Mobile Crane On Barges Part 1

The article below is first of a two part series that deals with crane on barges. The article brings to fore the different engineering considerations for lifts made by any crane secured to a barge.

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INTRODUCTION

The demands of heavy construction occasionally bring the lifting contractor to the water's edge and beyond. This may be part of constructing a structure, such as a bridges, over a body of water or one segment of marine transportation projects, shifting cargo from one vessel to another. Crossing this boundary creates the needs for a floating crane or derrick.

Floating cranes and derricks can be broadly divided into three groups. First are marine heavy-lift ships. These vessels are designed and built from the ground up for the intended service. In many ways, using a heavy-lift ship is not much different than lifting with a conventional crane in that all of the necessary load charts and operating instructions are readily at hand.

Second are barge cranes that have been constructed by permanently mounting a mobile crane on a barge. As with the heavy-lift ships, these cranes have (presumably) been fully engineered when initially built and commissioned and are provided with load charts, operating instructions, and other information.

Third are barge cranes that consist of temporary installations of mobile cranes. These cranes are typically set up by a lifting contractor for a specific project, most commonly using a leased barge and one of the contractor's cranes.

It is this last form of the floating crane that is of interest here. Many rigging contractors do not have in-house expertise in naval architecture or a familiarity with the standards that govern mobile crane installation on barges. The purpose of this paper is to review these standards and practices and to provide general guidance in the engineering of a mobile crane installation on a barge.

The engineering of a mobile crane installation on a barge may require the design of special equipment and will likely require the analysis of the barge structure. Laws in some areas or the owner's project requirements may dictate that such work be performed by a licensed professional
The contractor in charge of the project must assure that all such laws and requirements are met for each job.

**PRIMARY CONSIDERATIONS**

The design of a mobile crane installation on a barge can be broken down into four tasks. First is selection of the crane to be used. We recognize up front that the crane's normal load charts will not apply for a barge installation, so that crane selection initially has to be made on some assumed derating. Second is the selection of the barge. There are regulatory issues that affect the barge selection for all projects and there may be job-specific limits, as well. Third is the design of the crane installation on the barge. This work applies principles from naval architecture and structural engineering. Fourth is the development of load charts that are applicable to the specific installation.

The actual design work may not be as simple as step one, step two, step three, step four. The effort may iterate if the initial selection of, say, the barge does not produce the results needed. This will require revising any initial selections that do not produce satisfactory results and repeating the design work. The following sections discuss each of these four topics.

**Crane Selection**

The main crane selection issues sound, on their surface, exactly like those for selecting a crane for a normal land-based lift. The crane must have the physical reach, both vertically and horizontally, to place the load and it must have the capacity to safely lift the specified weight. However, the effects of the marine environment alter both of these areas.

Let us consider reach first. In addition to the usual concerns about boom interference and the like, the crane's ability is also compromised by the barge, itself. The barge crane is almost always lifting its load onto or off of some adjacent structure, be it another vessel, a dock, or a bridge foundation. Thus, the useful radius of the crane is measured from the edge of the barge, as illustrated in Figure 1.

![Diagram of crane and barge](image)

The width, or beam, of the barge figures significantly in the evaluation of the barge with respect to its stability and resistance to listing as the crane operates. This will be discussed in detail in the next section. For now, we must just keep in mind that the ability of the crane to do its job is affected by the length and width of the barge. Thus, when checking the layout of the lifts to be made, consideration must be given to the likely size of the barge.

The useful as discussed above applies to the useful physical reach of the crane only. Rated capacities are always determined with respect to the normal operating radius of the crane as measured from the center of rotation.

Making the first check of the crane's capacity may be relatively easy or virtually impossible. Some manufacturers publish load charts for barge service. Typically, these charts show rated capacities...
for conditions in which the crane is out of level by various angles. If charts are available, the one need only make an estimate of the maximum angle by which the crane will be out of level. Although this initial estimate may prove to be off, the error should not be great.

On the other hand, if barge load charts are not available, estimating rated capacities is very difficult, if not impossible. Depending on the boom length and operating radius, the barge service capacities may be on the order of 90% of the land service capacities or less that 50% of the land capacities. As will be discussed in the section on barge service load charts, there is no simple method by which a crane user can determine the rated capacity of a crane in an out of level condition.

In this case, the user is well advised to work with the manufacturer to determine suitable rated capacities. Again, an estimate will have to be made of the out of level angle of the crane, but the difficult job of determining the safe capacity is left to those best equipped to do that engineering work.

Barge Selection

The selection of a barge that is suitable for a crane installation requires investigation of two areas. First is the structural adequacy of the barge's deck and internal structure to safely support the loads from the crane. Second is a set of marine performance issues that are governed by ASME B30.8 and US Coast Guard regulations.

Flat deck steel barges of the sort most commonly used for crane work are constructed as follows. The deck is steel plate that is stiffened with rib members that run along the length of the barge (Fig. 2)

![Figure 2. Typical Deck Construction](image)

This deck structure spans between transverse trusses or bulkheads within the barge. The bulkheads are stiffened plate walls that divide the barge into a series of watertight internal compartments. The trusses are simply structural frames that provide support to the deck, sides, and bottom of the barge. Typical transverse trusses are illustrated in Figure 3.
Note one very significant difference between the truss configurations shown in Figure 3. The truss design of Figure 3a has the longitudinal ribs framed into the webs of the truss top chords. This design provides a series of relatively strong hard points at each truss, since the truss chords are generally fairly stout members. The design of Figure 3b has the longitudinal ribs landing on top of the truss chords. In this arrangement, concentrated loads on the deck will act to crush the ribs. Unless the ribs are relatively thick, this concentrated bearing can be the structural limit of the deck strength.

Consider first a truck crane on a barge. All loads from the crane will be impressed on the deck at the outriggers (lifting on rubber on a barge is clearly not advised). The typical barge deck construction (Fig. 2) will rarely be able to carry the outrigger loads from a large crane. Therefore, either the crane must be positioned on the deck such that the outriggers land on hard points, such as the intersection of transverse and longitudinal bulkheads, or steel grillages will have to be installed on deck to transfer the outrigger loads to the internal structure.

Crawler cranes present a similar challenge. On soil, the crawler’s load will be distributed along its length. On a barge deck, the crawler’s load will most likely be carried at a few hard points. The best advantage can usually be gained by setting the crane with the crawlers in the longitudinal direction. The spacing of the transverse trusses is commonly in the range of five to ten feet, so the crane can usually be located on deck such that the crawlers bear directly over three or more trusses.

Calculation of the outrigger or crawler track loads is performed in roughly the same manner as is done for a crane installation on land. One additional consideration must be made, though. When the crane leans to one side (e.g., Figure 7 below), the sideways movement of the boom tip will create a transfer of load to the low side. For example, if a level crawler crane is lifting directly over the front, the loads on the two crawlers will be equal. In this same situation, if the crane has a machine list of $3^\circ$, the boom tip will move toward the low side, thus increasing the load to that crawler. This effect must be included in the calculation of support reactions in order to be assured of knowing the maximum loads that will be imposed on the deck.

Once the crane’s reactions are known, the barge structure must be analyzed. This task must be performed by a naval architect or structural engineer. Because of the many different barge structures used in practice, there are no simple “rules of thumb” that allow a quick solution to this
requirement. The few regulations and industry standards that address mobile crane barge installations do not establish guidelines for this analysis work. The ABS Rules for Building and Classing Steel Barges bases barge structural requirements on required proportions, rather than load and stress calculations, so one cannot practically apply the Rules for this analysis. Use of the AISC allowable stress design specification is often an accepted standard upon which design factors can be based.

The second set of issues that affect the barge selection falls under the category of marine performance. A fundamental dimension of the barge that has significant effect on the barge's performance in service is its width, or beam. As discussed in the previous section, the beam affects the useful radius of the crane. In this respect, one might think that smaller is better. On the other hand, the beam affects the barge's stability in such a manner that larger is better. Thus, we have one more trade-off. In this case, however, there are regulations that provide some guidance.

The US Coast Guard publishes regulations (46 CFR 173 Subpart B) that establish minimum required intact stability of a barge used in lifting service. A barge's stability is measured by a value called the righting arm. This is a fairly important concept and is described in detail in the following paragraphs.

Consider the simple case of the barge shown in Figure 4.

![Image of a floating barge at rest](image)

Figure 4. Floating Barge At Rest

The point G is the composite center of gravity of the barge and any items on board. The point B is the center of the buoyant force (center of buoyancy). When the barge is at rest, B will always be directly under G.

Now consider that the barge as been caused to roll by wind or wave action, as shown in Figure 5. The submerged portion of the barge takes on a trapezoidal shape and the center of buoyancy shifts toward the right. The rolling motion also causes the center of gravity to move to the right. So long as the center of buoyancy moves more than the center of gravity, there will remain a tendency for the barge to return to its upright position. The strength of that tendency is measured by the righting arm.

Consider in Figure 5 the vertical line drawn through the center of buoyancy. The horizontal distance from the center of gravity to this vertical line, noted as line GZ in the figure, is the righting arm. The longer GZ is, the greater is the tendency of the vessel to right itself.
The value of GZ will change as the angle of roll changes. As seen in Figure 4, GZ = 0 when the barge is at rest. As the barge rolls, GZ will increase to some maximum and then drop back to zero at some point. When GZ drops below zero, the barge will capsize.

The Coast Guard stability requirements relate to the properties of a graph of the righting arm for a range of angles. A typical righting arm curve is shown in Figure 6.

ASME B30.8 also defines a stability requirement, but in this case, the requirement is based on damaged stability. Specifically, the barge must remain stable with any one compartment of the barge breached. This requirement applies to seagoing barges in the transit configuration (i.e., not while lifting).

B30.8 also defines maximum permissible angles of list and trim of the barge during lifting. The maximum allowable list or trim is 5° (8.75%), but shall not exceed the maximum allowed by the crane manufacturer. Further, the extremes of list and trim of the barge must be such that no part of the deck submerges and no part of the bottom of the barge emerges.

B30.8 also defines a wide variety of marine equipment requirements. Many are obvious, such as the need to have lifesaving equipment at the ready. Others are somewhat specialized, such as requirements for machinery and electrical equipment installations. The scope of B30.8 is extensive enough that not all of its coverage can be repeated here. B30.8 is a "must have" for anyone working
with barge-mounted cranes.

Last, a note about "crane barges." Just because a barge is so labeled by its owner does not guarantee its structural adequacy for every crane application. Although crane barges generally have stronger than normal deck structures, they still must be analyzed for the specific crane installation.

Crane Installation

Installation of a mobile crane on a barge can be divided into two tasks. The first is common to any crane setup analysis and that is to assure that the supporting surface is of adequate strength to carry the crawler track pressures or outriggers reactions. The second is to secure the crane to the barge deck.

The first of these two issues has already been discussed in the section above on barge selection. In summary, the crane's support reactions are calculated based on the lifts to be made. These reactions are then used to perform a structural analysis of the barge deck and internal structure (i.e., trusses and bulkheads). The most important caution here is to account for the effects of concentrated loads. Unlike soil, hard points created by the relatively unyielding trusses and bulkheads can result in concentrations of load that can cause localized failures.

If necessary, reinforcement may be required to adequately distribute the crane's reactions its the barge structure. In most cases, timber crane mats are not adequate for load spreading on a barge deck. Steel plate and beams are usually best in that they can be welded to the deck, thus resisting horizontal forces as well as distributing vertical loads.

Whereas accounting for the vertical loads is fairly straightforward, the issue of securing the crane is not. OSHA [29 CFR 1926.550 (f)(iv)] states that "mobile cranes on barges shall be positively secured." ASME B30.8 Section 8-1.2.2(b)(2)(e) states "cranes shall be blocked and secured to prevent shifting". The immediate question that comes to mind is: For what forces must the securements for the crane be designed? No guidance is given with respect to design loads or factors of safety by either OSHA or ASME.

Here again we must turn to the marine analyses performed to determine the barge's orientation throughout the lift range of the crane. The slope of the barge deck will result in a horizontal force acting in the plane of the deck that is created by the vertical weight of the crane plus its lifted load. A reasonable design force can be calculated by conservatively ignoring the benefit of friction between the crane and the deck.

As an example, consider a Manitowoc 2250 Series 3 crawler crane lifting a load of 150,000 pounds. The crane weighs 657,720 pounds, giving us a total weight of 807,720 pounds. If the barge deck slope is 5º, then there is a horizontal force acting between the bottom of the crane and the barge deck equal to 807,720 x sin 5º = 70,397 pounds. One day reasonably use this force as a horizontal design load for the crane's securement. These forces are illustrated in Figure 7.
If the barge crane is to be used in an environment where water movement might cause significant barge motions, then dynamic loads must also be considered. Unless the crane is to be used offshore, however, such dynamic loading is unlikely and, as an operational restriction, should be avoided.

Developing a design vertical load to the securements will most likely be more subjective. The load chart for the crane will be such that the crane's natural stability will prevent uplift (that is, the barge does not act as additional counterweight). Still, some vertical restraint is required. In the absence of a vertical force that can be arrived at by calculation, a suitable design load must be determined by empirical means, perhaps as some percentage of the total weight of the crane plus load. This must be evaluated on a case by case basis by an appropriately experienced engineer or naval architect. As previously noted, the analysis of the barge structure due to crane reaction forces and the design of the crane securements may be performed in accordance with the AISC allowable stress design specification.

Figure 7. Crane Restraint Force