The Carbon Sequestration Characteristics of Interlocking Cement Soil Brick Partially Stabilize Using Magnesium Oxide and Magnesium Carbonate

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Abstract. Global warming has become a major issue that are being discussed by scientists and policy makers throughout the world. Global warming occurs due to high content of carbon dioxide (CO2) in the atmosphere which is one of the factors that increase the temperature of the earth. Researcher has developed green technology to reduce the quantity of CO2 by producing brick that used less cement for stabilization. Cement manufacturing has been known to produce high carbon print and reducing the dependence of cement in construction may help the environment. Preliminary investigation has shown that it is possible to replace cement totally using magnesium oxide (MgO) or magnesium carbonate (MgCO3) which has lower carbon print in cement brick production. The resultant bricks are also found to act as CO2 absorber and if widely used, it can have a positive impact on the environment. The main focus of this study is to find out whether MgO and MgCO3 when use as cement replacement has the ability to absorb significant carbon dioxide gaseous in pressed soil-cement brick which is popularly used in third world countries. Three types of tests were carried out namely, carbon dioxide absorption test, water absorption and pH leachate test. About 20 full dimension samples of size 250 mm x 125 mm x 100 mm and 36 half-size samples of size 100 mm x 50 mm x 30 mm were produced throughout these studies. The result of the investigation has shown that MgO and MgCO3 as partial replacement of cement in pressed interlocking soil-cement brick has the ability to absorb substantial CO2 in the environment and therefore can play an important role as a green building material for the future.

Keywords — soil stabilizer; leachate; absorb gas; pH water; interlocking soil brick

INTRODUCTION

Brick manufacturers are faced with the challenges of producing bricks of satisfactory quality efficiently, economically and sustainably. Bricks either in the form of burned bricks or cement bricks has been used widely in constructions and has been known to produce a big carbon print during the manufacturing process. By totally replacing or decreasing the used of cement in brick production by adding a ratio of other binder as stabilizer apart from cement may reduce the carbon print hence creating better environment. There are various type of binders used as stabilizer
for soil namely lime, fly ash and the latest are magnesium oxide (MgO) or magnesium carbonate (MgCO3). Preliminary research has pointed out that magnesium oxide (MgO) or magnesium carbonate (MgCO3) which has much smaller carbon print compare to cement can be used to replace cement and interestingly the finished product has the ability to absorb free carbon dioxide from the environment. The focus of this investigation is to find out whether the carbon sequestration characteristics also applies to pressed cement-soil brick which is a cheaper alternative to burned brick and cement-sand bricks which has already gain popularity in the third world countries in the form of interlocking pressed soil bricks. Experimental investigations were conducted by partially replacing the cement content in the pressed soil brick and the specimens were tested for its carbon sequestration characteristics. Additional sample tests on absorption and leachate pH characteristics were also conducted to ensure the resultant products are sound and environmentally friendly.

**METHODS AND MATERIALS**

**Sandy Clay Soil**

Pressed soil-brick process requires sandy clay with enough plasticity to allow shaping and molding when mixed cement with water. The sandy clay also must have sufficient adhesive strength to hold the shape after pressing is completed. Sandy clay can be either taken directly from suitable sandy soil site or by mixing clay with certain amount of sand. In the later method, the clay is dried and later crushed to become powder. The powdered clay is then thoroughly mixed with sand and cement. Water is later added until the ingredient become moist enough with zero slumps characteristic.

- **Ordinary Portland cement (OPC)**
  
  OPC was used as a stabilizer/binder in this study. Control interlocking pressed soil brick specimen in this research were made using 100% OPC. Cement acts has binder and will increase the strength of the bricks overtime. The cement was kept in airtight condition before used. This is to avoid the cement from absorbing the moisture in the air that will affect the quality of the cement.

- **Magnesium Oxide (MgO) and Magnesium Carbonate (MgCO3)**

  MgO and MgCO3 were used as partial replacement of cement to stabilize the bricks. Magnesium oxide is white-yellowish in color and the density is about 1.57 x 10³ kg/mm³. This material is heavier than magnesium carbonate but lighter compare to cement density. The material also has to be kept in an airtight container to avoid it from being spoiled by the surrounding moisture content.

**Laboratory Work**

Three types of brick sample were produced namely using MgO with OPC (1:4), MgCO3 with OPC (1:7) and the control specimen using 100% OPC. The ratio of MgO and MgCO3 to OPC was determined after several trial and error productions to ensure that the pressed bricks achieve a minimum strength of 7 N/mm² for load bearing purpose.

The materials were weight according to their proportion and mixed in an electric power mixer. When the dry ingredients were thoroughly mixed, water was added into the mixture. The amount of water used was approximately 13 % of the weight of cement and produced a mixture that were not too dry or too wet. The blended material was then poured into a steel mould and pressed hydraulically at a constant pressure of 2000 psi. The fresh bricks were later cured in the open by spraying water at regular interval for 14, 21 and 28 days respectively depending on the types of test conducted.
Carbon Sequestration Test

A simple mini environmental chamber made of sturdy plastic box of size 475 mm x 650 mm x 400 mm was prepared with an air inlet and outlet valves. The mini chamber has to be airtight to prevent leakages when carbon dioxide gas is injected into the chamber. The CO$_2$ source was from fire extinguisher compressed CO$_2$ as shown in Figure 1(a). Once sufficient CO$_2$ was injected, the inlet and outlet valve were closed so that the gases will not escape. A carbon dioxide sensor as shown in Figure 1(b) was used to detect the concentration of CO$_2$ in the chamber through a pre-drilled hole on the upper lid of the chamber box.

Water Absorption Test

Water absorption test was conducted to measure the amount or quantity of water that being absorb by bricks under a particular condition as described in Malaysian Standard MS 76:1972. There are two types of method being used to measure the water absorption of bricks namely through 5 hours boiling test (Figure 2(a)) and 24 hours immersion in cold water (Figure 2(b)).
The purpose of this test was to measure the pH leachate of the bricks. Ideally, the leachate should not be too acidic nor too alkaline because it can pollute the stream and river. The test was conducted by grounding the hardened brick specimens and mixed with distilled water as shown in Figure 3(a). Using the pH meter as shown in Figure 3(b), the leachate reading was taken and recorded as shown in Table 3 in result and discussion section.

FIGURE 3. (a) Mixed the soil with water and (b) Reading pH value.

RESULT AND DISCUSSION

Carbon Sequestration

Before carbon sequestration test of the specimen was carried out, test on the chamber air tightness was conducted by injecting CO$_2$ inside the chamber. Figure 4 shows the CO$_2$ concentration inside the test chamber was stable after nearing 4 hours of continuous monitoring and the reading shows that there were no leakages occurred in the chamber. Carbon sequestration test was conducted by placing the specimens inside the chamber and injecting fresh CO$_2$ inside the chamber. Continuously monitoring of the CO$_2$ concentration was carried out for 5 hours.

FIGURE 4. Constant concentration of carbon dioxide inside test chamber without bricks specimen.
Figure 5 shows comparison of CO$_2$ absorption between control bricks and magnesium bricks. It can be seen that both types of bricks were found to absorb excess CO$_2$ at a very fast rate of about 5000 ppm in 125 minutes. Once reaching the air CO$_2$ concentration, the CO$_2$ absorption rate level off and in about 290 minutes the CO$_2$ concentration became almost zero ppm. The control bricks absorb CO$_2$ faster at the beginning compared to magnesium oxide bricks as shown by the steeper gradient of the control bricks but eventually at about 200 minutes both bricks have absorbed almost all of the CO$_2$ in the chamber.

FIGURE 5. The difference on absorption of carbon dioxide for both bricks.

The carbon sequestration occurs in the bricks is due to a chemical reaction known as carbonation process where free CO$_2$ reacts with Ca(OH)$_2$ in the bricks to form CaCO$_3$ and water.

Figure 6 shows that carbonation process clearly taking place in the bricks after absorbing the CO$_2$ in the chamber. The carbonation depth was determined by using a chemical called Phenolphthalein which was applied on the surface of the sawn brick specimens. The chemical will react with acidic carbonation surface and turns colourless and pink in alkaline dominant surface.

FIGURE 6. Carbonation process in the brick.
Table 1 shows the result of 5 hours boiling test (Figure 2(a)) and Table 2 shows the result of water absorption test for 24 hours immersion in cold water (Figure 2(b)). Water absorption was calculated using the following formula:

\[
Water\ absorption, W\% = 100 \left( \frac{ms - md}{md} \right)
\]

where, \(ms\) is a mass of saturated brick and \(md\) is a mass of dry brick.

Table 2 shows the data collected from 5 hours boiling test and 24 hours immersion in cold water. The result generally shows that each particular brick will absorb less water with age. It can be seen that control bricks satisfy the criteria of maximum 10% water absorption as stipulated in MS 76:1972 standard for building while the other two bricks absorbed more than 10% after 28 days. But this does not mean that magnesium oxide bricks and magnesium carbonate bricks are not applicable to be used in construction because it seems that the rate of water absorption become lesser with time. Hence, both bricks were projected to absorb less than 10% water if it is cured for more than 28 days.

**pH Leachate Test**

Based on the result in Table 3, all of the raw materials for the bricks are alkaline. Cement compound has the highest alkalinity of 11.94. Table 4 shows the data from the leachate pH testing for each type of bricks that were performed at different age according to BS 1924 procedures.
Table 4 shows that the pH value seemed to decrease with the age of various bricks. At earlier stage, the hydration process is very active the alkalinity is high but as the hydration process is near the completion stage, the brick is stabilized and lesser leachate is observed.

CONCLUSION

Magnesium oxide and magnesium carbonate used as partial replacement of cement in pressed interlocking pressed soil bricks has shown the potential to absorb excess CO$_2$ in the atmosphere thus, can be classified as green technology building material. Furthermore, water absorption and alkaline leachate of magnesium oxide and magnesium carbonate bricks is acceptable and becoming better as the brick ages.

REFERENCES