AMERICAN CRANES & TRANSPORT

February 2016
Volume 12 ■ Issue 2

AC&T

The magazine for the crane, lifting and transport industry

A KHL Group Publication

www.khl.com/act

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To prevent shear failure, increase the ground contact area using load spreading tools such as pads, mats, blocking or cribbing.

Kris Koberg discusses rules, standards and 'rules of thumb' to guide crane setup.

Setting up for success

OSHA states that cranes must be assembled on ground that is firm, drained and graded sufficiently, in conjunction with supporting materials, such as blocking, cribbing, pads or mats, to provide adequate support and degree of level. (OSHA 1926.1402). It can be difficult to know if the ground beneath your crane will support the weight and pressure under your outriggers, yet knowing this is critical to safe crane setup.

In response to this need, U.S. regulatory bodies and site owners continue to place emphasis on understanding ground conditions and using outrigger pads or crane mats that are sufficient to provide the necessary foundation support. In fact, Item No. 1 on OSHA's site inspection checklist for OSHA compliance officers (Compliance Directive for Cranes and Derricks in Construction Standard issued 10/17/14) is to determine the adequacy of ground conditions beneath the equipment set-up area such as the support/foundation, matting, cribbing and blocking.

OSHA has established that the responsibility for providing adequate ground conditions, including identifying underground hazards, belongs to the controlling entity. If there is not a controlling entity, this responsibility shifts to the employer. While this is a welcome addition to the newest Cranes & Derricks in Construction rule, OSHA's multi-employer policy remains in force.

Multiple employers can be cited for the same violation of hazardous conditions. Crane rental companies and their operators must remain vigilant in the evaluation of ground conditions and use of proper outrigger pads and crane pads. They must also notify the appropriate party if ground conditions are inadequate for safe crane setup before beginning or continuing operations.

Although OSHA does not have a rule regulating the construction, design, or materials used as foundation support, ASME B30.5 provides some insight. ASME states that outrigger blocking or cribbing must have sufficient strength to prevent crushing, bending, or shear failure. And it needs to be of such thickness, width, and length as to completely support the float, transmit the load to the supporting surface, and prevent shifting, toppling or excessive settlement under the load. (ASME B30.5-2011).

ESSENTIAL ELEMENTS TO KNOW BEFORE SIZING OUTRIGGER PADS: Knowing the outrigger reaction forces and the ground strength (ground-bearing capacity), or the allowable ground bearing pressure, are the essential pieces of information to establish a safe crane setup (see Illustration A, page 30). These data points will enable you to know what size outrigger pads or crane pads are needed for a specific crane or lift.

Unfortunately, industry rules of thumb are often used to estimate outrigger reaction forces and outrigger pad sizes. Beware: there are inherent flaws in these estimating methods. Rather than using rules of thumb, crane owners and operators need to understand the forces

LEFT: Engineered outrigger pads (top of photo) provide consistent, reliable strength and rigidly properties and are not susceptible to the elements. This is a clear distinction from more commonly used wood outrigger pads whose strength and stiffness properties can be ever changing (bottom of photo).

THE AUTHOR

This Rigging Review article, Part One of a two-part series, is excerpted from a presentation made by **Kris Koberg**, CEO, DICA Outrigger Pads, at the 2015 SC&RA Crane & Rigging Workshop in Denver, CO. It reviews pertinent standards and regulations governing crane setup. This article is specific to outrigger-enabled cranes and equipment, however the same principals apply to crawler cranes and other track-driven equipment. Part Two will appear in the March issue of *American Cranes & Transport*.

being emitted through the outriggers of their equipment, and they need to have an understanding of what pressures the ground they are setting up on can support. If the pressures being emitted to the ground are greater than the ground can support, a clear problem will arise.

UNDERSTANDING MAXIMUM OUTRIGGER REACTION FORCE (MORF): The maximum outrigger reaction force that a crane can exert is critical for understanding the strength needs of properly sized pads or mats for individual pieces of equipment. Every manufacturer provides MORF information, but some do a better job than others. Some clearly provide this information in their technical specifications, while others provide online calculators that allow users to calculate lift-specific outrigger reaction forces. Third-party software, such as 3-D Lift Plan, is also a source for similar information.

It is not likely a crane will be used in a scenario that generates the MORF. Generally, this force is generated when the crane is at maximum counterweight, maximum outrigger spread, shortest

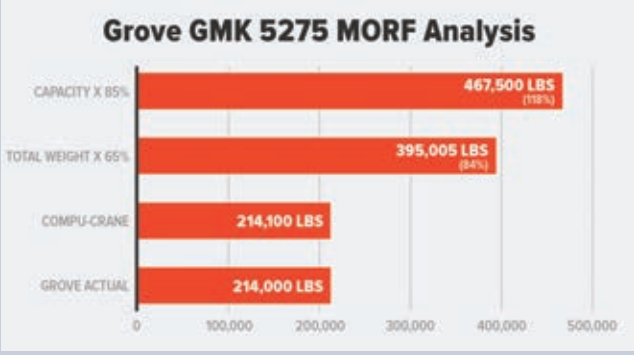
Example Crane **Grove GMK 5275, (Tier 3)**

- Rated capacity of 275 tons
- Total crane mass of 310,700 lbs
- Max Pick w/o additional equipment = 297,000 lbs
- Actual Maximum Outrigger Reaction Force (MORF) per Manitowoc = 214,000 lbs

Compu Crane Software
346,000 lbs lift (max counterweight and outrigger spread) = 214,100 lbs MORF

Rule of Thumb: Capacity x 85 percent
Outrigger Reaction Force
275 Tons, 550,000 lbs x 85 percent = 467,500 lbs

Rule of Thumb: (Total Crane Mass + Load) x 65 percent
Outrigger Reaction Force
310,700 lbs + 297,000 lbs = 607,700 lbs
607,700 lbs x 65 percent = 395,005 lbs



In this example, the two rules of thumb overestimate MORF by 118 percent and 84 percent. In contrast, the Compu-Crane software and the manufacturer data provide consistent, accurate MORF information.

boom length and radius, and executing the maximum pick possible for that crane with the boom positioned directly over one of the front outriggers. For a 100-ton crane this would mean it would be making a 100-ton lift. All other lifts would generate an outrigger force that is less than the maximum outrigger reaction force for that crane. As noted, rules of thumb have historically been a "go to" estimating tool, despite their inherent flaws. (See examples, page 27.)

IDENTIFYING THE GROUND BEARING CAPACITY (GBC): The ground bearing capacity can be simply defined as the strength of the ground, or its ability to support pressure. Because identifying this critical factor is difficult, geotechnical reports, ground penetrating radar, and a geotechnical engineer should be considered as resources when possible.

OSHA has established the responsibility for providing adequate ground conditions, including identifying underground hazards, belongs to the controlling entity. If there is not a controlling entity, then this shifts to the employer.

To assist in the assessment of the ground, many companies have implemented the use of roll tests or plate tests as methods for testing the surface, or crust of the ground. These tests are useful and are recommended in the assessment of the top layer of the ground, but be careful. The surface is supported by the subgrade, or the ground beneath the surface layers. In an accident in Queensland, Australia (December 2015) the subgrade gave way under the pressure of the outrigger, causing the crane to fall to the ground resulting in two fatalities.

To see below the surface of the ground and evaluate the subgrade you will need to employ the use of soil borings, dynamic cone penetrometers, ground penetrating radar, or other more advanced techniques to understand the strength of the subgrade and any unknown hazards.

UNDERSTANDING THE GROUND BEARING PRESSURE (GBP): The ground bearing pressure is defined as the pressure that is exerted onto the ground. The objective is to ensure that the ground bearing pressure (GBP) is always less than the ground bearing capacity (GBC).

If the ground bearing pressure is greater than the ground bearing capacity, the ground will move. As the ground moves it will compress and compact to a point where it will either support the pressure being imposed on it, or it will completely fail under the load. Unfortunately, sufficient ground compaction may not occur prior to the occurrence of a catastrophic accident. (See Illustration A, page 30.)

EXAMPLE:
Outrigger Reaction Force = 150,000 lbs
Outrigger Float = 2' x 2', Area = 4 ft²
Assumption: Outrigger Float Only.
No outrigger or crane pad is used.

- Pressure under the outrigger float = outrigger reaction force / outrigger float area
- 150,000 lbs / 4 ft² = 37,500 psf of Ground Bearing Pressure (GBP)

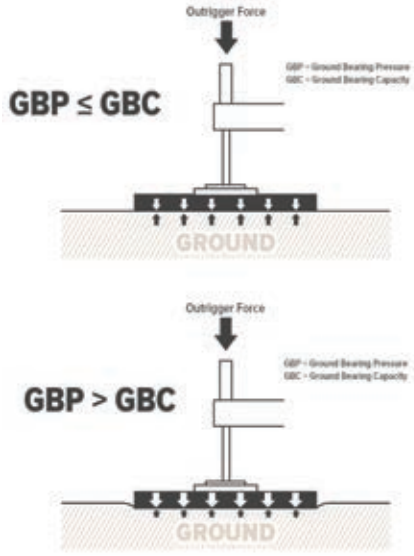
Assumption: A 6' x 5' properly designed and constructed crane pad is used.
6' x 5' = 30 ft² of area.

- Pressure under the crane pad = outrigger reaction force / crane pad area
- 150,000 lbs / 30 ft² = 5,000 psf of Ground Bearing Pressure (GBP)

By using the 6x5-foot crane pad the ground bearing pressure can be effectively reduced from 37,500 psf to 5,000 psf, approximately an 86 percent reduction.

HOW TO DECREASE GBP AND INCREASE GBC: The most common way to prevent the failure of the ground (shear failure) due to ground bearing pressures exceeding ground bearing capacities is to use outrigger/crane pads. Accurately sized and engineered outrigger pads increase the area the force is emitted through, reducing the ground bearing pressure.

Illustration A



Nabholz Construction, Rogers, Ark., uses SafetyTech and FiberMax crane pads on top of improved ground that is firm, drained and graded.

ASME states *"outrigger blocking or cribbing must have sufficient strength to prevent crushing, bending, or shear failure. And it needs to be of such thickness, width and length as to completely support the float, transmit the load to the supporting surface, and prevent shifting, toppling or excessive settlement under the load." (ASME B30.5-2011)*

To ensure that you have selected the right solution based on the ASME standard you will need the assistance of an engineer or a knowledgeable outrigger pad manufacturer. Remember, outrigger pads and crane pads need to be sized for both the outrigger reaction force and the ground bearing capacity, or the desired ground bearing pressure. The larger the load distribution area needed, the more rigid (generally thicker) the pad must be. If using materials that are not engineered such as wood, be sure to account for degradation that is caused by water, Ultra Violet light, insects, rotting and previous stress.

An additional measure to decrease ground bearing pressure and prevent failure of the ground is to improve the ground itself. The ground can be improved in many ways, such as compaction, adding rock or other dense inorganic materials, removing un-compacted surfaces, or allowing wet ground to dry.

According to Keith Anderson, author of *Rigging Engineering Basics*, 1st Edition, "It might make sense to do some of both…" That is, improve the ground *and* use outrigger pads or crane pads. (See photo above for an example of this method.) ■

EDITOR'S NOTE

PART 2 of this "Rigging Review: Setting up for success" series will guide crane owners in how to select the right size outrigger pad or crane mats. As mentioned, undersized pads can put you in an unstable condition, but oversized pads can be inefficient in terms of purchase, transportation costs and set-up and tear down time. Just as rules of thumb can provide inaccurate results in determining outrigger reaction forces, rules of thumb can also provide poor direction when selecting outrigger pad sizes.