FACE CONSULTANTS LTD
Global Flooring Consultants

FACE CONSULTANTS LIMITED

CONCRETE SOCIETY'S TECHNICAL REPORT: 4TH EDITION

PROFILEOGRAPH SURVEYS

Further explanatory information

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Why Flatness is Important:

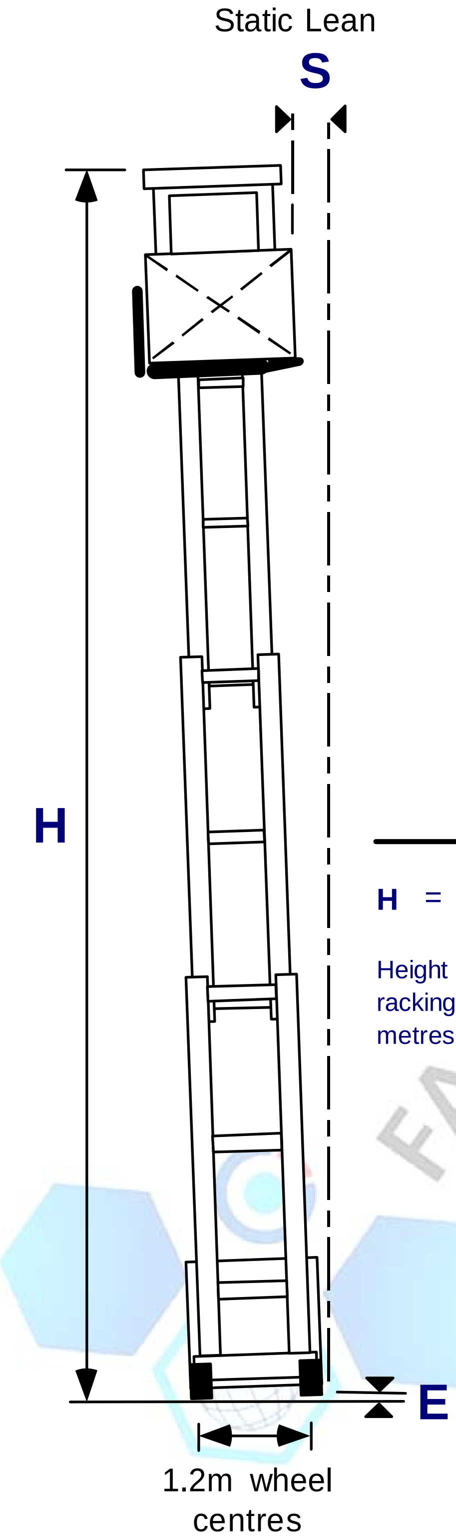
Flatness is an essential requirement of a ground floor slab in certain categories of industry. Undoubtedly, the most important of these categories is that of very narrow aisles in high warehouses where fixed path 'VNA' forklift trucks operate.

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 Transversely across the aisle and Longitudinally down the aisle, induce dynamic flexing 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 optimum performance at all times. 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, <u>assuming that the mast is a rigid structure</u>.

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 Classification:

The flatness classification that Face Consultants recommend is that contained within table 3.2 of the Concrete Society's Technical Report No.34 (4th Edition), in which section 3 discusses flatness requirements for very narrow aisle (VNA) warehouse floors, how to achieve them, the allowable values of the properties of flatness and how to measure them.

Table 3.2 (represented below) detail the allowable values of the properties of flatness for differing categories.

Table 3.2: Permissible limits on Properties dZ, dX, d^2Z and d^2X in defined-movement areas.

Floor classification	Racking top beam height	Property Z_{SLOPE}	Property dZ	Property d^2Z	Property dX	Property d^2X
Calculation	–	mm per m	$Z \times Z_{SLOPE}$	$dZ \times 0.75$	Fixed values $2 \times Z_{SLOPE} \times 1.1$	Fixed values
DM1	Over 13m	1.3	$Z \times 1.3$	$Z \times 1.0$	2.9	1.5
DM2	8–13m	2.0	$Z \times 2.0$	$Z \times 1.5$	4.4	2.0
DM3	Up to 8m	2.5	$Z \times 2.5$	$Z \times 1.9$	5.5	2.5

N.B The values shown for dX and d^2X are based on a longitudinal dimension of 2000mm (this is a fixed dimension)

It is not possible to specify and impose these limits for defined movement unless the exact design of the VNA installation is known before construction. The choice of classification 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 each model is designed to cater for different requirements and is therefore affected differently by surface regularity.

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 Digital Profileograph is used. The Profileograph is a self propelled wheeled instrument which travels across the floor taking 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 classification. These readings are collected on a data logger and subsequently downloaded to a PC where Face Consultants' specialised software generates the graphic traces and compliance results.

The Profileograph is set up to measure values dZ and dX along with d^2Z and d^2X of the Concrete Society's Technical Report No.34 (4^{th} Edition) classifications.

This is achieved by running the Profileograph along the aisle in the wheel tracks of the VNA forklift truck. Each wheel of the Profileograph runs along the centre line of one of the MHE wheel tracks – one for the left, one for the right and two for the rear wheels (configurable for MHE with three or four wheels and to any MHE vehicle footprint) – simultaneously measuring all four properties of the classification in a single operation.

With regard to very narrow aisle installations, there are three possible categories (DM1, DM2 & DM3) of flatness within the Concrete Society's Technical Report No.34 (4th Edition) and each category has four values. Each property has differing allowable values that are set out in Table 3.2 and some properties are variable to cater for varying forklift truck dimensions.

Value dZ and d^2Z refer to the Transverse tolerances, i.e. differences in elevation of the aisle between the two front load wheels of the MHE.

Value **dZ** is the maximum difference in elevation of the aisle between the two front wheels of the MHE. This limit is variable, as shown in Table 3.2.
This is represented by a graphic trace. Where the graphic trace is above the centreline the left side of the aisle is higher by the amount shown and where the graphic trace is below the centreline the right side of the aisle is higher by the amount shown. The red shading indicates where it exceeds the limit as defined by Table 3.2 (none of the aisle must exceed this limit).

Value **d^2Z** is the Transverse rate in change of elevation of the aisle between the two front wheels of the MHE for each 300mm travelled. This limit is variable, as shown in Table 3.2.
This is represented by a coloured bar above the graphic trace. Where the bar is shaded red this indicates where the limit exceeds the limit as defined by Table 3.2 (none of the aisle must exceed this limit).

Values dX and d^2X refer to the Longitudinal tolerances, i.e. differences in elevation of the aisle between the front and rear axles of the MHE.

Value **dX** is the elevational difference between the front and rear axles of the MHE. This limit is fixed by the flatness classification, as shown in Table 3.2.
This is represented by a graphic trace. Where the graphic trace is above the centreline the front of the profileograph is higher than the rear by the amount shown (the floor is running uphill) and where the graphic trace is below the centreline the front of the profileograph is lower than the rear by the amount shown (the floor is running downhill). The red shading indicates where it exceeds the limit as defined by Table 3.2 (none of the aisle must exceed this limit).

Value **d^2X** is the Longitudinal rate in change of elevational difference between the front and rear axles of the MHE for each 300mm travelled. This limit is fixed by the flatness classification, as shown in Table 3.2.
This is represented by a coloured bar above the graphic trace. Where the bar is shaded red this indicates where it exceeds the limit as defined by Table 3.2 (none of the aisle must exceed this limit).

The following examples are taken from a survey for a set of aisles where MHE with the following load wheel (transverse) dimension is to be used:
Transverse – 1300mm
The Longitudinal dimension is always measured at 2000mm.

Understanding the parameters of the Classifications:

The **Concrete Society's Technical Report No.34 (4th Edition)** classifications; DM1, DM2 and DM3, are designed to test a VNA installation in a manner suited to the specific individual model of MHE that is to be utilised. In this case, where the DM2 classification is applied and the forklift is of the dimensions stated above, the limits are as follows:

	Limit
dZ value:	**2.6 mm**
d²Z value:	**1.95 mm**
dX value:	**4.4 mm**
d²X value:	**2.0 mm**

These limits are calculated using the MHE transverse dimension and Table 3.2 as follows:

dZ value…

…specifies the maximum difference in elevation between the left and right wheel tracks.
In this case 100% of the length of the aisle must have a Transverse elevation differential of less than 2.6mm;
The dZ limits are derived from the MHE Transverse dimension Z (1300mm) and the figure given in the DM2 property Z_{SLOPE} column of Table 3.2 (2.0mm).
The figure given in Table 3.2 is the number of millimetres per metre for the DM2 classification and is used to calculate the limit, so in this case the formula would be:

1.3 (Z, the Transverse dimension of the MHE in metres)

x

2.00 (Z_{SLOPE}, the figure given by table 3.2 for DM2 classification in mm)

=

2.60mm

d^2Z value…

…specifies the maximum rate that the difference in elevation between the left and right wheel tracks can change.
In this case 100% of the length of the aisle must have no sections over which the Transverse elevation differential changes by more than 1.95mm over a distance of less than 300mm.
The d^2Z limits are derived from the MHE Transverse dimension (1300mm) and the calculation given in the DM2 d^2Z column (Z x 1.5).

In this case the formula would be:

1.3 (Z, the Transverse dimension of MHE in metres)

x

1.5 (the figure given by table 3.2 for DM2 classification)

= 1.95mm

dX value…

…specifies the maximum difference in elevation between the front and rear axle.
In this case 100% of the length of the aisle must have a Longitudinal elevation differential of less than 4.4mm.
The dX limits are derived from the fixed MHE Longitudinal dimension (2000mm) and the calculation given (longitudinal separation 2 x Z_{SLOPE} x 1.1).

In this case the formula would be:

2.0 (the fixed Longitudinal dimension of the MHE in metres)

x

1.1 (the figure given by Table 3.2 for calculating dX value)

X

2.0 (Z_{SLOPE} mm per m shown in table 3.2)

=

4.4mm

d^2X value..

…specifies the maximum rate that the difference in elevation between the front and rear axle can change.
In this case 100% of the length of the aisle must have no sections over which the Longitudinal differential changes by more than 2.0mm over a distance of less than 300mm.
The d^2X limit is specified in Table 3.2 as a fixed value dependant on the classification.

In the case of DM2 classification the fixed value is

2.0mm

Understanding the Profileograph Traces:

After downloading the data, Face Consultants' specialised software produces two differential traces for each survey run.

a) One graph showing the floor compared to Properties dZ and d^2Z, i.e. the two Transverse aspects of the classification.

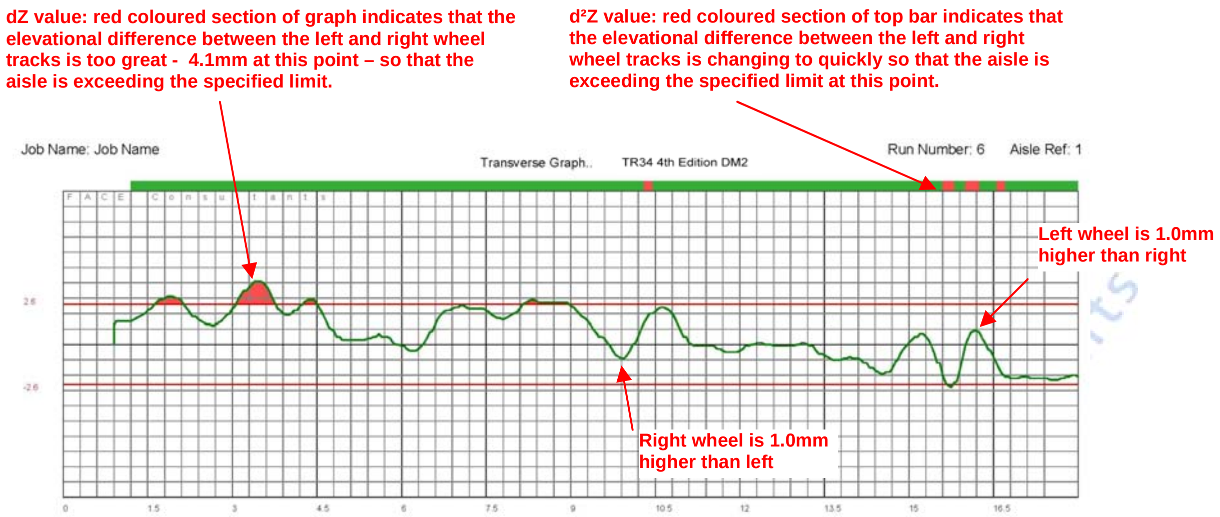
b) One graph showing the floor compared to Properties dX and d^2X, i.e. the two Longitudinal aspects of the classification.

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 millimetres and each 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 both the Transverse and Longitudinal graphs. The zero line corresponds to a perfectly flat and level floor.

Transverse values dZ and d²Z:

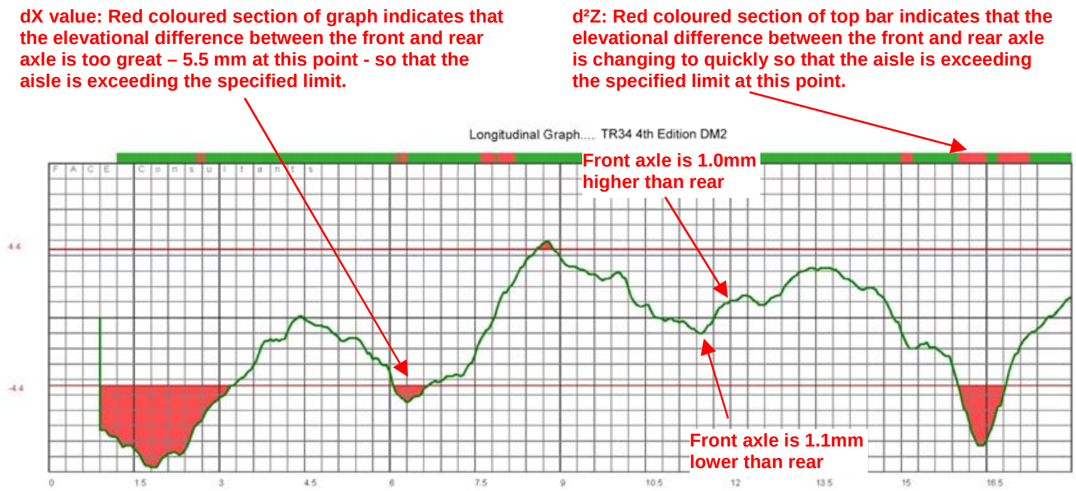


dZ value: When the graph deviates from the zero line it shows that there is a difference in elevation between the left and right wheel tracks of the amount indicated by the scale. If the graph is above the zero line then the left side of the aisle is at a higher elevation than the right, and if the graph is below the line then the right side of the aisle is at a higher elevation than the left. When a section of the aisle exceeds the specified limit then the corresponding section of the graph will be coloured red rather than green.

d²Z value: When the difference in elevation between the left and right wheel tracks changes by an amount that exceeds the specified limit over a distance of 300mm the bar at the top of the graph will turn red.

If any section of the graph or any section of the bar above the graph is coloured red then that aisle fails to comply with the classification.

Longitudinal values dX and d^2X:



dZ value: When the graph deviates from the zero line it shows that there is a difference in elevation between the front and rear axles of the amount indicated by the scale. If the graph is above the zero line then the front axle is at a higher elevation than the rear, and if the graph is below the line then the front axle is at a lower elevation than the rear. When a section of the aisle exceeds the specified limit then the corresponding section of the graph will be coloured red rather than green.

d^2Z value: When the difference in elevation between the front and rear axles changes by an amount that exceeds the specified limit over a distance of 300mm the bar at the top of the graph will turn red rather than green.

If any section of the graph or any section of the bar above the graph is coloured red then that aisle fails to comply with the classification.

Understanding the Summary Sheet:

Below is an example of the summary sheet of results from a Face Digital Profileograph survey.

These are the DM2 limits as automatically calculated for the classification selected and the particular MHE dimensions.

Summary Of Results

Job Name:	JOB NAME	Job Number:	FC/XX/XXXX
Location:	LOCATION	Date:	XX/XX/XXXX
Surveyor:	SURVEYOR NAME		

Specification	Description	Limit
TR34	Transverse Elevation	2.41 mm
4th Edition	Transverse ROC over 300mm	1.81 mm
DM2	Longitudinal Elevation	4.4 mm
	Longitudinal ROC over 300mm	2.0 mm

Transverse Axle Separation: 1205 Longitudinal Axle Separation: 2000

Run No.	Aisle Ref	Limits	Max Diff	Achieved	Run Length
1	9a	Transverse Elevation	7.0 mm	73.4%	34.9 m
		Transverse ROC over 300mm	3.4 mm	92.8%	
		Longitudinal Elevation	7.7 mm	84.7%	
		Longitudinal ROC over 300mm	3.5 mm	90.3%	
2	9	Transverse Elevation	8.3 mm	78.9%	44.7 m
		Transverse ROC over 300mm	3.7 mm	87.9%	
		Longitudinal Elevation	7.5 mm	78.1%	
		Longitudinal ROC over 300mm	4.2 mm	79.4%	

The figures indicate the maximum errors found on the aisle in millimetres: in order to comply with the chosen classification the figure must not exceed the limit, which can be compared with the four figures from the table.

The figures in red indicate the percentage of the aisle that complies with the specified limit of the chosen classification; in order to comply with the classification all figures should indicate 100% and be displayed in green.

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

Copies of the 2013 edition 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: (01276) 607140   FAX: (01276) 607141