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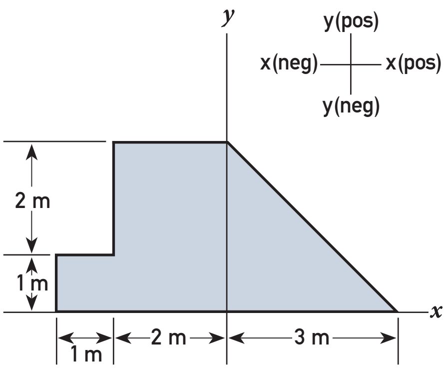
Central focus

A topic central in more ways than one both to lifting and transport operations is centre of gravity. CoG can be an issue that makes or breaks a project, writes MARCO VAN DAAL

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 esteemed companies and leading authorities 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.com/books/the-art-of-heavy-transport/

Van Daal has a real passion for sharing knowledge and experience – the primary reason for the seminars that he frequently holds around the world. He lives in Aruba, in the Dutch Caribbean, with his wife and daughters.

Feared by many, understood by few, the centre of gravity (CoG) is the single most under estimated and under valued property of a load. Since the vast majority of all transports and lifts comprise loads with a fairly centralised CoG there is not much incentive to dive into the theories of something that cannot be seen or measured with a tape.

If the CoG is not centralised, however, or the load is close to the limit of the transport or lift equipment, it becomes an increasingly more important property that can make or break the success of a project.

What is the centre of gravity? In mathematical terms, "The centre of gravity is the point at which an object's entire mass can be assumed". This may sound a bit abstract but with the below examples this will become clear. The CoG is not determined by shape or size, just by the weight and the location (co-ordinates) of each of its individual components.

It may be clear that the centre of gravity of a square box is right in the centre of that box and that handling, lifting, jacking or transporting it is not a complicated exercise from a mathematical point of view. That changes when it comes to objects built up from many individual items. Sooner or later everybody will get into this situation, where it becomes much more challenging. Such objects can be skids that contain components from different suppliers or, for example, vessels with varying diameters, oilers with a pressure vessel located on one side or just a wooden crate with unknown contents and a hand painted CoG mark that you may or may not be able to trust.

Finding out

Let's start the exercise with a simple way of determining the centre of gravity. This method can be applied to every object of which the CoG needs to be determined. Observe *Figure 1*, this is a two-dimensional object, for example, a steel plate with a random shape, for which the CoG needs to be determined. This cannot be done in one step, but has to be performed in a series of separate steps.

NOTE: *the distances are given in metres but this can be any unit of measure: feet, yards, etc. For the results of the calculation this makes no difference.*

STEP 1

Choose the location of the x-axis and the y-axis. These can be chosen in any location because the outcome will remain the same if these axes are chosen in a different location. Try it.

For this example in Figure 1 the x-axis is chosen at the base of the object and the y-axis is chosen so that it runs straight down between the triangular and rectangular shapes.

STEP 2

Choose which side of the x-axis is the positive side and which one is the negative side. This is necessary because a 1 metre distance from the y-axis could be on either side and without the "+" or "-" designation there is no way of knowing this and, by definition, the outcome of the calculation will be wrong.

FIGURE 2

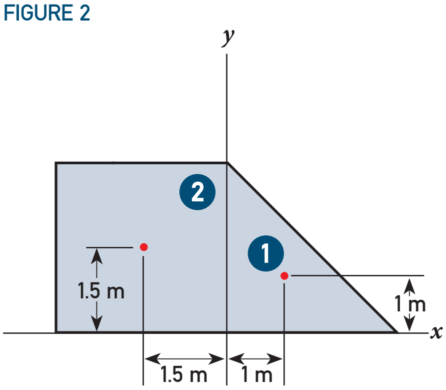
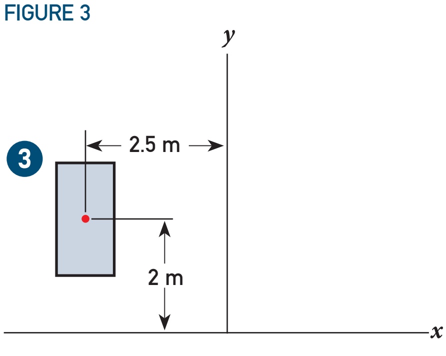


FIGURE 3



STEP 3

We now need to divide the object into smaller "sub-objects" for which we can easily determine the CoG. See *Figure 2* and *Figure 3*. There is no science behind choosing these smaller objects. Anything will do, as long as the total object is covered, obviously nothing should be forgotten or left out. In this example I have chosen;

1.) a triangle (a 3 x 3 m square cut in half)
2.) a square (3 x 3 m). Note that this box includes a void
3.) a rectangle (1 x 2 m). This is the void of the square mentioned above at 2.

STEP 4

Of each of these sub-objects the CoG should be determined and expressed in co-ordinates. See *figures 4* and *5*. By drawing assist lines (in red) from one corner to the opposite one the CoG can be found for squares and rectangles. By drawing (assist) lines from one corner to the centre of the opposite side the CoG can be found for triangles. This CoG is found at the intersection of these assist lines. The result is as follows:

CoG 1. (+1.0, +1.0)
CoG 2. (-1.5, +1.5)
CoG 3. (-2.5, +2.0)

Simplification

Earlier I stated that the CoG is determined by the weight and location (co-ordinates) of each of the individual components. Here is a hint to make the calculations easier. For two-dimensional objects, like the one in this example, the area of the object is proportional with its weight. When the area is twice as large, the weight also doubles.

For three-dimensional objects the volume of the object is proportional with its weight. These hints allow you to calculate CoG without knowing the object's weight or what it is made of.

STEP 5

Arrange all the numbers in order to perform the CoG calculation.

OBJECT	X- CO-ORDINATE	Y- CO-ORDINATE	WEIGHT/AREA
1	+1.0	+1.0	(3 * 3) / 2 = 4.5
2	-1.5	+1.5	(3 * 3) = 9
3	-2.5	+2.0	(1 * 2) = 2 (**)

(**) As object 3 is actually a void, the weight (area) needs to be entered as a negative value in the formula in Step 6.

STEP 6

The formula to calculate the CoG is

$$CoG = \frac{\Sigma D * W}{\Sigma \quad W}$$

In words it reads that the location of the CoG can be found by summing (Σ) the multiplication of the distance by the weight (area) and divide it by the summation of all the weights (areas).

Since this is a two-dimensional object, this calculation should be performed in x-direction as well as y-direction. For a three-dimensional object it should also be performed in the z-direction.

In x-direction the formula can be rewritten as

$$CoG_x = \frac{\Sigma D_x * W}{\Sigma \quad W}$$

Similarly for the y-direction

$$CoG_y = \frac{\Sigma D_y * W}{\Sigma \quad W}$$

In numbers;

$$CoG_x = \frac{(+1,0*4.5) + (-1.5*9) + (-2.5*-2)}{(4.5+9-2)} = \frac{-4}{11.5} = -0.35$$

$$CoG_y = \frac{(+1,0*4.5) + (-1.5*9) + (+2.0*-2)}{(4.5+9-2)} = \frac{13}{11.5} = 1.13$$

The CoG can be found at the co-ordinates (-0.35, 1.13), see *figure 6*.

NOTE: *When performing such calculation on a more frequent basis and experience is gained, some of the above steps can be combined to speed up the process.*

CoG calculations and, more important, the reliability of an accurate CoG, can become a very important property. The transport in the photograph illustrates this. The CoG is marked almost at the top of the white board that covers the intake. It is above the light post at the left of the transport. ■

NOTE: Every effort is made to ensure the accuracy of the contents of these articles. If you find any mistakes, a brief notification and explanation would be appreciated.

FIGURE 4

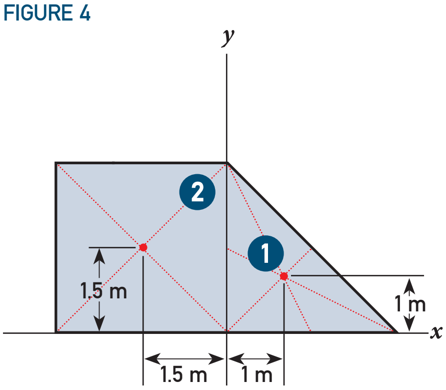


FIGURE 5

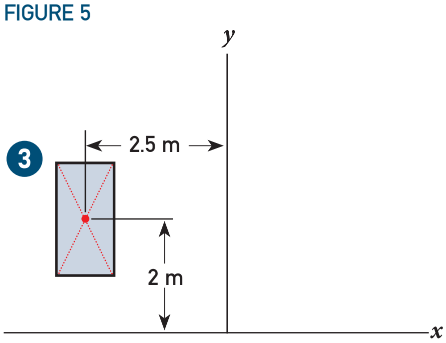


FIGURE 6