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Axially Loaded Solid Concrete Masonry Prisms Built by Different Methods of Construction

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Abstract
In this experimental investigation, the compressive strength results of a large number of masonry prisms built of solid concrete block units with different mortar mixes of 1:1 and 1:3 (cement : sand) proportions were tested under axial loads and reported.Different methods were adopted in the construction of the prisms. The block's length, width and height were documented as variables.Test results show that the change in mortar compressive strength has high effect on the prisms compressive strength for some methods of construction, and slightly low on other methods.
Keywords: Compressive strength, Mortar mixes, Solid blocks, Mortar joints. Method of construction

1. Introduction
Walls built from solid precast concrete masonry units which are joined with mortar, are commonly used in the construction of load-bearing walls in small buildings. Concrete block units are usually manufactured in dimensions ranging from 100 to 200 mm in width, but the most commonly used block has dimensions of 200 mm x 200 mm x 400 mm.

Previous Tests have shown that prisms compressive strength depends primarily on unit compressive strength, and very little on mortar compressive strength for machine-made clay and sand bricks. Similar conclusions were obtained for concrete units (Alcocer and Klingner 1994).

For walls under vertical load, the function of mortar joint is simply to produce a good uniform bearing between the blocks and provided the mortar is not so fluid that it could squeeze out like toothpaste, it's strength is irrelevant and the wall strength will correspond to the strength of the blocks (Roberts, Tovey and Fried 2001). The aim of this research is to study the effect of the block sizes and the location of the vertical joints on the compressive strength of concrete masonry walls.

2. Materials
2.1 Block Units
A medium strength mix of 1:2:4 (cement : sand : aggregate) proportions batched by volume were adopted to manufacture the precast concrete units. Three standard sieves were used to divide the size of the coarse aggregates having 12.5 mm, 9.5 mm and 4.75 mm apertures in accordance to ASTM C33-86 (Annual Book of ASTM Standards 1986). The size of coarse aggregates used are those retained on 9.5 mm and 4.75 mm aperture sieves. The Water content was adjusted to provide a low concrete slump. Three 100 x 100 x 100 mm cubes were casted with each batch in accordance with BS 1881: Part 108: 1983 (BS 1881: 1983). The cubes were then cured in a water tank and tested in compression after 28 days.

2.2 Mortar
Two mortar mixes of 1:1 and 1:3 (cement : sand) proportions batched by volume were adopted for the construction of the prisms. Three 100 x 100 x 100 mm cubes were casted with each batch in accordance with BS 1881: Part 108: 1983 (BS. 1881: 1983). The cubes were then cured in a water tank and tested in compression after 28 days.

2.3 Cement
Ordinary Portland cement was used in all the concrete and mortar mixes.

3. Block Manufacturing
A large number of solid-block units were manufactured using wooden forms. Concrete was placed in the forms then compacted using an electrical poker vibrator. The block units were then cured in water for more than 14 days.

4. Specimens Construction
More than 75 prisms were built by an experienced mason with a 10 mm mortar joint between the blocks. The built prisms were divided into two groups, group A and group B. The prisms of group A were constructed by building blocks with 1:1 (cement : sand) mortar mixes, while the prisms of group B were constructed by building

blocks with 1:3 (cement : sand) mortar mixes. The mortar was cured for seven days by wetting it with water twice a day.
Figure 1 shows the building method of each type of prism. Table 1 gives the size of the constructed blocks.

5. Strain measurements

Twenty-four hours before testing the prisms, demec points with a gauge length of 50 mm were glued onto particular locations perpendicular to the mortar joints, to measure the vertical and horizontal strains on some prisms. In order to study the change of vertical length for the blockwork prisms, some prisms were fitted by displacement measurement glued on the prism surfaces. Figures 2, 3 and 4 show the demec point locations. The location of the strain and displacement measurements are shown in Figure 3.

6. Testing Procedure

A hydraulic testing machine with 1.3 MN capacity was used for testing all prisms in axial compression. A loading rate of 10 N/mm^2 per minute was used for the tested solid block and prisms in accordance with BS 6073: Part 1: 1981(BS 6073: 1981). For units with strain measurements, initial readings were taken at zero load. The load then was applied until a stress of 0.5 N/mm^2 was reached, and the first set of readings were taken. After that, the load was applied in small increments and the next set of readings were taken at each increment until failure.
The compressive strength of the mortar and the concrete used in manufacturing the solid blocks were tested in accordance with BS 1881: Part 116: 1983 (BS 1881: 1983) at a rate of 0.2 – 0.4 N/mm^2 per second.

7. Results and Discussion

The average values of compressive strength of the mortar cubes used to build the prisms are 23.5 N/mm^2 and 13.7 N/mm^2 for group A and group B respectively. The average compressive strength for the block units is 15.1 N/mm^2.
Table 2 gives the compressive strength for group A prisms. The results show that the prisms constructed by methods 1 and 2 have higher compressive strength values.
Method 3 values are slightly lower than the previous two methods, namely methods 1 and method 2. The lowest values of compressive strength can be obtained when the prisms are constructed by method 4.
Table 3 gives the compressive strength for group B prisms. The results show that prisms constructed by methods 1, 2 and 3 have almost the same values compared to the compressive strength values of method 4.
Higher compressive strength values were noted when comparing the results of group A with group B for construction methods 1, 2 and 3.
A slight difference in the values of the compressive strength was noted when method 4 of the two groups, namely group A and group B were compared.
Figures 2, 3 and 4 show some of the tested prisms at failure. The prisms were built with construction methods 2, 3 and 4 respectively with strain measurements on each prism.
Tables 4, 5 and 6 gives the results of strain readings obtained from different places on the prisms surface for the same prims shown in fig. 2, 3 and 4. (Annual book of ASTM Standards 1986.)
Figure 2 shows longitudinal crack near the center on the smaller side of the prism. Longitudinal cracks passing through the vertical mortar joint were also noticed. Figure 3 shows a large crack on the face of the smaller block.
The dominate mode of failure for most of the tested prisms was by one or two longitudinal cracks passing through the vertical mortar joint in the case of construction method 2 and 3, and by two longitudinal cracks passing through the two vertical joints in the case of construction method 4 as shown in fig. 4.

8. Conclusion

The method of the construction of concrete blockwork masonry prisms is important as it results in high compressive strengths in some cases, and slightly lower in other cases**.**

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Table 1. Dimensions of a typical concrete block units used in the construction of the prisms

Construction Method	a (mm)	b (mm)	c (mm)	d (mm)	e (mm)
1	300 400	150 200	150 200	- -	- -
2	300	100 150 200	100 150 200	145 145 145	- - -
2	400	100 150 200	100 150 200	195 195 195	- - -
3	300	100 150 200	100 150 200	95 95 95	195 195 195
3	400	100 150 200	100 150 200	95 95 95	295 295 295
4	300	100 150 200	100 150 200	150 150 150	- - -
4	400	100 150 200	100 150 200	150 150 150	- - -

Table 2. Compressive strength for group A prisms (mortar mix of 1:1) for different methods of construction.

Construction Method	Prism breadth (mm)	Prism Thickness (mm)	Prism Hight (mm)	Number of Tested Prisms	Average Compressive Strength (N/mm^2)
1	300	150	470	3	17.7
1	400	200	620	3	14.6
2	300	150	470	1	19.0
2	400	150	470	3	18.5
2	400	100	620	2	14.5
2	400	150	620	3	14.2
3	300	150	470	3	15.8
3	300	150	620	1	13.3
3	400	100	470	1	16.7
3	400	150	470	3	14.9
3	400	100	620	3	15.2
3	400	150	620	3	14.8
4	410	150	470	2	13.4
4	460	150	470	4	14.5
4	610	100	470	2	17.9
4	610	150	470	3	13.4
4	610	150	470	3	13.5
4	610	100	620	3	11.4
4	610	150	620	1	11.6
4	610	200	620	1	9.4

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Table 3. Compressive strength for group B prisms (mortar mix of 1:3) for different methods of construction.

Construction Method	Prism breadth (mm)	Prism Thickness (mm)	Prism Hight (mm)	Number of Tested Prisms	Average Compressive Strength (N/mm^2)
2	30	100	470	5	13.4
2	300	150	470	3	17.1
2	400	100	470	3	12.0
2	400	150	470	5	13.9
2	400	200	620	3	14.5
3	300	150	470	1	23.5
3	300	150	620	1	14.5
4	410	150	620	1	11.3
4	460	100	470	1	14.9
4	460	150	470	1	11.2
4	610	100	620	2	11.0
4	610	150	620	2	12.6
4	610	200	620	2	9.2

Table 4. Strain readings obtained near failure for the prism shown in fig. 2
(built with mortar mix of 1:3 and construction method 2)

The location where the strain was taken	Method used		
	Demec mechanical strain gauge, 50 mm length		Measuring the change of length over 0.67 to 0.75 of the prism height
	Average Vertical Strain	Horizontal strain	Vertical strain
1-1 and 3-3	24.6×10^{-4}		-
2-2 and 4-4	33.0×10^{-4}		
5-5		79.4×10^{-4}	

Table 5. Strain reading obtained near failure for the prism shown in fig. 3 (built with mortar mix of 1:3 and construction method 3)

The location where the strain was taken	Method used		
	Demec mechanical strain gauge, 50 mm length		Measuring the change of length over 0.67 to 0.75 of the prism height
	Average Vertical Strain	Horizontal strain	Vertical strain
1-1 and 2-2	40.1×10^{-4}		0.0036
3-3		12×10^{-4}	
4-4 and 5-5	37.9×10^{-4}		

Table 6. Strain reading obtained near failure for the prism shown in fig. 4
(built with mortar mix of 1:3 and construction method 4)

The location where the strain was taken	Method used		
	Demec mechanical strain gauge, 50 mm length		Measuring the change of length over 0.67 to 0.75 of the prism height
	Average Vertical strain	Average Horizontal strain	Vertical strain
1-1 and 6-6	23.3×10^{-4}		-
2-2 and 5-5	24.0×10^{-4}		
3-3 and 4-4	21.4×10^{-4}		
7-7 and 9-9		134.7×10^{-4}	
8-8		-	

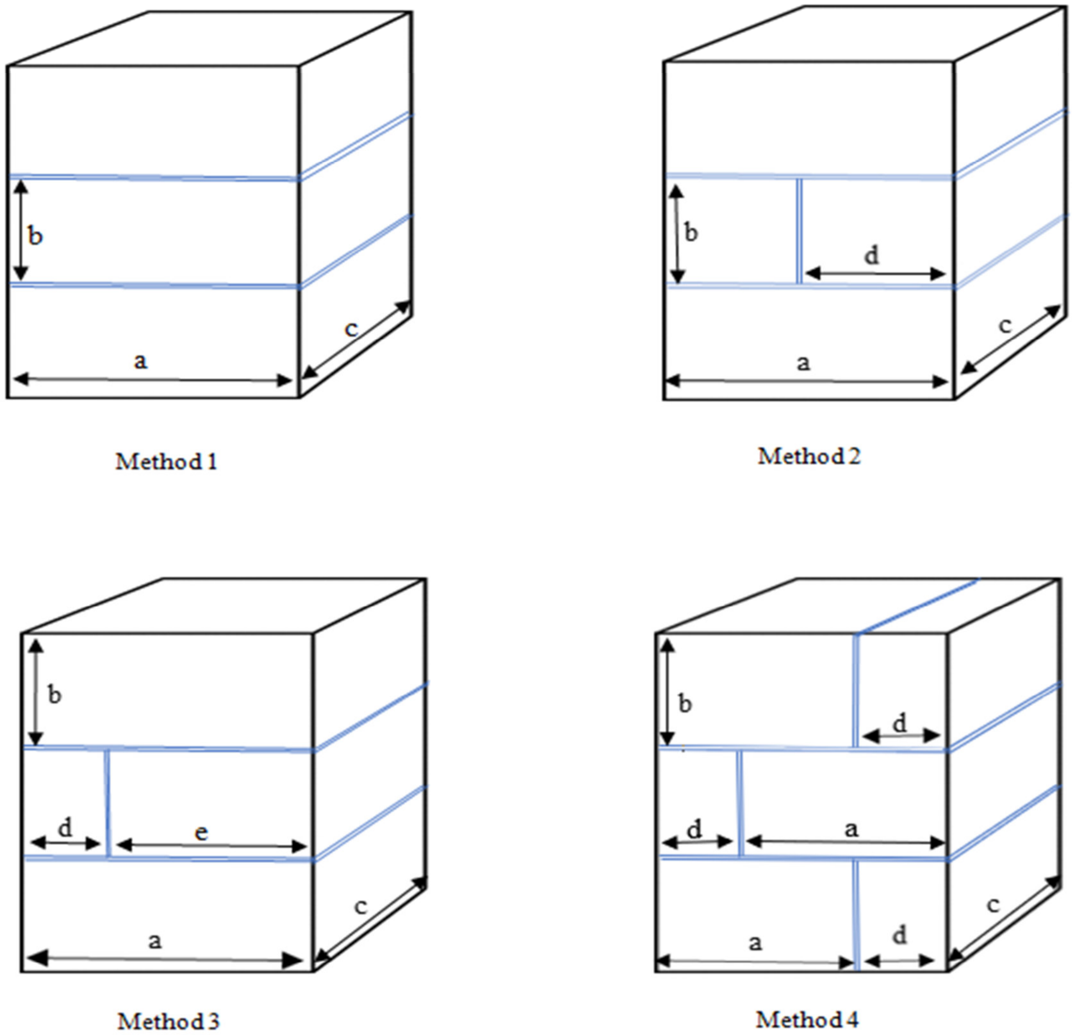

Figure 1: The method used in the construction of the prisms

Figure 2. A tested prism built with construction method 2 with strain measurements.

Figure 3. A tested prism built with construction method 3 with strain measurements.

Figure 4. A tested prism built with construction method 4 with strain measurements.