Is Bigger Better?

The Multiple Benefits of Modularization in Heavy Industrial Construction

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ABSTRACT

The following document offers an engineered heavy rigging and heavy transportation contractor's approach to highlighting the benefits of modularization as compared to conventional or “stick built” projects. Of course, the intent is to persuade the reader, where it is suitable, to choose a route for construction that includes handling and moving large loads. However, more than just a “use us” pitch, this approach evaluates the general benefits of schedule, safety, quality, and labor resources for the overall project. The question of which method to use is answered with a broad list of principles aimed at understanding the essential aspects of the suitable projects.

INTRODUCTION

In 2001, a large power producer in the southern states introduced me to the concept of building selective catalytic reduction units (SCR's) in large modular sections that would have to be handled with one of the largest cranes available at the time. Barnhart owned what proved to be the ideal crane for such a project. It was a high capacity (rated as an 1800T class) crane, with a relatively small footprint and a boom configuration that allowed for handling loads as heavy as 77 tons at a 361 foot radius. The power producer wanted to handle the heaviest loads possible while reaching over an operating boiler house in an older, very cramped seven unit coal-fired plant. As the rigging engineer, I was tasked with giving the design team at the power producer the parameters for what the crane could handle on site. The rest, as they say, is history.

That project set into motion a new way of thinking that aimed at turning every job that came my way into a rigging project. “Build it big, Move it once” became the mantra. While it is true that not every job in the crane and rigging industry fits such a model, the desire to develop a set of principles that evaluated each job for added value in this realm grew. With each new job walk, the thought that the successful completion of the project could involve one big move or one big lift inspired me to think about the benefits of such an approach to the client.

This paper is the summary of a decade of experience in meeting with dozens of customers (General Contractors, EPC firms, Design-Build Architects, government agencies, etc.), complements (suppliers, friends in the industry, etc.), and competitors who all want to achieve similar goals. We want to find a better way to do some good work. Whenever a “better” way is determined, it is expected that others will say “prove it.” In an attempt to do just that, the options in construction methods will be generally set on the table for discussion, a definition for which is better will be developed, projects for application will be reviewed, and one specific case study will be presented.
OPTIONS IN HEAVY INDUSTRIAL CONSTRUCTION

The two options available in the construction of heavy industrial facilities are conventional ("stick-built"), modular, or a mixture of both. Most jobs are a mixture of both. Deciding where the breakeven point is for using conventional and modular construction is unclear. Estimating is difficult in both cases, and the mixture of the two presents an array of challenges. Nevertheless, almost all projects will involve both. It is also true that there are some projects for which stick building is the only option. Some modularization makes sense (subassemblies) in virtually every case. But, especially in the case of maintenance in existing plants where space in a limited area is unavailable, piece by piece demolition and rebuilding is clearly the way.

But what about new construction or greenfield projects? What about older sites who are looking to add a process to their slate of products? What about large expansions for refineries that have not added to capacity in years? What about the next generation of nuclear power plants, poised to be erected in familiar and unfamiliar places?

In analyzing the decision whether to build conventionally or use a modular approach, the elements of time, money, and quality are always the primary measures:

“A plant should be modularized if it can be engineered, designed, shop assembled, tested, transported, installed, and commissioned at less cost and time than on-site [stick built] construction would afford and where very close control of quality or other similar factors during the course of construction is important.” (Malik & Key)

Only one other factor is of such importance as to be included with time, money, and quality. Human risk, or safety, should be another category for evaluation. Each of these categories will provide the guidance needed to evaluate the use of modularization over conventional construction. Still, even if the data can be provided to demonstrate the benefits of modularization in time, money, quality, and safety, many will still decide to build using conventional methods.

The reasons for this decision are simple. In many pockets of Heavy Industrial Construction, the experience level for implementing a modular concept is not available. Even though the approach has been around for some time, and the success of numerous projects has depended on it, modularization is still novel to many. Project Managers, engineers, and site leaders who are not comfortable with the approach can influence the decision towards their areas of expertise.

Another reason why firms would still choose a conventional approach is the argument of business model. Many construction firms have been built on the premise that revenue is generated on time and material alone. If material stays virtually the same but modularization reduces man-hours drastically, then overall revenue for some companies is going to be affected. This is the argument of feeding large labor forces. It is understandable for companies who are built as craft labor providers. It is just not efficient based on the principles of time, money, quality, and safety.
DEFINING “BETTER”

The variables of time, money, quality, and safety define “better” in the case of modular construction projects. Many assumptions are being made as the benefits of modularization are enumerated. They should be evaluated with each individual application:

Time

- Reduced on-site erection schedule requirements. Some estimates have the time on-site reduced by a full 50% for modular construction methods.

- Condensed schedule, due to parallel paths of permitting, foundation preparation, and fabrication. It is also true that foundations for modular-type installations are often easier to design and develop on-site.

- Better planning and avoidance of weather delays (planning for suitable or preferential seasons). In some cases, sites may even utilize large tent-like structures to mitigate weather impact. In any case, modular construction schedules can be managed to fit tighter windows.

Safety

- Fewer man hours on-site translate into reduced safety risks.

- Increased engineering oversight translates into better JHA’s and HASAP’s.

- Less elevated and less congested workspaces (reduction in major incident exposure; 277 out of 816 Fatal accidents in the category of construction for 2009 were the result of falls) (www.bls.gov).

Labor

- Productivity of shop craftsmen can be 30% to 50% higher than the field (Malik, Modularization).

- More flexibility for available craft labor. Location of site can push labor costs much higher.

- Labor disputes in fabrication are often easier to resolve than those in the field.

Quality

- Building modules in the shop provides for higher quality than “stick built” in the field.

- Quality control of materials is better managed in the fabrication shop than in the field.

- All highly skilled installations (electrical, paint, refractory, insulation) can likely be done in the shop.

These advantages are only the start. There are other factors that tend to lend to modularization as an appropriate solution for construction projects. They include the ability to manage loss control due to the fact that materials are more secure in a shop setting as
opposed to on site. Reduced schedules mean that many organizations can be first to market with a particular product or process. This first to market feature is often the competitive advantage businesses need to set themselves apart. For projects that affect the public directly (bridge replacements, for example), the quality of life provided by modular approaches is hard to argue against. This is why states like Utah and Massachusetts have committed to accelerated, modular type projects for virtually all of the new bridge projects.

“For currently operating U.S. nuclear plants, the average construction period was 9.3 years; the longest was 23.5 years. In Japan, close attention to modularization and construction sequencing has reduced construction times for the ABWR reactor design. In fact, units in Japan have been constructed in less than four years! One of the secrets to this speed was using modular construction techniques.”

www.powermag.com

DOES IT FIT?

The following examples are intended to give a small sampling of projects where modularization or a mixture of conventional and modular construction provided benefits in concert with the arguments given above.

3rd Avenue Bridge, New York, NY – The 300 ft long swing span bridge connecting Manhattan to the Bronx was replaced in 2004. The project was unique in that the replacement bridge (all 2800 tons of it) was completely built in Chickasaw, Alabama, just north of Mobile. The contractor who was awarded the construction of the bridge was in Russellville, Alabama. The port of Chickasaw provided a reasonable location to set up shop and build the bridge on a suitable barge for transport.

Once completed, the barge with the new 3rd Ave Bridge on the deck was floated through the Mobile Bay, around the Florida peninsula, and up the Harlem River in New York. It was docked for a time until the operation to remove the old bridge and install the new could be coordinated on site. The removal of the old and the installation of the new was accomplished primarily by the use of two additional barges fitted with falsework to support the bridge from the sections of the span outboard of the swing bearing island. Using primarily the ballasting of the barges, the new swing span was set in place in a weekend.

Refinery Expansion in Port Arthur – This expansion project is providing Port Arthur with the largest refinery in the US by taking refining capacity to 600,000 barrels per day. As a part of the expansion, the owner used modular construction for many of the conduit/pipes racks, process units, etc. where modules were constructed in several offsite shops. Dozens of modules from 400 to 1000T and beyond were manufactured, weighed, rolled on to a suitable barge, and tied down in Maine, South Carolina, and Mexico. Once they arrived, they were rolled off and transported to a waiting crane hook for setting into place.

Cell Tower Relocation – When traveling south on I-55 entering into Jackson, Mississippi, a cell tower would greet the driver in the form of the Washington Monument. The communications
company covered the cell tower in a façade reminiscent of the famous DC monument. (It was a bit startling to come upon it on the side of the Interstate.) The company decided to move the homage to Washington and faced the challenge of how to do so with the least cost impact and hassle. The solution was to reinforce the tower structure for lifting it from the bottom. This enabled a modular platform trailer to drive underneath the structure, lift it off of its foundations, drive to the new site, and set it on its new base.

**Lock Gate Replacement** – Like the Panama Canal, each of the locks on the Alabama River, Black Warrior River, and Tennessee-Tombigbee waterway, are 600 feet in length with 110 feet of space within the lock walls. The gates (miter style) used to seal the lock are 85 feet tall, 65 feet wide, and 7 feet thick. They each weigh 360 tons. Interestingly, the gates were manufactured in St. Louis near the contractor’s facility. They were transported via barge to the Black Warrior River near Tuscaloosa, Alabama to replace two aging gates at the John Hollis Bankhead Lock and Dam. The lock was one of several that are needed to feed the local foundries and power plants. Conventional replacement would shut the lock down for many months and potentially years. Instead, the replacement was designed as a heavy rigging project, and the outage for replacement was 30 days. The gates were functional in half that time.

**Pulp and Paper Plant** – In Oklahoma, a paper facility needed to move two 800 ton precipitators from their perch one hundred feet above grade to a new elevated location elsewhere on plant property. Modularization allowed the owner to evaluate the ability of the precipitators to be moved in one piece. Having approved the method, the units were skidded to a temporary hoisting tower structure that allowed the units to be lowered to the ground where platform trailers were able to transport them to the new structural steel supports. They were then lifted up and skidded horizontally into position.

**Combined Cycle Power Plants** – In many parts of the country, the trend in the last ten years has been to build combined cycle power plants. Many components of these plants are already large enough to make for a significant heavy rigging, heavy transport project. However, other parts of the plant are “stick built.” The condensers for the steam cycle are some of those components. Yet, it was not uncommon for the condenser units to be built out completely in a remote location to be hauled, set on a skid system, and then skidded into position under the steam turbines. This allowed for parallel paths for multiple areas of the site.

**Arena Projects** – The Dallas Cowboys have a new home. That new home has the largest, most technically advanced scoreboard on the planet with over 11,000 square feet of video board. The frame that those boards are mounted to weighs about 800 tons. It was built out as one unit on the stadium floor and then lifted in one shift using four strand jacks. The alternative would have taken many more months of difficult erection processes.

**Refinery Maintenance** – Aruba has some of the most beautiful beaches available. The island is also the home of a large refinery. Part of a maintenance outage included removing and replacing a large section of the convection furnace. This section was 400 tons and required a very unique traveling gantry crane in order to complete the scope.
California can claim some of the largest refineries in the country. In Torrance, one owner had decided to add two Electro-Static Precipitators (ESP’s) to their already congested site. The two precipitators were 81 feet long, 63 feet wide, 90 feet high and weighed in at an estimated 2800 tons each. In planning to add the precipitators, several specific issues faced the design and construction team:

- Space constraints (for constructability)
- Sensitive areas impacted by construction planning (Alky unit)
- Limited access for construction equipment
- The construction plan would cut off the “main vein” of traffic on site
- Outages for construction tie-ins would be very costly
- Labor costs in California are very high

With all of the challenges associated with conventional construction methods, several engineers (early in the process) considered using a modularized approach. The approach was to completely build out the two ESP’s in a less sensitive, less traveled, less congested part of the refinery. This presented significant advantages.

- Uninterrupted production for the refinery while the units were built
- The main avenue for traffic was unimpeded for the months of erection
- More controlled safety program for the fabrication area
- Higher quality in the build-out process.
- Shorter duration for fit up and commissioning.
- Reduced labor requirements for overall project
- Reduced schedule for build-out and installation

The choice seemed obvious. Selecting the path of modularization early on allowed the heavy rigging and heavy transport vendor to integrate their equipment into the plan so that the effort appeared seamless. As the two units were completed, the payoff was about to be realized.

One significant step that had to be inserted due to the decision to build the units out and move them was the requirement to ascertain a total weight with accurate results on the location of the center of gravity. The only way to obtain this data was to lift the ESP’s at several intervals throughout the process to ensure that the capacity of the lifting and transport equipment would not be exceeded. This data was obtained using sophisticated load cell systems and synchronized jacking operations. The determination of weight and location of the center of gravity are key data points for any lift, and especially when modularized components are concerned. The lifting and transportation operations are critically dependent on this data.

The actual lifting and transport of the units was straightforward. Using four high capacity strand jacks, and a set of substantial structural steel lifting beams, the units were raised off of the ground to a height that would allow them to be loaded onto supports and hydraulic platform trailers. Now loaded, the units could be driven around the refinery, through the sensitive Alky
unit, and over the steel column supports for the final fit up. This process was used for both units.

The results were impressive. Through the lifting, transport, setting and disassembly process, there were no safety incidents of any kind. This includes property damage (fender benders), personal injury (first aids, OSHA recordables, etc) or any violations of any of the Refinery’s stringent safety requirements. Moreover, the units were moved and set on their new support structures from beginning to end in 16 days (includes both units).

SUMMARY

In summary, the “better” method is so because:

- Reduced Schedule means reduced overall cost.
- Reduced Safety Risks means success in general, and reduced overall cost
- Reduced Labor requirements means reduced overall cost.
- Reduced concerns about quality means reduced overall cost.

To realize these benefits:

- Start design and engineering concepts for modularization early in the planning process. If the plan does not start with modularization, it is likely not to happen.
- Don’t fail to realize the full impact of the pre-planning and engineering for modular design. The fact that engineers are involved means that key safety preparations should be fully developed and carefully implemented.

- Use as much shop quality that can be provided rather than site fabrication. Insulation, refractory, electrical, etc. can all be done with greater care and higher reliability in the shop.

- Involve handling specialists early in the design to address road, water, and railway requirements through the design phase. Also consider the need to handle the loads from the top versus the bottom. Where will their equipment be able to apply loads? It makes a difference. Changes in the field are costly.

- Durations for the heavy transportation and heavy lifting can be minimized through good planning. Shorter durations mean lower costs in using heavy equipment.

- Enter into discussions with the building and trades early on. Many of the craft squabbles about modular work can be settled in assignment without delays caused by claims on site.

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