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Analysis of the compressive strength of concrete blocks used in the construction of houses in the city of Tuxtla Gutiérrez, Chiapas

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— Abstract—

In this work, the results of the laboratory tests applied to 30 pieces of concrete blocks are presented: 15 hollow and 15 solid ones, manufactured mechanically and handmade, in 3 manufacturing sites in the city of Tuxtla Gutiérrez, Chiapas. The purpose of the laboratory tests is to determine the geometric characteristics (dimensions) and the compressive strength of the pieces; likewise, compare the results obtained with current standards. The results show that the average compressive strength does not comply with what is established in the standard. On one hand, the average compressive strength obtained in hollow parts varies between 67.90 kg/cm^2 (mechanically manufactured) and 13.44 kg/cm^2 (handmade) and is below 90kg/cm^2, which corresponds to the value established in the standard. On the other hand, the average strength obtained in the solid block pieces varies between 68.22 kg/cm^2 (mechanically manufactured) and 12.67 kg/cm^2 (handmade), which, compared to the value of 150 kg/cm^2 of the standard, is observed that the results are extremely below the established recommendation. The previous results warn of the need to control the quality of the compressive strength of the concrete blocks, manufactured by the supplier companies, to guarantee that they comply with the standards of masonry structures for homes or other types of buildings, and with this, contribute to reducing the seismic vulnerability of the homes of low-income families in the state of Chiapas, who prefer the use of this material because of its low cost.

Keywords:

Concrete blocks; compressive strength; building standards; housing.

In the state of Chiapas, as in other entities of Mexico, the self-construction of housing in the low-income population sectors, both in urban and rural areas, is commonly carried out from the conventional system of masonry walls, based on pieces of hollow concrete blocks with two or three cells. This construction system is preferred by the inhabitants of this social sector, due to the extensive application of masonry structures that exists in the region and the ease of making the pieces with safe, durable, and economical materials; however, because low-income families have little possibility of receiving technical advice for the construction of their homes, resort to self-construction with techniques acquired by uses and customs from generation to generation or, in the best of cases, hire the labor of low-skilled masons. In these circumstances, the compressive strength of the concrete used in the elaboration of the blocks, made in the worksite or purchased at low cost from suppliers, do not meet the requirements established in the Mexican Standards of the Construction Industry of blocks, partitions, or bricks NMX-C-036-ONNCCE (2004), NMX-C-404-ONNCCE (2012), Complementary Technical Standards (2017) so the parts used are unsuitable for the construction of houses' walls, essentially, due to the poor proportion of gravel and sand (stone material) in relation to the amount of cement; that is, houses are built with informal masonry structures of concrete blocks, which warns that the houses present a certain level of vulnerability.

The compressive strength of the concrete, hollow, and solid block pieces, used in buildings as structural masonry elements, must comply with the recommendations established in the indicated standards, to guarantee the safety of the structure. This requires that the materials used in the manufacture of the pieces have the necessary qualifications, as well as the proportion of these with the cement is adequate.

This study aims to determine the geometric characteristics and the compressive strength of concrete, hollow, and solid block pieces, that are marketed in the city of Tuxtla Gutiérrez, Chiapas; mechanically-made or handmade. To do this, we analyzed and tested, in the Materials Laboratory of the School of Architecture of the Universidad Autónoma de Chiapas (UNACH), 30 pieces of concrete blocks, 15 hollows, and 15 solids, obtained in 3 sites or manufacturers. The results obtained were compared with the provisions of the Mexican standard applicable to hollow and solid concrete blocks, for structural use in buildings of national manufacture (NMX-C-404-ONNCCE, 2012). Derived from the above, it was observed that the compressive strength of the block pieces, obtained in the 3 manufacturing sites, does not comply with the standard.

METHOD

We chose 3 establishments in the city of Tuxtla Gutiérrez, Chiapas, which are dedicated to the manufacture and commercialization of concrete block pieces (specimens), hollow and solid. The official name of the three suppliers was changed to Company A, B, and C, to maintain their confidentiality in the study carried out. Companies A and B, elaborate the pieces mechanically, and the C company handmade. In each company, 10 block samples were obtained randomly; 5 hollow pieces (with 2 cells) and 5 solids, totaling 30 specimens of concrete blocks (15 hollow and 15 solid). It is also important to mention that companies were asked for information related to cement, the characteristics, and dosage of the materials used in the blocks' manufacture; however, the three selected companies reserved their comments.This type of character remains, partially, in “La tregua", whose anecdote focuses on another of the characteristics of indigenous literature: the detailed description of their beliefs, superstitions, customs, and rituals, the contrast with the Caxtlan, a white man, the devastating effects attributed to the pukuj, a kind of ominous indigenous spirit similar to the nahual, the consumption of posh brandy, as a measure of Creole control over the indigenous community. On the other hand, the following stories already present individual characters, the transformation of initial situations, external and internal conflicts, and not only the denunciation of the conditions to which Creoles and mestizos had confined the indigenous people but also the errors that lead the character to his physical-moral destruction.

The pieces were entered into the Materials Laboratory of the School of Architecture of the Universidad Autónoma de Chiapas and the corresponding tests were carried out based on the Mexican standard NMX-C-404-ONNCCE-2012. The procedure is described below:

1. At first, the geometric dimensions of each of the concrete block pieces were labeled and examined: length (L), width (A), height (h). In the case of hollow blocks, the thicknesses of the outer walls were also examined: (a), (c), (d), and (e), as well as the inner wall (b) (see Figures 1 and 2).

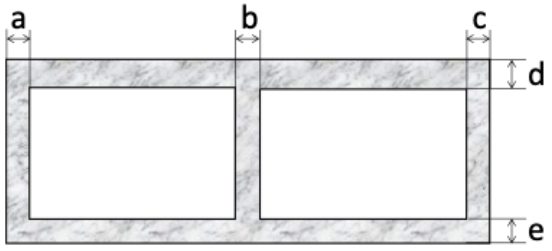


Figure 1. Longitudinal section of the piece. Source: Own elaboration

Figure 2. The prismatic shape of the piece. Source: Own elaboration

2. Then, with the dimensions obtained, the calculations were made to get, in each piece, the data corresponding to the total area, net area, equivalent percentage (in the case of hollow pieces), and volume; each specimen was also weighed on a platform scale.

3. In a second moment, the test was carried out to the compression of each block piece, based on the Mexican standard NMX-C-036-ONNCCE-2004, which establishes, among other aspects, to make the pitch on both sides of the pieces (upper and lower), intending to create a uniform surface, before placing the part on the machine for testing. The compression test was carried out with the equipment "Digital electric press with compression frame of 120,000 kgf, mark ELVEC". In each test, the load was applied with uniform and continuous speed without producing impact or loss, until reaching "the fault" by the maximum load applied, which was divided by the net area, and with it, the compressive strength of each analyzed block piece was determined (see image 1).

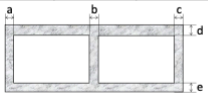
Image 1. Concrete block compression test. Source: Own elaboration

LABORATORY TEST RESULTS

The measurements made, the calculations and the results obtained in the compressive strength tests carried out on each of the 5 concrete block pieces, hollow or solid, manufactured in each company either mechanically or handmade, were recorded in tables. In the case of Company A, Table 1 shows the results obtained from the analyses carried out individually, in the pieces: a-1, a-2, a-3, a-4, and a-5, of hollow concrete blocks, manufactured mechanically.

Table 1

Company A's hollow concrete block tests results

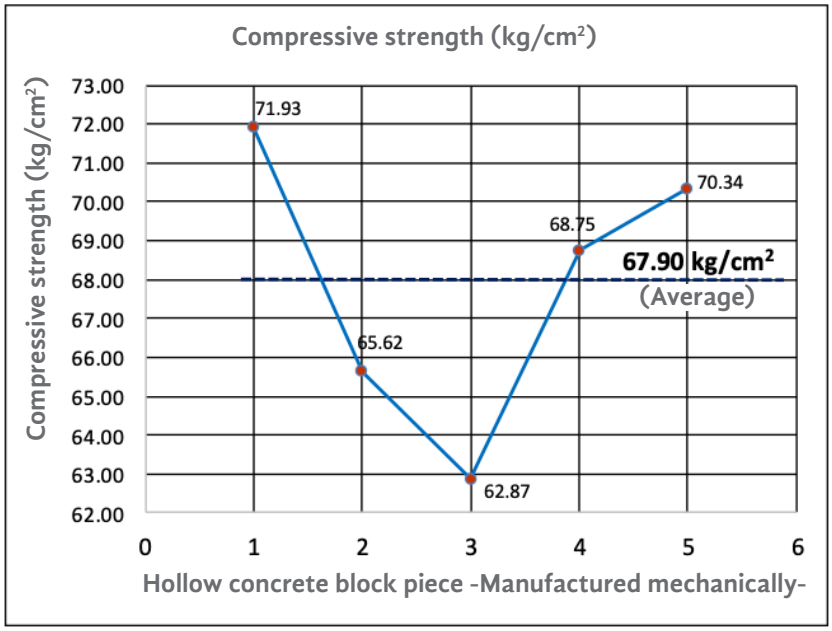
Tipo de Material: Bloque hueco de concreto		Fabricación: Mecánica				Empresas: A		
Prueba a la compresión								
Muestra número		a-1	a-2	a-3	a-4	a-5	Promedio	Especificaciones NMX-C-404-ONNCCE-2012
Dimensiones	Largo (L) en cm	40.00	40.00	40.00	40.00	40.00	40.00	39 cm ±2 mm
	Ancho (A) en cm	12.00	12.00	11.90	12.00	12.00	11.98	12 cm ±2 mm
	Alto (h) en cm	20.00	20.00	19.90	20.30	20.00	20.04	19 cm ±3 mm
	(a) en cm	2.50	2.80	2.60	2.80	2.50	2.64	Mayor a 2 cm
	(b) en cm	2.70	2.70	2.80	2.80	3.00	2.80	Mayor a 2 cm
	(c) en cm	2.70	2.70	2.70	2.60	3.00	2.74	Mayor a 2 cm
	(d) en cm	3.00	2.80	2.80	2.60	2.80	2.80	Mayor a 2 cm
	(e) en cm	2.70	2.90	2.80	2.80	2.60	2.76	Mayor a 2 cm
Área bruta en cm^2		480.00	480.00	476.00	480.00	480.00	479.20	
Área neta en cm^2		277.77	279.66	275.03	270.12	272.10	274.94	
Área neta (%)		57.87	58.26	57.78	56.28	56.69	57.37	75% > Aneta> 50%
Volumen en m^3		0.0055554	0.0055932	0.0054731	0.0054834	0.005442	0.01	
Peso en kg		13.5	13.9	13.4	13.6	13.5	13.58	
Peso volumétrico (kg/m^3)		2430.068	2485.1606	2448.3396	2480.1967	2480.7056	2464.89	
Carga en kg		19,980	18,350	17,290	18,570	19,140	18,666.00	
Resistencia a la Compresión en kg/cm^2		71.93	65.62	62.87	68.75	70.34	67.90	70 kg/cm^2 (Mínima individual) 90 kg/cm^2 (Media)
Dimensiones: L = Largo A = Ancho h = Alto Área total = (L) x (A) Área neta: [((L)x(A)) - (((L)-(a+b+c)) x ((A)-(d+e)))]					 Sección longitudinal de la pieza			 Forma prismática de la pieza

Source: Own elaboration

In the section indicated as "Dimensions", the following data were recorded: a) The geometric characteristics of the pieces: length, width, height, and thickness of the walls, b) The results of the calculations made: gross area, net area, equivalent percentage, volume, volumetric weight; and, finally, c) The value of the load applied in each test and the result obtained from the compressive strength.

As an example, the concrete block a-3 has the following dimensions: Length of 40 cm, a width of 11.90 cm, and height of 19.90 cm; external walls thickness: a, c, d, and e, measuring 2.60 cm, 2.70 cm, 2.80 cm, and 2.80 cm, respectively, and the inner wall thickness, 2.80 cm. With these figures, the route area of the hollow concrete block resulted in 476.00 cm^2 and its net area of 275.03 cm^2; therefore, the percentage of the net area represents 57.78%. On the other hand, when applying the test to compression, the analyzed piece bore a load of 17,290 kg, which when divided by its net area, it was determined that the compressive strength is 62.87 kg/cm^2 (see table 1).

In addition, with the results obtained in the analysis of each of the 5 pieces, the value of the representative means of the dimensions and the average compressive strength of the hollow blocks manufactured mechanically by Company A was calculated, which resulted in 67.90 kg/cm^2, as shown in graph 1 (see table 2 and graph 1).



Source: Own elaboration

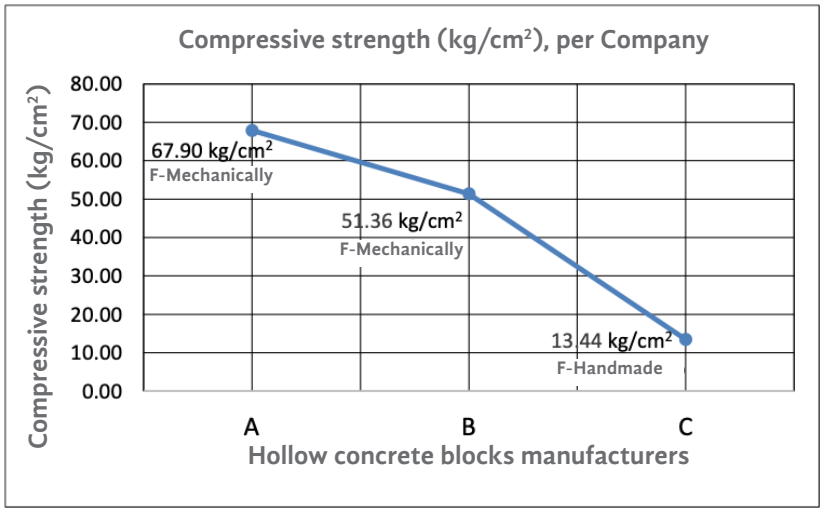
From the analyses carried out on each of the specimens of hollow concrete blocks of Companies B, manufactured mechanically and C, handmade, the average values of the dimensions were obtained (see table 1), and the average compressive strength of the pieces corresponding to each Company (see graph 2).

Table 2

The average value of hollow block dimensions per Company

	The average value of dimensions (cm)			
Dimensions Piece	Company A (F-mechanically)	Company B (F-mechanically)	Company C (F-handmade)	Specifications NMX-C-404-ONNCCE-2012
Length (L)	40.00	40.02	39.88	39 cm ± 2 mm
Width (A)	11.90	12.02	11.94	12 cm ± 2 mm
Height (h)	19.90	19.20	19.74	19 cm ± 3 mm
Wall thickness (a)	2.60	4.50	3.10	Greater than 2 cm
Wall thickness (b)	2.80	5.40	2.98	Greater than 2 cm
Wall thickness (c)	2.70	4.50	3.16	Greater than 2 cm
Wall thickness (d)	2.80	2.98	3.00	Greater than 2 cm
Wall thickness (e)	2.80	3.00	3.04	Greater than 2 cm
Net area	57.37%	67.83%	62.04%	75% > Net area > 50%

Source: Own elaboration



Source: Own elaboration

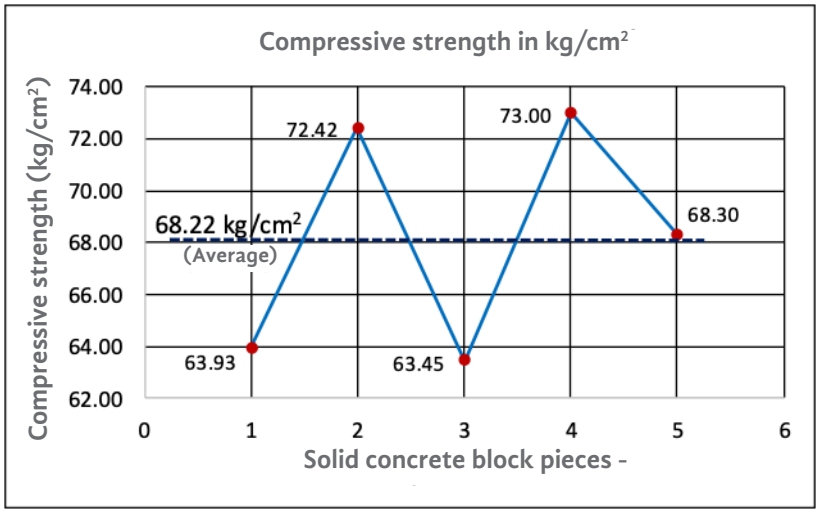
Table 3 shows the results obtained from the analyses carried out individually, in the specimens or pieces of solid concrete blocks: A-1, A-2, A-3, A-4, and A-5, manufactured mechanically by Company A; likewise, Graph 3 shows the average compressive strength obtained.

Table 3

Company A's solid concrete block tests results

Tipo de Material: Bloque macizo de concreto		Fabricación: Mecánica				Empresas: A		
Prueba a la compresión								
Muestra número		A-1	A-2	A-3	A-4	A-5	Promedio	Especificaciones NMX-C-404-ONNCCE-2012
Dimensiones	Largo (L) en cm	40.00	40.00	40.00	40.00	40.00	40.00	39 cm ± 2mm
	Ancho (A) en cm	12.00	12.00	12.10	12.00	12.20	12.06	12 cm ± 2 mm
	Alto (h) en cm	19.50	20.00	19.50	20.00	19.80	19.76	19 cm ± 3 mm
Area en cm^2		480.00	480.00	484.00	480.00	488.00	482.40	
Volumen en m^3		0.00936	0.0096	0.009438	0.0096	0.0096624	0.01	
Peso volumétrico (kg/m^3)		2094.0171	2145.8333	2076.7112	2093.75	2080.2285	2098.11	
Peso en kg		19.60	20.60	19.60	20.10	20.10	20.00	
Carga en kg		30,680	34,760	30,710	35,040	33,330	32904.00	
Resistencia a la Compresión en kg/cm^2		63.92	72.42	63.45	73.00	68.30	68.22	120 kg/cm^2 (Mínima individual) 150 kg/cm^2 (Media)

Source: Own elaboration



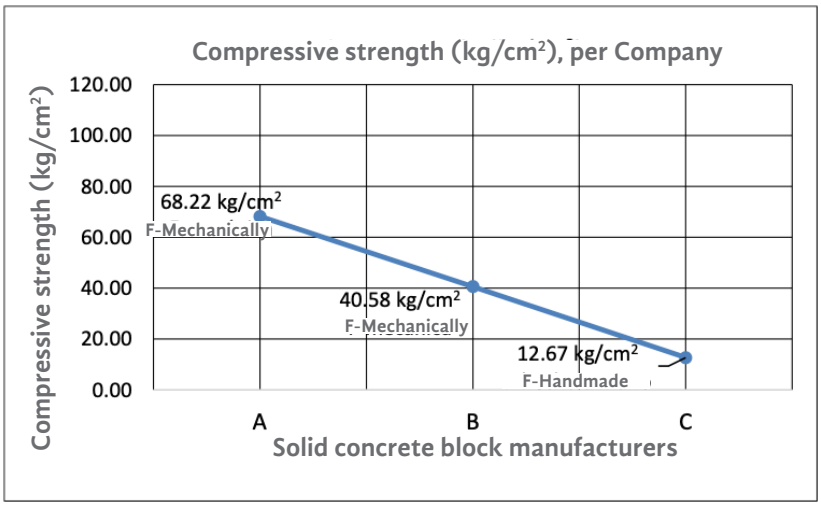
Graph 3. Average compressive strength of Company A's hollow concrete blocks. Source: Own elaboration

From the analyses carried out on each of the specimens of solid concrete blocks of Companies B, manufactured mechanically and C, handmade, the average values of the dimensions were obtained, shown in table 4. Graph 4 shows the pieces' average compressive strength results corresponding to each Company (see graph 2).

Table 4
The average value of solid block dimensions per Company

Data Piece	The average value of dimensions (cm)			
	Company A (F-mechanically)	Company B (F-mechanically)	Company C (F-handmade)	Specifications NMX-C-404-ONNCCE-2012
Length (L)	40.00	39.76	39.96	39 cm ± 2 mm
Width (A)	12.06	11.66	11.98	12 cm ± 2 mm
Height (h)	19.76	19.98	19.34	19 cm ± 3 mm

Source: own elaboration



Graph 4. Individual compressive strength average of solid blocks per Company. Source: Own elaboration

DISCUSSION OF THE RESULTS OBTAINED

The geometric characteristics of the concrete hollow block pieces manufactured by Companies A, B, and C (dimensions), as well as the net area thereof (75% > Net area > 50%), comply with the values established in the Mexican standard NMX-C-404-ONNCCE-2012, for masonry. In the case of solid concrete blocks, only those manufactured by Companies A and C comply with all the dimensions indicated, since the pieces manufactured by Company B, on average, registered 11.66 cm wide, which is below the value indicated in the standard (12 cm ± 2 mm) (see tables 2 and 4).

Concerning the minimum individual compressive strength for concrete hollow block pieces, the standard establishes 70 kg/cm² (NMX-C-404-ONNCCE, 2012). In this regard, only 2 of the pieces manufactured by Company A: a-1 and a-5, obtained values of 71.93 kg/cm² and 70.34 kg/cm² respectively, above what is indicated in the standard. However, in the case of the average resistance, as shown in Graph 2, none of the manufacturers comply

with the values established in the standard of 90 kg/cm^2 (see table 1). It is worth mentioning that Company C, whose hollow concrete block pieces are handmade, the average compressive strength obtained was 13.44 kg/cm^2, extremely below 90 kg/cm^2 set out in the standard.

On the other hand, the results obtained from the analysis of the compressive strength of the solid concrete block pieces, manufactured by Companies A, B, and C do not comply with the standard, since the minimum individual resistance and the average resistance are excessively below the established values (120 kg/cm^2 of individual minimum strength and 150 kg/cm^2 of average compressive strength; NMX-C-404-ONNCCE, 2012). Figure 4 shows that the average compressive strength of Company A, of 68.22 kg/cm^2, is 2.2 times its value below that indicated in the standard; Company B, with 40.58 kg/cm^2, registers 3.7 times below; and Company C that produces handmade solid concrete blocks, with 12.67 kg/cm^2 of average strength, is almost 12 times its value below the norm.

CONCLUSIONS

The results obtained in the tests carried out show that both the minimum individual strength and the average compressive strength of the concrete block pieces, hollow or solid, manufactured in Companies A, B, and C, do not comply with the specifications established in the Mexican standards referring to masonry structures (NTC, 2017 and NMX-C-404-ONNCCE, 2012). Specifically, the concrete hollow block pieces, manufactured mechanically in Company A, only 2 of the 5 pieces tested, registered a strength greater than 70 kg/cm^2, which corresponds to the minimum individual strength established by the standard; however, the average compressive strength obtained of 67.90 kg/cm^2 is below the value indicated in the standard of 90 kg/cm^2. Furthermore, the results of the tests on the solid concrete block pieces indicate that none of the parts obtained the minimum individual compressive strength of 120 kg/cm^2, since the highest value recorded was 73 kg/cm^2 and, consequently, the average compressive strength established in the standard (150 kg/cm^2) is above the average value reached (68.22 kg/cm^2).

On the other hand, the pieces made by Company C, handmade, the hollow concrete blocks registered an average compressive strength of 13.44 kg/cm^2 and the solid blocks of 12.67 kg/cm^2, which compared to the provisions of the standard (90 kg/cm^2 of average compressive strength for hollow concrete blocks and 150 kg/cm^2 of average compressive strength for solid concrete blocks; NMX-C-404-ONNCCE, 2012), the results obtained show that they are extremely below the values established in the standard.

The lack of information summited from the concrete blocks manufacturers, regarding the nature and characteristics of the aggregates, as well as

the dosage of the materials used, made it impossible, on the one hand, to carry out granulometric tests, the analysis of the physical properties of natural aggregates, among others, to identify the causality of the low compressive strength of the block pieces and. On the other hand, the performance of various tests to determine the optimal proportion of cement, according to the materials used and with it, obtain the appropriate compressive strength and make recommendations that guarantee compliance with the technical standards for the construction of masonry structures in homes or other types of building (NTC, 2017 and NMX-C-404-ONNCCE, 2012).

In conclusion, the study presented warns of the urgent need to control the technical quality of the compressive strength of concrete blocks manufactured by supplier companies of the city of Tuxtla Gutiérrez, Chiapas. Undoubtedly, the improvement in the structural quality of the concrete block pieces will reduce the vulnerability of low-income families' homes in the state of Chiapas, which are located in an area of high activity of telluric movements, per the seismic regionalization of the country (MOC-CFE, 2008).

REFERENCES

Comisión Federal de Electricidad [CFE] (2008). *Manual de diseño de obras civiles de Comisión Federal de Electricidad. Diseño por sismo* (pp. 4-53). México: Instituto de Investigaciones Eléctricas. Recuperado de http://es.scribd.com/doc/52197523/CFE-Sismo-08#scribd

NMX-C-036-ONNCCE (2004, julio 27). Norma Mexicana de la Industria de la Construcción de bloques, tabiques o ladrillos, tabicones y adoquines, Resistencia a la compresión y Método de prueba (pp. 1-6). *Organismo Nacional de Normalización y Certificación de la Construcción y Edificación S.C.*, México.

NMX-C-404-ONNCCE (2012, diciembre 13). Norma Mexicana de la Industria de la Construcción para Mampostería de bloques, tabiques o ladrillos y tabicones para uso estructural, Especificaciones y Métodos de ensayo (pp. 1-16). *Organismo Nacional de Normalización y Certificación de la Construcción y la Edificación S. C.*, México.

NTC (2017, diciembre 15). Normas Técnicas Complementarias para el Diseño y Construcción de Estructuras de Mampostería (pp. 614-688). *Gaceta Oficial de la Ciudad de México*. México: Gobierno de la Ciudad de México.