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Time to weigh

Following on from and linked to the centre of gravity topic from last month's article, is this month's equally important subject of weighing a load. MARCO VAN DAAL reports

Last month's article emphasised and explained the importance of centre of gravity (CoG) in relation to lifting and transport operations. It gave a theoretical explanation of how a CoG location can be determined from basic components. In reality, however, it is not always this straightforward. Equipment assemblies often contain components from suppliers who in turn also depend on their suppliers. In addition, field changes do not always find their way back to the engineers for a proper assessment of the impact on the CoG. This can result in the CoG and the weight being of questionable nature or not within the agreed accuracy.

For such cases, where a load with an estimated weight and CoG is to be lifted or transported or placed on a ship or barge with associated ballasting, a weighing can be performed. It provides the weight and the CoG in two dimensions, namely the X- and the Y-co-ordinates.

Certain aspects of the load need to be known before weighing. An estimated weight should be known, as should the location (co-ordinates) and the expected weight of the so-called strong points.

FIGURE 4 Load cell in application with Mammoet on a hydraulic jack

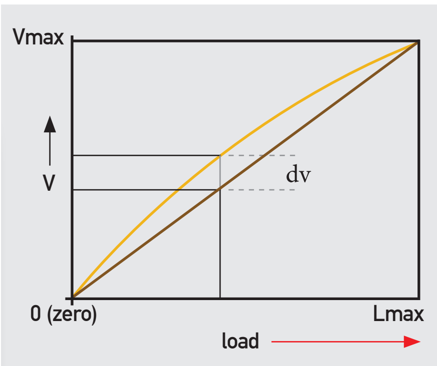
This may sound a bit contradictory. For a contractor to determine a weight, the weight is to be known prior to the work. This, however, is necessary for correct equipment selection.

In theory

A weighing is performed by using load cells. A load cell is a device (a transducer) that produces an electrical signal via a strain gauge when a load (force) is applied. See Figure 1 showing a typical load cell. The electrical signal, in millivolts (mV) can be shown on a digital readout and the applied load can be determined. The more modern systems show the weight directly on the display.

One would expect that when twice the load is applied, that an electrical signal (voltage) twice as strong is produced. This, however, is not the case as every load cell is subject to non-linearity. Non-linearity is the deviation (dv) from a straight line graph. See Figure 2. For this reason it

FIGURE 2 Graph showing the non-linearity of a load cell



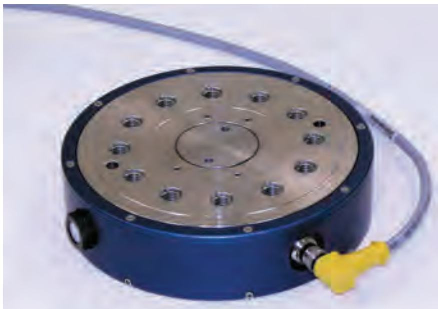


FIGURE 1 A load cell with its connecting cable

is important that the expected weights per "strong point" are known so that the contractor can select the appropriate load cells that work in the correct range with minimum non-linearity effects.

When the correct load cells are chosen and the applied loads are in the upper 30 % of their capacity, an accuracy of 0.25 % or better is not unheard of.

The weighing process

Load cells come in two basic layouts or set-ups. One where an individual load cell is placed on top of a hydraulic jack (Figure 3) and one where the load cell is part of the hydraulic jack (Figure 4). It goes without saying that multiple jacks and load cells are required to perform a weighing. Sometimes there are even multiple units per strong point (Figure 5). Note that figures 3 and 4 both show a scenario where the height of the jack with load cell perfectly fits in the cavity underneath the strong point. In many cases there is no such perfect fit and the "gap" is filled with steel shims.

As an example let us review the weighing of a structure built in Texas, USA, with its destination being Equatorial Guinea, just off the West coast of Africa. Figure 6 is a dimensional drawing of this structure with the locations (co-ordinates) of each load cell indicated. For this weighing a total of 16 load cells were used. Each load cell was placed on top of a hydraulic jack and the entire structure was lifted off its supports. At this point the readings (either in mV or volts or directly >

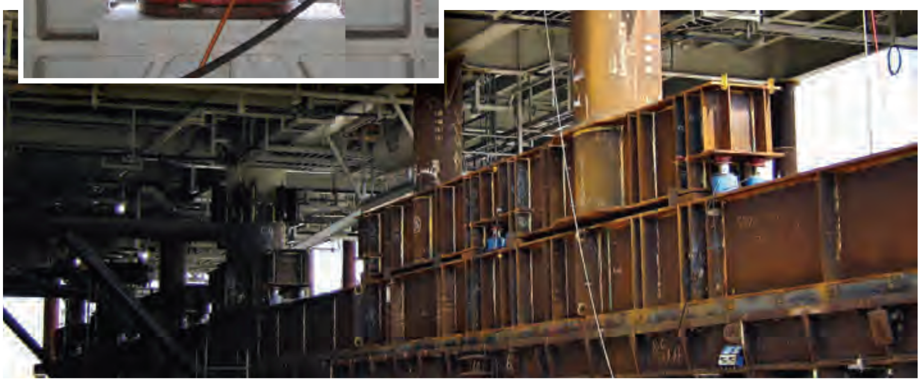


FIGURE 5 Multiple Versabar load cells and jacks per strong point

in a weight unit) are taken from each jack.

Figure 7 shows an overview of this first weighing; load cell identification, load cell co-ordinates in both X and Y direction, measured weight per load cell, moment per load cell in X direction and the moment per load cell in the Y direction.

Note: the moment is calculated by multiplying the measured load cell weight with the distance from the origin. The summation of all the measured load cell weights gives the total weight of the structure, in this case that is 1,159.778 short tons. Both the table (Figure 7) and the drawing (Figure 6) indicate this.

For the location of the CoG one additional calculation has to be made. The X-co-ordinate of the CoG is found by dividing the sum of the moments in X direction over the sum of the measured load cell weights.

CoG (X) = 175036.492 / 1159.788 = 150.921 feet or 150 feet – 11 inches

Likewise for the Y-co-ordinate;

CoG (Y) = -1847.359 / 1159.788 = -1.593 feet or -1 foot – 7.5 inches

Again, see the table and the drawing.

Operational implications

In the process of weighing loads, especially like in the above example, where the length approached 100 metres and 16 load cells were used, the question often arises if the torsional rigidity (or lack thereof) can affect the accuracy. At these lengths the structure does deflect.

To minimise the effect, weighing is often performed three times. After each the load is set down and the jacks extended in a different sequence. Results are reviewed and averaged. An sample weighing can be seen on my website.

On completion of the weighing, this structure was loaded on self propelled modular transporter (SPMT) and driven onto a barge. At the bidding stage of this load out, the estimated weight was 1,300 US (short) tons. The final 1,160 short tons weight is 11 % less than estimated.

If the fabricator or the owner had decided not to weigh the structure (which still happens) they would have been lucky to find out at the time of lifting that the structure was 140 short tons lighter than expected. Without a weighing, however, they could have found out, halfway around the world, that the actual weight turned out to be 11 % higher than expected – 1,440 instead of 1,300 short tons.

With a possible accuracy of 0.25 % or better it is important that each load cell is periodically calibrated by a recognised body. Calibration frequency is generally determined by the authorities, but is normally not less than once a year. Temperature changes, impact of load (such as dropping a load cell), humidity, exposure to higher than nominal capacity loads can all affect performance. ■

FIGURE 6 Centre of gravity and weight, from 16 weigh points, for an offshore structure

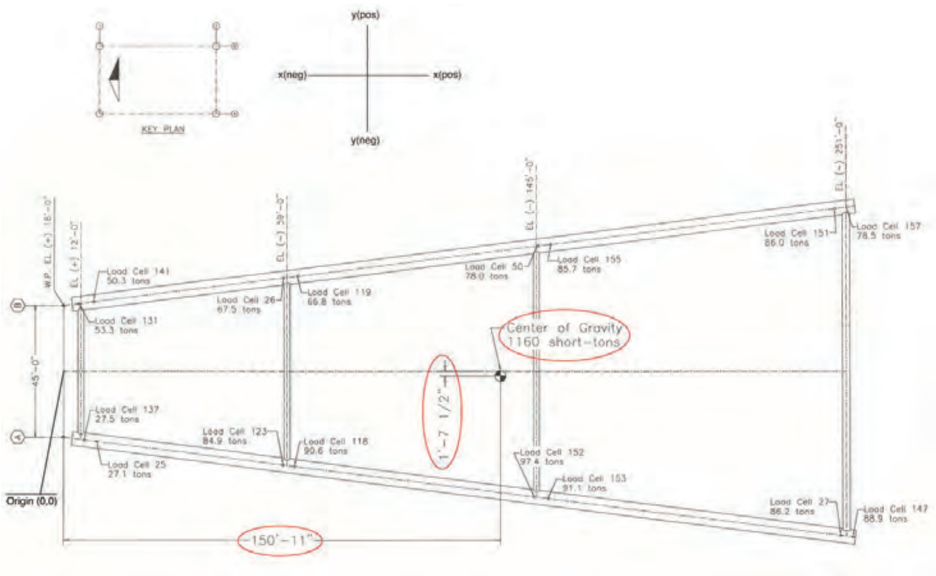


FIGURE 7 Table showing details of the first weighing for the structure in Figure 6

Centre of gravity summary

Load cell	X distance (ft)	Y distance (ft)	Average weight (tons)	Average X * weight (ft-tons)	Average Y * weight (ft-tons)
V150-137	7.25	-23.4	27.464	199.112	-642.651
V150-25	11.64	-23.95	27.09	315.329	-648.809
V150-131	5.35	23.17	53.315	285.235	1235.306
V150-141	10.48	23.81	50.261	526.74	1196.725
V150-123	75.74	-31.95	84.927	6432.37	-2713.417
V150-118	79.8	-32.46	90.641	7233.168	-2942.213
V150-26	75.99	31.98	67.541	5132.411	2159.949
V150-119	80.87	32.59	66.791	5401.372	2176.712
V500-152	162.33	-42.75	97.366	15805.353	-4162.378
V500-153	167.37	-43.38	91.147	15255.221	-3953.943
V500-50	163.98	42.96	77.954	12782.969	3348.923
V500-155	168.2	43.48	85.715	14417.244	3726.883
V500-27	267.54	-55.88	86.172	23054.345	-4815.268
V500-147	271.76	-56.4	88.853	24146.673	-5011.305
V500-151	265.72	55.65	86.03	22859.842	4787.559
V500-157	269.85	56.17	78.522	21189.109	4410.57
		TOTAL	1159.788	175036.492	-1847.359

Centre of gravity in the X direction: 175036.492 / 1159.788 = 150.921 ft

Centre of gravity in the Y direction: -1847.359 / 1159.788 = -1.593 ft

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.