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CONSIDERATIONS FOR LARGE CRANES

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BACKGROUND

Within the last five years, over twenty beyond post Panamax cranes have been placed in service in California ports. These cranes are designed to serve ships with containers stacked 5 high and 16 containers wide on the deck. These were the largest cranes to date. The crane owners are learning to work with these cranes.

As we are becoming familiar with the cranes serving 16 wide ships, a new generation of larger cranes is here. Maersk has reportedly ordered cranes to serve 20 wide ships. The ports of Oakland, California and Norfolk, Virginia have recently ordered cranes to serve ships with 22 wide containers stacked 6 containers high on deck.

A comparison of a crane serving 16 wide vessels and a crane on order for 22 wide vessels is shown in Tables 1 and 2. In general, the trolley runway length and lift height have increased. The rated capacity has increased to 65 LT to handle at least two 30 LT containers. The hoist speed has increased to compensate for the longer increased main hoist travel.

	Long Beach, California	**Oakland, California**
VESSEL SIZE	**16 wide**	**22 wide**
RAIL SPAN	**100'**	**100'**
OUTREACH	**165'**	**213'**
BACKREACH	**50'**	**60'**
TROLLEY TRAVEL	**315'**	**373'**
LIFT HEIGHT	**110'**	**115'**

Table 1 Crane Geometry

	Long Beach, California	**Oakland, California**
VESSEL SIZE	**16 wide**	**22 wide**
RATED LOAD	**50 LT**	**65 LT**
TROLLEY SPEED	**800 fpm**	**800 fpm**
MAIN HOIST SPEED	**200 fpm**	**230 fpm**

Table 2 Crane Performance

The larger 22 wide cranes raise many concerns, particularly considering the limited experience with the 16 wide cranes recently placed in service. If your plans require such large cranes, some considerations are:

- Cost
- Wheel loads and dock strength
- Effect of rope sag on rope wear, load control and operator comfort
- Rope trolley vs machinery trolley
- Avoiding excessive crane sway problems

DISCUSSION

Cost

Container crane costs have remained relatively soft over the last ten years. Each generation of cranes has increased in cost by about 10%. The purchase price for the cranes serving 22 wide ships is about 10% higher than the cranes serving 16 wide ships. The increased cost is not a significant factor in selecting the larger cranes.

Wheel Loads

With existing wharves, higher wheel loads may be a significant factor when selecting a crane size. A comparison of approximate wheel loads of 16 wide and 22 wide cranes is provided in Table 3.

VESSEL SIZE	16 wide	22 wide
TOTAL CRANE WEIGHT	2,300 kips	2,500 kips
FACTORED OPERATING WHEEL LOAD AT WATERSIDE 8 WHEELS / CORNER	200 kips / wheel	250 kips / wheel

Table 3 – Wheel Loads, 16 versus 22 wide

Although these approximate wheel loads can be reduced by shifting the balance of the weight of the crane and increasing the landside wheel loads, most existing wharves probably cannot support the new 22 wide cranes. The new 22 wide Oakland cranes are planned for the new Berth 55 facility. A comprehensive analysis of the existing wharf structure will be carried out with the modern techniques and proper load factors to determine the suitability of this new wharf.

If your wharf structure is inadequate to support the loads from the 22 wide cranes, you should seriously consider your future needs for such cranes as modifications to the wharf structure might be costly.

However, if you are building a new wharf for the cranes, the incremental cost to support the larger, 22 wide cranes is small. Considering the marginal increase in cost and historical increases in crane sizes, it may be worthwhile to build the wharf structure for larger cranes, even if you do not plan to purchase such cranes in the near future.

Rope Sag

Excessive rope sag causes rope damage from slapping, makes trolley positioning difficult and causes lifted containers to bounce.

Catenary trolleys were first introduced to control rope sag on post Panamax cranes. One catenary trolley is placed in front of the main trolley and a second trolley is placed behind the main trolley. In some cases, continuous rope supports are used instead of catenary trolleys. The catenary system and rope sag for a 22 wide crane is shown in Figure 1.

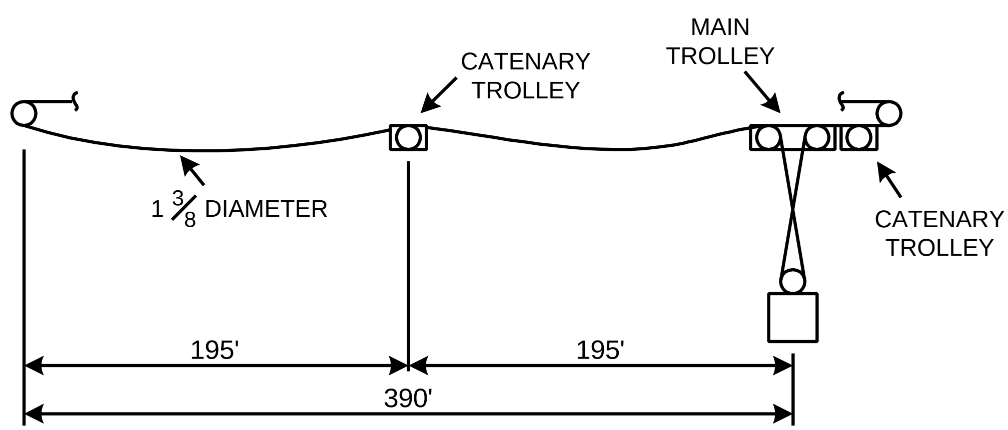

Figure 1 Elevation View of Rope Sag and Trolley System

The two-catenary trolley system has worked well for the earlier Post Panamax cranes. Although it has been tolerable, some owners of 16 wide cranes are complaining about increasing rope wear due to increased rope slapping.

In addition to rope wear problems, trolley positioning is complicated from rope sag because of increases in unbalanced pull on either side of the main trolley and oscillations in pull from slapping. Electronic antisway was introduced to position the boxes automatically and may help mitigate the positioning problems caused by rope sag.

The two-catenary trolley solution is planned to be used with the 22 wide cranes. The manufacturers are taking a wait and see approach. One thing we do know. Rope sag will increase significantly due to increased trolley travel distances and larger, heavier rope sizes.

Currently, many operators have comfort and productivity complaints and only use the antisway system to initially position the load.

Although electronic antisway will improve and mitigate some of the load control problems, currently there is no good solution to reduce rope sag and the rope wear problems from rope slapping. Rope sag reduction solutions include using more catenary trolleys or continuous rope supports. If additional catenary trolleys are used, trolley runway lengths will have to increase without an increase in the trolley operating range. Continuous rope supports complicate trolley design and maintenance.

Rope Trolley vs Machinery Trolley

APL recently purchased machinery trolley cranes for their Los Angeles, Kaohsiung and Karachi facilities. These cranes serve ships with 16 wide containers on deck. The ports of Miami and Vancouver also have machinery trolley cranes. APL decided on machinery trolleys after a detailed analysis concluded that the machinery trolley cranes provided the least lifetime cost. They are pleased with the cranes and plan to purchase machinery trolley cranes where practical.

Despite some machinery trolley cranes purchases, for various reasons many other ports have not embraced machinery trolley cranes. The larger size and lift capacity of the 22 wide cranes may result in additional reasons to purchase rope trolley cranes instead of machinery trolley cranes.

With lift capacities of up to 65 LT and higher speeds, the main hoist and trolley machinery weigh significantly more. See Table 4.

TROLLEY TYPE	ROPE TROLLEY	MACHINERY TROLLEY
TROLLEY WEIGHT	45 kips	180 kips
LIFT SYSTEM	37 kips	37 kips
LIFTED LOAD; 65 LT	145 kips	145 kips
TOTAL MOVING LOAD	227 kips	362 kips
MOVING LOAD FOR FATIGUE DAMAGE	150 kips	285 kips
FATIGUE DAMAGE	1.0	6.9

Table 4 – Trolley Weights and Fatigue Damage

To meet strength and particularly fatigue requirements, the heavier moving load results in a heavier, costlier structure. The heavier structure combined with the significantly heavier moving load results in much higher wheel loads. See Table 5. The higher wheel loads and the higher costs may offset the lifetime costs, i.e. the maintenance savings realized by APL for the 16 wide cranes.

TROLLEY TYPE	ROPE TROLLEY	MACHINERY TROLLEY
VESSEL SIZE	22 wide	22 wide
TOTAL CRANE WEIGHT	2,500 kips	2,700 kips
FACTORED WHEEL LOAD AT WATERSIDE 8 WHEELS / CORNER	250 kips / wheel	290 kips / wheel

Table 5 – Approximate Weights and Wheel Loads

The higher initial crane costs for machinery trolley cranes is apparent by the recent crane purchase by Ceres Terminals. Ceres Terminals invited bids for nine cranes for their Amsterdam Terminal and gave an option of rope trolley and machinery trolley cranes to the bidders. None of the bidders bid machinery trolley cranes because they cost more than the rope trolley cranes.

If you have plans to purchase machinery trolley cranes serving 22 wide ships, consider also asking for a quote for a rope trolley crane.

Excessive Crane Sway

A new problem has emerged with the construction of some larger container cranes, excessive sway of the gantry frame in the trolley travel direction during normal crane operation.

Why is it new? Two major reasons are changes in the dynamic characteristics of the structure and increasing lateral loads resulting from more demanding trolley performance.

The increase in lateral loads is caused by faster trolleys. Because this is inevitable, this paper will focus on changes in the dynamic characteristics of the structure and some factors that affect the dynamic response of the structure.

The lateral stiffness of the crane has historically been a secondary result of the strength necessary to resist wind loads. The increase in lateral stiffness has not kept pace with the increase in mass of the structure, particularly in low wind areas. The increase in mass and smaller increase in lateral stiffness has resulted in higher natural periods of sway, and larger magnitudes of sway.

The more significant factors affecting crane deflection in the trolley travel direction from normal crane operation, other than frame stiffness and mass, are discussed below.

VARIABLE LIFTED LOAD HEIGHT

Container cranes move containers to and from a ship. This operation results in a wide range of lifted load heights.

This range of lifted load heights includes heights at which the period of the hanging load is between multiples of the crane structure period.   When the hanging load period is between multiples of the crane structure period, the swinging hanging load will excite the frame.

To control the hanging load, an operator will vary the trolley acceleration time by a multiple of the hanging load period as shown in Figure 2. At certain hanging load periods, this is the worst thing the operator can do to minimize deflection of the structure as shown in Figure 3.

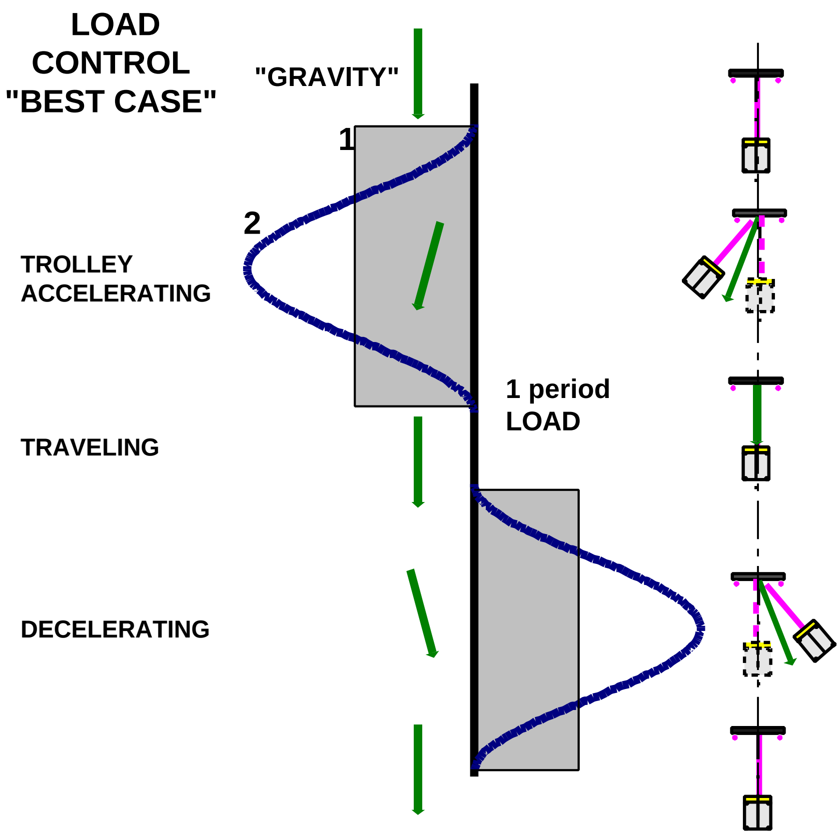

Figure 2 – Trolley Operation – Best Load Control

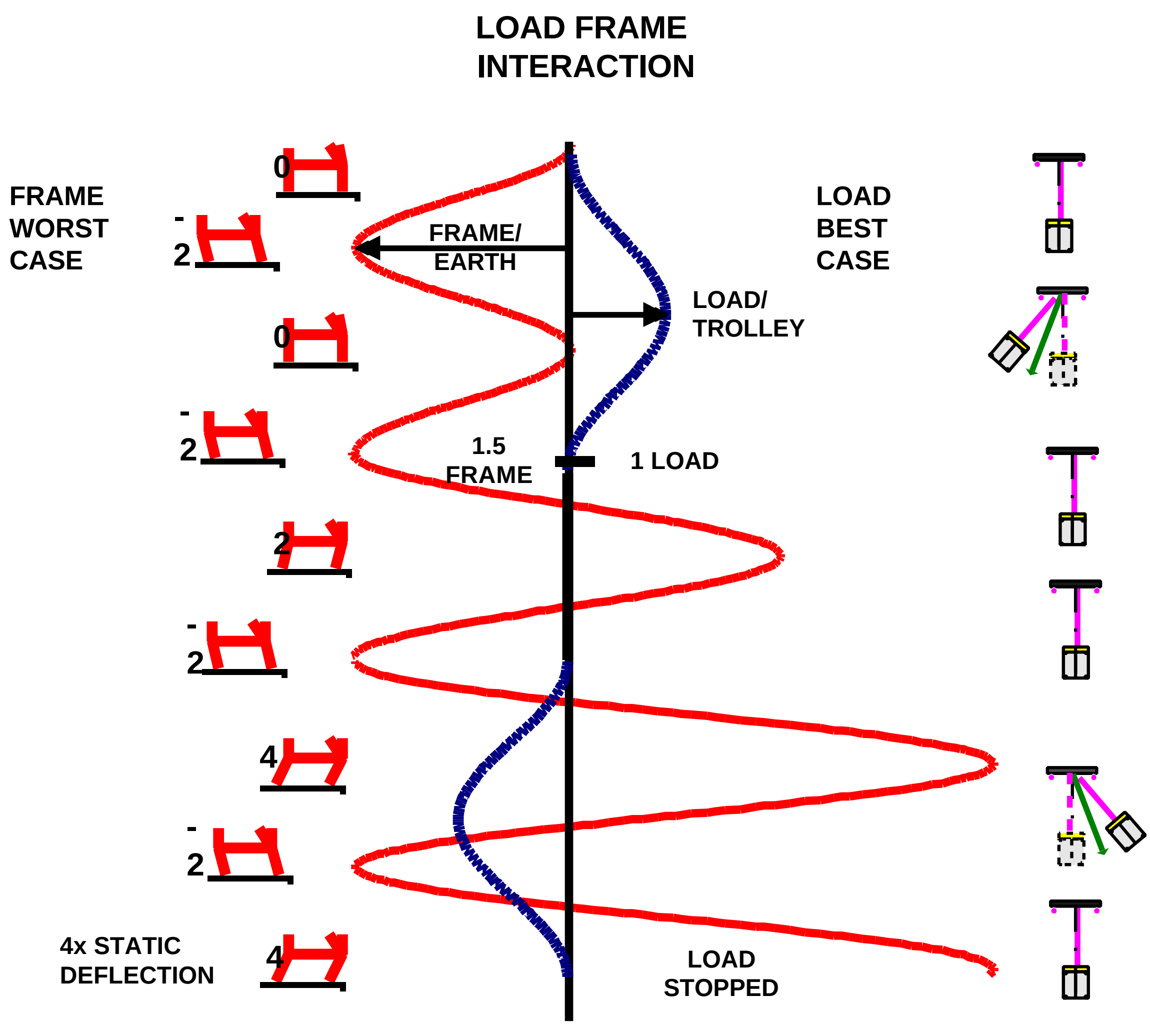

Figure 3 – Frame Response with Best Load Control

Optimal control of a hanging load having a period between multiples of the crane structure period results in the maximum response of the structure. Although this is true of all cranes regardless of their period, some periods may coincide with common hanging load heights. Additionally, as the period of the crane structure increases, the range of hanging load heights resulting in the maximum structural response also increases. It is impractical to place restrictions on hanging load heights to control crane sway.

IMPULSE LOADING INTERVALS

In addition to the loads applied to the structure from the sway of the hanging load, the movement of the trolley system is an impulse loading on the crane structure. The duration of the trolley accelerations and duration between accelerations can either decrease or increase the motion of the crane structure.

Similar to hanging load height, the time intervals between trolley movements and the duration of trolley accelerations vary during operation. Similar to controlling hanging load heights, it is also impractical to control the time intervals between trolley movements and the duration of trolley acceleration.

SWAY DAMPING

A certain level of damping, or attenuation of sway, is desirable in a container crane to prevent significant compounding of crane sway between trolley movements.

With container cranes, the hanging load system has some damping, and the crane structure itself has some damping. Typically, there is very little damping in the crane structure. Additionally, there is very little damping in the hanging load system when the load control system is electronic as the falls are nearly vertical.

Additional sources of damping can be added to a crane system to significantly increase the amount of damping. One such source could be a tuned mass damper. The addition of a tuned mass damper requires an analysis of the crane system, and the addition of a large sliding mass with viscous dampers that is tuned to counteract the natural motion of the structure. In addition to adding mass to the structure, a damping system would require some maintenance.

HANGING LOAD ANTI-SWAY SYSTEM

If the magnitude of the sway is too large, the anti-sway system may also exacerbate crane sway.

Some anti-sway systems work by calculating the sway and moving the trolley to minimize the sway of the hanging load. The sway of the hanging load is calculated by measuring the lateral forces exerted on the sheave block of the ropes holding the hanging load. Because the system references the ropes relative to the crane instead of the ground, if the crane structure sways significantly, the system will engage although the hanging load may not be swaying relative to the ground. Furthermore, if the period of the hanging load is between multiples of the crane structure period, the anti-sway system will apply impulses to the crane resulting in amplification of the crane sway.

SUMMARY

Many factors affect the magnitude of crane deflection in the trolley travel direction during normal crane operation. Some of the factors, such as hanging load height and trolley acceleration times, are very difficult and impractical to control. Factors such as frame stiffness are easy to control. Although there are other ways to control excessive crane deflections, modifying the stiffness of the crane structure to obtain a lower period of motion is simple and has worked well. For new cranes, a frame period of 1.5 seconds or less is recommended.