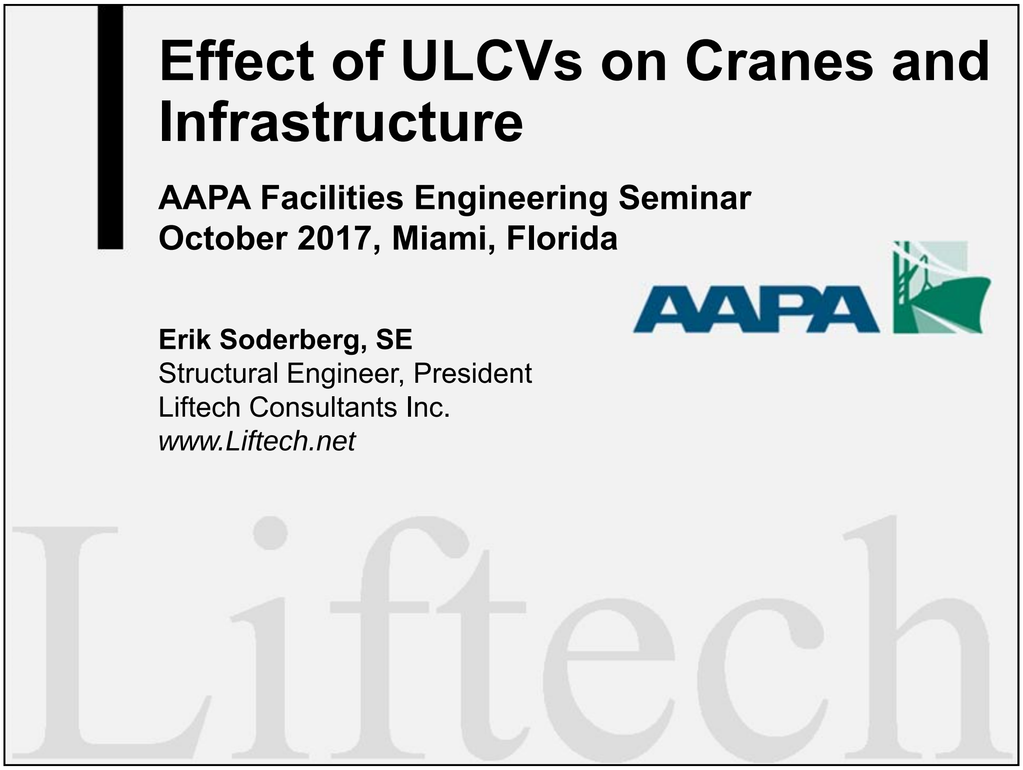


Erik Soderberg is Liftech's president and a structural engineer. He has 23 years of experience in the design, review, and modification of a variety of structural and crane related systems including over a hundred container cranes, over a dozen bulk loader structures, and over two dozen wharves. Other structures include crane lift and transfer systems and concrete and steel floats.

Liftech Consultants Inc. is a consulting engineering firm, founded in 1964, with special expertise in the design of complex marine 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.

This presentation provides an overview of some effects of ultra large container vessels (ULCVs or vessels) on existing STS cranes and wharf infrastructure. Costs presented in this presentation are estimates of construction costs based on recent projects and do not include other costs. Actual costs will vary.

# Overview

Section 1: Vessel Changes

Section 2: STS Crane Requirements

Section 3: Infrastructure Requirements



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# Section 1: Vessel Changes



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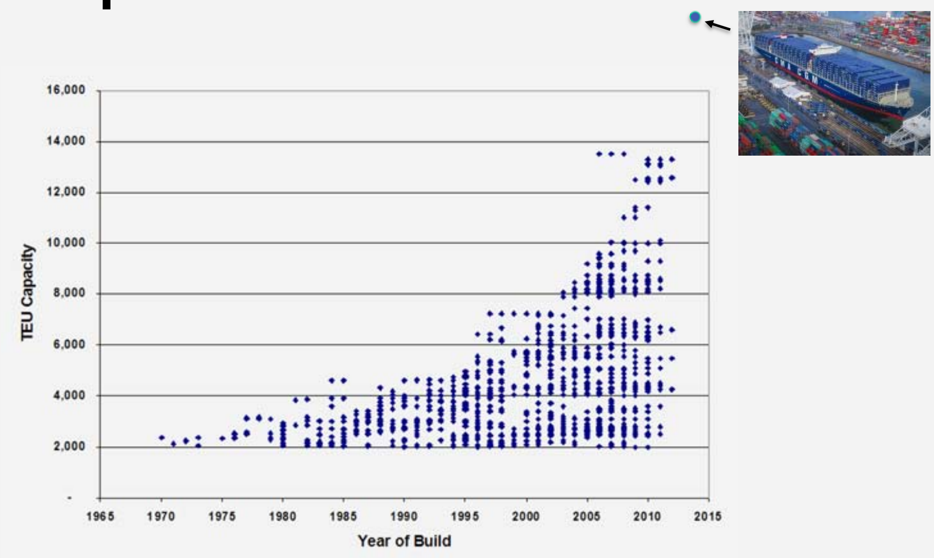
# Ship Size Growth

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This is a graph of container ship sizes and the year the ships were built.

Ship sizes have recently grown more rapidly than expected.

# Ultra Large Container Vessels


CMA CGM Benjamin Franklin at Port of Long Beach

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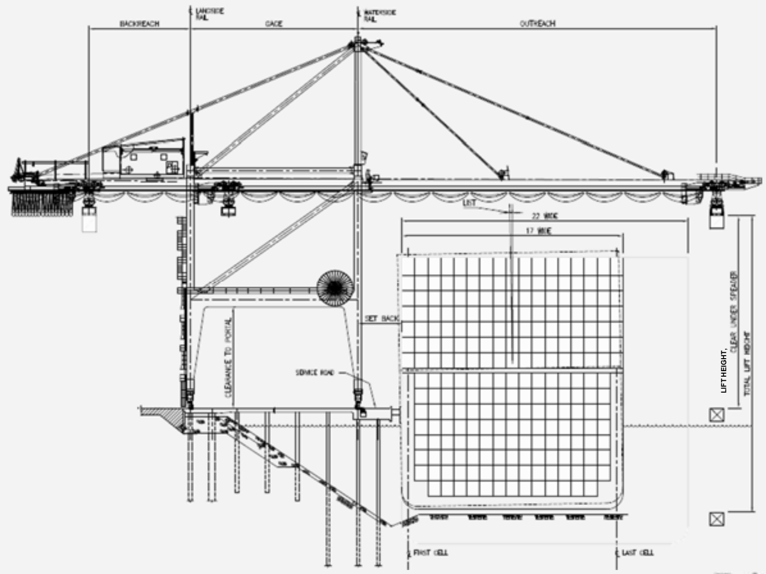
Vessels with capacities around 20,000 TEU have arrived and more are on the way.  Many operators and ports are asking how these vessels will affect their STS cranes and wharves. These vessels will typically affect existing STS cranes and infrastructure.

# Section 2:
# STS Crane Requirements

## Crane Geometry Terms

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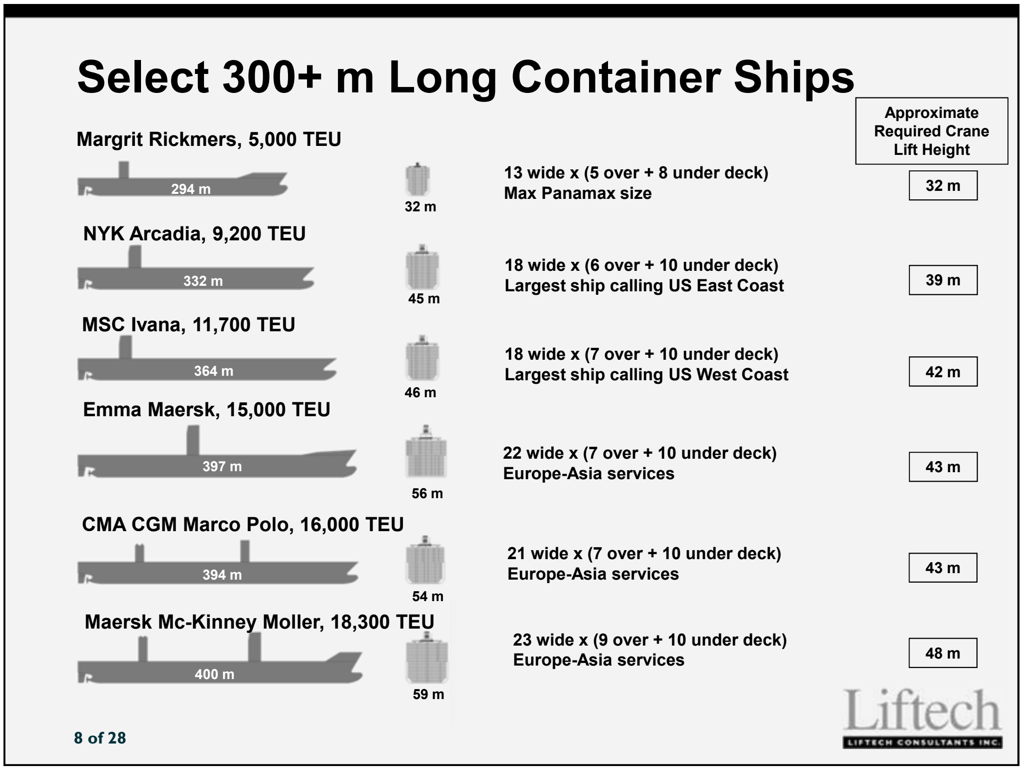
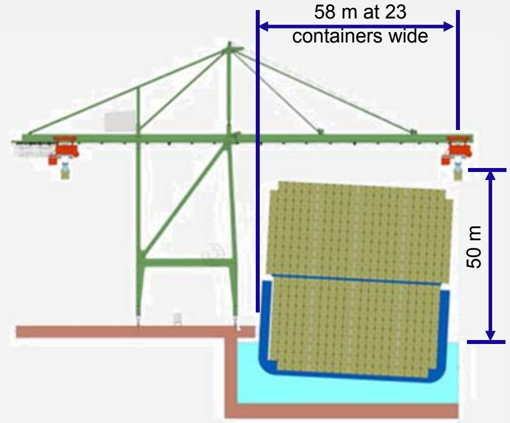
This slide presents common crane geometry terms. Lift height and outreach will be discussed on the next slides.




This is a summary of the ships presented. The main point is that the 5,000 TEU ships will be phased out of service and ships up to the 12,000 TEU size will make regular calls on the US East Coast. The 20,000 TEU ULCVs have started calling on the US West Coast.

# ULCV Crane Requirements




Notes:
1. Outreach based on 1 degree list and 1 m trolley overrun.
2. Lift dimensions depend on operations; amounts shown are approximate. Dimensions shown are based on: 8.5' tall top box with 1' clear, 1 degree list, and 12.5 m of draft.
3. Lift height from top of rail will depend on rail elevation and design high water elevation.

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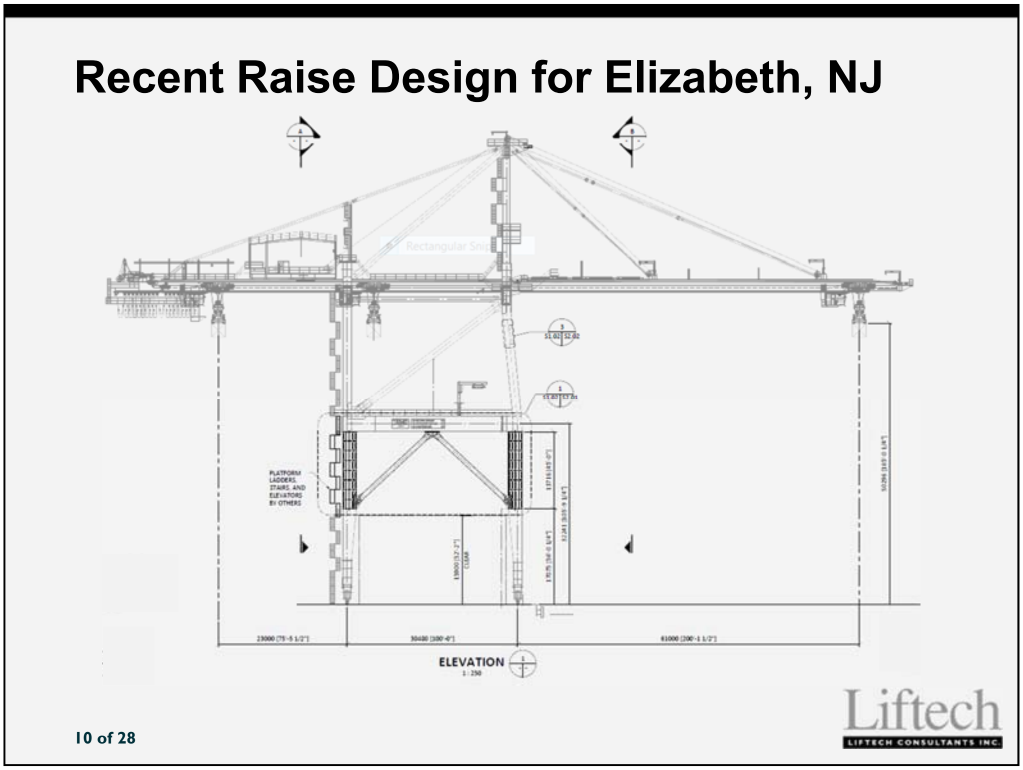
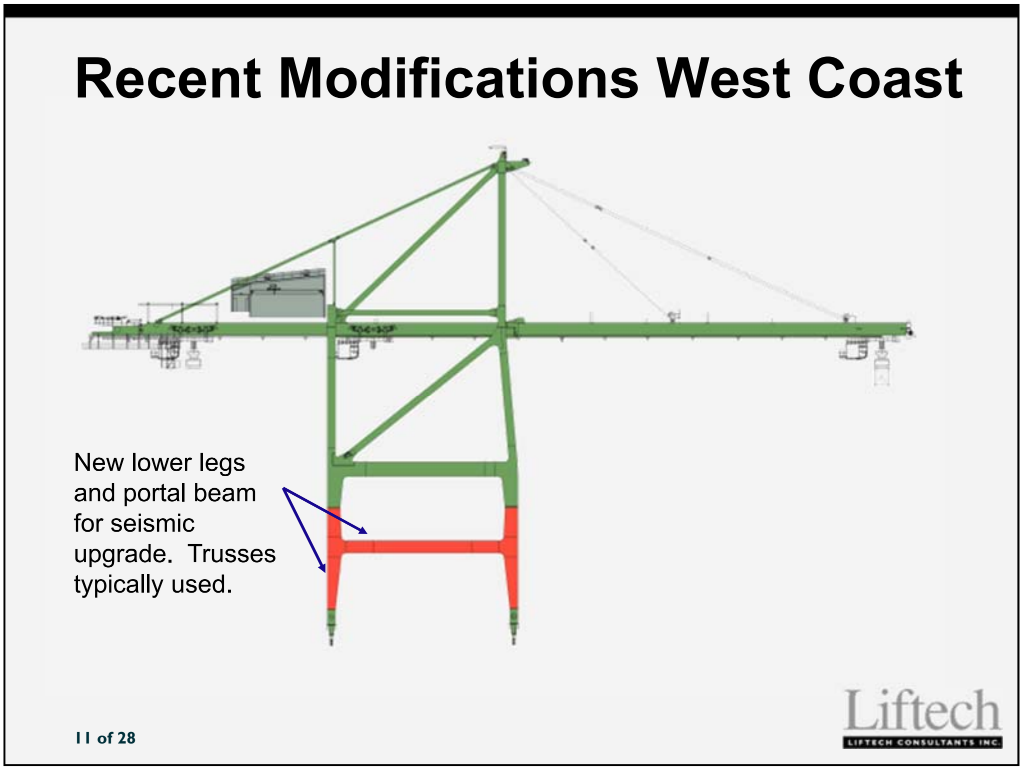
In summary, for a 3 m crane rail setback from the face of the fender, the outreach required is about 61 m.

For a crane rail elevation 3 m above the design high water, the lift height is about 47 meters.




On the East Coast, crane modifications for increase lift height typically involve leg inserts and bracing below the portal beam.

As shown in this design for Maher in New Jersey, a lift height suitable for UCLVs was chosen.




On the West Coast, raises often include modifications for seismic upgrades that typically result in replacing the lower legs and adding a lower tie with bracing to form a truss. In the raise shown, a new portal beam was added to control the crane period due to port concerns regarding the wharf loading in the earthquake.

The raise height is typically limited by the infrastructure, e.g., crane girder capacity.

# Boom Extension

Photo courtesy of Terminales Rio de la Plata S.A., Buenos Aires, Argentina

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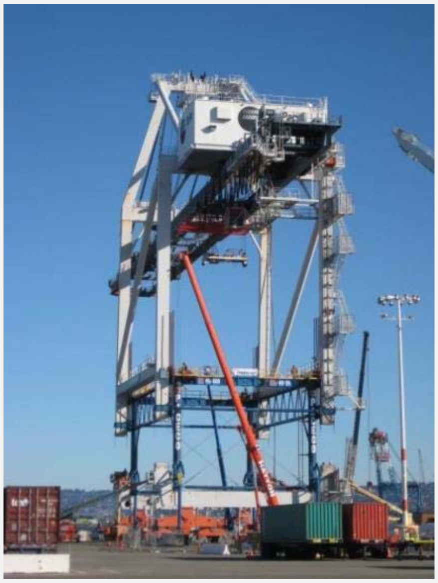
This slide shows a recent boom extension project. When modifying the boom, typically the crane is rolled back and land-based cranes are used to remove the boom so that the cutting and welding work can be performed on the wharf or yard.

## Crane Raises – Some Guidance Data



Operating wheel load will typically increase 2 to 5.5 t per meter for a 7 to 10 m raise.

Cost
US WC: $2M to $4M

US EC: $1.5M to $2.5M

Six weeks out of service per crane - with a proven system and experienced contractor.

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This photograph is from a crane raise in Oakland by Paceco. This project used a crane raise frame Liftech designed for Paceco in the 1990s. With a frame like this and an experienced contractor, you can expect each crane to be out of service about six weeks.

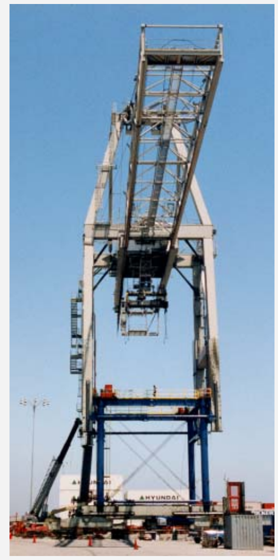
When raising later generation cranes with sufficient outreach for the big ships, larger crane lifting frames are required.

The cost of these raises on the US West Coast has increased to about $4 million per crane. On the US East Coast we expect the cost will be about $2 million.

When raising the larger cranes by 7 to 10 m, you can expect wheel loads to increase by 2 to 5-1/2 tonnes per meter from the increased dead load and lateral loads on the crane.

## Crane Modifications - Some Considerations

1. Design ship
2. Stability, ballast, and wheel loading/girder capacity
3. Construction impact to terminal operations
4. Electrical system upgrade?
5. Seismic upgrade?
6. Main hoist drum - rope capacity
7. Boom hoist lift capacity
8. Other – see speaker notes

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For the design ship, the decision is whether to design for an imminent larger ship or an even larger unknown future ship.

The crane wheel loads should be calculated to determine if the existing girder rated capacity will be adequate, or if a girder capacity study should be initiated to determine if strengthening will be required.

The terminal operator will want to know how the modification work will interfere with operations. Typically, modifications can be limited to a portion of the terminal by rearranging cranes during modifications.

The electrical system should be evaluated. Systems more than ten years old are often upgraded.

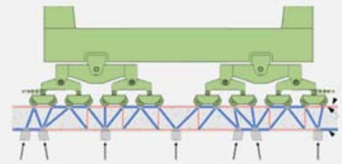
Incorporating seismic upgrades into the modifications, particularly for older cranes designed to more lenient criteria, is often worthwhile as the modifications are mostly limited to the portal frame of the crane, which will be modified in the raise.

Other considerations:

Boom extension:
1. Fatigue reliability
2. Method: Extend girder or local modifications to trolley, stops, and end platform
3. Tie-downs & stowage socket capacity
4. Gantry drives & brakes

Crane raise:
1. Tie-downs & stowage socket capacity
2. Gantry drives & brakes
3. Platforms, stairs, and ladders
4. Elevator
5. Lighting levels after raise
6. Service hoist
7. Limit switches and software
8. Spreader cable reel capacity
9. Cable reel – increase or maintain cable distance

# Section 3: Infrastructure



# Berth Space

ULCV lengths are not much longer than the previous generation.

Some berths require additional length – a costly option.

Less costly – install more compact crane stops closer to wharf end; add a mooring dolphin beyond the wharf *(see next slide).*



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Today's ULCV lengths are not much longer than those of the previous generation. However, some existing berths still require additional length—a costly option. Some less costly options, if practical, include:

Installing more compact crane stops closer to the end of the wharf.

Adding a mooring dolphin beyond the wharf so the vessel can be located closer to the end of the wharf.

# Mooring Dolphin

Add a mooring dolphin beyond the wharf so the vessel can be located closer to the end of the wharf.

Mooring Dolphin at IMTT Port of Richmond



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Mooring dolphin at IMTT Port of Richmond.

## Berthing Fenders

ULCV berthing velocities and angles are typically much less than those in traditional design guidelines.

Consider recent data when determining berthing energies.

A cost-benefit analysis may justify the acceptance of existing systems.

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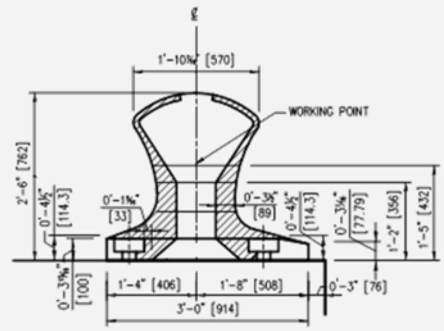
The fender energy required for vessel berthing is primarily influenced by vessel approach velocity perpendicular to the wharf and vessel mass. Current ULCV displacements are significantly more than the design mass used for many existing fender systems; however, the approach velocity for the ULCVs is less, reducing the increase in required energy. 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 for smaller ships. 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.

## Bollards

Increased mooring forces may require higher-capacity bollards. Installing higher-capacity bollards requires relatively little cost unless the wharf structure needs strengthening.




Consider site-specific wind speeds and directions when determining required bollard capacities.

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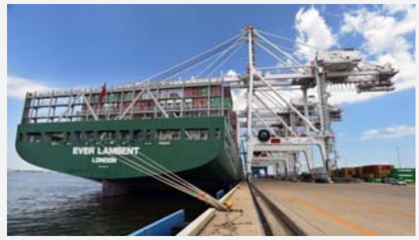
The wind area of today's loaded ULCV is significantly more than that of the original design ship used for most existing mooring systems. Forces of up to 250 t per bollard can occur for common design winds and mooring line arrangements (t = metric tonne). Additionally, ship captains may have concerns 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 locally is costly, with costs varying significantly depending on the existing structure. An economical strengthening approach that has worked on several older wharves consists of drilling holes into the wharf structure and installing grouted high-strength reinforcing.

The bollard shown is a design for a replacement bollard for the Port of Oakland that has a larger waterside leg to reduce the anchor tensions to enable reusing existing anchors.

# Arrangement and Bitt Loading

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Consider potential mooring line arrangements, especially if vessel clearance will decrease.  Be aware that actual arrangements may differ from ideal.

Also be aware that for double bitt bollards, the bitt load rating is half that of the bollard, e.g., a 200 t double bitt bollard will have a bitt rated load capacity of 100 t.

## Crane Wheel Loads

Wheel loads may exceed the design or rated capacity of existing wharf girders.

Options to address excessive crane loads include:

- Optimize crane design
- Analyze or load test structure & foundation *(see next slide)*
- Strengthen existing girders
- Replace girder systems with new, stronger systems
- Increase crane rail gage for new cranes

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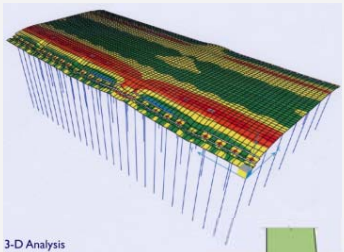
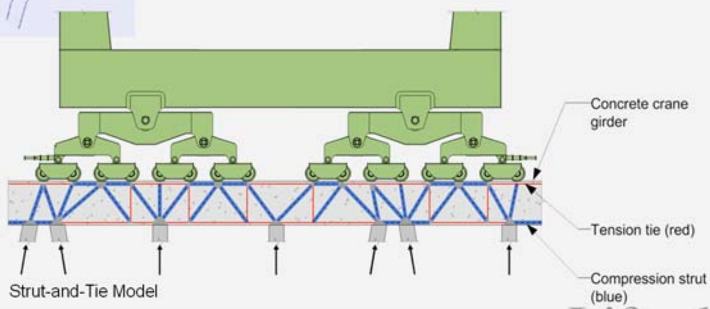
STS cranes suitable for up to 23-wide vessels typically have larger wheel loads than existing cranes procured for smaller design vessels. Wheel loads may exceed the design or rated capacity of existing wharf girders. Options to address excessive crane loads include:

- Optimizing the crane design to reduce crane reactions and better suit the distribution between available landside and waterside girder capacities
- Analyzing 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, as this can reduce wheel loads and will permit additional truck lanes for operations

Optimizing a new crane design or a crane modification design will reduce wheel loads some, but there are limits. Typically, this option is only worthwhile if the existing crane wheel loads are not significantly greater than the girder's rated capacity.

## Justify Increased Rated Girder Capacity – Girder Strength






We have evaluated many existing wharves. In most cases, the rated girder capacities can be increased by using more modern analysis methods.

Finite element analyses are particularly worthwhile when the girder is integrated into a deck or has cross beams that permit load distribution.

Strut-and-tie analysis is worthwhile when the shear strength calculated using more conventional methods is inadequate.

Other methods are available.

The engineering costs to evaluate an existing girder structure are typically a fraction of strengthening costs, and some of the engineering effort can be applied to the strengthening design, if needed.

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 US$30,000. If feasible, studies to justify additional capacity, typically involving one or more types of analyses, are often US$50,000 to US$100,000 and are usually successful.

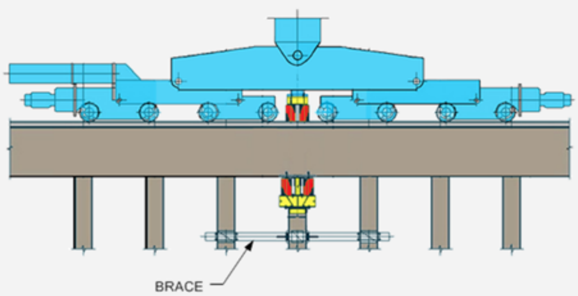
Strengthening or replacing a wharf girder will require significant costs and often requires new piling. If this is required, and in particular if new cranes will be procured, building a new landside girder and procuring larger gage cranes can limit girder construction costs, may reduce crane wheel loads,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

## Justify Increased Rated Girder Capacity – Piling Capacity

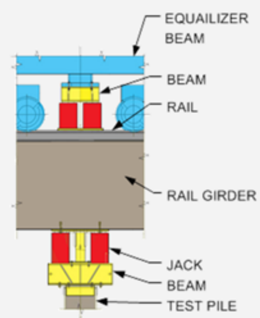
Analyze pile driving records

Pile dynamic analysis

Load test




PILE LOAD TEST ARRANGEMENT

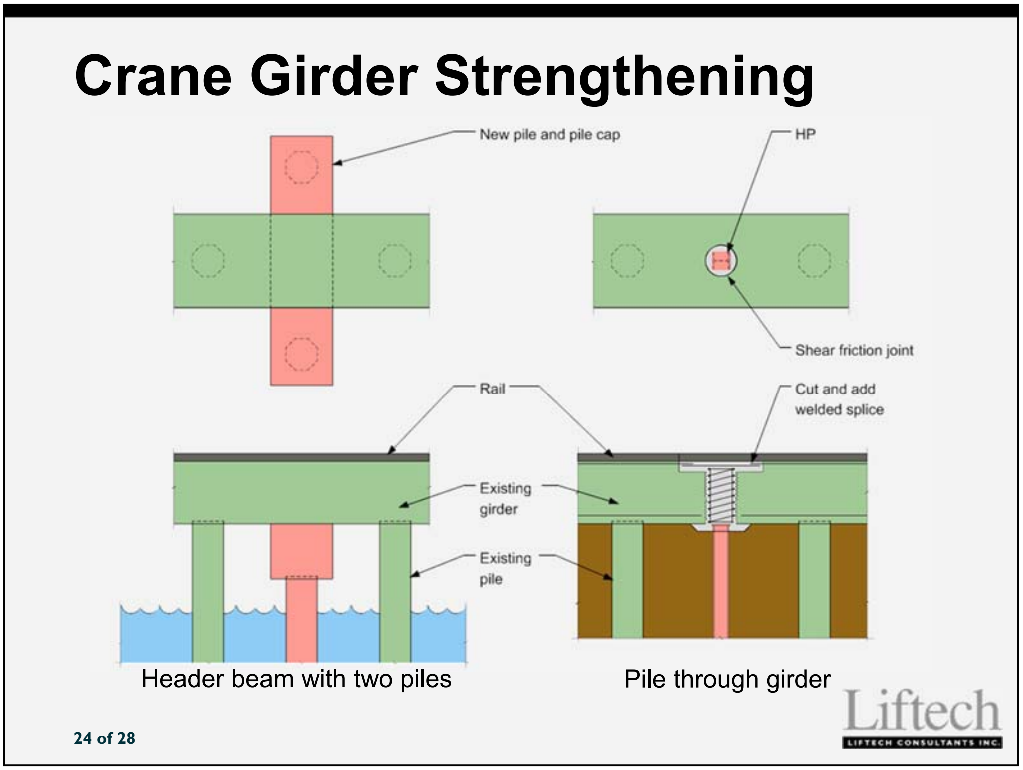



PILE LOAD TEST DETAIL



Pile driving records may justify greater loads.

The pile capacity can be determined by breaking the pile from the girder and performing a load test by jacking against the girder or performing a Case Pile Wave Analysis Program (CAPWAP) test.




Crane girder strengthening can be accomplished in many ways. One method is to drive piles on either side of the girder and install a header beam between them.

Liftech has projects where we considered coring a hole through the girder, installing an H-pile or auger pile, roughening the cored wall of the girder, and connecting the load from the girder to the pile with shear friction. The substantial longitudinal girder reinforcing will provide the required confinement forces. A similar approach has been successfully used in the offshore oil industry with grouting between the platform leg jacket and the leg.

# Summary

ULCV STS crane outreach 23 containers wide, 58 m from fender face. Lift height above design high water about 50 m.

Increase in vessel length is limited but may be significant. Consider low-cost modifications, such as new compact and relocated crane stops and mooring dolphins beyond wharf end.

Fenders for smaller 10-12,000 TEU-range vessels may be adequate.

Increased mooring forces and smaller space between vessels may require more and stronger bollards. Costs are limited unless wharf strengthening is required.

Consider performing a crane girder study to justify additional capacity before strengthening or replacing.

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

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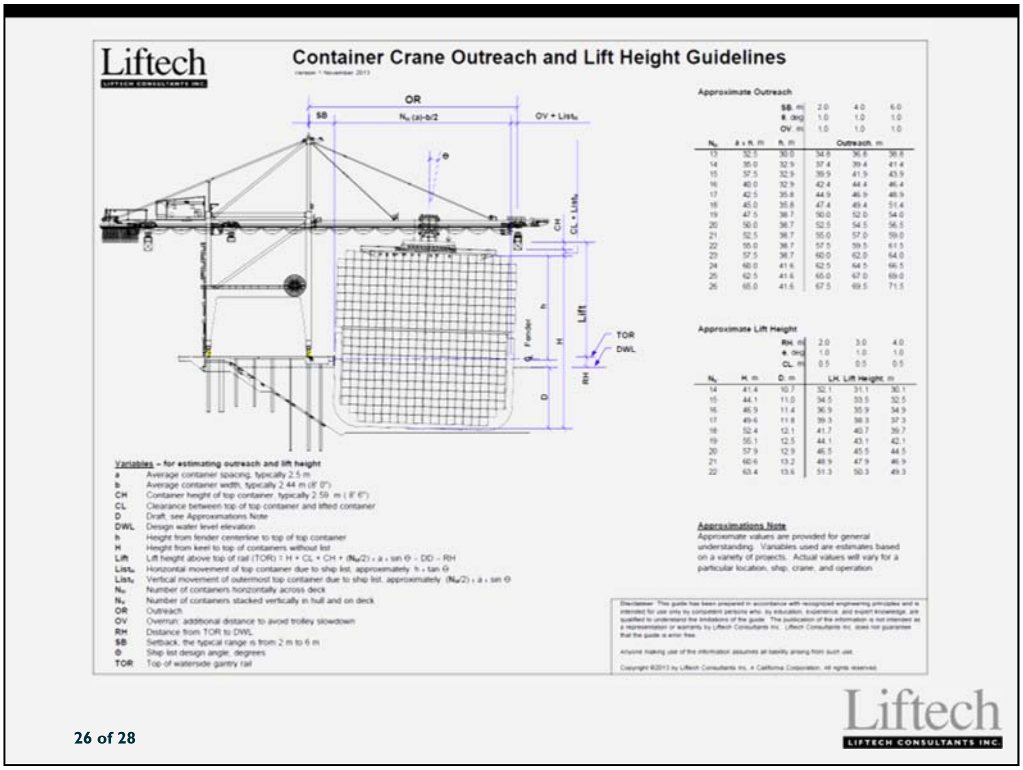
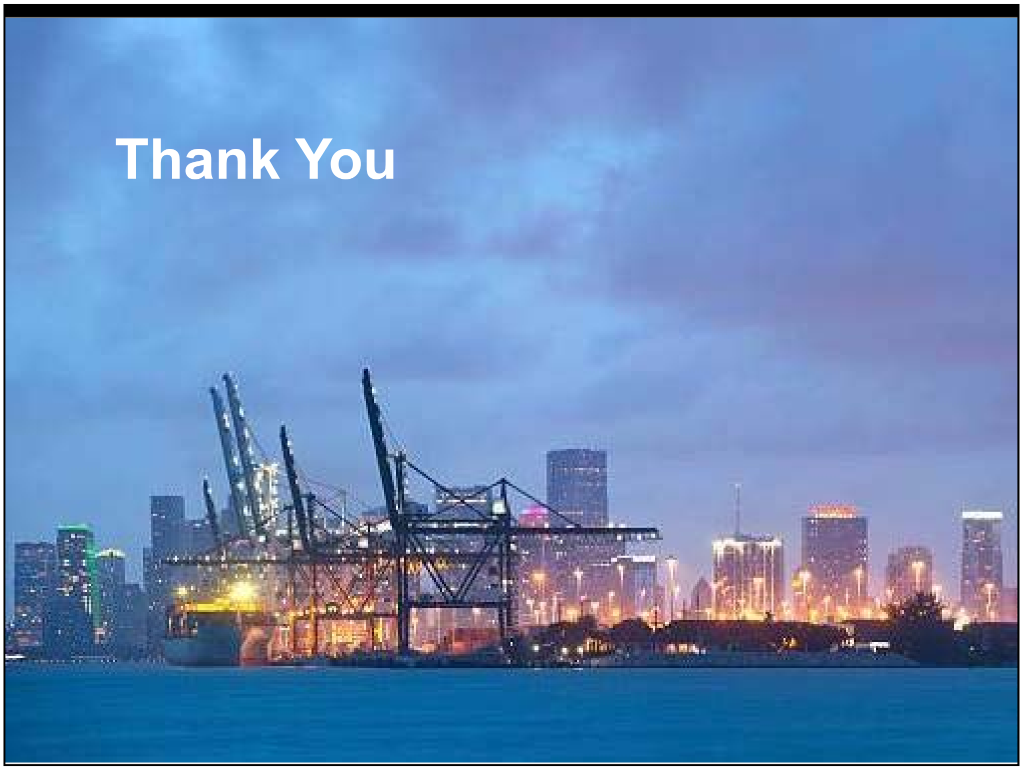



The presented handout provides some guidance on outreach and lift height and was developed to supplement this presentation.  It is available on our website.


Thank You

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