International Journal of
Science and Engineering Investigations vol. 10, issue 115, August 2021
Received on August 20, 2021 ISSN: 2251-8843

How to Avoid Implications in the Execution of Works by Means of Compatibility of Projects: A Case Study

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Abstract- The goal of this present study is to show the importance of good strategic planning to have good execution of civil works. In this regard, without having good planning involving all professionals, the project tends to have some unexpected issues and, sometimes, fail. Several excellent projects fail for not having engagement among the professionals involved. Bringing this theme to the execution of civil construction, prior planning, well carried out and discussed among everyone before the execution of the work, allows unexpected events to be resolved in a more effective way. In addition, flaws in the reading of projects by professionals, unforeseen situations, and doubts that may arise during the execution were previously discussed. The idea here is to show that the holding of meetings between those involved in order making all projects compatible, aware that the use of this procedure, can become essential for the success of the enterprise. As a consequence, the quality of the construction is highly increased, due to good prior planning, favoring an efficient execution. This is in line with the company's indicators such as meeting deadlines; the prior identification of risks and qualities; the proposal of solutions in a more agile and efficient way; not wasting work time dedicated to understanding each project design; customer satisfaction and other relevant aspects. Thinking about the company as a whole, if project compatibility is adopted in all civil projects, the company and its team will save not only money and time but also increase the quality of their work. Thus, the team will work in a more effective way, will have more time to devote to conquering new customers, doing various researches, improving its operation, reducing time and cost, optimizing resource allocation, among many other benefits. The result of using this project compatibility strategy in the planning stage, in which all professionals invest more energy planning before executing, will be a much more competitive and successful company in its execution of civil projects.

Keywords- *Civil Construction, Compatibility of Projects, Interferences*

I. INTRODUCTION

The inexistence of compatibility of the projects referring to a residential development compromises its final quality.

Due to the fact that the projects are not interrelated during their execution, several interferences may arise between the installations of the pipes and structures in divergence from what was idealized in the architectural project. The use of project compatibility of an enterprise is necessary to eliminate these interferences even in the planning phase.

The relevance of this case study is justified by the report of interferences, found in a set of construction projects analyzed, which, if not resolved, can directly affect the use and occupation of a building. Thus, we seek to answer the following questions throughout this work: How to make the projects compatible? What are the main interferences caused by the lack of interaction between the projects? What is the gain with productivity? What is the relevance of planning before the start of the work?

Through this, this article aims to show that the improvement of the standard of civil construction, with regard to residential buildings, becomes possible through the compatibility of architectural and complementary projects. These must be sent to the construction site without any interference, guaranteeing the perfect execution by those involved in the work and providing better comfort to the building users during the occupation phase.

II. METHODOLOGY

The methodological procedures for carrying out this work were initiated by a research related to project compatibility. Then, a case study was carried out to analyze each project of a particular building. In addition, the respective overlays of drawings were carried out to verify the interferences that one project caused in another.

The authors had the collaboration of the owners of a construction company whose company name was not authorized to be disclosed, being, therefore, identified in this article only as a construction company. This company is located in Belo Horizonte, with a strong presence in the real estate market in the construction and sale of multifamily homes that fall under the Minha Casa Minha Vida (MCMV) program, developed by the Brazilian government.

III. PROJECT PLANNING AND COMPATIBILITY

According to Borges (2009) and Azeredo (1997), project planning should start with a visit to the land chosen for the implementation of the project. After that, it is advisable to carry out an on-site drilling test so that the designers together opt for the most economically and commercially viable structure and layout. The drafts are prepared according to each characteristic of the terrain dimension, it is essential that the construction company, together with the designers, know it well, as it is from it that the first ideas related to the project appear.

Botelho (1984) emphasizes that the plants and projects that were unsuccessful occurred due to the lack of communication between the designers and the construction company.

According to Limmer (1997), in almost all residential constructions, there is no interaction between the professionals responsible for the elaboration of the projects: architectural, structural, electrical and hydraulic, during planning. With this, interferences arise, which will only be noticeable during the execution of the work. Currently, due to the large offer of housing on the market, the consumer population demands higher quality when they are about to make an acquisition. For this reason, it is necessary for the company to carry out the task of planning and controlling the elaboration phase of projects in order to ensure that they are walking in perfect harmony.

According to Thomaz (2001), the final quality of a work is linked to the quality of the projects that will be executed, which are often contracted according to the lowest cost found in the market; this entails the omission of details necessary for interpretation at a construction site. Thus, during execution, doubts will arise, which often will not be resolved due to the deadline and/or productivity pre-established by the construction company for the completion of the work.

IV. CASE STUDY

The project analyzed in this case study was presented to a small company, in the beginning of 2016, operating in the civil construction sector, in the city of Belo Horizonte/MG. At the time, a proposal was presented for the execution of a project related to the construction of a building composed of three floors and a stilt, comprising eleven apartments, with a parking space available for each unit.

The structural project should have been developed according to the elaborated architecture, thus covering all the necessary information for architectural follow-up.

After the preparation of the structural project, companies were contracted to prepare the electrical and hydraulic projects for the building under study. These should be developed together with the structure, so that they do not cause serious structural interference. In order to make the projects compatible, it was necessary to have a technical and critical eye from the engineers in training; there were also project overlaps with the help of the AutoCAD tool.

A. *Architectural versus structural*

The Technical Manual applied to buildings of the Municipality of Belo Horizonte – PBH – (BELO HORIZONTE, 2011), is intended to guide the authors of projects regarding the urban standards in force in the municipal territory. Through the pre-established terms in this manual, it is possible to know the rules for parking lots and garages for vehicles. This forecasts that a vehicle would need a free aisle of at least five meters to carry out maneuvers and park in spaces positioned at ninety degrees. However, the structural design of the project under study did not meet these parameters, as it included a pillar that would affect the rotation angle needed to park the vehicle, so it did not fit in the manual for not respecting the minimum area for vehicular maneuvers. From a critical perspective, it is noted that the best solution for recovering this parking space would be to reposition it, so that the structural integrity of the building is maintained, respecting the parameters required by the technical manual applied to buildings.

Considering the requirements of standard NBR 15.575-2 (ABNT, 2013), buildings must meet minimum rules regarding performance evaluation. The structure must be watertight from sources of moisture, whether from rainwater or soil moisture. Thus, the Brazilian standard requires that the conditions established in NBR 9574 (ABNT, 2008) be followed, which establishes requirements for the execution of waterproofing of structures that will be in contact with water or buried in the ground. In the respective study, there were beams and columns that would be buried due to structural design error. Therefore, when analyzing the projects, it was found that the most viable solution for this unforeseen event would be to adopt the waterproofing of structural elements as established in the standard.

The NBR 14859-1 (ABNT, 2002) aims to demonstrate the requirements for receiving and using prefabricated slab components and the elements that make it up. In order to comply with such NBR, those involved in the construction of the project needed to carry out the dimensioning and construction of a prefabricated lattice slab, as, according to the perception of the authors of this article, the structural project did not include the same over a room located in the first building pavement. Thus, it was necessary to follow the NBR standards to carry out the dimensioning of that slab.

Among some of the elements of the structural design, the dimension of the architecture was not respected, as one of the structural elements (pillar) was protruding from the masonry walls of the building. The structure was encroaching on a small percentage of the area belonging to the apartments due to its dimension being thicker than the walls. In an analysis of commercial viability and aiming at the convenience of future residents of this building, the pillars should be resized in accordance with the NBR 6118 standard (ABNT, 2003). This sets the minimum concepts to be adopted for the design of the structural elements in concrete, respecting, in the case of the project, the minimum coverings according to the aggressiveness class of the environment in which it fits. According to the standard, aggressiveness class II was adopted, since the projects would be carried out in an urban area.

The regions with openings in the kitchen of the apartments, in the future, would present cracks and fissures. Because, the structural dimensioning did not include the use of lintels and lintels, which are elements used at the top, in doors and windows, and at the bottom, in the case of window spans, to avoid loading on the frames or even openings that require reinforcement structural according to PINI [sd]. As noted by the engineers, the lintels and counter-lintels should be specified still in the design phase, respecting the established parameters: maximum dimension for use in spans of up to three meters. Emphasizing that the project under study will have openings with 2.05m, so these fit the required parameters. In addition, they must be stretched in both directions with at least twenty centimeters for better load distribution.

Law No. 9725 (BELO HORIZONTE, 2009) establishes standards for the execution of buildings, seeking to ensure minimum safety conditions and facilities. As established by law, a residential building for multi-family use must have a free span of 2.60 meters in height inside the rooms, that is, from the floor to the beginning of the slab or beam. In the respective case study, the existence of a beam which would not respect the minimum height was observed. Therefore, this would not fit the minimum requirements required in municipal territory. After the analysis, it was proposed to resize it, in accordance with NBR 6118 (ABNT, 2003), which establishes guidelines for the design of structural elements in reinforced concrete, so that the minimum ceiling height is respected.

The highlighted region in Figure 1 demonstrates how was the positioning of vacancy 7 and the location of pillar P11. However, in figure 2 it is possible to identify the change that was proposed, in order to enable the use of vacancy 07 and the structural guarantee of the building. The project cannot be fully disclosed.

TABLE I. SHOWS THE INTERFERENCES OBSERVED IN THE OVERLAPPING DESIGNS, AS DESCRIBED ABOVE

structural element	Interference	Proposed solutions
P 11	It affects parking space 07, as it does not respect the maneuver angle necessary to park the vehicle.	Change the position of the space below the stairwell and change the dimension of this pillar.
Slab 4 e 5	They occupy the same space as a permeable area.	Eliminate these slabs at the place of interference and resize the structure of this floor.
V108b B106b V121 V133	It occupies the same space as a permeable area.	Check the possibility of deleting and resizing the structure or adhere to the waterproofing of structural elements.
P1/P2 P9/P15	It occupies the same space as an area that will be grounded.	Check the possibility of the base of these being born on the first floor or adhering to the waterproofing of the structural elements.
roof	It does not have a slab over the first floor room.	Size this slab.
P3/ P4 / P7 / P8	The wall stands out, changing its internal area.	Change your dimensions.
Beams	The apartment kitchens are American kitchens, so they need beams in their openings.	Dimension the beams.
V401	Does not respect the minimum direct foot required by municipal law, which is 2.60m.	Resize it.

Source - Author, 2017

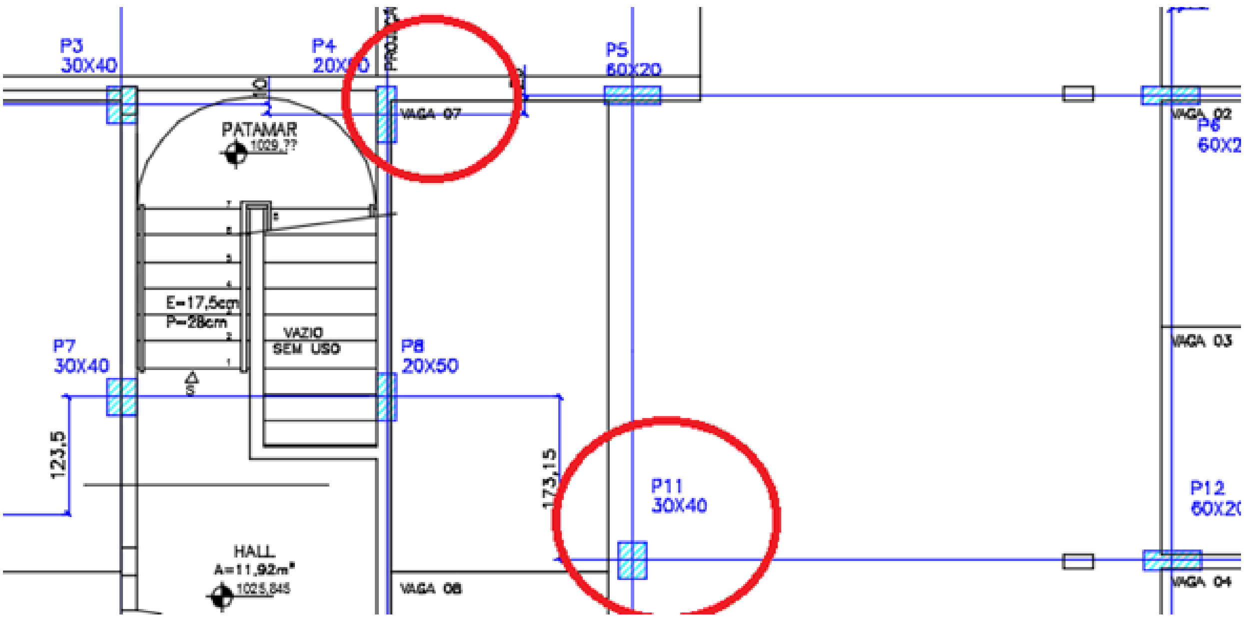

Figure 1. Wrong positioning of the P11 pillar / vacancy 7. Source – Construtora Collection, 2016

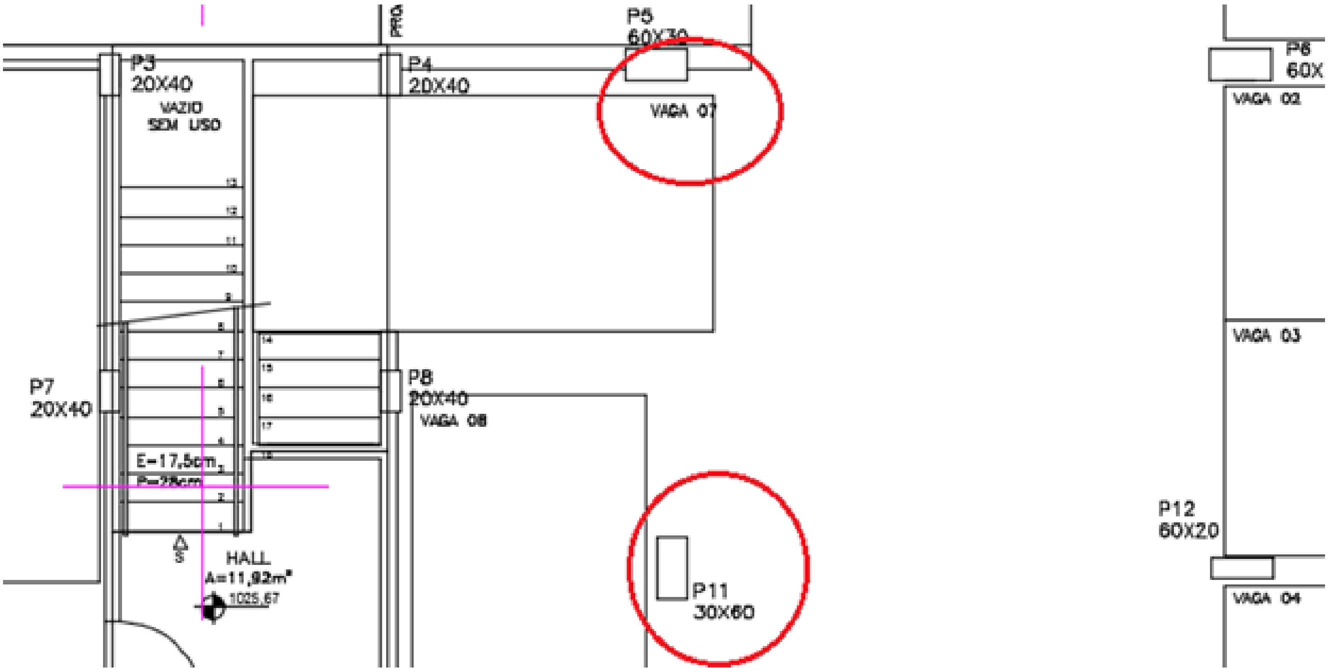

Figure 2. Modification of the P11 pillar / vacancy 07 positioning. Source – Construtora Collection, 2016

Figure 3 refers to the interference caused by the structural design in the architectural design, as where the architecture provided for a permeable garden, the structures of slabs 4 and 5 were found.

Figure 4 shows the proposed solution, which would be the removal of these slabs. Both figures show only an excerpt of the drawing because the project cannot be fully disclosed.

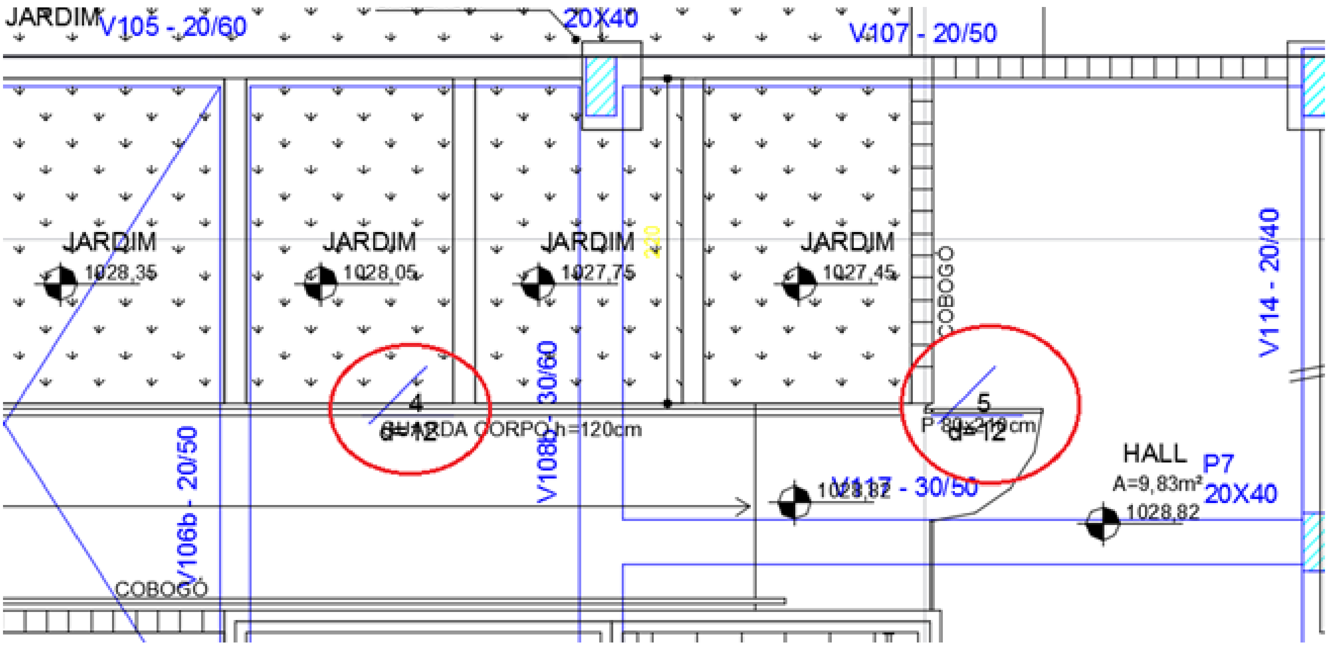

Figure 3. Slabs dimensioned over the permeable area / garden. Source – Construtora Collection, 2016

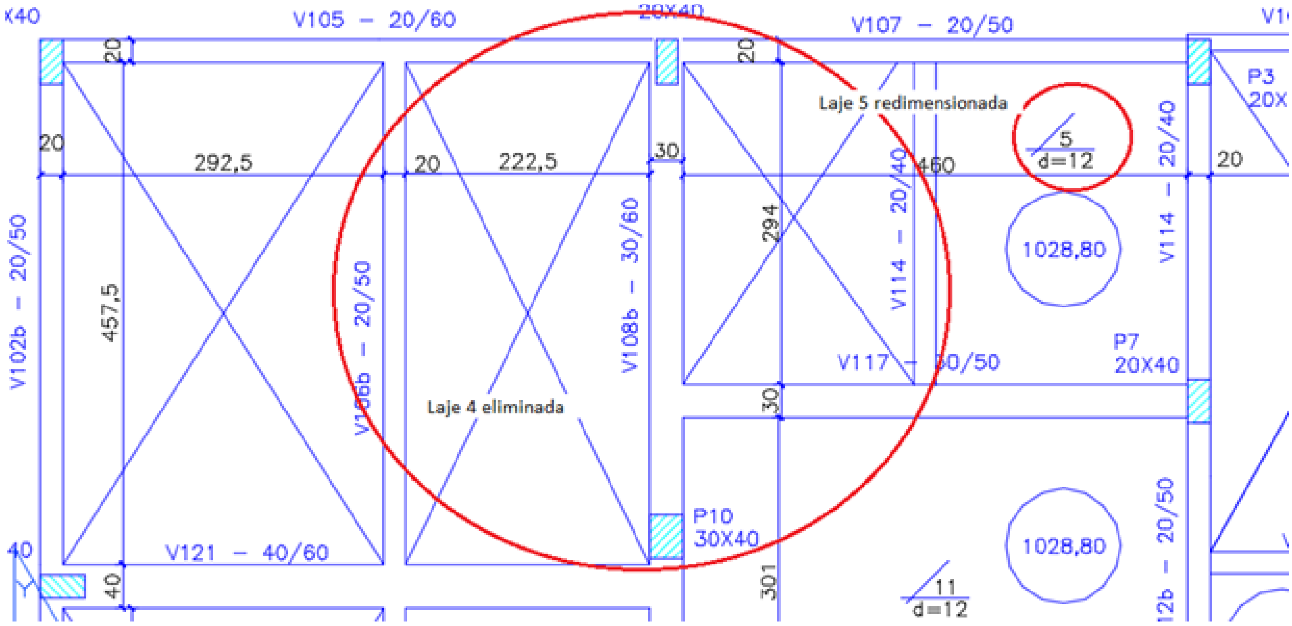

Figure 4. Slabs with sizing correction. Source – Construtora Collection, 2016

However, it is still worth noting that the structural design had many divergences regarding the dimensions of the structural elements. The frame of the beams and columns did not respect the dimensions specified in the form plan. There were also divergences regarding the dimension of the stirrups related to the reinforcement, as they did not respect the minimum necessary coverage, according to NBR 6118 (ABNT, 2014), to ensure the safety and integrity of the structural element.

In addition, the architecture underwent a change in the position of the windows to preserve the view of the landscape, as the building's construction site has a considerable altitude, favoring a beautiful panoramic view, being considered a positive factor for the sale of residential units.

B. Architectural versus structural versus electric

With regard to the project's electrical plant, it was developed based on the parameters in force in the NBR 5410 standard (ABNT, 2015). This standard is intended to establish conditions for low voltage electrical installations in order to ensure the safety of individuals and animals.

As established in the standard notes, it is advisable that the power points, the drives, the path of the tubes equipped with electrical conductors, be positioned in such a way that there is as little interference as possible with the hydraulic, architectural and structural plans. Thus, a load chart is an important instrument, as mentioned by Creder (2016), because, in addition to demonstrating how it was dimensioned, it is in it that the designer justifies all the elements necessary for reproducing the electrical project. It should be as detailed as possible to not there may be problems related to the purchase of electrical conductors and equipment in the future.

The electrical project was dimensioned right after the architectural and structural project was prepared. The architectural project provided only two shafts for this building. Soon, the electrical designer used one to pass the intercoms, telephones and antennas and the other to pass the electrical outlets and lighting. It should be noted that, as mentioned in the notes of NBR 5410 (ABNT, 2015), it is not recommended to pass all wiring in just one shaft, as there may be interference in the electromagnetic fields between the power circuit and wiring for communication. The observations for the electrical project under study stand out in relation to the others, as it was the one that perfectly suited the architecture, without causing structural interference.

This demonstrated compliance with technical standards, as the engineers' recommendation is that the technical responsible for execution pay attention to the electrical circuits for the protection of the individuals involved in the work and the future residents of the building. One of the parameters regulated in the NBR 5410 (ABNT, 2015) standard is that the wire gauges used in electrical circuits must be checked. The load distribution board is vital in the process, it measures the gauges of the cables in relation to each equipment, respecting its power. In this way, savings are made with the materials in question, buying the diameter that was calculated by the load table, enabling significant savings in the construction company's outlay on electrical material, since this has a great value in the cost of the work. When buying the wires without the proper dimensioning, costs can be increased and, even, the chances of future problems with the building's electrical system are great, due to the use of undersized conductors that do not meet the power of some equipment.

The project cannot be fully disclosed. So, in Figure 5, only a portion of it is shown, highlighting the location of the two shafts.

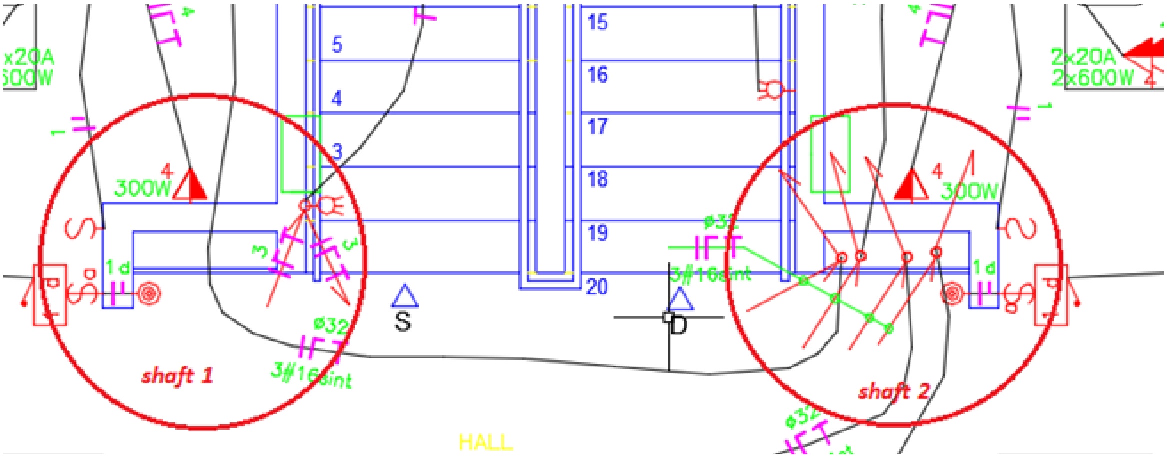

Figure 5. Shafts used to pass electrical cables / Antenna, telephone and internet. Source – Construtora Collection, 2016

C. Architectural versus structural versus hydraulic

The NBR 5626 standard (ABNT, 1998) proposes guidelines for the supply of cold water in a condominium. This emphasizes that the use of water reservoirs is necessary.

In Brazil there is a decline in public water supply, mainly through the direct method, that is, through the pressure of the water concessionaire. Thus, Creder (2006) points out that the alternative is to build superior reservoirs to supply the demand when there is a lack of water.

The hydraulic project of the project under study was the last to be elaborated, so there was no longer any shaft available for the passage of the cold water, sewage and ventilation pipes. As established in NBR 5410 (ABNT, 2015). It is not recommended to pass pipelines intended for hydraulic use together with pipelines intended for electrical use. Due to the moisture transmitted to the wiring through the pipes, this can lead to short circuits. With this, it is observed that, it would be necessary to create a new shaft, for the passage of the pipe. Therefore, it was proposed to create a small shaft in each apartment inside the kitchen, close to the corner wall, thus making the internal area of this room partially reduced, as highlighted in red in figure 6.

This project cannot be disclosed in full either.

On the roof of the garage, a pipe will be installed for the collection of sewage, which will be responsible for directing it to the street sewage system. The pipe will need a one percent (1%) fall, thus causing an unevenness in the total length of the pipe of approximately one foot. Thus, this pipe will need to go beyond the building's support beams, causing holes that can compromise its structural function. The NBR 6118 (ABNT, 2003) standard aims to establish the basic conditions required for concrete structures. According to this, during the elaboration of the structural project, holes must be foreseen in the beams for the passage of pipes. The respective NBR highlights some safety criteria for drilling holes in the structural element, namely: the distance from the support face and the opening of the zone is at least 2h where h is equal to the height of the beam; the maximum aperture dimension is 12cm and h/3; the minimum distance between the faces of openings in the same structural element is 2h;

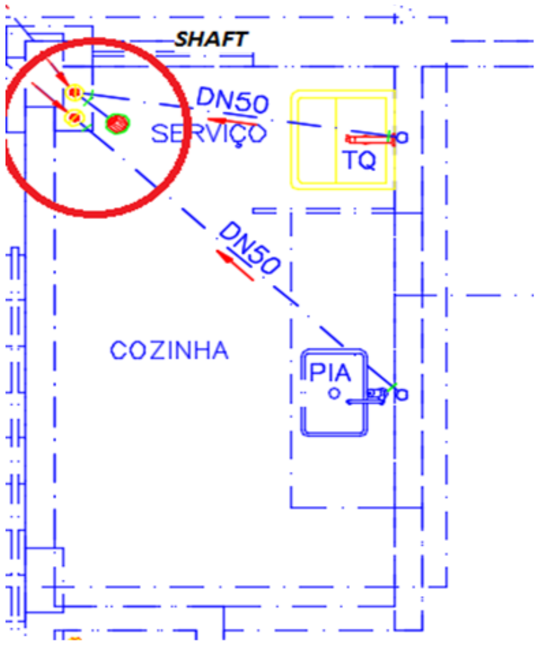

Figure 6. Improvised shaft for hydraulic network descending on the kitchen upright. Source – Construtora Collection, 2016

When analyzing the hydraulic project, it was verified that it foresees holes in the stilt roof beams, these holes need to be passed through some beams, and in two of them it will be necessary to open three holes for the passage of 100mm tubes. These tubes will be passed transversely over the beams, that is, the diameter of the holes cannot be greater than 12 cm and 1/3 of the height of the beam, which is equal to 70 cm. To carry out the passage of the tubes, a gap with a dimension of 30 centimeters will be needed, therefore, the criteria covered in NBR 6118 (ABNT, 2003) will not be met.

As shown in Figure 7, the analyzed beams are highlighted by a red circle. The image corresponds to only a small part of the project, as it cannot be fully disclosed.

NBR 15.575-6 (ABNT, 2013) corresponds to the performance standard for hydrosanitary systems, as established in this, every environment exposed to the open air must include means that allow the collection and conduction of rainwater. In analyzing this requirement, it was observed that on the balconies of the apartments there was no pipe to channel the flow of rainwater through hydraulic equipment: dry drain.

It is up to the engineer of the work to check the measurements of the openings of the holes. Measures such that if carried out without consulting NBR 6118 (ABNT, 2003) can compromise the stability of the structure. The standard aims to guarantee the integrity of the structure and its performance, to avoid problems involving cracks, fissures and/or shaking.

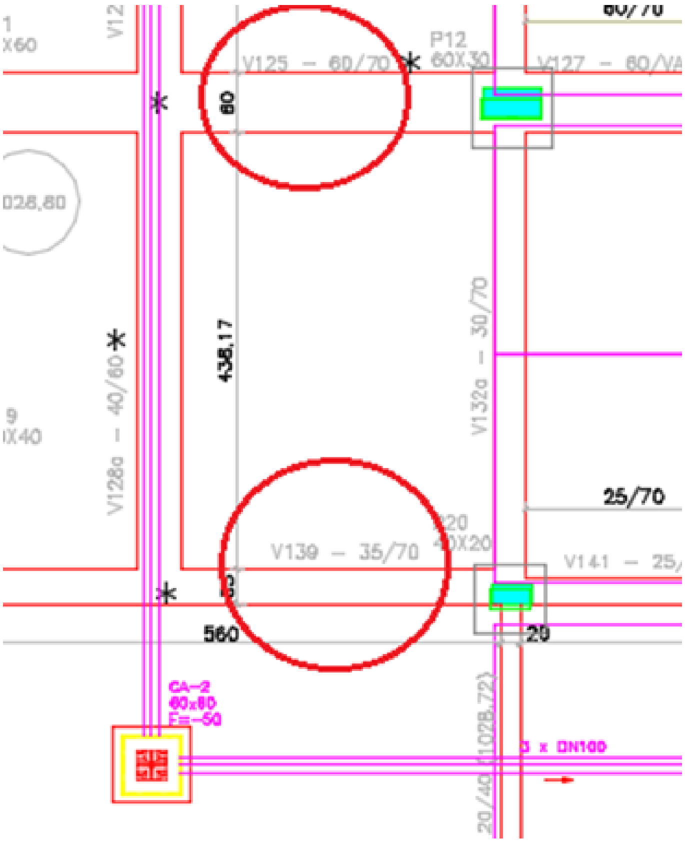

Figure 7. Beams analyzed for the passage of hydraulic piping. Source - Construtora Collection, 2016

V. ANALYZES AND DISCUSSIONS

When analyzing the projects and carrying out their compatibility through AutoCAD software, many interferences were found, as mentioned during the case study.

These were generated due to the lack of compatibility of the projects during the planning stage of the work. Failure to comply with the planning resulted in delays caused in the deliveries of each stage, often generating additional costs related to the hiring of labor and rework.

Reworks represent a variable cost of around 2.3% to 9.1% of the production cost, according to Cazelato (2014). The index variation occurs according to the quality of the planning and the project. In the project in question, the amount of investment planned for the execution was of the order of R$1,000,000.00 (one million reais), considering the worst percentage rate for reworks, there would be an increase in expenses equivalent to R$91,000 .00 (ninety-one thousand reais).

Important aspects, such as the interaction of the authors of the projects with the builder of the work, must be of paramount importance in order to keep everyone informed and accountable for the interference of the projects. In this way, a final product with better finishing quality is obtained.

As presented in this article, the interposition of projects proved to be an essential tool to solve problems and interferences in technical installations. In addition, the well-planned interposition makes it possible to minimize the frequent problems caused in works. It should be noted that it would be desirable for this procedure to be adopted by all builders in the area of civil construction to avoid rework, waste of time and construction materials.

VI. Conclusion

Through the development of the article, it was noted that it is ideal that the solution to minimize interference occurs through the compatibility of projects during their development phase, through simultaneous communication between the designers involved in the project design process.

Until now, the scope was to verify the problems in a traditional way, using only the critical eye of the engineers with the help of overlays performed in the AUTOCAD program, which facilitated the visualization methods.

Considering the extent of work in future studies, the authors of this article identified that a viable proposal for designers would be the use of the BIM (Building Information Modeling) platform. Through this, projects can be developed simultaneously and online, so that the interferences generated by each project are visible to each designer, thus facilitating the adaptation of the entire project that is still in the conception stage. Therefore, in a second phase for this study, it is intended to export all the projects belonging to the case study to the BIM platform, making it possible to generate simulations to mitigate the interference that the projects cause to each other.

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How to Cite this Article:

Pantaleão, C. Q. & Neves, R. C. (2021). How to Avoid Implications in the Execution of Works by Means of Compatibility of Projects: A Case Study. International Journal of Science and Engineering Investigations (IJSEI), 10(115), 36-43. http://www.ijsei.com/papers/ijsei-1011521-05.pdf