Salahaddin University-Erbil

College of Engineering

Surveying (Geomatics) department

“Control the verticality of skyscrapers buildings and estimations using total station”

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Certification of the supervisor:

I certify that the engineering project titled “Control the verticality of skyscrapers buildings and estimations using total station” was done under my supervision at the Geomatics (Surveying) Engineering Department, College of Engineering-Salahaddin University-Erbil. In the partial fulfillment of the requirement for the degree of Bachelor of Science in Geomatics (Surveying) Engineering.

Dedication

In the name of GOD, the most beneficent, the most merciful, we would like to express our heartfelt gratitude to our parents, who have been unwavering pillars of support throughout our academic journey and have consistently encouraged us to pursue our passions. Without their love, guidance, and sacrifices, this project would not have come to fruition. And thanks to all other Doctors, Mentors, and Lecturers, as well as our Dear Friends.

To the Geomatics (surveying) engineering department especially for our lovely and friendly lecturer Bakhtyar Ahmed Mala who supported us and tired with us.

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Year: 2023-2024

Abstract

As-built created by surveyors, architects, contractors, or a professional as-built surveying company. Surveyors are in charge of measuring the land and producing an intricate drawing that precisely depicts the current state of affairs. As-built drawings are sometimes produced by architects, especially for remodeling or restoration work. To make sure that their work complies with the design and requirements stated in the plans, contractors could be engaged in the creation of as-built drawings. There are also expert As-Built surveying firms available to relieve architects of this task. These businesses might provide drawing services, surveying services, or both.

As-built surveys are important for both commercial and residential properties. They provide accurate measurements and drawings that can help ensure that buildings meet safety standards and that projects are completed with worry-free timeliness and accuracy. In construction projects, “as built” drawings are used to track the many changes from the original building plans that take place during the construction of a building. As-built drawings are an important part of new construction, renovation, and maintenance.

Before starting any construction project, it’s important to know what the built drawings are used for, what information they include, how they are created, and how much the tolerance of deviations is. As built drawings are necessary to record these changes and maintain an accurate representation of the building as it actually exists, especially for commercial construction projects. As built drawings are created using a CAD software (Computer-aided-design) like AutoCAD and Civil 3D or a BIM software (building information modeling) such as Revit.

In this project, we used the reference coordinate system method to redraw the five floors of these buildings. And we used the total station Leica TS15 robotic instrument in order to get the coordinates of columns and shear walls. And we use the aiming method to control the verticality of buildings.

We have reached the amount of deviation between the six coordinates on each floor and the concrete volume of columns, shear walls, slabs, and beams.

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1 Chapter One:

1.1 Introduction

The as-built survey process involves conducting a survey of the completed construction project to create accurate and detailed as-built drawings.

As-built drawings are a set of plans created in preparation for a renovation or remodel and are an important starting point for all stakeholders involved in the completion of the project. These plans document any changes or modifications made after the original construction plans, including modifications made to the property throughout the years. They reflect the actual conditions of the project site and are created by surveying the property and taking precise measurements.

It is important to remember that As-built drawings provide an accurate representation of a building as it stands before any planned remodeling has begun.

1.1.1 Three types of as-built drawings:

Architectural As-Built Drawings:

These drawings include floor plans, elevations, and sections that show the layout of a building's interior and exterior. They provide accurate measurements and details for floors, walls, windows, and doors.

Structural As-Built Drawings:

Structural as-built drawings show the layout of a building's structural components, including columns, beams, framing, and foundations. They ensure that the building is structurally sound and up to code.

MEP As-Built Drawings:

MEP as-built drawings show the layout of a building's mechanical, electrical, and plumbing systems. In many cases, architects will need to address immovable MEP or consider what MEP might need to be moved to implement a new design along with understanding the cost of doing so.

As built drawings are created using a CAD software (Computer-aided-design) like AutoCAD and Civil 3D or a BIM software (building information modeling) such as Revit.

1.1.2 Difference between As-Built Drawings and Design Drawings

Design drawings, often the first visual representation of a project, are preliminary sketches and plans meticulously crafted by architects and engineers. These drawings encompass a range of details, from broad conceptual ideas to intricate specifications, all aimed at bringing a vision to life on paper. Design drawings provide the necessary details, ensuring the proposed structure adheres to zoning laws, building codes, and other regulations.

As-built drawings are created post-construction, capturing the building exactly as it was built. Unlike design drawings, which represent an idealized version of the project, as-built reflect the reality of construction, including any changes or deviations made during the building process. As-built drawings capture these nuances, detailing the exact materials used, dimensions, and any deviations from the original design drawings. As-built drawings are not just good practice, it's a legal requirement. These drawings ensure that any changes made during construction are documented, protecting stakeholders and providing transparency for future inspections or sales.

Understanding the distinctions between design and as-built drawings is more than just an academic exercise. These differences have real-world implications that can affect the legal standing, maintenance strategies, and financial aspects of a construction project.

1.1.3 What are as built drawings used for?

In any building project, detailed plans are vital for success. Over the course of a project, features of the building are likely to change as the contractor faces obstacles with materials, the site, or governmental agencies. As built drawings are necessary to record these changes and maintain an accurate representation of the building as it actually exists, especially for commercial construction projects.

As built drawings have different uses for new construction, renovation projects, and building maintenance.

- **New construction:** When constructing a new building that previously existed only on paper, contractors will face numerous challenges and must adapt their building plans in response. These drawings record these changes while construction is happening so that an accurate drawing of the building exists when construction is completed.

- **Renovation projects:** Before starting a renovation project, it is important to have a detailed understanding of the building as it currently exists. Therefore, working with up-to-date drawings is essential for a safe and efficient renovation.
- **Building maintenance:** Over the course of a building's lifespan, small improvements and changes will be made. A building's maintenance team is expected to update drawings to reflect any changes to the building so that an accurate drawing of the building exists at all times.

1.1.4 What should be included in as built drawings?

In order to have complete and useful as built drawings, it is important to include any changes to the following elements:

- **Locations:** Note all changes to the location of doors, window casings, plumbing, millwork, and any other essential features.
- **Materials:** Record all differences in materials used when changes are made from the original plan.
- **Dimensions:** Write down all modifications to the dimensions of all building elements.
- **Installations:** List specific alterations made to installation of building features like HVAC, electrical, or windows.
- **Fabrications:** Log all updates made to fabrications including columns, beams, and handrails.

One important note is that as built can also include supplemental documents, written notes, and pictures, including photographs or satellite imagery.

1.1.5 How are as built drawings created?

In order to create excellent as built drawings, it is essential to make sure you know who is responsible for creating them and what process to use when creating them.

It's important to know that as built drawings nowadays are most often created with construction technology and software like AutoCAD, which enables all stakeholders to have accurate plans of the building at all times.

Most often, the contractor responsible for construction will create the drawings for a project. Although an architect may sometimes be involved, this is less common, as they are not on the project every day to oversee the building process. Because the contractor is on site while the building is constructed, they are able to make frequent updates to the building plans as soon as changes are made.

When creating as built drawings, it's helpful to keep the following process in mind:

- **Color coding:** As built drawings use a standard color legend, with red for deleted items, green for added items, and blue for special information
- **Scale:** It is vital that any modifications made on drawings keep the same scale and proportions as the original plans.
- **Dates:** Any modifications that are noted on building plans should be dated and include supplemental documentation if necessary.
- **Obstacles:** All obstacles encountered along the way, whether due to environmental factors, governmental agencies, or anything else, should be included along with drawings.
- **Physical features:** While construction with earthmoving equipment is taking place, take special care to note any updates to elevations, grades, or other physical features that were discovered or changed during the construction process.
- **Underground utilities:** Make sure to note exact locations of underground utilities that are installed during construction.

1.1.6 Importance of As-Built Drawings

As-built drawings are essential in construction projects for the following reasons:

1. As-built drawings provide precise details about the changes performed at any interim stage of the project. It facilitates easy visualization of the upcoming steps, notice complications, and early solving of issues.
2. As-built drawings provide details of installations to the owners and clients to help them with any future modifications of the structure.
3. As-built drawings are valuable documents that provide future buyers with a clear idea of what is sold and purchased. It also forms a foundation to conduct future modifications.

1.1.7 Who creates As-Built Drawings?

Engineers and designers prepare the original drawing plan which serves as a base for an as-built drawing. However, final changes are made by the contractors as they are better aware of all the alterations made during the construction process.

A contractor must record all the changes made on the original drawing and is fully accountable for the actual construction. A systematic record of changes in the form of as-built drawings can help to avoid future disputes.

1.2 Aim of the project

As built surveys serve as a record of any changes or variations made throughout a construction project. The aim of this project is to show how many deviations there are in the construction of this building and how much the total concrete volume of columns, beams, and slabs is.

The aim of this project is to discuss about the how to prepare a document about this construction and discuss whether they did a good job or not.

The aim of an As-Built project is to accurately record and depict the project's final stage of construction, including any variations from the initial blueprints or plans. Usually, the introduction states the goal of the As-Built documentation and stresses the significance of correct records for compliance, maintenance, and future reference. Additionally, it might highlight the important project participants and their responsibilities for guaranteeing the authenticity of the As-Built documentation.

Sure! Creating updated documentation that reflects the real circumstances and modifications made during construction is the main goal of an As-Built project. It facilitates maintenance and upcoming modifications, ensures compliance with legislation, helps in comprehending deviations from the original plans, and acts as a reference for all parties engaged in the project's lifecycle.

Establishing the context and outlining the significance of precise As-Built documentation for the project's lifespan and success, the introduction sets the tone. It frequently highlights how these records improve decision-making, lower error rates, and increase project quality and transparency overall.

In As-Built construction, the purpose of using a Total Station TS15 is to precisely measure and document the positions, physical measurements, and variations of produced items from the original drawings or plans. This cutting-edge surveying tool makes it possible to create thorough As-Built records by ensuring high precision and thorough documentation of the built environment. With the help of the TS15, construction experts may more accurately generate representations of the actual built structures and systems by recording data points, measurements, and 3D coordinates. This data is essential for confirming compliance and enabling upcoming changes. Any upgrades, as well as keeping precise records throughout the project's duration.

1.3 Structure of project

In chapter one, we discussed the introduction of as-built drawings. We talked about what's the type of as-built drawing? What's the difference between as-built drawings and design drawings? What are as-built drawings used for? What should be included in the as-built drawings? How are as-built drawings created? What's the importance of as-built drawings? Who creates as-built drawings? And the aim of the project.

In chapter two, we discussed the literature review of as-built drawings. We read eight papers about as-built, and we wrote what we understood.

In chapter three, we discussed the methodology of as-built drawings. We discussed the procedure of the as-built survey. We talked about the location of the project and company. What is the instrument used? What's the specification of our instrument? And we talked about the reference line and the procedure for it. And we discussed the coordinate system and what's the procedure to create our coordinate system. We talked about the control points and the data that we collected. Finally, we talked about a very important way to control the verticality of a building using a total station.

In chapter four, we discussed the results and discussions of as-built drawings. As a result, we showed the as-built redrawing of five floors. And we talked about how to do the estimation of columns, shear walls, slabs, and beams and how to calculate the area and volume of columns, shear walls, slabs, and beams. In our discussions, we discussed the total concrete volume of columns, shear walls, slabs, and beams. And we showed the deviation of six coordinates between five floors according to the ground floor.

In chapter five, we discussed the conclusion of as-built survey drawings.

2 Chapter Two:

2.1 Literature Review

This chapter includes some research on related our project that reviewed and then were written a short summary for each research.

Researches related to the topics:

As-built schedules are crucial for highway construction projects, as they represent the actual sequences and durations of construction activities, taking into account change orders and schedule changes from the originally planned schedule (Jeong, December 2017)They are essential for ensuring project completion within contract time, verifying contractors' progress reports, identifying delays, validating contractors' claims for delay compensation, and aiding inexperienced schedulers in developing schedules for new projects (Jeong, December 2017). Existing commercial scheduling systems have limitations in collecting data for as-built schedule development throughout the project duration. Previous studies have focused on either manually developing as-built schedules using unstructured data or developing a customized data collection system.

(Jeong, December 2017) in their study identifies four types of as-built schedules based on the time and detail level of the schedule. The framework for automatic as-built schedule development consists of five components: database development, project selection, data processing, project performance evaluation, and visualization. A dataset is obtained from an existing DWR (durable water repellent) system, and a project is selected for as-built schedule development. A computational algorithm, As- Built Schedule System (ABSS), is developed with an MS Access database and a Visual C#.NET frontend. The framework is validated using a DWR (durable water repellent) dataset from an anonymous SHA's AASHTOW (American Association of State Highway and Transportation Officials)are Site Manager data-base, which contains 646,488 records.

The importance of as-built schedules is widely recognized, but there is a lack of distinction of various types of as-built schedules and a computational methodology to generate such as-built schedules using existing data (Jeong, December 2017). (Jeong, December 2017) in their study introduced the concept of four different types of as-built schedules; a) as-built schedule to date, b) final as-built schedule, c) project level as-built schedule, and d) activity level as built schedule. The study has identified Daily Work Report data as a rich bu.

Developing a computational algorithm to automate as-built schedule development using digital daily work reports involves parsing the reports, obtaining relevant data, comparing it to the project plan, and updating the as-built schedule repeatedly. In order to increase accuracy over time, the procedure usually calls for data analysis, machine learning, and natural language processing. The most recent information may be found by consulting recent papers or scholarly journals, as there may be continuing study or breakthroughs in this topic.

Data collection: Compile electronic daily work reports that show the precise status and tasks accomplished on a building project.

Data Parsing: Utilize algorithms to extract pertinent data from these reports, including completed tasks, deadlines, resources used, and any timetable deviations.

Comparison with Planned Schedule: To find inconsistencies, delays, or changes made during the project's execution, compare the retrieved data with the original project schedule.

Development of Algorithms: Create an algorithm that makes use of this information to update the as-built timetable automatically, taking into consideration any modifications or delays that are seen in the project's advancement.

Iterative Improvement: Use machine learning or iterative procedures to make schedule modifications and learn from historical data in order to continuously improve the algorithm's accuracy.

(Su, April 2018) In their study presents a Final As-built BIM (building information model) Model Management FABMM (Fractional Adams-Bash forth-Moulton Method) system for owners to handle final as-built BIM (building information model) model inspection, modification, and confirmation BMIMC work beyond project closeout. The system addresses practical problems such as model mismatch, lack of available models, and incorrect non- geometric information. The system was applied in a Taiwanese building to verify its effectiveness. The study identifies benefits, limitations, and suggestions for its further application.

The accuracy of final as-built BIM (building information model) models is crucial for facility management FM practices in Taiwan. Owners must confirm the correctness of these models during the construction phase, as it is difficult to handle FM services without the correct models (Su, April 2018). In Taiwan, there are many problems with obtaining correct as-built models, such as error model developments, model mismatch, and model without accurate information.

(Su, April 2018) In the study aims to develop a management system that enables inspectors to ensure the accuracy of final model modifications beyond project closeout. The main purposes of this work are to propose a framework for enhancing final models' management and develop a system for managing the accuracy of final models effectively beyond project closeout.

The study focuses on improving the accuracy of as- built BIM (building information model) models by utilizing a FABMM (Fractional Adams-Bash forth-Moulton Method) system. The system aims to automatically inspect non-geometric information, which is often manually entered and uninspected by laser scanners. The case study examines a new building project in Taiwan, where the system enhances the accuracy of final models beyond project closeout.

(Kala, January 2009) In their paper explores using photogrammetric image processing to document and verify as-built conditions. A university building's interior and exterior dimensions are compared to automated image processing, and strategies for improved accuracy are explored. The potential of image-based spatial data is assessed for 3D model generation.

- We test manual and image-based dimension verification surveys of existing building.
- We assess the image-generated 3D spatial data for 3D model generation.
- Image-based verification detects errors exceeding 5% in as- built BIM model.
- Image-based verification reduces on-site work and improves building accessibility.

As-built models and drawings are crucial documents used in the operations and maintenance of buildings, managing facility spaces, equipment, and energy systems. In the United States, only two to three percent of new construction occurs annually, and approximately 87% of current buildings will remain operational by 2050. Inefficiencies in processing, communicating, and revising these documents result in high costs for building owners, with an estimated $1.5 billion wasted annually due to unavailable and inaccurate as- built documents. Solutions are being investigated to improve the capturing and communicating of building information critical to operations and maintenance. Building Information Models (BIM) are one promising approach to improving as-built information management, reducing mismanagement and improving information access and presentation.

The 3D scene reconstructed for the building exterior included 41,235 automatically generated points and 104 stitched photos, with 72% of the photos unsuccessful. The remaining unstitched 28% were from the eastern half of the southern facade. The image-based survey had limitations like reduced accuracy and difficulties in image stitching with repetitive building elements and site clutter.

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(Kala, January 2009) Permitting deviations in position points, focusing on three groups: earthwork without specific accuracy requirements, earthwork subject to normal accuracy requirements, and in situ cast concrete structures focused by (Kala, January 2009) research. The setting out error should not exceed 1.5√Lm mm, and the farther the position point from the control point, the larger the permitted deviations from the measurements. The paper proposes an alternative approach by focusing on the location of control points and selecting appropriate equipment and technology to ensure accuracy. The paper also addresses the question of which permitted deviations from construction works are most important and align with achievable and required accuracy.

It was assumed that secondary points at the erection level were carried out every time from the same primary point. In case it is impossible, it must be taken into consideration errors due to the initial data. At long last one should take into consideration errors due to the thermal expansion of construction, but they are not well researched yet.

(panel Ankit Bhatla, December 2012) In their paper reviews the-state-of-the-art optical spatial data collection technologies and examines the accuracy of photogrammetry for developing as-built or as-is 3D models of infrastructure projects. The United States (US) economy is heavily dependent on its network of roads (4,059,302 miles of public road) and bridges (3697 million square feet of bridges in 2008). However, the repair and maintenance of this infrastructure are capital intensive and hence a major portion of this network is in a depleted state. Poor roadway conditions are also a significant contributor to traffic fatalities as they account for approximately one-third of total traffic fatalities. There are various plausible alternatives to reduce roadway congestion such as: building new facilities, such as roadways, interchanges and bridges, or expanding the capacity of current facilities. Taking the case of bridges in the US, 27% of bridges were found to be either structurally deficient (12.1%) or functionally obsolete (14.8%) [2] While 18% of bridges were structurally deficient or functionally obsolete in Texas. AASHTO in 2008 estimated. An under-construction bridge located in southern United States was used as the test project to assess the accuracy of photogrammetry for use in modeling highway infrastructure projects. The structure is a 2000 ft. long cable stayed steel bridge and it is scheduled for completion in March 2012. This project was chosen because it has characteristics that are typical of a highway infrastructure project.

This paper investigated the use of an off the shelf photogrammetry software package to model an under-construction bridge in southern United States to study the accuracy of the process for progress monitoring and infrastructure asset management purposes. The bridge was divided into 5 sections for modeling purposes. Although this technology is promising, the results indicate that in its present form it is not suitable for modeling purposes.

Finally, the range of tolerance and deviation of element dimensions is determined by comparing the photo-based model to the actual as-built model. Results show that this technology in its present state is not suitable for modeling infrastructure projects.

(Magdalena Turek, April 2023) Five surveys made with different measuring methods were analyzed in this *paper* (Magdalena Turek, April 2023) For this purpose, they obtained the data from the Tarnow district office based on a request for access to data were used. The data was filtered in terms of content using the necessary information for the purpose of the work. Three surveys of low-voltage connections using the total station method, one survey of medium- and low-voltage network and transformer station using the GNSS method were used. To illustrate the work using the indirect method, one inventory of the internal low voltage cable line located with the help of cable locator and frozen with GNSS method was used. Sketches and text files from the above-mentioned survey were also used.

The required measurement accuracies are 0.05 m (building structures and facilities and field-marked pickets); 0.02 m (sewer lines and facilities) and 0.10 m (earthen structures, flexible or electromagnetically measured underground land development network facilities and non-field-marked pickets.

In the case of the tacheometric method specific difficulties are dense buildings, which force the creation of polygonal sequences, which increases the time-consumption and the risk of errors. And also, atmospheric conditions that affect visibility, too much or too little sunlight, obstructions of visibility, smoke, dust or haze and rainfall, snow and high temperatures that create the phenomenon of mirages.

In this paper, inventories of low and medium voltage networks were analyzed. In the case of low-voltage cable lines, measurements can be made on live cables, while in the case of medium-voltage lines, measurements should only be made when the line is de-energized. Be careful not to damage the insulation of the cable with the tip of the pole. In addition, medium voltage cables are located at greater depths than low voltage cables. In the case of overhead lines of both low and medium voltage you must take special care not to touch or come too close to the pole which can cause an electric shock. For example, on low-voltage lines, the lowest voltage devices are the pole disconnections, which are installed on poles 3.2 - 3.5 m above the ground.

(Laura Klein, February 2014) In their study therefore addresses the advantages and limitations of commercial semi-automated photogrammetric image-processing software for the verification of interior as-built documentation. The image-based spatial data is used to assess the accuracy of an existing as-built BIM model currently undergoing verification by the University Of Southern California (USC) after the design and construction phase handover. Image based dimensions are compared to dimensions gathered through a traditional manual survey of two classrooms to assess the accuracy of the proposed method for capturing the complex interior environments of occupied buildings.

Pictures were taken with a fixed focal length using an off-the-shelf 8.0 mega pixel digital camera. Photographs were planned to optimize views of all critical geometry and building elements such as wall openings and floor and ceiling corners. A total of 130 images were acquired for the two interior rooms in a single session.

Two separate 3D scenes were reconstructed for the two interior rooms captured in the test bed. In the final 3D scene used to verify the as-built dimensions of Room 206, 60 of 67 photos were successfully stitched together, representing 89% of the attempted reconstruction. Resulting from the automated stitching process, 9,055 3D points were computed. An additional 18 3D points were modeled manually to aid in 3D coordinate and dimension extraction. For Room 207, 60 of 63 photos were successfully stitched, representing 95% of the attempted reconstruction. This high percentage can be attributed to the existence of posters and other feature points on the walls of Room 207 not present on the walls of Room 206. A total of 10,081 3D points were automatically computed and 22 points were manually modeled for Room 207. The percent errors of 7 image-based dimensions in Room 206 and 14 image-based dimensions in Room 207 exceeded 2% although the average percent errors in each room were close to the 2% threshold. The maximum absolute errors and maximum percent errors reported in Table 1 do not represent the same dimensions. In each room, the door widths saw the greatest discrepancies between as-built conditions represented in the existing BIM model and the true as-built conditions with percent errors exceeding 10% and absolute errors exceeding 10 cm. The manual survey also found the as-built BIM dimensions of the windows in both rooms to differ by 2 to 4% or 4 to 6 cm.

The results of the manual survey to verify the existing as-built BIM model revealed that true as-built conditions can differ by more than 10% from interior as-built documentation. This finding supports the need for improved methods for efficiently and automatically verifying as-built drawing and models. While work must still be done to improve image acquisition and image processing for complex environments such as the interiors of operational buildings, the image-based reconstructions of both interior rooms came close to the 2% standard threshold dictated by current FM practices. Even more, the greatest geometric errors found in the existing as-built BIM model through the manual field survey, the door widths in both classrooms, were also detected through the image-based survey. The proposed image-based survey method offers potential advantages to the currently employed manual survey method including: less time and labor spent on-site, increased accessibility to building geometry and features beyond the limits of traditional measuring devices, and the simultaneous generation of both 2D dimensions and 3D spatial data. These opportunities should motivate further research in remote sensing technologies, including automated photogrammetry, for capturing and verifying operational building exteriors and for automatically generating as-built documentation.

3 Chapter Three:

3.1 Methodology

3.1.1 Introduction

For our project "Control the verticality of skyscraper buildings and estimations using total station," we chose Candle Residence and the Hotel Kaminski project at Candle Company for performing estimations and practical work.

In the section below, we talked about this company and this project.

First, we have to rebuild the design; that's called as-built. In the section below, we talked about what the as-built and the procedure of as-built are, and what is the importance of as-built drawings? And what to include in as-built drawings?

Then we talked about reference lines because the as-built survey process can be strengthened by creating and using reference points, which provide accurate and reliable measurements in connection with a strong reference framework.

We started working with Leica Viva TS15 Total Station after we set up Total Station and then created our own reference and coordination system.

The goal of our work was to get the coordinates of the columns, that is, the X-Y columns. To see how many mistakes have been made in the installation of these columns or in the construction of these columns in the project, we take five floors since there were five floors completed in the project: the ground floor, the first floor, the second floor, the third floor, and the fourth floor.

The ground floor and the first floor consist of forty-seven Columns and nineteen Shear Walls, and the second, third, and fourth floors consist of thirty-one Columns.

We completed the ground floor on 24/10/2023. We completed the first floor on 26/10/2023. We completed the second floor on 28/10/2023. We completed the third floor on 30/10/2023 we completed the fourth floor on 1/11/2023. And we spent several days estimating the columns.

3.1.2 As-built

As built" refers to the final set of drawings or plans that reflect the actual construction or installation as completed on-site, incorporating any changes or modifications made during the building process. These documents are used to record the accurate details of the constructed project for future reference or maintenance.

As Built drawings are defined as “Revised set of drawing submitted by a contractor upon completion of a project or a particular job. They reflect all changes made in the specifications and working drawings during the construction process, and show the exact dimensions, geometry, and location of all elements of the work completed under the contract. Also called record drawings or just as-built”. By establishing and utilizing reference points, the as-built survey process can be more robust, ensuring accurate and reliable measurements in relation to a stable reference framework.

Performing an as-built survey with a Leica Viva TS15 total station in reference line mode involves several steps:

Setup: Set up the total station at an unknown position. Ensure the instrument is correctly leveled and oriented.

Figure 3-1: Total station set up

Establish Reference Line: measuring two or more control points with unknown coordinates to find the distance between two points and elevation of each point.

Figure 3-2: Establishing reference line on total station

Coordinate system: Assume the coordinate of the first point like (1000,1000), but for the second point we add the distance between two points to (X) or (Y) coordinate like (1000,1043.53) and we also record the elevation of both points. Enter these coordinates into the total station software. Then aim both points and store it.

Figure 3-3: Store two assumed coordinates

Set the total station: choose resection mode between two reference control points to set the total station.

Measure Points: after the total station set, we can measure points to get coordinate of points using reflector less (none prism).

Figure 3-4: List of measured points

Figure 3-5: measuring points

Distance measurement: measure the dimensions of columns and shear walls and measure the distance between of columns and shear walls by tape.

Figure 3-6: measuring dimensions and distances

Data Recording: Record the measured data in the total station's memory or directly transfer it to a computer for further processing.

Figure 3-7: Measure points using total station Leica TS15

Data Analysis: Process the collected data using surveying software to compute the precise positions of the measured points relative to the established reference line.

Documentation: Finally, generate reports, drawings, or documentation detailing the as-built conditions based on the collected survey data.
Finally, we get 289 points of ground floor, 295 points of first floor, 240 points of second floor, 236 points of third floor and 234 points of fourth floor.

3.1.3 Study area

3.1.3.1 Candle Company

For our project “Control the verticality of skyscraper buildings and estimations using total station,” we chose Candle Residence and the Hotel Kampinski project at Candle Company for performing estimations and practical work.

Candle residence and hotel Kampinski project: we chose Candle residence and hotel Kampinski project at the Candle Company for doing our project. The office of the company is located in Erbil, Kurdistan Region, Iraq, on Gullan Road (40m) opposite Park Sami Abdel Rahman, next to the Rotana Hotel in the AB center. The project is located in the most important areas of Erbil, in the Golden Square, between the Italian Village 1 and the English Village, opposite Park Sami Abdel Rahman, next to the Rotana Hotel. Built on approximately 25,000 square meters of land. a very luxurious and elegant residential project, using the best contemporary and modern architectural designs in its construction. In addition to using the best construction materials that are used in building the project, the project consists of four residential buildings, and each building consists of 40 floors, two commercial floors, and four floors of garages for cars. ***Click on the map to see the map of the project.***

Map of Candle Residence & Kempinski Hotel project

Figure 3-8: Design of Candle residence and hotel Kempinski project

3.1.4 Total station instrument

3.1.4.1 Total station:

A total station is an electronic or optical instrument used in modern surveying and building construction that uses an electronic transit theodolite in conjunction with an electronic distance meter (EDM). It is also integrated with a microprocessor, electronic data collector, and storage system. The instrument is used to measure the sloping distance of an object to the instrument, horizontal angles, and vertical angles. This microprocessor unit enables the computation of data collected to further calculate the horizontal distance, coordinates of a point, and reduced level of a point. Data collected from the total station can be downloaded to computers or laptops for further processing of the information. Total stations are mainly used by surveyors, either to record features, as in topographic surveying, or to set other features (such as roads, houses, or boundaries). They are also used by archaeologists to record excavations and by police, crime scene investigators, private accident Reconstructionist, and insurance companies to take measurements of scenes.

3.1.4.2 Leica Viva TS15 total station:

We use the Leica Viva TS15 total station for our project, and its models offer angle measurements of 3”. In prism mode, a distance of 3500m is achieved with an

Accuracy of 1mm on a single prism in standard measuring mode. On all surfaces, users can measure up to 1000 m and more with an accuracy of 2mm. We measure points only in reflector-less mode.

Specifications

Radius: 500m

Accuracy Hz, V: one second Display resolution: 0.1 mm

Method: absolute, continuous, diametrical

Compensator setting accuracy: 0.5 second

Table 1: Specifications of our total station (Leica Viva TS15)

Distance Measurement (Prism)	
Round prism	3500 m (12000 ft)
3 Round prisms	5400 m (17700 ft
360° prism	2000 m (7000 ft)
360° mini prism	1000 m (3300 ft)
Mini prism	2000 m (7000 ft)
Reflective tape	250 m (800 ft)
General	
Display resolution	0.1 mm
Shortest measurable distance	1.5m

Figure 3-9: Total station Leica Viva TS15 Robotic

3.1.5 Reference line

In surveying, a reference in total station typically involves setting up a known point with known coordinates, often referred to as a control point or benchmark. This known point serves as a reference for the total station, allowing surveyors to establish a coordinate system for their measurements. The total station then measures angles and distances relative to this reference point, aiding in accurate mapping and construction surveys. Reference lines are vertical or horizontal lines in a graph, corresponding with user-defined values on the x-axis and y-axis respectively. A reference line typically serves as a point of comparison or measurement in a given context, providing a standard or benchmark against which other things can be evaluated or understood. In various fields like engineering, statistics, or design, reference lines are used to indicate a specific value, boundary, or guideline.

Use reference lines to compare, reference, or measure against the data values displayed in the graph. It helps in orienting the instrument and ensuring accurate data collection. By establishing and utilizing reference points, the as-built survey process can be more robust, ensuring accurate and reliable measurements in relation to a stable reference framework.

When using a Total Station TS15, a reference line is established for surveying or construction purposes. The procedure involves several steps:

Setup Total Station: Place the Total Station in a suitable position with a clear line of sight to the area you're surveying.

Instrument Initialization: Power on the TS15 and perform instrument initialization to ensure accuracy. This includes setting the station over a known point if available or using coordinates to establish its position.

Targeting: Aim the Total Station at the point where you want to establish the reference line. This might involve sighting a prism or a reflector placed at the desired location.

Measurements: Take precise measurements to determine the position of the reference line. This might involve taking angles and distances from the Total Station to multiple points along the line or measuring the distance and angle between two known points.

Data Recording: Record the measurements and calculations in the Total Station's software or data collector. This information will help define the reference lines

Coordinates and attributes.

Verification: Check and verify the accuracy of the established reference line by taking additional measurements or using redundant methods to confirm its position.

Throughout this process, ensure proper calibration and adherence to surveying best practices to maintain accuracy in establishing the reference line with the Total Station TS15.

Figure 3-10: Views of reference point locations

3.1.6 Coordinate system

Creating a coordinate system using two reference points with a total station before measuring points of a building involves these steps:

1. Choose two points on the ground floor as a reference point for establishing coordinate system.
2. Use the total station to measure and record the precise coordinates (X, Y, and Z) of each reference point. To find the distance between two reference points and to measure the elevations of each reference points.

Figure 3-11: Measure the distance between two reference point

3. We use the distance between two reference points to add this distance to one of the coordinates of the second reference point.
4. Assuming the coordinates (X, Y) of each reference point, we assume that they are the coordinates of the first reference point (1000,1000) and the coordinates of the second reference point (1000,1043.53).

Figure 3-12: Assuming coordinates of reference points

5. Use the total station to store and record the two assumed reference points.
6. We can use resection mode on the total station to set the total station, and then the total station is connected to our reference coordinate system.
7. Finally, we can measure the points of each floor of this building by the total station Leica TS15 on our reference coordinate system.

Figure 3-13: Measuring by total station Leica TS15

3.1.6.1 Control Points

A surveying control point is a mark or monument that has an established horizontal and vertical position by way of being surveyed and is identifiable on the ground. Control points are established, managed, maintained and replaced by surveyors and are created at the start of any land development or civil construction project. Control points are very important and once established, need to be protected from being damaged or disturbed. If they do get disturbed and moved from their original surveyed position, a new survey will need to be completed to re- coordinate its new position. Establishing control points is one of the first things a surveyor would do on a new site. Without any survey control, a surveyor would not be able to complete their tasks. There is no rule for how many primary or secondary control points you need to have on a project. Where is the best place that we must put control points? Control point's must be putted on a place that you see in anywhere in the project. we putted two reference control points, the first control point on the bottom of first column of block A and second reference control point on the bottom of fifth column of block A, we use laser (none prism or reflector less) to put both of reference control points. Then I choose Resection mode and read the control points and set the total station. We started work to taking points by total station. Finally, we taken all points of columns and Shear Walls. We took it to the computer and put on the civil 3D to rebuild the design of block a building of five floors.

Figure 3-14: Establishing control points

3.1.7 Data collection

For the purpose of as-built, Control the verticality of skyscrapers buildings and estimations using total station, we measured points by total station Leica Viva TS15 robotic. We got the points within 10 days, two days for each floor and we spent6 days for estimation of columns, shear walls, beams and slabs. we got 1300 points of five floors in these buildings (block A) on Candle Residence and Hotel Kempinski project at Candle Company.

The number of points taken for each floor was as follows:

291 points on the ground floor

295 points on the first floor

240 points on the second floor

238 points on the third floor

236 points on the fourth floor

The difference between taking the number of points from one floor to another is that the ground floor and first floor consist of more columns and shear walls.

The ground floor and first floor consist of 51 columns and 19 shear walls, but we got 47 columns and 15 shear walls because, for some reason, we could not measure the points of a few columns.

The second floor, third floor, and fourth floor consist of 31 columns and 19 shear walls, but we got 30 columns and 15 shear walls.

The area of the ground floor is 4565.9579 m2.

The area of the first floor is 4562.4173 m2.

The area of the second floor is 2769.7669 m2.

The area of the third floor is 2775.6997 m2.

The area of the fourth floor is 2773.1085 m2.

The difference in height between the ground floor and the first floor is 5 meters; the difference in height between the first floor and the second floor is 4 meters; the difference in height between the second floor and the third floor is 3.1 meters; the difference in height between the third floor and the fourth floor is 3.1 meters; and the difference in height between the fourth floor and the fifth floor is 3.1 meters.

The thickness of slab was 0.22 m.

3.1.8 Another way to control the verticality of buildings

First set the total station, that is, you put on tripod and level the bubbles. The place you set it should not be very far from the buildings you are checking for verticality. Switch on the total station. You need not to set anything. Bisect the bottom of one corner of the building and clamp the alidade of the total station. Turn the telescope upwards as you sight through it. If the cross hairs move along the edge of the wall all along to top, then the building is vertical. But there may be small variations which are negligible e.g. deviations to left and right as you go up. But if there is a constant deviation to one side, then there is a problem with verticality.

This method is used to detect deviations to the right or to the left. And we have another method to detect the deviations, either forward or backward. That's how we do it.

First, set the total station; that is, you put on a tripod and level the bubbles. The place you set it should not be very far from the buildings you are checking for verticality. Switch on the total station. You need not set anything. Take the aim of the total station telescope to one corner of the first floor and measure the horizontal distance. Turn the telescope upward to the other floor, then measure the horizontal distance.

If the horizontal distance does not change from the first measurement to the second measurement, then the building is vertical. But if there are any changes in horizontal distance from the first measurement to the second measurement, there is a problem with verticality, either forward or backward.

The degree of verticality will depend on the structural design and loading of the building among other many factors such as the height. This should be provided by the structural engineer in charge. So, you can tell him to give you the error allowed as per his structural design.

Figure 3-15: While collecting data by Leica TS15 total station

3.1.9 Summary

As-built drawings are typically created by surveyors, architects, or contractors. Surveyors are responsible for taking measurements of the property and creating a detailed drawing that accurately reflects the existing conditions. Architects may create as-built drawings, particularly during renovation or remodeling projects. Contractors may be involved in creating as-built drawings to ensure that their work aligns with the design and specifications outlined in the drawings. Professional As-Built surveying companies also exist to take this work off of the hands of architects. These companies may offer surveying services, drawing services, or both.

4 Chapter Four:

4.1 Results

4.1.1 Redesigning

The result of an as-built survey conducted with a total station includes detailed measurements and spatial data of the constructed features. This information is typically presented in the form of plans, drawings, or reports, highlighting any variations from the original design. It serves as a valuable reference for construction verification, documentation, and future maintenance or modification projects. An as-built survey using a total station provides accurate measurements and spatial data of constructed structures or features, allowing comparison with the original design plans to ensure they match. It helps identify any deviations or discrepancies between the actual construction and the planned design.

Controlling the verticality of a building using a total station involves measuring and ensuring that the structure is plumb or vertically aligned according to the design specifications. The result of this survey will provide precise data on any deviations from the intended vertical alignment. This information is crucial for quality control in construction, allowing adjustments to be made if needed to ensure the building meets the required standards and safety regulations.

For that purpose, we used a Leica Viva TS15 total station, and we chose the Candle Residence and Hotel Kempinski project at the Candle Company for our project. The aim of this project is to determine the deviations or discrepancies between the actual construction and the planned design. We decided to take five floors of one building, which is block B. We had to measure the points of columns and shear walls to redesign the floors of these buildings.

Finally, we got 1300 points.

Ground floor: 291 points

First floor: 295 points

Second floor: 240 points

Third floor: 238 points

Fourth floor: 236 points

After measuring the points and processing the data, we obtained some new data that was measured by the total station instrument. We export these points from the total station to the computer and import these points into civil 3D software.

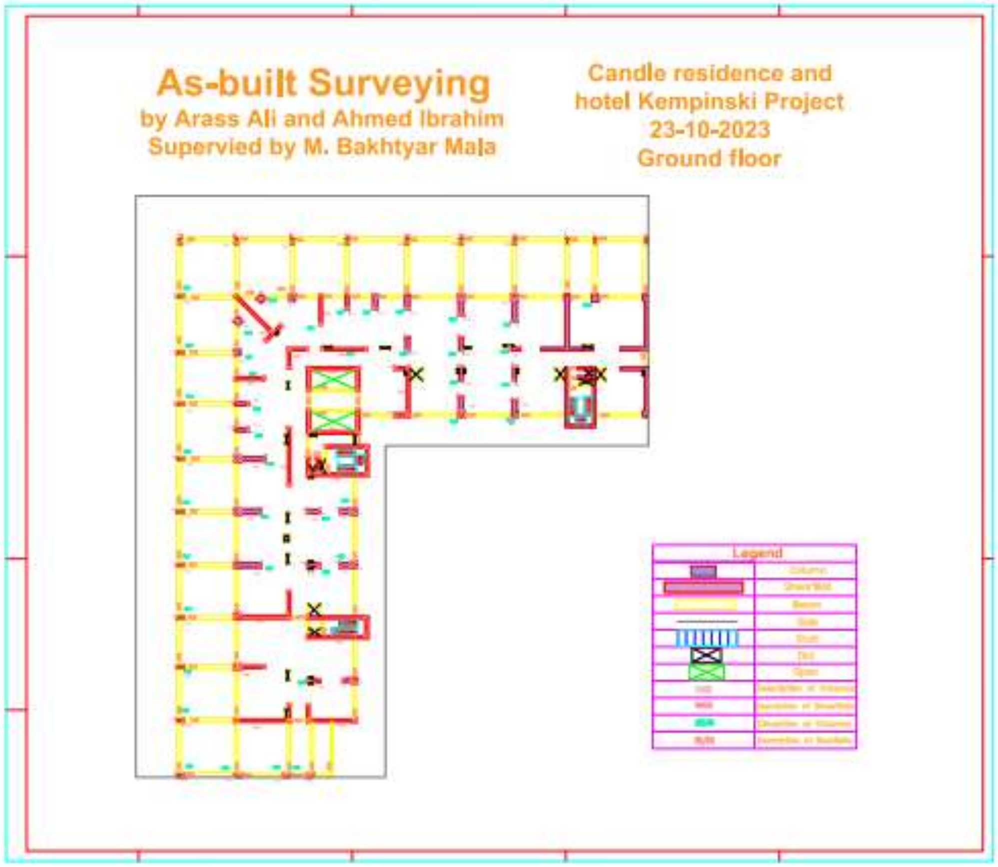

Figure 4-1: Ground floor as built redrawing

In the *Figure 4-1: Ground floor as built redrawing* Show the result of redesigning the ground floor. That consists of 51 columns, 19 shear walls, beams, 3 stairs, 2 openings, and some ducts. Area of this floor is 4565.9579. We measured 291 points for rebuilding this design. In each column, we got three points, but in each shear wall, we got all points. But we cannot measure 4 columns and 4 shear walls because they were taken by formwork and other tools.

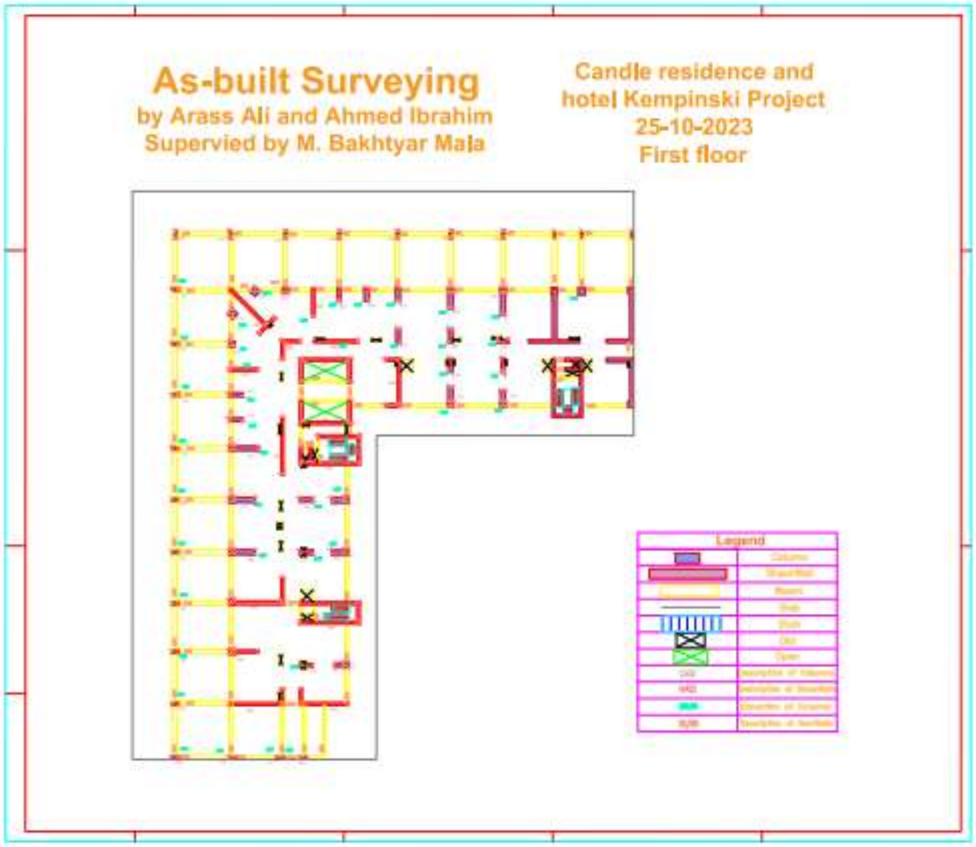

Figure 4-2: First floor as built redrawing

In the *Figure 4-2: First floor as built redrawing* Show the result of redesigning the ground floor. That consists of 51 columns, 19 shear walls, beams, 3 stairs, 2 openings, and some ducts. Area of this floor is 4562.4173. We measured 295 points for rebuilding this design. In each column, we got three points, but in each shear wall, we got all points. But we cannot measure 4 columns and 4 shear walls because they were taken by formwork and other tools.

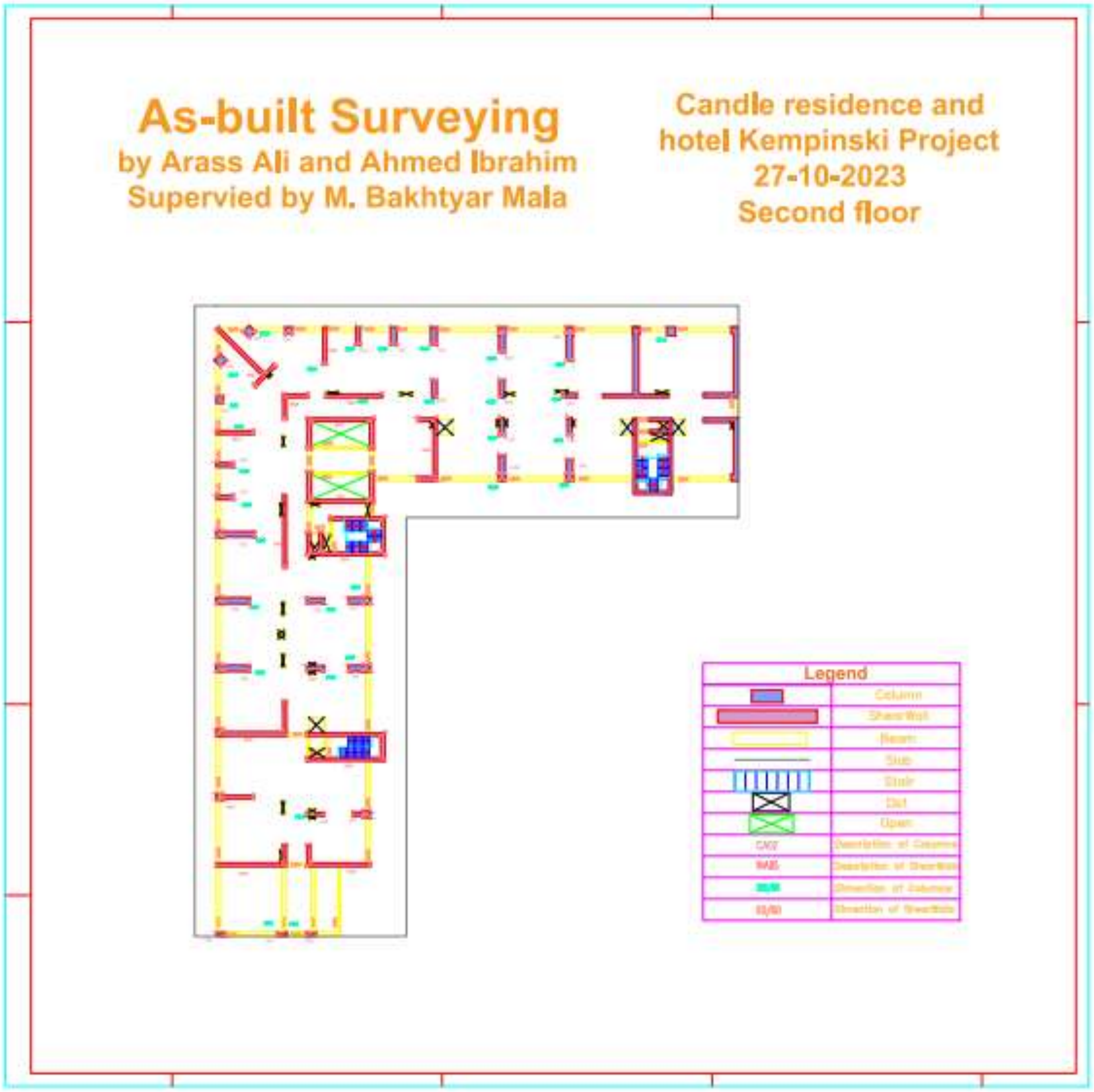

Figure 4-3: Second floor as built redrawing

In the *Figure 4-3: Second floor as built redrawing* Show the result of redesigning the ground floor. That consists of 31 columns, 19 shear walls, beams, 3 stairs, 2 openings, and some ducts. Area of this floor is 2769.7669. We measured 240 points for rebuilding this design. In each column, we got three points, but in each shear wall, we got all points. But we cannot measure 1 column and 4 shear walls because they were taken by formwork and other tools.

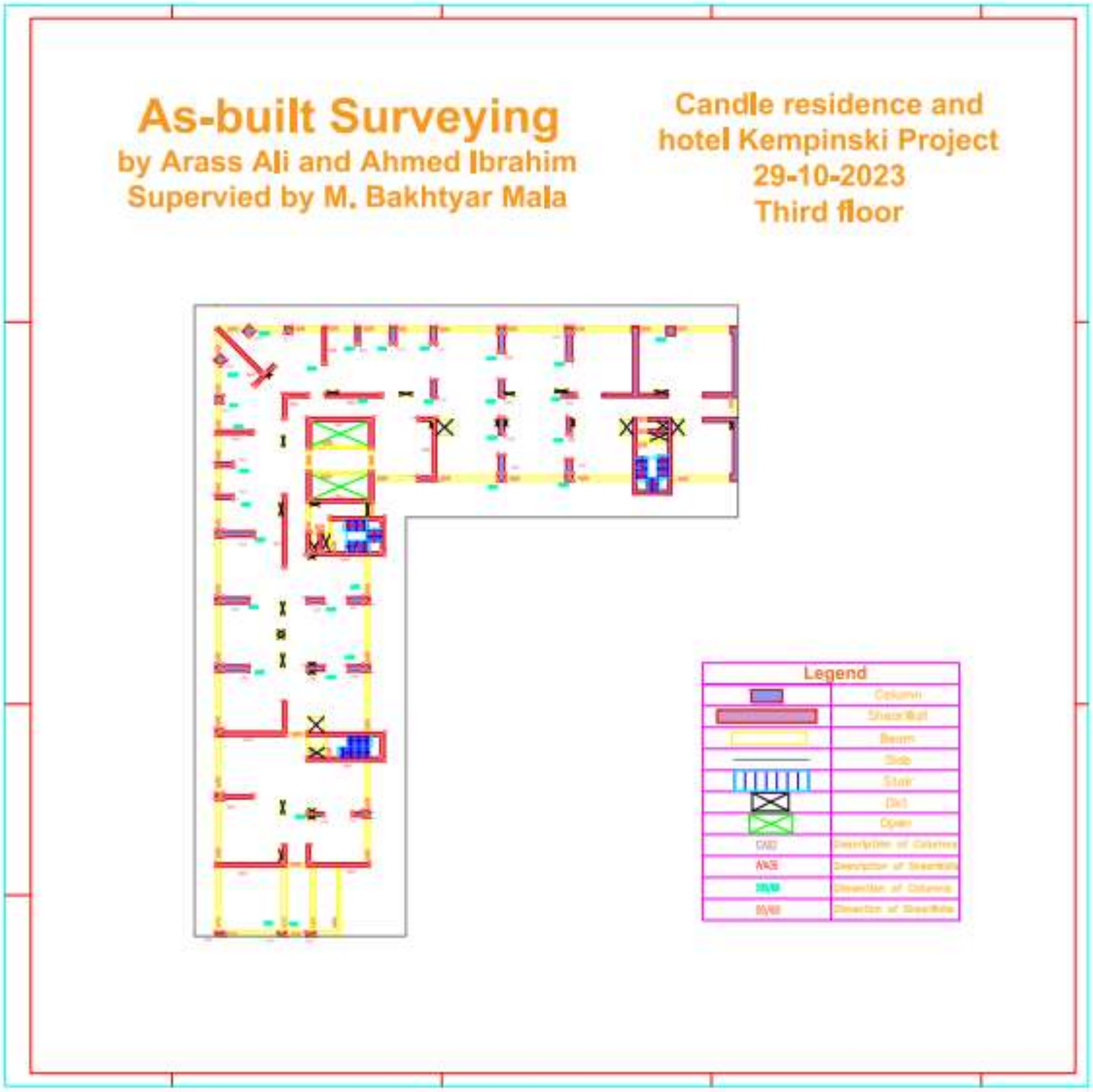

Figure 4-4: Third floor as built redrawing

In the *Figure 4-4: Third floor as built redrawing* Show the result of redesigning the ground floor. That consists of 31 columns, 19 shear walls, beams, 3 stairs, 2 openings, and some ducts. Area of this floor is 2775.6997. We measured 238 points for rebuilding this design. In each column, we got three points, but in each shear wall, we got all points. But we cannot measure 1 column and 4 shear walls because they were taken by formwork and other tools.

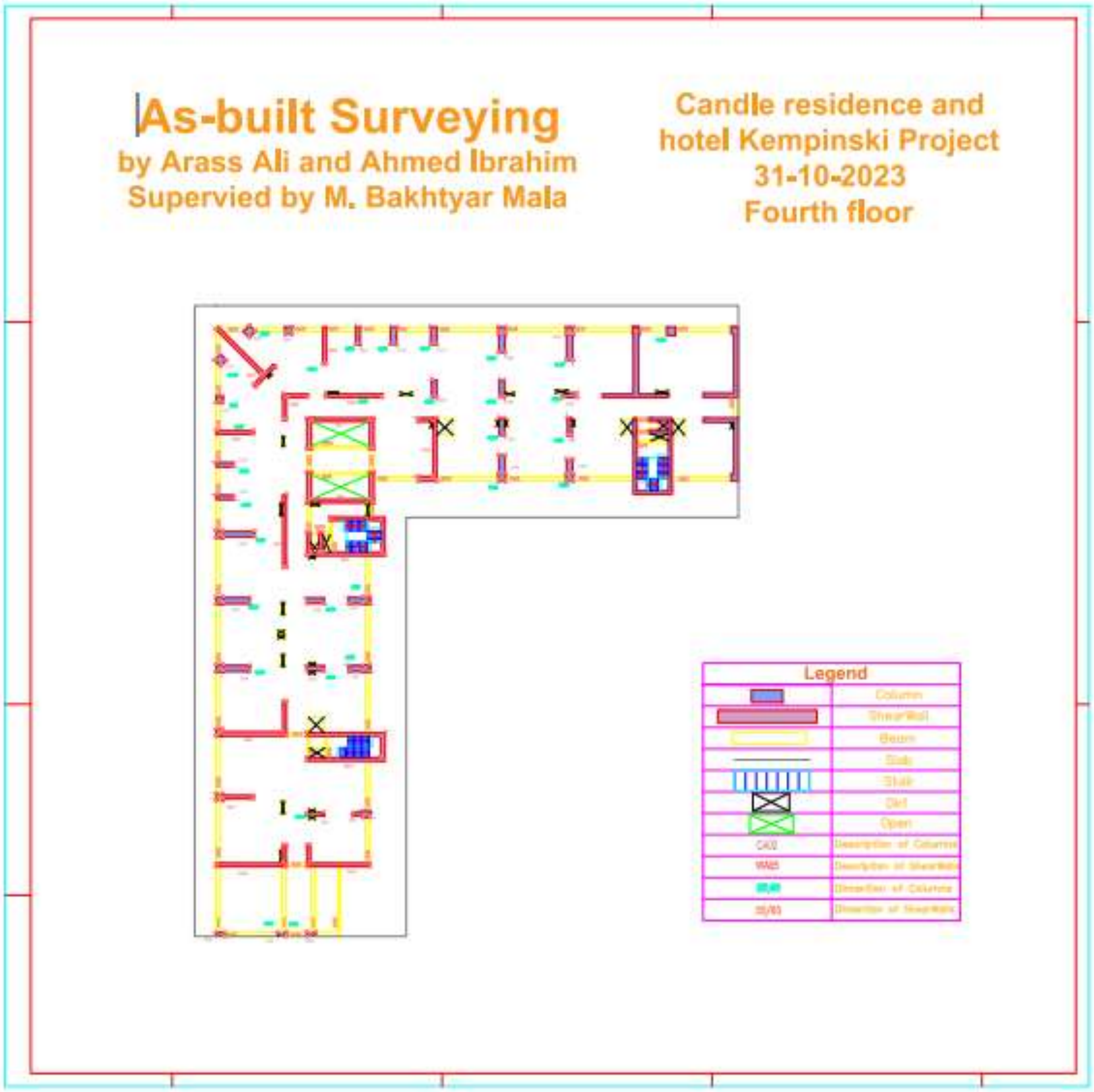

Figure 4-5: Fourth floor as built redrawing

In the *Figure 4-5: Fourth floor as built redrawing* Show the result of redesigning the ground floor. That consists of 31 columns, 19 shear walls, beams, 3 stairs, 2 openings, and some ducts. Area of this floor is 2773.1085. We measured 236 points for rebuilding this design. In each column, we got three points, but in each shear wall, we got all points. But we cannot measure column and 4 shear walls because they were taken by formwork and other tools.

4.1.2 Estimation

4.1.2.1 Columns and Shear walls

To estimate the number of columns and shear walls for a building, you typically need architectural or structural engineering plans. The number of columns and shear walls depends on factors such as the building's design, size, and load-bearing requirements. A structural engineer or architect would be best suited to provide an accurate estimation based on the specific details of the project.

To measure the dimensions of columns and shear walls in construction, use a tape measure or any suitable measuring tool. Measure the width, depth, and height of each column and shear wall. Ensure that your measurements are accurate, as they are crucial for calculating material quantities accurately. If the columns have irregular shapes, measure the dimensions at multiple points to capture the variations.

To measure the area of a column and shear wall, you'll need to consider its cross-sectional shape. If the column is cylindrical, the formula for the area (A) is:

$$A = \pi \times (radius)^2$$

If the column is rectangular, the formula is:

$$A = Width \times Depth$$

Measure the width, depth, or radius of the column and shear wall, depending on its shape, and use the appropriate formula to calculate the area. Repeat this process for each column and shear wall, summing up the individual areas if you have multiple columns.

To estimate the concrete required for columns and shear walls in construction, you'll need the dimensions (height, width, and depth) of each column and shear wall. The formula for the volume of a rectangular column is:

$$Volume = Width \times Depth \times Height$$

Once you have the volume for each column and shear wall, you can multiply it by the number of columns and shear walls to get the total concrete volume needed. Keep in mind that you may need to account for factors like wastage and variations in column sizes.

Table 2: Estimation of columns and shear walls in ground floor

	Ground Floor +106.12					
Code	**No.**	**Length (m)**	**Width (m)**	**Height (m)**	**Area (m^2)**	**Volume (m^3)**
CA02	1	2.5	0.8	4.80	2	9.6
CA03	1	2	0.5	4.80	1	4.8
CA04	1	1.6	0.5	4.80	0.8	3.84
CA05	1	3.9	0.8	4.80	3.12	14.976
CA06	1	3	0.8	4.30	2.4	10.32
CA07	1	2	0.6	4.80	1.2	5.76
CA08	1	2	0.6	4.80	1.2	5.76
CA09	1	3	0.8	4.30	2.4	10.32
CA10	1	2	0.6	4.80	1.2	5.76
CA11	1	2	0.7	4.10	1.4	5.74
CA12	1	2	0.7	4.30	1.4	6.02
CA13	1	2	0.5	4.30	1	4.3
CA14	1	0.8	0.8	4.30	0.64	2.752
CA15	1	1	1	4.30	1	4.3
CA16	1	1	1	4.30	1	4.3
CA17	1	0.8	0.8	4.30	0.64	2.752
CA18	1	2	0.5	4.30	1	4.3
CA19	1	2	0.5	4.30	1	4.3
CA20	1	4.5	0.8	4.80	3.6	17.28
CA21	1	2.5	0.8	4.80	2	9.6
CA22	1	2	0.6	4.80	1.2	5.76
CA23	1	3.9	0.8	4.80	3.12	14.976
CA24	1	2.5	0.8	4.80	2	9.6
CA25	1	2	0.6	4.80	1.2	5.76
CA26	1	3.9	0.8	4.80	3.12	14.976
CA27	1	2	0.8	4.80	1.6	7.68
CA28	1	2	0.4	4.80	0.8	3.84
CA30	1	1	0.4	5.00	0.4	2
CA31	1	1	0.4	5.00	0.4	2
CA32	1	1	0.4	5.00	0.4	2
WA05	1	0.5	1.8	4.80	0.9	4.32
WA05	1	0.4	1.8	4.80	0.72	3.456
WA05	1	0.4	7.35	4.80	2.94	14.112
WA06	1	4.35	0.4	4.80	1.74	8.352
WA07	1	10.9	0.4	4.80	4.36	20.928
WA08	1	6.65	0.4	4.80	2.66	12.768
WA09	1	5.5	0.4	4.80	2.2	10.56
WA10	1	14.2	0.4	4.20	5.68	23.856
WA11	1	14.2	0.4	4.80	5.68	27.264
WA12	1	4.35	0.4	4.80	1.74	8.352
WA13	1	8.5	0.4	4.80	3.4	16.32
WA14	1	24.2	0.4	4.30	9.68	41.624
WA15	1	0.5	7	4.80	3.5	16.8
WA15	1	0.4	4.05	4.80	1.62	7.776
WA15	1	0.3	0.8	4.80	0.24	1.152

WA16	1	0.4	8.6	4.30	3.44	14.792
WA16	1	0.4	8.6	4.30	3.44	14.792
WA16	1	0.5	3.3	4.30	1.65	7.095
WA17	1	4.35	0.8	4.80	3.48	16.704
WA18	1	9.45	0.4	4.80	3.78	18.144
WA19	1	10.3	0.4	4.80	4.12	19.776
CA66-CA82	16	1	0.4	4.80	6.4	30.72
SUM	67	185.65	69	241.9	117.61	545.035

Table 3: Estimation of columns and shear walls in first floor

	F1 (+110.12)					
Code	**No.**	**Length (m)**	**Width (m)**	**Height (m)**	**Area (m²)**	**Volume (m^3)**
CA02	1	2.5	0.8	3.78	2	7.56
CA03	1	2	0.5	3.78	1	3.78
CA04	1	1.6	0.5	3.78	0.8	3.024
CA05	1	3.9	0.8	3.78	3.12	11.7936
CA06	1	3	0.8	3.78	2.4	9.072
CA07	1	2	0.6	3.78	1.2	4.536
CA08	1	2	0.6	3.78	1.2	4.536
CA09	1	3	0.8	3.78	2.4	9.072
CA10	1	2	0.6	3.78	1.2	4.536
CA11	1	2	0.7	3.78	1.4	5.292
CA12	1	2	0.7	3.78	1.4	5.292
CA13	1	2	0.5	3.78	1	3.78
CA14	1	0.8	0.8	3.30	0.64	2.112
CA15	1	1	1	3.30	1	3.3
CA16	1	1	1	3.30	1	3.3
CA17	1	0.8	0.8	3.30	0.64	2.112
CA18	1	2	0.5	3.78	1	3.78
CA19	1	2	0.5	3.78	1	3.78
CA20	1	4.5	0.8	3.78	3.6	13.608
CA21	1	2.5	0.8	3.78	2	7.56
CA22	1	2	0.6	3.78	1.2	4.536
CA23	1	3.9	0.8	3.78	3.12	11.7936
CA24	1	2.5	0.8	3.78	2	7.56
CA25	1	2	0.6	3.78	1.2	4.536
CA26	1	3.9	0.8	3.78	3.12	11.7936
CA27	1	2	0.8	3.78	1.6	6.048
CA28	1	2	0.4	3.78	0.8	3.024
CA30	1	1	0.4	3.40	0.4	1.36
CA31	1	1	0.4	3.40	0.4	1.36
CA32	1	1	0.4	3.40	0.4	1.36
WA05	1	0.5	1.8	4.80	0.9	4.32
WA05	1	0.4	1.8	4.80	0.72	3.456
WA05	1	0.4	7.35	4.80	2.94	14.112

WA06	1	4.35	0.4	3.78	1.74	6.5772
WA07	1	10.9	0.4	3.78	4.36	16.4808
WA08	1	6.65	0.4	3.78	2.66	10.0548
WA09	1	5.5	0.4	3.78	2.2	8.316
WA10	1	14.2	0.4	3.78	5.68	21.4704
WA11	1	14.2	0.4	3.78	5.68	21.4704
WA12	1	4.35	0.4	3.78	1.74	6.5772
WA13	1	8.5	0.4	3.78	3.4	12.852
WA14	1	24.2	0.4	3.30	9.68	31.944
WA15	1	0.5	7	4.80	3.5	16.8
WA15	1	0.4	4.05	4.80	1.62	7.776
WA15	1	0.3	0.8	4.80	0.24	1.152
WA16	1	0.4	8.6	4.30	3.44	14.792
WA16	1	0.4	8.6	4.30	3.44	14.792
WA16	1	0.5	3.3	4.30	1.65	7.095
WA17	1	4.35	0.8	3.78	3.48	13.1544
WA18	1	9.45	0.4	3.00	3.78	11.34
WA19	1	10.3	0.4	3.78	4.12	15.5736
CA66-CA82	16	1	0.4	4.80	6.4	30.72
SUM	67	185.65	69	200.94	117.61	456.0226

Figure 4-6: Picture of removed columns from the other floors

Table 4: Estimation of columns and shear walls in second floor

	F2 (+113.22)					
Code	**No.**	**Length(m)**	**Width (m)**	**Height(m)**	**Area(m²)**	**Volume(m³)**
CA02	1	2.5	0.8	2.88	2	5.76
CA03	1	2	0.5	2.88	1	2.88
CA04	1	1.6	0.5	2.88	0.8	2.304
CA05	1	3.9	0.8	2.88	3.12	8.9856
CA06	1	3	0.8	2.88	2.4	6.912
CA07	1	2	0.6	2.88	1.2	3.456
CA08	1	2	0.6	2.88	1.2	3.456
CA09	1	3	0.8	2.88	2.4	6.912
CA10	1	2	0.6	2.88	1.2	3.456
CA11	1	2	0.7	2.88	1.4	4.032
CA12	1	2	0.7	2.88	1.4	4.032
CA13	1	2	0.5	2.88	1	2.88
CA14	1	0.8	0.8	2.40	0.64	1.536
CA15	1	1	1	2.40	1	2.4
CA16	1	1	1	2.40	1	2.4
CA17	1	0.8	0.8	2.88	0.64	1.8432
CA18	1	2	0.5	2.88	1	2.88
CA19	1	2	0.5	2.88	1	2.88
CA20	1	4.5	0.8	2.88	3.6	10.368
CA21	1	2.5	0.8	2.88	2	5.76
CA22	1	2	0.6	2.88	1.2	3.456
CA23	1	3.9	0.8	2.88	3.12	8.9856
CA24	1	2.5	0.8	2.88	2	5.76
CA25	1	2	0.6	2.88	1.2	3.456
CA26	1	3.9	0.8	2.88	3.12	8.9856
CA27	1	2	0.8	2.88	1.6	4.608
CA28	1	2	0.4	2.88	0.8	2.304
CA30	1	1	0.4	2.40	0.4	0.96
CA31	1	1	0.4	2.40	0.4	0.96
CA32	1	1	0.4	2.40	0.4	0.96
WA05	1	0.5	1.8	4.80	0.9	4.32
WA05	1	0.4	1.8	4.80	0.72	3.456
WA05	1	0.4	7.35	4.80	2.94	14.112
WA06	1	4.35	0.4	2.88	1.74	5.0112
WA07	1	10.9	0.4	2.88	4.36	12.5568
WA08	1	6.65	0.4	2.88	2.66	7.6608
WA09	1	5.5	0.4	2.88	2.2	6.336
WA10	1	14.2	0.4	2.40	5.68	13.632
WA11	1	14.2	0.4	2.88	5.68	16.3584
WA12	1	4.35	0.4	2.88	1.74	5.0112
WA13	1	8.5	0.4	2.88	3.4	9.792
WA14	1	24.2	0.4	2.40	9.68	23.232
WA15	1	0.5	7	4.80	3.5	16.8
WA15	1	0.4	4.05	4.80	1.62	7.776
WA15	1	0.3	0.8	4.80	0.24	1.152
WA16	1	0.4	8.6	4.30	3.44	14.792
WA16	1	0.4	8.6	4.30	3.44	14.792
WA16	1	0.5	3.3	4.30	1.65	7.095
WA17	1	4.35	0.8	2.88	3.48	10.0224
WA18	1	9.45	0.4	2.88	3.78	10.8864
WA19	1	10.3	0.4	2.88	4.12	11.8656
SUM	51	184.65	68.6	158.82	111.21	342.2278

Table 5: Estimation of columns and shear walls in third floor

	F3 (+116.32)					
Code	**No.**	**Length(m)**	**Width(m)**	**Height(m)**	**Area(m²)**	**Volume(m³)**
CA02	1	2.5	0.8	2.88	2	5.76
CA03	1	2	0.5	2.88	1	2.88
CA04	1	1.6	0.5	2.88	0.8	2.304
CA05	1	3.9	0.8	2.88	3.12	8.9856
CA06	1	3	0.8	2.88	2.4	6.912
CA07	1	2	0.6	2.88	1.2	3.456
CA08	1	2	0.6	2.88	1.2	3.456
CA09	1	3	0.8	2.88	2.4	6.912
CA10	1	2	0.6	2.88	1.2	3.456
CA11	1	2	0.7	2.88	1.4	4.032
CA12	1	2	0.7	2.88	1.4	4.032
CA13	1	2	0.5	2.88	1	2.88
CA14	1	0.8	0.8	2.40	0.64	1.536
CA15	1	1	1	2.40	1	2.4
CA16	1	1	1	2.40	1	2.4
CA17	1	0.8	0.8	2.88	0.64	1.8432
CA18	1	2	0.5	2.88	1	2.88
CA19	1	2	0.5	2.88	1	2.88
CA20	1	4.5	0.8	2.88	3.6	10.368
CA21	1	2.5	0.8	2.88	2	5.76
CA22	1	2	0.6	2.88	1.2	3.456
CA23	1	3.9	0.8	2.88	3.12	8.9856
CA24	1	2.5	0.8	2.88	2	5.76
CA25	1	2	0.6	2.88	1.2	3.456
CA26	1	3.9	0.8	2.88	3.12	8.9856
CA27	1	2	0.8	2.88	1.6	4.608
CA28	1	2	0.4	2.88	0.8	2.304
CA30	1	1	0.4	2.40	0.4	0.96
CA31	1	1	0.4	2.40	0.4	0.96
CA32	1	1	0.4	2.40	0.4	0.96
WA05	1	0.5	1.8	4.80	0.9	4.32
WA05	1	0.4	1.8	4.80	0.72	3.456
WA05	1	0.4	7.35	4.80	2.94	14.112
WA06	1	4.35	0.4	2.88	1.74	5.0112
WA07	1	10.9	0.4	2.88	4.36	12.5568
WA08	1	6.65	0.4	2.88	2.66	7.6608
WA09	1	5.5	0.4	2.88	2.2	6.336
WA10	1	14.2	0.4	2.40	5.68	13.632
WA11	1	14.2	0.4	2.88	5.68	16.3584
WA12	1	4.35	0.4	2.88	1.74	5.0112
WA13	1	8.5	0.4	2.88	3.4	9.792
WA14	1	24.2	0.4	2.40	9.68	23.232
WA15	1	0.5	7	4.80	3.5	16.8
WA15	1	0.4	4.05	4.80	1.62	7.776
WA15	1	0.3	0.8	4.80	0.24	1.152
WA16	1	0.4	8.6	4.30	3.44	14.792
WA16	1	0.4	8.6	4.30	3.44	14.792
WA16	1	0.5	3.3	4.30	1.65	7.095
WA17	1	4.35	0.8	2.88	3.48	10.0224
WA18	1	9.45	0.4	2.88	3.78	10.8864
WA19	1	10.3	0.4	2.40	4.12	9.888
SUM	51	184.65	68.6	158.34	111.21	340.2502

Table 6: Estimation of columns and shear walls in fourth floor

	F4 (+119.42)					
Code	**No.**	**Length(m)**	**Width(m)**	**Height(m)**	**Area (m^2)**	**Volume (m^3)**
CA02	1	2.5	0.8	2.88	2	5.76
CA03	1	2	0.5	2.88	1	2.88
CA04	1	1.6	0.5	2.88	0.8	2.304
CA05	1	3.9	0.8	2.88	3.12	8.9856
CA06	1	3	0.8	2.88	2.4	6.912
CA07	1	2	0.6	2.88	1.2	3.456
CA08	1	2	0.6	2.88	1.2	3.456
CA09	1	3	0.8	2.88	2.4	6.912
CA10	1	2	0.6	2.88	1.2	3.456
CA11	1	2	0.7	2.88	1.4	4.032
CA12	1	2	0.7	2.88	1.4	4.032
CA13	1	2	0.5	2.88	1	2.88
CA14	1	0.8	0.8	2.40	0.64	1.536
CA15	1	1	1	2.40	1	2.4
CA16	1	1	1	2.40	1	2.4
CA17	1	0.8	0.8	2.88	0.64	1.8432
CA18	1	2	0.5	2.88	1	2.88
CA19	1	2	0.5	2.88	1	2.88
CA20	1	4.5	0.8	2.88	3.6	10.368
CA21	1	2.5	0.8	2.88	2	5.76
CA22	1	2	0.6	2.88	1.2	3.456
CA23	1	3.9	0.8	2.88	3.12	8.9856
CA24	1	2.5	0.8	2.88	2	5.76
CA25	1	2	0.6	2.88	1.2	3.456
CA26	1	3.9	0.8	2.88	3.12	8.9856
CA27	1	2	0.8	2.88	1.6	4.608
CA28	1	2	0.4	2.88	0.8	2.304
CA30	1	1	0.4	2.40	0.4	0.96
CA31	1	1	0.4	2.40	0.4	0.96
CA32	1	1	0.4	2.40	0.4	0.96
WA05	1	0.5	1.8	4.80	0.9	4.32
WA05	1	0.4	1.8	4.80	0.72	3.456
WA05	1	0.4	7.35	4.80	2.94	14.112
WA06	1	4.35	0.4	2.88	1.74	5.0112
WA07	1	10.9	0.4	2.88	4.36	12.5568
WA08	1	6.65	0.4	2.88	2.66	7.6608
WA09	1	5.5	0.4	2.88	2.2	6.336
WA10	1	14.2	0.4	2.40	5.68	13.632
WA11	1	14.2	0.4	2.88	5.68	16.3584
WA12	1	4.35	0.4	2.88	1.74	5.0112
WA13	1	8.5	0.4	2.88	3.4	9.792
WA14	1	24.2	0.4	2.40	9.68	23.232
WA15	1	0.5	7	4.80	3.5	16.8
WA15	1	0.4	4.05	4.80	1.62	7.776
WA15	1	0.3	0.8	4.80	0.24	1.152
WA16	1	0.4	8.6	4.30	3.44	14.792
WA16	1	0.4	8.6	4.30	3.44	14.792
WA16	1	0.5	3.3	4.30	1.65	7.095
WA17	1	4.35	0.8	2.88	3.48	10.0224
WA18	1	9.45	0.4	2.88	3.78	10.8864
WA19	1	10.3	0.4	2.40	4.12	9.888
SUM	51	184.65	68.6	158.34	111.21	340.2502

4.1.2.2 Beam

To measure the dimensions of a beam, you need to determine its length, width, and height. Use a tape measure or another suitable measuring tool for accurate measurements.

1. Length: Measure the overall length of the beam from one end to the other.

2. Width: If the beam is rectangular, measure the width (distance across the shorter side). If it's a different shape, measure the appropriate dimension.

3. Height: Measure the height (distance across the taller side) of the beam. For rectangular beams, this is typically the side oriented vertically.

Ensure to take precise measurements, especially if the beam has irregular shapes or variations in dimensions.

The area of a beam depends on its cross-sectional shape. Here are the formulas for calculating the area based on common beam shapes:

1. Rectangular Beam:

$$Area = Width \times Height$$

2. Circular or Cylindrical Beam:

$$Area = \pi \times (Radius)^2$$

Measure the width, height, or radius of the beam, depending on its shape, and use the appropriate formula to calculate the area.

To measure the concrete volume of a beam, you'll need the cross-sectional area of the beam and its length. The formula for calculating the volume is:

$$Volume = Area \times Length$$

1. Rectangular Beam:

$$Volume = Width \times Height \times Length$$

2. Circular or Cylindrical Beam:

$$Volume = \pi \times (Radius)^2 \times Length$$

Measure the dimensions (width, height, or radius) and length of the beam. Then, plug these values into the appropriate formula to find the concrete volume.

4.1.2.3 Slab

To measure the dimensions of a slab, such as a concrete floor slab, you typically need to determine its length, width, and thickness. Here's how you can measure each dimension:

1. Length: Measure the distance from one end of the slab to the other.

2. Width: Measure the distance across the slab, perpendicular to the length.

3. Thickness: If the slab has a uniform thickness, measure the thickness at any point. If there are variations in thickness, measure the thinnest and thickest parts.

Use a tape measure or another suitable measuring tool for accurate measurements. Ensure that your measurements are precise, especially if the slab has irregular shapes or variations.

If you have specific design plans or need to ensure the slab meets certain structural requirements, consulting with a construction professional or engineer is advisable.

To measure the area of a slab, you'll use the formula for the area of a rectangle, as slabs are typically flat and rectangular:

$Area = Length \times Width$

1. Length: Measure the longer side of the slab.

2. Width: Measure the shorter side of the slab.

Once you have these measurements, multiply the length by the width to find the total area of the slab. Ensure that your measurements are accurate, especially if the slab has irregular shapes or variations.

To measure the concrete volume of a slab, you need to consider the slab's area and thickness. The formula for calculating the volume is:

$Volume = Area \times Thickness$

1. Area: Measure the area of the slab using the formula

$Area = Length \times Width$, as mentioned before.

2. Thickness: Measure the thickness of the slab. If the slab has a uniform thickness, measure it at any point. If there are variations in thickness, measure the thinnest and thickest parts.

Once you have the area and thickness measurements, plug them into the formula to find the concrete volume.

Table 7: Estimation of beam and slab in ground floor

<table>
<tr><th rowspan="2"></th><th colspan="10">Ground Floor +106.12</th></tr>
<tr><th colspan="5">Concrete Beam quantity</th><th colspan="5">Concrete Slab quantity</th></tr>
<tr><th>No.</th><th>Width</th><th>Height</th><th>Length</th><th>Area</th><th>Volume</th><th>Width</th><th>Height</th><th>Length</th><th>Area</th><th>Volume</th></tr>
<tr><td>1</td><td>0.600</td><td>0.700</td><td>289.949</td><td>173.969</td><td>121.778</td><td rowspan="5">75.421</td><td rowspan="5">0.220</td><td rowspan="5">36.738</td><td rowspan="5">2770.805</td><td rowspan="5">609.577</td></tr>
<tr><td>2</td><td>0.500</td><td>0.700</td><td>195.731</td><td>97.865</td><td>68.506</td></tr>
<tr><td>3</td><td>0.500</td><td>0.600</td><td>22.804</td><td>11.402</td><td>6.841</td></tr>
<tr><td>4</td><td>0.300</td><td>0.600</td><td>7.601</td><td>2.280</td><td>1.368</td></tr>
<tr><td>5</td><td>0.400</td><td>0.600</td><td>2.004</td><td>0.802</td><td>0.481</td></tr>
<tr><td>6</td><td>0.400</td><td>0.700</td><td>8.652</td><td>3.461</td><td>2.422</td><td rowspan="6">36.811</td><td rowspan="6">0.220</td><td rowspan="6">48.767</td><td rowspan="6">1795.152</td><td rowspan="6">394.934</td></tr>
<tr><td>7</td><td>0.250</td><td>0.700</td><td>9.308</td><td>2.327</td><td>1.629</td></tr>
<tr><td>8</td><td>0.500</td><td>0.800</td><td>5.401</td><td>2.701</td><td>2.160</td></tr>
<tr><td>9</td><td>0.300</td><td>0.700</td><td>19.404</td><td>5.821</td><td>4.075</td></tr>
<tr><td>10</td><td>0.500</td><td>0.700</td><td>2.400</td><td>1.200</td><td>0.840</td></tr>
<tr><td>11</td><td>0.500</td><td>0.600</td><td>14.003</td><td>7.001</td><td>4.201</td></tr>
<tr><td>Sum</td><td>4.750</td><td>7.400</td><td>577.256</td><td>308.829</td><td>214.302</td><td>112.231</td><td>0.440</td><td>85.505</td><td>4565.958</td><td>1004.511</td></tr>
</table>

Table 8: Estimation of beam and slab in first floor

<table>
<tr><th rowspan="2"></th><th colspan="10">First floor (+110.12)</th></tr>
<tr><th colspan="5">Concrete Beam quantity</th><th colspan="5">Concrete Slab quantity</th></tr>
<tr><th>No.</th><th>Width</th><th>Height</th><th>Length</th><th>Area</th><th>Volume</th><th>Width</th><th>Height</th><th>Length</th><th>Area</th><th>Volume</th></tr>
<tr><td>1</td><td>0.600</td><td>0.700</td><td>289.411</td><td>173.647</td><td>121.553</td><td rowspan="5">36.738</td><td rowspan="5">0.220</td><td rowspan="5">75.421</td><td rowspan="5">2770.805</td><td rowspan="5">609.577</td></tr>
<tr><td>2</td><td>0.500</td><td>0.700</td><td>197.793</td><td>98.896</td><td>69.227</td></tr>
<tr><td>3</td><td>0.500</td><td>0.600</td><td>36.738</td><td>18.369</td><td>11.021</td></tr>
<tr><td>4</td><td>0.300</td><td>0.600</td><td>7.587</td><td>2.276</td><td>1.366</td></tr>
<tr><td>5</td><td>0.400</td><td>0.600</td><td>2.396</td><td>0.958</td><td>0.575</td></tr>
<tr><td>6</td><td>0.400</td><td>0.700</td><td>8.635</td><td>3.454</td><td>2.418</td><td rowspan="4">36.738</td><td rowspan="4">0.220</td><td rowspan="4">48.767</td><td rowspan="4">1791.612</td><td rowspan="4">394.155</td></tr>
<tr><td>7</td><td>0.250</td><td>0.700</td><td>9.284</td><td>2.321</td><td>1.625</td></tr>
<tr><td>8</td><td>0.500</td><td>0.800</td><td>5.391</td><td>2.695</td><td>2.156</td></tr>
<tr><td>9</td><td>0.300</td><td>0.700</td><td>19.367</td><td>5.810</td><td>4.067</td></tr>
<tr><td>Sum</td><td>3.750</td><td>6.100</td><td>576.603</td><td>308.427</td><td>214.008</td><td>73.476</td><td>0.440</td><td>124.188</td><td>4562.417</td><td>1003.732</td></tr>
</table>

Table 9: Estimation of beam and slab in second floor

	Second floor (+113.22)									
	Concrete Beam quantity					Concrete Slab quantity				
No.	Width	Height	Length	Area	Volume	Width	Height	Length	Area	Volume
2	0.500	0.700	198.243	99.122	69.385	24.693	0.220	63.382	1565.092	344.320
3	0.500	0.600	36.789	18.395	11.037					
4	0.300	0.600	7.598	2.279	1.368					
5	0.400	0.600	2.399	0.960	0.576					
6	0.400	0.700	8.648	3.459	2.421	24.693	0.220	48.786	1204.675	265.029
7	0.300	0.700	19.396	5.819	4.073					
8	0.250	0.700	9.297	2.324	1.627					
9	0.500	0.800	5.398	2.699	2.159					
Sum	3.150	5.400	287.769	135.057	92.646	49.386	0.440	112.168	2769.767	609.349

Table 10: Estimation of beam and slab in third floor

	Third floor (+116.32)									
	Concrete Beam quantity					Concrete Slab quantity				
No.	Width	Height	Length	Area	Volume	Width	Height	Length	Area	Volume
1	0.500	0.700	198.367	99.183	69.428	63.472	0.220	24.708	1568.282	345.022
2	0.500	0.600	36.813	18.406	11.044					
3	0.300	0.600	7.603	2.281	1.368					
4	0.400	0.600	2.401	0.960	0.576					
5	0.400	0.700	8.653	3.461	2.423	24.708	0.220	48.867	1207.418	265.632
6	0.300	0.700	18.607	5.582	3.907					
7	0.250	0.700	9.303	2.326	1.628					
8	0.500	0.800	5.402	2.701	2.161					
Sum	3.150	5.400	287.147	134.901	92.536	88.180	0.440	73.575	2775.700	610.654

Table 11: Estimation of beam and slab in fourth floor

	Fourth floor (+119.42)									
	Concrete Beam quantity					Concrete Slab quantity				
No.	Width	Height	Length	Area	Volume	Width	Height	Length	Area	Volume
1	0.500	0.700	198.363	99.182	69.427	24.708	0.220	63.420	1566.980	344.736
2	0.500	0.600	36.812	18.406	11.044					
3	0.300	0.600	7.602	2.281	1.368					
4	0.400	0.600	2.401	0.960	0.576					
5	0.400	0.700	8.653	3.461	2.423	24.708	0.220	48.816	1206.128	265.348
6	0.300	0.700	18.606	5.582	3.907					
7	0.250	0.700	9.303	2.326	1.628					
8	0.500	0.800	5.402	2.701	2.161					
Sum	3.150	5.400	287.142	134.898	92.534	49.416	0.440	112.236	2773.108	610.084

4.2 Discussion

4.2.1 Concrete quantity

After we measured the dimensions, area, and volume of columns as mentioned above, we considered that the total volume of columns on the ground floor and first floor was very close together, and the total volume of columns on the second, third, and fourth floors was very close together. But the total volume of columns on the ground floor and first floor is greater than the other floors because the ground floor and first floor consist of 20 columns more than the second, third, and fourth floors. See *Table 12: Total volume of Columns* and *Figure 4-7: Total volume of Columns*.

Table 12: Total volume of Columns

Total volume of Columns	
floors	Total Volume (m^3)
G-F	545.035
F-1	456.023
F-2	342.228
F-3	340.250
F-4	340.250

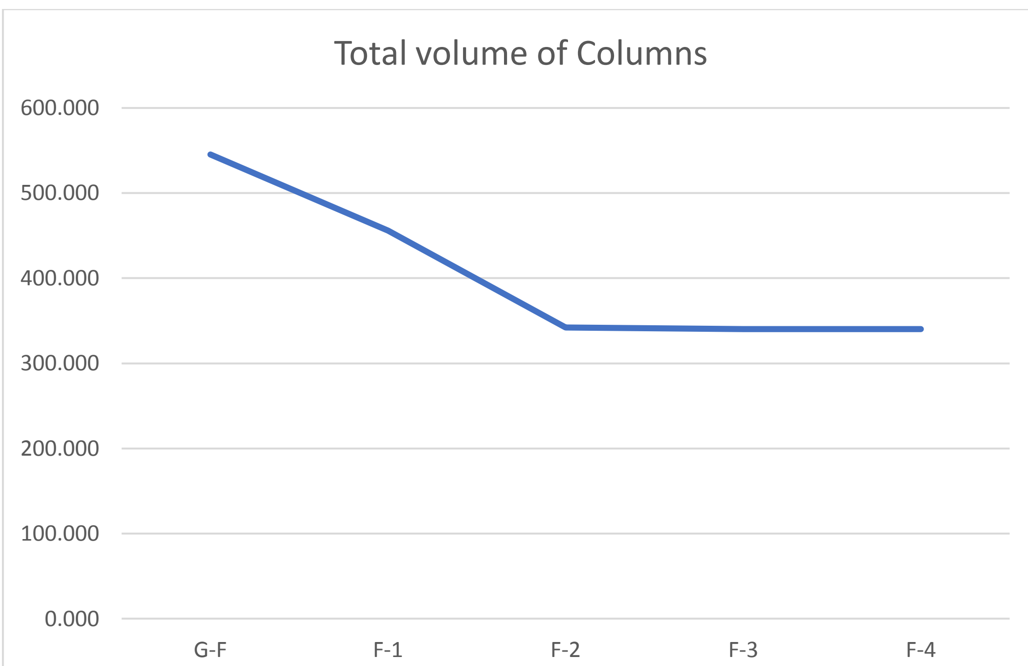

Figure 4-7: Total volume of Columns

The difference between the total concrete volume of columns on the ground floor and the total concrete volume of columns on the first floor is 89.012m^3. The difference between the total concrete volume of columns on the first floor and the total concrete volume of columns on the second floor is 113.795m^3. The difference between the total concrete volume of columns on the second floor and the total concrete volume of columns on the third floor is 1.978m^3. The difference between the total concrete volume of columns on the third floor and the total concrete volume of columns on the fourth floor is 0m^3.

Figure 4-8: Show the concreted shear walls

After we measured the dimensions, area, and volume of slabs, we considered that the total volume of slabs on the ground floor and first floor was very close together, and the total volume of slabs on the second, third, and fourth floors was very close together. But the total volume of slabs on the ground floor and first floor is greater than the other floors because the ground floor and first floor consist of a larger area than the second, third, and fourth floors. *See Table 13: Total volume of Slab* and *Figure 4-9: Total volume of Slab*

Table 13: Total volume of Slab

Total volume of Slab	
floors	Total Volume (m^3)
G-F	1004.511
F-1	1003.732
F-2	609.349
F-3	610.654
F-4	*610.084*

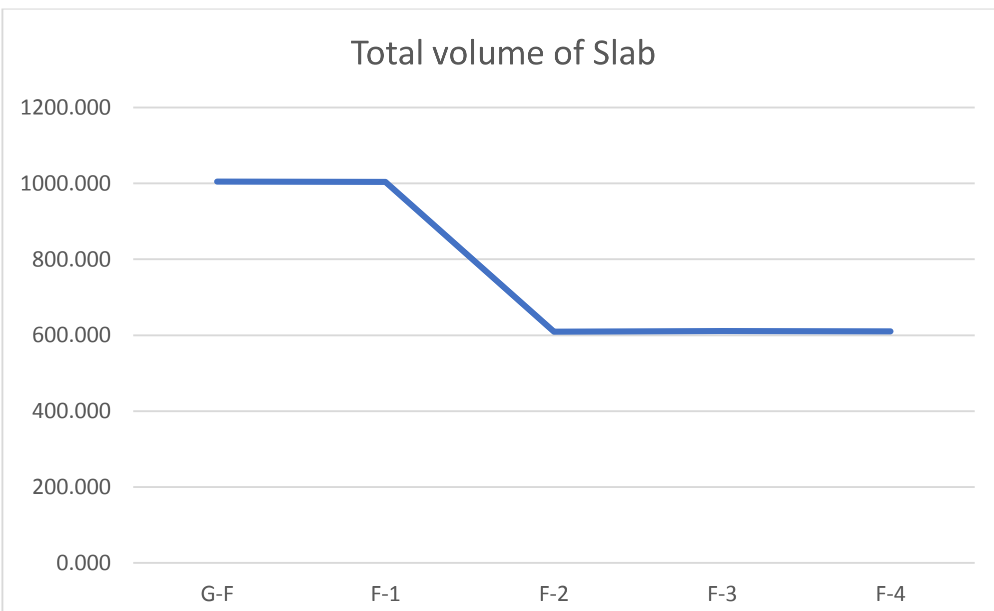

Figure 4-9: Total volume of Slab

The difference between the total concrete volume of slabs on the ground floor and the total concrete volume of slabs on the first floor is $0.779m^3$.

The difference between the total concrete volume of slabs on the first floor and the total concrete volume of slabs on the second floor is $394.383m^3$.

The difference between the total concrete volume of slabs on the second floor and the total concrete volume of slabs on the third floor is $1.305m^3$.

The difference between the total concrete volume of slabs on the third floor and the total concrete volume of slabs on the fourth floor is $0.570m^3$.

Figure 4-10: Show the concreted beams and slab

After we measured the dimensions, area, and volume of beams, we considered that the total volume of beams on the ground and first floor was very close together, and the total volume of beams on the second, third, and fourth floors was very close together. But the total volume of beams on the ground floor and first floor is greater than that on the second, third, and fourth floors because the ground floor and first floor consist of 20 columns more than the second floor, third floor, and fourth floor. And the ground floor and first floor consist of a larger area than the second floor, third floor, and fourth floor. See *Table 14: Total volume of beam* and *Figure 4-11: Total volume of beam.*

Table 14: Total volume of beam

Total volume of Beam	
floors	Total Volume (m^3)
G-F	214.302
F-1	214.008
F-2	92.646
F-3	92.534
F-4	92.536

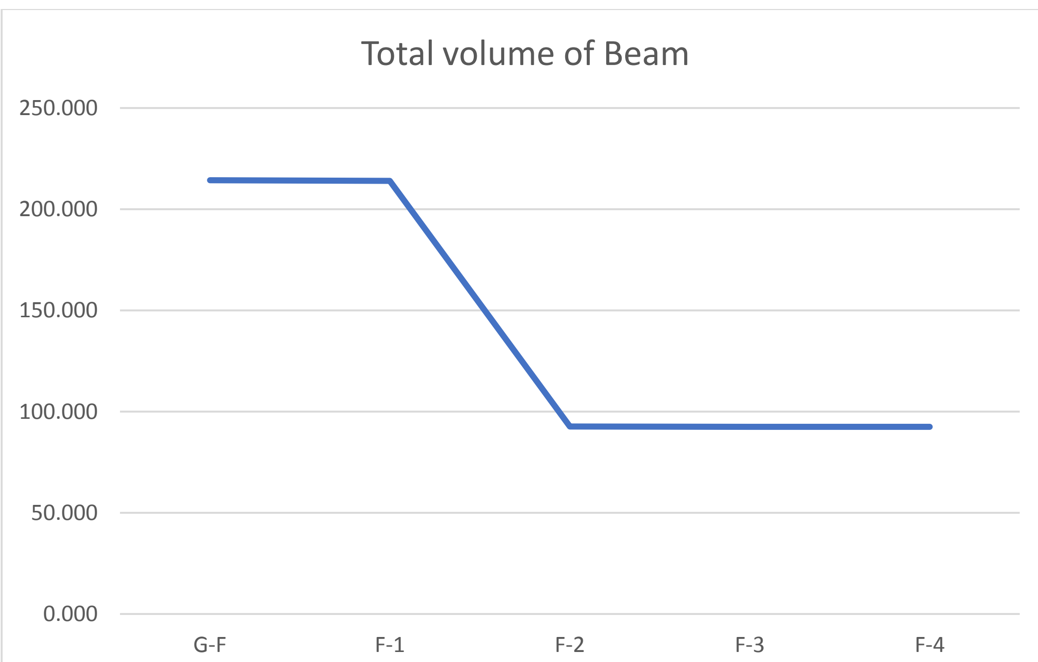

Figure 4-11: Total volume of beam

The difference between the total concrete volume of beams on the ground floor and the total concrete volume of beams on the first floor is $0.294m^3$. The difference between the total concrete volume of beams on the first floor and the total concrete volume of beams on the second floor is $121.362m^3$. The difference between the total concrete volume of beams on the second floor and the total concrete volume of beams on the third floor is $0.112m^3$. The difference between the total concrete volume of beams on the third floor and the total concrete volume of beams on the fourth floor is $0.002m^3$.

After comparing and analyzing this data for our project, in the end ‹we realized that there's a good construction because the total concrete volume of columns between floors was very close together, but the total concrete volume of columns in the ground floor and first floor was much higher than the second, third, and fourth floors because the ground floor and first floor consisted of 20 more columns.

Because of this, the volumes of the concrete columns were higher than others. Another point that we should discuss is why the total concrete volume of the ground floor was much higher than that of the first floor. Because the height of the ground-floor columns was higher than the height of the first-floor columns, that’s why the total volume of the ground-floor columns was higher than that of the first-floor columns.

Difference G.f-1st .f= 89.012

Difference 2nd .f-3rd .f= 1.978

Difference 3rd .f-4th .f= 00.00

Difference 2nd .f-4th .f= 1.978

The total concrete volume of slabs was less than the total concrete volume of slabs because the thickness of the slab was 0.22 m, which was very low. The total volume of slabs on the ground floor and first floor were close together, and the total volume of slabs on the second, third, and fourth floors were close together.

Difference G.f-1st .f= 0.779

Difference 2nd .f-3rd .f= 1.305

Difference 3rd .f-4th .f= 0.570

Difference 2nd .f-4th .f= 0.735

The total concrete volume of Beams was less than the total concrete volume of Beams because the ground floor consisted of 20 more columns that should be added beams to connect columns. That's why it had a higher volume. The total volume of beams on the ground floor and first floor were close together, and the total volume of the second-floor beam, third floor beam, and fourth floor beam were close together.

Difference G.f-1st .f= 0.294

Difference 2nd .f-3rd .f= 0.112

Difference 3rd .f-4th .f= 0.002

Difference 2nd .f-4th .f= 0.110

4.2.2 Deviations

The deviation in an as-built survey refers to the differences between the constructed building and the original design. Using a total station for surveys allows for precise measurements, but discrepancies may arise due to various factors such as construction errors, material variations, or unforeseen site conditions.

We took six coordinates of six points on the ground floor as a base for calculating the deviation between floors. All points were measured on the columns or shear walls of CA05, CA02, WA11, WA18, WA19, and WA07

In ground floor we took coordinate of point 17, 89, 105, 171, 192, 294

In ground floor we took coordinate of point 306, 304, 307, 305, 302, 303

In ground floor we took coordinate of point 295, 296, 297, 298, 299, 300

In ground floor we took coordinate of point 295, 296, 297, 298, 299, 300

In ground floor we took coordinate of point 297, 298, 299, 300, 301, 302

We got these points from the same place on all floors.

For that purpose, we used the deviation formula to find the deviations and discrepancies of coordinates (Easting, Northing and Elevation) of six points between ground floor with first floor, then ground floor with second floor, after that ground floor with third floor, and ground floor with fourth floor.

Deviation formula is the positive square root of the variance. It is one of the basic methods of statistical analysis. Deviation formula is denoted by the symbol 'σ’ and it talks about how much data values are deviated from the mean value. If we get a low deviation formula then it means that the values tend to be close to the mean whereas a high deviation formula tells us that the values are far from the mean value.

$$Deviation = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

X_2= Easting of ground floor points.

X_1= Easting of other floor points.

Y_2= Northing of ground floor points.

Y_1= Northing of other floor points.

Table 15: ground floor selected points to find the deviation from verticality

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	Ground floor		
Points	**x**	**y**	**z**
1	1007.601	1007.701	106.122
2	1025.982	1053.703	106.143
3	1007.580	1070.332	106.145
4	1025.549	1007.678	106.128
5	1049.244	1070.627	106.127
6	1049.258	1052.660	106.133

Table 16: first floor selected points to find the deviation with the ground floor (Table 15)

	First floor		
Points	**x**	**y**	**z**
1	1007.588	1007.667	110.138
2	1025.969	1053.625	110.130
3	1007.576	1070.214	110.134
4	1025.521	1007.678	110.129
5	1049.225	1070.613	110.124
6	1049.231	1052.640	110.142

Table 17: second floor deviation points with the ground floor

	Second floor		
Points	**x**	**y**	**z**
1	1007.602	1007.697	113.242
2	1025.995	1053.685	113.230
3	1007.600	1070.295	114.240
4	1025.547	1007.698	113.228
5	1049.237	1070.581	113.250
6	1049.238	1052.636	113.247

Table 18: third floor deviation points with the ground floor

	Third floor		
Points	**x**	**y**	**z**
1	1007.601	1007.702	116.332
2	1026.006	1053.718	116.328
3	1007.600	1070.339	116.346
4	1025.557	1007.703	116.341
5	1049.263	1070.625	116.353
6	1049.263	1052.669	116.348

Table 19: fourth floor deviation points with the ground floor

	Fourth floor		
Points	**x**	**y**	**z**
1	1007.601	1007.702	119.441
2	1026.005	1053.717	119.449
3	1007.600	1070.337	119.453
4	1025.557	1007.702	119.439
5	1049.262	1070.623	119.448
6	1049.263	1052.668	119.451

Table 20: result of deviations for all floors with the ground

	Deviation			
Points	**First Floor (m)**	**Second Floor (m)**	**Third Floor (m)**	**Fourth Floor (m)**
1	0.0144	0.0005	0.0002	0.0001
2	0.0193	0.0132	0.0240	0.0237
3	0.0176	0.0221	0.0200	0.0203
4	0.0274	0.0025	0.0091	0.0087
5	0.0184	0.0085	0.0191	0.0184
6	0.0269	0.0203	0.0058	0.0051

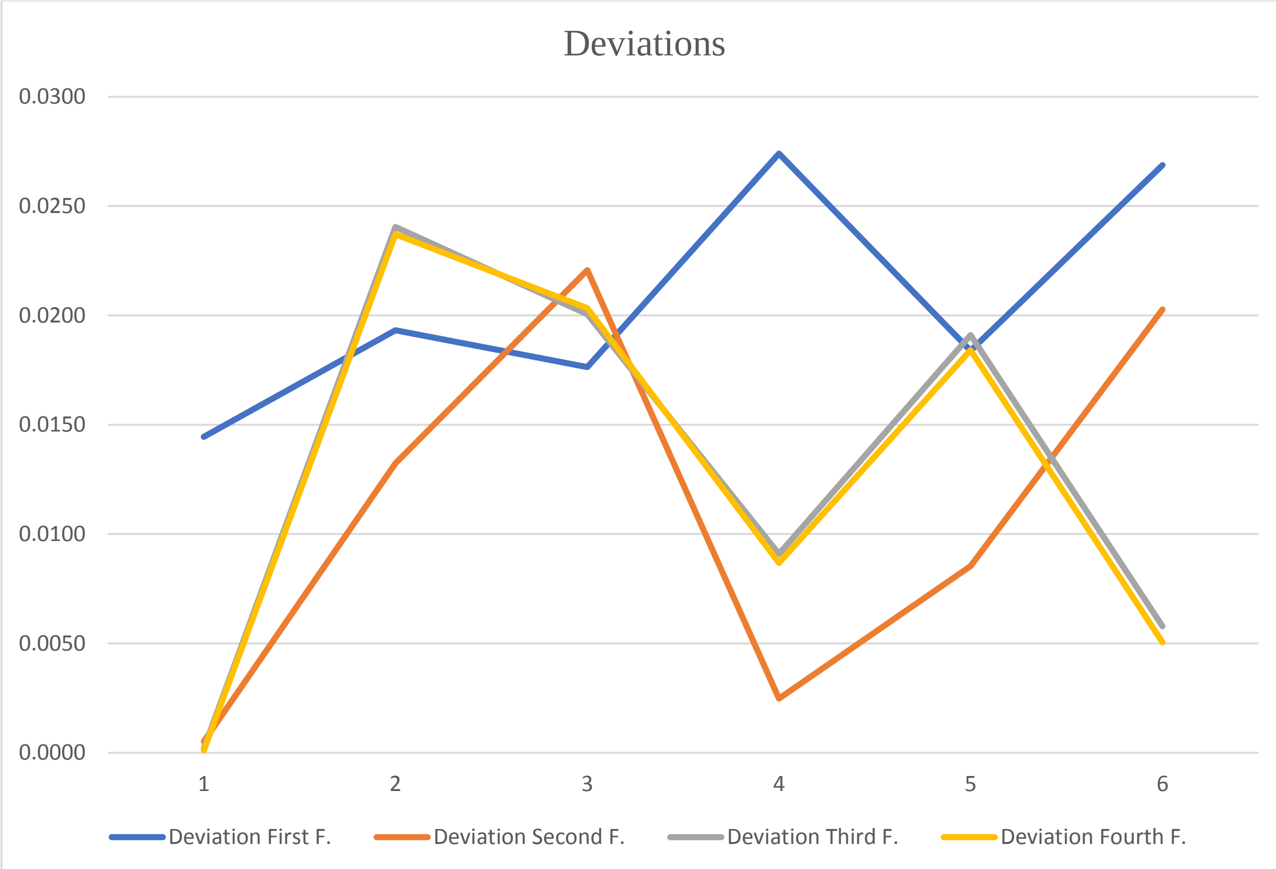

Figure 4-12: result of deviation for all floors with the ground floor

We see in this *Table 20: result of deviations for all floors with the ground* and *Figure 4-12: result of deviation for all floors with the ground floor* that the deviation of the first floor is between 1.44cm and 10.85cm, the deviation of the second floor is between 0.05cm and 2.21cm, the deviation of the third floor is between 0.02cm and 2.40cm, and the deviation of the fourth floor is between 0.01cm and 2.37cm. The divisions on the coordinates of points between floors were not more than 0.0274m and not less than 0.0001m.

5 Chapter Five:

5.1 Conclusion

Finally, we talked about the as-built drawings. We got 1300 coordinates (X, Y, and Z) of columns and shear walls that we used to redraw the five floors of these buildings in this project. We had all the points using the total station, the Leica Viva TS15 Robotic.

After comparing and analyzing this data for our project, in the end ،we realized that there's a good construction because the total concrete volume of columns between floors was very close together, but the total concrete volume of columns in the ground floor and first floor was much higher than the second, third, and fourth floors because the ground floor and first floor consisted of 20 more columns. We realized that these floors were well constructed because the coordinates of each point on the ground floor were too close to the other floors. We realized that it had small divinations between floors. We realized that these floors were well constructed because the total concrete volume of columns, shear walls, slabs, and beams on the ground floor and first floor is close together. And the total concrete volume of columns, shear walls, slabs, and beams on the second floor, third floor, and fourth floor is close together. We used the deviation formula to find the deviations and discrepancies of coordinates (E., N. and E.) of six points between ground floor with first floor, then ground floor with second floor, after that ground floor with third floor, and ground floor with fourth floor. The deviation in an as-built survey refers to the differences between the constructed building and the original design. We used the divination formula to find the divinations. Divination formula talks about how much data values are deviated from the mean value. If we get a low deviation formula then it means that the values tend to be close to the mean whereas a high deviation formula tells us that the values are far from the mean value. The purpose was to see how many errors there were in the columns and shear walls or in the construction of the columns and shear walls. We got five floor redrawing's and estimations of columns, shear walls, slabs, and beams. with division between the coordinates of five floors. After receiving all the information related to As Built, our goal here was to know whether the results of the column or the foundation of the project were correct or not. It was good that the construction of the columns was successful and there is no risk of collapse in the future, which is due to the people who participated in the construction of the building.

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