FACE CONSULTANTS LTD
Global Flooring Consultants

FACE CONSULTANTS LIMITED

Table 4.3 of The Concrete Society's Technical Report Number 34 (2003)

DIGITAL PROFILEOGRAPH SURVEYS

Further explanatory information

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Why Flatness is Important:

Flatness is an essential requirement of a ground floor slab in certain categories of industry. Undoubtedly, the most important of these categories is that of very narrow aisles in high warehouses where fixed path 'VNA' forklift trucks operate.

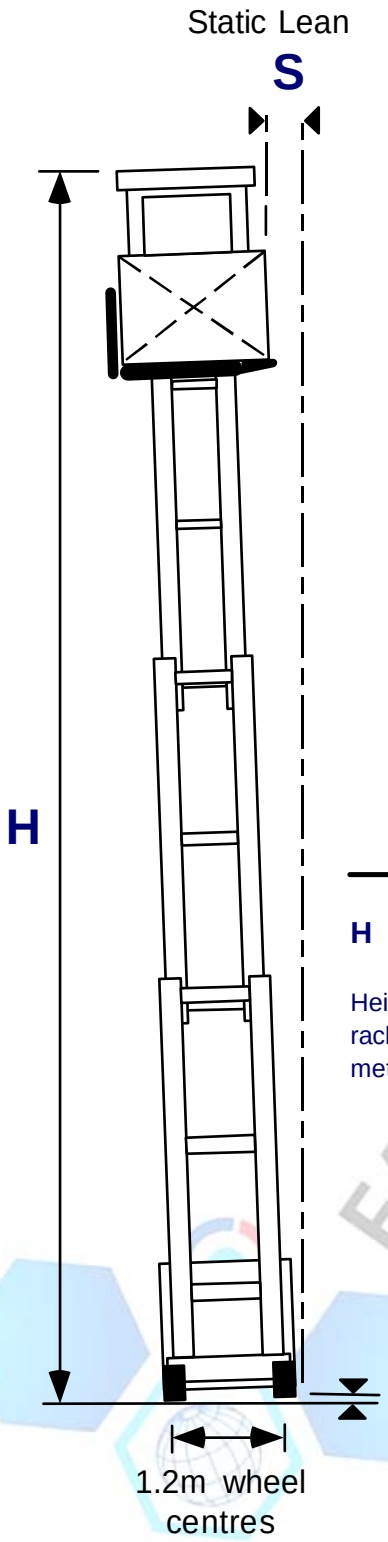
The static lean table (overleaf) indicates how the variations in level across the aisle between the load wheel tracks of the truck are magnified in direct proportion to the height of the racking. However, one can readily appreciate that this value, calculated directly from geometrical considerations, forms only part of the potential movement at the top of the mast of the truck.

Variations in level, both laterally across the aisle and longitudinally down the aisle, induce dynamic movements in the mast which are much greater in magnitude than can be calculated from geometrical considerations alone. The stresses which are set up within both the mast and body sections of the truck can cause premature failure of welds and disrupt the performance of the electronic components that are now an essential feature of all trucks.

Floors with poor flatness characteristics also create conditions whereby there is a high risk of collision between the load on the carrying head of the truck and the stock or racking. As the majority of such collisions cause no serious human injury, there are no statistics recording the frequency of these incidents. It is, however, well known that they are quite numerous in all countries where there are high density warehouses working with typical clearances between the truck mounted load and the racked loads in the order of 100 and 150mm. These clearances are directly related to the floor flatness. If the value of this clearance is limited to 100mm then the requirements to construct the floor to a high standard of flatness becomes even more important.

Warehouses are designed to have a throughput of a given number of pallets per hour. To achieve this, the VNA trucks must operate at their peak performance. A warehouse manager faced with numerous collisions between the truck and the racking and long periods of down-time during repair has no alternative but to reduce the speed of the VNA trucks to below their optimum speed: this reduces the efficiency of his warehouse operations.

Static Lean Table:



This table shows the relationship between the static lean of a forklift truck due to the difference in elevation between the left and right hand forklift truck load wheels and the height of the racking, assuming that the mast is a rigid structure.

However, due to the mechanical tolerances in the mast and the dynamic considerations when the truck is moving with a load at a height, the figure shown below could multiply by up to a factor of three.

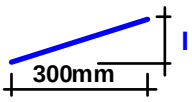
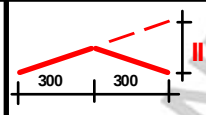
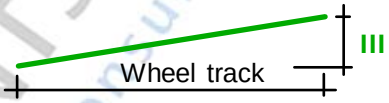
This particular set of figures is based on a typical wheel spacing of 1200mm from centre to centre of the outer load wheels.

H = Height of racking in metres	E (mm) = The difference in elevation between left and right hand VNA truck wheels									
	3	4	5	6	7	8	9	10	11	12
6	15	20	25	30	35	40	45	50	55	60
6.5	16	22	27	33	38	43	49	54	60	65
7	18	23	29	35	41	47	53	58	64	70
7.5	19	25	31	38	44	50	56	63	69	75
8	20	27	33	40	47	53	60	67	73	80
8.5	21	28	35	43	50	57	64	71	78	85
9	23	30	38	45	53	60	68	75	83	90
9.5	24	32	40	48	55	63	71	79	87	95
10	25	33	42	50	58	67	75	83	92	100
10.5	26	35	44	53	61	70	79	88	96	105
11	28	37	46	55	64	73	83	92	101	110
11.5	29	38	48	58	67	77	86	96	105	115
12	30	40	50	60	70	80	90	100	110	120
12.5	31	42	52	63	73	83	94	104	115	125
13	33	43	54	65	76	87	98	108	119	130

The Specification:

The flatness specification that we recommend is that contained within the Concrete Society's Technical Report No. 34. In which, section 4 discusses flatness requirements for warehouse floors, how to achieve them, the allowable values of the properties of flatness and how to measure them.

Table 4.3 (represented below) details the allowable values of the properties of flatness for differing categories.

Category	Location	Allowable limits (mm)							
		PROPERTY I		PROPERTY II		PROPERTY III			
		 Difference in elevation over 300mm		 Difference in slope over 600mm		 Wheel track up to 1.5m		Wheel track over 1.5m	
		A	B	A	B	A	B	A	B
Superflat (SF)	VNA warehouses with minimum clearance between fixed and moving pallets. Maximum throughputs, truck speed and permitted racking height. i.e over 13m	0.75	1.00	1.00	1.50	1.50	2.50	2.00	3.00
Category 1	VNA warehouses with racking height between 8 and 13m. Top guided trucks between 13m and 20m	1.50	2.50	2.50	3.50	2.50	3.50	3.00	4.50
Category 2	VNA warehouses with racking height less than 8m. AGV's	2.50	4.00	3.25	5.00	3.50	5.00	4.00	6.00

The floor, within the very narrow aisles, shall be considered satisfactory when:-

a) Not more than 5% of the total number of measurements exceed the particular property limit in Column A, **and**

b) None of the measurements exceed the particular property limit in Column B

Tolerance of level to datum plane: All Categories = +/- 15mm

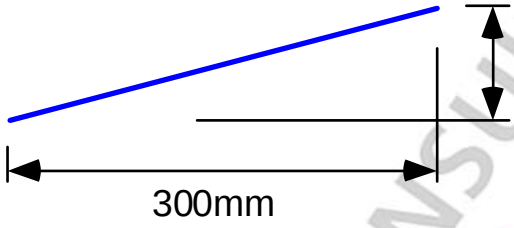
It is not possible to specify and impose these limits for defined movement, unless the precise position of the very narrow aisles is known, before construction. The choice of category to specify is dependent upon the height of the top beam of the racking.

However, the recommendations of the VNA fork lift truck manufacturer should also be sought, as they are all built for different requirements and are, therefore, affected differently by surface irregularity.

With regard to narrow aisle installations, there are three possible categories of flatness, and each category has three properties. Each property has differing allowable values as set out in Table 4.3.

Properties I and II refers to the longitudinal tolerances, i.e. running down the length of the aisle.

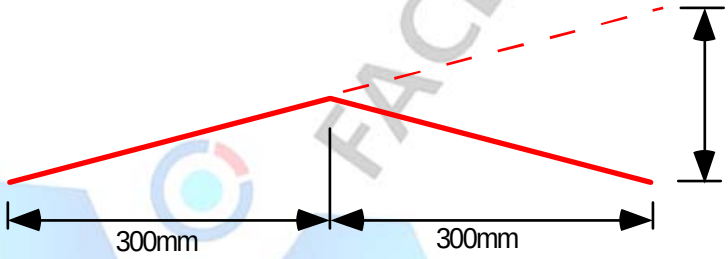
Property I is the maximum difference in elevation of any two points 300mm apart in the load wheel path of the forklift truck.



Property I

The difference in elevation over 300mm

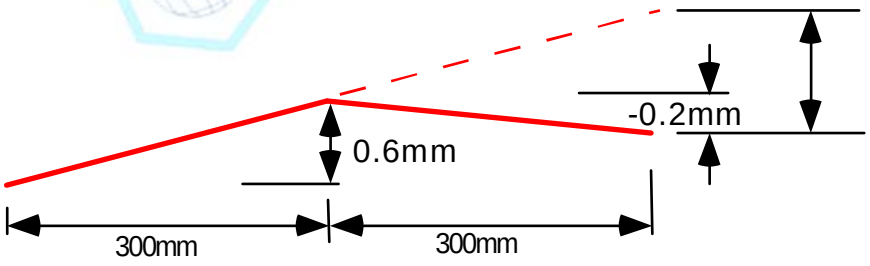
Property II is used to control the 'rate in change' at which the floor slopes up and down. It is measured over 600 mm with readings taken at 300 mm. i.e.



Property II

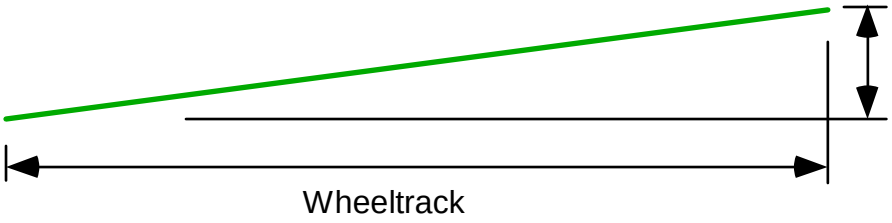
The difference in slope over 600mm

For example:



(0.6)-(-0.2)
= **0.8mm**

Property III is the transverse tolerance and controls the difference in height between the left and right-hand wheel tracks of the forklift truck. Although the easiest of the properties to understand, it is often considered the most important as it determines the static and dynamic lean of the truck.



Property III

Difference in elevation across the wheel track of the VNA forklift truck
a) up to 1.5m
b) over 1.5m

Copies of the Concrete Society's Technical Report No.34 (TR34) can be purchased through Face Consultants Ltd, or direct from the Concrete Society on:-

TEL: (01753) 693313 FAX: (01753) 692333

Test Instruments:

It is recommended that a continuous method of measurement should be adopted in all cases of defined traffic movement.

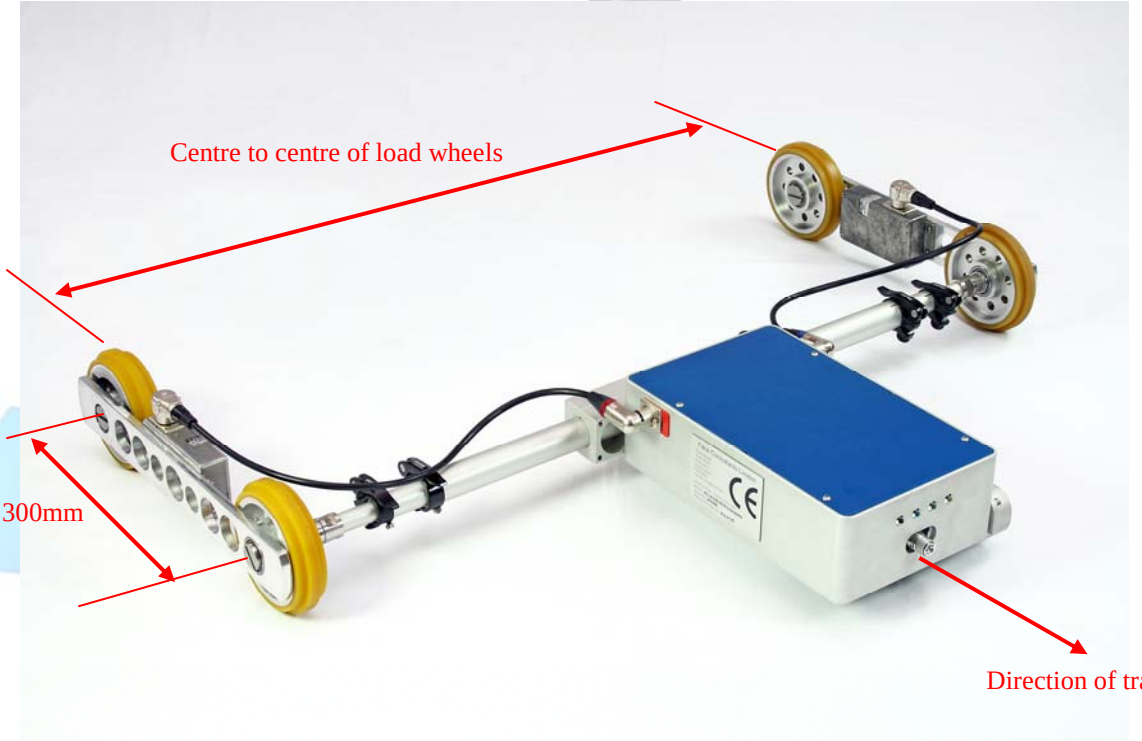
For continuous measurement the Face Profileograph is used. The Profileograph is a self propelled, wheeled instrument and as it travels across the floor take continuous measurements both transversely and longitudinally.

These readings are generated by the tilt sensors, which are set up to measure the longitudinal and transverse properties of the specification. These readings are collected on a data logger and subsequently downloaded to a PC where our software generates the graphic traces and compliance results.

Longitudinal:

The Profileograph is set up to measure Properties I and II of the Concrete Society's TR34 Specification.

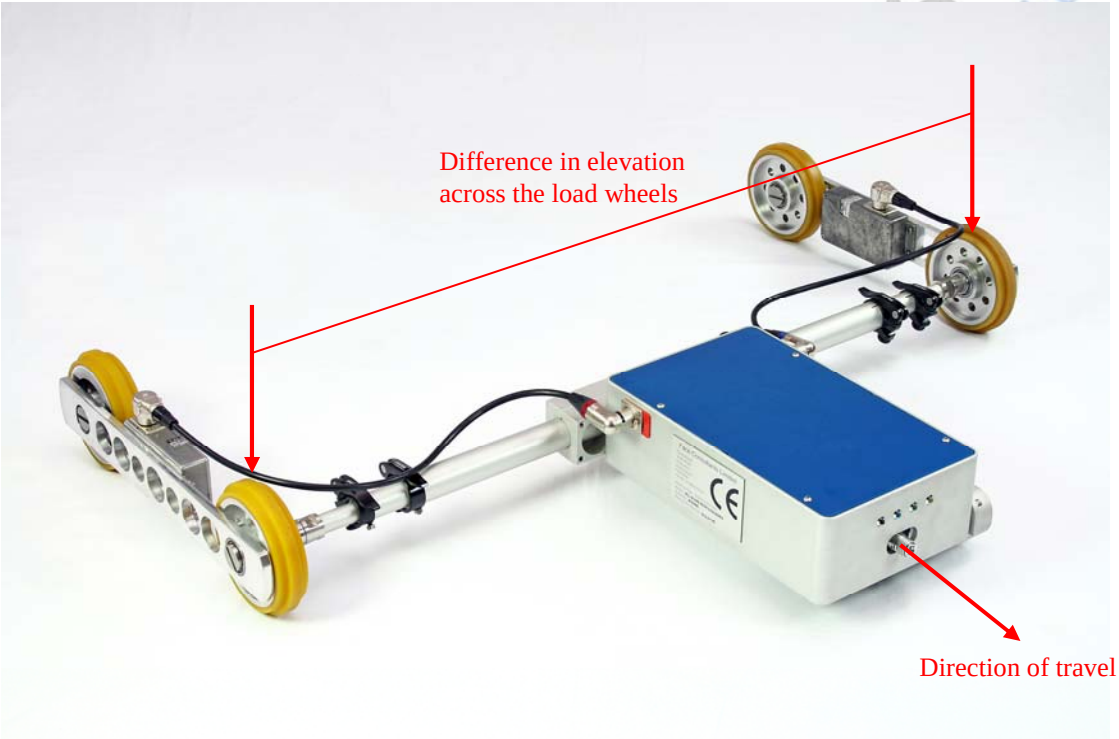
This is achieved by running the Profileograph along the outer load wheel tracks of the VNA forklift truck. Each skate of the Profileograph runs along the centre line of one of the wheel tracks, one left and one right, measuring the difference in elevation between the front and rear wheels of the skate, which are set 300mm apart.



Transverse:

The Profileograph is adjusted to measure the difference in elevation between the front wheels of its two skates.

The Profileograph is run along the outer wheel paths of the forklift truck, and produces a continuous graph depicting the difference in elevation between the two wheel paths of the truck.

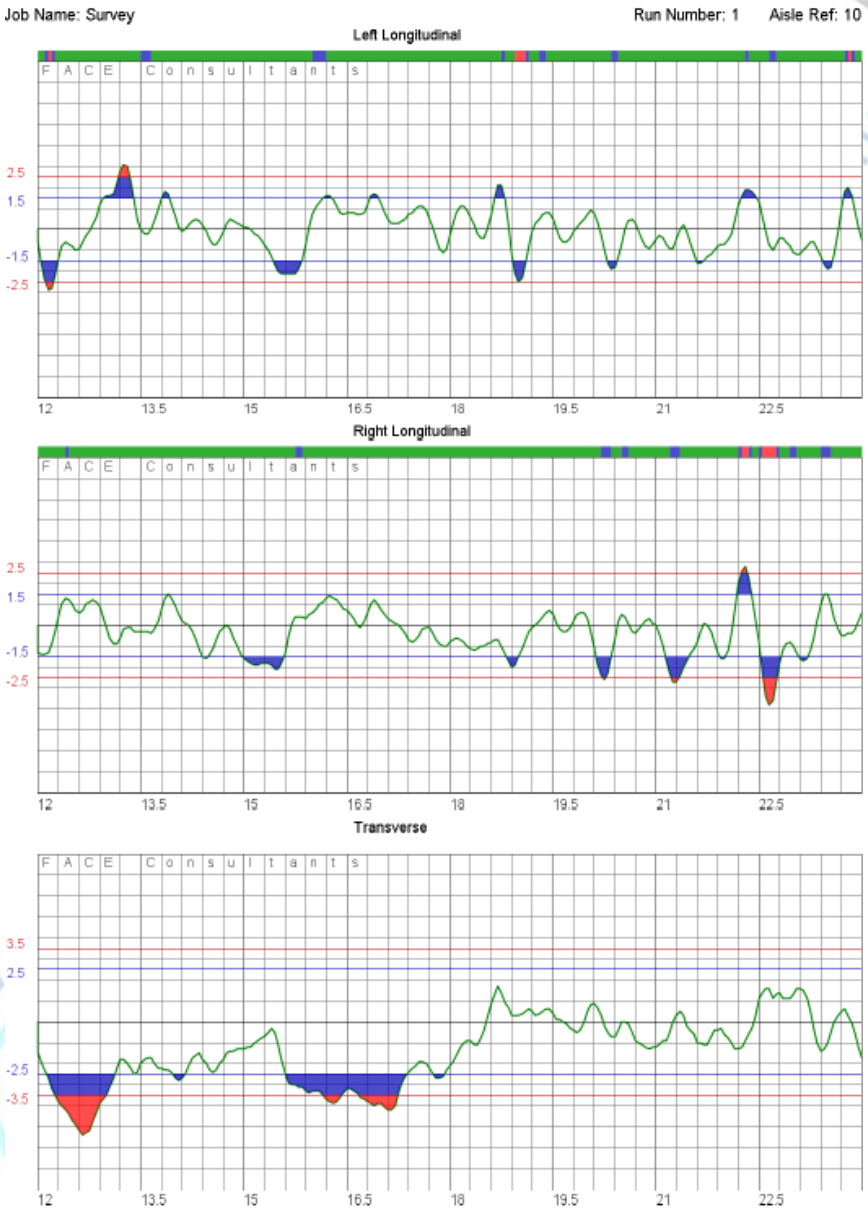


Understanding the Profileograph Traces:

After downloading the data, the software will produce three differential traces of each survey run.

a) Two graphs checking compliance with Properties I and II, i.e. longitudinally along each of the two load wheel tracks.

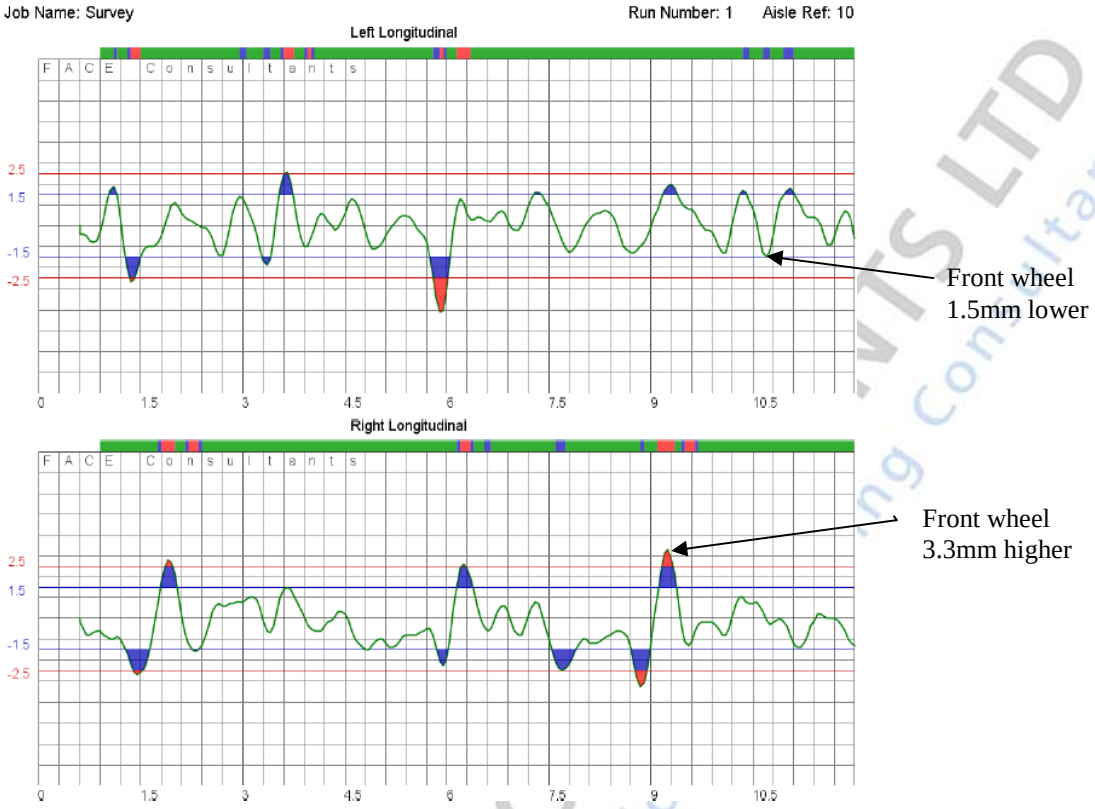
b) The other, checking compliance with Property III, i.e. showing the difference in elevation transversely across the track width of the VNA forklift truck's outer load wheels.



The Graphic traces are read in the direction of travel of the Profileograph, which is from left to right

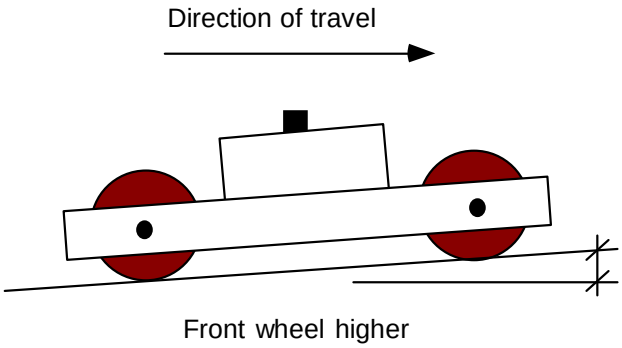
The vertical scale of the graph is in mm, 1 line represents 1mm. The horizontal scale is in metres and each line represents 300mm of travel along the aisle.

A “zero” line is set along the length of each graph for both the left and the right wheel tracks. The zero line corresponds to a perfectly flat and level floor.



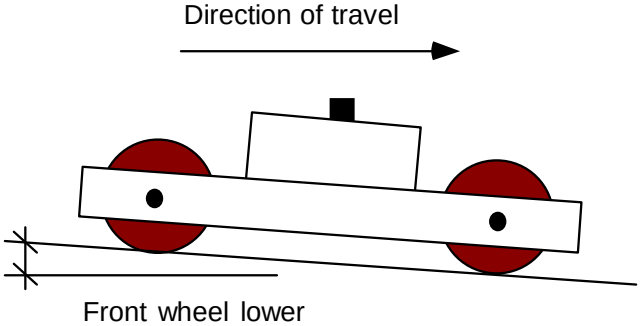
Whenever the graph departs from the zero line, it shows a difference in elevation between the front and rear wheels of the measuring skate.

When the graph is above zero line, it shows that the front wheel was higher than the rear, by the degree shown on the graph trace.



Front wheel higher

When the graph is below the zero line, it shows that the front wheel was below the rear wheel, by the degree shown on the graphic trace.

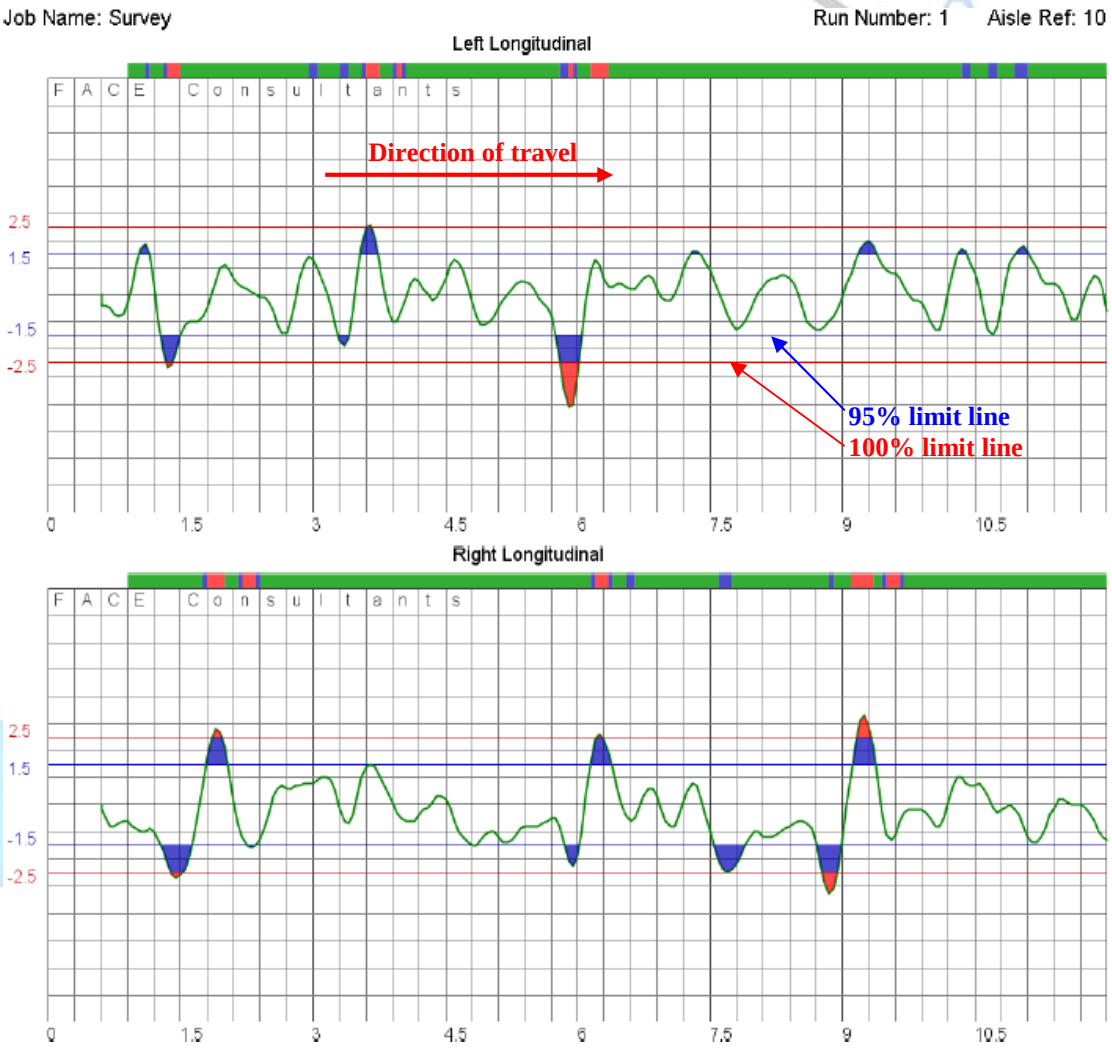


Front wheel lower

Measuring Property I

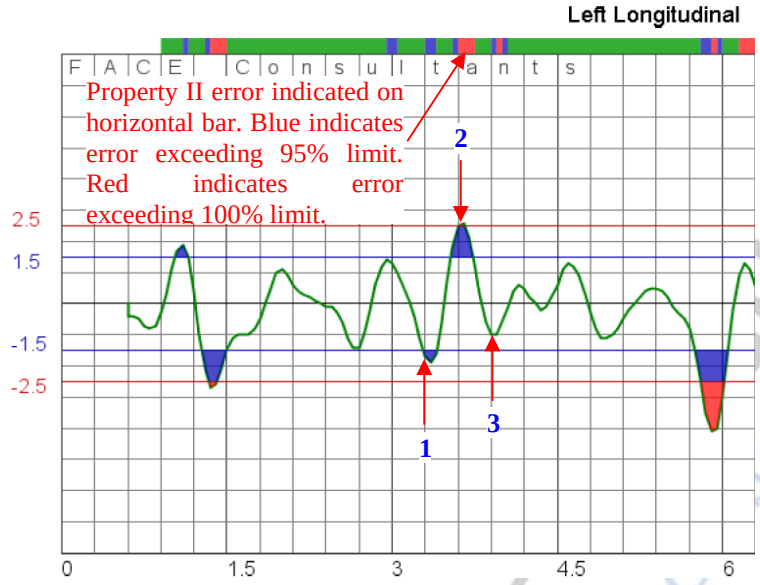
The sample graphic trace, below, shows the elevational difference between any two points set 300 mm apart along each individual wheel track. The Category 1 tolerance bands have been shown on this graphic trace, at 1.5 and 2.5 mm i.e. the maximum difference in elevation between the front and rear wheels of the skate should not be greater than 2.5 mm for 100% of the surveyed length, and 95% of the surveyed length should not exceed 1.5mm. When the graph falls between the 95% and 100% limits it turns blue. When it exceeds the 100% limit the graph turns red. The total extent of these 'errors' is measured and checked for compliance with the specification.

The percentage error is calculated by taking the total length of the graph shown out of tolerance, and dividing it by the length of the test run (i.e. the length of the aisles) then multiplied by 100.



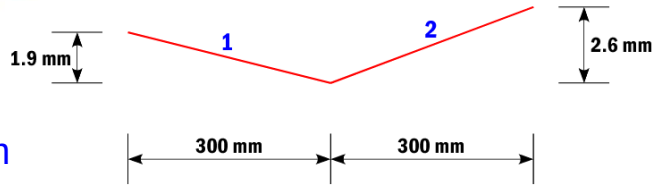
Measuring Property II

The Profileograph skate is 300mm long and so only needs to move forward by 300mm in order to obtain the rate in change of slope over 600mm. When measuring Property II on the graph, it is therefore only necessary to look at 2 points 300mm apart on the horizontal scale to ascertain if the rate in change is within tolerance.
The maximum 'rate in change of slope' error is calculated by finding the largest vertical difference between two points 300mm apart on the horizontal scale. The percentage rate in change error is calculated by finding the total distance of the graph in which 2 points 300mm apart exceed the Property II limit in column A of the specification, and dividing it by the length of the test run (i.e. the length of the aisle) then multiply by 100. Errors are indicated on the graph on the bar at the top of each of the graphs. If the bar is green then the floor complies with the specification. Blue sections indicate property II readings over the 95% limit and red sections indicate readings over the 100% limits.

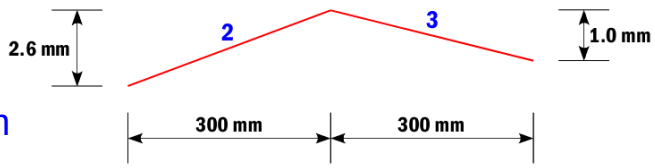


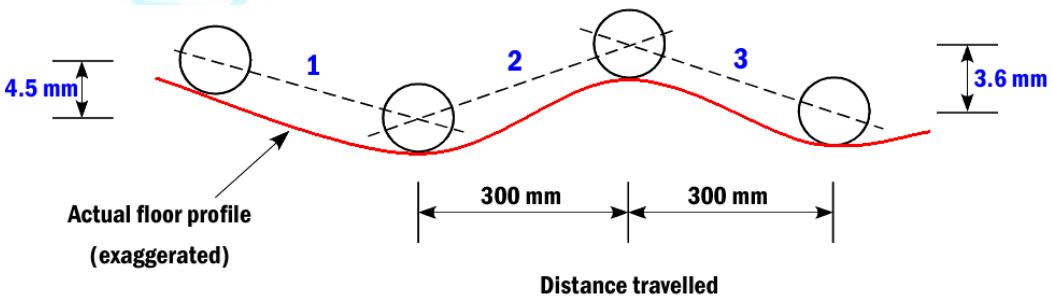
At point 1 on the graph the front wheel of the skate is 1.9 mm lower than the rear wheel. Moving 300mm along the horizontal scale to point 2, there is a 2.6mm difference between the front and rear wheels, indicating a rate in change of slope of 4.5mm. Moving 300mm on to point 3 on the graph, the front wheel is 1.0mm lower than the rear wheel, which indicates a rate in change of slope of 3.6mm between points 2 and 3.

At Point 1 the reading, over 300mm, is -1.9mm
At Point 2 the reading, over 300mm, is 2.6mm
Therefore, the rate of change of slope (Property II)
Between positions 1 and 2 = (–1.9) – (2.6) = 4.5mm



At Point 2 the reading, over 300mm, is 2.6mm
At Point 3 the reading, over 300mm, is -1.0mm
Therefore, the rate of change of slope (Property II)
Between positions 2 and 3 = (2.6) – (–1.0) = 3.6mm



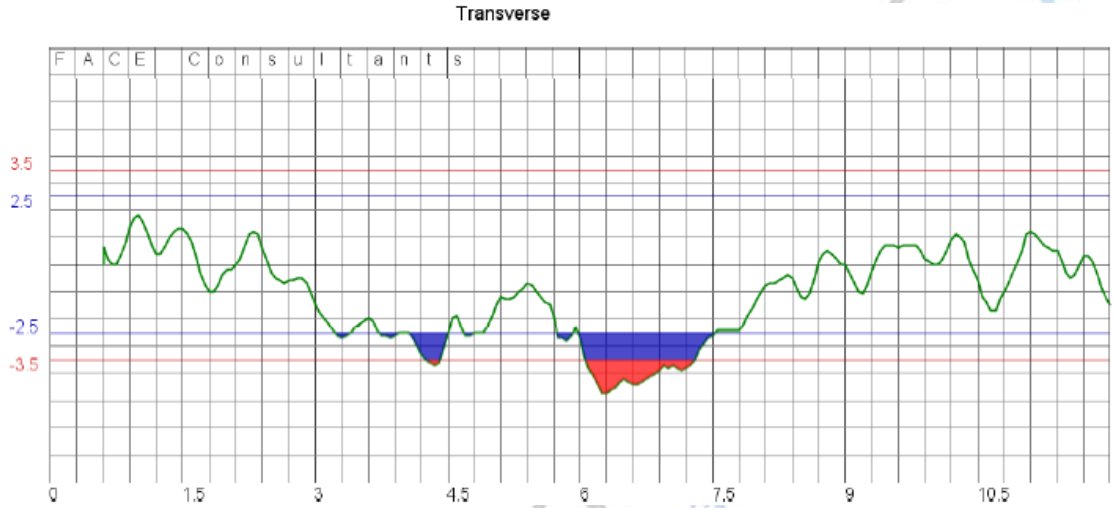


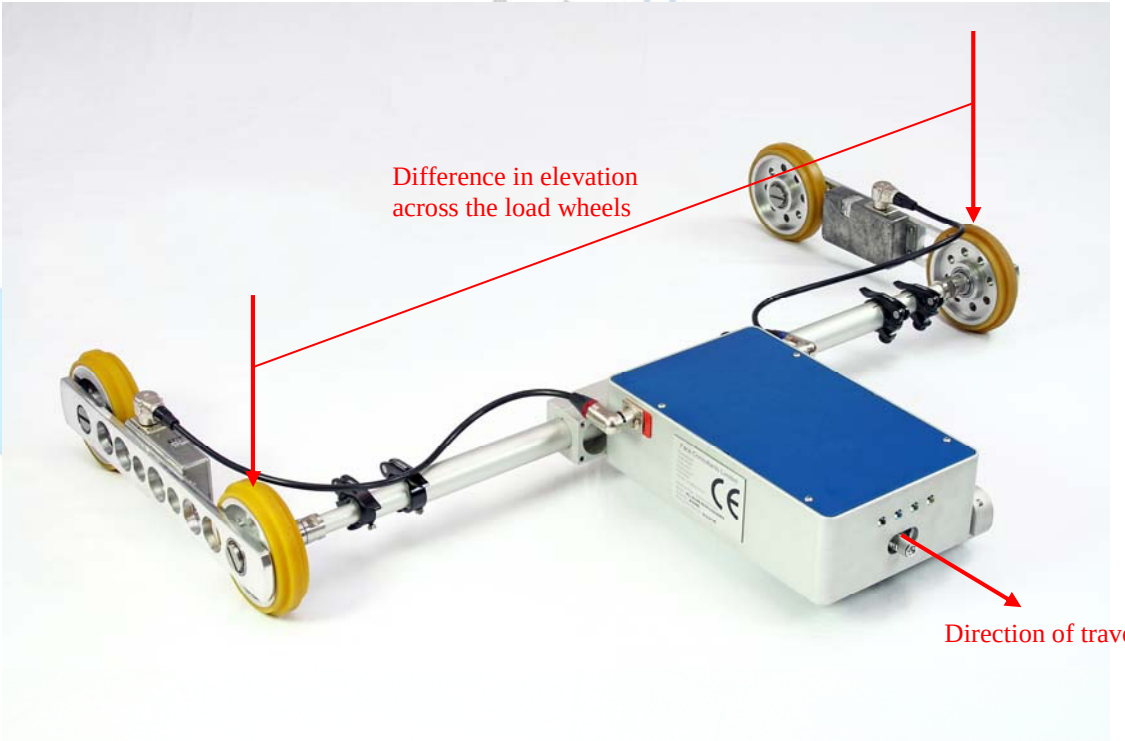
The Transverse Traces

Measuring Property III

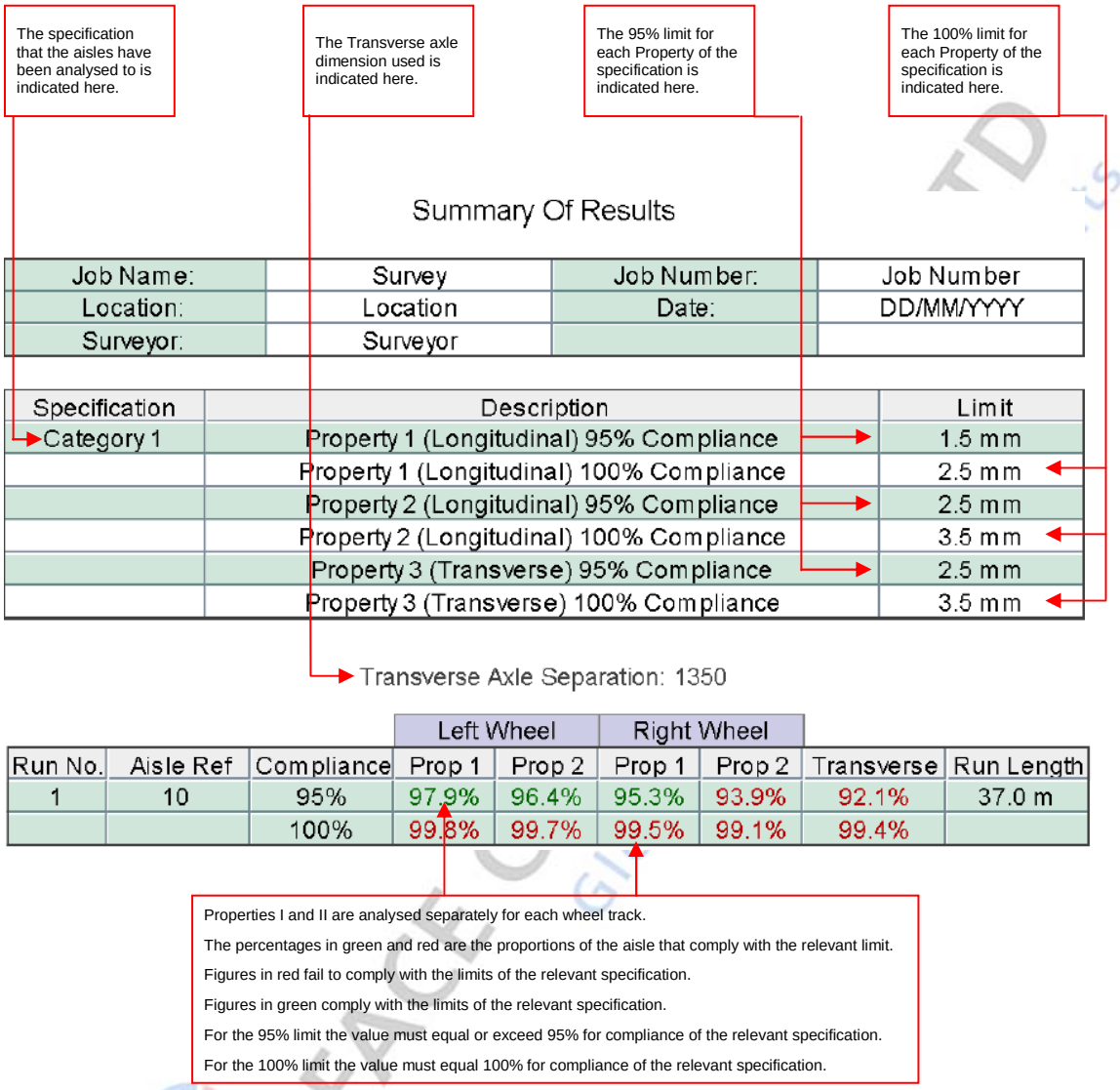
The profileograph will also produce a graphic trace showing the difference in elevation between left and right load wheel tracks of the forklift truck. Below is an example of the transverse trace that the Face digital Profileograph produces. Where the graph is above the zero line, the left side of the aisle is higher than the right and where the graph is below the zero line, the right side of the aisle is higher than the left.

The percentage error is calculated by taking the total length of graphic trace that exceeds the lower limit, and dividing it by the length of the test run, then multiply by 100.





Understanding the Summary Sheet:



Further queries on these specifications or on any other floor flatness issue can be answered by calling Face Consultants Limited direct on:
TEL: 01484 6000 90 FAX: 01484 6000 95 www.face-consultants.com

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