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To cite this article: J P Rojas-Suárez *et al* 2019 *J. Phys.: Conf. Ser.* **1388** 012020

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Cost comparison between reinforced concrete moment resistant gantry system and reinforced concrete industrialized structural wall system

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Abstract. The system of porticoes resistant to moments of reinforced concrete is a set of beams and columns connected by means of knots that allows the generation of adequate spaces with facility before changes by the same users, whereas the industrialized system of structural walls of reinforced concrete, they are used for numerous, repetitive and of low price real estate, but they are completely immobile and in some occasions with problems of segregation and anthills. In this research work, a comparative study of the costs and budgets of the two proposed structural systems of the building was carried out in order to determine the structural system with the lowest costs and execution times, showing the results in explanatory graphs.

1. Introduction

The current demand in the cement sector requires efficient, safe, reliable and highly competitive processes that take national production to higher levels with the optimal use of available resources [1]. Therefore, the reinforced concrete frames with masonry cladding (RCFMC) have been the subject of numerous structural studies in recent decades [2], being a system that forms a concrete frame of beams and columns connected by knots of masonry, commonly used in the construction of multi-storey buildings, although they are not used solely for architectural purposes and to separate internal spaces from the external environment, they are also employer to provide cut resistance to the structure in the complementary plane [3]. One fact is that they are arranged non-uniformly on different floors for functional reasons that cause buildings to have vertical irregularities, however, they increase the initial stiffness and decrease the natural period of the structure, causing benefits depending on the frequency of seismic movement [4].

Filler walls can have a beneficial effect on structural response, as long as they are placed regularly along the structure and do not cause failures in the cutting of columns [5]; these structures are very likely to suffer severe damage or even collapse during moderate to strong earthquakes, as recent seismic events demonstrate [6].

While reinforced concrete structural walls are commonly used to resist actions imposed on buildings due to seismic ground movements, as they provide considerable lateral strength and stiffness [7], but due to the non-combustibility and low thermal conductivity of concrete, reinforced concrete (RC) walls are known for their good fire performance, often functioning as fire walls to suppress the spread of fire in a building [8]. The main advantage of this method is the significant reduction in construction time, as non-structural divisions or facades are significantly reduced or not needed [9]. Since the late 1980s it has been common to use rectangular concrete walls to optimize economy and design. Since the 1970s,



Japan has used bar-shaped concrete walls consisting of a network of thin walls and one or two columns at the edges of the network walls [10].

The present work presents a comparison between the system of porticos resistant to moments of reinforced concrete and the industrialized system of structural walls of reinforced concrete, determining the structural system that, complying with the established standards, represents a lower cost and less time of execution.

2. Methodology

Adequate rigidity is very important in high-rise buildings to support lateral loads caused by wind or seismic events [11], which is why information was collected on the Altos de Santander building in the city of San José de Cúcuta, costs, budget and plans (architectural and structural), in order to analyze and identify the characteristics of gantry systems resistant to moments of reinforced concrete with respect to the NSR-10 [12] standard and industrialized systems of structural walls, by means of research references [13], the analysis of the advantages of each of them was carried out by means of comparative graphs.

3. Results

3.1. Analysis of the cost and duration between the two systems

For the Altos de Santander building, an analysis was made of the cost and duration according to the aporcado system (porticoes) represented in Table 1 and the industrialized system (structural walls) in Table 2, observing that the most economic aporcado system is the system of structural walls because less materials are used for its construction, with a difference of \$21686.56 for each floor and for this case, the total difference for 5 floors is \$108432.8. The total duration in days is 71.37 and the total cost is 59589.83 for Table 1 and 18 days, with a total cost of 37903.27 for Table 2.

Table 1. System aporcado per floor.

System	Floor	Materials	V/Partial	Duration	
			\$U.S dollars	Days	Weeks
Structure	1.01	Solid plates $e=0.1\text{m}$ $f_c = 21\text{ Mpa}$	\$8868.51	12.36	1.8
	1.02	Beams 0.25×0.35 $f_c = 21\text{ Mpa}$	\$8558.04	13.42	1.9
	1.03	Columns T1 $f_c = 21\text{ Mpa}$	\$22156.32	24.28	3.5
	1.04	Columns T2 $f_c = 21\text{ Mpa}$	\$621.30	7.73	1.1
	1.05	Columns T3 $f_c = 21\text{ Mpa}$	\$5780.54	1.03	0.1
Masonry	2.01	Masonry Block No 5 $10 \times 20 \times 30$ first	\$6268.83	4.81	0.7
Wall finish	3.01	Pañete	\$7336.29	7.74	1.1
		Suma	\$59589.83	71.00	10.2

Table 2. System industrialized per floor.

Floor	Structure	V/Partial	Duration		N° of week
		\$U.S. dollars	Days	Weeks	
1.01	Concrete wall screen 3000 psi includes reinforcement	\$21735.37	8	1.1	1.1
1.02	Solid plate thickness 12 cm including reinforcement	\$16167.90	10	1.4	2.6
	Suma	\$37903.27	18	2.5	3.7

3.2. Cost of the elements of the "Altos de Santande"r building

Table 3 and Table 4 show the percentages of incidence that each element has on the total value of the first floor of the structure, achieving that the predominant cost of the construction for the aporcado system is present in the columns with a percentage of incidence of 48.81%, due to the generated dimensions and in the structural wall system the predominant cost in the construction is attributed to the structural walls, resulting in a percentage of incidence of 57%, but in this system shows certain parity in the percentage of incidence between the elements that compose it, unlike the first structural system

analyzed.

Table 3. Incidence on the cost of the elements of each structural aporticado system.

	Elements	Value/Partial	% Incidence
1	Solid plates $e=0.11m$ $f_c = 21$ Mpa	\$8868.20	14.86%
2	Beams 0.25×0.35 $f_c = 21$ Mpa	\$8558.04	14.34%
3	Columns T1 $f_c = 21$ Mpa	\$29121.98	48.81%
4	Masonry Block No 5 $10 \times 20 \times 30$ first	\$5780.24	9.69%
5	Plastering	\$7335.91	12.30%

Table 4. Structural wall system.

	Elements	Value/Partial	% Incidence
1	Concrete wall screen 3000 psi includes reinforcement	\$21735.74	57.34%
2	Solid plate thickness 12 cm including reinforcement	\$16168.18	42.66%

Depending on the systems and materials used for the buildings, the incidences of each input have in the total cost of the aporticada structure and the system of cutting walls, as is the case of [14], demonstrating in Figure 1 and Figure 2, that steel and concrete are the elements with the highest total cost of each system.

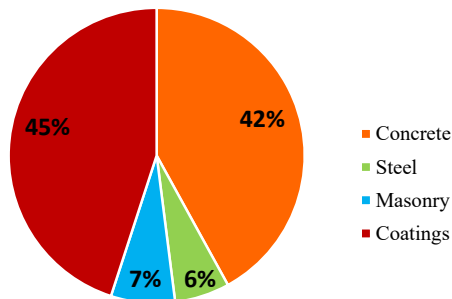


Figure 1. Participation of inputs in the total cost of the aporticado system.

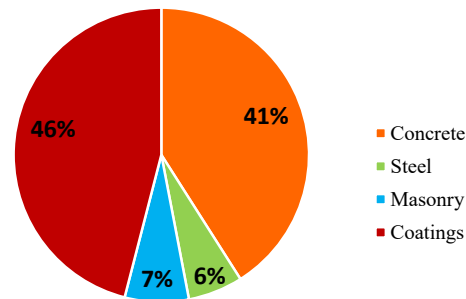


Figure 2. Participation of inputs in the total cost of the A.S.W.C.

3.3. Execution time according to the structural system of the “Altos de Santander” building

In this Figure 3, the decrease in the cost of the structure according to the structural system used is analyzed, being evident that the structural wall system is built in less time than the aporticado system, obtaining a difference of 7 weeks per floor, but to the being of five floors, the total difference is of 35 weeks; for the plate of the structure by floor, it is appreciated that the structural wall system is constructed in less time than the aporticado system, obtaining a difference of 3 days and because they are five floors, the total difference is of 15 days.

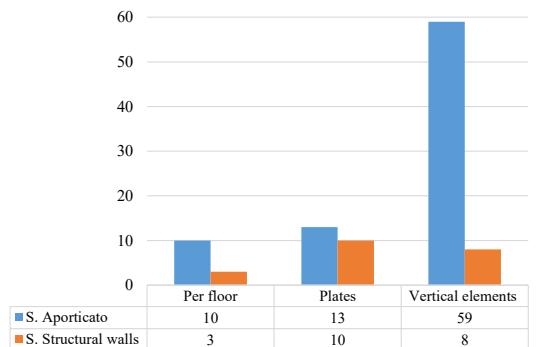


Figure 3. System execution time.

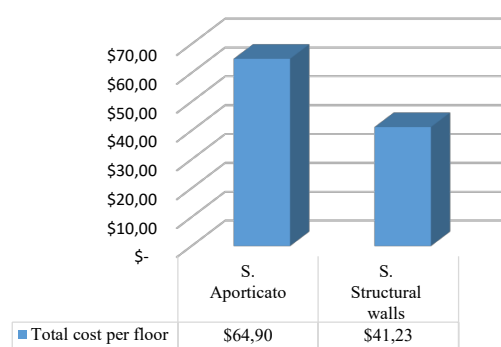


Figure 4. System execution time.

Finally, the execution of the vertical elements per cubic meter of the system of structural walls is 51 days faster than the structural walls of the system of structural walls. Figure 4 shows the total cost per floor, showing a lower cost for the industrialized system of structural walls.

3.4. Incidence on the execution time of the elements of each structural system of the "Altos de Santander" building

Table 5 and Table 6 illustrate the percentages of incidence that each element has on the total time of the first floor of the structure. This shows that the longest duration in the construction for the aporricado system is presented in the columns due to the dimensions that were generated, resulting in an incidence percentage of 46, 30%, and in the system of structural walls the longest duration in construction is attributed to the slab, resulting in an incidence percentage of 55.6%, but in this system certain parity is shown in the percentage of incidence between the elements that compose it, as opposed to the first structural system analysed. The total number of days in Table 5 is 71.37 and in Table 6 is 18.

Table 5. Incidence in the execution time of the elements for the aporricado system.

Elements	Days	% Incidence
1 Solid plates $e=0.11m$ $f_c = 21$ Mpa	12.36	17.33%
2 Beams 0.25×0.35 $f_c = 21$ Mpa	13.42	18.80%
3 Columns T1 $f_c = 21$ Mpa	33.05	46.30%
4 Masonry Block No 5 $10 \times 20 \times 30$ first	4.81	6.74%
5 Plastering	7.74	10.84%

Table 6. Incidence on the execution time of the elements for the structural wall system of the Altos de Santander building.

Elements	Days	% Incidence
Concrete wall screen 3000 psi includes reinforcement	8	44.44%
Solid plate thickness 12 cm including reinforcement	10	55.56%

3.5. Advantages and disadvantages of structural systems

The analysis of advantages and disadvantages carried out in Table 7 corresponds to the results of the analysis of the own information of the research and also compared with other researches [15-17].

Table 7. Advantages and disadvantages [15-17].

System	Advantages	Disadvantages
Aporricado S.	Admits internal modifications.	Slow, heavy and expensive construction.
	The heat that they transmit to the interior of the house is very little.	
Structural walls S.	Greater structural rigidity.	It does not admit internal modifications.
	Monolithic system between slabs, walls and facades.	

4. Conclusions

The study of RC buildings are quite good systems to allow the generation of spaces suitable for the construction of housing for the type analyzed, providing ease before changes by end users in the location and reforms of dividing walls, even so, the care that must be taken for this system and in general, is the correct distribution in floor plan and height of the proposed spaces, obeying an adequate symmetry to obtain a good structural performance.

The coupled cutting walls of RC allow to obtain buildings with great lateral rigidity and great resistance against seismic actions. It is very convenient in relation to the aporricados buildings, for its greater rigidity and resistance, achieving with less thickness more resistance and evidently more useful spaces. Although this advantage in behavior ceases to be so in the spatial sphere given that these are

completely defined and are immovable, in the same way, cracking problems are observed in walls and slabs due to the effects of the shrinkage of the concrete and the changes and temperatures in the setting process, for which reason the use of controlled shrinkage concrete and polypropyleneoxide fibres is advisable.

For the Altos de Santander building in the city of San José de Cúcuta, a study of the costs and budgets of the system of porticos resistant to moments of reinforced concrete (beams, columns and solid slabs) together with the walls and their paneling, to be on an equal footing with the other structural system proposed for the construction of the building, it is detailed that the structural system that offered the lowest cost was the industrialized system of structural walls of reinforced concrete, with a cost of 36.39% below the system of porticos resistant to moments of reinforced concrete; and in reference to the time of execution the industrialized system of structural walls of reinforced concrete, presents a considerable diminution, when realized in the 30% of the time that requires the system of porticos resistant to moments of reinforced concrete. The above evidences that for the analyzed characteristics: time and cost, it is the industrialized system of structural walls of reinforced concrete that presents the efficient results.

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