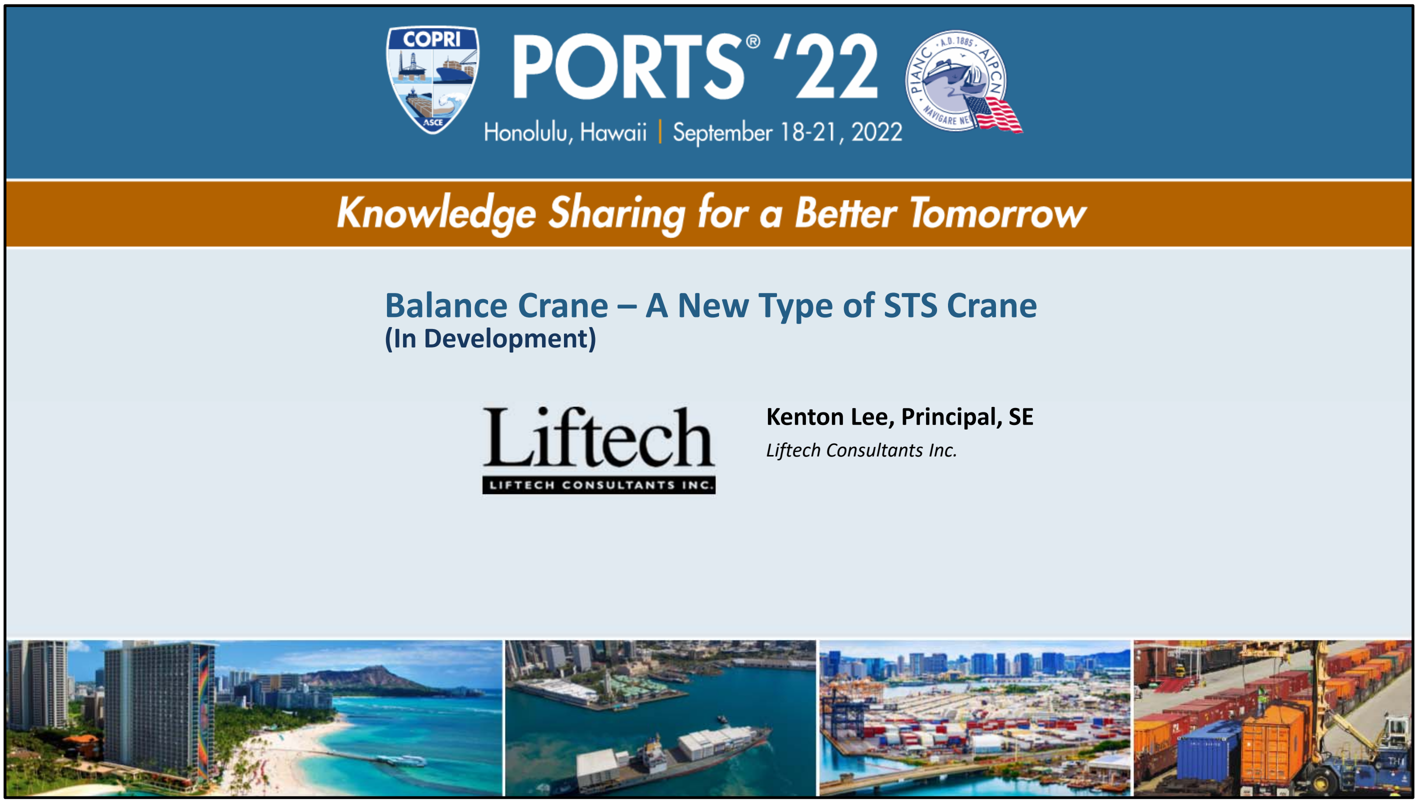
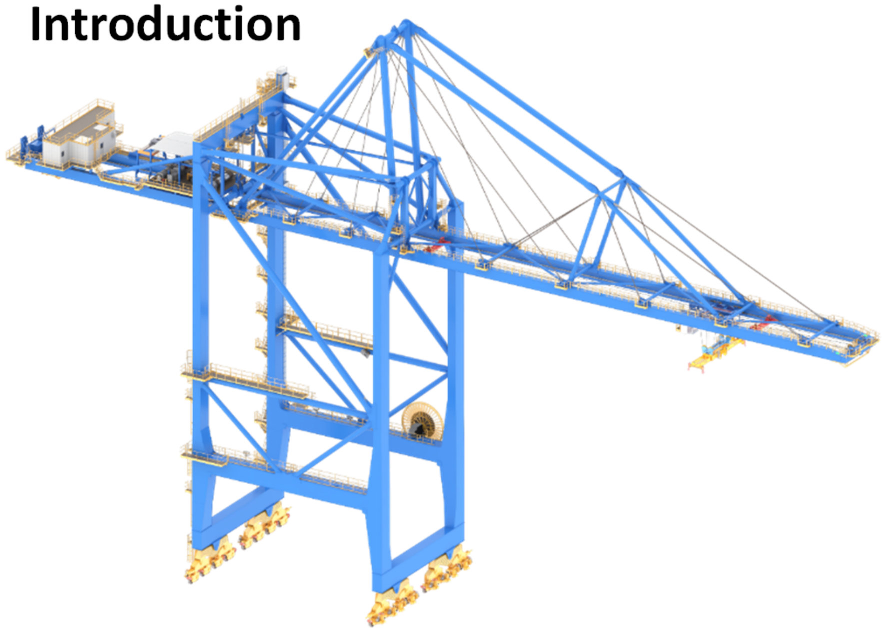


Liftech Consultants Inc. is a consulting engineering firm, founded in 1964, with special expertise in the design and procurement of dockside container handling cranes and other complex structures. Our experience includes structural design for wharves and wharf structures, heavy lift structures, buildings,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

Mr. Lee is experienced in design, analysis, and project management of container cranes, floating cranes, rigging, and special structures. He specializes in container and floating crane procurement projects and crane modification projects. He is also involved in preparing structural maintenance programs. Some of the technical aspects of his work that are of special interest to him are steel connection design, wind effects on structures, wind tunnel testing, and structural fatigue of steel structures.

Introduction



Images and animation courtesy of Shanghai Zhenhua Heavy Industries Company Limited (ZPMC)

2

Known for concept cranes and innovations, Liftech conceived the Balance Crane (BC) and developed the design in collaboration with crane manufacturer ZPMC, Shanghai, China. This future crane, also called articulating balance crane (ABC), is a new type of STS container crane developed to address a need for reduced wheel loads and reduced tie-down loads.

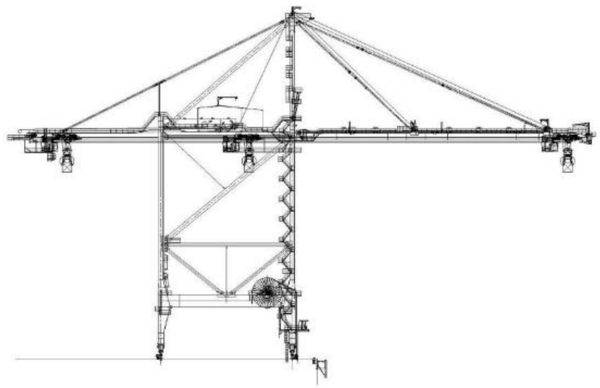
STS container cranes have increased in height and outreach to accommodate ever-increasing ship sizes, while the crane footprint has not changed.

Vertical loads on the wharf due to crane lateral loads have increased significantly, resulting in large wheel loads and tie-down loads on the wharf, which are especially problematic in high wind regions and when a terminal wants to place larger cranes on an older wharf with limited wheel load capacity.

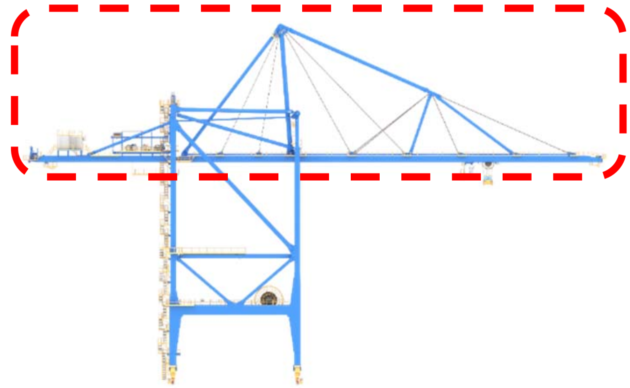
The BC has reduced wheel loads and tie-down loads compared to a standard STS container crane but functions similarly. There are advantages in terms of operation and maintenance that include improved access to the trolley and machinery and improved trolley rail maintenance.

In this talk, I will describe how the BC works and discuss selected design features and advantages.

Balance Crane Versus Conventional STS Crane - Boom Down



Conventional crane

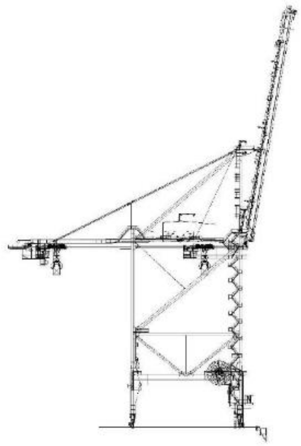


Balance crane

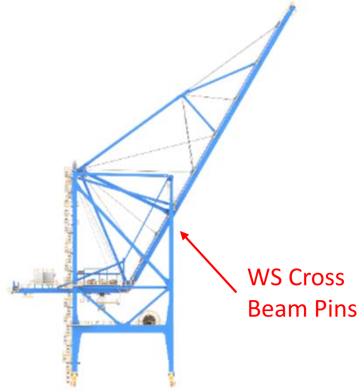
3

This slide shows the BC compared with a conventional STS crane the same size: same lifting height, outreach, and backreach. Notice, the BC has a special upper works design that I will discuss soon.

Balance Crane Versus Conventional STS Crane – Boom Up



Conventional crane



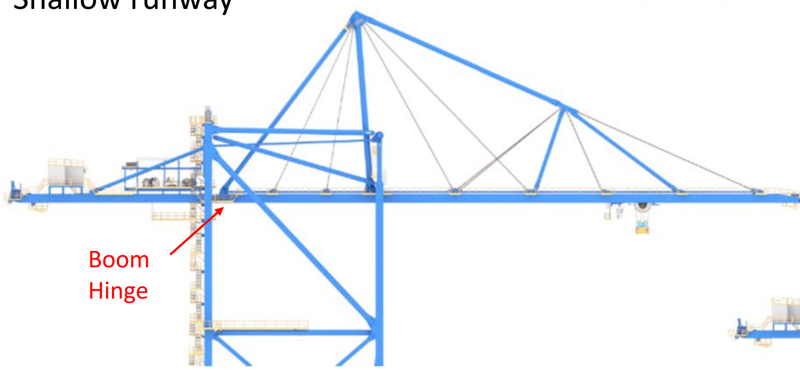
Balance crane

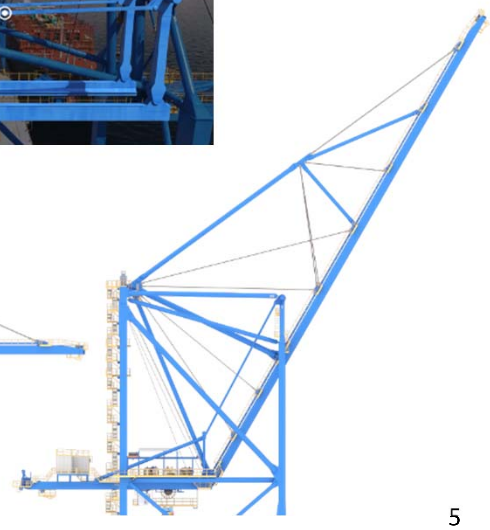
4

Due to the special upper works design, when the boom is raised, the landside part of the boom, and the trolley girder, machinery house, and trolley are lowered as the boom rotates about pins at the waterside cross beam. The BC balances the weight of the upper works at the WS pins, hence the name, balance crane.

Upper Works

- Boom hinge location
- Parallel linkage
- Pylons and cable stays
- Shallow runway





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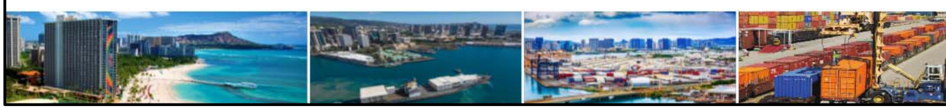


1. The rail joint transition, normally at the waterside support, is now at the landside support, so the trolley rails are continuous from the boom tip to the landside support cross beam. More on that later.
2. When the boom is rotated, a "parallel-linkage" holds the trolley girder parallel to the ground.
3. The pylons to the apex connect to the boom directly and rotate with the boom. Instead of four folding stays, 14 cable stays and pipes support the boom. The support members do not change position relative to the boom when it is raised. The total wind force of the round pipe diagonals and cable stays is less than the conventional I-beam forestay sections due to a lower drag coefficient.
4. The boom depth is shallower thanks to the increased number of supports, which reduces the weight and the wind area.
5. The stowed position of the trolley girder is lower, so the storm wind load and overturning effect are reduced. Wind load is also reduced because wind pressures increase with height.

Boom Hoist Animation

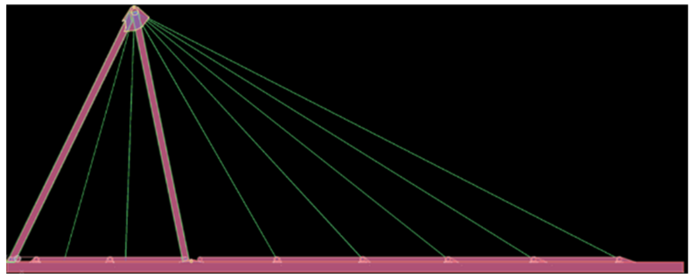
6

The animation shows the boom being raised from operating position to stowed position.
(Contact Liftech for video.)

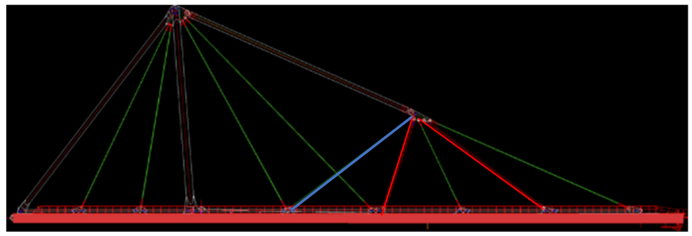
Also note that there is access to the trolley in both the boom up and boom down positions. We expect that the operator can be in the cab during boom rotating.

Boom Support

Initial concept



Latest concept



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The boom support concepts investigated:

Initial concept—Fan-type with cable stays (shown in green). Although it's a configuration similar to that used in many cable-stayed bridges, after some analysis, we found it to be problematic for the BC, mainly because the stays cannot be properly pretensioned since the boom is light, slender, and cantilevered, unlike a cable-stayed bridge. Some notes:

Pretensioning is important to mitigate vibration of the cable stays.

The boom must be raised on a crane, and the tributary dead load on the cable stays is reduced when the boom is raised. Analysis showed wind blowing in the trolley travel direction toward the land (right to let in image above) would cause the cables to sag excessively and overstress the boom.

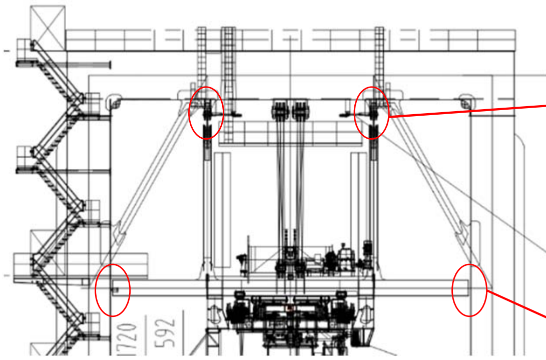
Cranes must travel on rails on the wharf and are subject to lateral inertial motion unlike a cable stayed bridge.

Latest concept—Boom support minimizes sag/vibration of the cable stays and increases the overall stiffness of the boom. The struts shown in red and the counter tensioning stay shown in blue allow proper pretensioning of the cable stays.

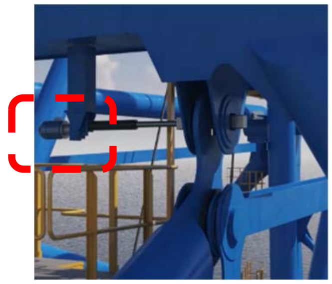
The design was verified by detailed wind load and vibration modelling by cable-stay bridge specialists at Tongji University of Shanghai, China.

The cable stays shown in green in the lower image will likely be fully locked coil cables for stiffness and corrosion resistance: common and proven in cable-stayed bridges.

Boom and Girder Stowage – Boom Down



Landside Upper Frame



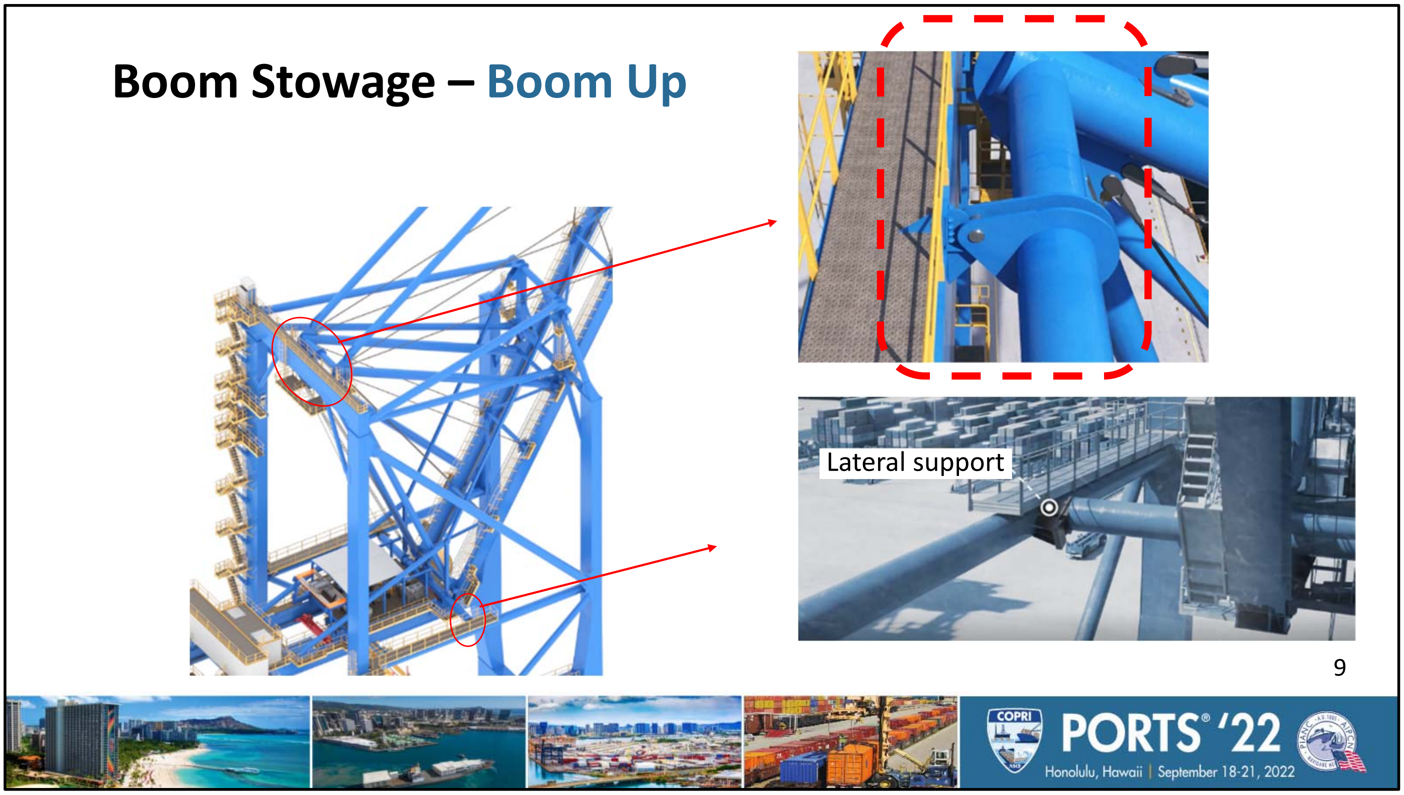
Vertical support

Lateral support

8

The boom-girder assembly is supported as shown when the boom is down, in the operating position.

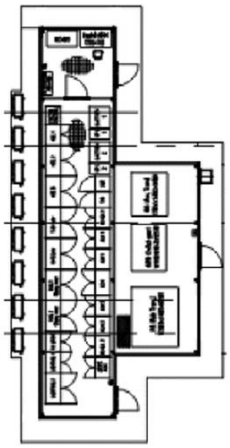
1. The boom-girder assembly is supported vertically by pins at the landside and waterside cross beams. The waterside pins allow the boom to rotate, for raising and lowering. The landside pins are retractable with a screw jack to allow the girder at landside to rotate to the stowed position. The pin is automatically inserted when returning to operating mode.
2. Side lateral loads in the wharf rail direction are resisted by a strut that pushes against the landside legs. The strut has a mechanism to engage and disengage against the leg prior to the boom-girder being lowered.



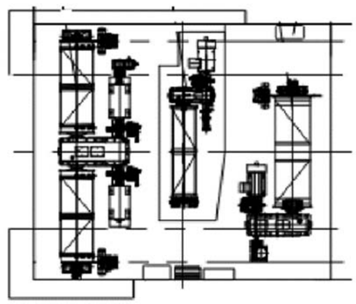
… However, when the boom is up, in the stowed position, the boom-girder assembly is supported as shown above.

1. The apex of the pylons connects to the landside cross beam (upper right image). This connection resists trolley direction lateral loads from the stowed boom-girder.
2. The strut that was previously pushing against the inside of the landside legs when the boom was down, now pushes laterally against the upper portal beams to resist lateral loads (lower right image). Like at the legs, there is a device on the portal beam that engages and disengages.

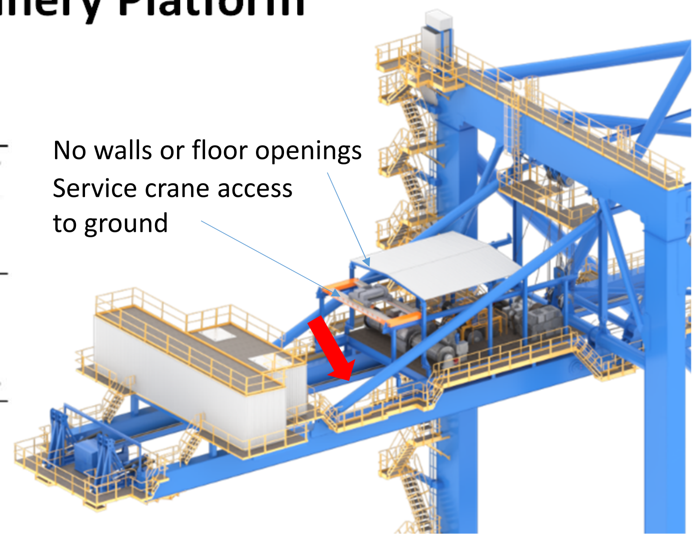
Electrical House and Machinery Platform



Electrical house



Machinery platform



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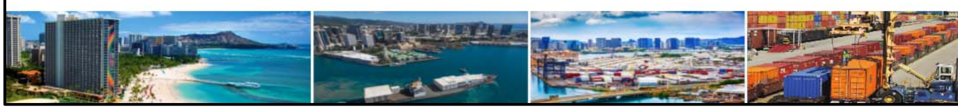

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1. The electrical house is closed, air-conditioned, and located between the machinery platform and the trolley girder landside end tie. The electrical house is located farther landside than on conventional cranes, to act as a counterweight to limit waterside wheel loads.

2. The machinery platform has the same layout as on a standard rope-towed crane. To reduce the wind area, the platform does not have walls. There is a fixed roof above the machinery platform to provide some protection from sun and rain. The machinery platform does not have a floor opening for the service crane to lower/raise components of the machinery house and trolley; instead, the service crane lowers and raises components just landside of the platform (at the arrow location).

Wheel Load and Uplift Load Comparison

ASD level for wheel loads, LRFD for storm uplift

	Landside	Waterside
Operating Wheel Loads, tonne/wheel		
STS	60	90
BC	65	80
% Change	+10	-10
Storm Wheel Loads, tonne/wheel		
STS	135	145
BC	110	135
% Change	-19	-6
Storm Uplift + Dead Load, tonne/corner		
STS	750	1045
BC	560	830
% Change	-26	-20
Crane Dead Load, tonne		
STS	1450	
BC	1410	
% Change	-2	

Operating wheel loads: Does not govern

Storm wheel loads and storm uplift + dead load: Governs

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This table shows calculated wheel loads and uplift or tie-down loads of the BC and compares to a similarly sized conventional crane, the ZPMC Bahamas crane, which was commissioned in 2018. Both cranes are designed to the same criteria as follows:

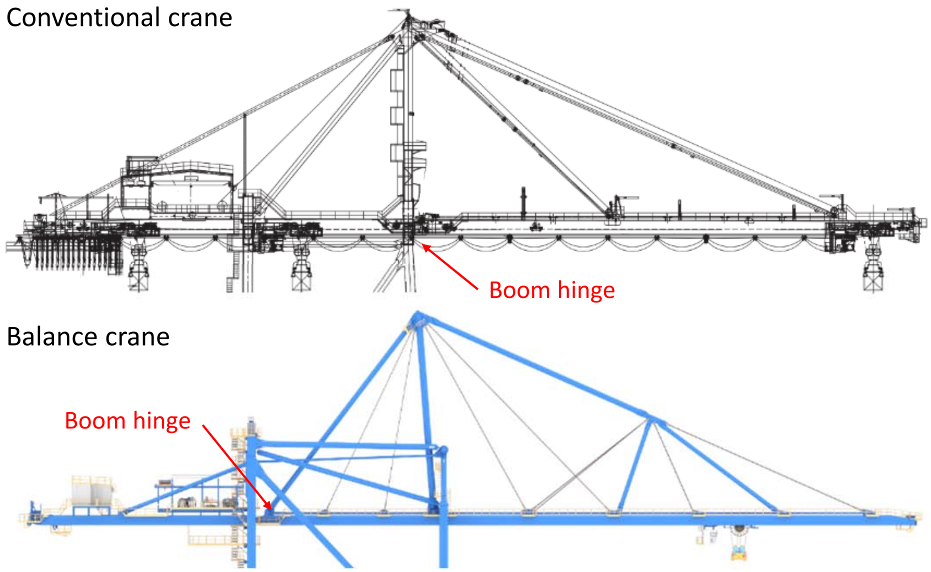
30.5 m rail span,
48 m lift height,
68 m outreach, and
61 t rated load.

The Bahamas is a severe hurricane region. We chose this high-wind location to design this crane for storm wind and to illustrate the benefits of this design for severe wind regions. For less severe wind regions, the benefit of wheel load reduction for storm wind will likely be less.

The table shows the BC has lighter wheel loads than the conventional crane for all conditions except for the landside operating wheel load, but that does not govern over the landside storm loads as the magnitude of the landside storm loads are much larger than that of the operating loads.

Notice that the crane dead loads are nearly the same, so it is the distribution and magnitude of the wind loads of the BC that reduce the wheel loads and uplift loads compared to conventional.

Maintenance Advantages: Boom Hinge Maintenance



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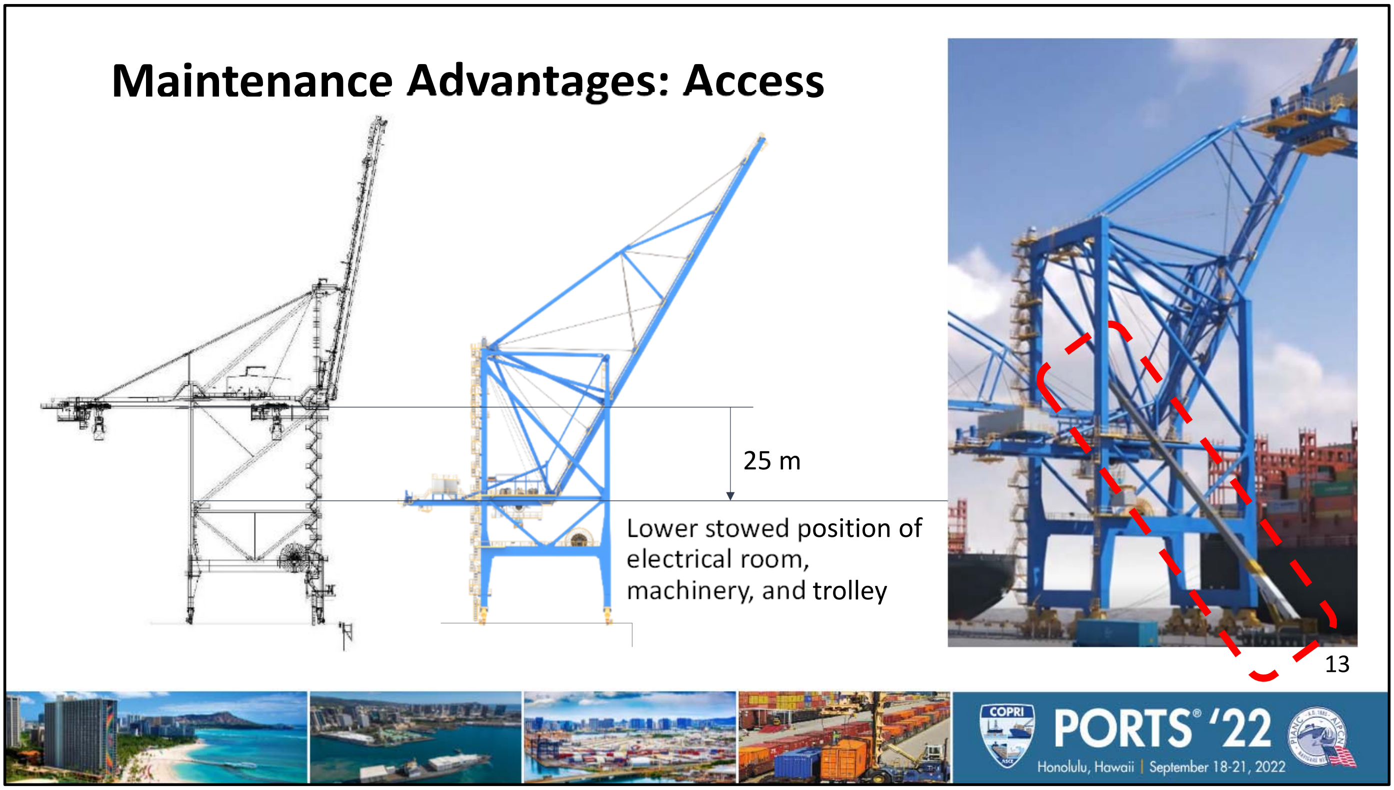
Boom hinge location is a maintenance advantage of the BC.

In typical terminals, most of the trolley cycles are from between the legs to the outreach above the ship. The trolley girder-to-boom hinge rail joint, where the rail has a discontinuous transition, is moved from waterside to landside, where there will be fewer load cycles from trolley movement, reducing wear and related maintenance at the rail joint. The rail joint is an area of significant maintenance in conventional cranes.

Moving the transition also reduces the number of shocks on the operator when the trolley passes by the joint and increases his/her comfort.

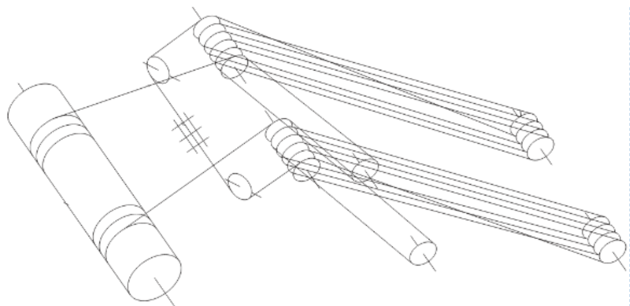


Another maintenance advantage is access:

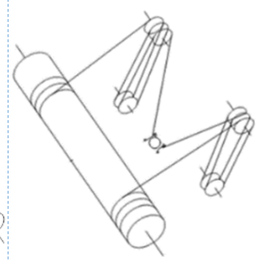
1. The lower elevation stowed position of the electrical room, machinery house, and trolley means that maintenance access will be faster and easier, and personnel access times and service crane hoisting times to the ground are reduced.
2. The service crane runs parallel to the trolley rail. The service crane can lower machinery to the ground between the machinery platform and the electrical house and can service the trolley directly.
3. The low elevation also makes it practical to use a separate mobile crane to more easily service some big components, such as electrical house transformers, which are more difficult to remove from a conventional crane.

Boom Hoist

Boom hoist rope: 10 parts vs. 20
Sheaves: 10 vs. 24
Smaller boom hoist drum
Reduced hoisting time



Conventional crane



Balance crane

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Boom hoist comparison, BC versus conventional crane:

1. Boom hoist loads of the BC are significantly smaller than for a conventional crane.
2. Boom hoist rope length, sheaves, drum:

   Only 10 parts of boom hoist rope are required instead of 20. There are only ten boom hoist sheaves on the BC versus 24 on a conventional crane.

   Each rope part is much shorter than on a conventional crane: less than half as much boom hoist rope is required.

   The boom hoist drum is smaller and easier to handle.

Conclusion

Reduced wheel loads

Reduced tie-down loads

Reduced maintenance

Reduced boom hoist rope/time

Conceptual Rendering Only

15

The BC has a unique upper works design that helps reduce wheel loads, uplift/tie-down loads, maintenance, and boom hoist rope and boom hoist time. Note that the image shown is a conceptual rendering only.

Acknowledgement

Liftech conceived the concept and did preliminary design but acknowledges and thanks ZPMC for their role in collaborating with us and helping to further develop the design.


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