Installation of RMG Cranes at Intermodal Rail Yard

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ABSTRACT

This paper presents the requirements, analysis, and items to be considered during design and installation of rail-mounted gantry (RMG) cranes at an intermodal rail yard or IMY. Installing RMGs at intermodal rail yards has been considered for various locations; indeed, some are under construction and others are in operation at locations in the United States.

RMG cranes increase throughput in an intermodal rail yard, allow densification of the yard, and represent a huge reduction in diesel emissions associated with the yard. The new generation of RMGs is typically electrically powered, resulting in a 100 percent reduction in diesel emissions from container handling equipment and greatly reducing noise pollution. RMGs can transfer containers directly between train and truck, thus eliminating the need for diesel-powered container handling equipment in the yard.

RMGs are installed on foundations with a continuous crane rail supported by a continuous or noncontinuous foundation. Key elements in the structural and civil design of an intermodal rail yard are the layout of the yard and terminal entrance for efficiency; other considerations include the loading and stripping tracks, truck travel paths, the amount of ground storage, and the electrical supply.

INTRODUCTION

RMG cranes are increasingly used at intermodal rail yards for reasons that include higher container throughput, higher densities, zero diesel emissions, and extremely quiet operation. Conceptual design and planning studies have evaluated the installation of RMG cranes at numerous intermodal rail yards throughout the United States, and RMG installations have been completed and are operational in Washington and Tennessee. BergerABAM designed the first in the United States, which is located in Seattle, and this paper describes some of the considerations that were involved in the design and the design process from the planning/conceptual stage through construction, focusing on the design elements that are associated with RMG cranes.

Several reasons lead to the expectation of higher productivity for RMG cranes in intermodal yards. The new generation of RMG cranes is capable of cycle times of up to 40 to 50 lifts per hour. Also, RMG cranes can pick a container from an inside stack without moving all the outside containers. The combination of faster cycle time and improved pickability results in fewer, faster moves from stack to truck. Also, with RMG cranes, aisleways only need to be wide enough for truck travel along the stack, and the RMG cranes can be much wider than current rubber-tired gantry cranes, thereby reducing the number of craneways. The width of the aisleway does not need to accommodate maneuvering by a container lift truck, and the reduction in the number of craneways allows that space to be allocated to containers, trucks or trains. Narrower aisleways and a reduced number of craneways yield denser yards.

Another benefit of RMG cranes is their contribution to a greener facility. Electric RMG cranes not only have zero diesel emissions; they regenerate electricity when the containers are lowered, thus reducing electrical usage and utility bills. Because the cranes are more productive, trucks idle less on the yard and street, and their extremely low levels of operating noise result in better working conditions on the yard and fewer noise complaints from the neighbors.

PLANNING/CONCEPTUAL DESIGN

Planning and completing the conceptual design of a yard begins with discussions of the operational requirements and desires with the owner/operator. These operational requirements are ranked by importance to determine which to sacrifice if the project budget is not sufficient for all. Typically, several yard layout options that meet the critical criteria are prepared, along with cost estimates. Additional meetings to evaluate the positives and negatives yield options that meet the critical criteria and at least some of the desirable criteria, with cost estimates in sufficient detail to allow comparisons. After a preferred option has been chosen, work starts on the various design elements. Critical items to consider in the planning and conceptual design effort are as follows.

Maximizing efficiency in travel routes and gate operations. Trucks must be able to enter, exit, and travel through the yard as quickly as possible to take advantage of the speed of the new generation RMGs and reduce costs and truck emissions. Newer technologies, such as automated gate systems with optical character resolution and radio frequency identification tags, can reduce dead times and gate delays.

Balancing the number of tracks with the numbers of container stacking areas and truck loading lanes on the yard. The required throughput of containers through the yard, the lifts per hour of the cranes with the operators, the time of day and how long it takes to switch the train cars, the time of day and number of trucks serving the yard, the typical dwell time of containers on the yard, and what type of crane is being used—all of these variables go into determining these crucial numbers. The number of tracks, the number of truck loading lanes, and the amount of container stacking will control the crane gauge, which in turn will control the size of the yard.

Choosing the correct type of RMG crane. In this paper, stacking cranes are defined as cranes that move containers between trucks, container stacks, and trains. Stacking cranes typically give priority to loading or unloading trucks because trucks are frequently the bottleneck in a rail yard. Stripping cranes move containers between trains and container stacks, with no truck involvement. Because they focus on stripping and loading trains, they are generally recommended in facilities where trains must be switched frequently. Figures 1 and 2 are cross sections of intermodal rail yards with these types of cranes.

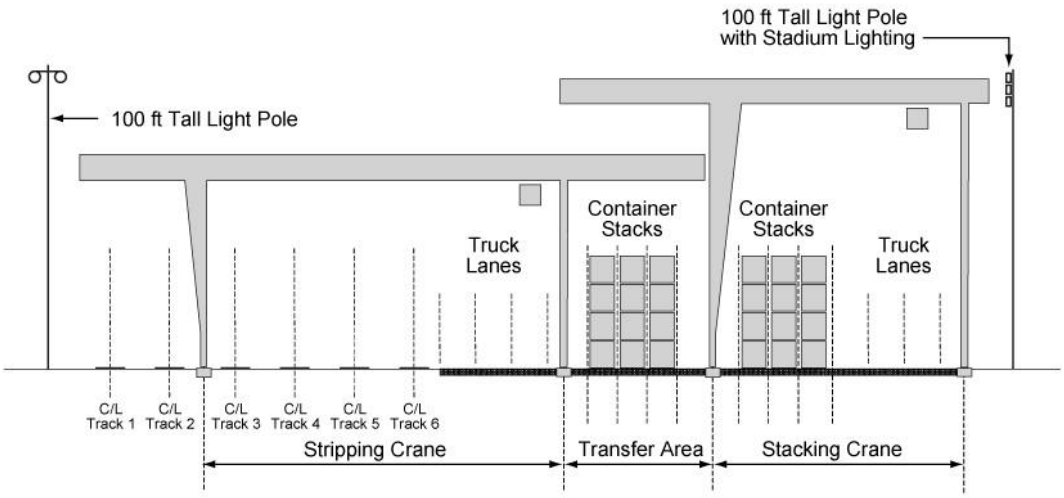


Figure 1. Typical intermodal rail yard cross section with stripping and stacking RMG cranes.

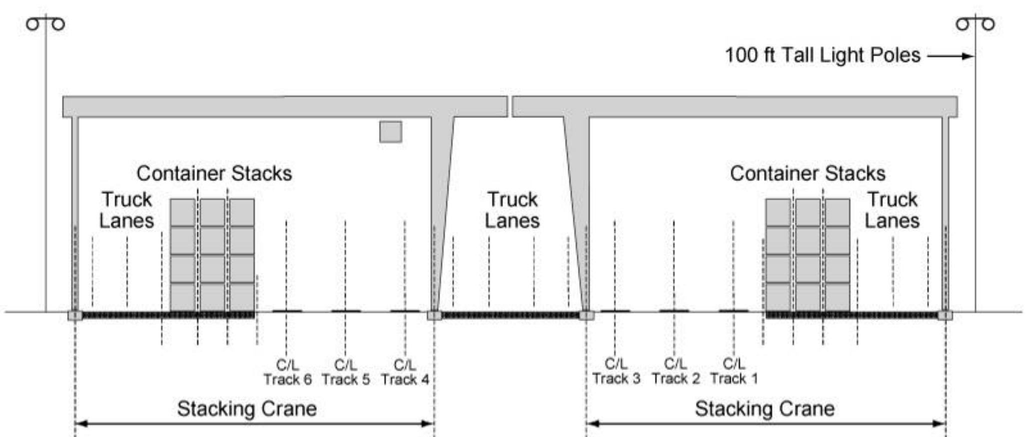


Figure 2. Typical intermodal rail yard cross section with stacking RMG cranes.

Planning for the future. It is important to plan for the anticipated lifespan of the facility. Planning can into take account future advances in gate technology for increased truck throughput, potential locations for additional track and container stacks and security requirements, possible rezoning, and redevelopment of the areas around the facility.

DESIGN ELEMENTS

Design elements specific to RMG installations are the crane rail, crane rail foundations, and electrical power. This paper does not discuss design elements, such as storm drainage, HMA pavement, buildings, fencing, and security elements, that are associated with intermodal yards in general.

Crane rail. The size and type of crane rail depends on the size and resulting wheel loads of the RMG crane. Most likely, the crane rail will be a heavy crane rail either 171# or 175# with a standard or head hardened surface for cranes with higher wheel loads. The crane rail should be continuous along the travel path of the crane(s). Flash butt welding is recommended whenever possible because of its proven durability. Wheel loads from RMG cranes are frequently quite heavy and any sort of damage, such as a nick or modification to the rail cross section, can introduce a stress riser in the rail and concentrate forces resulting in a failure at that location. Hence, extreme care should be taken to protect the rail from damage during handling and installation.

Crane rail foundation. The foundation supporting the crane rail is one of the most crucial aspects of the design. The crane rail provides a load transfer path to transmit the load from the wheels into the foundation. The foundation is responsible for supporting the crane rail in place within the tolerances required for construction and operation and for transmitting the load from the crane rail to the supporting soil. The new generation of RMG cranes requires extremely tight tolerances in the crane rail elevation and gauge in order to work properly. Figure 3 is a partial listing of these tolerances. The table has been excerpted from International Standard ISO 12488-1, Cranes – Tolerances for wheels and travel and traversing tracks.

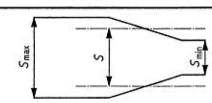
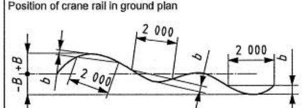
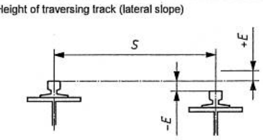
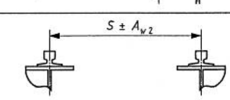
Tolerance parameter			Tolerance				
Symbol	Description with respect to this table	Graphical representation	Class 1	Class 2	Class 3	Class 4	Unit
A_{w1}	Tolerance of span S of crane rails related to rail centre at each point of travelling track	 $+A = S_{max} - S$ $-A = S_{min} - S$	± 10 Valid for all spans $S \leqslant 16$ m ± [10+0,25(S–16)] S in metres, valid for all spans $S > 16$ m	± 16 Valid for all spans $S \leqslant 16$ m ± [16+0,25(S–16)] S in metres, valid for all spans $S > 16$ m	± 25 Valid for all spans $S \leqslant 16$ m ± [25+0,25(S–16)] S in metres, valid for all spans $S > 16$ m	± 40 Valid for all spans $S \leqslant 16$ m ± [40+0,25(S–16)] S in metres, valid for all spans $S > 16$ m	mm
B_{B1}	Tolerance of horizontal straightness of rail head at each point of travelling track	Position of crane rail in ground plan 	± 10	± 20	± 40	± 80	
E_{w1}	Tolerance of height related to opposite measuring points at right angles at each point of travelling track	Height of traversing track (lateral slope) 	± 10	± 20	± 40	± 80	
A_{w2}	Tolerance of span S of crab rails related to rail centre at each point of traversing track		± 6 Valid for all spans $S \leqslant 16$ m	± 10 Valid for all spans $S \leqslant 16$ m	± 16 Valid for all spans $S \leqslant 16$ m	± 25 Valid for all spans $S \leqslant 16$ m	

Figure 3. Tolerances for crane rail installation and operation.

As one can see, the tolerances are quite tight—for example, +/- 10 mm in elevation and +/- 6 mm in gauge distance between the two rails under operational conditions. These tolerances are difficult to achieve, considering that the foundation is supported by soil that is never fully uniform and reacts differently over the distances involved, which can be more than 100 feet in gauge distance and up to several thousand feet in length. Also, intermodal rail yards are often constructed close to or on a waterfront or along a river to take advantage of water transportation and the typically flat topography of these areas. The soils in these areas often have poor structural properties, including low bearing capacities, low densities leading to short- and long-term settlement, and susceptibility to liquefaction during seismic events.

The choice of foundation type is critical to meeting the required crane tolerances and can be considered a tradeoff: the cost of the foundation versus the risk of poor performance or failure. The foundations with the least risk of failure typically cost the most. For example, supporting the crane rail foundation on piles greatly reduces the amount of influence the upper soil layers have on the foundation and therefore reduces the risk of either differential or uniform settlement. However this is a very expensive option. The opposite end of the spectrum is supporting the crane rail on standard ties, a very inexpensive option that is susceptible to lateral and vertical movement, most likely beyond the stated criteria. The engineer needs to clearly identify the reasons for selection of a given type of foundation to the client and get buy-in for the choice.

The design of the crane rail foundation is a function of the supporting soil and the applied loads. Geotechnical investigations need to be performed along the alignment of the crane rail to obtain geotechnical parameters suitable for design. These geotechnical parameters include soil type, bearing capacity, short- and long-term uniform and differential settlement estimates, coefficient of friction, lateral bearing capacities, and characterization for seismic analysis. The soil type may require additional investigation to determine its response during earthquakes. For example, sites with very fine grained soils may be susceptible to liquefaction during an earthquake and require the development of a site-specific response spectrum to design the foundation for earthquake loading. Figure 4 is an example of a soil boring log that is fairly typical of the type of soils encountered at intermodal yards combined with the design section including the crane beam and material underneath the crane beam required to support the loads.

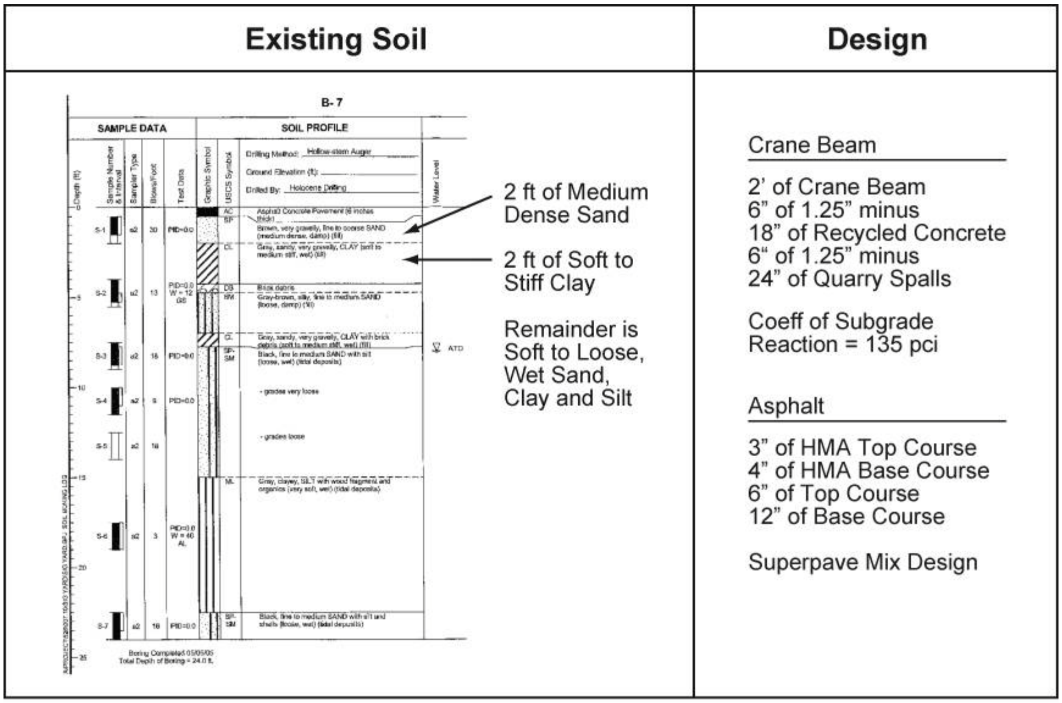


Figure 4. Soil boring log.

An accurate knowledge of the applied loads is just as important as the geotechnical parameters. The typical RMG crane is tall because it is capable of lifting a single container over the top of a stack of three or four containers. RMG cranes are typically designed with a pin connection at the top beam on one side of the framing for added flexibility so that the crane does not bind on the crane rail. The framing on the other side of the pin is a moment connection that provides the resistance to swaying from wind, seismic, or container handling loads. Consequently, the cranes are relatively flexible in the lateral direction and their structures have longer natural periods of vibration. This characteristic, combined with poor soils which amplify ground motions during earthquakes, results in significant wheel loads from seismic events, often 50 percent higher than dead plus live loads. Due consideration must also be paid to dynamic effects from the acceleration and braking of the trolley and crane during trolley and crane movement. Figure 5 is a free-body diagram of an RMG crane showing the loads from the wheels to the foundations resulting from DL+LL and DL+EQ load combinations.

Once the geotechnical support conditions and the design loads have been determined, the structural design of the foundation is straightforward and will not be discussed in detail. It is worth noting that the design of the foundation is also affected by the required operational tolerances on the gauge, elevation, and straightness of the crane rails. The foundation will frequently be governed by deflections under operational loads resulting in a foundation that is overdesigned for strength. The foundation needs to be stiff enough to prevent the immediate, short- and long-term movement of the rail from exceeding the operational tolerances of the crane. Short- and long-term uniform and differential settlements need to be estimated so that they can be combined with the elastic deflections of the structure and the foundation designed such that the sum of the immediate structural and short- and long-term geotechnical movements are within the required tolerances.

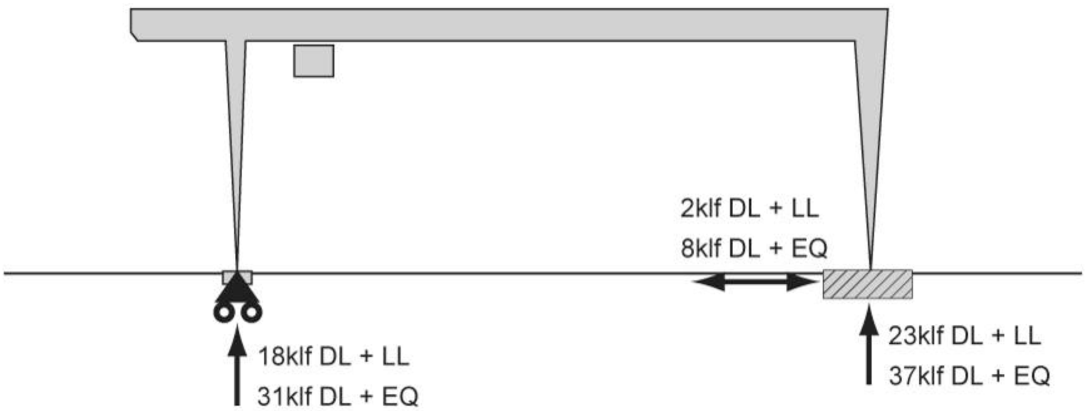


Figure 5. Crane rail foundation design loads.

Foundations should be designed to have sufficient structural capacity (1) to support the elastic deflections and accommodate the settlements while maintaining these tolerances over a long period or (2) to support the elastic deflections within tolerances and sufficient adjustability to accommodate the short- and long-term settlements by adjusting the location of the crane rail with respect to the foundation. The selected foundation is frequently another tradeoff: up-front capital cost versus the ongoing maintenance cost of monitoring the crane rail location, comparing it against the required tolerances, and adjusting each crane rail support as required to maintain the crane rail within those tolerances.

The type of soil and its load bearing properties will have the greatest impact on the type of foundation selected for the project—typically, the better the soil, the less expensive the foundation. It is important to note that the foundation design includes considering the soil supporting the foundation in addition to the structural design of the foundation. Ground improvements, such as densification, removal and replacement of material, and cement or lime treatment of soils, may be considered in the design of the foundation. Types of foundations capable of supporting RMG cranes range from pile-supported crane beams to continuous concrete grade beams to individual ties. Figure 6 is a section through a continuous cast-in-place concrete grade beam as an example of a suitable foundation.

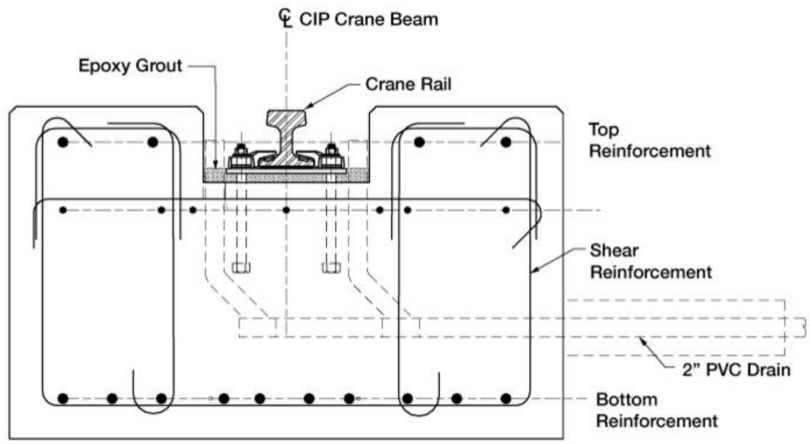


Figure 6. Typical section of a crane rail foundation.

Electrical power. Secure, stable electrical power is an important element of the design. RMG cranes are electrically powered and a failure in the power supply will shut the yard down, resulting in expense and lost time. It may be desirable to obtain separate, independent sources of power for the facility to prevent downtime and economic loss from an electrical outage. Designing the electrical supply for an RMG crane requires close coordination by the local power company, crane manufacturer, electrical engineer and the site designer. The power requirements for these cranes are typically large enough to require a substantial electrical substation on the site. The substation must be located in an out of the way area to avoid disrupting operations, but must be close enough to the crane to reduce the cost of bringing power to the cranes.

Upgrading the supply lines between the substation and the facility may be necessary, which will add time and cost, if there is a not a substation located nearby with sufficient excess capacity to supply the crane. An agreement on the availability of power must be obtained, and any upgrades to the utility systems that are required to supply that power must be designed and constructed before the first cranes come on line.

The designer must receive the power requirements for the cranes, including the desired quality of power, from the crane manufacturer. RMG cranes are serviced with medium voltage power and require a way to receive the power as it moves along the track. This is frequently done with power cables extending from the power vault to the cranes. The cables typically lie in a trench or trough, and the cranes have cable reels to store and release the cable as the cranes move. The cable trench may need to be covered to protect the cable from damage and to prevent slips, trips, or falls by yard personnel. Whether covering the trench will be necessary depends on its location and the layout of the yard. An electrically powered RMG draws power when it transits along the rails and lifts containers and regenerates power when it lowers containers. This power regeneration reduces the global power requirements of the facility, resulting in lower electrical costs.

CONSTRUCTION

Construction of a facility for RMG cranes is not significantly different from construction of any other intermodal rail yard. Elements of the project that deserve some additional attention are construction tolerances and erection of the RMG cranes. The installation tolerances for RMG crane rails are tighter than can be achieved by using typical construction tolerances. Use of standard construction tolerances may result in a situation where it is impossible to place the crane rail in its final location within the required tolerances. Therefore, the final installation tolerance and the need for additional quality control during construction need to be not only identified, but highlighted in the contract documents. Additional quality control must be planned for to check that the crane rail and preliminary construction elements are installed within tolerances.

Erection of the RMG cranes themselves will occupy a significant portion of the yard for several weeks. Space is required to lay out the structural, mechanical, and electrical components; containers of spare parts; rigging; and associated hardware in the correct location. Figure 7 illustrates one of the main cross-beams being lifted for installation on the legs. A location and a space for temporary anchors and supports required to erect the legs and main beams will need to be provided, along with the electrical service and compressed air required for the erection process. Until the power supply is complete and inspected, the RMG cranes cannot be operated or tested. The governing agency may have requirements for certifying the cranes, including UL listing of electrical components and systems, certifications for strength and safety, load tests, and inspections.

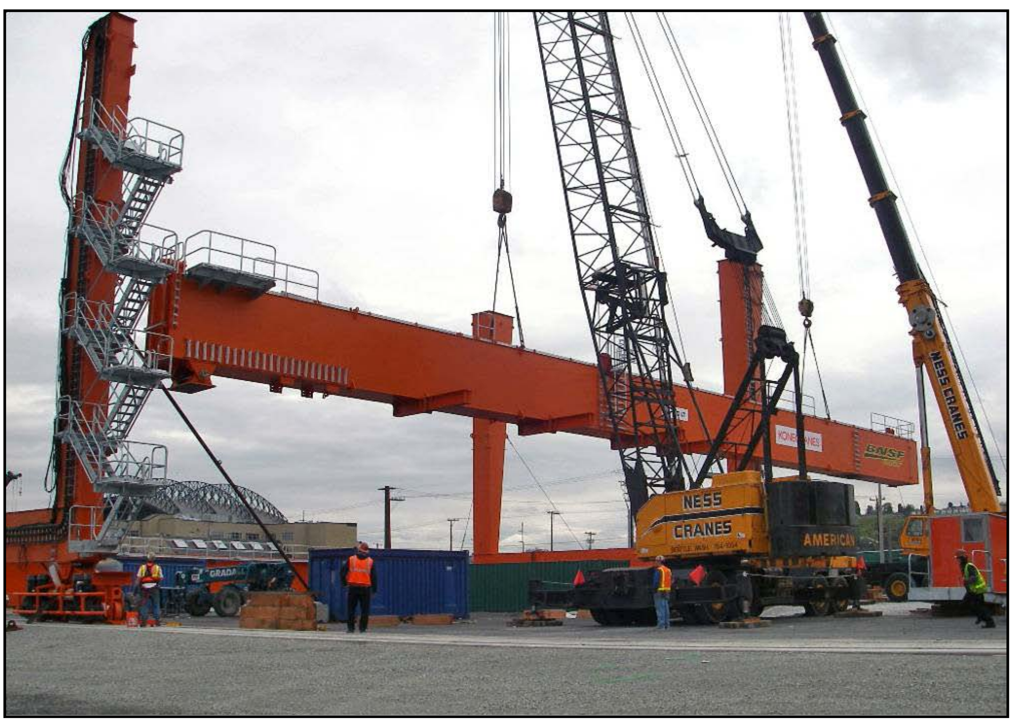


Figure 7. Erection of rail-mounted gantry crane.

SUMMARY

This paper has presented some of the requirements, analysis, and items to be considered during design and installation of rail-mounted gantry (RMG) cranes at an intermodal rail yard. These items are the layout of the yard and terminal entrance for efficiency, including the loading and stripping track, truck travel paths, amount of ground storage, and the structural and civil design of the intermodal rail yard.

Consideration of these items will assist owners and engineers in the development of rail intermodal facilities with RMG cranes to increase throughput in the yard, allow densification of the yard, and reduce the diesel emissions associated with the yard. The new generation of RMGs is typically electrically powered, resulting in a 100 percent reduction in diesel emissions from cranes and greatly reducing noise pollution. The RMGs are capable of transferring containers directly between train and truck and eliminate the need for diesel powered container handling equipment in the yard. All of these advantages contribute toward a more sustainable future for us all. Figure 8 shows four cranes erected at an intermodal yard.

Figure 8. RMGs at Intermodal Yard.