This technical paper was presented by Erik Soderberg at the Port & Terminal Technology Conference earlier this year in Norfolk, Virginia, United States.

The effect of ultra large container vessels on cranes and infrastructure

Erik Soderberg, President and Michael Jordan, Chief Structural Engineer, Liftech Consultants Inc., provide an overview of some effects of ULCVs on existing STS cranes and wharf infrastructure.

Ultra large container vessels (ULCVs) with capacities around 20,000 TEU have arrived and more are coming. ULCVs are wider and slightly longer than the previous generation of 12,000 TEU to 15,000 TEU vessels and have significantly higher container stacks on deck: ten instead of seven containers high. (See Figures 1 and 2).

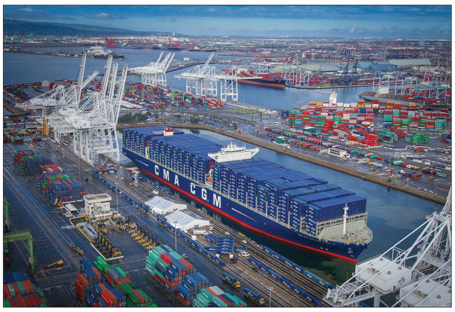

Figure 1: CMA CGM Benjamin Franklin at Port of Long Beach

STS crane requirements

A lift height above the rail of about 50m is required for servicing ULCVs. The lift height will vary depending on the vessel, crane rail and water elevations, and desired clearances between containers on the vessel and the lifted container. The outreach is about 60m beyond the fender face to the centre of the trolley. The outreach will vary, depending on the vessel and desired trolley overrun distance. For a more detailed understanding of the factors involved in deciding outreach and lift height, see: http://www.liftech.net/wp-content/uploads/2014/09/OutreachLiftHeightGuidelines.pdf. Relative to most existing STS cranes commissioned in the last ten years, ULCV's require additional lift height of 5m 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 or trolley rail system to extend travel. Costs of modifying existing cranes vary significantly depending on the scope of modifications, location, and local labour. The scope of modifications can vary significantly and include mechanical, electrical, and other modifications, such as to rope drums, trolley cable reel, machinery house service cranes, cabling, lighting, access stairs and walkways, new wire rope, etc. Estimated costs per crane vary from about USD1.5 million for a short raise with low labour cost, to about USD5 million for a tall raise with a boom extension and high labour cost and improvements to the crane structure's seismic performance.

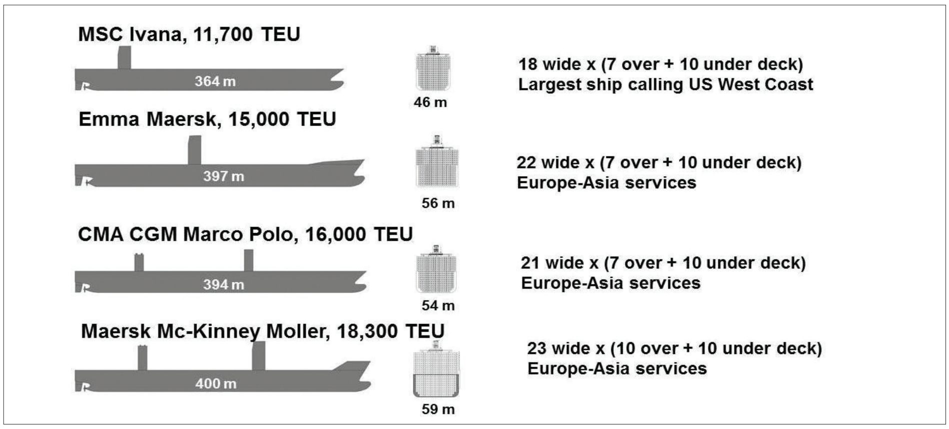

Figure 2: Vessel size progression

Wharf berthing space

Today's ULCV lengths are not much longer than those of the previous generation, however some existing wharves will require additional length - 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). Another option to consider is providing mooring systems that do not require mooring lines. These systems will decrease the required space between vessels and allow for the ends of vessels to extend beyond the end of the wharf. The construction cost of a new mooring dolphin with access structure, lighting, and capstan is approximately USD 500,000 to USD 750,000, depending on location, water depth, soil conditions, construction, and required operations coordination. Some additional crane travel distance can often be obtained at little cost by installing more compact crane stops and relocating the stops closer to the end of the wharf.

Berthing fenders

Required fender energy capacity is primarily due to vessel displacement and approach velocity normal to the wharf. ULCV displacements are significantly larger than earlier vessels; however, the approach velocity is less. Typically, fenders with more energy capacity than existing fender systems are required to meet industry guidelines.

However, it is often reasonable to continue using existing fender systems with acceptable risk of damage to the fender system, wharf, and vessel structure. The cost of replacing current fender systems is usually not justified by the risk of improbable future damage. Berthing data for the larger vessels 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, replace with deeper fenders to limit the fender reaction on the wharf and vessel. If larger fender reactions result, confirm that the wharf structure is adequate. Typically, only local wharf strengthening is required at moderate cost. Wharf strengthening costs will vary significantly depending on the capacity of the existing structure - from a fraction of

Figure 3: Crane being raised with a jacking frame

Figure 4: Mooring dolphin at IMTT Port of Richmond

the fender system cost to more than the fender system cost. If strengthening the existing structure for ULCVs is impractical, for instance if a stronger crane girder is also needed one alternative is replacing or extending the waterside of the wharf 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 velocities and angles before deciding on upgrades.

Mooring bollards

The wind area of today's loaded ULCV is significantly greater than the design ship used for most existing mooring systems. Forces of up to 250 t per bollard can occur due to common design wind speeds and mooring line arrangements (t = metric tonne). Additionally, ship captains may have concerns about relying on older, lower capacity bollards, and they may not be willing to moor their ship at the berth. Consider site-specific wind speeds and directions based on historical data when determining required bollard capacities, as these may justify significantly lower loads. It is also worth considering realistic mooring line arrangements as these may differ significantly from optimal arrangements (See Figure 5). When specifying double bitt bollards, be aware that unless specified otherwise, each bitt will only have half the capacity of the entire bollard. Specifying larger bitt capacities results in little additional cost. New bollards with increased capacity are relatively inexpensive.

Strengthening the wharf local to the bollard, if needed, is more expensive, with costs varying significantly depending on the existing structure. Strengthening by drilling holes into the wharf structure and installing grouted high strength reinforcing is often practical.

STS crane girders

STS cranes suitable for ULCVs typically have larger wheel loads than smaller cranes. Wheel loads may exceed the design or rated capacity of existing wharf girders. Options to address excessive crane girder 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 gage for new cranes, which reduces crane loads and permits additional truck lanes for operations as well

Optimising a new crane design or a crane modification design will reduce crane girder loads 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 since it is the least costly of these options and often yields significant results. Girders often have more capacity than stated for the original design loads. See Figure 6 for an example of a strut-and-tie girder analysis, which can often justify additional girder shear capacity. For more information on this approach, see: http://www.liftech.net/wp-content/uploads/2015/01/PT60_Article_YourWharfMayBeStrongerThanYouThink.pdf. A feasibility study by a structural engineer is a good first step to decide if analysis or testing will probably be a fruitful approach. Feasibility study costs will vary, but are typically less than USD 30,000. If feasible, studies to justify additional capacity, typically involving one or more types of analyses, are

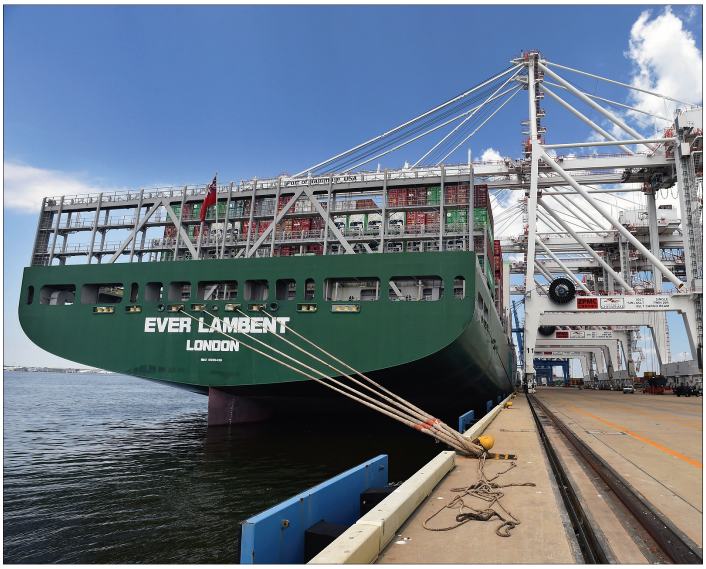

Figure 5: Suboptimal mooring line arrangements - all lines to one bollard

Figure 5: Suboptimal mooring line arrangements - all lines on one bitt

***** Costs presented in this paper and article are estimates of construction costs based on recent projects and do not include other costs. *****

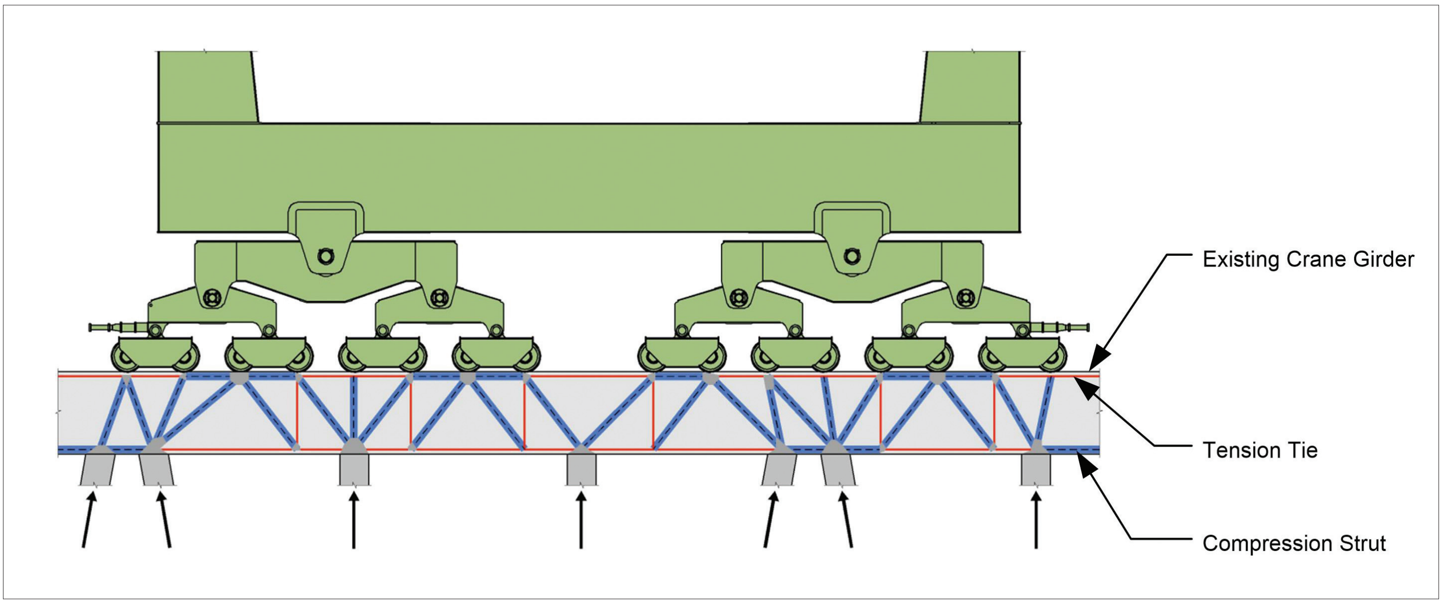

Figure 6: Strut-and-tie girder analysis

often USD 50,000 to USD 100,000 and are usually successful. Strengthening or replacing a wharf girder will often require new piling, and costs can be significant. If strengthening or replacing a wharf girder is required, and if new cranes are to be procured, then building a new landside girder and using 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 ULCVs 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 infrequently require increased outreach. Increased vessel lengths may require changes to berthing arrangements, extending the wharf or only the crane girders, modifications to crane stop locations and structure, adding mooring dolphins, using mooring systems without mooring lines, 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 increase 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, and less than optimal mooring line arrangements when determining bollard loads. Be careful when specifying bollards with multiple bitts that the bitt has the desired capacity. 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. Finally, consider performing a study to determine your terminal requirements and the most cost effective approaches. WPD