TECHNICAL BULLETIN – TB255

Understanding Dead Loads on Floors

January 2025

INTRODUCTION & SCOPE

A common question, ARDEX Technical Services receives, and is clearly something the inquirers struggle with, is the concept of loading on floors in relation to the properties of the floor smoothing cements. Two questions arise on this matter.

1. I have a wheeled trolley which carries x tons of material, can the smoothing cement take this load?
2. I want to put a structure on the smoothed floor, will it indent the floor?

The product datasheets supply compressive strength data and ball pressure hardness, and the reality is that these questions can be answered by examining the contents of this bulletin.

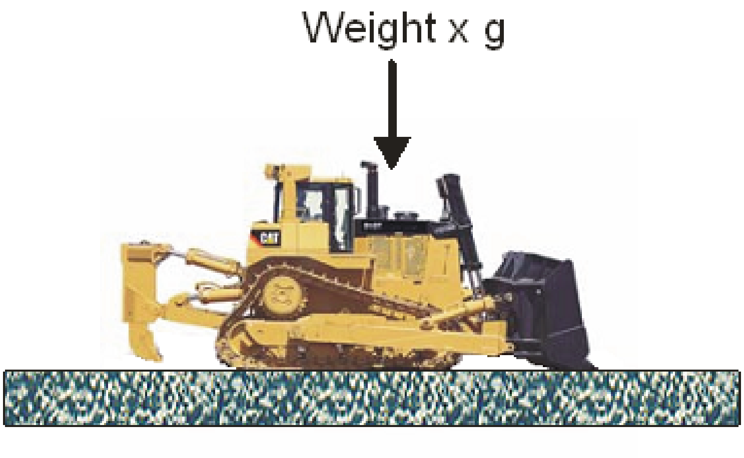
BASICS

The smoothing cements supply the metrics of Compressive Strength, Flexural Strength and some also give Ball Pressure Hardness. The measurement units are given as either N/mm^2 or MPa which are the same thing. To be precise, N/mm^2 means a certain force in Newtons applied over an area of $1mm^2$.

Force

For the purposes of this discussion, the force in Newtons (F) based on the classical physics formula F = ma and is the dead weight in kg of an object (m) multiplied by the acceleration due to gravity (a) which is simplified to $10ms^{-2}$.

For example, this 67-ton bulldozer exerts a force on the ground of 670000N (670kN).



$$\therefore 67000kg \times 10ms^{-2} = 670kN$$

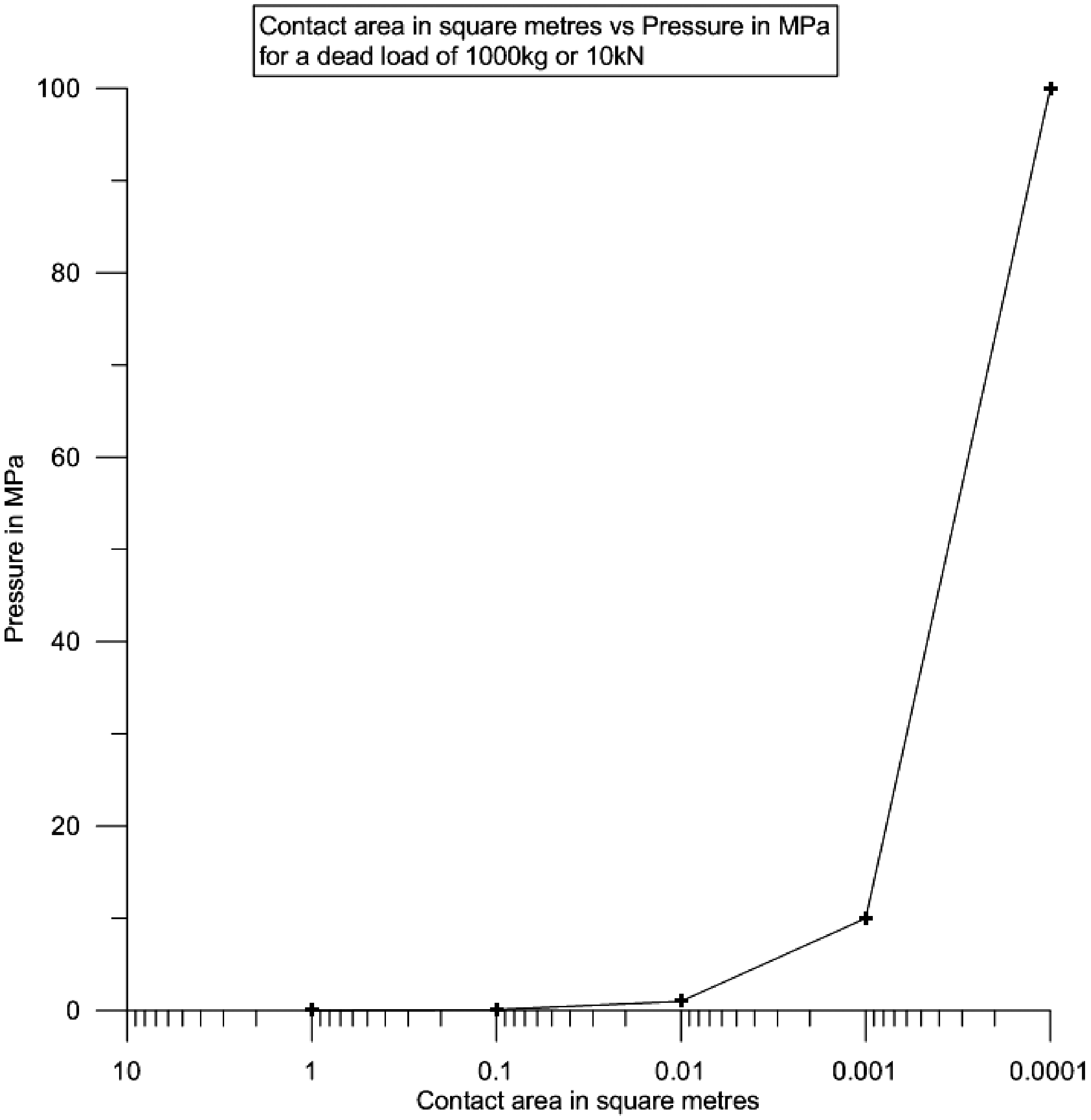
The force exerted by the load of the bulldozer is then supported over the area of its caterpillar tracks on the ground to indicate how much pressure it creates on the ground surface (called ground pressure).

Pressure

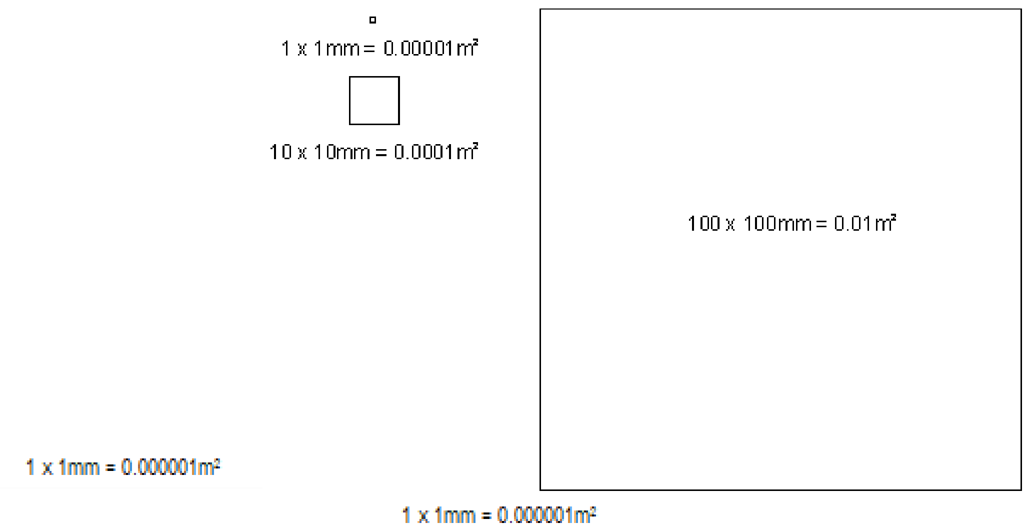
The expression Pa (Pascal) is a measure of pressure, and pressure is simply defined as force applied over a unit area.

An MPa is a Megapascal or a million pascals. One square metre is 1000 x 1000mm or 1 million (10^6) square millimetres, so $1N/mm^2$ is same as $10^6 N/m^2$, which is identical to 1MPa of pressure. This is equivalent to 100 tonnes weight on a square metre.

As might be surmised, when you increase the load applied (force) and reduce the contact area, the result is that pressure exerted per unit area increases.



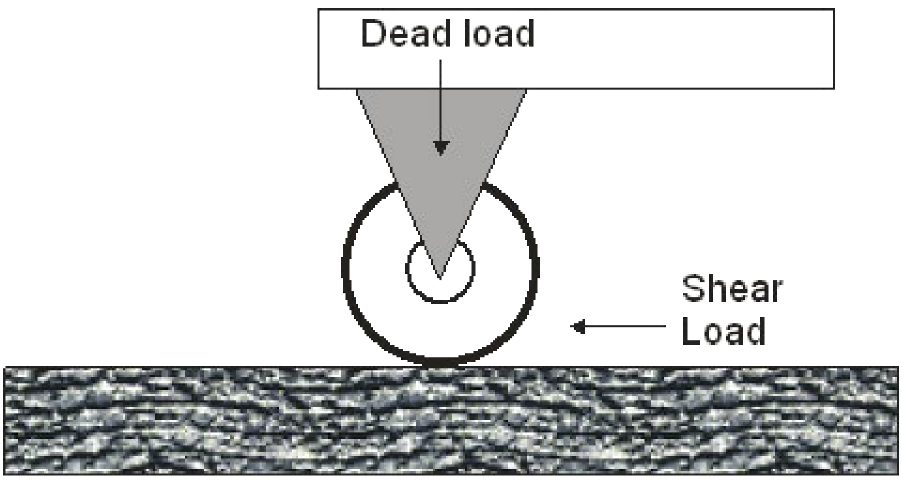
This can be seen in the following graph where a 10kN force (1000kg or 1 tonne dead load) is applied to a floor with differing contact areas for the force/load to be applied over



This is the basis of determining the flood loadings that a floor can withstand, and the following figure showing area squares shows comparative sizes to give an idea of the scale of this graph.

Dynamic loads

Forces created by moving objects are called dynamic loads. The next thing to consider is that when things are rolled across floors the force exerted is a mixture of dead load from the weight, and shear load from the force of pushing the trolley across the floor, as transmitted by the turning wheels (there is also another type of dynamic load called 'impact load' which we will not consider here).

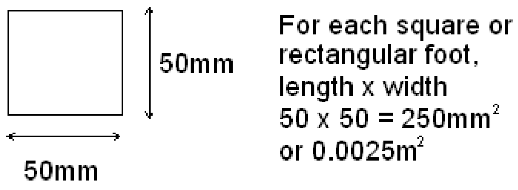


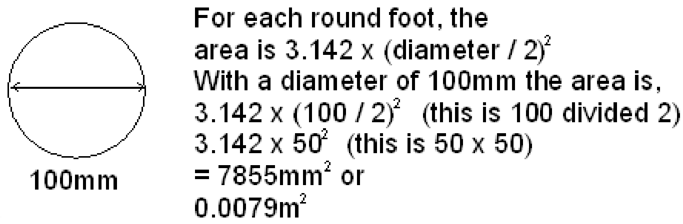
A typical example of a dynamic load is shown in the following diagram, a roller trolley or pallet jack wheel on a floor. For the purposes of this discussion, we restricted the discussion to dead loads, since shear and dynamic loads are hard to quantify, and the involved forces are more complex to analyse.

The final part of this examination is to consider the contact area or footprint of the object which is sitting on the floor.

SOME EXAMPLES OF APPLYING THE BASICS

For stationary objects, such as tanks, pieces of non-moving machinery or storage racking for example, the contact is simply the area of the feet in square metres. A tank would be the area of the base in contact, whilst for the other items the feet ends might be squares or round pieces of plate at the bottom of legs.





$2500mm^2$

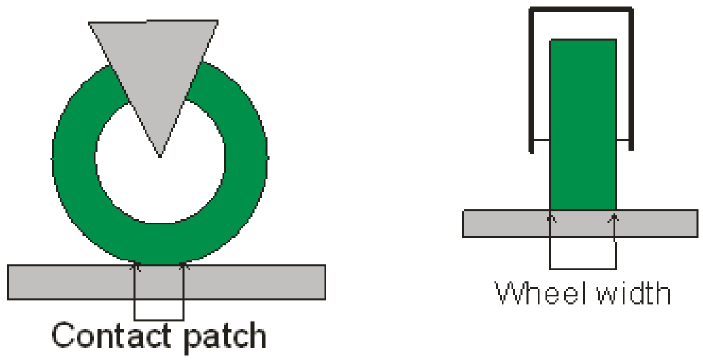
These are shown schematically on below.

The convention is to calculate in square metres rather than millimetres, so in the above examples, the values can be directly calculated as 50mm/1000 = $0.05m^2$ and 100mm/1000 = $0.1m^2$ which are then multiplied through. The other option is to divide the area in square millimetres by 1 million (10^6), so taking the example above of the square shaped foot above.

$$2500mm^2 \div 10^6 = 0.0025^2 m$$

$$2.5 \; x \; 10^3 mm \div 10^6 = 2.5 \; x \; 10^{-3} m$$

The situation for wheels is more complex because of the composition on the wheel and the curvature of the wheel. The larger the wheel width and the lower the curvature of the wheel circumference, the greater the contact patch will be.



This is shown in the next schematic, where the contact patch is effectively calculated as a rectangle, in the method used above.

For wheels which are not flat across their width but also curved, the contact patch starts to be become a point load instead of a flattened area, and this creates much higher loads.

The composition of the wheel also becomes important. Steel or metal wheels are rigid and non-resilient so directly transfer the load and pressure onto the subfloor. Wheels made of hard plastic are more resilient, but still effectively transfer the load, whilst solid rubber or soft plastic, and inflated wheels are resilient and transfer the load less than the hard wheels. This has the effect that hard wheels are more damaging to the surface than soft ones, though softer wheels create more shear due to frictional and 'smushing' effects on the surface.

The following page shows a worked example for a stationary object with four legs sitting on a floor.

What is the exerted pressure for a set load?
A 4000kg piece of equipment has 4 legs with contact surface area 50 x 50mm per leg.
How much pressure is exerted on each leg?

1. What is the force exerted?
   a) Force is weight x gravity
   b) 4000 x 10 = 40kN
2. What is the surface area?
   c) 50mm = 0.05mm so area for each leg is
   d) 0.05 x 0.05 = 0.0025m^2
3. The force is divided over the four legs
   e) 40kN ÷ 4 = 10kN per leg
4. Pressure per leg is force / area
   f) 10000 ÷ 0.0025 = 4x10^6 Pa or 4 MPa

There are four bits to problem.

In this case, it would be clear that with each foot only exerting 4MPa on the floor, then a smoothing cement topping with a nominal compressive strength of 30MPa would not indent. However, that does not mean it won't scratch if the object is dragged across the topping on its feet. It also does not mean that resilient flooring won't mark either; resilient flooring is far softer than topping systems.

The calculation for wheels is no different in theory, except that determining what the actual contact area is more difficult because of the wheel curvature. For simplicity it easiest to treat wheel contacts as rectangles, but with one dimension much smaller than the other.

The following is a table showing contact areas for different size and shape feet.

Square feet sides in mm	Contact area in square metres	Circular feet diameter in mm	Contact area in square metres
10	0.0001	10	0.0001
20	0.0004	20	0.0003
30	0.0009	30	0.0007
40	0.0016	40	0.0013
50	0.0025	50	0.0020
60	0.0036	60	0.0028
70	0.0049	70	0.0038
80	0.0064	80	0.0050
90	0.0081	90	0.0064
100	0.01	100	0.0079

SAFETY FACTORS

With all engineering considerations involving stress and strain, there is the concept of safety factors. These are a reduction applied to the absolute performance properties of a component in a system, to allow for ageing, or poor installation or even vagaries in the properties of the material itself.

A typical safety factor is a reduction between 1.1 and 2.5 times the proof number; the larger the factor the more conservative the working value and the lower the risk of failure.
Typically, safety factors are not usually applied to smoothing cements, but in critical cases this might need to be done.

For example, a 35MPa compressive strength smoothing cement might have a safety factor applied of 1.25, which would mean a load capacity of,

$$35 \div 1.25 = 28MPa$$

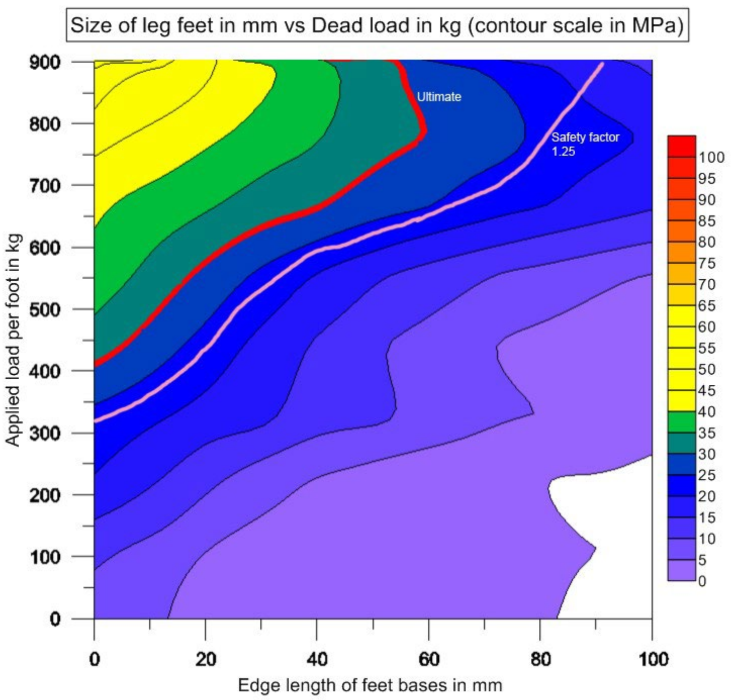
for design considerations, but for example if a highly conservative value was used of say 2, then the strength would be reduced to 18MPa and there is a large margin of safety.

Clearly low strength highly resilient products such as Arditex NA do not have the same capacity of resistance to damage than compared with strong products such as K15M or K80. It also doesn't consider that resilient floor coverings are more easily damaged than the topping systems.

The table and graph on the next page give some indications of the sort of pressures exerted on surfaces depending on the size of the feet and the dead load.

A final consideration concerns the curing properties of the smoothing cements. The strength develops over time, with most of the performance developed within the first 14 days.

This has a follow-on effect, especially when a safety factor is applied, that an applied topping will not have the same load capacity as when nominal full cure is achieved at 28 days. The product datasheets normally give strengths at certain periods of time up to the 28-day period.



Loading	Weight in kg per leg	25	50	75	100	150	200	250	500	750	1000
	Force in N	245	491	736	981	1,472	1,962	2,453	4,905	7,358	9,810
Square feet sides in mm	Contact area in square mm	Calculated dead load per foot in MPa (N/mm^2)									
10	100	2.45	4.91	7.36	9.81	14.72	19.62	24.53	49.05	73.58	98.10
15	225	1.09	2.18	3.27	4.36	6.54	8.72	10.90	21.80	32.70	43.60
20	400	0.61	1.23	1.84	2.45	3.68	4.91	6.13	12.26	18.39	24.53
25	625	0.39	0.78	1.18	1.57	2.35	3.14	3.92	7.85	11.77	15.70
30	900	0.27	0.55	0.82	1.09	1.64	2.18	2.73	5.45	8.18	10.90
40	1600	0.15	0.31	0.46	0.61	0.92	1.23	1.53	3.07	4.60	6.13
50	2500	0.10	0.20	0.29	0.39	0.59	0.78	0.98	1.96	2.94	3.92
75	5625	0.04	0.09	0.13	0.17	0.26	0.35	0.44	0.87	1.31	1.74
80	6400	0.04	0.08	0.11	0.15	0.23	0.31	0.38	0.77	1.15	1.53
90	8100	0.03	0.06	0.09	0.12	0.18	0.24	0.30	0.61	0.91	1.21
100	10000	0.02	0.05	0.07	0.10	0.15	0.20	0.25	0.49	0.74	0.98

SUMMARY

The determination of the load capacity of a topping surface can be easily enough estimated by comparing the published compressive strength for the product, and then calculating the applied pressure. To calculate the pressure per foot you need to know the weight of the object being supported and the size of the feet.

Conversion notes

1mm = 1/1000th of a metre or 1/10th of a centimetre
1cm = 1/100th of a metre
1 square metre = 1 million square mms or 10000 square cm's
1MPa = 1 million Pascals
10Pa = 1kg (10N) applied over 1 square metre
1Pa = 1N applied over 1 square metre
1MPa = 1N/mm^2 = 145psi = 10 bars of pressure

REASON FOR REVISION
ARDEX Logo and address update.

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