

# ***COMPRESSIVE STRENGTH OF LARGE BRICK MASONRY***

by

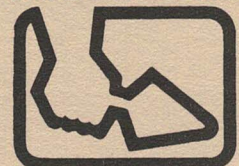
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MASONRY  
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## INTRODUCTION

With the introduction of new large clay brick units in the market and the increasing use of engineered masonry, information concerning the compressive strength of walls composed of these units is becoming of greater concern to Architects, Engineers and Specifiers. Knowledge of the strength to be used in the design, can result in economic benefits and will provide for a more realistic evaluation of safety factors. While there is a number of factors which influence the compressive strength of a masonry wall, it has become apparent from results of structural testing that the most important ones are: strength of masonry units, type of mortar and workmanship.

In this paper the compressive strength of wall specimens constructed with large size units and types M, S and N mortars are evaluated and design values are proposed.

## EXPERIMENTAL PROGRAM AND TEST PROCEDURES

### a) Masonry Units.

Two types of units were tested, namely Monarch brick units and Giant brick units, both manufactured by I-XL Industries. The units are shown in Photos 1 to 4, and schematically in Figure 1, where also the actual dimensions

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of the units are shown. Special 200 mm units are shown in Figure 2. Figure 3 shows 150 mm Giant brick units, and Table 3 summarizes the physical properties of these units.

The material strength for these units, obtained by testing small cut-off sections nominally 30 mm x 30 mm in cross section and 90 mm long, was 42.2 MPa for the Monarch and 27.4 MPa for the Giant units, based on the average of five tests.

The average initial rate of absorption for the Monarch unit was 24.06 and that for the Giant unit was 10.52.

Physical properties and other technical data are given in Tables 1 and 2.



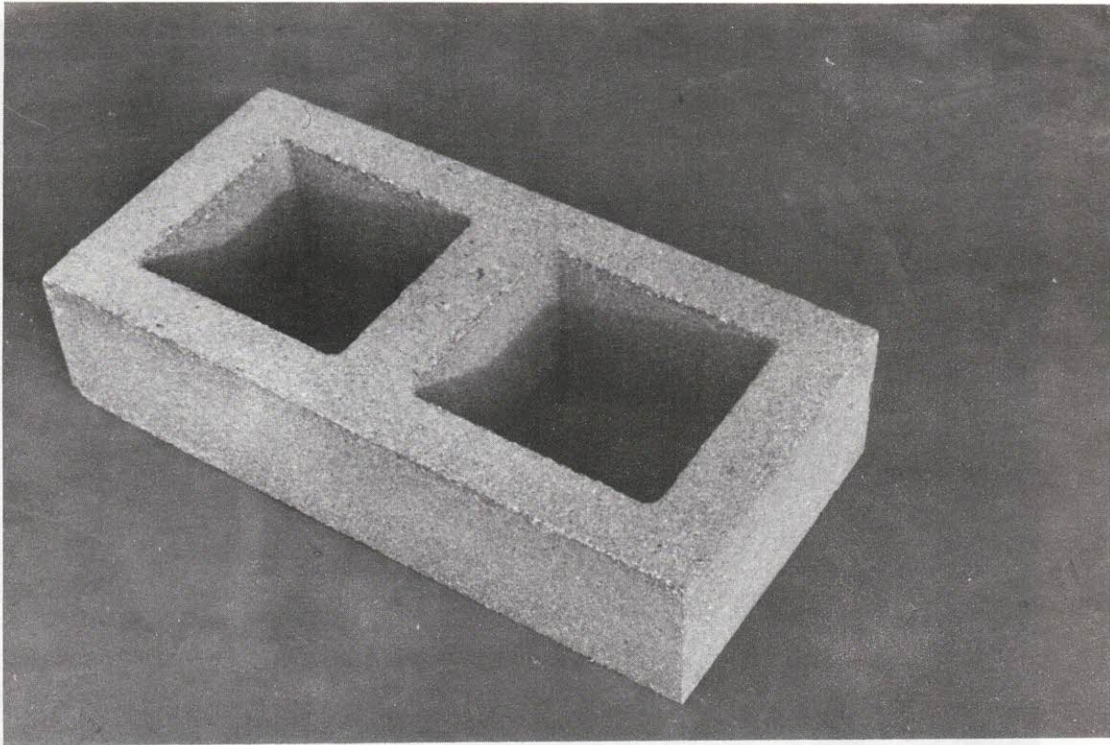


PHOTO 1 STRETCHER GIANT UNIT

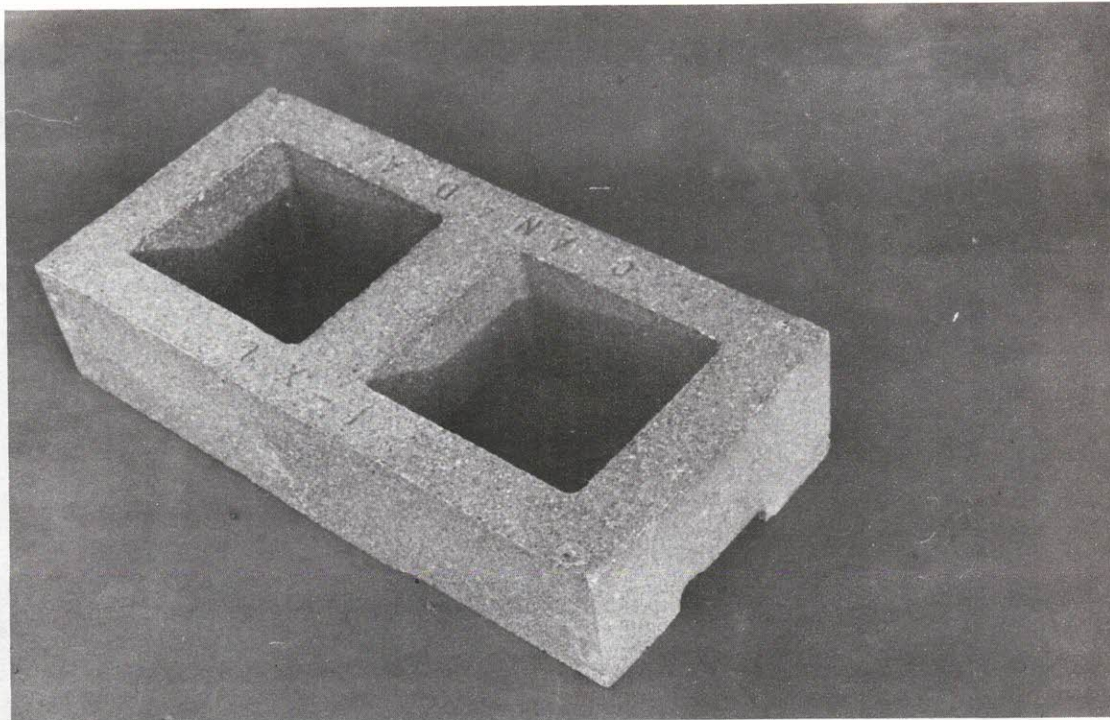


PHOTO 2 BOND BEAM GIANT UNIT



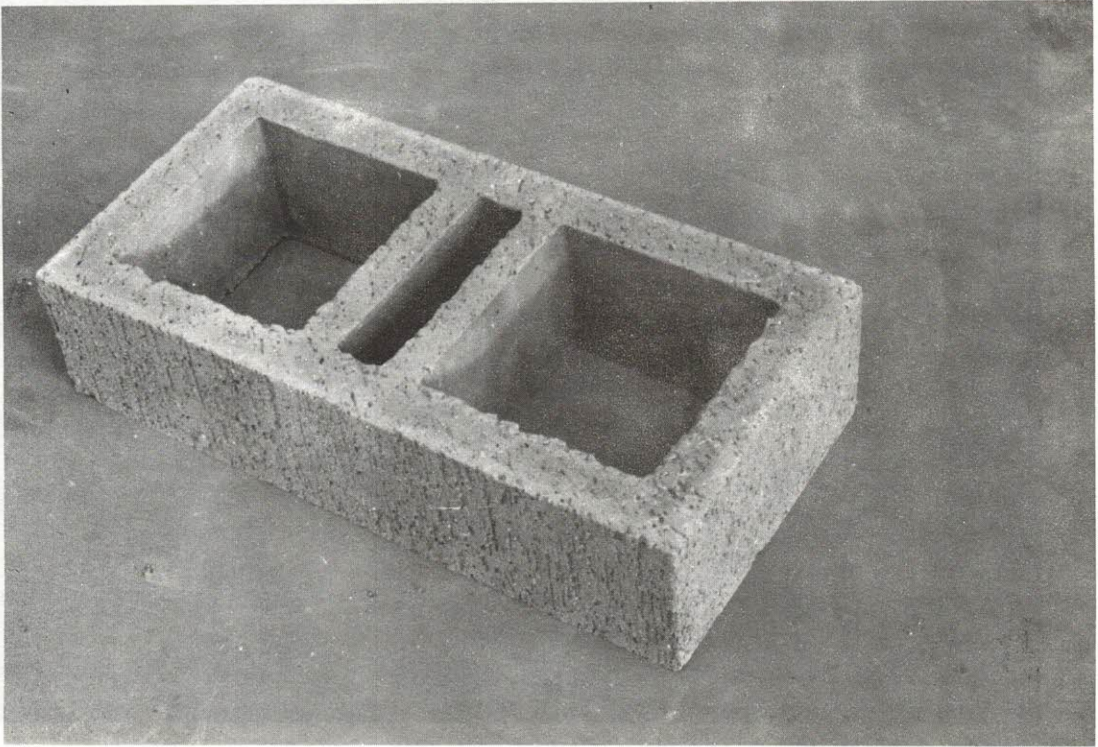


PHOTO 3 STRETCHER MONARCH

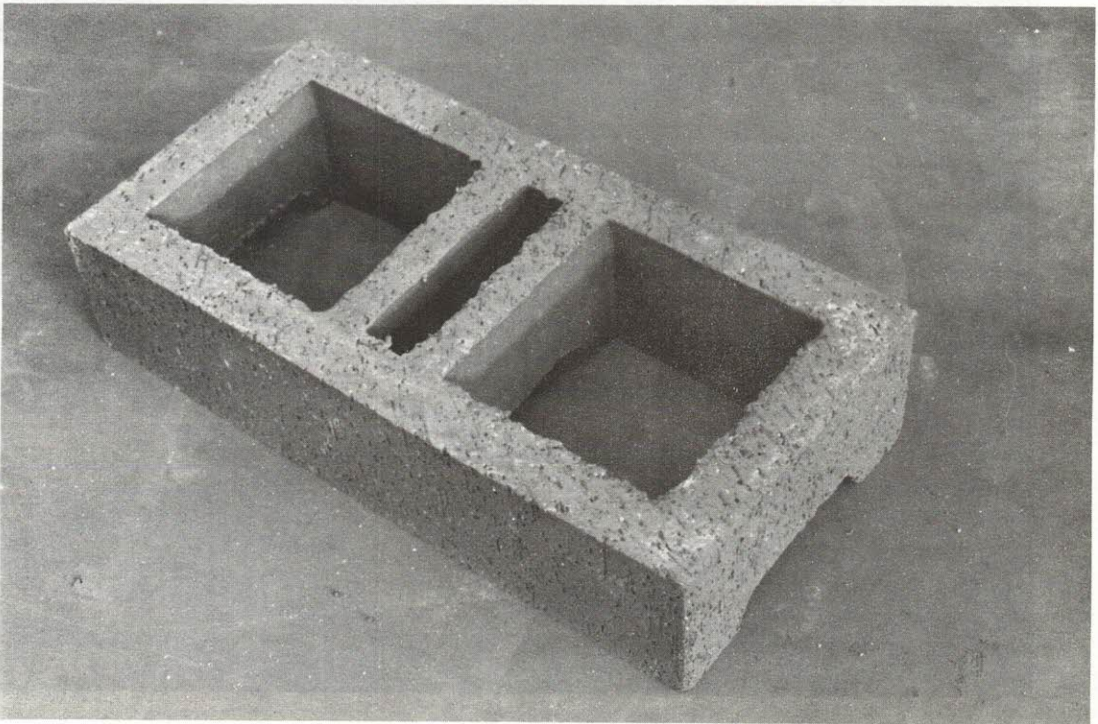
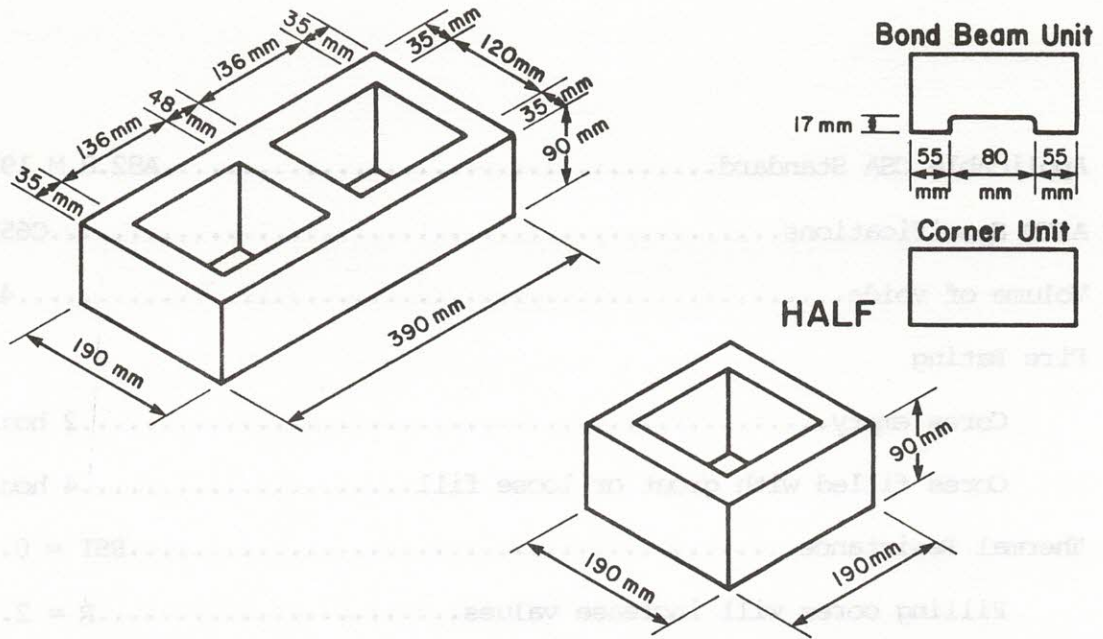


PHOTO 4 BOND BEAM MONARCH



a) GIANTS

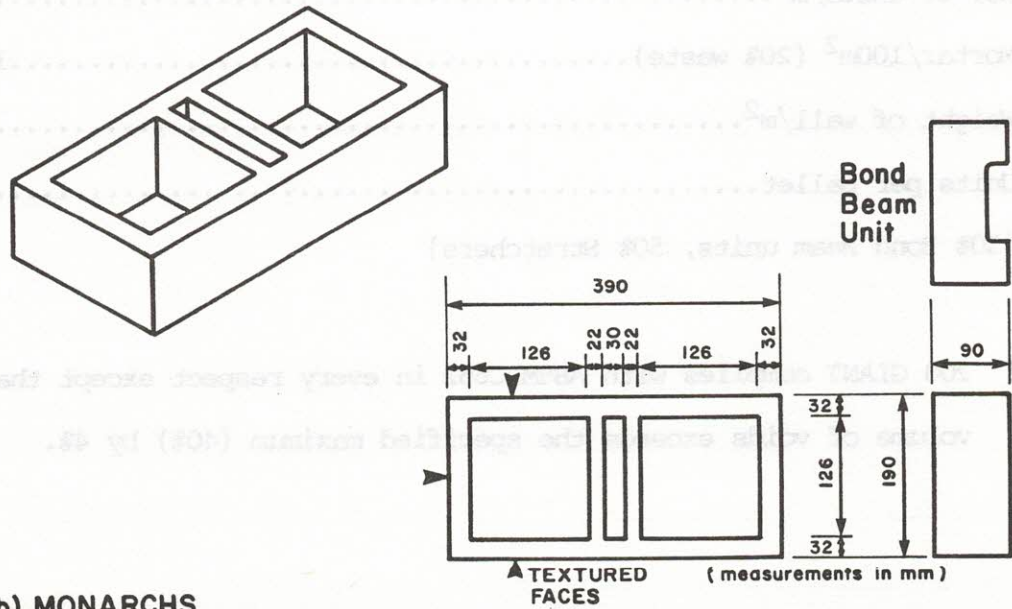


FIGURE 1 MASONRY UNITS



TABLE 1 PHYSICAL PROPERTIES AND TECHNICAL DATA  
FOR THE 200 mm GIANT BRICK UNITS

Applicable CSA Standard.....	A82.8 M 1978
ASTM Specifications.....	C652*
Volume of voids.....	44%
Fire Rating	
Cores empty.....	2 hours
Cores filled with grout or loose fill.....	4 hours
Thermal Resistance.....	RSI = 0.42
Filling cores will increase values.....	R = 2.38
Sound Transmission Class with cores (filled).....	49 db
Weight per unit.....	7.8 kg
No. of units/m <sup>2</sup> .....	25
Mortar/100m <sup>2</sup> (20% waste).....	1.10 m <sup>3</sup>
Weight of wall/m <sup>2</sup> .....	213 kg
Units per pallet.....	108
(50% Bond Beam units, 50% Stretchers)	

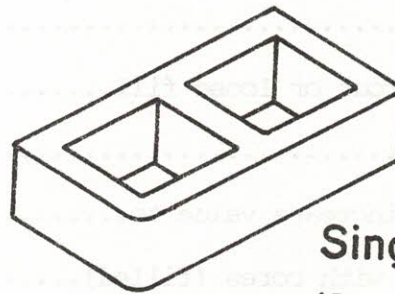
- \* 200 GIANT complies with ASTM C652 in every respect except that volume of voids exceeds the specified maximum (40%) by 4%.



TABLE 2 PHYSICAL PROPERTIES AND TECHNICAL DATA  
FOR THE 200 mm MONARCH BRICK UNITS

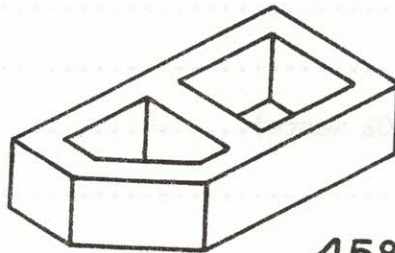
Applicable CSA Standard.....	A82.8 M 78
ASTM Specifications.....	C652*
Volume of voids.....	max. 49%
Fire rating	
Cores empty.....	2 hours
Cores filled with grout or loose fill.....	4 hours
Thermal Resistance.....	RSI = 0.42
Filling cores will increase value to.....	R = 2.38
Sound Transmission Class with cores (filled).....	49 db
Weight per unit.....	7.8 kg
No. of units/m <sup>2</sup> .....	25
Mortar required/100 m <sup>2</sup> (20% waste).....	1.10 m <sup>2</sup>
Weight of wall/m <sup>2</sup> .....	177 kg
Units per pallet.....	104

\* 200 MONARCH complies with ASTM C652 in every respect except that volume of voids exceeds the specified maximum (40%) by 9%.

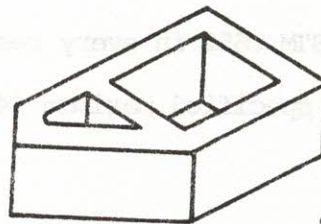


**Single Bullnose**

(Double End Bullnose  
also available)



**45° Cant**



**45° Squint**

FIGURE 2 SPECIAL 200 mm GIANT UNITS



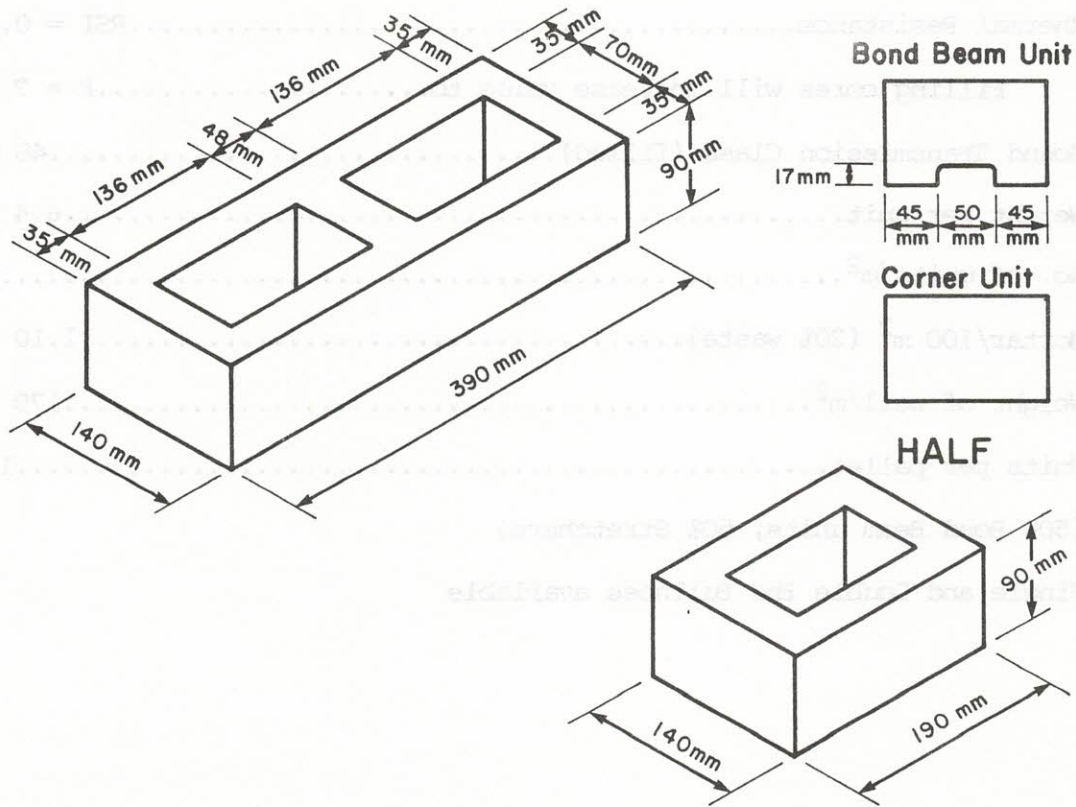


FIGURE 3 DIMENSIONS OF 150 mm GIANT BRICK UNIT

TABLE 3 PHYSICAL PROPERTIES AND TECHNICAL DATA  
FOR THE 150 mm GIANT BRICK UNITS

Applicable CSA Standard.....	A82.8 M 1978
ASTM Specification.....	C652
Volume of voids.....	34%
Fire Rating (clay brick is noncombustible)	
Cores empty.....	1 1/2 hours
Cores filled with grout or loose fill.....	2 hours
Thermal Resistance.....	RSI = 0.37
Filling cores will increase value to.....	R = 2.08
Sound Transmission Class (filled).....	48 db
Weight per unit.....	6.4 kg
No. of units/m <sup>2</sup> .....	25
Mortar/100 m <sup>2</sup> (20% waste).....	1.10 m <sup>3</sup>
Weight of wall/m <sup>2</sup> .....	179 kg
Units per pallet.....	144
(50% Bond Beam units, 50% Stretchers)	
Single and Double End Bullnose available	



b) Mortars

The mortars were prepared in the laboratory and were mixed in proportions by volume as recommended by CSA Standard A179-1977 M, "Mortar and Grout for Unit Masonry"(1), using normal cement, lime and sand. The mortars obtained had compressive strengths ranging from 15.0 MPa to 6.6 MPa (average of 5 cubes).

c) Test Specimens

All specimens were constructed by an experienced mason in running bond and face shell mortar bedding. A schematic drawing of the test specimens showing overall dimensions is shown in Figure 4. The specimens were cured in a laboratory environment at a temperature of 21°C and 32% relative humidity, and no extra moisture was provided.

A total of 20 specimens were built using Monarch units and 12 using Giant units. Photo 5 shows Monarch brick specimens during construction. Note that the shape of the units shown in Photo 5 differs from the units shown in Photo 3 and 4.

The shapes shown in these Photos are the final shapes adopted for production.

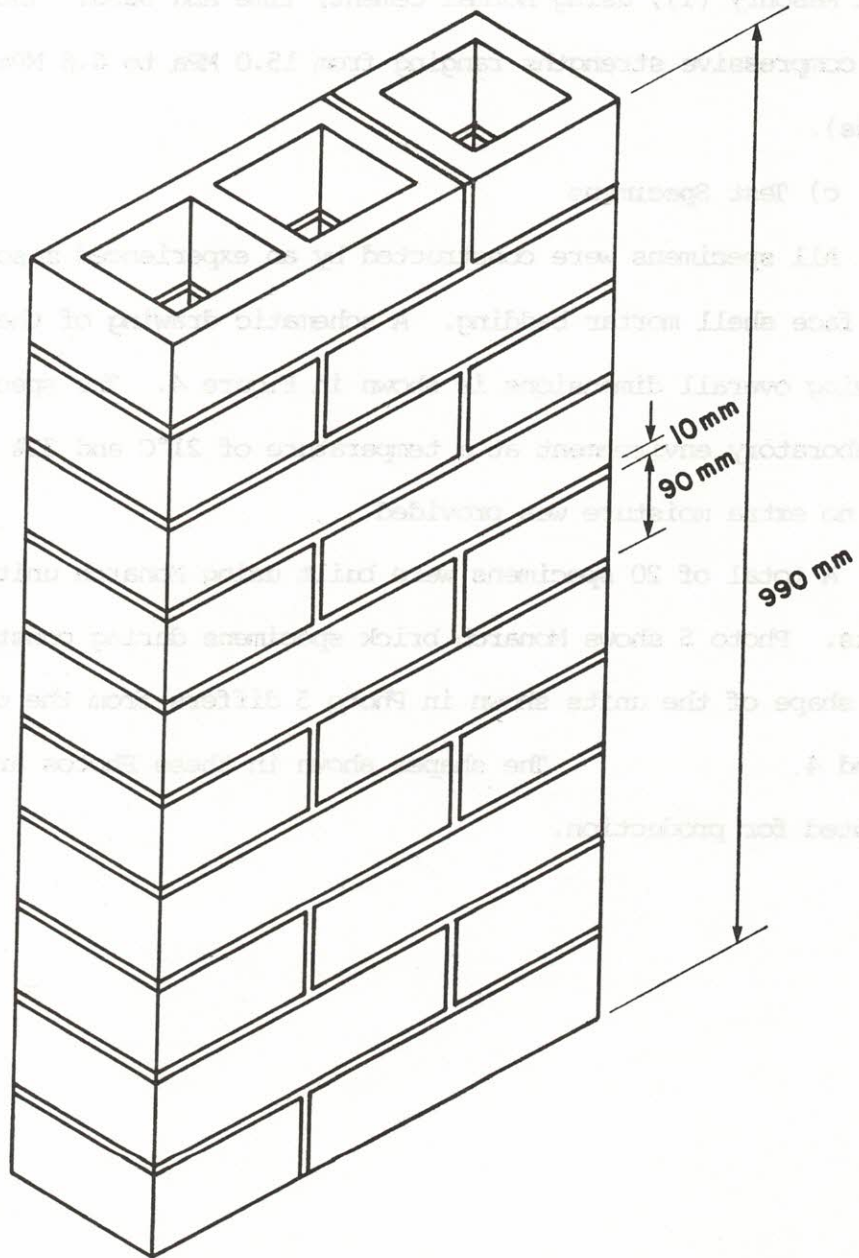


FIGURE 4 TEST SPECIMEN





PHOTO 5 MONARCH SPECIMENS DURING CONSTRUCTION

d) Testing Procedures

The specimens were tested in axial compression using a 7.1 million kN MTS testing machine, all specimens were capped using plaster of paris and neoprene pads. A small load was applied immediately after the placement of the plaster and neoprene pads to ensure even bearing. The rate of load application was 200 kN/minute. A Monarch specimen is shown in Photo 6 prior to testing.

Test Results

Typical failures of the specimens are shown in Photos 7 and 8. The failures observed were mainly splitting of the webs. They were sudden and similar to those obtained for concrete block units. The ultimate loads and the compressive strength of the mortar for each group of specimens is presented in Table 4.

The test results are also plotted in Figures 5 and 6.

From Figure 5 it is observed that the mortar strength has very little influence on the actual load capacity of the specimen manufactured with the Monarch brick units. Earlier research on concrete masonry walls showed similar results. For the Giant brick units the test results as shown in Figure 6 indicate an increase of assembly strength with increasing mortar strength. This may be attributed to the smoothness of the loaded surface of the Giant brick as compared to the of the Monarch units. For smoother surfaces fewer stress concentrations exist.



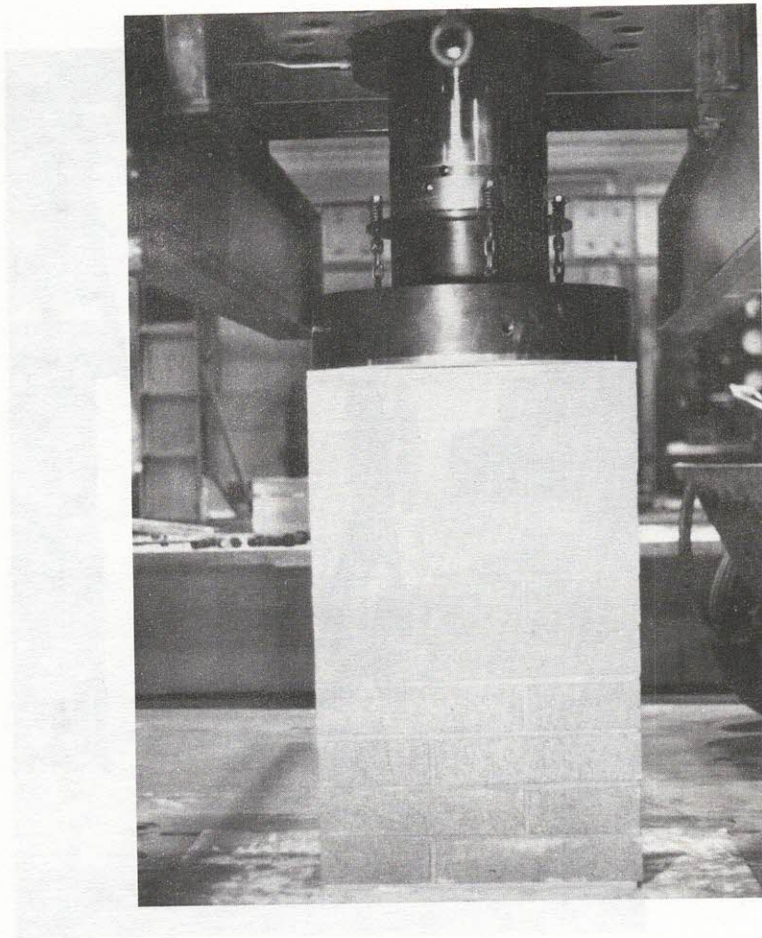


PHOTO 6 MONARCH SPECIMEN PRIOR TO TESTING

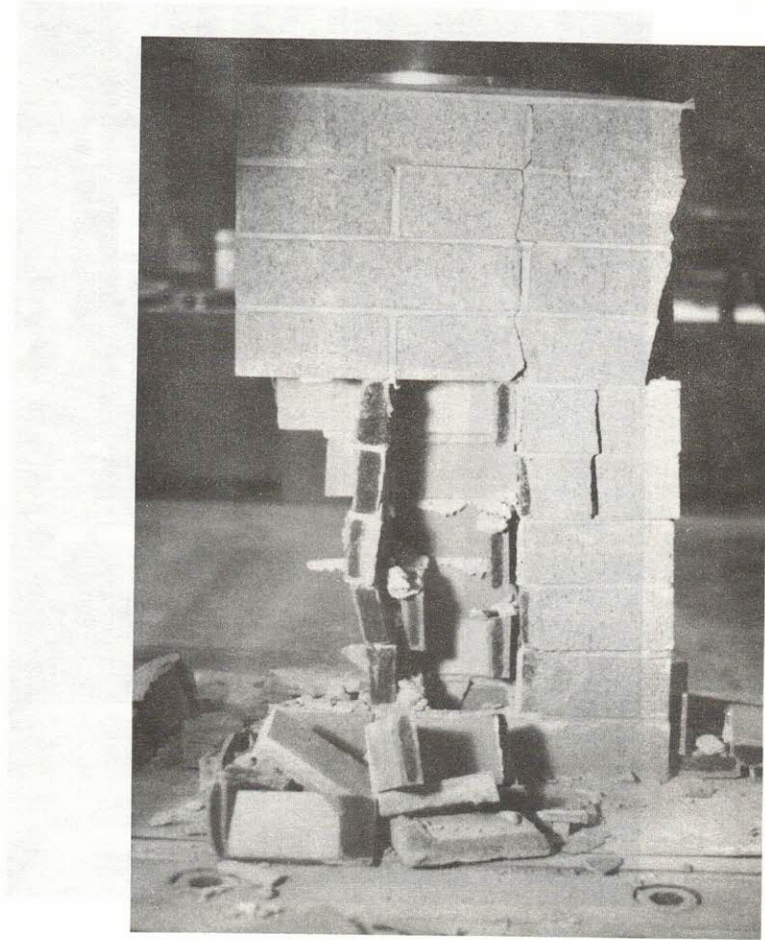


PHOTO 7 MONARCH SPECIMEN AFTER FAILURE

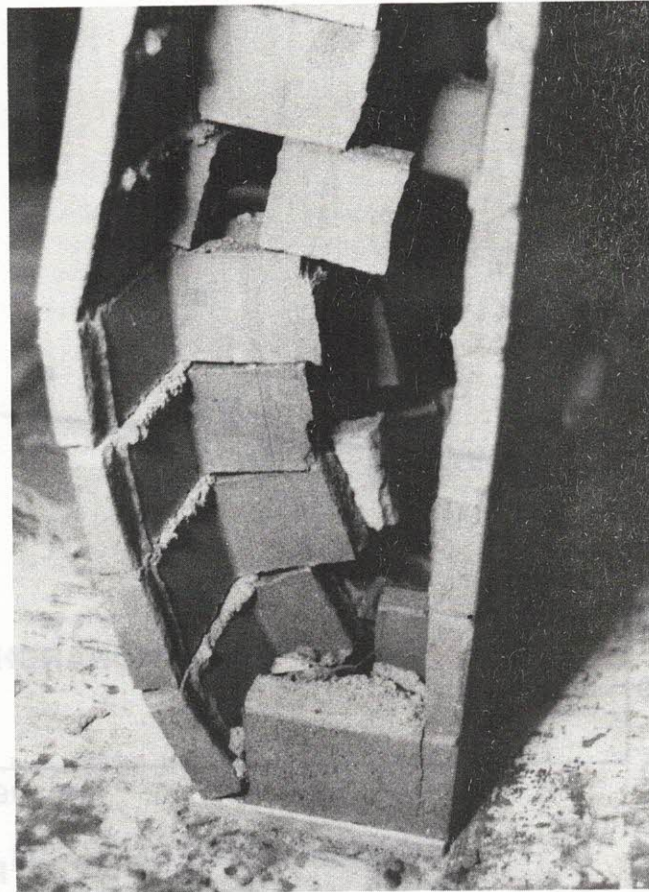


PHOTO 8 TYPICAL FAILURE OF MONARCH SPECIMEN



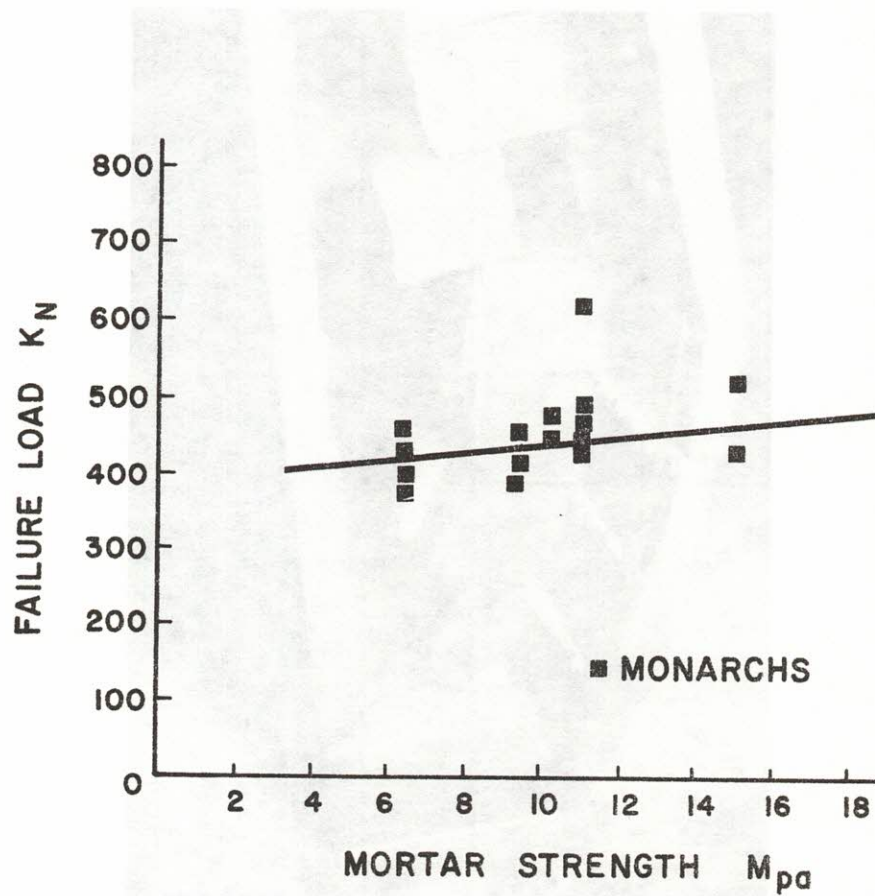


FIGURE 5 - EFFECT OF MORTAR STRENGTH ON THE COMPRESSIVE STRENGTH OF PRISMS MANUFACTURED WITH MONARCH UNITS.

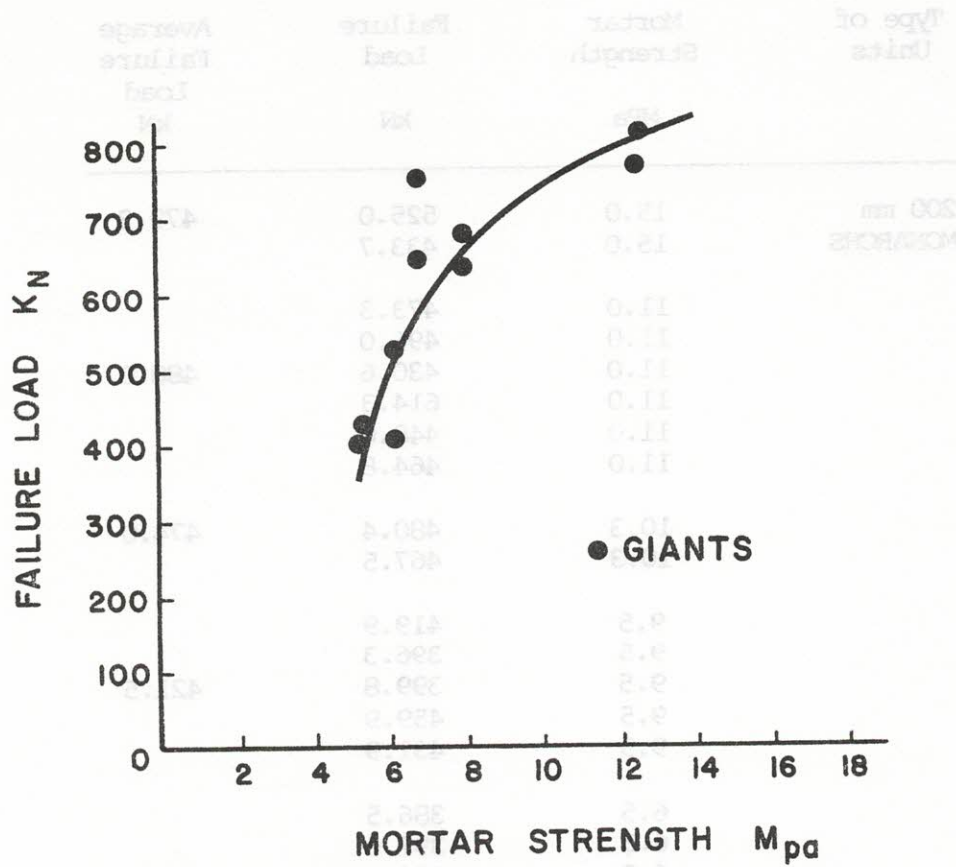


FIGURE 6 - EFFECT OF MORTAR STRENGTH ON THE COMPRESSIVE STRENGTH OF PRISMS MANUFACTURED WITH GIANT UNITS.

TABLE 4 TEST RESULTS

Type of Units	Mortar Strength	Failure Load	Average Failure Load
	MPa	kN	kN
200 mm MONARCHS	15.0	525.0	479.3
	15.0	433.7	
	11.0	473.3	488.0
	11.0	496.0	
	11.0	430.6	
	11.0	614.3	
	11.0	448.0	
	11.0	464.8	
	10.3	480.4	474.0
	10.3	467.5	
	9.5	419.9	421.5
	9.5	396.3	
	9.5	399.8	
	9.5	459.9	
	9.5	431.9	
	6.5	386.5	412.6
	6.5	397.6	
	6.5	384.3	
	6.5	456.6	
	6.5	438.1	
200 mm GIANTS	12.50	779.8	792.5
	12.50	805.2	
	7.93	755.7	696.6
	7.93	637.4	
	6.60	685.9	667.2
	6.60	648.5	
	6.20	525.0	465.1
	6.20	405.2	
	5.20	406.6	405.5
	5.20	404.4	



## DESIGN COMPRESSIVE STRENGTH AND DISCUSSION OF TEST RESULTS

The design values for the compressive strength of the two units can be obtained from Table 2 of CSA Standard CAN 3-5304-M78 (2).

For the Monarch units (compressive strength 42.25 MPa), Table 2 gives  $f'_m$  = 15.6 MPa for Type M mortar, 13.45 MPa for Type S and 11.45 for Type N.

The values of  $f'_m$  for the 27.4 MPa Giant brick are: 10.8 MPa for Type M mortar, 9.7 MPa for Type S and 8.0 MPa for Type N mortar.

Design strength can also be evaluated using the procedure of Section 4.3.2.3 of the above Standard as follows:

$$f'_m = \bar{x} \left[ 1 - \frac{1.5}{x} \right] \frac{\sum (x - \bar{x})^2}{n - 1} \quad [1]$$

where

$\bar{x}$  = average of individual test results

$x$  = an individual test result

$n$  = number of specimens tested

In applying the above equation, a minimum number of five tests are required.

The compressive strength of an individual specimen is calculated by dividing the ultimate test load by the net cross-sectional area, and multiplying the result by the appropriate correction factor give in Table 1 of Reference 1.

For these tests,  $h/t$  was 5.0 and the correction factor is 1.0.

The net area was 56 685 mm<sup>2</sup> for the Monarch brick specimens and was 62 244 mm<sup>2</sup> for the Giant Brick specimens. The gross area of each specimen was 111 150 mm.

Since the results obtained for the Monarch were not very sensitive to the

compressive strength of the mortars they are grouped in two categories namely those with mortar strength larger than 10 MPa and those with mortar strength smaller than 10 MPa. The average compressive strength for the first group was 480.4 kN or 7.7 MPa. Application of Eq. [1] yields a compressive strength of 7.0 MPa.

This value compares very reasonably with the one obtained using Table 2. For mortar strength less than 10 MPa Eq. [1] yields a design value for  $f'_m$  of 6.0 MPa.

For the specimens constructed using Giant brick units the values obtained for 12.5 MPa mortar were 15.0 MPa, 13.2 MPa for mortar strength of 7.93 MPa, 12.63 MPa for 6.6 MPa mortar, 8.81 MPa for 6.2 MPa mortar and 7.68 MPa for 5.2 MPa mortar.

These values are in good agreement with the values obtained using Table 2 of Reference 1 for Types M and S mortars and they appear to be lower than those obtained from Table 2 for Type N mortar.

TABLE 5 RECOMMENDED COMPRESSIVE STRENGTHS

Brick Unit	Mortar Type	Strength for Design MPa
Monarch	M	7.5
	S	7.0
	N	6.0
Giant	M	10.8
	S	9.7
	N	8.0



### CONCLUSIONS

The results of tests made on prism specimens manufactured using the two large brick units confirm that such units can be used successfully in structural load bearing masonry applications.

Based on these tests a set of recommended compressive design strengths are proposed.

### REFERENCES

1. CSA Standard A179-1977M, "Mortar and Grout for Unit Masonry", Canadian Standard Association, 178 Rexdale Boulevard, Rexdale, Ontario, M2W 1R3
2. CSA Standard S-304-1978M, "Masonry Design and Construction for Buildings", Canadian Standard Association, 178 Rexdale Boulevard, Rexdale, Ontario, M2W 1R3.