TRANSFERRING CONTAINER CRANES AROUND CORNERS USING CURVED RAILS – DESIGN CONSIDERATIONS

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ABSTRACT

Many wharves have nonlinear berths that meet at a corner. It is often economical to share cranes between these berths. To share, cranes must transfer between them. This is no simple task. Transfer methods range from shuttle systems that move the cranes between the berths to curved rails that the cranes gantry on. Recently, the most popular method has been the curved rail. This seemingly simple method is actually quite complicated to design and has many options for the owner. Larger curve radii use up valuable yard space. Smaller radii may require a side shift mechanism in the gantry system to accommodate gage change. Working to the corner requires switches and a power transfer method.

This paper presents the following:

1. A brief overview of the different crane transfer methods.

2. Explanations of the various design considerations with the curved rail transfer method.

TRANSFER METHODS

The best transfer method depends on the situation. If many cranes must be transferred, it is usually more economical to use a shuttle or turntable system, both of which require little or no modification of the gantry system of the cranes. If only a few cranes require transfer, it is usually more economical to use the cheaper curved rail system and modify the gantry system of the cranes.

The various systems are briefly summarized below. A tabular comparison of the various systems is also provided in Appendix A.

Shuttle Systems

Shuttles move a crane by carrying it to its desired location. There are two types of shuttle systems: above grade and below grade. See Figures 1, 2, and 3.

A shuttle system costs less than a turntable system and more than the curved rail system. The primary disadvantages of shuttle systems are that the above grade system needs to be stowed, and the below grade system uses the entire corner, prohibiting the use of container cranes at the corner.

Figure 1 – Below Grade Shuttle System – Oakland

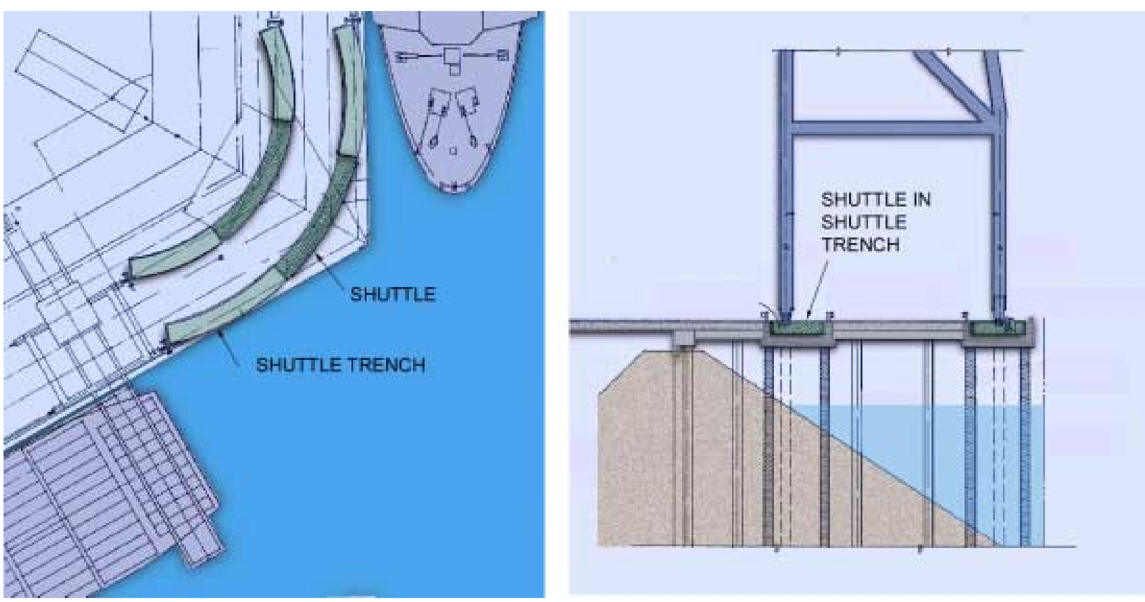

Figure 2 – Below Grade Shuttle System

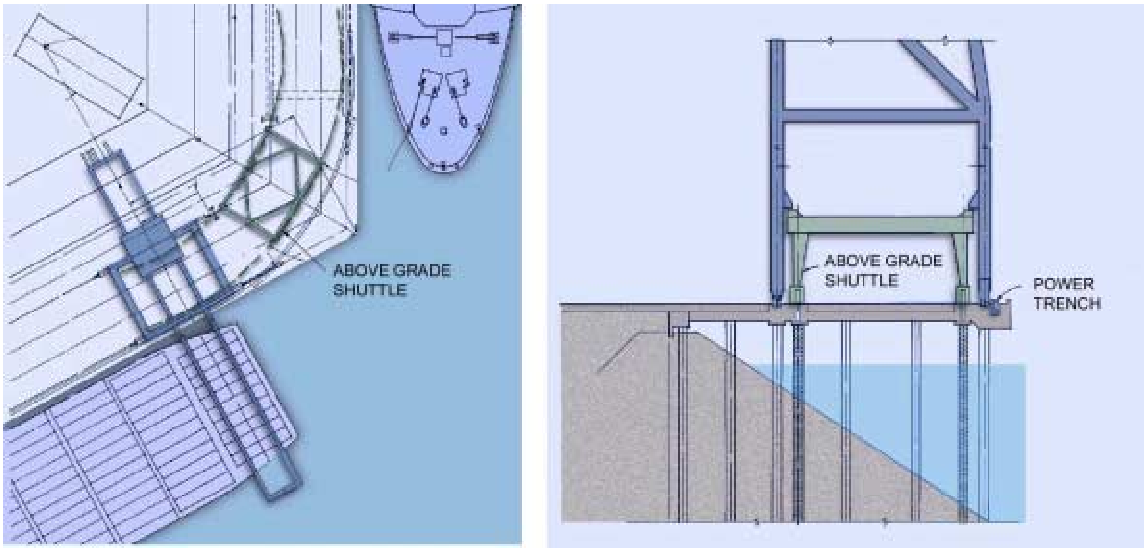

Figure 3 – Above Grade Shuttle System

Turntable Systems

A turntable consists of a donut structure that supports gantry rails. The turntable itself rotates on rails that are supported by the wharf structure. See Figure 4.

The turntable system is the most expensive transfer system, but also the simplest to operate. Turntables also permit crane operation to the end of a berth.

Figure 4 – Turntable at SeaLand – New Jersey

To transfer, the crane first gantries onto the turntable. The turntable then rotates until the rails of the turntable are aligned with the rails of the adjacent berth. The rotated crane then gantries from the turntable onto the adjacent berth.

Because of the size of the turntable, the setback, which is the distance from the waterside face of the wharf to the waterside rail, is important. If the setback is too small, the turntable will stick past the face of the wharf into the ships berthing area, complicating ship mooring near the turntable.

Curved Rail

The last transfer system discussed is the curved rail. A curved rail connects two non-linear berths as shown in Figure 5. The curved rail has recently been the most popular transfer method and is the focus of this paper.

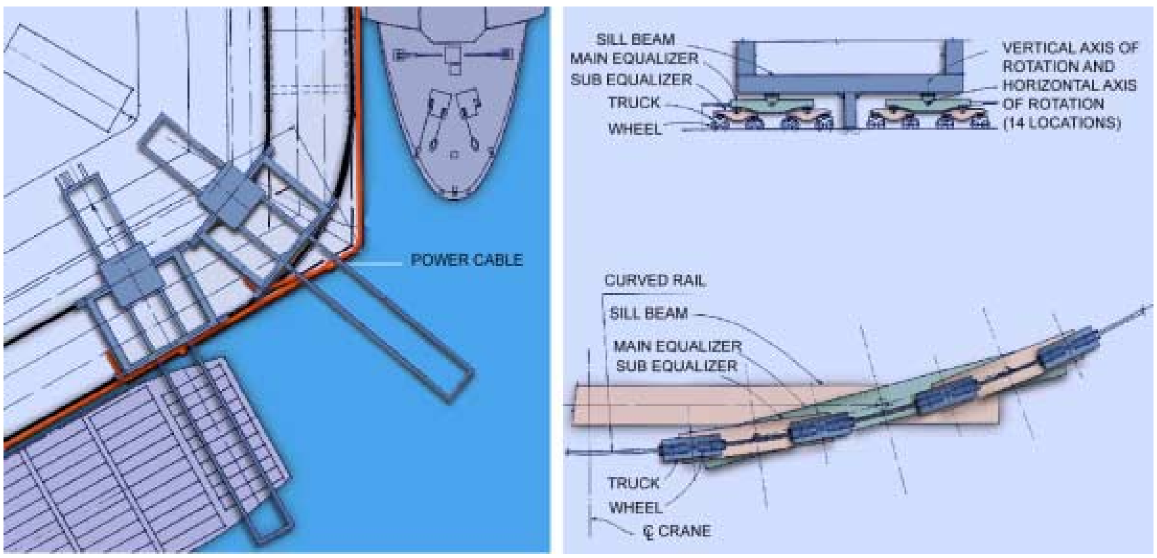

Figure 5 – Curved Rail

CURVED RAIL DESIGN CONSIDERATIONS

Despite its seeming simplicity, the curved rail system is complicated and requires many design considerations. There are two types of curved rail systems: with switches and without switches. Switches are provided if the straight gantry rails go past the curve to permit crane operation to the end of the berth. If switches are provided, the additional design considerations include the switch, the frog, and power transfer. The more significant design considerations are presented below. Design considerations common to curves with and without switches are presented first.

Design Considerations Common to Curves with and without Switches

Curve Geometry

When a gantry crane travels on parallel or circular rails, the leading and following main equalizer pins will follow identical paths. But when a crane makes a transition from a set of parallel rails to a set of curved rails, the leading and following equalizer paths will not be identical. See Figure 6. Since the paths are not identical, the gage, which is the distance between the landside and waterside equalizer pin paths, will vary. The goal is to find a curved rail layout that minimizes the difference in the gages.

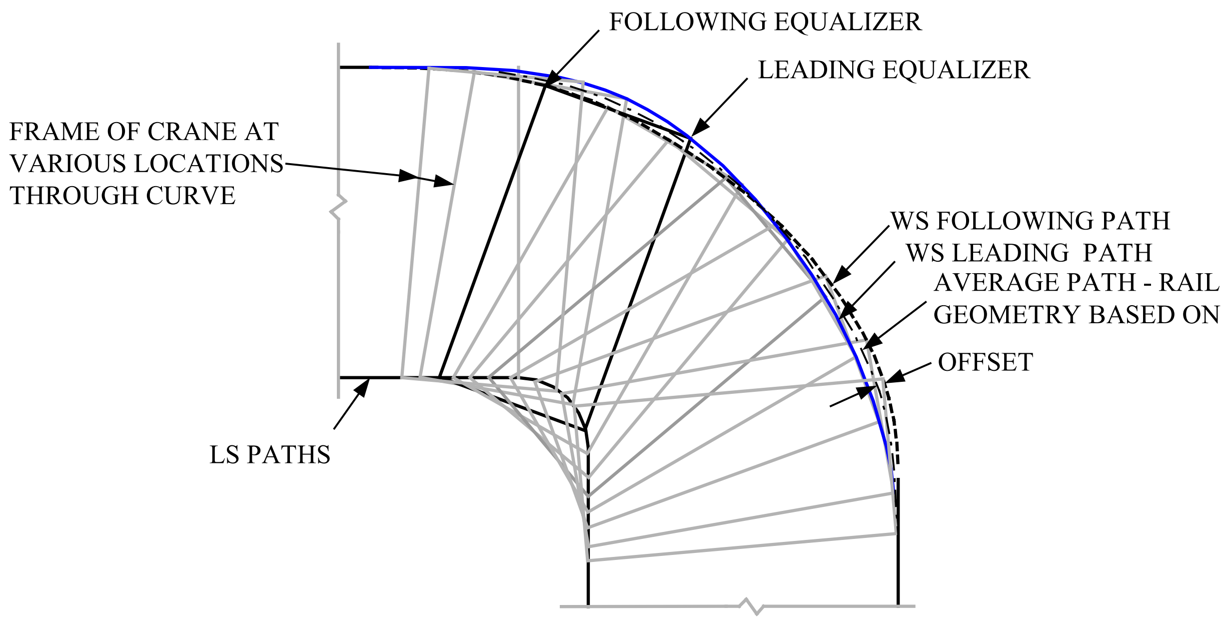

Figure 6 – Equalizer Paths

The ideal solution for a given length of curve is for one set of wheels, in this case the landside, to follow the landside rail, and the other set, the waterside wheels, to follow a curve centered between the leading and following wheel paths. The maximum distance between the waterside rail and the two paths is the offset. The offset increases as the average radii of a set of curves decreases. If the offset is small enough, the clearance between the wheel flanges and rail head will accommodate the offset. If the offset is too large, the clearance between the wheel flanges and rail head will not accommodate the offset and a side shift mechanism will be needed in the gantry system. The side shift mechanism significantly increases the cost of the crane and is, therefore, undesirable.

For small offsets, the near-optimal rail geometry for the landside rail is not a circular curve, but a spiral curve. By using the near-optimal geometry, the amount of wharf space consumed by a curve can be significantly reduced.

For the Port of Los Angeles Pier 400 project, the required average landside curve radius for various curve geometries and offsets is provided in Figure 7. To keep the offset less than the typical 25 mm rail head to wheel flange clearance, an average circular radius of 140 meters is required. A spiral curve requires an 85 meter average radius. For the same 25 mm offset, the circular geometry would have required an additional 26 meters of each berth, or a total of 52 meters of wharf.

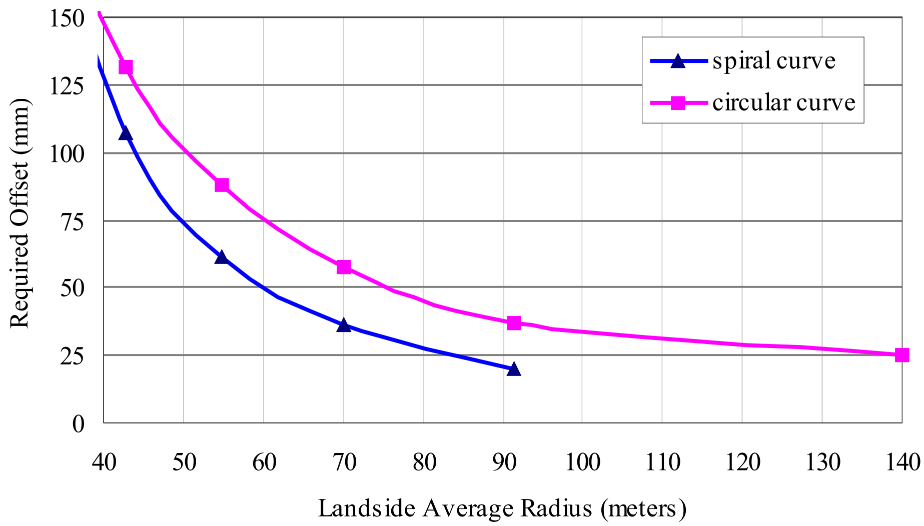

Figure 7 – Comparison of Average Curve Radii for Spiral and Circular Curve Geometries

In addition to optimizing the curve geometries, the amount of wharf space consumed by curves can be reduced without the use of side shift mechanisms by increasing the offset the rail head to wheel flange gap can tolerate. This is done by increasing the width of the wheel and by using a narrower rail head through the curve.

Gantry System Articulation

Regardless of whether a side shift mechanism is required in the crane's gantry system, it is necessary to articulate the trucks and equalizers of the crane's gantry system to avoid significant noise and wear problems. As a crane moves along a curved path, the systems of wheels and equalizers are forced to rotate relative to one another or to skid on the rail. Skidding can be facilitated with oils such as vegetable oil; however, the results to date have been undesirable.

ADDITIONAL DESIGN CONSIDERATIONS FOR CURVES WITH SWITCHES

The Switch

The switch required to transfer a crane from a straight portion of rail onto a curved portion of rail is more complicated than a railroad switch. The container cranes are double flanged to permit load transfer simultaneously through both waterside and landside rails. Because the wheels are double flanged, the switched position must allow the wheel to clear the curved rail, if the crane is traveling on the straight rail, or the straight rail, if the crane is traveling on the curved rail.

The most common switch is the rotational switch. See Figure 8. The rotational switch pivots about one end on a series of ultra high molecular weight polyurethane pads.

Engaged **Unengaged**

Figure 8 – Rotational Switch

The Frog

A frog is required where rails cross one another. To permit crossing, the head of the intersecting rails cannot exist at the crossing. See Figure 9.

Figure 9 – Rail Frog

To cross the rail head gap, the wheels cannot ride on the head of the rail but must ride on their flanges. See Figure 10.

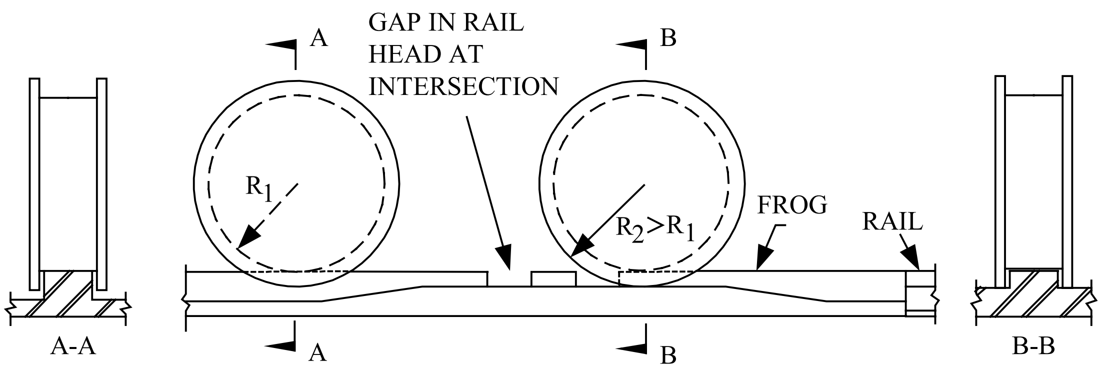

Figure 10 – Section through frog

When a wheel rides on its flanges, its circumference is increased relative to the adjacent wheel. Because wheels are typically geared together, they are forced to rotate at the same rate, causing at least one of the two wheels to slide on its traveling surface. The forces that develop in the system prior to and during sliding must be considered in the mechanical design of the wheel gearing. If the frog is kept clean or if it is lubricated, and the distance of differential wheel rotation is minimized, the required sliding is not a problem on ordinary gear systems.

Power Transfer

Power transfer around a curve having switches is a major consideration for cranes with cable or conductor power systems. Most solutions used to date have been simple, including the following:

1) Provide auxiliary power on the crane so the crane's collector or cable can be disengaged until it is through the curve.

2) Remove the power cable from the trench and carry it as the crane travels through the curve to the adjacent berth.

Conceptual studies have been made for more elaborate power transfer methods that reduce the amount of operator effort. One method provides a cable guide arm that swings out from the crane to the power trench as the crane travels the curve. See Figure 11.

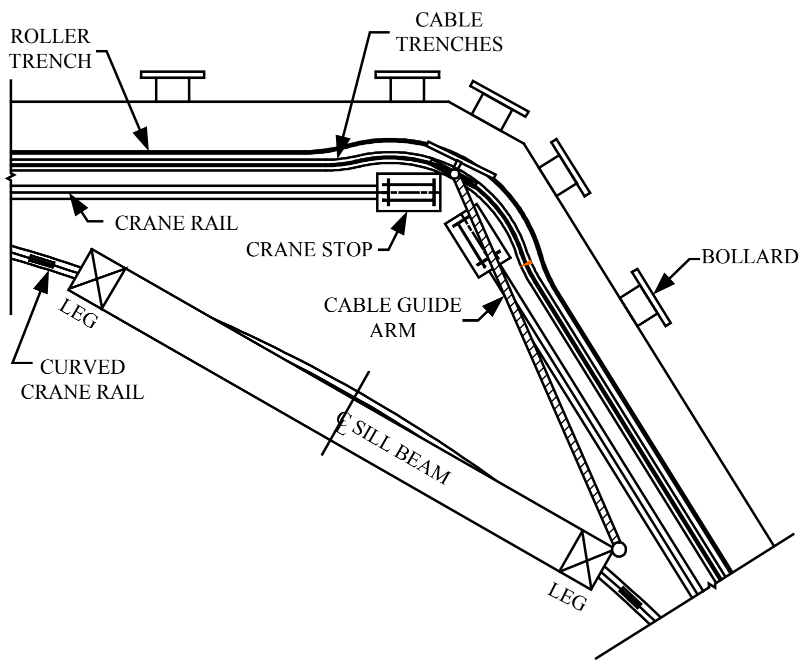

Figure 11 – Cable Guide Arm for Power Transfer

SUMMARY

Many crane transfer methods are being used. Recently the most popular has been the curved rail system. Many considerations are required in the design of a curved rail system. This paper provides a review of the crane transfer methods and the most significant design considerations of the most popular transfer method, the curved rail.

APPENDIX A – COMPARISON OF TRANSFER METHODS

Method	**Previous LCI Projects**	**Rough Estimate of total cost** [1]	**Pros**	**Cons**
Shuttle below grade.	Oakland	$450,000+ $50,000 / crane	Similar to turntable but costs less.	Lose use of corner.
Turntable below grade.	Sealand N.J.	$1,500,000	1. Simple to operate. 2. Gives crane continuous operation. 3. Saves yard space. 4. Power cable easily transferred around corner.	1. Expensive design and construction. 2. May project beyond bulkhead. 3. Maintenance.
Turntable & Shuttle above grade.		Turntable = $1,200,000, Shuttle = $350,000+ $50,000 crane	Same as below grade systems and the following: 1. Lower cost. 2. Less Maintenance.	1. Same as below grade systems except the above grade shuttle system needs to be stowed.
Curved rail, no switch.	Oakland, S curve at Tacoma	$200,000+ $250,000 / crane	1. Simple to build. 2. Easy to negotiate. 3. Least civil cost. 4. Power cable can follow rail. 5. No switch mechanism. 6. Power cable easily transferred around corner.	1. Uses significant yard space depending on the radius of the curve. 2. Layout is difficult. A) Optimal crane layout requires computer analysis. Liftech has a proprietary program to for this. B) Changes in the gage or other crane components may be necessary despite optimum rail layout. 3. Costs associated with possible crane modifications.
Curved rail, with switch.	Port of Guam, Port Everglades Authority	$500,000+ $350,000 / crane	1. Allows operation close to the corner.	As above with the following: 1. The switch is large. 2. Maintenance of switch.

NOTES:

1. Rough estimates. Actual costs will vary depending on situation.

2. If operation is required to the end of the wharf, a turntable is an acceptable method if there is room. Otherwise, a curved rail with a switch is required.