A REINFORCING BAR DESIGN AND CONSTRUCTION SUPPORT USING VR AND 3D CAD

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ABSTRACT: Traditionally, reinforcing bar design of reinforced concrete (RC) structures has been represented on 2D drawings. In 2D drawings, main reinforcing bars and sub reinforcing bars may not be easily distinguished. Thus, at construction site, construction workers may misunderstand the important reinforcing bars. In the lifecycle (design, construction, maintenance) of RC structures, currently, many problems can be identified. These problems are attributed to the usage of 2D drawing in design. Thus, we developed a 3D reinforcing bar design support approach with Revit Structure (a 3D CAD system) and NavisWorks (a VR software) of Autodesk. We proposed a new direct 3D design approach and described an application case to consider the feasibility.

KEYWORDS: VR, 3D CAD, Reinforcing Bar, Reinforced Concrete, Clash Check.

1. INTRODUCTION

In the construction industry, cost reduction and quality assurance are crucial issues, and thus, information technology is expected to play a significant role and has been investigated in multiple disciplines. Especially, 3D model-based design and construction, as known as Building Information Modeling (BIM), has attracted much attention recently (Barak et al., 2007; Gu et al., 2008).

Traditionally, reinforcing bar design of reinforced concrete (RC) structures has been represented on 2D drawings, which are useful for illustrating detailed reinforcing bar situations in a simple and quick way. However, since reinforcing bars are often highly densely arranged partially due to the revisions of seismic design codes in Japan, there are reported troubles such as reinforcing bars cannot be properly arranged as indicated by the designer or concrete cannot be cast appropriately under the dense reinforcing bars. The most influential cause of these problems is the design method relying n 2D drawings. Therefore, in this research, to solve such problems, 3D reinforcing bar design and construction support approach (Yabuki and Shitani, 2004) was developed based on Building Information Modeling (BIM) using Virtual Reality (VR) and 3D CAD (Fujisawa et al., 2009; Kobayashi and Igarashi, 2009).

2. CURRENT PROBLEMS RELATED TO REINFORCING BARS

In the lifecycle (design, construction, maintenance) of RC structures, currently, the following problems can be identified.

2.1 Problems due to the Design

The following problems are often seen because of the usage of 2D drawing system in design of RC structures.

- As each member is drawn in each drawing, when the members are superimposed or connected, clash of members often occur.
- In 2D drawings of reinforcing bars,.the diameter of each reinforcing bar is usually not illustrated, and each bar is represented by a single line. Therefore, many clash cases of reinforcing bars occur.
- In 2D drawings, main reinforcing bars and sub reinforcing bars may not be easily distinguished. Thus, at

construction site, construction workers may misunderstand the important reinforcing bars.

2.2 Problems in Construction

The following problems are seen in construction.

- At the connection of head of piles and underground beams or box culverts, reinforcing bars may not be placed as indicated in the 2D drawings.
- Additional supplementary reinforcing bars may be placed at a pitch designated in the drawing at hunches and opening of a box culvert and other special sections.
- Since the procedure of placing reinforcing bars may not be considered, reinforcing bars, especially stirrups, may not be placed properly.
- The number of good reinforcing bar placing workers is decreasing (Yabuki and Li, 2007).

2.3 Problems in Construction Management

The following problems are often heard at construction sites.

- Contractors inspect whether the placement of reinforcing bars are done properly with the owner engineer's presence before casting concrete, checking drawings and taking pictures, which takes time and effort.
- If they find reinforcing bars which cannot be placed actually, they have to change design, which takes time and effort.
- As densely placed reinforcing bars are increasing, it is difficult to confirm that concrete is properly cast under the dense reinforcing bars.

2.4 Problems in Maintenance

- Although design drawings exist, as built drawings are not provided. Thus, if cracks in the concrete member are identified, it is difficult to precisely locate the reinforcing bars in the concrete.
- As precise reinforcing bars locations cannot be identified, main reinforcing bars are sometimes cut in the borehole inspection.

3. 3D REINFORCING BAR DESIGN SUPPORT APPROACH

3.1 Overview of the Approach

Most problems described in section 2 are due to the usage of 2D drawing in design. Thus, we developed a 3D reinforcing bar design support approach with Revit Structure (a 3D CAD system) and NavisWorks (a VR software) of Autodesk. In this approach, the user, first, makes a 3D reinforcing bar model from 2D drawings, using Revit Structure, as shown in Figure 1. Then, the DWF data of the 3D model is exported to NavisWorks, by which the user checks clash of reinforcing bars. If a clash is detected, the design is modified in the 3D model of DWF, using Revit Structure. Then, the same check is done until no clash is detected. In NavisWorks, the procedure of how to place reinforcing bars can be checked as well.

3.2 Strengths and Limitations of the Approach

3.2.1 Strengths of the Approach

- Since places of reinforcing bars can be confirmed and clash detection can be performed, mistakes in arranging complex reinforcing bars decrease.
- From the 3D model, the user can make a precise bill of quantity of reinforcing bars easily, which leads to more precise cost estimation.
- Placing procedure of reinforcing bars can be investigated easily, which can decrease mistakes and thus, quality of RC structures can be improved.

- Since the cover, pitch, diameter of reinforcing bars are often modified according to the actual construction conditions, the changes can be checked and verified by using this system.

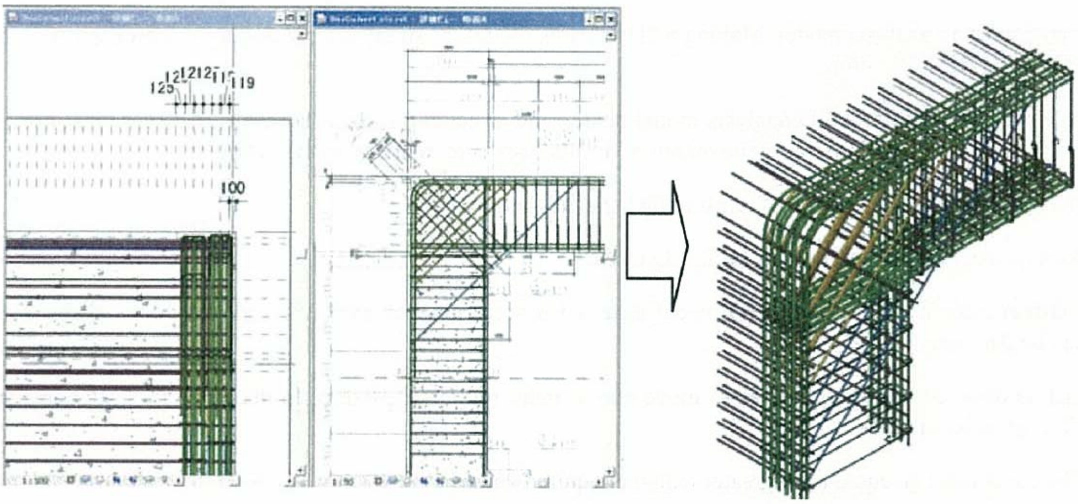

FIG. 1: Making a 3D reinforcing bar model from 2D drawings using the proposed approach

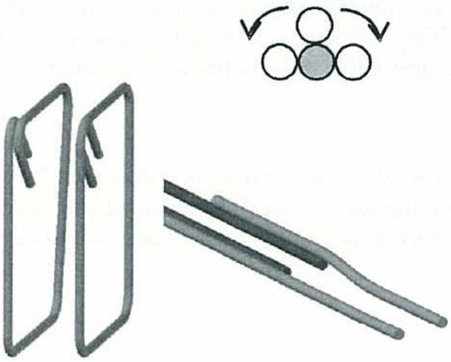

FIG. 2: Different kinds of placement of reinforcing bars with 3D consideration

3.2.2 Limitations of the Approach

- As some particular 3 dimensional considerations are not given, multiple different design cases can be generated, depending on the engineer, as shown in Figure 2.
- Precision at the construction site is different from that of 3D CAD.
- It is difficult to check whether concrete can be filled properly under densely placed reinforcing bars.

4. NEW DIRECT 3D DESIGN APPROACH

The limitations of the 3D system described in the previous section are due to the adopted method, in which 2D drawings are drawn first and then, 3D model is generated from the 2D drawings. If members are designed directly using the 3D system without drawing 2D plans anymore, various limitations can be eliminated. We are trying to adopt a new direct 3D design approach instead of the traditional 2D drawing method, using the 3D reinforcing bar design support system.

4.1 Overview of the New Direct 3D Design Approach

The flow of the new direct 3D design approach is as follows.

1) Preparation: Determining input data such as soil properties, loads, etc., for analysis.

2) Assumption of structural type: Making an assumption of the structural type and size of each member, based on the experience and previous design examples.

3) Creation of an analysis model: Making a 3D analysis model for simulation, including soil properties, loads, etc., using Revit Structure.

4) Analysis: Exporting the 3D analysis model data to the structural analysis software packages such as SAP 2000 and running the program. The output of the analysis is represented in the 3D model.

5) Determination of the number of reinforcing bars and their sizes.

6) Arrangement of reinforcing bars in the 3D model.

7) Clash detection: Exporting the 3D model data to VR software such as NavisWorks. In NavisWorks, clash can be detected.

If a clash is detected, the designer has to move one or more reinforcing bar(s). In that case, the following two conditions must be satisfied.

- The cover must be equal to or greater than the required value.
- The pitch must be equal to or less than the required value.

Since the location of main reinforcing bars is determined from the shape of the member, main bars do not usually clash with other members. However, stirrups tend to do if they are densely arranged. In that case, stirrups can be moved somewhat. Stirrups of columns can be moved vertically, while those of beams horizontally.

4.2 Application of the New Approach

In order to investigate the applicability of this approach, a rigid RC frame railway elevated bridge was selected (Figure 3). In the design of such viaducts, a clash of reinforcing bars occurs if the height of both longitudinal and lateral beams is the same (Figure 4). This problem can be solved by modifying the beams, based on their mutual relationship.

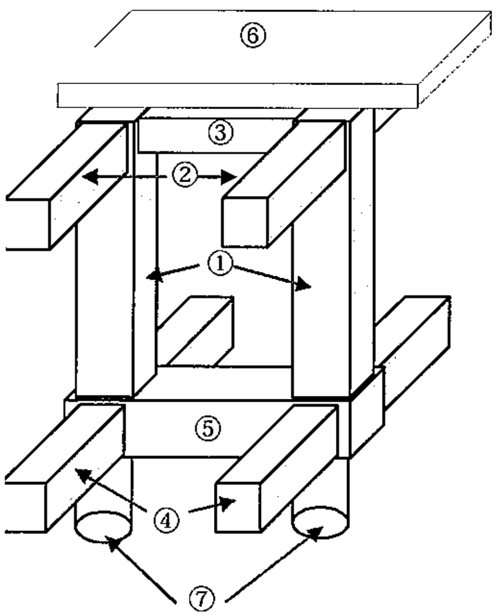

FIG. 3: A rigid RC frame railway elevated bridge

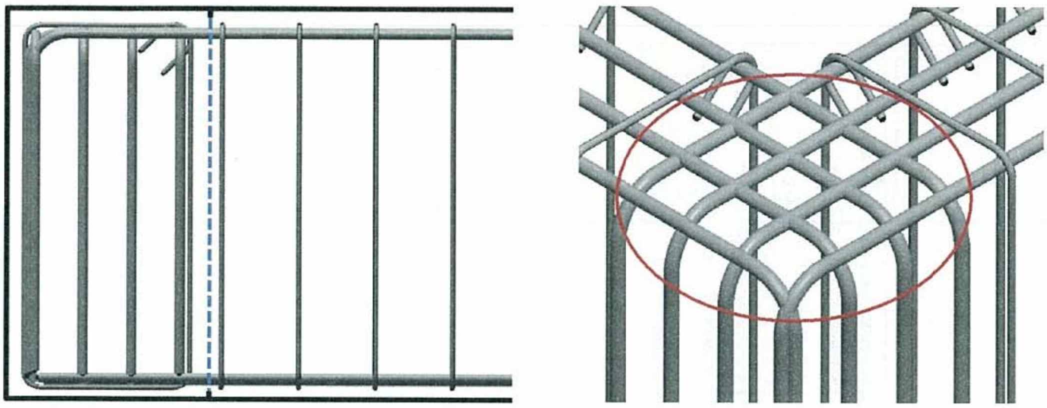

FIG. 4: Clash of reinforcing bars in the connection of longitudinal and lateral RC beams

In the present Japanese railway field, design of elevated bridges is based on the following concept. In Japan, where large earthquakes occur frequently, seismic performance has high priority. It would be extremely expensive if a structure is designed so that it would never collapse even if a very strong earthquake occurs near the site. Thus, more reasonable approach is adopted such as some type of member should be collapsed if a large earthquake occurs so that other parts should be maintained. To have a weak part in the structural system is similar to have a fuse in the electric system. In the elevated bridge system, since columns do not directly support the railway and are above ground, it would be easier to repair compared to beams or footings. Thus, columns are designed so that they collapse first before beams and other members do. So, after executing analysis, the sequence of section design is 1) determine the column section, 2) determine the longitudinal beam section, 3) determine the lateral beam section. Based on the design concept described above, the new 3D design approach can be applied as the following.

1) Assume section size of each member and properties of each member and soils. Generally, the width of longitudinal beams is designed smaller than that of columns, and the width of lateral beams is larger than that of columns. The height of longitudinal beams is greater than that of lateral beams.

2) Execute structural analysis.

3) Design the section of columns, based on the result of the analysis (Figure 5).

FIG. 5: Arrangement of reinforcing bars for a column

4) Design the section of longitudinal beams, based on the number of reinforcing bars in the column and the analysis result (Figure 6).

5) Design the section of lateral beams. The height of the lateral beam is smaller than that of longitudinal beam. Place the main reinforcing bars of the lateral beam inside of those of longitudinal beam (Figure 7).

6) Make a 3D model of the reinforcing bars (Figure 8).

7) Export the 3D model data to VR software and check clash.

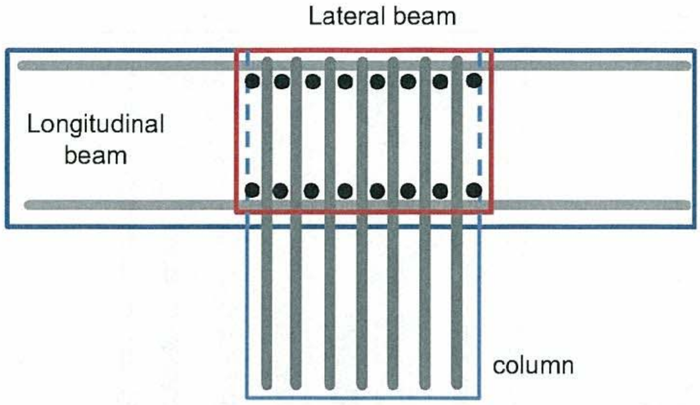

FIG. 6: Design of a longitudinal beam

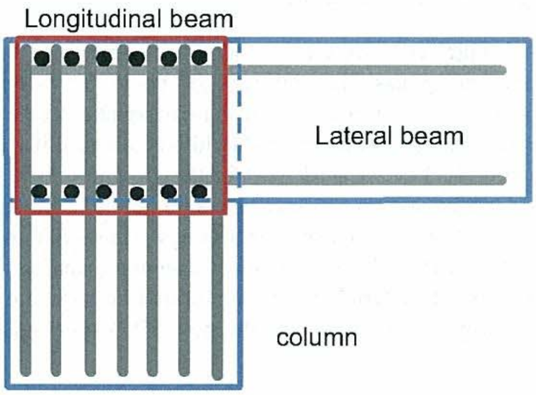

FIG. 7: Design of a lateral beam

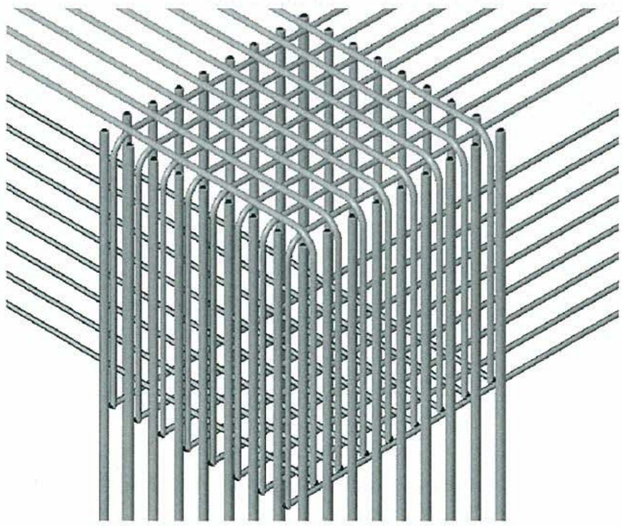

FIG. 8: 3D model of reinforcing bars

5. CONCLUSION

In the design of reinforced concrete structures, engineers still draw 2D plans. Many problems occur due to the use of 2D drawings. Thus, we had proposed a 3D reinforcing bar design support approach, using a 3D CAD and VR systems. We evaluated this approach and pointed out strengths and limitations. In this paper, we proposed a new direct 3D design approach and described an application case to consider the feasibility. As a future work, we are investigating more detailed figures and properties of reinforcing bars, such as fixing length, shape and location of fixing,

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