PED Crane and Infrastructure Upgrade Project: Overview and Lessons Learned

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ABSTRACT

Container terminals worldwide that are near airports often have significant height restrictions requiring low profile ship-to-shore container cranes (LPCs). Current generation LPCs are significantly heavier and more complex, and present challenges for crane and wharf designers. They can weigh 6,000 kip (2,680 tonne), with 400 ft (122 m) long, 20 ft (6.1 m) deep truss booms that shuttle back and forth, resulting in unusually large loads on the wharf girder system.

This paper follows the paper co-authored by Arun Bhimani and Anna Dix of Liftech and Claude Gentil of Port Everglades for the ASCE COPRI Ports 2019 Conference outlining key considerations for design of the infrastructure supporting some of the largest LPCs. It presents an overview of the recently completed construction of the crane rail girder system and other infrastructure to support up to eight LPCs. It briefly explains the crane and girder systems, design and construction issues encountered, and key lessons learned.

Ports that require LPCs or standard A-frame type ship-to-shore container cranes will benefit from this paper.

INTRODUCTION

Some marine container terminals are situated adjacent to airports and military airfields. Ship-to-shore (STS) cranes and other structures at these terminals, if located in the flight path, are subject to the height restrictions. Such terminals in the USA are at Port Everglades (PED) near Fort Lauderdale Airport in Florida, Massachusetts Port Authority (Massport) near Boston Logan Airport in Massachusetts, parts of New York/New Jersey marine terminals near Newark Liberty International Airport in New Jersey, and parts of Virginia International Terminals.

A majority of container terminals worldwide are equipped with conventional STS cranes, called A-frame cranes (AFCs). These cranes generally do not meet the height restrictions near airfields, so cranes with lower overall height, such as articulated boom cranes or LPCs, must be used. Figure 1 (ZPMC 2005, 2009, 2018) shows typical heights of an A-frame STS crane, an articulated boom crane, and the PED low profile STS crane to serve ships with 22 containers across.

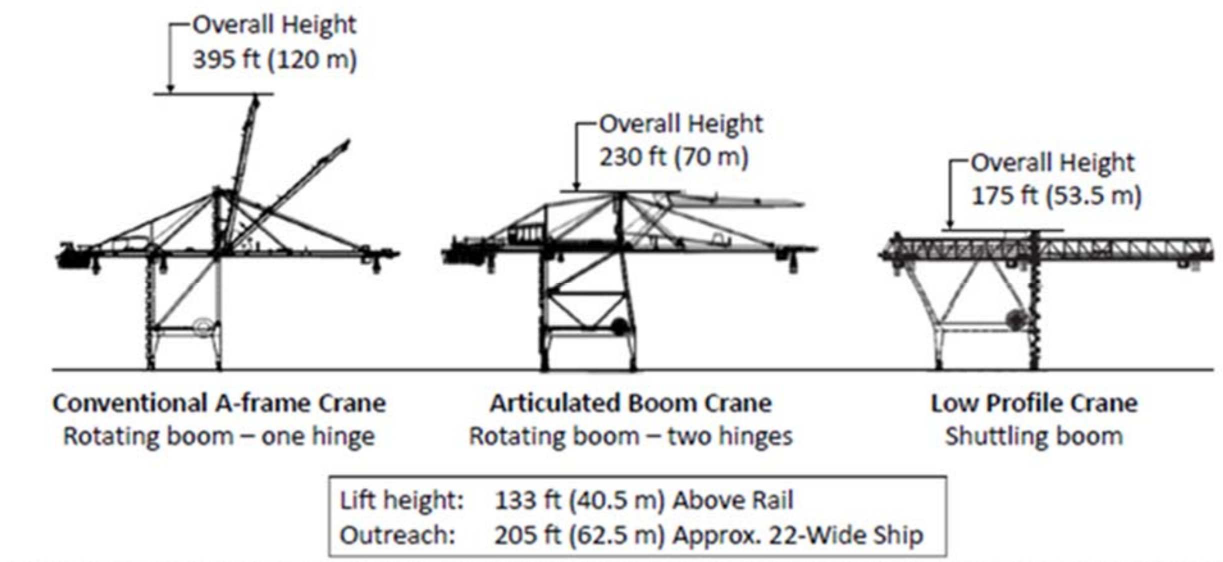

Figure 1. Ship-to-shore crane types.

LPC booms, made of deep truss work, shuttle horizontally as opposed to AFC booms that rotate up and down. The booms shuttle to extend over the vessel for ship loading operations and retract back to allow ships to berth, the cranes to traverse the berth, or to secure the cranes for high wind conditions. See Figure 2 (ZPMC 2018).

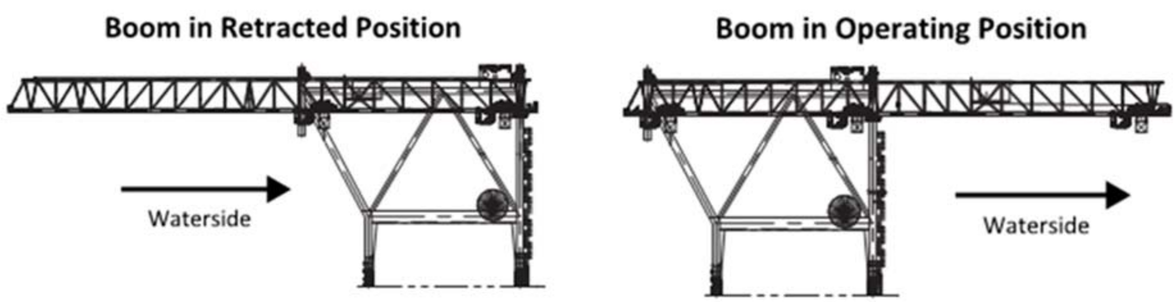

Figure 2. Low profile crane boom positions.

PED Facility and Cranes

Prior to 2020, the Southport terminal consisted of approximately 3,700 ft (1,130 m) of L-shaped container wharf with seven LPCs. Berths 31–33, with a total length of 2,800 ft (850 m), aligned approximately north-south and Berth 30, with an approximate length of 900 ft (275 m), aligned east-west, as shown in Figure 3.

Figure 3. Pre-upgrade facility aerial photograph. (*Google Maps*)

Prior to 2020, PED operated seven 100 ft (30.48 m) rail span Samsung low profile cranes (LPCs) at Southport at near full utilization ("rail span" is the center-to-center distance between landside and waterside rails). Due to the anticipated increases in demand for containerized cargo in the south Florida area, PED decided to upgrade the Samsung cranes, acquire new, larger LPCs, construct new infrastructure, and upgrade existing infrastructure, while continuing the shipping operations with minimal impact. See Figure 4 for PED Master Plan.

Pre-Upgrade **Planned**

Figure 4. PED Master Plan.

New Cranes

PED received three new LPCs in late 2020 to operate at Berths 31 and 32 and has ordered three additional similar cranes to be delivered in December 2023 to operate at Berth 30. The new LPCs, manufactured by ZPMC of China, have a 120 ft (36.6 m) rail span and are suitable for servicing 15,000 TEU vessels with 22 containers across deck, a maximum stack height of seven high-cube containers or four high-cube and four standard-cube containers above deck, and an average draft of 41 ft (12.5 m). They have 65 LT (66 t) capacity under the spreader and operate on separate 120 ft gage rails and 13.2 kV power *(1 Metric tonne (t) = 1,000 kg = 2.2 kip = 2,204 lb)*.

The new cranes weigh about 4,600 kip (2,100 t) each including 330 kip (150 t) of total ballast in the landside and waterside sill beams and legs. A comparable size and capacity AFC weighs approximately 3,300 kip (1,500 t). Although the PED LPC weighs about 40% more than a comparable AFC, the wheel loads for the LPC are nearly twice as large because of the significant boom weight and change in boom center of gravity when retracted or extended.

Figure 5a shows the new 120 ft (36.6 m) rail span cranes (blue) after delivery, on the Berths 31–32 new wharf girders, between the existing 100 ft (30.48 m) rail span cranes (black) on the adjacent, original wharf girders. Figure 5b shows the layout of the new and original rails.

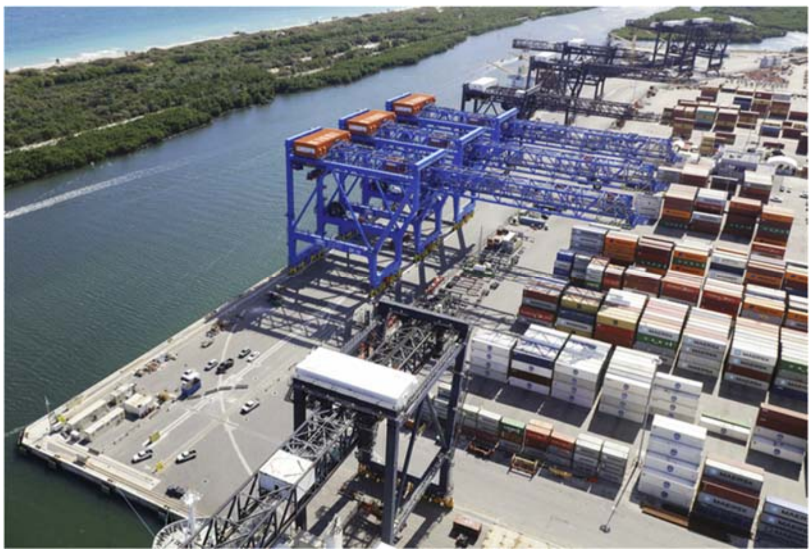

Figure 5a. Port Everglades crane procurement and crane girder system.

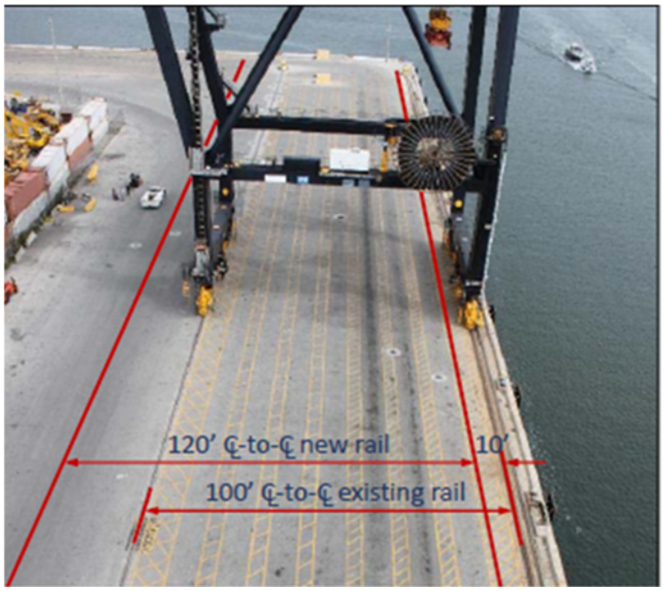

Figure 5b. New rail girder plan.

Pre-Upgrade Infrastructure

The typical pre-upgrade wharf structure section has a sheet pile retaining wall at the waterside with tie rods connected to sheet pile anchor walls. The 100 ft (30.48 m) span crane rails are supported on isolated concrete girders with auger cast piles, and the waterside rails are set back 9 ft (2.7 m) from the wharf face. See Figure 6 (Williams et al 1990).

The Samsung cranes have 4,160 V power delivered by underground cables from switchgear located in the port crane maintenance building.

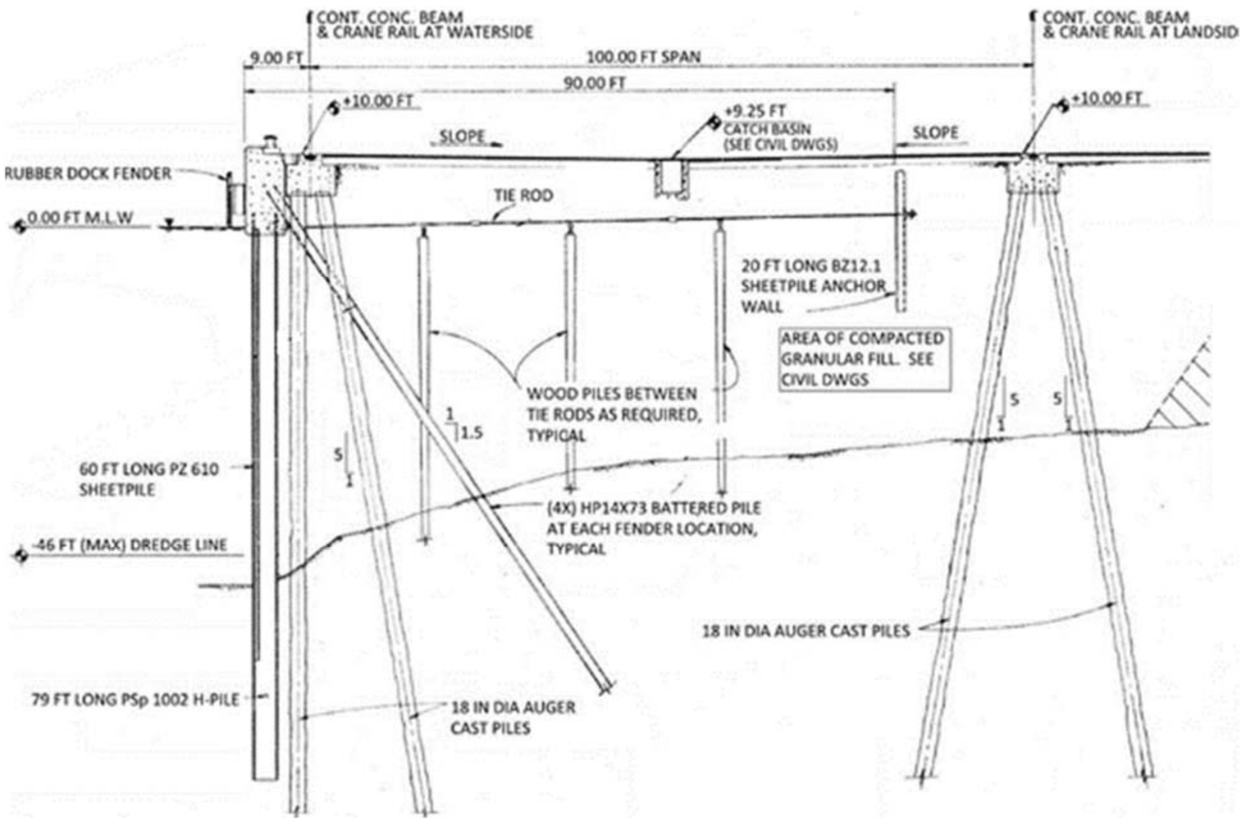

Figure 6. Pre-upgrade wharf section.

New Infrastructure

The original 100 ft (30.48 m) span crane girders and rails did not have sufficient capacity to support loads from the new cranes, so new 120 ft (36.6 m) span crane girders were constructed. Providing new girders also permitted using a larger, more favorable rail span for the cranes, and allowed for the Samsung cranes to work in all areas outside the active construction zones and travel past the construction areas during the new wharf girder installation work. The new waterside crane girders are 10 ft (3 m) landside of the 100 ft (30.48 m) span waterside crane girders, and the new landside crane girders are 30 ft (9.1 m) landside of the 100 ft (30.48 m) span landside crane girders. See Figure 7 (Liftech 2016).

New switchgear located in a new building provides 13.2 kV power to the new cranes through cables installed in underground duct banks. Duct banks are also constructed between the new switchgear and Berths 30 and 30 Extension to install 4,160 V power cables for possible future 100 ft (30.48 m) span cranes and 13.2 kV power for the new 120 ft (36.6 m) span cranes.

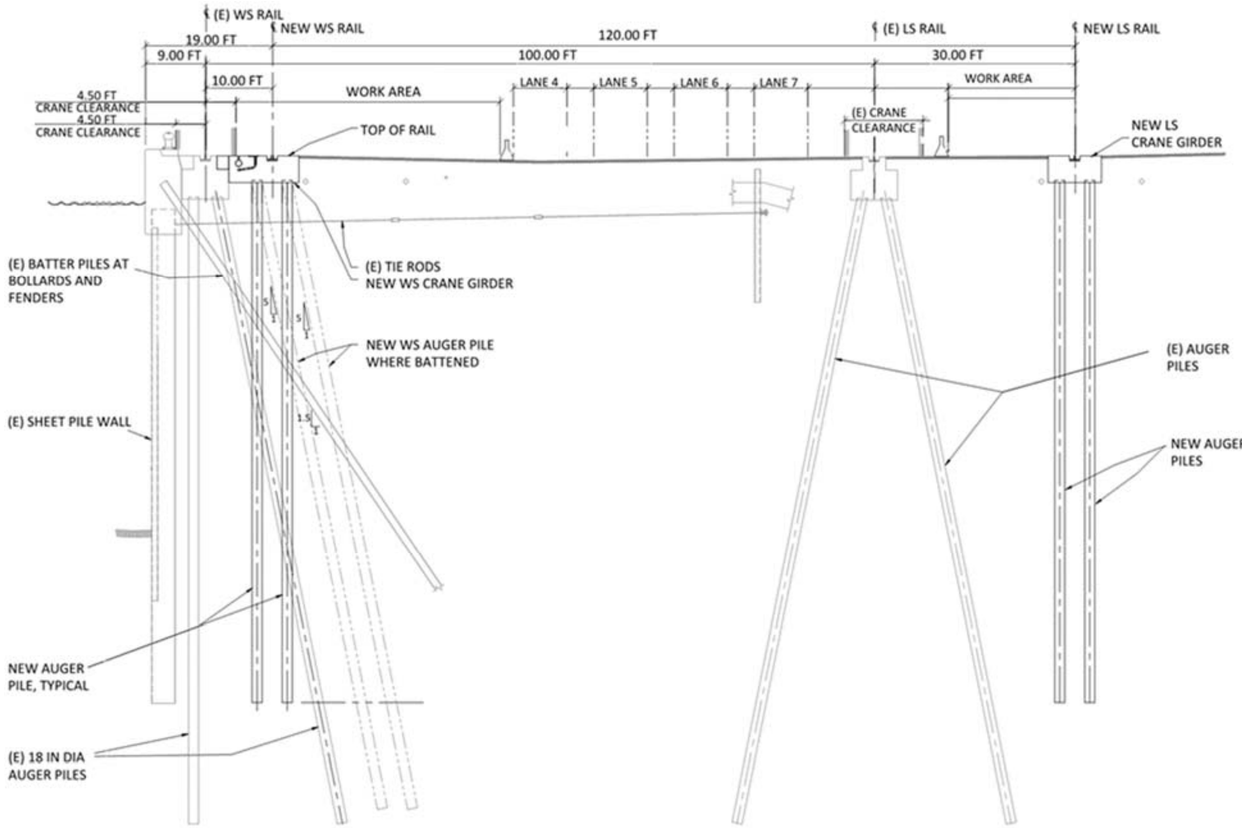

Figure 7. Modified wharf section.

LESSONS LEARNED – INFRASTRUCTURE CONSTRUCTION

Construction in Operating Terminal

Upon the start of the Phase 1 construction, it became apparent that despite all the planning during the infrastructure design phase, significant coordination between terminal operations and construction activities was necessary.

Among the first activities on the project schedule was installing auger cast piles. Although the design documents showed phased construction and cautioned that the pile drill rig may interfere with the Samsung LPC booms, the amount of crane movement disruptions due to the height of the drill rig was not anticipated until work was under way. Crane rail girder construction had to be suspended to allow the Samsung cranes to travel over construction areas on short notice. Realizing that this would be recurring throughout Phase 1 construction, the port solicited input from the port tenants. Weekly coordination meetings among the various stakeholders were held to coordinate the construction activities. Attendees included port staff, port tenants, the construction manager, and the engineer, who in turn helped coordinate construction activities to minimize impact as much as possible. The construction manager communicated with the harbormaster routinely to accommodate ship schedules to minimize disrupting terminal operations and construction activities. This close coordination among stakeholders served the port well in maintaining the terminal operations and allowing the contractor to plan orderly construction.

Auger Pile Alignment Tolerances

The new crane girders are supported by dual auger piles spaced approximately 2 ft-3 in (0.7 m) from center to crane rail on each side of the crane rail with varying spacing along the girder. See Figure 7 (Liftech 2016). To avoid below grade conflicts and due to unintentional installation misalignments, some of the piles were installed away from the design location, as much as 12 in (30 cm), which was significantly greater than the 3 in (8 cm) maximum out-of-tolerance distance specified in the construction documents. This resulted in unequal crane load distribution in the two piles, and additional girder torsional reinforcing. A lesson learned is to provide a girder with provisions for significantly increasing torsional capacity and transverse bending capacity to accommodate more pile misalignment than specified. The locally added reinforcing was little additional cost relative to the cost to meet a small pile location tolerance.

Crane-to-Wharf Stowage Hardware Alignment Tolerances

The locations of some of the wharf stowage pin sockets and tie-down hardware embedded in the new crane girders were installed out-of-tolerance, resulting in misalignment between the crane hardware and wharf stowage pin and tie-down embedments. Some hardware probably moved during concrete placement.

When the new cranes arrived, the crane-to-wharf stowage hardware alignments were measured, and some wharf stowage pin sockets required simple modifications. Modifying tie-down embedments would have been more difficult but fortunately was not required as the designs allowed more misalignment than specified.

Misalignments could have been mitigated by using stronger formwork to hold the hardware in place during concrete pour. Another lesson reinforced from past projects is to design the wharf hardware to accommodate significant misalignment—more than specified. The additional cost is insignificant to the risk of having to adjust hardware after construction.

High Strength Material for Stowage Hardware

To reduce handling loads, some wharf stowage hardware was designed using ASTM A709 Grade 100 ksi steel. The hardware fabricator requested substituting ASTM A514 material due to the unavailability of A709 steel in the US, although they were cautioned that A514 steel is more difficult to fabricate with than A709 steel.

The first set of fabricated hardware cracked during the hot-dip galvanizing process, and the fabricator was reluctant to fabricate additional sets. A review of the galvanizing procedures determined many practices problematic with galvanizing high strength steels, e.g., inducing large thermal stresses. Lessons learned include:

Having strict fabricator and galvanizer requirements, e.g., require the galvanizer be qualified with high strength steel.

Using a more readily available, lower strength, easier to weld and galvanize material such as ASTM A709 HPS 70W. The reduced difficulty in construction may be worth the increased weight.

Compact Crane Stops

Crane stops can be large and reduce available rail length. They can be significant obstructions to operations, and vehicles occasionally get damaged when navigating around them.

It was practical to design a compact stop that is 6.5 ft long, to resist a 1,500 kip (680 t) factored load and a stop that is mostly rounded to help mitigate the risk of vehicles catching on it and getting damaged. This was practical by using large, high strength anchor rods with anchor plates with a tension anchor connection, using longitudinal rib plates to transfer the anchor loads into the stop structure (see Figure 8).

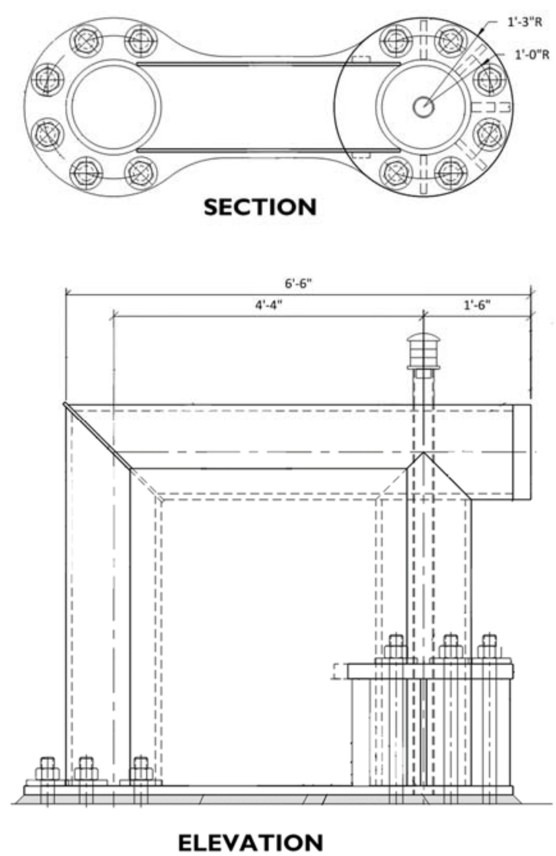

Figure 8. Compact crane stop.

Pavement Performance

Due to the operational requirements, the port could only allow a short window to install pavement overlay at night. The port resumed container handling operations 24 hours after paving, before it could cure completely, resulting in rutting from the yard equipment tires making sharp turns and indentations from container corners castings. The rutting occurred in a localized area and was monitored. After a couple of months of operations, rutting damage appeared to stop; however, pavement indentations from placing cargo containers and ship deck hatch covers continues impacting the pavement condition.

The asphalt overlay design originally consisted of 2 in (5 cm) of recycled SP 12.5 and a top lift of 2 in (5 cm) virgin SP 9.5, which is consistent with the Florida Department of Transportation Standard Specifications. Although the contractor tried to accelerate the asphalt surface curing by spraying water for 24 hours, the asphalt did not achieve adequate strength to prevent the rutting described above. To provide increased pavement hardness and durability within the short curing time, an adjustment to the top lift using 2 in (5 cm) SP 12.5 asphalt with larger aggregate and stronger binder was recommended by the asphalt supplier in lieu of SP 9.5. Additionally, the top lift requirement was changed to allow the use of recycled asphalt to help offset the cost of the increased aggregate and stronger binder, resulting in a no-cost-difference change to the pavement design. The damaged area was repaired using tow lifts of SP 12.5 with acceptable performance.

New 13.2 kV Power Service

Existing power supply from Florida Power & Light (FPL) was not adequate to support the power demand from the planned new cranes and upgraded existing cranes. FPL supplied additional 13.2 kV power from a new substation and power feeders from the substation to the port switchgear building. The port built a new switchgear building for the new cranes and the upgraded existing cranes.

For planners for similar facilities, we recommend the following:

> As part of the project design and construction schedule, allow significant time for working and coordinating with the local electric utility, particularly if new utility feeders, equipment, and/or system testing are required for the project.
>
> Include in the A/E design and construction administration adequate budget for interacting and coordinating with the utility.
>
> Early in the design phase, determine and document project expectations and needs from the utility, including budgeting and schedules, and any special utility agreements that may be needed. For the PED project, FPL asked for a separate agreement with the port. Ensure preliminary costs and owner/client budgets can support potential additional costs with the utility.

CONCLUSION

Container terminals in the flight paths of adjacent airfields may require low profile ship-to-shore container cranes. LPCs have more severe load demands on the wharf structures than conventional A-frame cranes, and it is likely that the existing infrastructure will not be able to support the LPCs to serve the current generation ships, requiring new infrastructure. A recent example of this is Port Everglades, Florida, which purchased three new LPCs suitable for operating 15,000 TEU vessels with 22 containers abeam. To accommodate the new LPCs and allow the existing cranes to operate without significant interruptions due to construction, the port built a new crane girder system next to the existing crane girders and new electrical infrastructure to service the new cranes. The local utility built a new substation and power feeders to supply additional 13.2 kV power for the new cranes and upgraded existing cranes.

There were many lessons learned on this project. Some of the more significant include:

> Facilitating continuous communication between stakeholders was worthwhile to limit construction and container operations disruptions.
>
> Sizing the rail girders to readily increase the torsional strength helped accommodate significant pile out-of-tolerances.
>
> Designing the wharf hardware to accommodate larger than expected crane and wharf misalignments was worth the additional cost in avoiding post-construction hardware modifications.
>
> It was unexpectedly difficult for the contractor to purchase the specified high strength steel for some of the stowage hardware. The substituted steel proved difficult and costly to fabricate and galvanize. Requiring the fabricator and galvanizer to prove successful experience with the chosen materials is worthwhile. Designing for a lower strength and easier to fabricate and galvanize material is also worthwhile.
>
> Compact crane stops to maximize the length of rail girder and minimize the obstacles to vehicular operations are practical and worthwhile.
>
> Check if curing time for the paving is too long for operations and specify a design to suit.
>
> If your project requires new power service, provide significant time in the schedule, provide for significant effort in the budget, and determine and document utility needs and agreements early on.

Port Everglades has been able to construct this large-scale project and minimize inconvenience to port operations. Despite the challenges described above, as well and the impacts of COVID-19, this project remains on schedule and under budget. Construction of Phase 3 of crane rail infrastructure commences in April 2022 and the entire project is anticipated to be completed in July 2023.

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