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## Below the hook

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ROUGH TERRAIN CRANES ■ SPMT ■ ESTA NEWS ■ THE KNOWLEDGE

# Under pressure

**Allowable ground bearing pressure is a tricky subject at the best of times but even more so when it is for a temporary road to carry a limited number of specialized transport loads over a relatively short time. MARCO VAN DAAL reports**

If there has ever been a controversial topic in the heavy transport industry, it must be the determination of the ground pressure underneath a transport combination. To arrive at a calculated allowable ground bearing pressure one would have to get geophysicists involved to carry out a full soil analysis followed by a recommendation for soil improvement.

Although this is the recommended method when preparing soil for a permanent structure such as a hotel, office building or heavy petrochemical and power generation components (to stay within our industry) it will become quickly apparent that this is difficult, if not impossible, to apply this method to the construction of a temporary heavy haul road.

To start with, the soil analysis carried out for above-mentioned structures assumes that these structures pose a permanent load on the soil for many decades with only a minimal allowable settlement. It takes into account worst case environmental loads such as wind, snow, ice and sometimes earthquakes. This assumption is invalid for temporary heavy haul roads, as the name already implies. Such roads often experience a fair amount of traffic with one (1) or a small number of extreme heavy loads over a period of a few weeks at best to a few years in the worst case.

Temporary heavy haul roads are often found on petrochemical plants, both during construction and on turn around projects. Also, they are used at power plants, temporary storage facilities, wind energy farms and similar projects. Those who are or have been involved in such projects know that these temporary roads are put in place and often do not last the duration of the project as the progress of the project claims the real estate in question and the temporary roads are diverted. This fact alone makes a lengthy soil analysis an unlikely solution.

There are various types of soil that a road can be made of. Some are very suitable for medium to heavy loads, some are unsuitable for even light traffic. Table 1 is from Keith Anderson's book *Rigging Engineering Basics* and shows the allowable bearing capacity of a number of different soils. The allowable bearing capacity is derived from the ultimate bearing capacity (at which the soil support fails in shear) with a factor of safety of around 2.5 applied.

There are two methods of ground pressure calculation that are well accepted in our industry. Neither one is a scientific approach but both methods produce an acceptable outcome that is workable in practice and have been used for many years by many companies large and small.

The first is the shadow area method.

## Shadow area method

Let's assume that we have a 6-axle line transporter set up in a three point suspension with four axles per each suspension group and four tyres per axle (meaning eight tyres per axle line). The axle distance (DAS) is 1.5 metres (4 ft 11 inches).

This combination is carrying a 100 ton transformer. See Figure 1. The transformer is placed on the transporter in such a way that each axle carries an equal load. The transporter and power pack combined weigh 26 tons. This gives a gross vehicle weight (GVW) of 126 tons.

Each axle line carries 21 tons (126 tons / 6 axle lines), each axle carries 10.5 tons and each tyre (48 in total) carries 2.6 tons.

Figure 2 shows the plan view of the transporter in question. The shadow area is »

FIGURE 1

## ABOUT THE AUTHOR

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

| TABLE 1 | | Bearing capacity (presumptive) | | | |
|---|---|---|---|---|---|
| SOIL TYPE | | tons/sq. ft. | ksf | kN/m² | t/m² |
| Rock (not shale unless hard) | Bedrock | 60 | 120 | 5746 | 586 |
| | Layered | 15 | 30 | 1436 | 146 |
| | Soft | 8 | 16 | 766 | 78 |
| Hardpan (cemented sand or gravel) | | 10 | 20 | 1958 | 98 |
| Gravel, sand and gravel | Compact | 8 | 16 | 766 | 78 |
| | Firm | 6 | 12 | 575 | 59 |
| | Loose | 4 | 8 | 383 | 39 |
| Sand, coarse to medium | Compact | 6 | 12 | 575 | 59 |
| | Firm | 4.5 | 9 | 431 | 44 |
| | Loose | 3 | 6 | 287 | 29 |
| Sand, fine, silty or with trace of clay | Compact | 4 | 8 | 383 | 39 |
| | Firm | 3 | 6 | 287 | 29 |
| | Loose | 2 | 4 | 192 | 20 |
| Silt | Compact | 3 | 6 | 287 | 29 |
| | Firm | 2.5 | 5 | 239 | 24 |
| | Loose | 2 | 4 | 192 | 20 |
| Clay | Compact | 4 | 8 | 383 | 39 |
| | Firm | 2.5 | 5 | 239 | 24 |
| | Loose | 1 | 2 | 96 | 10 |

FIGURE 2

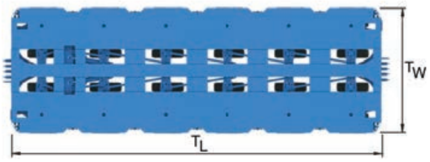



FIGURE 3

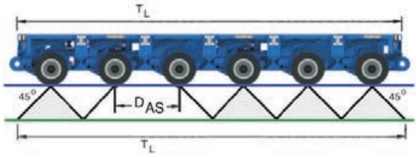
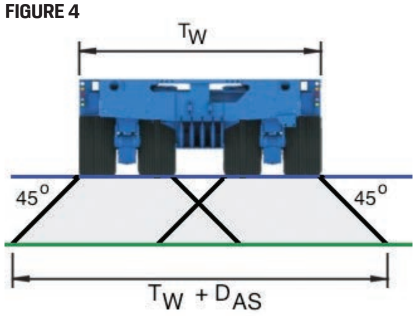



FIGURE 4




determined by multiplying the transporter width (Tw) by the transporter length (TL). In numbers; Tw = 3 metres (9 ft 10 inches) and TL = 6 * 1.5 m = 9 m (29 ft 6 inches).

The shadow area is therefore Ashadow=Tw * TL = 3 * 9 = 27 square metres (290 ft$^2$)

The ground pressure is P = F/A = 126 ton/ 27 m$^2$ = 4.7 tons/m$^2$ (962 PSF)

## Extended shadow area method

The second method is the extended shadow area method. In this method the ground forces dissipate at a 45 degree angle. Figures 3 and 4 show these ground forces in a side and end view. Looking at the side view of this 6-axle line combination we can see that the ground forces run at 45 degrees from each tyre at the contact area with the surface. At a depth of half the axle distance (0.5 * DAS) these forces intersect and here a true uniform ground pressure occurs. Therefore, the extended shadow area consists of a length that runs from the centre of the first tyre to the centre of the last tyre (5 * DAS) plus half an axle distance at the front (0.5 * DAS) plus half an axle distance at the rear (0.5 * DAS) of the transporter. The total length of the extended shadow area is thus (5 * DAS) + (0.5 * DAS) + (0.5 * DAS) = 6 * DAS = TL.

Compared to the shadow area method, the extended shadow area method uses the same length (TL), but a different approach to arrive at this length.

The width of the extended shadow area is

FIGURE 5

determined in the same way. The forces run at 45 degrees from the edge of each tyre. At a depth of half an axle distance the total width (Tw) has been increased by 2 * (0.5 * DAS), therefore the width of the extended shadow area is Tw + 2 * (0.5 * DAS) = Tw + DAS.

Ashadow = (Tw + DAS) * TL = (3 + 1.5) * (6 * 1.5) = 40.5 m$^2$ (435 ft$^2$)

The ground pressure is P = F/A = 126 ton/ 40.5 m$^2$ = 3.1 ton/m$^2$ (634 PSF)

The question may now arise which of the two methods should be applied. To answer this question, let's look at a typical construction site road and review the ground loading of a loaded concrete truck. Like the one shown in Figure 5.

In rough numbers the concrete truck itself weighs approx. 12.5 ton (27,500 pounds) and the 7 cubic metres of concrete weighs 17.5 ton (38,500 pounds). The GVW is therefore 30 ton (66,000 pounds). This weight is supported by the 10 tyres on this truck, assuming (for now) that 80 % is carried on the rear eight tyres and 20 % is carried on the front two steer tyres. The rear tyres each carry (30 ton * 80% / 8 tyres) 3 ton/tyre. The front steer tyres carry (30 ton * 20% / 2 tyres) 3 ton/tyre. This is less per tyre than the transporter that carries the 100 ton transformer as it carries only 2.6 ton/tyre.

**NOTE:** *the tyre width and therefore the footprint of a concrete truck is a bit larger than from a tyre on a transporter. This, however, is offset by the much higher velocity of the concrete truck and the associated dynamic impact on the road surface as well as by the fact that the concrete truck has fewer tyres and, therefore, the weight is not as uniformly distributed to the surface as is the case with a transporter.*

In short, if the tyre loading of the transporter does not exceed that of a loaded concrete truck, the extended shadow area could be safely applied to determine the ground pressure which is up to 3 ton/m$^2$. If the tyre loading does exceed that of a loaded concrete truck, the more conservative shadow area could be safely applied with a side note that at a depth of half an axle distance the ground bearing pressure reduces to the value of the extended shadow area.

The validity of the application of the shadow area and extended shadow area method lies in the uniform distribution of the transporter tyres on the soil. The 6-axle line transporter in this example has 48 tyres spread out over an area of 9 by 3 m (29 ft 6 inches x 9 ft 10 inches) in a very uniform distribution. Although the contact area of each tyre appears to apply a higher load to the soil than the results of the shadow area calculations I will suffice here by stating that the loads at the contact area are extremely complex to determine.

These loads depend on tyre pressure, tyre deflection, type of soil, homogeneous state of the soil, moisture content of the soil, wash boarding of the soil, rutting of the soil (formation of tyre tracks in the soil), elasticity of the soil, plastic deformation of the soil, number of passes, etc. A slight acceptable settlement in the road surface combined with a slight deflection of the tyre can increase the contact area by as much as 15 to 20 %. Settlement increases the soil density which has a positive effect on the load imposed on the same surface.

## Bed of nails

An analogy here is in place with an inflated balloon. If the balloon is slightly pushed against a nail it will pop. If, however, the balloon is placed on a bed of nails (uniformly distributed) it takes a great force to achieve the same. Even if not all nails are protruding evenly and one nail protrudes a bit more than all others. See Figure 6.

It is not the intention here to underestimate the applicable ground pressure under a heavy transport as this does not benefit anybody. Next month we will dive deeper into the consequences of improperly prepared roads and how the transporter design plays a role in this.

This article is limited to heavy haul roads made of compacted soil and dirt, and to heavy haul roads made of concrete and asphalt. This article is not applicable to driving on bridges and barges. ■

FIGURE 6