

# Surface regularity – the ups and downs

**Most warehouse floors in the UK are tested for compliance to one of the specifications in The Concrete Society's Technical Report 34 (TR 34)<sup>(1)</sup>. More often than not, the independent surveying company instructed to carry out the test has been instructed by the flooring contractor as part of its overall package. But who tests the testers?**

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With respect to surface regularity, or more commonly stated 'floor flatness', there are two floor classifications, or uses, of a floor surface: free movement and defined movement. Free movement floors are those floors that have materials handling equipment (MHE) which is able to move in a random manner. This will include the majority of warehouse use, including block stacking, wide-aisle racking and manufacturing, to name but a few. Defined movement floors are those where the MHE is guided down a defined wheel path, by either outrigger wheels running on a guide rail, or by sensors on the MHE picking up a low-frequency signal from a wire embedded in the floor and steering becoming automatic. This, in most cases, refers to narrow-aisle or very-narrow-aisle (VNA) warehouses.

## Testing free movement floors

The free movement specifications in TR 34 are defined in section 4, Tables 4.2 and 4.4. The specification has four classifications of flatness depending on the typical use of the floor, with FM1 being the highest standard. Each classification has three properties to comply with:

- level to datum
- Property II, the short wavelength characteristic of the floor
- Property IV, the long wavelength characteristic of the floor.

The first stage in carrying out a free movement floor survey is to mark the test floor on a 3 × 3m grid. It is important that this is done accurately for repeatability purposes. In practice, the survey is usually carried out in an operational building environment and therefore the material used to mark the floor must be sufficiently robust to endure foot and site traffic. The marked grid is first used to survey all the intersection points of the grid, with an engineer's precise level, fitted with a parallel plate micrometer reading onto an invar staff, fitted with its own spirit bubble. A surveyor's assistant has often been seen holding a staff with little regard of its plumbness. A staff that is not plum could result in levels having a variance of 10mm or more and the surveyor may not be aware of this. The data collected from the level survey are then used to determine compliance with properties of the specification, level to datum and Property IV. It is best to use a simple software programme, with the results being colour-coded for ease of visual recognition of areas of floor that do not comply.

The next stage of the survey is to check compliance with Property II of the specification. A representative sample of the floor is required to check compliance and TR 34



**Figure 1: Checking compliance with Property IV limits using engineer's precise level, ppm and invar staff.**



**Figure 2: Checking Property II limits with the Face Prop II meter.**

gives clear instructions as to the number of readings to take and where generally they should be taken. However, the surveyor has to use his best judgement as to what is regarded as 'distributed uniformly across the floor'. Using the grid lines set up for the Property IV compliance check, the surveyor will check a number of lines with a total linear metre length equal to the test area in square metres divided by ten. Half of the test lengths must be tested in one direction on the grid and the other half in the perpendicular direction of the grid. Although there is no guidance on the minimum length of line, it is suggested that this should be 3m. Although these lines could be measured with an optical level at 300mm centres, it would be extremely time-consuming. There are a number of proprietary electronic

● It is intended that a detailed study of the report as detailed in Table 1 will form the basis of an article for a future edition of CONCRETE.

**Table 1: Results of 115 floors (780,000m<sup>2</sup>) surveyed in 2005**

Category	Property	Best standard deviation (SD)		Worst standard deviation		Average standard deviation		TR 34 limits					
		SD	Equivalent property limits	SD	Equivalent property limits	SD	Equivalent property limits	95%	100%	Equivalent SD			
			95%	100%	95%	100%	95%	100%					
FM1	II	0.70	1.40	2.10	1.52	3.04	4.56	0.93	1.86	2.80	2.50	4.00	1.25
FM2 Sp	II	0.89	1.78	2.67	1.23	2.46	3.69	1.07	2.13	3.20	3.00	4.50	1.50
FM2	II	0.89	1.78	2.67	1.28	2.56	3.84	1.11	2.22	3.33	3.50	5.50	1.75
FM3	II	1.16	2.32	3.48	2.80	5.60	8.40	1.86	3.72	5.58	5.00	7.50	2.50
FM1	IV	2.07	4.14	6.21	2.45	4.90	7.35	2.18	4.35	6.53	4.50	7.00	2.25
FM2 Sp	IV	2.00	4.00	6.00	3.50	7.00	10.50	2.69	5.38	8.07	6.50	10.00	3.25
FM2	IV	2.24	4.48	6.72	4.80	9.60	14.40	3.19	6.38	9.57	8.00	12.00	4.00
FM3	IV	2.56	5.12	7.68	6.02	12.04	18.06	4.36	8.72	13.07	10.00	15.00	5.00

**Figure 3 right: Face TR 34 digital profileograph checking compliance with Table 4.3. Only the outer two wheel tracks are tested.**

**Figure 4 far right: Face Appendix C/F<sub>min</sub> digital profileograph checking compliance with the specification. All wheel tracks are tested.**



**Figure 5: The UKAS mark is the proof of accreditation.**

surveying instruments that are built specifically for measuring this characteristic of the floor such as the Face digital Prop II meter.

**Compliance**

The floor must be within ±15mm from the given datum. Property II and Property IV must comply with two limits contained within the tables. No readings taken must exceed the 100% limit in the table and at least 95% of all the readings taken must comply with the 95% limits in the table, representing approximately three and two standard deviations.

**Table 2: Choice of surface regularity category is determined by height of racking**

Rack Height	Section 4, Table 4.3	Appendix C, Table C.1
>13m	Superflat	DM1
8–13m	Category 1	DM2
< 8m	Category 2	DM3

**Table 3: Comparison of property limits between TR 34 Table 4.3, TR 34 Appendix C Table C1 and the USA F<sub>min</sub> specification**

Rack Height	Specification	Transverse	Transverse rate of change	Elevation over 300mm	Elevation over axle*	Rate in change
> 13m	Superflat	1.5	-	0.75	4.5+	1.0
	F <sub>min</sub> 100	1.93	1.0	-	2.34	1.0
	DM1	1.7	1.3	-	2.6	1.3
>8 <13	Cat 1	2.5	-	1.5	9.0+	2.5
	F <sub>min</sub> 75	2.58	1.33	-	3.12	1.33
	DM 2	2.6	2.0	-	4.0	2.0
<8	Cat 2	3.5	-	2.5	15+	3.25
	F <sub>min</sub> 50	3.87	2.0	-	4.69	2.0
	DM3	3.3	2.5	-	5.0	2.5

\* The elevation over the axle dimension in TR 34 Table 4.3 specification assumes the rear wheels are running on the same floor profile as the front wheels. If just the outer two wheels have been ground, the elevation could be far greater than the limit shown but still be compliant.

*“All floor surveying companies should be able to demonstrate compliance with BS EN ISO/IEC 17025 to carry out floor flatness testing to TR 34. UKAS accreditation will demonstrate this.”*

**Non-compliance**

Unfortunately, some floors fail the specification, but finding a solution to rectify the floor, if needed, is always a potential problem when the analysis is based on only a sample of data. It is not advised to sort out the locations of the floor where the data were collected, as the rest of the floor will be excluded. On many occasions, a floor has failed the specification for the sake of one or a few readings, despite the general characteristic of the floor being very good.

All floors surveyed by Face Consultants come with the benefit of having the standard deviation (SD) calculated, which gives an indication of the general quality of the floor and a greater understanding of its nature.

Face Consultants recently carried out a survey on 115 floors cast in the UK during 2005 involving over 780,000m<sup>2</sup>. The floors were assessed on what was actually achieved and Table 1 shows some interesting results.

**Testing defined movement floors**

The defined movement specifications in TR 34 can be found in section 4, table 4.3 and a recently introduced specification in Appendix C, Table C.1. Both Tables have three categories which are determined by the height of the racking.

The specification in TR 34, section 4 controls three properties of surface regularity but only in the outer two load wheel tracks of the floor. Property I controls the longitudinal elevation of the floor, in the outer wheel tracks, over a distance of 300mm. Property II controls the rate of change of the Property I limits, thus controlling the short wavelength characteristic of the floor, again only in the outer two load wheel tracks. Property III, which is common to both specifications, controls the elevation difference across the load wheel tracks (the transverse difference). Although the floor can be checked for compliance, using a level taking readings at 300mm centres down each of the outer wheel tracks, it is time-consuming. The

accepted practice for testing a defined traffic floor is by the use of the Profilegraph, taking readings of all three properties as it travels down the aisleway and producing differential graphs which can be easily read to determine compliance, or otherwise. Some profilegraph results will show all properties and will be highlighted with different colours for the 95% and 100% limits.

The alternative specification in Appendix C is a new introduction to TR 34 and concentrates on the floor profile taken from the point of view of a forklift truck, measuring all the wheel tracks not just the front two wheels. This becomes more important when the floor needs to be ground to achieve compliance with a specification. Ignoring the rear wheels of a forklift truck may result in reducing the operational speed and increased maintenance costs. TR 34 states that this specification requires further research to justify the approach and tolerances given. The Appendix C principle of measuring the floor surface regularity is exactly the same as the American  $F_{min}$  specification, which has been used by American companies worldwide since the late 1970s, before TR 34 was even considered.

$F_{min}$  100 has always been regarded as a 'superflat floor' and has, in the past, been accepted as equivalent to the TR 34 Superflat category. Similarly,  $F_{min}$  75 and  $F_{min}$  50 have always been regarded by Face Consultants as the equivalent to TR 34's Category 1 and Category 2 respectively. If the property limits of each of these specifications for a typical forklift truck with the front wheels set at 1.3m from centre to centre and the front-to-rear axle dimension of 1.8m are considered then the following can be concluded (see Table 3).

It is clear that the Appendix C property limits cannot be regarded as overspecification; in fact, Appendix C is a clear relaxation of the  $F_{min}$  limits. If we then consider that the Appendix C limits stated above are the 95% limits and that the allowable limits could be 1.5 times as great for 5% of the length of the aisle, Appendix C should not be regarded as an onerous specification. If there is an argument, it is whether the property limits should be tightened.

Again the specification is checked for compliance using a profilegraph, only this time the test instrument is set up to replicate the wheel spacing of the proposed forklift truck. Appendix C checks four properties of surface regularity: the elevation of the front to rear axle; the rate in change of the elevation difference for every 300mm of travel; the transverse elevation difference (as with Section 4); and the rate in change in this elevation difference for every 300mm of travel.

**Testing the testers**

Apart from the instruments that are used to check Property IV of the free movement specification, all the UK's floor surveying companies use their own proprietary equipment to check compliance with TR 34. UKAS is recognised by the UK Government as the sole UK national accreditation body responsible for assessing and accrediting the competence of organisations in the fields of inspection, measurement, testing and the certification of systems, products and personnel. All floor surveying companies should be able to demonstrate compliance with BS EN ISO/IEC 17025<sup>(2)</sup> to carry out floor flatness testing to TR 34. UKAS accreditation will demonstrate this.

**Concluding remarks**

Most materials used in concrete floors are tested by UKAS accredited laboratories. Surface regularity survey results are used to determine contractors' contractual obligations and are invariably used to evaluate lettable rates for the building. The floor surveying companies that check these floors with their proprietary testing equipment must be regulated and be accredited by an independent authority. Ensure your floor surveyor is UKAS accredited. ■

**References:**

1. THE CONCRETE SOCIETY. Technical Report 34, *Concrete industrial ground floors – a guide to design and construction*. Third edition, Camberley, 2003.
2. BRITISH STANDARDS INSTITUTION. BS EN ISO/IEC 17025: *General requirements for the competence of testing and calibration laboratories*. 2005.

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Reader Enquiry Number 321