Design and Fabrication Technology of a PAU and PAR Project

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Abstract. This paper describes the design and fabrication process of a solvent deasphalter unit which included 5 PAUs (Pre-Assembled Process Module Units) and 5 PARs (Pre-Assembled Piperacks) at a refinery in Rotterdam. This paper summarizes the method and experience successfully applied to the shop design and construction process of PAUs and PARs, illustrates the prefabrication and the assembly process of PAU and PAR modules. Many challenges were encountered during the one and a half years’ fabrication, such as mass drawing sheets, fabricate in line with DEP specification and Eurocodes, assembly sequence optimization, the integrate construction method, dimension control and quarantine etc. Design and fabrication processes such as relevant code and standards, shop design softwares, work process of shop design, the application of management system, module arrangement, the process of prefabrication and assembly sequence, the integrate construction method and loadout are highlighted. In the shop design process, 3D Model played a key role. The application of management systems such as PCMS and WIMS significantly improved the efficiency of construction management. Reasonable construction sequence and schedule ensure good performance of fabrication activities. The integrate construction significantly reduced the workload of high altitude work and minimized the project period with efficient construction. It is hoped that the construction experience of this project can give some reference and benefit to similar project in the future.

1. Introduction
This paper describes the design and fabrication process of a solvent deasphalter unit at a refinery in Rotterdam. The unit is built in a modularized manner which can get relevant time and cost savings in the construction of onshore process plants [1]. COOEC (Offshore Oil Engineering Co.Ltd) undertook the construction work of 10 modules (include 5 PAUs and 5 PARs, see figure 1 and figure 2) in this project. The work scope for COOEC include purchase, storage, shop design works, construction at yard, inspection, pre-commissioning and testing, weighting, sea fastening grillage and loadout. The total weight of these 10 modules is about 5,800 tons, the largest module is about 1,614 tons and the smallest one about 30 tons. When the fabrication completed, COOEC is also responsible to load out these modules from fabrication site onto the sea transportation vessel supplied by owner.

2. Design and management
Detail design which provided by the general contractor includes steel connections, rough drawings, S3D (Smart 3D Software) and Naviswork model. COOEC (Qingdao)’s work is to design and work out a set of shop design drawings and plans to satisfy the requirement for prefabrication, assembly, erection, corrosion protection and quality control etc.

2.1. Code and standards
As Netherlands belongs to the European Union, products access to the European market legally must own the CE certificate. All the permanent materials purchased by COOEC satisfied the CE certificate and all structural steel engineered and fabricated according to EN-1090 execution class 2 in this project [2]. The module fabrication activities of this project had been implemented in line with DEP specification and relevant standards & Eurocodes, such as DEP 34.28.00.31-Gen, EN 1090-2 etc. COOEC trained and certified structure welders under EN 1090-2 Standard and piping welders under NORSOK M601 Standard, piping welders meet the requirements of PED (Pressure Equipment Directive, EU directives).

2.2. Shop design works
Shop Design work includes fabrication and assembly of structure, piping, pipe supports, electrical, instrumentation, mechanical, insulation, surface protection, Fireproof painting (PFP) etc. According to the detail design files, COOEC prepared structural model by Tekla 20.0 software. The S3D”*.stp” files can be imported into Tekla, the property of material should be changed according to the detail specification. Then the connection refine works can be made according to the connection drawings. Then the Tekla BIMsight files and AutoCAD 3D drawings can be exported and submitted to Company for review and approval. Each member has a unique number in Tekla model. Then structure discipline made shop design drawings by Tekla, and work out a set of shop design plans in quick succession. Piping discipline prepare 3D shop drawings by Spoolgen software, and prepare the construction procedures, plans, drawings to meet the requirement of site, shop design works for other disciplines do at the same time. Change Registration Form (CSA), Contract Site Instruction (CSI) and work package files are official contact between detail design and shop design in this process. 3D Model played a key role in the whole shop design work. By using Tekla Structure 3D model, clashes or mistakes can be easily found. Drawings such as the plan and elevation, sectional, isometric, stiffer lay out, gratings, and piece mark for girders or H-shapes can be exported easily. According to the NC files outputted from Tekla, cutting plan for plates and H-shapes can also be compiled easily. The material take-off report and weight control report can also be easily exported. During the shop design process, COOEC received huge amount of pipe supports files from detail design. Take PAU03 as an example, 1455 pieces of mechanical pipe supports (MPS) in dozens of batches COOEC received. For the new batches of MPS received in successively, and the old ones modification proceeds at the same time, the status of each MPS needs to be tracked accurately and timely. Modeling, compiling the shop design files, prefabrication and installation of these MPS in a limit time is also a challenging work.

2.3. Management system
The use of project management (PM) software for managing and organizing work is indispensable for engineering projects [3]. The PCMS (Project Construction and Management System) which is a construction management system has been used in this project from shop design to construction management by COOEC. Take piping discipline as an example, data reports of material, welding beads, pipe or pipe supports can be generated easily by Spoolgen, which is a high efficiency software for piping discipline. By importing these data reports to the PCMS system, the system generated kinds of work package documents for site construction and received feedbacks from site. By using the PCMS system, the construction progress can be clearly reflected, documents approval can be achieved online and work flow can be propelled automatically. The system can also give some guidance for management of construction, and helpful to the allocation of human resources or working machine. Besides, the material management program MATMAN which provide by the contractor also been used to manage the materials. The Welding Inspection Management System (WIMS) has been used to manage welding information. By using the system, all welds can be traced, including visual inspection and NDT report etc.
3. Prefabrication process

3.1. Integrate construction

COOEC implemented the “Pancake” execution principle to fabricate and assemble all modules. The pancake construction can be seen as integrate construction[4], which means that horizontal panels fabricated on the ground and installed with the supports for machinery, piping and electricity instrument systems after the completion of the structure. Handrails, grating, cable tray, pipeline and scaffolds which can be installed onto pancake will be installed before the pancake transported to the assemble site, or fixed onto the pancake before lifting operation. Figure3 shows a typical integrate construction work. Actually, the integrate construction can significantly reduce the workload of high altitude work, and can help to improve the construction efficiency. While the integrate construction can’t work well without fine management, thorough planning and rigorous shop design works. Safety and have no influence to the assembly schedule should be the precondition of these works[5].

3.2. Pancake partition

Considering to the requirement of integrate construction, much things need to be considered in advance, such as pipeline arrangements and equipment location, etc. There were some difficulties in the pancake partition of some modules. Such as pancake 2 of PAU05 module, the height for this pancake reached 21m, exceed the height limit of working shop. If the column be divided, it will be hard to control the dimension because of much bolt connections exist in this module. So the lay down construction method has been used for this pancake. However, with 9m height and 13m width also makes it’s hard to fit-up, and can’t be turned over in work shop.

3.3. Prefabrication process

The prefabrication of pancake is done in the work shop. Take PAU03 module as an example, the prefabrication process shows in figure4. During the pre-fabrication, fit-up the beams are welded integrated. When the prefabrication of pallet finished, the pre-outfitting members of other disciplines
were installed, then the whole pancake and ordinary piping would be transported to the painting workshop for blasting, painting and PFP by transporters 100t, 270t or 370t. When painting and PFP have been done, the pallets would be wrapped with aluminium foil which can help to protect paint and reduce workload for paint mending. Then the pancake would be transported to the assembly site. The middle and top level pancakes would be prefabricated in the same way as that of the lower pancake.

**Figure 4. Prefabrication Process of Pancake.**

### 4. Assembly process

The assembly and erection work shall proceed on a flat and level surface. Frequent checks needs be made on the supports, and any movement out of the level shall be immediately rectified by appropriate shimming to re-establish a level plane. Then layout temporary supports at assembly site and have the levelness inspection, and stools will be arranged under the columns. At the same time, after finishing the prefabrication of Pancake, the anti-corrosion, installation of piping and gratings have been done in sequence. Then the assembly work can be started. The final integration assembly was done with unit of pancake instead of individual pallet, this will maximize the amount of work that can be completed at ground level.

#### 4.1. Module arrangement

Consider to layout of worksite, lifting capability and project schedule, the modules assembled on the South Assembly Area of dock. COOEC constructed the modules implementing the “Pancake” execution principle. According to the final location of modules at the refinery, some modules fabricated with POD modules method. POD modules can benefit the connection between modules and help comprehensive management to find out problem in time. Typical POD modules in this project marked in figure5.

#### 4.2. Assembly sequence

The general assembly sequence of these modules is from bottom to top, Lift the pancakes one by one from the lower to top and install equipment, pipelines and bulk members between different levels. Take PAU03 module as an example, the assembly and erection process is shown in figure6. Firstly, the 1# Pancake will be lifted onto the stools at the assembly site by using 800T gantry crane. Then equipment at EL 102.900, bulk members between EL 102.900 and EL 109.400 will be installed, the 2# Pancake installed following. Then install pipelines between EL 102.900 and EL 109.400, equipment at EL 111.400, and bulks between EL 111.400 and EL 118.400, the 3# Pancake installed following. Then Install pipelines between EL 111.400 and EL 118.400, service platforms at EL 124.150, then install equipment at EL 120.400 and other bulk members. When the assembly work finished, mechanical
completion, commissioning, weighting and quarantine compliance need to be done. The modules would be weighed few days prior load-out operation to validate design weight and COG assumptions.

Figure 5. Layout of typical POD modules.

![Figure 5. Layout of typical POD modules.](image)

5. Loadout

All modules would be transported from Qingdao, China to Rotterdam, Netherlands by vessel. Modules would be loaded out from the fabrication yard onto vessel by vessel cranes and SPMT (Self Propelled Modular Transporter). The PARs were loadout by lifting with vessel cranes. The PAUs which are much heavier than PARs were loadout by Ro-Ro type of transportation, because of the limitation of capability with vessel cranes.

The loadout transportation for PAUs used COOEC’s own SPMT which are Scheuerle type and the max capacity is 40T per axle line. COOEC provided 216 axle lines with 8 PPU for this project. It’s a real first application for COOEC to compile loadout procedure and operate SPMT independently for loadout. The PAUs transported by SPMT used the longitudinal transport method (see figure7), which is especially suit for the narrow and long modules. During the transportation process, transport beams had been used to distribute loads. Based on the ballast capacity of vessel and the classification of GL Guidelines, the loadout of PAUs were classified as Class 1[6]. Longitudinal loadout method[7] that transport from stern to entrance of the vessel be used during the loadout process. Vessel stern ramps had been used for bridging the gap between the vessel and the quay side. The height differences between jetty and vessel deck should always be kept between 0 to100 mm during loadout process to ensure safety, and SPMT should moving slowly to match the ballast operation until it reached the final location. The load-out process by SPMT shows in figure8. Module would be jacked-down on grillage and then sea-fastened to vessel deck. When all modules and loose items had been fixed onto the vessel and the final inspection of sea-fastening finished, vessel can be sail away.

Figure 6. Fabrication sequence of PAU03.

![Figure 6. Fabrication sequence of PAU03.](image)
6. Conclusions
The fabrication work of this solvent deasphalter unit was challenging. In the shop design process, 3D Model played a key role. The application of management systems such as PCMS and WIMS significantly improved the efficiency of construction management. Reasonable construction sequence and schedule ensure good performance of fabrication activities. The integrate construction significantly reduced the workload of high altitude work and minimized the project period with efficient construction. The purpose of this paper is to summarize the successful experience and benefit the future construction of similar project.

7. References
[1] Cigolini R and Castellano A 2002 Using modularization to manage construction of onshore process plants a theoretical approach and a case study J. Project Management Journal. 33(2) 29-40.
[2] 2008 S. EN 1090-2: Execution of steel structures and aluminium structures- Part 2: Technical requirements for the execution of steel structures.
[3] Matthew J. Liberatore, Bruce Pollack-Johnson and Colleen A. Smith 2001 Project management in construction: Software use and research directions J. Journal of Construction Engineering and Management. 127(2) 101-107.
[4] Song Q, Guo Q, Wang H, Gao B, Sun Z and Shang B 2016 Advantage analysis on integration construction process of offshore platform and application suggestion J. Petroleum Engineering Construction. 42(4) 30-33.
[5] Zhan X 2018 Integrated management and optimization of construction project schedule, cost and quality C. 2018 International Workshop on Advances in Social Sciences (IWASS 2018). 622-625.
[6] 2013 S. GL Noble Denton: Technical policy board guidelines for load-outs 0013-ND_7.
[7] Liu C 2015 High position fabrication method of topside based on transverse loadout C. International Society of Offshore and Polar Engineers (ISOPE). 1299-1304.