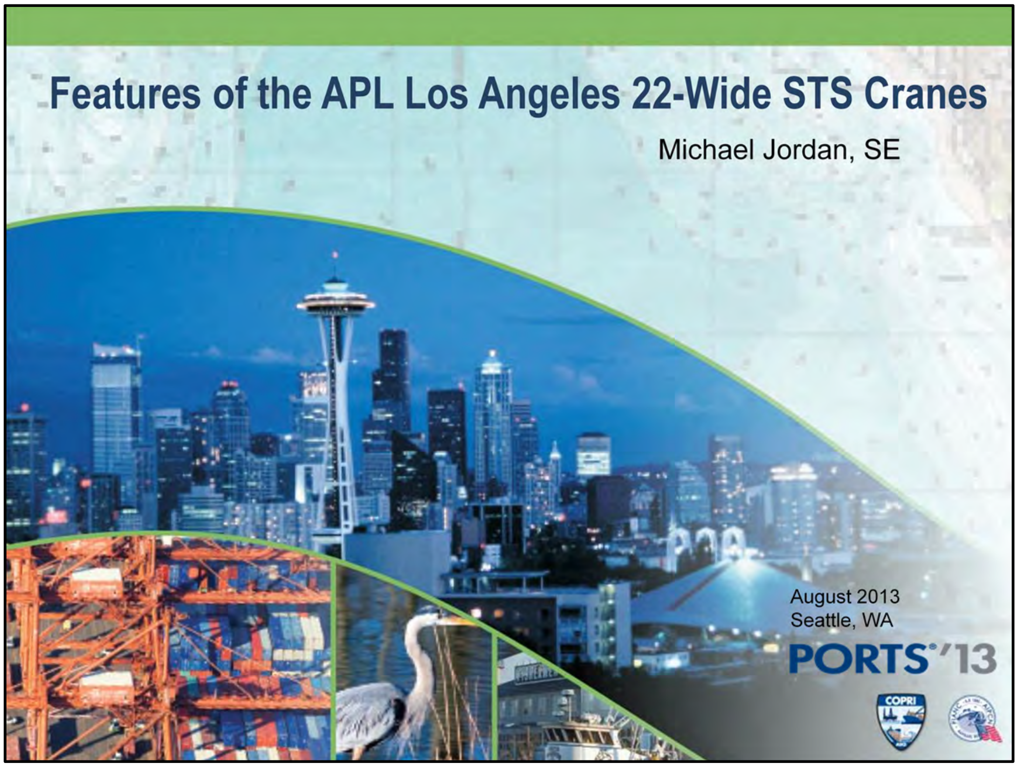


Liftech Consultants Inc. is a consulting engineering firm, founded in 1964, with special expertise in the design and procurement of dockside container handling cranes and other complex structures. Our experience includes structural design for wharves and wharf structures, heavy lift structures, buildings,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

Mike Jordan is a Liftech structural engineer. He has worked in the industry for over 50 years on the design, review, modification, and repair of a variety of structures. He was the engineer of record for the structure of the first dockside container crane built in 1959. Since then he has performed structural engineering on over 2,000 container cranes, dozens of bulk loader structures, and many other structures ranging from turntable systems that transfer cranes between non-linear berths to some of the largest derrick cranes in the world.

He has recently been working on a variety of crane modification and wharf projects.

He has presented at various industry conferences such as ASCE, AAPA, TOC, and PTI. He has authored dozens of articles and papers for industry publications and events, and has served on a variety of committees.

Throughout his career he has pioneered many of the designs that have become industry standards such as the A-frame container crane, the low profile container crane, and the articulated boom. In this presentation he will present a new crane seismic isolation system developed for the recently constructed APL Port of Los Angeles Pier 300 cranes.

Transition slide for introducing the project overview.

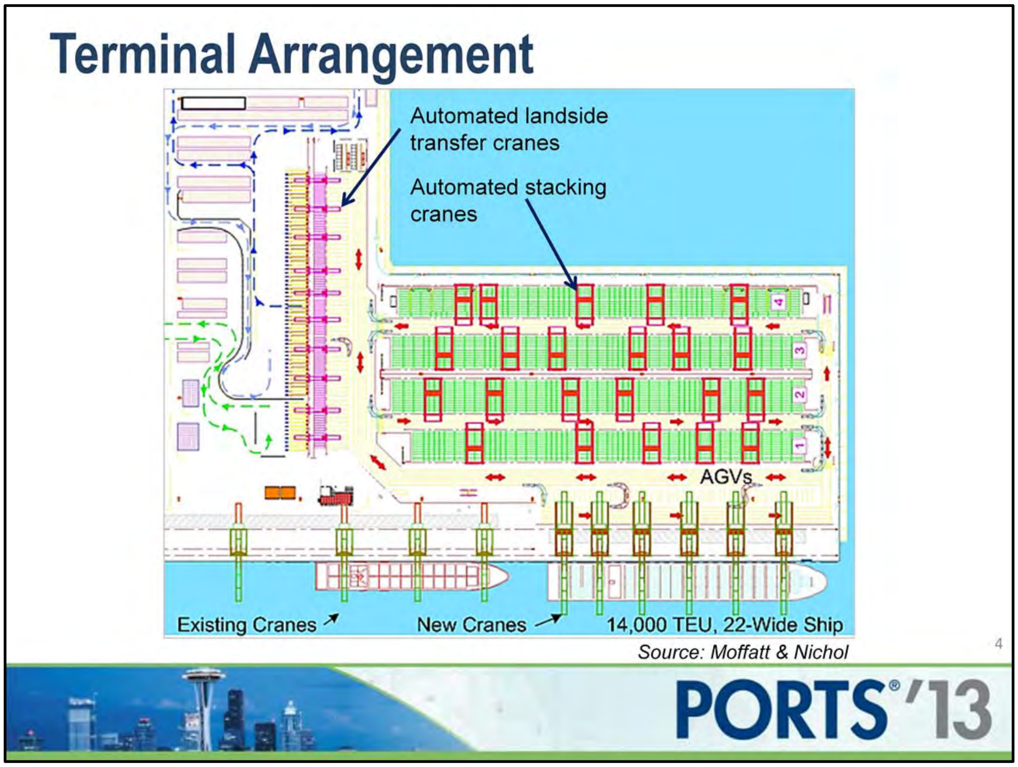
The APL Port of Los Angeles Terminal is being expanded to service modern, large container ships carrying 14,000 TEUs and with 22 containers abeam on deck.

The expansion includes a stacked container yard serviced by automated stacking cranes, automated guided vehicles, and six jumbo ship-to-shore cranes.

These cranes are large, over 120 m trolley runway, 80 m tall, and heavy, over 2,000 tonnes. They are designed to meet the POLA seismic requirements for the wharf and the Liftech recommended requirements for seismic performance for ship-to-shore cranes.

This presentation will show you some salient features of the following:

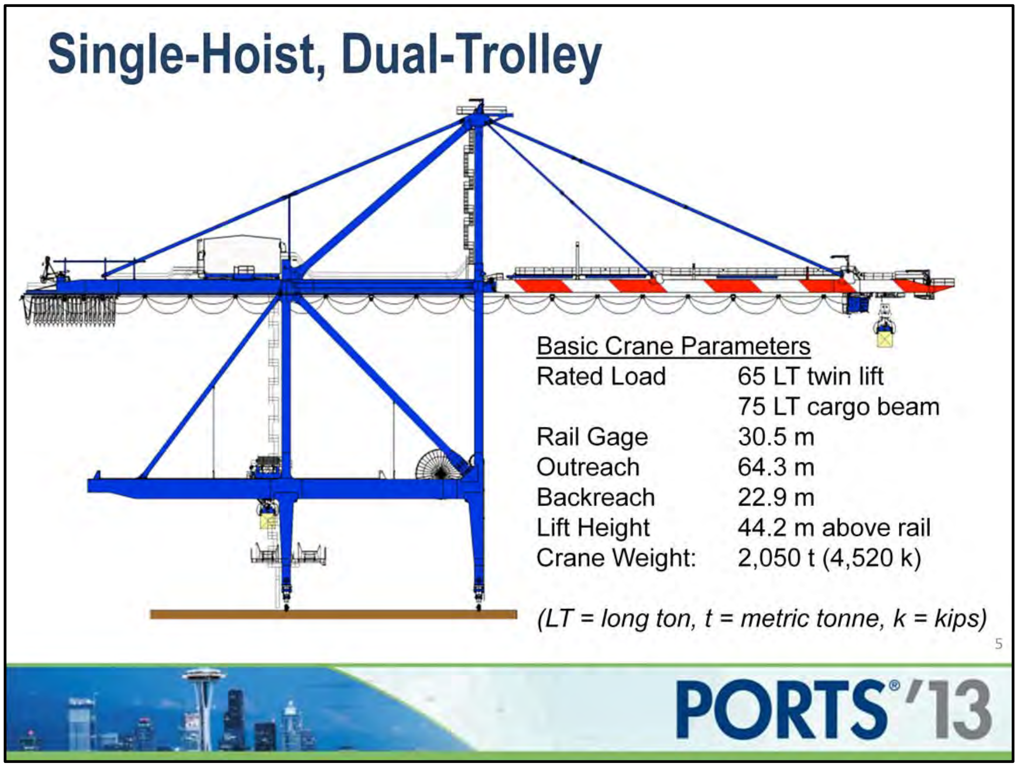
- The terminal as it relates to the cranes
- Crane operation
- Crane components
- Ship trolley
- Shore trolley
- Seismic design
  - Performance criteria
  - Seismic friction damper that reduces the demand on the wharf and damage, if any, to the cranes
  - Crane seismic response
- Wharf loads



The ship-to-shore cranes function as part of the terminal system, including a container yard, which uses:

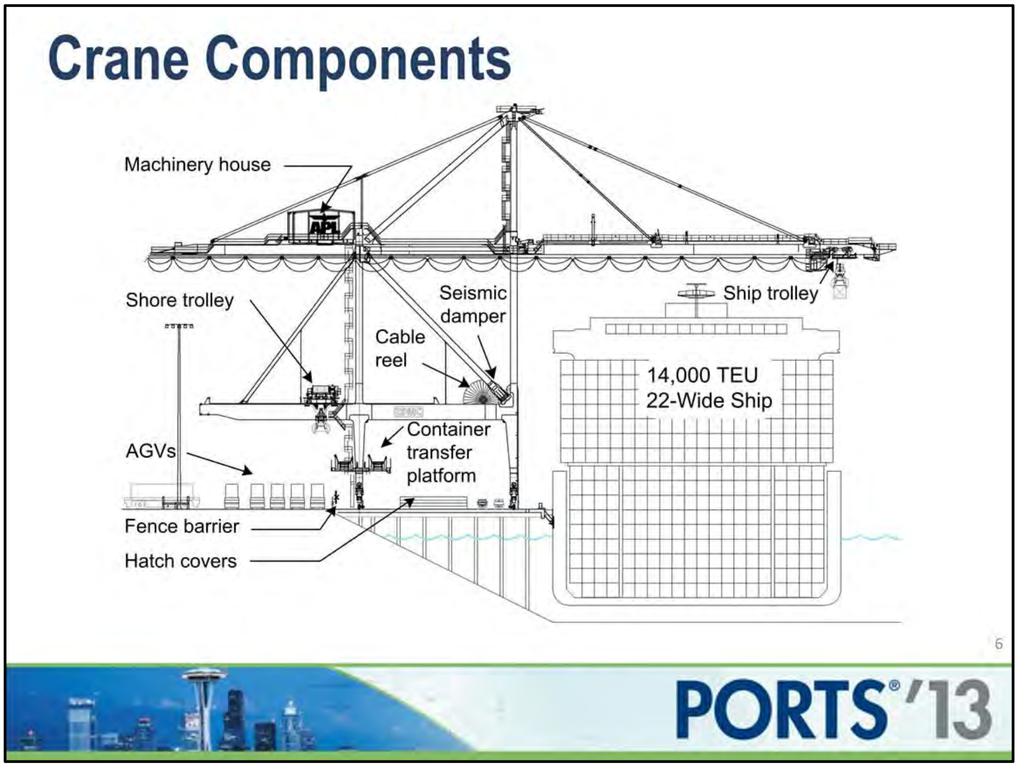
- Automated stacking cranes to store and retrieve containers in the yard
- Automated landside transfer cranes that load and discharge containers from road truck chassis
- Automated guided vehicles (AGVs) that transport containers in the yard and to the ship-to-shore cranes

APL retained Moffatt & Nichol Engineers for the design of the system.



The semi-automated, dual-trolley crane has an operating weight of 2,050 t, an outreach of 64 m, a crane rail gage of 30 m, a backreach of 25 m, and a lift height of 44 m above the crane rail.

The power supply voltage for these cranes has been increased from the existing 4.16 kV to 12.47 kV to handle the demands of the two trolley cycle. The RMS load based on a 65 LT container load duty cycle is 2,320 kVA.



Ship trolley: The trolley is controlled manually when it is over the ship and automatically back to the container transfer platform.

Single-hoist, twin-20' lift trolley

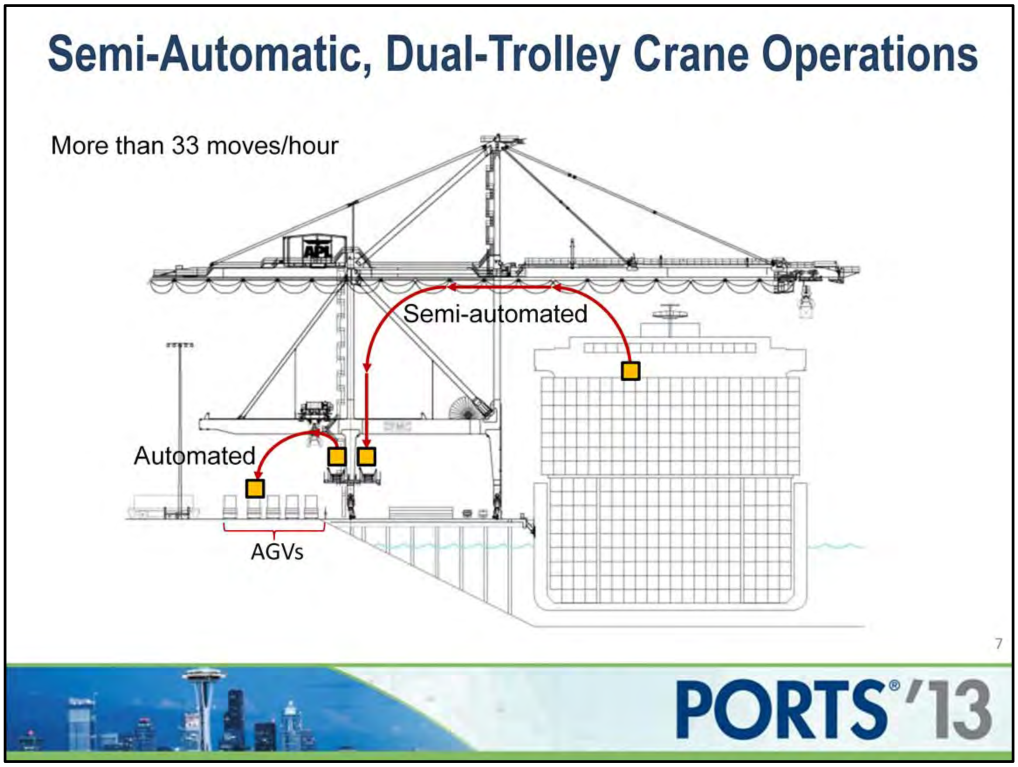
Shore Trolley: The trolley is fully automated. Rigid reeving, which you will see later, controls the load position precisely.

Coning and Transfer Platform: Containers are set and picked from the platform automatically by both trolleys. The platform also buffers the difference in the production of the two trolleys.

Cable Reel: A cable reel was selected, since it is more reliable than a power trench and can provide integral fiber optics.

Personnel and Vehicle Barrier: No persons are allowed in the automated yard during operations.

Seismic Damper: The damper design and effect will be discussed later.



Basic operation:

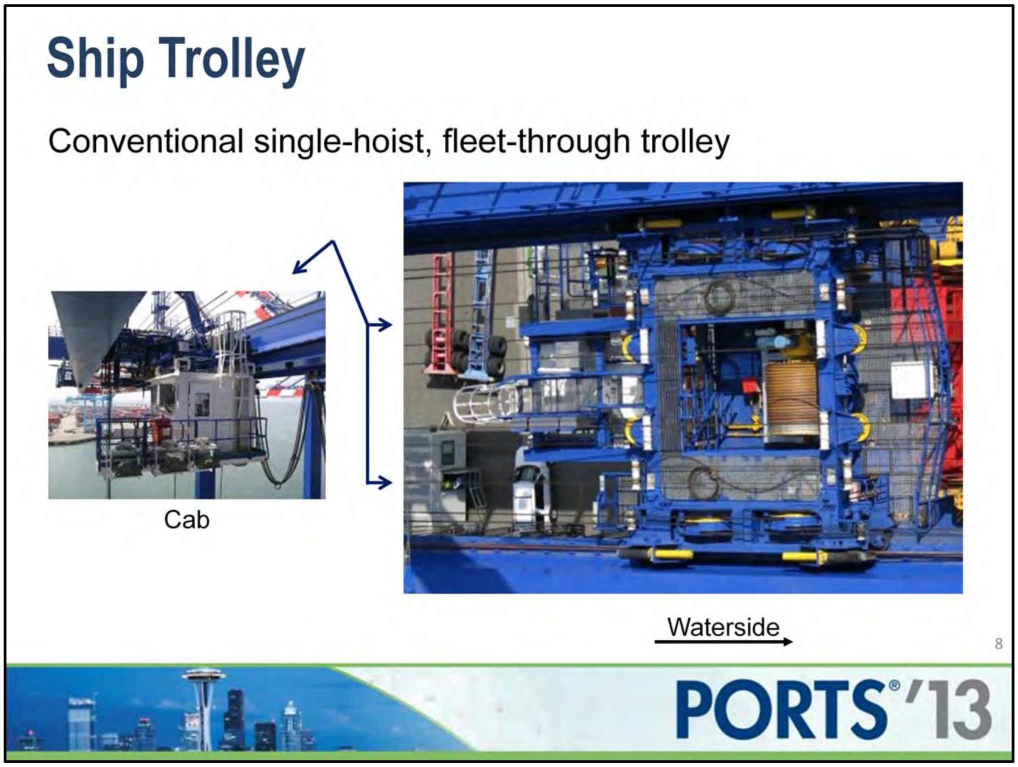
The ship trolley picks the container under manual control, moves it landside, and sets it on the coning platform. Once landside of the waterside legs, the operation is fully automated.

The shore trolley picks the container from the platform and sets it on an AGV.

The operation can be either single cycle or double cycle.

Single cycle:	unload or load one container each trolley cycle
Double cycle:	unload one container and then load one container each cycle

The crane is expected to produce at least 33 net moves per hour.



This is a conventional single-hoist trolley.

The main hoist is located in the machinery house, not on the trolley.

A single-hoist, twin-20' lift trolley was selected rather than a dual-hoist tandem lift trolley because a dual-hoist trolley would increase weight, initial cost, and maintenance costs, and might not significantly increase the overall system productivity.

Ship Trolley: Near Vertical Reeving

Ropes must clear the container stacks

Load position controlled by anti-sway

Position is not precise

9

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Nearly vertical reeving is not rigid. The vertical reeving is required, since it must clear the stacks and guides on the ship.

Anti-sway software controls the load position, but not very precisely.

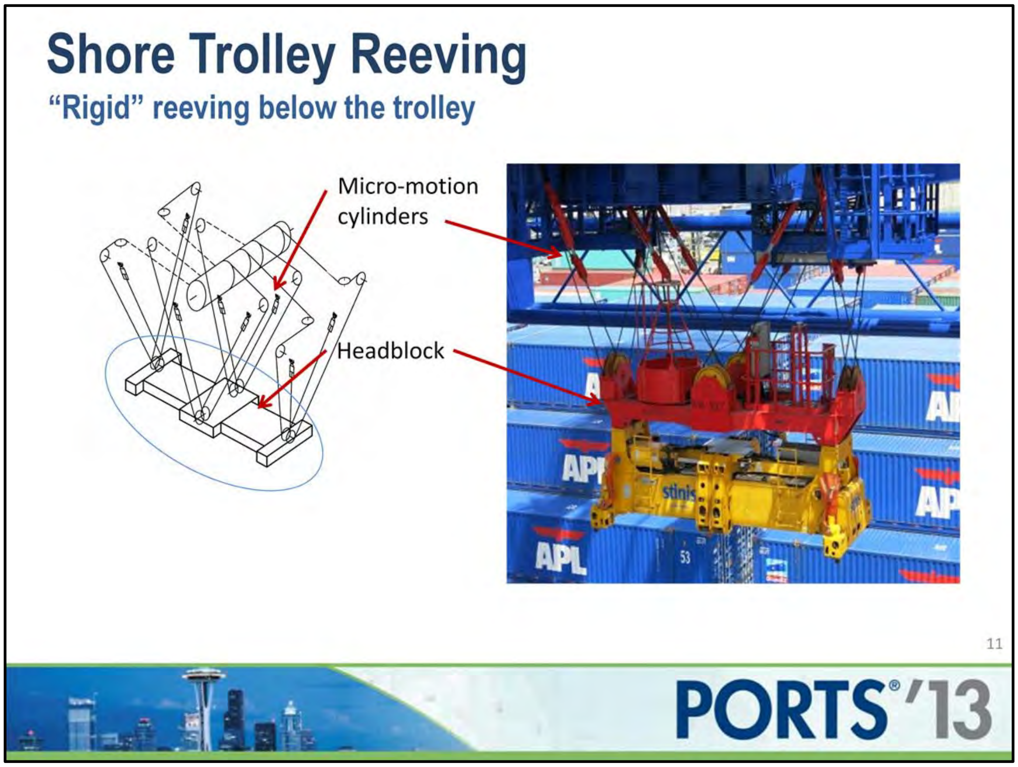
The shore trolley is very different.

It travels on the portal beam and the landside extension of the portal beam.

Since there is no clearance problem, the reeving is inclined in both directions. This provides precise position control.

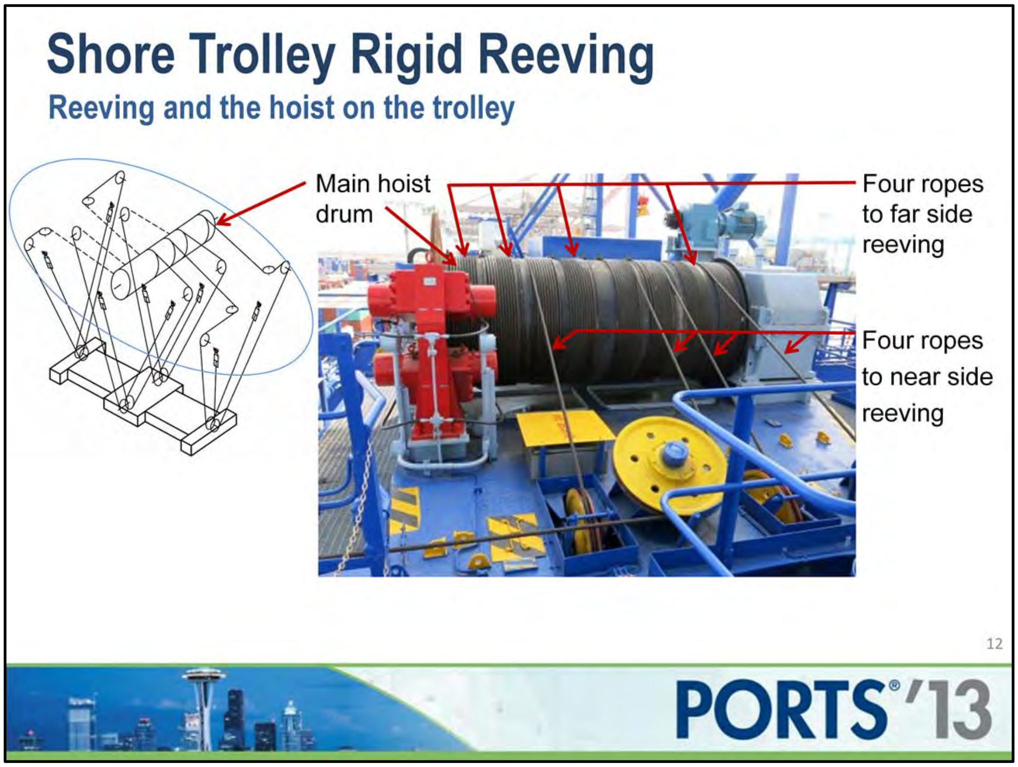
The portal beam deflects enough to cause significant variation in the rail gage.

> This variation is handled by hinged trucks on one side that function the same as a hinged leg on a gantry crane.



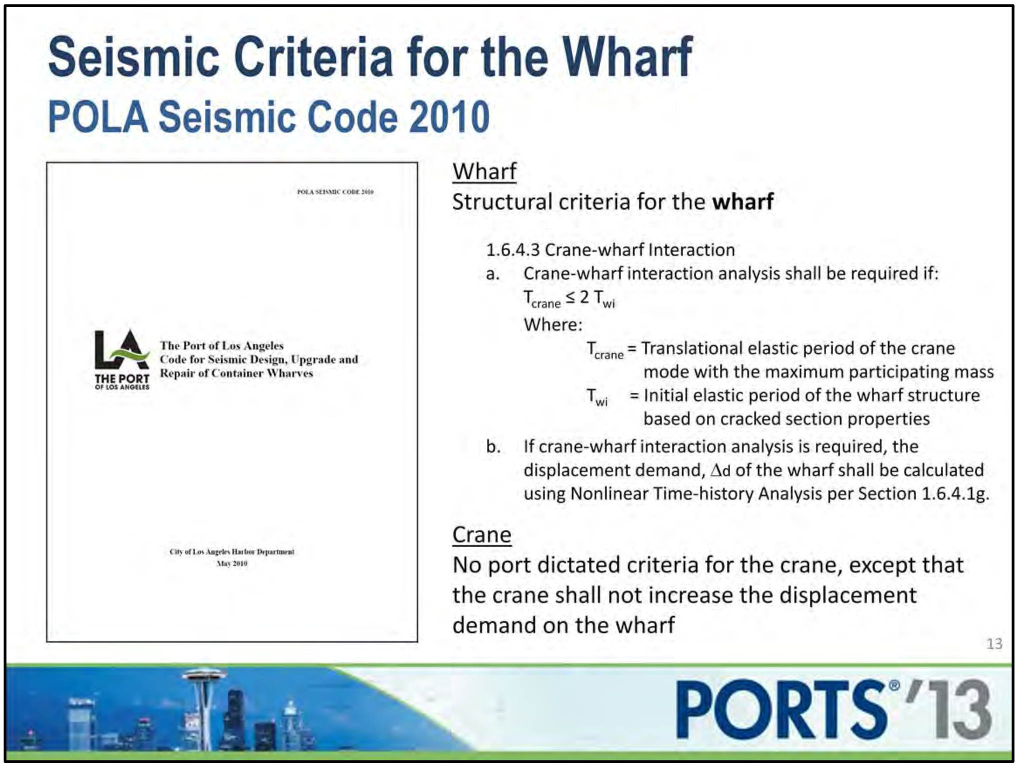
Rigid reeving is the key to controlling the position of the load precisely.

Hydraulic cylinders provide fine adjustment, so the spreader can be located over an AGV or the platform within a few centimeters of the desired position.



Since all four hoist blocks must remain in a plane while the spreader is raised and lowered, there can be no change in the free length of all the ropes.

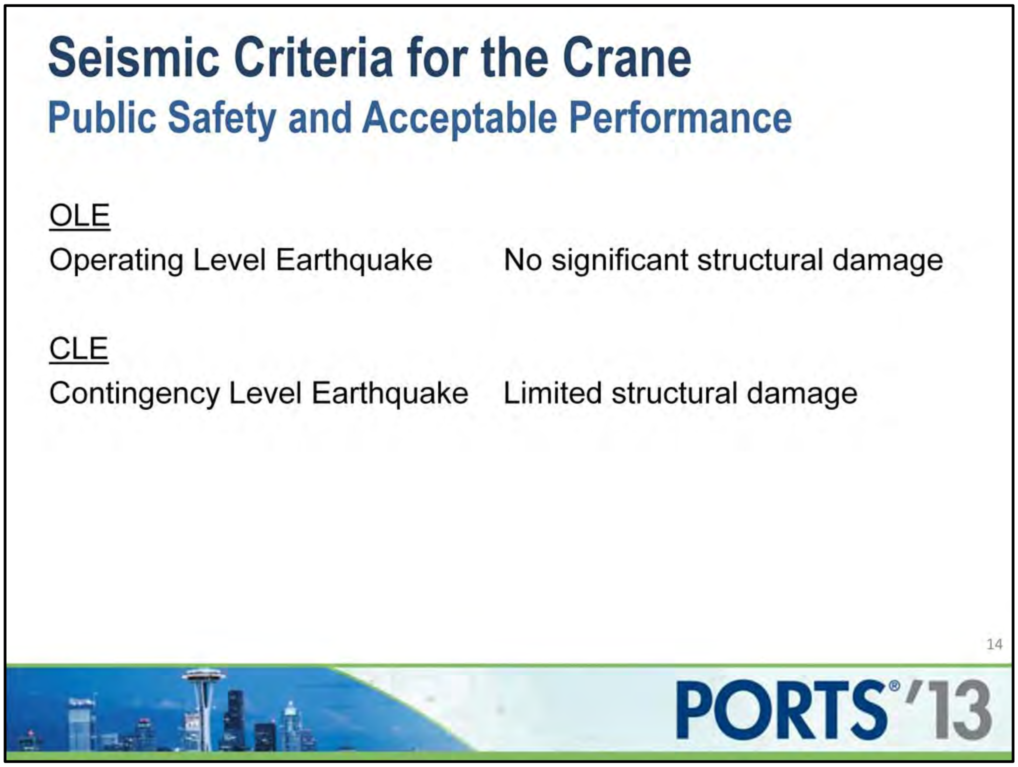
This is achieved by running all eight hoist ropes to a single drum.



Since the crane period in the trolley travel direction should be 1.5 s or less for proper operation, and the wharf period is greater than 0.75 s, that is, greater than one half the crane period, the POLA code required a time history analysis.

The time history analysis indicated that a special device would be needed to meet the POLA code. Consequently, a seismic structural damper was used in the frame.

Notice that the POLA code only addresses the performance and safety of the wharf. It places no seismic requirements on the crane.



Liftech recommends that seismic loads be considered for all new cranes and for cranes being modified.

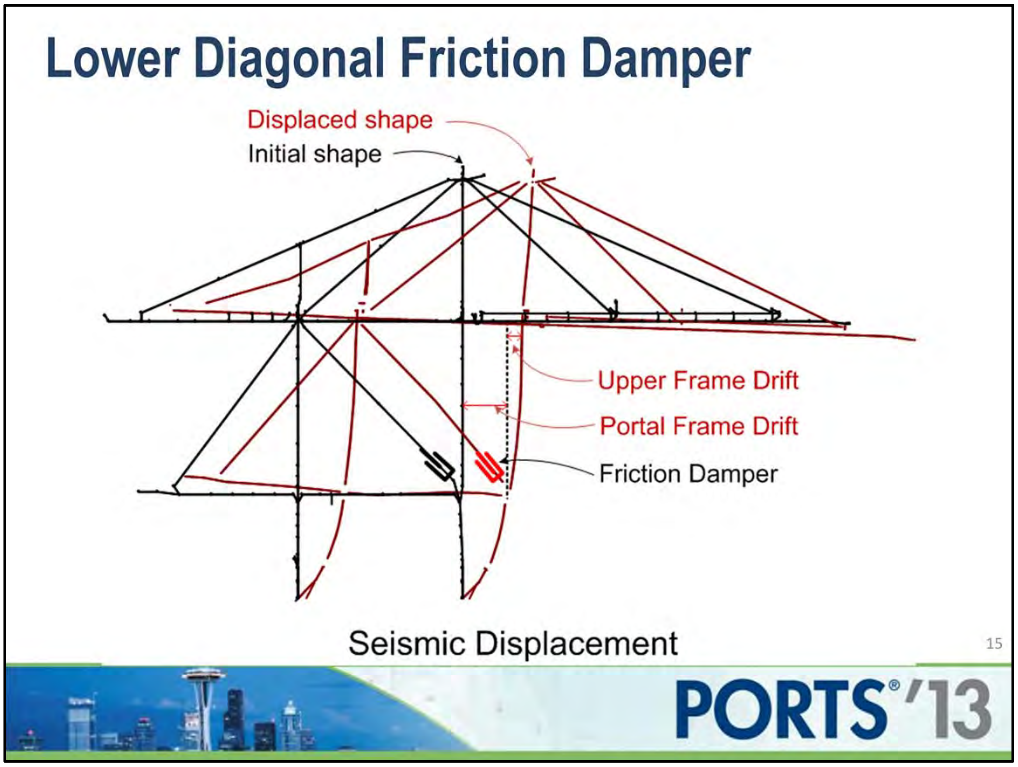
The performance criteria for the wharf are based on an acceptable risk analysis.

So the logical performance criteria for the cranes are the performance criteria for new wharves. Consequently, these criteria were used for the cranes.

<u>OLE</u>
Operating Level Earthquake — No significant structural damage

<u>CLE</u>
Contingency Level Earthquake — Limited structural damage

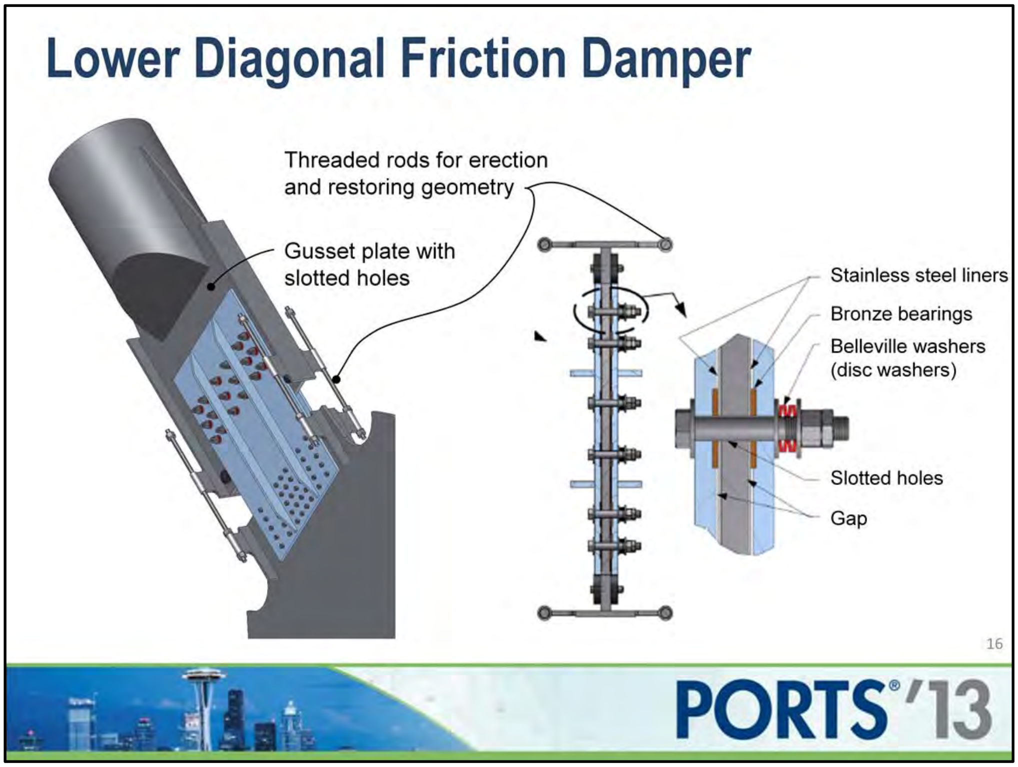
After considering several alternatives, a friction damper was selected to protect the crane. The cost of the damper is relatively small and the benefit is great.



The damper is incorporated into the connection of the diagonal connecting the trolley girder level to the portal tie beam level.

The damper design was developed using time history analysis. POLA provided site-specific ground motions for each earthquake level.

The damper allows the diagonal to lengthen and shorten once a threshold force is reached. The frame drifts just enough to reduce the displacement demand on the wharf to the code allowable. And more significantly, the stresses in the lower legs are reduced by a factor of two.



The friction damper consists of two side plates clamped to a central plate by high-strength bolts. The faying surfaces are stainless steel and bronze.

Slippage of the friction joint does not occur until the force in the diagonal brace exceeds the static friction strength of the damper. The dynamic friction is less than the static friction, but only slightly. The reduced sliding force is not a problem.

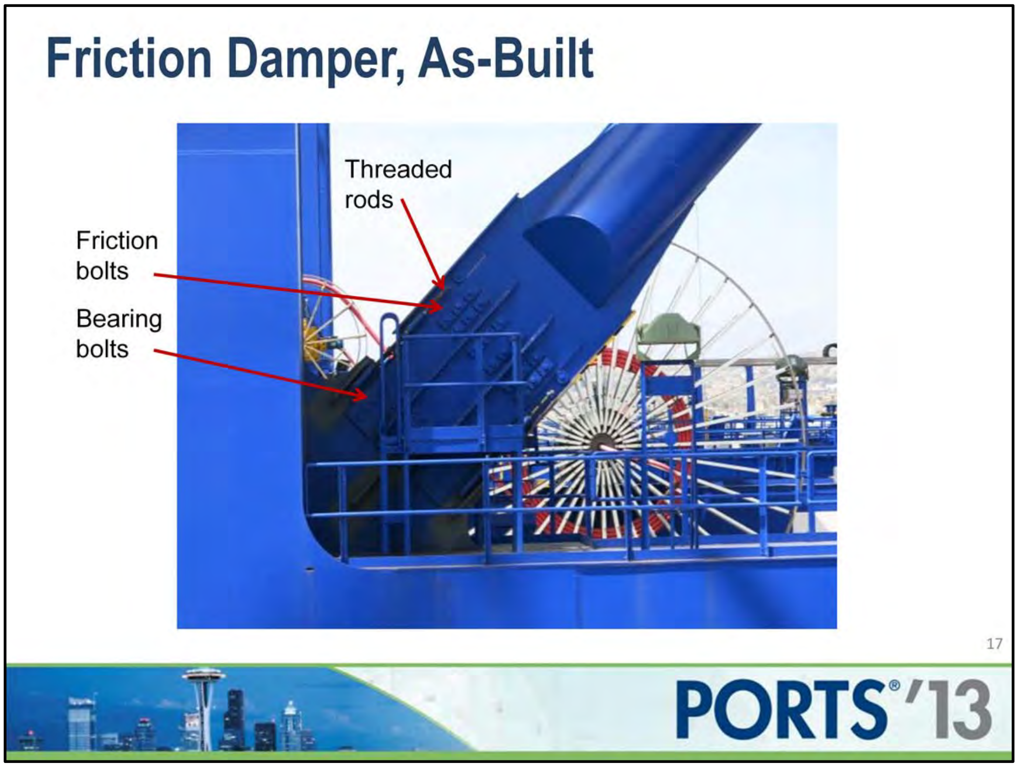
A special triggering mechanism is not required since the joint slides at a prescribed "fuse" load, which is higher than any loads due to operations or stowed wind.

After the activated joint comes to rest, the original geometry can be restored using threaded rods—maintenance is minimal.

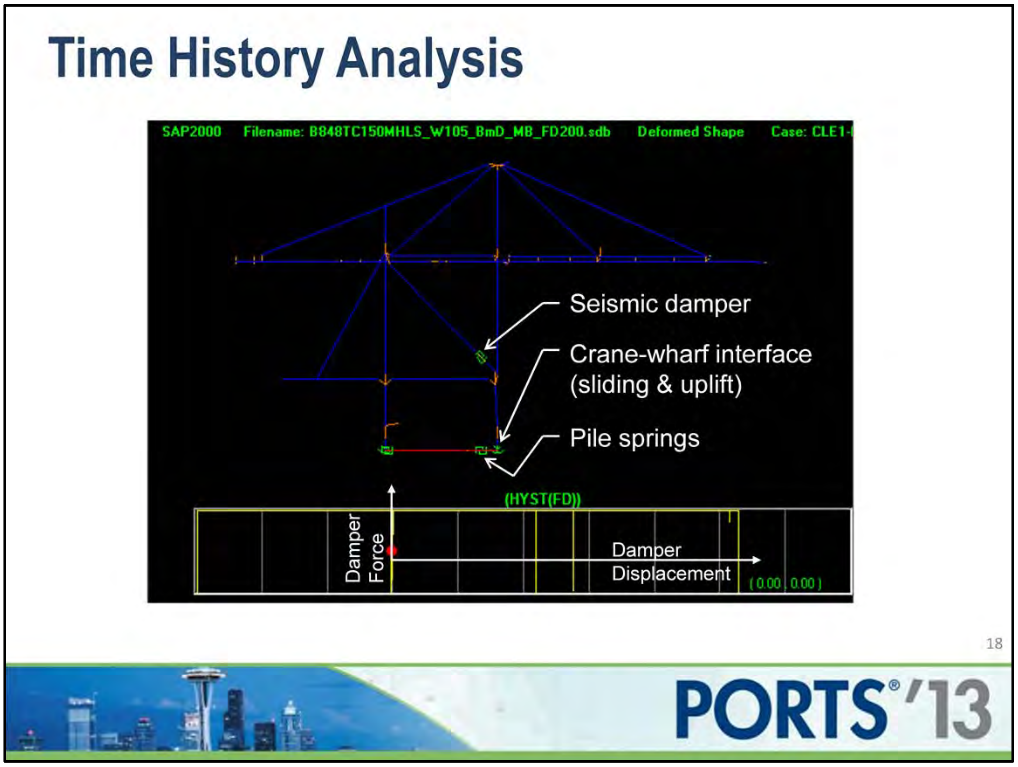
ZPMC performed extensive tests and suggested improvements to the original design. The test data were used to determine the bolt pretension.

Notice the threaded rods are for erection and restoring the geometry. The threaded rod concept was developed years ago to align the boom on a crane damaged by a ship collision. ZPMC regularly adds the threaded rods to most of their cranes.

Therefore, the use of the dampers is routine. This is one reason why the damper is not expensive.



This is the as-built friction damper.



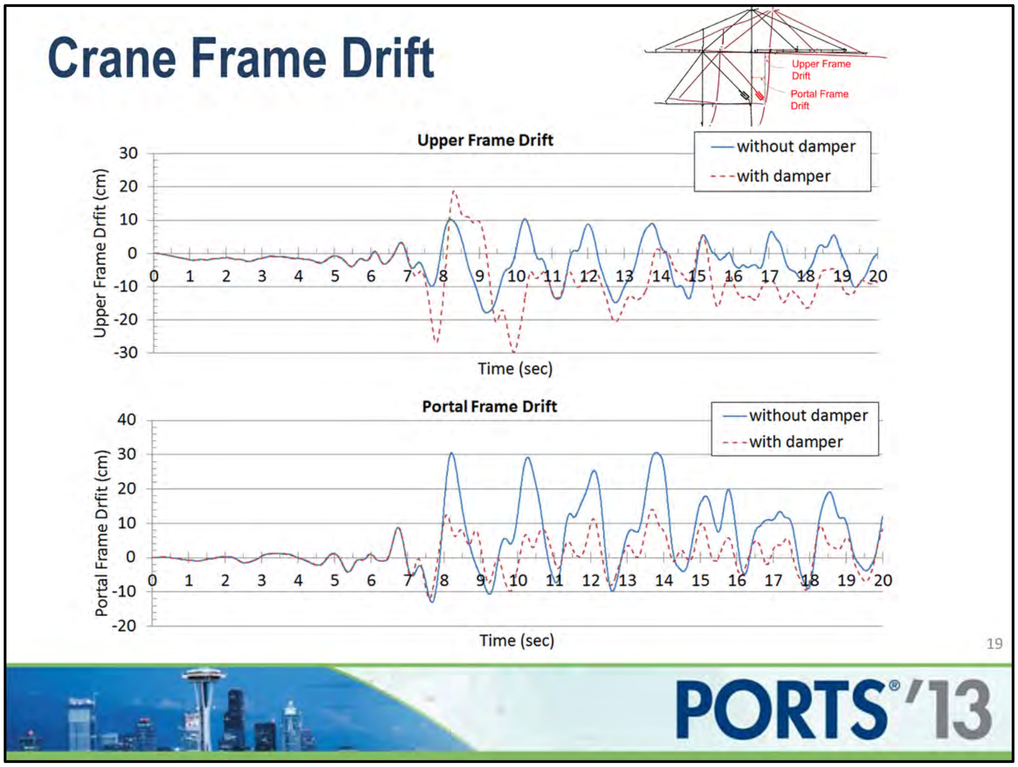
POLA provided site-specific ground motions for each earthquake level.

Since the wharf design was not complete when the time history analysis was performed, the wharf model parameters were bounded according to the expected range of the wharf properties.

The analysis results indicated that the displacement demand satisfied the POLA code for the wharf.

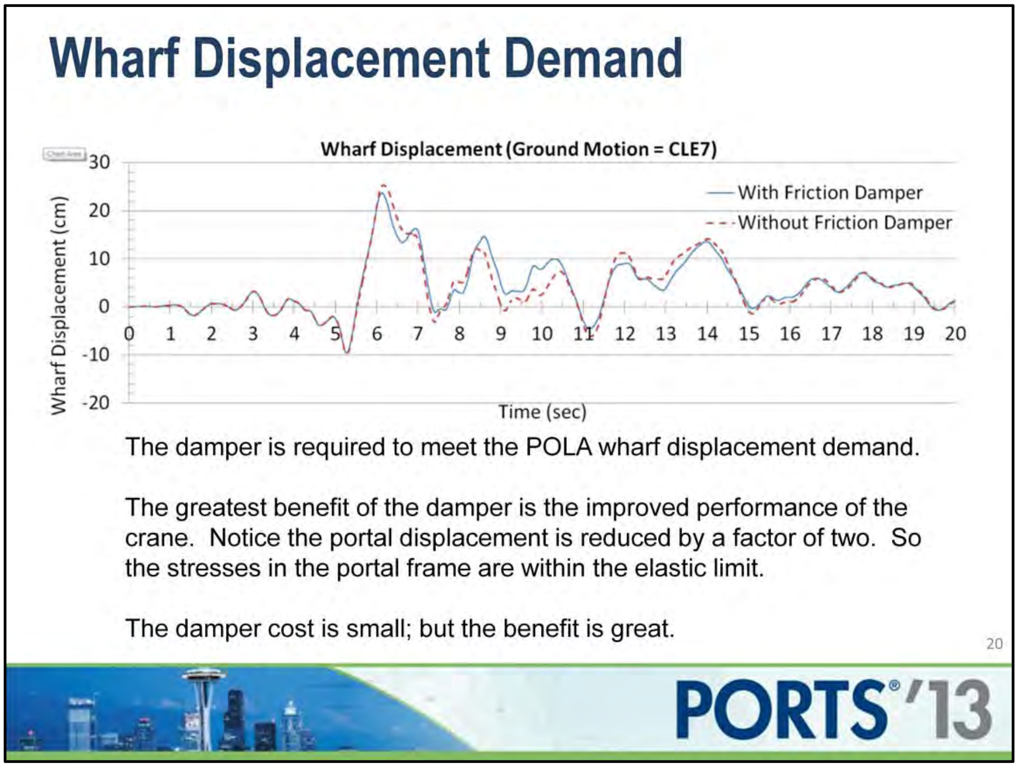
The stresses and displacements in the crane structure conformed to the crane design criteria.

The model shown here is simplified for demonstration purposes. One can see the legs lift and the gage reduce during the design seismic event.



Notice that with the damper the upper frame displacement increases, since the damper allows more distortion of the upper frame.

The portal frame drift is reduced by a factor of two, indicating a comparable decrease in the leg strain and stress.



The damper is required to meet the POLA wharf displacement demand.

The greatest benefit of the damper, however, is the improved performance of the crane.

The damper cost is small; but the benefit is great.

Calculated Corner Loads, *t /corner (k / corner)*

	Typical Post-Panamax				APL Dual-Trolley Crane			
	Service		Factored		Service		Factored	
	LS	WS	LS	WS	LS	WS	LS	WS
Operating	*400 (900)*	*650 (1,450)*	*520 (1,150)*	*840 (1,850)*	*830 (1,830)*	*850 (1,870)*	*1,060 (2,340)*	*1,080 (2,380)*
Stowed	*460 (1,010)*	*670 (1,480)*	*620 (1,370)*	*950 (2,090)*	*970 (2,140)*	*990 (2,180)*	*1,300 (2,870)*	*1,320 (2,910)*
Seismic	-	-	-	-	-	-	*2,200 (4,850)*	*2,000 (4,410)*

Dead Load	Typical post-Panamax crane	= 1,300 t (2,870 k)
	APL dual-trolley crane	= 2,050 t (4,520 k)
Operating	Dead load + moving load + gantry inertia load	
Stowed	Dead load + trolleys + lift systems + ASCE 7-05 stowed wind	
Seismic	Time history analyses of seven CLE ground motions	

LS is landside; WS is waterside

21

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During the CLE, the maximum vertical load at a crane corner is about 2,200 t (4,400 k). This load is significantly larger than the operating and stowed loads. The duration of the large load is short.

Based on excellent wharf performance when cranes collapse or overturn, the usual practice is to ignore extreme accidental loads and vertical seismic loads for the design of typical reinforced concrete, pre-stressed, pile-supported wharves.

There are many extreme calculated loads, e.g., collision and stability loads, on wharf crane girders that are commonly not reported to or considered by the wharf designer. Notice if the crane begins to tip about a rail, the load on that rail is over 2,000 tonnes unfactored dead load.

Neglecting these loads is reasonable for a number of reasons:

Most extreme loads occur suddenly and for a short duration. Typical short-span concrete girders resist the short duration loads through inertia forces and increased strength due to the high rate of loading.

The wharf designer should be aware of the possible extreme loads and their design considerations and implications.

Although the usual practice is reasonable, further investigation may be justified for some situations.

The paper and presentation will be available on our website, www.Liftech.net.

I would like to thank my co-authors, especially Mr. David Olsen of APL, who contributed to the paper and presentation.

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23

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