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Study of Modularization of Industrial Pipe Rack Structure

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Abstract- **Petroleum Industries both on shore and offshores have emerged as the vital part of any nations industrial and economical development. Also it has evolved through numerous engineering and technological innovative development. One of the important aspect among it has been the pipe rack structures. Since a decade or more the modularization of pipe rack structure is gaining massive importance due to various virtues involved. This paper shall explore some imperative procedures involved in modularization, its requirement and the industrial practices followed. Also it shall explain some merits and demerits of modular structure compared to conventional stick built structure..**

Keywords— **pipe rack, modular structure, stick-built structure, process industries practice (PIP)**

I. INTRODUCTION

A. *What is modularization?*

Modularization is fabricating and pre-assembling plant elements far from the actual plant location. A module is a product resulting from a series of remote assembly operations, transportation of the same module via road or sea and finally the installation process at the site. It divulges many benefits in the construction process.

It is a healthier option when there is a dearth of skilled labour sat the site. Construction activities are not easy, particularly when unwelcoming work conditions due to bad weather like storm, hurricane or heavy rain/snow fall occurs; modularization is helpful in all those situations. Every single owner of project seeks for faster and economical procedure so as to activate their plant activities as soon as possible; module strategy satisfies this demand.

Merits of modularization

1. ***COST REDUCTION:***
   - i) Reduced on site labour leading to reduction in indirect costs such as employee transportation costs, camp accommodation costs, consumables etc.
   - ii) Accessing a greater global pool of module construction yards.
2. ***RISK REDUCTION:***
   - i) Reduction in on-site man hours thereby reducing HSE risk
   - ii) Reduction of environmental risk by reducing activities and foot print on sensitive sites.
   - iii) Minimising manufacturing risks by fabricating modules in a controlled workshop environment, and in-turn minimises potential impact of unavailability of skilled labour on site
   - iv) Reduces the potential of weather related delays and issues with construction window
3. ***SCHEDULE REDUCTION***:
   - i) Ability to undertake concurrent fabrication of modules,
   - ii) Ability to construct at a dedicated fabrication yard with associated infrastructure,
   - iii) Removing of construction away from environmental and climate constraints such as poor weather conditions.

What is pipe rack:

Pipe rack is a structure whose basic geometry is like a portal frame having multi-tiers which are provided to support piping assembly, cable trays and (with) fin-fan coolers or without coolers. Pipe rack is the main artery of a process unit. It connects all equipment with lines that cannot run through adjacent areas. Because it is located in the middle of the most plants, the pipe rack must be erected first, before it becomes obstructed by rows of equipment [1]. Pipe racks carry process, utility piping and also include instrument and electrical cable trays as well as equipment mounted over all of these.

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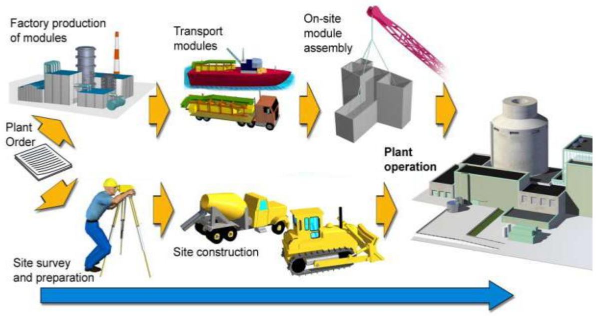

Fig.1 Picturised procedure of modularization.

II. GENERAL PROCEDURE

Initially the models are prepared using appropriate software available or recommended by the owner. Conventional stick built analysis or more popularly known as in-place analysis is carried out viz. wind analysis, seismic analysis and others as guided by the process industries practices (PIP).

Then after the whole structure is divided in to numbers of parts, horizontally or/and vertically, as the requirement is needed to satisfied. It generally depends on the lateral and longitudinal dimensions of the structure. The carriage vehicles (SPMT or ships or barrage's) have the dimensional limitations which are taken care about. Again all the static analysis is done on these individual modules and are checked for serviceability and other criterions.

Then after each module is analysed for transportation viz. road and sea transport. Various additional forces act when the module is being transported.
To be specific for land transportations the acceleration forces are additionally considered as 10% to 20% of the gravity loads.

For sea transportation the acceleration force and wind force are additionally considered as 25% to 30% of the gravity loads as the consequence of tidal effects such as heave, etc..

Finally, the modules are designed for the lifting. When the lifting process is done the wind forces are generally avoided as the lifting is not advised in windy conditions. The columns in lifting are generally observed to being tension along with compression. Additional Supporting beams are installed where required.

III. MINUTES OF 'PIP'

PIP STC01015 is the guideline published by Construction Industry Institute, The University of Texas at Austin to facilitate the global industries involved in petroleum and petrochemical field. It very specifically defines and articulates the diversified details viz. the architectural and structural specifications. Also it mentions the thumb rules for considering the componential loads of various structures.

In general, the codes of practice only talk about the general loads and load combinations whereas the PIP minutely bifurcates the load definitions. For example, the dead load in normal codal scriptures is here designated and defined as Ds, Df, De, Do, and Dt, where

Ds = Structure dead load is the weight of materials forming the structure (not the empty weight of process equipment, vessels, tanks, piping, nor cable trays), foundation, soil above the foundation resisting uplift, and all permanently attached appurtenances (e.g., lighting, instrumentation, HVAC, sprinkler and deluge systems, fireproofing, and insulation, etc.).

Df = Erection dead load is the fabricated weight of process equipment or vessels (as further defined in Section 4.1.2.4).

De = Empty dead load is the empty weight of process equipment, vessels, tanks, piping, and cable trays (as further defined in Sections 4.1.2.4 through 4.1.2.6).

Do = Operating dead load is the empty weight of processequipment, vessels, tanks, piping, and cable trays plus the maximum weight of contents (fluid load) during normal operation (as further defined in Sections 4.1.2.4 through 4.1.2.7).

Dt = Test dead load is the empty weight of process equipment, vessels, tanks, and/or piping plus the weight of the test medium contained in the system (as further defined in Section 4.1.2.4). [5]

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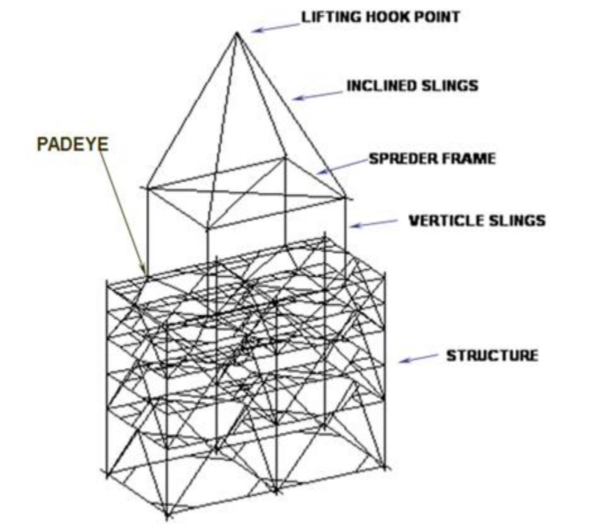

Fig.2 Lifting of the module with the spreader frame

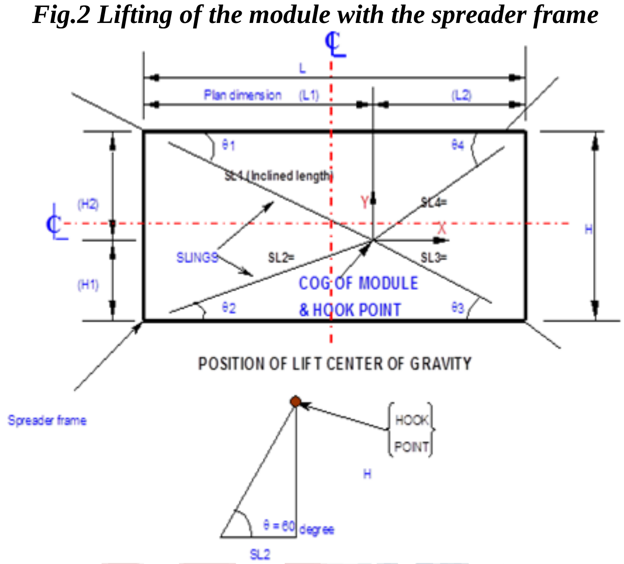

Fig.3 Position of the hook above the Center of gravity of the Module

IV. VARIOUS BASIC LOAD CASES CONSIDERED

Compared to normal residential buildings the load cases in industrial building particularly in pipe rack structure do vary a lot. Some of the load cases used are explained here. In addition to Dead load, Live Load, wind load and seismic load the following loads are considered and further the load combinations are made for design.

1) Floor Load:
It is uniformly distributed load spread across the horizontal area. It is provided for facilitating the platforms for equipment.

2) Pipe Empty Load:
It is the empty weight of pipe.

3) Pipe operating load:
Load applying on the pipe rack while pipes running through the structure are in operation condition is called pipe operating load.

4) Pipe testing load:
Pipes are tested by filling with water at full periodically for maintenance purpose. Force acting meanwhile is called pipe testing load.

5) Thermal anchor load:
To restrict the lateral and longitudinal displacement of the pipe due to the content running through it, pipes are restrained at several intervals by providing anchors. The force acting dynamically at that point is defined as thermal anchor load.

6) Thermal friction load:
Due to variation in temperature between the fluid running within the pipe and the external atmosphere, the thermal friction is observed. Unless specified this load is considered as 20-30% of the pipe operating load.

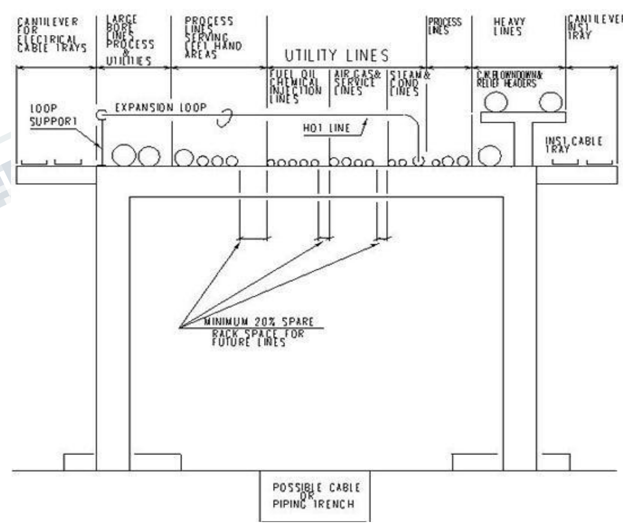

Fig.4 General Pipe Rack Layout (Functional) (Source: http://red-bag.com/design-guides)

V. PROBLEM DEFINITION

Akbar Shahiditabar and Seyed Rasoul Mirghaderi analysis the pipe and pipe rack interaction under dynamic loading condition. Pipe networks are considered as main components of industrial complexes like refineries and petrochemicals that transfer fluid and gas and any damage in their structures may be dangerous. Pipe rack behavior influences pipe behavior directly. According to recent studies, pipe damages in earthquake are mainly caused by pipe rack which is one of the most important reported reasons of pipe damages.

This study aimed to propose a new method for considering pipe and pipe rack interaction instead of current method in order to solve current problems. In the proposed method, pipe is framed to pipe rack in all points and then pipe and supporting structure are design simultaneously. The proposed method is assessed by modeling in Sap and Caesar programs with nonlinear static analysis which results confirm our claims. In suggested method, current problems were solved and the amount of used materials is reduced up to 29%.

Fabrizio Paolacci, Md. Shahin Reza**, **Oreste S. Bursi says Pipe racks are necessary for arranging the process and service pipelines throughout the plant, and they are used in secondary ways; principally to provide a protected location for auxiliary equipment, pumps, utility stations, manifolds, and firefighting and first-aid stations. Recent seismic events showed a quite high vulnerability of these structures, where damage ranges from the simple failure of joints to the failure of supporting structures. For example, the failure of a bolted flange connection is shown in. Also he discusses European and American standards for the seismic design of piping systems. Author carries out a case study where the supporting steel structure is composed by seven transverse moment resisting frames placed every 6 m, realized with commercial HEA/B steel profiles. In the longitudinal direction it behaves like a truss structure, which is reinforced with 6 braces. Horizontal bracings are also installed to avoid excessive relative displacements between the pipe supports. Also the author analysis the model for seismic vulnerability by design response spectrum method, in-structure spectra (ASCE 7) and time history analysis. Consequently calculation of the seismic response of the case study is carried out and presented.

Kasi V. Bendapudi articulates on the design of steel pipe support structure design. He narrates that lack of uniform industry standards for this topic leads each organization to adopt its own engineering standards without clear understanding of the underlying theoretical concepts and cost applications. The particular paper represents the temperature load effect on the pipe support structure. Various bracing condition can help out in encountering the temperature stress in the structural elements. Further author suggests that pipe rack should be designed for all gravity and natural hazards such as wind and seismic loads, internal forces due to restraint of thermal expansion, pipe anchor and guide support loads. in conclusion he discusses about the various helpful codal provisions of ASCE and International Building Code.

RICHARD M. DRAKE and ROBERT J. WALTER puts forward the in general procedures and design consideration for structural steel pipe rack. Author narrates that pipe racks are structures in petrochemical, chemical and power plants that support pipes, power cables and instrument cable trays. To allow maintenance access under the pipe rack, transverse frames (bents) are typically moment-resisting frames that support gravity loads and resist lateral loads transverse to the pipe rack. He explained various design consideration taking the model as shown in figure 2. Further he explains the difference in consideration of design loads between ASCE standards and PIP recommendations, listing all the categorized loads of industrial facility. Consequently author describes the available methods of stability analysis and design. Finally on concluding notes author utters that Pipe racks are not only non-building structures that have similarities to structural steel buildings but also have additional loads and design considerations. Engineering practices vary and are, at times, influenced by client requirements and regional practices. Additional and updated design guides are needed so that consistent design methods are used throughout the industry.

PIP STC01015 Structural Design Criteria is a document prepared by PIP, a group of 27 industries leading the field of Process industries. It has published guidelines for the worldwide industries for process plant design and considerations including various departmental classifications viz. architectural, structural, and piping, instrumentation, etc. department.

PIP STC 1015 is particular Structural design guidelines. It provides the generalized design philosophy for design of various structural elements of process industry. Practice is intended to be used in conjunction with PIP ARC01015, PIP ARC01016, PIP CVC01015, PIP CVC01017, and PIP CVC01018, as applicable. It describes the various aspects of design loads, load combinations, etc.

VI. CONCLUSION

The main points that came out from the study are as follows

1. In general the module structure is costly than the conventional structure

2. Although in unfriendly natural sites the modularization avails us to have in time schedule completion.
3. Lack of skilled labour is nullified.
4. As the fabrication is done in controlled environment the desired degree of acuteness in the work can be attained.
5. Though it proves costlier when tonnage of steel used is concerned, modularization is preferred for the benefit of overall economy and safety.

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