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A Feasibility Study on the Mechanical Properties of Concrete by Replacing Cement with Animal Bone Powder

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Abstract: The indiscriminate disposal of animal waste in the environment has led to the search for solution by recycling these wastes, which includes the use of animal bone waste in the construction industry, as a partial replacement of cement in concrete. The aim of this project is to study the properties of the concrete by partial replacement of cement with animal bone powder. The bone powder is replacing cement partially by weight in mix proportion (3%, 6%, 9%, 12% and 15%). The objectives of this research are to protect the environment from the harmful effects of animal wastes by using animal bone powder in concrete as a partial replacement for cement, to study the possibility of using animal bone powder in the concrete mix and to investigate the effect of animal bone powder on the compressive and the spilt tensile strength of the concrete mixture. Conduct preliminary tests on the basic materials, including fine aggregate, coarse aggregate and cement. The mix design was developed for C30 grade concrete using the ACI method. The mix proportion used is 1: 1.67: 2.34 with water cement ratio of 0.5. Cube samples with dimension of 150mm×150mmx150mm and cylinder samples of 150mm diameter and 300mm height respectively were used to prepare concrete mix. Concrete samples were cast during this study replacing the cement with the animal bone powder. A total of 18 cubes and 18 cylinders were cast in this study and the samples were cured in the water tank for 28 days under normal conditions. Cube samples were tested for compressive strength and cylinder samples for split test in a UTM. The research has shown that the use of animal bone powder as a partial replacement of cement in concrete can affect the properties of the concrete. The results of the experiments showed an increase in compressive strength and split tensile strength when compared with the results of the normal mix however; as the bone powder content increased a reduction in the workability of the concrete was observed and recorded. Furthermore, the results showed the optimal replacement percentage of BP in concrete is 6 percent with compressive strength of 36.2 N/mm^2 when compared with other replacement ratios. Therefore, from an environmental and technical perspective, there is an opportunity to utilize waste animal bones in concrete for construction applications.

Keywords: Concrete, Partial replacement, Animal bones, Compressive strength, Slump test, Split tensile strength.

INTRODUCTION

Concrete is the most important element of any structure and buildings. It consists of cement, fine aggregate, coarse aggregate and water. All these components are mixed together to get the concrete mixture however, the strength and hardness of the concrete depend on these elements. Comparing the concrete with the other materials used in the construction industry, concrete consumes a high quantity of natural resources. The cost of the concrete elements depends on the availability of these materials. For example, fine and coarse aggregate can be obtained from sea sand or river sand and by crushing natural aggregate respectively. So, the cost of providing and producing them will be less. Also, it has less effect on the environment. For cement production, it involves the release of huge amounts of Carbon- dioxide gas into the atmosphere which is the main provider for green house effects as well as global warming. It is costly when it is produced from the factories [1].

Depending on the effects of the cement production on the environment and high cost of production, researchers did a lot of studies to investigate different materials that can replace cement. Most of the studies focused on waste materials to be used it as a full or partial replacement of cement in concrete. These materials which are used as an alternative for cement must focus on sustainable construction in order to reduce environmental hazards and at the same time improve the properties of the concrete [2].

One of the most important material that is used in previous studies is animal bone powder. Bone powder is inorganic materials produced from animal bone. It can be found in landfill with large quantities and also from slaughter houses and abattoirs. The disposal of these bones in the landfill can cause danger to the human health and affect the animal life. However, many ways can be followed to use these bones in concrete such as drying and heating bones in high temperature or burning in the air and then grinding to fine powder. It has the same chemical composition of the Ordinary Portland Cement. It can be used in a building material and industrial areas. There are many positive effects of the bone powder in the concrete properties, which are increased setting time, increase in the compression and tensile strength of concrete. There are many researchers who compared between the cost of producing bone powder and cost of Ordinary Portland Cement where, they found that the cost of concrete with bone powder is less than concrete with the Ordinary Portland Cement [3].

In this study, animal bone powder will use as a partial replacement of cement. Where it will have right affected into the environment and properties of the concrete. For the environmental benefits, this helps to reduce the diseases resulting from these bones like Allergy and Skin diseases. Also, it helps to reduce the unpleasant odors come from this waste bone. In the other hands, by adding animal bone powder to the concrete it provides technical benefits to the concrete. In addition, cement properties are same somewhat identical to the bone properties. The table1 shows the composition of BP. Also, it explains the chemical relationship that support the use of bone powder as an alternative to cement through the ratio of the components [4].

Table-1: Chemical Composition of BP

S.N	Percentage Composition	BP
1	Loss of ignition	3.29
2	Silica Oxide(SiO2)	0.24
3	Calcium Oxide(CaO)	53.2
4	Magnesium(MgO)	0.21
5	Phosphate(P2O5)	14.06
6	Sodium Oxide(Na2O)	1.36
7	Potassium Oxide(K2O)	0.2
8	Manganese Oxide (MnO)	8.52
9	Aluminum Oxide(Al2O3)	Trace
10	Iron Oxide(Fe2O3)	0.008

The aim of this study is to study the mechanical properties of concrete by partial replacement of cement with animal bone powder. Specific objectives of the study would include:

- To protect the environment from the harmful effect of animal wastes by using animal bone powder in the concrete as a partial replacement for cement with mix proportion of (3%, 6%, 9%, 12% and 15% BP).
- To investigate the effect of animal bone powder on the compressive and spilt tensile strength of the concrete mixture.
- To study the possibility of replacing cement with animal bone powder in the concrete mix.

There are many studies handle this topic. The suitability of replacing the cement with the Rice Husk Ash and bone Powder in the concrete was studied in this research. The objective of this study is to study the suitability of replacing the cement with rice husk ash and bone powder mixture in the concrete. This study presents the result of this test in case of comparing between normal concrete and this mixture. However, the results showed that the mixture of rice ash and bone powder can be used in the production of normal weight concrete. There is an abundance of this material in developing countries and it will help in removing thousands of tons of waste from the environment annually. The replacement of the cement by this mixture should not be more than 10% to get best results. In addition, the compressive strength of the concrete with the mixture at 5% replacement is more than the compressive strength of the normal concrete. Compressive strength decreased with increase in percentile replacement. As well as, reduce in the density of 0-

10% replacement of material and an increase in density from 10-20% replacement materials, which lead to a reduction in the total self-weight of the concrete [5].

This research paper about the effect of replacing the cement with the pulverized bone. The objective of this study is to study the potential use of pulverized bone (PB) as a pozzolanic material and supplement cementing material in the production of concrete. Contribution from the authors in this study is to replace the cement by pulverizing bone at different percentages of replacement from 0 to 10 % at an interval of 10%. However, the result showed that the by adding pulverized bone into the cement, resulted low water demand that will a chives by 30% of cement without adding pulverized. Reduced in water demand as the percentage of cement replacement with the pulverized bone increased and by increase the percentage of replacement, the compressive strength will increase. Also, add pulverized bone will reduce setting time of the paste. These results indicate that the pulverized bone can be used as a partial replacement material, but it should not exceed 20%. Chemical composition of the pulverized bines is almost same to the Ordinary Portland Cement. The specific gravity of the paste containing pulverized bones was decreased by increased in the percentage of the pulverized bone. Also the specific gravity of control is higher than paste with pulverized bone, which means it has higher density and Lower density of paste with pulverized bone is means that the porous internal matrix compared with the control [6].

This study presents when we can use crush cow bone in concrete. The aim of this research paper is to study the strength properties of concrete containing of crushed cow bone as a partial or fully replacement with fine aggregate. Replaced the fine aggregate with crush cow bone up to 100% with 10% intervals. However, the main properties studied in this research were workability, density and the compressive strength. The workability of the concrete was studied by slump test and the compacting factors. For the density and compressive strength, they were used 150mm cubes samples. However, the results shown that, increase the percentage of crush cow bone led to decrease the workability of the concrete. Replaced crush cow bone with fine aggregate resulted in different types of concrete. Also, up to 20% of fine aggregate replaced with crush cow bone resulted compressive strength that was not significantly different from the normal concrete [7].

This research paper about the effect of partial replacement of cement with bone ash and wood ash in concrete. The objective of this study is use of animal and vegetative wastes in the construction industry, especially in the partial replacements of cement in concrete. The authors work to replace the cement with the bone ash and wood ash to analysis their pozzolanic properties. However, in this study, the authors found that the bone ash has better pozzolana when compared to the wood ash. Also, the compressive strength test showed that the wood ash is not a good material for replacing cement in the concrete.10% of the bone ash can be replaced with the cement which gives good value of compressive strength. Wood ash has low compressive strength with an increase in the percentage of replacement. Bones ash and wood ash have very high aluminum and iron oxide. From the chemical analysis, bones have high calcium oxide than the cement and wood ash have a lower calcium oxide than the cement. This lead the bones to be better replacement materials for the cement and it will work to improve the properties of the concrete. Also Bones ash has a very low silica oxide when compares it with cement and wood ash [8].

The used of bone powder in the concrete in case of improving field applications of concrete, properties of it and other features of ordinary concrete requires. It is one of the normal pozzolanic material which replaces cement. The objective of this study is to study the possibility of utilizing Bone Powder Ash (UBPA) as partial replacement of construction material like cement in the form of ash. This replacement provides more environmental and technical benefits to the concrete. The result obtained by the authors is the compressive strength of the concrete is higher than the compressive strength of the normal concrete. As well as, the workability of the concrete with the bone powder was higher than the normal cement. However, they discussed the main problems of the concrete that they can solve it in this study. One of these problems is the high cost of the concrete component and search for materials to fully replace or partially replace the cement with this material, which do the same works as well as reduce the cost and they found that bone powder is the suitable materials to solve this problem. By adding APP, we can improve the properties of concrete such as strength, workability, density, weight and etc [9].

Experimental Section/Material and Methods:

The purpose of the research is to study the properties of the concrete by partial replacement of the cement with animal bone powder. Materials that used in the mix design of the concrete were, Ordinary Portland Cement, fine aggregate, course aggregate, water and animal bone powder. Prepared 18 cubes and 18 cylinders with different percentage of partial replacement of cement with animal bone powder (0%, 3%, 6%, 9%, 12% and 15%). First mix was prepared without bone powder, which is normal control mix, which were designed using American concrete institute (ACI) method for C30 Grade.

MATERIALS USED IN CONCRETE

Cement

Cement is the most important material in production of the concrete. It is in the powder form and it is made from limestone, sand or clay bauxite and iron. In this study, Ordinary Portland Cement which is the best type of cement was used for casting concrete samples. Around one to two bags of cement was used for preparing the samples.

Fine Aggregate

It is sand made of a mix of small partials of grains and materials that can be passed through sieves size 9mm. It can be used for construction activities like mixing concrete. Using fine aggregate size between 5-75 µm.

Coarse Aggregate

It is finding from crushing the rocks into pieces by using crush machine. The size of the coarse aggregate can be divided by using big sieves in different sizes. Main size that used for construction purposes are 6mm, 12mm and 20 mm.

Animal Bone Powder

Animal bone powder is used as a partial replacement of cement in the concrete mix in this research. The material is collected from the slaughter houses and landfill. Choose the pelvic bones because it is very strong. Then clean the outer face of the bones and crush it. After that clean and wash it from the inside to make it ready to use. Dry it for a period of one day until it becomes dry. Use the machine which is available in the college to crush the bones in small parts and then use grinder to crush the bones in powder form (Figure-1).

Fig-1: Bone Powder

After that, sieve the bone powder by using sieve size 75 µm to check its form as the cement and then start to use it in the concrete mix.

Mix Design Calculations for C30 Concrete Grade According to the (ACI)

Mix design is the process of calculating mix proportion of various ingredients of materials such as cement, fine and coarse aggregate to achieve suitable strength in concrete. In this study, concrete mix design is done by using ACI method of mix proportioning as mentioned in Concrete Technology book [10]. For C30 grade concrete, the mix proportion for 1m3 of concrete mix is 1: 1.67: 2.34 with W/C of 0.5.

Mix design is the process of determing the properties of selecting amount of concrete depending on the ratios of cement, coarse and fine aggregate to achieve suitable strength in structure. However, in this study the concrete mix design done by using ACI method of mix proportioning as mentioned in Concrete Technology book. For C30 grade concrete, the following steps were explained the mix proportion design was achieved:

Bulk volume of dry- rodded coarse aggregate per cubic meter of concrete from table 10.9 is 0.6 m^3

Mass of coarse aggregate per cubic meter of concrete= 0.6 x density = 0.6 x 1600= 960 kg/m^3

Water cement ratio from table 10.12 = 0.54 and limited to 0.5 which is depending on the grade of concrete C30. Water content per meter cube of concrete for slump of 75 to 100mm and maximum size of aggregate is 20mm from table 10.11 = 205 kg.

- Cement content = 205/0.5 = 410 kg/m^3.
- For maximum size of aggregate of 20mm, the entrapped air content is 2.0%.

Fine aggregate content absolute volume of maximum ingredients per m^3

- Volume of cement= C/Sc= 410/ (3.15 x 1000) = 0.13m^3
- Water= W/1000= 205/1000= 0.205m^3
- Coarse aggregate= Ca/Sca = 960/ (2.6 x 1000) = 0.37 m^3
- Entrapped air= 0.02 m^3

Total= 0.725m^3

- Volume of fine aggregate required= 1-0.725= 0.275 m^3
- Mass of fine aggregate=0.275 x specific gravity of fine aggregate x1000 =0.275 x2.5 x1000= 687.5 kg.

Mix proportions by mass per cubic meter

Table-2: Mix proportion by mass per m^3

Cement	Fine aggregate	Coarse aggregate
410	687.5	960
1	1.67	2.34

Volume of three cubes= 3(0.15 x 0.15 x 0.150) = 0.010125m^3
Add 5% for wastage = 0.05 x 0.010125 = 5.0625 x 10^{-2} m^3
Total= 10.631 x 10^{-3} m^3

For the normal concrete cubes (Mix0):

- Weight of cement for 3 cubs= 410 x 0.010631 = 4.36 kg
- Weight of fine aggregate= 4.36 x 1.67 = 7.28 kg
- Weight of coarse aggregate = 4.36 x 2.34 = 10.20 kg
- Weight of water = W/C = 0.5
- 4.36/C = 0.5, W= 2.18 kg

Preparation of concrete mix, casting of cube, cylinder, curing and testing is carried at Caledonian College of Engineering at Material Testing Laboratory, Muscat and shown in the figures below2-10.

Taking the weight of the coarse, Fine, cement and bone powder by using the balance to insure the exact amount of the quantities shown in Figure-2.

Figure-2: Taking the quantity of materials (Source: CCE ML)

All these components are mixed together to get the concrete mixture by concrete mixer then again manually by hand to insure proper mixing because the material are segregating while mixing in the mixer machine shown in Figure-3 & 4.

Fig-3: Mixing the quantities of materials (Source: CCE ML)

Fig-4: manually mixing of the materials (Source: CCE ML)

Before pouring the concrete mixture to the moulds, the slump test is carried out to check the workability of the mixture. Then the oil is applied to remove the concrete cube easily after drying shown in Figure-5 & 6.

Fig-5: Slump test Measure (Source: CCE ML)

Fig-6: Applying oil to the moulds (Source: CCE ML)

Adding the concrete mixture to the moulds in layers, each layer compacted 35 times by using the tamping rod. After that the moulds should be dried. Then, the concrete specimens are cured for 28 days in the curing tank shown in figure-7 & 8.

Fig-7: Casting Cubes and Cylinders of Porous concrete (Source: CCE ML)

Fig-8: Curing of Samples (Source: CCE ML)

The concrete cubes and cylinders are tested after the curing period is over in the UTM machine to determine the compressive and split tensile strength shown in figure-9 & 10.

Fig-9: Compressive Strength test (Source: CCE ML)

Fig-10: Spilt Tension test (Source: CCE ML)

RESULTS AND DISCUSSIONS

Physical and mechanical properties of the fine aggregates, coarse aggregates are evaluated and presented in table3. Concrete is prepared according to the mix proportion. Cubes and cylinders have been cast and tested for compressive and split tensile strength after curing the samples for a period of 28 days.

Table-3: Physical Properties of Aggregates.

Tests on Coarse Aggregates			
Sl. No.	Property	Units	Results
1	Fineness modulus of coarse	%	4.326
2	Water absorption	%	0.4
Tests on Fine Aggregates			
Sl. No.	Property	Units	Results
1	Fineness modulus of fine	%	4.486
2	Water absorption	%	0.2

The following table-4 shows the quantity of materials required to cast 3 cubes for each mix.

Table-4: Pervious Concrete Mix Proportions & Quantities for Cube Moulds

Mix No	Weight of Cement (Kg)	Percentage of BP (%)	Weight of BP (Kg)	Weight of FA (Kg)	Weight of CA (Kg)	Weight of water (L)
Mix1	6.56	0%	0	10.95	15.3	3.28
Mix2	6.36	3%	0.197	10.95	15.3	3.18
Mix3	6.16	6%	0.394	10.95	15.3	3.03
Mix4	5.97	9%	0.590	10.95	15.3	2.98
Mix5	5.77	12%	0.787	10.95	15.3	2.88
Mix6	5.57	15%	0.984	10.95	15.3	2.78

Compressive strength test has been done for the cubes of 6 mixes with the different percentage of bone powder replacement. The size of the cubes used were the 150mmx150mmx 150mm. Table-5 shows the results of compressive strength for each mix.

Table-5: Cube Strength of Concrete at 28 Days (S=SAMPLE)

Materials	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
Bone Powder percentage (%)	0	3	6	9	12	15
Compressive Load (KN)	722.25	771.75	814.5	720.1	546.5	543.7
Compressive Strength (N/mm^2)						
At 28 days	32.31	34.3	36.2	32.0	24.4	23.9

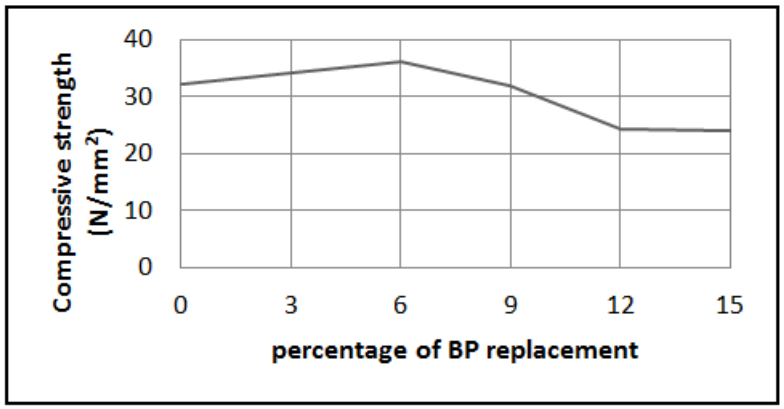

Fig-11: Compressive strength after 28 days

There is a gradual difference in the compressive strength results due to the amount of bone powder replaced in the concrete mixture as shown in figure-11. For example, the compressive strength value for mix 6 (15%BP) has the lowest value among the other results which decreased up to 23.9N/mm^2. However, the highest value of compressive strength is 36.2N/mm^2 with the percentage of 6% of bone powder. However, the remaining results of compressive strength for the other mixes have dramatically reduced with an increment of the amount of the bone powder.

The following table-6 shows the quantity of materials required to cast 3 cylinders for each mix.

Table-6: Pervious Concrete Mix Proportions & Quantities for Cylinder Moulds

Mix No	Weight of Cement (Kg)	Percentage of BP (%)	Weight of BP (Kg)	Weight of FA (Kg)	Weight of CA (Kg)	Weight of water (L)
Mix1	4.36	0%	0	7.28	10.2	2.18
Mix2	4.23	3%	0.131	7.28	10.2	2.11
Mix3	4.1	6%	0.261	7.28	10.2	2.05
Mix4	3.96	9%	0.392	7.28	10.2	1.98
Mix5	3.84	12%	0.523	7.28	10.2	1.92
Mix6	3.60	15%	0.654	7.28	10.2	1.85

Split tensile strength test has been done for the cylinders of 6 mixes with the different percentage of bone powder replacement. The size of the cylinders used were the 150mm diameter and 300mm height. Table-7 shows the results of spilt tensile strength for each mix.

Tabl-7: Concrete Split Tensile Strength of Concrete at 28 Days (S=SAMPLE)

Materials	S1	S2	S3	S4	S5	S6
Bone Powder percentage (%)	0	3	6	9	12	15
Split Load (KN)	190.33	206.5	209.074	186.25	175.279	166.068
Split Tensile Strength (N/mm^2)						
At 28 days	2.69	2.8	2.95	2.635	2.5	2.34

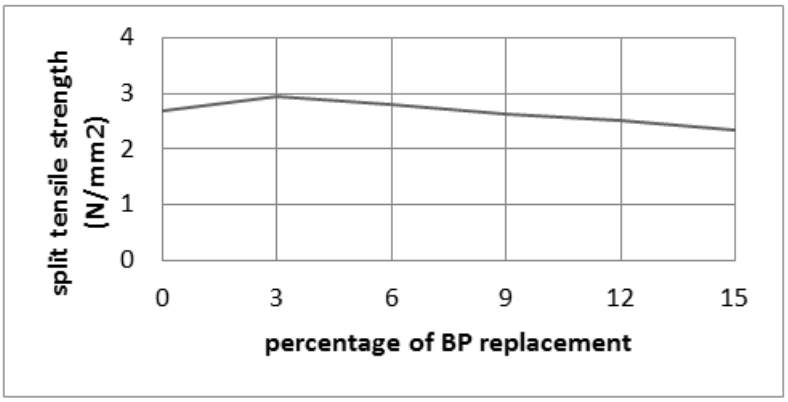

Fig-12: Split tensile strength after 28 days

It's clear that there is variation in the values of the spilt tensile strength shows in figure-12. Mix 3 which has 6% bone powder has 2.95 N/mm^2 tensile strength, while mix 6 has the lowest split tensile strength. However, the value decreases as the result of increasing the bone powder in the concrete mixture to 2.5N/mm^2 in mix 6 of 15% bone powder replacement.

Based on the recent study future work and research are suggested as follows:

- Chemical admixture such as super plasticizers may be used to increase the strength of the concrete.
- For further research work, the effect of bone powder in the concrete for different replacement levels can be carried out.
- Recommended to use animal bones as full replacement of fine aggregate and study the physical properties of concrete.
- Study on the flexural strength of beams and compressive strength of cylinders can be done replacing cement with a combination of bone powder and admixtures.
- In this research hydrogen peroxide was used to clean bones hence in further studies other methods of cleaning and processing the bone powder can be carried out.

CONCLUSION

Bones in general consider as a waste material especially in Sultanate of Oman, which cause environmental impact and health issues for the society. This study is investigating the utilization of waste bone as a partial replacement for cement in concrete. It helps to reduce bone wastes from ending up in local landfills. Tests were conducted on fresh and hardened concrete.

- Results show that the slump value decreased when the replacement ratio of bone powder increased in the concrete affecting the workability of concrete.
- The compressive strength of the bone powder concrete compared with the control mix shows increment in strength around 5.8%.
- The mix replacement containing (3% BP), showed positive signs in strength when compared to other concrete specimens, while the compressive strength remains higher than the control mix.
- When compared to the control mix the replacement of (15% BP) incurred highest loss of compressive strength by nearly 23.9 N/mm^2. This confirms that loss of strength in the concrete is imminent.
- The specimens showed higher tensile strength results in mix 2 of 3% BP.
- The optimal replacement percentage of BP in concrete is (6%BP), with strength of 36.2 N/mm^2 when compared with other replacement ratios.
- This study reflects the possibility of using animal bone powder as a partial replacement of cement in concrete to some extent.

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