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A CASE STUDY OF QUALİTY CONTROL APPLICATION WITH BIM-LASER SCANNING COLLABORATION IN BUILDING CONSTRUCTION PROCESS

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Housing accounts for the largest share of the volume of the construction sector. Housing is the living space that people use on a permanent or temporary basis. Living space is also expected to have the desired quality. Quality requires construction in accordance with specified conditions and rules. In order to minimize possible errors in the design and construction process and to achieve the desired level of quality, continuous, scientific and instrumental controls are required. In recent years, with the rapid development of technology, methods have been developed that have achieved good results using integrated technology, which has begun to replace the quality controls performed by traditional methods. This new technology partnership called Building Information Modelling and Laser Scanning is described in this study. The aim of the study is to show that human error in building inspection can be minimized with the help of technology. In the study, a building was selected from a sample public housing project. Two dimensional projects of the building were converted into three dimensions using Building Information Modelling. In the current state of construction, point clouds were captured using laser scanning. The point clouds were converted to three dimensions. The construction defects were calculated by overlaying the BIM model with the real point cloud data. After checking, it was found that 2.2 % of the productions were defective productions. It was found that 97.8 % of the productions were within acceptable tolerance limits. The results obtained on a sample residential building demonstrate the importance of these new solutions for quality control and error-free production

Keywords: building information modeling; laser scan, quality, quality control, construction, building

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1. Introduction

The fact that each existing or under construction building in the construction sector has many factors such as its unique function, location, size, climate, construction technique gives it a different identity, and this situation, together with the uncertainty of the quality method, makes it difficult to apply the concept of quality in the construction sector [1, 2]. At the same time, a quality control process based on human initiative, carried out by traditional methods, involving experts with different professional knowledge and experience, naturally prevents the establishment of a universal minimum quality standard in the construction sector [3].

At this point, there is a need for the establishment of an innovative quality system fueled by technology in the construction industry. In line with this need, BIM-Laser scanning integration, which has been emphasized by researchers in recent years, emerges-[4].

Building Information Modelling (BIM) technology, which has started to be used in developed countries in recent years and has been made compulsory in the design and construction process of government buildings, is an innovative approach to eliminate human-oriented errors and defects in the design and construction process of buildings and to ensure interdisciplinary integration [5]. Monitoring the creation of projects in digital environments and comparing and monitoring them in a virtual environment both increases the efficiency of the project and gives project managers a high opportunity to foresee potential problems and take measures [6].

The process of quality inspection and approval of construction works is critical to the success of any project. All components of the project are constructed according to the requirements contained in the contract between the project participants and the approval of the construction depends on the results of quality inspections, measurements and calculations. Measuring or monitoring progress is an important part of every construction project as it verifies whether the work has been completed [7, 8].

The cost arising from manufacturing defects during the construction process is approximately 5 % of the total construction cost [9]. Considering this 5 % rate, the importance of quality control and early defect detection, which should be carried out continuously during manufacturing in the construction industry, is easily understood [10]. Considering this situation, it can be seen that the quality control process carried out by traditional methods based on observation and expert experience may be insufficient in large-scale projects with developing technology and new construction techniques [11].

At the same time, it is known that an application error overlooked in the quality control process carried out by traditional methods may cause other technical defects and cost losses in both the application and usage stages of the building [12]. At this point, the need for a quality control system that combines Building Information Modelling and Laser Scanning Technologies in an innovative and real-time automated manner in the construction industry is better understood.

When used to monitor and control construction progress, 3D laser scanning is useful even before a structure is fully built. Verification of a BIM model can also be carried out with 3D laser scanning. In other words, when a phase of a project is completed, laser scanning can be used to depict the built model and compare it with the original BIM model to see if there are any discrepancies [13].

Although research on the integration of BIM and Laser Scanning Technology has increased in recent years, these studies are still at the initial level in terms of understanding and dissemination of the technology. Academic and practical studies of these new technologies are at a very low level.

The advantages that new technologies can offer to science and practice are much more advanced than current findings and uses.

For this reason, studies that adapt current technology to the construction industry and are dedicated to providing advantages in cost, quality and time parameters are scientifically important.

2. Literature review and problem statement

Paper [14] stated in their research in 2019 that the methodology they presented will help governments and people responsible for heritage buildings to understand how important it is to use HBIM in their management and operations, and also help academic researchers to understand where their previous studies fell short and how to correct them. On the other hand, this review will help people who make decisions about historic buildings and work in management to understand the current trends and new technology as well as the possible impacts and benefits of using HBIMs to manage heritage buildings. This study is not about modern buildings, but about historical buildings.

In [15], the author presented feasible ideas to improve the effectiveness of quantity surveying management by utilizing the latest technologies of the industrial revolution. This research suggests that the use of BIM modelling in combination with 3D laser scanning can improve the precision and efficiency of the quantity surveying management process by utilizing the advantages and features of these two technologies. As a presentation for the research project, the case study included several examples of joint activities to measure precision and efficiency. The study dealt with the relationship between laser scanning and quantity surveying, but not with quality control.

In [16, 17] the researchers explained BIM as the production of the building in a virtual environment, bringing together the work of other disciplines, exchanging information and managing the processes of the building. In other words, Building Information Modelling technology is grouped under three main headings: product, process and system. Product; consists of a parametric virtual model. Process; Building Information Modelling Technology covers a process starting from the design phase and continuing throughout the life of the building. System interoperability, dimensional controls, quality system and productivity organizations. In those studies, studies have been carried out on BIM, but no studies have been carried out for usability with laser scanning.

Paper [4] The researcher created BIM models of historical buildings and created the second BIM model with laser scanning data and investigated whether the defects and errors are within the tolerance limits by overlapping the door and window elements on the exterior of the building. As a result of the research, error detections were obtained with millimetre precision. The study was limited to the doors and windows on the façade of a historical building.

In [18] stated that by integrating multidimensional CAD modelling and 3D laser scanning technologies, it will be possible to visualize the 3D status of the project and automate some of the steps involved in project control. These steps are as follows: 3D progress tracking, productivity monitoring, construction grade quality assessment and quality control (QA/QC). Although the study provides good theoretical and practical results, it does not provide information on the control and management of the structural systems of an existing construction.

In the literature researches, there is an increasing trend of studies on the benefits and problems of using BIM-Laser scanning technology in the construction sector in recent years. Some of these studies consist of theoretical researches and some of them consist of application researches. The lack of studies on the quality control of the structural systems of housing constructions made with traditional methods has led to the need to introduce a new study to the literature on this subject.

3. The aim and objectives of the study

The aim of the study is to develop a combined quality control methodology for the quality control of structural systems of residential construction using laser scanning and BIM technology.

This will ensure the desired quality of the building structural elements during the construction of the building and reduce the cost and time losses due to quality problems.

To achieve this aim, the following objectives are accomplished:

– to make the registration of the created BIM model and the model obtained from Laser Scanning data;

– to evaluate the tolerance limits and acceptance criteria as a result of the overlaps.

4. Materials and methods

4. 1. Object and hypothesis of the study

Object of research is Atışalanı 580 unit apartment construction site. With the Building Information Modeling (BIM) and 3D Laser Scanning integration technique, Atışalanı district 2nd Stage 3 Region 580 apartment construction site was selected as the application area within the scope of obtaining the errors and defects in the x, y, z dimensions of the wall building element on the façade surfaces of traditional buildings, dimensional deviations caused by manufacturing, and dimensional quality assessment.

The main hypothesis of the study is that quality control in collaboration with BIM laser scanning provides significant advantages in terms of quality assessment during the construction phase of a construction.

The assumptions made in the study are that individual inspections during construction are error-prone and vary according to the individual performance and experience of the inspectors. It is foreseen that controls with technological solutions will reduce these errors to a much lower level.

Simplifications adopted in the study; a sample block was selected from the construction site. Only the structural elements of this sample building block were determined as the subject of the study.

4. 1. 1. Atışalanı 580 Unit Apartment Construction Site

This project, which was selected as an application area, is a project consisting of 580 houses under construction in Atışalanı district of Esenler District of Istanbul. Employer Public Apartment Authority, Contractor Tek-Çelik A.Ş. The company is illustrated in Fig. 1. The consultant (control) is EPP A.Ş. The construction of the project started in 22/06/2020 and the duration of the work is 550 days. The construction of the project is continuing at the time of the work.

The project consists of 16 blocks and two different types. The block names are A, B, C....., M, N, O, and P. The blocks have 5 floors from the ground floor. However, basement floors have different numbers of basement floors according to the land elevation where the blocks sit. Qualification information and descriptions of all blocks in the project area are given in Table 1.

The study was carried out in M Block. The reason for choosing the M block building in this study is the lowest block after the A block in terms of progress percentage. Since the work is mainly aimed at examining the carrier system and external walls, it is the block where laser scanning can be measured most clearly in the work area. A block was not chosen because its fabrications were far behind.

M block has a total of 7 floors with 1 basement floor, ground floor, and 5 normal floors. There are a total of 24 residences in the block, each with 3 rooms. The total construction area of the block is 3,597.26 m^2. The project type and area information of the floors for M Block is given in Table 2.

Table 1

Workspace block information, attributes, and project progress

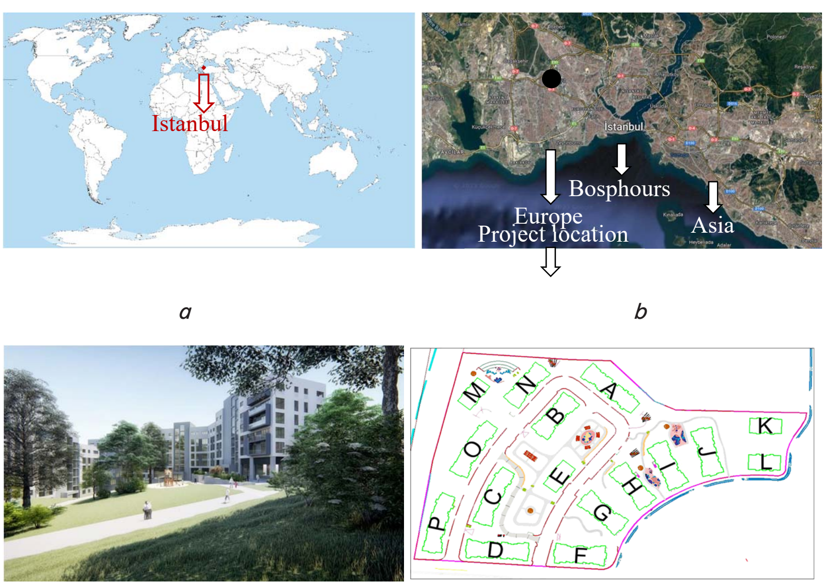
Block No.	Block Name	Project Type	Number of Floors	Number of Apartment	Block Area	Percentage of Progress
1	A	B1 Type	1B+G+5	46	7,500.46	12.00 %
2	B	A9 Type	2B+G+5	36	6,866.04	36.20 %
3	C	A10 Type	2B+G+5	48	8,264.86	40.30 %
4	D	A1 Type	3B+G+5	44	7,615.11	45.80 %
5	E	B6 Type	1B+G+5	24	3,784.15	45.85 %
6	F	A9 Type	1B+G+5	36	6,565.11	70.25 %
7	G	A9 Type	2B+G+5	36	8,512.48	65.50 %
8	H	A9 Type	2B+G+5	36	7,443.66	60.60 %
9	I	A9 Type	2B+G+5	36	7,354.86	53.25 %
10	J	A9 Type	2B+G+5	36	8,213.25	55.68 %
11	K	B6 Type	1B+G+5	24	3,280.27	65.70 %
12	L	B6 Type	1B+G+5	24	3,505.85	66.00 %
13	M	B6 Type	1B+G+5	24	3,597.26	38.00 %
14	N	A3 Type	2B+G+5	36	6,907.22	40.50 %
15	O	A10 Type	2B+G+5	48	7,562.18	39.00 %
16	P	A10 Type	2B+G+5	46	8,610.53	41.10 %
Total				580	105,583.29 m^2	

At the time of the fieldwork, the structure of the building was completed except for the 5th floor. The 5th-floor formwork scaffolding has been prepared and the iron reinforcements have been placed and made ready for concrete pouring. From the basement floor, the construction of the outer walls has begun, and the outer walls have been largely completed. By measurement time, the block was 38 % complete.

Table 2

M Block (Type B6) field

Block No.	Block Name	Project Type	Number of Floors	Block Area
1	M Block	B6 Type	Basement	864.54
2	M Block	B6 Type	Ground floor	545.76
3	M Block	B6 Type	First Floor	454.76
4	M Block	B6 Type	Second Floor	456.28
5	M Block	B6 Type	Third Floor	454.76
6	M Block	B6 Type	Fourth Floor	456.28
7	M Block	B6 Type	Fifth Floor	451.88
Total				3,597.26 m^2



a *b* *c* *d*

Fig. 1. Example of location of the project on the world and Turkey and visual and layout plan: *a* – Istanbul's location on a global map; *b* – the exact location of the project in Istanbul; *c* – 3D Rendering of project; *d* – site plan (prepared by authors)

4. 2. Method of this study

The method of this study is based on fieldwork and consists of the following processes with the help of 'BIM Technology and Laser Scanning Integration Systems'.

Manual modelling of the traditional building with Building Information Modelling (BIM) technology and creating a common source of information about the building, extracting the current condition of the traditional building with 3D laser scanning integration system, automatically overlapping the model made with Building Information Modelling (BIM) technology and the traditional structure extracted with 3D laser scanning integration, The Building Information Modelling (BIM) technology and 3D laser scanning integration system consists of the processes of comparing the works and proposed dimensions with the information provided by the system, finding structural defects and performing dimensional checks, and all these methods were carried out as shown in the flowchart (Fig. 2).

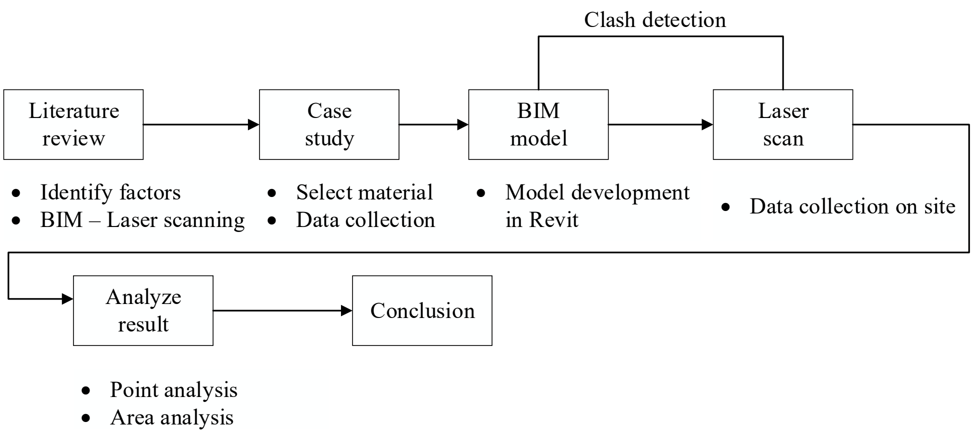


Fig. 2. Flowchart was shown study step method

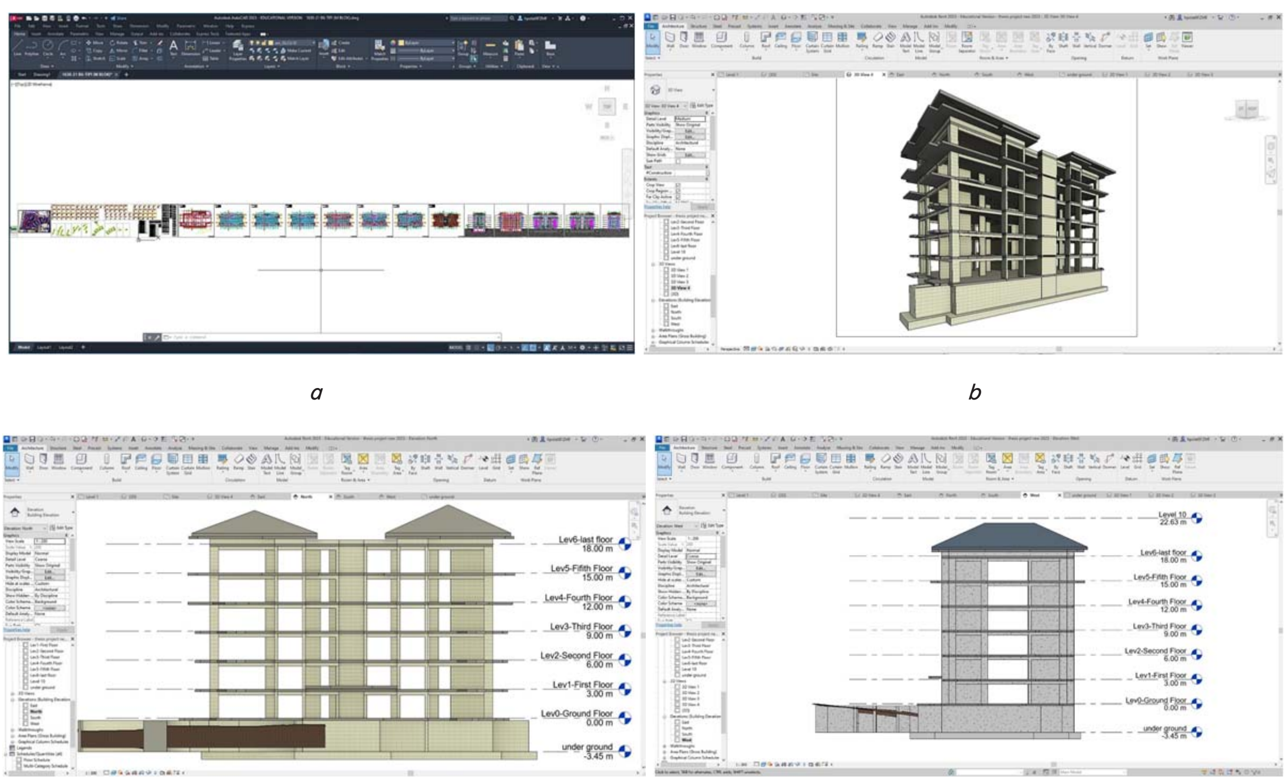
As it is clearly seen in the workflow chart above, firstly, deficiencies were identified by conducting a literature review. Then, the study area was determined and the data of this study area were obtained. The data obtained were analyzed in BIM environment and the findings were discussed and conclusions were reached.

5. Results of quality control of building structural elements by BIM and laser scanning

5. 1. Overlaying the created BIM models

5. 1. 1. Creation of three-dimensional building information model of structure

After the Atışalanı district 2nd Stage 3rd Region 580 Housing Construction Site located in the Esenler district of Istanbul was selected, the architectural and static projects received from the consultant (control) company EPP A.Ş. in two dimensions in the dwg environment were created by using Autodesk Revit 2023 software as shown in Fig. 3.



a *b* *c* *d*

Fig. 3. Example of BIM model creation with Autodesk Revit created with Revit 2023, *a* — 2D data received from EPP A.Ş.; *b* — 3D model; *c* — BIM model front view; *d* — BIM model side view (prepared by authors)

Each building element that forms the façade of the building was selected under the categories of these objects in the Revit program and introduced directly to the computer perception to form the information model. This virtual model creates both give all the architectural information about the facades of these traditional buildings and serves as a base for the overlapping process to be performed after the laser scanning process.

5. 1. 2. Extraction of the current state of the structure with three-dimensional laser scanning system

As a second step, up-to-date scanning measurements were carried out using a three-dimensional laser scanner to determine the deviations that occurred in the *M* block façade surfaces, the carrier system, and the flooring of the building community built by the Mass house Administration by providing the interaction of Building Information Modeling and Laser Scanning technology.

The laser scanning study was carried out with the Leica RTC360 as illustrated in Fig. 4. The RTC360 is a terrestrial laser scanner that makes 2 million points in seconds, can take HDR photos in 1 minute, has a range of 130 m, and has a distance accuracy of 1.0 mm+10 ppm.

Fig. 5. Three-dimensional point cloud view in Leica Cyclone Register software (prepared by authors)

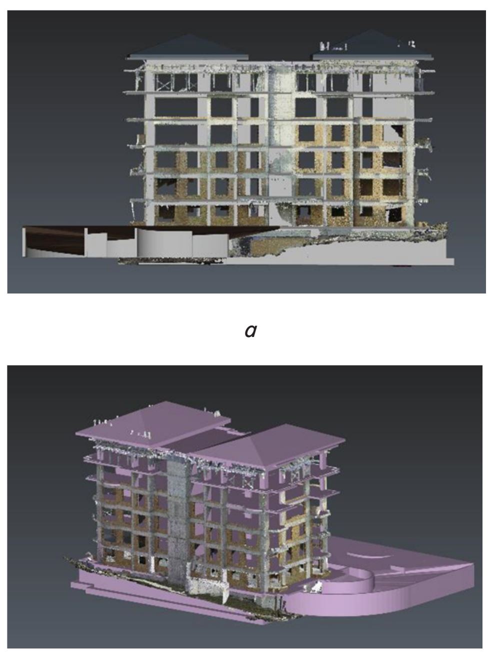
Fig. 4. The photograph was taken during laser scanning in the work area (prepared by authors)

Within the scope of the study, a total of 69 stations were scanned at 6mm resolution at 10 m and HDR photographs were taken. Leica Cyclone Register software was used in the data integration and control phase, and Leica Cyclone 3DR software was used in the 3D analysis phase.

5. 1. 3. Merging, cleaning, and overlapping of three-dimensional point clouds

After the data obtained during the laser scanning process was transferred to a laptop with sufficient storage space, the three-dimensional point clouds obtained as a result of 69 different station installations in the office environment were first combined. This joining process was carried out with the help of Leica Cyclone Register software based on the common points of different three-dimensional point clouds on a predetermined reference coordinate plane and as a result, the point clouds obtained as a result of the installation of different stations were turned into a single point cloud as shown in Fig. 5.

In the second stage, the necessary format conversions of the working information model were carried out in the office environment and the Leica Cyclone 3DR software was used to make a three-dimensional comparison as shown in Fig. 6. A preliminary comparison of the point cloud model obtained as a result of laser scanning and the BIM model was made and the background modeling outside the fa ade in the model, which is not in the point cloud, will affect the overlapping process, so the cleaning process is made and made ready for the overlapping process. Construction wastes that are found in the three-dimensional point cloud but not in the building information model and external point clouds such as construction materials on the ground will not be taken into consideration in the analysis and interpretations within the scope of the study.

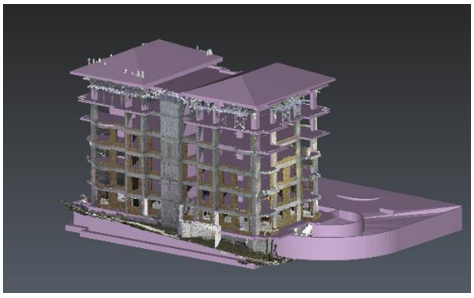


a

b

Fig. 6. Examples of deletion of unnecessary point clouds in Leica Cyclone 3DR software; *a* — axonometric perspective; *b* — axonometric perspective from the other angle (prepared by authors

After the necessary cleaning and sorting of the three-dimensional virtual information model created with the help of the three-dimensional point cloud and structure information modeling technology obtained as a result of laser scanning in the application area, the overlapping process was carried out with the help of Leica Cyclone 3DR software to make a three-dimensional comparison of the front the relay as shown in (Fig. 7). The image of the overlapping process is shown in Fig. 7 below.



a

b

Fig. 7. Overlapping BIM model with laser scan model; *a* – front view; *b* – axonometric perspective (prepared by authors)

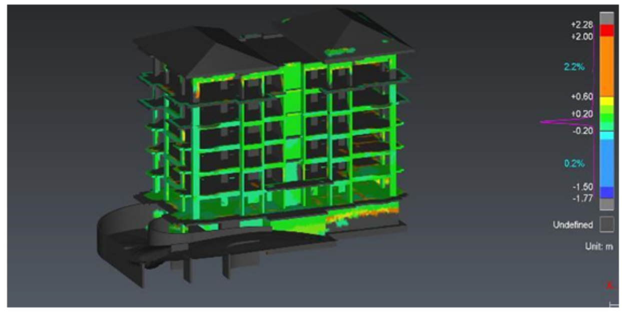
By overlapping the three-dimensional model obtained from the point clouds as well as by the Building Information Model and Laser Scanning created with the information obtained from the project, two different data groups were obtained spatial analysis and point analysis.

5. 1. 4. Overlapping the created BIM models

The registration of the BIM models created from the projects of the building and the BIM models created from the data taken from the field were handled in two ways. The first is surface registration and the second is point registration.

All analyses were performed within ±40 cm range and different colour values were assigned in the ranges shown in the graph. Areas outside the ±40 cm range and shown in grey were considered as large errors and were excluded from the evaluation in order not to affect the total data. In the building envelope, 2.2 % of the total data marked in controlled orange and 0.2 % marked in blue are outside the tolerance limits, while 97.8 % in the green region are within the specified ±3 cm tolerance ranges. It was observed that the orange and blue region outside the tolerance limits were placed in a way that cannot be defined as a manufacturing defect.

The values found as a result of the spatial analysis performed on the superimposed 3D model are reflected in Fig. 8 below with the help of graphs.



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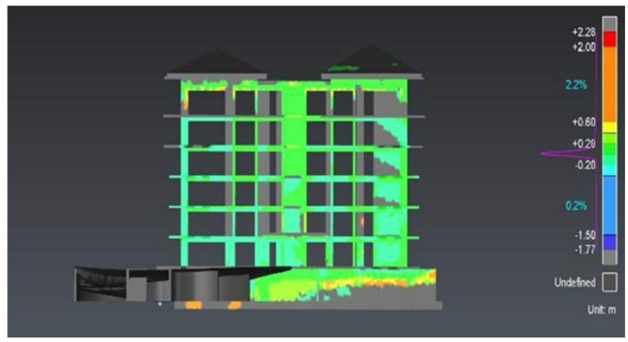


b

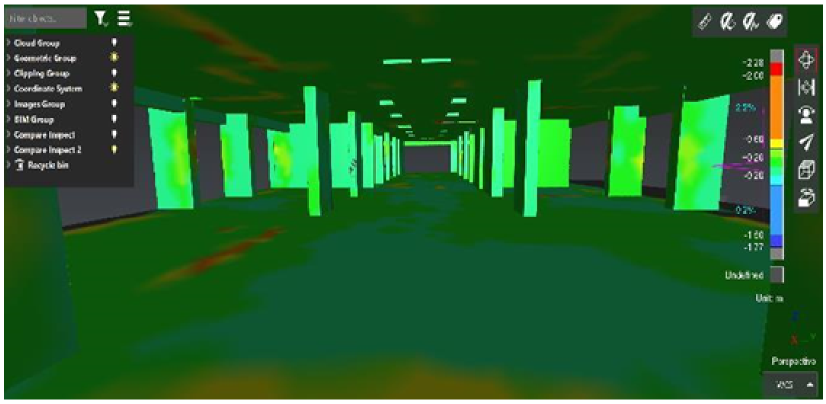
Fig. 8. Examples of building shell analysis; *a* – areal analysis of the building shell surface (perspective); *b* – areal analysis of the building shell surface (frontline)

Inside the building, the basement floor and the building structural system (columns, floors, and beams) on the ground floor were checked by the overlapping process. The values found as a result of the spatial analysis on the overlapping 3D model are reflected in Fig. 9 below with the help of graphs.

The 2.2 % value marked in orange and 0.2 % value marked in blue are outside the tolerance limits, while the remaining 97.8 % in the green region is within the specified tolerance range of ±3 cm. It was observed that the orange and blue regions outside the tolerance limits are places that cannot be defined as manufacturing defects.

Following the spatial analyses performed on the building envelope within the scope of the study, point analyses were obtained by overlapping laser scanning and building information modelling technology. As shown in Fig. 10 below, overlapping labels were assigned to 6 different points on the analyzed building envelope. Green labels in the model indicate areas within the tolerance range, while red labels indicate areas outside the tolerance range.

Table 3 with the results of the comparison of the found values. It is also shown below. In the table, green result values are within the tolerance limits and red result values are outside the tolerance limit. 5 of the 6 different points (points 6, 8–11) are within the tolerance limits. Point 7 is point wise outside the tolerance limit with a deviation of 0.574 m. At this point, it is thought that there is a point of migration or scraping.



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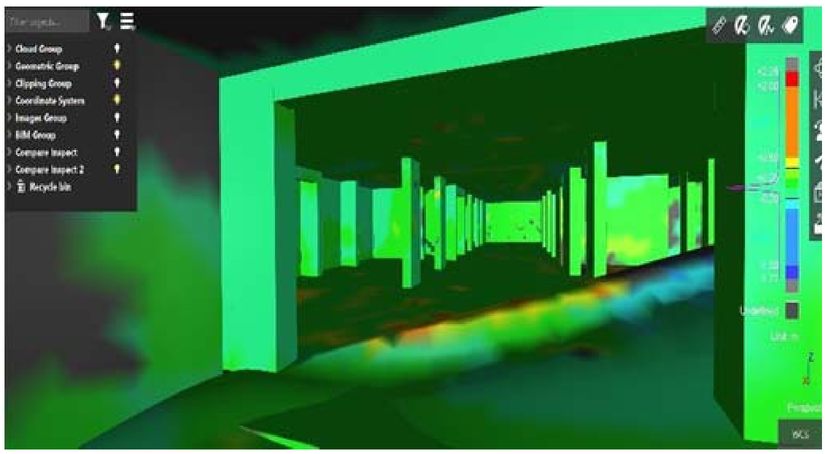

b

Fig. 9. Examples of building spatial analysis; *a* – basement floor spatial analysis; *b* – ground floor spatial analysis (prepared by authors)

Table 3

Building shell (surface) point analysis

Point	Measurement (Point Cloud)			Reference (BIM Model)			Deviation		
	X-Axis (m)	Y-Axis (m)	Z-Axis (m)	X-Axis (m)	Y-Axis (m)	Z-Axis (m)	X-Axis (m)	Y-Axis (m)	Z-Axis (m)
Point 6	8.888	7.634	0.181	8.888	7.634	0.177	0.000	0.000	0.004
Point 7	–5.637	9.173	0.742	–5.636	9.178	0.168	–0.001	–0.005	0.574
Point 8	–14.000	9.679	0.162	–14.000	9.679	0.159	0.000	0.000	0.003
Point 9	12.456	10.413	10.221	12.456	10.435	10.221	0.000	–0.022	0.000
Point 10	–16.282	10.470	7.877	–16.282	10.456	7.877	0.000	0.014	0.000
Point 11	–1.846	9.320	14.038	–1.846	9.297	14.038	0.000	0.023	0.000

After the spatial analyzes made within the scope of the study on the bearing structural elements in the building, the point analyzes were obtained by overlapping the laser scanning and building information modeling technology. As shown below in Fig. 11, overlapping labels were assigned to 5 different points in the analyzed basement. Green labels in the model represent areas within the tolerance range, and red labels refer to areas outside the tolerance range.

Table 4 with the results of the comparison of the found values. It is also shown below. In the table, green result values are within the tolerance limits and red result values are outside the tolerance limit. 4 of the 6 different points (point 12–15) are within the tolerance limits. Point 16 is point wise outside the tolerance limit with a deviation of 0.554 m. At this point, it is thought that there is a point of migration or scraping.

After the spatial analyzes made within the scope of the study carried out on the bearing structural elements on the ground floor of the building, the point analyzes were obtained by overlapping the laser scanning and building information modeling technology. Overlapping labels were assigned to 6 different points on the ground floor where the analysis was done as shown below in Fig. 12. Green labels in the model represent areas within the tolerance range, and red labels refer to areas outside the tolerance range.

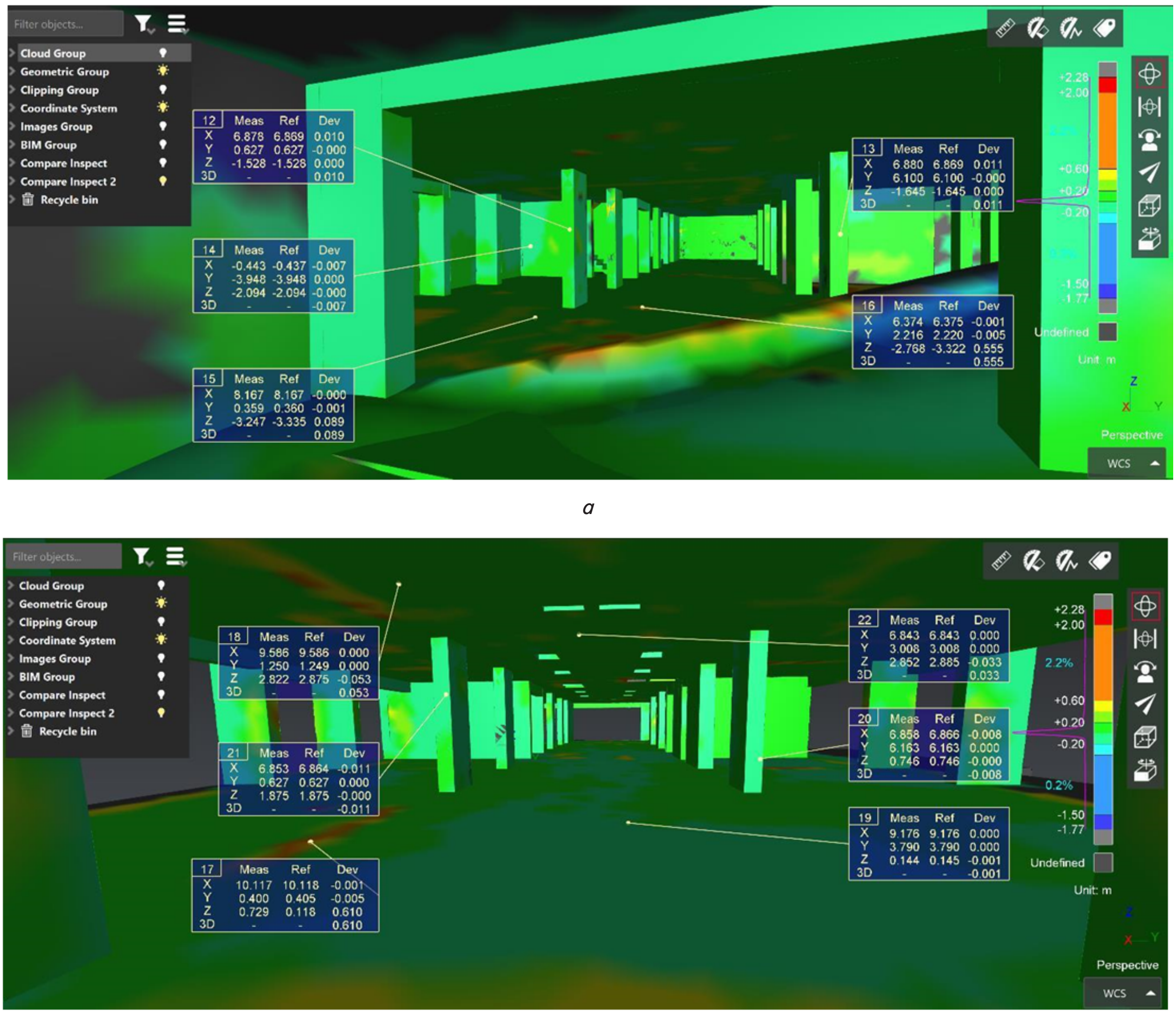

Fig. 10. Examples of point analyses of the building; *a* — basement point analysis data; *b* — ground floor data point analysis data (prepared by authors)

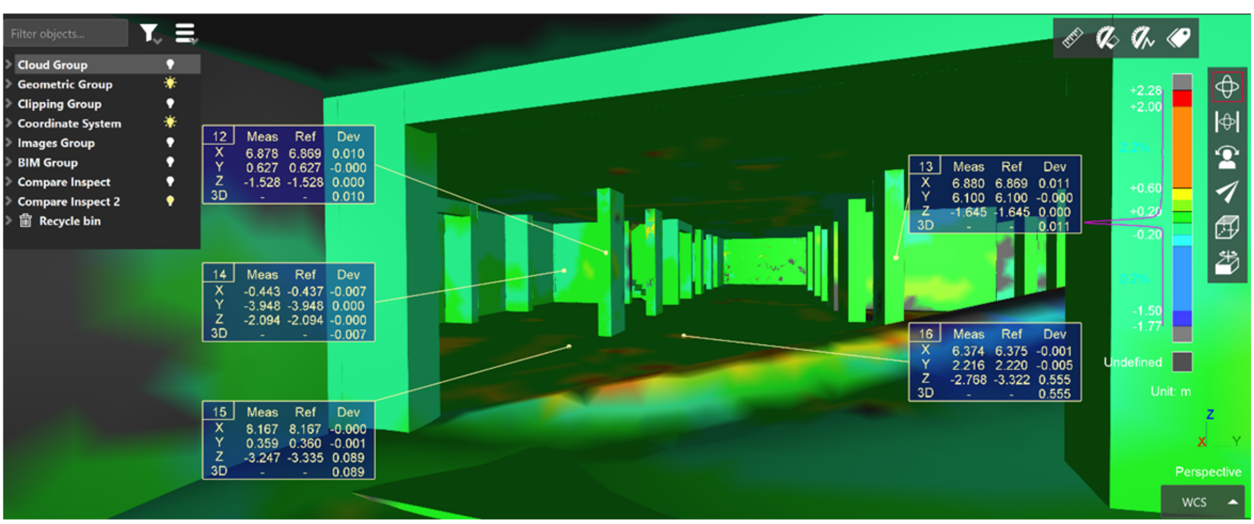

Fig. 11. Basement point analysis data

Table 4

Basement structural elements point-based analysis table

Point	Measurement (Point Cloud)			Reference (BIM Model)			Deviation		
	X-Axis (m)	Y-Axis (m)	Z-Axis (m)	X-Axis (m)	Y-Axis (m)	Z-Axis (m)	X-Axis (m)	Y-Axis (m)	Z-Axis (m)
Point 12	6.878	0.627	1.528	6.869	0.627	1.528	0.009	0.000	0.000
Point 13	6.880	6.100	1.645	6.869	6.100	1.645	0.011	0.000	0.000
Point 14	–0.443	–3.948	2.094	–0.437	–3.948	2.094	–0.006	0.000	0.000
Point 15	8.167	0.359	–3.247	8.167	0.360	–3.335	0.000	–0.001	0.088
Point 16	6.374	2.216	–2.768	6.375	2.220	–3.322	–0.001	–0.004	0.554

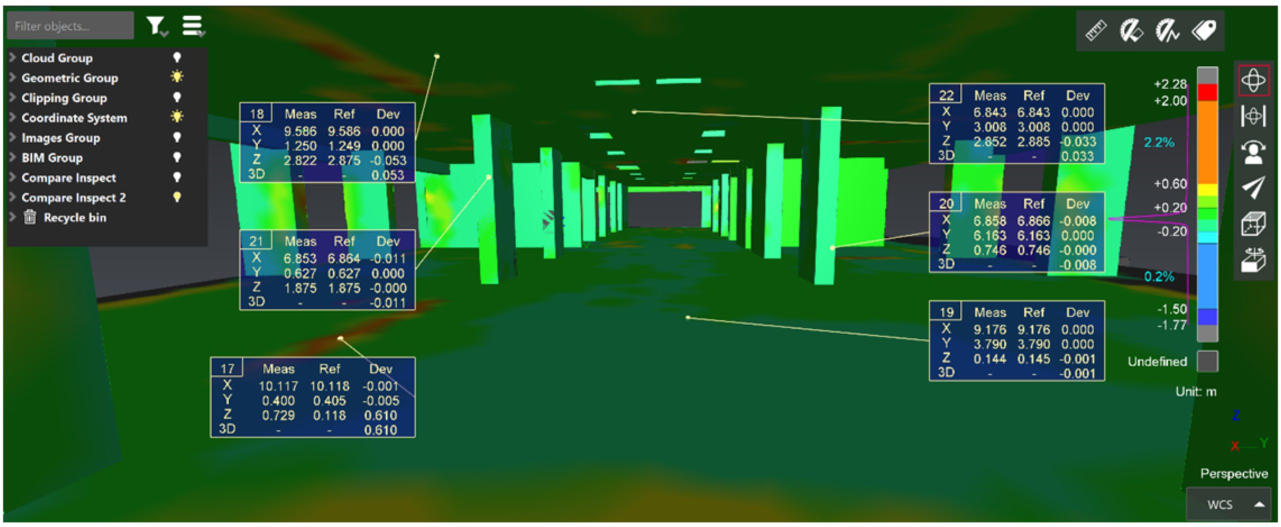

Fig. 12. Ground floor data point analysis data

Table 5 with the results of the comparison of the found values it is also shown. In the table, green result values are within the tolerance limits and red result values are outside the tolerance limit. All 6 different points (points 17–22) are within the tolerance limits.

Table 5

Basement structural elements point-based analysis

Point	Measurement (Point Cloud)			Reference (BIM Model)			Deviation		
	X-Axis (m)	Y-Axis (m)	Z-Axis (m)	X-Axis (m)	Y-Axis (m)	Z-Axis (m)	X-Axis (m)	Y-Axis (m)	Z-Axis (m)
Point 17	10.117	0.400	0.729	10.118	0.405	0.118	–0.001	–0.005	0.611
Point 18	9.586	1.250	2.822	9.586	1.249	2.875	0.000	0.001	–0.053
Point 19	9.176	3.790	0.144	9.176	3.790	0.145	0.000	0.000	–0.001
Point 20	6.858	6.163	0.746	6.866	6.163	0.746	–0.008	0.000	0.000
Point 21	6.853	0.627	1.875	6.864	0.627	1.875	–0.011	0.000	0.000
Point 22	6.843	3.008	2.852	6.843	3.008	2.885	0.000	0.000	–0.033

All results of the field and point measurements are described in detail above. The next section summarizes the results of all field and point measurements.

5. 2. Evaluation of tolerance limits and acceptance criteria after overlap

The tolerance range was determined as ±3 cm while overlapping. This tolerance determination is the tolerance level of the dimensional margin of error of the structural elements in the technical specifications of this work. In other words, the maximum margin of error that the control engineers can accept during construction is ±3 cm.

As summarized in Table 6, in the point analysis, measurements were made at a total of 17 points, 6 on the building shell, 5 on the basement floor and 6 on the ground floor. In the measurements, it was observed that one point in the building shell (point 7) and one point in the basement floor (point 16) exceeded the tolerance limits.

Table 7 summarizes the conditions within and outside the tolerance limits for the building envelope; the reinforced concrete slab of the basement floor and reinforced concrete columns and beams; the reinforced concrete slab of the ground floor and reinforced concrete columns and beams.

According to these data, 97.8 % of the measured parts of the building envelope were manufactured in an acceptable manner, but 2.2 % of them were faulty. Similarly, there are defects in the basement and ground floor of the building. In the basement floor reinforced concrete slab and reinforced concrete bearing columns and beams of the building, 97.8 % acceptable manufacturing was made, but 2.2 % faulty manufacturing was observed. In the ground floor of the building, 97.8 % acceptable manufacturing was made, but 2.2 % faulty manufacturing was observed.

Table 6

Model validation according to point analysis

Point Analysis	Building shell		Basement floor		Ground floor	
	Suitable	Unsuitable	Suitable	Unsuitable	Suitable	Unsuitable
	(Point ratio)		(Point ratio)		(Point ratio)	
	5/6	1/6	4/5	1/5	5/6	1/6

Table 7

Model validation according to spatial analysis

Spatial Analysis	Building shell		Basement floor		Ground floor	
	Suitable	Unsuitable	Suitable	Unsuitable	Suitable	Unsuitable
	(Percentage rate)		(Percentage rate)		(Percentage rate)	
	97.8 %	2.2 %	97.8 %	2.2 %	97.8 %	2.2 %

6. Discussion of the results of clash detections

The study describes the comparison of the results obtained by superimposing the 3D model obtained from point clouds taken from the field and the perfect 3D model that should be according to the projects.

Section 5. 1 describes in detail the process of overlaying the field data with the perfect model. Numerical data were found for each overlaid point and surface (Fig. 3–11, Tables 3–5).

Before registration, the acceptable margin of error was considered to be 3 cm. This decision was accepted according to the technical specifications.

In Section 5. 2, two results were obtained: within tolerance limits and outside tolerance limits (Tables 6, 7).

According to the point records, an error rate of 2.2 % was observed. 97.8 % of the results were within tolerance. Similarly, a 2.2 % error rate was observed in the surface records taken according to the point records. 97.8 % of the results were within tolerance.

It was observed that the 2.2 % errors obtained from the point registration were local errors and did not affect the overall situation. However, it was clearly seen that it is a situation that the control team should pay attention to.

The error rate of the models with respect to the surface registration was 2.2 percent. 97.8 percent of the results were within tolerance. It was observed that the surface defects consisted of manufacturing defects. These surfaces were found to be predominantly on the reinforcement.

If the quality control of this construction had been done with BIM-laser scanning integration and not with conventional methods, these defects would not have been accepted and the defects would have been corrected by the construction company.

With this study, unlike the very few previous studies in the literature, it has been revealed that the manufacturing of the load-bearing elements that support the building during the construction of a building can be terminated flawlessly. Although some studies have been carried out on different elements of the building, no such result has emerged that reveals a real result.

However, due to the high rental cost of the laser scanning device at the time of this research and the exceeding of the research budget, the study was limited to only one block in the complex. In addition, block control was limited to reinforced concrete columns, beams and slabs. Having laser scanning devices and BIM software requires significant budgets. These are actually insignificant budgets for medium and large-scale companies in the construction sector. However, they are high budgets for academic research. In order to create better quality structures, there may be government contributions related to these budgets and administrations can encourage companies and researchers by supporting these budgets.

Apart from the budget, another important deficiency is that the number of professionals using these new software and tools is quite low. Regarding this deficiency; device manufacturer companies, universities, professional organizations can provide training and make their use widespread.

If the number of manufacturers and developers of these devices and software increases in the future and if government support is provided for these technologies, investment costs can be reduced and the number of users can be increased.

7. Conclusions

1. Point cloud scanning was performed with laser scanning during the continuation of construction in the field. A real situation 3D model was obtained from the point clouds. A perfect 3D model was also created from the building application projects and these models were overlapped in the BIM environment. The registration was done in two directions. On the one hand, surface overlays were made and on the other hand, point overlays were made and the results were analyzed.

2. An error rate of 2.2 % was observed in the point analysis. 97.8 % of the results were within tolerance limits. It was observed that the 2.2 % errors obtained from the point registration were local errors and did not affect the overall situation. The error rate in surface analysis was also 2.2 per cent. 97.8 per cent of the results were within tolerance. It was observed that the surface defects consisted of manufacturing defects.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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Data availability

All data are available in the main text of the manuscript.

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