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G C Prada-Botía[1], J P Rojas-Suárez[1], and M S Orjuela-Abril[1]
[1] Universidad Francisco de Paula Santander, San José de Cúcuta, Colombia

E-mail: gaudycarolinapb@ufps.edu.co

Abstract. The selection of suitable materials for a construction defines the costs and characteristics that can contribute to the building, being of vital importance to make a correct choice. Lightening is an element to reduce costs and optimize resources, adding a better index of resistance against earthquakes, being of vital importance the good choice of this: concrete, clay or EPS. In this investigation a comparison of costs and incidence of the three types of lighteners that are used in the construction of three levels houses with reinforced concrete portico based on the requirements of NSR-10 was made by means of statistical samples/data, graphs and tables of data analysis, on the quotations and information collected from different studies on lightening costs in structures.

1. Introduction

The structural gantry system is composed of a spatial gantry, resistant to moment, without diagonals, that resists all vertical loads and horizontal forces [1] it is an excellent system to resist vertical loads for a long time without failing, but it is not considered an ideal system to resist the lateral forces that are generated in high impact earthquakes, because they do not have great resistance and rigidity [2]. Seismic-resistant design has as its main objective the protection of life, improving the seismic behavior of buildings to reduce collapse [3] and due to the fact that in conditions of dense construction of modern cities and the increase in the price of land for construction, many designers and clients bet on the increase in the number of floors of buildings [4], but at the same time vulnerability to earthquakes is increased; being the cause of great financial losses and interruptions in public services for the whole community for long periods of time [5].

Over the centuries, it has been a problem for researchers and engineers to develop different seismic construction designs and technologies to mitigate the effects of earthquakes on buildings, bridges and potentially vulnerable content [6],although in some countries they have created the design rules provided by modern codes (capacity design, force hierarchy) [7].

The main objective of lightening buildings is to optimize resources and reduce the economic cost of construction under predicted functional, aesthetic and safety conditions, adding better anti-seismic behavior [8], being lighter, smaller, easier to handle and transport [9].

The development of the research is focused on a statistical study on the comparison of costs for a type of housing, of three levels, with reinforced concrete portico using different types of lightening according to NSR-10 guidelines [8] in the city of San José de Cúcuta, Colombia, based on the fact that the statistic is the analysis of data that is frequented in several areas, generally used in two areas:

(i) Briefly describe the terms of form, central trend and dispersion of its simple frequency distribution, and
(ii) Make decisions about the properties of the statistical population from sample statistics [10]; with the purpose of being a useful and practical guide that can guide the builder at the time

of building, in turn, taking into account the levels of energy dissipation present in each region.

2. Methodology

The research was applied to buildings constructed with reinforced lightweight plate that applied any of the 3 models (concrete, clay and EPS) in an address located in the city of San José de Cúcuta, Colombia, based on information (grade work) and NSR-10 [8] standards based on earthquake-resistant construction. By means of a statistical study in the collection of data on the quotations of materials it was determined by means of graphs and tables of information, on the quantities of work and costs for the construction [11], in order to compare in percentage form the costs of a housing depending on the lightening that is implemented.

3. Result and discussion

3.1. Analysis of structural cost overrun by type of lightening

Table 1 illustrates the total values and per square meter of the structural model, according to the three types of lightening used; presenting the percentage variations of the costs, demonstrating in this way that the value of a structure with lightweight material in concrete, increases a 7% with respect to the model that uses a lightening in EPS and 3% in relation to the lightening of clay, likewise the structure lightened with block in clay presents an additional cost of 4% with respect to EPS. In addition, EPS can be easily incorporated with different contents in the concrete to produce lightweight concrete with a wide range of density, but has low overall strength [11].

Table 1. Structural cost overruns according to type of lightening.

Lightening	Construted area	Total value(USD)	EPS cost overrun	Clay cost overrun
Concrete	313.17	38394.70	7%	3%
Clay	313.17	37186.88	4%	0%
EPS	313.17	35774.52	0%	Does not apply

Figure 1 shows the decline in the cost of the structure according to the type of lightening used. It is notorious that the structure lightened with EPS is the most economical among the three types of lightening, obtaining a difference of $2621.33 with the lightened concrete model and $1412.98 with respect to the lightened clay model, while there is a difference between the lightened concrete model and the lightened clay model of $1208.35. Although the price of lightweight concrete is the most expensive, it is a valuable building material due to its good thermal insulation and strength properties [12].

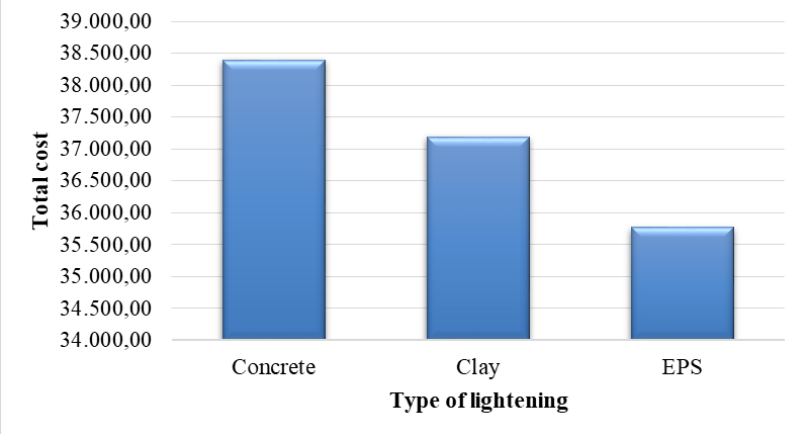

Figure 1. Cost comparison of models by type of lightening.

Table 2, Table 3 and Table 4 show the percentages of incidence of the three structural elements on the total value of the structure, highlighting the cost of the columns due to the dimensions generated in each of the models, taking for each of these, values between 32.53% and 35.83%, but on the contrary the foundation beams showed lower percentages with respect to the total structure, with values between 5.09% and 5.50%; even so, the percentage of costs of the mezzanine and roof plates is perceived, affecting between 15.93% and 18.75% of the total structures without showing greater variation.

Table 2 shows the incidence of the clay block, Table 3 the incidence of the concrete block and Table 4 the incidence of the EPS.

Table 2. Incidence of the cost per element of the structure. Clay block.

Item	Value per ítem (USD)	Incidence
Footing	3173.73	8.53%
Foundation Beams	1945.76	5.23%
Columns	13323.44	35.81%
Mezzanine floor plate h:2.90mt	6085.60	16.36%
Mezzanine floor plate h:5.80mt	6300.40	16.93%
Cover plate	6375.77	17.14%
Total	37204.70	

Table 3. Incidence of the cost per element of the structure. Concrete block.

Item	Value per item (USD)	Incidence
Footing	3631.65	9.45%
Foundation Beams	1955.73	5.09%
Columns	13763.69	35.83%
Mezzanine floor plate h:2.90mt	6118.97	15.93%
Mezzanine floor plate h:5.80mt	6469.67	16.84%
Cover plate	6471.31	16.85%
Total	38411.02	

Table 4. Incidence of the cost per element of the structure. EPS.

Item	Value per item (USD)	Incidence
Footing	2341.01	6.54%
Foundation Beams	1970.15	5.50%
Columns	11643.91	32.53%
Mezzanine floor plate h:2.90mt	6497.50	18.15%
Mezzanine floor plate h:5.80mt	6709.66	18.75%
Cover plate	6627.50	18.52%
Total	35789.73	

For the mezzanine, deck and foundation beams the variation between them is minimal, while in the footing the changes are more noticeable presenting a maximum difference between the concrete model and EPS of $1290.93. The most significant change is manifested in the columns, being $2120.26 between the concrete structure and EPS, $1679.04 for the clay model and $441.22 for the concrete and clay design, illustrated in Figure 2.

Its incidence level tends to behave simultaneously between concrete and clay, having one of the highest indicators in footings and columns compared to EPS with 2.45%, 3.29% respectively; the indicator with the highest percentages is EPS in Foundation beams (0.34%), Mezzanine floor h: 2.90 m (2.01%), Mezzanine floor h: 5.80 m (1.87%) and cover plate (1.53%) difference between the other two indicators.

3.2. General analysis of the total cost of the building by type of lightening

For practical effects, a constant increase in the cost of the finishes of a typical building for a house was contemplated, for which, for the investigation we worked with $400.000 / m^2, with the objective of

obtaining the economic incidence in percentage values of the structure with respect to the total cost of the building.

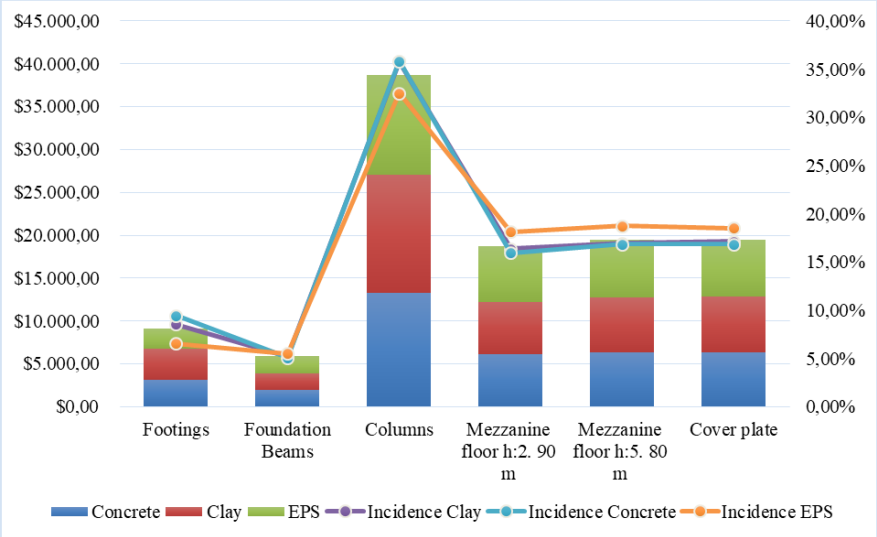

Figure 2. Cost of the element according to type of lightening.

Table 5 and Figure 3 above shows the incidence that each model has in a comparative way with respect to the total cost of the building including the increase per square meter of finishes, it is evident that the concrete model represents an extra cost with respect to the clay model of 1.6%, likewise the structure of the clay model is above the cost of EPS by 1.9%. Finally, the greatest difference is shown in the comparison between the concrete model and the EPS model, presenting a percentage of 3.4% with respect to the total cost of the work.

Table 5. Incidence of the cost of the different models with respect to the total cost of the building.

Item	Clay	Concrete	EPS
Built Area	313.17	313.17	313.17
Value per m^2 of finishes (USD)	0.12	0.12	0.12
Template structural total value (USD)	37214.25	38419.81	35797.93
Comparisons	Concrete-clay	Concrete-EPS	Clay-EPS
Value of comparisons (USD)	1208.60	2621.89	1413.28
Total building value (USD)	75533.20	76741.80	74121.12
Incidence	1.6%	3.4%	1.9%
Trend	1.6%	3.4%	1.9%

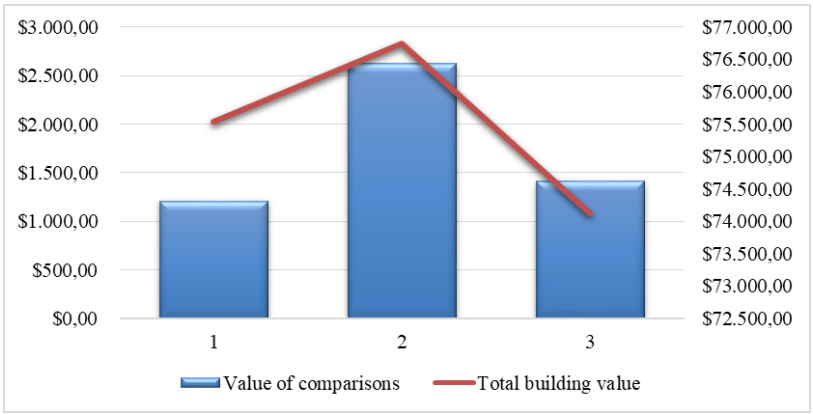

Figure 3. Cost comparison.

4. Conclusions

In this way, it is very frequent to find construction companies that base their choice of lighteners on the cost and not on the impact they have on a structure, ignoring the effects generated by the loads on the magnitudes of the seismic forces that, in turn, have a percussion on the dimensioning of the elements that make up the structure model.

The modeling of the structure was designed for a sector with special energy dissipation degree (DES), resulting in a 22% increase in the value per square meter of the lightweight material of EPS over the clay material, while a 4% surcharge was obtained in the lightweight model with clay compared to the lightweight model of EPS being this of $1413.88; with respect to the lightweight material of concrete has an surcharge of 6.5% of the value per square meter of the material compared to EPS.

For a structure of three levels aporticada with reinforced concrete, plates lightened and located in an zone with degree of dissipation of special energy, it is possible to be chosen for a lighter material more economic than the clay or the concrete, being the EPS the ideal one when showing benefits of $2623.17 in comparison to the lighter materials previously mentioned, without diminishing positive contributions to the structure.

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