



FACE CONSULTANTS LTD
Global Flooring Consultants

FACE CONSULTANTS LIMITED

**Concrete Society's Technical
Report Number 34**

Digital Table C1 2003

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.

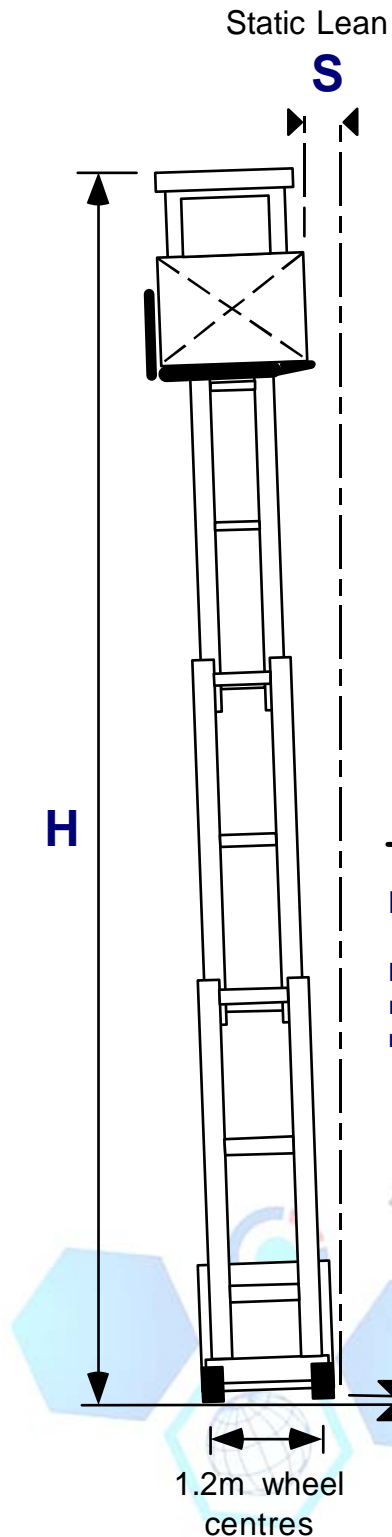
Variations in level, both Transversely across the aisle and Longitudinally down the aisle, induce dynamic flexing movements in the mast which are much greater in magnitude than can be calculated from geometrical considerations alone. The stresses which are set up within both the mast and body sections 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, 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 Face Consultants recommend is that contained within Appendix C of the 2003 edition of 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. Appendix C also describes the reasons for the development of and the methods of surveying the DM specifications.

Table C1 (represented below) details the allowable values of the properties of flatness for differing categories.

Floor classification	MHE Lift Height (m)	Property A _{unit}	Property B	Property C _{unit}	Property D
		Transverse elevational difference unit value – mm per m of front axle length.	Transverse rate of change for each 300mm of forward travel. Fixed % of Property A _{MHE} value.	Longitudinal elevational difference unit value – mm per m of front to rear axle length = A _{unit} x 1.1	Longitudinal change in elevational difference for each 300mm of forward travel (mm) = A _{unit} .
DM 1	Over 13	1.3	75	1.4	1.3
DM 2	8 to 13	2.0	75	2.2	2.0
DM 3	Up to 8	2.5	75	2.8	2.5

MHE = Mechanical Handling Equipment

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 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 each model is designed to cater for different requirements and is therefore affected differently by surface regularity.

Appendix C of the 2003 edition of the Concrete Society's Technical Report No. 34 states that if the wheel configuration and wheelbase dimensions of the MHE are not known at the time of the survey that a three-wheel configuration should then be assumed and that the following wheelbase dimensions should be used:

Transverse: 1300mm

Longitudinal: 1800mm

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 which travels across the floor it 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 specification. 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 Properties A, B, C, and D of Appendix C of the 2003 edition of the Concrete Society's TR34 Appendix C DM1, DM2 and DM3 Specifications.

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 specification in a single operation.



With regard to narrow aisle installations, there are three possible categories (DM1, DM2 & DM3) of flatness within Appendix C of the Concrete Society's Technical Report Nr. 34 and each category has four properties. Each property has differing allowable values that are set out in Table C1 and some properties are variable to cater for varying fork lift truck dimensions.

Properties A and B refer to the Transverse tolerances, i.e. differences in elevation of the aisle between the two front load wheels of the MHE.

Property **A** is the maximum difference in elevation of the aisle between the two front wheels of the MHE. This limit is fixed by the flatness category, as shown in Table C1.

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 blue shading indicates where the graph exceeds the 95% limit (5% of the length of the aisle may exceed this limit) and the red shading indicates where it exceeds the 100% limit (none of the aisle must exceed this limit).

Property **B** 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 C1.

This is represented by a coloured bar above the graphic trace. Where the bar is shaded blue, the rate in change exceeds the 95% limit (5% of the length of the aisle may exceed this limit) and the red shading indicates where it exceeds the 100% limit (none of the aisle must exceed this limit).

Properties C and D refer to the Longitudinal tolerances, i.e. differences in elevation of the aisle between the front and rear axles of the MHE.

Property **C** is the elevational difference between the front and rear axles of the MHE. This limit is fixed by the flatness category, as shown in Table C1.

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 blue shading indicates where the graph exceeds the 95% limit (5% of the length of the aisle may exceed this limit) and the red shading indicates where it exceeds the 100% limit (none of the aisle must exceed this limit).

Property **D** 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 variable, as shown in Table C1.

This is represented by a coloured bar above the graphic trace. Where the bar is shaded blue, the rate in change exceeds the 95% limit (5% of the length of the aisle may exceed this limit) and the red shading indicates where it exceeds the 100% limit (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 wheelbase dimensions is to be used:
 Longitudinal – 1600mm, Transverse – 1150mm

Understanding the parameters of the Specifications:

The Appendix C specifications; 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 specification of the Appendix C is applied and the forklift is of the dimensions stated above, the limits are as follows:

	95% limit	100% limit
Property A:	2.30 mm	3.45 mm
Property B:	1.72 mm	2.58 mm
Property C:	3.52 mm	5.28 mm
Property D:	2.00 mm	3.00 mm

These limits are calculated using the MHE dimensions and Table C1 as follows:

Property A...

...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 3.45mm; while 95% of the aisle must have a Transverse elevation differential of less than 2.30mm.

The Property A limits are derived from the MHE Transverse dimension (1150mm) and the figure given in the DM2 Property A column (2.0).

The figure given in Table C1 is the number of millimetres per metre for the DM2 specification and is used to calculate the 95% limit, so in this case the formula would be:

1.15 (the Transverse dimension of the MHE in metres)

x

2.00 (the figure given by C1 for DM2 Property A)

=

2.30 (the 95% limit for Property A)

The 100% limit is stated in Appendix C (outside Table C1) simply to be 1.5 times the 95% limit, so in this case the formula would be:

2.30 (the 95% limit for Property A)

x

1.50 (the figure given by Appendix C)

=

3.45 (the 100% limit for Property A)

Property B...

...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 2.58mm over a distance of less than 300mm; while 95% of the aisle must have no sections over which the Transverse elevation differential changes by more than 1.72mm over a distance of less than 300mm.

The Property B limits are derived from the MHE Transverse dimension (1150mm) and the percentage figure given in the DM2 Property B column (75).

The figure given in Table C1 is the percentage of the Property A limit for the DM2 specification and is used to calculate the 95% limit, so in this case the formula would be:

2.30 (the 95% limit for Property A)

x

75% (the figure given by C1 for DM2 Property B)

=

1.72 (the 95% limit for Property B)

The 100% limit is stated in Appendix C (outside Table C1) simply to be 1.5 times the 95% limit, so in this case the formula would be:

1.72 (the 95% limit for Property B)

x

1.50 (the figure given by Appendix C)

=

2.58 (the 100% limit for Property B)



Property C...

...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 5.28mm; while 95% of the aisle must have a Longitudinal elevation differential of less than 3.52mm.

The Property C limits are derived from the MHE Longitudinal dimension (1600mm) and the figure given in the DM2 Property C column (2.2).

The figure given in Table C1 is the number of millimetres per metre for the DM2 specification and is used to calculate the 95% limit, so in this case the formula would be:

1.60 (the Longitudinal dimension of the MHE in metres)

x

2.20 (the figure given by C1 for DM2 Property C)

=

3.52 (the 95% limit for Property C)

The 100% limit is stated in Appendix C (outside Table C1) simply to be 1.5 times the 95% limit, so in this case the formula would be:

3.52 (the 95% limit for Property C)

x

1.50 (the figure given by Appendix C)

=

5.28 (the 100% limit for Property C)



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Property D...

...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 3.0mm over a distance of less than 300mm; while 95% of the aisle must have no sections over which the Longitudinal elevation differential changes by more than 2.0mm over a distance of less than 300mm.

The 95 % Property D limit is specified in the DM2 Property D column, while the 100% limit is stated in Appendix C (outside Table C1) simply to be 1.5 times the 95% limit, so in this case the formula would be:

2.00 (the 95% limit for Property B as stated in Table C1)

x

1.50 (the figure given by Appendix C)

=

3.00 (the 100% limit for Property B)

Understanding the Profilegraph 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 A and B, i.e. the two Transverse aspects of the specification.
- b) One graph showing the floor compared to Properties C and D, i.e. the two Longitudinal aspects of the specification.

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

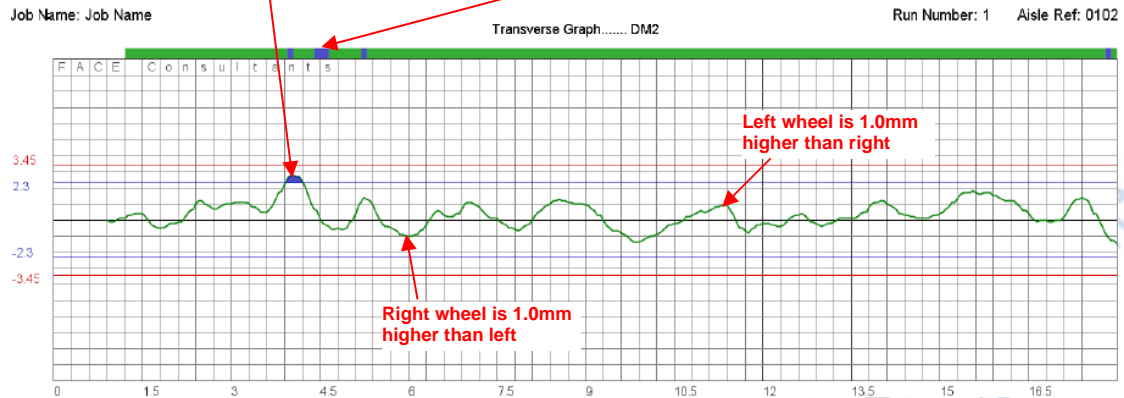
The vertical scale of the graph is in millimetres and each line represents 1mm. The horizontal scale is in metres and each line represents 300mm of travel along the aisle.

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 Properties A and B:

Property A: Blue coloured section of graph indicates that the elevational difference between the left and right wheel tracks is too great – 2.9mm at this point – so that the aisle is exceeding the 95% limit.

Property B: Blue coloured section of top bar indicates that the elevational difference between the left and right wheel tracks is changing too quickly so that the aisle is exceeding the 95% limit at this point.



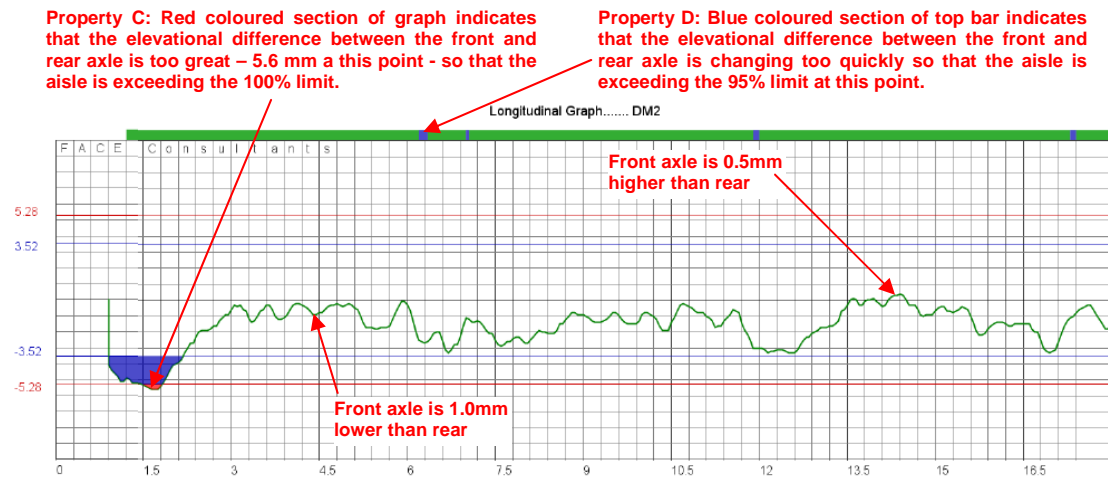
Property A: When the graph deviates from the zero line it shows that there is a difference in elevation between the left and right wheel tracks of the amount indicated by the scale. If the graph is above the zero line then the left side of the aisle is at a higher elevation than the right, and if the 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 95% limit then the corresponding section of the graph will be coloured blue rather than green. Should a section of graph exceed the 100% limit then the corresponding section of the graph will be coloured red.

Property B: When the difference in elevation between the left and right wheel tracks changes by an amount that exceeds the 95% limit over a distance of 300mm the bar at the top of the graph will turn blue. Should the 100% limit be exceeded, 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 specification.



Longitudinal Properties C and D:



Property C: 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 95% limit then the corresponding section of the graph will be coloured blue rather than green. Should a section of graph exceed the 100% limit then the corresponding section of the graph will be coloured red.

Property D: When the difference in elevation between the front and rear axles changes by an amount that exceeds the 95% limit over a distance of 300mm the bar at the top of the graph will turn blue. Should the 100% limit be exceeded, 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 specification.



Understanding the Summary Sheet:

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

These are the 95% and 100% limits as automatically calculated for the specification selected and the particular MHE dimensions.

Summary Of Results

Job Name:	Job Name	Job Number:	FC/XX/XXXX
Location:	Location	Date:	DD/MM/YYYY
Surveyor:	Surveyor		

Specification	Description	Limit
DM2	Transverse Elevation, 95% Compliance	2.3 mm
	Transverse Elevation, 100% Compliance	3.45 mm
	Transverse ROC over 300mm, 95% Compliance	1.72 mm
	Transverse ROC over 300mm, 100% Compliance	2.58 mm
	Longitudinal Elevation, 95% Compliance	3.52 mm
	Longitudinal Elevation, 100% Compliance	5.28 mm
	Longitudinal ROC over 300mm, 95% Compliance	2.0 mm
	Longitudinal ROC over 300mm, 100% Compliance	3.0 mm

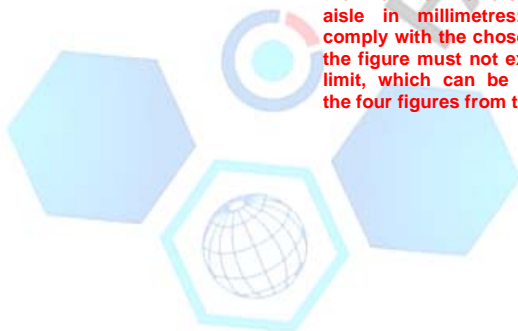
Transverse Axle Separation: 1150 Longitudinal Axle Separation: 1600

Run No.	Aisle Ref	Limits	Max Diff	Compliance	Achieved	Run Length
1	0102	Transverse Elevation	2.8 mm	95%	99.2%	93.0 m
		Transverse ROC	2.3 mm	95%	98.9%	
		Longitudinal Elevation	4.3 mm	95%	99.1%	
		Longitudinal ROC	2.9 mm	95%	98.9%	
2	0304	Transverse Elevation	2.8 mm	95%	99.6%	92.8 m
		Transverse ROC	2.1 mm	95%	99.4%	
		Longitudinal Elevation	4.7 mm	95%	96.2%	
		Longitudinal ROC	4.0 mm	95%	97.4%	

The figures in red and green indicate the maximum errors found on the aisle in millimetres: in order to comply with the chosen specification the figure must not exceed the 100% limit, which can be compared with the four figures from the table.

The figures in green indicate the percentage of the aisle that complies with the 95% limit of the chosen specification; in order to comply with the specification the figure must be between 95% and 100%.

The figures in red indicate that the aisle fails to comply with the 95% limit of the chosen specification.



Further queries on these specifications or on any other floor flatness issue can be answered by calling Face Consultants Limited direct on:

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Copies of the 2003 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: (01753) 693313 FAX: (01753) 692333



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