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Comparing the lateral stiffness of different ISSB wall plans

F. Qamar, (NHRA staff), T.H.Thomas

This experimentation was performed at NHBRA Lab, Tanzania 2016

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Introduction

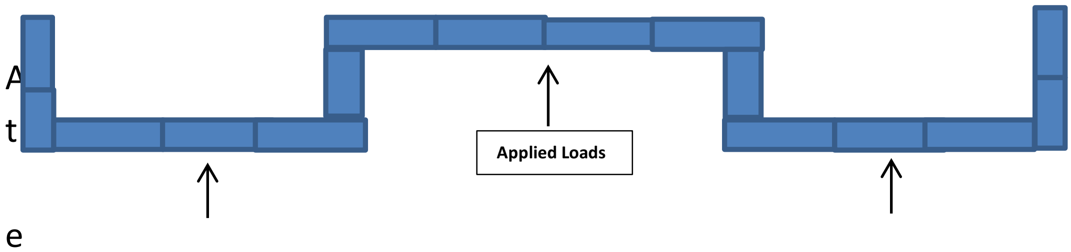
In July 2016, tests were performed on sections of unbuttressed straight wall and of crenelated wall at NHBRA, Dar es Salaam.

The main objective of these experiments was to compare the lateral strength and stiffness of a crenelated wall with that of a straight wall of similar dimensions and to observe the failure mechanism for the former. The walls were subjected to lateral (i.e. out-of-plane) loading applied at 3 points. Both walls were made of ISSB blocks (300mm*150mm*100mm) so that their 'local thickness' was 150mm. This thickness, giving a slenderness ratio of 10 for the straight wall, is below normal practice for external walling.

Experimental Setup and Results

(i) Set-up for the crenelated wall

A wall of 3m length, 1.5m height and of thickness 100mm and offset by 450mm was constructed using ISSB blocks. Returns are provided at the end of the wall to minimize the effect of having free ends. The offset distance between the front and rear sections of the wall (centreline to centreline) is 450mm. As blocks have proportions 2*b*:*b* and there is one cross brick per 4 in-line bricks, the offsetting and the extra brick increases the 2nd moment of the wall about its longitudinal axis by a factor of 34.

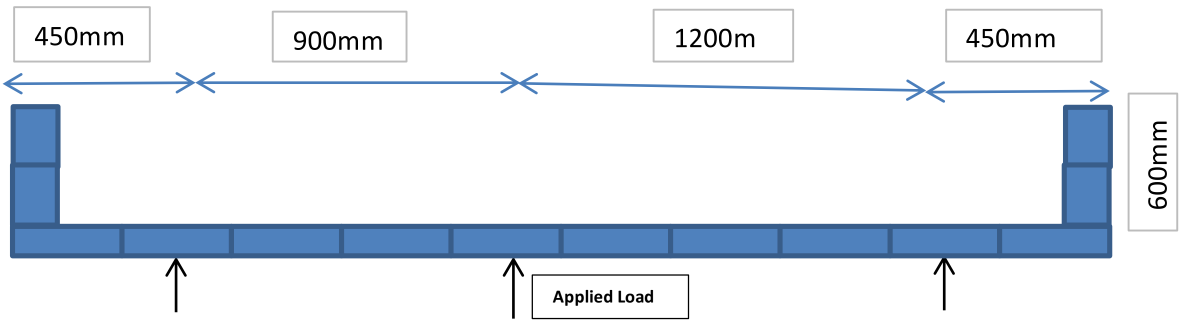


Lateral load is applied at a height of 1.0m (i.e. at 2/3 wall height) at 3 points as shown in above figure by using the bespoke pulley systems shown in figure 1. As use of unmortared blocks leaves open the possibility of lateral sliding until the block interlock surfaces engage, large lateral forces should not be applied to the top course of blocks. Thus loading was applied to a lower course where the weight of higher courses increases the frictional resistance to sliding.

To crudely simulate wind-loading, lateral load was applied in increments equally at 3 locations along the wall and displacement was recorded by using a theodolite and measuring scale resting at top of the mid-point of the wall. The loading increment was a firstly restricted to initial displacement of under 2mm. Loaded was then continued to find the onset of cracking and the collapse load.

Figure 1: Pulley system for lateral load application to crenelated wall

(ii) Set up for straight wall



A straight wall of 3m length, 1.5 height and of thickness 100mm was constructed by using ISSB Blocks and lateral loads were applied at 3 points at a height of 1.0m as shown in the figure 2.

Figure 2: Bespoke Pulley System for Lateral Load Application of straight wall

(iii) Results

The result of straight and crenelated walls is detailed in the form of table and graph (load vs displacement) below;

Wall Test	Sample	Face of Wall load Applied	Total Applied Lateral load (N)	Displacement (mm)	Stiffness (kN/m)
Stiffness	Straight Wall	Front	35	1	35
			85	2	42
			127	4	32
			157	5	32
			187	6	31
			210	8	26
			230	10	23
			264	23	12
			284	33	8
			314	collapse	

Table 1: Stiffness of Straight Wall

all Test	Sample	Face of Wall load Applied	Applied Lateral load (N)	Displacement (mm)	Stiffness (kN/m)
Stiffness Test	Crenelated Wall	Front	35	0.25	140
			85	0.75	113
			127	0.75	169
			157	0.75	209
			187	0.75	249
			217	1	217
			247	1	247
			277	5	55
			317	5	63
			340	5	68
			417	7	60
			577	11	52
	Loading bucket broke.		616	After unloading the displacement went back by 1mm, leaving 10mm displacement from the original position. Thus the elastic stiffness during unloading = appr 616 kN/m No more loading could be applied.	

Table 2: Stiffness of crenelated wall

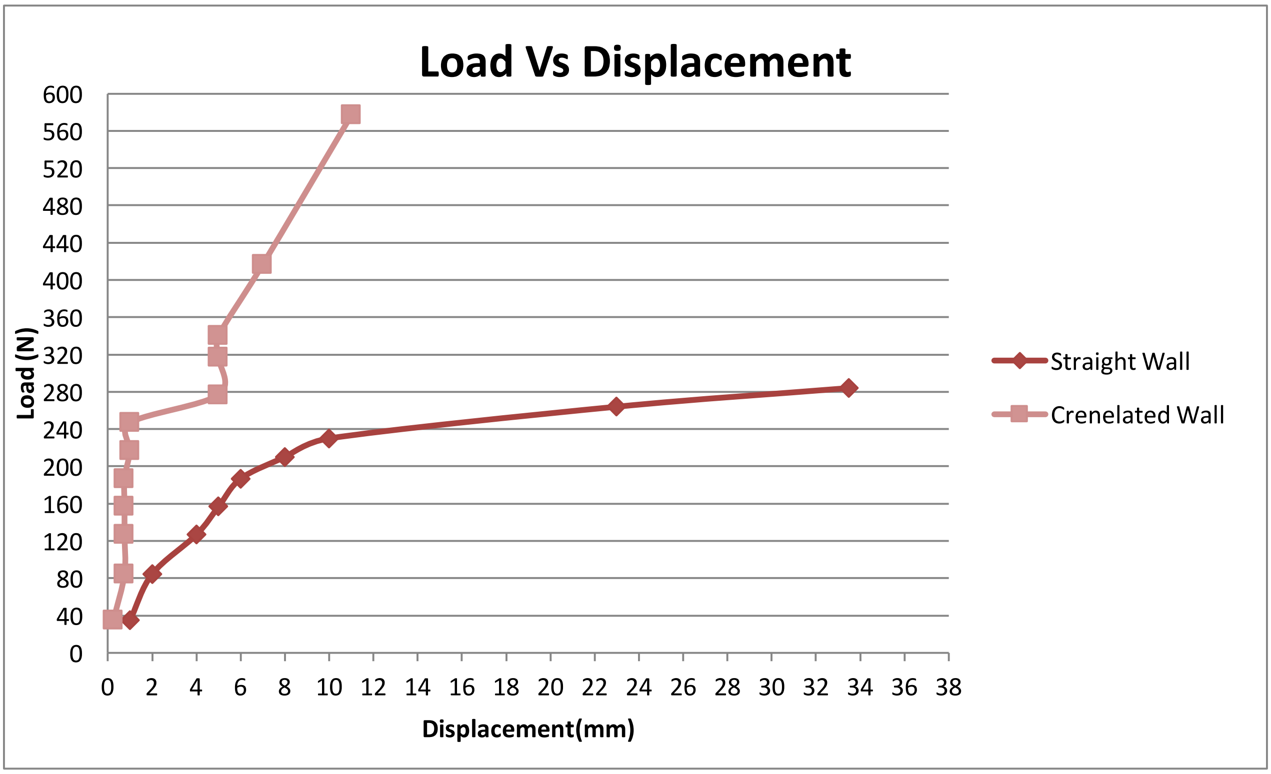


Figure 3: Straight and Crenelated Wall Load vs Displacement Graph

Comparison with theoretical expectations:

The complex shape of a crenelated wall and of its constraints (both cantilevered from the ground and partly restrained at the two ends) make analysis complex. Moreover other experiments show that the stiffness of a mortarless masonry wall is much less than of a continuous wall of the same material. However in all cases lateral stiffness is some multiple of the wall plan's 2nd moment of area. So we restrict ourselves to the expectation that the *ratio* of the crenelated and straight wall stiffnesses should match the ratio of their 2nd moments. Allowing for the extra (1 in 7) longitudinal bricks and the minor contribution from the (2 in 7) cross bricks, this ratio was calculated as 34.

Discussion of Findings

1. Initial stiffness at a displacement (1mm) of crenelated wall was ca 250 kN/m in loading and ca 620 kN/m during unloading from a higher displacement. The initial stiffness of the straight wall was 35 kN/m. The ratio of stiffnesses therefore lies between 8 and 18. The crenelated wall therefore shows a very substantial improvement in lateral stiffness but by less than the factor of 34 predicted by theory. The 'cost' of this improvement is a 43% increase in the number of blocks used and any cost incurred by having a less convenient wall line.
2. The behaviour shown in Figure 3 suggests a mixture of sliding and of elastic bending is taking place. This is probably peculiar to mortarless block masonry and not to be expected in mortared walling. For vthe crenelated wall at cessation of loading (before failure) irreversible sliding accounted for about 90% of the final deflection.
3. Crenelated wall accepted twice the load than straight wall failure load without incurring failure.
4. Failure of straight wall occurred at the 6th course of blocks, at 600mm.

The strength and stiffness enhancement achieved by crenellating can be translated into

- Use of fewer bricks than a stiff straight or buttressed wall would require.
- Use of thinner, weaker or more hollow blocks.

This experiment used quite deep (450mm) crenelation. 300mm crenelation would be expected to yield about half the stiffness improvement seen here.