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Biocalcification using Ureolytic Bacteria (UB) for strengthening Interlocking Compressed Earth Blocks (ICEB)

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Abstract. Interlocking compressed earth blocks (ICEB) are soil based blocks that allows for mortarless construction. This characteristic resulted to faster the process of building walls and required less skilled labor as the blocks are laid dry and lock into place. Recently, implementation in using bacteria as construction material improvement is vigorously used in research in order pursuit the sustainable construction works. This paper provide the results of ureolytic bacteria (UB) throughout enrichment process in soil condition to acclimatize the ICEB environment, compressive strength of 1%, 3% and 5% UB and SEM analysis of ICEB. The bacteria were added as partial replacement of limestone water in ICEB. The results showed the optimal growth achieved based on the days and absorbance from optical density (OD) test which are in 12th days with absorbance of 0.55 whereas the results for strength shows the increment of 15.25% with 5% UB on 28th days of testing compared to control specimen. Therefore this study hopes that positive results from the UB as improving in strength of ICEB which will lead to improve others ICEB properties and others construction materials.

1. Introduction

Interlocking compressed earth block (ICEB) is a cost effective, dry stacked and sustainable construction material which has potential to bring durable and affordable homes to developing counties around the world [1]. However there are also others problems associated with ICEB namely low strength, higher water absorption, low fire resistance and high porosity [2].

Previous studies had taken different approach to improve the properties of construction material such as bioconcrete [3], an addition of PET [4] and polyolefin fibers [5]. The use of bacteria is one of new fundamental research in improving construction material in order to pursuit sustainable construction. Researcher such as Muynck et al., [6] used *Bacillus sphaericus*, Dhami et al., [7] used *Bacillus megaterium*, Mukherjee [8] used *Bacillus megaterium* and Bernadi et al., [9] used *Sporosarcina paseurii*. All bacteria used by previous studies resulted in increasing on compressive strength and reduction on water absorption by comparing control sample and treated sample with bacteria. Positive results from previous studies indicated that the successfulness of using bacteria as an environmental friendly solution in improving the durability of construction material. According to Siddique & Chahal [10], bacteria are able to promote the precipitation of calcium carbonate ($CaCO_3$) in the form of calcite. These calcite acts as bio-sealant by filling the pores which lead to reduction in water absorption, porosity, permeability, enhance the strength and prevent water ingression. Hence it will improve the durability of the material properties.

Even extensive of research incorporated bacteria in construction material, less knowledge were found on adapted bacteria in ICEB. The understanding on fundamental precipitation calcium carbonate ($CaCO_3$) had been applied in this research with the use of ureolyric bactreria (UB) to improve the durability of ICEB. Therefore, this research hope that an environmental friendly solution to improve the durability and properties of ICEB would be produced by introducing the used of bacteria in ICEB.

2. Experimental works

Isolated strain UB from fresh urine was used in the biocalcification studies. The standard Nutrient Broth (NB) media were used to demonstrate and compare the efficiency of microbial induced calcite precipitation (MICP) by UB in ICEB. Enrichment process was done follows previous researcher method by Irwan et al., [11]. In order to ensure the survival of UB in ICEB environment, enrichment process was done with addition of soil sample to acclimatize the ICEB condition. The composition for optimal growth was 300ml nutrient broth added with 120ml of 40% urea, 1mg of soil substances and lastly 1 cyrogenic bead of ureolytic bacteria. Control experiment in enrichment process is flask without soil sample. Optical density of UB in both treatment and control flask were measured daily. This method to determine optimal growth condition

The UB that need to be added in the concrete will be shake in the liquid nutrient broth first until turbid following the optimum day in growth measurement. Addition of UB as partial replacement of limestone water with 1%, 3% and 5% UB are added into ICEB mix. The compressive strength (fc) was measured for 7th, 14th and 28th days. The test was carried out according to the BS 3921:1985, [12] which specify for the testing of bricks. The scanning electron microscopy (SEM) analysis was done in determination of pore size and morphology precipitation calcium carbonate ($CaCO_3$).

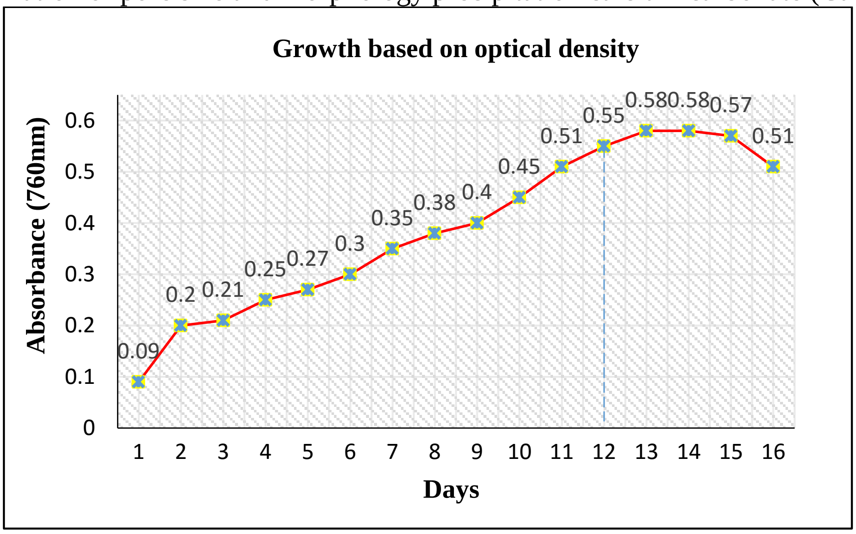


Figure 1. The growth curve for ureolytic bacteria.

3. Optimal growth profile

Survival and growth of urease producing bacteria are very essential for biocalcification activity to take place. The optimal growth of UB was monitored for 16^{th} days in order to ensure that sufficient number of UB cell survived to allow continued biocalcification in soil condition. According to the growth chart depicted in figure 1, the highest absorbance rate was on the 13-14th day of growth. Which means, by the 12th day, UB reach optimum growth. However, when continuing to the next day which is 15^{th} day, the amount of absorbance started to decrease. This shows that the bacteria started to become inactive and die due to depletion of nutrient provided in nutrient broth liquid [8]. Therefore to obtain the best results for bacteria growth, the number of days that was chosen are in 12th days where the results of turbidity was 0.55 absorbance. According to Siddique & Chahal [10], logarithmic phase refers to rapid growth of bacteria where the nutrient are actively being used by the bacteria. Therefore the chosen range of bacteria growth are suitable to be used in preparing the sample of ICEB.

4. Compressive strength

Figure 2 shows the results of compressive strength for 7th, 14th and 28th days of testing. The addition of UB as a liquid culture of 1%, 3% and 5% in ICEB increased the compressive strength within time compared to control specimen. The patterns of compressive strength increment are the same for all bacterial specimens. Addition of 5% UB indicates the highest increment by 15.25% in strength at 28th days compared to control sample follows with 3% of UB with 14.34% and 1% of UB with 10.71%. The highest compressive strength recorded was 6.35 N/mm^2 at the 28th days of testing for 5% addition of UB.

The positive result indicates the successfulness of UB surviving in ICEB environment and deposition of calcium carbonate, $CaCO_3$ for the strength enhancement of ICEB. The increment of compressive strength with added bacteria agreed with Dhami et al., [7] studies which state that compressive strength can be significantly increased by application of bacteria calcite.

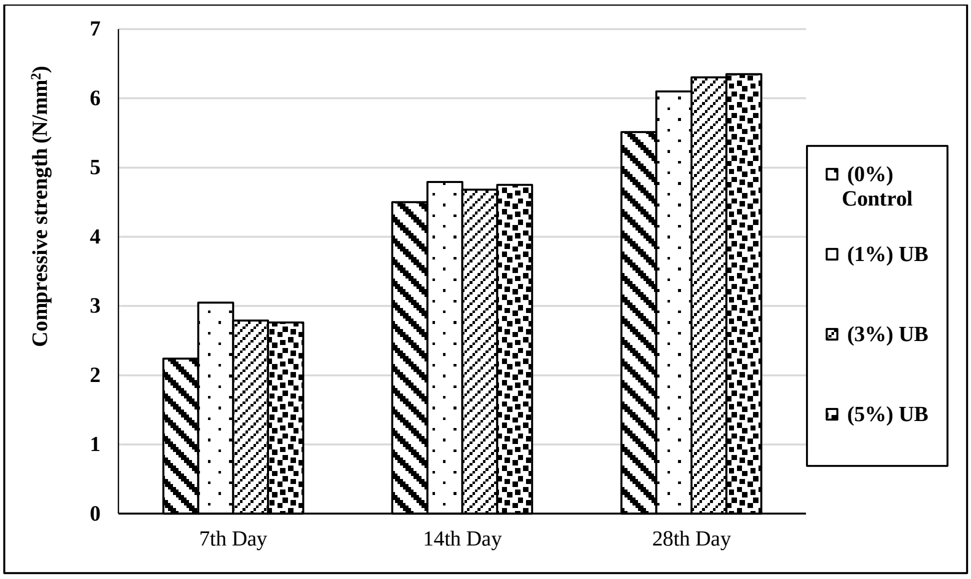
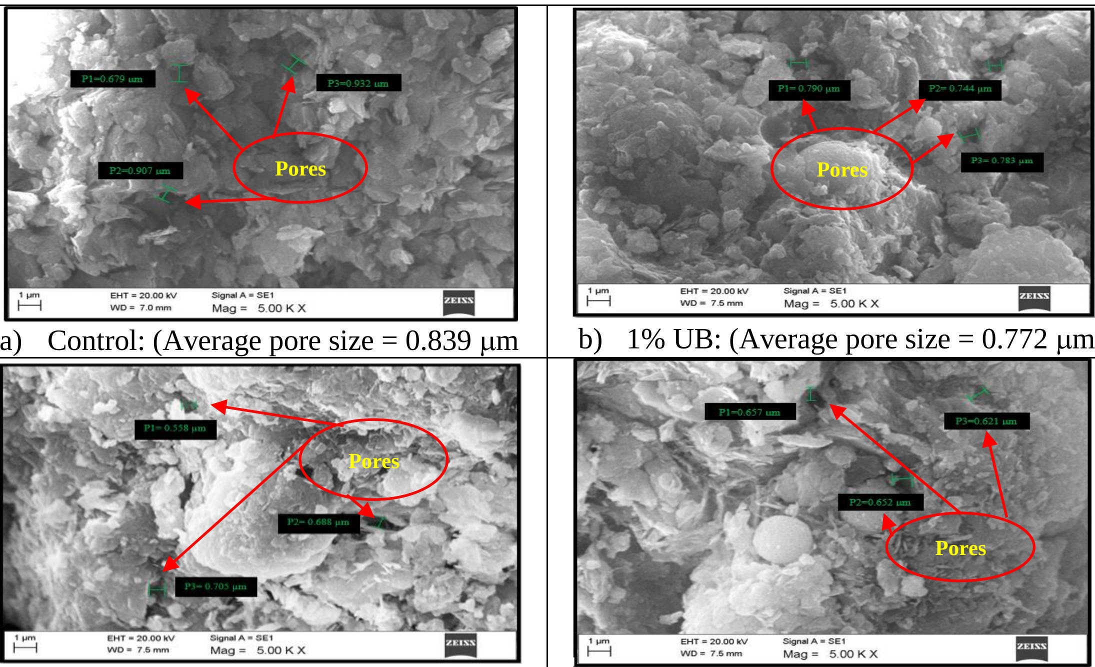


Figure 2. Compressive strength of control and bacterial ICEB.

5. SEM analysis

Microstructure analysis using SEM image shows that UB successful to grow well inside the ICEB specimens with less oxygen condition and also capable to tolerate in alkaline environment. The pore size analysis was determine by using small size of crushed ICEB passing 64 micron sieve. Figure 3 shows the average results for pore size analyses conducted on control ICEB and bacterial ICEB. Control image generally show more rough and uneven surface. This porous surface from control samples led to increase the absorption capacity of ICEB and hence decrease in durability and strength. In bacterial ICEB some part of the porous surface has been filled by calcite precipitation, thus reduction in pore size. Addition of 5% UB resulted highest reduction in average pore size with 0.643μm follows with 3% UB by 0.650μm and 1% UB with 0.772μm compared to the control specimen which was 0.839μm. There are also appearance of calcite precipitation which can be seen as smooth surface of round sphere in bacterial ICEB microstructure image. The smooth surface of round sphere indicated the bacterial forms of calcium carbonate. The average size of calcite forms was evaluated and compared between control and bacterial ICEB. As shown in figure 4, control sample which can be seen without precipitation of bacterial calcite due to 0% percentage of UB addition. Addition of 3% UB indicate highest average size of bacterial calcite form which is 12.469μm follows with 1% of UB with 9.212μm and 5% of UB by 7.815μm. The calcium carbonate precipitation was to prove that addition of UB in ICEB promote to bacterial calcite precipitation.



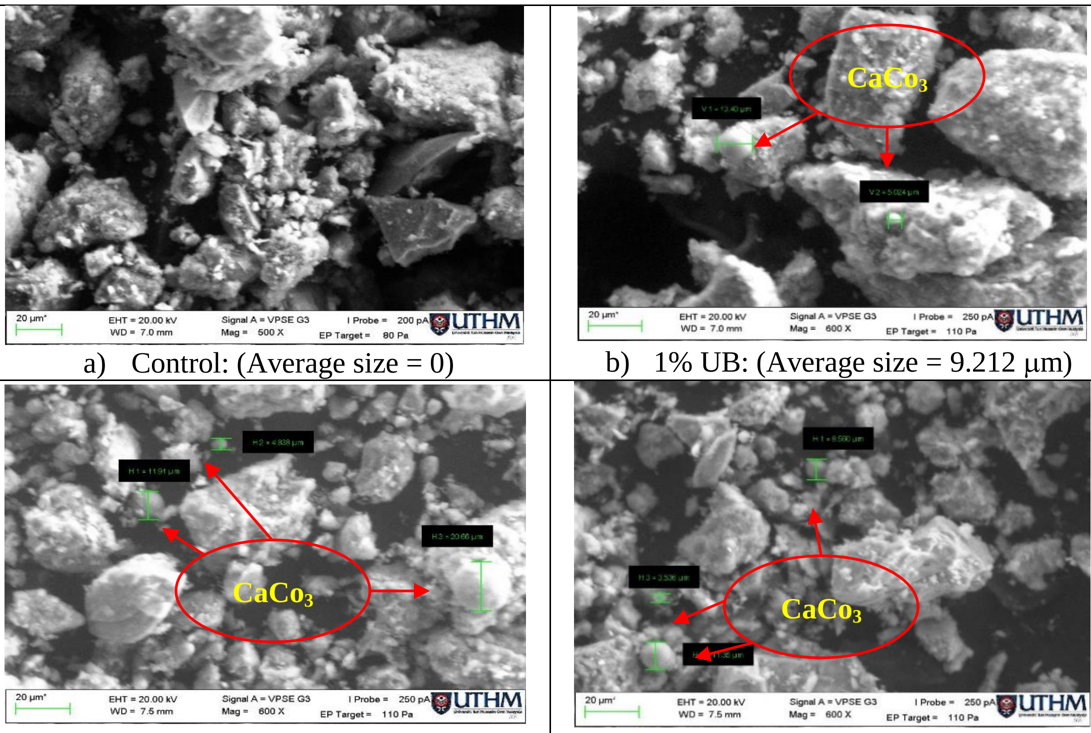
a) Control: (Average pore size = 0.839 μm

b) 1% UB: (Average pore size = 0.772 μm)

c) 3% UB: (Average pore size = 0.650 μm)

d) 5% UB: (Average pore size = 0.643 μm)

Figure 3. Pore measurement for ICEB with and without addition of UB.



a) Control: (Average size = 0)

b) 1% UB: (Average size = 9.212 μm)

c) 3% UB: (Average size = 12.469 μm)

d) 5% UB: (Average size = 7.815 μm)

Figure 4. Precipitation of calcium carbonate for ICEB with and without addition of UB.

Based on the images obtained through Scanning electron microscope (SEM), the samples which contained bacteria has shown pores being filled and surface for these samples appear more compact and smooth compared to control which is rough and porous in nature. There are also decrement in pore size of bacterial ICEB compared to control ICEB. Addition of 5% UB in ICEB indicate the highest reduction of pore size compared to the control sample by 23.36%. Therefore the results from microstructure analysis prove that by addition of UB in ICEB resulted in reducing the pores and bacterial calcite precipitation. Thus improvement the strength properties of ICEB. This findings agreed with Siddique & Chahal, [10] studies which indicated the improvement of material engineering properties due to deposition of calcium carbonate. These enchantment of ICEB strength may lead to reduction of construction cost maintenance over long period of time.

6. Conclusion

The present study suggests that addition of UB in ICEB resulted in improving the compressive strength due to biocalcification activity of UB grown in ICEB compared to control specimens. SEM analysis shows that the successful of UB in depositing the calcium carbonate and reducing the pore size of ICEB. Hence this will further improve the properties of ICEB. Positive results form addition of UB shows that the effectiveness of introducing the use of bacteria in improving the ICEB properties and potential of replacing chemical substances enchantment to achieve sustainable construction. This can favourably reduce the frequency of required maintenance for civil structures especially in bricks.

7. Acknowledgement

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8. References

[1] Laursen P T, Herskedal N A, Jansen D C and Qu B 2012 Interlocking compressed earth blocks Out-of-plane structural response, *Journal of Material and Structure*, **48**, 321-36
[2] Irwan J M, Zamer M M and Othman N 2016 A review on Interlocking Compressed Earth blocks (ICEB) with addition of bacteria, *MATEC Web Conferences*, **47**, 01017
[3] Irwan J M and Othman N 2013 An overview of bioconcrete for structural repair, *Applied mechanics and Materials*, **389**, (2013), 36-39
[4] Irwan J M, Asyraf R M, Othman N, Koh H B, Annas M M K and Faisal S K 2013 The mechanical properties of PET fiber reinforced concrete from recycled bottle wastes, *Advanced Materials Research*, **795**, 347-51
[5] Wan Ibrahim M H, Jamaludin N, Irwan J M, Ramadhansyah P J and Suraya Hani A 2014 Compressive and flexural strength of foamed concrete containing polyolefin fibers, *Advanced Materials Research*, **911**, 489-93
[6] De Muynck W, Debrouwer D, De Belie N and Verstraete W 2008 Bacterial carbonate precipitation improves the durability of cementitious materials, *Journal of Cement and Concrete Research*, **38**(7), 1005-14
[7] Dhami N K, Reddy M S and Mukherjee A 2012 Improvement in strength properties of ash bricks by bacterial calcite, *Journal of Ecological Engineering*, **39**, 31-35
[8] Mukherjee A, Dhami N K, Reddy B V V and Reddey M S 2013 Bacterial Calcification for Enhancing Performance of Low Embodied Energy Soil-Cement Bricks, *Journal of Sustainable Construction Material and Technology*, **1**, 1-10
[9] Bernadi D, Dejong J T, Montoya B M and Mattinez B C 2014 Bio-bricks: Biologically cemented sandstone bricks, *Journal of Construction and Building Material*, **55**, 462-69
[10] Siddique R and Chahal N K 2011 Effect of ureolytic bacteria on concrete properties, *Journal of Construction and Building Materials*, **25**(10), 3791-801
[11] Irwan J M, Anneza L H, Othman N, Husnul T and Alshalif A F 2016 Isolation and Identification of Concrete Environment bacteria, *IOP Conference Series: Materials Science and Engineering*, **136**(1), 012088
[12] British Standard Institution, BS 3921: 1985, Specification for Clay Bricks, Clay Product Standards Committee, London, England