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VIRTUAL CONSTRUCTION OF TRANSFER FLOORS IN REINFORCED CONCRETE BUILDING USING BIM

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ABSTRACT: Building Information Modeling (BIM) is being widely spread in AEC industry worldwide and also in South Korea. Although the creation of digital model is better to be started at design stage, it can also improve the productivity of construction by simulating the actual construction process and environment. This paper presents application of BIM-based simulations related with design changes to transfer floors in 58-storey reinforced concrete office building. Transfer floor is not only a structurally important part of the building but also a challenging part of the actual construction in terms of sequence and period due to the complexity of the work. Preconstruction of rebar, mechanical, and plumbing is performed to review the construction drawings and to perform clash detection. Each item of application is evaluated for its effectiveness on actual construction and for the development potential.

Keywords: Virtual construction, Building Information Modeling (BIM), transfer floor, reinforcement, preconstruction, mechanical, plumbing, clash detection

1. INTRODUCTION

The ultimate goal of BIM is to build an integrated management system through 3D models in the full range of the lifecycle of a building from project planning, design, and construction to maintenance and demolition. Various factors in the current AEC industry make this goal difficult to reach and after a partial BIM – which is made up of step-wise application in planning, design, construction phases – is first to be developed and should be combined into an integrated system and procedure. At present, the organization taking the lead in introducing BIM is the client. According to the client's demand, the introduction of BIM to the design stage has been most active, but the urgency of BIM adoption diminishes as the business goes along the phases, such as in the construction phase. One of the reasons for this is that 3D model made in the design phase cannot be utilized in the construction phase but 3D model for the construction should be made again. However, although the 3D data from the design phase cannot be used right away in the construction phase and the immediate introduction of BIM is not an urgent matter, it is the contractor's position that the present condition of the market cannot be overlooked with regard to BIM. After all, contractors should prepare the adoption of BIM by finding the way by themselves to use 3D model to enhance the productivity within their work scope and to confirm the validity of its application with pilot test bed.

This paper describes a case study in which the 3D model is used in the review of design changes and deliberation of detailed shop drawing for rebar during the consultation process between client, consultants, and contractor for ongoing construction project of high-rise office building, KLCC Tower in Malaysia. See Figure 1 for the expected panoramic view of the KLCC Tower when it is completed.

2. OUTLINE OF PROJECT SUBJECT

(1) Project name: KLCC Tower Project – Superstructure Main Contract Works
(2) Location: Malaysia, Kuala Lumpur, City Center KLCC LOT 171
(3) Construction Outline
- Height: 4 basement levels, 58 floors above ground, 267m
- Building layout: office with lower level retail area
- Gross area: 155,00m^2
(4) Client: Arena Merdu Sdn. (100% owned by KLCC, a subsidiary of KLCC Holdings Sdn. Bhd., the client that commissioned the Petronas Twin Towers)
(5) Design : Pelli Clarke Pelli Architects (architecture), Meinhardt (structure)
(6) Construction Period : 142 weeks (72 weeks for retail area)
(7) Structure : reinforced concrete with flat plate

This project was handed over as being completed for the pile and raft. The contractor for the superstructure is in unfavorable condition that it has to finish the structure and finishing in 142 weeks, including the partial opening of the lower retail area where the building is connected to the neighboring Petronas Twin Tower within 72 weeks. The contractor should go on with the ordinary construction condition as part of the building is open for operation.

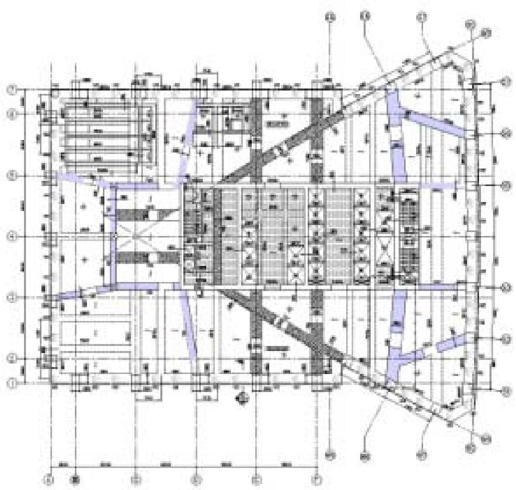
Figure 1. Expected panoramic view of KLCC Tower with Petronas Twin Tower

Another challenging part of the project is that there are three transfer floors where the location of columns is changed and, therefore, the construction is very complex in this region. The first and second transfer floors exist on the first, fifth and sixth floors, in which the central core structure layout changes from mega column to thick walls. On the 30th floor, the third transfer floor exists due to the change of plan shape from rectangle layout to a triangular one.

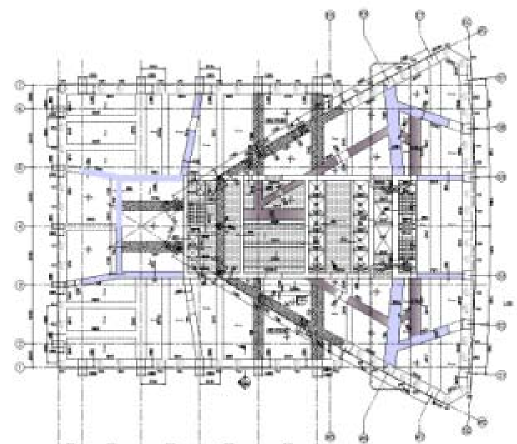
The target floor to improve the constructability using 3D model is the third transfer floor. The original two level transfer floors (Levels 29 and 30) are changed to only one level (Level 30) due to the design change for the outriggers and belt walls on the client's request. See Figure 2 for the detailed design changes in these levels. Amidst working night and day due to the tight schedule, the design for the Level 30 were not determined, and due to the transfer floor being reduced the reinforcement placing of the transfer wall had to be concentrated on Level 30, many problems with the workability of the floor plan were discovered during review. To determine the constructability and design suitability involved with the design changes, 3D model was used to review the layout of the reinforcement and the routing of machinery equipment channel in the process of the design changes.

3. TRANSFER WALL REINFORCEMENT

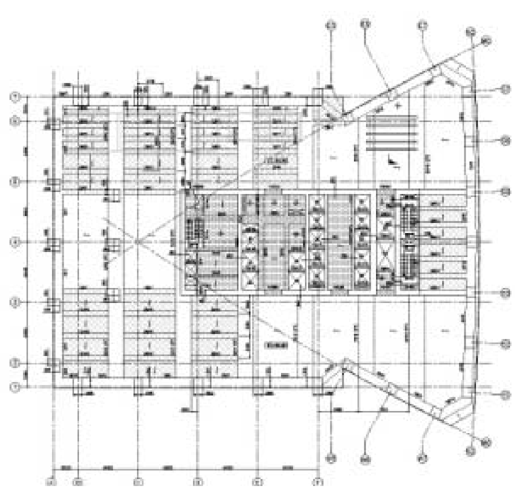
The transfer floor which initially would span from Level 29 to Level 30 is reduced to only one floor, Level 30. As the amount of reinforcement is concentrated on one floor



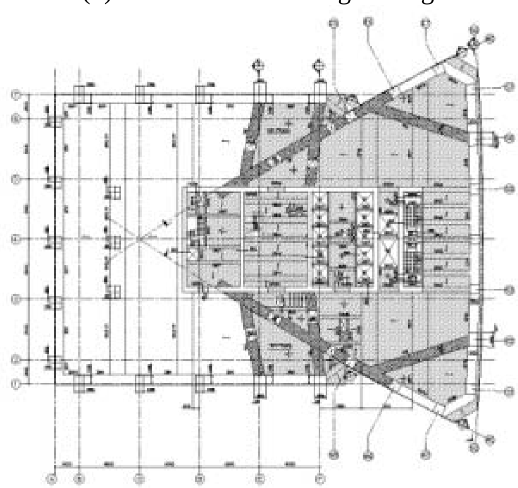
(a) Level 29 before design change



(b) Level 30 before design change



(c) Level 29 after design change



(d) Level 30 after design change

Figure 2. Design changes in transfer floors

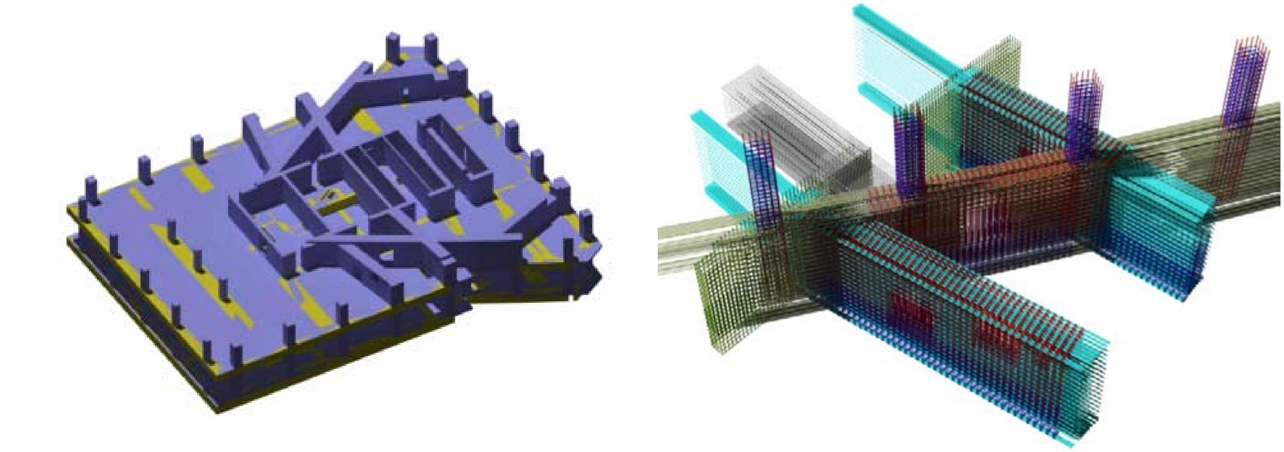


Figure 3. 3D models for Level 30 transfer floor: Structure (left) and reinforcement (right)

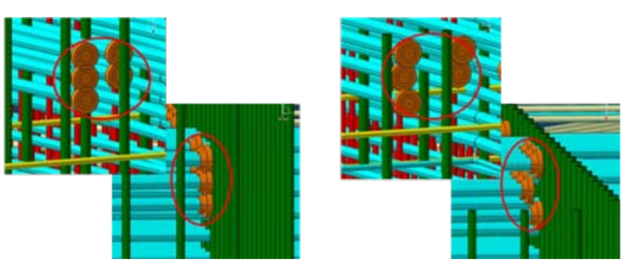
and it was expected that reinforcement construction would prove difficult (See Figure 3). The site team did recognize this factor from the moment them received the revised construction drawings from the client with their past experiences, it was still hard for them to explain to the client or design consultants the problems in the current construction drawings and persuade them to take more feasible construction methods by conventional means of communication. Visual presentation of the problems originating from the revised construction drawings based on 3 dimensional modeling of the congested connection areas of transfer walls and core walls was selected as an effective communication method between the contracting parties. By this way the problems with the design changes could be grasped by the client followed by reassessment orders to structural design consultants. Also, a quick decision could be made in such an urgent situation with consultations through the 3D model in the process to reassess the design changes, and details of the construction method statement which is usually prepared after the agreement on the drawing is reached could be discussed at the same time.

Followings are the examples of problems in the original construction drawings and the solutions presented in graphical 3D presentation:

- Clashes are found at core wall anchorage zone between the terminators of longitudinal reinforcement of transfer wall. This is solved by rearranging the terminator while maintaining the nominal spacing of the reinforcement (See Figure 4).
- Figure 5(a) shows clashes of intersecting longitudinal reinforcement in the connection of transfer walls. The workability was improved by sequentially rearranging the reinforcement and modifying the nominal spacing to 40mm (See Figure 5(b)).
- The couplers for preceding core wall reinforcement shown in Figure 6(a) were originally designed to be located in a line, which makes the connecting work for transfer wall reinforcement almost impossible. The couplers are aligned in a slant line to avoid congestion and to give an enough room for construction (See Figure 6(b)).
- Figure 7(a) shows an example of inadequate bending layout for longitudinal reinforcement of column located above the transfer wall. In Figure 7(b), the reinforcement is spliced directly with transfer wall reinforcement.

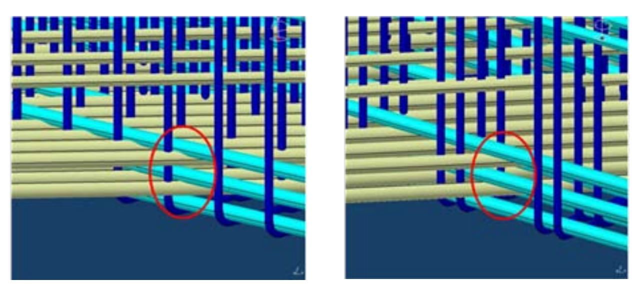
Revised drawings for changed design were first by the contractor. The drawings are converted to 3D model by the contractor and feedbacks are given to the consultant and the client at the same time. Final construction drawings are agreed by all contracting parties based on 3D modeling. The already made 3D model was used again in the making of the shop drawings and approving them.

After the first trial, when the changes are made to the floor plans, 3D modeling work was first carried out. Then the problems are soon noticed in the design and consultation process and are solved. Even the discussions about the construction details can be handled at the same time drastically shortening the time previously allotted for design changes.



(a) Before (b) After

Figure 4. Rearranging rebar terminators at core wall anchorage zone to prevent clash



(a) Before (b) After

Figure 5. Rearranging rebars to prevent clashes between longitudinal reinforcements of intersecting transfer walls

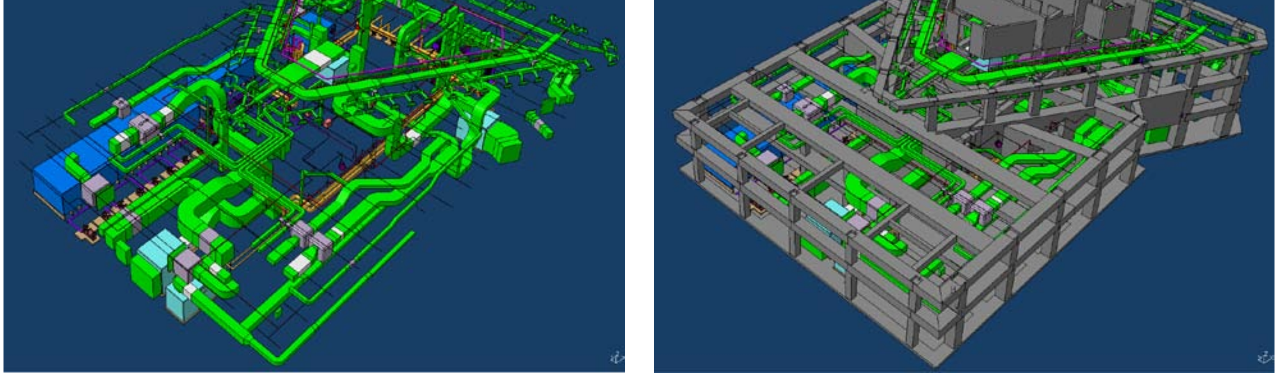


Figure 9. 3D models for transfer floor MEP (left) and combined modeling with structure (right)

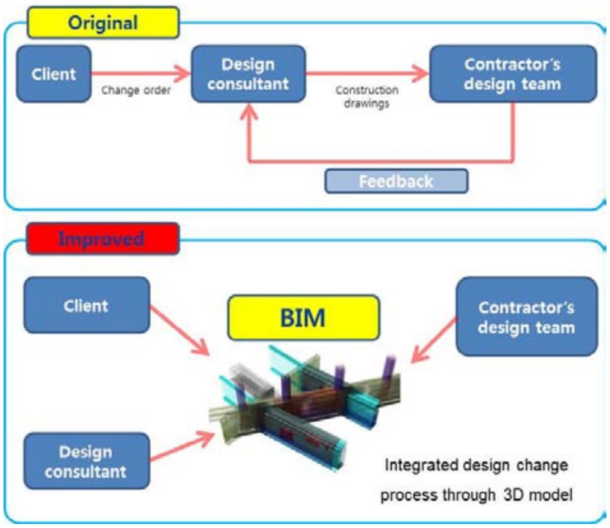
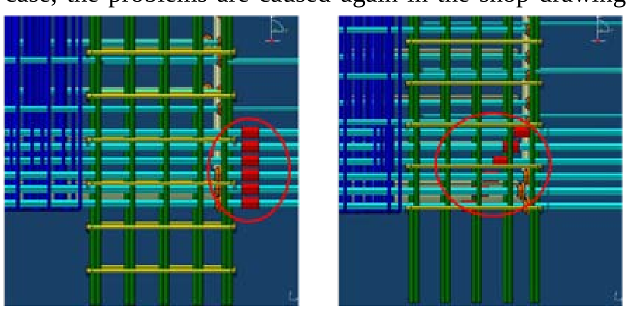


Figure 8. Comparison of design change process, original (above) vs. improved (below)

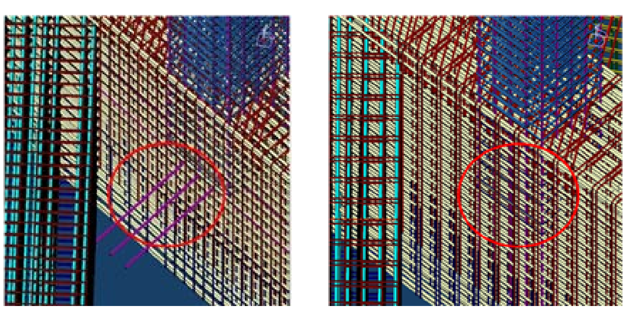
It should be noted that these improvements in the design change process based on 3D model, not conventional 2D drawings, was first proposed by the contractor but progressed smoothly by all contracting parties. There is a limit as to what you can really see with 2D drawings. When entering design change discussions based on such limited information, the results are not perfect. In that case, the problems are caused again in the shop drawing process and, as in the current design changes process, the process of design – review – feedback has to be repeated (See the upper diagram of Figure 8).

Three dimensional modeling of the reinforcement layout in the transfer wall performed to improve the construction method has ultimately become an opportunity to confirm the combined usability and possibilities for the integrated work process pursued by BIM.



(a) Before (b) After

Figure 6. Rearranging couplers between reinforcement in preceding core walls and transfer walls to improve constructability



(a) Before (b) After

Figure 7. Modifying anchorage of longitudinal reinforcement of column located above transfer wall

4. MACHINE EQUIPMENT ROUTING

In the process of structural design changes, mechanical rooms occupying the two level transfer floors were also condensed to be located in one level and became more complex. A review for the clashes between the structure and MEP was already conducted based on original drawings but, in the changed structural configuration, the layout of MEP and its clashes with structure were not checked since the design changes are under progress.

In case of the 30th floor transfer floor, an opening must be set up on the transfer wall in order to set up the equipment for the air conditioning duct and pipes. Since the main structure, transfer walls with thickness of 1500mm, cannot be modified after it has been constructed, the preliminary check for the clashes between the building structural elements and the air conditioning duct equipment is urgent. Therefore, 3D models were created for the machine equipment (ducts, pipes, machinery) in Levels 29 and 30 (See left image of Figure 9), and through clash check with the structural model for changed design – still unfixed – assessments for MEP could be proceeded together with the design changes for the structure (See right image of Figure 9).

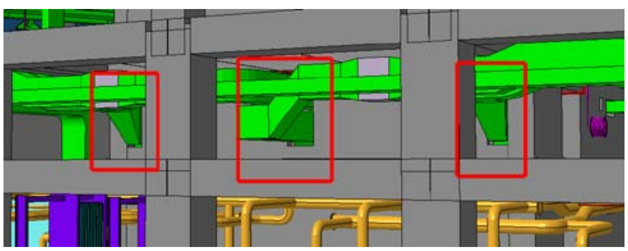
Followings are the examples of problems found in the review of original design of MEP and changed design of structure, and the solutions are also presented in graphical 3D presentation:

- In Figure 10, the suitability of horizontal ducts openings that penetrate the transfer walls are assessed.
- Another check for the suitability of the location and size of the openings in the slab of Level 30 for the vertical duct is shown in Figure 11.
- Shown in the Figure 12(a) is clashes between the structure (transfer walls, core walls, and beams) and ducts and fire-extinguishing pipes. The routes for the fire-extinguishing pipes are changed to solve the problem (See Figure 12(b)).
- Changes are made in the route and level for duct to prevent clashes between the structure and air conditioning and fire-extinguishing pipes (See Figure 13).
- Figure 14(a) shows clashes between vertical duct and various pipes (fire-extinguishing and sanitary pipes) and it is prevented by changing the routing and level of pipes in Figure 14(b).

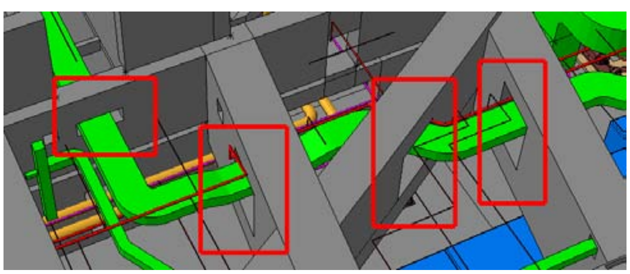
5. CONCLUSION

Applications of three dimensional modeling and its usage to the on-going construction project were explained in detail, especially for structural reinforcing construction and MEP routing and layout. These may be a small example for the contractor who wants to adopt BIM as a development motive. However, these kinds of small trials and errors shall gather and gradually become a truly integrated work flow. Project management system shall be established based on this improved work flow.

One of the values of BIM is its efficiency in approaching the information through three dimensional models. As shown in this paper for the case of design changes during construction period, BIM can help to understand more information in a more accurate manner, and it will eventually enhance the overall work efficiency for AEC industry.



(a) Elevation view



(b) Plan view

Figure 10. Review of horizontal duct openings penetrating transfer walls

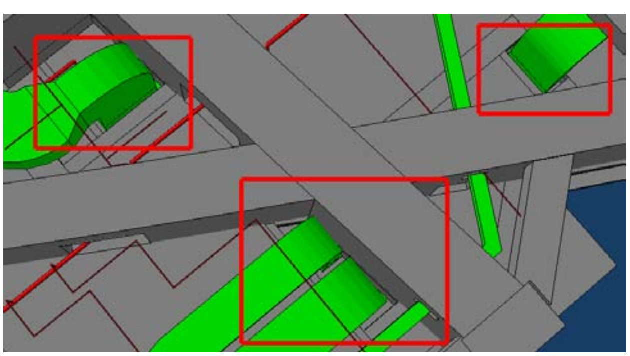
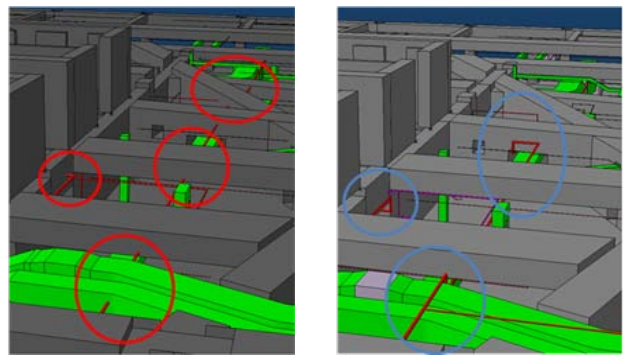
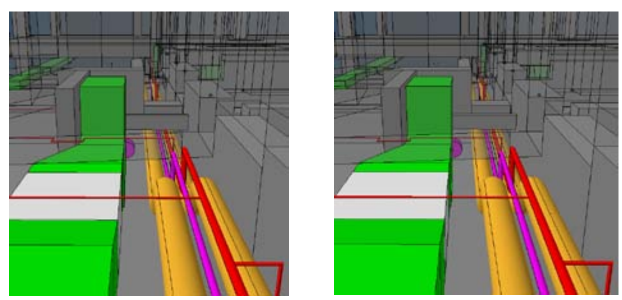


Figure 11. Review of slab openings at Level 30 for vertical duct



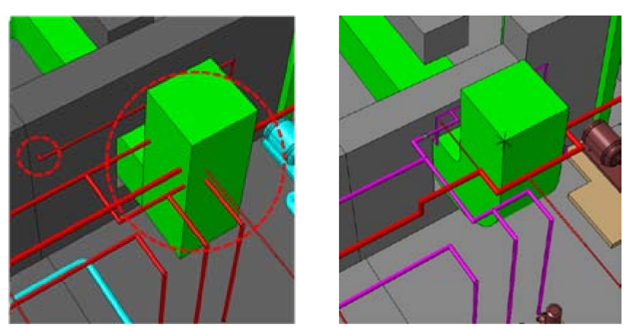
(a) Before (b) After

Figure 12. Route changes for fire-extinguishing pipes to prevent clashes between structure and MEP



(a) Before (b) After

Figure 13. Changes of route and level for duct to prevent clashes between structure and MEP



(a) Before (b) After

Figure 14. Changes of route and level for pipes to prevent clashes between ducts and pipes