SASBE 2025 aims to encourage the international exchange of innovative ideas between researchers from academia and industry. In addition to knowledge dissemination, the conference offers a valuable platform for professional networking, particularly benefiting university professors, graduate students, and postdoctoral researchers.

Research Article/ Review Article/ Perspective Article (Remove where relevant)

Development of an Automated Rebar Modeling Tool for RC Structures

Koji Yoshimura[1], Fumiya Matsushita[1], Sheng Lian[1], Yuko Ishizu[2]

SHIMIZU CORPORATION
GEL CORPORATION
Correspondence: k_yoshimura@shimz.co.jp

Abstract (250 words)

In Japan, the labor shortage due to population decline is becoming severe, and a productivity improvement has become an urgent issue in construction sites. Particularly, in construction projects dealing with diverse structures, the complexity and individuality of design pose significant barriers to productivity improvement. To address this challenge, the utilization of Building Information Modeling (BIM) has been mandated under "i-Construction 2.0, and the goal is to achieve semi-automated design through parametric modeling. This study proposes a novel method for automatically generating rebar models reflecting design parameters specified by the designer, to contribute to achieving this goal. Considering that conventional automation tools were constrained by specific structural body shapes and could not always fully meet designers' needs, this proposed method investigates an approach capable of robustly addressing these constraints and needs. The proposed method assumes typical civil engineering structural body shapes and categorizes them into shape-dependent and shape-independent parts. Subsequently, modules were constructed for the shape-independent parts. As a result, by developing additional programs only for the shape- independent parts, it becomes possible to efficiently achieve rebar modeling that accurately reflects design intent, not only for simple rectangular structures but also for diverse and complex structural bodies. As a demonstration, automatic rebar modeling was performed for rectangular, cylindrical, and inclined rectangular structural bodies using a modeling system constructed based on the proposed method. The results confirmed that each rebar was modeled with appropriate placement and shape in compliance with design standards, demonstrating the feasibility of semi-automatic rebar design through parametric modeling.

Keywords: Building Information Modeling, Parametric Modeling

Highlights

- Japan's construction industry faces severe labor shortages and aging infrastructure, necessitating a 50% productivity improvement by 2040 through BIM.
- This study proposes a novel parametric method for automatic rebar model generation, classifying structural elements into shape-dependent and shape-independent parts to extend conventional tools.
- The method successfully automates accurate rebar modeling for diverse shapes, including cylindrical and inclined elements, significantly reducing manual effort, errors, and overall project costs.

1 Introduction

In Japan, the decline in the productive working-age population due to the declining birthrate and aging population is causing a severe labor shortage in the construction industry. According to estimates by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), the number of workers in the construction industry decreased from approximately 3.29 million in 2018 to about 3.26 million in 2023. In contrast, the required workforce, considering the progress of work style reforms, increased from approximately 3.31 million in 2018 to about 3.47 million in 2023 (Ministry of Land, Infrastructure, Transport and Tourism, 2018). As a result, a labor shortage of approximately 210,000 people occurred in 2023. Furthermore, many civil engineering structures in Japan were constructed during the period of rapid economic growth and are rapidly aging. According to MLIT data, among approximately 730,000 bridges nationwide, the proportion of those aged 50 years or older is projected to sharply increase to approximately 59% by 2032 (Ministry of Land, Infrastructure, Transport and Tourism, 2022). Against this backdrop, a goal has been set to improve construction site productivity by 50% by 2040.

To achieve this goal, the introduction and utilization of Building Information Modeling (BIM) are being promoted. BIM is a method for managing and sharing information based on 3D models throughout the design, construction, and maintenance phases of buildings (Milyutina, 2018). Information regarding quantities, construction sequence, quality, materials, contractors, suppliers, and execution time can be added to the objects within the model. The greatest advantage of BIM compared to standard 2D methods is the high compatibility ensured by directly extracting drawings from the model (Saeed, 2011). According to the BIM/CIM Promotion Committee, the current stage is "Level 1," where BIM models are created based on 2D drawings. In a few years, the aim is to reach "Level 2," where BIM models and 2D drawings are linked, and eventually "Level 3," where all BIM models, including detailed objects, are constructed, enabling semi-automatic design through parametric modeling (Ministry of Land, Infrastructure, Transport and Tourism, 2025).

Parametric modeling is a design technique used to establish design environments and geometric relationships within a model. Its greatest feature is that the entire design is automatically adjusted and updated by changing only a few parameters (Jabi, 2014). Furthermore, changes made by adjusting these parameters propagate throughout the model via dependencies, eliminating the need for manual deletion or redrawing (Taghipourarasteh, 2021). This design method is realized when graph systems like Dynamo and Grasshopper integrate with the APIs of BIM software such as Revit, allowing updates in the graph system to be directly reflected as models in the BIM environment (Janssen, 2015). Currently, BIM and parametric modeling technologies in the civil engineering field are showing a rapid development trend, and their wide range of applications is leading a new wave of ideological transformation in the construction industry.

Under these circumstances, this study proposes a novel method for parametrically and automatically generating rebar models by dynamically reflecting design parameters specified by the designer, such as concrete cover, working plane, rebar shape, number, and length. Considering that conventional automation tools have been constrained by specific structural element shapes and have not always fully met designers' needs, the proposed method explores an approach capable of comprehensively addressing these constraints and needs. The proposed method targets representative civil engineering structural element shapes and classifies their models into shape-dependent and shape-independent parts. By additionally developing programs specialized for shape-independent parts, it becomes possible to efficiently achieve rebar modeling that accurately reflects design intent, not only for simple rectangular elements but also for diverse and complex structural elements. This method is expected to significantly contribute to improving the efficiency of rebar modeling, reducing design and drawing creation time, minimizing rework, and ultimately enhancing overall productivity and reducing costs in the construction industry.

2 Literature Review

Many researchers are conducting deep and systematic studies on BIM and parametric modeling technologies, with some research examples applying BIM technology to the field of rebar engineering. Yankai combined the C# language with the Revit API to generate rebar using standard drawing sets and specifications as benchmarks (Yankai, 2024). They optimized the corresponding algorithms due to compatibility issues between stirrups and longitudinal rebar, ensuring that the parametric modeling process for rebar is accurate and fast. Based on this, they analyzed the differences in various types of specially shaped columns and developed an automatic rebar creation procedure for variable cross-section columns in frame structures, achieving automation and accuracy in rebar creation.

Girardet et al. developed and evaluated a parametric tool that facilitates the generation of all types of bridges, considering the curvature existing in 3D space, for the design and analysis of various bridge projects such as steel-concrete composite bridges, variable cross-section segmental bridges, and complex-shaped bridges (Girardet & Boton, 2021). However, there are currently few studies that delve into detailed discussions regarding rebar modeling frameworks for structural elements with special shapes, such as inclined or circular forms.

3 Methodology

Figure 1 shows an overview of the proposed method. This method is categorized into three stages: classifying the target structural element for rebar generation into shape-dependent and shape-independent parts, applying conventional rebar generation programs to the shape-dependent parts, and creating and applying additional programs corresponding to the shape-independent parts.

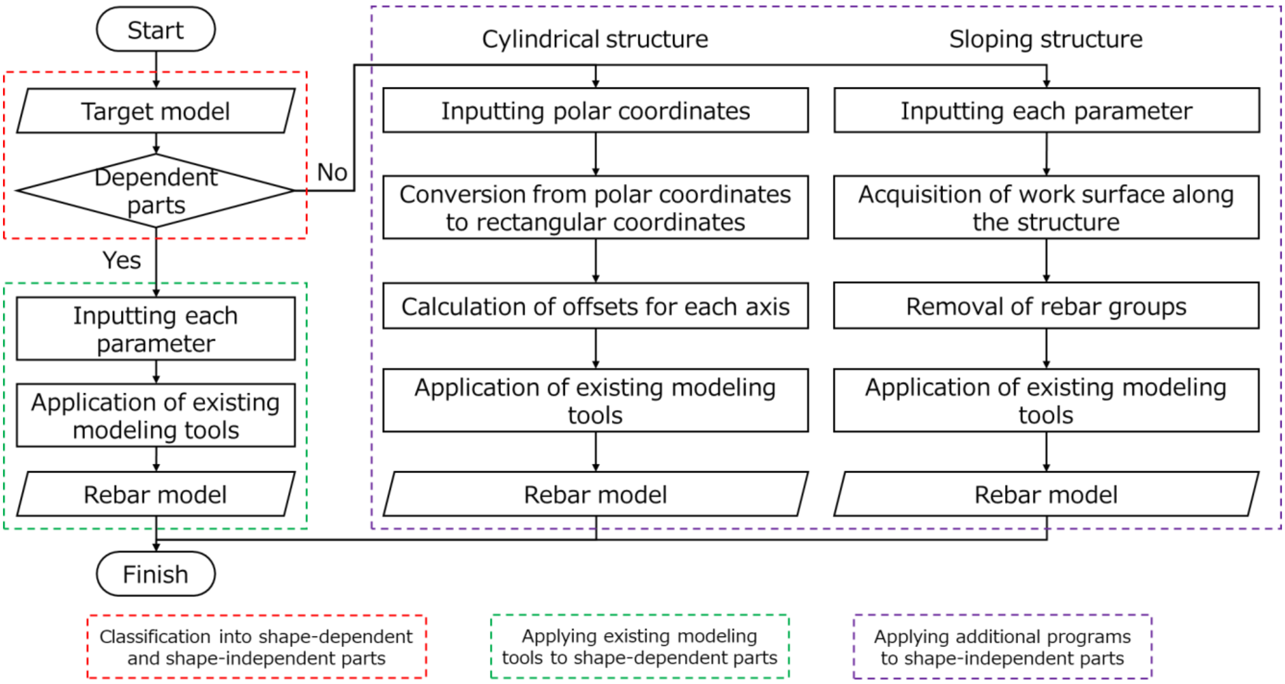


Figure 1. Overview of the proposed method

3.1 Stage of Classifying into Shape-Dependent and Shape-Independent Parts

The stage of classifying into shape-dependent and shape-independent parts involves categorizing them into parts that are shape-dependent and can be applied to the existing rebar modeling tool, RebarModelingTool, and parts that are shape-independent and cannot be applied to RebarModelingTool. Here, RebarModelingTool is a semi-automatic rebar modeling tool for the BIM software Revit, developed by utilizing Rhino.Inside.Revit and its plugin, Grasshopper. Rhino.Inside.Revit is an add-in for Revit that loads Rhinoceros 3D. Rhinoceros 3D is a surface modeling application with a reliable freeform geometry engine that supports meshes and point clouds. Since Rhinoceros 3D supports multiple file formats, it serves as a powerful interoperability tool. Grasshopper is a visual programming environment tightly integrated with Rhinoceros 3D's modeling tools. Grasshopper requires no knowledge of programming or scripting, but still allows designers to build generative forms from the simple to inspiring.

RebarModelingTool, developed within these environments, achieves a semi-automated rebar modeling process, as shown in Figure 2. This process converts complex NURBS models, parametrically generated in Rhinoceros 3D using Grasshopper programs based on prepared text data for rebar parameters, into rebar BIM models in Revit. By utilizing the python library based on Revit API for this conversion, information from 19 Rhinoceros Shapes can be linked to 36 Revit Shapes, enabling the generation of rebar models in Revit from Rhino's NURBS models (representing rebar centerlines) and Rebar Shapes. Since the tool is primarily intended for modeling rebar in rectangular structural elements, in this method, rectangular parts are classified as dependent parts, and non-rectangular parts such as circular or inclined sections are classified as independent parts.

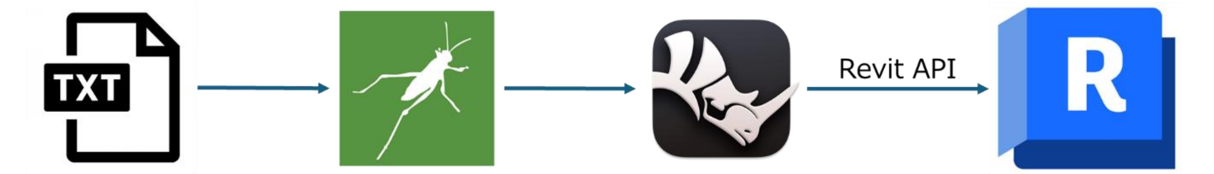


Figure 2. Overview of RebarModelingTool

3.2 Stage of Applying the Rebar Generation Program to Shape-Dependent Parts

The stage of applying the rebar generation program to shape-dependent parts utilizes the existing rebar modeling tool, RebarModelingTool. First, RebarModelingTool requires different comma-separated values (CSV) files as input for Grasshopper to model rebar within Rhinoceros 3D. These files contain parameters for the rebar to be modeled (name, working plane, offset for each axis, major axis, minor axis, shape, diameter, number, spacing, and length of each side). Even if rebar types such as main rebar, distribution rebar, and shear reinforcement are represented, each type can have different rebar shapes. Since each of these shapes has different length requirements, an independent CSV file must be created for each rebar type. Table 1 shows the parameters that need to be prepared in advance and their respective descriptions.

Next, using RebarModelingTool opened on a Revit file containing the structural element model, specific Revit elements where rebar will be placed and elements within the excavation area are specified. This allows for distinguishing between the panel's ground surface and excavation surface. Then, by selecting a specific rebar type (e.g., main rebar, shear reinforcement, distribution rebar) from the available options and inputting the CSV file containing the rebar parameters, the rebar is modeled in Rhinoceros

3D. The rebar model created in Rhinoceros 3D is then modeled into Revit's model space by the Revit API's Rebar Class. After this, by repeating the above process for each rebar type to be modeled, parametric rebar modeling can be performed.

Table 1. Input parameters and their overview

Parameters	Overview
Name	Depending on the modeler preference, the nomenclature may be project specific. However, some items to consider in the naming are rebars with the same rules, in the same panel, and within the same section of a panel.
Face	Defines the side of the panel into which the rebar will be modeled and sets the local coordinate origin Grasshopper will consider.
X-Y-Z Offsets	Used to define the starting position of the rebar (i.e., three dimensional offsets)
Rebar Shape	One rebar type may have multiple shapes and Grasshopper needs to identify this. Hence, modelers must assign the shape the rebar will have as a parameter.
Rebar Diameter	The diameter of the rebar to be modeled. This parameter is dependent on the rebar families within Revit. If a different nomenclature (i.e., diameters in inches instead of millimeters) is used in the CSV files for Grasshopper to interpret, and Revit does not have the same nomenclature within a family, then no rebar will be instantiated (i.e., modeled) in Revit.
Number	Amount of rebars that are included in a group. This works in conjunction with the spacing, indicating X amount of bars are to be modeled by Y spacing separating them.
a-g elements	This are type and shape dependent values that modelers must calculate. These values will define the total length of the rebar that will be modeled.

3.3 Stage of Program Creation and Application for Shape-Independent Parts

In the stage of program creation and application for shape-independent parts, the functionality of RebarModelingTool is extended to enable its application to cylindrical and inclined structural elements, which were difficult to handle with the conventional RebarModelingTool. First, the application to cylindrical structural elements will be described. For rebar modeling in cylindrical structural elements, a polar coordinate system is typically used instead of a Cartesian coordinate system. A challenge with applying the conventional RebarModelingTool directly to cylindrical structural elements was the need for manual conversion from polar to Cartesian coordinates by the modeler. Therefore, this method constructs a system by adding a conversion module from polar to Cartesian coordinates to RebarModelingTool, allowing users to input parameters related to the polar coordinate system (e.g., radius, angle) instead of X-Y-Z Offsets in the CSV file. This conversion module automatically calculates the X-Y-Z Offsets relative to the cylindrical element's bounding box based on the input polar parameters, enabling rebar modeling along an arc.

Next, the application to inclined structural elements will be described. When the conventional RebarModelingTool was applied to inclined structural elements, rebar was modeled along the bounding box of the structural element, leading to the problem of rebar models protruding beyond the element. To address this issue, this method constructs a system by adding modules to RebarModelingTool that stop the use of the bounding box, set the structural element's surface as the working plane, and ungroup rebar. This ensures that rebar models are accurately modeled along the inclined surface without protruding beyond the structural element. This module forms a working plane along the inclined surface of the structural element, allowing not only rebar groups but also individual rebar within a group to be placed along the inclined surface.

As demonstrated by the application examples for cylindrical and inclined structural elements above, combining modules for geometric shape transformation with RebarModelingTool enables parametric rebar modeling on Revit for various structural element shapes.

4 Results

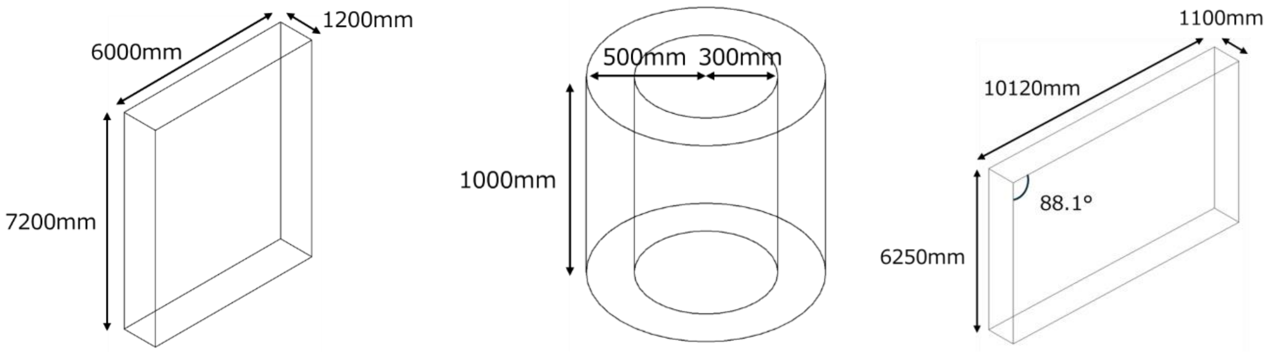
The results of automatically modeling main rebar in rectangular, cylindrical, and inclined structural elements, in addition to rectangular elements applicable with conventional rebar modeling tools, using the proposed method described in the previous chapter, are presented to demonstrate that the proposed method can significantly improve the efficiency of rebar modeling. Figure 3 shows the bird's-eye view and dimensions of the rectangular, cylindrical, and inclined structural element models targeted for automatic rebar modeling, respectively. The inclined structural element model is tilted by 1.9 degrees relative to the horizontal.

For rebar modeling of the rectangular structural element model, it was determined that automatic modeling using the conventional RebarModelingTool was possible because the target element has a horizontal rectangular shape. The necessary parameters for modeling were prepared, and Table 2 shows the parameters used for main rebar modeling of the rectangular structural element model. For example, the rebar group named "test0" is defined with a working plane on the excavation side, a Z-axis offset of 100mm, a Y-axis offset of 112mm, an X-axis offset of 265mm, a major axis along the Z-axis, a minor axis along the Y-axis, a straight shape, a diameter of 25mm, 20 rebars in the group, a rebar spacing of 130mm, and a length of 6600mm. By inputting a CSV file containing these parameters into RebarModelingTool, the main rebar was automatically modeled in Rhinoceros 3D and the target structural element in Revit's model space.

For rebar modeling of the cylindrical structural element model, since the target element does not have a horizontal rectangular shape, automatic modeling was enabled by using the polar-to-Cartesian coordinate conversion program integrated into the conventional RebarModelingTool. The necessary parameters for modeling were prepared, and Table 3 shows the parameters used for main rebar modeling. For the rebar group named "test," parameters for Y-axis and X-axis offsets, number of rebars in the group, and rebar spacing were not entered; instead, polar coordinate parameters of radius 400mm and angle 30mm were input. By inputting a CSV file containing these parameters into the system constructed by the proposed method, the polar coordinate parameters were converted to Cartesian coordinate offsets, and the main rebar was automatically modeled in Rhinoceros 3D and the target structural element in Revit's model space by RebarModelingTool.

For rebar modeling of the inclined structural element model, since the target element does not have a horizontal rectangular shape, automatic modeling was enabled by using the function to acquire a working plane along the inclined surface and the rebar ungrouping program integrated into the conventional RebarModelingTool. The necessary parameters for modeling were prepared, and Table 4 shows the parameters used for main rebar modeling. By inputting a CSV file containing these parameters into the system constructed by the proposed method, a working plane along the inclined surface was automatically acquired, and the main rebar was automatically modeled one by one in Rhinoceros 3D and the target structural element in Revit's model space by RebarModelingTool.

Figure 4 shows the rectangular, cylindrical, and inclined structural element models with main rebar modeled in the Rhinoceros model space, and Figure 5 shows them in the Revit model space.



(a) Rectangular structure (b) Cylindrical structure (c) Inclined structure

Figure 3. Structural element models targeted for automatic rebar modeling

Table 2. Parameters used for main rebar modeling of the rectangular structural element model

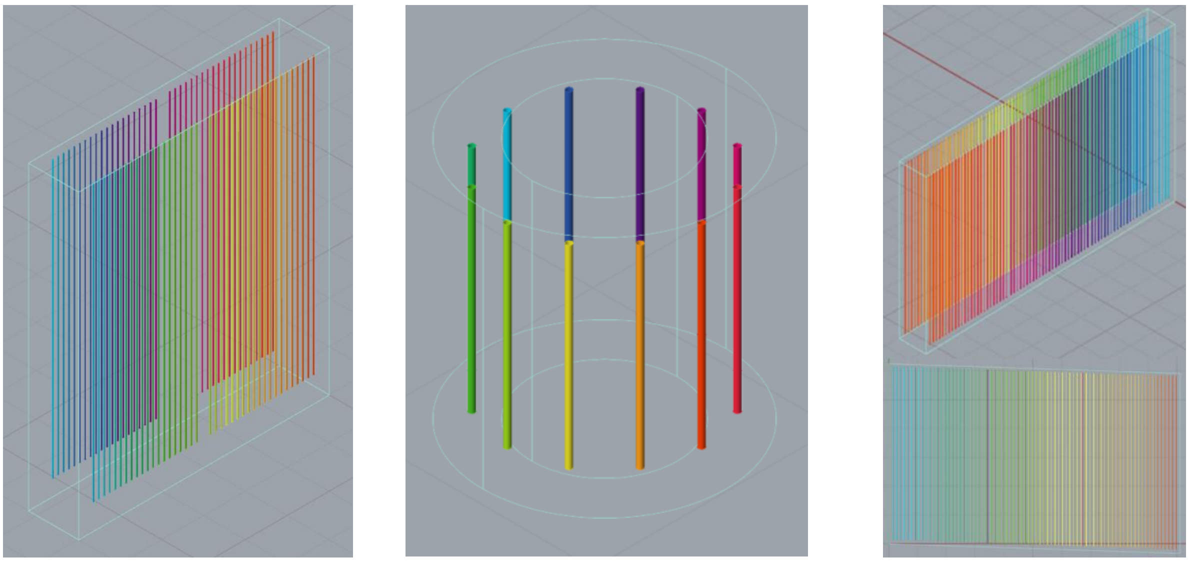
name	face	z_offset	y_offset	x_offset	main_axis	sub_axis	shape	diameter	number	spacing	a
test0	2	100	112	265	z	y	00	25	20	130	6600
test1	2	100	112	3065	z	y	00	25	20	130	6600
test2	1	100	112	465	z	y	00	29	20	130	6600
test3	1	100	112	3265	z	y	00	29	20	130	6600

Table 3. Parameters used for main rebar modeling of the cylindrical structural element model

name	face	z_offset	main_axis	sub_axis	shape	diameter	a	radius	degree
test	1	100	z	y	00	25	800	400	30

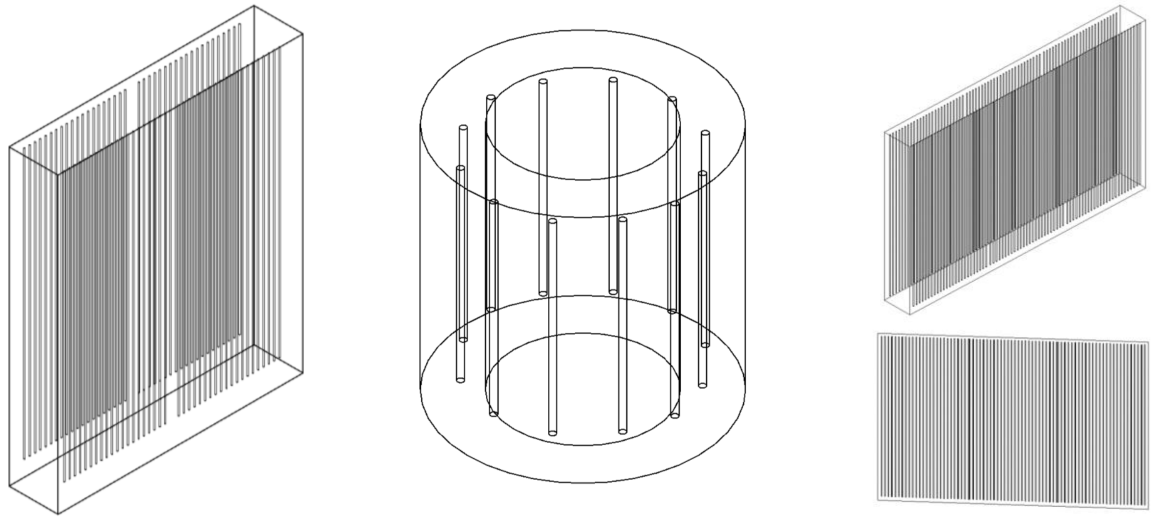
Table 4. Parameters used for main rebar modeling of the inclined structural element model

name	face	z_offset	y_offset	x_offset	main_axis	sub_axis	shape	diameter	number	spacing	a
test0	2	100	112	265	z	y	0	25	25	130	6000
test1	2	100	112	3565	z	y	0	25	25	130	6000
test2	2	100	112	6865	z	y	0	25	25	130	6000
test3	1	100	112	265	z	y	0	29	25	130	6000
test4	1	100	112	3565	z	y	0	29	25	130	6000
test5	1	100	112	6865	z	y	0	29	25	130	6000



(a) Rectangular structure (b) Cylindrical structure (c) Inclined structure

Figure 4. Structural element models with main rebar modeled in the Revit model space



(a) Rectangular structure (b) Cylindrical structure (c) Inclined structure

Figure 5. Structural element models with main rebar modeled in the Rhinoceros model space

5 Conclusion

In this study, to address the severe labor shortage in the construction industry and achieve the goal of improving construction site productivity, a new method was proposed for parametrically and automatically generating rebar models by dynamically reflecting design parameters specified by the designer, amidst the demand for semi-automatic design through parametric modeling. The proposed method classifies structural elements into shape-dependent parts that can be handled by the conventional rebar modeling tool, RebarModelingTool, and shape-independent parts that cannot. By developing additional programs only for the shape-independent parts, it became possible to efficiently achieve rebar modeling that accurately reflects design intent, not only for simple rectangular structural elements but also for diverse and complex ones.

Using the developed system, automatic modeling of rebar models was performed for three types of structural body models—rectangular, cylindrical, and inclined—with a focus on the main reinforcement bars. As a result, it was confirmed that each was modeled at the appropriate position according to the input parameters. In particular, the cylindrical structural element model was modeled along an arc, and the inclined structural element model was modeled along an inclined surface, demonstrating its applicability to various structural element shapes.

Thus, the creation of rebar BIM models by users becomes possible simply by inputting parameters into a CSV file, eliminating the need for users to operate BIM software. Furthermore, adjustments to model placement by software are not required during design changes, significantly reducing the person-hours incurred by rework during the design and construction phases. Moreover, human errors associated with manual model creation can be greatly reduced, improving model quality and accuracy. These contributions are expected to significantly enhance overall project productivity and reduce costs. Future developments include the development of modules that enable application to a broader range of structural bodies, such as those with variable cross-sectional geometries.

References

Ministry of Land, Infrastructure, Transport and Tourism. (2018). Recent Situation Surrounding the Construction Industry: https://www.mlit.go.jp/common/001268636.pdf, Last Access: July 28, 2025.

Ministry of Land, Infrastructure, Transport and Tourism. (2022). Initiatives for Aging Infrastructure Countermeasures: https://www.mlit.go.jp/road/sisaku/yobohozen/torikumi.pdf, Last Access: July 28, 2025.

Milyutina, M. A. (2018). Introduction of Building Information Modeling (BIM) Technologies in Construction. Journal of Physics: Conference Series, 1015, 4. doi: 10.1088/1742-6596/1015/4/042038

Saeed, I. (2011). BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors. John Wiley & Sons, Inc. ISBN: 9781119287537

Ministry of Land, Infrastructure, Transport and Tourism. (2025). 13th BIM/CIM Promotion Committee BIM/CIM Handling Guidelines (Draft): https://www.mlit.go.jp/tec/content/001867346.pdf, Last Access: July 28, 2025.

Jabi, W. (2014). Parametric spatial models for energy analysis in the early design stages. SIMAUD 2014, 13-16. Retrieved from https://orca.cardiff.ac.uk/id/eprint/59227/1/047-AsPublished.pdf, Last Access: July 28, 2025.

Taghipourarasteh, E. (2021). Parametric Design in Architecture Based on BIM. International Master of Science in Construction and Real Estate Management Joint Study Programme of Metropolia UAS and HTW Berlin. (Document No. s0572568).

Janssen, P. (2015). Parametric BIM workflow. Proceedings of the 20th International Conference on Computer-Aided Architectural Design Research in Asia. doi:10.52842/conf.caadria.2015.437

Yankai, H. (2024). BIM-based Rebar Modeling for Variable Section L-shaped Columns. Journal of Engineering Research and Reports, 26, 12, 249-260. doi: 10.9734/jerr/2024/v26i121355

Girardet, A., & Boton, C. (2021). A parametric BIM approach to foster bridge project design and analysis. Automation in Construction, 126, 103679. doi:10.1007/978-3-031-44328-2_63