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The simulation of bridge pier planning using Revit: A building information modelling approach

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ABSTRACT

Building Information Modeling (BIM) represents a transformative approach to architectural design and construction management globally (Babalola, 2023). The construction industry is increasingly recognizing BIM's potential to mitigate project risks, improve cost estimation accuracy, and enhance regulatory compliance. This study highlights how BIM can enhance predictive maintenance, lifecycle cost analysis, and sustainability metrics in bridge infrastructure. Revit's BIM framework empowers engineers to innovate, streamline workflows, and deliver sustainable infrastructure solutions that meet evolving societal needs. The research methodology employed in this study involves systematically collecting data from online sources and using Revit for practical application. The combination of data from Google Scholar and practical application through Revit enhances the robustness and applicability of the research findings. Embracing BIM in bridge pier planning not only enhances project efficiency but also sets a benchmark for future advancements in civil engineering practices.

INTRODUCTION

A bridge connects 2 points separated by a river, lake, or infrastructure built under the bridge (Nahla, Zainuddin, & Suji'at, 2022). Bridges are not just used as connections. Sometimes, a bridge can become an icon of a city. Bridges, especially in Indonesia, are among the most essential infrastructures because Indonesia has thousands of islands (Wang, Zhu, & Yang, 2020). Excellent connectivity to boost every aspect of a town or a country bridge built to connect a few islands in Batam, Indonesia. Barelang Bridge is well known by the people of Batam, built between 1992-1998, and consists of 6 bridges connecting Batam-Rempang-Galang Islands.

A bridge must be able to resist expansion and contraction; if a bridge can't resist both, it will result in continuous failure until its structure is damaged (Arockiasamy, P.E, Butrieng, & Sivakumar, 2004). Bridges commonly have two structure elements: lower and upper structures. The ability to resist expansion and contraction is by having a good quality of structure supporting the bridge. A lower structure is pivotal in helping the bridge, where we know the abutment is located.

Bridge piers are vertical structural elements supporting a bridge's top, such as rafters and road floors. These pillars are the main supports that transfer loads from the top of the bridge to the foundation below. Geometrically, bridge piers are usually cylindrical or rectangular, with varying dimensions depending on the location's design and geotechnical conditions (Naeimi, 2020). Bridge piers can include various construction materials such as concrete, steel, or a combination. These are selected based on the required strength, working environment, and material availability at the construction site. Besides bearing structural loads, bridge pillars must be designed to overcome lateral forces such as wind, earthquakes, and lateral forces from vehicles passing over them (Montenegro, 2021). Strategically positioned along the bridge, these pillars are critical in ensuring the bridge's safety, reliability, and overall performance.

Bridge pillar planning is a very complex and essential process in bridge engineering. This planning stage involves an in-depth analysis of various technical factors such as structural loads, construction material characteristics, and geotechnical conditions at the installation site (Ji, 2022). In addition, planning must also consider environmental factors such as the impact on local ecosystems and the availability of sustainable natural resources.

The planning process for bridge pillars begins with selecting a strategic location that suits transportation needs and is resistant to earthquakes and other natural disasters. The structural design of pillars must consider optimal strength and stability and comply with strict safety standards (Pan, 2023). The cost aspect is also a significant consideration in planning, considering not only initial construction costs but also long-term operational and maintenance costs. Bridge piers, like foundations, are categorized into two main types: deep and shallow foundations, depending on the soil and load-bearing requirements (Anggarini, Muzaidi, & Fitriansyah, 2023). The primary function of a pier is to transfer the loads from the bridge deck into the lower structure and ultimately into the ground. Piers, whether shallow or deep, are critical components in distributing the weight of the bridge and its loads, ensuring the stability and durability of the entire bridge structure.

Bridge piers are vertical supports designed to bear the bridge's vertical loads and resist horizontal forces such as wind and seismic activity (Aviram, Mackie, & Stojadinovic, 2008). They play a pivotal role in maintaining the alignment and integrity of the bridge, especially in multi-span bridges where intermediate support is necessary. The design of piers often includes considerations for hydraulic forces, ice loads, and debris impacts, ensuring the bridge's resilience in various environmental conditions. Moreover, piers are essential in stabilizing the bridge by counteracting lateral forces generated by traffic loads and ground movements (Bounds, 2024). Their construction often incorporates pile caps and caissons to enhance stability and prevent soil erosion. Piers also contribute to the overall aesthetics of the bridge, with their structural design frequently reflecting the style and character of the surrounding environment (Liliwarti, Silvianengsih, Candra, Satwarnirat, & Archenita, 2022). Additionally, piers serve as critical points for inspection and maintenance, allowing engineers to assess the bridge's condition and perform necessary repairs or upgrades. Piers are fundamental bridge infrastructure components, providing functional support and aesthetic value to the entire structure.

Bridge planning is a multidisciplinary process encompassing various stages from conceptualization to construction, aiming to create safe, efficient, and sustainable structures (Passoni, 2022). The initial phase involves feasibility studies and site selection, where engineers evaluate environmental impacts, geological conditions, and traffic patterns to determine the bridge's optimal location and design parameters. The design phase of bridge planning focuses on structural integrity, functionality, and aesthetics. Engineers employ advanced software tools like Finite Element Analysis (FEA) and Building Information Modeling (BIM) to simulate and optimize the bridge's performance under various loads and environmental conditions. Collaboration between architects, engineers, and environmental experts is crucial throughout these phases to integrate diverse perspectives and achieve comprehensive solutions that meet both technical requirements and societal needs.

Building Information Modeling (BIM) is a transformative approach to global architectural design and construction management (Babalola, 2023). BIM integrates various facets of building information into a coherent digital model, encompassing geometric data, spatial relationships, and functional properties of building components (Babalola, 2023). This method enhances stakeholder collaboration, improves project visualization, and facilitates more efficient decision-making throughout the project lifecycle. Internationally, BIM adoption has revolutionized construction practices by streamlining workflows, reducing errors, and optimizing resource allocation. Countries like the United States, the United Kingdom, and many in Europe have embraced BIM as a standard, emphasizing its role in enhancing construction productivity and sustainability.

In Indonesia, BIM adoption has been steadily gaining traction, albeit with unique challenges and opportunities (Van Roy, 2020). The construction industry increasingly recognizes BIM's potential to mitigate project risks, improve cost estimation accuracy, and enhance regulatory compliance. However, the widespread implementation of BIM faces hurdles such as limited technological infrastructure and varying levels of industry readiness. Despite these challenges, Indonesian initiatives promoting BIM education and training and government support for digital transformation signal a promising future for its integration into mainstream construction practices (Van Roy, 2020). The Indonesian experience underscores BIM's adaptability across diverse construction contexts, highlighting its potential to elevate efficiency and innovation in building projects locally and globally.

This research aims to study factors that influence the design and performance of the pier, such as structural response to specific loads, strength, and ability. It also aims to optimize efficiency and design a safe bridge pier. The research is expected to provide insight into the bridge pier planning process and contribute to safety.

METHOD

The research methodology employed in this study involves systematically collecting data from online sources and using Revit for practical application. Initially, the research topic is clearly defined, and relevant keywords are identified. Google Scholar is chosen as a primary source due to its extensive repository of peer-reviewed articles, theses, books, and conference papers. Comprehensive searches use these keywords, utilizing advanced search filters to refine results. The search results are then screened by reviewing titles and abstracts to identify and select relevant articles based on relevance, credibility, and publication date. This ensures the collection of high-quality and pertinent data. In addition, Revit is employed to model and simulate the practical aspects of the research, allowing for a detailed and accurate representation of the concepts studied. The combination of data from Google Scholar and practical application through Revit enhances the robustness and applicability of the research findings.

RESULTS AND DISCUSSION

General Information of the Pier & Pier Head

Before using Revit, we need to know some essential things, such as file storage location, how to open the application, how to start a new project, how to familiarize ourselves with the interface, and basic settings, such as units. Revit modules can generally still be used by users of other versions of Revit with some adjustments. The most important thing is the availability of data for modeling. The following is the data that will be used in Revit modeling in this paper.

Table 1. Data of pier structure

	Description	***Specification***	
Pier Head	Bottom Width	4500	mm
	Top Width	8000	mm
	Height	2500	mm
	H1 (Height 1)	1500	mm
Pier	Widht	4500	mm
	Dept	1500	mm

Modelling Process

The authors start by setting up a project template. The template used here is "Structural Analysis-DefaultMetric." We can easily find this template inside the English family template.

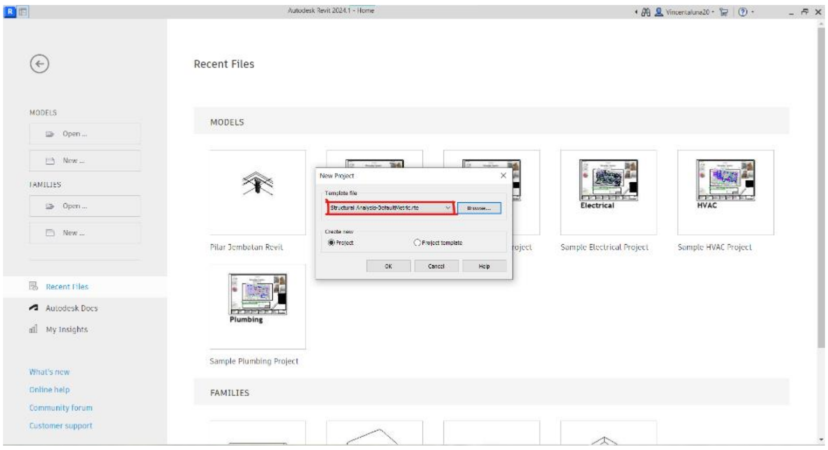

Figure 1. Template Setup on Revit

The authors start by working on the south elevation tab. Here, the author begins by adding a grid for the level later used for the pier model. Four grids were added here, starting with 00-Piles, 01-Base, 02-Pier, and 03-Pier Head.

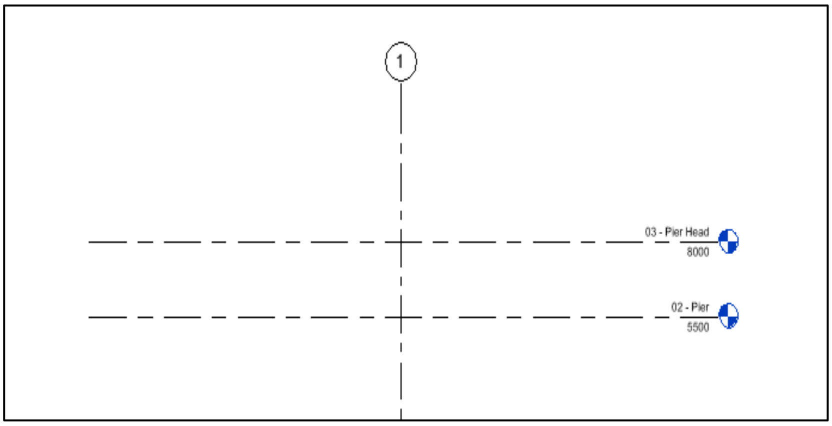

Figure 2. Setting up Grids & Levels

After setting up the grids and levels for the working area, the authors start by adding the slab used for the piles and setting up piles in size and type. When creating a bridge pier model in Revit, it is essential to separate the various elements of the design for more straightforward price estimation and construction planning.

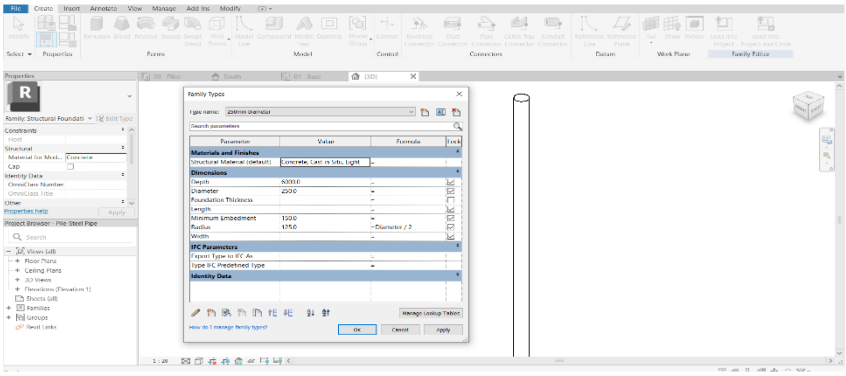

Figure 3. Pile Settings

As shown in Figure 4, the authors adjusted the depth and diameter of the pile. Based on the sequence of steps above (creating reference planes, creating dimensions, and creating labels), continue creating the Family Pier model according to the reference image above. Creating a Level line has the same steps as creating a Grid. The reference line used to create a Level line is the Ref Level 0 line.

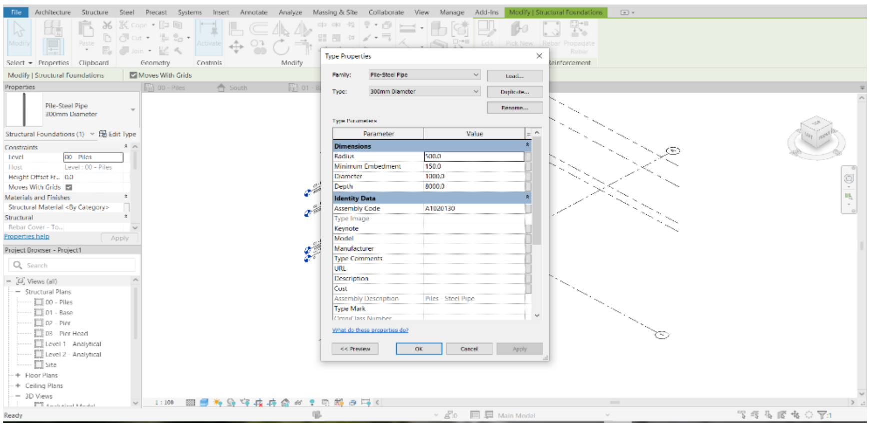

Figure 4. Pile size Setting

They are shown in Figure 5. The pile was inserted into the working paper after inserting the slab. We can create another Parameter Label in the form of Total Pier Height, considering that if at any time there is a change in the pier height, we can easily change the total abutment height by only inputting a value in one parameter, namely the Total Pier Height parameter. To create this parameter, one of the existing parameters must be deleted first, as shown in the image above. Generally, changes in the total abutment height occur in the pier section, which in this case is represented by the H parameter, so the H parameter is deleted to become a free variable in the total pier height.

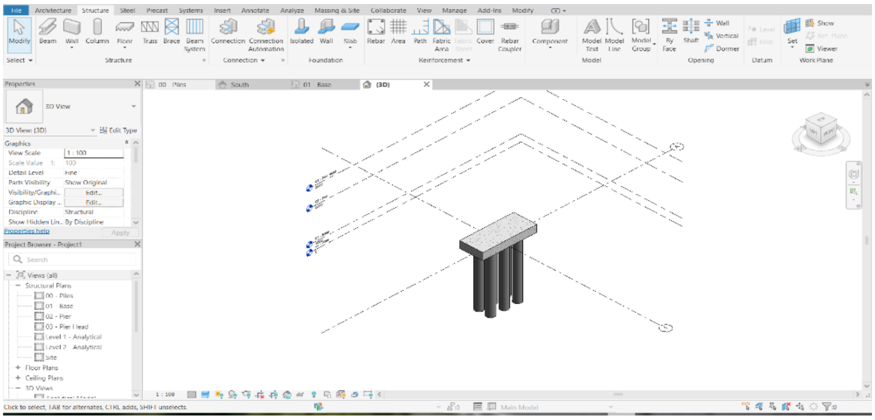

Figure 5. Pile Model in 3D View

In the next step, the authors will make the model for the Pier by clicking on file > New> Family, which will open a new sheet for the custom family. This will be shown in Figure 6.

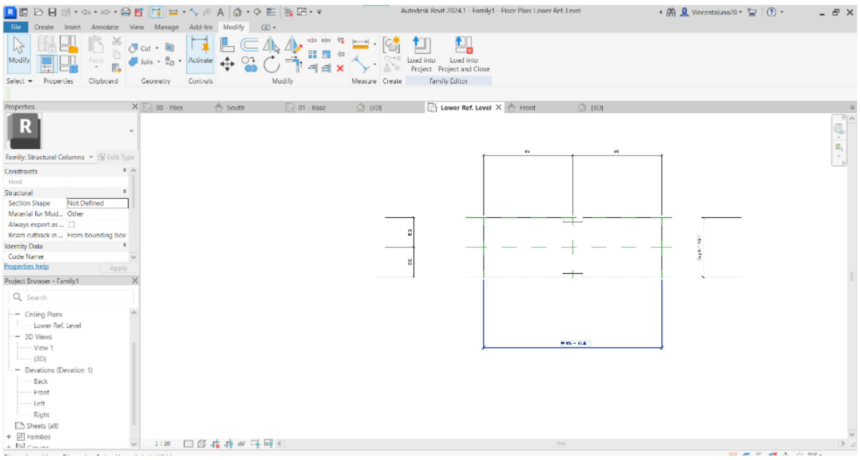

Figure 6. Pier Design

Figure 7 is the final model in 3D view of the custom pier authors made using the custom family option.

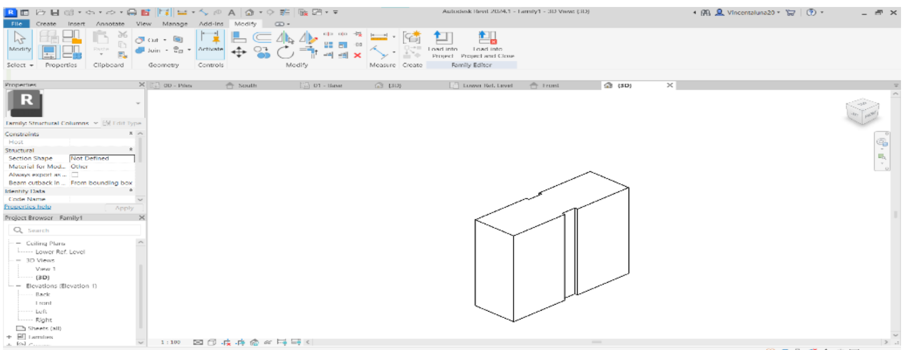

Figure 7. 3D Model view of the Pier

Next, shown here, is when the authors successfully uploaded the pier model into the working area above the pile they modeled. By adjusting these parameters, we can easily modify the bridge pier's design to meet a project's specific needs.

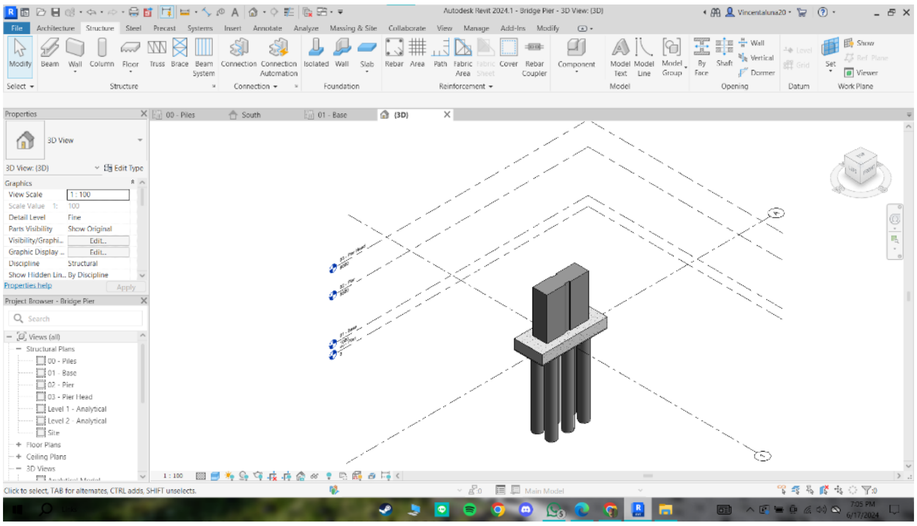

Figure 8. Pier and Pile Model in 3D View

The authors will advance into the detailed modeling stage, focusing on creating a new family for the pier head using Revit. This will involve intricate design work, ensuring the new pier head family fully integrates with the existing architectural elements and meets all required specifications and standards.

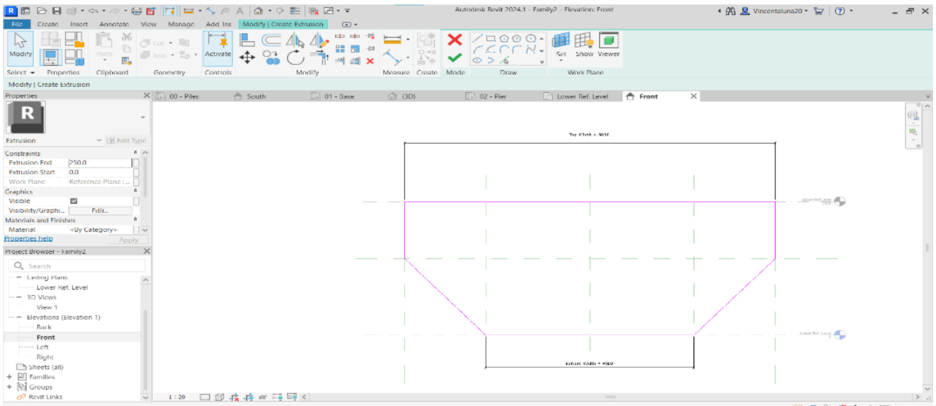

Figure 9. Pier Head Design

The authors have completed the modeling of the pier head, finalized the design in Revit, and ensured all elements were accurately represented and ready for integration into the overall project.

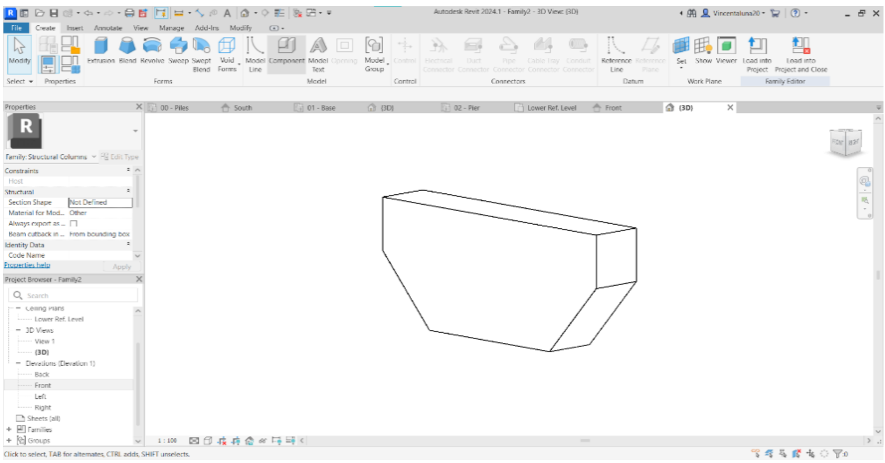

Figure 10. 3D Model view of the Pier Head

The authors have successfully inserted the pier head family model into the working area, ensuring its seamless integration and precise alignment with the existing architectural framework. This achievement marks a significant milestone in the project, demonstrating the effective translation of design concepts into functional and detailed components within the Revit environment.

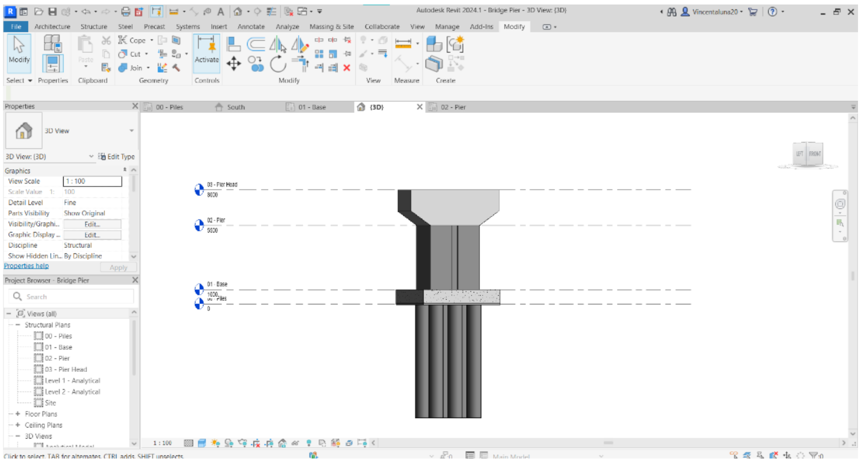

Figure 11. 3D View of Pier Head Family Model Integrated into Working Area in Revit

3D Views of the Bridge Pier

The 3D view function is pivotal in visualizing building designs and models in a three-dimensional space. This feature allows users to interactively explore and analyze their projects from various perspectives, providing a comprehensive understanding of spatial relationships and design elements. The 3D view function in Revit enables architects, engineers, and designers to navigate through the virtual model, zooming, rotating, and panning to examine details and ensure design integrity. It facilitates the detection of clashes, coordination of building systems, and communication of design intent to stakeholders. An example of the 3D modelling of the Bridge Pier is shown below.

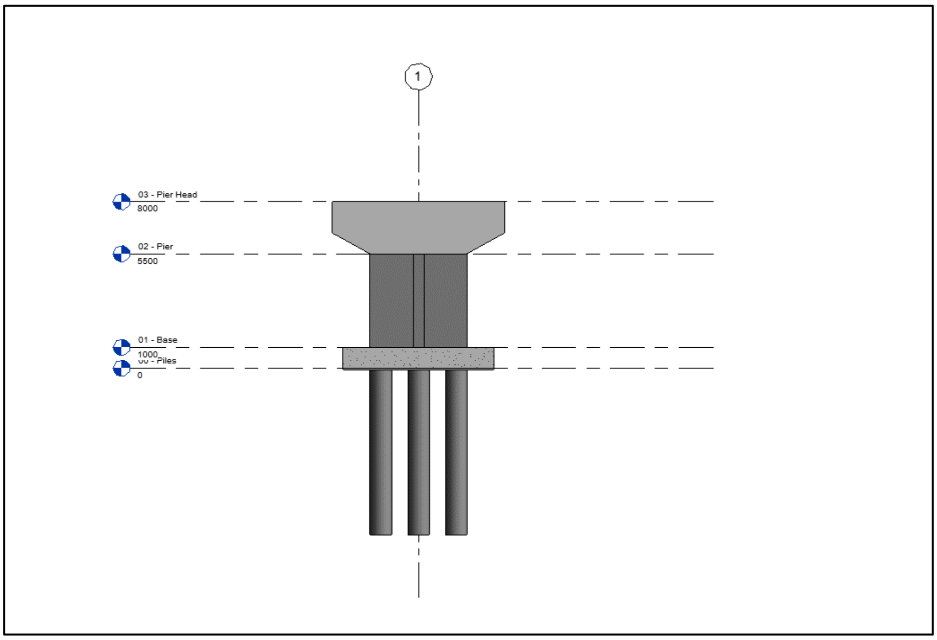

Figure 12. Front View

It should be noted that the Revit application does not, by default, provide a template to create bridge element models such as abutments, pillars, and so on instantly. But don't worry—we can still create detailed bridge modeling with the Revit application, but we must create a new Family to be able to create bridge element models such as abutments, pillars, girders, and so on. The drawing of the pier cross-section in this Family is carried out in 3 dimensions, so we will create an edge line from the pier cross-section, which is then changed to 3 dimensions with the extrusion command (AutoCAD: Extrude). Draw the outer edge of the pier cross-section using the following steps.

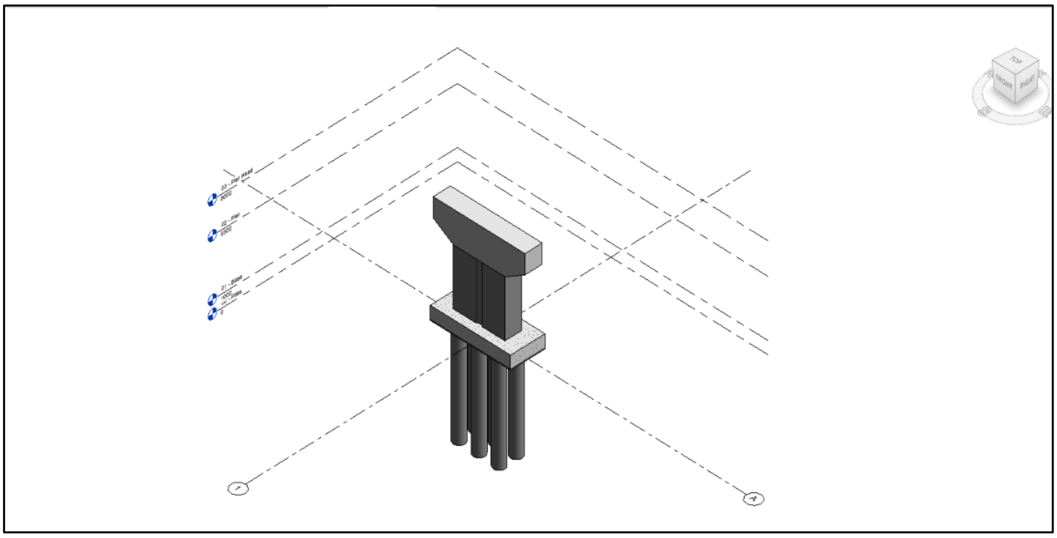

Figure 13. Side Top View

In Revit, Figure 12 and Figure 13 depict 3D views of a bridge pier, illustrating the functionality of Revit's robust 3D modeling capabilities. These views allow engineers and designers to visualize the bridge pier from different angles and perspectives, aiding in detailed analysis and design refinement. Revit's 3D view feature enables users to manipulate the model in real time, rotating it, zooming in and out, and adjusting viewpoints to examine intricate details such as structural components, connections, and spatial relationships. This interactive approach facilitates precise coordination between disciplines, identifying potential clashes and optimizing design integration. Furthermore, users can effectively enhance these views with annotations, dimensions, and rendering effects to communicate design intent. Revit's 3D view functionality ultimately empowers professionals to create, analyze, and present complex structural designs with clarity and accuracy, ensuring efficient project development and collaboration.

CONCLUSION

The study explores the use of Building Information Modeling (BIM) in civil engineering projects, focusing on bridge pier planning simulation using Revit software. BIM allows engineers to plan, design, and analyze bridge piers precisely and accurately. It facilitates collaboration among multidisciplinary teams, enhances decision-making processes, and optimizes structural performance. As infrastructure demands increase, BIM empowers engineers to innovate, streamline workflows, and deliver sustainable infrastructure solutions. This study sets a benchmark for future advancements in civil engineering practices. Future research could explore BIM's application in bridge construction and maintenance, focusing on the long-term benefits of integrating BIM with real-time data from sensors and monitoring systems. Comparative studies between different BIM platforms and integrating AI and machine learning could further optimize design, construction, and maintenance processes in civil engineering projects.

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