Assessment the Mechanical Properties of Soil Cement Interlocking (SCI) Bricks: A Case Study in Malaysia

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ABSTRACT

The research assessed and examined the mechanical properties of the Soil Cement Interlocking brick (SCI) to provide the information for the possible and appropriate development and revision of the (SCI) brick due to the substantial benefits which can be obtained by improving these sorts of bricks. Therefore, drastic efforts and accurate attention were paid precisely on the laboratory tests. Some of the laboratory investigation on (SCI) bricks were conducted in conjunction with the use of various masonry standards to evaluate the Compressive Strength, Dimensional Tolerance, Water Absorption, Initial Rate of Suction and Modulus of Rapture. Results illustrated that the water absorption for (SCI) brick ranged from (13.566% - 17.045%), the Initial Rate of Suction ranged from (1.746-3.573) kg/m², the compressive strength on the other hand fell in range between (7.733-12.33)N/mm² for (SCI)bricks without mortar, whereas the compressive strength for (SCI)bricks filled with mortar ranged from (12.406-15.098)N/mm² and Modulus of Rapture was found to be ranged between (0.004-0.023) Pa for (SCI) bricks without mortar, whereas, Modulus of Rapture for (SCI)bricks filled with mortar was (0.004-0.017) Pa. The study revealed a good quality that can be produced from soil and cement by pressing method whereby contributing to sustainable development.

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1. INTRODUCTION

Brick masonry is a well proven building material possessing excellent properties in various terms, for example, appearance, durability, cost. However the quality of masonry in building depending on the material used and hence all the brickworks must certain minimum amount of standard. The basic component of brickworks are brick and mortar [2].

The latter being in itself a composite of cement, lime and sand and sometimes of other constituents. All these bricks are either produced by machines or manually using skilled or unskilled require mortar joints and some degree of skill replacement when building walls[5]. It’s also consume labour’s time. Furthermore, since bricks are mostly solid, the wall become rather massive and oversized for single storey load bearing construction while being insufficient stable for multi-storey construction. In addition, conventional mortar joint allow only light reinforcement to be used making the wall an unstable structural component in earth quake zones[1].

(SCI) brick is inexpensive and can be used without cement or mortar, easy to handle, mould and manufacture, the hollow portions allow insertion of certain fixtures or conduits without having to do extra
work on the building structure, no need fire treatment and therefore ease the fast depletion of the forest cover, 
need less water for their production and treatment compared with the production of other bricks and use very 
small amount of cement per brick. Moreover, (SCI) brick can be produced at or near the site — reduced 
transportation cost, Green technology—Zero carbon emission, Energy Efficient, Uses local available 
materials, Reduces the. Given unskilled or semiskilled labour can easily and quickly construct the wall [4].

The interlocking brick is deferent from the other normal brick. They are rectangular, but they don’t 
require mortar for the masonry work because they interlocked with each other by positive and negative frogs 
on the top and the bottom of the bricks which do not allow horizontal movement between them They can be 
used for all kinds of structures like load bearing walls, lintels, sills and wall corners [2].

There is significant heterogeneity between the normal bricks used for construction and the 
interlocking bricks which will be addressed accordingly Firstly, Interlocking bricks are not baked, it is just 
mud in high density pressed using a pressing machine and allowed to solidify by drying naturally. Some 
chemicals are added for increasing the bond strength. Whilst, normal bricks are baked ones. Secondly, size of 
interlocking brick is more. It is approximately 2.5 times more in volume than the baked bricks .Thirdly 
weight of Interlocking bricks is more than equivalent volume of baked bricks. [3] .However, there are certain 
drawbacks which might be caused by (SCI) bricks represented by the technology being relatively new, 
people may be reluctant to apply it. Hence, a well co-ordinate dissemination strategy to introduce it to 
potential builders is vital. Although skilled masons are not needed for constructing walls, a certain amount of 
training is required to ensure that the walls are properly aligned and no gaps are left. Also in the production 
of the blocks training is needed not only in determining the correct type of soil, correct mix proportion and 
moisture content, but also in producing uniform sized blocks (that is, avoiding under or over-filling the block 
moulds before compaction).Even with the greatest care in assembling the walls, the joints are not entirely 
resistant to wind and rain penetration, therefore, plastering the interior wall surfaces is usually necessary [8]. 

Tests on Compressive Strength, Water Absorption, Initial Rate of Suction and modulus of Rapture 
were conducted and results were discussed.

The bricks have been conventionally made by mixing the raw material in an industrial mixer, pour 
the mix in moulds and leave it for (1-2) days after applying pressure on the mix inside the moulds and then 
dry the samples after demoulding them in an oven for approximately 24 hour at temperature ranged from 
(103-105) °C, and then sintering at temperature varying from (800 – 1200)°C [1-12]. Firing of bricks resulted 
in an enormous green house gas emission and hence not sustainable.Gas release, crystalline structure and 
ceramic properties were analyzed during firing of clay raw materials and extruded bricks. Carbon monoxide, 
carbon dioxide, nitrogen oxides, and methane emissions were measured during the firing cycle for the 
powder of the raw material of the clay brick and for the clay brick itself, gas emissions were found to be 
8600ppm of CO2 released from the powder, and 6500ppm released per brick, on the same manner around 
1100ppm of CO released from the powder. Besides, 800ppm released per brick [13].Therefore, there must be 
alternative solution in producing the bricks with no gas pollutants and energy consumption. A case study was 
held in Taiwan in developing bricks from reservoir sediments with fly ash in two methods, the first one 
involved vitrifying bricks at high temperature approach 1000°C and the second one involved pressing bricks 
at 15000 Psi without vitrifying[7].Another study was carried out in Hanson Brick Company, in Stewartry, 
Bedfordshire, it had developed unfired clay bricks by pressing granulated blast furnace slag, lime, clay brick 
and less of Portland cement without applying the samples to sintering process and the results for mechanical 
properties for the unfired clay brick were satisfactorily acceptable[13].

2. MATERIALS AND TEST METHODOLOGY

This study examine the mechanical properties on soil cement interlocking bricks (SCI) which were 
manufactured by KNK Manufacturing Sdn Bhd, Rawang, Selangor, Malaysia. Laboratory investigations 
were performed on samples of (SCI) bricks at the Structural Laboratory of civil engineering department in 
Universiti Tenaga Nasional (UNITEN), Selangor, Malaysia.

Tests were conducted to examine the compressive strength, Water Absorption, Initial Rate of 
Suction, Dimensional Tolerance and Modulus of Rapture. Tests methods were mostly based on 
BS3921:1985, the ASTM: C67. The (SCI) bricks were claimed to be processed from the following materials 
and proportions consistently table 1[5].

| No. | Material | By Volume (%) |
|-----|----------|---------------|
| 1   | Cement   | 10            |
| 2   | Sand     | 45            |
| 3   | Soil     | 45            |
3. **DIMENSIONAL TOLERANCE**

Dimensional tolerances were measured from the respective length, width and height of overall dimension of 24 bricks and individual brick dimension. Tests were conducted on 24 bricks to examine the dimensional tolerance in accordance to BS 3921. The 24 bricks were selected at randomly from a batch. For the measurement of overall lengths, the bricks were placed in two rows, each of 12 numbers, on a flat surface in the laboratory. For individual Dimensions the venire caliper were used in which a measurement to two decimal places was recorded. The results for the individual dimension of length, width and height are shown in Table [2]. Table [3] shows the overall dimensions for length, width and height in the samples[5].

3.1. **Initial Rate of Suction Test**

Initially ten bricks were dried in a ventilated oven for two and a half days at temperature of 110 °C. In accordance to BS 3921 constant mass is assured if bricks are subjected to heating at 110 °C for not less than 48 hours. The bricks were removed from the oven and cool to room temperature for a period of approximately 4 hours. Cooling was assisted by passing air over the bricks using an electric fan for a period of 2 hours. Upon cooling, the bricks were weighed and the dry mass $m_d$ was recorded. In the tests a large shallow rectangular pan of size $600mm \times 600mm$ giving, an area of $0.36m^2$ was used. The pre-weighed dry brick was placed on the pan and the water level is closely observed with a measuring gauge to ensure that depth of the immersion for the brick was maintained at $3 \pm 1mm$ throughout the duration of immersion, 1 minute. After 1 minute, the brick was removed from the water and excess water wiped off with a damp cloth. The brick was reweighed and the mass $m_w$ was recorded[10-14]. The initial rate of suction due to gross area of immersion (IRS gross), in kg/m2.min is calculated using the following equation:

$$ IRS = 1000 \left( m_s - m_d \right) / A_{gross} $$

3.2. **Water Absorption Test**

The same 10 bricks used for initial rate of suction tests were used for water absorption test. The dry mass $m_d$, were as recorded earlier in the initial rate of suction test. A large urn was used to accommodate two sets of samples comprising of 20 bricks. The bricks were arranged into two tiers with spaces between bricks and tires, were boiled for 5 hours and then allowed to cool naturally in the water for about 18 hours[15]. A minimum of 16 hours and a maximum of 19 hours of cooling Periods were recommended by BS 3921. Each brick was weighed and the saturated mass $m_s$ were recorded. Water absorption $W$, in percentage was calculated using the Following equation:

$$ W = 100 \left( m_s - m_d \right) / m_{dm} $$

3.3. **Compressive Strength Test**

The compressive strength test for the brick was held according to the ASTM: C67 and that was representing by applying the(SCI) bricks in their dry curing condition to the test. Firstly, the test was hold for the(SCI) brick without mortar inside the machine with the maximum load approach (253.340KN), whereas, the maximum load for (SCI)brick filled with mortar was found to be approximately (471.834KN). The load was applied to one half of the expected maximum load after which adjust the machine controls, so that the remaining load was applied at uniform rate not less than 1 nor 2minute[9]. The compressive strength of the specimen was calculated from the following equation:

$$ C = W / A $$

3.4. **Modulus of Rapture Test**

The modulus of Rapture was held according to the ASTM:C67, 10 bricks were examined in the testing machine by applying the load to the bricks into two cases, with mortar and without mortar. Bricks were supported and the load was applied in the direction of the depth on a span approximately 1in (25.4mm) less than the basic unit of length. The load was applied to the upper surface of the specimen through the steel bearing plate ¼ in (6.35in) in thickness and (38.10mm) in width, and a length is at least equal to the width of the specimen [7-11]. The maximum load was found to be approximately (25KN) for (SCI)bricks without mortar, whilst the maximum load for (SCI) bricks filled with mortar was merely (18KN). The modulus of Rapture can be evaluated from the following equation:

$$ S = 3w \left( l / 2 - x \right) / bd^2 $$
4. RESULTS AND ANALYSIS

Results for Dimensional Tolerance, Initial Rate of Suction, Water Absorption, Compressive Strength and Modulus of Rapture will be addressed accordingly. Efflorescence, doesn’t seem to be major hence (SCI) bricks could be satisfactorily used for facing construction purposes without resulting in salt deposition on the surfaces [16]. Therefore, results from efflorescence test and soluble salt content were deduced from Observations based on small samples and hence found not required to be analyzed by the statistical approach as described in this study.

4.1. Dimensional Tolerance

The results from the Tolerance test illustrated that the dimension of the test specimen was found to be (250.176mm×125.58mm×99.38mm). The Dimensional satisfy the Tolerance given in BS 3921 and fit the T1 category for the European Standard EN771-1 for the Dimensional Tolerance. Results for Dimensional Tolerance for individual and overall dimensions will be illustrated in table (2) and table (3).

Table (2) shows the results for Dimensional Tolerance for individual brick.

| Brick | Length | width | Height |
|-------|--------|-------|--------|
| 1     | 253    | 126   | 100    |
| 2     | 250    | 124   | 99     |
| 3     | 250    | 125   | 99     |
| 4     | 250    | 124   | 98     |
| 5     | 250    | 125   | 97     |
| 6     | 250    | 125   | 100    |
| 7     | 250    | 126   | 100    |
| 8     | 250    | 126   | 100    |
| 9     | 250    | 126   | 99     |
| 10    | 250    | 127   | 100    |
| 11    | 250    | 126   | 99     |
| 12    | 250    | 126   | 100    |
| 13    | 250    | 125   | 99     |
| 14    | 250    | 127   | 100    |
| 15    | 250    | 126   | 100    |
| 16    | 250    | 125   | 99     |
| 17    | 251    | 125   | 100    |
| 18    | 250    | 126   | 100    |
| 19    | 250    | 127   | 99     |
| 20    | 250    | 126   | 98     |
| 21    | 250    | 125   | 100    |
| 22    | 250    | 126   | 100    |
| 23    | 250    | 125   | 100    |
| 24    | 250    | 125   | 99     |
| Average: | 250.2 | 125.6 | 99.4  |
Table (3) shows the results for overall dimensions

| Size Test                      | Length of 24 Bricks Together | 2900 | 2902 | 2901 | 2902 | 2898 | 2895 |
|--------------------------------|--------------------------------|------|------|------|------|------|------|
| Average                        | 2899.66667                    |      |      |      |      |      |      |
| Width of 24 Brick              | 2289                          | 2276 | 2280 | 2284 | 2279 | 2275 |
| Average                        | 2280.5                        |      |      |      |      |      |      |
| Height of 24 Bricks            | 6003                          | 5903 | 5970 | 5907 | 5990 | 5980 |
| Average                        | 5958.83333                    |      |      |      |      |      |      |

### 4.2. Initial Rate of Suction

The Initial Rate of Suction for (SCI) bricks range from (1.746 - 3.573) kg/m².min, indicating high suction property thus implying the necessity of wetting brick before laying. Results for Initial Rate of Suction will be illustrated in Table (4), which seem to be accepted from both of the BS3921:1985 and the European standard EN771-1 which symbolize the Initial rate of Absorption test as a measurement to how quickly the water is absorbed through the bricks, shwon table 4.

Table (4) shows the results for Initial Rate of Suction

| Brick | Dry mass | Wet mass | Length | Width | Immersed area (mm²) gross | IRS (kg/m².min) |
|-------|----------|----------|--------|-------|---------------------------|----------------|
| 1     | 4623     | 4711     | 250    | 125   | 24622.5                   | 3.5739669       |
| 2     | 4558     | 4615     | 250    | 125   | 24622.5                   | 2.314955833     |
| 3     | 4629     | 4723     | 250    | 125   | 24622.5                   | 3.817646462     |
| 4     | 4643     | 4731     | 250    | 125   | 24622.5                   | 3.5739669       |
| 5     | 4706     | 4772     | 250    | 125   | 24622.5                   | 2.680475175     |
| 6     | 4962     | 5005     | 250    | 125   | 24622.5                   | 1.74637019      |
| 7     | 4716     | 4783     | 250    | 125   | 24622.5                   | 2.721088435     |
| 8     | 4634     | 4719     | 250    | 125   | 24622.5                   | 3.45212712      |
| 9     | 4496     | 4556     | 250    | 125   | 24622.5                   | 2.436795614      |
| 10    | 4672     | 4739     | 250    | 125   | 24622.5                   | 2.721088435     |

### 4.3. Water Absorption

Water Absorption test for the (ISC) brick under Water Absorption test showed considerable growth in Water Absorption of (SCI) bricks and it was ranged from (13.566%-17.045%) and, therefore, it doesn’t
fit the category of water Absorption of the BS3921:1985 for the engineering brick class A or class B which suppose to have Water Absorption approach 4.5% for class A and 7% for class B. However, the values of Water Absorption of (SCI) bricks satisfy the requirement of the SW (Severe Weathering) bricks in ASTM, shown Table 5.

Table (5) illustrate the results for Water Absorption test:

| Bricks | Dry mass | Wet mass | % |
|--------|----------|----------|---|
| 1      | 4617     | 5404     | 17.0457007 |
| 2      | 4728     | 5413     | 14.4881557 |
| 3      | 4682     | 5401     | 15.3566852 |
| 4      | 4600     | 5429     | 18.0217391 |
| 5      | 4813     | 5525     | 14.7932682 |
| 6      | 4968     | 5642     | 13.5668277 |
| 7      | 4786     | 5470     | 14.2916841 |
| 8      | 4749     | 5448     | 14.7188882 |
| 9      | 4586     | 5378     | 17.269952 |
| 10     | 4724     | 5394     | 14.1828959 |
| Average: | 4725.3 | 5450.4 | 15.3735797 |

4.4. Compressive Strength
The test for compressive strength for (SCI) brick clarify that for a brick without mortar, the stress was found to be varied from (7.733-12.336) N/mm², bearing in minds that these were collected from true area (20455.5mm²) and from true loads, whilst the compressive strength result for (SCI) bricks filled with mortar was found to be considerably higher than the above pattern, the results were ranged from (12.026-15.098) N/mm², These results seem to be satisfactorily recommended from the ASTM: C67 which required that the stress should be 10.3 N/mm² for NW and not less than 17.2 N/mm² shown table 6,7.

Table (6) shows the results for compressive strength for (SCI) bricks without mortar.

| Width | Thickness | Area | Maximum load | Stress N/mm² |
|-------|-----------|------|--------------|--------------|
| 1     | 250       | 125  | 31250        | 156.162      | 4.997184   |
| 2     | 250       | 125  | 31250        | 212.581      | 6.802592   |
| 3     | 250       | 125  | 31250        | 192.61       | 6.16352    |
| 4     | 250       | 125  | 31250        | 251.302      | 6.041664   |
| 5     | 250       | 125  | 31250        | 250.318      | 6.010176   |
| Average | 250    | 125  | 31250        | 212.5946     | 6.8030272  |
| Min   | 250       | 125  | 31250        | 156.162      | 4.997184   |
| Max   | 250       | 125  | 31250        | 212.5946     | 6.8030272  |

| True Area | True Load | Stress N/mm² |
|-----------|-----------|--------------|
| 20455.5   | 158.200736| 7.73389729   |
| 20455.5   | 214.619736| 10.4920308   |
| 20455.5   | 194.648736| 9.51571636   |
| 20455.5   | 253.340736| 12.3849691   |
| 20455.5   | 252.356736| 12.336847    |

Table (7) shows the results for compressive strength for (SCI) bricks filled with mortar.

| Width | Thickness | Area | Maximum load | Stress N/mm² |
|-------|-----------|------|--------------|--------------|
| 1     | 250       | 125  | 31250        | 469.796      | 15.033     |
| 2     | 250       | 125  | 31250        | 373.791      | 11.961     |
| 3     | 250       | 125  | 31250        | 460.481      | 14.735     |
| 4     | 250       | 125  | 31250        | 385.652      | 12.341     |
| 5     | 250       | 125  | 31250        | 412.128      | 13.188     |
| Average | 250    | 125  | 31250        | 420.3696     | 13.4516    |
| Min   | 250       | 125  | 31250        | 373.791      | 11.961     |
| Max   | 250       | 125  | 31250        | 469.796      | 15.033     |

| True Area | True Load | Stress N/mm² |
|-----------|-----------|--------------|
| 31250     | 471.834736| 15.0987116   |
| 31250     | 375.829736| 12.0265516   |
| 31250     | 462.519736| 14.8006316   |
| 31250     | 387.690736| 12.4060336   |
| 31250     | 414.166736| 13.2533356   |

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4.5. Modulus of Rupture

Modulus of Rupture was conducted for five bricks with and without mortar, for (SCI) bricks without mortar the modulus of Rupture fell in range from merely 0.0042 pa as a miniature value to approximately 0.0371 pa higher value and for (SCI) bricks filled with mortar the results of Modulus of Rupture was observed between approximately 0.00499 pa to 0.017 pa which found to be satisfactorily accepted from the ASTM: C67 which suppose that the Modulus of Rapture should be determinate to the nearest 1psi (0.01MPA) shown Table 8 .

Table (8) shows the result for Modulus of Rapture

| Max Load KN | Value of (x) | (b) | (d) | (s) |
|-------------|--------------|-----|-----|-----|
| 1           | 20.662       | 2.63333333 | 95  | 100 | 0.023139151 |
| 2           | 11.002       | 3.83333333 | 95  | 100 | 0.004256353 |
| 3           | 24.429       | 2.46666667 | 95  | 100 | 0.037128406 |
| 4           | 26.962       | 1.1      | 95  | 100 | 0.021247948 |
| 5           | 25.561       | 0.73333333 | 95  | 100 | 0.014312744 |

| Max Load KN (filled) | Value of (x) | (b) | (d) | (s) |
|----------------------|--------------|-----|-----|-----|
| 1                    | 11.873       | 2.76666667 | 95  | 100 | 0.010984019 |
| 2                    | 10.426       | 2.43333333 | 95  | 100 | 0.017064872 |
| 3                    | 9.733        | 3.26666667 | 95  | 100 | 0.005449941 |
| 4                    | 18.864       | 1.06666667 | 95  | 100 | 0.014335222 |
| 5                    | 7.281        | 0.96666667 | 95  | 100 | 0.00499756  |

5. CONCLUSION

The results above for Compressive strength showed that the compressive strength for (SCI) brick was satisfactorily accepted from the ASTM: C67.

The results for water absorption test showed the water absorption foe (SCI) bricks which lied outside the specified limits for Engineering bricks in BS3921:1985 the results on the overall dimensions of 24 bricks showed that both the length and the width fall within the permissible tolerance of the British Standard. British Standard tolerance limit considerably by about 37 mm.

The content of calcium, magnesium, potassium, sodium and sulphate in the bricks was very negligible and thus they fall under the durability designation of ”Low” (L) of soluble salt content as per BS 3921:1985. In accordance to European Standard, the bricks could be applied even for the worst condition of construction application. The result for Initial rate of suction for (SCI) bricks found to be accepted from both BS3921:1985 and EN771-1 . The result for Modulus of Rapture found to be slightly accepted from the ASTM: C67 to sum up, from the mechanical test which was held on (SCI) brick according to BS3921:1985 and ASTM: C67 showed the results were accepted from the both standards based on the test that was held.

For future recommendation, wall testing should be held to study the failure mode of the wall which will be so important for residential utilizations of (SCI) bricks.

ABBREVIATION

| Symbol | Description |
|--------|-------------|
| SCI    | Soil Cement Interlocking Brick |
| BSI    | British Standard Institution |
| ASTM   | American Society for testing Material |
| EN     | European standard |
| IRS    | Initial rate of suction int( kg/m².min) |
| mw     | The mass of the wet brick in (gram).
| md     | The mass of the dry brick in (gram).
| A goss | The gross area of the immersed face of the brick in( mm²).
| md     | The dry mass |
| ms     | The saturated mass |
| C      | The compressive strength of the specimen (Kg/cm²) |
| W      | The maximum load (N) |
| A      | The average of gross area (cm²) |
| S      | The modulus of Rapture (pa).
| W      | The maximum load (N) |
| L      | The distance between supports. |
| B      | The net width (mm). |
| D      | The depth (mm). |
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