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Advanced Construction Techniques for Nuclear Power Plants: A Theoretical Perspective

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Abstract—*Many countries have decided to build several Nuclear power plants (NPPs') to meet their growing energy needs and as an integral part of the National Security System. Considering the architectural design fundamentals, modern, construction techniques and all operating precautions is mandatory to achieve optimum safety, to minimize the construction time and to avoid possible hazards.*

The present study is a humble effort towards the theoretical perspective of advanced construction process and its potential application on the Nuclear power plant construction. Also it discuss some special construction considerations that should be considered and provides an introduction about some of the future trends of Nuclear power plants.

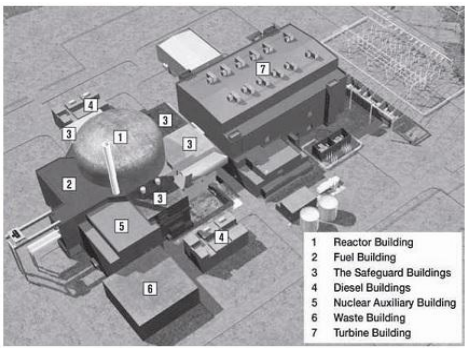
Keywords*: Nuclear power plant, Construction technique.*

1. INTRODUCTION

Constructional engineering is a science that includes a variety of disciplines including soil, structure, geology, mechanical equipment and other fields. It also involves the design, construction and maintenance of works including roads, bridges and buildings. Thus the development of constructional engineering is closely associated with the advancement in these sciences.

 # Main buildings of NPP

There are many types of Nuclear power plants. The figure shows the main buildings of a standard Nuclear power plant.



#Construction Methodology-

Old Methodology	Modern Methodology
• Multiple prime contractors. • Immature design at onset of construction. – 25% design completion at start. • Models were not detailed or used. • Stick-built approach. • Manual techniques. – Scheduling tools. – Document and data control. – Measurement and positioning systems. – Primarily manual welding. • Complicated I&C cabling and systems. • Limited heavy lifting capabilities.	• EPC Approach. • Design complete before construction. – 85% Design completion before construction. • 3D CAD models with interactive features. • Standardized modular approach. • Automation. – Sophisticated scheduling software. – Automated data and document control. – GPS and laser measurement and positioning systems. – Automated and enhanced manual welding techniques. • Simplified digital and fiber optic systems. • Expanded lifting and hauling capabilities.

 # Construction planning –

For the advanced construction process, the following constructional preparation should be considered, planned and designed before starting to construct a Nuclear power plant –

1. 3D Modelling and 6D planning :

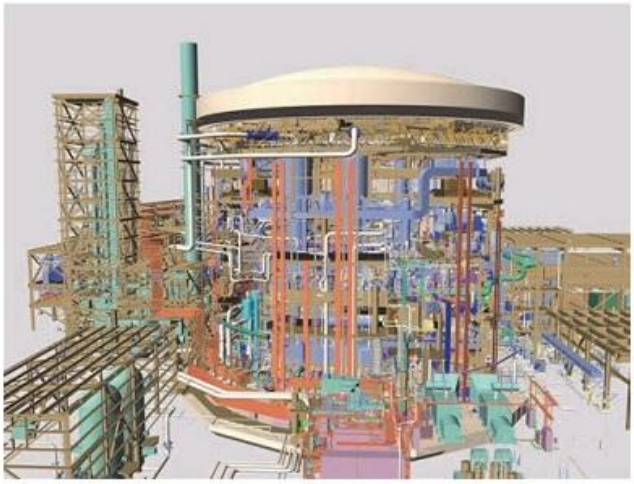
6D planning is based on the well known 3D-Model of development of design documentation along with three more components :

Time : In the form of scheduling.

Equipment : As information on configuration, procurement and delivery of necessary materials and aggregates.

Resources : Labour, technical, financial and other.

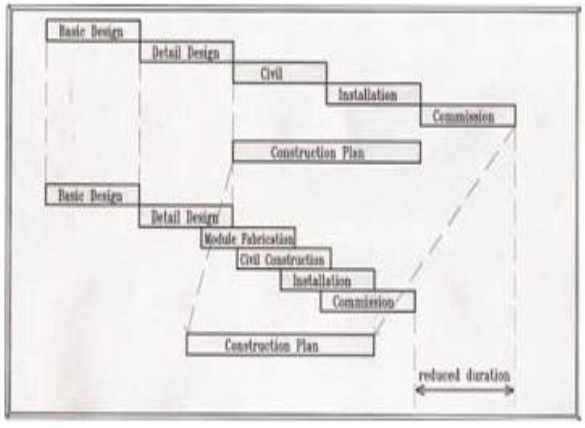
2. 3D MODEL FOR NUCLEAR POWER REACTOR



2. Nuclear power plant site development

Site development is not just site preparation, it is much more than that. It is the launching pad, completed for power island construction take off. Focused attention to nuclear site development is much more important to launch a nuclear project and is commonly misunderstood for its estimate at completion schedule, cost and length of preparation.

Having full site development underway at the time of first nuclear concrete lowers the overall site population, provides the infrastructure for power island focus planning teams and completes the site to grade around the power island such that there are no major or minor interferences to the nuclear critical path construction schedule for personnel, cranes and all equipment.



Parallel Construction Work On Site

3. Parallel construction

According to applying the nuclear construction techniques in constructing Nuclear power plant, the ability to have parallel construction on site reduces the construction duration.

 # Advanced construction Methods for New Nuclear power plants

Relative to coal fired and Natural gas fired power plants, nuclear power plants are more expensive to build but relatively less expensive to run. The present study describes the advanced Construction Methods to reduce nuclear power's construction cost, mainly by shortening the time needed to build a plant.

Reactor	Country	Construction period (months)*	Start of commercial operation	Type of reactor (approx. MW(e)) **
Kasiwazaki Kariwa-6	Japan	48	Nov. 1996	ABWR (1350)
Kasiwazaki Kariwa-7	Japan	48	Jul. 1997	ABWR (1350)
Lingao-1	China	60	May 2002	PWR (1000)
Lingao-2	China	62	Jan. 2003	PWR (1000)
Qinshan 3-1	China	54	Dec. 2002	PHWR (720)
Qinshan 3-2	China	58	Jul. 2003	PHWR (720)
Tarapur-3	India	75	Aug. 2006	PHWR (540)
Tarapur-4	India	66	Sep. 2005	PHWR (540)
Shin Kori-1	Republic of Korea	54 (planned)	Dec. 2010 (planned)	PWR (1000)
Olkiluoto-3	Finland	70 (planned)	Jun. 2012 (planned)	EPR (1600)
Kudankulam-1	India	84 (planned)	Mar. 2009 (planned)	PWR (917)

3. REACTORS BUILT RECENTLY USING ADVANCED CONSTRUCTION TECHNIQUES

Each of the Methods described below has been used in one or more of the projects listed in the table. None is unique to the Nuclear Industry, nor to any specific nuclear power plant design. Most are also used for other large construction projects such as fossil fuel power plants, large civil construction projects and shipbuilding.

1. Open Top Installation

Constraints on installing major components inside the reactor and containment buildings can have a major impact on the construction schedule with temporary openings to allow the entry of large equipment. In open top installation, the reactor and containment building is built with a temporary roof with an opening through which major pieces of equipment such as the reactor vessel and steam generators can be lowered into position using very heavy lift (VHL) cranes. Today's VHL cranes can lift equipment weighing more than 1000 tonnes with very long reach. Once the equipment is placed inside, piping and electrical systems can be installed at the same time that construction of the reactor and containment building is being finished, including the replacement of the temporary roof by a permanent containment dome.

Very Heavy Lift Crane At Qinshan, China

Open top installation has been used successfully with modularization to shorten the construction schedule. VHL cranes add additional costs but these are more than compensated for the shortened construction time.

2. Modularization with pre fabrication and pre assembly

Pre fabrication and pre assembly of Modules are construction technique used in many industries, including Nuclear power plants. As module is an assembly consisting of multiple components such as structural elements, piping, valves, tubing, conduits, cable trays, reinforcing bar mats, instrument rocks, electrical panels, supports, etc.

Modules may be fabricated at a factory or at a workshop at the plant site and multiple modules can be fabricated while the civil engineering work is progressing at the site in preparation for receiving the modules. This reduce site congestion, improves accessibility for personnel and materials and can shorten the construction schedule. It can also significantly reduce on site work force requirements.

Modularization also facilitates mass production of modules in the event that several reactors are being built at the same time. Mass production reduces the production time and labour requirements. Modularization makes it easier to assure a controlled production environment with associated improvements in quality and efficiency. It makes it possible to manufacture modules before the site itself is available and in the case of concrete, if facilitates the use of accelerated curing techniques.

The decision to apply a modular approach should be made in the conceptual design stage and then it must be followed throughout the project for detailed design, engineering, procurement, fabrication and installation through to the completion of commissioning. This allows equipment to be designed to conveniently fit into a module and for Modules to be sized to match the capacity of VHL cranes and transport routes to the site.

Installing The Upper Drywell Super Large Scale Module At Kashiwazaki Kariwa-7 In Japan:

3. Advanced Welding Technique

Nuclear power plant construction involves numerous welds to connect both components of structures and components of pressurized systems. It also involves weld cladding which refers to one metal being deposited onto the surface of another to improve its performance characteristics. Quality welding is both crucial and time consuming and techniques to increase the rate at which weld metal can be deposited, while maintaining high quality can reduce construction time.

Automatic Piping Welding At Kashiwazaki Kariwa-7 in Japan

Recent advanced welding technologies that meet this objective include gas metal Arc welding, gas tungsten arc welding and submerged arc welding.

4. Steel plate Reinforced concrete and slip forming

Reinforced concrete is used in the foundations of Nuclear power plants and in structure such as reactor containments, auxiliary buildings, turbine buildings and spent fuel storage areas conventionally reinforced concrete is fabricated in place using reinforcing bars (rebar) with external forms to frame the structure prior to pouring the concrete. The time required to place the reinforcing bars and to construct and remove the forms into which the concrete is poured is considerable. It is a major part of the construction schedule.

Reinforced Concrete

Steel plate reinforced concrete is an alternative to conventionally reinforced concrete and can be used for most floors and walls. The concrete is placed between permanent steel plate forms with welds to tie the steel plates, rebar and tie-bars together. The forms can include any necessary penetrations and piping runs.

Steel Plate Reinforced Concrete

Because of the structural credit for the steel plate concrete combination, the amount of rebar may be reduced and because the steel plate structure can be self supporting, reinforced concrete sections can be Modularized and pre-fabricated off site, followed by placement and welding on site.

5. Rebar Replacement for Reinforced concrete

Rebar Installation by the individual placement of bars is quite time consuming. Large Amounts of rebar are needed in the base wall, containment walls, containment dome and structural walls of the reactor and turbine buildings. The use of pre-fabricated modular rebar assemblies for these areas can shorten construction schedules.

An Automatic Scaffold And Horizontal Rebar Feeding Machine At Kashiwazaki Kariwa-6 In Japan:

6. Advanced concrete composition

In addition to these advanced methods for pouring and installing concrete, there have been recent advances in the composition of concrete to improve strength, workability and corrosion resistance. Examples are self compacting concrete, high performance concrete and reactive powder concrete.

These are used not only in Nuclear power plants but in other large Civil projects such as bridges, highways, large buildings and dams.

7. All weather construction and working around the clock

To ensure that work can continue in all weather condition an all weather cover dome can be put over the reactor building. This method was used, for example at Kashiwazoki-Kariwa-6 in Japan.

Working around the clock, both indoors and outdoors, can save considerable time at critical stages of construction. For example during excavation, concrete pouring, Structural Steel erection, Calandria Vault construction and various welding activities.

Night View Of Site Activities At Tarapur , India:

4. SUMMARY

The construction methods available for new nuclear power plants are generally the same as those used for other large construction projects. There have been considerable improvements in the construction methods in the past few years and recent experience in nuclear power plant construction has shown that those advanced methods are fully applicable and can help shorten construction schedule.

Recent nuclear construction projects have been completed in as little as four years.

The decision to apply some of these methods must be made in the conceptual design stage and then followed through consistently.

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