EXPERIMENTAL INVESTIGATION ON THE PERFORMANCE OF INTERLOCKING BRICK WALL WITH OPENING-WINDOW

IAN RODERICK JAFFERY

FACULTY OF ENGINEERING

UNIVERSITI MALAYSIA SABAH

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A THESIS IS SUBMITTED TO FACULTY OF ENGINEERING, UNIVERSITY MALAYSIA SABAH IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR REWARD OF THE DEGREE OF BACHELOR OF ENGINEERING WITH HONOURS (CIVIL ENGINEERING)

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ABSTRACT

This study is mainly focusing on the experimental investigation on the performance of the interlocking brick wall with and without opening-window. An attempt is also made in determining the properties of the interlocking bricks that are used for the production of the interlocking brick wall. The production of the interlocking brick involves using the major constituents of brick which are soil, sand, cement and water. Literature review on the interlocking brick system was conducted to gain deeper understanding on the topic. Laboratory tests are also outlined in this report in order to continue the study of the performance of interlocking brick wall. The results and discussion of the experimental data can also be found in this case study.

ABSTRAK

Kajian ini terutamanya memberi tumpuan kepada penyiasatan eksperimen pada prestasi dinding bata yang saling berkaitan dengan dan tanpa tingkap pembukaan. Percubaan juga dibuat dalam menentukan sifat-sifat batu bata yang saling berkaitan yang digunakan untuk pengeluaran dinding bata yang saling berkaitan. Pengeluaran bata interlocking melibatkan penggunaan konstituen utama bata iaitu tanah, pasir, simen dan air. Kajian kesusasteraan mengenai sistem bata interlocking telah dijalankan untuk mendapatkan pemahaman yang lebih mendalam mengenai topik ini. Ujian makmal juga digariskan dalam laporan ini untuk meneruskan kajian prestasi dinding bata yang saling berkaitan. Laporan ini juga disertakan dengan hasil kajian daripada kerja makmal dan penjelasan mengenai topik yang dikaji.

TABLE OF CONTENT

	Page
BORANG PENGESAHAN STATUS THESIS	i
DECLARATION	ii
CERTIFICATION	iii
ACKNOWLEDGEMENT	iv
ABSTRACT	v
ABSTRAK	vi
TABLE OF CONTENT	vii
LIST OF TABLES	iix
LIST OF FIGURES	xi
i**LIST OF ABBREVIATIONS**	xiii

CHAPTER 1 : INTRODUCTION

1.1	Overview		1
1.2	Background of Study		1
1.3	Problem Statement		3
1.4	Objective of Study		3
1.5	Scope of Work		4

CHAPTER 2 : LITERATURE REVIEW

2.1	Introduction		5
2.2	Materials of Interlocking Bricks		5
2.3	Types of Interlocking Bricks		8
	2.3.1	Thai Interlocking Bricks	8
	2.3.2	Hydraform Blocks	10
	2.3.3	Haener Block	12
2.4	Properties of Interlocking Brick		13
	2.4.1	Compressive Strength	13
	2.4.2	Density	17
	2.4.3	Water Absorption and The Moisture Content	18
2.5	Mechanical Properties of Interlocking Brick Wall		19

CHAPTER 3 : METHODOLOGY **21**

3.1 Introduction 21
3.2 Methodology Flowchart 22
3.3 Material Preparation and Testing 23
3.3.1 Material Collection 23
3.3.2 Soil 23
3.3.3 Sand 24
3.3.4 Cement 24
3.3.5 Water 24
3.3.6 Material Testing 25
3.4 Interlocking Brick Production and Testing 25
3.4.1 Design Mix of Interlocking Brick 25
3.4.2 Manufacturing of Interlocking Bricks 26
3.4.3 Interlocking Brick Testing 28
3.5 Interlocking Brick Wall Production and Testing 29
3.5.1 Interlocking Brick Wall Production 29
3.5.2 Interlocking Brick Wall Testing 31

CHAPTER 4 : RESULT AND DISCUSSION

4.1 Introduction 34
4.2 Material Testing Results 34
4.2.1 Sieve Analysis of Sand and Soil 35
4.2.2 Specific Gravity and Water Absorption of Materials 38
4.3 Interlocking Brick Testing Results 43
4.3.1 Water Immersion Test Result 43
4.3.2 Density of Interlocking Brick 45
4.3.3 Compression Strength of Interlocking Brick 47
4.4 Interlocking Brick Wall Testing Result 50
4.4.1 Interlocking Brick Wall Compression Result 50
4.4.2 Deflection of Interlocking Brick Wall 57
4.4.3 Cracking Result of Interlocking Brick Wall 61

CHAPTER 5 : CONCLUSION AND FUTURE WORK

5.1 Research Conclusion 69
5.2 Outlook and Recommendation in Further Work 70

REFERENCES **71**

LIST OF TABLES

		Page
Table 1.1:	Scope of work	4
Table 2.1:	Soil stabilization techniques based on soil type	7
Table 3.1:	The method of material testing	25
Table 3.2:	The amount of material used in kilograms (kg)	25
Table 3.3:	Interlocking brick testing methods	28-29
Table 3.4:	The total number of bricks required to build 4 samples	29
Table 3.5:	Parameters of the interlocking brick wall samples	31
Table 4.1:	Sieve analysis result for soil	35
Table 4.2:	Data analysis for particle distribution curve of soil	35
Table 4.3:	Sieve analysis result for sand	36-37
Table 4.4:	Data analysis for particle distribution curve of sand	37
Table 4.5:	Testing standard used in material testing	38
Table 4.6:	Raw experiment data of material testing for sand	39
Table 4.7:	Calculation and results for the specific gravity and water absorption of sand	39-40
Table 4.8:	Raw experiment data of material testing for soil and specific gravity of soil	41
Table 4.9:	Water absorption of soil	42
Table 4.10:	Calculation and results for the specific gravity and water absorption of soil	42
Table 4.11:	Water immersion test result	43
Table 4.12:	The interlocking brick dimension and the average	45
Table 4.13:	Density of interlocking brick	45
Table 4.14:	Masonry bricks weight category in accordance to ASTM C90	45
Table 4.15:	Raw data of compression load of interlocking bricks	47
Table 4.16:	Compression strength of interlocking brick	48

Table 4.17:	Compressive strength of interlocking bricks from past researches	49
Table 4.18:	Compression load data for interlocking brick wall without opening-window	50-51
Table 4.19:	Compression load data for interlocking brick wall with opening-window	52-53
Table 4.20:	Maximum compression load of past researches	55
Table 4.21:	Comparison of interlocking brick to wall strength of current case study with past researches	56
Table 4.22:	Dial gauge readings for interlocking brick wall with and without opening-window	58
Table 4.23:	Cracking measurement data for interlocking brick wall without opening-window	66-67
Table 4.24	Cracking measurement data for interlocking brick wall with opening-window	67

LIST OF FIGURES

		Page
Figure 2.1:	The major components of interlocking brick	6
Figure 2.2:	Model 1 of TISTR Interlocking Brick (1982)	9
Figure 2.3:	Model 2 of TISTR Interlocking Brick (1998)	9
Figure 2.4:	Model 3 of TISTR Interlocking Brick	10
Figure 2.5:	Model 4 of TISTR Interlocking Brick	10
Figure 2.6:	Hydraform block	11
Figure 2.7:	Placement of the ridge and bed on the hydraform block	12
Figure 2.8:	The Haener blocks	13
Figure 2.9:	The standard size of Haener block	13
Figure 2.10:	28-day compressive strength test result	15
Figure 2.11:	28-day compressive strength test curing curve	15
Figure 2.12:	Compressive load at break results	16
Figure 2.13:	Compressive strength results of interlocking bricks	16
Figure 3.1:	Crusher machine	27
Figure 3.2:	Mixer machine	27
Figure 3.3:	High-pressure compaction machine	27
Figure 3.4:	The shape and size of bricks that can be produced in the factory	28
Figure 3.5:	The dimensions for the interlocking brick wall sample without opening-window	30
Figure 3.6:	The dimensions for the interlocking brick wall sample with opening-window	30
Figure 3.7:	The equipment set up for uniaxial compression test	32
Figure 3.8:	Dial gauge placements on both samples of interlocking brick wall	33
Figure 4.1:	Particle size distribution curve of soil	36
Figure 4.2:	Particle size distribution curve of sand	37
Figure 4.3:	Typical values of specific gravity	41

Figure 4.4:	Water immersion test graph	44
Figure 4.5:	Compression test for the interlocking brick and the condition of the brick after it was compressed	47
Figure 4.6:	Compression of interlocking brick graph	48
Figure 4.7:	Force-displacement graph for interlocking brick wall without opening-window	52
Figure 4.8:	Force-displacement graph for interlocking brick wall with opening-window	53
Figure 4.9:	Combined force-displacement graph for interlocking brick wall with and without opening-window	54
Figure 4.10:	Location of the dial gauge for both interlocking brick wall samples	57
Figure 4.11:	Deformation of the interlocking brick wall without opening-window	59
Figure 4.12:	Deformation of the interlocking brick wall with opening-window	59
Figure 4.13:	Deformation of interlocking brick wall with opening-window as observed in the laboratory	60
Figure 4.14:	Cracking pattern at the left side of the interlocking wall without opening-window	61
Figure 4.15:	Cracking pattern at the right side of the interlocking wall without opening-window	62
Figure 4.16:	Wall cracking diagram for interlocking brick without opening-window	62
Figure 4.17:	Cracking pattern at the left side of the interlocking wall with opening-window	63
Figure 4.18:	Cracking pattern at the right side of the interlocking wall with opening-window	64
Figure 4.19:	Cracking pattern at the top side of the interlocking wall with opening-window	65
Figure 4.20:	Wall cracking diagram for interlocking brick with opening-window	65

LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
BMTPC	-	Building Materials & Technology Promotion Council
BS	-	British Standard
C_c	-	Coefficient of curvature
C_u	-	Uniformity coefficient
ICEB	-	Interlocking Compressed Earth Blocks
MS	-	Malaysian Standard

CHAPTER 1

INTRODUCTION

1.1 Overview

In this chapter, an introduction to the interlocking brick was highlighted. Several problem statements and objectives were also discussed in this chapter. Moreover, the scope of work of this research is also included in this section.

1.2 Background of Study

The use of interlocking mortarless bricks has increased field profitability and effectiveness while reducing the requirement for highly specialized work teams. Furthermore, the use of interlocking blocks has grown rapidly in popularity in a number of foreign countries as a viable alternative to traditional blocks for the construction of stable and long-lasting structures.

Interlocking bricks or also known as interlocking compressed earth blocks (ICEB) are made up of soil, sand, Portland cement and water of desirable ratio (Onyeakpa and Onundi, 2014). These bricks can be used in construction in a form of dry stack masonry construction and interlocking bricks are also known as a low cost building material (Stirling, 2011). These bricks are made in a way that they can be set with mortar or as interlocking bricks that don't require any mortar. The hollow or solid blocks of the previous brick might be used. The interlocking brick system saves a lot of mortar since it employs grooves and protrusions to key or lock the bricks together instead of mortar along the vertical and horizontal alignment (Onyeakpa and Onundi, 2014). Interlocking bricks can be manufactured with vertical perforations or as solid interlocking bricks. Since there is no mortar being utilized between the blocks, ICEB construction is both easier and faster (Bales *et al.*, 2009). Instead, grout is poured into the openings in the blocks to create vertical grout columns that connect the wall. The vertical reinforcement goes from the foundation to the top channel block and is connected to the horizontal reinforcement. Reinforcement is spaced according to local building practice, which changes depending on the region's seismic activity.

The ICEB provides environmental and construction advantages. This is because the ICEB's manufacturing process is environmentally benign, relying solely on manual or mechanical compression (Ocholi and Joel, 2013 as cited in Abdullah *et al.*, 2021). As a result, there will be no toxic or dangerous gaseous or ash emissions. In terms of building and the environment, the ICEB reduces waste and maximizes value, while also being more energy efficient and cost effective than traditional bricks (Nasly *et al.*, 2010 and Stirling *et al.*, 2012 as cited in Abdullah *et al.*, 2021). In the construction industry, the use of interlocking brick system can contribute to a rapid and low cost construction system that offers good alternative solution in the construction industry (Ahmad et al, 2011). Furthermore, the shape of the interlocking brick varies with simplicity, resulting in simple and quick production and installation in masonry systems (Dhanraj, 2019).

Because there is no precise standard for this technology in Malaysia, interlocking bricks are not extensively employed (Ahmad *et al.*, 2011). Furthermore, due to limited research undertaken in the fabrication and installment of the system for local needs, the usage of the interlocking brick system in construction industry has been hampered (Ahmad *et al.*, 2011). As a result, the attempt to determine the effectiveness of an interlocking brick construction technique must be accelerated.

1.3 Problem Statement

Interlocking brick system was heavily inspired from the mechanisms of children's which was the Lego bricks (Kintingu, 2009). It was not until the 1970s that the interlocking bricks that require no mortar were invented for building construction, especially houses which had been developed in Africa, Canada, the Middle East and India (Kintingu, 2009). However, there is still only a handful of research being conducted on the interlocking brick wall system even though it had been invented several decades already.

The problem statements below will be outlined in this study which are:

1. What are the materials of manufacturing interlocking bricks?
2. What effects does the materials have to the brick?
3. What guidelines that can be used for interlocking brick mix design?
4. How would the interlocking brick wall would behave with and without opening-window?

1.4 Objective of Study

The aim of this study is to do experimental investigation on the performance of the interlocking brick wall with and without opening-window. The objectives of this study are as the following:

1. To study the properties of materials of interlocking brick such as sand, cement, water and soil
2. To analyze the effects of materials used to the interlocking brick
3. To determine the physical and mechanical properties of the interlocking brick
4. To investigate the performance of interlocking brick wall with and without opening-window

1.5 Scope of Work

The summarization of the scope of work is shown in Table 1.1.

Table 1.1: Scope of work

Target	Scope of Work	Source, Equipment and Material Need
Objective 1	Conduct literature review on the properties of materials of the interlocking brick	• Journals • Books • Articles • Internet Sources
Objective 2	Conduct material tests before using it to manufacture the interlocking bricks • Soil and sand particles • Specific gravity • Water absorption	• Sieve analysis method • ASTM C 128
Objective 3	Conduct laboratory tests to investigate the physical mechanical properties of the interlocking brick which includes: • Compressive strength • Density • Water absorption	• Compressive strength test • Water immersion test
Objective 4	Conduct laboratory tests to investigate the performance of interlocking brick wall with and without opening-window which includes: • Axial compression • Deflection • Cracking	• Uniaxial compression test using hydraulic jack

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, literature reviews from journals, articles, research papers, books and other relevant sources are being discussed and presented regarding on the topic of interlocking brick wall with opening-window. The purpose of conducting literature review is to get an extensive and in-depth review of the research topic which is on the materials of interlocking bricks, the types of interlocking brick wall, the properties of interlocking brick and the mechanical properties of an interlocking brick wall with and without opening-window.

2.2 Materials of Interlocking Bricks

In order to produce ICEB, four main raw materials needed are water, clay soil, sand and ordinary Portland cement (OPC) (Abdullah *et al.*, 2021). These four materials are the major components that make up the interlocking brick.

(a) Cement (b) Soil (c) Sand

Figure 2.1: The major components of interlocking brick

Source: Abdullah *et al.* 2021, p. 2

Cement is used in interlocking brick as a stabilizing agent. Cement has the ability to set and solidify when mixed with water (Onyeakpa and Onundi, 2014). The most common type of cement that can be found in almost any construction firms is Portland cement (Assiamah *et al.*, 2016). It reacts with the water in the mixture to form an insoluble cementation colloidal gel, a material that can disperse into pore spaces where it sets and hardens, generating a continuous matrix of high strength that surrounds and binds the soil particles. However, the percentage of cement used in the soil can affect the brittleness of interlocking brick. According to Bales *et al.* (2009), the higher the reliance on the resulting cement matrix in the soil, rather than both the matrix and frictional surfaces between the cement and host grains, the more brittle the failure.

Soil is a natural collection of mineral particles that may or may not contain organic materials, and it exists in three phases: solid, liquid, and gaseous, according to Assiamah (2014). Uncemented aggregates of mineral grains and degraded organic matter make up soil, with liquid and gaseous filling the vacuum spaces between the solid particles. In order to use soil for interlocking brick, soil stabilization must be conducted. Soil stabilization can be conducted through adding a stabilizing agent into the mix. According to Nasly *et al.* (2009), there are several major methods in soil stabilization which are bitumen stabilization, cement stabilization, gypsum stabilization, lime stabilization, mechanical stabilization and pozzolana stabilization. The type of soil used for stabilization will determine which stabilization techniques need to be applied. Table 2.1 shows Kintingu (2009) recommending which stabilization techniques need to be applied according to the type of soil.

Table 2.1: Soil stabilization techniques based on soil type

The type of soil	**Stabilization techniques**
Low shrinkage soil (High sand content)	• Portland cement • Compressed with high power machines (more than 4 MPa)
High shrinkage soil (High clay content)	• Lime stabilization • Compressed with low power press machines (to 2 MPa)

River sand was found to be the most often used material in the research papers examined. A cohesionless aggregation of rounded, sub-rounded, or angular bits of rocks or mineral grains is referred to as sand (Onyeakpa and Onundi, 2014). Sand is defined as particles with a diameter ranging from 0.06mm (or 0.075mm) to 2.0mm (or 4.75mm) according to Onyeakpa and Onundi (2014). The strength and load bearing capability of interlocking blocks are affected by aggregate size (Onyeakpa and Onundi, 2014). According to Reddy and Gupta (2005), their research in soil-cement blocks using highly sandy soils show that there is 2.5 times increase in strength for doubling of cement content from 6%. Ahmad et al (2011) added that the saturated water content of the blocks is not affected by the cement content. However, the rate of moisture absorption is considerably affected by the cement content (Ahmad *et al.*, 2011).

In order to initiate the hydration process, water is necessary in the cement and aggregate mix, and a sufficient water-cement ratio is required to provide optimal consistency within the mix (Onyeakpa and Onundi, 2014). The cement paste holds the aggregate together, fills cavities, and allows it to flow more freely. Water is required in order to achieve the optimum moisture content in a cementitious mix. According to Kintingu (2009), the optimum moisture content for producing interlocking bricks is the proper mix consistency, which can be determined by a simple field drop test; if the soil ball breaks into a few (4-6) lumps, the water content is correct. Water is also used in the curing process of interlocking brick. As can be seen in Bales et al (2009) and Phadatare *et al*. (2018), water was used in the design mix and also for the curing process of interlocking bricks.

2.3 Types of Interlocking Bricks

2.3.1 Thai Interlocking Bricks

The Thai interlocking brick system was developed by the Human Settlement Division of the Asian Institute of Technology (HSD-AIT) in Bangkok, Thailand and was cooperated with Thailand Institute of Scientific and Technical Research (TISTR) (Kintingu, 2009). According to Chaimoon *et al*. (2019), Thailand Institute of Scientific and Technical Research (TISTR) developed the interlocking brick in an attempt to find an alternative for a cheaper and faster construction material for the housing sector. The dimension of Thai interlocking brick is usually found in 300mm in length, 150mm in width and 100mm in height (Kintingu, 2009). According to Bredenoord *et al*. (2019), the dimensions, weight and form of the blocks can vary internationally, but the Thai interlocking bricks cannot be shifted. Thailand's interlocking bricks were created as a load-bearing building material with a hole pattern that allows for the installation of horizontal and vertical reinforcements in the walls (Bredenoord *et al*., 2019).

The initial interlocking brick, created in 1982, was discovered to be too heavy for building use, and the vertical grooves on the outside of the brick received negative feedback from consumers (Bredenoord *et al*., 2019). The second model brick was improved according to the issues where it was made lighter and had no exterior grooves Bredenoord *et al*., 2019). The design of the Thai interlocking bricks was improved over the years due to practical experiences. The current designs for Thai interlocking bricks are Model 3 and 4, which both contain two holes to link bricks in the vertical direction for a better and more stable interlocking function (Janbunjong, 2019 as cited in Bredenoord *et al.*, 2019). The design of the model 4 of the interlocking brick system have link-hole depression, which is significant for constructing buildings that have more than 2 stories (Bredenoord *et al.*, 2019). According to Chaimoon (2019), the Thai interlocking brick system provides an alternative method in the construction of masonry buildings and an alternative to framed buildings.

Figure 2.2: Model 1 of TISTR Interlocking Brick (1982)

Source: Bredenoord *et al.* 2019, p. 4

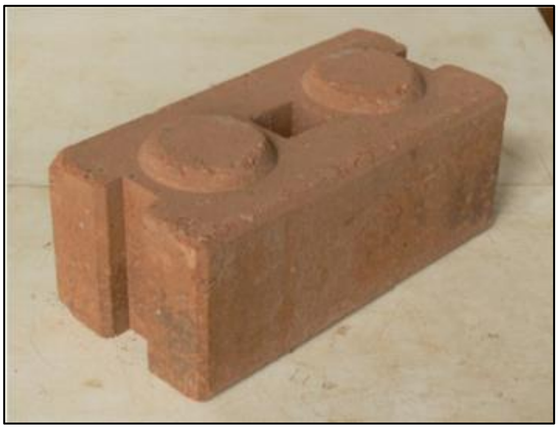

Figure 2.3: Model 2 of TISTR Interlocking Brick (1998)

Source: Bredenoord *et al.* 2019, p. 4