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BUILDING RESILIENCE

TECHNICAL SPECIFICATION 01:2021

SURFACE REGULARITY REQUIREMENTS FOR CONCRETE FLOORS

CONTENTS

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GENERAL – SCOPE & APPLICATION

This technical specification provides surface regularity requirements for internal concrete floors that are either supported by the ground or are suspended. The provisions can apply to a range of building uses including industrial, warehousing, institutional, retail, commercial, office and accommodation, where different tolerances are required for the specific use (e.g. high reach forklifts) and/or take account of final floor finishes that may be applied (e.g. tiles).

Guidance on methods for measuring surface regularity are also provided in this technical specification.

The requirements and methods of assessing surface regularity are provided for two distinct floor areas:

- Free-movement (FM)
- Defined-movement (DM)

The requirements for surface regularity in this technical specification assume that the floor is to be horizontal, cast to a constant finished floor level. Floors laid to falls or follow a camber may require further consideration.

The requirements in this technical specification are intended to modify and/or supersede surface regularity requirements currently provided in NZS 3109 and NZS 3114 for concrete floors.

The relevant contents of NZS 3109 and NZS 3114 that are modified/superseded for concrete floor construction are:

- NZS 3109:1997 Table 5.2 (Profile tolerances for *in situ* construction)
- NZS 3114:1987 Clause 304.1 (Surface plane variations) and Table 3 (Tolerances for abrupt deviations or offsets and gradual variations)

ABBREVIATIONS & DEFINITIONS

Datum – a reference point taken for surveying.

Defined-movement areas – narrow aisles in warehouses where materials handling equipment (MHE) move only in defined paths.

Departure from datum – the deviation in height of the surface from a fixed datum.

Flatness – surface regularity over short distances.

Free-movement areas – where MHE can travel randomly in any direction, typically in warehouses with wide aisle racking systems, factories, retail outlets and food distribution centres.

Levelness – surface regularity over a longer distance, typically 3 m.

MHE – Materials Handling Equipment e.g. forklifts, high-access devices (this technical specification is not intended to apply to ASRS – automated storage and retrieval systems or other more specialised equipment, manufacturers should be consulted for specific floor surface requirements).

Propping – temporary support provided for suspended slabs during construction.

Side-shift – the ability of a truck to adjust the pallet transversely to the fork direction.

Surface regularity – generic term to describe the departure of a floor profile from a theoretical perfect plane.

VNA – Very Narrow Aisles.

GENERAL SURFACE REGULARITY REQUIREMENTS – FREE-MOVEMENT AREAS

Surface profiles of floors must be controlled so that departures from a theoretically perfect flat plane are limited to an extent appropriate for the planned use of the floor. Three properties for determining concrete floor surface regularity are provided in this technical specification:

- **Departure from datum**
- **Flatness**
- **Levelness**

DEPARTURE FROM DATUM

To meet **departure from datum** requirements the deviation in height of the surface of all new floor construction shall be within **± 15 mm** of a fixed datum plane. Where a datum plane is not available, no point shall be outside **± 15 mm** of the mean floor level, based on the survey results to determine the levelness of the floor.

Greater accuracy to a datum can be specified for small rooms, along the line of partition walls, in the vicinity of door openings and where special equipment is to be directly installed on the floor.

It may be important to determine the as-built floor datum to be used as the basis of measurements, to avoid confusion if the as-built datum is not the same as any assumed design datum.

FLATNESS AND LEVELNESS

The floor should have an appropriate **flatness** in order to provide a suitable surface for the operation of items such as material handling equipment (MHE) and/or very high racking, and an appropriate **levelness** to ensure that the building can function satisfactorily.

Flatness is generally related to variations over shorter distances whereas levelness is generally related to longer distance. The differences between flatness and levelness are illustrated in **Figure 1**.

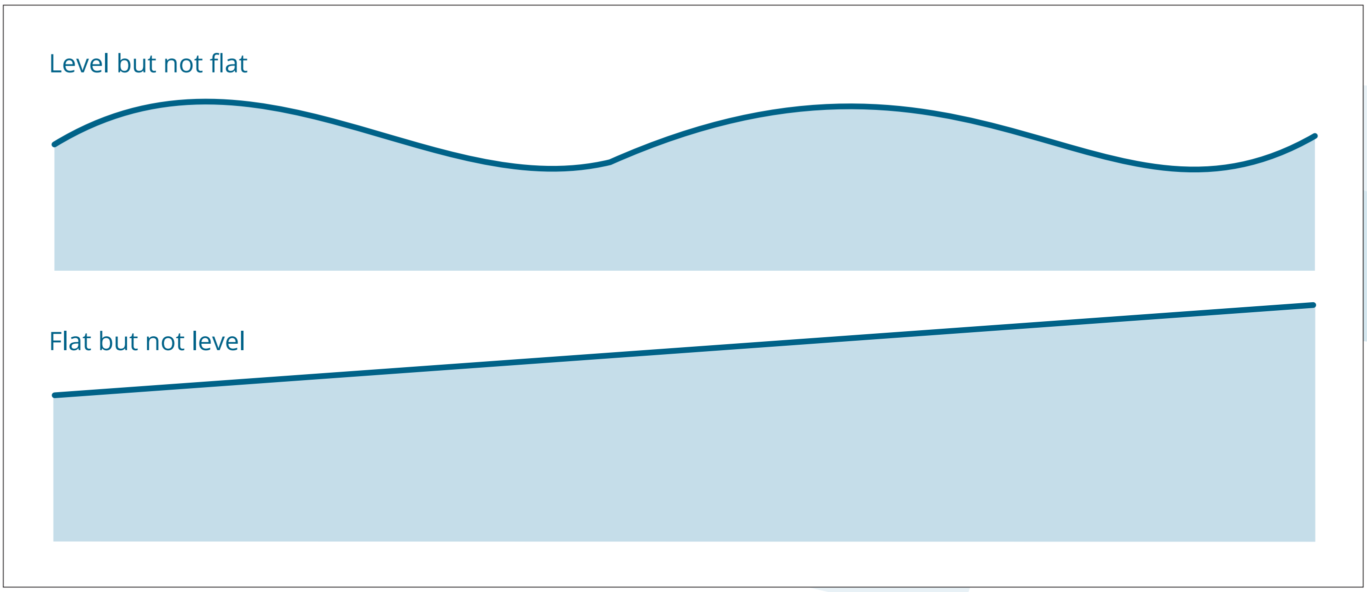

Figure 1: Flatness and levelness

Levelness (E) and flatness (F) requirements for five different floor classes as applicable for general free-movement areas are prescribed in **Table 1**.

Table 1: Floor classes and permissible 95th percentile limits on levelness (E) and flatness (F) for free-movement floor areas

Floor Class	Typical floor use	Property	
		E (mm)	F (mm)
FM1	Where very high standards of flatness and levelness are required. Reach trucks operating at above 13 m without side-shift.	4.5	1.8
FM2	Reach trucks operating at 8-13 m without side-shift.	6.5	2.0
FM3	Retail floors to take directly applied flooring (such as thin sheet tiles). Reach trucks operating at up to 8 m without side-shift. Reach trucks operating at up to 13 m with side-shift.	8.0	2.2
FM4	Retail Floors to take applied screeds. Workshops and manufacturing facilities where MHE lift heights are restricted to 4 m.	10.0	2.4
FM5	General use floors - where surface regularity is less critical or achieving tighter tolerance controls is not practical – typically suspended concrete floors.	15.0	3.0

Notes:

1. The E (mm) and F (mm) values are the permissible 95th percentile limits for levelness and flatness respectively.
2. Specific properties may also be prescribed to meet individual project requirements.
3. The specification of F properties may be optional for some projects.
4. For suspended concrete floors, particularly composite slabs on metal decking, setting tight surface regularity requirements is often not practical and may come at considerable construction cost. If tight surface regularity requirements are essential (i.e. suspended slabs for use in storage facilities or supporting specialist equipment) it is recommended that this is considered at the outset of a project, obtaining appropriate input, to ensure the structure is designed and constructed with tight surface regularity requirements in mind. If tight tolerances for a suspended floor are required, the use of a levelling screed could also be considered.
5. Critical dimensions (e.g. minimum slab thickness) for achieving compliance with structural design requirements may govern and influence levelness.

METHODS FOR MEASURING SURFACE REGULARITY – FREE-MOVEMENT AREAS

In the suggested method for measuring flatness and levelness a 3 m grid of points is accurately set out on the whole of the floor area – see **Figure 2**. Elevation measurements are taken on or between these points. The grid location should be recorded accurately so that the points can be revisited if subsequent level checks are needed. Areas within 1.5 m of a wall, column or other structure should not typically be surveyed.

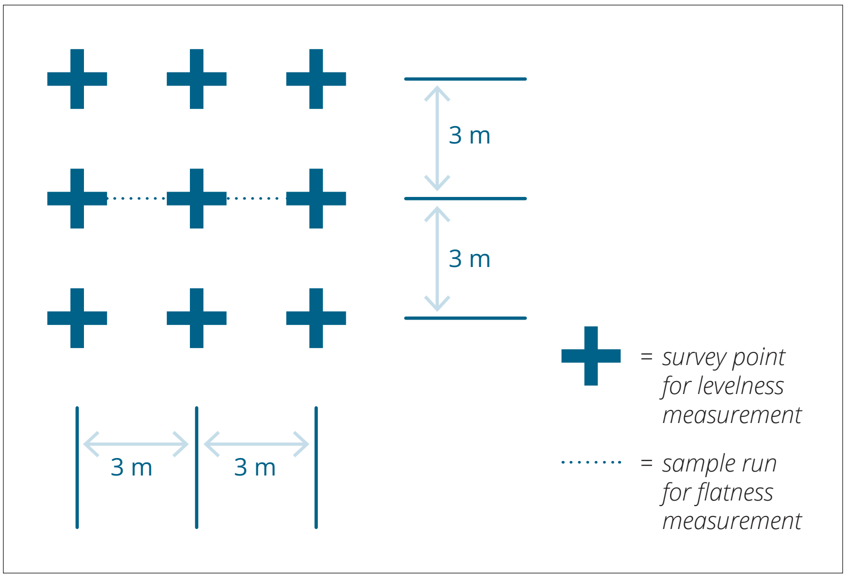

Figure 2: 3 metre grid set out for establishing surface regularity

Levelness (E) is measured between all adjacent survey points 3 m apart on the grid. Property E is the elevation difference (in mm) between adjacent survey points 3 m apart (not across the diagonals).

Flatness (F) is measured across a sample of the grid lines used to measure Levelness. The sample should consist of a minimum total length of survey runs in metres calculated as the floor area in square metres divided by 10. The runs should be distributed as evenly as practically possible over the entire slab to get a fair and even distribution of data. The individual lines can have different lengths as long as the cumulative lengths of the lines in each direction are within 5 percent of each other.

Property F is the change in elevational difference between two consecutive measurements of elevational difference, each measured over 300 mm – see **Figure 3**.

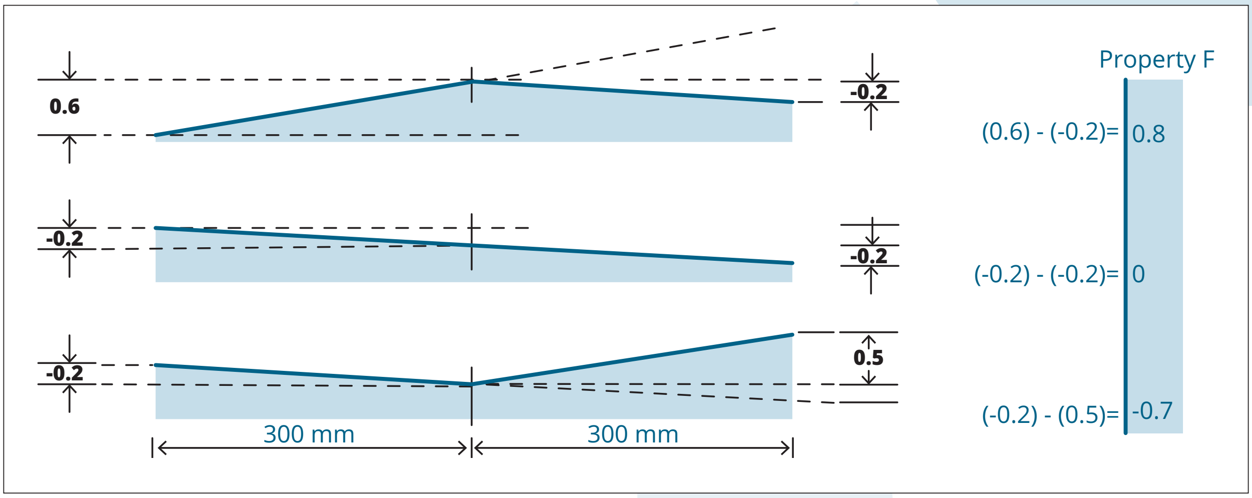

Figure 3: Examples of determining Property F elevational differences

SURVEYING REQUIREMENTS

Levelness and Flatness is measured using a precise level and staff, or other specialist digital equipment with appropriate accuracy.

All surveying instruments shall be calibrated to an accuracy of 0.2 mm and all survey data should be reported to 0.1 mm.

Surveys should be carried out within 28 days of pouring a floor, or major sections of it, to check that 'as-built' it complies with this technical specification.

For suspended floors, surface regularity measurements should be checked for compliance with this technical specification before propping is removed.

DATA ANALYSIS AND PERMISSIBLE LIMITS

Levelness (E) and Flatness (F) data should be analysed and the 95th percentile value is calculated.

Upper limits on the 95th percentile values for properties E and F are given in **Table 1**. The floor is non-compliant if:

- the maximum permitted 95th percentile value is exceeded.
- any point on the levelness survey grid is outside the ±15 mm of the determined floor datum.

For small floor areas (less than approximately 150 m^2 and/or generating less than 20 points) the small sample size may not provide reliable statistical data and judgement if compliance is achieved may need to be applied.

REPORTING

The 3 m grid layout should be shown in relation to the building set-out. The level of each grid point should be shown. The difference between each adjacent grid point should be shown and the 95th percentile should be calculated from this data.

The location of the flatness runs should be shown and linked to the levelness grid. Flatness (F) values should be presented for each run and the 95th percentile should be calculated from this data.

ADDITIONAL CONSIDERATIONS

Where the required property limits are exceeded, it is recommended that individual measurements are examined in detail to determine the significance of any possible effect on the performance of a floor.

The specified limit may be relaxed subject to the interested parties being satisfied that equipment can be operated safely and the intended use of the floor is not adversely affected.

Settlement of ground supported slabs due to compression of the sub-grade under load with time can produce changes in level and surface regularity.

Deflection of suspended slabs under load with time can also cause changes in level and surface regularity.

It is recommended that surveys are carried out within one month of completing the whole floor, or major sections of it, to check flatness and levelness.

SURFACE REGULARITY REQUIREMENTS – DEFINED-MOVEMENT AREAS

Defined-movement is usually associated with very narrow aisles (VNAs). In these aisles, the surface regularity of the floor is a critical factor in the performance of the MHE.

If the precise positions of the aisles are not known at the time of floor construction, it is not appropriate to specify the surface regularity of the aisles as defined-movement areas.

The survey methods are applicable only to the MHE pathways and are not relevant to the areas of floor under the racking. Areas away from racking such as general goods movement/ loading/unloading areas should be regarded as free-movement areas.

Figure 4. shows the static lean and how the variation in floor level across an aisle between the wheel tracks of MHE is magnified at the top of the mast in direct proportion to its height. Variations in level also induce dynamic movements in the mast that can magnify the static lean.

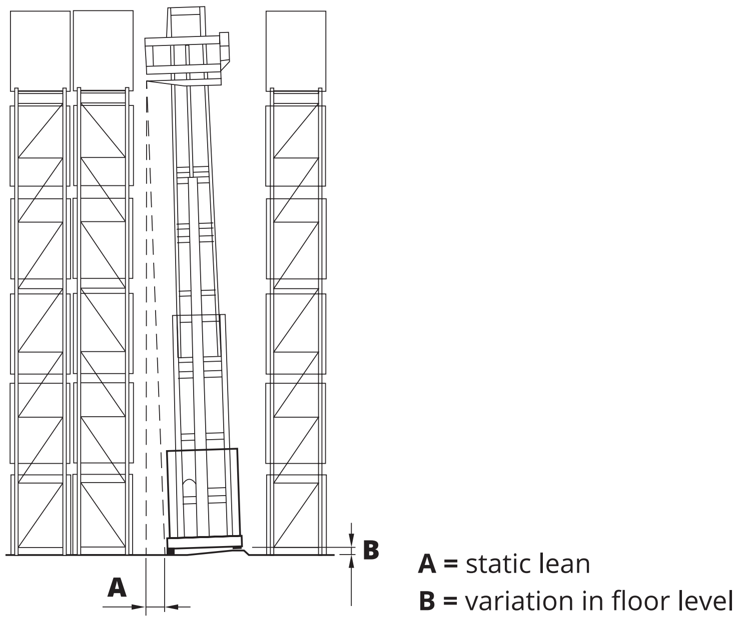

Figure 4: Static lean

The defined-movement specification appropriate for the racking top beam height needs to be specified. Classifications of floors based on racking top beam heights are given in **Table 2**.

*Table 2: Permissible limits on properties dZ, dX, d_2Z, d_2X in defined-movement areas. Refer to **Figures 5-7** for descriptions of properties.*

Floor Classification	Racking top beam height	Property Z_{SLOPE}	Property dZ	Property d_2Z	Property dX	Property d_2X
Calculation	-	mm per m	Z x Z_{SLOPE}	dZ x 0.75	Fixed values 2 x Z_{SLOPE} x 1.1	Fixed values
DM1	Over 13 m	1.3	Z x 1.3	Z x 1.0	2.9	1.5
DM2	8-13 m	2.0	Z x 2.0	Z x 1.5	4.4	2.0
DM3	Up to 8 m	2.5	Z x 2.5	Z x 1.9	5.5	2.5

METHODS FOR MEASURING SURFACE REGULARITY – DEFINED-MOVEMENT AREAS

SURVEYING TECHNIQUES

Aisles are surveyed over their full length along the wheel tracks of the MHE starting with the load axle at the first rack upright.

Properties dZ and dX are measured using specialist digital equipment, commonly known as profileographs. These produce continuous or semi-continuous data readings. Data readings should be taken at not greater than 50mm intervals. Properties d_2Z and d_2X are derived by computation of the data for Properties dZ and dX. Refer to **Figures 5-7.** illustrating the symbol and determination defined-movement properties and **Table 3** for definitions of properties.

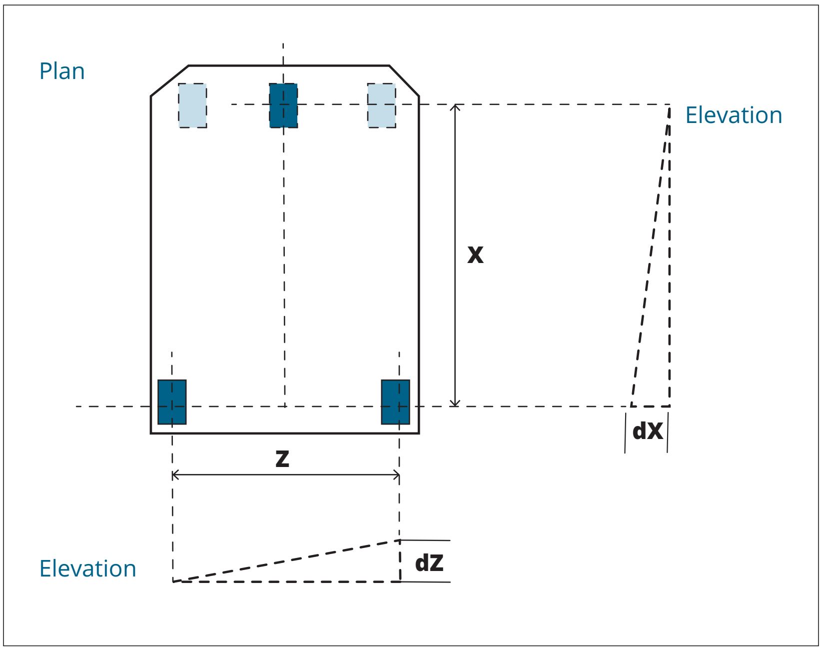

Figure 5: Symbols for dimensions

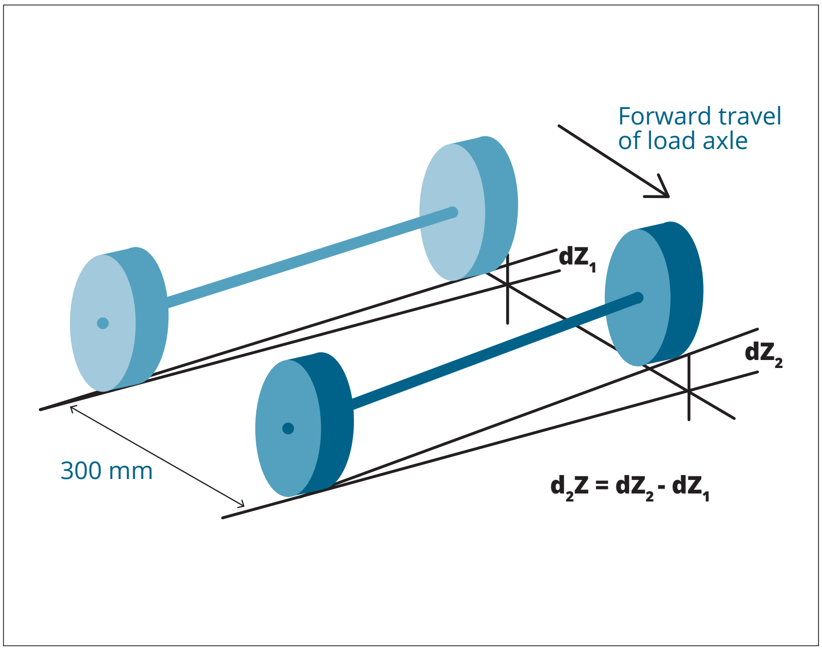

Figure 6: Determination of d_2Z

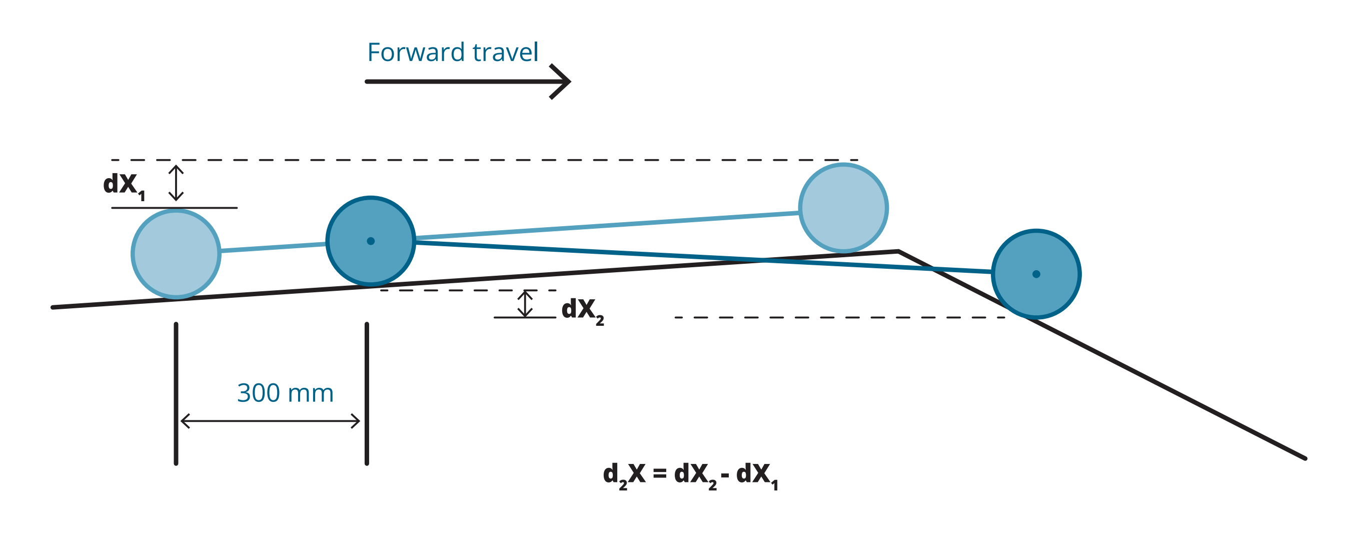

Figure 7: Determination of d_2X

Table 3: Defined-movement properties

Property Z	the transverse dimension between the centres of the MHE front wheels, in m
Property X	the longitudinal dimension between the centre of the front and rear MHE axles, in m
Property Z_{SLOPE}	the cross-aisle slope between the centres of the MHE front wheels in mm/m
Property dZ	the elevational difference in mm between the centres of the MHE front wheels
Property dX	the elevational difference in mm between the centre of the front axle and the centre of the rear axle
Property d_2Z	the change in dZ mm over a forward movement over 300 mm along the wheel tracks
Property d_2X	the change in dX mm over a forward movement over 300 mm along the wheel tracks

DATA ANALYSIS AND PERMISSIBLE LIMITS

The survey data are analysed and compared with the permissible limits for properties dZ, dX, d_2Z and d_2X as given in **Table 2**. The floor is non-compliant if any measurement in any aisle exceeds any permissable limit.

REPORTING

Data are typically presented graphically and should be in relation to the building layout. Summary data should be provided for each aisle with non-compliances highlighted.

REMEDIATION

Where limits are exceeded, it may be possible to grind the high areas of the surface or to fill the low areas of the surface. If wheel tracks have been ground or filled, the wheels should be in full contact with the floor surface so that no transverse thrust or other stresses on wheels are created. Grinding and filling may affect the appearance of the floor.

REFERENCES

The requirements in this document take into account provisions contained in the documents listed below.

The Concrete Society, *TR 34 Concrete industrial ground floors: A guide to design and construction,* Fourth edition, 2013.

The Concrete Society, *TR 75 Composite concrete slabs using steel decking,* 2016.

EN 15620 *Steel static storage systems. Adjustable pallet racking. Tolerances, deformations and clearances,* BSI, London, 2008.

The Concrete Centre, *National structural concrete specification for building construction,* Camberly, 2010.

MCRMA, *Composite slabs and beams using steel decking using steel decking; best practice for design and construction,* Technical Paper No. 13/SCI P300, Prenton Merseyside 2009.

Cement Concrete & Aggregates Australia, *Tolerances for concrete surfaces,* 2018.

ACKNOWLEDGEMENTS

Concrete NZ would like to thank The Concrete Society (UK) who have permitted reproduction of material provided in this technical specification.


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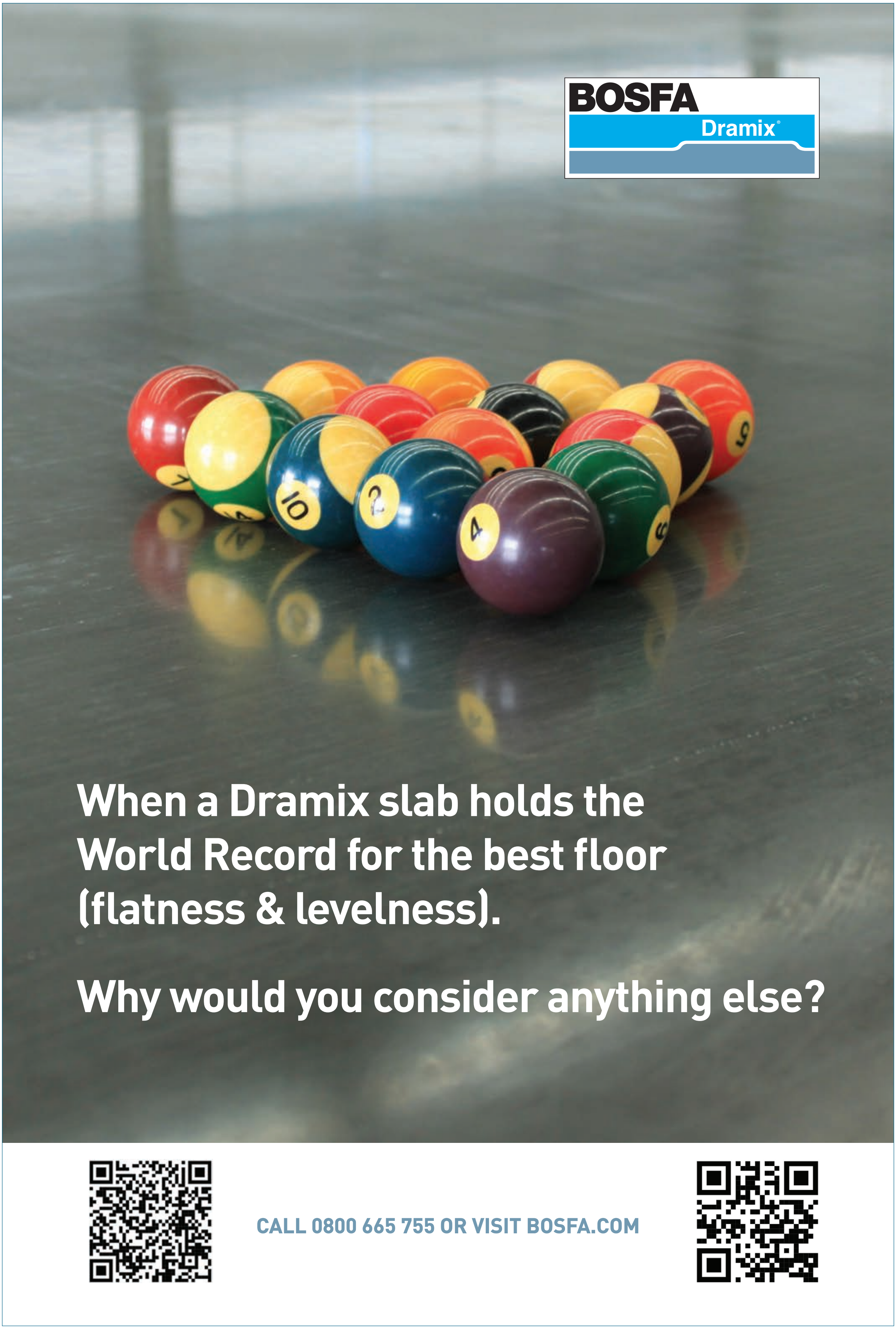
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