International Journal of Advances in Applied Sciences (IJAAS)
Vol. 1, No. 2, June 2012, pp. 77~84
ISSN: 2252-8814

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

Ali Ahmed Mohammed*
* Departement of Civil and Structural Engineering, Faculty of Engineering, The National University of Malaysia (UKM) 43600 Bangi, Selangor Darul Ehsan, Malaysia, Assistant Lecturer in Ministry of Higher Education and Scientific Research- Office Reconstruction and Projects Department, IRAQ.

Article Info

Article history:

Received Apr 3, 2012
Revised May 19, 2012
Accepted June 4, 2012

Keyword:

Soil cement Interlocking brick (SCI),
compressive strength
water absorption
Initial Rate of Suction and
Modulus of Rapture.

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 to 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.

Corresponding Author:

Ali Ahmed Mohammed,
Department of Civil and Structural Engineering,
The National University of Malaysia (UKM) 43600 Bangi,
Selangor Darul Ehsan, Malaysia.
Email: aliukm@yahoo.com

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 Stewartby, 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].

Table 1. Materials and proportions consistently

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 md was recorded .In the tests a large shallow rectangular pan of size 600mm × 600mm giving, an area of 0.36m2 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 ± 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 mw 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:

$$\mathrm{IRS} = 1000\left(\mathrm{m_w} - \mathrm{m_d}\right) / \mathrm{A\ gross} \quad (1)$$

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 md, 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 ms were recorded. Water absorption W, in percentage was calculated using the Following equation:

$$\mathrm{W} = 100\left(\mathrm{m_s} - \mathrm{m_d}\right) / \mathrm{m_d}\ \mathrm{m} \quad (2)$$

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 up 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:

$$C = W / A \quad (3)$$

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:

$$S = 3w\left(l/2 - x\right)/bd^2 \quad (4)$$

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. Dimennsional 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 (mm^2) gross	IRS (kg/m^2.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 o Water Absorption of (SCI) bricks satisfy the requirement of the SW(Severe Weathering) bricks in ASTM, shwon 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/mm^2 ,bearing in minds that these were collected from true area (20455.5mm^2) 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/mm^2 , These results seem to be satisfactorily recommended from the ASTM: C67 which required that the stress should be 10.3 N/mm^2 for NW and not less than 17.2N/mm^2 shown table 6,7 .

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

	Width	Thickness	Area	Maximum load	Stress N/mm^2
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	8.041664
5	250	125	31250	250.318	8.010176
Average	250	125	31250	212.5946	6.8030272
Min	250	125	31250	156.162	4.997184
Max	250	125	31250	251.302	8.041664
	True Area	True Load	Stress N/mm^2		
1	20455.5	158.200736	7.73389729		
2	20455.5	214.619736	10.4920308		
3	20455.5	194.648736	9.51571636		
4	20455.5	253.340736	12.3849691		
5	20455.5	252.356736	12.3368647		

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

	Width	Thickness	Area	maximum load	stress N/mm^2
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/mm^2		
1	31250				
2	31250	471.834736	15.0987116		
3	31250	375.829736	12.0265516		
4	31250	462.519736	14.8006316		
5	31250	387.690736	12.4061036		
		414.166736	13.2533356		

Average	31250	422.408336	13.5170668
Min	31250	375.829736	12.0265516
Max	31250	471.834736	15.0987116

4.5. Modulus of Rapture

Modulus of Rapture was conducted for five bricks with and without mortar, for (SCI) bricks without mortar the modulus of Rapture fell in range from merely 0.0042pa as a miniature value to approximately 0.0371pa higher value and for (SCI) bricks filled with mortar the results of Modulus of Rapture was observed between approximately 0.00499 pa to 0.017pa 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	(L)	Value of (x)	(b)	(d)	(s)
1	20.662	224.6	2.63333333	95	100	0.023139151
2	11.002	224.6	3.83333333	95	100	0.004256353
3	24.429	224.6	2.46666667	95	100	0.037128406
4	26.962	224.6	1.1	95	100	0.021247948
5	25.561	224.6	0.73333333	95	100	0.014312744
	Max Load KN(filled)	(L)	Value of (x)	(b)	(d)	(S)
1	11.873	224.6	2.76666667	95	100	0.010984019
2	10.426	224.6	2.43333333	95	100	0.017064872
3	9.733	224.6	3.26666667	95	100	0.005449941
4	18.864	224.6	1.06666667	95	100	0.014335222
5	7.281	224.6	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 gross	Initial rate of suction in($kg/m^2.min$)
mw	The mass of the wet brick in (gram).
md	The mass of the dry brick in (gram).
A gross	The gross area of the immersed face of the brick in(mm^2).
md	The dry mass
ms	The saturated mass
C	The compressive strength of the specimen (Kg/cm^2)
W	The maximum load (N)
A	The average of gross area (cm^2)
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).

REFERENCES

[1] Eduardo A.Dominguez, Rosa Ullman,Ecological bricks made with clay and steel dust pollutant, Clay science journal,11(1996) 237-249.

[2] Halil Mural Algin, Pki Turgut, Cotton and limestone powder wastes as brick material, Construction and Building Material, 22(2008) 1074-1080.

[3] Geiza E.Oliveira, Jose Nilson Holand , Use of mix of clay/solid waste from steel works for civil construction materials, Waste Management ,22(2004) 358-363.

[4] Quintilio Piattoni, Enrico Quagliarini,Stefano Lenci, Experimental analysis and modeling of the mechanical behavior of earthen bricks, Construction and Building Material 25(2011)2067-2075

[5] Abdul G.Liew, Azni Idris,Calvin H.K.Wong, Abdul A.Samad ,Megat Johari, M.M.Noor, Aminuddin M.Baki, Incorporation of sewage sludge clay in clay brick and it's characterization, journal of Waste and Management Research, 22(2004)226-233

[6] K.C.P. Faria, R.F. Gurgel, J.N.F. Holanda, Recycling of sugarcane bagasse ash waste in the production of clay bricks, Environmental Management, 101(2012) 7-12.

[7] Rebeca Alonso-Santurde, Alberto Coz, Natalia Quijorna, Javier R. Viguri, Ana Andrés , Valorization of Foundry Sand in Clay Bricks at Industrial Scale, Industrial Ecology ,14(2011) 217-230.

[8] Nagaharu Okunu, shiro Takahashi , Full scale application of manufacturing bricks from sewage, Water Science Technology,36 (1997) 243-250.

[9] Ilker Bekir Topc-u, Burak Is-ıkdag, Manufacture of high heat conductivity resistant clay bricks containing perlite, Building and Environment,42 (2007) 3540–3546

[10] M. Gutovic , D.S. Klimesch, A. Ray, Strength development in autoclaved blends made with OPC and clay-brick waste, Construction and Building Materials 19 (2005) 353–358.

[11] Taner Kavas, Use of boron waste as a fluxing agent in production of red mud brick, Building and Environment ,41 (2006) 1779–1783

[12] R. Toledo, D.R. dos Santos, R.T. Faria Jr., J.G. Carrio, L.T. Auler, H. Vargas, Gas release during clay firing and evolution of ceramic properties, Applied Clay Science,27 (2004) 151– 157

[13] J.E. Oti, J.M. Kinuthia, J. Bai, Engineering properties of unfired clay masonry bricks, Engineering Geology,107 (2009)130–139

[14] http://www.hydraformasia.com

[15] www.scholar.google.com

[16] www.unicef.org

[17] http://myprodview.blogspot.com

BIOGRAPHY OF AUTHOR

Mr Ali Ahmed Mohammed His obtained his graduated BSc in Civil and Structural Engineering, Department of Building and Construction, University of Technology, IRAQ (1st Class Honours). The M.Sc. degree in Civil and Structural Engineering, The National University of Malaysia (UKM) (Graduated with Honours) in the year 2010 with specialization in Transportation Engineering , Sustainable urban design, Intelligent Urban Traffic,Materials , Advanced theory of Traffic Flow, modelling, logit, Computational in Highway &Transportation, Remote Sensing GIS, Coastal Engineering, Urban Transportation. Currently He was Assistant Lecturer in Ministry of Higher Education and Scientific Research- Office Reconstruction and Projects Department, IRAQ, He has many papers published in various National and International Journals in USA, Canada, Malaysia, India,Iraq, Singapore, and Australian.