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Interlocking Mortarless Bricks: Column Straightness and Stiffness Testing, Data-set B

Kombo (Warwick University) African Field Course, Kagadi, 2010.

0731562

School of Engineering

ES4A2 African Field Course: Interlocking Mortar less Fired Bricks

by

[0731562] Kombo

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Affiliation: Year 4 Engineering

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Summary

This report is based on a field course conducted in Uganda from the 5th/07/2010 to the 23rd/07/2010.
The report focused on investigating the possibility of reducing the overall cost of cheap rural housing by using Tanzanian Interlocking Brick systems.

Five columns of ten bricks were constructed and their deflection under loading in different scenarios was measured.
The deflections were then used to calculate the stiffness and natural frequency of the brick columns.

This technology has the potential to provide adequate housing to a lot of the people that cannot afford it and this project identified key areas of research that needs to be further investigated.

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Introduction

This report is based on a field course conducted in Uganda from the 5th/July/2010 to the 23rd/July/2010. The project focused on investigating the stability of columns created from the Tanzanian Interlocking Brick (TIB) system whilst under different scenarios of bricklaying. The first scenario consisted of mortar-less columns, the second contained mud mortar in between the brick layers and the third had no mortar in between its layers but had cement plastered sides. A control test was also conducted in which the column consisted of cement mortar in between brick layers as this is common practise.

This report covers the history of interlocking bricks in Uganda, describes the experimental methods applied and interprets conclusion from the experiments results. Along with this, the environmental and social impact of these bricks is analysed.

It is hypothesised that the interlocking brick columns, whilst having a lower stiffness than mortared columns, will have a high enough stiffness to withstand construction regulations when subjected to some physical and bricklaying technique manipulations.

1.0 Theory

The psychologist Maslow[1] established a hierarchy of human needs in which property falls under the second tier of the hierarchy, within the security category. Property once again comes up under article 2 in the list human rights[2] as declared by the United Nations.

Current estimates place approximately 1 billion people living in less than acceptable housing. These people are predominantly spread throughout Eastern Asia, South Asia and Sub-Saharan Africa. Such a statistic reveals that the world needs to provide 35 million homes over the next 25 year along with basic infrastructure such as sanitation, schools and hospitals[3].

Uganda currently has a population of 31.8 million[4] with projections of reaching 53 million by the year 2025.
Such a rapid increase in the population will induce a high demand for housing and via proxy of association, construction materials too.

[1] http://psychology.about.com/od/theoriesofpersonality/a/hierarchyneeds.htm
[2] http://www.buzzle.com/articles/list-of-human-rights.html
[3] http://www.unhabitat.org/content.asp?typeid=19&catid=282&cid=789
[4] http://www.ubos.org/index.php?st=page&id=11&p=Quick%20Statistics

With the majority of the Ugandan population living in poverty (GDP per capita is US$467[5]), expensive infrastructure is not an option. In order to ensure that the housing is affordable the prices of materials and construction need to be reduced to as much is acceptable taking into account the safety of the buildings tenants/ users.

1.1 Local context of technology

Rural communities predominantly reside in mud huts, crude small structures created from mud and cow dung that have thatched roofs.

Figure 1: Mud hut

In some cases these 'houses' play host to families larger than eight people.

In more 'sophisticated' areas, cheap housing consists of corrugated iron structures. These areas are known as shanty towns.

Figure 2 Corrugated iron shelter

[5] http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/AFRICAEXT/UGANDAEXTN/0,,menuPK:374963~pagePK:141132~piPK:141109~theSitePK:374864,00.html

The next step up in housing is to move to kiln-fired brick housing. This generally costs too much for the average Ugandan and the workmanship on these houses is extremely poor. Most of these structures collapse long before they should and almost in every case too much cement mortar is used (about 4cm)

Figure 3 Brick shelter with bad mortar technique

Up until 2007, most of Uganda's construction material was imported from Japan and South Africa through Kenya[6], however after Kenya's election violence escapade; Uganda has started to move towards manufacturing its own materials.
When considering local communities, road access is difficult and economic stability is low. It is thus beneficial for such communities to possess the ability to conjure up their own construction materials.

A further problem results from the low school completion rate in Uganda. (54% primary, 13% secondary)(This will change with the new compulsory education scheme that has been established). The lack of skilled labour means that elaborate structures cannot be erected unless seemingly extortionate prices are paid.

[6] Structural Engineer August 2010

1.2 Significance of interlocking bricks

Interlocking bricks have revolutionised construction in developing countries, mainly due to two reasons;

- They have the potential to greatly reduce the construction costs of local projects.
- They require less skilled labour when being laid, when compared to normal bricks.

There is a large variety of different styles of interlock used in different countries.

Figure 4 Brick from India

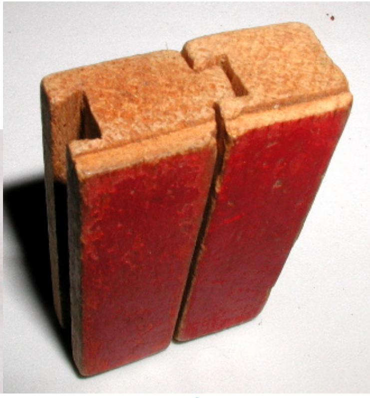


Figure 5 Brick from America

In this project, the TIB system was chosen upon due to its frequent use in a neighbouring country implying that the technology would easily adapt into Ugandan society.

Figure 6 TIB system brick

A mixture of soil, sand, cement and water is created from onsite materials (the cement being procured from a local supplier) and placed into a press. Mechanic presses do exist however these are extremely heavy and rather expensive. When considering rural Ugandan settlements, a mechanical press is not a viable option, so a manual press was used. In order to provide the required force for the press a lever arm system is used.

It is important to maintain a high level of accuracy when regarding the brick dimensions, if this is not enforced, the bricks will not interlock properly. The length and flatness of the brick are particular important.

Extensive PHd research has been conducted by Simion Kintingu[7] from the University of Warwick. His research suggests that brick interlock can be improved in two ways:

- Brick modification to attain a minimum, yet stable, contact area between two bricks
- Keen assembly procedures when setting up a wall/ column that ensure the bricks are as level as they can be.

These findings have been incorporated into the project and shall be discussed in full detail within later sections.

In Uganda a typical 1.5l brick costs approximately 100 UGX (£0.03). Due to substandard expertise, the amount of cement mortar used per brick ranges between 3-4 cm, when all that is needed is 0.5 cm.
This means that the price of the amount of mortar use per brick is (approximately 0.8l [three quarters of this being concrete]) is 300 UGX (£0.08)
A typical cheap home in Uganda has walls that measure approximately 2.5m by 7.5m (each wall being 20 by 25 bricks). For such a house the estimated cost would be 800,000 UGX (£222) and this does not include costing such as the contractor's fee, transportation fee and roofing.

An ideal situation in which interlocking walls required no mortar would mean that the cost of a typical house can be reduced to 200,000 UGX (£55). This would be a great advantage to the poverty stricken Ugandan people.

[7] Design of interlocking bricks for enhanced wall construction flexibility, alignment accuracy and load brearing.
Thesis by Simion Hosea Hintingu,
University of Warwick, School of Engineering,
June 2008

2.0 Objectives

As Uganda is subject to earthquakes, a structure with a low natural frequency would superimpose the earthquakes vibrations and oscillate to a point of destruction. With such obvious health and safety concerns, the wall stiffness of buildings is very important.

By furthering the previous work on interlocking bricks by performed by prior field course students; this project aims to identify methods of improving the stiffness of interlocking brick columns resulting in cheaper method of construction that is acceptable by Ugandan building standards.

The task to task objectives are set out below in table1.

Main activity	**Related tasks**
Brick Inventory	Rasp the bricks Number the bricks Modify the Bricks shape Attach base bricks to the platform
Experiment Apparatus Fabrication	Place support rails in the platform Create support frame Create T-frame for lever arm Create Lip for attaching loads to column
Brick Feeler Test	Spacing measurements under the brick
Mortar-less Brick testing	Perform tests
Mud Brick testing	Perform tests
Plaster Brick testing	Perform tests
Cemented Wall Testing	Perform tests

3.0 Project activities

3.1 Brick inventory

Before any of the testing could be conducted, the assortment of bricks had to be inspected and the defect bricks disposed of.

3.12 Apparatus used

The following pieces of apparatus were used:

- Chipped pieces of brick.
- Chalk.
- Angle grinder.
- Tape measure.
- Spirit level.
- Safety Goggles.

3.13 Method

Once the acceptable bricks were identified, a number of tasks were performed upon them:

- The bricks were rasped by rubbing pieces of chipped brick along the surface of whole bricks in order to file out any irregularities in the form of bumps and chips upon the bricks profile. Using chipped brick as a rasp was desirable as it was hard enough to perform the filing and yet soft enough to ensure that the top of the bricks would not get damaged. Rasping would result in improved stability as the bricks would be able to sit on one another with less rocking.

Figure 7 Rasping the bricks

- The bricks were numbered using the chalk in order to keep the experimental work as constant as possible. This meant that the same brick could be used in the same place during column construction in different scenarios.

Figure 8 Numbered bricks

- The middle of each brick was deepened using an angle grinder in order to facilitate the stability of one brick sitting on another. Having only two thin contact points between each brick reduced the second moment of area thus increasing the stiffness of the column (displayed in the appendices). It also meant that the bricks had less of the ability to rock.

Figure 9 Using Anglegrinder on the bricks

- The base bricks were chosen and attached to concrete testing platform using cement at spaces of 170mm, in order to assure enough testing space between any two columns. A spirit level was used to ensure that there was no tilt on the bricks.

Figure 10 Placing the base bricks on the testing column

3.2 Experiment Apparatus Fabrication

3.21 Apparatus

The following pieces of apparatus were used:

- Hacksaw.
- Rawl bolts.
- Pneumatic hammer drill.
- Electronic drill.
- Welding kit.
- Threaded pipe.
- Bolts.
- Electronic metal cutting circular saw.
- Pipe bender.

3.22 Fabrication process

The experiments design rig consisted of different frames.

- The attachment railings on the testing platform were designed to provide an easy method of changing the brick column being tested. Two parallel 40 by 40mm square steel tubes were attached to the testing platform. In order to do so, the electric drill was used on the metal tube (Top to bottom) to drill in 12mm holes and the pneumatic hammer drill was used on the concrete platform. A rawl bolt was inserted into the railing to secure it to the platform.

Figure 11 Rawl bolt

The electric drill was also used to drill 16mm on the railings (front to back) at strategic locations that corresponded with the centre testing point of each column. These holes would be used to attach the support column to the metal railings when running the experiment.

- The support frame was designed to provide security against falling bricks, whilst at the same time act as a datum for the deflection measurements of the columns. Two sections of 40 by 40mm square steel tube were cut using an electronic metal cutting circular saw to a length of 1600mm and two third smaller sections were cut to 390mm. The sections were welded together as shown.

Figure 12 Support Frame

The bottom of the parallel tubes was drilled through with 16mm holes in order to allow for the support frame to be connected to the attachment railings.

- In order to add a load onto the brick columns, two more 40 by 40mm square steel tube bars were cut and welded together in the following dimensions.

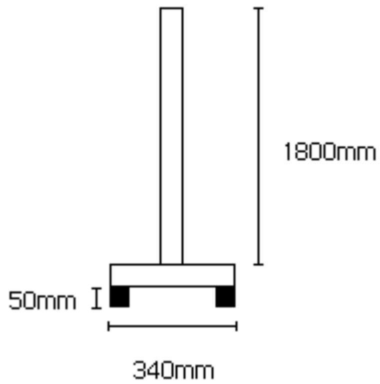


Figure 13 T-Bar

The detachable hinges at the bottom eliminated friction whilst loading, improving the accuracy of the results.
The T-bar was also drilled into at regular intervals to allow for a graduate increase in loading on the brick columns (further explained in section 5.2).

Figure 14 Holes in T-Bar at regular intervals

- A lip was fabricated out of a flat steel plate using a metal bender and a handle was welded onto it. This allowed for attachment from the T-bar to the brick wall (further explained in section 5.2).

Figure 15 Fabricated Lip

4.0 Testing/ Analysis

4.1 Brick Feeler Test

To ensure stability it is important for bricks in a column to sit on each other firmly, without any rocking.

The clearance under the bricks was measured at six points using the amount of sheets of paper that could fit under the clearance. Each sheet of paper had a thickness of 0.105mm.

This information allowed us to calculate whether the brick was sagging or hogging and the extent to which the brick was warping.

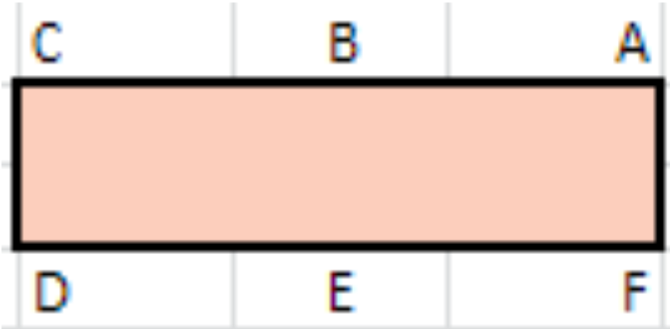


Figure 16 Side of bricks for analysis

4.12 Brick Feeler Results

The results are as follows:

	A	B	C	D	E	F	Sagging/Hogging		Twist/Warp
	0.32	0.11	0.00	1.26	0.00	0.00	-0.74	Sagging	0.0105
	0.00	0.00	0.84	2.42	0.00	0.11	-1.68	Sagging	0.0098
	1.16	0.00	0.63	0.95	0.00	1.37	-2.05	Sagging	0.0007
	0.00	0.32	0.00	0.00	0.32	0.00	0.32	Hogging	0.0000
	0.74	0.11	0.00	1.05	0.00	0.00	-0.84	Sagging	0.0119
	3.26	0.00	0.11	0.74	0.74	0.00	-1.68	Sagging	0.0259
	0.21	0.00	0.53	0.21	0.00	0.11	-0.53	Sagging	-0.0014
	2.73	0.00	1.05	0.00	0.00	0.42	-2.10	Sagging	0.0084
	2.00	0.00	0.74	0.42	0.00	1.05	-2.10	Sagging	0.0042
	1.05	0.21	2.84	2.63	0.00	1.37	-3.83	Sagging	-0.0035
	1.47	0.00	0.74	1.58	0.00	0.95	-2.36	Sagging	0.0091
	1.16	0.00	1.05	1.58	0.00	0.53	-2.15	Sagging	0.0077
	2.94	0.00	2.00	1.47	0.00	0.21	-3.31	Sagging	0.0147
	2.10	0.00	3.05	1.47	0.32	0.74	-3.52	Sagging	-0.0014
	3.47	0.00	0.95	1.58	0.00	0.84	-3.41	Sagging	0.0217
	1.79	0.00	2.42	1.58	0.00	0.11	-2.94	Sagging	0.0056
	1.26	0.00	1.16	1.26	0.00	1.26	-2.47	Sagging	0.0007
	0.53	0.11	1.79	0.00	0.00	1.05	-1.63	Sagging	-0.0154
	0.42	0.00	0.74	1.68	0.11	1.68	-2.21	Sagging	-0.0021
	2.10	0.11	0.00	0.00	0.32	0.21	-0.95	Sagging	0.0126
Average	1.43	0.05	1.03	1.09	0.09	0.60	-2.01		0.0060
Standard Deviatio	1.0823	0.0867	0.9339	0.7905	0.1905	0.5568	1.09118		0.0094

The sagging/hogging is calculated using the following formulae:

$$\frac{(B+E)}{2} - \frac{(A+F)}{2} - \frac{(C+D)}{2}$$

The angle of Twist/ warp is calculated using the following formulae:

$$\frac{[(A+D)-(C+F)]}{150}$$

4.13 Brick Feeler Analysis

The table above displays that most of the bricks were sagging and that there was an average warp of 0.0060 radians in the clockwise direction (looking at the brick from side AF to side CD)

4.2 Brick Column Testing

The brick columns were tested using the following set up:

Figure 17 Testing rig

Once a brick column was installed under the support frame, the lip and T-bar was set up in order to apply horizontal loading onto the column. This horizontal loading was a tension force caused by the vertical load from the weight of the T-bar.

The angle of the T-bar was progressively increased in order to cause the horizontal force on the column to rise.

Once the maximum angle was attained (approximately 45°), a bucket was added to the set up in which water was steadily added to increase the horizontal load.

Throughout this process the deflection of the brick column was repeatedly measured using a ruler until the column collapsed.

4.21 Brick Column Results

The average deflections (at every 4mm) and stiffness measurements are as follows:

Motarless

Side 1

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
4	9.16	2.3
8	15.17	1.9
12	20.49	1.7
16	22.02	1.4
20	25.59	1.3

Side 2

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
4	8.68	2.2
8	15.34	1.9
12	19.58	1.6
16	22.03	1.4
20	22.39	1.1

Both Sides

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
4	8.92	2.2
8	15.26	1.9
12	20.03	1.7
16	22.03	1.4
20	23.99	1.2

Mud Motar

Side 1

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
4	11.76	2.9
8	17.67	2.2
12	22.79	1.9
16	25.25	1.6
20	27.74	1.4

Side 2

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
4	12.92	3.2
8	22.85	2.9
12	26.27	2.2
16	26.60	1.7
20	29.80	1.5

Both Sides

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
4	12.34	3.1
8	20.26	2.5
12	24.53	2.0
16	25.93	1.6
20	28.77	1.4

Plaster One-Side

Side 1

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
0.5	10.64	21.3
1	8.39	8.4
1.5	9.61	6.4
2	11.17	5.6
2.5	11.66	4.7
3	11.78	3.9
3.5	11.96	3.4
4	12.14	3.0
4.5	12.60	2.8

Side 2

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
0.5	10.09	20.2
1	10.39	10.4
1.5	12.31	8.2
2	10.80	5.4
2.5	9.28	3.7
3	12.37	4.1

Both Sides

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
0.5	10.37	20.7
1	9.39	9.4
1.5	10.96	7.3
2	10.99	5.5
2.5	10.47	4.2
3	12.08	4.0
4	12.14	3.0
4.5	12.60	2.8

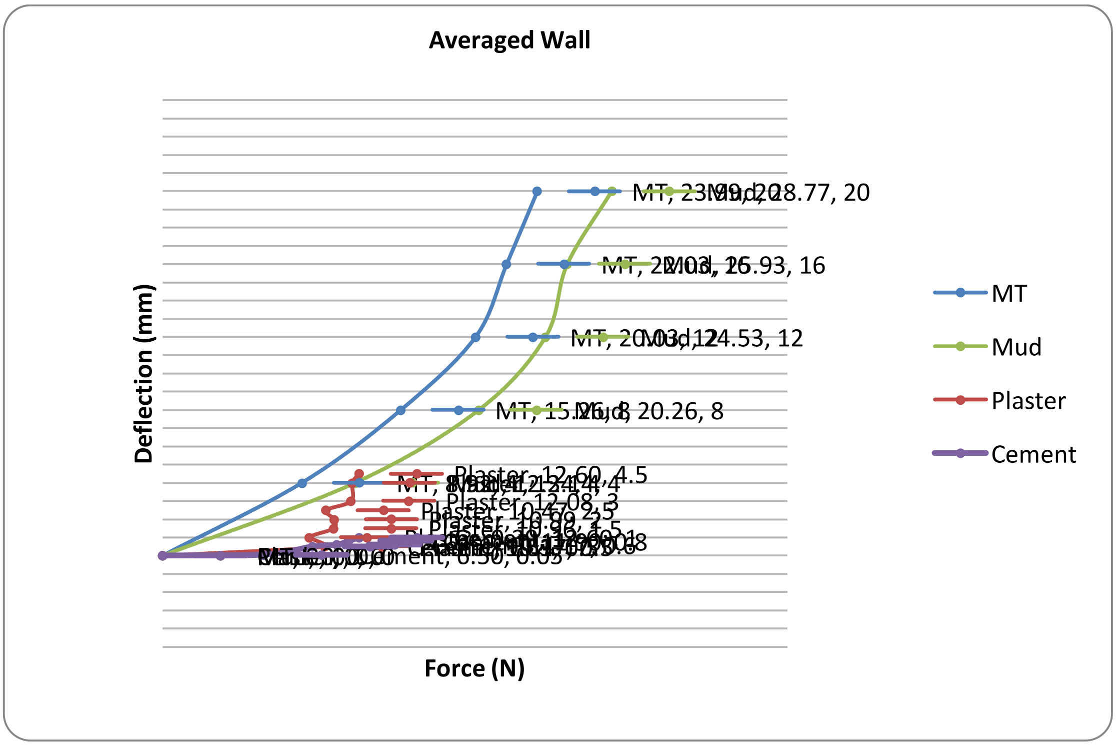
Cement

Both Sides

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
0.05	6.50	130.0
0.5	9.61	19.2
0.6	11.17	18.6
0.8	11.90	14.9
1	12.60	12.6

Stiffness is calculated using the following formulae: $\frac{FORCE}{DEFLECTION}$

The following is a graph that displays the average deflection for the six different columns in the four different scenarios:



4.3 Brick Column Analysis

The graph above displays that the stiffest brick column was the cement mortared column followed by the plastered column, the mud mortared column and finally the mortar-less column.

If one continuous brick column was used then, the stiffness of the column would be 758 kN/m (displayed in the appendices)

Taking the deflections at 5N horizontal force for each column, the initial stiffness of the columns can be calculated. This is displayed in the column below:

	Deflection	Stiffness (N/mm)	Stiffness ratio compared to whole wall
Mortarless	2.19	2.283105023	332.1573
Mud	1.538	3.250975293	233.26846
Plaster	0.238	21.00840336	36.09746
Cement	0.045	111.1111111	6.82515

It can be observed in the above table that the brick columns are not as stiff as the cemented mortar column in any of the tested scenarios.

Every object tends to vibrate at one particular frequency called the natural frequency. The measure of this depends on the composition of the object, its size, structure, weight and shape. Using the stiffness of the different columns, its natural frequency can be calculated using the following formulae[8]:

$$F = (\frac{1}{2\pi}) \times \sqrt{(\frac{K}{m})}$$

The results are displayed below.

	Stiffness (N/m)	Mass (Kg)	Natural freqency (Hz)
Mortarless	2283.105023	117	0.703056367
Mud	3250.975293	136.4643	0.776814709
Plaster	21008.40336	187.2	1.686023925
Cement	111111.1111	262.8	3.27254929

The average frequency of seismic activity in Uganda is approximately 2HZ[9]. If a wall had a frequency that was lower or the same as an earthquake it would violently shake until collapse. From the table above, the only column that would withstand an earthquake was the cemented mortared brick column.

5.0 Discussion of Results

The results to the stiffness testing are of no surprise. Cement mortar has been used for years to stabilise walls and removing it would inevitably make the columns less stiff. However, manipulating the brick laying methods did improve the column stiffness when compared to completely mortar-less brick columns.
Using mud mortar did not have a significant effect as it increased the columns stiffness by just a factor of 1.4.
Subjecting the columns to plaster had a more significant effect, improving the stiffness by a factor of 9.2.

The natural frequency of the plastered column was relatively high whilst the mud mortar hardly had an effect on natural frequency when compared to the mortar-less columns.

Testing singular columns only roughly represents the walls of a house. Brick laying techniques when regarding walls have a hop scotch arrangement creating further interlock for the bricks. Also a house has multiple walls joining each other; these walls provide additional resistance in the direction of their profiles.
Considering this, the stiffness and natural frequency of the walls in a house are higher than that of a singular column.

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8 http://www.ehow.com/how_5171316_calculate-natural-frequency.htm

9 Quote from Dr Terance Thomas, 13/10/2010

This reasoning indicates that it is possible create adequately safe cheap housing using interlocking bricks, however before the required safety levels are attained there has to be some manipulation of the bricks (physically) and of the method in which they are laid.

6.0 Recommendations and Future Work

Before this technology can be fully relied upon some further investigation into the following areas should be conducted.

- The stiffness of interlocking brick walls in a hop scotch arrangement under the same scenarios conducted in this project.
- The stiffness of walls/ columns when plastered on both the inside and the outside.
- The stiffness of walls/columns when both mud mortar and plaster is used.
- The stiffness of interlocking brick walls whilst using different types of plaster.
- The optimum feasible amount of plaster that can be applied to a wall and still provide enough stiffness.

The calculations for the natural frequency contain a lot of assumptions. In order to acquire reasonable figures an experiment has to be set up in which different brick columns are subject to known vibrations and the frequency is thus measured.

Using fired bricks is damaging to the environment as the source of fuel is wood. This leads to deforestation and as the demand for cheap bricks rises, the rate of deforestation will become alarming.
Interlocking Stabilised Soil Bricks (ISSB) is a new brick making technology. It is similar to fired bricks in the sense that the bricks can be made from local material however the amount of cement in the brick mix is slightly higher. The mixture is moistened and set in press, once the required shape is acquired; the bricks are set out to dry in the sun for seven days where after they can be used for construction. The moulds of the bricks can be created to any type of interlocking system.

The ISSB system of brick making is slightly more expensive than kiln firing bricks however no tree's are required and so in the long run will be more beneficial to the local communities.

7.0 Conclusion

As the project progressed, the author and groups interaction with the interlocking bricks improved. This was also the case for the group's ability to interpret the model situations required for the project, hence achieving valuable data for the stiffness of brick columns under different conditions.

Throughout the project, the author and assistant encountered various fabrication problems throughout the two weeks forcing changes to be made to the planned setup.
Futher error resulted from the fact that the bricks used were left over from previous reay field courses. With a year worth of weathering, the bricks were not as accurate as they would have been if they were freshly cast.

The project results indicated as expected that mortar-less walls would be less stiff than ordinary mortared walls, however it is possible to cut the building costs of interlocking walls by using a combinations of mud mortar and plaster.

The author and group hence gained a good level of knowledge about interlocking bricks and identify some key areas for future research, whilst at the same time expanding their technical knowledge by practising welding and other pieces of specialised equipment.

9.0 References

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Appendices

Paper Gaps (Amount of paper that fit underneathe) — Actual Gap

A	B	C	D	E	F		A	B	C	D	E	F	Sagging/Hogging		Twist/Warp
3	1	0	12	0	0		0.32	0.11	0.00	1.26	0.00	0.00	-0.74	Sagging	0.0105
0	0	8	23	0	1		0.00	0.00	0.84	2.42	0.00	0.11	-1.68	Sagging	0.0098
11	0	6	9	0	13		1.16	0.00	0.63	0.95	0.00	1.37	-2.05	Sagging	0.0007
0	3	0	0	3	0		0.00	0.32	0.00	0.00	0.32	0.00	0.32	Hogging	0.0000
7	1	0	10	0	0		0.74	0.11	0.00	1.05	0.00	0.00	-0.84	Sagging	0.0119
31	0	1	7	7	0		3.26	0.00	0.11	0.74	0.74	0.00	-1.68	Sagging	0.0259
2	0	5	2	0	1		0.21	0.00	0.53	0.21	0.00	0.11	-0.53	Sagging	-0.0014
26	0	10	0	0	4		2.73	0.00	1.05	0.00	0.00	0.42	-2.10	Sagging	0.0084
19	0	7	4	0	10		2.00	0.00	0.74	0.42	0.00	1.05	-2.10	Sagging	0.0042
10	2	27	25	0	13		1.05	0.21	2.84	2.63	0.00	1.37	-3.83	Sagging	-0.0035
14	0	7	15	0	9		1.47	0.00	0.74	1.58	0.00	0.95	-2.36	Sagging	0.0091
11	0	10	15	0	5		1.16	0.00	1.05	1.58	0.00	0.53	-2.15	Sagging	0.0077
28	0	19	14	0	2		2.94	0.00	2.00	1.47	0.00	0.21	-3.31	Sagging	0.0147
20	0	29	14	3	7		2.10	0.00	3.05	1.47	0.32	0.74	-3.52	Sagging	-0.0014
33	0	9	15	0	8		3.47	0.00	0.95	1.58	0.00	0.84	-3.41	Sagging	0.0217
17	0	23	15	0	1		1.79	0.00	2.42	1.58	0.00	0.11	-2.94	Sagging	0.0056
12	0	11	12	0	12		1.26	0.00	1.16	1.26	0.00	1.26	-2.47	Sagging	0.0007
5	1	17	0	0	10		0.53	0.11	1.79	0.00	0.00	1.05	-1.63	Sagging	-0.0154
4	0	7	16	1	16		0.42	0.00	0.74	1.68	0.11	1.68	-2.21	Sagging	-0.0021
20	1	0	0	3	2		2.10	0.11	0.00	0.00	0.32	0.21	-0.95	Sagging	0.0126
						Average	1.43	0.05	1.03	1.09	0.09	0.60	-2.01		0.0060
						Standard Deviatio	1.0823	0.0867	0.9339	0.7905	0.1905	0.5568	1.09118		0.0094

Motarless

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 271; Starting Deflection (mm): 99

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0	0		0.00		0	0.0
24	✗		7.38	96	3	2.5
28	✗		8.52	95	4	2.1
30	✗		9.07	94	5	1.8
32	✗		9.61	93.5	5.5	1.7
36	✗		10.66	93	6	1.8
38	✗		11.17	92.5	6.5	1.7
40	✗		11.66	92	7	1.7
44	✗		12.60	91	8	1.6
44	✓	600	20.85	87	12	1.7
44	✓	967.5	24.33	83	16	1.5
44	✓	1100	25.59	79	20	1.3

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 271; Starting Deflection (mm): 93

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0		0	0.0
22	✗		6.80	97	4	1.7
36	✗		10.66	98	5	2.1
40	✗		11.66	99	6	1.9
42	✗		12.14	100	7	1.7
42	✗		12.14	100.5	7.5	1.6
42	✓		14.53	101	8	1.8
42	✓	590	19.74	105	12	1.6
42	✓	700	20.71	109	16	1.3

Mud Motar

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 120

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0		0	0.0
26	✗		7.95	118	2	4.0
32	✗		9.61	116	4	2.4
42	✗		12.14	115	5	2.4
44	✗		12.60	112	8	1.6
44	✓		16.18	109	11	1.5
44	✓	340	19.40	108	12	1.6
44	✓	760	23.38	104	16	1.5
44	✓	1220	27.74	100	20	1.4

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 119

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0		0	0.0
26	✗		7.95	121	2	4.0
36	✗		10.66	122	3	3.6
38	✗		11.17	123	4	2.8
48	✗		13.48	124	5	2.7
48	✓		17.60	125	6	2.9
48	✓	210	19.89	127	8	2.5

Plaster One-Side

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 96

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0.00	0	0	0.0
26	✗		7.95	94	2	4.0
34	✗		10.14	93	3	3.4
42	✗		12.14	92	4	3.0
44	✗		12.60	91.5	4.5	2.8

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 94

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0.00		0	0.0
24	✗		7.38	96.5	2.5	3.0
38	✗		11.17	96.5	2.5	4.5
42	✗		12.14	97	3	4.0
44	✗		12.60	97	3	4.2

Wall B

Motarless

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 271; Starting Deflection (mm): 94

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0		0	0.0
26	✗		7.95	92	2	4.0
28	✗		8.52	91	3	2.8
30	✗		9.07	90	4	2.3
42	✗		12.14	89	5	2.4
44	✗		12.60	87	7	1.8
44	✓		15.17	86	8	1.9
44	✓	560	20.47	82	12	1.7

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 271; Starting Deflection (mm): 87

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0		0	0.0
22	✗		6.80	89	2	3.4
28	✗		8.52	90	3	2.8
34	✗		10.14	91	4	2.5
44	✗		12.60	91.5	4.5	2.8
44	✓		15.17	92	5	3.0
44	✓	120	16.30	95	8	2.0
44	✓	560	20.47	99	12	1.7
44	✓	927.5	23.95	103	16	1.5

Mud Motar

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 93

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0		0	0.0
22	✗		6.80	91	2	3.4
32	✗		9.61	90	3	3.2
42	✗		12.14	89.5	3.5	3.5
48	✗		13.48	89	4	3.4
48	✓		17.60	88.5	4.5	3.9
48	✓	180	19.56	85	8	2.4

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 97

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0		0	0.0
24	✗		7.38	98	1	7.4
36	✗		10.66	99	2	5.3
52	✗		14.29	99.5	2.5	5.7
52	✓		19.04	100	3	6.3
52	✓	290	22.68	101	4	5.7
52	✓	1030	31.97	105	8	4.0
52	✓	1180	33.86	109	12	2.8

Plaster One-Side

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 109

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0.00	0	0	0.0
24	✗		7.38	108	1	7.4
32	✗		9.61	107.5	1.5	6.4
44	✗		12.60	107	2	6.3
48	✗		13.48	107	2	6.7

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 109

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0.00	0	0	0.0
28	✗		8.52	109.5	0.5	17.0
32	✗		9.61	110	1	9.6
42	✗		12.14	110.5	1.5	8.1
46	✗		13.05	110.5	1.5	8.7

Wall C

Motarless

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 271; Starting Deflection (mm): 102

Centre of gravity: 680; Height: 130

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
			0		0	0.0
20	✗		6.20	99	3	2.1
28	✗		8.52	98	4	2.1
34	✗		10.14	96.5	5.5	1.8
42	✗		12.14	96	6	2.0
42	✓		14.53	95	7	2.1
42	✓	245	16.70	94	8	2.1
42	✓	710	20.80	90	12	1.7
42	✓	765	21.29	86	16	1.3

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 271; Starting Deflection (mm): 99

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)	Av Stiffnes
			0		0	0.0	
24	✗		7.38	101	2	3.7	2.9
36	✗		10.66	102	3	3.6	2.8
38	✗		11.17	103	4	2.8	2.3
48	✗		13.48	105	6	2.2	2.1
48	✓		16.43	106	7	2.3	2.2
48	✓	330	20.03	107	8	2.5	2.3
48	✓	580	22.75	111	12	1.9	1.8
48	✓	620	23.19	115	16	1.4	1.4

Mud Motar

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 105

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
			0		0	0.0
24	✗		7.38	103	2	3.7
32	✗		9.61	102	3	3.2
48	✗		13.48	101	4	3.4
48	✓		17.60	99	6	2.9
48	✓	370	21.63	97	8	2.7
48	✓	680	25.01	93	12	2.1
48	✓	980	28.28	89	16	1.8

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 103

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)	Av Stiffnes
			0		0	0.0	
24	✗		7.38	106	3	2.5	3.1
32	✗		9.61	107	4	2.4	2.8
46	✗		13.05	109	6	2.2	2.8
46	✓		16.89	110	7	2.4	2.7
46	✓	190	18.82	111	8	2.4	2.5
46	✓	540	22.37	115	12	1.9	2.0
46	✓	960	26.64	119	16	1.7	1.7

Plaster One-Side

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 112

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0.00	0	0	0.0
20	✗		6.20	111	1	6.2
32	✗		9.61	110.5	1.5	6.4
40	✗		11.66	110	2	5.8
44	✗		12.60	109	3	4.2

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 112

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0.00	0	0	0.0
22	✗		6.80	112.1	0.1	68.0
36	✗		10.66	112.3	0.3	35.5
40	✗		11.66	112.5	0.5	23.3
44	✗		12.60	112.7	0.7	18.0

Wall D

Motarless

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 271; Starting Deflection (mm): 86

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0		0	0.0
22	✗		6.80	84	2	3.4
32	✗		9.61	83	3	3.2
38	✗		11.17	82	4	2.8
46	✗		13.05	81	5	2.6
46	✓		15.80	80	6	2.6
46	✓	340	19.26	78	8	2.4
46	✓	610	22.00	74	12	1.8

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 271; Starting Deflection (mm): 83

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0		0	0.0
18	✗		5.61	85	2	2.8
22	✗		6.80	87	4	1.7
38	✗		11.17	88	5	2.2
44	✗		12.60	89	6	2.1
44	✓		15.17	91	8	1.9
44	✓	550	20.38	95	12	1.7

Mud Motar (High Winds)

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 74

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0		0	0.0
22	✗		6.80	73	1	6.8
28	✗		8.52	72	2	4.3
30	✗		9.07	70.5	3.5	2.6
44	✗		12.60	70	4	3.2
48	✗		13.48	69.5	4.5	3.0
48	✓	320	21.09	66	8	2.6
48	✓	580	23.92	62	12	2.0
48	✓	640	24.57	58	16	1.5

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 74

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0		0	0.0
20	✗		6.20	76	2	3.1
28	✗		8.52	78	4	2.1
38	✗		11.17	79	5	2.2
44	✗		12.60	79.5	5.5	2.3
44	✓		16.18	80	6	2.7
44	✓	540	21.30	82	8	2.7
44	✓	810	23.86	86	12	2.0
44	✓	960	25.28	90	16	1.6

Plaster One-Side

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 99

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0.00		0	0.0
24	✗		7.38	98	1	7.4
34	✗		10.14	97	2	5.1
40	✗		11.66	96.5	2.5	4.7
44	✗		12.60	96	3	4.2

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 98

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0.00		0	0.0
22	✗		6.80	98.2	0.2	34.0
34	✗		10.14	98.5	0.5	20.3
38	✗		11.17	99	1	11.2
44	✗		12.60	99	1	12.6

Wall E

Motarless

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 271; Starting Deflection (mm): 95

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0		0	0.0
22	✗		6.80	93	2	3.4
28	✗		8.52	91	4	2.1
34	✗		10.14	89	6	1.7
42	✗		12.14	87	8	1.5
42	✓		14.53	86	9	1.6
42	✓	430	18.33	83	12	1.5
42	✓	670	20.45	79	16	1.3

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 271; Starting Deflection (mm): 92

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0		0	0.0
24	✗		7.38	93	1	7.4
28	✗		8.52	96	4	2.1
36	✗		10.66	100	8	1.3
42	✗		12.14	103	11	1.1
42	✓		14.53	104	12	1.2
42	✓	650	20.27	108	16	1.3
42	✓	890	22.39	112	20	1.1

Mud Motar

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 86

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0		0	0.0
24	✗		7.38	84	2	3.7
26	✗		7.95	83	3	2.7
32	✗		9.61	82	4	2.4
38	✗		11.17	80	6	1.9
40	✗		11.66	79	7	1.7
48	✗		13.48	78	8	1.7
48	✓		17.60	77	9	2.0
48	✓	480	22.83	74	12	1.9
48	✓	660	24.79	70	16	1.5

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 83

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0		0	0.0
26	✗		7.95	84	1	8.0
32	✗		9.61	86	3	3.2
38	✗		11.17	86.5	3.5	3.2
44	✗		12.60	87	4	3.2
48	✗		13.48	88	5	2.7
48	✓		17.60	89	6	2.9
48	✓	430	22.28	91	8	2.8
48	✓	680	25.01	95	12	2.1
48	✓	945	27.89	99	16	1.7
48	✓	1120	29.80	105	20	1.5

Plaster One-Side

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 74

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0.00		0	0.0
22	✗		6.80	73.8	0.2	34.0
32	✗		9.61	73.5	0.5	19.2
40	✗		11.66	73.5	0.5	23.3
44	✗		12.60	73	1	12.6

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 74

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0.00		0	0.0
22	✗		6.80	74.3	0.3	22.7
34	✗		10.14	75	1	10.1
40	✗		11.66	75	1	11.7
44	✗		12.60	75.5	1.5	8.4

Cement Plaster

Side 1 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 96

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0.00		0	0.0
20	✗		6.20	95.95	0.05	124.1
32	✗		9.61	95.5	0.5	19.2
38	✗		11.17	95.4	0.6	18.6
42	✗		12.14	95.2	0.8	15.2

Side 2 — mass of lever (g): 3535; Bucket Weight (g): 378; Starting Deflection (mm): 96

Degrees (°)	Bucket?	Water Used (ml)	Load (N)	Readings (mm)	Deflection (mm)	Stiffness (KN/m)
0			0.00		0	0.0
22	✗		6.80	96.05	0.05	135.9
32	✗		9.61	96.5	0.5	19.2
40	✗		11.66	97	0.8	14.6
44	✗		12.60	97	1	12.6

Average Sides at regular intervals of 4mm deflecti note: not every value is divided by each wall as not every wall made it to 12mm deflection

Motarless

Side 1

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
4	9.16	2.3
8	15.17	1.9
12	20.49	1.7
16	22.02	1.4
20	25.59	1.3

Side 2

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
4	8.68	2.2
8	15.34	1.9
12	19.58	1.6
16	22.03	1.4
20	22.39	1.1

Both Sides

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
4	8.92	2.2
8	15.26	1.9
12	20.03	1.7
16	22.03	1.4
20	23.99	1.2

Mud Motar

Side 1

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
4	11.76	2.9
8	17.67	2.2
12	22.79	1.9
16	25.25	1.6
20	27.74	1.4

Side 2

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
4	12.92	3.2
8	22.85	2.9
12	26.27	2.2
16	26.60	1.7
20	29.80	1.5

Both Sides

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
4	12.34	3.1
8	20.26	2.5
12	24.53	2.0
16	25.93	1.6
20	28.77	1.4

Plaster One-Side

Side 1

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
0.5	10.64	21.3
1	8.39	8.4
1.5	9.61	6.4
2	11.17	5.6
2.5	11.66	4.7
3	11.78	3.9
3.5	11.96	3.4
4	12.14	3.0
4.5	12.60	2.8

Side 2

Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
0.5	10.09	20.2
1	10.39	10.4
1.5	12.31	8.2
2	10.80	5.4
2.5	9.28	3.7
3	12.37	4.1

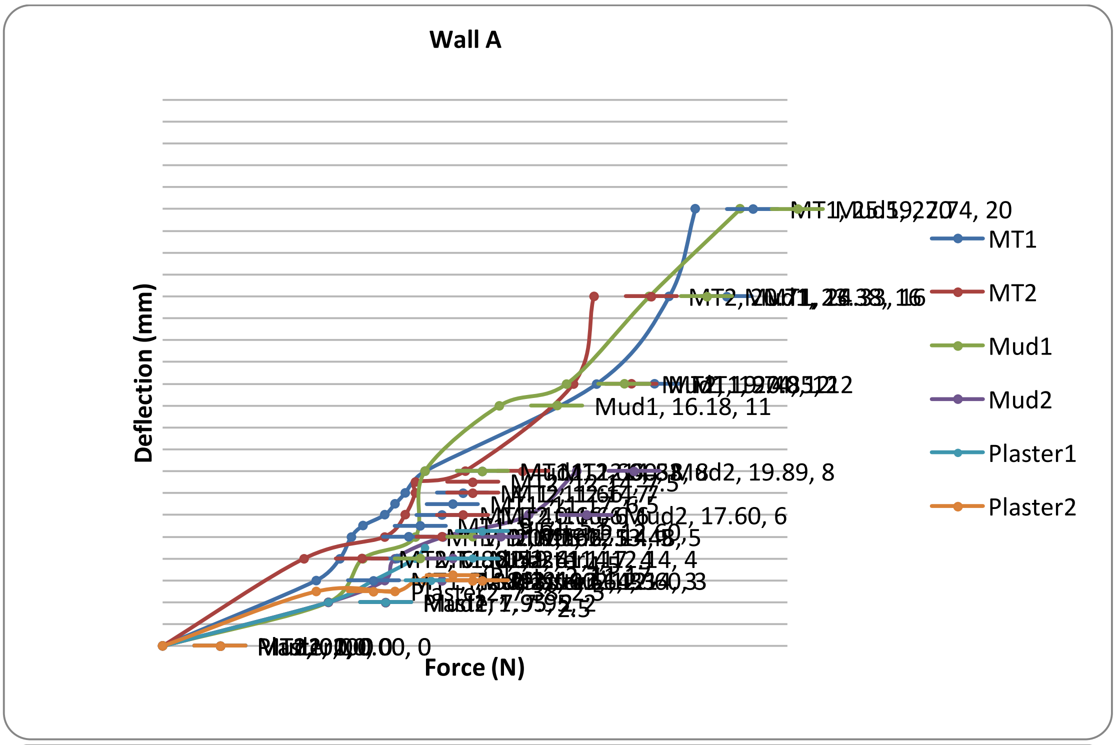
Both Sides

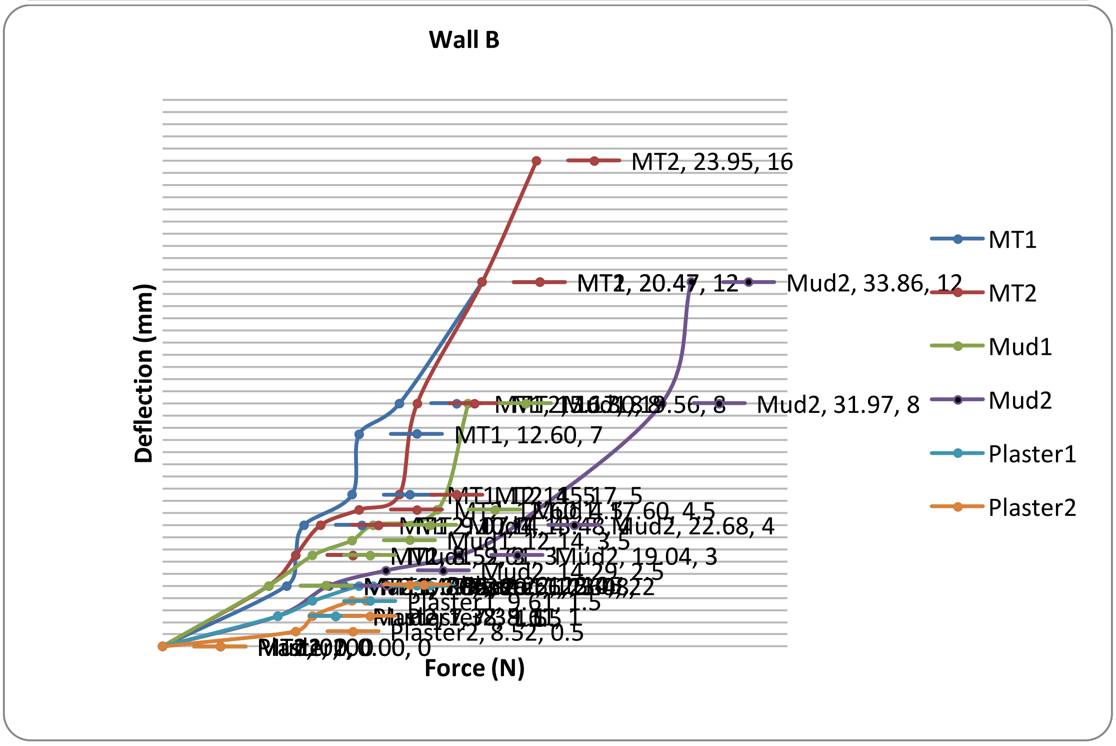
Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
0.5	10.37	20.7
1	9.39	9.4
1.5	10.96	7.3
2	10.99	5.5
2.5	10.47	4.2
3	12.08	4.0
4	12.14	3.0
4.5	12.60	2.8

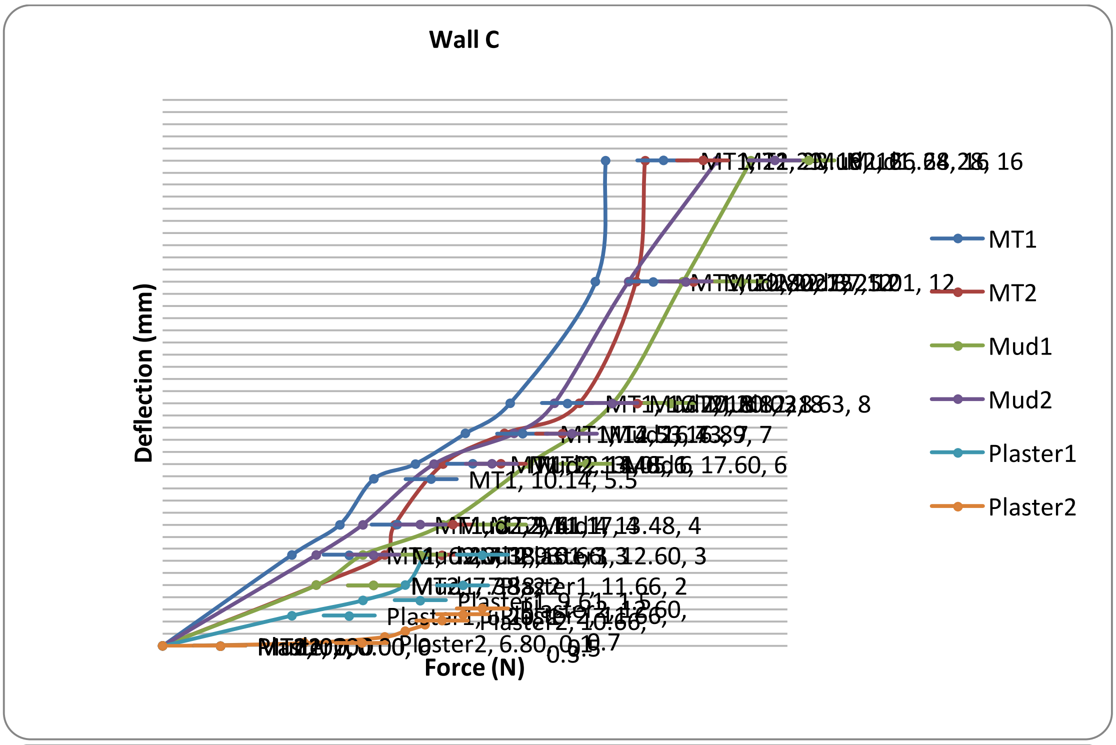
Cement

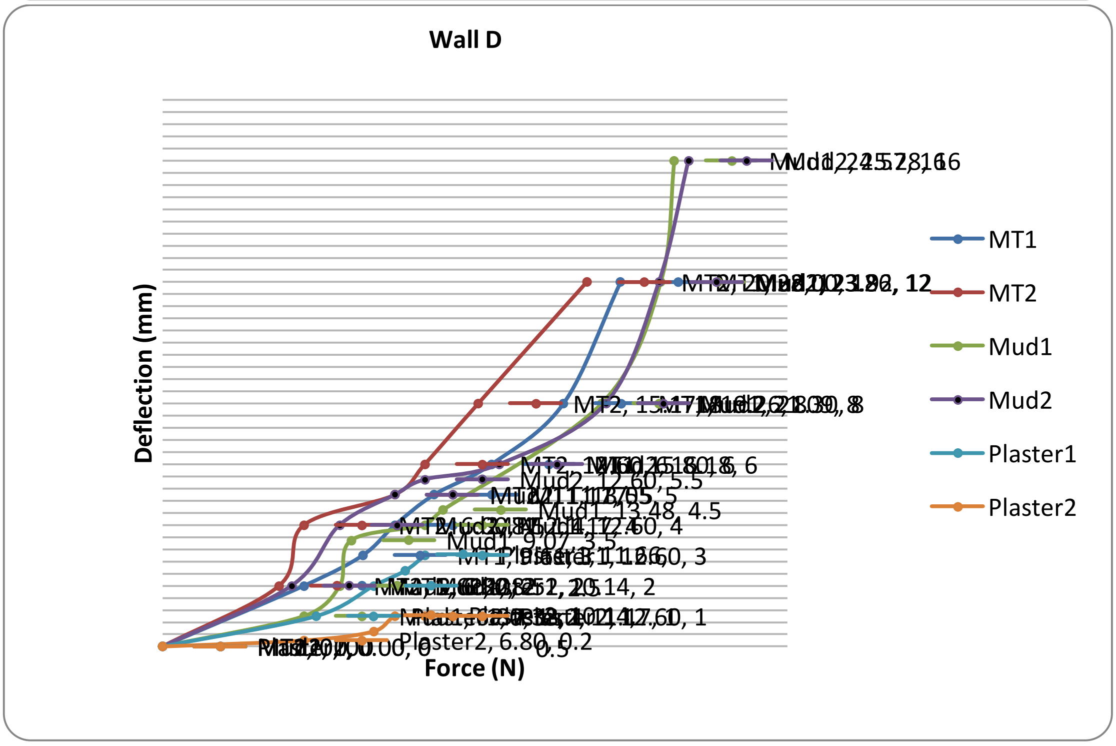
Both Sides

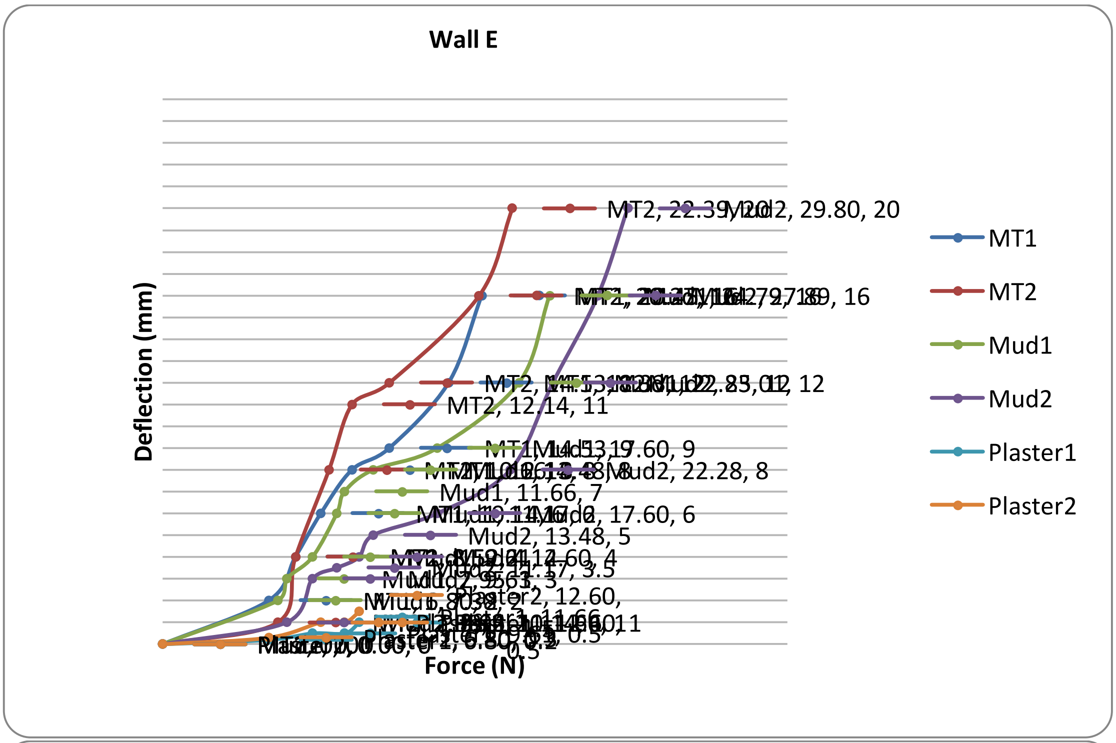
Deflection (mm)	Force (N)	Stiffness (KN/m)
0	0	0
0.05	6.50	130.0
0.5	9.61	19.2
0.6	11.17	18.6
0.8	11.90	14.9
1	12.60	12.6

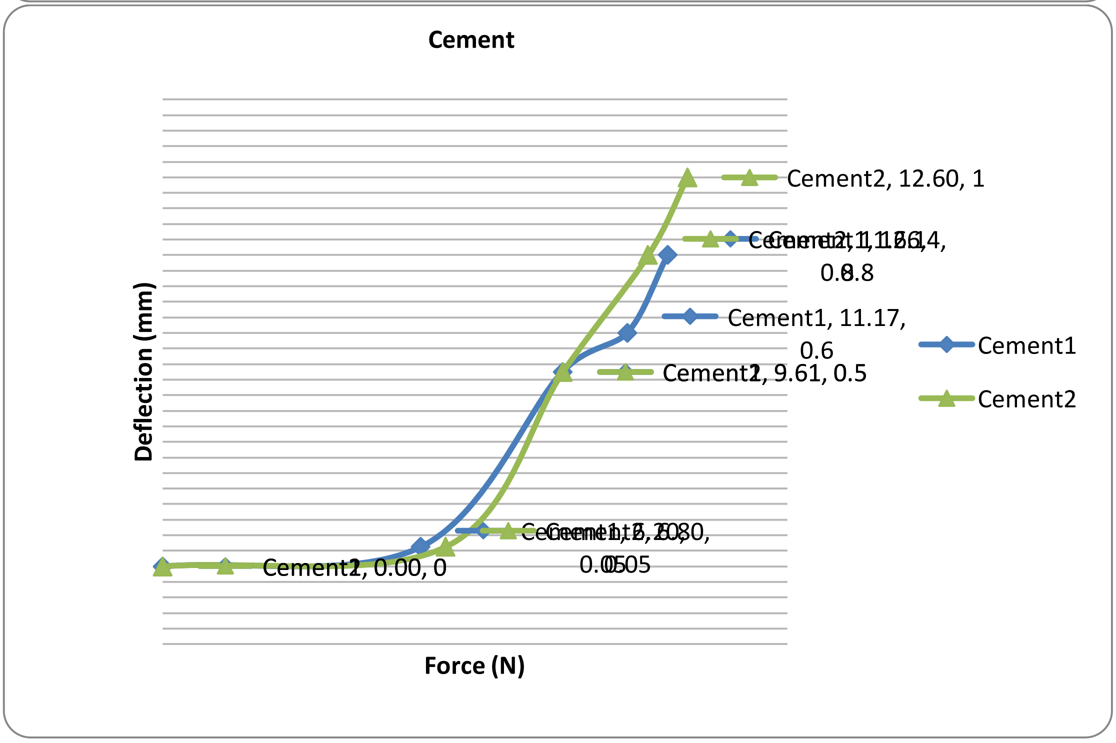

Wall A
Deflection (mm)
Force (N)
MT1
MT2
Mud1
Mud2
Plaster1
Plaster2
Mud1, 16.18, 11
Mud2, 19.89, 8
Mud2, 17.60, 6

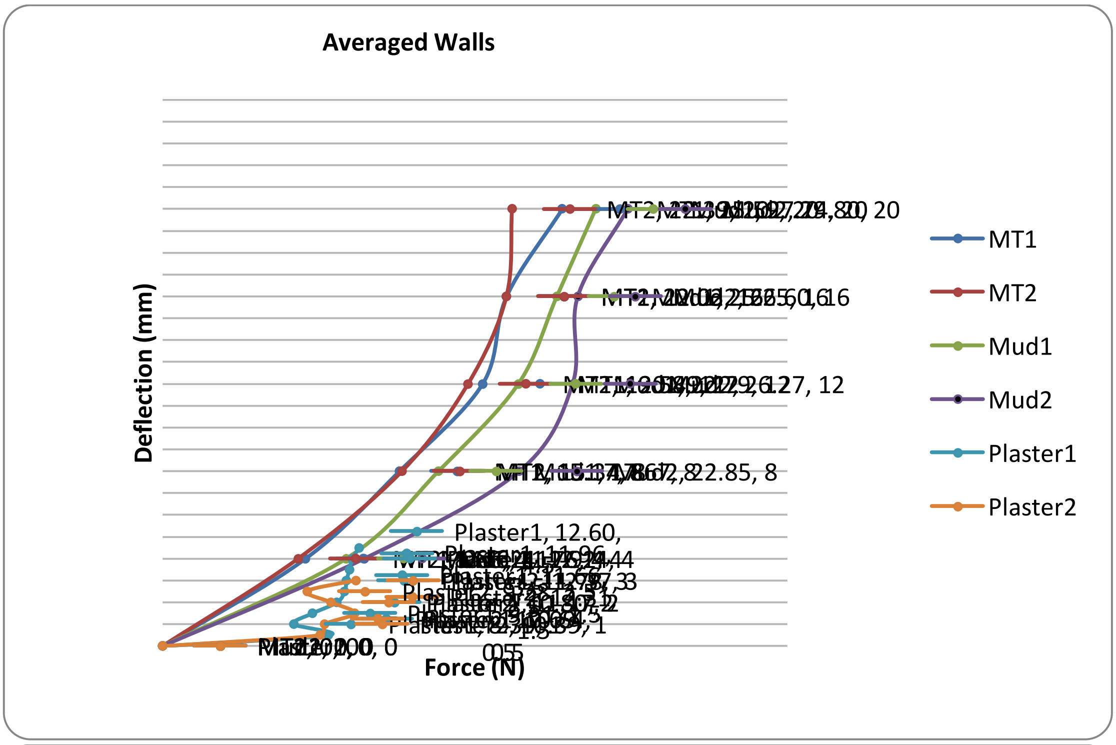

Wall B
Deflection (mm)
Force (N)
MT1
MT2
Mud1
Mud2
Plaster1
Plaster2
MT2, 23.95, 16
Mud2, 33.86, 12
Mud2, 31.97, 8
MT1, 12.60, 7
Mud2, 22.68, 4
Mud1, 12.14, 3.5
Mud2, 19.04, 3
Mud2, 14.29, 2.5
Plaster1, 9.61, 1.5
Plaster2, 8.52, 0.5

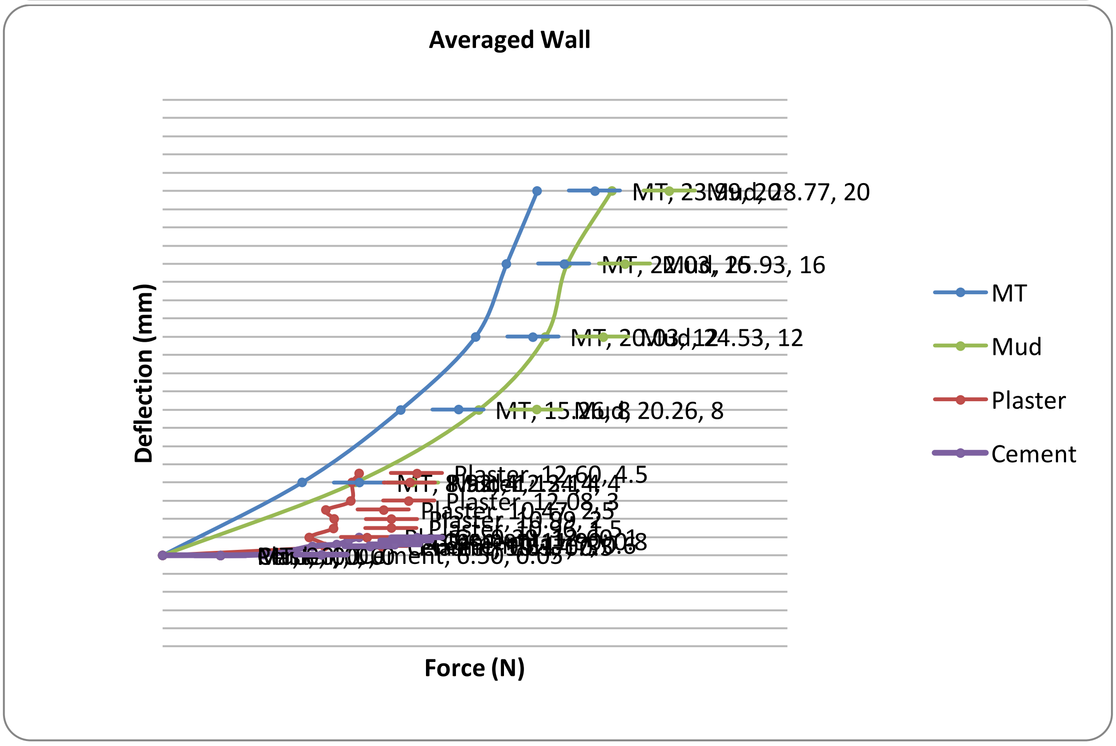

Wall C
Deflection (mm)
Force (N)
MT1
MT2
Mud1
Mud2
Plaster1
Plaster2


Wall D
Deflection (mm)
Force (N)
MT1
MT2
Mud1
Mud2
Plaster1
Plaster2


Wall E
Deflection (mm)
Force (N)
MT1
MT2
Mud1
Mud2
Plaster1
Plaster2
MT2, 12.14, 11
Mud1, 11.66, 7
Mud2, 13.48, 5


Cement
Deflection (mm)
Force (N)
Cement2, 12.60, 1
Cement1, 11.17, 0.6
Cement1
Cement2





Second moment of area (I)				
I = Bd³/12				
B (Width)	0.3		I (continous column)	8.4375E-05
d (Depth)	0.15			
B	0.26		I (for brick with hole)	2.8838E-05
d	0.11			
			I (Total)	5.5537E-05

Stiffness (K)					
K=3EI/L³					
K=EBd³/4L³					
E (Y M)	1E+10		This was recorded from the CES EduPack 2010 [Brick (Common, Hard)(2.03)], assuming it was at		
L	1.3		the lower end of the brick due to the bricks not being professionally made and using local red soil		
B	0.3				
d	0.15				
				N/m	KN/m
Estimated stiffness of			K (Without Holes)	1152139.28	1152.14
continuous beam			K (With holes)	758352.299	758.35

Force(N)	5		Deflection	Stiffness (N/mm)	Stiffness ratio compared to whole wall
		Mortarless	2.19	2.283105023	332.1573
		Mud	1.538	3.250975293	233.26846
		Plaster	0.238	21.00840336	36.09746
		Cement	0.045	111.1111111	6.82515

	Stiffness (N/m)	Mass (Kg)	Natural freqency (Hz)
Mortarless	2283.105023	117	0.703056367
Mud	3250.975293	136.4643	0.776814709
Plaster	21008.40336	187.2	1.686023925
Cement	111111.1111	262.8	3.27254929

Density Bricks	2000	ces
Volume Bricks	0.0585	
Mass of bricks	117	
Density Mud	1602	earth wet excavated
volume mud	0.01215	
Mass Mud	19.4643	
Density Cement (plaster)	1800	ces ordinary portland
Volume plaster	0.039	
Mass Plaster	70.2	
Density Cement (mortar)	1800	ces ordinary portland
Volume mortar	0.081	
Mass mortar	145.8	
$F = (1 / 2\pi) * \sqrt{(k / m)}$		