

**LAS ESTRUCTURAS INDUSTRIALIZADAS COMO ELEMENTO INNOVADOR
BAJO EL CONTRASTE DE LAS PERCEPCIONES DE LOS INGENIEROS.****INDUSTRIALISED STRUCTURES AS AN INNOVATIVE ELEMENT UNDER
THE CONTRAST OF ENGINEERS' PERCEPTIONS**

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Abstract. The objective of the research was to make known the experiences of calculating engineers in the face of the behavior of industrialized buildings in earthquakes of great magnitude in the departments of Santander and Norte de Santander, Colombia. This industrialized construction system for houses was taken as object of study due to its novel implantation in the departments. The planning, execution and application of the 2010 seismic standard applied in Colombia in the field of building construction was analyzed. In addition to the field experiences of the professionals and university professors of both departments, the research was based mainly on the technical knowledge of the specialists. These two characteristics were taken into account due to the absence of information on the structural behavior under earthquakes of great magnitude of the buildings constructed with the system in the departments. The interpretative method was used with the support of the computer-assisted qualitative analysis program ATLAS.ti, which allowed the association of codes through the relationships of the interviews. The results concluded in the feasibility of implementing the system as a method of construction of buildings resistant to earthquakes of great magnitude subject to strict monitoring of the parameters described in the relevant regulations for the country, however the information provided is of great importance for individuals and contractors in the construction area in Colombia, since the expert engineers in calculations have some contradictions as for the industrialized system, and this can be factor of incidences in the response to earthquakes of these buildings, it is for that reason that the information revealed is a novelty to take into account the types of systems that calculate them the same but really have many structural differences and this could be a key element in an earthquake of great magnitude.

Palabras clave: *Keywords: perception, engineering, structure, resistance*

1. INTRODUCTION

Throughout history the constructions have been affected by the telluric movements that appear randomly in the different continents, these defined

by, (Martinez 2010) the movement that the earthquakes generate consists of a vibration in the surface of the earth whose direction contains the three spatial components: two horizontal and one

vertical, (Ospina 2010) this has been a constant threat in the civilizations, and directly affects their lives in the communities because the earth in its natural movement shakes any structure that the man has constructed. In these movements man has gone through various situations where, (Abarca 2016), the knowledge about the behavior of structures over time has been improving the quality of it, behaving better in these actions of the earth.

Before these situations the evolution of the knowledge on the behavior of the structures is developed by means of the different earthquakes that have been presented, where each one of them has specific characteristics and they leave facts that are studied to learn and to be able to improve the constructive systems, it is for that reason (Vega 2014), for the seismic design certain objectives of performance of the structures are established in implicit or explicit form before different levels of the intensity of the seismic action, these refer to be able to absorb these movements of the best way so that the structure does not suffer some type of anomaly that can make it collapse.

The modifications that constructive systems have undergone over time to improve the response of these in earthquakes have been significant, helping to reduce the impact on constructions, (Gomez 2005). In 1997 the standard of resistant seismic design was promulgated that replaced the 1977 version. With this, a series of modifications were presented that, in agreement with the specialized committee, are contributing to reduce damages in the constructions, based on the facts of what happened in the Atico earthquake of June 2001, practically every time an earthquake occurs, we learn about them and their responses in the buildings.

Likewise, (Tena 2004), thanks to the study of these earthquakes and their effects, it has been possible to develop numerous tools that have made it possible to carry out increasingly complete and reliable structural vulnerability studies, to develop seismic warning, to improve construction regulations, to detect structural systems that are vulnerable to earthquakes, and to develop and implement new technologies in structures for the control of seismic response, thus one of the protocols generated by these scenarios are seismic warnings and behavioral behaviors in these situations before and after the events (Oviedo 2009). In Colombia, for example, the population is located in more than 85% of the zones of telluric movements. This means that all the information that can be taken into account in order to improve

the antiseismic systems in the buildings and with it learn more and more about how the structures of this country behave. Pérez, J, Castro, J (2018).

In addition (Serrano 2015), due to these seismic events in which loss of life can occur, mostly due to the collapse of buildings that were not designed for earthquake resistance and whose trigger was the 1983 Popayán earthquake in Colombia that resulted in 200 deaths, had a beginning to start with the resistant seismic norms trying to protect people's lives with decree 1400 of 1984, which practically established that structures must resist earthquakes, this decree lasted 14 years and was replaced by Law 400 of 1997 that adopts the norms of resistant earthquake construction and already in 1998 the resistant earthquake norm of 98 (NSR-98) is regulated, being updated 12 years later, giving rise to the resistant earthquake norm of 2010 (NSR-10), which is still in force.

With these changes in construction norms, primordial factors of the responses of constructions to seismic actions such as the types of horizontal and vertical movements of the tectonic plates are taken into account, evaluating the levels of the building that suffer in the first instance and how the collapse of the same occurs, in the same way to reinforce the already existing structures so that they respond better in earthquakes and avoid future collapses. Castellanos J, Alvarado R.T., Aranguren Zambrano S. (2015).

In this scenario and following studies of earthquakes with the behavior of buildings in front of them, Benavent quoted from (Perez 2018). He explains that other reinforcement techniques can be used such as adding structural walls of reinforced concrete, as well as diagonal bars, pillars with steel clips and taking into account the joints of the beams with the pillars so that they join the structure and respond better in earthquakes.

In the same way that some characteristics have been changed to improve seismic weaknesses, new models of constructions have also been presented, drastically changing traditional systems and embracing new knowledge to engineers to find out about new systems that contribute criteria to buildings, among them (Lozano 2012), the lack of knowledge of the various options available at the time of construction, and the lack of information about the different construction systems that currently exist is evidenced by fear, mistrust that exists at the time a construction is proposed by an uncommon method, and this lack of knowledge

may stop focusing some contributions on advances that are already available.

These types of construction have been present in different countries since 1935, but in Colombia since 1968 with an increase in the last decade (Sarmiento 2017) and (Fernandez 2009), this increase has been significant throughout the country and more so with the subsidy policies of social interest housing, where construction with the implementation of the industrialized construction system (SCI) is the only alternative that Colombia has to improve plans for massive housing development since there is a saving in time. However, it is necessary to take into account the conditions in which these types of works are constructed in this country and thus be able to establish the safety fundamentals of these buildings that are being used in a residential manner since their use is incipient in the ICS of the country (Marcela 2010). Faced with this situation and changing the traditional housing models that were being worked on, families and civil engineering professionals themselves perceive the use of these types of buildings, and even more so in the department of Norte de Santander-Colombia, which has seen a significant increase in the number of buildings constructed with the ICS in the last five years, since the increase in construction licenses in the department was 13.6%, and this in buildings for the construction of social interest housing of industrialized type (Acevedo 2012).

It is therefore important to know from the hands of professionals in the construction sector the responses of these buildings to telluric movements, it is known that these buildings for approval must be calculated so that they meet the minimum requirements and among them are the antiseismic requirements, however we proceeded to learn the experiences of engineers based on the seismic behavior of the departments of Santander and Norte de Santander-Colombia as they are areas of high seismic risk according to studies provided by the University Francisco de Paula Santander-Cúcuta (UFPS) (Salgado 2016).

2. METHOD

the research addressed a qualitative methodology, where the interpretative procedure was used, with the support of ATLAS.ti, a computer-assisted qualitative analysis (QDA) program, which allowed the association of codes through the relationships of interviews with civil engineers and teachers specializing in structures, key informants

of the research, which was intended to search for patterns based on the experiences of experts, and where this subjective character provides a fundamental value to knowledge (Gutierrez 2016) describing the experiences of experts (Mardones 2018) and (Barrientos 2019).

For this reason, key informants were chosen at the convenience of the researcher, and it was adopted for working with the civil engineers in charge of training future professionals in the area at the Francisco de Paula Santander University (UFPS) and the Pontificia Bolivariana-Bucaramanga University (UPB), being the universities that offer the civil engineering program in their cities of origin and that in turn allow the high level preparation of the graduate by offering postgraduate programs in the structural branch. An absolute sample of teachers with previous experience in structural calculation was taken, where 4 civil engineers from UFPS and 4 civil engineers from UPB were selected. For the interview with the experts, descriptive questions were formulated based on the parameters established in the structural design of a building constructed by means of the SCI following the parameters established by the NSR-10 and whose answers were nuanced with the technical knowledge and the previous experiences. The questions asked are described below:

- What have been the experiences in structural calculations in construction scenarios?
- Between the most significant differences of the types of construction with the ICS and the traditional one, which do you consider more important?
- How do you consider the response of industrialized buildings to telluric movements compared to traditional systems?
- How do you perceive the behaviour of industrialised buildings in the event that they have to act on a large earthquake, and to what extent do you think the building can withstand a seismic moment?
- On what does it depend that a good structural calculation can withstand earthquakes of great magnitude above 7 degrees?

3. RESULTS

Within the process of open categorization began with the relations between the categories considered as the perception of engineers on the structural resistance of industrialized buildings, also the resistance to earthquakes of great

magnitude and the experience in structural calculations of industrialized type, between this a causal relation is evidenced on the resistance to earthquakes and the experience in the calculations of the structures, However, the relationship between perception and experience is contradictory since the position of engineers who have little experience is not very adjusted to reality, contrary to what happens with engineers who have experience in structural calculations, however these experiences are more attached to the types of traditional structures and not to industrialized buildings, and a relationship of association between structural resistance and the perception of the same in terms of behavior in earthquakes. Figure 1 shows engineers' perception of the structural resistance of industrialized buildings.

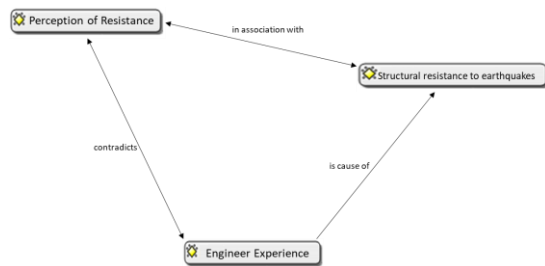


Figure 1. Open categorization process unveiled with Atlas.ti.

In the relation on semantic networks an important relation on the resistance of the types of constructions with the ICS is revealed with the experiences of the engineers, but it can be detailed that the categories express some situations that can express with some gaps of consistency, since the resistance of these structures is related in the earthquakes but analogies are made on the types of traditional constructions and these types of structures are very different in their processes and integration of their structures, and in the interviews they express with security this type of resistance, likewise, established arguments are generated a priori such as the heights of the types of structures where the types of industrialized structures are limited and in the traditional ones they can be elevated. However, this can counteract the reality of the cities of Cúcuta and Bucaramanga since with the industrialized systems, residential buildings with more than fifteen floors have already been constructed, within the categories of perception the codes that show the same positions as those revealed in other codes, such as the experience of engineers, the taking of the factors that influence when supporting earthquakes, and the equal behavior of industrialized buildings with those of

the traditional type. Figure 2 shows the semantic networks in relation to the structural perception of ICS, given by experts, in terms of its seismic resistance.

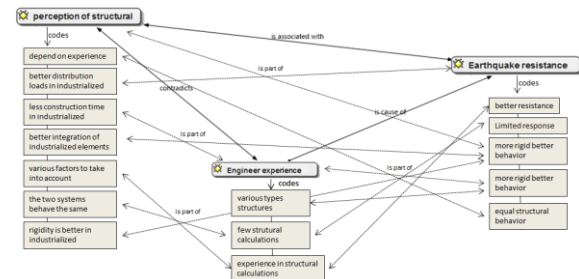


Figure 2. Semantic network processing with Atlas.ti

4. DISCUSSION

With the application of the in-depth interviews of the key informants it was possible to appreciate with the answers of the engineers expert in structural calculations the behaviour of the materials using the same concrete but in a different way to the traditional one, thus entailing less manpower but this manpower must be more specialized, in addition on the behaviours of these structures before the earthquakes there is a coherence between the experts since each one is located in positions on the response in earthquakes of great magnitude, however two established that these structures could not behave like the traditional ones, this leaving contexts for further research in this regard and to improve understanding so that the structures that are designed have the best performance in any large telluric movement, likewise appeared contradictions by dividing the positions expressing that in industrialized constructions could not be high as traditional, and this leaves many questions for further research since in the cities where the universities are and engineers work, industrialized buildings of more than fifteen floors have already been made, added to this the advantages of industrialized buildings are multiple because they minimize the environmental impact and costs in the works, reaching that this type of buildings reach the populations with fewer resources.

CONCLUSIONS

The ICS is being implemented and have been evolving for some time, however in some Latin-Americans countries due to their short-sighted technological development and innovation, are

joined to the implementation of construction systems with the absence of traditional structural elements such as columns, beams, and masonry walls, it is therefore important to continue research in this field in order to promote its implementation in future housing projects. In our country and more exactly in the departments of Norte de Santander and Santander due to its geographical location which coincides with geological faults of great importance and seismic latency, the research results provide knowledge for the selection of the appropriate construction system in future housing projects, studies in which we had as a primary basis the structural characteristics of ICS through structural calculations where they took into account all considerations for these buildings to withstand in addition to the imposed loads, the seismic threat. It is true that the only way to verify that these calculations will be complied with is when the buildings go through an earthquake of great magnitude (Hurtado 2018), in the meantime they will remain attached to what the different studies show.

In the same way, the objectives of the research were fulfilled since the instruments were applied to the professionals of the two universities that offer the professional program of civil engineering in their cities, in addition it was possible to know the perception of the engineers, specifically the experts in structural calculations, before the answers of buildings constructed with the SCI and how they can behave in telluric movements, having thus a first hand information since they are in charge of calculating the buildings so that they can absorb the different earthquakes that can be presented in the zone (Hurtado 2018), However, it is necessary to highlight some contradictions among the specialists regarding the seismic resistance of industrialized buildings, since it could be believed that due to the fact of being a specialist in the area they were all pointing out the same ideas and with this analysis it was verified that this is not so, it is for this reason the importance of continuing to contribute on these subjects since the perception is very subjective and the calculations are objective and this combination entails unexpected results such as those that have been found.

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