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Features of the APL Los Angeles 22-Wide STS Cranes

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ABSTRACT

APL commissioned four new ship-to-shore (STS) container cranes at its Port of Los Angeles (POLA) Pier 300 terminal facility earlier this year (2013). The cranes will service container ships up to 22 containers wide with high cube containers stacked nine high on deck. The semi-automatic dual-trolley cranes have an outreach of 64.3 m (211 ft) from the waterside rail, a lift height of 44.2 m (145 ft) above the rail, and weigh 2,050 tonne (4,520 kip) including trolleys and lift systems.

In addition to meeting usual non-seismic specification provisions, the cranes comply with the POLA Seismic Code 2010 for the seismic design of container wharves. Furthermore, the cranes are designed to be operational, with minor repairs, after the design Operating Level Earthquake (OLE) and not collapse during the design Contingency Level Earthquake (CLE).

This paper describes the cranes' general characteristics and salient operational and technical features, including: critical dimensions, wheel loads, shore power demand, selection of a cable reel rather than a collector system, semi-automation, ship trolley and shore trolley operation, transfer of containers between the trolleys and to automatic guided vehicles (AGVs), handling oversized loads, and also includes a brief description of special seismic components to protect the crane and the wharf.

The paper explains the basis for various design decisions including the choice of a single-lift ship trolley rather than tandem-lift, the container deconing and transfer platform, the personnel access to the crane considering the AGV operating zones, and the waterside utility traffic lane.

A brief overview of the container yard arrangement and operation is also presented to provide a perspective of the cranes' function in the entire container handling system.

INTRODUCTION

The APL Terminal is being expanded to service modern, large container ships up to 22 containers wide. The expansion will include a stacked container storage yard serviced by automated stacking cranes (ASCs), an automated guided vehicle (AGV) to road chassis transfer facility, and six jumbo ship-to-shore (STS) cranes. Initially, four STS cranes will be installed on the existing wharf; two more will be added when the expansion project is completed. See Figure 1.

This paper provides a plan of the yard and information about the cranes, wheel loads to the gantry rails, and a brief description of the special seismic design. The special design is necessary to meet the POLA Seismic Code 2010.

The POLA code only addresses the performance requirements for the wharf, not the cranes. The APL crane specifications, however, applied similar performance standards used for the wharf's performance to the crane.

The crane structure includes relatively simple seismic dampers, which protect the wharf and the crane during the POLA-specified design ground motions. The cranes and wharf will be able to operate after an OLE. This performance requirement is unusual for jumbo STS cranes.

THE YARD

The STS cranes are designed to function as part of an overall terminal system including a container yard using ASCs for storing and retrieving containers, automated landside transfer cranes (LTCs) that facilitate the loading and discharging of containers from road truck chassis, and AGVs that provide horizontal transport around the yard between the STS cranes, ASCs, and LTCs. See Figure 1.

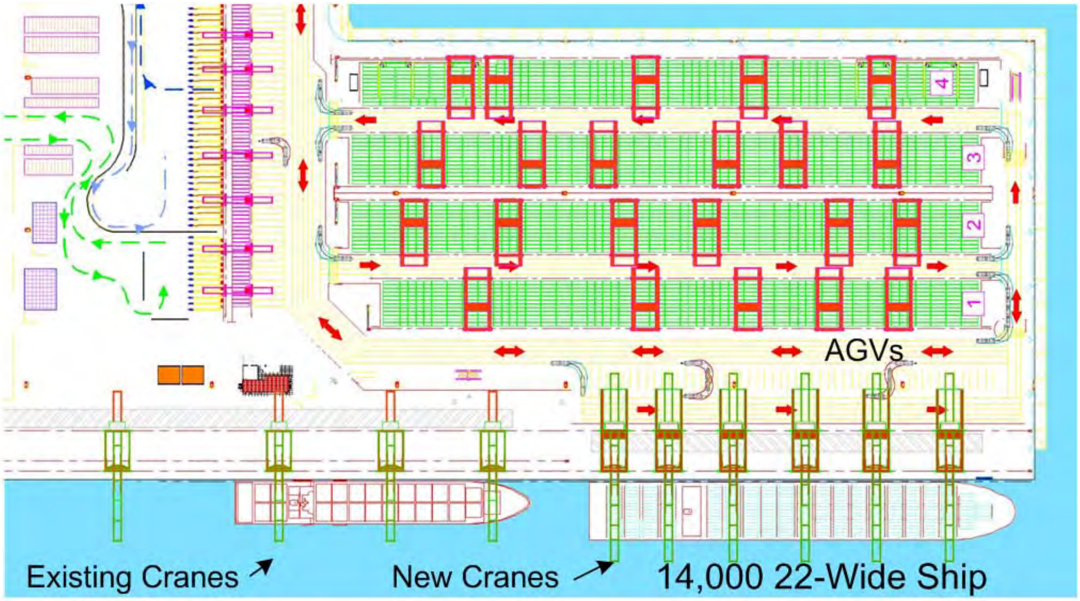


Figure 1. APL Terminal Expansion, POLA, Pier 300. *Source: Moffatt & Nichol.*

THE CONTAINER CRANE

The general arrangement and salient components are shown in Figure 2.

The semi-automatic, dual-trolley crane has an operating weight of 2,050 t (4,520 k), an outreach of 64.3 m (211 ft), a crane rail gage of 30.48 m (100 ft), a backreach of 25 m (82 ft), and a lift height of 44.2 m (145 ft) above the crane rail. (Note: 1 t = 1 metric tonne = 1,000 kg; 1 k = 1 kip = 1,000 lbs.)

Operation can be either single or double cycle using both the semi-automated ship trolley and the fully automatic shore trolley. The crane is expected to produce at least 33 net moves per hour.

The power supply voltage for these cranes will be 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 (66 t, 146 k) duty cycle is 2,320 kVA.

THE COMPONENTS

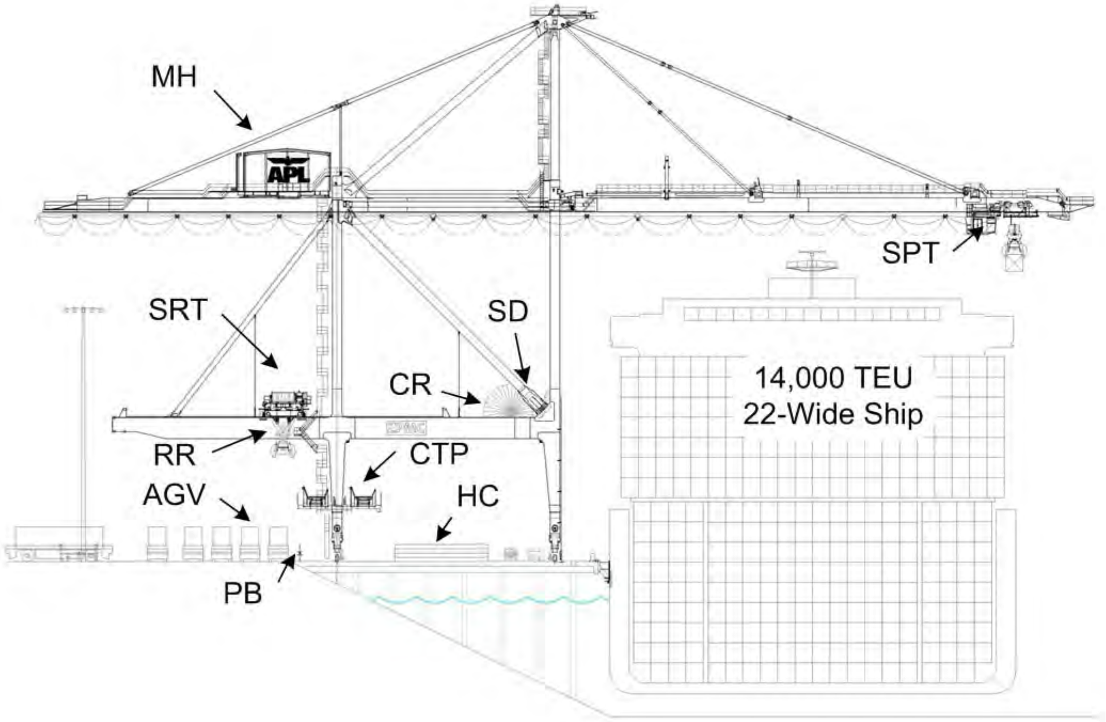


Figure 2. Crane features.

SPT Ship trolley: Fleet through reeving; rated load 65 LT (66 t, 146 k); one 20’/40’/45’, separating twin-twenty spreader; single-hoist; 244 m/min (800 ft/min) trolley speed, 90 m/min (295 ft/min) hoist speed at rated load. The trolley is controlled manually when it is over the ship and automatically back to the CTP.

A single-hoist, twin-twenty trolley was selected rather than a tandem-lift, dual-hoist trolley (two 40 ft containers in parallel), as the tandem-lift trolley would increase weight, capital cost, and ongoing maintenance costs, and would not significantly increase the overall system productivity.

MH Machinery House: The MH is conventional. The drives are AC with automation and safety controls.

CTP Coning and Transfer Platform: Containers are set and picked from the platform automatically by both trolleys. Triple redundant controls prevent the container from landing too hard. Personnel access is provided to the platform for setting or removing stacking cones for on-deck containers. Sensors and safety procedures are designed so that both trolleys are clear of the platform when personnel are on the platform. This operation may be automated later. The platform also buffers the difference in the production of the two trolleys.

SRT Shore Trolley: Machinery on the trolley, rated load and spreader match the SPT; 122 m/min trolley speed, 60 m/min hoist speed. The trolley is fully automated. Rigid reeving controls the load precisely.

RR Rigid Reeving: The rigid reeving is conventional. See Figure 3. A single-hoist drum ensures constant speed for all the falls. Hydraulic cylinders provide micro-motions over the AGV: ± 300 mm (12 in) longitudinal, ± 150 mm (6 in) transverse, and ± 3 deg skew.

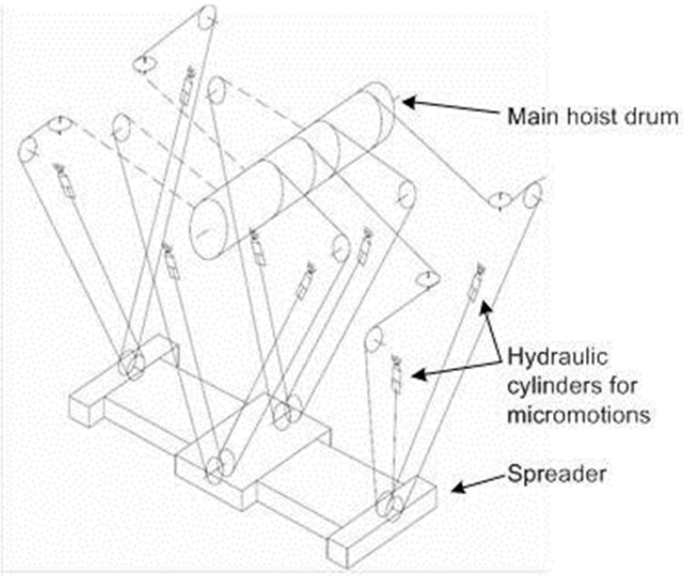


Figure 3. Shore trolley rigid reeving.

AGV Automatic guided vehicle: The AGVs are battery powered and free ranging on a transponder grid.

CR Cable Reel: A medium voltage cable reel capable of either 4.16 kV or 12.47 kV, 60 Hz; 450 m (1,500 ft) cable travel each way; fiber optics; ground and ground check in the cable. A cable reel was selected as it is more reliable than a power trench and can provide integral fiber optics. The original wharf design provided structure to incorporate either a cable reel or power trench system.

HC Hatch Covers: HC stowage is between the legs. The lanes waterside of the HCs are for manned highway vehicles. The lanes waterside of the crane are for ship's supply and maintenance traffic.

PB Personnel and vehicle barrier: No persons are allowed in the automated yard during operations.

SD Seismic Damper: See the next section for discussion of the SD.

THE SEISMIC CRITERIA, SEISMIC DESIGN, AND CORNER LOADS

Criteria

The POLA Seismic Code 2010 specifies structural criteria for the wharf but not for the crane other than the requirement that the crane shall not increase the displacement demand on the wharf. Three levels of site-specific ground motions are identified:

Operating Level Earthquake (OLE), Contingency Level Earthquake (CLE), and Design Earthquake Level (DE).

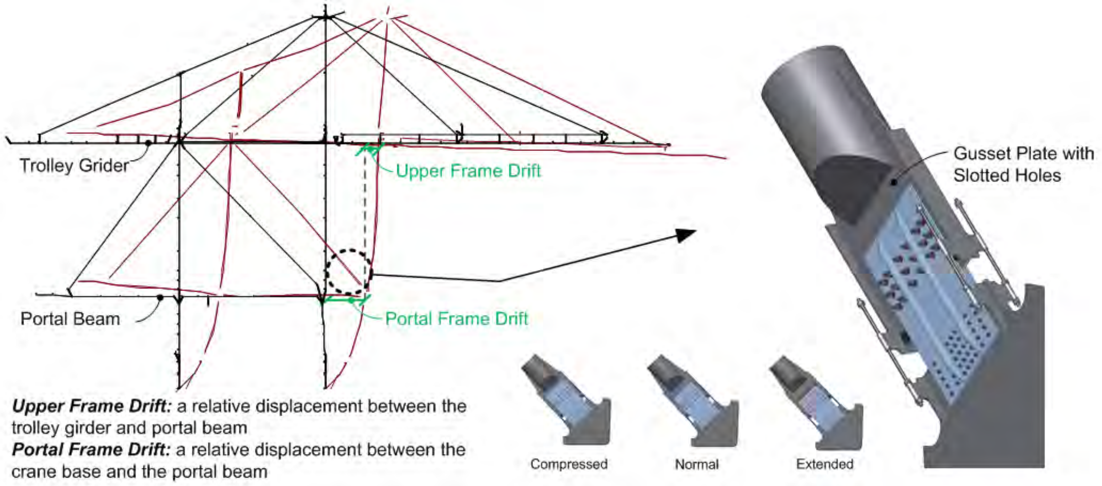
The performance goals for the wharf structures for each level are:

1. Operating Level Earthquake (OLE): No significant structural damage. Damage location to be visually observable and accessible for repairs. Minimum or no interruptions to wharf operations during repairs.
2. Contingency Level Earthquake (CLE): Controlled inelastic structural behavior and limited permanent deformations. Damage location to be visually observable and accessible for repairs. Temporary or short-term loss of operations may occur.
3. Design Earthquake Level (DE): Safeguard against major structural failures and loss of life.

Depending on the dynamic properties of the wharf and crane, a time history analysis may or may not be required to determine if some special consideration is needed so that the displacement capacity of the wharf is not exceeded.

Seismic Design

Based on the expected dynamic properties of the APL wharf and on the operational requirements of the APL crane, the time history analysis indicated that a damper or base isolation device was required so that the crane seismic response did not cause the wharf displacement demand to exceed the capacity of the wharf.



Upper Frame Drift: a relative displacement between the trolley girder and portal beam
Portal Frame Drift: a relative displacement between the crane base and the portal beam

Figure 4. Crane drift and friction damper.

Initial time history studies indicated that the proposed crane would need damping devices to meet the POLA requirements. Several solutions were studied. The studies indicated that a friction damper was the best solution. See Figure 4. The beneficial features are:

A special triggering mechanism is not required since the joint slides at a prescribed load.

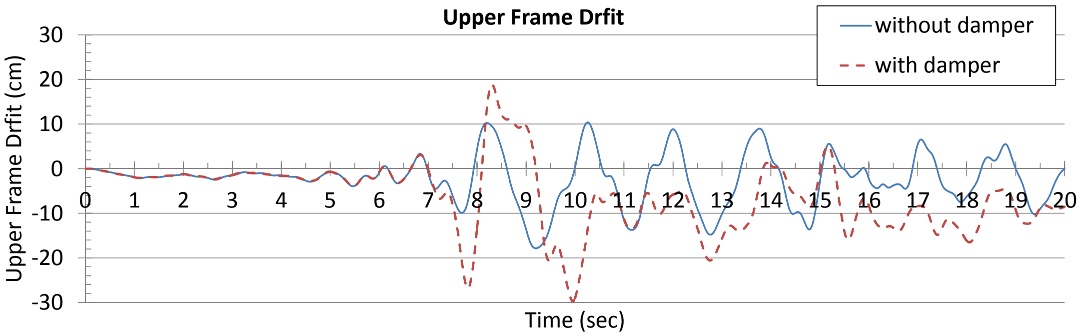
After the activated joint comes to rest, the original geometry can be restored using threaded rods—maintenance is minimal.

The cost is relatively small.

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. The damper controls the wharf displacement demand, the relative motions of the crane frame, and keeps the strains to acceptable levels.

No slippage of the friction joint occurs until the force in the diagonal brace exceeds the static friction strength of the damper. The dynamic friction is, of course, less than the static friction, but only slightly. The reduced sliding force is not a problem.

The damper design was developed using time history analyses. POLA provided site-specific ground motions for each earthquake level. Each ground motion record consisted of three orthogonal components: fault normal, fault parallel, and vertical. The wharf was modeled using four “super piles,” as described in Reference “POLB WDC,” and the anticipated mass and stiffness of the wharf. The wharf design was not complete when the time history analyses were performed. The wharf model parameters were bounded according to the expected range of the wharf properties. The crane model for the time history analyses was identical to the detailed model used for the crane stress analysis. The analysis results indicated stresses and displacements in the crane, and the displacements and time history of the leg lift and loads to the wharf. The crane displacement time history for one of the CLE ground motions is shown in Figure 5. The plots show the lateral frame displacement (see Figure 4) at the trolley girder level (upper frame) relative to the portal level (portal frame) and the portal level relative to the wharf. Notice the combined drift at the trolley level (upper frame plus portal frame) is about 40 cm (16 in) each way, 80 cm (32 in) total.



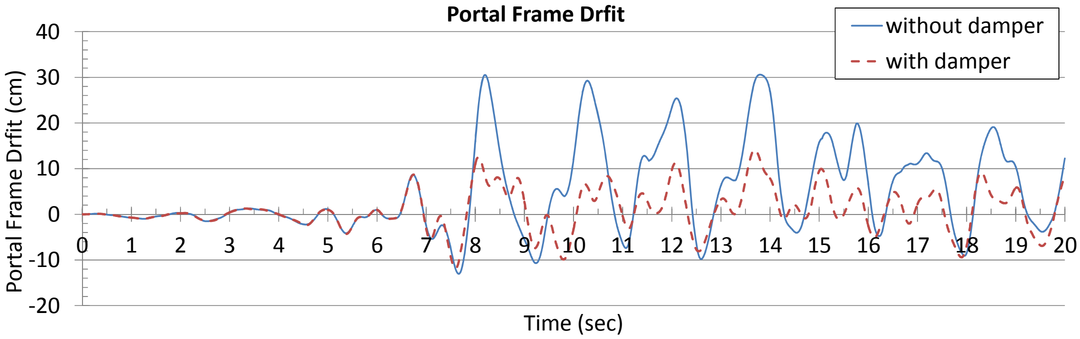


Figure 5. Time history of crane displacement.

The calculated stresses were elastic for the OLE, and were slightly above elastic for the CLE. The damage due to the CLE will be minimal and reparable. After a large earthquake, the crane legs will probably be off and between the rails because as the crane rocks and lifts off the rails, the crane wheel gage decreases. The reason for this is clear if one envisions the deflected shape. The maximum stresses are compressive and on the inside face of each leg during lift-off.

No tie-downs are required and would be detrimental. Additionally, the stowage sockets, which resist stowed wind loads, should allow for the crane wheels either sliding along the rails or rotating when the brakes are overridden.

The APL crane is not the first to be designed to modern seismic requirements. Significant revisions were made to Liftech's crane specification requirements in 2007 to address seismic performance issues. Since then, many other cranes have been designed according to the improved performance criteria.

For some cranes, the crane's effect on the wharf was limited to the maximum effect caused by existing cranes, i.e., the displacement demand was not increased. However, the wharf design was not necessarily in compliance with the OLE, CLE, and DE criteria stated above. In some cases, the cranes were designed for tipping or using special moment frames. A time history analysis was performed for a proposed low profile, shuttle boom crane. In all of these cases, the wheel loads due to seismic events were large and the crane-wharf interactions were comparable to those of the APL cranes.

Seismic Corner Loads

During the DE, the maximum vertical load at a crane corner is about 2,000 t (4,400 k). This load is significantly larger than the operating and stowed loads. The duration of the large load is small: the load goes from zero at 8.3 s, to 2,000 t (4,400 k) at 9.0 s, and back to zero at 9.3 s. See Figure 6 and Table 1.

The usual practice is to ignore extreme accidental loads and vertical seismic loads for the design of typical reinforced concrete prestressed pile supported wharves. There are many extreme loads on wharf crane girders that are commonly not reported to the wharf designer or considered by the wharf designer.

This is reasonable for a number of reasons.

1. Most extreme loads occur suddenly and for a short duration. The typical short-span concrete girders resist the short duration loads through inertia forces and increased strength due to the high rate of loading. See Figure 6.
2. The wharf designer should be aware of the possible extreme loads and their design considerations and implications.
3. Although the usual practice is reasonable, further investigation may be justified for some situations.

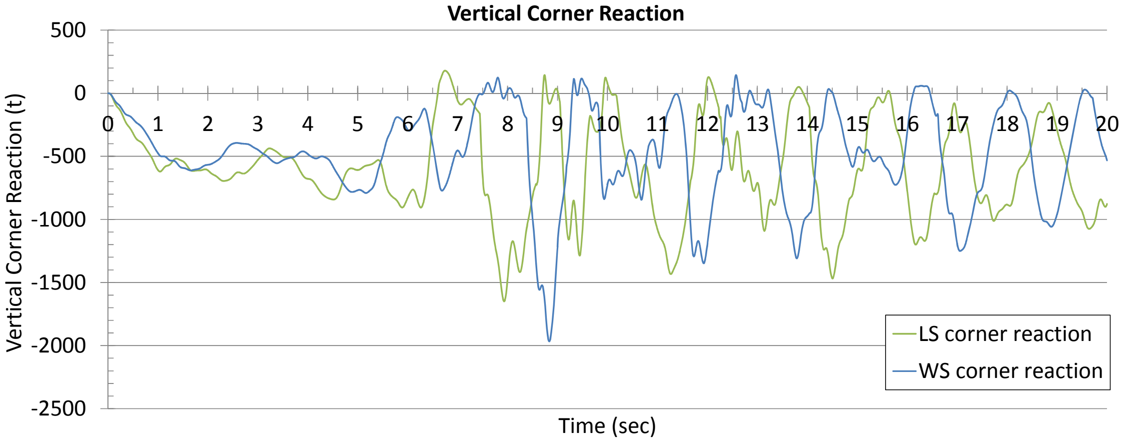


Figure 6. Time history of crane vertical corner reaction.

Corner Design Loads for all Design Conditions

The corner loads for dual-trolley, semi-automatic cranes with 22-wide capabilities are significantly larger than those for single-trolley 22-wide cranes. The peak corner loads for both the APL cranes and Port of Oakland single-hoist 22-wide cranes are shown in Table 1.

Table 1. Typical Maximum 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	410 *(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)*

Notes:

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 + Stowed Wind, with ASCE 7-05 137 km/hr (85 mph) basic wind speed

Seismic: From time history analyses, maximum of seven CLE ground motions

LS is landside; WS is waterside.

CONCLUSION

The APL jumbo STS crane is a harbinger of container cranes servicing 22-wide or more vessels and supporting automated yards. The future cranes will have a remote controlled or semi-automated ship trolley and a fully-automated shore trolley. The ship trolley will lift one spreader, like the APL crane, or lift two spreaders that pick containers in tandem, side to side, like some cranes currently under construction. The dual-spreader trolley has advantages and disadvantages. The better solution will depend on the situation and the coming experience with tandem-spreader trolleys. The shore trolley will have rigid reeving and micro-motion control to set the container on the AGV without relocating the gantry crane or shore trolley. Handling interbox connectors will remain problematic. Some automation of this may occur, but not for a while.

Jumbo STS cranes with dual trolleys will exert larger loads than today's conventional post-Panamax cranes. Some allowance, 20% or 25%, may be justified to allow for even heavier cranes in the future.

In seismically active regions some jumbo cranes will need to include special mechanisms to avoid overloading the wharf. Devices such as friction dampers are practical, relatively inexpensive, and protect both the crane and the wharf. The instantaneous vertical impact loads caused by a leg lifting during an earthquake are extremely large. But due to short duration of loading, a rapid rate of loading, and inertia effects, these impact loads are not expected to cause collapse or significant damage to a conventional reinforced concrete prestressed pile supported wharf.

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