Energy & Low-Income Tropical Housing – ELITH Working Paper EWP IIB-8-4

Column lateral stiffness and strength, for variants of ISSB assembly

NHBRA 2016.

This experimentation was performed at NHBRA Lab, Tanzania, July 2016

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Introduction

In July 2016, different experiments are performed at NHBRA Dar es Salaam.
The main objective of these experiments was to determine the enhanced lateral stiffness of low cost walling (pressed stabilised blocks) by the addition of natural fibers within render of wall when subjected to lateral load and to compare the effect on lateral stiffness of fibrous and non-fibrous plastering of ISSB.

Experimental Setup and Results

The following variables are considered which include Unplastered U, Plastered P 8mm , Plastered P 20mm, Sisal S, Rice R, No fibre N and these variable give following combinations

Variable Combinations	Sample Symbol
Unplastered U	A (U)
Plastered P 8mm No Fibre	F(P,8,N)
Plastered P 20mm No Fibre	E (P,20,N)
Plastered P Sisal-fibre S 8mm thick	B(P,S,8)
Plastered P Sisal-fibre S 20mm thick	G(P,S,20)
Plastered P Rice-fibre R 8mm thick	C(P,R,8)
Plastered P Rice-fibre R 8mm thick	D(P,R,20)

5 samples of each variable combination column with 1.5m height made of interlock stabilised soil blocks (ISSB), each of 300mm length 150mm width and 100mm depth, were tested under a lateral load, applied through a bespoke pulley system as shown in Figure 1.

Figure 1: Bespoke Pulley System for Lateral Load Application

A lateral load increased in small increments was applied at a height of 1m and the corresponding displacements were recorded by using a theodolite and measuring scale resting at top of column. Loading was restricted initially to that giving a displacement of 1mm to 2mm; loading was later increased to find the onset of cracking and collapse load.
The result of each sample is detailed in the form of a load vs displacement below;
The average values of all samples are detailed in Tables 1 and 2.

Table 1 Average values for lateral displacements of columns with 20mm of plaster
3 types of plaster (R=rice fibre, S = sisal fibre, N = no fibre); sample size = 5

Sample D(P,R,20)		
Load (N)	Displacement (mm)	Stiffness (kN/m)
35.0	0.3	116.7
84.5	1.0	84.5
126.8	1.7	76.2
156.8	2.4	64.3
186.8	3.1	61.0
244.0	4.1	59.3
291.3	5.0	58.3

Sample G(P,S,20)		
Load (N)	Displacement (mm)	Stiffness (kN/m)
35.0	0.6	58.3
84.5	1.2	70.4
126.8	1.9	68.5
156.8	2.5	64.0
186.8	3.2	58.4
216.8	4.1	52.9
246.8	5.3	46.6
278.8	8.0	35.1
316.8	9.0	35.2
346.8	13.0	26.7

Sample E(P,N,20)		
Load (N)	Displacement (mm)	Stiffness (kN/m)
35.0	0.6	56.0
65.0	1.3	48.8
95.0	1.8	51.8
125.0	2.8	44.1
155.0	2.5	62.0
185.0	3.0	61.7
215.0	3.5	61.4
245.0	4.0	61.3
287.3	5.0	57.5

Table 2 Average values for lateral displacements of columns with 8mm of plaster
Same 3 types of plaster as Table 1; sample size = 5

Sample C (P,R,8)		
Load (N)	Displacement (mm)	Stiffness (kN/m)
35.0	0.1	350.0
83.5	0.8	104.4
126.8	2.0	62.2
156.8	2.3	67.2
186.8	2.5	74.7
204.8	3.5	58.5
207.8	3.0	69.3
212.8	3.3	65.5
228.0	3.4	68.1
232.8	4.0	58.2
252.8	5.0	50.6
272.8	6.0	45.5

Sample B (P,S,8)		
Load (N)	Displacement (mm)	Stiffness (kN/m)
35.0	0.6	63.6
84.5	1.4	62.6
126.8	3.1	41.6
156.8	4.5	34.8
186.8	6.0	31.1
216.8	10.4	20.9
246.8	6.3	39.5
276.8	9.0	30.8

Average Sample F (P,N,8)		
Load (N)	Displacement (mm)	Stiffness (kN/m)
35.0	0.6	56.0
84.5	1.6	52.0
122.7	2.8	44.6
136.3	3.0	45.4
166.3	4.0	41.6
196.3	5.0	39.3
226.3	6.0	37.7

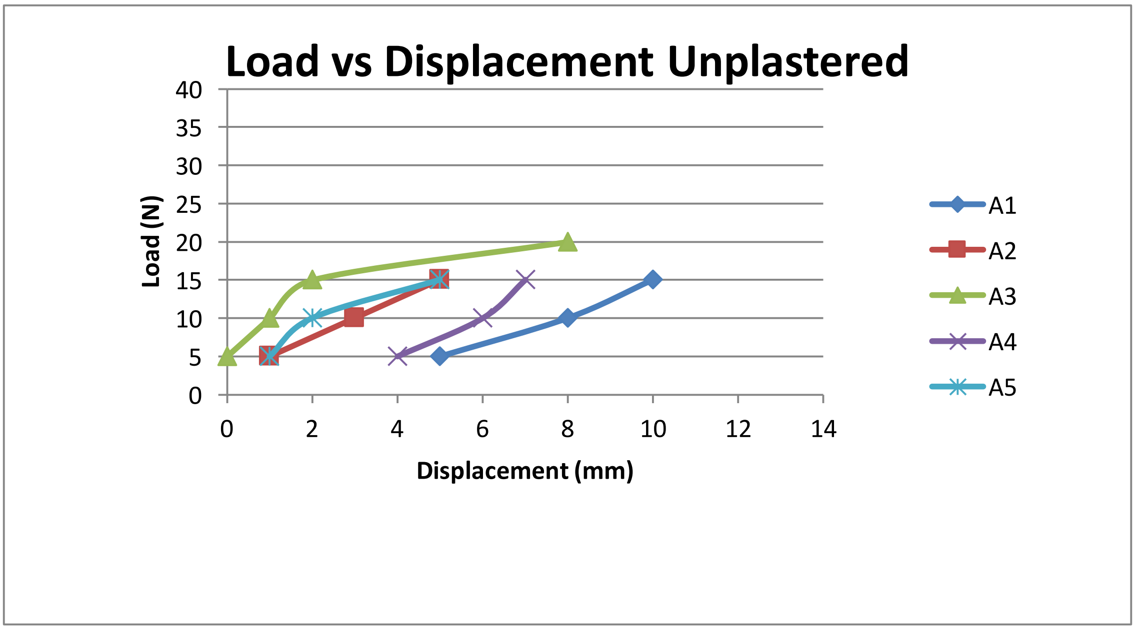

Figure2: Unplastered Columns, Load vs Displacement Graphs for 5 Samples

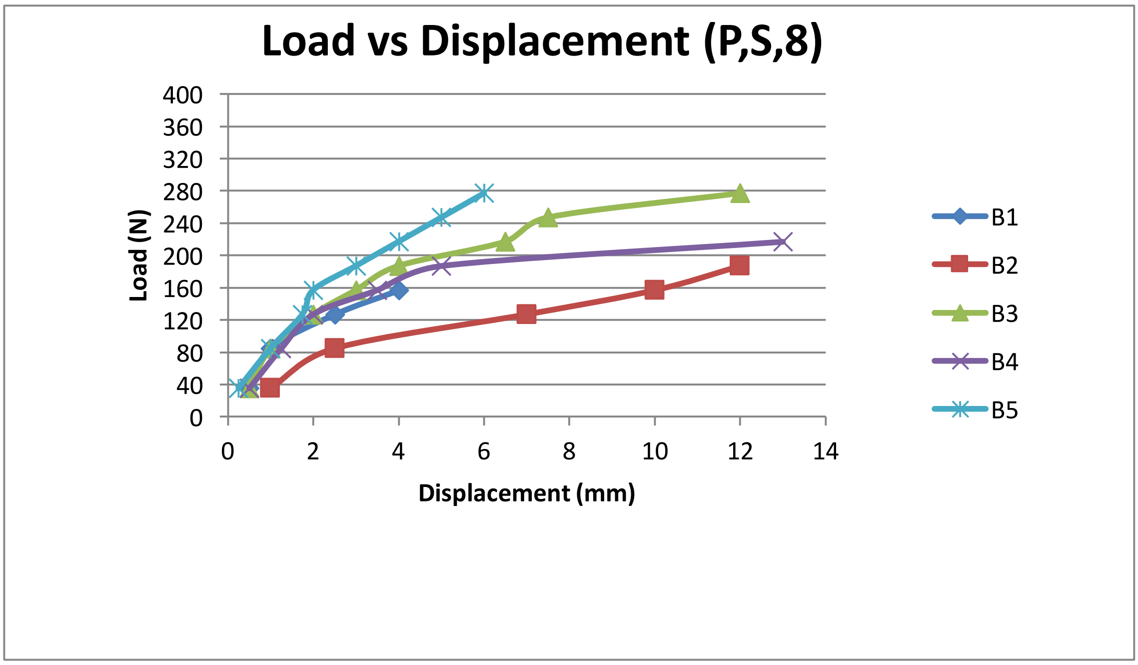

Figure 3: Sisal fibre thinly-plastered Column - Load vs Displacement Graph for 5 Samples

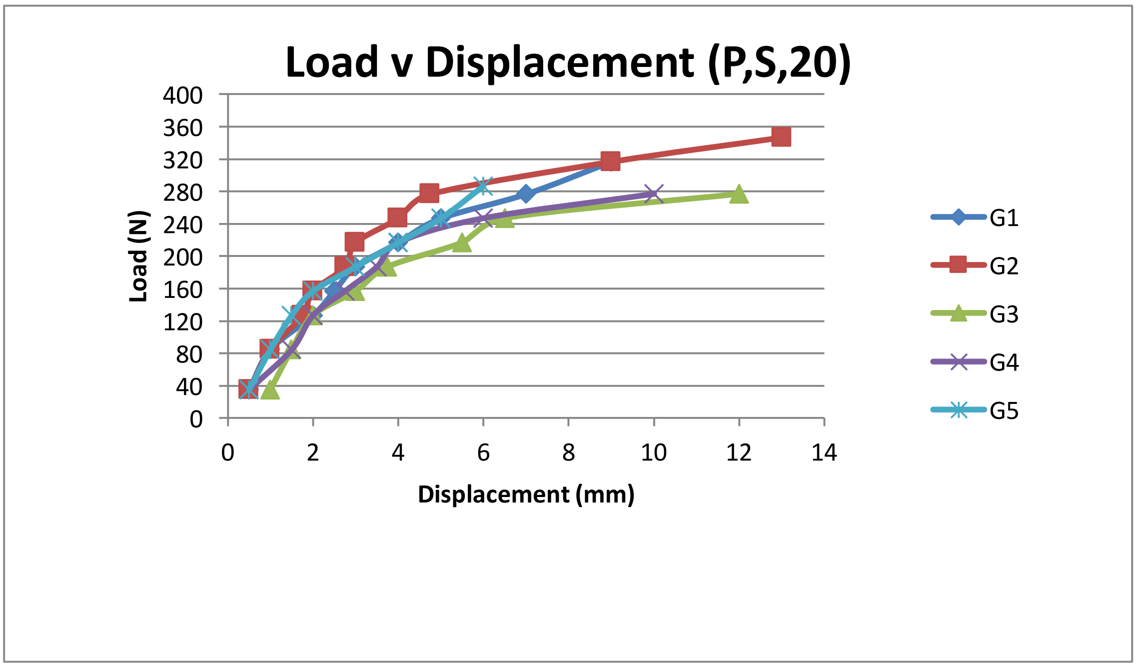

Figure 4: Sisal-fibre thickly-plastered columns: Load vs Displacement Graph for 5 Samples

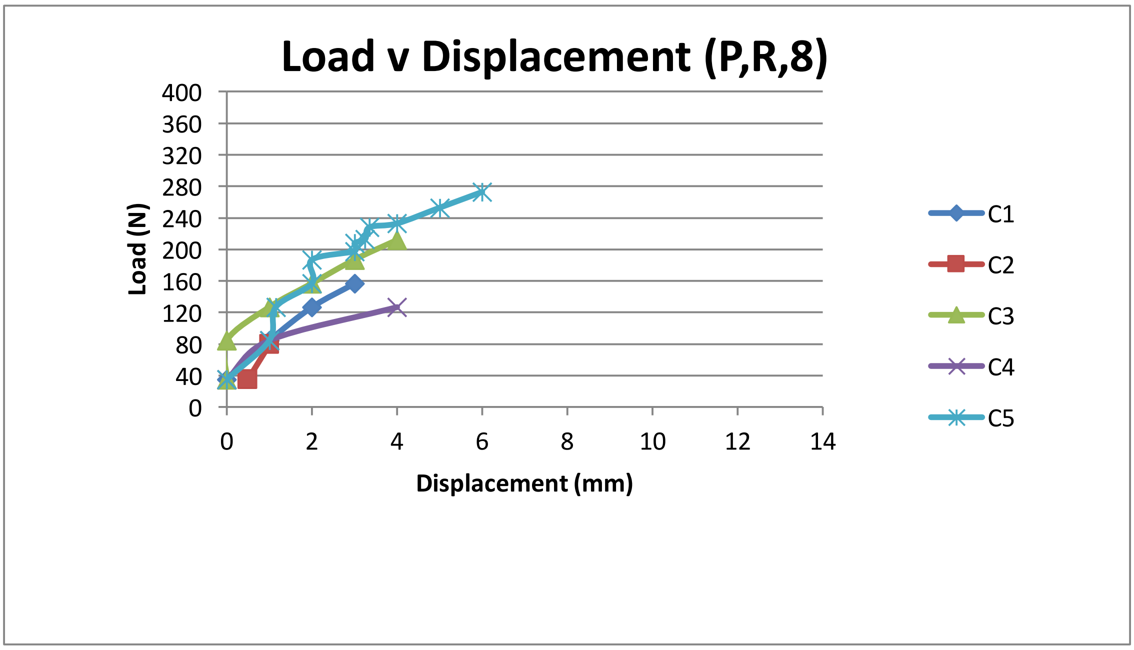

Figure 5: Rice-straw-fibre thinly-plastered columns: Load vs Displacement graph for 5 Samples

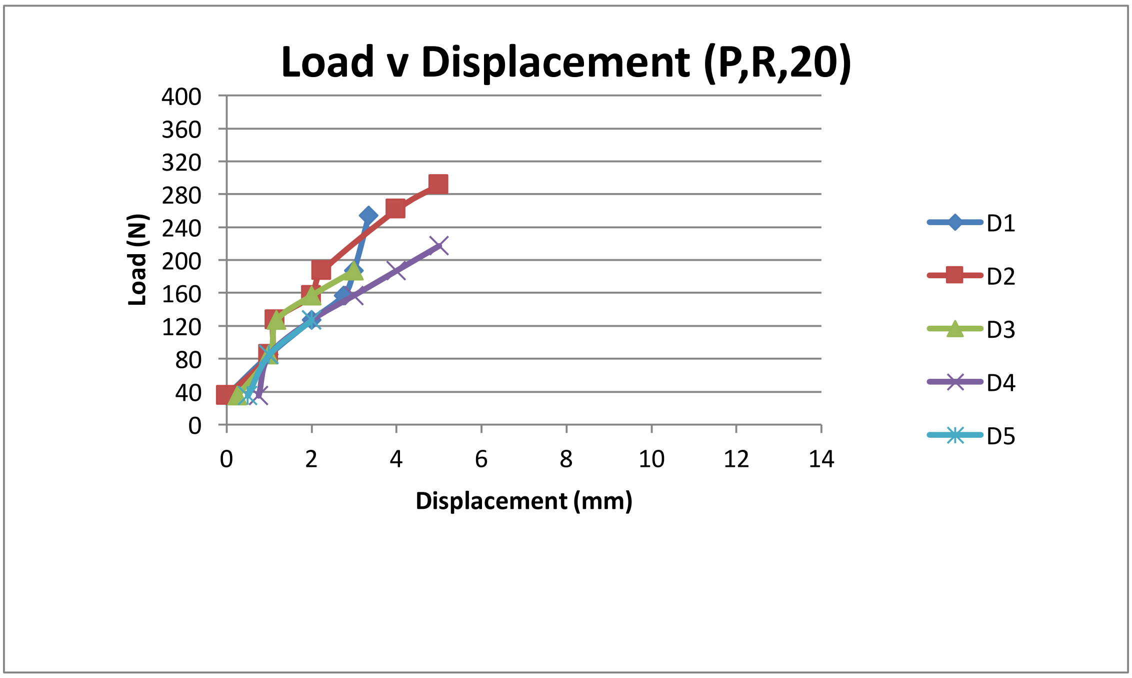

Figure 6: Rice-straw-fibre thicky-plastered columns: Load vs Displacement graph for 5 Samples

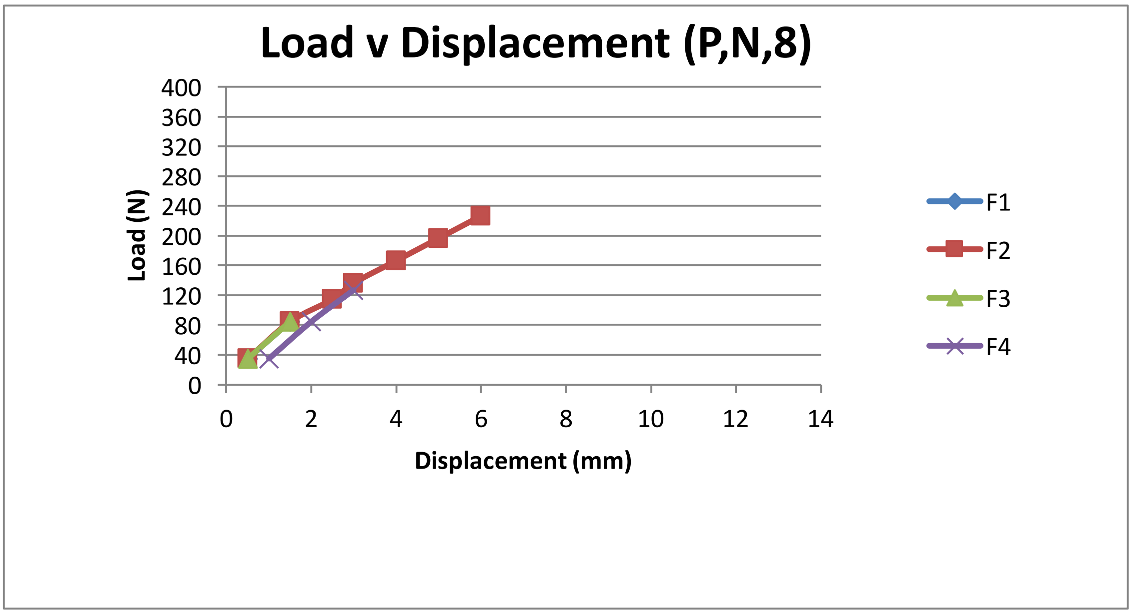

Figure 7: Non-fibrous thinly-plastered columns: Load vs Displacement graph for 4 Samples

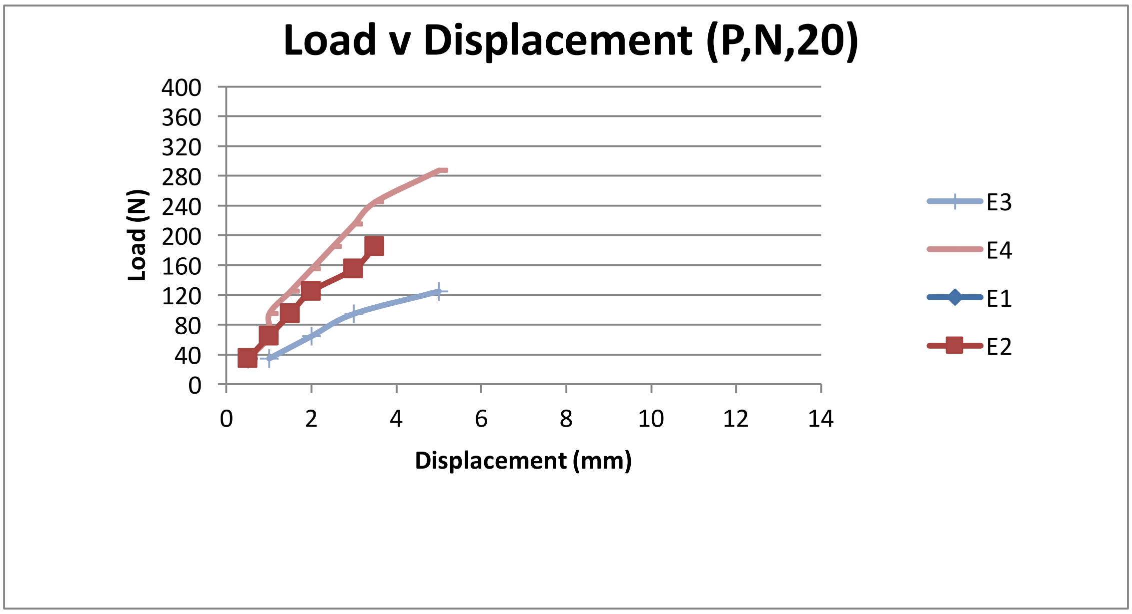

Figure 8: Non-fibrous thickly-plastered columns: Load vs Displacement graph for 4 Samples

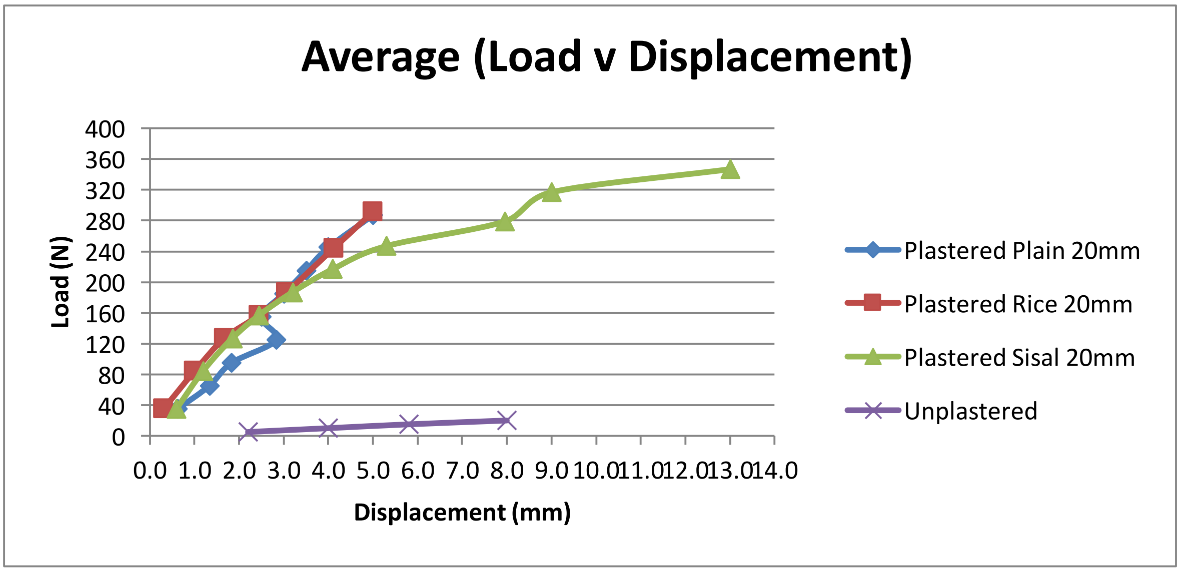

Figure 9: Average Values of 5 thickly-plastered samples: Load vs Displacement Graph

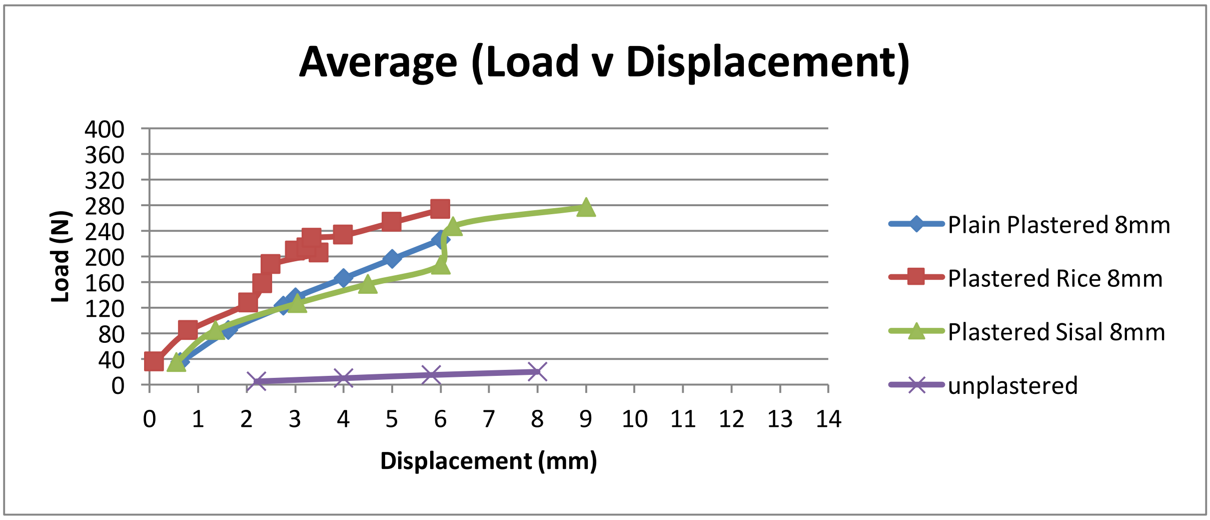

Figure 10: Average Values of 5 thinly plastered samples: Load vs Displacement Graph

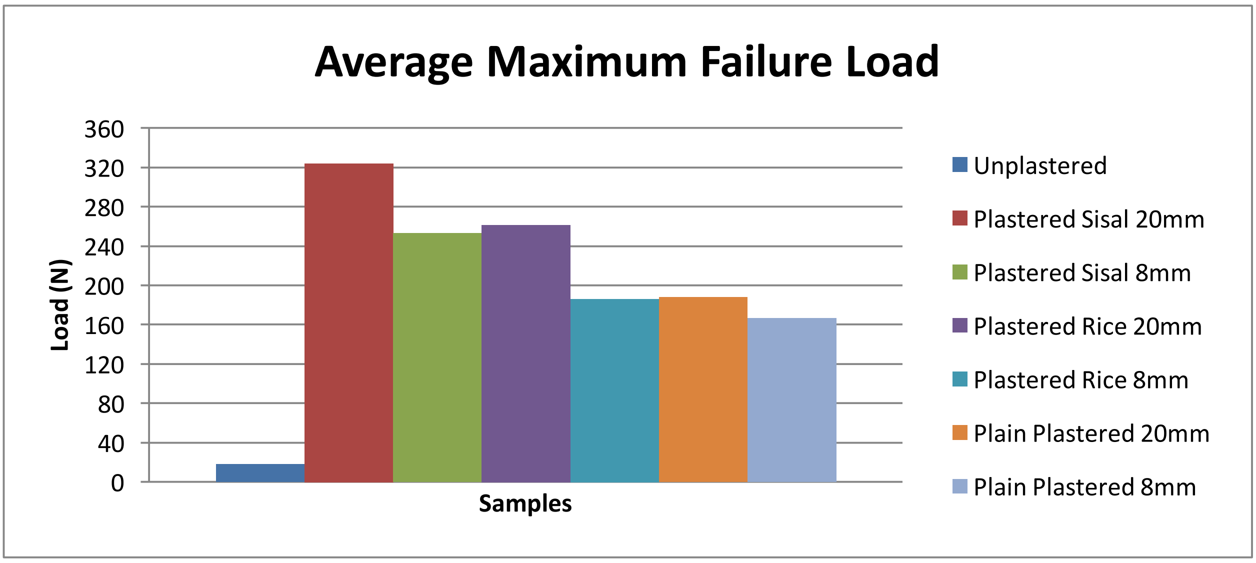

Figure 11: Average Values of 5 samples Failure Load

Comparison with theoretical expectations:

Stiffness is the ability of material to distribute the load and resist deflection or deformation and this parameter indicates how the materials resist the applied loading. Stiffness is defined as the force per unit of displacement at any particular force (i.e. $k = F/\delta$); stiffness generally reduces as the load F is increased.

The formula for the deflection δ of the top of a cantilevered uniform column of height h and 2nd moment of area I, when load is applied at a distance "a" from its restrained bottom, is

$$\delta = \frac{F(3h-a)}{6EI}$$

therefore,

$$k = 6EI/a^2(3h-a)$$

Where k = Stiffness in kN/m, P = Applied Lateral Load (N), δ = Displacement (m), E= Elastic Modulus of ISSB blocks (assumed), h = Height of column, a = Distance of applied load from bottom of column

For a hypothetical continuous column of the sane plan as the ISSBs actually used, we can calculate a stiffness under the same loading as applied to the tested (masonry) columns. The block plan contains two holes on its centre line which only very slightly affects column stiffness. Assumed Young's modulus for very lean concrete is taken as E = 10 GPa, the expected stiffness of a continuous column from the formula above (with a = 1.0m and h = 1.5m) is $k_{continuous}$ = 1437 kN/m

The table above shows the theoretical stiffness of continuous column including the holes. For all samples Initial stiffness are considered for average displacement of 1mm. The comparison of initial stiffness of experimental samples with continuous column stiffness is detailed in the table below.

Table 3: Comparison of initial stiffness with that of a continuous column

Sample Type	Stiffness for 20mm (kN/m)	Stiffness for 8mm (kN/m)	Stiffness normalised to that of a continuous column (as %) 20mm plaster	8mm plaster
Plain Plastered	52	55	4%	4%
Plastered with Rice	85	98	6%	7%
Plastered with Sisal	66	63	5%	5%
Unplastered	1	1	0.1%	0.1%

It can be observed from the above table that an unplastered column is not as stiff as any plastered column.

Discussion of Finding and their implications:

1. Unplastered columns are much less stiff than plastered columns: the maximum measured stiffness improvement by plastering was a 33-fold increase. This is much more than the approx. doubling in stiffness expected just from the increase in column thickness from 150mm to 190mm. It is therefore almost certain that the continuous form of the plaster (in contrast to the discontinuous form of mortarless blockwork), and hence the former's ability to carry some tensile stress, accounts for some or all of this improvement.
2. The initial stiffness of fibrous-plastered column improved by 62% and 79% (for 20mm and 8mm thick fibrous plaster respectively) as compared to non-fibrous plastered columns.
3. Stiffness (measured at 5mm displacement) with rice-straw fibrous plaster of thickness 8mm and 20mm increased 29% and 1% respectively as compared to using non- fibrous plaster at those same thicknesses.
4. Stiffness of sisal fibrous plaster column decreased as compared to plain and rice straw fibrous column by 17% and 19% for 8mm and 20mm respectively but it takes more load and failure occurs after having 13mm average displacement.
5. The collapse load for plastered column with sisal fiber is much higher than all other column types, e.g. it is 72% higher than for a plastered column with no fiber.
6. The behaviour of plastered column with sisal fiber was more ductile with onset of cracking and enough time before collapse.
7. The majority of the column failures occurred at the joint between the 1st and 2nd blocks, i.e. at approximately 100mm above the base. The failure mode was hinging.
8. The increase in stiffness of fibrous column by increasing the plaster thickness from 8mm to 20mm was 26%. The corresponding increase for non- fibrous column was 36%.

From the experimental data, it became evident that the plastering of interlocking block columns causes a major increase in column stiffness and also some increase in column (latera;l) strength.

Addition of fibers like rice straw and sisal within the plaster further enhances the lateral stiffness of columns. contributes to the lateral stiffness of mortarless interlocking block column. And it results in enhanced strength of wall when subjected to lateral load.

This strength contribution can be beneficial for reduction in cement contents by reducing thickness of plaster for a specific required strength to make it more economical.

Inclusion of fibers also enhanced the ductile behaviour of columns, by contrast non-fibrous columns failed without any sign of cracking showing brittle failure. This enhanced ductile failure can play a major role for earthquake loading which needs investigation in further study.