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Lock-brick system technology is an ecological building material innovation

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Abstract. The rapid development of housing requires the support of building materials technology innovation. The problem is that the cost of building materials produced not affordable by people in rural areas or for the lower-middle-class people. The buildings in the city are magnificent, but in contrary, in the village many houses still consist of bamboo-wall and leaf-roof. Some tried to build their houses using bricks, but they could not finish the building construction due to limited budget for purchasing material. It encourages for development of an environmentally friendly, safe and cheap building material: lock-brick. Villagers could make this material by themselves since the raw materials are soils plus a little cement with a ratio between 1:8-10. First, this technology was piloted for simple house building, then for dormitories building and household-scale rainwater management, consisting of rainwater reservoir and runoff catchment ditches. Then, this system implemented for retaining-walls construction and currently also being tested for campus parking area. The trials results are good, and the construction costs are also much cheaper. It could reduce by 50%. Once again, the construction is very environmentally friendly, so can be said that this lock-brick system is an ecological building material innovation.

1. Introduction
The rapid development of housing requires the support of building materials innovation technology. Some building materials are developed, such as precast concrete walls, columns and beam precast, light brick, concrete blocks and other construction materials. They are intended to make the building robust, and construction works could be finished faster. However, the price of these building materials is quite high since the materials require non-local materials such as cement.

This expensive material is the problem for lower-middle-class people who mainly live in rural area. They could not afford the price. But it is not the case for people in urban area. People in the city could buy any materials needed whatever the price is. It is obvious that the buildings in the city are magnificent, but in the village many houses still consist of bamboo-wall and leaf-roof (figure 1). Often, when people build house from bricks, they cannot finish due to lack of money for finishing-work. Therefore, there is a need to develop an environmentally friendly, safe and cheap building material. People in rural area could make the material from locally available raw materials.

The need for food and drinking is very close to the need for water for agriculture and household needs while the need for elimination, sleep and sex presupposes the basic human needs of clothing and healthy house. The two basic human needs for living are water and healthy house, triggering for the development of a building material that is simple, cheap and easily made by the people themselves.
Inspired by the development of appropriate technology by Habitech Centre, established in 1988 [1]. In the form of lock-brick technology system, the development of this technology is continued not only for healthy house but also for other infrastructures, such as water building infrastructure that supports the development of local scale rainwater management technology to meet the need for irrigation water and household water [2].

1.1. The Need for Ecological Building Materials

The world faces many challenges and problems due to global warming and climate change. It was noted that the construction industry is the most contributor to these challenges. The utilisation of inappropriate technologies, appliances, and materials in buildings have threatened the environment and human health.

It is said that it needs a development concept, which considers the environmental conditions to prevent these. This concept is known as the green building concept, as the follow up of the green building concept. The concept has a goal to reduce the environmental impact caused by the construction process of a building [3]. The environmental impact caused by the building construction process is relatively large because at this stage requires fuel, electricity, water is relatively large, as well as construction waste. Green construction is a new concept that is believed to reduce the occurrence of environmental damage caused by various developments in Indonesia. The issue of depletion of various types of natural resources used as building materials and the build-up of construction waste generated from the construction process and those sourced from the expired buildings has become a major problem for human life on earth. Besides, population growth tends to increase in significant amounts resulting in increased demand for various infrastructures as life support. It is shown by the increasing value of construction from year to year, which means that the use of natural resources will be higher, and the amount of construction waste discharged into the environment is greater. If development is not well managed it can result in future environmental disasters.

1.2. Lock-Brick System Technology

Lock-brick is a type of brick that is set in a way to lock to each other for wall construction or other purposes. Those lock-bricks are made from local soil as the main material and small portion of cement. The materials are mixed in dry condition first, and then put water to meet a certain level of materials’ moisture. Next step is pressing the materials using a pressing machine up to 60% for forming interlocked bricks (figure 2) [4]. Three types of lock-brick stone, which is half brick, full brick and U brick (figure 3) [4]. U lock-brick stone used to form the beam structure by placing one concrete bar in the U curve and fill the arch with a concrete material (figure 4) [4]. The full and half lock-brick stone is set to form a wall of healthy house building, reservoir pond walls, retaining wall
and other construction. To form a column, then the lock-brick stone hole filled with one steel rood and filled with concrete material (figure 5) [4].

![Figure 2. The lock-brick making process.](image1)

![Figure 3. Three types of lock-brick stone.](image2)

![Figure 4. Construction of beam structure.](image3)

![Figure 5. Construction of column.](image4)
2. The Lock-brick Systems Development

Established in 1988, Habitech Centre has conducted research and developed various building components that are environmentally friendly, energy-efficient and cost-effective. This cost-effective building system is called Habitech Building System. This system has been tested, demonstrated and disseminated through various housing projects in Thailand and other countries throughout Asia and Pacific [1].

Literature review of the lock-brick system shows that most of these systems are used for house building construction [5, 6, 7, 8]. The summary of this literature review results is shown as in Table 1.

**Table 1. Summary of articles literature review.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Year</th>
<th>Author</th>
<th>Title</th>
<th>Note</th>
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</thead>
</table>

“Lock-brick Concrete Modular for Alternative Wall Materials that Meets the Quality Standard of SNI at Low Cost”, concludes that the cost per m² of modular lock-brick wall is 24% cheaper than the cost of the conventional brick wall [9]. From the reviews for various patents associated with the lock-brick system are presented as in Table 2 Patent development is widely available in the United States. That is also registered, the “Modular Lock-brick System for Constructing Buildings”. Patent Registration Number, S00201401680, Date: March 21, 2014, Director General of Indonesian Law Ministry [10].

**Table 2. Summary of lock-brick patents review.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Year</th>
<th>Inventor</th>
<th>Title</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2013</td>
<td>M.A. Kashinath</td>
<td>Interlocking Brick</td>
<td>No.: 3434/MUM/2013</td>
</tr>
<tr>
<td>2</td>
<td>2012</td>
<td>Janssens et al</td>
<td>Building Blocks with Mating Coupling Means for Constructing Wall and Associated Method</td>
<td>US 2012/0102868</td>
</tr>
<tr>
<td>4</td>
<td>2009</td>
<td>Steve Eugene Everett</td>
<td>Structural Building Block System and Method Comprising Same</td>
<td>Patent No.: US 7472520</td>
</tr>
<tr>
<td>5</td>
<td>2000</td>
<td>Simmons, Scott.</td>
<td>Modular Building Materials</td>
<td>US Nr.US06,088,987</td>
</tr>
<tr>
<td>7</td>
<td>1997</td>
<td>Williams et al</td>
<td>Flue Walls Using Interlocking</td>
<td>Patent Number: 5676540</td>
</tr>
<tr>
<td>8</td>
<td>1981</td>
<td>Khoo Tian</td>
<td>Bricks</td>
<td>No. 4,299,071</td>
</tr>
<tr>
<td>9</td>
<td>1970</td>
<td>Zagray</td>
<td>Interlocking building block construction</td>
<td>Patent US 3534518</td>
</tr>
<tr>
<td>10</td>
<td>1939</td>
<td>A. J. Cilento</td>
<td>Interlocking Brick</td>
<td>Serial No. 251260</td>
</tr>
</tbody>
</table>
Habitech centre develops lock-brick base on soil material. The lock-bricks are made from the main ingredients soil, which is added a little cement, with the comparison of 1-part cement and 8-part soils. These materials thoroughly mixed in dry conditions and be dampened with water to a level sufficiently moist. Then, poured to the pressing machine until 60% pressed, forming interlocked bricks. The lock-bricks arranged to form the walls of the liveable house. Columns and beams could be constructed by this system also, with the special moulding, which forms the place to lay the irons. Lock-brick construction system could be an alternative solution for many problems, especially concerning finance, environment and people participation. It also could be implemented for water infrastructures such as small ponds, channels and other infrastructure water buildings. Lock-brick systems are used for a wide range of building infrastructure but still considering the strength of the structure, according to the standards [4].

3. The methodology of the Study
The methodology of the study is described in figure 6 as follow:

First, this technology was piloted for simple house building, then for dormitories building and household-scale rainwater management, consisting of rainwater reservoir and runoff catchment ditches. Then, this system implemented for retaining-walls construction and currently also being tested for the campus parking area.

4. The Application Trials of the Lock-Brick System Technology
4.1. The Application for Liveable House and Dormitories Buildings
The main purpose of lock-brick development is to help people who still live in "unhealthy" houses to have healthy and livable houses which are affordable. The first application of the lock brick was building several houses, facilitated by cooperative, of people living on the slope areas of Mount Merapi (figure 7). This method was then developed in a coastal area in Nunsui, Kupang for a fisherman house (figure 8). Furthermore, it was developed in Tli'u village for farmer's house (figure 9)
and dormitories at Nasipanaf, Kupang (figure 10). It was used for toilet construction as shown in figure 11.

**Figure 7.** The former house and the lock-brick development at Jlarem village, Central Java.

**Figure 8.** The former house and the lock-brick development at Nunsui, Kupang.

**Figure 9.** The former house and the lock-brick development at Tli’u village, South-Middle Timor.
4.2. The Application for Water Building Infrastructures
Lock-brick system technology can also be applied to water infrastructure buildings such as for rainwater reservoir ponds and rainwater run-off ditches catcher (figure 12 and 13). In principle, the lock-brick stone is set based on needs. To meet the strength of the structure, then some lock-brick holes are filled with concrete bar and concrete materials. Additional material for a waterproofing coating is the provision of the holding pool.
4.3. The Lock-brick System for Retaining Wall

The lock-brick system technology applied to the retaining wall needs to meet the quality standard as well. Each lock-brick stone hole needs to be filled with concrete bar and concrete (figure 14) to withstand the load from the ground (earth pressure).

4.4. The Lock-brick System for Others

The lock brick could be used for water conservation measure such as creating rainwater drainage schemes which could be combined with a pond for collecting rainwater. The water could then be used during the period of water shortage (dry season). This concept is known as an ecological drainage concept. Lock-brick stones can be applied in the construction of these drainage channels. Lock-brick system can also be applied in floor construction or as good as pavement floor combination material. The lock-brick stone set horizontally before the floor filled with concrete material, asphalt and so on (figure 15)
Figure 15. The lock-brick development for the ecological drainage system and pavement floor.

5. Conclusions and Recommendations

5.1. Conclusions
The conclusions that can be given from this lock-brick system are:

• Lock-brick technology has multiple purposes and is simple and cheap.
• This lock-brick technology system can be applied to various building infrastructures, such as healthy houses, reservoirs, ditches or canals, floors, and retaining walls.
• Implementation of technology lock-brick system for various building infrastructures is simply by arranging it that will form the building component without applying of mortar filler because of direct interlocking of brick. For structural components that require special strength, it simply adds a concrete bar and concrete mixture.
• Lock-brick system technology is an ecological building material innovation.

5.2. Recommendation
Lock-brick system technology as an ecological building material innovation can be further developed to assist the community, especially to support the acceleration of the development of underdeveloped regions.

References
[2] Susilawati 2016 Rainwater Management for Agriculture and Life in The Household Scale Ciencia E Tecnica 31 (2)
[8] Simion HK 2009 Design of Interlocking Bricks for Enhanced All Construction Flexibility Alignment Accuracy and Load Bearing (UK: The University of Warwick)