Hitachi’s Experience and Achievements in ABWR Construction

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Hitachi, Ltd. (Hitachi) is taking charge of the turbine island of Chubu Electric Power Company’s Hamaoka nuclear power plant Unit No. 5 (Hamaoka 5), and all facilities of Hokuriku Electric Power Company’s Shika Nuclear Power Station Unit No. 2 (Shika 2). Hitachi has achieved shorter schedules and lower costs in the two projects with the following construction methods.

First, Hitachi applied modularization and the area-by-area method. These methods enable us to undertake building and installation work in parallel. Second, the floor packaging construction method enables us to finish installation in every area earlier than conventional methods. Moreover, manpower can be distributed evenly. This paper reports the application of these advanced construction methods to the Hamaoka 5 and Shika 2 projects. Installations such as RCCV modules and condenser blocks are presented in this paper.

In addition, Hitachi is using 3D-CAD engineering and our own construction management system to optimize the planning of construction procedures and the installation of equipment in these projects. Thus Hitachi is always striving to improve the reliability, safety and economy of ABWR construction technologies.

KEYWORDS: ABWR, parallel construction, modularization, open-top method, area-by-area construction method, floor packaging construction method, 3D-CAD, IT

1. Task of Plant Construction

I. Introduction

The following obstacles need to be overcome to shorten the construction period and reduce costs:

- It is difficult to shorten the critical paths.
- Simply reducing the construction period is not sufficient; on-site work should also be reduced at construction peak so that even distribution of labor also reduces cost.

Hitachi has been improving our construction methods and cooperating with major civil construction companies.

II. Construction Methods

II. Modularization

Modularization is one of our plant construction techniques. Modular components such as equipment, piping, valves and...
operation stages, are assembled in a shop or on-site assembly area, and then carried in by a large crane. Modularization has the following advantages:
- Shortening the construction period by removing work from critical paths
- Reducing on-site work and distributing manpower evenly
- Improving safety and product quality
- Reducing construction costs

However, modularization also has these disadvantages:
- Transportation costs are increased.
- Temporary support costs are increased. Temporary structural support is required for module transportation.
- Delivery dates for module components are earlier than with the conventional method. Therefore earlier engineering and planning are necessary.

To expedite modularization, assembly is carried out at a newly established Module Factory. By concentrating on module assembly at this factory, various benefits are gained, such as lower transport cost for the module components and also modules themselves, and reduced manufacturing costs due to mass-production.

The factory is located in Hitachi port, facing the Pacific Shore, and the building is 135m long, 32m wide and 21m high. The factory has two ceiling cranes (with a capacity of 50 tons), six wall cranes (with a capacity of 2 tons), as well as a radiographic testing facility. These provide a far superior fabrication environment than does a construction site. Furthermore, large modules can be transported directly to the quayside by electric transporter for shipment.

4. Open-Top Method

In the open-top method, mechanical equipment, pipes, valves, operating stages or modules and blocks are carried in before construction companies complete the wall work. This pre-carrying in of objects has been extensively employed in the construction of Hamaoka 5 and Shika 2. Equipment, operating stages and modules are aligned during intervals between ceiling concrete pouring and the start of full-scale installation. Then hooks, hangers and monorails are fixed on the ceiling. Finally, pipes are hung along the piping route. Figure 2 shows pre-installation sequences.

Pre-carrying in before the start of installation is essential for shortening the construction period. In addition, Hitachi coordinates the installation start date with civil construction companies. Equipment and drawings for construction must be delivered to the site to maintain the installation schedule. Therefore Hitachi puts a great deal of effort into planning the delivery schedule and using it as an input for the equipment manufacturing schedule. The area-by-area construction method allows us to determine reliable delivery schedules.

5. Area-by-Area Construction Method

Hitachi has adopted the area-by-area construction method, in which the work schedule of every construction area is planned and implemented. Construction areas are determined by dividing a building into small regions of every floor, taking into account the planned rooms and
equipment arrangement. In the Shika 2 project, where Hitachi is in charge of all facilities, there are about 300 such areas.

Master construction schedules are broken down into schedules specific to each construction area for actual implementation. The purposes of an area construction schedule are:
- Optimizing the installation sequence
- Estimating on-site manpower requirements
- Planning delivery dates of products

An area construction schedule is the basis for actual construction, and is prepared at the Hitachi office. The area schedule is also broken down to 3-month and 3-week schedules at the site to expedite daily progress management. Thus construction planners can come to a detailed understanding of the interface with civil construction companies, and we can then formulate the best possible plan for installation procedures, integrating them with the civil construction schedule. Moreover, workload estimation for every area results in an accurate manpower planning chart.

In addition, an area schedule also coordinates delivery schedules for equipment manufacturing and drawings submission. We are able to monitor project progress with the following indices:
- Product delivery date
- Drawing submission
- Work progress

5. Floor Packaging Construction Method

The area-by-area construction method manages manpower and equipment delivery dates effectively by planning for installations in every small area. The floor packaging construction method includes and expands the idea of the area-by-area construction method, and Hitachi adopted this construction method for the Hamaoka 5 and Shika 2 projects.

Hitachi inspects pipe welding with a hydro pressure test in each floor in the floor packaging construction method when a hydro pressure test is beyond the scope of the area-by-area construction method alone, to reduce on-site work at construction peak and to distribute on-site work evenly throughout the construction schedule. The concept of the floor packaging construction method is illustrated in Figure 3.

As shown in this figure, the conventional construction method leaves hydro pressure testing until piping work is completed in all floors, even if installation is complete in the basement floor area. In addition, Hitachi has to install insulation and sleeve filling in an entire building concurrently after hydro pressure testing. Therefore temporary facilities such as scaffolding must be left in every area for a long time. Difficulties which have not been resolved by the area-by-area construction method are:
(a) On-site workload peaks in the hydro pressure test period. However it is difficult to train workers adequately in a short time. New workers lack site-specific experience and skill.
(b) It takes a long time to prepare for the hydro test and installation and to move between areas because Hitachi must inspect and install in every area simultaneously. Moreover, work efficiency is impaired by an influx of new workers at construction peak.
(c) For these reasons, temporary material costs are high, e.g., scaffolding. Furthermore, the capacity of on-site facilities and accommodations is determined by the on-site workforce peak. Consequently, indirect costs are high.

The installation sequence determined by the floor packaging construction method is illustrated in Figure 4. Installation procedure is as follows:
(a) Pre-installation period
Equipment and pipes are carried in while construction companies build slab and walls. Hitachi has also carried in equipment before pouring ceiling concrete in the conventional method. The floor packaging construction

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**Fig.3 Concept of Floor Packaging Construction**

**Fig.4 Floor Packaging Construction Method**
method enables us to shorten the period of installation on a floor by increasing the pre-carrying in of objects and by advancing the schedule of mechanical work. Permanent installation starts after concrete curing and wall painting by construction companies. The following items explain the mechanical work in pre-installation period:
- Carrying in and alignment of equipment, modules
- Carrying in piping and valves, hanging up along piping route for welding.
- Carrying in bases of electric panels and instrument racks.
- Carrying in and installing operating stages and monorails.

(b) Installation period of the floor packaging construction method.

The floor packaging construction method focuses on the period when only Hitachi performs mechanical/electrical installation when building work is almost finished. Hitachi inspects every system of piping with a hydro pressure test after all pipes on a floor are welded and supported. Piping on a floor is partially inspected. Hitachi installs insulation and sleeve filling. Mechanical work performed in the installation period is:
- Installation of equipment and modules
- Installation of pipes and support
- Installation of electric panels
- Installation of cable conduits, trays
- Installation of heat ventilating and air conditioning ducts
- Instrumentation

After installation work is complete, civil construction companies finish their work. The floor packaging construction method is completed when scaffolding is disassembled.

(c) After installation completion

When installation in an area is completed, the working group moves to the next work area or floor, taking along their construction equipment and material, enabling Hitachi to use resources effectively. Only cabling work remains at this time. After installation on all floors has been completed by the floor packaging construction method, pipe cleaning and system sequence testing are carried out before fuel loading.

Advantages of the floor packaging construction method are:
(a) Installation is completed on each floor. The on-site work peak is reduced and the manpower histogram is spread out evenly.
(b) Spreading out on-site work results in better work efficiency. Working groups and workers are concentrated in small areas where their abilities can be applied more effectively.

(c) Efficient use of temporary facilities and lower manpower requirements reduce indirect costs.

III. Construction Method Examples

1. Optimization of Modularization Strategy

Hitachi is in charge of BOP of Hamaoka 5, and all facilities (reactor, turbine, heat exchanger and radioactive waste building), of Shika 2.

In Hamaoka 5, because Hitachi’s scope is limited to turbine building, Hitachi used a relatively small tower crane, with a capacity of 6500 ton-m. Therefore, small but numerous modules were used. These modules, blocks, equipment and piping were carried in before the start of mechanical installation. Building work and installation were conducted in parallel.

In Shika 2, Hitachi used a large crawler crane with a capacity of 900 tons. Hitachi shares its use with the rest of the construction operations in the entire plant. We used several large-sized modules to get the maximum benefit from the large crawler crane. For example, Hitachi used a ‘composite module’ that assembled mechanical equipment such as the RCCV lower liner and building members such as rebar. Also, the condenser upper shell and neck heaters were prefabricated at the module factory and installed as units.

In these projects, we achieved cooperation between installation companies and civil construction companies. On-site work was distributed. Thus we improved quality and shortened the construction period.

The following paragraph explains the procedure in Hamaoka 5 and Shika 2.

2. RCCV Modules Installation

In an ABWR, RCCV construction is a critical path process. The process is as follows:
(a) Base mat work (building work)
(b) RCCV lower liner installation (mechanical work)
(c) RCCV building (building work)

Hitachi and civil construction companies used composite modules

(1) Base Mat Module

In R/B base construction, anchor bolts such as RPV pedestal and base reinforcements were modularized at the on-site RCCV assembly area. Then the base mat module was carried in by the large crawler crane. In Shika 2, the modularized rebar area is larger than that in Kashiwazaki 7. The diameter was increased from about 39m to 41.6m, the weight changed from about 460 tons to 675 tons. Advantages are as follows:
- Assembly in a safer work area
- 1-month shorter construction period

(2) RCCV Lower Liner Module
**Figure 5** shows the RCCV lower liner module installation. RCCV lower liner parts (1st to 5th layers) were prefabricated at the RCCV assembly area located at the site. In the Shika 2 RCCV, 1 layer of rebar was assembled in the lower liner block. This increased the weight of the RCCV lower liner module from about 430 tons (Kashiwazaki 7) to 630 tons.

(3) RCCV Upper Drywell Module
**Figure 6** shows the installation of the RCCV upper drywell module (650 tons). This module includes gamma shield, pipe whip restraint structures, pipes/valves, ducts, cable trays, etc.

(2) Condenser Upper Body Block
In Shika 2, Hitachi installed the condenser upper body blocks. These blocks consist of condenser upper shells, 2 neck heaters, and upper inside flame structure. The weight of an upper body block is about 326 tons. **Figure 8** shows the installation of the condenser.

**3. Condenser Installation**
In condenser installation, construction initiative switches between civil construction companies and Hitachi in the following sequence:
(a) TG pedestal construction (building work)
(b) Condenser base setting (building work)
(c) Lower blocks installation (mechanical work)
(d) Neck heaters and internal truss (mechanical work)
(e) Upper shells or blocks installation (mechanical work)
(f) TG pedestal beam construction (building work)

(1) Condenser Lower Body Block
Lower upper bodies were blocked in the on-site assembly area or shop. Lower body blocks were installed by crane. Dimensions of the lower body blocks and assemblies are determined by the capacity of the crane.
In Hamaoka 5, lower bodies are divided into 4 blocks. These blocks, assembled at the module factory, were transported to the construction site by ship. Then the lower body blocks were installed by the tower crane.
In Shika 2, the lower blocks were enlarged and divided into 2 blocks because Hitachi used a high-capacity large crawler crane. These blocks were assembled at the module factory. Condenser tubes were also assembled at the shop. **Figure 7** shows the lower body block used in Shika 2.
The advantages of condenser blocks are:
- We can start critical path piping work around the condenser earlier.
- The area needed for temporary storage of the condenser in the yard can be reduced.

TG pedestal modules are essential for condenser blocks to be carried in before TG pedestal beam completion. In the conventional method, temporary support is necessary for TG pedestal beam construction. However, temporary support obstructs carrying in of condenser blocks. While TG pedestal modules needs no temporary support so that we can install condensers using modularization.

4. Module Installation

As mentioned, Hitachi has been carrying in equipment, pipes/valves, operation stages, etc. in almost all areas before permanent installation starts. Modularization is effective in areas that have high equipment densities. Hitachi has deployed about 80 modules in the turbine building of Hamaoka 5 and about 200 in all buildings of Shika 2. Hitachi is able to design and assemble compact modules with minimal temporary support based on our 20 years of experience and Hitachi’s 3D CAD system. An actual module is illustrated in Figure 9.

III. IT Application to Construction Work

1. 3D-CAD Engineering

(1) 3D-CAD Data Utilization
Hitachi has applied its 3D-CAD system to the design and engineering of nuclear power plants at all stages from basic design to equipment layout and module design. Advantages of 3D-CAD engineering are:
- 3D visualization enables us to grasp essential relationships more easily.
- Advances in construction engineering result from the ease with which we can examine many hypothetical scenarios with 3D-CAD.
- 3D visualization enables us to plan more accurately.
- A visualized construction sequence makes worker training more effective.
- 3D-CAD is the tool of choice for making effective presentations to customers.

Civil companies and installation companies must adjust their schedules because parallel construction has become increasingly common. Moreover, we have to continuously re-examine construction possibilities because the alternation between building work and installation becomes ever more complex.

(2) Coordination with Construction Companies

In the construction planning stage, construction companies plan building construction schedules while Hitachi plans installation schedules. It takes a lot of time and effort to adjust both plans in detail. Moreover, only skilled engineers understand the know-how hidden in the schedule chart or drawing.

Hitachi routinely exchanges 3D-CAD data with civil construction companies, enabling construction engineers to adjust their construction plans more precisely and with less effort. Well-considered plans can reduce expensive on-site reworking. Hitachi provides 3D-CAD data on such elements as equipment, pipes, modules and operation stage, while civil construction companies provide us with information on building members such as slabs, walls, and temporary stages. Moreover, collaboration with construction companies enables us to complete engineering plans earlier and more accurately.

(a) Entire Construction Schedule Animation

Figure 10 shows an image from the construction sequence animation for Shika 2. The animation displays the sub-master schedule of building and installation work.

Consequently, the construction sequence can be reviewed more easily in the early engineering phase. Recently, some customers have required a construction outline at the time of bidding. This animation enables us to give an effective presentation. Thus animations are used to facilitate comprehension of construction plans not only for contractors but also for other concerned parties such as customers.

(b) Detailed Planning of Open-Top Construction Method

As mentioned before, the open-top construction method is necessary for parallel construction. Building work and

Fig.9 MSR Drain Tank Module

Fig.10 An Image of Construction Sequence Animation
pre-carrying in are performed in parallel, and the construction sequence is very complicated. Moreover, carried-in objects such as mechanical equipment, modules, pipes, valves, and operation stages must be temporarily placed in a small construction area that has scaffolding for building work.

Hitachi and construction companies plan and visualize the pre-carrying in sequence using 3D-CAD. In this collaboration, Hitachi supplies 3D-CAD data describing the carried-in objects, while construction companies prepare slab, walls, scaffolding and rebar.

**Figure 11** compares temporary layout planning and actual layout. We can devise a detailed engineering layout plan with less effort and better accuracy by using 3D-CAD data. Moreover, visualization helps us understand the temporary layout. The actual layout is the result of accurate planning. As shown in this figure, 3D-CAD engineering enables us to implement parallel construction even if the construction procedure is quite complicated.

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2. Construction Support System

1. System Function

The construction support system has been developed to make indirect work at the site more efficient by using 3D-CAD data. The system has 7 subsystems as shown in **Figure 12**:

(a) **Schedule Planning System**

This system provides support for 3-monthly and 3-weekly schedules that are automatically created by breaking down the construction area schedules described in previous sections. Achieved tasks, which are input by workers or foremen, are summarized into a higher-level schedule. Moreover, this system links with the “work instruction system” and the “inspection support system”. It enables us to submit work instructions and inspection requests in timely coordination with the construction schedule. The results are collected electronically and stored in the database.

(b) **Document Control System**

This system manages document control functions, i.e., acceptance of document, its distribution to several sections at the site office, and also document return and disposal. This system performs management functions for documents created in the site office and can display documents via the internet.

(c) **Commodity Control System**

This system supports the management of products and material delivered to the site based on digitized invoices. This provides warehouse controls such as receiving, checking and inventory management, which originate from the electronic supply list issued by the design section. Moreover, this system gives notification prior to use of products and materials in the warehouse, and handles the paperwork.

(d) **Work Instruction System**

Foremen download work instruction data, which is matched with 3-weekly or 3-monthly construction schedules, and after supervisors’ and chief supervisors’ review and approval, the instructions are conveyed to workers via palm computer and downloaded instructions, or by printed-out instruction sheets. Achieved results are uploaded via the palm computer or directly input by workers and stored in the database. After supervisors’ approval, the results are forwarded to the quality control section as inspection requests.

(e) **Inspection Support System**

Inspection section people download inspection request data to a palm computer or print it out, and inspection is executed based on the inspection request. The inspection

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![Planned layout](image1) ![Actual layout](image2)

**Fig.11 Planned Carrying-in Layout and Actual Carrying-in**
results are input by uploading via the palm computer or by direct input, and stored in the database after receiving the quality manager’s approval.

(f) Labor Control System

This system manages all field workers’ information, such as their employing company and work qualifications (welding, permission to use some special equipment, etc).

(g) Progress Evaluation System

This system evaluates delivery progress and work progress by construction area, building, system and subcontractor.

(2) System Advantages

The construction support system has been used with subsidiary companies and vendors in Hamaoka 5 and Shika 2. The advantages are as follows:

(a) The system manages the delivery date and construction drawings, which the area-by-area construction method also manages.

(b) The system supports the area-by-area construction method with schedule planning. An area schedule is linked with 3-month and 3-week schedules, which are detailed construction schedules utilized at the site.

(c) The construction progress function makes it easier for us to find problems at an earlier stage.

(d) Indirect costs are decreased because of the effective management of commodities and the document control system.

IV. Conclusion

Hitachi has developed construction methods to shorten the construction period and to reduce construction costs for nuclear power plants. We have applied these construction methods to the Hamaoka 5 and Shika 2 projects. These construction methods and their advantages are:

- Hitachi introduced modularization and the area-by-area method. Then we implemented parallel construction of building and installation work.
- The floor packaging construction method is expanded from the area-by-area construction method. Consequently, the floor packaging construction method enables us to finish installation of every area earlier than with the conventional method. Moreover, manpower can be distributed evenly.

Hitachi implements improved construction methods in the actual projects thus:

- 3D-CAD Engineering supports implementation of advanced and efficient construction methods.
- Visualization enables us to plan accurate construction procedures and to install equipment or modules optimally.
- Our construction management system enables use of the area-by-area construction method by facilitating the monitoring of essential information.

In these ways, Hitachi can construct nuclear power plants more efficiently, more safely, with shortened construction periods, and with lower construction costs.

References