Enhancement and Future Deployment of Hitachi Integrated Construction Coordination System Intended Specifically for On-site Field Work

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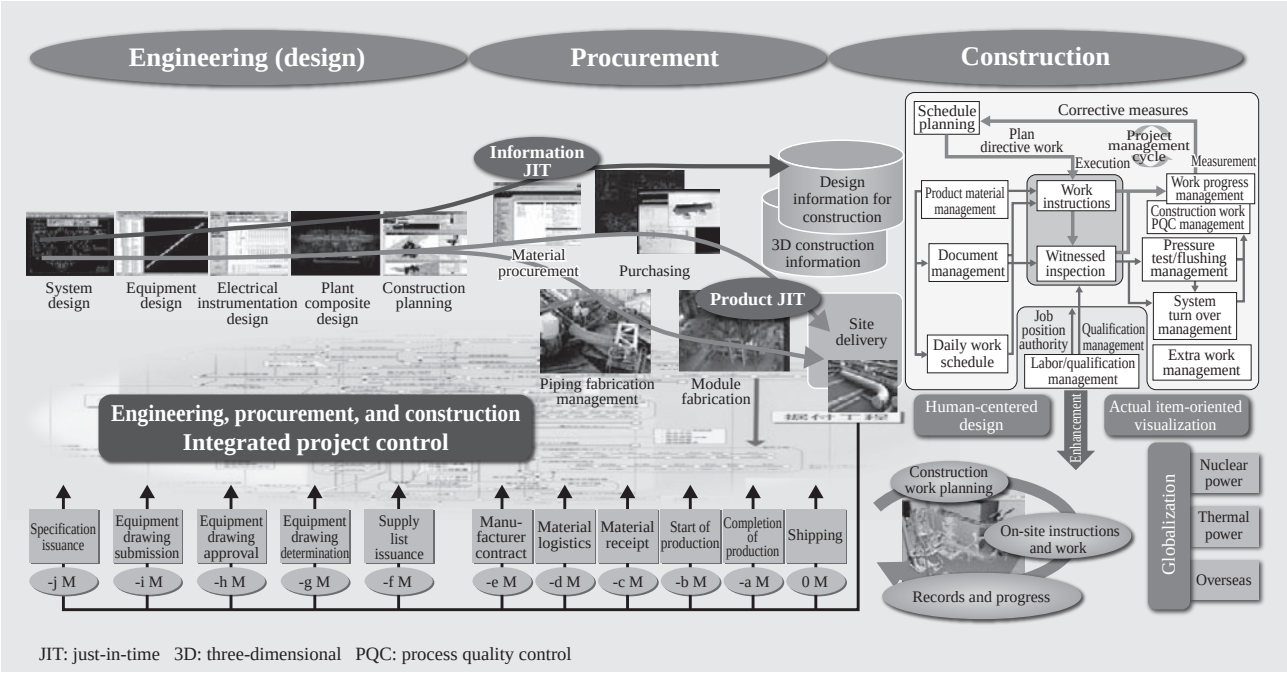
OVERVIEW: Ever since the 1990s, Hitachi has been pursuing the application of IT and systemization to power plant construction, with a focus on securing project integration, coordinated control, improvements in work efficiency, and quality assurance. Although efficiency has been improved through the application of this technology to actual plants and the expansion of functions, this process of improvement and streamlining has reached the limit of what can be done with a management-side approach centered on systems. Therefore, Hitachi has returned to the starting point of manufacturing, and is working to enhance systems that introduce human-centered design approach and 4D visualization techniques.

INTRODUCTION

IT is the mission and mandatory task of a plant builder to offer higher quality, reliability, and lower costs in the construction of a plant that will provide stable electric power. To this end, Hitachi has improved construction methods and technologies as well as management techniques, and has worked to apply information technology (IT) and systemization to the construction field since the 1990s. Construction is positioned as the farthest point downstream in a project, and the on-site construction workers play a leading role in the work.

This article discusses Hitachi's efforts up to the present focusing on the creation of user-oriented systems designed for on-site use in order to improve both productivity and quality of work at construction sites, as well as the expansion, enhancement, and deployment policies Hitachi currently follows.



JIT: just-in-time 3D: three-dimensional PQC: process quality control

Fig. 1—Overall Configuration of Hitachi Integrated Construction Coordination System.
An overview of the Hitachi integrated construction coordination system, which achieves integrated project control and centralized management of design, procurement, and construction information.

HITACHI'S APPROACH TO INCORPORATING IT INTO CONSTRUCTION

Hitachi Integrated Construction Coordination System

Hitachi has been pursuing the incorporation of IT into construction based on the following three points since the 1990s, with the aim of promoting construction oriented smooth project management:
(1) Meticulous planning before the start of construction work
(2) Just-in-time provision of materials and information in synchronization with the site construction work
(3) On-site Plan, Do, Check and Action (PDCA) management

The Hitachi integrated construction coordination system achieves integrated project control from design through procurement and construction (see Fig. 1).

On-site Construction Systems

The on-site construction system component of this Hitachi integrated construction coordination system is comprised of the following 12 subsystems for use at construction sites. Through these, the project management cycles of issuing plan directives, executing, measuring, and taking corrective measures is implemented.
(1) Schedule planning subsystem
(2) Work instruction subsystem
(3) Inspection support subsystem
(4) Work progress management subsystem
(5) Labor and qualification management subsystem
(6) Product material management subsystem
(7) Document management subsystem
(8) Daily work schedule subsystem
(9) Construction work process quality control (PQC) management subsystem
(10) Pressure test and flushing management subsystem
(11) System turn over management subsystem
(12) Extra work management subsystem

These subsystems encompass the details of on-site tasks from beginning to end in order to implement management that is based on actual on-site conditions.

For instance, when piping work is performed on-site, the supervisor of primary subcontractors provides work instructions regarding each joint point based on the detailed construction schedule, and the supervisor or foreman of secondary subcontractors confirms the details of the directives before outputting the work instruction form/record on a paper log sheet, and finally carrying this to the site where work is performed. In this workflow, information including the work record and pass-fail result is written on the work instruction form/record after the work is performed, and the superior (on the construction work side and the quality control side) is asked to review and approve the work. Also, work records can be registered using a portable terminal, or personal digital assistant (PDA), and devices have been created to allow handwritten work records to be registered in the system without transcription errors. Furthermore, an alarm is generated if values are registered in the work record that differ from the values indicated in the design instructions, and an interlock function prevents moving on to the next step until the values are corrected. Subsystems (2) and (3) systemize this series of tasks.

The management items and format used for these work instructions are defined for the sake of quality assurance and with convenience in mind, based on the combination of work classifications. These include quality management classification, product classification, and work classification (for piping this would include fitting up, welding, non-destructive inspection, pressure testing, and so on). In the example of piping, 45 types of logs amounting to a total of 115,000 sheets are created and managed for each plant, covering more than 50,000 joint points and including several dozen management items per sheet. High-quality construction is achieved in this way through the cumulative effort of exhaustive management activities that extend to the minutia of each separate work task.

IMPROVEMENTS AND ENHANCEMENTS DESIGNED FOR USE ON CONSTRUCTION SITE

The Hitachi integrated construction coordination system has shown its effectiveness through continuous operations at five plants over the course of approximately 20 years, starting in the 1990s. Although at present, the Hitachi integrated construction coordination system is indispensable at construction sites, it took a long time (around a decade) for it to completely take hold as a system designed specifically for on-site use.

In the current state, however, simply strengthening the system in terms of management and control will not be enough to improve reliability and quality and reduce costs further.

No matter how systems and hardware technology develop, plant construction work will still be centered on on-site manufacturing by humans. In order to allow the system to evolve and develop even further, it was decided to review and improve the nature of the system from the beginning with a focus on the human element.

Although the system was built based on the opinions of users before, under actual conditions, it was not always used as intended, and users were not always satisfied. System improvement efforts were conducted using a "human-centered design approach" so that more people would be able to use the systems and services, people would find the systems and services convenient, and people would be glad they used the systems and services.

Furthermore, actual item-oriented visualization techniques were considered and systemized in keeping with the construction site, in order to apply new added values and benefits through the computerization of information, and to make the representation of instruction details and intentions as well as the communication of information fundamentally more intuitive and efficient during on-site work.

The details of these efforts are described below.

Construction Site Improvement Using Human-centered Design Process

A "human-centered design approach" was introduced to achieve manufacturing that is both easy-to-use and easy-to-understand for users, based on a process of unlocking the latent ideas of on-site workers with a focus on the actual conditions of on-site manufacturing. Human-centered design was stipulated in 1999 with ISO 13047/JIS Z8530 (currently revised as ISO 9241-210), and was characterized by the participation of users in the development process, as well as by the fact that it is an interdisciplinary project conducted by professionals with a variety of different techniques and skills in the area of investigating people, including psychology and anthropology.

With conventional development from the end user's perspective, hearings and questionnaire-based studies were generally used to directly ask users what problems they have, or what types of features they want. However, these were superficial events, rather than latent, and were affected by a problem whereby the degree of accuracy of the features requested by users was low. This is why the decision was made to promote human-centered design that can efficiently extract the end user's latent needs and essential on-site issues, by following the steps described below.

(1) Clarification of essential issues hidden on-site and user's approach to job

Rather than conducting hearings to directly ask users questions, ethnographic research (living with, observing, and interviewing subjects for a long period in order to clarify the lifestyles of a group or culture, using a social science methodology based on cultural anthropology and sociology) with a focus on on-site observation and interview-based studies seeking to deeply investigate the background of each site were repeated in order to clarify the essential issues latent in the site, as well as the end user's approach to his or her job.

(2) Clarification of overt and latent user needs

Various innovations and efforts are applied to resolving the essential issues revealed by the ethnographic and interview-based studies, and overt and latent user needs are clarified.

(3) Development of systems based on user needs, improvement policies, and idea deployment

The functions and user interfaces that must be built in order to satisfy overt and latent needs are considered. In the case of certain ideas, prototypes or scenarios are created so that concerned parties can easily share a common purpose.

(4) User evaluation of systems

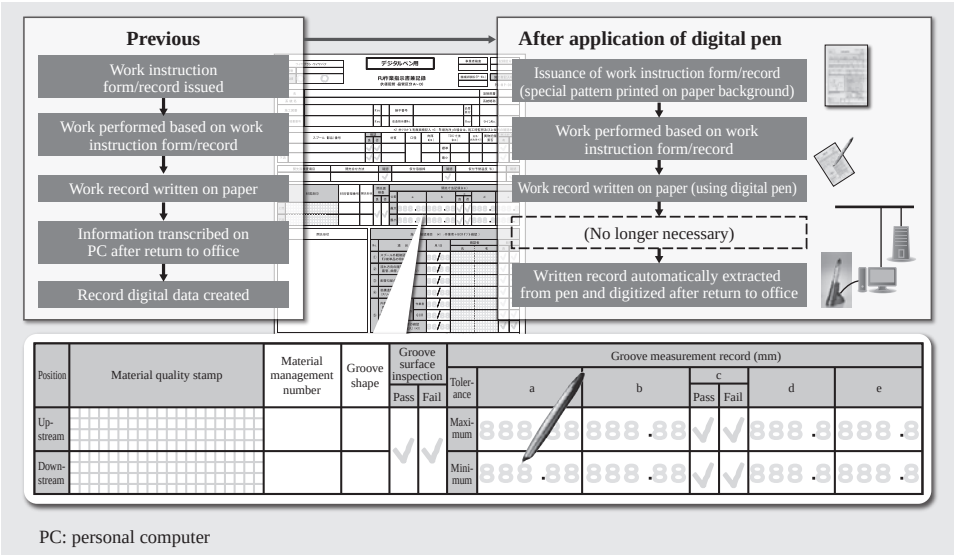
Actual users are asked to operate the prototypes and implement the scenarios that were created during idea development, and an evaluation study is conducted to determine if any of the ideas from the development side are mistaken, or if they are mistaken, how they should be different. If improvement is required, steps (1) through (3) are redone.

Enhancement of On-site Construction Systems

In order to extract essential on-site issues, the previously described human-centered design approach was used during two or three days of on-site observations with interviews conducted three times each. Examples of system enhancement efforts based on the results of this process are introduced below.

Application of digital pen to work instructions

In order to improve on-site work instructions and record creation, the previous paper-based log method was systemized in such a way that instruction details could be confirmed and records could be registered using portable terminals that are carried on-site. Based on the results of the observations conducted during the aforementioned human-centered design approach, however, in some cases workers decided not to use the portable terminals because of problems related to portability and operating speed, instead writing on paper by hand and transcribing to a personal computer (PC) at the office later. This revealed the need for an easy-to-use system that would be less of a burden for workers, and so a digital pen with a miniature camera that can digitize what the worker writes was introduced.



PC: personal computer

Fig. 2—Example of Work Instruction Flow and Digital Pen with Special Paper. A workflow comparison between previous work instructions and the adoption of the digital pen is shown, along with an example of the special paper.

The differences in workflow between the previous method of using a pen and a log and the new method based on the digital pen are shown in Fig. 2. When a digital pen is used, the records are written to paper during on-site work just as before, but there is no need to transcribe the records at the office because the digital registration eliminates the need for this step while increasing efficiency and reducing transcription errors at the same time. Also, in order to improve both usability and recognition accuracy, a human-centered design approach was utilized to revise the layout of the log based on a consideration of the size and position of characters in the input fields, input order, and overall ease of viewing. At present, on-site work is being streamlined through the use of either this digital pen or a fast, lightweight mobile PC system, based on the user and the situation.

Application of 4D visualization system

In order to satisfy the need for "providing the information necessary for work in a simple, easy-to-understand manner" as determined during on-site observation, a system was adopted that incorporates 4D visualization (a time axis added to three-dimensional information).

During construction work, sometimes text, symbols, and numerical values are not enough to represent the work plan, work process, and intention of the planner as written on the schedule chart. In order to resolve this problem, a 4D format was adopted by adding a time axis to the space information of three-dimensional computer-aided design (3D-CAD), thereby resulting in a system for conveying the information involved in a variety of different scenarios including the construction planning process, work instructions, and progress management to on-site workers, supervisors, and planners, in a manner that is intuitive, simple, easy-to-understand, and without the risk of misunderstandings.

This 4D visualization system has functions that make it possible to represent the work procedures, actions, and states of a construction site from any viewpoint or using any cross-section or viewing method, and to simulate using static images or dynamic simulation that matches actual objects (see Fig. 3). The introduction of tablet terminals is being promoted as a means of improving the accuracy and efficiency of on-site work using this function. An integrated construction system is realized by applying 4D simulation to various on-site scenarios, including construction work, the planning process, work open-top carrying-in/temporary placement plans, and operating instructions (see Fig. 4).

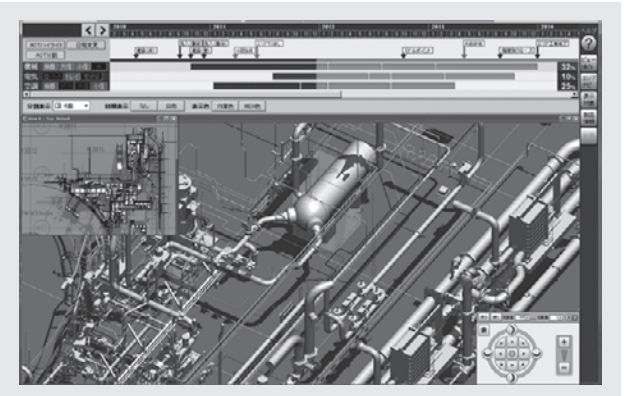


Fig. 3—Example of "4D" Visualization System. 4D visualization is applied to simulate work procedures and states from any viewpoint and using any viewing method.

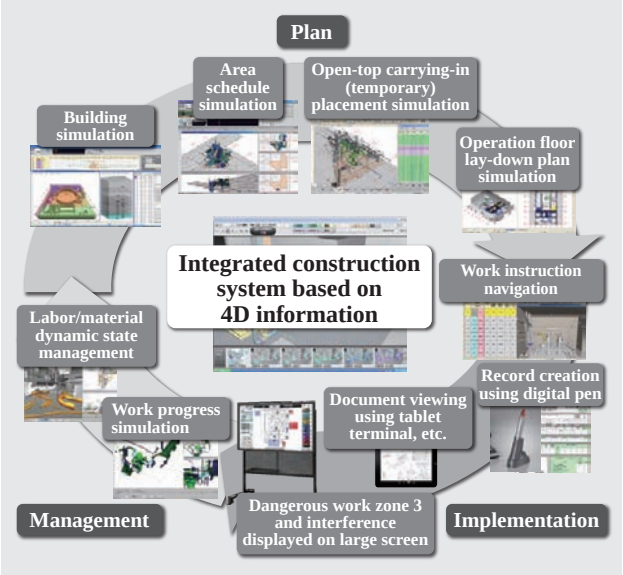


Fig. 4—Overall Configuration of 4D Hitachi Integrated Construction Coordination System.
This integrated construction system is based on information in 4D format that can convey information in ways that are simple, intuitive, easy to understand, and unlikely to lead to misunderstandings.

CONCLUSIONS

This article covers the previous efforts of Hitachi focusing on the creation of a user-oriented system designed for on-site use with an emphasis on improving the productivity and quality of manufacturing at a construction site, as well as the expansion, enhancement, and deployment policies Hitachi is currently following.

These efforts involve the creation of a shared and global system that offers total optimization through deployment over plant fields, both domestically and internationally. At present, the system is being applied to three nuclear and thermal power plants in Japan, and one plant overseas.

The first overseas application at the thermal construction site was begun in 2012. As international deployment requires the resolution of issues particular to that country and region, emphasis was placed on the following points:
(1) Support for multiple languages (switching between English and Japanese)
(2) Incorporation of operational standards particular to the region (such as product management)
(3) Strengthened IT infrastructure security (system servers)

Since both Japanese and international employees work under the same system when it comes to construction overseas, there is no way to avoid problems stemming from different cultures and ways of thinking, or from language barriers. In spite of this, plant construction projects still must manage huge amounts of material in this type of environment, in a safe, high-quality, and highly efficient manner. Human-centered design approach and 4D visualization systems are being introduced and enhanced because of the extreme importance of issues such as how to give work instructions to foreign workers, how to proceed with work in a smooth fashion, how to convey information in a manner that is simple, intuitive, and unlikely to lead to misunderstandings, and how to make other people understand.

Hitachi will continue promoting construction IT dedicated for on-site work, while working non-stop to run and improve systems.

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