Optimization of Cuttlefish Bone Towards Compressive Strength of Foam Concrete

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Abstract. Development and testing of other foam concrete materials, as well as the inclusion of a marine-based filler, cuttlefish bone powder, may be one of the most advanced products suitable for cementitious materials to be added in concrete to provide a sustainable environmentally friendly alternative solution on construction industry in Malaysia. Cuttlefish bone will have some advantages and benefits in foam concrete since it contains high amounts of calcium carbonate, which is believed can improve the concrete's strength and encourage foam concrete to achieve an early strength. The objectives of this research is to determine the optimum percentage of cuttlefish bone additive towards increasing the strength properties of foam concrete. In this research, there were 42 foam concrete cube samples prepared, each group of samples containing different amounts of cuttlefish bone additive (1%, 2%, 3%, and 4%). All the samples were tested for compressive strength at 1, 3, and 7 days of age. According to the findings, an improvement in the foam concrete when the cuttlefish bone additive content from 1% to 4% added which result in the enhancement of the behavior of foam concrete. In addition, this research reveals that cuttlefish bone additive has better characteristics to normal OPC, making it an effective addition to concrete.

1. Introduction

Lightweight concrete, also known as foam concrete, is a form of aerated concrete that has been identified as a special precast product application and has been used in a modern world since nearly a century to provide a decent environmental sustainability system. Foam concrete is now recognized as a new revolutionary material for sustainable building and civil construction that satisfies many of the criteria for a sustainable project construction [1]. Concrete has been commonly used as a major building material for nearly a century. Concrete has undergone numerous improvements and modifications in order to improve its performance, especially in terms of strength and toughness. The latest application of foaming agents into concrete mixtures seems to be a success. The use of a foaming agent produced from palm oil protein in concrete was seen to be one of the most successful methods for producing lightweight concrete of high strength, toughness, and durability [1].

According to [2] study, potential building demand in developing countries like Malaysia necessitates the use of light, reliable, convenient, cost-effective, and environmentally friendly materials. Since concrete is used as a primary component in almost every building and structure, the demand for concrete is increasing by the day. Instead of relying solely on ordinary portland cement to improve the strength of concrete, an innovation to incorporate more environmentally sustainable materials into the mix is needed to minimize reliance on portland cement. Another demand in the building industry is the short time it takes to construct and complete a building, which has inspired an engineer to invent a solution to speed up the concrete hardening process, which takes 28 days to meet the ultimate tensile point [2].

The current issue is that any construction process today intends to achieve the standard of concrete hardness in a relatively short time that takes for regular concrete to harden. As a result, engineers must consider what components should be applied and how they should be used to reduce the time it takes for concrete to harden. Concerns
Concrete has a density ranging from 400 kg/m³ to 1800 kg/m³, with a strength of up to 12 MPa. Possible cementitious material to be introduced in a concrete to have environmentally friendly results [6]. Foam concrete, along with agriculturally based materials such as fly ash, rice husk, superplasticizer, pozzolans, and others, is used to make lightweight concrete. Improvement and testing of foam concrete resources, such as cuttlefish bone, may be one of an innovative way and a better outcome as a possible cementitious material to be introduced in a concrete to be have environmentally friendly results [6]. Foam concrete has a density ranging from 400 kg/m³ to 1800 kg/m³, with a strength of up to 12 MPa.

In Malaysia’s building industry, the use of cuttlefish bone in foam concrete is relatively new. This study would contribute to a better understanding of the suitability and performance of cuttlefish bone powder as a foam concrete additive. Typically, the used of foam concrete for infrastructure projects development are rapidly increase. It has become a suitable choice because of its lightweight and thermal insulation properties, and it is also widely used in the construction of houses, particularly for the construction of walls and columns. Aside from that, this kind of concrete is also ideal for maintenance work. In addition to understanding the high demand in the building industry for high-strength concrete to withstand higher loads, this foam concrete can offer a lightweight concrete of greater strength and durability. Cuttlefish bone is a good material to use in foam concrete because it has a high calcium carbonate content, which is thought to improve the early strength of the concrete. There are four percentages of cuttlefish bone additive will be conducted with the different amount densities of foam concrete to determine the suitable cuttlefish bone percentage and foam concrete density for producing strong concrete strength.

2. Literature Review

Ordinary concrete with natural aggregate has a high density, ranging from 2200 kg/m³ to 2260 kg/m³. It also adds a significant portion of the dead load on building structures due to its high density. The density of lightweight foam concrete is usually in the region of 2000 kg/m³ or less; if it is higher, it is known as ordinary concrete [4]. Lightweight foam concrete is an aerated concrete form that uses various methods and agents to create air voids in the concrete. Air entraining, chemical gas formation, or protein foaming may all be used to create foam concrete. Lightweight foam concrete is a kind of aerated concrete that is made with foaming agents. Synthetic or protein bases foaming agents may be used [4].

2.1 Cuttlefish Bone

Cuttlefish is well-known for its numerous unique applications in food, science, fisheries processing, and consumer demand. Cuttlefish bone is a bone made up of calcium phosphate, phosphorus, and usually hydroxyl apatite. Cuttlefish bone is a type of marine life creature that lacks a shell and belongs to the Cephalopodan subclass. Cuttlefish bone was chosen as a marine life additive because of its higher calcium content, which is thought to improve the early strength of concrete. A previous research was performed to determine the components of cuttlefish bone, and they discovered that calcium carbonate made up 85% of the cuttlefish bone components [6]. Cuttlefish commercial services, on the other hand, are currently in high demand due to their value in human consumption and medical and biological science models. Numerous waste material products were used as an admixture material to improve the mechanical properties of concrete in this modern age of globalization. Fly ash, rice husk ash, coconut shell and husk are examples of agricultural materials, while seashells, eggshells, fish bone, and cuttlefish bone are examples of marine materials.
Apart from serving as an admixture or a mortar substitute, partial substitution of coarse and fine aggregates has been a hot subject of science [7]. Furthermore, using cuttlefish bones as one of the marine waste material materials will help to increase the strength and water absorbing capacity of foam concrete.

2.2 Cuttlefish Bone Composition and Physical Structure
Cuttlefish bone is more than just a skeleton; it is also abundant in calcium phosphate, phosphorus, and hydroxyapatite (Figure 1). Cuttlefish bone, which belongs to the Cephalopods class and the Sepiida family, contains approximately 85% calcium carbonate [6].

![Sample of Cuttlefish Bone](image1)

Figure 1. Sample of Cuttlefish Bone

2.3 Cuttlefish Bone Calcination and Grinding Process
Cuttlefish bone is based marine product that consist a high calcium and can be utilized for a variety of uses when treated properly. Calcium carbonate (CaCO3) can gradually turn to calcium oxide (CaO) as bones are calcined at the correct temperature. According to [6] calcined shells at the proper temperature facilitate the conversion of calcium oxide, CaO, from CaCO3.

![Cuttlefish Bone Powder After Grinder](image2)

Figure 2. Cuttlefish Bone Powder After Grinder

2.4 Foam Concrete Mixture and Composition
The foam concrete mix design used in this study is mix of cuttlefish bone, sand, clay, water, and pre-formed foam that conducted under precaution. Ordinary Portland cement, sand, and fine fly ash with a density of 960 kg/m³ were used for this research. Foaming agent was used to make the rubber, and water was used to make the foam concrete. Foam is a critical component of foam concrete, and it has been created with the help of a foam generator with a 30-32 lit/min output [8]. Then, to make the foam, a palm oil-based foaming agent (protein) was used, which was mixed with water in a 1:33 ratio and then aerated to a density of 74 kg/m³.

3. Research Methodology
This analysis provided a total of 42 foam concrete cube samples. Six (6) cubes of control foam concrete with a density of 900 kg/m³ and six (6) cubes of control foam concrete with a density of 1800 kg/m³ containing no additives and only a combination of clay, sand, foam, and water. There are 24 cubes with differing cuttlefish bone
adds (1, 2, 3, and 4%) were prepared for an 1800 kg/m³ concrete density. Only 6 cubes were made for the 900 kg/m³ concrete mass, with just 2% cuttlefish bone applied to the mixture. All of these samples were put into a compression test to determine the best combination of cuttlefish bone additive and foam concrete compressive power.

3.1 Concrete Mix Design of Foam Concrete
After curing, foam concrete absorbs between 50 kg/m³ and 200 kg/m³ of the overall mix, making it impossible to obtain the desired real gravity. A mix design was determined by conducting several trials to achieve a target plastic density, and the results of the trials were used to create the foam concrete mix design. As a plastic density resistance, an additional 100 kg/m³ of target plastic density is applied.

4. Analysis of Compressive Strength
The properties of foam concrete which is compressive strength data with densities of foam concrete of 900 kg/m³ and 1800 kg/m³ with 1 percent, 2 percent, 3 percent, and 4 percent cuttlefish bone added will be outlined in this part. Both foam density and OPC, foam concrete with and without cuttlefish bone inclusion, will be compared. To get an estimate of the compressive strength analysis, a total of 6 cubes measuring 100 x 100 x 100 mm were cast for each specimen. Two cubes were examined on each of the three days after curing: 1, 3, and 7. Table 1 shows the outcome of the average compressive strength test. The optimal percentage for cuttlefish bone inclusion is 2 percent, according to the average compressive strength findings from foam concrete density of 1800 kg/m³. As a result, only 2% cuttlefish bone additive was applied to a mixture for foam concrete density.

| Specimen/ Density = 1800 kg/m³ | 1 days | 3 days | 7 days |
|-------------------------------|--------|--------|--------|
| 0% (Control)                 | 7.350  | 12.19  | 14.55  |
| 1%                           | 10.355 | 12.50  | 15.74  |
| 2%                           | 10.725 | 13.915 | 18.315 |
| 3%                           | 9.910  | 12.000 | 14.245 |
| 4%                           | 7.593  | 11.325 | 13.440 |

| Specimen/ Density = 900 kg/m³ | 1 days | 3 days | 7 days |
|-------------------------------|--------|--------|--------|
| 0% (Control)                 | 0      | 0.657  | 0.789  |
| 2%                           | 0      | 0.945  | 1.104  |

Figure 3. Compressive Strength Graph for 1800 kg/m³ Foam Concrete
Figures 3 and Figure 4 show that the compressive strength of foam concrete improved as the percentage of cuttlefish bone applied increased with both stiffness and density of foam concrete. On 7 days, the density of foam concrete tends to achieve more strength concrete. The findings of 2% cuttlefish bone applied to the mixture for a density of 1800 kg/m$^3$ tend to be correlated with a previous study that observed 16.0 Mpa compressive strength of foam concrete without any additive after 28 days. This shows that by applying just 2% cuttlefish bone to foam concrete and curing it for 7 days, the strength can be obtained. According to research [4] high early strength of foam concrete can be obtained using rapid hardening cement. Within 28 days, foam concrete had reached a strength of 16.0 Mpa thanks to the use of rapid hardening cement.

The findings do not seem to be consistent with previous studies, and the required early intensity was not reached within 7 days after adding 2% cuttlefish bone for a density of 900 kg/m$^3$. According to the findings of [4], the strength of foam concrete obtained for 28 days of curing process is 5.5 Mpa, while in this study, the compressive strength is 1.104 Mpa. This study found that adding cuttlefish bone additive to a foam concrete give significant impact on achieving an early strength in low density foam concrete.

According to the strength analysis graph, 1 percent of cuttlefish bone added increases the early strength of concrete, but the optimum level of additive is 2 percent for foam concrete to attain a desirable early strength. The compressive intensity of the mixture is reduced when 3%, 4%, or more cuttlefish bone additive is added into the foam concrete mixture. Unfortunately, analysis from this research found that, by added the recommended percentage of 2% cuttlefish bone additive into the foam concrete seems would become less consistent and reliable to increase the early strength of foam concrete density of 900 kg/m$^3$. After 7 days, there are just a few differences in specimen strength between control and 900 kg/m$^3$ specimens which are 1.104 Mpa and 0.789 Mpa. Besides that, it was found that adding 2% cuttlefish bone to low-density concrete was ineffective.

The greater or weaker bond between the additive and the mixture is one of the key reasons why the additive is useful in 1800 kg/m$^3$ specimens but not in 900 kg/m$^3$ specimens. The amount of foam used in the mixture with the 1800 kg/m$^3$ density is less than the amount of foam used in the 900 kg/m$^3$ specimen. Since there are less pores of foam concrete after drying and the physical condition is more compact and harder, its cause the bonding between the addition of additive and the mixture in the 1800 kg/m$^3$ specimen is increase and greater. The physical condition of the 900 kg/m$^3$ specimen is porous after curing process, and the several pores form, resulting in less reaction and weaker bonding between the additive and the concrete mixture.

5. Conclusion
The optimum amount of cuttlefish bone additive use in this study can improve the early compressive strength of foam concrete mixture at 3 days and 7 days, according to the results and interpretation obtained in this study. According to the findings, when 2% cuttlefish bone additive is added into 1800 kg/m$^3$ density of foam concrete specimens, the compressive strength is higher than normal foam concrete mixture. Usually, normal foam concrete mixture was curing for 28 days, while when added additive into foam concrete mixture, it was only 7 days of curing process. It’s obviously shows that by adding 2% cuttlefish bone additive into 1800 kg/m$^3$ foam concrete mixture will improve the strength at early age of foam concrete mixture. Unfortunately, where 3% to 4% of cuttlefish bone is
added, the compressive strength of foam concrete seems to be reduced. As a result of this research, the optimum amount of cuttlefish bone additive needed to enhance early strength of foam concrete mixture is 2%. An excessive amount of the cuttlefish bone additive added into the foam concrete mixture for both densities will reduce the strength of foam concrete mixture.

Besides that, the compressive strength of 900 kg/m³ foam concrete specimens seems to be increasing. Despite 7 days of curing, the compressive strength is only 5 times weaker than the previous study's findings. Furthermore, we can conclude that the cuttlefish bone additive is only effective for concrete with a density of 1600 kg/m³ or higher. This would be less effective for foam concrete with a lower density and there will be less cement in the mix proportion with a lower density concrete. Low cement ratio is needed to produce a good concrete with a lower density and as less cement is used, the reaction between calcium carbonate inside a cuttlefish bone with the cement is weak, therefore resulting in lower strength of foam concrete mixture.

6. References

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