RECENT TREND IN CIVIL ENGINEERING AND BUILT ENVIRONMENT
e-ISSN: 2773-5303

RTCEBE

Vol. 6 No. 1 (2025) 233-244
https://publisher.uthm.edu.my/periodicals/index.php/rtcebe

Sheep Bone Powder (SBP) as a Partial Cement Replacement in Concrete

Nuradila Lile[1], Norfaniza Mokhtar[1]*

[1] *Faculty of Civil Engineering and Built Environment*
Universiti Tun Hussein Onn Malaysia (UTHM), Batu Pahat, Johor, 86400, MALAYSIA

*Corresponding Author: norfaniza@uthm.edu.my
DOI: https://doi.org/10.30880/rtcebe.2025.06.01.025

Article Info

Received: 09 January 2024
Accepted: 15 April 2024
Available online: 6 May 2025

Keywords

Cement replacement, sheep bone powder, sustainabe concrete

Abstract

Animal bone take a longer time to be disposed compared to other domestic waste. The indiscriminate of the animal bone in the environment has led the search for the solution by recycling the bone to form a new product in the construction industry such as a partial cement replacement in concrete. Hence, the cement was replaced by weight in mix proportion (2%, 4%, 6%, 8%, 10% and 12%). The propose of the study is to determine the optimum percentage of Sheep Bone Powder as a partial cement replacement in the concrete and understand its effect on the concrete's microstructure. To ensure that the objective will be achieve, a combination of deep literature study and data gathered from the laboratory testing is necessary. The literature review provides an insight about the previous study to support the data collection. The data was obtained from the compressive strength test and SEM-EDX analysis on sample sized for C30 grade concrete. The mix proportion used is 1:1.8:3.2 with 0.5 of water cement ratio. The cube sample with dimension of 100mm x 100mm x 100mm were used and tested after cured in water for 7 days and 28 days. The study concludes that 8% SBP is the optimum proportion, exhibiting the highest compressive strength which is 35MPa and shows a favourable microstructure. Furthermore, the result shows that if the SBP powder increase, the workability of concrete also increased. Following the findings, a several recommendations being proposed to improve the concrete performance. These suggestions have a potential to improve the concrete properties and can help to minimize the environment impact.

1. Introduction

Concrete is one of the materials that widely use in the construction industry all over the world. The main materials to produce concrete are cement, aggregates, and water. Concrete is widely used in construction because of the criteria of the concrete that have a high compressive strength that allows to support heavy loads and can resists the internal or external forces such as wind, gravity and the seismic activities. Other than that, concrete is also suitable to withstand the bad environment condition such as the fluctuation of the temperature and the chemical exposure. World will facing a serious problem due to the construction activities and the process that included in the production of the construction material such as cement. As every country in this world aim to be a developing country and manage to compete, the construction sector also become a competitive field. However, it is undeniable that the construction industry is one of the biggest contributors to the pollution.

Animal bone may contribute to the waste problem towards the environment since animal bone needs years to be disposed. Rizvi, et. al. (2015) stated that minimum domestic waste that human produce daily is 275kg where 27.5% from the waste is an animal bone. Animal bone consists of 80% of magnesium and calcium and 10% of carbonate while the primary raw materials used to produce cement also have a similar chemical composition with the animal bone. As a result, animal bone powder might have a same pozzolanic properties as cement. For this reason, the study was conducted to use sheep bone powder (SBP) as a partial cement replacement in concrete. The propose of the study is to determine the optimum percentage of Sheep Bone Powder as a partial cement replacement in the concrete and understand its effect on the concrete's microstructure.

1.1 Consideration in Selection SBP as Partial Cement Replacement

1.1.1 In Aspect of Strength

The chemical composition of the sheep bone powder is so much similar with the chemical composition of the cement. Other than that, the highest chemical composition of the sheep bone ash is calcium. Calcium in the sheep bone combine with the carbon and oxygen to form the calcium carbonate ($CaCO_3$).

The calcium carbonate is the biggest contribution to the formation of the C-S-H (Calcium Silicate Hydrate). The appearance of the C-H-S is very important to the concrete mixture especially for the hydration process. C-H-S give a positive impact towards the hydration process and give a strength effect. Besides, it also can enhance the density and improve the microstructural properties.

1.1.2 In Aspect of Economic

Animal husbandry is one of the sectors that have high demand in Malaysia. Thus, this sector has been providing employment opportunities for many farmers and contributes to the country's economy.

Based on Department of Veterinary Services, the population of sheep in Malaysia is around 399,045 in a year. Which also predict that there will be an increment in the future because of the demand. The increment of the demand of the sheep will lead to the waste increment of the sheep bone in the landfill area. The idea to reuse the waste material is to overcome the problem related to the waste production. So, the farmers can farms more efficiently according to the demand without considering the issues that occur in the environment and can help the farmer to increase their income.

1.1.3 In Aspect of Social

Sheep bones are found to be the waste material from the natural resources. Implementing an eco-friendly practice such as reuse the waste material to produce new product will raise an awareness among the public about the beneficial of implementing a sustainable practice in the construction industry by comparing the existing concrete mixture and a partial cement replacement using a eco-friendly approach.

1.1.4 In Aspect of Environment

The main reason to use the sheep bone powder as the partial cement replacement in the concrete because to reduce the raw material consumption, generation of waste and effect of the greenhouse aligning with the aim of the Sustainable Development Goal (SDG) which is to sustain the development and responsible resource management.

Cement production relies heavily on quarried materials such as limestone. The extraction of the raw materials of the cement can destroy the natural beauty, lead to the deforestation, and contribute to soil erosion when heavy rainfall. The proposed of sheep bone powder as the partial cement replacement in the concrete can reduce the demand of the extraction in the long term. Besides, the implementation of sheep bone powder as a partial cement replacement gives an advantage on the reduction of the carbon emissions. The cement production process is energy-intensive and emits substantial amounts of CO_2.

1.1.5 Life Cycle Assessment Analysis of SBP

Life cycle assessment of materials is obtained according to standard of ISO 14040 and ISO 14044 which aim to evaluate the environment impact from entire life cycle of a product or usually call as 'cradle to grave'. Fig 1 shows the general sheep bone life cycle.

Recent Trend in Civil Engineering and Built Environment Vol. 6 No. 1 (2025) p. 233-244

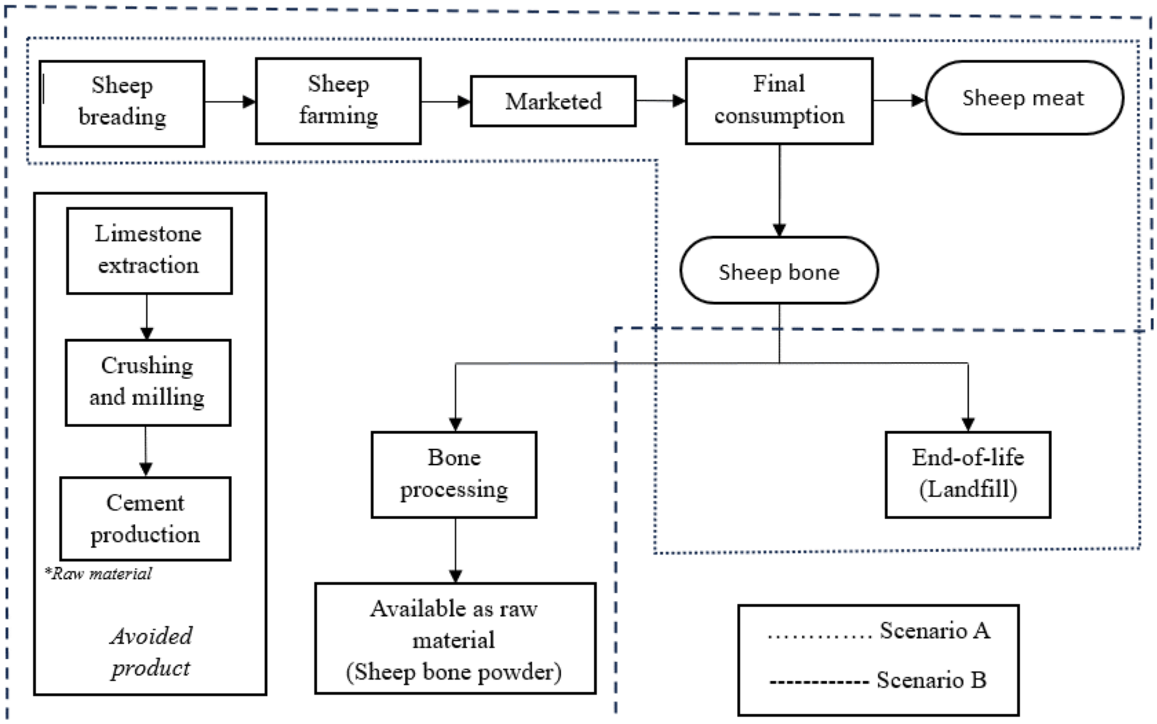


Fig. 1 *General sheep bone life cycle*

2. Literature Review

2.1 Animal Bone Powder

Sheep bone powder is used as a partial cement replacement in the concrete mix in this study. Animal bone will produce a change to the properties of the concrete mixture by Nadia, et. al (2017). Sheep bone powder is selected as the partial cement replacement in the concrete mixture is because of the animal bone have a similar composition with the concrete by Nadia, et. al (2017), Shumet Getahun & Bahiru Bewket, (2020), Mohd Ramli, M., (2023). Table 1 show the chemical composition of sheep bone while table 2 shows the chemical composition for OPC.

Table 1 *Chemical composition of sheep bone, Nadia, et. al (2017)*

Chemical Composition	Constituent (%)
Silica Dioxide (SiO_2)	0.24
Iron Oxide (Fe_2O_3)	0.008
Calcium Oxide (CaO)	53.1
Magnesium Oxide (MgO)	0.21
Phosphorus Pentoxide (P_2O_5)	14.06
Potassium Oxide (K_2O)	0.2
Manganese Oxide (MnO)	Trace
Sodium Oxide (Na_2O)	1.36
Loss on Ignition (LOI)	3.29

Table 2 *Chemical composition for Portland Cement, Mohammed et al, (2014)*

Chemical Composition	Constituent (%)
Silica Dioxide (SiO_2)	19.01
Iron Oxide (Fe_2O_3)	3.2
Calcium Oxide (CaO)	66.89
Magnesium Oxide (MgO)	0.81
Phosphorus Pentoxide (P_2O_5)	0.08
Potassium Oxide (K_2O)	1.17
Manganese Oxide (MnO)	0.19
Sodium Oxide (Na_2O)	0.09
Loss on Ignition (LOI)	2.48

3. Previous Study of Partial Cement Replacement in Concrete

Opeyemi, and Makine (2012) mention that, using rice husk and bone powder as cement replacement give an effect towards the concrete properties where the optimum content for the studies is 5% of the partial replacement. Based on the observation, the percentage 10% , 15% and 20% shows the density of the concrete is increasing and lead to the voids reduction.

Akinyele et. al, (2016) stated bone ash rich with the calcium oxide where contribute to the acceleration of the hydration process than wood ash. The studies of the comparison between wood ash and bone ash shows that the bone ash can perform better in as the cement replacement than wood ash with the optimum partial percentage is 10%. Other than accelerate the hydration process that also contribute to the strength, the bone ash also reduces the concrete porosity with the aids of the calcium. Aligned with the study about mussel shells as the partial cement replacement by Wan Mohamad, (2018) mention that, since the mussel shell have higher calcium oxide contain, make the concrete harden faster than usual. It is because the increment of the formation of C-H (Calcium Hydrate).

Nadia et. al. (2017) conducts a study about the animal bone as partial cement replacement in the concrete. The studies shows that the slump value is decrease when the percentage of the cement replacement increase. It is because of the rapid oxidation consume more water and make the concrete drier if the animal bone contain increase. Hence, compare to the control sample, the bone animal bone powder shows 5.8% increment in compressive strength which is 36.2N/mm^2 for 6% of replacement. Other than that, Shumet Getahun & Bahiru Bewket, (2020) the increment of the bone ash in the concrete have led to the decreasing of slump value due to the better water absorption.

4. Methodology

Materials that used in the mix design were Ordinary Portland Cement (OPC), fine aggregate, coarse aggregate, water and Sheep Bone Powder (SBP). Prepared 42 cubes with different percentage of SBP (0%, 2%, 4%, 6%, 8%, 10%, and 12%) using concrete C30 grade with the ratio of 1:1.8:3.2 by referring to the DoE calculation.

4.1 Material Used in Concrete

4.1.1 Cement

Cement is a pillar of the concrete mixture since cement is important to bind all the materials. According to BS EN 197-1:2011, cement is form from a different material such as limestone, sand, bauxite, and iron. OPC is one of the cements widely used in Malaysia for casting concrete as well as this study.

4.1.2 Fine Aggregate

According to ASTM D1073 the maximum size of fine aggregate is 4.75mm. Fine aggregate act as a crucial filler, impacting overall strength and durability. Both adhere to BS EN 12620:2013 for sieve analysis. For the fine aggregate preparation, the sand has been put into the mixture to wash it with the water to remove unwanted materials apart from the sand. Then, the sand will be left 24 hours at the open space to get a fully dry sand.

4.1.3 Fine Aggregate

The size of coarse aggregate significantly affects the concrete properties. A smaller size of aggregate will give a better effect on workability while a bigger size will boosts paste bonding for stronger concrete adhere to BS EN 12620:2013 for sieve analysis. The bigger size of aggregate will give a positive effect in terms of strength but the probability to have a bigger void is higher. To prevent the issue from happening coarse aggregate passing of 10mm and 20mm sieve has been used which usually using a ratio of 1:2 respectively.

4.1.4 Sheep Bone Powder (SBP)

Sheep bone powder is a partial cement replacement in the concrete mixture. The sheep bone was collected from the local market in Parit Raja. Then, the bone will be cleaning using a brush and water to ensure it is free and clean from the dirt. Then, the bone will be dried using the oven for 100°C to remove the moisture content that can interfere with the cementitious properties and chemical reaction during the mixing and curing process. After that, the bone will be crushed using grinding machine before burns into furnace in 900°C for 3 hours to get the completely white, indicating that it had calcined. Once again, the bone will go through the milling process until it become fine and sieve <20 µm to get the optimum bone powder. Fig.2 is the preparation of SBP.

Fig. 2 *Preparation of SBP*

4.2 Design Mix of Calculation

Mix design is a process to determine the properties of the selection amount depends on the ratio of the cement, coarse aggregate, and fine aggregate to achieve the suitable strength of the concrete. In this study, concrete mix design is done by referring to the Design of Normal Concrete Mixes (Teychenne et. al, 1988). Table 3 is the design specification for concrete mixture. Table 4 shows the mix proportion by mass per meter cube with 20% of wastage and Table 5 define the mix proportion for concrete with different amount of SBP.

Table 3 *Design specification for concrete mixture*

Grade of the concrete	C30
Target mean strength	46MPa
Maximum size of aggregate (angular)	20mm
Proportion defective	2.5%

Table 4 *Mix proportion by mass per meter cube*

Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)
0.4	0.7	1.2
1	1.8	3.2

Table 5 *Mix proportion for concrete with different proportional of SBP*

% of SBP	Water (kg)	Cement (kg)	SBP (kg)	FA (kg)	CA Cement (kg)	
					1	2
0	1.2	2.76	-	4.9	2.9	5.8
2	1.2	2.70	0.06	4.9	2.9	5.8
4	1.2	2.65	0.11	4.9	2.9	5.8
6	1.2	2.59	0.17	4.9	2.9	5.8
8	1.2	2.54	0.22	4.9	2.9	5.8
10	1.2	2.48	0.28	4.9	2.9	5.8
12	1.2	2.43	0.33	4.9	2.9	5.8

4.3 Sample Preparation and Testing

The cube with the dimension of 100mm x 100 mm x 100mm were widely used in compressive strength testing concrete which is sufficient to accommodate the necessary equipment such as compression testing machine by providing a suitable cross-sectional area for applying the load. Thus, it has been standardized in many testing procedure and specification including ASTM (America Society for Testing Material), IS (Indian Standard) and BS EN 12390-3:2002 standard (British standard EN 12390,2002). The steps to prepare the concrete cube are as in Fig. 3.

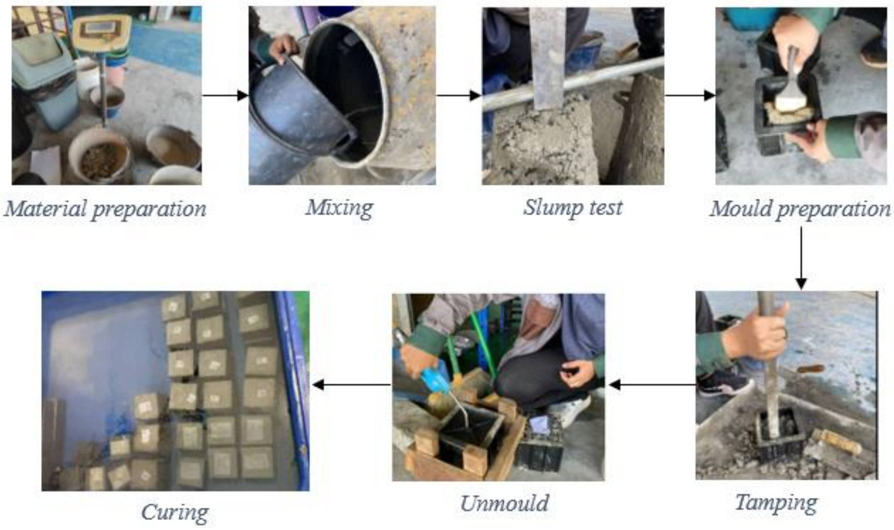


Fig. 3 *Sample preparation*

According to the BS EN 1992-1-1 (1992) standard, strength of the concrete is a crucial factor considered for the concrete. Compression tests are carried out after curing for 7 days and 28 days. The number of samples will be tested is three sample each proportion and each curing time as shown in Fig 4.

Fig. 4 *Compressive strength test*

After the compression test, a small particle within 5mm dimension is cut from the tested sample for SEM-EDX analysis. SEM and Energy Dispersive X-ray (EDX) are used to determine the microstructure of the concrete mixture and determine the chemical composition concrete mixture. The test is conducted by using the same specimen from the compressive test. Use the failure specimen, make sure to get the nearly flat surface area to get the result uniformly. The test can generate the information about the topography composition in the specimen. To get the image, electron beam is swept in a raster scan pattern and its position in coupled with the detected signal's intensity of component on sheep bone in the concrete. The SEM-EDX analysis machine as in Fig. 5.

Fig. 5 *SEM-EDX analysis machine*

5. Result and Discussion

Fig. 6 shows the result from the slump test. Throughout the graph, a clear trend shows that the increment of the SBP percent will reduce the slump value. The scenario is happened due to the water absorption is increase aligned with the increment of the SBP. The data can be support with the previous research by Getahun & Bahiru Bewket, (2020) which stated that if the percentage of bone in concrete is increase, the slump value will be decrease due to the water absorption.

Furthermore, during the mixing process, it was notified that the workability of the concrete mixture is increasing as the percentage of the SBP is increase. Changing the proportions of SBP might influence the flowability of the mixture. The higher contain of SBP can contribute to the increment of the overall moisture content of the concrete and have resulting in a heavier feel during the mixture.

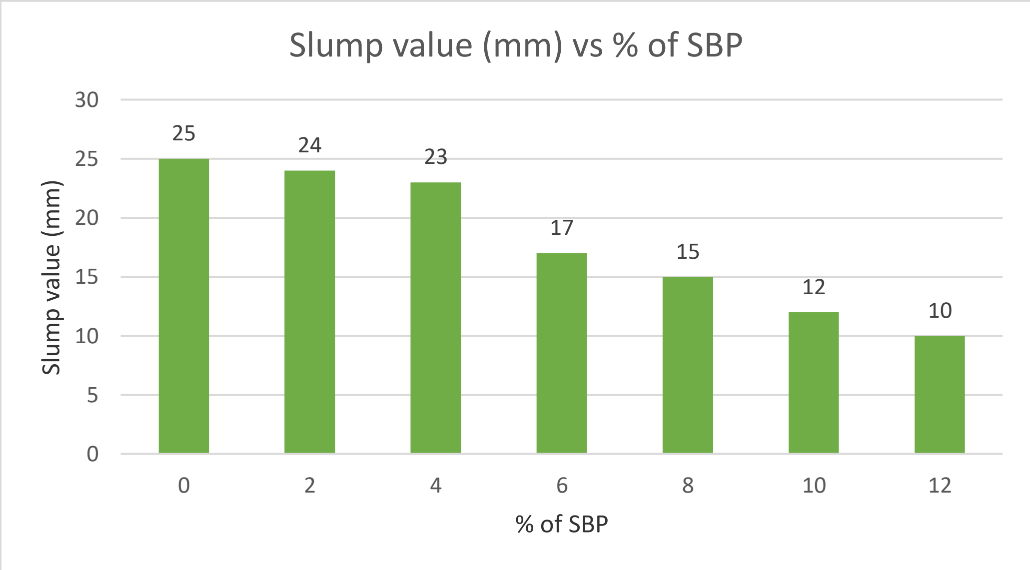


Fig. 6 *Slump value (mm) vs % of SBP*

Fig 7 shows the graph based on the strength of 7 days and 28 days and the percentage of SBP. At 2% and 4%, the SBP content might be not sufficiently to give an effect towards the strength of the concrete the statement was supported by Dodson (2013) stated that insufficient amount of the material replacement will make the performance of concrete as similar as the normal concrete. The larger content of cement has been dominant towards the concrete properties. Hence, it has made the concrete act like a normal concrete.

The reaction of the SBP have been shown when the mixture is reaching the 6% of partial cement replacement resulting an improvement of the strength from 6% to 8%. The increased of the strength maybe because of the sufficient content of the SBP to interact with other materials in concrete especially the present of the calcium oxide in the concrete mixture facilitating the interactions with other materials. The sufficient contain of the calcium oxide will have a positive impact towards the concrete properties particularly in the formation of the Calcium Silicate Hydrate (C-S-H) play an important role for the concrete hardening process and also for the binder effect for the concrete mixture. Binder and hardening process in the concrete mixture have a patriot role in the concrete properties especially to give a strength to the concrete. For 10% to 12%, shows the reduction of the strength. This is also happened because of the insufficient amount of SBP. Align with Al Tawaiha, et. Al. (2023) stated that high calcium content without adequate proportions of other necessary materials like silica or ion can hinder the formation of C-S-H compound. This inadequacy in the formation of the binding effect may result in reduced concrete strength, affecting its load-bearing capacity and durability of the concrete.

Based on the compressive strength data, the optimum percentage of SBP as the cement replacement is 8% with the highest strength among the partial replacement data which are 27MPa for 7 days and 35MPa for 28 days. Even all the sample did not achieve strength by the control sample, but the data is above from JKR standard. This indicate that in terms of strength, SBP have a potential to be the cement replacement in the concrete mixture.

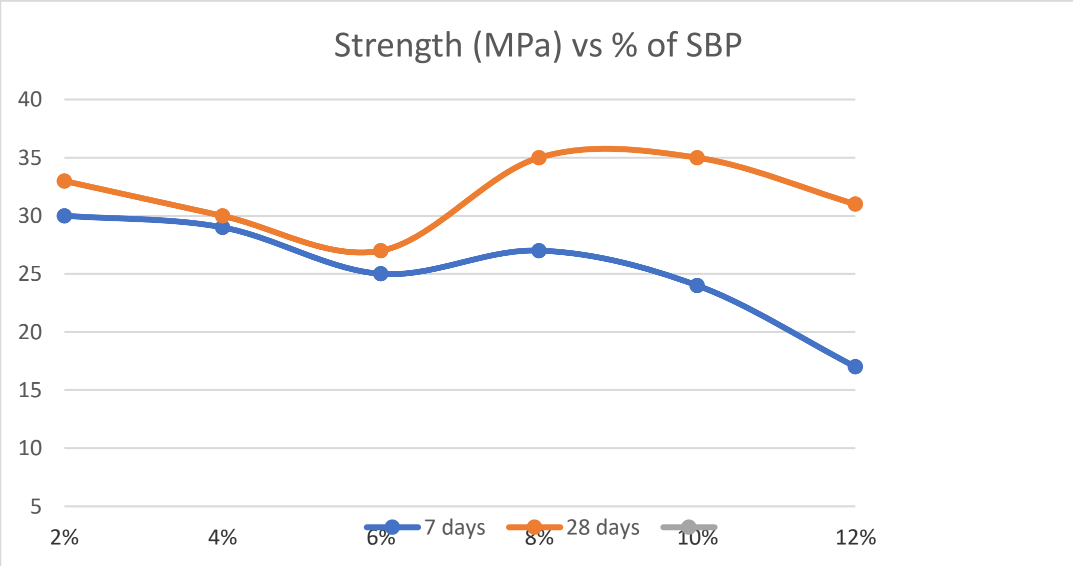
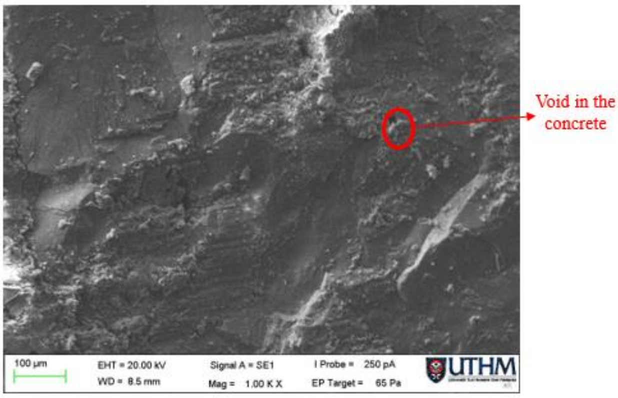
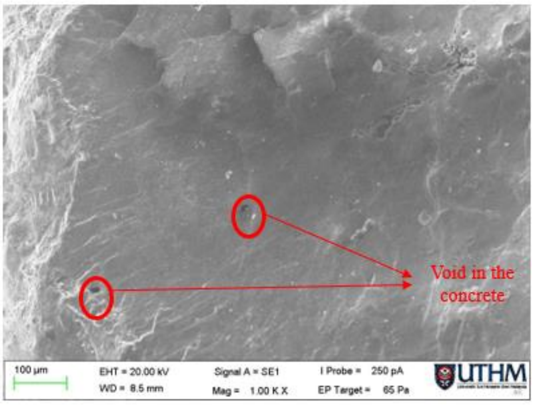


Fig. 7 *Strength (MPa) in 7- and 28-days vs % of SBP*

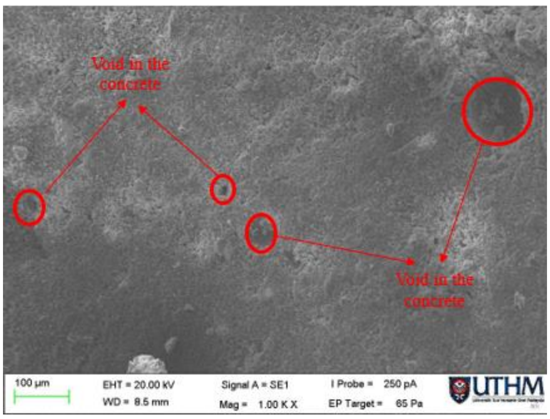
Fig. 8 shows the 1000x mag monograph of concrete structure in a different SBP proportion. Bright regions cold correspond components with high atomic numbers such as calcium, silicon, and metals. The brighter region appears due to the higher density or composition., (e) and (f) which is represent 8% and 10% of SBP is having a most stable topography condition. The presents of the high atomic composition such as calcium can make the concrete denser by minimizing the presence of void or pores within the concrete. Petrounias, et al. (2021) stated that the lower amount and smaller voids will make the concrete denser and increase the strength of the concrete.



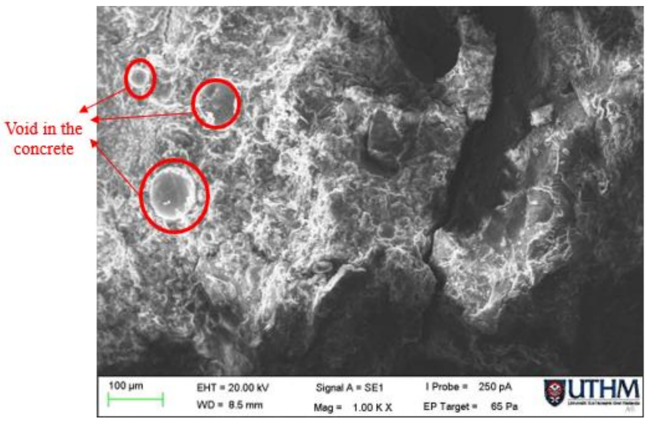
(a)



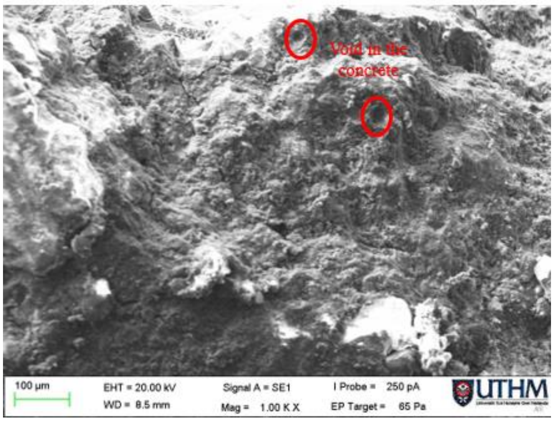
(b)



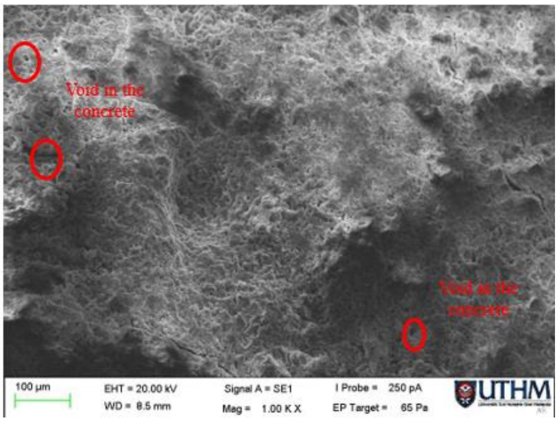
(c)



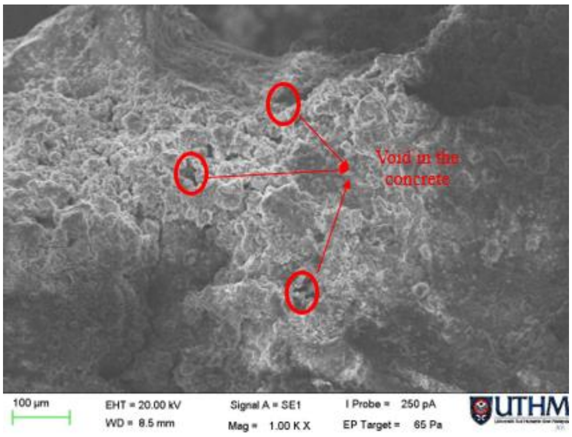
(d)



(e)



(f)



(g)

Fig. 8 *Particle monograph of concrete structure for: (a)0%, (b)2%, (c)4% (d)6% (e)8% (f)10% (g)12%*

Table 6 shows the different in term of percentage of the chemical content for SBP 0% and 8%. Based on the table, the Oxygen and Calcium content of the SBP 0% have a lower percentage compare with the SBP 8%. The difference shows that the hydration process for SBP 8% is faster than 0% SBP because of the reaction between the calcium and oxygen to will form calcium oxide which will accelerate on hydration process. However, the presents of carbon, silica, and ion (Fe) in SBP 8% is lessen than SBP 0%. The different between this chemical composition may effect on the strength of the concrete because of the element is help on giving a binder effect for the concrete. Teshome, et. al. (2019) the bone has a high calcium content, while the composition of other constituents such as Si, Fe, Al, and others are less in bone it was effects of the strength and quality of concrete.

Table 6 *Different of chemical composition for SBP 0% and 8%*

Element	SBP 0%	SBP 8%
	Percentage %	
O	36.91	37.59
Ca	27.5	47.08
C	17.58	4.53
Si	9.73	5.12
Fe	4.63	1.69
Al	2.58	1.48
Mg	0.59	0.34
S	0.48	0.47

Recent Trend in Civil Engineering and Built Environment Vol. 6 No. 1 (2025) p. 233-244

6. Conclusion and Recommendation

6.1 Conclusion

Bone is general consider as waste materials that have cause an environment impact as well as the production of the concrete. This study is to be conducted purposedly to reduce the impact by reuse the waste material into a new product. Based on the studies the conclusion was made:

- Result shows that the value of the slump decrease when the SBP proportion increase affecting the workability of the concrete.
- The strength of the concrete did not show increment for all proportion compare with the control sample.
- The optimum percentage of SBP as partial cement replacement is 8%. with 35MPa strength and favourable topography conditions.
- There is a similarity of the chemical composition of SBP concrete and normal concrete.
- Study reflects the possibility of using SBP as partial cement replacement of cement in concrete if there any other pozzolanic materials as admixture to enhance the quantity of silicate to form Calcium Silicate Hydrate C-H-S.
- Generally, SBP do not suitable to be the cement replacement without any other addictive materials to stabilize the chemical compound to give a better effect towards hydration and binder for the concrete. It is because, the SBP is only give a positive impact toward the hydration process without giving an essential binding characteristics of cement. This has been proven by the increment of SBP proportion, the binder effect on the concrete is decrease which subsequently reduce the concrete performance.

6.2 Recommendation

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

- Adding another admixture materials that have high silica content such a pozzolanic material such as metakaolin (optimum content is 10-25% of the cementitious content).
- Conduct a high early strength of the concrete for Self-Compacting Concrete.
- Add more testing for better understanding for the evolution of the SBP properties over time such as permeability test and water absorption test.

Acknowledgement

We would like to express our sincere gratitude to staff of Faculty of Civil Engineering and Built Environment and those who have contributed to the completion of this study. We would also like to thank reviewers of the paper which have helped improve quality of the paper

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Nuradila Lile, Norfaniza;* ***data collection:*** *Nuradila Lile;* ***analysis and interpretation of results:*** *Nuradila Lile, Norfaniza;* ***draft manuscript preparation:*** *Nuradila Lile. All authors reviewed the results and approved the final version of the manuscript*

References

Akinyele, J. O. (2016). The effect of partial replacement of cement with bone ash and . Annals of the Faculty of Engineering Hunedoara, , 14(4).

Al Tawaiha, H. A. (2023). A Review of the Effect of Nano-Silica on the Mechanical and Durability Properties of Cementitious Composites. Infrastructures, 8(9), 132.

Dodson, V. H. (2013). Concrete admixtures. South Melbourne, Victoria 3205, .
Dodson, V. H. (2013). Concrete admixtures. Springer Science & Business Media.

Mehta, K. &. (2014). Concrete: microstructure, properties, and materials. University of California, Berkeley: Mc Graw Hill Education.

Mohammad., W. (2018). Mussel shells ash as a partial cement replacement in concrete mixture. Universiti Tun Hussein Onn Malaysia.

Mohd Ramli, M. (2023). The utilization of metacarpal bone of sheep (MBS) as partial cement replacement in concrete. Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia.

Nadia Nasser Rashid Al-Bahri, C. K.-H. (2017). A Feasibility Study on the Mechanical Properties of Concrete by Replacing Cement with Animal Bone Powder. Saudi Journal of Civil Engineering (SJCE): scholar's middle east publishers, 51-61.

Opeyemi, D. (2012). Suitability of replacement of cement with rice husk ash and bone powder in concrete structure. International Journal of Emerging Technology and Advanced Engineering, , 2 (9), 261-265.

Teychenné D C, F. R. (1975). Design of normal concrete mixes. London: UK: HM : Stationery Office.