THE FUNCTION OF INTERLOCKING COMPRESSED EARTH BRICK IN BUILDING WALL SYSTEMS: A LITERATURE REVIEW

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ABSTRACT

To achieve sustainable and green technology in construction, more alternative methods were produced to replace the conventional construction materials which lack concern on elements of sustainability especially on humans, economics, and the environment. The conventional bricks especially the Fired Clay Brick (FCB) consume and emit high energy due to the production process where the flaming process is involved. Also, high carbon emissions caused by combustion can contribute to the greenhouse effect. Thus, the Interlocking Compressed Earth Bricks (ICEB) is produced and acts as an alternative method in replacing the conventional bricks. ICEB gives more advantages in terms of cost, time, and sustainable development. The aim of this paper to present the latest and related research on the performance and effectiveness of ICEB for wall elements as a load-bearing structure. The review of literature on the ICEB give a positive impact before, during, and after construction. This paper also aware the public of the existence of the ICEB system in construction as well as a reference on future practices.

Key words: Sustainable, interlocking, compressed, load-bearing, green technology.

INTRODUCTION

As the bricks are one of the main construction materials in residence construction, thus the process of brick production and brick materials was improved to add sustainability elements in construction and to achieve green technology.

Previously, brick production contributes to environmental issues especially in releasing Carbon Dioxide (CO2) and the production process is difficult and takes a long time to complete. Thus, the ICEB was produced which is fast, easy, and low cost which contributes to low carbon emission (Asman et al., 2020). Both FCB and ICEB have different ways to gain their strength. The FCB gains strength from the combination of clay during the firing process where a glassy product is formed (Riza et al., 2010) different from ICEB where the strength gains at two stages, early stages the ICEB gain strength from compression which give high density that contributes to strength. At later stages, the ICEB gains strength from the hardened stabilizer (cement) over time. The ICEB gives more positive and advantages in every aspect such as environmental, sustainability, cost, and time.

The time of completion for conventional construction takes a long time with the high cost for the material and labors. Even the waste is al accumulated a lot. Thus, the construction using ICEB will reduce the time of completion, reduce the cost for the total construction, and produce less waste during construction. The wall using ICEB has a very unique design since no frame structure needs to be constructed, no plastering, and bed mortar joint. Different from the FCB wall where plastering and bed mortar is needed. For the FCB wall, a frame structure is constructed where beam and column need to be completed before the FCB wall is installed. The ICEB wall is considered as a wall bearing system wall as the load applied to the wall is transmitted from one to another directly. The difference between both walls leads to different structural behavior (Fundi et al., 2018). Thus, ICEB used fewer materials than traditional house building methods. The construction also can speed up, apart from low cost and also environmental-friendly.

This paper has divided into several sections. Sections 2 describe the general information of the ICEB such as the production of ICEB and properties of ICEB. Sections 3 describes results on the application of the ICEB in-wall system. Finally, the conclusion of this paper is stated in section 4.

INTERLOCKING COMPRESSED EARTH BRICKS

Production of ICEB

The ICEB is produced from mixes of soil, sand, cement, and water. The soil used for the ICEB usually is laterite soil or clay soil because of the availability and cohesiveness properties itself (Han et al., 2020). A previous study found that soil having Plasticity Index (PI) below 15 are more suitable to use cement while soil which having PI above 15 suggested using lime as a stabilizer (Guettala et al., 2002). Sands are added into the mixes to improve the plasticity index of the soil since high stickiness will cause difficulties during the demolding of bricks (Mirasa et al., 2020; Tonduba et al., 2019). The ideal plasticity index for the soil is between 5% to 15%. To improve the ICEB durability, cement is added and acts as a stabilizer in the mixture to bind the particles of the mixture. Without moisture, cement will have no function at all, thus water is added into the mixture so that the cement is activated and acts as a binder (Riza et al., 2010). The amount of cement added should less than 10%, otherwise, the production becomes uneconomical (Riza et al., 2010) but to keep the quality of the bricks, the amount of cement cannot be less than 5% otherwise the ICEB will be brittle. The content of cement added also for the brick gaining strength over time (Mujahid et al., 2011).

There are four stages of ICEB production which include crushing, mixing, compacting, and curing (Abdullah et al., 2020). The crushing process is for soil preparation where the soil is crush below 2 mm since extracted soil is varying in size. Then all the materials will be mixed using a mechanical mixer drum where the dry and wet mixing process involves. Both mix process is to ensure the mixture in a homogenous state. The main process in ICEB production is the compacting process where all the mixture is conveyed from mixer drum to hydraulic compression machine (Abdullah et al., 2020; Fundi et al., 2018). The final process in the production of the ICEB is curing. The ICEB will be cured right after the initial setting is done and the curing process will continuously conduct until enough strength is gained (Assiamah et al., 2015; Sharma & Mayya, 2017).

Properties of ICEB

Compressive Strength

The value of compressive strength for interlocking brick can be determined by following standards such as MS 76:1972, ASTM C 109, ASTM C 67, EN 772-1:2000, EN 1052-1:2009, and BS 3921-1985 (Abdullah et al., 2020) where BS3921:1985 stated the minimum value is 2.8 N/mm2 for non-load bearing and 5.8 N/mm2 for load-bearing while MS 76:1972 state the minimum value is 7 N/mm2. A previous study found that the value of compressive strength on day 7th and 28th for interlocking brick is slightly higher than a sand-crete block (Assiamah et al., 2015). The compressive strength of the ICEB increased simultaneously with the age. Compressive strength can be done in two (2) ways, either dry test or wet test. The wet test is considered a worst-case scenario. The dry test led to high-value compressive strength compared to the wet test. Based on the past study, it is found that the dry test is 35% more than the saturated block (Riza et al., 2010). The compressive strength of ICEB can be affected by other parameters such as stabilization of soil, mechanical stabilization, and dynamic compaction (Bahar et al., 2004). For stabilization of soil, the mixture can be added with chemical or green material. While for the mechanical stabilization, ICEB can be produced either using manual compression or semi-auto hydraulic compression machine and dynamic compaction can be done with various compaction values to produce ICEB.

Water Absorption

Water Absorption for ICEB can be determined by the following standards such as ASTM C 140, ASTM 90, MS76:1972, EN 772-7, BS 3921-1985 and IS 3495 (Part II)-19767 (Abdullah et al., 2020; Sharma & Mayya, 2017). Indian Standard IS 1077 (1992) state the water absorption shall not more than 20% while ASTM 90 state the maximum allowable for water absorption is 17%. The higher value of water absorption will contribute to the low durability and quality of the ICEB. It is found that water absorption value can be affected by dynamic compaction. A previous study found that water absorption can be decreased from 13% to 10% with a 50% increment in compressive strength (Riza et al., 2010).

Density

It is found that the density of the ICEB is within the range 1500 -2000 (Ngian & Huei, 2015) and there is no much difference between the density of ICEB and FCB (Kadir et al., 2017). Density can be affected by the degree of compaction during production. The early strength of ICEB depends on the compression force applied. Based on the previous study, the strength of bricks can increase up to 70% when increasing the compaction from 5 MPa to 20Mpa (Guettala et al., 2002). By following, standards such as ASTM C 140 and BS 1924-2, the density of bricks can be obtained (Bahar et al., 2004; Oti et al., 2009).

Thermal Conductivity

Most construction materials especially bricks have good thermal conductivity. Good conductivity refers to low conductivity which can keep a house warm in winter or cool in the summer season. It is found that compressed stabilized earth bricks give a good thermal conductivity value to be compared with FCB (Oti et al., 2009). This is due to the high density of compressed bricks produced from the high compression method. The high value of conductivity for FCB is maybe due to the production process where the firing process is involved (Riza et al., 2010). By following standards such as BS EN 1745, ASTM C 518-91, and ASTM C 1132-89, the thermal value of bricks can be obtained (Oti et al., 2009).

APPLICATION OF WALL

Normally, for the FCB, the compressive strength of the wall is depending on the type of the bricks, types of joint, and mortar mix (for vertical and horizontal joint) but different with the ICEB wall which is no mortar joint. For the FCB wall panel, the load applied is transmitted from beam to column but for the ICEB wall panel, the load applied is transmitted from one brick to another. Thus, more study is conducted to get more information on this matter. A previous study found that the eccentricity distance can contribute to the value of the strength. A study on various eccentricities with constant axial load found that the value of interlocking brick is quite lower compared to the wall made of soil brick (Ahmad et al., 2011). It is found that ICEB walls can exhibit ductile behavior, stable energy dissipation under cyclic loads, and good mechanical strength (Carrasco et al 2013; Qu et al., 2015). The value of compressive strength of the whole structure mostly lower than a single unit brick (Ahmad et al., 2011; Carrasco et al., 2013)

Compare to the FCB wall, a mortar bed is added in between bricks every layer as resistance against the movement. Different from ICEB, where the interlocking feature resists the movement and increased the stability by adding the mortar and steel bar inside the bricks. The dry stack method is used as an improvement as the lack of strength on mortar joints (Ahmad, 2014). When the mortar joint is weak (either perpend joint or bed joint), this will lead to low axial and flexural strength. Both strengths are affected by the mortar mix used (Han et al., 2020). It is found also the strength of the ICEB wall panel is reduced due to the eccentricity in loading (Ahmad et al., 2011).

Due to the low consumption of cement during the construction wall, it is found that energy released during the process for ICEB is low compare to a conventional brick. The ICEB creates about 22 kg CO2/ton compared to fired clay bricks about 200 kg CO2/ton (Morton, T., 2008). A different study found that the ICEB consumed less than 10% of the input energy for manufacturing compared to conventional bricks. Compare to blocks walling, the number of ICEB is higher than blocks since the size of ICEB quite smaller than blocks, but the mortar usage is less since plastering is eliminated (Assiamah et al., 2015). Thus, contribute to the low consumption of cement and speed up the wall construction. This is also lead to cost reduction since the materials cost is contributed by mortar jointing and plastering.

The size of the wall also needs to be taken into consideration since the study on flexural found out that the ratio size (height to width) influenced the strength where wall panel with a large ratio is more ductile compare to a small ratio (Qu et al., 2015) and the flange is added increase the flexural strength of the wall. A single unit brick unit a highly durable form in construction but some aspects such as workmanship, materials used, and quality of mortar will affect the durability of the whole structure (Ahmad, 2014). Both, conventional bricks and ICEB walls are included in this matter. Thus, to keep the quality of the wall element structure, a single unit brick needs to be checked for the properties and condition.

Some disadvantages of ICEB walls reported by previous researchers are the changes in the color of the wall after a long period exposed to sunlight and water and some imperfections joint which cause some spaces between the bricks (Jhan et al., 2017). The disintegration of the bricks might also occur especially at the edges of the bricks. To overcome and minimize the problems, some solutions may be done such as using water coating paint and proper filling mortar.

CONCLUSION

From these findings, some of the valuable information such as determination of bricks properties and produce of production of the ICEB that can be used as standard procedure especially in Malaysia. Since there is no specific standard procedure on production and application in construction. The ICEB will improve the construction industry in terms of time cost, and sustainability. This is due to the use of the ICEB can reduce the time of completion and reduce the total cost especially in materials and waste management. In term of sustainability, the ICEB contribute to elements of the sustainability especially social, human, economic, and environmental. By exposed and improved knowledge and skills on green technology, maintaining high and stable levels of economic growth and lastly protection on natural capital. However, there still a lot of investigation that needs to be conducted to improve the use and application of interlocking compressed earth bricks in construction to achieve green and sustainable development. The ICEB can be considered as new innovative construction materials.

FUTURE RESEARCH AND RESEARCH GAPS

Several gaps need to be focus on ICEB as follows:

1. Detailing on costing and carbon emission for the whole construction.
2. Performance of ICEB structure in a fire and seismic situation.

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