

The Modularization Using Prefabrication at the Pedestal Columns in APR1400

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1. Introduction

The main function of a power plant is to generate electricity by making steam to drive a turbine. In case of nuclear power plants, it is heated from the controlled splitting of atoms that is generating the heat. For pressurized water reactors, the heat is transferred to a separate water loop to turn it into steam which is then sent through the turbine to generate electricity. The TGB (Turbine Generate Building) is a specially designed building which encloses the turbine, generator and its auxiliary components for protection from the outdoor environment. The TGB is classified as seismic category II in accordance with 10 CFR 50, Appendix A, General Criteria 2 [1]. This paper describes some of the advanced rebar work being applied on the TGB in order to shorten construction periods. These features include modularization using prefabricated rebar and very heavy lift crane.

2. Modularization at the Pedestal Columns

The pedestal columns in the TGB are the massive concrete structures which support high-pressure turbine unit 1, low-pressure turbine unit 3 and the generator installed on the operation deck at elevation 136 ft. 6 in. As illustrated in Fig. 1, a total of 12 pedestal columns are placed symmetrically towards the axis of rotation of the generator. The dead and live load from equipment were transferred to the basemat through the operation deck and pedestal columns. In order to support the equipment's load, the pedestal columns are to be connected to the basemat at elevations 52 ft. and 73 ft. The TGB pedestal columns use #18 rebar and BMS (Bar-coupler Mechanical Splice) for its fabrication according to the design drawing, and typical concrete for this work scope has a minimum compressive strength of 5,000 psi at 91 days.

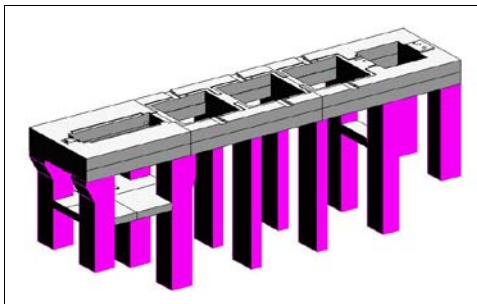


Fig. 1. Pedestal columns in TGB.

2.1 Modularization

Modularization is known as one of the best ways to shorten the construction period of a nuclear power plant construction project. It is also an innovative and powerful tool to improve productivity [2]. The pedestal modules can be built in rebar fabrication shop located at the site area. Fabrication of modules in a rebar shop environment enhances productivity and improve quality control due to the availability of a controlled work environment in a shop compared to the construction site. In a rebar shop, generally well trained and experienced work personnel are available and better quality control measures can be implemented [3]. It is also possible to reduce on-site workforce requirements.

2.2 Prefabrication

Prefabricated rebar assemblies can improve construction safety, improve construction schedule, and reduce construction cost. Prefabrication is one way for modularization. The details of the advantages and disadvantages are as follows.

2.2.1 Advantages of prefabricated rebar assembly

- Shorten the construction schedule
- Increase productivity and quality under the factory environment
- Improvement of the constructability for areas with heavy rebar congestion
- Reduce field work and levelized on-site manpower
- Increase safety and efficiency at ground level work

2.2.2 Disadvantages of prefabricated rebar assembly

- Need higher capacity lifting equipment
- More complex rigging and fit-up requirements
- Difficulties interfacing prefabricated rebar assemblies with embedded plates
- Damage during transportation

Rebar installation by individual placement of bars is very time consuming and produces long durations for critical path activities [4]. Fig. 2 and Fig. 3 illustrate the traditional on-site rebar fabrication process on pedestal column.

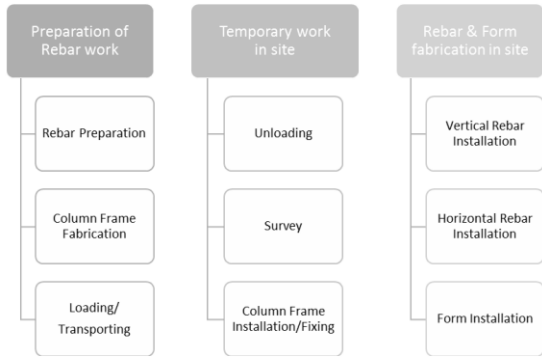


Fig. 2. On-site rebar fabrication process on pedestal column.

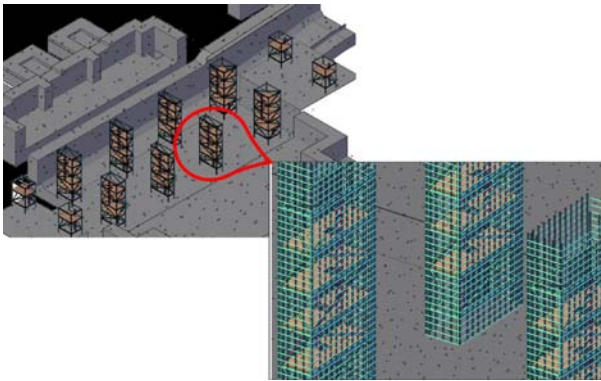


Fig. 3. Column frame installation and on-site rebar fabrication.

Off-site rebar fabrication process can be seen in Fig. 4. and Fig. 5. The vertical and horizontal rebar works are prefabricated in a prefabrication shop, making rebar work on the site unnecessary.

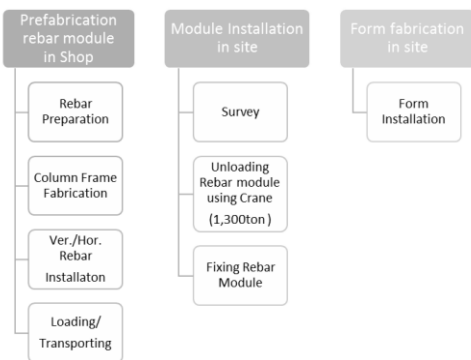


Fig. 4. Off-site rebar fabrication process on pedestal column.

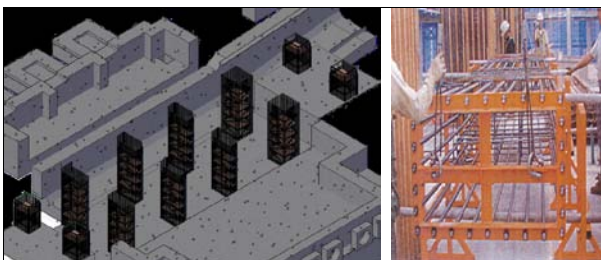


Fig. 5. Rebar module installation of pedestal column in site.

The BMS of the pedestal columns are connected at elevations 79 ft. and 82 ft. as shown Fig. 6.

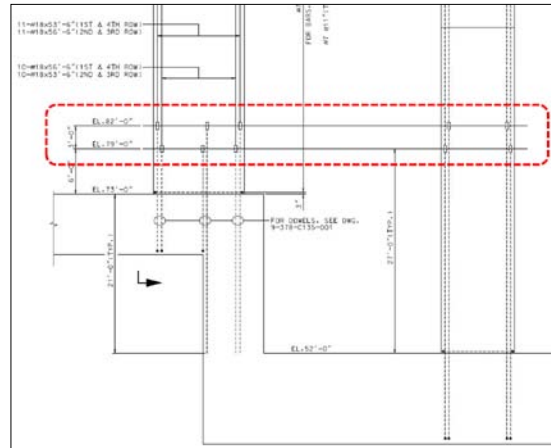


Fig. 6. BMS connection points in the pedestal columns.

In case of rebar modularization apply at the pedestal columns, it will be expected that interference with dowel bar of the basemat and BMS connection will be difficult. As a solution to this, when placing rebar in the column frame (Fig. 5, Left) at the off-site rebar shop, use the Template shown in Fig. 7 to position the rebar in the exact position. If the pedestal dowel bar by using the Template installs in the basemat as shown in Fig. 8, it can also minimize the interference between the dowel bar in the basemat and BMS connection in the pedestal module. In addition, by installing an internal working platform for connecting BMS as shown Fig.5, it is possible to secure the safety and improve the efficiency of the BMS connection work.



Fig. 7. Template for rebar placing [6].



Fig. 8. Template for dowel bar in the basemat [6].

2.3 Schedule

The use of prefabricated modular rebar assemblies for pedestal columns can shorten the construction schedule [4]. In order to meet a shorter schedule, pedestal columns are related with several activities on the critical path such as 'Erect condenser in TGB'. The schedule and milestone of the pedestal column can be found in Fig. 9. Modularization of pedestal column shows that the work duration is reduced by two months.

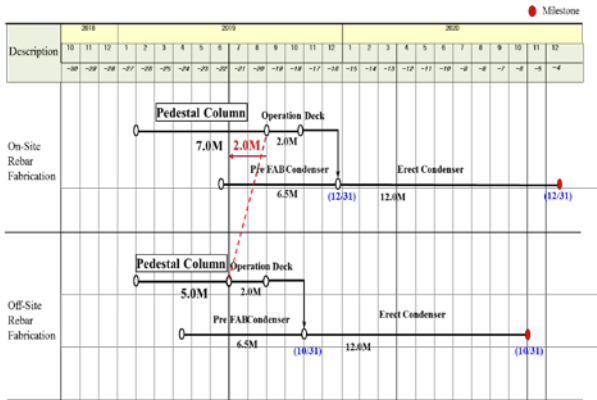


Fig. 9. Shortening schedule due to rebar prefabrication.

In order to meet a shorter schedule, it is necessary to reduce the time to fabricate rebar on the site. Fig. 10 shows details of the construction block at pedestal columns. The pedestal columns were divided into two or three stages, so it took longer than modularization because the fabrication period was required for each stage of rebar work on site.

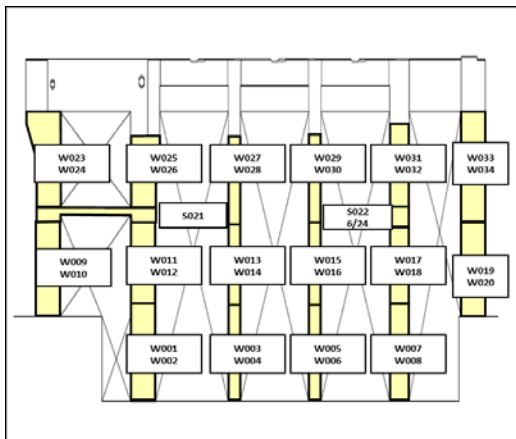


Fig. 10. Construction blocks at pedestal columns for on-site rebar fabrication.

Table I compares the spent time for on-site and off-site rebar fabrication per construction block. This implies that the construction period can be reduced by 60 days (2 months).

Table I: Comparing days for rebar fabrication

Stages	Block	On-site	Off-site
Stage 1	W001~W008	15 days	8 day
Stage 2	W009~W020	42 days	10 days
Stage 3	W023~W034	31 days	10 days
Total		88 days	28 days

2.4 Very Heavy Lift Crane with Modularization

VHL (Very Heavy Lift) cranes are capable of lifting and moving modules weighing more than 100 tons and reaching several hundred feet. The advent of these cranes permits very heavy loads to be placed. This allows the large-scale use of techniques such as modularization [5]. As shown in Fig. 11, a VHL crane with a 2,300 ton capacity was used for the first time at Shin-Kori unit 5 for the lifting of the 191 ton CLP (Containment Liner Plate) module on 28 Feb. 2018.



Fig. 11. VHL crane for lifting CLP module in Shin Kori Unit 5 [7].

The following figure shows the six types pedestal columns.

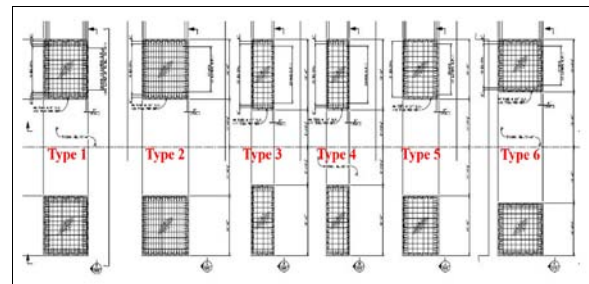
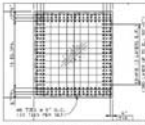
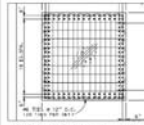
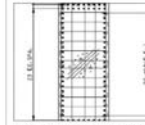
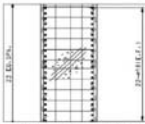
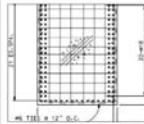
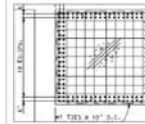


Fig. 12. The section plan of the pedestal columns in TGB.

Table II shows the weight of the prefabricated rebar module of each pedestal column type. In case of the heaviest Type 1, the lifting for modularization is 88.2 ton.

Table II: Review the lifting load of pedestal columns

<p>Type 1</p>  <p>Main Rebar : 50.8 Stirrup : 37.4 Total : 88.2 Ton</p>	<p>Type 2</p>  <p>Main Rebar : 48.1 Stirrup : 18.4 Total : 66.5 Ton</p>	<p>Type 3</p>  <p>Main Rebar : 32.1 Stirrup : 18.5 Total : 50.6 Ton</p>
<p>Type 4</p>  <p>Main Rebar : 32.1 Stirrup : 18.5 Total : 50.6 Ton</p>	<p>Type 5</p>  <p>Main Rebar : 42 Stirrup : 19.1 Total : 66.1 Ton</p>	<p>Type 6</p>  <p>Main Rebar : 37 Stirrup : 13.5 Total : 50.3 Ton</p>

Considering the lifting ability of the VHL crane, lifting the pedestal column module has enough margin. However, in order to shorten the construction period, it is important that the backfill work around the TGB should precede the setup of the VHL crane as below Fig. 13.



Fig. 13. Backfill area to use VHL crane around the TGB and lifting work of the pedestal column module.

As the VHL crane is used for pedestal column module lifting, it is necessary to review about the equipment moving route, securing lifting area, interference with yard work, and safety review of the ground condition in advance. Therefore, in order to put the pedestal column modularization into practical implementation, it needs to minimize the interference between the cranes by reflecting the crane equipment operation plan at the design stage.

3. Conclusions

When the rebar of the pedestal columns were fabricated on-site, the construction period was 7 months. This means the construction period reflects the input of labor force, site work conditions, and weather conditions when installing rebar on site. In case of prefabrication of the rebar in the off-site rebar shop, it is shown that the construction period is reduced by about 2 months. The reason for this result is that the rebar work

is dictated by the skill of the field worker and the working conditions at the site, prefabrication work at the off-site shop can minimize these interferences.

Another reason to modularize the pedestal column is that there is no interference with other piping or electrical work. For reinforced concrete work, most of the piping and electrical works must be preceded and parallel. However, the pedestal column has almost no piping or electrical work.

There may be some doubts about the capacity of the very heavy lift crane when installing the module on-site after rebar modules are prefabricated off-site, but calculations show there is enough capacity. Although it would be necessary to review the economic feasibility of using very heavy lift cranes, this problem can be solved if the containment liner plate lifting schedule and the pedestal column module lifting schedule are not overlapped.

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