Influence of Pulverized Cow Bone as Partial Replacement of Cement and Demolished Concrete as Full Fine Aggregates on Properties of Foam Concrete

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Abstract. Cement is partially replaced by cow bone powder, and demolished concrete is used as fine aggregates in manufacturing foam concrete. Cow bone powder is a waste product with a high calcium content that may be used as a partial substitute for cement, and fine demolished concrete particles may be used to act as fine aggregates in foam concrete. Cow Bone powder is replaced in cement at 18%, 20%, and 25%. The study aims to determine the performance of the cow bone powder and demolished concrete mixture foam concrete compared to conventional foam concrete in terms of compressive strength, air voids, and fire resistance test. Comparing foam concrete with cow bone to ordinary foam concrete, the compressive strength of the foam rose at 18% and 20% replacement. However, foam concrete's compressive strength dropped at 25% replacement of cow bone powder. The results show that cow bone powder significantly affects the foam concrete's compressive strength. Additionally, since destroyed concrete wastes and a tiny amount of cow bone is fully utilized, the samples can receive more air, making this material perfect for lightweight partitioning. Pulverized Cow Bone as a partial replacement of cement and Demolished Concrete Waste does not influence the fire resistance of the samples. This study is limited to concrete walls but can serve as a reference for future researchers interested in developing durable concrete materials.

1 Introduction

Concrete is an essential composite engineering material in building and construction because it has become the premier, most favored, and most versatile among all construction materials. It has an annual output of more than 10 billion tons. It is favored for its durability, fire resistance, water impermeability, cost efficiency, energy efficiency, and ability to be manufactured on-site [1]. It is composed mainly of aggregate, water, and cement, as well as a filler and a binder. Cement is a crucial component in concrete manufacturing [2]. Cement is the costliest raw material used in concrete. It is a hydraulic binder grinding a combination of natural limestone and clay following high-temperature treatment. However, cement manufacturing and production cause severe environmental damage since cement

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manufacturing is a great producer of carbon dioxide (CO2) among all industrial CO2 emissions. A significant amount of non-renewable natural resources is required to produce cement, which leads to the depletion of non-renewable resources and causes serious environmental concerns [3]. Environmental contamination worsens when the population grows owing to waste creation and unrestricted usage of basic materials [2]. Industrial and agricultural waste is also becoming a health and environmental problem, especially in developing nations where technology for efficient waste disposal is lacking. Studies have shown that these wastes can be processed and used as partial replacements for cement. Reusing these wastes will help cleanse the environment and reduce the volume of cement being used.

Foam Concrete (FC) is a practical building material that combines thermal insulation and structural qualities well [4][5]. The increased interest in foam concrete is due to its high thermal isolation performance, capacity to dispose of diverse waste, and other vital properties [6][7]; according to research done by Kado et al., [8] foam concrete is an aerated lightweight concrete made by combining cement, sand, and water to make cement paste, which is then combined with preformed stable foam generated by a foam generator. Foam concrete may be created with any density between 300 and 1850 kg/m^3 dry density. It can be used for heat and sound isolation, flame protection, and blast viscosity; however, the low mechanical and physical properties of Foam Concrete significantly restrict the scope of its application in concrete structures, and it has a factor of magnitude lower tensile strength than its compressive strength [5]. Bone is a high calcium content waste extracted from slaughtered animals (oxen and cows). Calcium oxide, on the other hand, accounts for 60% to 67% of Portland cement. It suggests that bone waste can partially replace cement [9].

Using pulverized cow bone in civil engineering construction has numerous environmental benefits. It decreases landfill trash, pollution, and energy demand while stimulating the economy and reducing cement imports [10]. Pulverized cow bone is an inorganic material obtained from cow bones, dried outside at an average temperature of 30°C for 48 hours, and ground to fine powder utilizing a processing machine [11]. Fapohunda et al. [12] cited in their study that recent works have shown the suitability of incorporating pulverized bone as a replacement for cement in producing foam concrete. Using this cow bone ash as a partial replacement of cement in concrete creation will upgrade managerial advancement of the environment. Compared with Portland cement, the expense of cow bone ash is lower because of the accessibility of cow bones in massive amounts [9]. Using large amounts of natural resources for producing construction materials such as cement has been an issue in sustainability for the past years. The depletion of our natural resources and the demand for construction materials such as aggregates has been increasing; thus, we must look for or address this problem efficiently [13]. Concrete manufacturing, construction, and demolition waste creation are significant sources of continuous CO2 emissions into the atmosphere [14]. Innovative eco-efficient concrete was created and described to decrease the environmental effect of building and demolition waste, natural aggregate extraction, and Portland cement CO2 emissions [15][16].

The study's general objective is to utilize cow bone powder (pulverized bone) and demolished concrete and develop it as an alternative concrete mixture material for construction-related works. The study specifically aims to test the physical & and mechanical properties of the material in comparison to conventional foam concrete in terms of air content, compressive strength, and fire resistance test.

The study will be beneficial in improving foam concrete's physical and mechanical properties. Additionally, the by-product that will be produced will be an alternative to conventional foam concrete using raw materials. Finally, the study can be used as a reference for future researchers interested in developing durable concrete materials.

The researchers intend to focus only on assessing the suitability of a newly developed concrete mixture. The study is limited only to applying the concrete mixture to concrete walls.

2 Materials and methods

2.1 Research materials

The cow bones were gathered in local restaurants in Davao City. Demolished concrete as aggregates were collected from a demolished building in Brgy. Bucana, Davao City. The foaming agent (Amide 90) Coconut oil diethanolamine condensate was obtained, and ASTM Type 1 Cement was used.

2.2 Research procedure

The cow bones were separated from the muscles, flesh, tissues, intestines, and lipids, washed, and sun-dried for 48 hours at an average temperature of 30 degrees Celsius [11]. The indication of entirely dried-up cow bone is when the removable waste of the cow bone would be readily removed. In preparation for sieving, the dried cow bones were treated and crushed using a grinder, and the ASTM C702-87 quartering procedure was followed [17]. ASTM C136 [18] was utilized for sieving, and the fraction that went through a sieve with a mesh size of 150 µm was then packed in bags and stored in a cool area [19]. The demolished concrete wastes were crushed ASTM C136 and sieved as per ASTM C702-87 [18]. The demolition waste passed through less than 2mm as a sand fraction from the sieve were used as fine sand aggregatse to make foam concrete.

2.2.1 Mixing process

In a mixing container, Portland Cement Type I, fine demolished concrete particles, cement, and cow bone powder were combined following proportions indicated in Table 1. Table 1 shows five (5) different compositions. All five had a constant amount of foaming agent, which was 90 grams, and had ten samples each. CV1 and CV2 were the conventional mixtures, while T1, T2 and T3 were the experimental ones. The water-cement ratio used was found to be 0.58.

Table 1. Mixing Composition

Variables	%	Cement	Natural Sand	Foaming Agent	Water	CB	CDW
CV1	0	500g	250g	90g	290g	0	0

CV2	0	500g	0	90g	290g	0	250g
T1	18	410g	0	90g	290g	90g	250g
T2	20	400g	0	90g	290g	100g	250g
T3	25	375g	0	90g	290g	125g	250g

Water was gradually added to mix the dry ingredients. The water-to-cement ratio should be adjusted to achieve the desired consistency. Meanwhile, the foaming agent was prepared following the manufacturer's instructions for the foaming agent used. The foaming agent must be diluted with water to create a foaming solution. The foam was then generated using the foam machine. As the foam was generated, it was introduced into the concrete mixture. The foam would expand and incorporate into the concrete, creating a lightweight foam mixture. The foam injection rate could be adjusted to achieve the desired density of the foam concrete. Concrete and foam were mixed thoroughly until the foam was evenly distributed throughout. This can be done using a concrete mixer or by hand with a shovel. Then, the mixture was cast into a 150 by 300 mm [6 by 12 in.] cylinder mold; this must be done immediately after mixing, as foam concrete could set relatively quickly. Finally, the foam concrete was covered with plastic sheeting or wet burlap to ensure proper strength development and kept moist for 14 days of curing. This helps prevent cracking and improves the overall quality of the concrete.

2.2.2 Testing methods

The following testing procedures were conducted in this study: Air Content Test, Compressive Strength Test, and Fire-Resistance Test. The Air Content Test is an essential procedure in concrete quality control and is typically conducted to determine the percentage of air voids in fresh concrete. This test helps ensure that the concrete mix has the desired amount of entrained air, which is crucial for freeze-thaw resistance and durability, especially in cold climates. The air content is typically expressed as a percentage of the total volume of the concrete. Air content is given by the formula:

$$AC (\%) = [(P - Ps) / (Pc - Ps)] \times 100 \quad (1)$$

Where:

P is the pressure gauge reading (in psi) from the air content test.
Ps is the pressure at zero air content (typically the pressure gauge reading when the calibration flask is filled with water and connected to the apparatus).
Pc is the pressure at full air content (typically the pressure gauge reading when the mold is pressurized without concrete)

The foam concrete mixture was filled into 150 by 300-mm [6 by 12-in.] cylinders per Test Method C495 [24] for the compressive strength test. This is determined by determining the highest load sustained divided by the cross-sectional area of the sample [22]. Fire resistance properties of the samples were determined by weighing and placing them on a surface, open-fired for one hour at a controlled temperature at stable fire conditions. Once the samples cooled down, samples were weighed, and the weight loss of each experimental mixed proportion was determined. Finally, experimental foam concrete testing results will be compared to conventional foam concrete testing method results.

3 Results and discussion

3.1 Air content

Fig. 1. illustrates the air content per composition. Among the test batches, T1 has the most air content in Foam Concrete production at full replacement of natural sand in the mixture. Foam concrete typically contains more air when demolished concrete aggregates are used, as concrete aggregates often contain a significant amount of porosity and voids due to the presence of old mortar and the fracture patterns resulting from the demolition process. When these porous wastes are incorporated into a new concrete mix, they can trap air within their voids, increasing air content in the fresh concrete. However, increasing the partial replacement of Cow Bone Powder into the mixture significantly reduces the presence of air as these are denser and less porous than traditional lightweight aggregates like expanded clay or shale. When cow bone powder is used as a replacement for these lightweight aggregates, it typically reduces the overall air content of the foam concrete. The bone powder does not contribute as many air voids or lightweight properties as the traditional aggregates.

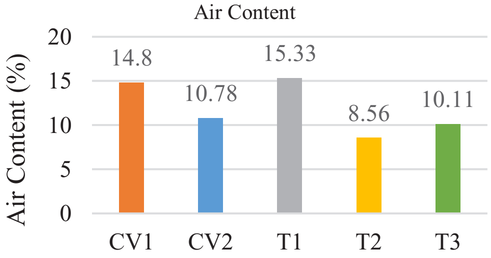


Fig. 1. Air Content of foam concrete mixtures

3.2 Compressive strength

Fig. 2. shows the mean values of compressive strength of foamed concrete production from different ratios. It determines the compressive strength from the CV1 to the three experimental ratios. It can be observed that CV1 and CV2 have vast differences in terms of compressive strength. The addition of demolished concrete in the foam concrete production resulted in having the capacity to withstand more compressive strength than the natural fine sand as aggregate [26]. Furthermore, the addition of pulverized cow bone in the foam concrete has an upward trend that starts at T1 and peaks at T2. Due to its high calcium content and without compromising strength, pulverized bone could partially replace cement [9][12]. However, at 25% of cow bone replacement, the compressive strength of the foam concrete decreases.

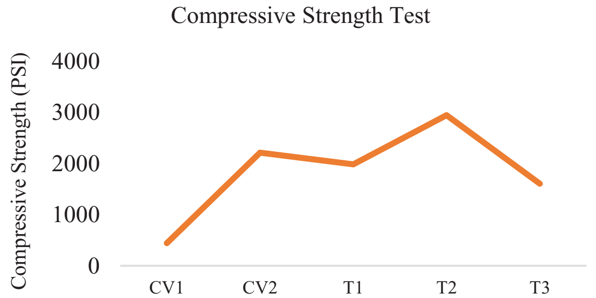
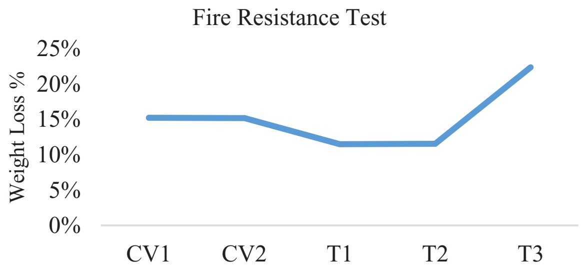


Fig. 2. Compressive Strength of foam concrete mixtures

3.3 Fire-Resistance Test

Fig. 3 illustrates the mean weight loss of CV1, CV2, and experimental ratios. However, the mean weight loss of CV1 is 15.21%, and CV2 is 15.16%. T1 has a mean weight loss of 11.47%, T2 has a mean weight loss of 11.52%, and T3 has a mean weight loss of 22.33%. Although T3 has a more significant mean weight loss than CV1, it still shows no significant changes in the mixture. Fire-resistance tests are essential to foam concrete because they help determine the foam concrete's ability to withstand fire or provide protection against fire. Although T3 has a more significant mean weight loss than CV1, it shows no significant difference with or without adding cow bone and utilization of demolished concrete as fine aggregates.



4 Conclusion

Based on the results, pulverized Cow Bone and Demolition Concrete Waste have a significant effect if used as an alternative for Foam Concrete production, especially in compressive strength. The compressive strength of foam concrete has increased with an 18% and 20% replacement of cow bone to cement compared to conventional foam concrete, especially since it also used demolished concrete waste, contributing more to the strength gain. However, at 25% of cow bone replacement, the compressive strength of the foam concrete decreases due to the reduced amount of cement. Moreover, the full utilization of demolished concrete wastes and a small percentage of cow bone allows better air entry into the samples, making it ideal for lightweight partition purposes. Finally, fire resistance among samples do not significantly differ from one another.

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