Auxiliary structures at excavation works in urban areas
The case of the building at Avenida Almirante Reis, 53, in Lisbon

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Abstract: In view of the growth of the flow of tourist that Portugal has felt in recent years, more specifically in the city of Lisbon, thus increasing significantly the daily population density present in the city, it is necessary to have a housing volume corresponding to the volume of demand. Since most of the built houses are unable to meet the current expectations of real estate due to its obsolete and technical deficiencies, it becomes increasingly common to have rehabilitation works, which due to the current legislation, obliges the conservation of the existing centennial façades in the city of Lisbon, especially in the central zone, in contrast to the decrease of the root construction. While the demolition of the interior of the building is executed, simultaneously the façade containment structure is implemented, which allows to ensure its safe storage and is later integrated into the new structure.

In this way, this document aimed at identifying actions that will influence the behaviour of the tower crane as well as the containment system of the façade of a neighbour building and was carried out with support of the base elements referring to the implementation plan of what will be the new Hotel Estrela Santos, located on Avenida Almirante Reis, Nº53, in Lisbon. In view of the above, a brief modelling of the façade restraint system is presented using the SAP2000 finite element software, trying to obtain realistic results on the present efforts at its base. It was also made a brief design of the micropiles, present in the indirect foundation by micropiles, where is based the equipment of elevation existing in work, the tower crane, that in this case is the model Potain MC 68B.

Keywords: Urban Rehabilitation, Containment of Façades, Tower Crane, Numerical Modeling

1. Introduction

In order to respond to the volume of demand for real estate in the city of Lisbon, due to the substantial increase in tourism-related demand, it is increasingly common to have works in the center of Lisbon, making obsolete buildings in modern buildings. In this way, and considering that the majority of the residential buildings, present in the center of the city, are centennial buildings, under neighborhood effect (coupled), with a high level of precarious integrity, putting at risk the equilibrium of the building, it's usual to need the neighboring buildings as supports, guaranteeing their stability. So, when demolishing a neighboring building, it is necessary to use, as a form of stabilization, the implementation of structures to contain façades. However, since these areas are densely populated, with plenty of transport infrastructures as well as a high volume of buildings, it is necessary to be very careful in the demolition processes to be carried out.

So, it is necessary a correct and conscientious design of the geotechnical structures of peripheral containment, as well as containment structures of façade. The fact that the geotechnical structures present the particularity of their surroundings can undergo changes over time, can open space for doubts, since it is not an exact science. In this way, it is indispensable to verify the structural adaptation to new conditions of equilibrium, considering all the actors, be they actions or resistances.

In view of the above, this dissertation has as main objective the study and modeling in the software SAP2000 of the recommended solution regarding the containment of façade, more properly, the containment of the wall of the neighboring building, which confronts the street Álvaro Coutinho. In addition, it was carried out the dimensioning of the indirect foundation by micropiles of the tower crane.

2. Case Study – Hotel Estrela dos Santos

The building, which will be study, is located at Avenida Almirante Reis, Nº53, in Lisbon, with a total area of 225 m^2 per floor, is made up of 7 elevated floors destined for rooms and 2 buried floors, reserved for restoration and technical areas, which will be Hotel Estrela dos Santos, whose promoter is "Manuel Santos Marques, Lda". Figure 1 shows the aerial view of the site.

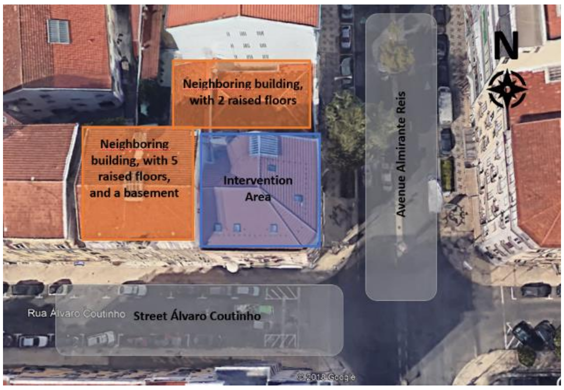

Figure 1 - Aerial view of the place of intervention (GOOGLE, 2018)

In this way, with the purpose presented, several activities will be carried out, which can be highlighted in a succinct way, for a better understanding:

• Implementation of yard area;

• Tower Crane Installation;

• Demolition of the building, while assembling the containment structure of the wall of the adjacent building;

• Execution of the peripheral containment structure, with definitive Berlin walls and slab bands, with simultaneous excavation work being performed;

• Execution of the remaining structure of the building.

2.1. Main Restraints

The main constraints in the construction to be carried out are essentially the state of conservation of the neighbouring buildings, in which the building that needs containment does not present a very good state of conservation, unlike the other building of only two floors that presents a good state of conservation . In addition, the constructive nature is also a factor to be taken into account, with most of the buildings in this area going back to a time when it was not being built in the right way, giving the structures serious structural deficiencies. Another point to take as reference is the geological and geotechnical nature that in the present case is characterized by alluvial deposits and/or landfills of Holocene age (a), by limestones of Entrecampos (Real - Miocene Bank) (M_{EC}), clay sands and sand and clay sandstones.

. Table 1 presents the description and parameterization of the geotechnical zones, with the geomechanical parameters that will be adopted in the design of geotechnical structures

Table 1 – Parameters and geotechnical zones [1]

Geotechnical Zones	Depth [m]	E [MPa]	γ [kN/m3]	Ø' [º]	C' [kPa]
GZ1	15-22	100	20	38	-
GZ2	22-27	30	18	31	-
GZ3	27-33.4	10	16	26	-

In order to verify these values, a geological and geotechnical prospection campaign was carried out, where it was possible to obtain more realistic values from the SPT (Standard Penetration Test) test. Thus, confirming that the surface layers had very low values, between 3 to 8 to a depth of 10 meters. Meaning, that they don't have adequate strength characteristics which, on their own, ensure the stability of any type of structure which has a considerable weight to bear. These surface layers are mainly clay material, classified as a soft clay, presenting organic material, it is expected that considerable settlements will occur, even reaching unacceptable values, making it impossible to execute direct foundations.

2.2. Adapted Solution

The solution to the presented problem is to dimension an indirect foundation by micropiles, for all the structures involved in the work. That is, both the peripheral containment structure, supported by slab bands, as well as the very foundation of the superstructure executed by continuous foundation, the containment structure of the façade and the tower crane, all these structures will resort to the use of micropiles. These structural elements are the key to solve the problem, referring all the existing loads existing on the surface for competent layers in depth.

Figure 2, adapted from [1] shows the foundation mass of the tower crane, where the feet of the structural element are embedded in this mass. In these cases, the use of these masses allows the uniformization of the loads and later takes them through the micropiles to more resistant layers. The same happens with the other structures, as it is present in figure 3, adapted by [1] referring to the containment structure of the façade.

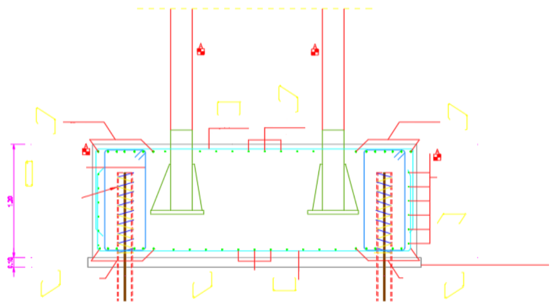

Figure 2 - Foundation mass of the tower crane [1]

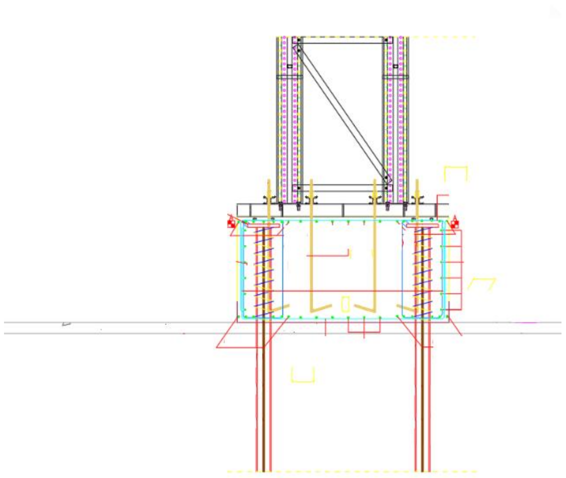

Figure 3 - Foundation of the façade containment [1]

2.3. Tower Crane Foundation

Taking into account the loads present in the tower crane, it is possible to verify the combinations for the different positions of the tower crane both in service and at rest, identifying the worst position in terms of most conditioning values. To better understand the positions that a tower crane can have, in order to assess the worst-case scenario of pressures and stress that the foundation mass can be subject, Figure 4 and 5 are presented, allowing to verify the most conditioning value that the micropiles have to sustain.

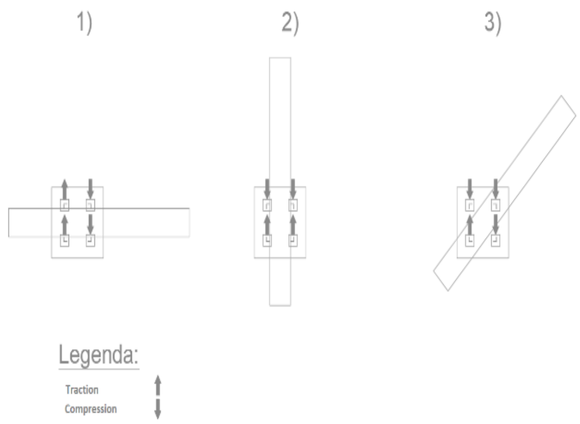

Figure 4 - Different positions of the tower crane

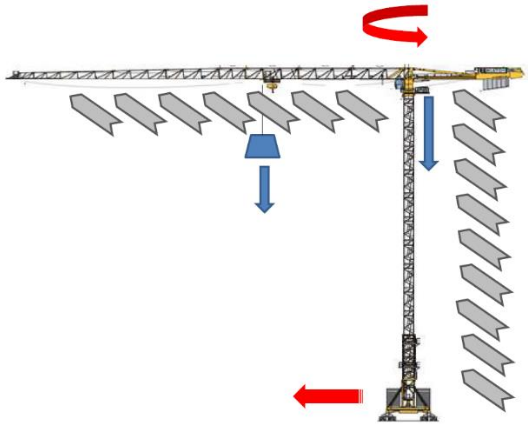

Figure 5 – Efforts System at the tower crane, adapted from [2]

In analyzing the figures, we have presented arrows, which indicate us both traction and compressive forces existing in each foot of the crane tower. These efforts are the result of the bending moments, which by binary effect generate axial forces. It should be noted that the maximum effort corresponds to the situation in which the tower crane is at rest, when the movement of the spear is 45º. In this case, only two micropiles are absorbing the bending forces by binary effect.

In addition to these efforts from the tower crane, the weight of the foundation mass, composed of reinforced concrete, is also distributed among the 4 micropiles that will be materialized, corresponding to each foot of the tower crane. These micropiles will be composed of a metal tube ∅127,0x9mm, and steel of type N80 (fy>560 MPa).

After obtaining these values of efforts and their increase by applying coefficients of majority, the final limit strength state of the section is verified by equation 1, obtaining the efforts present in table 2.

$$\frac{N_{Ed}}{N_{Rd}} \leq 1$$

Equation 1

Table 2 – Safety check to the ultimate strength limit state

Type of solution	N_{Ed}[kN]	N_{Rd}[kN]
Micropiles Ø127,0x9mm	1094	1107

Subsequently, the verification calculation is performed in relation to the ultimate capacity limit state where the safety check associated with the geotechnical calculation is made, using the method of Bustamante and Doix [2], where the resistance of the connection between the cement mix and the ground is verified. This method consists in quantifying the length of the sealing bulb, which will be indispensable to carry out the friction mobilization necessary to overcome the demands transmitted to the ground. This length can be calculated from equation 2.

$$L_{bulb} = \left[\frac{N}{(\pi \times D_s \times q_s)}\right] \times FS$$

Equation 2

With this equation it is possible to obtain the sealing length needed to check the safety, which in this case is 9 meters.

2.4. Structure for the containment of the Neighbouring Building Façade

As was mentioned above, in this type of construction, called banded buildings, walls are of paramount importance in their stability. For this reason, when demolishing a building located in the middle of two others without any preventive measures, causing decompression in the neighboring structures, may cause differential settlements, or even rotation, starting or aggravating existing cracking processes in adjacent structures. Therefore, there is a need to carry out a containment system, since there is no confinement effect characteristic of this type of construction. The system of containment of walls is based on the same philosophy of the system of containment of façades.

Considering the provisional nature of the structure in question, the recommended solution points to a patented metal structure solution. In general terms, the containment is guaranteed by confinement of the wall by means of 2 UNP 120 beams, placed on the exterior face of the building wall adjacent to the slab level. The metal structure does not have any physical connection to the wall of the building, and the profiles are expected to be well placed against the wall. These elements are tied to two equal vertical towers, installed along the façade. The system is capable of effecting the compensation of the horizontal deformations in the wall.

Each tower is constituted, by two towers, although coupled. Each tower belongs to the same product, called "Carl + Multidirectional Tower" belonging to the company Carldora, these have different characteristics. Figure 5 demonstrates the structure in debate.

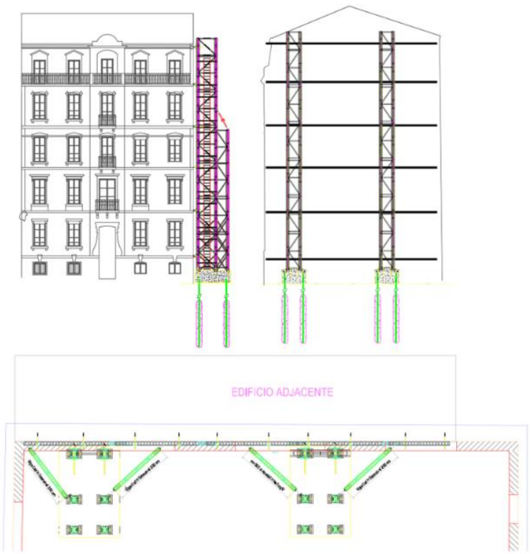

Figure 6 - Containment structure of the wall of the building that confronts Street Álvaro Coutinho, different perspectives [1]

In order to facilitate the understanding of the structural composition and the format of the sections, table 3 is presented, as well as the figures from 7 e 8 where the towers, profiles, are distinguished, respectively.

Table 3 - Different characteristics between towers

	Tower A	Tower B
Height [m]	≅ 19,50	≅ 12,00
Dist. Between vertical elements lateral face[m]	1,50	1,00
Dist. Between vertical elements back face [m]	1,00	1,00
Beam Carl H	×	–
Beam Carl +	×	×

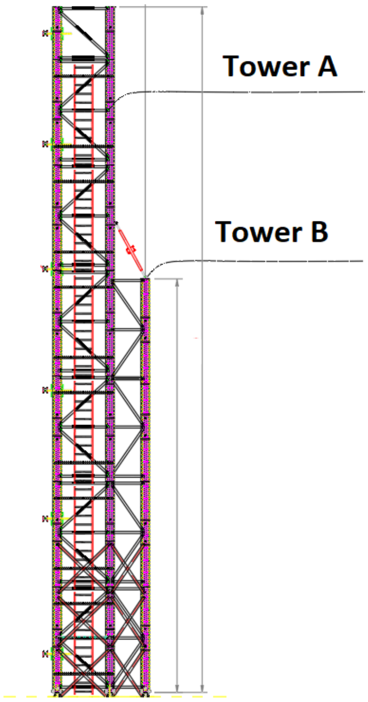

Figure 7 - Vertical towers, wall containment structure [1]

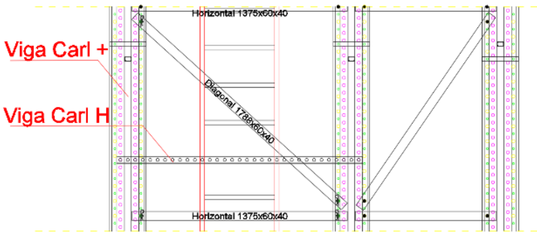

Figure 8 – Different profiles[1]

To start the assembly of this structure, it must first be executed the foundations guaranteeing stability. These foundations, presented in figure 9, are composed of reinforced concrete masses, more concretely solid masses of dimensions 2.0 [m] x3,0 [m] x1,0 [m] (BxLxH), supported by 4 micropiles.

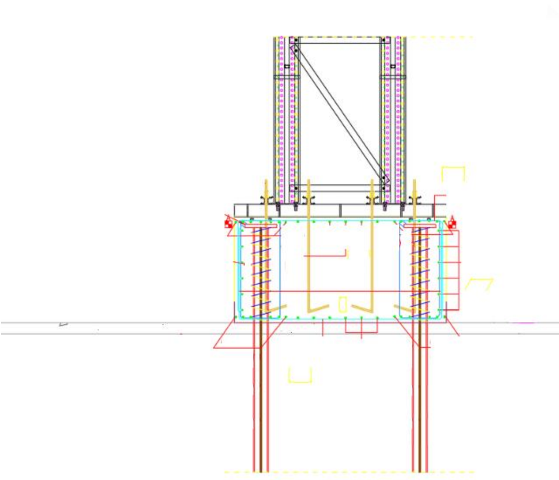

Figure 9 - Constructive detail, solid foundation of the containment towers of the wall, supported by micropiles, adapted from [1]

2.5. Modeling the containment structure

Aiming to study the metal structure to contain the façade of the neighboring building that will be unprotected, safeguarding the structural integrity of the same building, it will be used the finite elements program SAP 2000 to perform the modeling of the structure in theme, obtaining values of efforts, which will be sent to the micropiles, and can serve as a comparative term for the values of the designer of the structure that will be implemented in the work.

In addition to the modeling of the provisional containment structure, it was also verified the possibility of modeling the gable of the adjoining building, which would be heterogeneous properties and discontinuities at the beginning of a masonry wall building. construction of his time. In view of this, it is perceptible that its mechanical characteristics may diverge along the façade area and should be analyzed as the demolition is carried out.

Some difficulties were encountered with regard to the introduction of the characteristics of the structural elements that make up the containment structure, since it is a patented system. To solve this problem, profile approximations were assumed.

The structural model of the containment of the façade is presented in the following figure. It has also been assumed that the connection between the system of containment and the mass foundation represents a fix support, thus allowing full transfer of effort. In addition to figure 10, figure 11 is also shown where it is possible to visualize the 3D model.

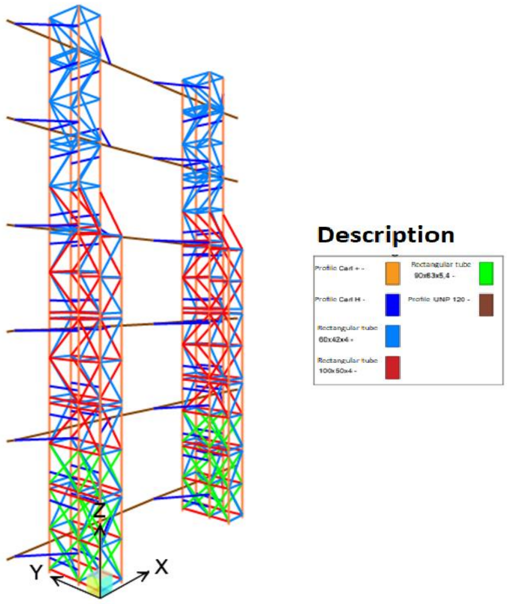

Figure 10 - Global model of containment structure, with "standard" view and its subtitle

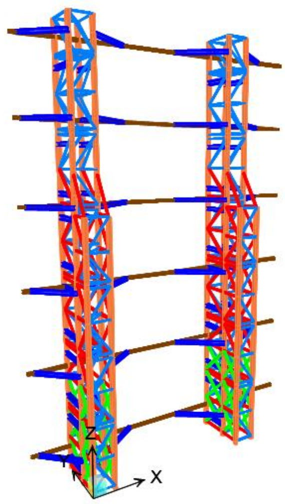

Figure 11 - Global model of containment structure, with view "extrude"

2.5.1. Actions

To represent the reality that the façade containment structure will face *in situ*, it will be necessary to identify the actions in it. In the present case, in view of the base elements provided, as permanent actions beyond the actual weight of the containment structure, automatically calculated by the program itself due to the specification of the profiles, the action of the building to be contained will also be assumed, which according to the Project of stability, for the purpose of calculation it was considered that the action of the lateral building is similar to the action of the wind. In the case of a dissertation in which everything works perfectly in terms of work carried out on site, as well as the surrounding nature itself, it was assumed that the vibrations as well as collisions and or accidents, which could result from demolition work and from the work itself are not significant. Considering the period of return of the seismic action and treating this structure as temporary, having a very short time of operation, this same action was also not accounted for.

In figure 12 it is possible to visualize the representation of the global model, already with the wind action implemented.

However, this model, while realistic, does not allow conclusive efforts. The reason why this happens is that the UNP profiles, which allow the contact of the containment system to the adjacent building, are already functioning as a resistive element, not conveying the forces in results. In addition to the above, the attempt to detail the containment system has proved to be an obstacle, since the software has limitations on the level of nodal connections, making it impossible for the specificity of the different profiles to be connected to the same node, and it is not possible to present the different reinforcements between elements.

In this way, the UNP profiles were eliminated and the pressure exerted on the nodes that in the previous model served as connection of these elements to the system itself, as well as the elements of connection between profiles were applied directly.

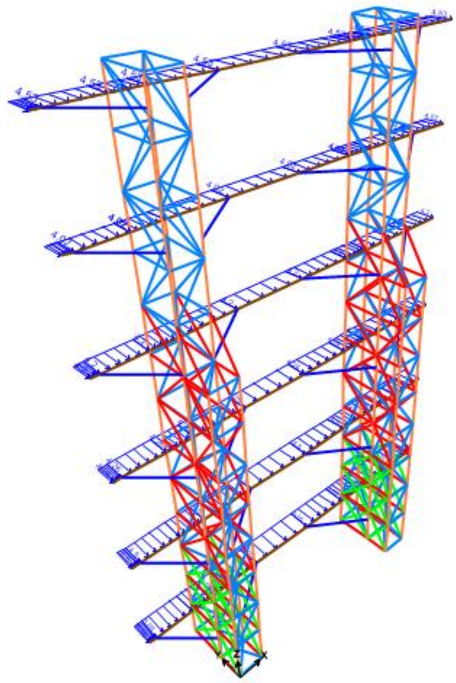

Figure 12 - Representation of the SAP2000 model with the wind action

As a result, the model shown in figure 13 was obtained.

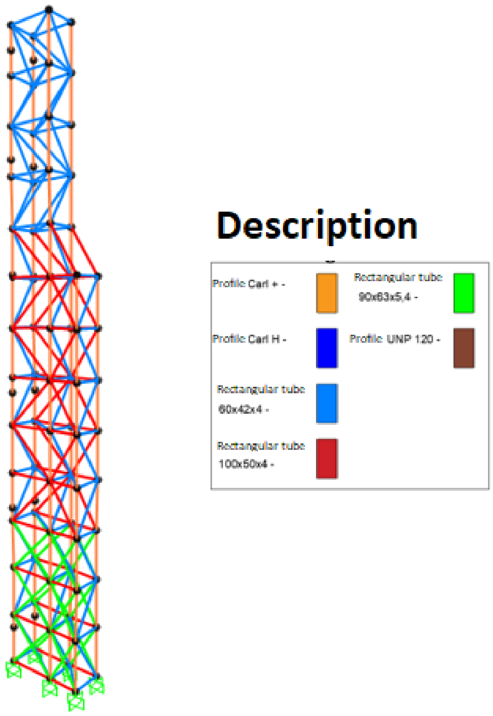

Figure 13 - Final model of the containment structure, with "standard" view and its legend

In order to obtain the efforts in the structure, two combinations were executed, in a first one the actions previously mentioned were increased and in a second only the actions coming from the façade were increased. As can be seen in figure 14, the greatest axial forces, as expected, arise in the vertical profiles present in the end zones of the containment. Being a containment system that receives pressure from the façade, guaranteeing its equilibrium previously established with the building to be demolished, we have efforts of compression in the vertical profiles more distant and intermediate of the façade, whereas the profiles near the same are at traction

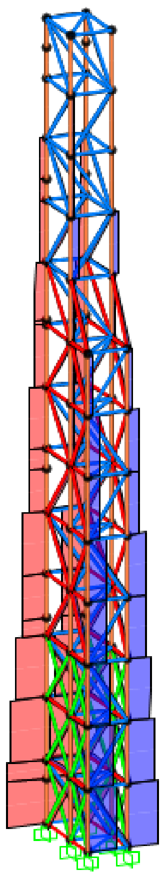

Figure 14 - Axial stress diagram

2.6. Plan of instrumentation and observation

The instrumentation and observation plan are a very important role for the monitoring and validation of different existing activities on site. In a work inserted in a densely built urban environment, with demolition and excavation processes, based on diversified geological information in which there may be randomness in the substrates found, monitoring of local conditions is essential. For this reason, there must be a control of the deformations of the surrounding buildings, in order to verify that the work is carried out in accordance with the established in the project, safeguarding the safety of all those involved in the work as well as the users of the surrounding infrastructures.

Before the beginning of the different works of the present work, an initial reading campaign must be carried out in order to assess the zero values, this being the base value that will serve as a comparative term. A correct and periodic interpretation of the data from these plans, allows to be on the side of security, as was mentioned for the different cases, creating alarm and alert criteria, it is possible to intervene minimizing the impacts caused.

3. Main Conclusions

It is noteworthy, based on the instrumentation readings, that there is a trend of settlement of the crane header mass, the values from the displacements in axes XX and YY, may be related to the work of the lifting equipment. As for contiguous buildings, there are no movements to emphasize. However, the façade of the building to be intervened has some positive z-displacements, such displacements may be due to the fact that the soil reaction "increases", since the weight of the building is decreasing, alleviating the pressure exerted on the building. ground. In none of the monitored targets were values close to the alert criterion recorded.

As for the modeling of the façade containment structure, realized in SAP2000 finite element software, some difficulties were found, namely the correct modeling of the containment system as well as the definition of the own profiles integrating the containment structure. These obstacles are due to the fact that it is a patented, well-detailed façade containment system with no public information on profiles forming part of the system, making it difficult to obtain realistic effort results. However, the results obtained were very close when compared to the values obtained by the responsible designer, and it can be assumed that the results were satisfactory. Even though an extensive analysis of the peripheral containment structure has not been made, it is important to mention its importance in a work with this location, and there are numerous constraints for its safe execution.

Although it was not possible to incorporate in the present dissertation, in a more in-depth way, specific knowledge of the area of geotechnical specialization, knowledge acquired during the academic formation was applied, allowing to remember that in this area of engineering, all means are interconnected, not being possible to carry out a work only with knowledge of only one area of specialization

4. Future Developments

With the follow-up of the work, it will be possible to follow the monitoring, allowing to draw information about the actual behaviour of the structures described in this document. Notwithstanding the above, in order to simulate a more realistic behaviour of the containment structure of the façade, namely in terms of displacements, it is suggested as future development and possible object of study in another dissertation the modelling of the structure of containment, using ETABS software, or other software of the BIM type, allowing a detailed description of the connections of the more contained containment system, which may be the crux element for the reason of the impossibility of obtaining results of the global system of containment of the façade.

5. Bibliography

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[2] A. M. Manitowoc, “FEM Product Group,” Cranes and Lifting Equipment, 2015.