v. 3, n. 10, 2023

Journal of
Engineering
Research

COMPRESSIVE STRENGTH OF MASONRY STRUCTURES SUBJECTED AT VARIOUS LOADING RATES

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Abstract: A comparative study based on experimental results of masonry wallettes subjected at vertical compression for various loading rates is herein presented. The specimens were made with general purpose mortar and two material groups: dense and lightweight concrete blocks. The loading rates were established as moderated (according to Mexican Regulations), slow (50% slower than the moderated rate) and fast (50% faster than the moderated rate). The presented results are mean compressive stress-strain relationships from three specimens tested at the same rate. The main individual properties of mortar and blocks were also investigated. This investigation shows that the compressive strength can vary about 11% among the group of specimens made of normal concrete blocks tested at different rates, meanwhile this variation of the wallettes made of lightweight concrete blocks is approximately 11.24%. Therefore, this change in the compressive strength of masonry structures needs to be considered when designing future masonry structures.
Keywords: Masonry, compressive strength, blocks, mortar, loading rate.

INTRODUCTION

Masonry has been used widely around the world. In America continent, from the Prehispanic era there have been some evidences of masonry structures in Mexico; however, the first scientific investigations made to study their mechanical and structural behaviours, started in 1970's and this study has been mainly dominated by the seismic effects (Meli, 1979: Treviño et al, 2004; Hernández and Meli, 1976; Meli and Salgado, 1969; Cano, 1997). Due to that the general seismic behaviour in the materials is similar, other works need to be conducted to research when parameters such as elevated and lower temperatures are applied into the structural materials.

In general, it has been demonstrated when the blocks used for masonry have a high tensile strength, a lower compressive strength is obtained (Meli and Reyes, 1971; Meli and Hernández, 1971; Mayes and Clough, 1975; Priestley and Elder, 1982). In the case of the material used for the blocks, concrete is the most predominant in actual masonry structures, its use has been maximized due to the variety of components that can be included and the development of new techniques of fabrication. The compressive strength of masonry depends on the individual properties of blocks and mortar, but also loading rates, processes of curing and fabrication.

The effect of loading rate on masonry structures has a direct influence on determining the compressive strength, it has observed aggregate particles having minor deformations when increasing loading rates, but higher levels of deformation if loading rate is decreasing. This can be explained due to much loading exposition time (Priestley and Elder, 1982).

In addition to this, it has observed different loading rates in codes and regulations around the world that could lead changes in the material properties, this would cause new investigations to demonstrate and to confirm the behaviour has not been modified when different load rates are been applied. Therefore, the aim of this investigation was to determine the compressive strength of masonry specimens made with local materials that depict constructions from the North of Mexico. For this investigation, three different loading rates were applied based on a Mexican code (NMX-C-464-ONNCCE, 2010).

EXPERIMENTAL PLAN

The compressive strength of mortar specimens and blocks was evaluated. In the case of the masonry structures, nine specimens known as wallettes were made for each type of block with an average geometry of 80x80cm and made with general purpose mortar. Once the specimens were made, they were covered with plastic sheet to avoid drying up and removed after three days, the specimens were then cured at ambient temperature (about 29 degree C) and tested after 28 days.

Variation in the compressive strength with loading rates was investigated, *moderated* was defined as the rate based on the Mexican Codes, which sets a value of 440 Kg/sec, this rate was increased 50% to set as *fast* with a final value in the order of 660 Kg/sec; finally, the moderate rate was reduced 50%, a value of 220 Kg/sec in order to set it as *slow rate*.

SPECIMEN FABRICATION

All the specimens used for this investigation were made to be tested experimentally according to Mexican and American codes such as G.O.D.D.F., 2004; NMX-C-036-ONNCCE, 2013; ASTM-307, 2012. (See figure 1).

TEST EQUIPMENT

To test all mortar specimens and individual blocks, a DX 600 Instron was used to compressive and tensile tests. This equipment has a loading capacity of 60ton and is capable to control rates with a high precision, a Tinnius Olsen testing machine to carry out the compressive test of the masonry wallettes was also used, it has a capacity of 200ton and can control rates with accuracy, additional steel plates and LDVT´s were added into it to calibrate the specimens properly (see figure 2).

RESULTS AND DISCUSSION

The experimental results from testing nine mortar cubes are shown by compressive stress strain relationships (figure 3). Each one of these curves depict a 5x5cm mortar cube tested at vertical uniaxial compressive loads. The values of the maximum strength vary from 157 to 188 Kg/cm².

Most of these curves are characterized by a similar tendency with a linear performance up to 140 Kg/cm² and after following a no linear phase, the average curve has a strength of 171 Kg/cm2.

Figure 4 shows the stress strain curves from the experimental tensile specimens known as briquettes, it can be observed that there is a great dispersion among them, strength values vary from 12.61 to 22.19 Kg/cm², the mean curve is about 17 Kg/cm².

Experimental stress strain relationships from testing normal concrete blocks under uniaxial compressive tests are shown in figure 5. The compressive strength values are in the range of 79 to 101 Kg/cm², meanwhile, the average strength was 90.67 Kg/cm² with a strain value of 0.0033.

In the case of the results from lightweight concrete blocks (see figure 6), they were characterized by greater levels of deformation in comparison with that from normal concrete blocks, the curves are predominant linear up to 95% of the maximum strengths. The level of stresses was lower than those obtained from normal concrete blocks. The mean stress LW blocks was 51.24 Kg/cm².

The average maximum load for the normal concrete blocks was 52.38ton and for LW concrete blocks the mean failure load was 29ton. The coefficients of variation for normal concrete blocks were in the order of 8.15%, meanwhile, for LW concrete blocks was 4.6%.

The stress strain relationships from the normal concrete masonry wallettes are shown in figure 7, these curves represent three wallettes tested at different load rates, ti can be observed that each of these curves have a predominant lineal behaviour and after the curves adopt a parabolic shape until the ultimate stress. The compressive stress values

Figure. 1 Specimens tested in the investigation.

Figure. 2 Test equipment used in the investigation.

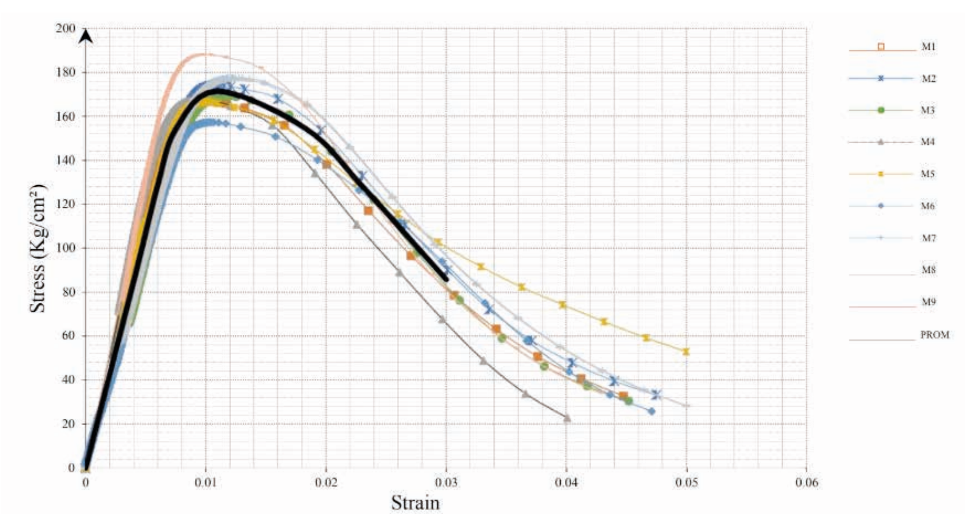

Figure. 3 Compressive stress strain relationships of mortar cubes

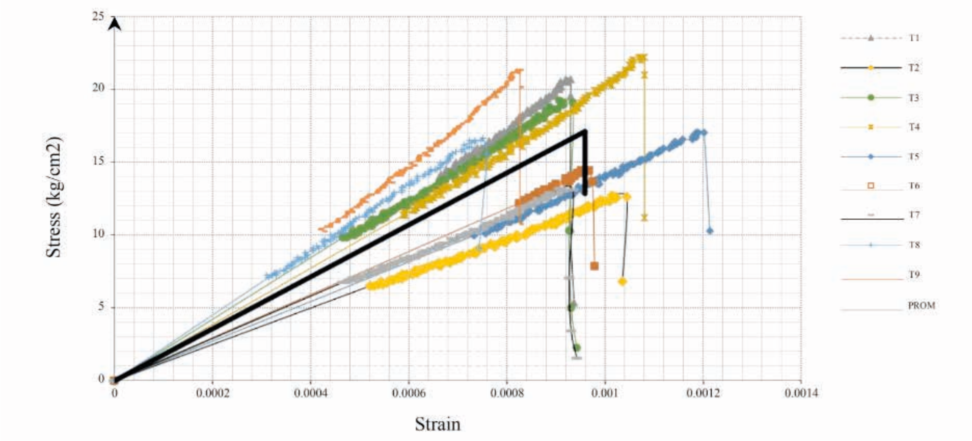

Figure. 4 Tensile stress strain relationships of mortar briquettes.

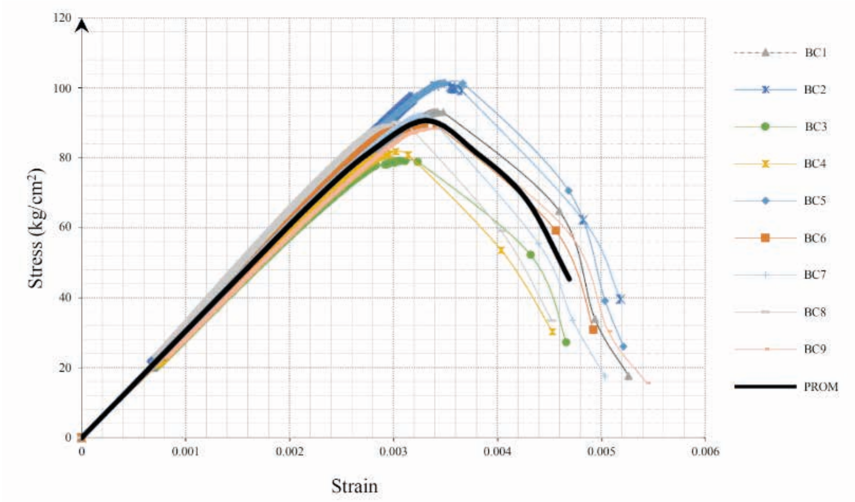

Figure. 5 Compressive stress strain relationships of normal concrete blocks.

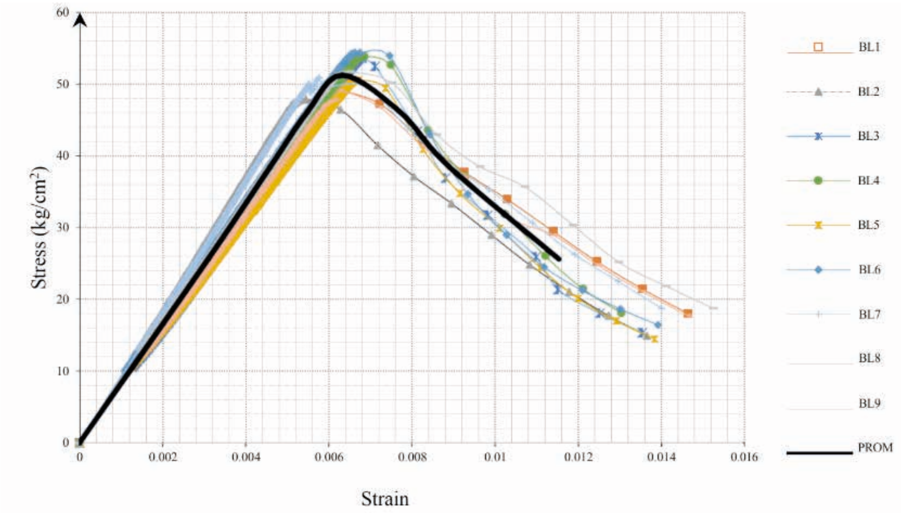

Figure. 6 Compressive stress strain relationships of lightweight concrete blocks.

range from 4.35 to 4.76Mpa, whose differences represent approximately 11%. Maximum deformations are from 0.000148 for the fast and moderate curves and 0.00145 for the slow curve. Coefficients of variation were from 5.34% for the fast rate wallettes, 4.69% for the moderate rate wallettes and 2.92% for the case of wallettes subjected at low rate.

In the case of lightweight concrete wallettes, the experimental results can be observed in figure 8. The curves are from testing three specimens at different loading rates and they are predominant linear in all the length, these curves are characterized by lower stress values in comparison with those values obtained from normal concrete wallettes. From these values, the variation is ranging 2.375 to 2.67Mpa, which represents approximately 11.24%. Deformations are from 0.00162 to 0.00453 which are greater than those from the normal concrete wallettes. For the case of coefficients of variation, the values are 4.87% for the wallettes at fast rate, 5.3% for the wallettes subjected at moderate rate and finally 6.72% for slow specimens.

Compressive tests of lightweight and normal concrete wallettes were determined and the results were compared. These tests were also conducted at various loading rates, according with them, normal concrete specimens exhibited a better behaviour than that from lightweight concrete wallettes. The normal concrete wallettes achieved greater stress values with minor strain values in comparison with those obtained from the lightweight concrete specimens.

The concretes made of dense aggregates tend to behave as continuous solids that permit low levels of deformations when subjected at loading systems. Lightweight concrete is characterized by mixing porous rocks like pumice, clay, shale and others that are subjected at heat process that expands the material creating internal pores in the aggregate, being this the main cause of producing major deformations than in dense concretes.

Stress differences are presented due to loading rate variation, this is demonstrated by the results from the investigation reported herein. The variation is about 11% from slow to faster loading rate for the normal concrete wallettes, meanwhile. It is 11.24% for the case of lightweight concrete specimens.

ACKNOWLEDGEMENTS

The authors acknowledgement the Faculty of Civil Engineering, UANL in Mexico for the given facilities to development of this investigation. It is also thankful for the projects: PRODEP (PROMEP/103.5/13/8942), PAICYT 2015 and PAIFIC- 2015-1.

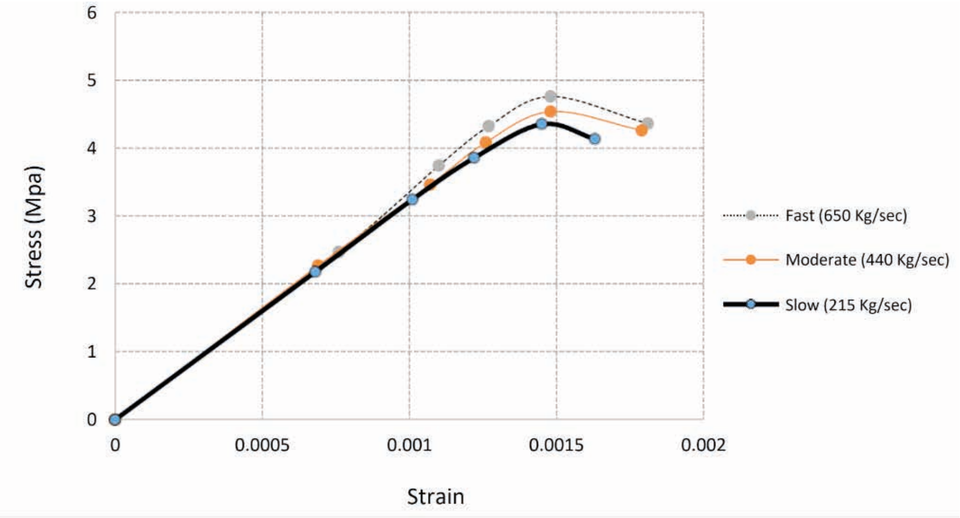

Figure. 7 Compressive stress strain relationships of normal concrete wallettes

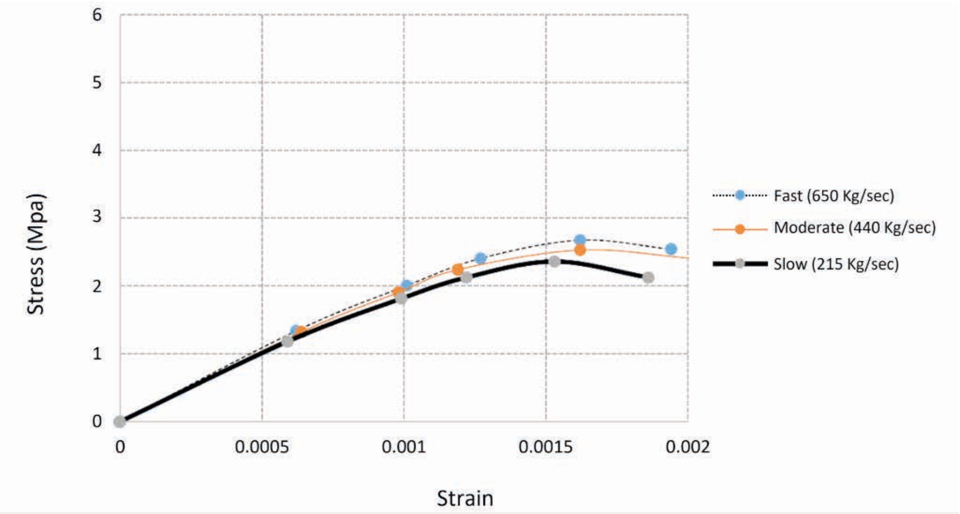

Figure. 8 Compressive stress strain relationships of lightweight concrete wallettes.

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