DEVELOPMENT OF VISUALIZATION SYSTEM OF CONSTRUCTION PROCESS

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Abstract

This technology displays each 3-dimensional stage of construction based on building model, construction plan model and process model, and is utilizable for the presentation in order-received stage and work directions in construction management stage. Moreover, this method not only can reduce input time sharply as compared with the method using conventional CAD and CG, but also can reduce correction time according to the structure that can compares automatically the attribute of floor, construction section, and part that each model has, even when one of models is changed

Keywords: Building Model, Construction Planning Model, Process Model, Construction Process, and Simulation

1. Introduction

In today's building production, concern of the project persons concerned is increasing by the distrust by the opacity of a process and the fault of construction by excessive competition to the construction planning and management, which was the general contractor's territory. However, it is difficult except a construction planner with abundant construction experience to understand a construction process from 2-dimensional drawing and progress schedule and to judge whether the construction method and procedure are proper. Therefore, by visualizing a construction process, the play that extracts a problem of the project from various aspects a problem and realizes a proper quality, a term of work, and cost is increasing As the method of visualizing a construction process serially, 4-dimensional CAD that added the time factor to 3-dimensional CAD is advocated, and much trial [1],[2],[3] is performed. However, except for some systems that had the scope limited, it is not used widely from the time and effort of the model input power and reduction by 3-dimensional CAD, and the problem of the processing speed of a computer.

This paper describes the method which is made to compare two models automatically and can visualize a construction process easily by giving a "floor", "construction work area", and a "part" to the construction plan model and the process model, the system which developed based on that method, and the application result

2. Visualization method of construction process

2.1 Visualization method by automatic collation of construction planning model and process model

This method gives the same attribute of "floor", "construction work area", and "part" to the construction planning model which added the content of a construction planning to the original 3-dimensional building model which can reduce input-power time sharply by taking in the building common sense of a frame structure as compared with commercial 3-dimensional CAD, and the process model created by developed the process of planning and the management system, and can visualize a construction process by making two models compare automatically.

As shown in Fig. 1, each component in construction planning model has the attribute of "floor", "construction work area", and "part" in addition to "position", "section", "pallet length", "weight", etc. which were inherited from the building model. On the other hand, each job in a process model has the attribute of a "floor", a "construction work area", and a "part" in addition to "activity name", an "start time", an "finish time ", "productivity ", etc.

Therefore, when the component defined as floor"1" –construction work area"1"-"column" exists in construction planning model, and the frame work defined
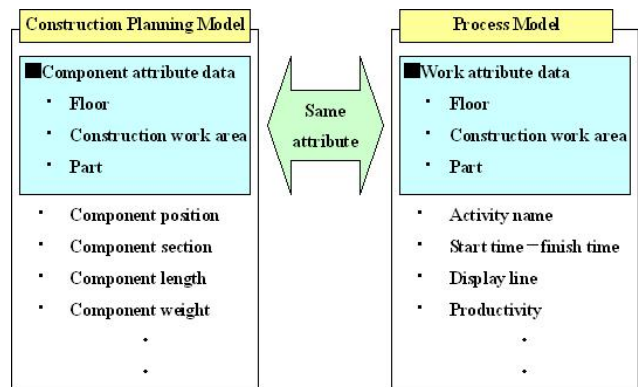

Fig.1 Data of construction-planning model and process model

as floor "1"-construction-work-area "1" - "column" in process model is performed on April 1, it can visualize by displaying on the work performance color, which means that the "frame work" is performed on April 1 in the component defined as floor "1"-construction-work-area "1" - "column" in a construction-planning model.

Thus, the method of visualizing a construction process by setting up the same attribute as a construction-planning model and a process model, and comparing the value automatically, Not only building components but the temporary materials and the equipments, such as "tower crane" and "scaffold", can be expressed by defining how to attach the value of "floor", "construction work area", and "part" attribute. The display method about the component which constitute building and the temporary materials and equipments is described below.

2.2 Display method of building component

Although the building component is usually completed through two or more works, the work is done continuously and intermittently. Then, in order to display a building component appropriately according to progress of construction work, the following display methods were defined.

(1) When all works about the component are before start, make the component un-displaying.

(2) Display the component at the same time the first work about the component is started, and makes it the work performance color.

(3) When the work is completed, change a work performance color into translucence. However, when all works are completed, it changes into the part completion color.

(4) Change into the enforcement color of the next work at the same time the next work is started.

(5) Repeat (3) and (4).

Fig. 2 shows the example which automatic-compares the column steel frame piece of step1 (the 1-4 floor) and step2 (the 4-7 floor) of a construction work area "1", and the activities of progress schedule, and displays them. If "the steel erection of the column of step1" of the first work starts, the steel frame piece of the column of step1 will be displayed as "red" which is the work performance color. Since a Final bolt tightening will start continuously if a steel erection is completed, the steel frame piece of the column of step1 is changed into the "blue" which is a work performance color of the Final bolt tightening

from red. Since there is no work to the following fire-resisting coating when a Final bolt tightening is completed, the steel frame piece of the column of step1 is changed into "the translucent blue" which is the completion color of a Final bolt tightening. Moreover, since the steel erection of the column of step2 is started simultaneously, the steel frame piece of the column of step2 is displayed for the first time as "red" which is the work performance color of steel erection. While the work of step1 is stopping, since the work is completed in order of steel erection and final bolt tightening "blue", it is changed into "translucent blue".

And if fire-resisting coating is started, the column steel frame piece of each step will be changed into the "green" which is the work performance color of fire-resisting coating from translucent blue, and if fire-resisting coating is completed, it will be changed into the "gray" which is the completion color of steel frame piece.

2.3 Attribute setup and display method for temporary materials and equipments

2.3.1 Necessity for attribute setup

The attribute of "floor"," construction work area" and "part" which were set up in order to make the construction planning model and the process model compare automatically, corresponds to the building component defined in the building model. Therefore, it is difficult to apply this attribute as it is to temporary materials and equipments. Then, the value was set as the attribute of "floor", "construction work area", and "component" to temporary materials and equipments so that the automatic collation of a construction-planning model and the process model could be carried out. In it, the attribute value and display method based on the attribute value is shown about
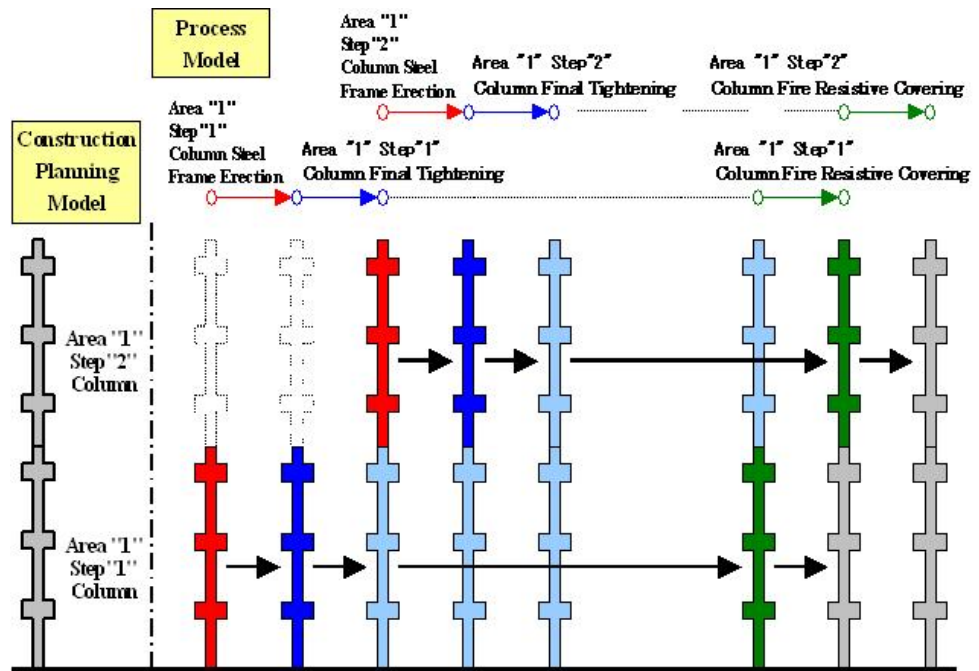

Fig.2 Display method of building component in construction process visualization method

characteristic "tower crane" and "frame scaffold".

2.3.2 Tower crane

The data of the tower crane set up in the construction planning model is setting position, model, name, length of jib, number of times of climbing, height of installation, height of each climbing, etc. Moreover, the data of the tower crane set up in the process model is work name, installation schedule, climbing schedule of each time, demolition schedule, etc. Then, the attribute value for making construction planning model and process model compare automatically was set up. The "floor" attribute was basically made into "the number of climbing". However, the tower-crane installation in the construction planning model and the tower-crane assembly in the construction-planning model, which cannot apply the number of climbing, connected as "the first floor". Moreover, the "floor" attribute of the tower-crane demolition in a process model was made into the "climbing last round."

Based on this attribute value, the example, which automatic-compares the construction-planning model, which climbs 3 times, and the process model about assembly, climbing and demolition, and displays them is shown in Fig. 3. If the tower-crane assembly is started, the installation model will be displayed in "red" of work performance color, and if the assembly is completed, it will change into "ocher" of tower-crane display color. Next, if the 1st tower-crane climbing is started, the 1st climbing model will be displayed in "red", and if the climbing is completed, it will change into "ocher." If the 2nd time and the 3rd tower-crane climbing are started similarly, each climbing model will be displayed in "red", and if each climbing is completed, it will change into "ocher." And if tower-crane demolition is started, the last climbing model (here the 3rd climbing model) will be changed into "blue" of the work performance color of demolition, and if demolition is completed, the model will be deleted.

2.3.3 Frame scaffold

The data about the frame scaffold set up by the

construction-planning model is installation position, scaffold name, installation construction work area, installation level, the number of stages, etc. Moreover, the data about the frame scaffold set up by the process model is work name, construction schedule, demolition schedule, etc. Then, the attribute value for making a construction planning model and a process model compare automatically was set up. The "floor" attribute was made into "each floor" with the height installed, all "construction-work-area" attributes were made into "the construction work area which installs scaffold", and the "part" attribute was made into the "external scaffold" or the "internal scaffold" by the place installed.

Based on this attribute value, the example which automatic-compares the construction-planning model of the frame scaffold for the third floor and the process model of erect frame scaffold and remove frame scaffold, and displays them is shown in Fig. 4. If the erect frame scaffold of the first floor is started, the frame-scaffold model of the first floor will be displayed in "red" of work performance color, and if the work is completed, it will change into the "ocher" which is display color of frame scaffold. If the erect frame scaffold of the second floor and the third floor is started similarly, the frame scaffold model of the second floor or the third floor will be respectively displayed in "red", and if the work is completed, it will change into "ocher." If this construction is completed and the remove
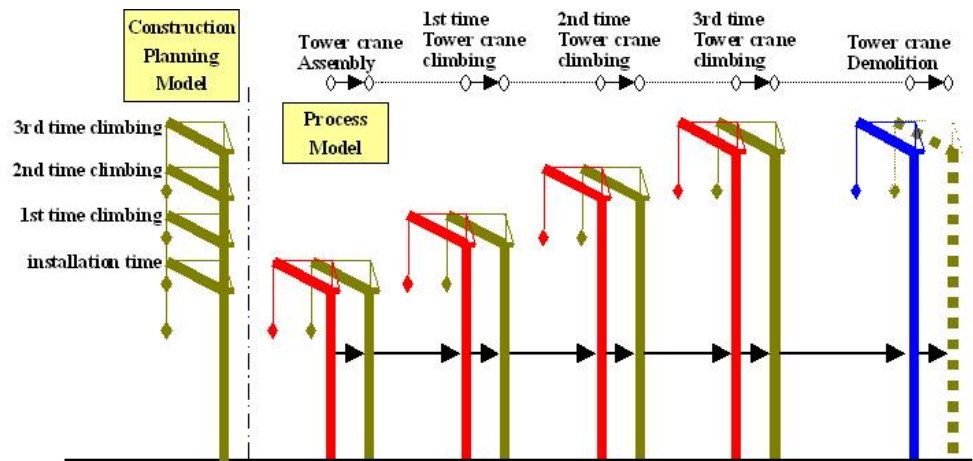

Fig. 3 Display method of tower crane in construction process visualization method

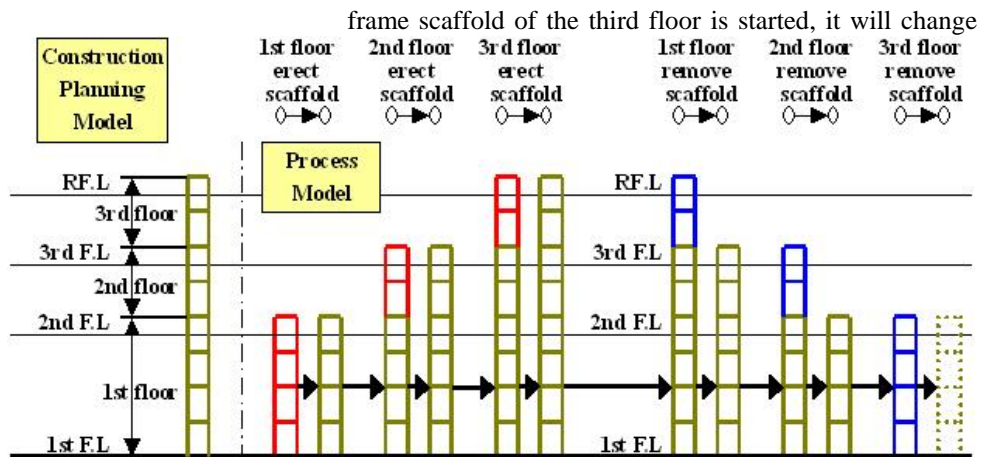frame scaffold of the third floor is started, it will change

Fig. 4 Display method of scaffold in construction process visualization method

into "blue" of the work performance color of demolition of the frame -scaffold model of the third floor, and if the work is completed, the third floor frame-scaffold model will be deleted. If the remove frame scaffold of the second floor and the first floor is started similarly, the frame-scaffold model of the second floor or the first floor will be changed into "blue", and if the work is completed, the second floor or the first floor scaffold model will be deleted.

3. Outline of construction simulator

3.1 System configuration and flow

This system consists of four subsystems, building model creation, construction-planning creation, process of planning and management, and construction simulator, as shown in Fig.5. There is a meaning that clarifies the division of roles that designer use building model creation system, construction planner use construction-planning creation and scheduling systems, all the project persons concerned use a construction simulator. Each system can use upriver data effectively by a data import function. The contents of each subsystem are shown below.

3.2 Building model creation system

The building model creation system has taken the construction common sense of frame structure into the system rather than adhered to detailed settlement of component. Then, inputting building form, such as grid lines, span lengths, and floor height, can automatically create building model. Therefore, even if it inputs all manually, as compared with commercial 3-dimensional CAD, input time and effort is sharply reducible. Furthermore, in order to attain laborsaving, data import from structural design system was enabled. Here, in addition to the plane and section of the model created or imported, the 3-dimensional display is checked, and final model is decided.

3.3 Construction planning creation system

Since the imported building model data is the building component divided by grid lines and floor level, it adds the contents of a construction planning shown below. In a setup of division and integration of a component, while setting up the division line for dividing a component first, the part to

divide is specified. Although a division line is set up according to a floor, it can be collectively copied to other floors. The component integration not only can unify component separately, but about column, it can carry out component integration automatically based on the steel-erection method. Moreover, the all the 34 kinds part attribute containing the column with bracket and floor panel other than a column, beam, floor, wall and balcony which are set up automatically in a building model creation system can be set up.

Construction-work-area division inputs a construction work area as a polygon of a picture drawn without lifting the brush from the paper, and specifies construction work area name, a screen display color, the part belonging to the construction work area. Although construction work area division is set up according to floor, it can be collectively copied to other floors. Moreover, in consideration of construction work area changing with classification of work, five kinds of construction work areas, such as building frame, finish, and equipment, can be set as the same component. In the stage which construction work area division setup completed, all the attributes of a "floor", "construction work area", and "part" are added to building component.

The temporary materials and the equipments which can be registered have 16 kinds including "crane" and scaffold." As the example, while a "scaffold" setup specifies the starting point and finish point which install a scaffold, scaffold name, installation construction work area name, installation level, and number of stages are set up. And based on the number of stages of the set-up scaffold, the attribute of the "floor" corresponding to order is automatically added by the system side from the bottom so that each floor level +900mm (height considered to be safe when managing) can be secured.
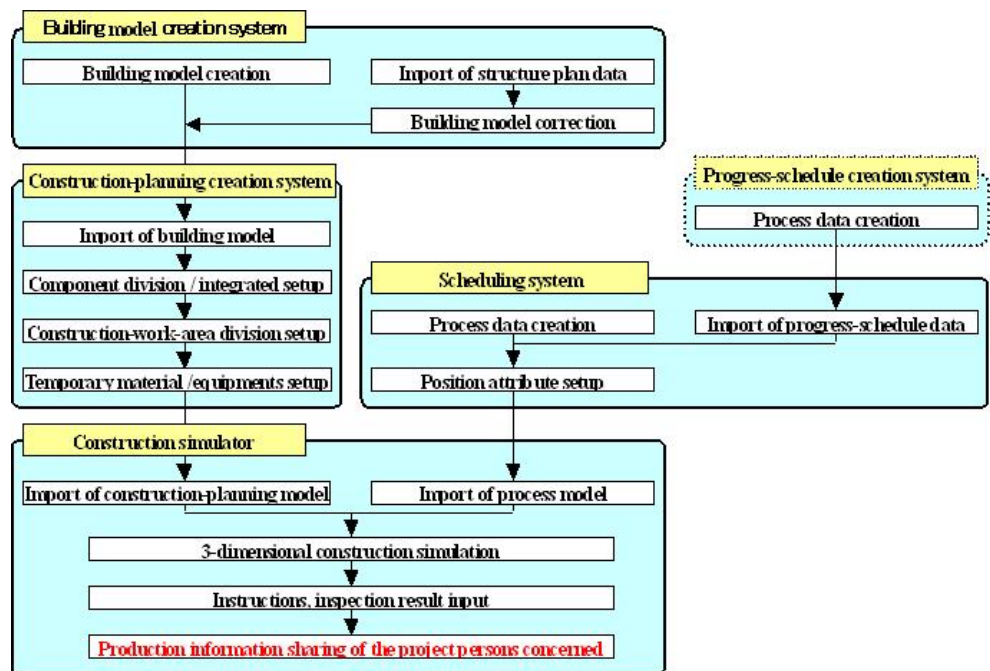
Fig. 5 Composition and flow of construction process visualization system

In addition, also when building model is changed and imports building model again, the existing construction work area division, and temporary materials and equipments data can be reflected.

3.4 Scheduling system

Creation of a process model utilizes developed scheduling system. In this system not only the work name displayed on each process line, it has the attribute of floor, construction work area, part and activity, furthermore, resource data of labor, materials and equipments, cost, etc. Therefore, It not only can create the proper process in consideration of resource allocation by performing a resource allocation simulation, but the automatic collation with a construction-planning model is attained. Moreover, it is utilizable by importing the process data created by the progress-schedule creation system, and adding the attribute of "floor", "construction work area", and "part."

3.5 Construction simulator

This 3-dimensional construction simulation cannot only carry out continuation play of each construction situation from groundbreaking of a project to completion. It can display as a slide show by saving two or more specific scenes. Moreover, the building component, and the temporary materials and the equipments which are displayed on a screen are divided into the part completion color, temporary materials and equipments display color, and the work performance color, and can distinguish work situation and construction progress situation clearly.

This construction simulation has the two display methods, the appearance display for grasping a construction procedure and situation overall from the building outside as shown in Fig. 6, and walk-through display for checking the settlement building inside and construction situation as shown in Fig. 7.

In the appearance display, the method of moving a construction-planning model can be adopted, and scene can be changed with the command button of "front-back", "left-right", "top-bottom" and "rotation."

Moreover, in a walk-through display, it can move freely in virtual space without changing a button by adopting the method of moving a false experience person's viewpoint, and collecting various command functions, such as movement and change of direction, on one screen, Furthermore, blue "*" mark put on the column on the left-hand side of Fig. 7 means that the information on a memo or a photograph is added about the component. The memo information leaves exchange of the project persons concerned, report of construction track record, etc. as history. The photograph information can check inspection result and construction situation by graphics file. By adding this function, it is utilizable not only for the simulation before construction but construction management and check of traceability after construction. This appearance display and walk-through display can be changed easily, it
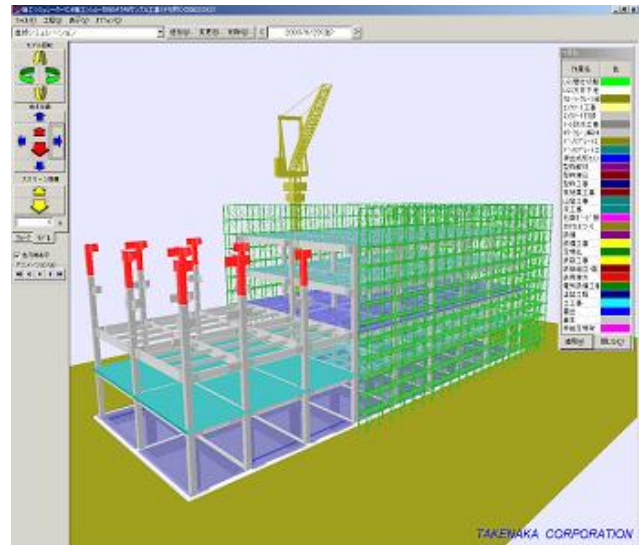

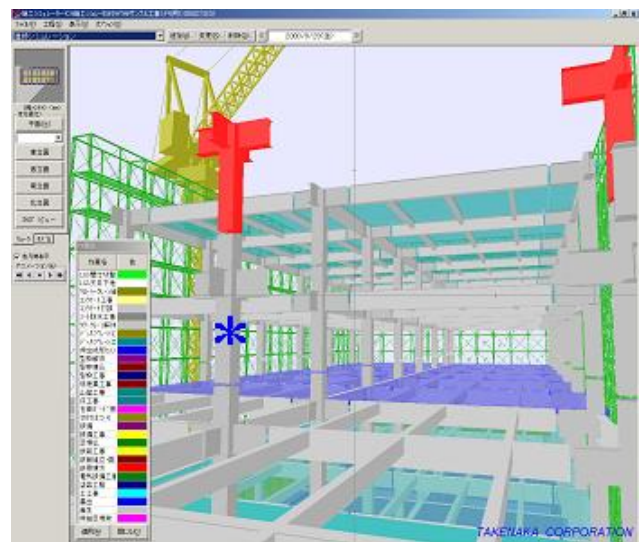Fig. 6 Appearance display by construction simulator

Fig. 7 Walk-through display in construction simulation

not only can perform proper use according to the user's use, but it can find out the problem of construction easily.

4. Application in project and future deployment.

4.1 Application in project

Although this system was applied to 60 or more projects by the present, that example of application is shown in Fig. 8 and Fig. 9. The use purpose in ordering stage is for client and designer to understand the construction method which general contractor proposes, and the height of the technical capabilities and management accuracy. As result of utilizing this system for the presentation to client and designer, we were estimated "Since it is easy to understand the image of not only the construction method but the completed building, it can discover various problems at an early stage. The use purposes in construction management stage are that project persons concerned understand the
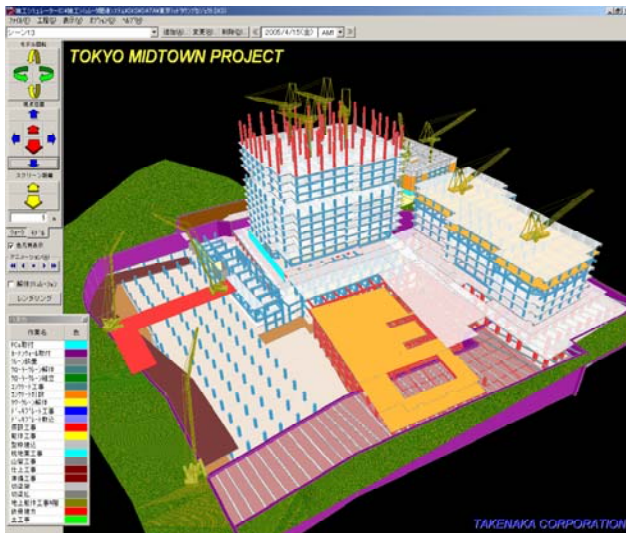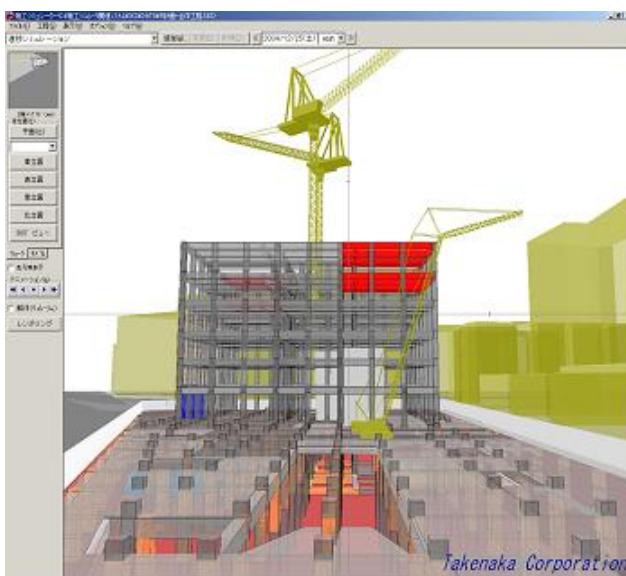
Fig. 8   Example 1 of project application

Fig. 9   Example 2 of project application

construction method and to transmit the contents to persons concerned, when change arises at design or process. The concrete practical use are the explanation to neighborhood, the workmanship instruction in a construction meeting, a progress condition report of the construction which is hard to check visually, etc. As result of applying system, the opinion "the degree of comprehension about construction procedure and safety not only increases, but also it contributes to cost reduction by reduction in redo etc." was acquired from the project persons concerned.

4.2 Future deployment

Although utilizing this method has reduced input time and effort, the problem for visualizing a construction process is who inputs time-consuming data. The general contractor has taken over the input alone now. However, in order to make the building production better, the project persons concerned recognize each role and sharing of information and construction of the structure which can do free exchange of opinions are important

5. Conclusions

This paper described the method which is made to compare two models automatically and can visualize a construction process easily by giving a "floor", "construction work area", and a "part" to the construction plan model and the process model, the system which developed based on that method, and the application result. This system was applied to 60 or more projects by the present, and was able to be utilized for the presentation to client and designer in an ordering stage, the workmanship instruction in a construction-management stage. And compared with the method using conventional CG, it was checked by utilizing this system that input time is sharply reducible and that correction time can be minimized when change occurs. While extending the handling range of temporary materials and equipments and corresponding to the overall construction planning from now on, a function utilizable as information-sharing tool of the project persons concerned in construction-management stage is added.

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