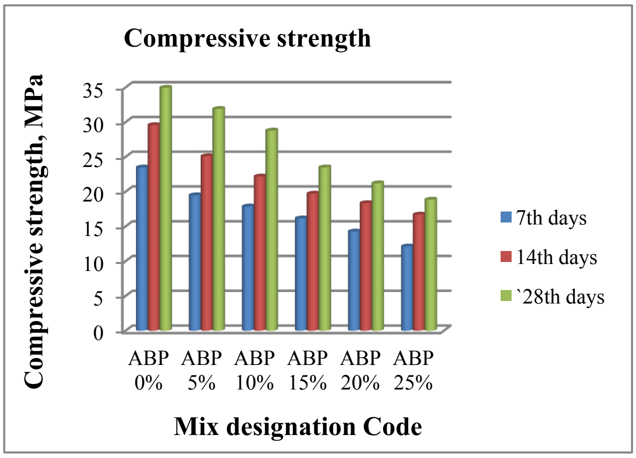

Figure 2. Average Concrete Compressive Strength Results with varying dosage of ABP

3.2.3. Effects of ABP on the Concrete Flexural Strength

In this test, the plain (unreinforced) concrete beam is subjected to flexure strength test using two-point loading test. At 7th day curing period, results indicated the rate of flexural strength with varying percent dosage of ABP from 3.14MPa (i.e. ABP 0%, control specimen), 2.65MPa (ABP 5%), 2.44MPa (ABP 10%), 2.30MPa (ABP 15%), 1.92MPa (ABP 20%), and 1.55MPa (ABP 25%). It showed that the rate of flexural strength development of concrete for ABP 5% dosage replacement by 0.49MPa or 15.6% reduction from the control specimen of 0% dosage. For ABP 10% dosage cement replacement, the rate of flexural strength reduced by 0.7MPa or 22.29%, 0.21MPa or 7.92% from ABP 0% and ABP 5%, respectively. For ABP 15% mix bone powder concrete, the amount of flexural strength declined by 0.84MPa or 26.75%, 0.14MPa or 5.73% from ABP 0% and ABP 10%. In placed of ABP 20% cement replacement, the mixed concrete indicated a total of flexural strength declined by 1.22MPa or 38.85%, 0.38MPa or 16.52% from ABP 0% and ABP 15% respectively. Likewise, for ABP 25% dosage replacement, the result of mix concrete for flexural strength indicated there was a reduction of 1.59MPa or 50.63%, 0.37MPa or 19.27% from ABP 0% and ABP 20% respectively.

At 14th day curing period, test results on the flexural strength with ABP 5% dosage cement replacement indicated (-)14.25% reduction of strength from the control value of 0% dosage of ABP, followed by ABP 10% dosage by (-)21.86%, ABP 15% by (-)28.74%, ABP 20% by (-)38.32%, ABP 25% by (-)49.6%. Hence, all of which indicated as the percent dosage increases, the flexural strength decreases.

The curing period at 28th day, flexural strength test results showed the highest flexural strength with 4.66MPa without ABP (i.e. 0% dosage of ABP as control specimen). The rate of flexural strength development of ABP 5%, ABP 10%, ABP15%, ABP 20% and ABP 25% dosage of animal bone powder replacement, the concrete strengths indicated 4.28MPa, 3.94MPa, 3.46MPa, 2.92MPa and 2.33MPa, respectively. This indicates the rate of flexural strength development of ABP 5% dosage, decreased by 0.38MPa or 8.15% from ABP 0%. For ABP 10%, reduced by 0.72MPa or 15.45%, 0.34MPa or 7.94% from ABP 0% and ABP 5% respectively. For ABP 15% dosage replacement, the amount of flexural strength declined by 1.2MPa or 25.75%, 0.48MPa or 12.18% from ABP 0% and ABP 10% respectively. While, for ABP 20% dosage replacement, the total of flexural strength declined by 1.74MPa or 37.33%, 0.54MPa or 15.6% from ABP 0% and ABP 15% respectively. Lastly, for ABP 25% dosage of cement, the flexural strength dropped by 2.33MPa or 50%, 0.59MPa or 20.2% from ABP 0% and ABP 20% respectively.

A similar pattern observed for all curing periods at 7th day, 14th day & 28th day wherein the flexural tensile strengths for different percent dosages of cement replacement by animal bone powder increased. Based on the result at 28th day flexural test, the strength reduction from the control specimen (i.e. ABP 0%) showed 8.15%, 15.45%, 25.75%, 37.33% and 50 %, represented by ABP 5% dosage, ABP10% dosage, ABP15% dosage, ABP 20% dosage and ABP 25% dosage cement replacement, respectively. These indicate that the difference of flexural strength from the control up to the quarter of cement replacement experienced loss by half strength from the overall. Therefore, the ABP in the properties of concrete contributed negative effect on the flexural strength when the percentage replacement of ABP increased.

Table 6. Average Flexural Strength Results of Concrete with varying dosage of ABP

Mix Code	ABP-0%	ABP-5%	ABP-10%	ABP-15%	ABP-20%	ABP-25%
Age (days)	Mean Flexural strength (MPa)					
7th	3.14	2.65	2.44	2.30	1.92	1.55
14th	4.07	3.49	3.18	2.90	2.51	2.05
28th	4.66	4.28	3.94	3.46	2.92	2.33

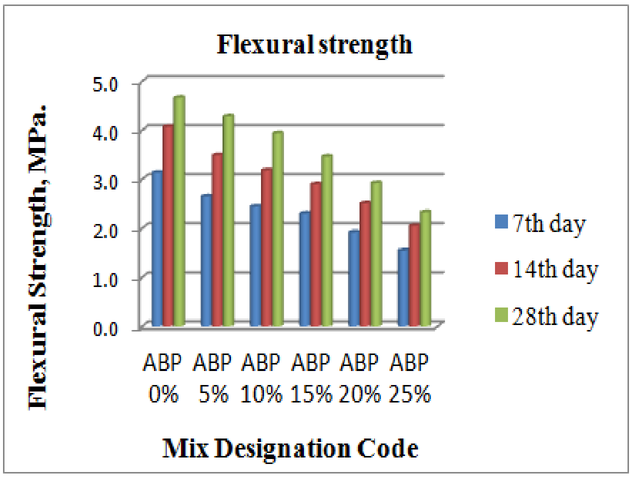

Figure 3. Average Flexural Strength Results of Concrete with varying dosage of ABP

3.2.4. Effects of ABP on the Concrete Split Tensile Strength

The Split Tensile Strength of cylindrical molded concrete with ABP varying percent dosage for cement replacement samples are determined. The laboratory test conducted based on ASTM C 496.

At the age of 7^{th} day, the results of split tensile strengths with ABP varying percent dosage showed a decline from the strength of control specimen. The maximum split tensile strength recorded was 2.27MPa for ABP 0% replacement, while for ABP 5% dosage indicated 2.1MPa, ABP 10% with 1.97MPa, ABP 15% with 1.85MPa, ABP 20% with 1.6MPa, and ABP 25% with 1.36MPa.

In the same manner age at 14^{th} day, the tensile strength with varying bone powder dosage also decreased from the control specimen. Also, it indicated the average split tensile strength achieved about 56% greater strength than the 7^{th} day age average result.

From all curing periods of the concrete samples, the maximum split tensile strength was recorded at 28^{th} day testing age. It was indicated 3.65MPa tensile strength without ABP cement replacement. Similar with other testing methods previously discussed, the split tensile strengths with varying ABP percent dosage of cement replacement decreased. The results of control specimens at different ages of curing period are shown in Table 7.

The relationship between compressive strength and tensile strength express as $f_t = a\,(f_c)^{b}$ where f_t = tensile strength, f_c = compressive strength, constants a = 0.30 and b = 0.67 [12]. When the values of ABP 0%, ABP 5%, ABP 10%, ABP 15%, ABP 20% and ABP 25% compressive strength substituted to the equation, the equivalent values of f_t (tensile strength) are 3.24MPa, 3.05MPa, 2.84MPa, 2.48MPa, 2.32MPa & 2.14MPa. This indicates that the all mixed design cement replacements for split tensile strength values are greater than the relationship strengths of minimum values. Therefore, the split tensile strength test results satisfied the required tensile strength with corresponding compressive strength.

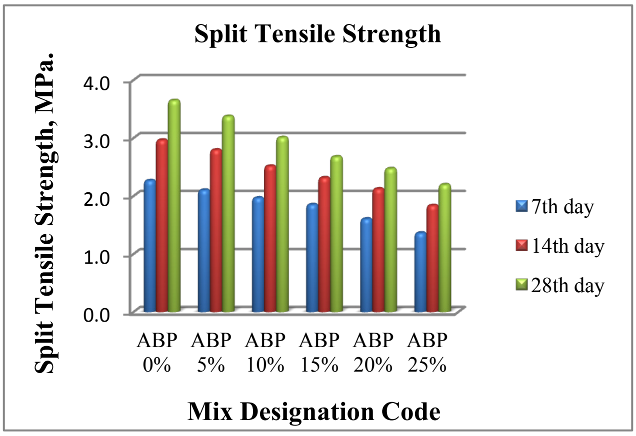

Figure 4. Average Split Tensile Strength Test Results of Concrete with varying dosage of ABP

3.3. The Optimum Percentage Dosage Replacement of Animal Bone Powder (ABP) for Cement in C-25 Concrete Production

The results of compressive strength at ABP 0%, ABP 5%, and ABP 10% indicated 34.93MPa, 31.89MPa and 28.77MPa, respectively. The ABP 5% dosage replacement produced a compressive strength which is comparable with the control specimen (i.e. ABP 0%) of 91.29%. The ABP 10% dosage replacement, the compressive strength gained more than the required C-25MPa mix design values.

On the other hand, the relationship between flexural strength and compressive strength, the flexural tensile strength of normal-weight concrete is often approximated as 0.7 to 0.8 times the square root of the compressive strength. The result of strengths provided 4.13MPa (ABP 5%), 3.95MPa (ABP 10%) and 3.75MPa (ABP 15%). However, the actual results of flexural strength up to ABP 15% dosage replacement, are still above the minimum values. In the split tensile strength results, the values representing the relationship between compressive strength and tensile strength indicated that all mixed design ABP replacement of varying dosage for split tensile strength are more significant than the minimum value.

Based on the laboratory test results and analyses of the compressive strength, flexural strength and split tensile strength of concrete with varying percent dosage of Animal Bone Powder (ABP) as partial replacement of cement, the optimum amount of bone powder for normal concrete strength is 10%. The main reason why ABP cannot adequately substitute the cement beyond the 10% dosage in concrete because of its lack of binding properties with the concrete components (i.e. small amount of silicate oxides).

Table 7. Average Split Tensile Strength Results of Concrete with varying dosage of ABP

Mix Code	ABP-0%	ABP-5%	ABP-10%	ABP-15%	ABP-20%	ABP-25%
Age (days)	Mean Split Tensile strength (MPa)					
7^{th}	2.27	2.10	1.97	1.85	1.60	1.36
14^{th}	2.96	2.79	2.51	2.31	2.12	1.84
28^{th}	3.64	3.37	3.01	2.68	2.47	2.19

4. Conclusion

The experimental works in the laboratory to evaluate the fresh and hardened properties of partially replaced cement with Animal Bone Powder (ABP) have been carried out. Based on the findings of the laboratory test results; the conclusions are drawn:

The silicate chemical analyses of ABP compared with the cement content of Portland cement chemical components based on ASTM C 150, revealed that the amounts of calcium oxide, CaO in ABP was 48.4%, which was below in the cement content from 60.6% to 66.3%. In other words, this results indicated that ABP contained 79.86% of cement by weight of the same chemical composition. Also, the ABP did not possess any pozzolanic and cementitious behavior.

On the other hand, for Concrete strength partially replaced the cement by ABP of varying percent dosage, it was seen that the combination of ABP and cement strongly affected the workability of the fresh concrete. The test results indicated that as the replacement percent dosage of ABP increased, the workability tends to decrease significantly. Therefore, the optimum dosage of animal bone powder (ABP) to replace cement for normal concrete strengths is 10% by weight.dd

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