International Journal of Engineering & Technology, 7 (4.35) (2018) 516-520

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Compressive Strength of Vege-Grout Bricks

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Abstract

Brick is one of largest material used in construction of infrastructure all over the world. A conventional bricks such as clay brick and concrete brick are produced from clay with high temperature kiln firing and from ordinary Portland cement (OPC) concrete respectively. Both of this activities lead to CO_2 emission. The burning process requires high temperature at the same time release carbon dioxide and pollute the environment. At present, carbon emissions has become a crucial issues in the society that must be solved. Several studies had demonstrated that brick can be produced from bacteria based on Microbial Induced Calcite Precipitation (MICP). The objective of this study is to develop cement free- brick from vegetables waste with added eggshell as calcium additive to induce biocementation of brick. Brick specimen was cast in the mould size 210 x 90 x 65 mm and casting for 28 days. The study showed that there was an increased in compressive strength up to 0.062 N/mm^2 as the curing period increased to 28 days which showed the occurrence of biocementation activities. SEM-EDX analysis confirmed the presence of calcite precipitation. The result indicated that vege-grout can be used as binding agent for biocementation to produce bricks.

Keywords: *biocementation; brick ; compressive strength; eggshells;* vege-grout

1. Introduction

Brick is one of largest material used in construction of infrastructure all over the world [1] . As a developed country, Malaysia also experience rapid urbanization. Construction industry consumes a large amount of materials from non- renewable resources such as concrete and cement [2-3] . Most of this materials contributes CO_2 emission to the surrounding. There are many different methods in producing the bricks that indirectly attracted researchers to do more detailed study on it. A conventional bricks such as clay brick and concrete brick are produced from clay with high temperature kiln firing and from Ordinary Portland cement (OPC) concrete respectively [4-5] . Current methods have thing in common where it produced CO_2 emission or carbon footprint. According to [6] the production of one ton of cement commonly results in the release of 0.65 to 0.95 tons of CO_2 depending on the efficiency of the process, fuels used, and specific type of cement product. At present, carbon emissions has become an urgent problem of the human society that should be solved.

Grout is a binding material that usually used as a filling in the crack of building. However, chemical grout substance grouts based on acrylamides, lignosulfonates, and polyurethane are toxic and environmentally harmful [7]. In the past few year, a novel technology of grouting had been successfully developed using bacteria for grouting [8- 9]. This application using the biotechnological activity of microorganism is known as bio-grout. Most studies on bio-grout development were predominantly based on microbial induced calcite precipitation (MICP) [10-13] .This method have been utilized widely used in the geotechnical area for soil and ground improvement.

A study by [12] shows that *Bacillus Pasteurii* and *Bacillus Subtilis* were discovered in the fermented vegetable waste called vege-grout. The micaceous soil was mixed with different percentage of vege-grout classified as 15.0%, 17.5%, 20.0% and 22.5% respectively and pressed into brick mould. The sample was tested after 7, 14, 21, 28 and 35 days of curing time. The result showed that 20.0% of vege-grout mixture gives the highest strength during 21 days of curing and improved the permeability of soil. This happened due to the bio cementation process induced by ureolytic of microorganisms in the vege-grout.

Calcium carbonate ($CaCO_3$) is one of the important minerals deposited by the bacteria through the phenomenon called bio cementation. It is a an eco-friendly treatment technique which used the application of microbial technology to enhance the geotechnical features of sub- standard soils [13]. Such deposits have recently emerged as promising binders for protecting and consolidating various building materials [14]. The bio cementation process involves the introduction of bacteria and nutrients to sand through process of calcite precipitation that binds soil particles together, ultimately creating a sandstone material [15]. The presence of calcium mineralization will be confirm by Scanning Electron Micrograph (SEM), Energy Dispersive X-Ray (EDX) or X-ray Diffraction (XRD) analysis [16-17].

Previous studies had used the MICP concept to construct new building materials such as bricks. Recently, "Bio Mason brick was developed using sand, bacteria and urease enzyme and technology has been commercialized [18]. The present research is aimed to develop cement free-brick from vege-grout as a source of bacterial growth and nutrient media. Eggshells will be used as calcium supplement for biocementation process. One study has demonstrated that eggshell can be used as an alternative of calcium chloride to induced biocementation and increased unconfined strength [19].

2. Materials and Test Method

2.1 Sample Preparation from Vegetable Wastes

In this research, the micro-bacteria from agriculture waste were obtained from the fermentation process of vegetables. About 4 types of vegetables used which is cabbage, long bean, spinach and cucumber. These vegetables is identified to have minerals such as silica, ferum and calcium which can be used to stabilize the soil.
Approximately about 10kgs of each types of vegetable used. These vegetables were selected as its universal availability and most common vegetables in Malaysia. All vegetables was washed and cut before put into the container to prevent any contaminant bacteria from outside (Figure 1). The container completely seal with plastic wrapping around during the fermentation period because the fermentation process only can be done in the absent of the oxygen. It took about one month period time for the fermentation process before can be used for further experiment. The container were put in the control room temperature. After a month, the vegetables waste was filter to get the liquids. All the liquid was filter and placed in one container and the pH value were monitor every day called mother liquor.
Ammonia test also been carry out to test the level of ammonia presence in the bio-grout. 5mL of vege-grout was taken and put into the test tube before added with a few drop of ammonia test solution. After that the mixture was shake vigorously for 10 sec and the colour of mixture changed. Based on the testing, its shows that the ammonia level in the vege-grout is about 0.5-1.0 ppm (mg/L) which is consider safe for the surrounding (Figure 2).

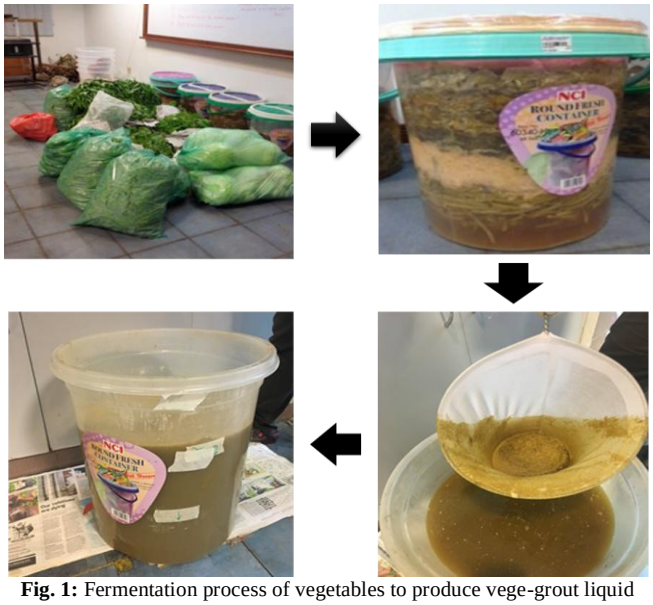
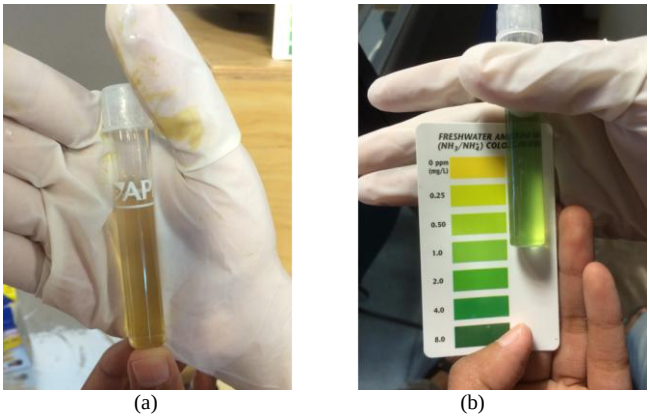


Fig. 1: Fermentation process of vegetables to produce vege-grout liquid



(a) (b)

Fig. 2: (a) Before added with the solution and shake (b) After shaking with the solution

2.2 Eggshells

The eggshells are considered as waste material in the food industry because it is one of the main ingredients in food preparation. Eggshells is known rich in calcium carbonate and was used as stabilizing agent for concrete [20] .Choi et al [19] in his study used eggshell and vinegar as a substitute for sources of calcium and proved that soil treated with eggshell and vinegar give higher in strength rather than sample treated with calcium chloride. In this study the eggshells were collected from food stall in the nearby area. The eggshells were rinsed and sun dried for 2 day (Figure 3). After that, they were grounded using blender before sieved through the pan (Figure 4).

(a) (b)

Fig. 3: Eggshells was clean by using water before sundried for 2 days (a) before clean (b) clean eggshell

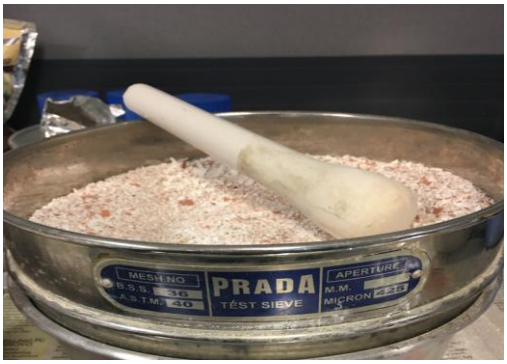


Fig. 4: Grinded eggshell filtered using sieving passing through 425µm pan

2.3 Preparation of Brick Sample

This brick was produced by the combination of sand, vege-grout and crushed eggshells. Eggshell contain higher calcium carbonate and it will be used as an additive to the brick mixture. Sand and eggshell was mixed well before adding vege-grout liquid (Figure 5). After mixing, the mixture was placed into the mould (210mm x 90mm x 65mm) and pressed to compact. All nine samples was curing in the mould for 7, 14 and 28 days. After taken out, the bricks has been sundried for 24 hours before compressive strength testing can be done. Figure 6 shows the vege-grout mixture in the brick mould and the brick after taken out from the mould.

Fig. 5: Hand mixing of soil with vege-grout

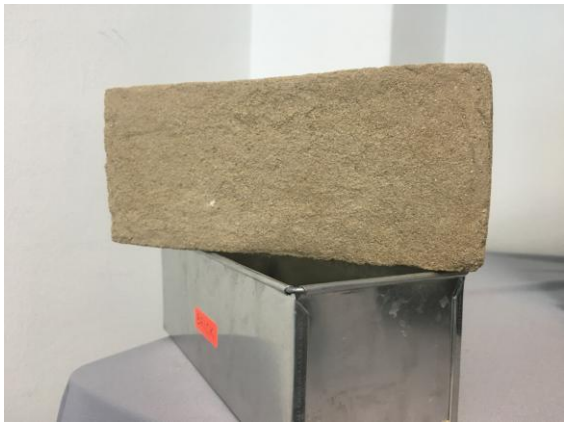


Fig. 6: Brick sample after 28 days

3. Results and Discussion

3.1. Micro Biological Analysis

Chemical test was conducted by using API Kit 20NE/20E (Figure 8) to identify the bacteria in the vege-grout. The objective of this test was to certify which bacteria is essentially aid to increase the strength of the soil. The procedure of the test was shown in Figure 7. The sample that was tested is 1 milliliter. This method only can be used to classify major bacteria live in the vege-grout.

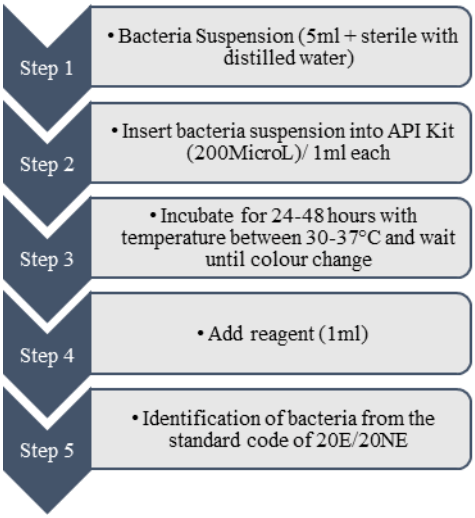


Fig. 7: API Kit 20E/20NE Process

Fig. 8: API Kit 20NE(-ve) / 20E (+ve) with reagents

Result showed several bacteria had been identified are Pseudomonas Aeruginosa, Clostridium Botulinum, Flav Meningoseptum, Vibrio Fluvialis and Campylobacter Jejuni. All bacteria found to have effect to increase the strength of soil except for Flav Meningoseptum, as the used of this bacteria is still unknown for the soil improvement.

3.2 SEM & EDX Analysis

The SEM analysis after the MICP process revealed distinct calcite formation as bacteria cells close in contact with calcite crystals were visible on the surface of the brick from vege-grout (Figure 9). The presence of calcium amounts was detected in EDX analysis that confirmed the existence of calcite in the form of calcium carbonate as shown Figure 10. The formation of calcite precipitation can be clearly observed at the surface of the bricks as shown in Figure 11.

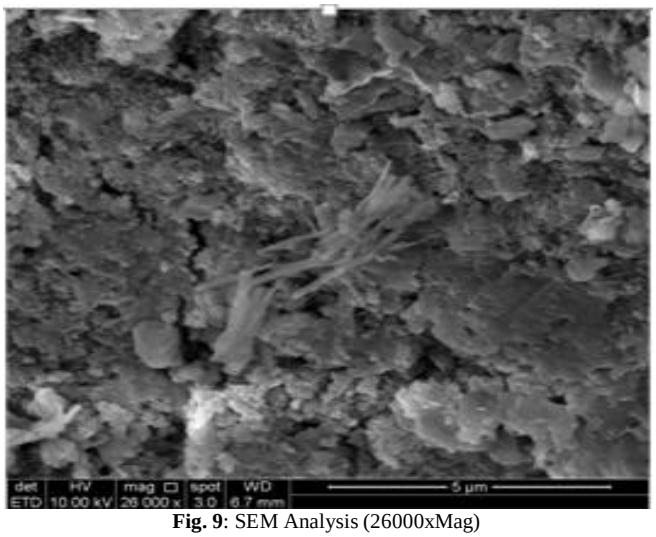


Fig. 9: SEM Analysis (26000xMag)

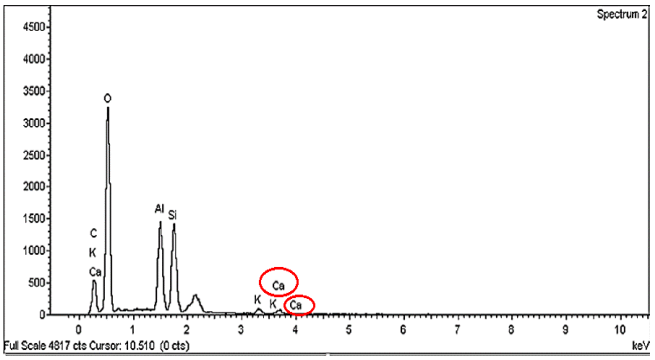


Fig. 10: EDX Analysis of Brick from vege-grout.

Fig. 11: Evidence of biocementation occur

3.3 Compressive Strength

Compressive strength of the vege-grout brick were conducted using the universal testing machine (Figure 13). The brick samples at 7, 14 and 28 days of curing days were analysed (Figure 12). It was observed that the compressive strength had increased as the curing period increased from 7 to 28 days. It can deduce that biocementation process has occurred within the soil particles. During the first 7 days, the strength was considerably low (0.02 N/mm^2) due to the insufficient amount of microbial community, but as the curing period progressed, more bacteria were produced and their bio activities induces the biocementation process. Thus, the strength of brick was also increased up to 0.062 N/mm^2 at the end of 28 days of curing.

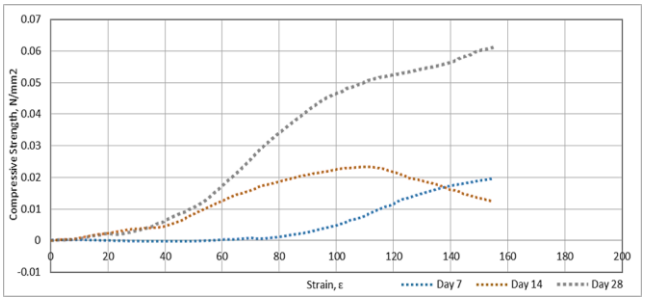


Fig. 12: Compressive strength of BVG brick for 28 days of curing.

Fig. 13: Universal Testing Machine (UTM)

Fig. 14: Brick specimen after compression test

4. Conclusion

A novel technology of vege-grout can be used as the substitute of urea and medium because it contain microorganism that can induce calcite precipitation. The formation of calcite precipitation was obviously can be seen at the surface of the bricks sample.

Eggshells is needed to enhance the process of biocemention between sand and vege-grout as it act as a binder between this two particles. Eggshells shows higher potential for a cement replacement as it rich in calcium. The strength of brick shows slightly increased as the curing date increased up to 0.062 N/mm^2. However it is lower than strength provided study by Bernadi [15] which up to 2 N/mm^2. This is happened because didn't enough calcium sources from the eggshell for the microbial induces calcite precipitation process. Thus, the process of biocementation of the bacteria and sand did not well deform results low in strength of brick. Further test will be conducted in the future to increase the strength of brick.

Overall this research conclude that combination vege-grout from vegetables waste with eggshell calcium additive to persuade biocementation of brick by using bacteria to produce cement- free brick and serve as an important tool to improve the durability of materials constructed with the vege-grout brick in the future.

Acknowledgement

The author would like to thank UNITEN R&D SDN BHD for funding this research under TNB Research Grant (U-TS-RD-17-03) with research title "Sustainable Streetscape for Improvement of TNB Street Furniture".

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