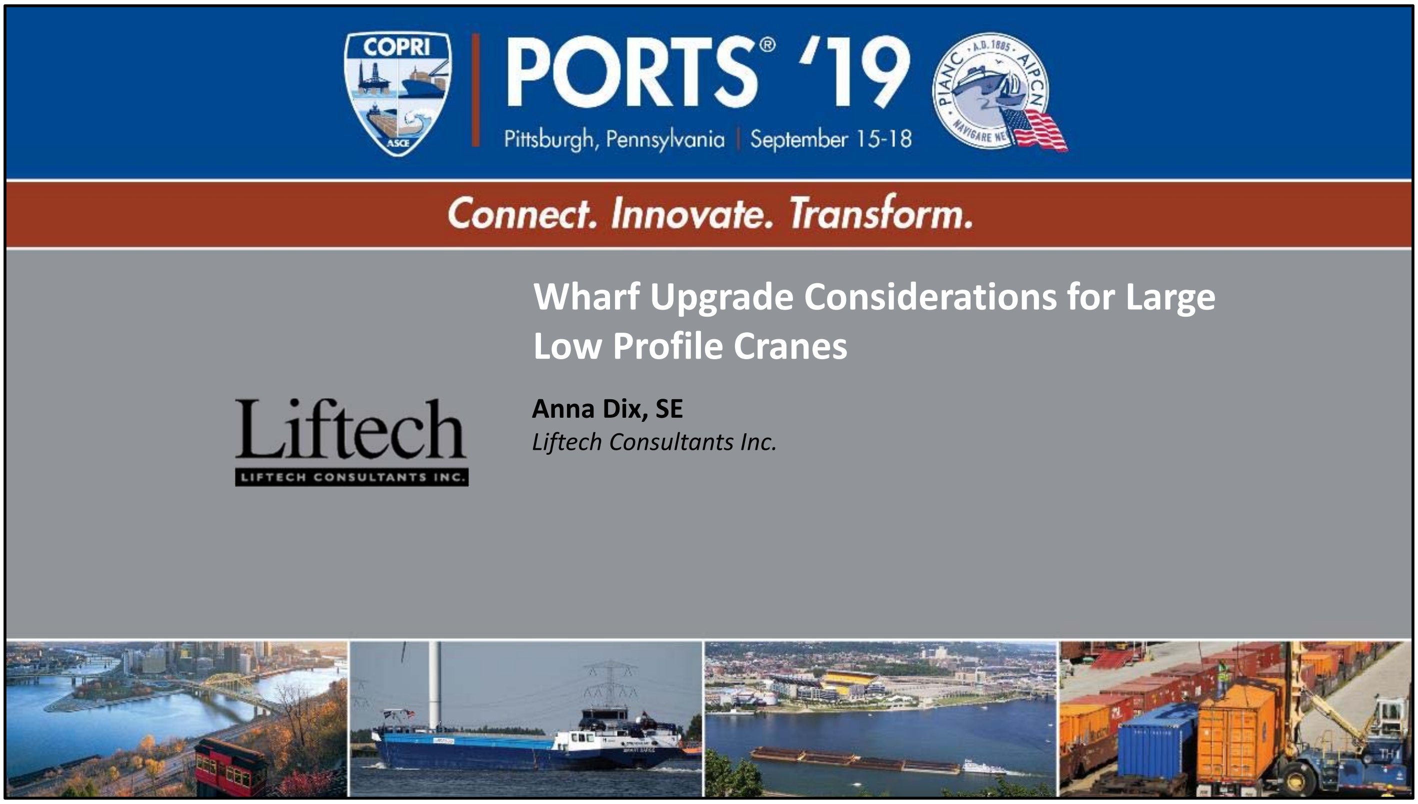


Liftech Consultants Inc. is a consulting engineering firm, founded in 1964, with special expertise in the design and procurement of dockside container handling cranes and other complex structures. Our experience includes structural design for wharves and wharf structures, heavy lift structures, buildings,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

Anna is a registered structural engineer in California with experience in the design and analysis of various steel and concrete structures. Her focus is on ship-to-shore cranes and other structures that reside next to, in, or on top of the water, such as heavy lift and container handling equipment, wharves, and floating cranes. She likes earthquake and fatigue engineering topics and working with clients.

Topics

Ship-to-shore crane types

Low profile crane boom weight

Crane loads on wharf

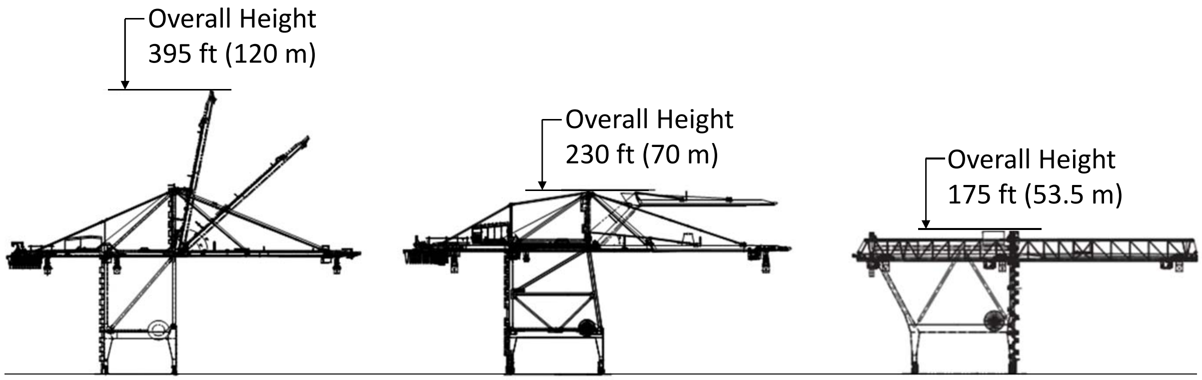
Case study: New low profile cranes and infrastructure upgrade for Port Everglades

Summary

This is a special topic because low profile cranes are only required at ports that are close to an airfield and have strict height limitations. Low profile cranes have needs beyond a typical ship-to-shore (STS) crane, and existing infrastructure may not be able to support them.

This presentation discusses the features of low profile cranes compared to other types of cranes, the effects on the infrastructure, and an ongoing project at Port Everglades in Florida.

Ship-to-Shore Crane Types



Conventional A-frame Crane
Rotating boom – one hinge

Articulated Boom Crane
Rotating boom – two hinges

Low Profile Crane
Shuttling boom

Lift height:	133 ft (40.5 m) Above Rail
Outreach:	205 ft (62.5 m) Approx. 22-Wide Ship

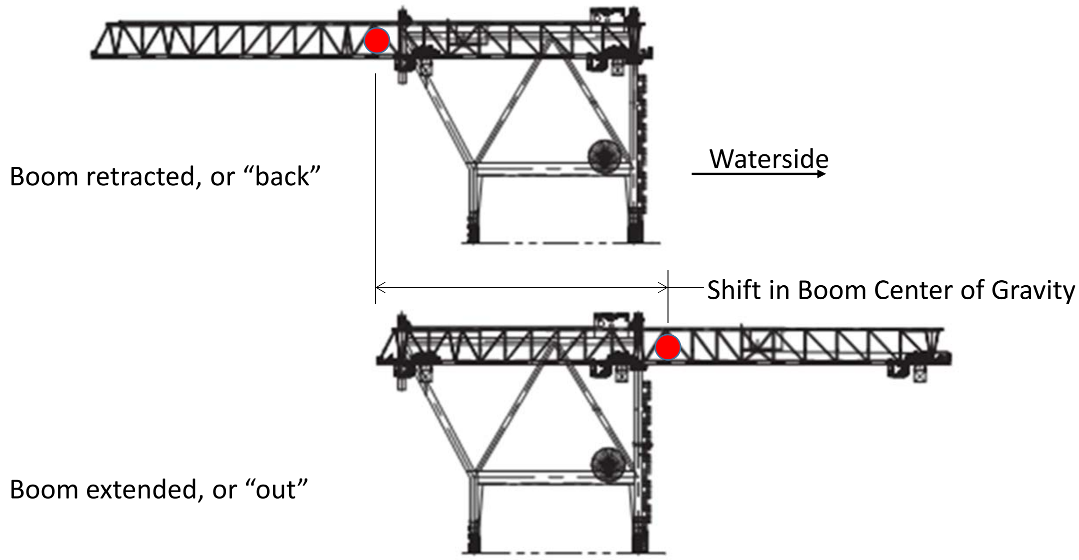
There are three types of STS crane. The heights shown are for the same lift height and outreach. However, the rail spans are not necessarily the same.

A-frame: Single hinge, rotates up for stowage or ship passing. This crane is the most common and most economical.

Articulated Boom: Double-hinge, rotates in two segments. This crane is somewhere in between, when it comes to cost.

Low Profile: Boom shuttles back and forth. It has the smallest overall height for the given lift height, but it is 30 to 40% more expensive and has the largest wharf loads.

Low Profile Crane Boom Weight



This figure shows the low profile crane boom positions. The top is the boom retracted, or back over the land, and the bottom is the boom extended, or out over the water.

The boom on these cranes is at least 25% to 30% of the total weight of the crane, weighing around 1,300 k (600 t). So when the boom shuttles back and out, the CG shifts significantly, about 150 ft (50 m) or more. The shift reduces the crane's stability, which we can address with a wide rail gage, a lot of ballast, or, if the port allows it, the boom can also be stowed for storm wind in the centered position. What does this mean for the wharf structure?

Crane Loads on Wharf

	Typical AFC				PED Low Profile Crane			
	Service		Factored		Service		Factored	
	LS	WS	LS	WS	LS	WS	LS	WS
Operating Wheel Loads, kip/ft (t/m)	37 (55)	44 (65)	44 (65)	54 (80)	56 (84)	51 (76)	69 (102)	64 (95)
Stowed Wheel Loads, kip/ft (t/m)	54 (81)	52 (77)	75 (112)	75 (112)	78 (116)	54 (80)	105 (156)	74 (110)
Tie-down Loads, kip/corner (t/corner)	-	-	412 (187)	1090 (495)	-	-	529 (240)	397 (180)

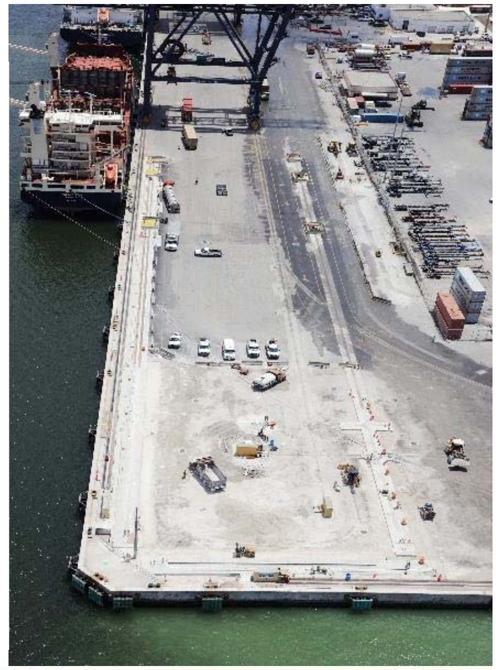
Notes:

Dead Load: Typical AFC = 3,300 kip (1,500 t)
PED LPC = 4,400 kip (2,000 t)

Operating: Dead Load + Moving Load + Gantry Inertia Load

Stowed: Dead Load + Trolley + Lift System + Stowed Wind

LS is landside; WS is waterside.



This table shows a sample comparison of wheel loads for an A-frame crane and a low profile crane. The two have similar stowed wind criteria, lift heights, and outreaches, but the gage is 100 ft (30.48 m) for the A-frame crane and 120 ft (36.58 m) for the low profile crane. The low profile crane boom is stowed centered to reduce ballast and stowage loads.

Please note:

1. Green: The low profile crane weight is approximately 1/3 greater than for the typical A-frame crane.
2. Red: The landside operating and stowed wheel loads are more than 40% greater for the low profile crane.
3. Red: The waterside operating wheel loads are more than 15% greater.
4. Blue: The tie-down loads are somewhat skewed because of the boom being stowed centered, but if the boom cannot be stowed at the centered position, the waterside tie-down loads may be 50% greater.

The low profile crane loads have a significant impact on the design of the wharf structures including crane rails, girders, piles, crane stops, and crane stowage hardware. Chances are that any existing infrastructure is not going to be adequate to support the crane and its loads.

Case Study: New Low-Profile Cranes and Infrastructure for Port Everglades, Florida (PED)

Port Everglades master plan

Existing facility

Planned facility

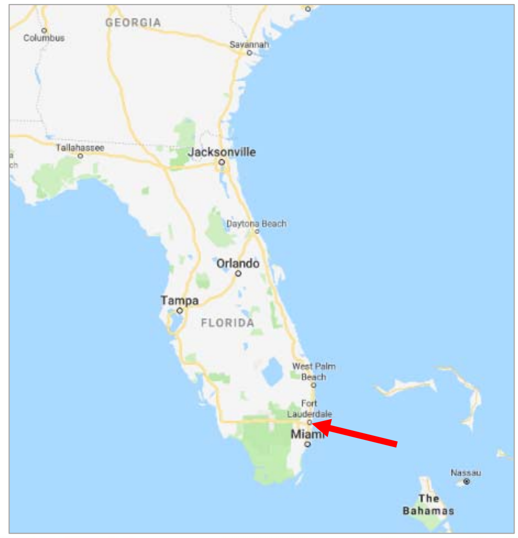
New cranes and infrastructure

Wharf and crane rails

Infrastructure phasing

Girder construction sequence

Construction challenges



A great example is at Port Everglades in Florida, also known as Port Everglades Department of Broward County or PED.

PED is a busy port and they are getting busier. They decided to increase their capacity by purchasing new, large low profile cranes to supplement their existing cranes. The port is in the flight path of the Fort Lauderdale airport.

The next topics include:

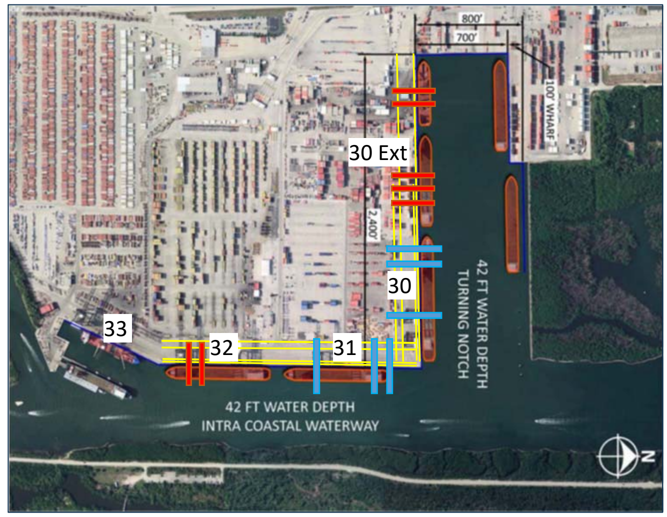
The planned facility to support the new cranes.

The new cranes and infrastructure.

How we addressed the challenges associated with major infrastructure work at a busy port.

Port Everglades Master Plan

Existing



Planned

This is a comparison of the existing and planned facilities. The port will procure new cranes, build new infrastructure, and add new berths by extending the turning notch.

The project is broken into two design parts:

> Crane Rail Project, designed by Liftech Consultants. This includes procuring new cranes, upgrading existing cranes, and designing new crane rail girders and piling. Existing cranes are shown in red and new cranes are shown in blue. We will focus on this portion of the project.
>
> Turning Notch Project, designed by Louis Berger. This involves turning notch dredging and the new wharf.

Moss/Kiewit is the contractor for both parts of the project.

Existing Facility

Multiple tenants

Four container berths

Seven low profile cranes

- 16 containers wide
- 151 ft overall height
- 100 ft gage

4,160 V utility power

There are four container berths:

Berths 31-33:	2,800 ft (850 m)
Berth 30:	900 ft (274 m)

B30 and B31 are connected by a curved rail.

Seven low profile cranes:

Post-Panamax ,16 containers wide

Rail gage:	100 ft (30.45 m)
Capacity:	40 LT (41 t)
Overall height:	151 ft (46 m)

Three cranes can go around the curved rail.

The cranes run off 4160 V utility power, which is converted from the terminal supply of 13.2 kV by transformers and switchgears in the switchgear building. The electricity is carried to vaults at the waterside rail by a system of duct banks. Then cables carry it from the vaults to the cranes. The cranes have a spool of cable that unreels into a pocket in the wharf.

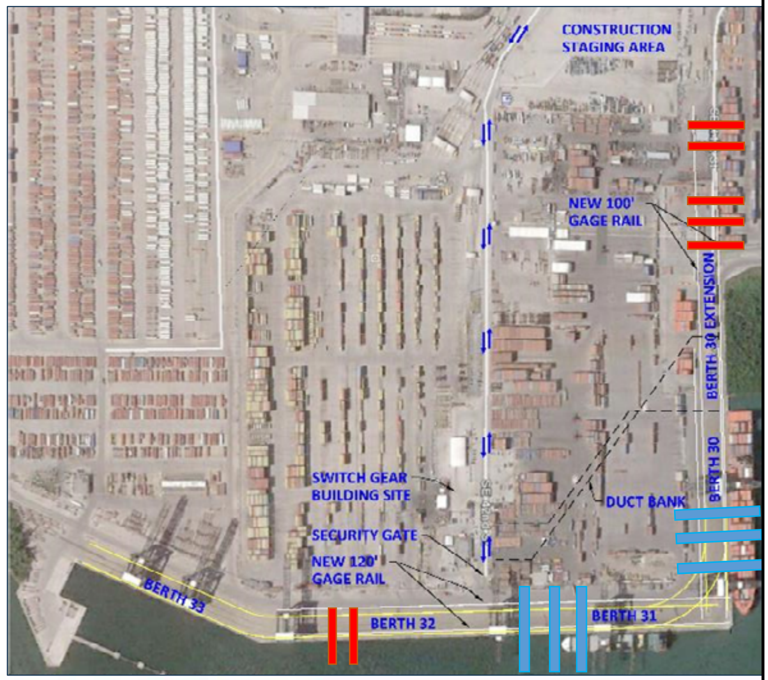
Planned Facility

Berth 30 Extension

6 new, larger low profile cranes

New crane girders

13.2 kV utility power
- 6 new electrical vaults
- New switchgear building



The port is purchasing six new cranes, shown in blue. The existing cranes are shown in red.

The crane girders on B30 will be extended by 1,500 ft (460 m). Approximately 3,500 ft (1,070 m) of crane girders for the new cranes will be added on the B32 through B30 extension. The curved rail is being demolished in some parts.

The new cranes will run off 13.2 kV utility power, so there is no need for step-down transformers, but the existing electrical infrastructure is inadequate. The plan is to add the following:

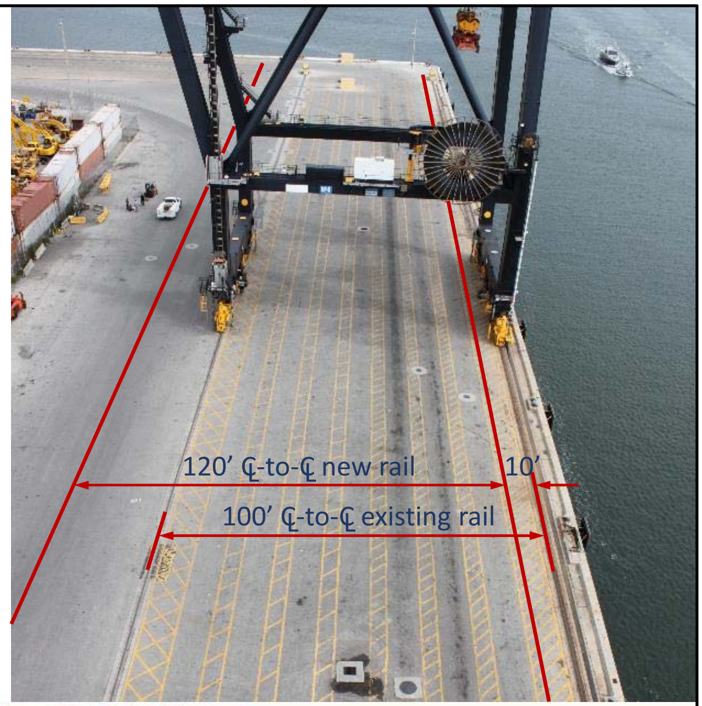
- A new substation (not shown)
- A new switchgear building
- 7,000 ft (2,130 m) of duct banks
- Six strategically placed electrical vaults and cables

New Cranes and Infrastructure

New low profile cranes

- 15,000 TEU vessels, 22 containers wide
- FAA aviation clearance 175 ft

New crane girders – 120 ft gage



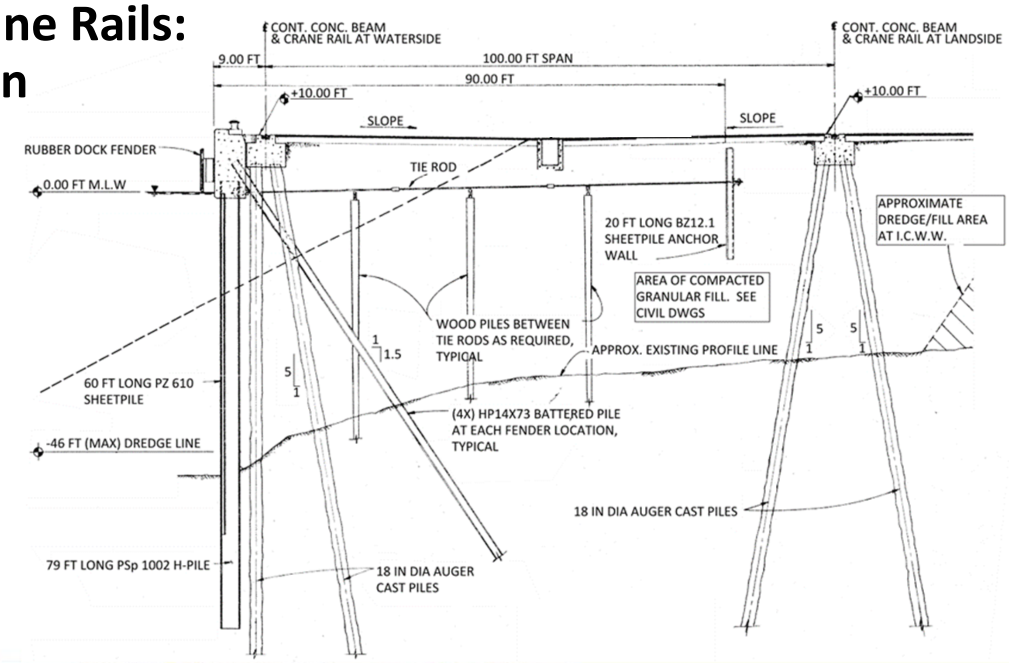
The new cranes:

- Can serve 15,000 TEU vessels with 22 containers wide
- Overall height 175 ft (53.3 m), which is an increase recently approved by the FAA
- Capacity: 65 LT (66 tonne)
- Rail gage: 120 ft (36.58 m)

The 120-ft gage has the following benefits:

- It was not practical to retrofit the existing crane girders to handle the new crane loads.
- The new crane has better stability and smaller loads with a wider gage.
- → Most importantly, without disturbing the existing girders, the port can maintain its operations.

Wharf and Crane Rails: Existing Section

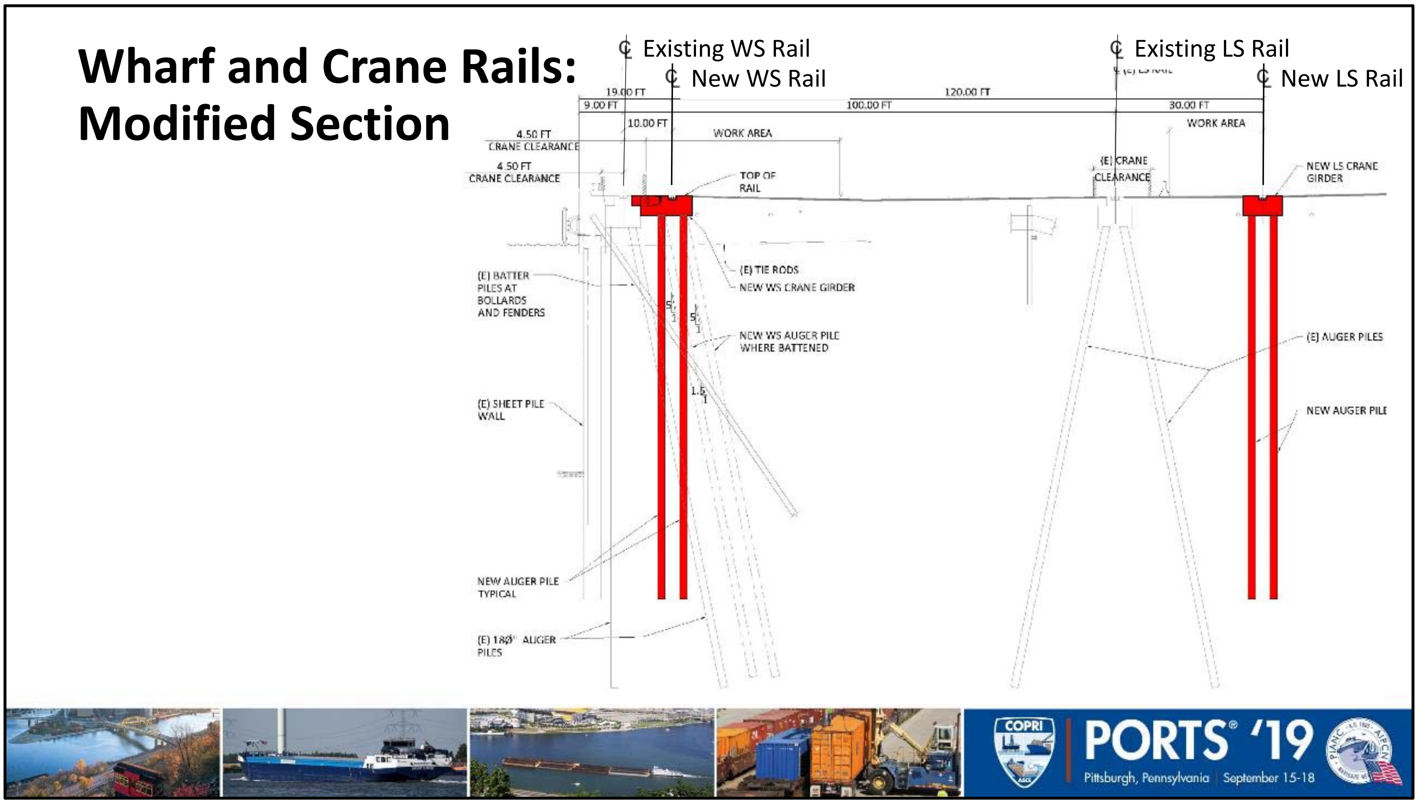


The existing wharf structure is made up of sheet pile bulkhead with tie rods connected to a sheet pile anchor wall.

The crane girders are reinforced concrete supported by auger piles.

There are steel H-piles at the fenders.

The existing cranes run on 171 lb crane rails.



The new crane girders are shown in red. They consist of reinforced concrete girders and auger piles.

The new girders are offset 10 ft (3.0 m) and 30 ft (9.1 m) back from the existing rails. The pile layout needed to avoid the existing battered piles, the tie rods, and other electrical and civil lines. This was most difficult on the waterside, as you can see in this drawing.

Other upgrades include:

- A larger crane rail size—A150
- A new set of transponders to measure crane position along the wharf
- New stowage hardware
- New crane stops that were designed to tip the crane with the boom fully retracted or fully extended

Infrastructure Construction Phasing

	Summary	Schedule
Phase 1	B31 and B32: New 120 ft gage rail girders, new switchgear building, 13.2 kV power – terminal operations must continue	75% complete May 2020
Phase 2	B30 Extension: New rail girders (100 ft gage and 120 ft gage) and 13.2 kV infrastructure after Turning Notch bulkhead completed – minimal impact on terminal operations	Nov. 2019 – Mar. 2021
Phase 3	B30: New 120 ft gage rail girders—terminal operations must continue	Mar. 2022 – Jun. 2023

Now we'll spend some time talking about the construction side of the project. As previously mentioned, PED is an active and busy port, and they need to maintain their operations through several years of new project construction.

The infrastructure project was broken into three phases:

Phase 1 is shown in red. This phase includes building new 120-ft (36.58 m) gage rail girders for B31 and B32 and adding a new switchgear building. This phase is still in progress. After this phase is complete, the new cranes will arrive and begin operation, and then the port will start to release the existing cranes for upgrade.

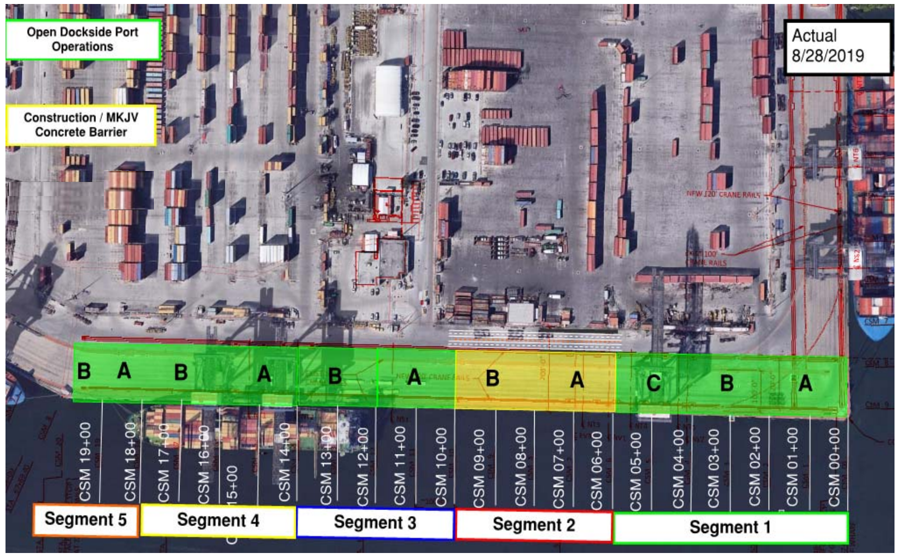
Phase 2 is shown in green. This phase includes building new 100-ft (30.48 m) gage and 120-ft gage rail girders for B30 Extension. This work overlaps with the Turning Notch Project. After Phase 2 is complete, two of the existing cranes will be moved to the B30 Extension and the port will release B30 for phase 3 work.

Phase 3 is shown in blue. This phase consists of building the remaining new 120-ft gage rail girders for B30.

B31-B32 Rail Girder Construction Sequence

Diagram by: Moss Kiewit

- Drive auger piles and construct rail girders in segments
- Cranes able to move past active segments
- Suspend construction periodically if required
- Continue terminal operations in other areas



PORTS® '19
Pittsburgh, Pennsylvania | September 15-18

This is a breakdown of the construction sequence for Phase 1. B31 and B32 are broken into five segments. The port releases one segment at a time for construction. During construction, cranes can pass the active segment.

Segment 1 is completed and Segment 2 is currently active. Segment 1 is longer than the other segments. It is 600 ft long, in part to berth and serve a small vessel while Segment 2 is active. The sequencing helps minimize disruptions to the port.

Rail Girder Construction Sequence
Segment 1 in Progress

Notice that the existing rails (in blue) are untouched and clear of equipment. The new rail girders, being built, are shown in red.

Construction Challenges

Challenge	Solution
Coordinating Berth 30 extension rail girder design with wharf structure designed by Turning Notch Project designer.	Extensive coordination with Turning Notch design team, port, and tenants early in design process.
Potential construction conflicts with two design teams: (1) Crane and crane rail infrastructure (2) Marine facilities including bulkheads, anchor walls and tie rods, turning notch dredging, civil and electrical for turning notch extension and berths.	Construction Manager at Risk—provided review and comments to reduce potential for construction conflicts.
Minimizing disruptions to Port operations.	Offsetting new crane rails allowed existing cranes to traverse active construction zones. Performed construction work in three phases that allowed port tenants to adjust operations as needed with minor inconveniences to clients.
Unexpected disruptions – crane movement disruptions from height of drill rig required installation of auger cast piles.	Port solicited input from tenants who agreed to share their planned operations in weekly coordination meetings with port staff, construction manager, and engineer.

There were a few construction challenges that needed to be addressed. This is by no means an exhaustive list.

1. The design work on the B30 Extension was an overlap of the two engineering firms. There was extensive coordination among the teams, the tenants, and the port.
2. Coordinating construction – The CM at Risk and the CM reviewed design contracts and provided comments on the construction plans.
3. Minimizing disruptions to port operations - The primary solutions were offsetting the new crane rails, keeping the existing rails clear, and careful planning and phasing work.
4. Even with all the planning, there were still some unexpected disruptions. For example, during auger pile drilling the cranes were passing the active segment more often than expected, and every time the crane passed, the drill rig needed to be moved. To address that, there were weekly coordination meetings with the port, the CM, the engineer, and the port tenants.

Summary

Low profile cranes may be required if aviation clearances are limited

Low profile cranes are expensive and impart high loads on the wharf structure

Existing infrastructure may be inadequate

Port Everglades case study:

- New cranes are taller and heavier than existing cranes and serve larger vessels
- Existing crane girders are not suitable for new cranes
- New, offset wharf girders and new electrical infrastructure are required
- Careful construction phasing, coordination with port tenants, and keeping stakeholders informed reduced terminal disruptions

Sometimes low profile cranes are required to meet the geometric requirements of the port; but they are expensive, heavy, and often need new infrastructure to support them.

Port Everglades needed to upgrade the infrastructure, which could have meant major disruptions to their daily operations. With careful design, planning, and coordination, PED is able to keep operating throughout the construction schedule, which is still ongoing as of this presentation (in September 2019).

Thank You

Wharf Upgrade Considerations for Large Low Profile Cranes

Presenter
Anna Dix, SE
Liftech Consultants Inc.

Coauthors
Arun Bhimani, SE
Liftech Consultants Inc.

Claude Gentil, PE
Port Everglades

COPRI PORTS® '19
Pittsburgh, Pennsylvania | September 15-18

I would like to thank Arun Bhimani of Liftech and Claude Gentil, PE, Port Everglades for their significant contributions to the paper and presentation.

Copyright 2019 by Liftech Consultants Inc. All rights reserved.

This material may not be duplicated without the written consent of Liftech Consultants Inc., except in the form of excerpts or quotations for the purposes of review.

The information included in this presentation may not be altered, copied, or used for any other project without written authorization from Liftech Consultants Inc. Anyone making use of the information assumes all liability arising from such use.