Quantity Optimization of Structure Works with Building Information modeling for Politeknik Negeri Padang's Integrated Technology Laboratory Building Design

Andi Syukri[1], Hendra Alexander[2], Indra Agus[3], Afdhil Akbar[4], Reyhan Bukhari[5], Darma Hendra[6]

{andisyukri@pnp.ac.id, hendra.alexander@gmail.com, indra_daguchi@yahoo.co.id}

Civil Engineering Department, Padang State Polytechnic Campus
Limau Manis, Pauh District, Padang City 25164, West Sumatra Province Indonesia[1]

Abstract. BIM is a digital representation of physical and functional building qualities that is used to regulate construction processes such as design, construction, and management. BIM becomes the dominant data source later in a structure's operation, health monitoring, and longevity. In this project, conventional Detailed Engineering Design (DED) Politeknik Negeri Padang‘s Integrated Technology Laboratory Building papers will be used, and the planning process will be disrupted by remodeling the building structure utilizing licensed Building Information Modelling (BIM) software from TEKLA Structure educational licensed (TIMBLER). The aim is to collect effective structure volume data and then conduct a comparison study of BIM and traditional budget calculation efficiency for structural elements in concrete, steel bar, and formwork. As a result, there are variants of volume deviation, the structural parts of the floor slab, Superior Beam, and Inferior Beam, that indicate the necessity of budget construction estimation.

Keywords: BIM, volume, structure, and budget.

1 Introduction

Within the last two decades, building planning has been developed computationally. The planning steps were purely manual and calculated by hand; but, since the development of computers, the design and calculation procedures have switched to computation [1]. However, building needs fluctuate from time to time and are quite large, causing issues in construction planning, particularly for buildings. Particularly, building elements are becoming increasingly complicated, necessitating extensive and integrated accuracy and analysis. There are still many errors and reasons since they are still in the conventional planning stage and no sustainable system has been developed. It is necessary to have information technology that can combine phases and data into a full system, allowing for effective and efficient decision-making. There is a full and real-time data record that may be utilized for the process of monitoring assessment during and after building construction.

ABEC 2023, September 21, Bengkalis, Indonesia

DOI 10.4108/eai.21-9-2023.2342895

BIM is defined as the methodologies and software systems used to produce virtual representations of buildings and infrastructure to assist their design, construction, operation, and reuse/recycling across all relevant disciplines [4]. This term emphasizes the interaction between individuals and their working techniques. This concept encourages information exchange among parties involved in proposing new building and infrastructure projects, planning, constructing, maintaining, and finally dismantling these facilities. Using BIM generally results in the lowest possible cost for a project. The most major advantage of using BIM in the construction sector is cost reduction or cost management [2]. When implemented properly and comprehensively, BIM may also minimize construction time [2][4]. Designers gain from BIM by minimizing manual verification labor and facilitating rapid decision-making in a variety of project responsibilities [4]. BIM allows the entire model to be automatically updated based on modifications made [7] reducing the time required to prepare drawings and other building procedures. If design revisions are necessary to satisfy project standards, BIM's virtual 3D, 4D, and 5D knowledge repository can assist with speedy updates [6]. BIM repositories allow for automatic coordination via virtual modeling 3D view sessions, which promotes communication and trust among stakeholders while eliminating the requirement for conventional coordination meetings [1][2] Better coordination and collaboration can also help to spot disputes earlier, decrease mistakes, and rework, make decisions faster, and lower the risk of budget overruns [1][2][3]. Due to the BIM methodology, design correctness and documentation improvement are two major components associated with quality compliance [2]. BIM also allows for construction verification before the start of construction, which immediately enhances the accuracy of on-site construction work and decreases the potential for rework. As a result, the total efficiency and quality of the building will improve [3]. Furthermore, because all project teams must update the BIM model during the project's ongoing life cycle, BIM contains up-to-date information. As a result, BIM is seen as lifetime data that may assist facility managers in more effectively operating and maintaining buildings [1]. Based on the benefits listed above, BIM makes the construction process easier, less difficult, and more successful, and it serves the building efficiently throughout its life.

In this study, conventionally planned existing Detailed Engineering Design (DED) documents will be used, which will then be intervened in the planning process by remodeling the building structure using licensed Building Information Modelling (BIM) software from TEKLA Structure (Timbler). In general, this study begins with recalculating volume from the first planning inquiry, followed by specification determination and cost budget analysis. Finally, the plan for the construction process of the structural components of the Politeknik Negeri Padang’s Integrated Technology Laboratory building has been rescheduled. Furthermore, this BIM output may be used as resource data for building monitoring, utilities, and energy usage, by the goal of the Politeknik Negeri Padang Campus's first green and smart building concept.

2 Research Methods

This study's research framework is depicted in Fig 1. For primary data collecting, this study uses qualitative methodologies. The investigation begins with a Document Review of the current DED from the Politeknik Negeri Padang‘s Integrated Technology Laboratory Building Planning. The process of verifying the data acquired is then carried out by conducting interviews with the stakeholders engaged in the planning process. Furthermore, the data and information gathered will be analyzed and the outcomes established to create a more effective plan. Furthermore, the constraints of this study look at the structural elements in structural work, namely foundations, basement structure work, first-floor structure work, second-floor structure work, third-floor structure work, and fourth-floor structure work. The amount of work under consideration is the volume of concrete, reinforcing volume, and formwork volume to compare the findings of BIM and traditional reports.

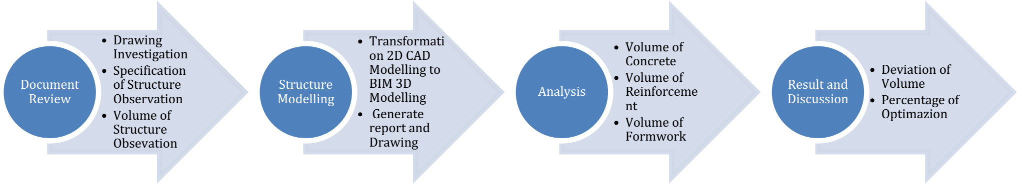


Fig. 1. Research framework

Document review and interviews were utilized to collect data to meet study objectives. These research methodologies work in tandem to demonstrate the study's validity. A literature review was conducted early on to determine the application of BIM technology. At the same time, documents on guidelines, processes, and other building design work process materials were studied to understand the existing work process and assist in generating interview questions. The second step of the study was primary data collecting, which involved using semi-structured interviews to comprehend and assess the planning process.

The modeling is then continued using CAD drawing data, which is then transformed into a 3D BIM model that includes structural components such as dimensions, reinforcement, specifications, types of joints, and some detailing that would be overlooked if conventional volume calculations were used. After determining the volume of each structural element in the structure, a classification calculation is performed to determine how significant the change is and if there is a decrease or rise in the number of volumes. The volumes under consideration in this study are those of concrete, steel, and formwork.

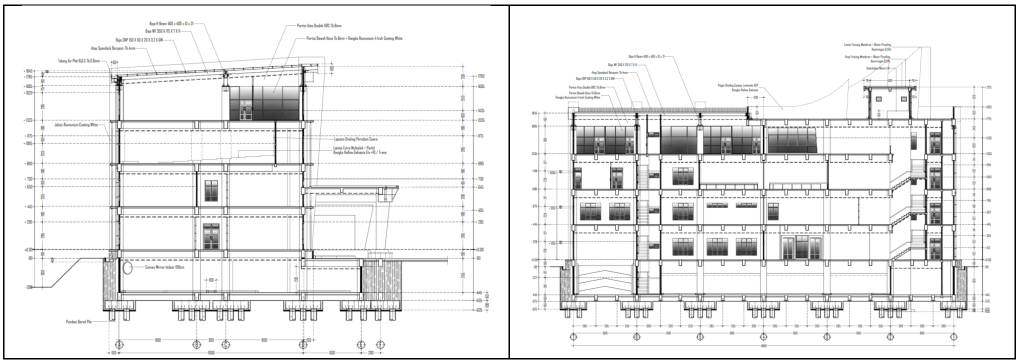
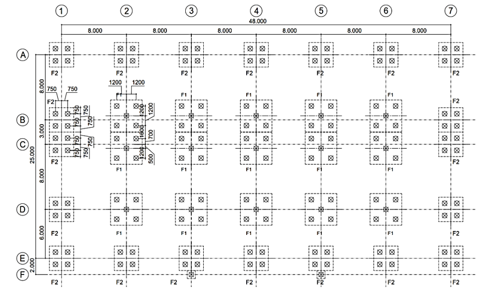
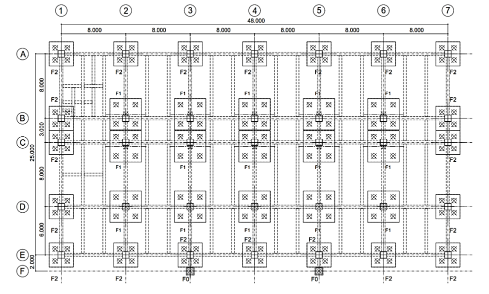


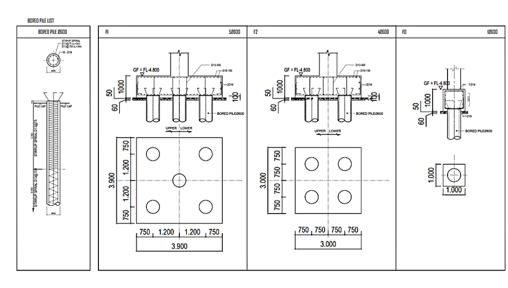
Fig. 2. Section of building



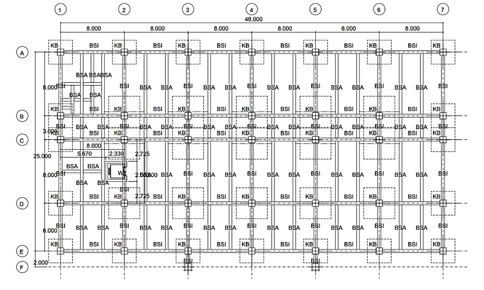
Bored Pile



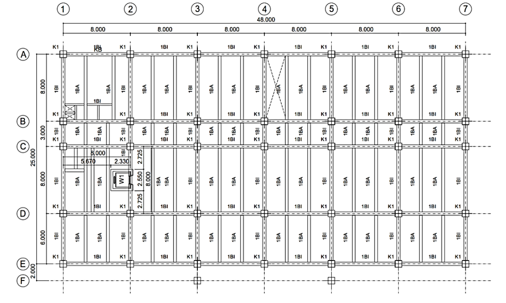
Pile Cap



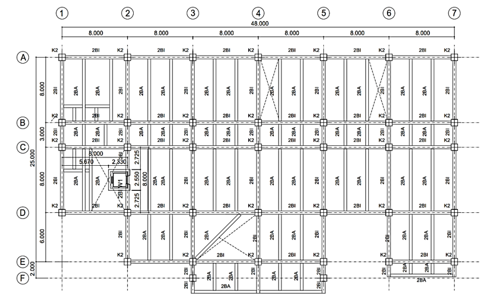
Pile Cap Detailing



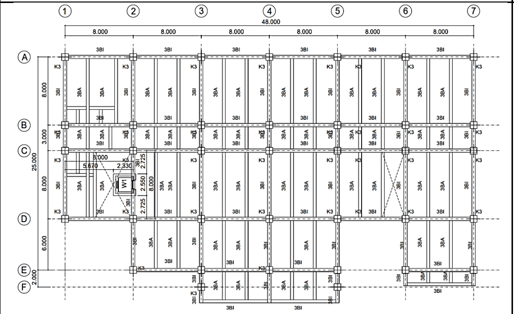
Sloof Beam



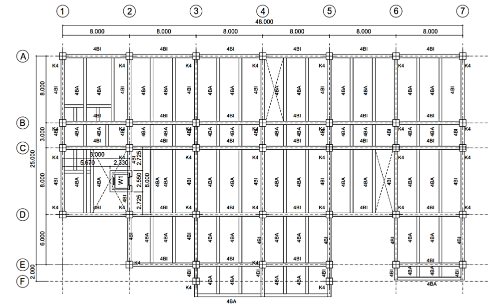
First Floor Beam



Second Floor Beam



Third Floor Beam



Fourth Floor Beam

Fig. 3. Structure plan for pile cap, sloof, and beam

Based on the Detail Engineering Design (DED) as a reference for the priority scale in Fig. 2 and Fig. 3, the Politeknik Negeri Padang proposes the development of facilities and infrastructure in the form of the construction of the Integrated Technology Laboratory Building, along with complete contents such as laboratory equipment and furniture, to meet the needs of implementing the Teaching and Learning Process within the Politeknik Negeri Padang. The planned building's price is determined by the building unit price per meter, material prices, and labor. The building's pricing has been changed by the Minister of Public Works and Public Housing Regulation No. 22/PRT/M/2018 of 2018 and the List of Unit Prices per Square Metre for the highest Physical Construction Standard Building in Padang City in 2022. The Padang State Polytechnic Integrated Technology Laboratory structure is a non-standard style of structure with reinforced concrete construction and a bored-pile base. In Padang City in 2022, the construction unit price (non-standard) for the building with an area of 5,389,59 meter square is Rp.8,080,065.-, and the multiplication coefficient for the 5th story building is 1.135, therefore this building is planned with a unit price of Rp.8,080,065.-.

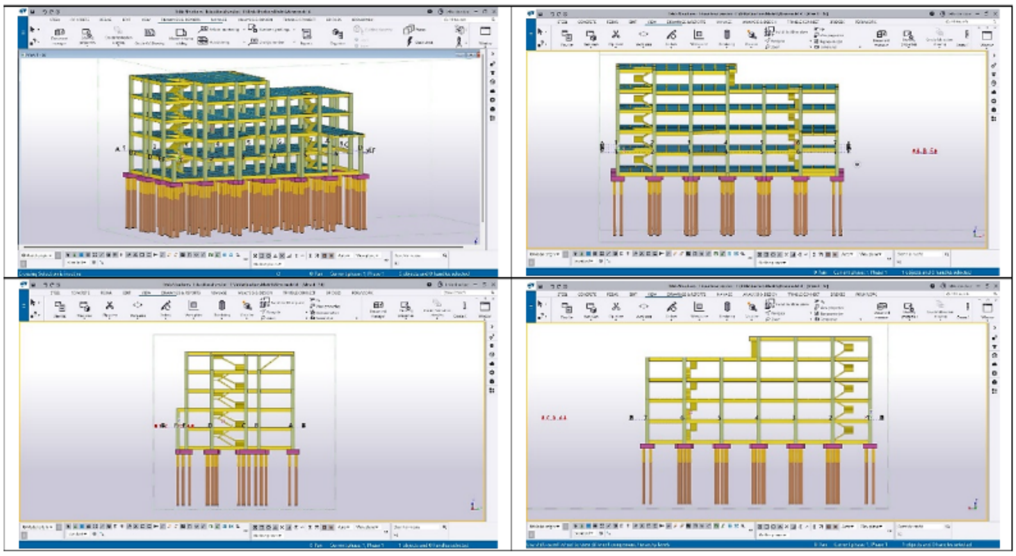


Fig. 4. 3D BIM modelling of building structure.

In BIM modeling processing, CAD drawings are converted into three-dimensional modeling in BIM. The BIM TEKLA Structure educational (licensed by TIMBER) solely remodels the structural components of the building, namely the Foundations, Columns, Beams, and Floor Slabs, including concrete specification components, steel reinforcement, and formwork. The specifications of the building are a Bored-pile foundation with a depth of 12 meters, a Pilecap with a size of 100x100, a Pilecap with a size of 300x300, a Pilecap with a size of 390x390, and a Superior Beam with a size of 800x400 are the structural components assessed. Inferior beams 700x350, Floor Slab (basement, first to fifth floors), and Column 800x800 (first to fifth floors).

3. Result and Discussion

The findings of structural modeling using the TEKLA Structure 3D BIM model reveal a rise in volume and a decrease in overall volume, which is separated into three parameters: concrete volume, reinforcement volume, and formwork volume. The discussion in the findings and discussion takes the form of a comparison of the conditions between the volume of reinforcement and the volume of concrete, which are addressed concurrently with the structural groups stated above.

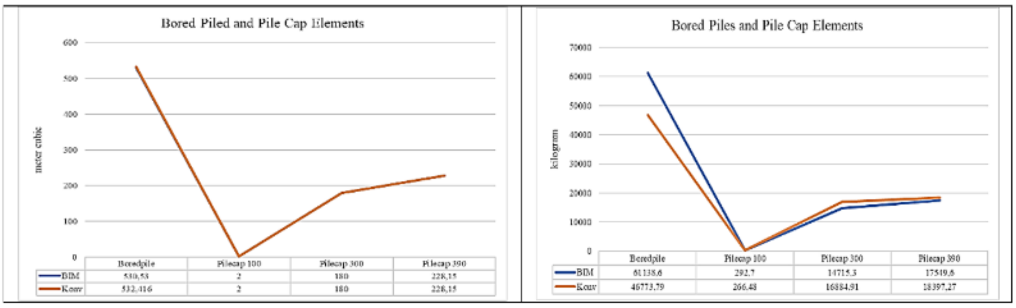


Fig. 5. Deviation of concrete and rebar volume for bored piled and pile cap

According to Fig 5, the overall volume of the Bored-pile and Pilecap constructions demonstrates that the amount of concrete does not change much, implying that the volume of concrete computed by BIM is the same as that of traditional concrete. There is a variance with an average of 5.77% volume increase in the BIM estimate of the reinforcement in the structure.

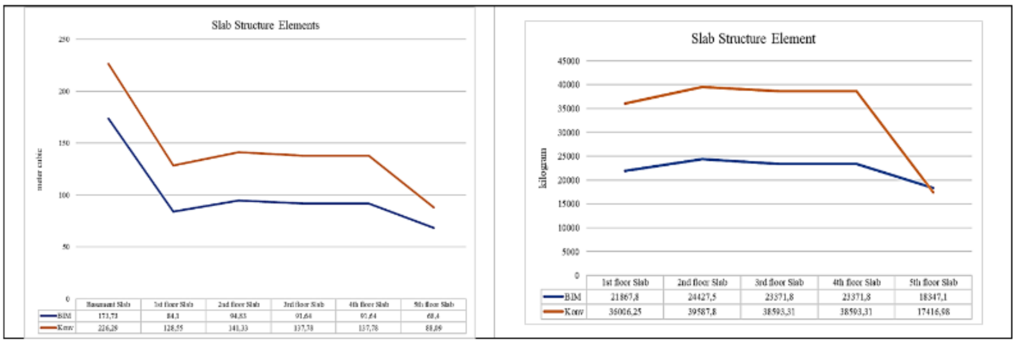


Fig. 6. Deviation of concrete and rebar volume for slab structure elements

Furthermore, in the floor slab structure, the volume calculation indicates a considerable difference between the BIM and conventional calculation findings. In the computation of the concrete volume, there is a volume efficiency of concrete with an average of 30.01% and a very large efficiency occurs for all floor plates except the fifth-floor plate, where the percentage is not different at roughly 30.22%. The two graphs in Figure 6 show the same deviation on each floor plate at each level.

In the column element structure in Fig.7, each floor has the same column size, namely 800x800, with a height of 3.98 meters on the basement floor and 4.45 meters on each floor from the first to the fourth floor, and the number of columns on the basement floor is more than on the other floors. The column volume calculation displays volume fluctuations on each floor. The cellar, first and fourth floors all show a substantial change. Meanwhile, the amount of concrete on the second and third floors tends to be the same in BIM and conventional estimates. Furthermore, for column reinforcement, a very substantial variance in reinforcement volume still occurs on the basement column and first floor with the same pattern with deviations in the concrete volume, although on the remaining floors, the reinforcement volume tends to be the same. The variance in the amount of concrete in the column spans from a decreasing percentage of 10.59% to an addition of roughly 2.6%.

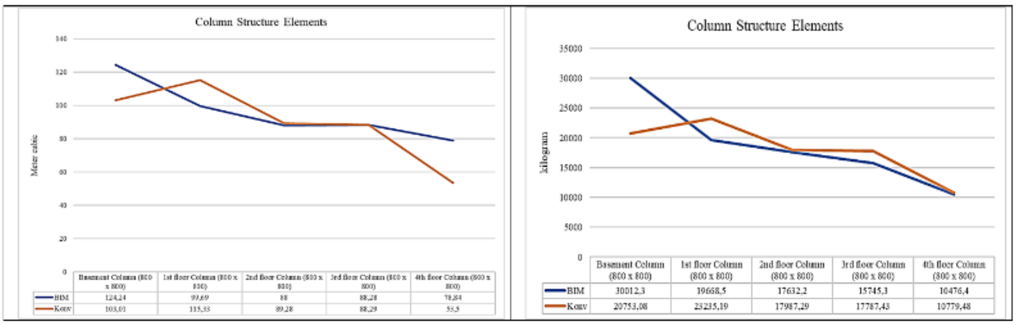


Fig. 7. Deviation of concrete and rebar volume for column structure elements

Superior beam structural parts in Fig. 6 with dimensions of 800x400, in particular, do not reveal substantial volume variations in BIM and conventionally with a divergence of just 4.18%. However, this criterion is inversely related to the volume of the reinforcement, which is substantially different; the BIM volume calculation reveals a very considerable increase of reinforcement to the superior beams on floors 2, 3, and 4, with a deviation of 51.70%.

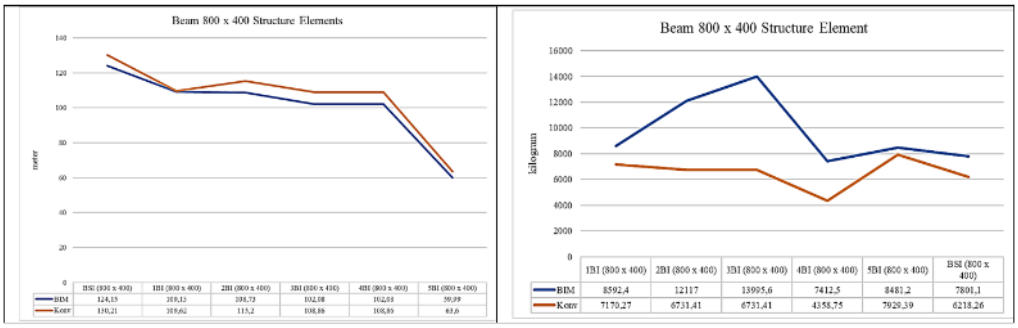


Fig. 8. Deviation of concrete and rebar volume for superior beam structure elements

Meanwhile, inferior beams measuring 700x350 on the basement level, first floor, second floor, and third floor have minimal variations in lowering the volume of concrete, as shown in Fig. 9. However, there was a large increase in concrete volume in the inferior beams on the fourth level.

Where BIM estimates are much higher than traditional calculations, the variance in the quantity of reinforcement is fairly uniformly distributed on each level. The average variance of the increase of concrete volume in this lower beam is 21.07%, whereas the volume decrease in the reinforcement is roughly 51.70%.

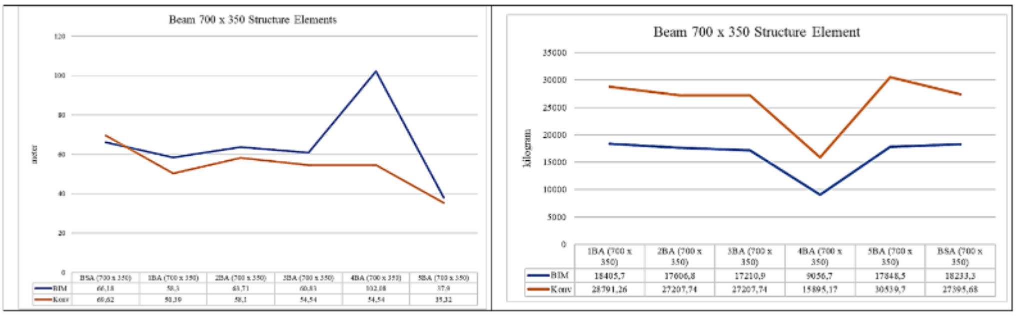


Fig. 9. Deviation of concrete and rebar volume for inferior beam structure elements

Then, a review of the formwork volume in Fig.10 with a unit area count as a component reveals that in the column structure elements, there is a very significant addition of formwork volume to the 700x350 beam size with a percentage addition of around 40.6% formwork volume, while the 800x400 beam size has an additional formwork volume of around 16% only. However, in typical calculations, the formwork volume varies. Furthermore, the column and floor slab structural parts did not reveal any reductions or increases, resulting in deviations of 5.4% and 4.8%, respectively.

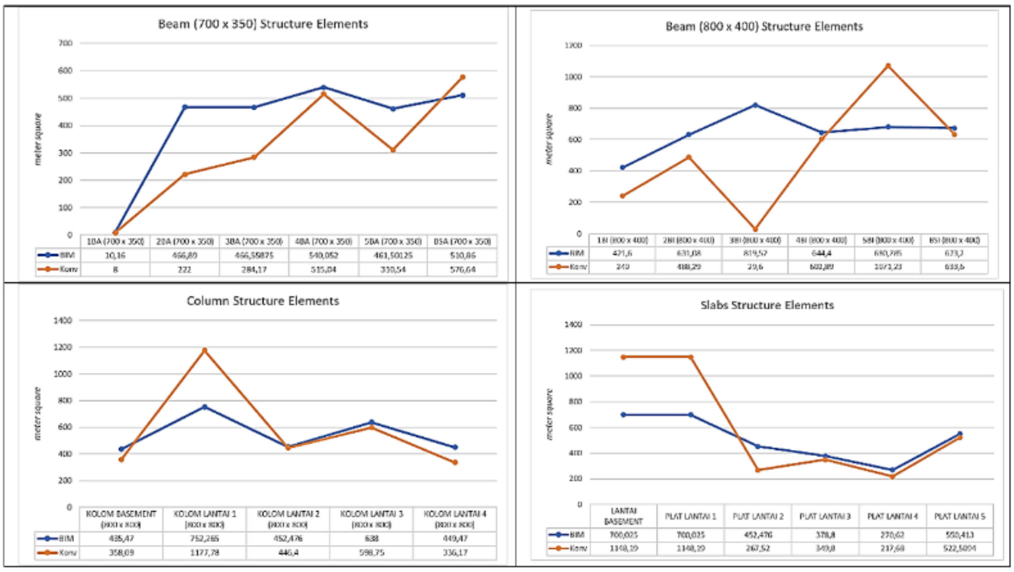


Fig. 10. Deviation of formwork volume for beam, column, and slabs structure elements

Table 1 illustrates the percentage addition and decrease of concrete volume, reinforced bars, and formwork for each structural element detailed above. On average, foundation structural elements have a volume reduction of about 1.89%, floor slabs have an addition of 18.46%, columns have a volume reduction of about 6.20%, superior beams have a volume reduction of about 10.19%, and inferior beams have a volume reduction of about 19.07%.

Table 1. Deviation volume of structure elements between bim vs. conventional calculation

No.	Structure Elements	Concrete	Reinf. Bar	Formwork	Average
1	Foundation	0,09%	-5,77%	0%	-1,89%
2	Floor Slab	30,01%	30,22%	-4,84%	18,46%
3	Columns 800x800	-10,59%	-2,60%	-5,42%	-6,20%
4	Superior Beam 800x400	4,81%	-51,70%	16%	-10,19%
5	Inferior Beam 700x350	-21,07%	37,69%	41%	19,07%

4. Conclusion

Finally, there are various variants of volume reduction and increase, and this is especially important in the structural parts of the floor slab, Superior Beam, and Inferior Beam. This is owing to the enormous number of joints and reinforcing details between columns, beams, and floor slabs, which are traditionally very difficult to complete full calculations so that BIM modeling can calculate complicated joint components comprehensively.

Acknowledgments

Thanks to Politeknik Negeri Padang, DANA DIPA Penelitian Teknologi Terpadu Contract No.154/PL9.15/PG/2023, who supported this research and publication. Then, thanks to Afdhil Akbar and Rayhan Bukhari, Diploma III Civil Engineering Students – Politeknik Negeri Padang, who contributed and participated in this research as their Final Project.

References

[1] Azhar, S. (2011), “Building information modeling (BIM): trends, benefits, risks, and challenges for the AEC industry”, Leadership and Management in Engineering, Vol. 11 No. 3, pp. 241-252, doi: 10.1061/(ASCE)LM.1943-5630.0000127.

[2] Bryde, D., Broquetas, M. and Volm, J.M. (2014), “ScienceDirect the project benefits of building information modeling (BIM)”, International Journal of Project Management, Vol. 31 No. 7, pp. 971-980, (June 2011).

[3] Chou, H.Y. and Chen, P.Y. (2017), “Benefifit evaluation of implementing BIM in construction projects”, IOP Conference Series: Materials Science and Engineering, Vol. 245 No. 6, pp. 0-8, doi: 10.1088/ 1757-899X/245/6/062049.

[4] Doumbouya, L., Gao, G. and Guan, C. (2016), “Adoption of the building information modeling (BIM) for construction project effectiveness: the review of BIM benefits”, American Journal of Civil Engineering and Architecture, Vol. 4 No. 3, pp. 74-79, doi: 10.12691/ajcea-4-3-1.

[5] Eastman, C., Teicholz, P., Sacks, R. and Liston, K. (2008), “BIM handbook a guide to building information modeling for owners, managers, designers, engineers, and contractors”, Notes and Queries, Vol. s7-II No. 32, pp. 93-145, doi: 10.1093/nq/s7-II.32.110-e.

[6] Fadeyi, M.O. (2017), “The role of building information modeling (BIM) in delivering the sustainable building value”, International Journal of Sustainable Built Environment, Vol. 6 No. 2, pp. 711-722, doi: 10.1016/j.ijsbe.2017.08.003.

[7] Garavaglia, E., Anzani, A., Maroldi, F. and Vanerio, F. (2020), “Non-invasive identification of vulnerability elements in existing buildings and their visualization in the BIM model for better project management: the case study of cuccagna farmhouse”, Applied Sciences (Sciences), Vol. 10 No. 6, p. 2119, doi 10.3390/app10062119.

[8] Goh, K.C., Goh, H.H., Bilal, K., Toh, T. and Nasid, M.A. (2019), “Malaysian construction research”, International Conference on Innovation and Management (ICIM), Vol. 2 No. 2, p. 270.

[9] Goucher, D. and Thurairajah, N. (2009), “Usability and impact of BIM on early estimation practices: cost consultant’s perspective”, SPE Production and Operations Symposium, Proceedings, pp. 555-570, available at: http://nrl.northumbria.ac.uk/id/eprint/38622

[10] Hunt, C.A. (2013), “The benefits of using building information modeling in structural engineering”, pp. 31-37.

[11] Lu, W., Lai, C.C. and Tse, T. (2018), “Big data for construction cost management”, BIM and Big Data for Construction Cost Management, Routledge, doi: 10.1201/9781351172325-6.

[12] Mesaros, P. and Mandicak, T. (2017), “Exploitation and benefits of BIM in construction project management”, IOP Conference Series: Materials Science and Engineering, Vol. 245 No. 6, pp. 0-7, doi: 10.1088/1757-899X/245/6/062056.

[13] Othman, I., Al-Ashmori, Y.Y., Rahmawati, Y., Mugahed Amran, Y.H. and Al-Bared, M.A.M. (2021), “The level of building information modeling (BIM) implementation in Malaysia”, Ain Shams Engineering Journal, Vol. 12 No. 1, pp. 455-463, doi: 10.1016/j.asej.2020.04.007.

[14] Welch, D.P., Sullivan, T.J. and Filiatrault, A. (2014), “Potential of building information modeling for seismic risk mitigation in buildings”, Bulletin of the New Zealand Society for Earthquake Engineering, Vol. 47 No. 4, pp. 253-263, doi: 10.5459/bnzsee.47.4.253-263.