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Modifying Your Cranes to Serve Larger Ships

Growth in the size of container ships continues to shape port infrastructure. In addition to deeper approach channels and wider turning basins, larger ships require larger cranes. How large do the cranes have to be? What are the limitations on crane size? What else must be considered?

The nature of the shipping industry drives constant infrastructure upgrades

Global shipping grew at an average pace of nine percent per year between 1980 and 2013. In spite of this exponential growth, the shipping business has typically been characterized by low profit margins. Low margins may be driven by a constant inflow of new and ever larger ships meant to reduce operating costs. The operating cost per container is lower on a larger, fully loaded ship.

In 1980, the average ship size was 1,000 TEU and the largest was 3,500 TEU. In 2014, globally the average ship size is 3,500 TEU and the largest is 18,500 TEU. According to the US Department of Transportation, the average ship calling at US ports increased in size an average of four percent per year between 2002 and 2014. For the US East Coast, the average ship size increased from 2,900 TEU to 5,000 TEU in this period.

According to the Alphaliner database, the largest ships calling at US East Coast ports are 9,200 TEU and 18 containers wide. In the current rotation for the West Coast, the largest ships are 11,700 TEU (18-wide) although ships up to 13,800 TEU (20-wide) have called in the past. Meanwhile, 15,000 TEU (22-wide) and 18,000 TEU (23-wide) ships now serve trades between Europe and Asia, and it is reasonable to expect these ships will soon also call at US ports.

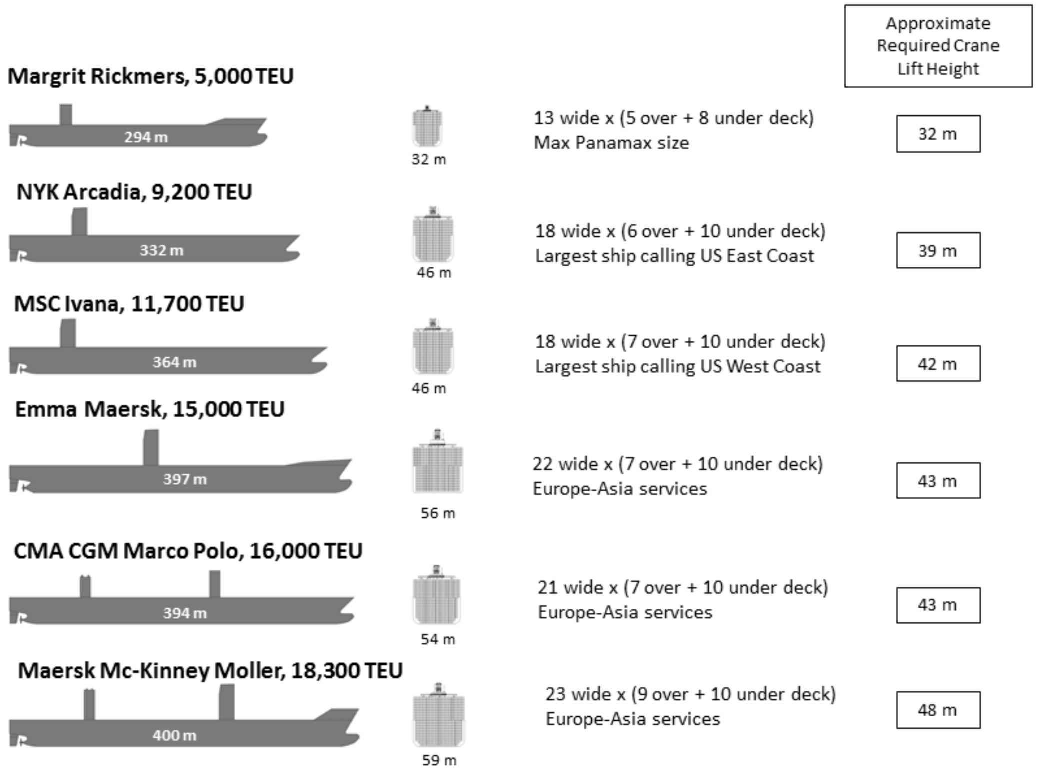

Figure 1: Important ship sizes currently in service

New ship deliveries in 2014–2015 will increase the available global TEU ship capacity by nearly twenty percent. Eighty percent of this new capacity is in the 10,000 to 18,000 TEU range. The expected growth of demand is about nine percent over this period.

The biggest ships are more cost efficient than smaller ships when fully loaded, but cost more to operate per TEU when partially loaded. Therefore, the bigger ships will be filled first and will continue to displace smaller ships on all routes. The Panama Canal expansion from 13-wide to 19-wide vessels will further accelerate this trend.

The state of the existing crane fleet and the need for crane raises

Fortunately, many crane orders in the past ten years had conservative outreach requirements and many existing cranes are suitable for 22-wide ships, typically requiring an outreach of approximately 63 meters (m).

Extra lift height makes a crane structure more flexible, moves the operator away from the load, and may impact the operation if it is excessive. Rather than initially specifying extra lift height in anticipation of larger ships, many owners ordered new cranes prepared for a future raise. For this reason, there are now many cranes with adequate outreach but insufficient height for the big ships requiring lift heights in the 41 to 48 m range. Since these cranes typically are less than ten years old, a crane raise is often a better choice for the operator than buying new cranes.

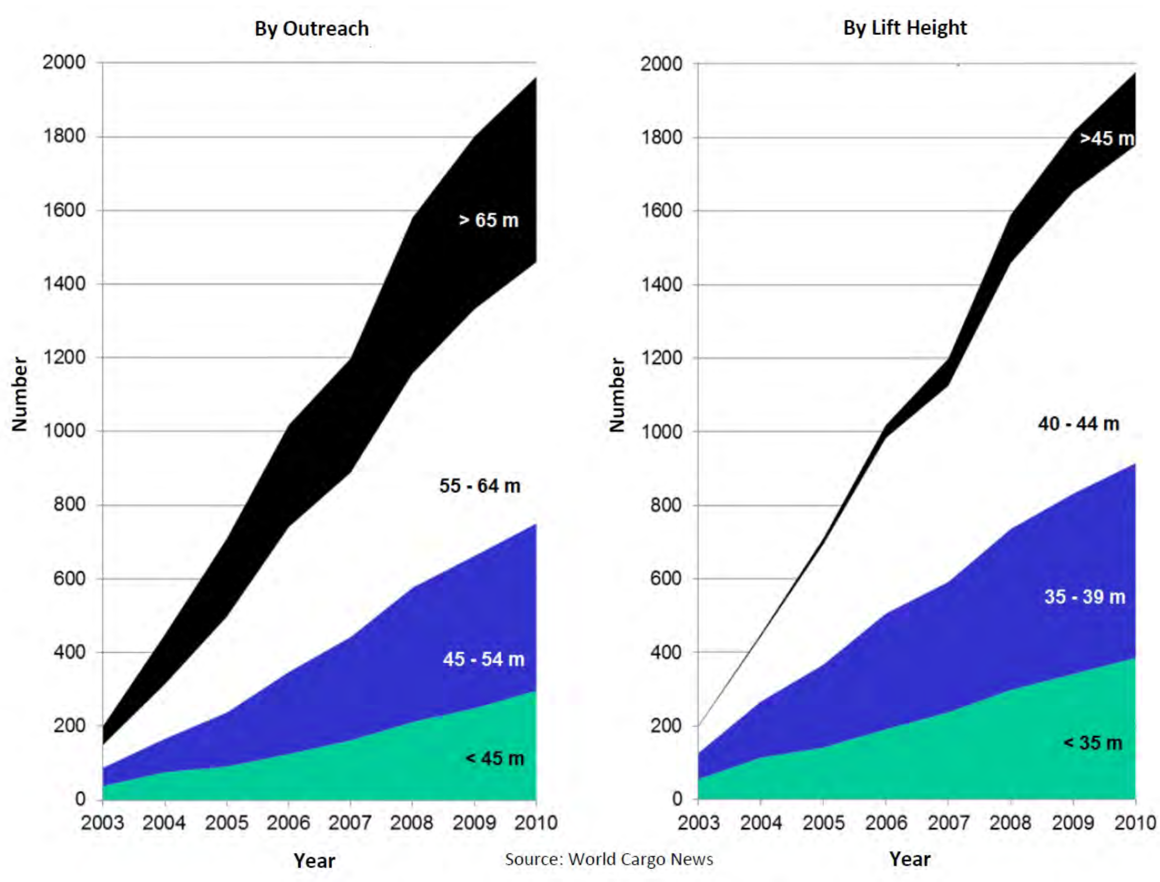

Figure 2: Outreach and lift height of STS cranes ordered 2002–2009

As a result, a number of crane modification projects of already large cranes are underway on the US West Coast, and more projects are planned. Cranes have recently been raised in Antwerp, Belgium; Algeciras, Spain; Yantian, China; and Hong Kong, and are planned at other terminals in Spain, Germany, and Sweden. These raises will typically provide lift heights between 44 m and 47 m under the spreader.

The largest ship today, the Maersk Triple-E class, is 59 m wide with a maximum of ten high cube containers (2.91 m high) under deck and nine over deck. The maximum draft of this vessel is about 16 m. If a high cube container is lifted over this level ship with 1 m clearance, 12.5 m draft, 2 m height of crane rail over mean high water, 3.5 m height of ship keel and hatch cover, all conservative assumptions, then the required lift height to handle the largest ship in service today is 48 m.

Crane raises and infrastructure

How much a crane can be raised or its outreach increased is practically limited by the infrastructure capacity and cost. Typically, the first step in a crane modification project is to determine the maximum amount of raise and outreach that can be added without exceeding the allowable wharf loading.

On the US West Coast, crane raises often incorporate seismic retrofit to improve seismic performance. With a retrofit, raising cranes in the range of 8 to 10 m will result in a wheel load increase in the range of 1 to 3.5 tonnes per meter due to the weight of the new structure and another one to two tonnes per meter due to operating wind loads. If the cranes are already designed to the new seismic standards, the increase in weight and wheel loads resulting from a crane raise retrofit will be less.

On the US East and Gulf Coasts, the impact of a raise on operating wheel loads will be similar, but storm wind loads rather than seismic criteria will govern the design. An important consideration when raising cranes in a region with hurricane wind loads is the increase in tie-down forces to the wharf.

In considering the load capacity of the wharf, engineering analysis often justifies greater capacity than indicated in the original design criteria. The reasons for this may be one or more of the following: the allowable load shown on the drawings is the design load rather than the as-built capacity; modern analysis methods predict strength more accurately than earlier methods; if the crane is weighed the dead load is known more accurately so the dead load safety factor can be reduced; the actual pile capacities are larger than used for the original design. Examples of modern analysis methods include finite element and strut-and-tie analysis.

Extensive crane modifications are feasible. The example shown in Figure 3, from a Liftech study in 2012, increased the crane lift height by 6.4 m and outreach by 4 m. The backreach was also extended and ballast was added in the backreach to reduce waterside wheel loads. The project also included a gage change from 30 m to 35 m.

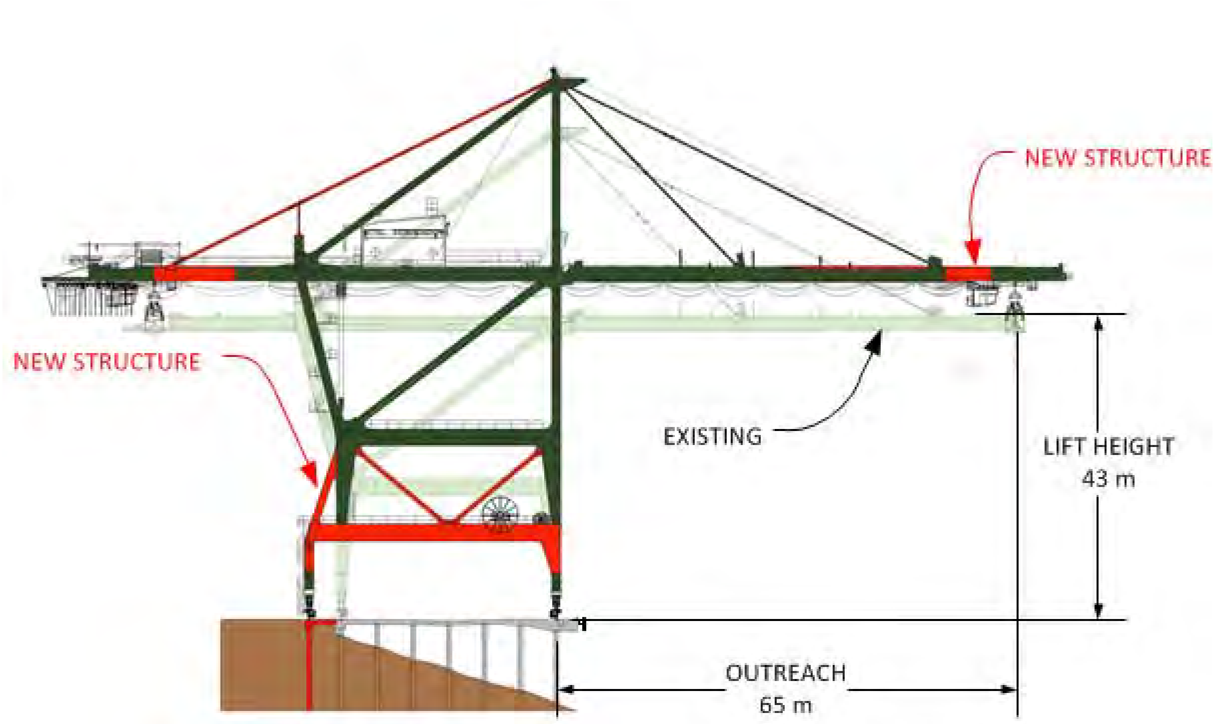

Figure 3: An example of a crane modification project showing new lift height and outreach

Recent crane raise projects on US West Coast

The main cost component of a crane raise is the cost of additional structural steel required for new leg segments, portal beams, and some local strengthening. The added steel weight is in the range of 100 to 165 tonnes for a raise of between 7 m and 11 m, satisfying stringent seismic requirements.

Some West Coast port seismic provisions are intended to protect wharves from damage from increased lateral displacement due to the seismic forces from the cranes. The seismic forces from the cranes can be reduced by decreasing their lateral stiffness. However, a reduction in stiffness usually results in excessive lateral displacement during normal operation. Clearly, the requirements for wharf seismic performance conflict with those for crane operational performance. The required seismic performance can be achieved by one of the following approaches: keep the crane stiff and make the legs strong enough so the crane legs can lift without causing collapse, allowing the crane to rock; design the portal frame so it can bend plastically without collapse; add a damper that reduces the seismic response of the crane. Each method has been used on cranes in Long Beach and Los Angeles ports.

The mechanical and electrical modifications for these projects are a relatively small component. In one case, however, it was necessary to replace the main power cable reel. Often the cranes are already designed to accommodate a raise—the hoist drum has sufficient grooves to accommodate the longer hoist rope without major modification.

There have been several waves of crane raises on the West Coast, most recently in the early 1990s. At that time, Liftech designed a number of crane raise systems for different contractors. These systems are still in use today for smaller crane raises. For cranes ordered in the past ten years, weighing well over 1,100 tonnes, new and larger crane raise systems are required.

The cost of raising a crane on the West Coast, shown in Figure 4, is in the range of 2 to 4 million dollars per crane. We estimate the cost on the US East Coast will be 1.5 to 2.5 million dollars per crane. This design includes provisions to increase seismic performance.

Figure 4: Pier 300 Los Angeles cranes

The Pier T cranes, shown in Figure 5, currently service 20-wide vessels. After the raise, they will be ready to service some of the largest vessels in the world. In this project, a section of the lower legs is removed and replaced with a stronger section. The new portal frame without diagonals is required to meet port seismic criteria more stringent than the original design.

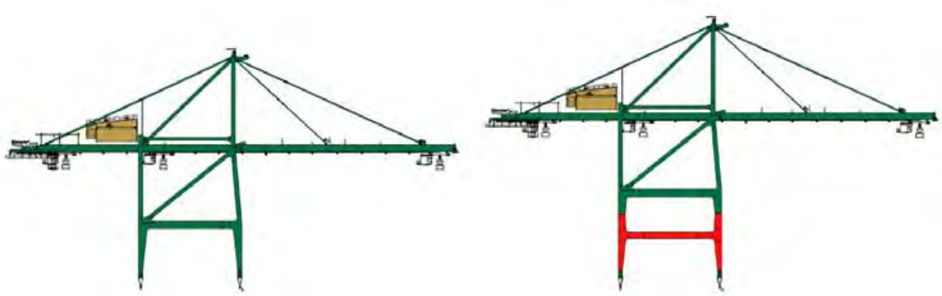

Figure 5: Pier T Long Beach cranes

Although similar in size and capacity to the Pier T cranes, the WBCT cranes, shown in Figure 6, are located inside of the Vincent Thomas Bridge and are designed to allow the upper works to be erected after delivery to the quay. In this project, a simpler design and reinforcing scheme was possible because the original seismic design met current requirements. ZPMC is the contractor.

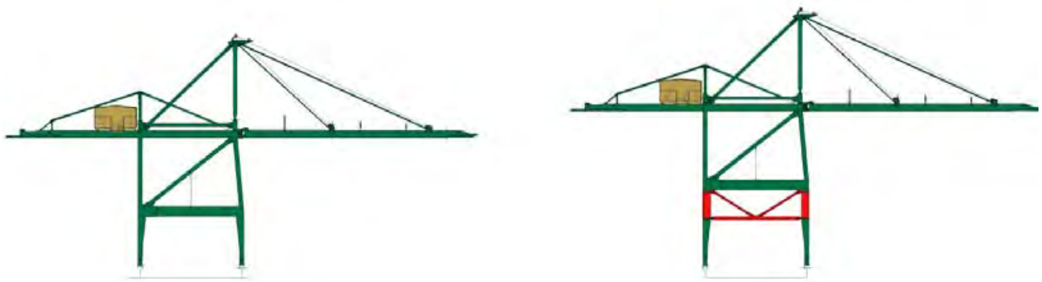

Figure 6: WBCT Los Angeles cranes

The following photos show the raise of the first of these cranes using the new ZPMC jacking frame.

Photograph 1: Crane components for several cranes at the site before the start of a crane raise

Photograph 2: Raised crane on jacking frame, with the new leg sections on the ground

Photograph 3: The raised cranes with the new section installed

Other considerations when modifying cranes

A crane modification involves more changes than the structural work discussed here. Other considerations include suitable modifications to the main hoist system, cable reels, stairs, elevators, wiring, and lighting. Because dead loads and lateral moments are larger after a raise, the performance of the gantry driving and braking systems must be evaluated and tie-down designs must be checked.

Extending the outreach and the boom typically involves rolling the crane back into the yard to provide access for land-based cranes to temporarily remove the boom. Although boom extensions are less common than crane raises, many projects involve extending both. The cost for such projects can vary significantly.

An important consideration when modifying cranes is the operational impact during construction. The out-of-service time for raising a crane is at least six weeks. The contractor needs a suitably large work area. Unless they are rolled back to a separate area, the out-of-service cranes will block part of the quay.

Crane modification projects in the US have typically been completed with a design-bid-build process with an independent engineer preparing a design that is put out to bid for execution by a contractor. In Europe, the design-build process is more prevalent and the owner typically works with the original crane manufacturer. In the Americas, the design-build approach has been used with recent projects executed by ZPMC and Cargotec, and past projects by Konecranes. For these projects, the owner typically retains an independent engineer to review the designs and execution by the contractor.

Modifying your cranes to service larger ships can be accomplished through careful consideration of your wharf capacity, the needs of your customers, and a sound engineering approach.