MODULARISATION AND PRE-ASSEMBLY PAPER #2 DEFINITIONS AND SCALE

AUTHOR © ~ MARK STARKOFF MANAGING DIRECTOR - SIGMA ENGINEERING PTY LTD
www.sigmaengineering.com.au - info@sigmaengineering.com.au
Paper for the Modular Construction and Pre-Fabrication Conference 11-12 May 2010 Brisbane (iQ Construction - Division of IQPC)

INTRODUCTION AND OVERVIEW

This paper has been developed as a supplement to the paper by the author, Modularization And Pre-Assembly Paper #1 - Underpinning Parameters And Considerations. The paper refers to and discusses both modules and pre-assemblies an will extend the discussion related to these basic component blocks of a modular or pre-assembly delivered project to provide the reader with a basis of reference that can be applied to project work. However, the discussion will not be so presumptuous as to prescribe the defining terminology that should be adopted by industry to describe the extent of "out of final position construction", generally referred to as modularisation or pre-assembly.

"The Oil & Gas industry has unquestionably influenced the terminology used by the project managers of land based minerals processing , petro-chemical and heavy industrial projects."

During the past 5 to 10 years of development of onshore modular and pre-assembly delivered projects, there has been a relatively loose reference to blocks of constructed plant finished to varying degrees of completion in off site locations as "Modules". While there is nothing inappropriate with this labeling, it has produced a platform of general reference that is cloudy and difficult to apply to all areas of industry. The Oil & Gas industry have unquestionably influenced the terminology used by the project managers of land based minerals processing, petro-chemical and heavy industrial projects. As a consequence, the term Module has become the all embracing descriptive terminology for all blocks of plant constructed off site and out of the final operation position.

WHAT IS A MODULE OR PRE-ASSEMBLY

To enable a clear general project reference, there must be a set of descriptive parameters available to project owners, designers and management that provides a reasonably accurate and accepted description of the scale and value of "out of final position" construction that is in essence, modularisation or pre-assembly. A module or pre-assembly is the sum of its component construction material commodities; i.e. a module or pre-assembly is a set of construction commodities such as structural steel, pipe, electrical cable, instrumentation, insulation, refractory, architectural cladding, mechanical, electrical and process equipment that has been assembled to some state of greater complexity and value in a location away from its final operational life location.

Some of the common references used by project owners and the project management industry resources include, but are not limited to the following.

- Super Module, SPAM
- Module, PAM;
- Pre-Assembly;
- Flat Pack Panel;
- Pre-Fabrication Site Erected Elements (Stick Build), Hook Up Kits, Site Assembled Materials (SAM).

For most readers, each of these descriptions have a differing connotation as to the extent of the final construction level in regard to the complexity and value for each of these categories.

Let us consider the importance of the descriptions and their connotations to our collective requirements for categorisation. Why would we want to

"The value or richness component of any "out of final position" modularisation or pre-assembly is linked to the "fundamental currency" of all modularization and pre-assembly, which is, the construction hour of the base unit commodity."

MODULARISATION AND PRE-ASSEMBLY PAPER #2 DEFINITIONS AND SCALE

HISTORY SNAPSHOT

The recent Australian Alcan G3 Project pursued the concept of a fully modularised project delivery approach to the bounding limits of the economic and practical possibilities. The project managers targeted the highest possible concentration of construction hours within a module. The remote Gove site operational location held the great fortune of extremely close proximity to the receiving berth and this key advantage led the ability of the management team to fully exploit the potential of modularisation in the fullest extent. The targeted commodities included structural steel, piping, insulation, electric, instruments, architectural cladding, mechanical, electrical and process equipment and foundation concrete. All these commodities were fully incorporated during off site construction and the finished module shipped to site as complete as possible.

This project also developed the acronym,PAM. It has been widely interpreted throughout industry as Pre-Assembled Module. This interpretation begs the question, if a module was not pre-assembled what would the module be? In fact, the initial meaning for the acronym PAM, was Process Assembled Module and reflected the desire of the project team to export as many site hours from the remote and expensive Gove site location as possible. By maximizing the potential for as many testing and commissioning hours off site as possible, the maximum economic efficiencies could be targeted. While not comprehensively successful in this aspect of delivery, this project provides a strong benchmark and learning platform for future projects.

This project also coined the terms Super PAM and SAM. Super PAM referred to a module that incorporated concrete footing foundations and SAM was the acronym for Site Assembled Materials which generally reflected all site installed or assembled materials and corresponds with other industry descriptions such as “stick build’ or Hook Up Kits etc.

The introduction of concrete footings to the module was an innovative and unique extension to a modular concept that only a few projects with extremely close coastal proximity locations can extract economic benefits. Transportation complexities resulting from the high mass generally limit the extent of applicability for remote inland projects. The economics of shipping and transporting large volumes of concrete versus site form and placement also vary from project to project. In the case of G3, the benefits of reducing the requirement for civil resources accommodation in a fixed capacity camp at a time of high demand for other construction disciplines added substantially to the Super PAM concept and benefits.

have such an array of descriptions? The answer is grounded in the fundamentals we collectively need to be able to qualify and quantify the complexity and richness value of any “out of position” construction delivery. The value or richness component of any “out of final position” construction is based in the fundamental currency of all modularization and pre-assembly, that is, the base commodity construction hour. The density of high value construction hours captured by the module or pre-assembly delivery approach is the key to the underpinning economic viability and the financial driver by which a modular or pre-assembly delivery approach is embraced by a project. The corresponding description therefore provides us with an immediate indication of its potential value to a project delivery and grounds our expectations to a common platform of value across many different project scenarios.

There is almost an infinite range of possibilities and options for the scale and complexity of delivery between a super module and a flat pack panel and “stick Build” delivery. A project pursuing the maximum possible benefit from a modular or pre-assembly delivery will often adopt as many of the categories as possible to maximise the synergies of off site fabrication and assembly with the maximized utilization chartered shipping.

This paper assumes that every project, regardless of execution methodology, should employ pre-fabrication to the maximum extent possible. Pre-fabrication should comprehensively extend to the greatest complexity development of site erect “Stick Built” elements such that they require no special oversize requirements for shipping, road transport or specialised site installation. In essence, the traditionally defined “stick build” element must have the maximum value added off site even though it is not integrated into a module of pre-assembly when it arrives at site..

CATEGORISATION OF DESCRIPTIONS

With a general feel for the range of classifications for modules and pre-assemblies carried by industry, it is reasonable to begin the definition process and the interpretation of the extent of complexity and value each category of modularisation and pre-assembly holds. It should be noted that these general descriptions are in reference to land based modules and pre-assemblies, predominantly in the mining, minerals processing, petro-chemical and heavy industrial sectors. Even between these sectors, there is some depth of disparity in definition and description.

Super Module

General industry reference to this category of land based Super Module describes a structure that is

AUTHOR - MARK STARKOFF, MANAGING DIRECTOR SIGMA ENGINEERING PTY LTD (31-1-2010) (COPYRIGHT ©)
www.sigmaengineering.com.au - info@sigmaengineeriing.com.au

probably over the 1000 tonne mass range and has varying physical dimensions well outside conventional highway transportation applicability. This highly prized project objective will hold all the high end value adding construction hours for all construction disciplines and the associated commodities of construction. This category of module will include all structural commodities, maximized piping, (especially small bore), insulation, electrical tray runs and electrical terminations, equipment insulation, instrumentation and tubing and architectural cladding etc. It may even incorporate refractory materials or concrete foundation bases in some applications. This type of module also has the greatest opportunity to achieve the transfer of testing and commissioning hours off site.

Given the scale and mass of this category of module, it is limited to projects with final operational locations with very close proximity to the receiving berth or port and can transport highly over dimensional structures without clashing with public or existing infrastructure. High cost and complexity of overland transportation systems, including transportation equipment and requirements for extensive civil transport corridor preparation make this scale of module less economic for inland project locations.

Module

This category generally refers to structures that extend to the 1000 tonne range and have varying dimensional characteristics similar to the Super Module. Modules capture a concentration of the high density, high value construction hours associated with the base construction commodities. They include all structural commodities, maximized piping, (especially small bore), insulation, electrical tray runs and electrical terminations, equipment installation, instrumentation and tubing and architectural cladding etc.

As a result of their lower overall mass, and in many cases smaller dimensional characteristics than Super Modules, they have higher applicability to coastal project locations but have more application to inland project locations than the Super Module category. The opportunities for testing and pre-commissioning activities prior to final placement remain high with Modules, they inherently contain the key elements of complete process systems and in some cases, some level of pre-placement test or commissioning is possible. Interestingly, a fully complete accommodation unit for a land based site could fall into a module classification if it were delivered to site fully fitted out and ready to be attached to power, potable water and sewerage utilities. Such a Module could be fully tested and proven off site! This conceptual alert may sponsor the future innovations for design of process systems to fit modules rather than pre-assemblies to build systems.

Pre-Assemblies

Pre-assemblies generally fall into a mass range well below 1000 tonne, with a more typical range from 50 to 600 tonne. However, extremely large structurally framed process buildings for land based projects do preside in the current project delivery horizon and very heavy pre-assemblies are known. A pre assembly is by categorization a structure consisting of predominately structural commodity components such as structural members, plate, bins and ducts, floor mesh or decking ready for concrete pour on site, handrails and access steps and ladders etc. A pre-assembly may also include pipe and cable tray as in the cases of pipe racks sections. Invariably the reference to pre-assembly generally excludes major inclusion of mechanical, electrical or process related equipment and the associated higher density of construction hours.

Pre-assemblies have wide application in both coastal and inland projects, they can form the core of the delivery strategy or they can support a full modular delivery. They offer versatility in shipping, transport and site placement methods that make a pre-assembly approach a robust component of an off site and in some cases on site assembly strategy

Flat Pack Panels

This category of pre-assembly is in essence the base structural element of a pre-assembly and a module. They are sometimes referred to as 2 dimensional pre-assemblies due to their small depth aspect. They can be configured as floor, wall or roof panels that can be assembled on site with relative ease and high efficiency. Flat pack assemblies offer strong possibilities for shipping and transport efficiencies due the ability to condense large packages of panels into a single transportable load. These building blocks can be used to construct site based pre-assemblies or modules in the case of multiple work front delivery strategies that have restrictive transportation and logistics parameters.

Flat pack panels are versatile across the range of project locations from coastal to inland positions. They are excellent targets to optimize shipping efficiencies by filling unused oversize cargo vessel spaces. They can also move many hours off site when coupled with more encompassing pre-

AUTHOR - MARK STARKOFF, MANAGING DIRECTOR SIGMA ENGINEERING PTY LTD (31-1-2010) (COPYRIGHT ©)
www.sigmaengineering.com.au - info@sigmaengineeriing.com.au

assembly and modular delivery strategies.

Pre-Fabricated Site Erected Elements

This category of elements is the commonly referenced "stick build" fabricated elements. They should be considered to include the maximum complexity such that the elements can be fully shipped, transported and handled by conventional, non oversize load carrying ships, road transport equipment or site installation equipment. These stick build elements generally form at least 25% to 30% of the total quantities of all land based modular and pre-assembly delivery strategies. These "stick build" quantities require close integration and association links to modules, pre-assemblies and flat pack panels. For greatest efficiencies in cost, "stick build" elements should form part of the oversize cargo shipments in a module or pre-assembly delivery strategy to minimize bulk freight costs through shipment with modules or pre-assemblies yielding positive benefits to overall project economics.

GENERAL CONCEPTS RELATED TO MODULES AND PRE-ASSEMBLIES

The following brief introduction to key points applicable to modules and pre-assemblies is not intended to be comprehensively inclusive, rather, to frame the readers thoughts to assist in looking at a module from a wider perspective.

- Modules, pre-assemblies and flat packs are fundamentally composed of commodities of construction such as structural steel, piping, equipment, electric and instrumentation etc. All of these commodities form the basis of the total quantities of the module, pre-assembly or flat pack;
- Inclusion of the maximum high value construction hours by maximizing the inclusion of commodities in a module, pre-assembly or flat pack is the principle objective and yields the greatest positive economic position;
- The more labor intensive a commodity is to install on site, the more benefit it will deliver to a positive economic position if it is installed off site in a module or pre-assembly. Commodities such as piping, especially small bore, insulation, electric tray, local isolations and terminations, Motor Control Centers, equipment installation and electrical isolations, lighting, instrumentation and tubing, architectural cladding etc have strong positive contributions to positive module and pre-assembly economics;
- Pre-assembly, (as opposed to modularization), is usually adopted because the governing process envelope is to large for a module, the equipment is too heavy or not economically incorporated at off site locations or the logistics network complexity and economics does not support the introduction of the equipment off site;
- Pre-assemblies consisting predominantly of structural steel, floor mesh, handrails etc can still be highly economic for off site construction; the mix of 3 dimensional assembly and panelling needs to be carefully balanced to maximise positive economics and the site based inclusion of equipment and high density construction hours;
- As the mass of a module or pre-assembly increases, the cost for shipping and transport increases, but the potential to load the module or pre-assembly with high value construction hours considerably increases;
- As module size and mass increases, options for shipping and transportation reduce. Super modules find only a small pool of options for shipping while pre-assemblies of less mass find a wider range of shipping options;
- Ocean acceleration forces affect all modules and pre-assemblies in direct proportion to their inherent dimensional and mass characteristics, and the location of their center of gravity relative to the composite metacentric height of the transport vessel and the module or pre-assembly. Smaller modules or pre-assemblies by nature are less affected by ocean acceleration forces than larger pre-assemblies or modules;
- The maximum footprint or area of a module or pre-assembly is ultimately governed by mass distribution over the footprint and the ability of a transport system to lift, move, transfer or place the module or pre-assembly. Modules consisting of multiple pre-assemblies can be shipped as a single unit and land transported as pre-assemblies.

AUTHOR - MARK STARKOFF, MANAGING DIRECTOR SIGMA ENGINEERING PTY LTD (31-1-2010) (COPYRIGHT ©)
www.sigmaengineering.com.au - info@sigmaengineeriing.com.au

MODULARISATION AND PRE-ASSEMBLY PAPER #2 DEFINITIONS AND SCALE

FURTHER DISCUSSION

The holly grail of land based project delivery is the all encompassing, completely operationally module, ready for energizing after placement. This prized objective is common within the offshore Oil and Gas industry. Sadly, from a land based project perspective, it is a difficult deliverable to manifest from not only a conceptually accepted possibility, but also from the practical limitations of equipment and process designs that shackle such lofty goals.

"This "holy grail" of land based modules, fully tested and commissioned prior to placement has proved an elusive achievement on a large scale. "

The ultimate level of completion extends to a point where a module can be fully tested and commissioned as a "process logic unit" prior to final placement in its operational position. This "holy grail" of land based modules, fully tested and commissioned prior to placement has proved an elusive achievement on a large scale. However, looking at the concept in more detail it is fully applicable, and regularly achieved in a smaller scale on compressors, generators, hydraulic power packs etc, and not surprisingly, pilot plant scaled projects. The limiting factors for larger scale application seem to relate to the process requirements, and the ability to condense the key equipment and processes into a scale acceptable to the applicable land based industries. Engineering for land based minerals processing, petro-chemical and heavy industrial projects will require the redevelopment of the basic design for processes such that they can be contained within an economically shipped, transported and handled dimensional envelope. In some cases, the basic process technology and physical requirements of a process just do not permit a condensed dimensional envelope to be an achievable consideration.

Super modules seem to be our most promising near term hope of accomplishing the maximum potential benefit of a modularized project delivery. By nature, super module and large module scale delivery programs are fully comprehensive from the perspective of inclusion of the maximum density concentration of high cost construction hours from all commodities and most definitely include high value hours associated with equipment installation, small bore piping, instrument tubing, electrical terminations etc. These are the key requirements to test, if not fully commission. The limitations for application of these highly prized module types is the limited economic applicability for inland project locations and the high shipping, transportation and handling costs. These limitations aside, they are most certainly a prize well worth pursuing and the establishment of economic applicability on a project specific basis.

Given that it is not economically possible to ship and transport super sized modules to inland locations, another option may be available for the project beleaguered by inland isolation. There has been some success in fully modularising a building offshore, shipping it as a single module. The module can be subsequently reduced to its component pre-assemblies when it arrives at the project port and they can be transported to site. Innovative application of design can facilitate the splits and junctions such that testing could be achieved off site and the corresponding hours removed from site. All is not lost for the land based project.

In contrast to maximizing the out of position construction hours, pre-assemblies offer a greater spectrum of opportunity for the less construction hour dense process plant from both a project delivery scale and assembly location perspective. Pre-assemblies can form the core of a project delivery strategy or can be used to supplement and extract the maximum value from a modular delivery strategy. Pre-assemblies are by composition more economically flexible than the more composite fully modular option. They offer greater options for fabrication and assembly location and access a greater pool of suitable shipping and less demanding land transportation requirements. Pre-assemblies also offer the capacity to incorporate quantities that may otherwise be allocated to site erected quantities in a fully modular delivery. This supplementary enhancement to a modular approach can be used to increase the extent of off site construction and improve economics. Given their inherent flexibility they are uniquely adaptable to high quantity remote land locked projects. The ability to design pre-assemblies for the inclusion of key equipment either off site or on site makes them a very versatile design option suitable for offshore, off site or on site pre-assembly prior to final installation. The versatility of scale and design of a pre-assembly also provides key flexibility for range of fabrication and assembly facilities, shipping options and capacity for a more versatile range of oversize land transport options. Another critical and key aspect of pre-assembly versatility is the method of placement, jacking, crane or trailer placement can be cost effectively applied to this style of execution delivery.

Pre-assembly can also be reduced in scale to a point where they are complex wall, floor and roof

AUTHOR - MARK STARKOFF, MANAGING DIRECTOR SIGMA ENGINEERING PTY LTD (31-1-2010) (COPYRIGHT ©)
www.sigmaengineering.com.au - info@sigmaengineeriing.com.au

structure panel systems. These panels are sometimes referred to as 2 dimensional pre-assemblies due to the small depth aspect. These types of pre-assemblies can provide significant advantage where the economics of transportation and shipping preclude larger more complex pre-assemblies. They can be particularly attractive for site locations with large land transport distances and poor access road infrastructure.

CONCLUDING DISCUSSION

While the size, mass and physical presence of grandiose modules and pre-assemblies will always will capture the attention of project owners, designers and project management teams, it will always be the humble base construction hour on site and its economic transfer to a lower cost location that will finance all modular and pre-assembly project delivery models regardless of the prevailing scale.

The base construction hour is the unit of currency of the module and pre-assembly delivery market. The description of these structures, constructed and assembled away from their final operational location must identify and convey the same framing categorization and description of inherent value to all stakeholders related to land based projects. A common description for scale, complexity and value is a fundamental requirement for common communication across industry sectors and allows a common platform the overall growth and development of the project delivery method.

As such, there needs to be some formalization within the module and pre-assembly delivery community as to the applicable terminology for land based projects. Either by formal institute development or by consolidated agreement of leading commercial suppliers of design and delivery services, the underpinning requirement is for a base platform of terminology that brackets and defines the value and complexity levels held by a consolidation of construction hours completed in locations other than their final operation location.

The requirement for common collective terminology to describe the level of sophistication, complexity and value that a module or pre-assembly holds is more than an administrative requirement. It is the first step in coalescing the hard won progress in the area of modular and pre-assembly project delivery technique into a structured project management and delivery methodology that can be applied to projects with predictable and reproducible standards.

AUTHOR - MARK STARKOFF, MANAGING DIRECTOR SIGMA ENGINEERING PTY LTD (31-1-2010) (COPYRIGHT ©)
www.sigmaengineering.com.au - info@sigmaengineeriing.com.au