THE EFFECT OF MEGA-SHIPS

CRANES AND INFRASTRUCTURE

Erik Soderberg, President; and, Michael Jordan, Founder and Chief Structural Engineer, Liftech, California, USA

BACKGROUND

Ultra-large container vessels with capacities nearing 20,000 TEU, also referred to as 'mega-ships' or 'ULCVs', have arrived and more are on the way. Many operators and ports are asking how these vessels will affect their ship-to-shore (STS) cranes and wharves.

This article provides an overview of some of the effects of mega-ships on existing STS cranes and wharf infrastructure. Costs presented in this article are estimates of construction costs based on recent projects, and do not include other costs. Actual costs may vary.

VESSEL CHANGES

Vessels with 18,000 to 20,000 TEU capacity are wider and slightly longer than the previous generation of 12,000 to 15,000 TEU vessels. They have significantly higher container stacks on deck (See Figures 1 and 2). The largest vessel to date is 19,224 TEU, but has similar dimensions to the 18,300

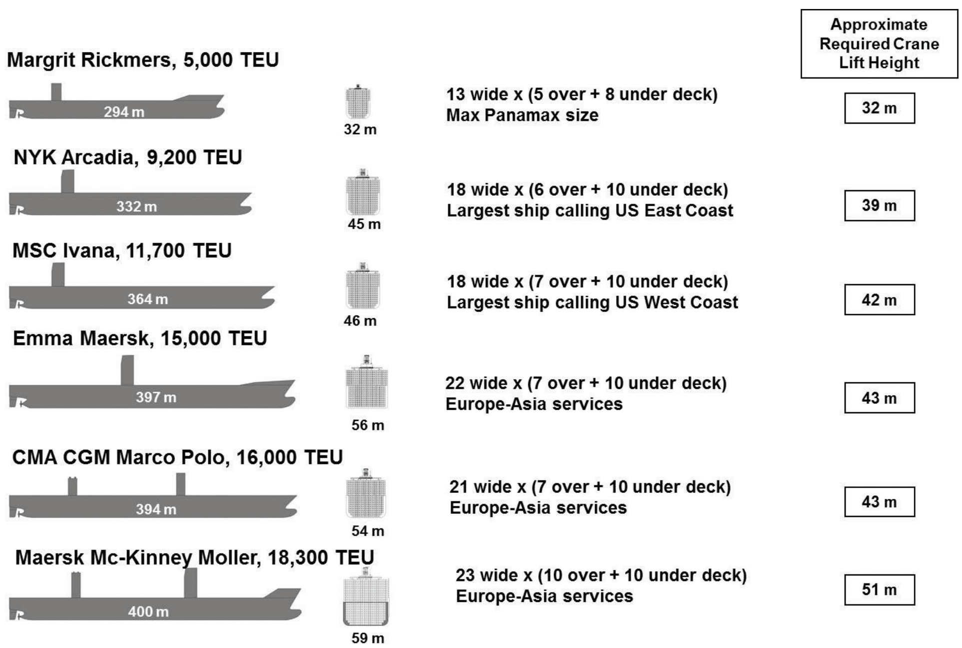

Figure 2. Vessel size progression

Top: Figure 4. Mooring dolphin at IMTT Port of Richmond; Bottom: Figure 3. Crane being raised with a jacking frame

TEU Maersk "EEE" or "TripleE" class vessel shown in Figure 2.

STS CRANE REQUIREMENTS

A lift height above the rail of about 51 metres is required for servicing mega-ships. This will vary depending on the particular vessel, wharf and design water elevations, and desired clearances between containers on the vessel and the lifted container. The outreach is about 60 metres beyond the fender face. This will vary, depending on the particular vessel and desired trolley overrun distance.

Relative to most existing STS cranes commissioned in the last ten years, today's mega-ships require an additional lift height of 5 metres or more, necessitating crane raise modifications (See Figure 3). Most cranes built in the last ten years have adequate outreach, but some may require small extensions or localised modifications to trolley rail and bumpers.

Costs of modifying existing cranes vary significantly depending on the scope of modifications, location and local labour; and to a lesser degree, the associated mechanical, electrical, and other modifications, such as to rope drums, trolley cable reel, machinery house service cranes, cabling, lighting, access ways, new wire rope, etcetera. Estimated costs per crane vary from about $1.5 million for a short raise with low labour cost, to about $4.5 million for a tall raise with a boom extension and high labour cost.

WHARF BERTHING SPACE

Today's mega-ship lengths are not much longer than those of the previous generation. However, some existing berths still require additional length, which is a costly option. A less costly option, if practical, is to add a mooring dolphin beyond the wharf so the vessel can be located closer to the end of the wharf (See Figure 4).

The construction cost of a new mooring dolphin with access structure, lighting, and capstan is about $500,000 to $750,000, depending on location, water depth, soil conditions, construction, and operations coordination.

Some additional STS crane travel length on the wharf can usually be obtained with relatively little cost by installing more compact crane stops and relocating stops closer to the end of the wharf.

BERTHING FENDERS

Fender energy required for vessel berthing is primarily influenced by vessel approach velocity perpendicular to the wharf and vessel mass. Current mega-ship displacements are significantly more than the design mass used for many existing fender systems, but the approach velocity for the mega-ships is less. Often, fenders with more energy capacity are required to meet industry guidelines. However, it is often practical to continue using existing fender systems with acceptable risk of damage to the fender system, wharf, and vessel structure, but with a plan to replace the existing systems with higher energy systems if damage does occur. The cost of replacing the current fender system is usually not justified by the cost of improbable future damage.

Berthing data for the larger ships indicate that the berthing velocity and angles are significantly less than recommended in design guidelines. Additionally, contacting only a single fender is significantly less probable than for smaller vessels.

If replacing fender systems, if practical, we suggest replacing with deeper fenders to limit the fender reaction on the wharf and vessel structures. If larger fender reactions result, confirm that the wharf structure is adequate. Typically, only local strengthening of the wharf is required, at a moderate cost.

New fender systems for mega-ships, rated at 1,500 kN-m, cost about $70,000 per fender system furnished and installed. They can typically be spaced 20 metres to 25 metres on centre. Lesser spacings may be advantageous to align with stronger portions of the wharf.

Wharf strengthening costs will vary significantly depending on the capacity of the existing structure—from a fraction of the fender system cost to more than the fender system cost. If strengthening the existing structure for mega-ships is impractical, for instance if a stronger crane girder is also needed, one alternative is removing the waterside face of the wharf and rebuilding with new structure.

Again, the risk of significant single fender loading is usually small. A study should be made of the berthing conditions and expected berthing speeds and angles before deciding on upgrades.

MOORING BOLLARDS

The wind area of today's loaded mega-ship is significantly more than the design ship used for most existing mooring systems. Forces of up to 250 tonnes per bollard can occur for common design winds and mooring line arrangements. Additionally, ship captains may have concerns about relying on older, lower capacity bollards and can decide they are not willing to moor their ship to a particular system.

Consider site-specific wind speeds and directions based on historical data when determining required bollard capacities as these may justify significantly lower loads.

New bollards with increased capacity are relatively inexpensive. Strengthening the wharf local to the bollard, if needed, is more costly, with costs varying significantly depending on the existing structure. A less costly strengthening approach that has worked on several older wharves consists of drilling holes into the wharf structure and installing grouted high-strength reinforcing.

STS CRANE GIRDERS

STS cranes suitable for up to 23-wide vessels typically have larger wheel loads than existing cranes procured for smaller design vessels. Wheel loads may exceed the design or rated capacity of existing wharf girders. Options to address excessive crane loads include:

- Optimising the crane design to reduce crane reactions and better suit the distribution between available landside and waterside girder capacities
- Analysing or load testing the existing structure and foundation to justify increasing the rated capacity
- Strengthening the existing girders
- Replacing girder systems with new, stronger systems
- Consider increasing the crane rail span for new cranes, as this can reduce wheel loads and will permit additional truck lanes for operations

Optimising a new crane design or a crane modification design will reduce wheel loads

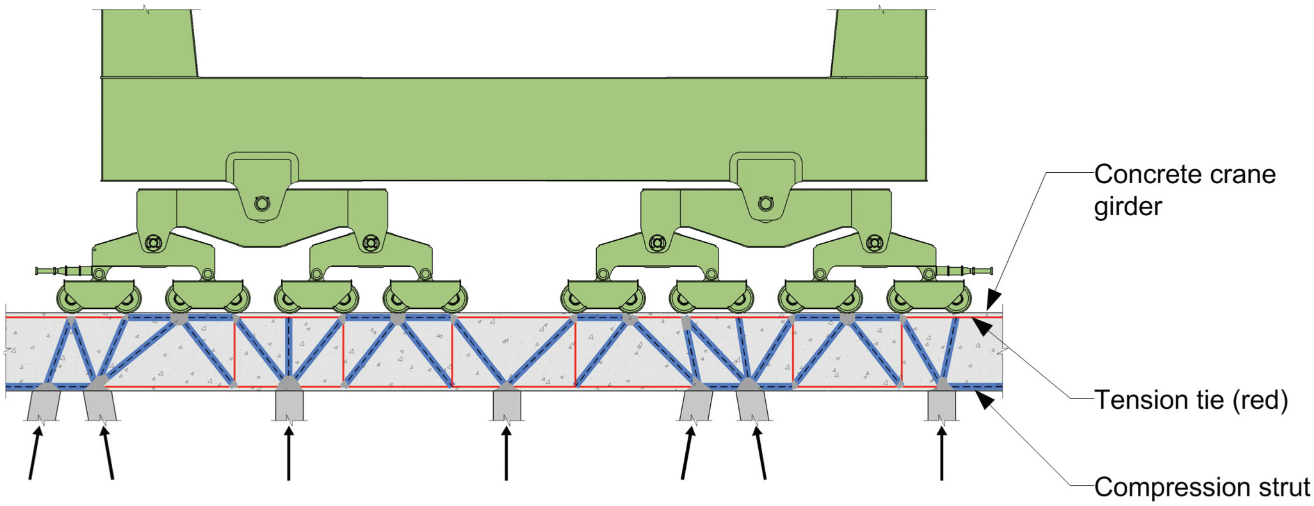

Figure 5. Strut-and-tie girder analysis

some, but there are limits. Typically, this option is only worthwhile if the existing crane wheel loads are not significantly more than the girder's rated capacities.

Analysis or load testing of the existing girder structure to justify additional capacity is usually worthwhile as it is the least costly of these options and often yields significant results. Girders are often designed to have more capacity than stated for the original design loads. A feasibility study by a structural engineer is a good first step to decide if this approach is practical. Feasibility study costs will vary, but are typically less than $30,000. If feasible, studies to justify additional capacity, typically involving one or more types of analyses, are often $50,000 to $100,000 and are usually successful. See Figure 5 for an example of a "strut-and-tie" girder analysis, which can often justify additional girder shear capacity.

Strengthening or replacing a wharf girder will require significant costs, often requiring new piling. If this is required, and in particular if new cranes will be procured, building a new landside girder and procuring larger gage cranes can limit girder construction costs, reduce crane wheel loads, and increase the truck lane space between the crane legs.

SUMMARY

Today's mega-ships up to 20,000 TEU will typically affect existing STS cranes and may affect existing infrastructure.

Existing STS cranes will probably require increases to lift height and sometimes increases to the outreach to service the new vessels.

Increased vessel lengths may require changes to berthing arrangements, extending the wharf or just crane girders, modifications to crane stop locations and structure, adding mooring dolphins, or combinations of these.

Fender berthing velocities and angles are typically much less than recommended in design guidelines; consider recent data when determining berthing energies. If a system with increased energy is required, accepting additional risk with existing systems is often reasonable.

Increased mooring forces may require larger, higher-capacity bollards. Installing higher capacity bollards requires relatively little cost unless the wharf structure needs strengthening, in which case costs can vary significantly. Consult ship captains and local pilots to ensure they will be comfortable with the planned mooring system. Consider site-specific wind speeds and directions when determining bollard loads.

Increased crane wheel loads may exceed existing rated girder capacities. Engineering analyses or load testing can often justify additional capacity. Strengthening existing or building new girders will be costly. If new structure and cranes are required, building a new landside or waterside girder can limit crane wheel loads and girder construction costs.

Consider performing a study to determine your terminal requirements and the most cost effective approaches.

ABOUT THE AUTHOR

Erik Soderberg is Liftech's President and a structural engineer with 22 years' experience in the design, review, and modification of a variety of structural and crane related systems including hundreds of container cranes, over a dozen bulk loader structures, and over two dozen wharves. Other structures include crane lift and transfer systems and concrete and steel floats.

Michael Jordan is Liftech's Founder and chief structural engineer with over 50 years of experience. He is an internationally recognised expert in the container crane industry. He has been involved in container industry evolution since participating in the structural design of the world's first ship-to-shore container crane for Matson in 1958. Since then, he has designed structures of hundreds of duty cycle cranes, prepared numerous specifications for the design of duty cycle cranes, and investigated fatigue damage problems and failures caused by fatigue crack growth and brittle fracture.

ABOUT THE ORGANISATION

Liftech Consultants Inc. is a consulting engineering firm, founded in 1964, with special expertise in the design of ship-to-shore container handling cranes and other complex structures. Our experience includes structural design for wharves and wharf structures, heavy lift structures, buildings, container yard structures, and container handling equipment. Our national and international clients include owners, engineers, operators, manufacturers, and riggers.

ENQUIRIES

Liftech Consultants Inc.
344 – 20th Street
#360
Oakland
CA 94612-3593
USA
Tel: +1 510 832 5606
Email: Liftech@Liftech.net
www.Liftech.net