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Don't crack under pressure

In this, the last article for the time being on ground pressure, MARCO VAN DAAL focuses on crawler cranes

This is the last article in the series about ground pressure. No other topic has been covered this extensively in *The Knowledge* series. Ground pressure is one of the most critical, undervalued, misunderstood and controversial topics in our industry. It is important to understand what ground pressure is, how it is developed and how its maximum value changes when the parameters of a lift, or transport, changes. And… in case not all parameters are known (and this happens more often than one realises), it is equally important to be able to make a justified judgement so that the ground can be prepared for, or protected against, excessive ground pressure loads.

After having covered ground pressure under hydraulic platform transporters and cranes on outriggers, this article covers ground pressure crawler cranes. As stated in last month's article, this article follows Method 2.

METHOD 1: Determine the weight distribution of each of the two centres of gravity (CoG) both for the fixed and rotating parts, and add up the results to arrive at the total weight per outrigger. This is the method used in last month's article.

METHOD 2: Determine the combined CoG of the two CoGs (fixed and rotating part) before calculating the weight distribution. This method is used in this article.

ABOUT THE AUTHOR

MARCO VAN DAAL has been in the heavy lift and transport industry since 1993. He started at Mammoet and later with Fagioli from Italy, both leading companies in the industry. His 20-year-plus experience extends to five continents and more than 55 countries. His book *The Art of Heavy Transport*, is available at: www.khl-infostore.com/books. Van Daal has a passion for sharing knowledge and holds training seminars around the world.

At first glance one might think that the calculation of weight distribution is easier for crawler cranes than for cranes on outriggers as there are four outriggers and only two crawlers. This can be deceiving. Indeed, there are only two crawlers and determining the load on each of them, conveniently called the Heavy Crawler and the Light Crawler, is a straight forward calculation. However, the way this load dissipates into the soil below the crawlers is what makes it quite a bit more difficult as this is subjected to load moments due to the offset of the combined CoG of the carrier, upper part and load.

The best way to show this is with a few sample calculations. Consider Figure 1 which shows a crawler crane with the upper body rotated 90 degrees from the crawlers.

We recognise three CoGs in this example.

1. The one that is shown in the centre is the CoG of the fixed lower part or carrier. This one is located (for this exercise) exactly in the centre of rotation (i.e the centre of the slew ring).
2. The one that is shown near the crawler (in the upper part of the figure) is the CoG of the upper part and includes boom, rigging, load, hook block and so on.
3. The remaining one is the 'combined CoG' (CoG_{tot}) of the entire crane with load. As you can see, this CoG is 820 mm (2'-9.5") from the centre of rotation.

FIGURE 1

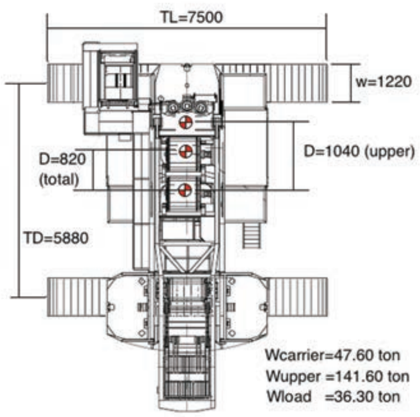
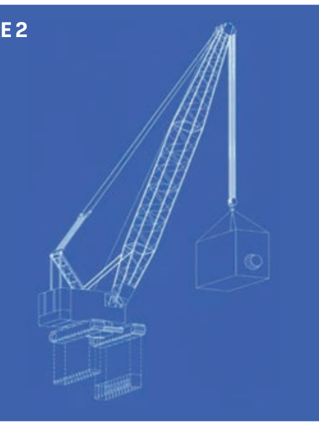


FIGURE 2



NOTE: When talking about crawler cranes the term 'fixed lower part' is less applicable as crawler cranes can 'walk' or 'crawl' with a load. The term 'carrier' is more applicable and will be used for the remainder of this article.

Other important information about the dimensions in Figure 1 is:

- The distance between the centrelines of the crawlers (TD) is 5,880 mm (19'-3.5")
- The length of the crawlers (TL) is 7,500 mm (24'-7.3")
- The width of the crawlers (w) is 1,220 mm (4'-0")

Information on weight is:

- Weight of the carrier is 47.6 tons
- Weight of the upper part is 141.6 tons
- Weight of the load is 36.3 tons
- Total weight is (47.6 + 141.6 + 36.3) 225.5 tons

Lift example 1

In this situation, with the upper part rotated 90 degrees (angle α) from the crawler direction, the crawler at the top of the figure is the Heavy Crawler, the other one is the Light Crawler.

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The following formulae can now be applied:

$Load_{Heavy\ Crawler} = W_{tot} / 2 + (W_{tot} * CoG_{tot} * \sin\alpha) / TD$
$= 225.5 / 2 + (225.5 * 0.82 * \sin 90) / 5.88$
$= 144.2$ ton

$Load_{Light\ Crawler} = W_{tot} / 2 - (W_{tot} * CoG_{tot} * \sin\alpha) / TD$
$= 225.5 / 2 - (225.5 * 0.82 * \sin 90) / 5.88$
$= 81.3$ ton

A quick check shows that the Heavy Crawler + Light Crawler = 144.2 + 81.3 = 225.5 ton (OK!)

With the upper part rotated 90 degrees from the crawler direction, the shape of the ground pressure diagram underneath each of the crawlers is rectangular, see Figure 2, and the ground pressure can be determined by dividing each crawler load by the crawler foot print (length * width = TL * w).

The ground pressure is now:

$Ground\ pressure_{Heavy\ Crawler} = Load_{Heavy\ Crawler} / (TL * w)$
$= 144.2 / (7.5 * 1.22) = 15.76$ ton/m^2

$Ground\ pressure_{Light\ Crawler} = Load_{Light\ Crawler} / (TL * w)$
$= 81.3 / (7.5 * 1.22) = 8.88$ ton/m^2

The ground preparation or matting has to be such that it can withstand the loads as determined above.

Lift example 2

For the second example it is assumed that angle α=0 degrees. This load case is also called an 'over the front' lift.

$Load_{Heavy\ Crawler} = W_{tot} / 2 + (W_{tot} * CoG_{tot} * \sin\alpha) / TD$
$= 225.5 / 2 + (225.5 * 0.82 * \sin 0) / 5.88$
$= 112.8$ ton

$Load_{Light\ Crawler} = W_{tot} / 2 - (W_{tot} * CoG_{tot} * \sin\alpha) / TD$
$= 225.5 / 2 - (225.5 * 0.82 * \sin 0) / 5.88$
$= 112.8$ ton

FIGURE 3

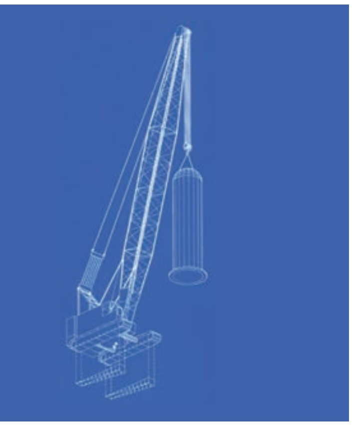
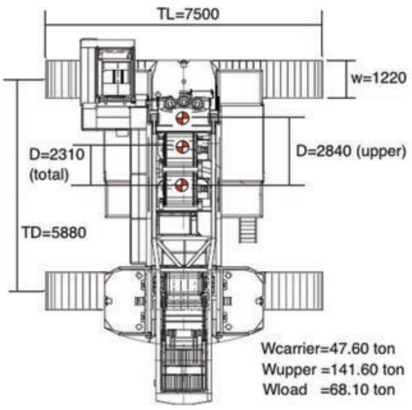


FIGURE 4



A quick check shows that the Heavy Crawler + Light Crawler = 112.8 + 112.8 = 225.6 ton (OK!)

This result is not surprising, as the lift takes place over the front, so both crawlers are loaded equally. The shape of the ground pressure diagram, however, is no longer a rectangle, see Figure 3. It is no longer a matter of dividing the crawler load by the footprint. A new term has to be brought into the equation, the 'eccentricity' or 'e'. The eccentricity determines the length of the track that carries weight. The more load one lifts over the front (obviously within the capacity chart) the more load the front end of the crawlers carry and the less load the rear end of the tracks carry, to the extent that the rear end of the tracks carry no load at all.

The eccentricity 'e' is calculated as:

$e = (W_{tot} * CoG_{tot} * \cos\alpha) / W_{tot}$
$= (225.5 * 0.82 * \cos 0) / 225.5$
$= 0.82$ metres (2'-9.5")

The bearing length 'L' of the crawlers can now be determined;

$L = 3 * (TL/2 - e)$
$= 3 * (7.5/2 - 0.82)$
$= 8.79$ metre (28'-10")

The fact that 'L' is longer than the length of the crawlers means that the crawlers carry load over their full length and that the ground pressure diagram has a trapezium shape, see Figure 3.

Each crawler carries the highest load at the front end and the lowest load at the rear end.

Here is how to calculate the ground pressures caused by these loads.

$Ground\ pressure_{max\ load}$
$= (Load_{Heavy\ Crawler} / (W * TL)) * (1 + (6 * e) / TL)$
$= (112.8 / (1.22 * 7.5)) * (1 + (6 * 0.82) / 7.5)$
$= 20.4$ ton/m^2

$Ground\ pressure_{min\ load}$
$= (Load_{Heavy\ Crawler} / (W * TL)) * (1 - (6 * e) / TL)$
$= (112.8 / (1.22 * 7.5)) * (1 - (6 * 0.82) / 7.5)$
$= 4.2$ ton/m^2

NOTE: Since the lift is performed over the front these values apply to each crawler.

Lift example 3

For this example it is assumed that the load increases from 36.3 ton to 68.1 ton while lifting 'over the front'. Figure 4 indicates that the load has increased and that the location of the CoGs has been changed. The total weight is now (47.6 + 141.6 + 68.1) 257.3 ton.

What is the effect of this load increase on the ground pressure?

$Load_{Heavy\ Crawler} = W_{tot}/2 + (W_{tot} * CoG_{tot} * \sin\alpha) / TD$
$= 257.3 / 2 + (257.3 * 2.31 * \sin 0) / 5.88$
$= 128.7$ ton

$Load_{Light\ Crawler} = W_{tot}/2 - (W_{tot} * CoG_{tot} * \sin\alpha) / TD$
$= 257.3 / 2 - (257.3 * 2.31 * \sin 0) / 5.88$
$= 128.7$ ton

A quick check shows that the Heavy Crawler + Light Crawler = 128.7 + 128.7 = 257.4 ton (OK!)

The eccentricity 'e' is calculated as:

$e = (W_{tot} * CoG_{tot} * \cos\alpha) / W_{tot}$
$= (257.3 * 2.31 * \cos 0) / 257.3$
$= 2.31$ metre (7'-7")

The bearing length 'L' of the crawlers can now be determined:

$L = 3 * (TL/2 - e)$
$= 3 * (7.5/2 - 2.31)$
$= 4.32$ metre (14'-2")

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FIGURE 5

The fact that 'L' is shorter than the length of the crawlers means that the crawlers carry load over less than their full length and that the ground pressure diagram now has a triangular shape, see Figure 5.

For this reason, there is no need to calculate the ground pressure at the rear end of the crawlers as this is zero. There is, however, a need to calculate the ground pressure at the front of the crawlers. Looking at the ground pressure diagram this load has increased considerably.

Ground $\text{pressure}_{\text{max load}} = (2 * \text{Load}_{\text{Heavy Crawler}} / (w * L))$
$= (2 * 128.7 / (1.22 * 4.32)$
$= 48.9$ ton/m^2

Lift example 4

For the last example the crane slews to an angle of α=25 degrees, see Figure 6. The calculation becomes a bit more extensive now. Figure 6 reveals that the Heavy Crawler is subjected to a higher loading at the front end. The calculations below will show this.

$\text{Load}_{\text{Heavy Crawler}} = W_{tot}/2 + (W_{tot} * \text{CoG}_{tot} * \sin\alpha) / TD$
$= 257.3 / 2 + (257.3 * 2.31 * \sin 25) / 5.88$
$= 171.4$ ton

$\text{Load}_{\text{Light Crawler}} = W_{tot}/2 - (W_{tot} * \text{CoG}_{tot} * \sin\alpha) / TD$
$= 257.3 / 2 - (257.3 * 2.31 * \sin 25) / 5.88$
$= 85.9$ ton

A quick check shows that the Heavy Crawler + Light Crawler = 171.4 + 85.9 = 257.3 ton (OK!)

The eccentricity 'e' is calculated as:

$e = (W_{tot} * \text{CoG}_{tot} * \cos\alpha) / W_{tot}$
$= (257.3 * 2.31 * \cos 25) / 257.3$
$= 2.1$ metre (6'-10")

The bearing length 'L' of the crawlers can now be determined:

FIGURE 6

$L = 3 * (TL/2 - e)$
$= 3 * (7.5/2 - 2.1)$
$= 4.95$ mtr (16'-2.9")

As before, since 'L' is shorter than the length of the crawlers, the load is not carried over the full length of the crawlers but only over length 'L'. Figure 6 confirms this.

Below is the ground pressure at the front end of each crawler.

For the Heavy Crawler:
Ground $\text{pressure}_{\text{max load}} = (2 * \text{Load}_{\text{Heavy Crawler}} / (w * L))$
$= (2 * 171.4 / (1.22 * 4.95)$
$= 56.6$ ton/m^2

For the Light Crawler:
Ground $\text{pressure}_{\text{max load}} = (2 * \text{Load}_{\text{Light Crawler}} / (w * L))$
$= (2 * 85.9 / (1.22 * 4.95)$
$= 28.4$ ton/m^2

The above four lift examples show that the ground pressure can increase considerably during the performance of a lift. It is not uncommon that the ground pressure can increase ten-fold between a best case scenario and a worst case scenario. This in itself does not necessarily pose a problem as long as it is known and the right precautions (compaction, matting, spreading) are taken. ■