Implementation of hydraulic and sanitary engineering under the concept building information modeling, in a nine-floor intelligent building, Zapopan, Jalisco

Implementación de ingeniería hidráulica y sanitaria bajo el concepto de modelado de información para la construcción BIM, en un edificio inteligente de nueve niveles, Zapopan, Jalisco

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Abstract

Building Information Modeling (BIM) is the way to work in a coordinated manner among the actors involved in the construction project. This modeling includes all phases of the project: Design, Execution and Maintenance, providing real time information on the building modeling. BIM focuses on empowering and facilitating the understanding of the work program of all the actor in the construction process: Engineers, Architects, Owners, Product Manufactures, Subcontractors, etc., ordering and coordinating the information in each phase of the project, in order to make decisions, avoiding the minimum mistakes or unexpected calculations. The goal of this project is the modeling of the engineering hydraulic and sanitary, for an intelligent building of 9 floors, using REVIT software, the results obtained were the sizing of the pluvial water retention tank and the determination of available pressures (high and low pressure). It is concluded that the use of BIM tools allowed to display 3D, evaluating a logical sequence despite the complexity of its use.

Building Information Modeling, Design, Execution, Project

Resumen

El Modelado de Información para la Construcción (BIM) es la forma de trabajar de manera coordinada entre todos los actores que intervienen en el proyecto constructivo. Dicha modelación comprende todas las fases del proyecto: Diseño, Ejecución y Mantenimiento, aportando información en tiempo real sobre el modelado del edificio. BIM se enfoca en potencializar y facilitar el entendimiento del programa de obra de todos los actores del proceso constructivo: Ingenieros, Arquitectos, Propietarios, Fabricantes de Productos, Subcontratistas, etc., ordenando y coordinando la información en cada fase del proyecto, con el objeto de tomar decisiones, evitando el mínimo de errores o cálculos inesperados. El objetivo de este proyecto es la modelación de la ingeniería: hidráulica y sanitaria, para un edificio inteligente de 9 pisos utilizando el software REVIT, los resultados obtenidos fueron el dimensionamiento tanque de retención de aguas pluviales y la determinación de presiones disponibles (alta y baja presión). Se concluye que el uso de las herramientas BIM permitió desplegar vistas en 3D, evaluando una secuencia lógica a pesar de la complejidad de su uso.

Modelado de información para la construcción, Diseño, Ejecución, Proyecto

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Introduction

In the construction and building industry it is still common to carry out projects with traditional processes, although they tend to be very effective, they are not effective and efficient, usually presenting delays in delivery times, cost over runs and sometimes even project abandonment (Arcudia, *et al*., 2005).

The BIM methodology is revolutionizing the 4th Industrial Revolution and takes more and more a great importance in the field of civil engineering (Campos, 2019) thanks to the excellent results obtained with this tool, there are reflected in the minimum mistakes that are made, this methodology is able to identify and give solutions to design that are not visible with Auto-CAD tools, but if they are visible at the time of project execution.

One of the benefits of BIM is that it can be applied to any construction project, whether it is a building, roadway, dam, mining or environment project, to name just a few. Our case study focuses this methodology in the design and construction of hydraulic, sanitary and pluvial installations of the project called Toren 54.

In this work an analysis of hydraulic and sanitary engineering feasibilities is made, in order to show that BIM modeling together with REVIT software tools are compatible to be used in this and other projects related to hydraulic installations.

The goal is to create a project engineering for vertical housing, implementing the BIM (Building Information Modeling) methodology as well as processing the modeling information with Revit tool. The execution of BIM consists of the modeling of geometric elements duly parameterized, with the determination of making a series of layers of information, designed with a coordinated documentation for analysis and control information that carries each phases of the project in construction (Sánchez, 2017).

Justification

Currently, the vast majority of architectural projects in Mexico are developed with CAD (Computer Assistant Design) technology and other software that facilitate tools of design, this work methodology has been transcendent in recent years in construction, however most of the projects present inconsistences, cost overruns in the terms and contracts (Ocampo, 2015).

The solution that technological development is offering to all these problems the BIM (Building Information Modeling) methodology, which offers a control of the information generated, for example: designs and technical studies, construction and management, to name just a few some. In addition, BIM modelling allows simultaneous work between contractors, designers and administrators in a virtual way *(ibid).*

Applying this methodology in the Toren 54 intelligent social interest building project, it will be possible to observe how all the layers of information are integrated in the same model, in the other words, there is control over the critical points that would be generated with the traditional work progress program model.

Background

The origins of BIM modeling date back to the second half of the 20th century, but its first real applications in construction appear at the beginning of the 21st century. In the early days of computing, the first designs based on objects, parameters and a database related to a model appeared, for all this it was necessary graphic interfaces in order to interact with the project under construction (Rodríguez, 2015).

Today in countries such as the United States or Spain the use of BIM has had a great boom in both public and private sector projects reaffirming that BIM modeling has become a paradigm shift in all stages of the work (design, construction and operation) (Mojica & Valencia, 2012).

The implementation of BIM in each phase of the project allows the exchange of information and thus obtain prototypes in an efficient manner, where the performance and operability of the building can be observed (*ibid*).

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Theoretical framework

The BIM Methodology integrates technologies and processes with the purpose of modeling the information in an orderly manner, necessary for the development of an architectural, engineering and construction project, in addition to functioning as a database where information can be stored and shared, types of materials to be used, as well as their different construction systems (Farfán & Chavil, 2016).

The database that was generated and will be built in the Toren 54 project will be a guide for future stage in terms of: energy efficiency simulation, work progress program, to name a few. The benefits that BIM offers is that it models three-dimensional objects that allow automatic editing, in addition to this, the construction of the project is made from materials that have different, physical, chemical, mechanical and manufacturing characteristics (Jobim *et al.,* 2017).

BIM Modeling in European and Latin American Countries

The United States has implemented the BIM philosophy in public and private sector projects, proving that BIM has become a methodology in the different layers of the work (design, execution and operation).

On the other hand, the United Kingdom worked on a much more ambitious project in the implementation of the BIM methodology, which consists that from 2016 all public works projects will be executed with BIM.

Nevertheless, in Latin America the Building Information Modeling (BIM), there is little clarity about it, factors such as resistance to change, lack of training to obtain seek in BIM, notwithstanding the benefits provided by the implementation of BIM in construction projects (Ocampo, Hurtado, 2015).

Methods and materials

The virtual modeling was done throught the Revit 2019 computer program starting the analysis and design with the constructive architectural building plan of the Toren 54 in CAF format, this plan only contained architectural information which was verified with field visits that allowed to corroborate actual measurements and dimensions, in addition to defining the types of materials, storage tanks, grids, pumping and fire systems, as well as the structural design to avoid as little an possible the obstruction of plumbing and hydraulic installations.

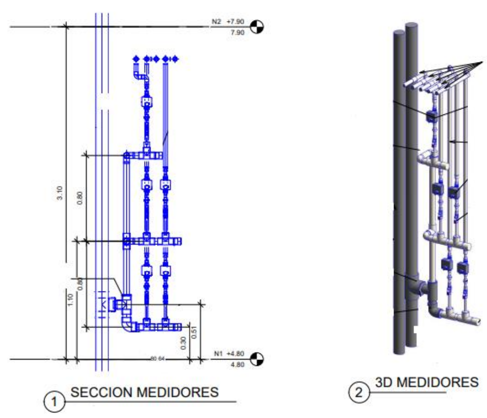

Figure 1 Meter lines
Source: Díaz Candelario, 2022

Hydraulic and sanitary installations in a house is related to "plumbing" works and is defined as the art of installations pipes, accessories and other pumping devices and equipment to carry and discharge water supply (Enriquez, 2000).

From this definition it is established what is a plumbing system that includes: distribution pipes for waters supply, fittings and traps, ventilation pipes, sanitary and rainwater drainage, including devices and connections inside the building with the exterior.

The hydraulic installation is a set of pipes and connections of different diameters and materials, with the purpose of supplying and distribution water inside the construction (Pérez, 2005).

This installation will supply water to all points and places of the Toren 54 architectural project that require it, so that it reaches both in quantity and adequate pressure to all levels and equipment of the apartments such as: furniture, sinks and drains.

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Our project to be executed is located on Guadalupe Avenue and Pintores Street, in the municipality of Zapopan, Jalisco. The paradigm shifts to be followed is to promote vertical housing in a sustainable and ecological context, catching rainwater and storing it in retention tank according to the design capacities, as well as a cistern proposed and designed for a capacity of 60 m³.

Drinking water supply systems in buildings

All housing developments to be planned in Guadalajara city must have an Integral System for the supply of drinking water, which must satisfactorily serve its inhabitants, as well as the various existing and/or planned municipal and industrial uses, with an efficient service and adequate domestic supply, for its various urban facilities and the areas intended for commercial, industrial and service use (SIAPA, 2000).

The most common systems used to supply water to a building can be classified as follows:

- Direct supply systems.

- Combined and pressure supply systems.

Direct supply system

In order to supply cold water directly to every piece of furniture in the building, it is necessary that the building is of low height and that the municipal network has sufficient pressure, so that it reaches the furniture of highest levels, which in our project the maximum 117 ft, this will be achieved with the necessary pressure from the household tap, as well as maximum efficiency available in the equipment and pumping sumps.

To be sure that the water reaches the highest levels and that the equipment works efficiently, it is necessary to measure the gauge pressure at the highest point of the building or open the check valve and that the water column freely reaches a height of 6.56 feet column water.

Combined supply systems

A combined system is designed when the pressure of the network is not enough to reach apartment, therefore there is the possibility of building cisterns or storage tanks in the lowest part of the building (basements).

Once the design and location of the cistern or storage tank of the Toren 54 project proposed, which are located in the basement by means of an auxiliary system, water is elevated to the maximum height level, to be distributed by pumping to all levels and furniture in a particular or general way, depending on the type of installation and/or service.

Pressure supply system

The pressure supply system is more complex and depends on the characteristics of the building, type of service, volume water required, pressures, simultaneity of services, number of levels, number of furniture, characteristics of the latter, etc. They can be solved by means of hydro pneumatic equipment.

Figure 2 Cross section of the Toren 54 project
Source: Díaz Candelario, 2022

Sanitary installation

The sanitary installation can be defined as a system from which wastewater from building is discharged to the most appropriate place such as septic tanks and/or the municipal network. The objective is to safely dispose of the wastewater in a way that meets the requirements of the corresponding standards and regulations of the place where it is being installed.

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The specifications can be consulted in the descriptive memories of the project, as well as the calculation memories, of course these must comply with the corresponding standards and regulations of each region of the country, which in our case are based on the Building Regulations and the Complementary Technical Standards for Hydraulic Installation (NTCIH) of Mexico City (DGCOH, 2010).

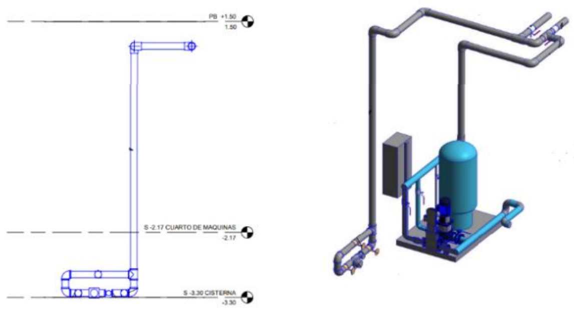

Figure 3 Pressure regulator seen in 2D y 3D, designed under BIM-REVIT modeling
Source: Díaz Candelario, 2022

Characteristics that a sanitary installation must comply with

The design that a sanitary installation depends on the flow rate and discharge pressure of each furniture. In order to have a good performance in an installation it is necessary to comply with certain requirements.

a) Types of materials

The sanitary rooms must have waterproof and non-slip floors and walls.

b) Pipelines

The diameters of the drainage pipes must not be less than 1¼ in, nor less than the drainage mouth of each piece of furniture, and they must be installed with a minimum slope of 2‰. The pipes that carry wastewater to the outside of a property must be at least 8” diameter.

The sewers must have registers greater than 4” between each one and change of address of each sewer. The sewer is the horizontal conduit into which the rainwater downspouts flow, so smooth pipes should be used, as well as a minimum slope of 2‰ as indicated in the previous paragraph.

For great buildings, the same diameter of the pipe that as the sewer is adopted, in addition, the service connection may or may not have a general siphon, this will depend on those being applied for the design of the plumbing installation, so the records must be from 15 * 24 in for depths up to 1 yd., 20 * 28 in for depths more than 2 yd.

Sewage and rainwater downspouts

The downspouts will be made of smooth materials, supported on a masonry pillar and fastened to a wall at separations @ 2 yd. by means of clamps.

The downspouts will be as straight as possible with their respective speed reducer @ 5 yd. by means of clamps. The joins with the branches and the horizontal sewer must be made with 45° angles. For reasons of economy, the number of sewage downspouts should be as small as possible, so it is advisable to overlap bathrooms, sinks and other sanitary services on successive floors so that they can be served by the same downspout.

Results

Applying the BIM methodology to the Toren 54 intelligent and sustainable building project and measuring the proposed objectives results in a virtual model containing information corresponding to the design of hydraulic, sanitary and rainwater installations. The methodology employed and used trough the REVIT software represents information a 3D model in floor and elevation plans as shown in figures 1, 2 and 3.

The hydraulic installations model was projected by modeling the nine levels, as well as verifying on site the ducts, position of high and low pressure piping, hydrants panels, records, etc. as shown in figures 4, 5 y 6.

Drinking water supply

For the calculation of the potable water supply, the different types of buildings indicated in the project data should be considered being the average amount necessary for a person to cover his or her basic daily needs.

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In certain developments destined for residential areas with special characteristics, another enough supply may be determined as deemed appropriate by Intermunicipal Drinking Water and Sewage System (SIAPA) and with prior justification by the calculator.

The water supply for the Toren 54project is considered medium, due to a lack of hydraulic coverage by the municipality and its added value that is considered water supply marked by the SIAPA and CONAGUA of 300 lt/hab/day, it turns 4 apartments for floor plus two apartments in pent-house were projected, estimating approximately 150 people in the intelligent building of nine floors, so the average consumption of the Toren 54 building is equivalent to 16425 m³ by year and 1638 by month.

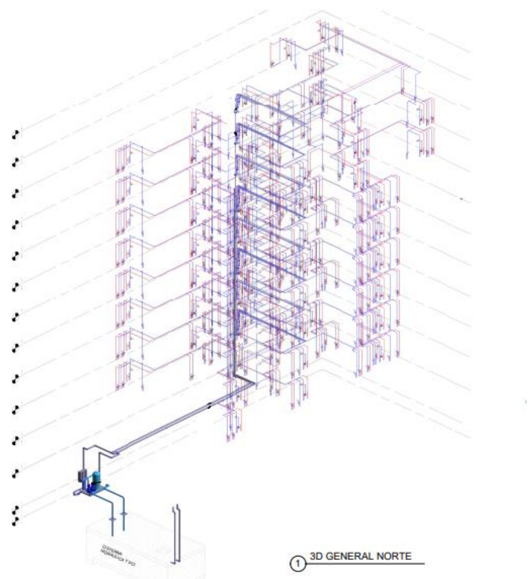

Figure 4. 3D isometric of the hydraulic installation of the Toren 54 project, displayed in BIM-REVIT
Source: Díaz Candelario, 2022

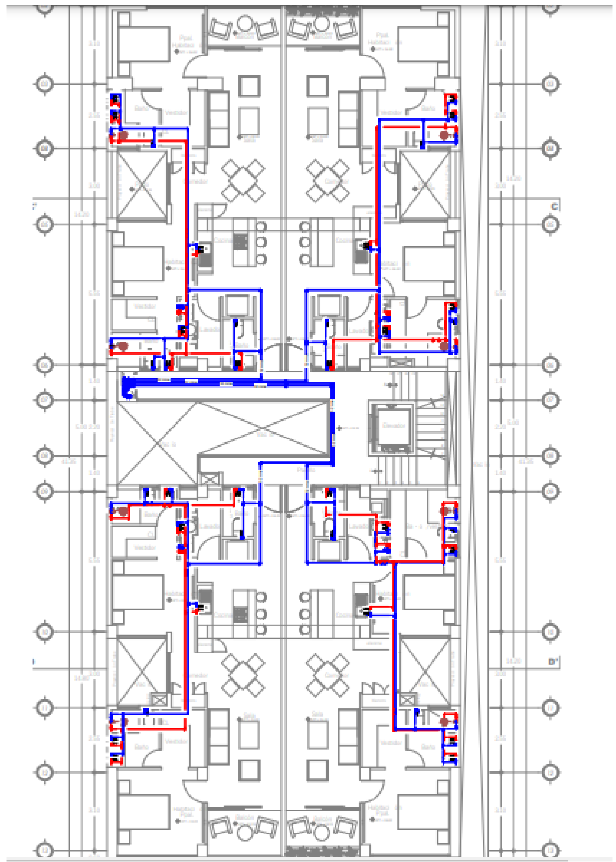

Figure 5 Architectural plan of the Toren 54 project, as well as the placement of furniture hot and cold water pipes
Source: Díaz Candelario, 2022

Design flows

The design flow is the amount of water required to meet the needs of the population in an average day of consumption. The expression that defines the average flow is as follows:

$$Qmed = \frac{Pob * Dot}{86400} \quad (1)$$

$$Qmed = \frac{150 * 300}{86400} = 0.520\ lt/seg$$

Maximum daily flow

This flow is used to calculate the daily extraction from the supply source, the pumping equipment, the conduction and the regularization and/or storage tank, it is obtained from the following expression:

$$Qmd = CVD * Qmed \quad (2)$$

$$Qmd = 1.4 * 0.520 = 0.730\ lt/seg$$

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Maximum hourly flow

This flow is required to satisfy the needs of the people on the day and at the time of maximum consumption. It is used to calculate the distribution networks and in some cases for the pipelines and is obtained from the following expression:

$$Qmh = CVH * Qmd \quad (3)$$

$$Qmh = 1.6 * 0.730 = 1.166\ lt/seg$$

Calculation of pump power

Once the maximum hourly flow has been determined, as well as the difference in level to be overcome by the pump itself, the pump power formula is applied, which is as follows:

$$P = \frac{\gamma\ Q\ Hb}{76\ \eta} \quad (4)$$

$$P = \frac{1000*1.116*38.75}{76*0.70} = 0.850 \text{ HP}$$

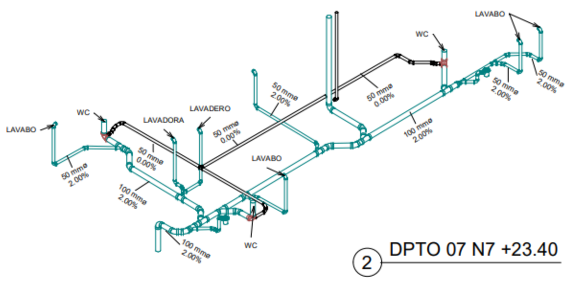

Figure 6 Isometric installation, including sinks, drains, and downspouts
Source: Díaz Candelario, 2022

Conclusions

The information is the most importance in the development of the BIM methodology, that is why it is very clear from the project planning to start collecting, organizing and analyzing quality information in order to establish the necessary guidelines for the whole modeling process and the logical development of the project.

In this way, quick access to information is achieved and there is an order in the entire work progress program that facilitates communication with the purpose of making the most of the BIM methodology and thus achieve more than a simple 3D model.

The REVIT software is not BIM, but it is part of the methodology that allows transforming the information into a virtual model, this makes it necessary that the knowledge and handing of the tool is adequate.

For our project we modeled with REVIT software, which allowed us to observe and solve mistakes in the pipes and in the design of plumbing installations, such as location of panels, valve connections, etc. Avoiding as little as possible the shock with the concrete structures (beams, footings and columns).

Being able to identify and solve these types of problems in the virtual model is what makes the BIM methodology totally innovative, since avoids altering the estimated time and costs when the work is being executed.

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