

# High-stress ceramic floor coverings

## 1. Introduction

The physical properties of ceramic tiles and slabs make them ideal for areas which are subject to severe mechanical or abrasive stress.

## 2. Stress factors and requirements

### 2.1 Stress factors

Floor coverings are subject to mechanical stress resulting from stationary loads caused by items of furniture, machines, etc. or from nonstationary loads induced by walking or driving over the floor surfaces. While stationary mechanical stress is not generally problematic and doesn't impose special requirements on the ceramic surface, nonstationary loads resulting from MOVING VEHICLES must receive due consideration during the planning stage. Floor coverings which are exposed to stress as a result of transport operations with industrial trucks or vehicles imposing a similar load, such as occur at food retail stores or wholesale centres, do-it-yourself stores, other commercial premises, canteens, production plants, etc. are to be regarded as being subject to high levels of mechanical stress.

The traffic frequency does not constitute a key criterion here (a vehicle passing over a floor only once may be sufficient to cause damage, if the floor covering was not designed for the imposed load).

Regulations and guidelines for floor coverings subject to high levels of mechanical stress are contained in specifications issued by the „Fachverband des Deutschen Fliesengewerbes“ („German tiling association“) at the central association of the German building industry (ZDB), the industrial association „Keramische Fliesen und Platten“ e.V. („Ceramic tiles and slabs“) and the „Arbeitsgemeinschaft für Industriebau“ („Study group for industrial construction“).

The pressures imposed on floor coverings by industrial transport vehicles depend on the type of vehicle, the wheel forces and the roller materials.

Depending on these factors, pressures within a range from 0.7 to 150 N/mm<sup>2</sup> apply.

Steel and polyamide rollers should be avoided as a general principle. This restricts the pressures to the range < 6 N/mm<sup>2</sup>, with a corresponding reduction in the risk of damage.

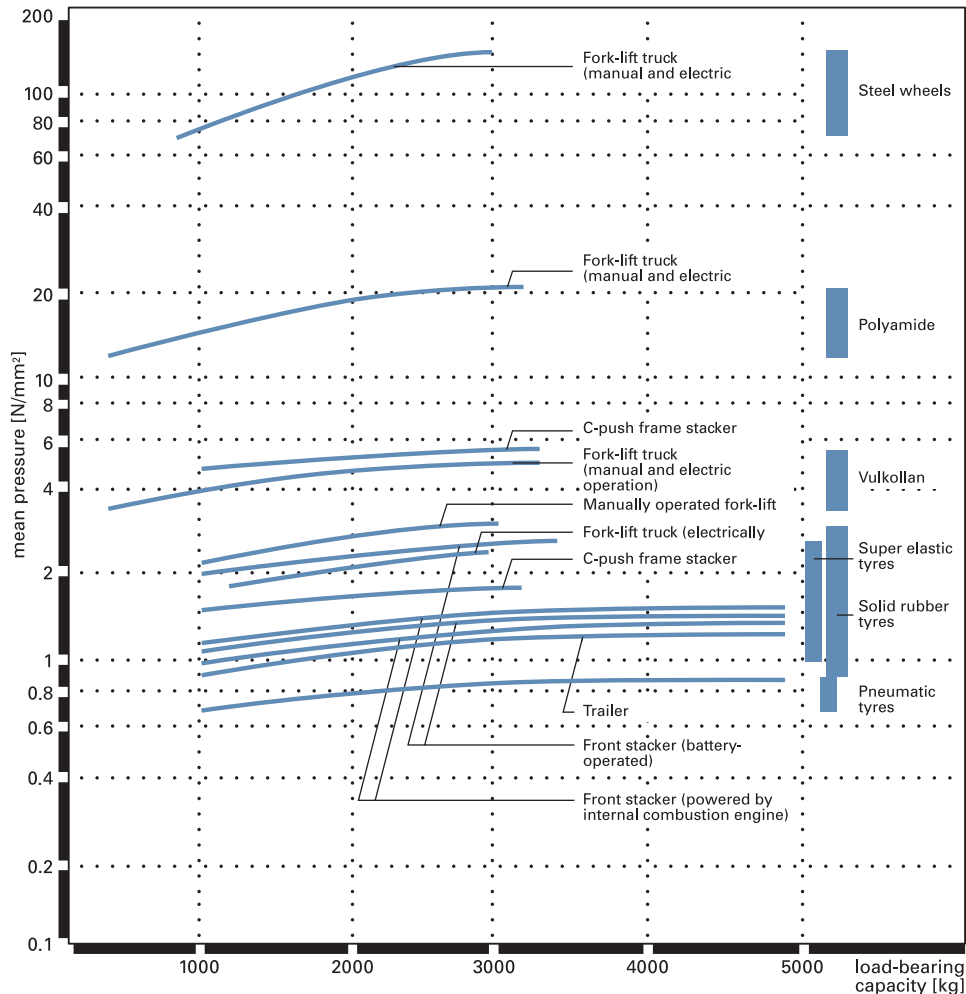


Figure 1: Mean pressure in N/mm<sup>2</sup> imposed by transport vehicles as a function of load-bearing capacity and type of roller material.

## 2.2 Requirements for ceramic coverings

Ceramic coverings in areas subject to high levels of mechanical stress are to be planned with due consideration to the attendant requirements and the expected stress levels. According to the ZDB specification [8], the following are suitable as ceramic covering materials:

- Dry-pressed ceramic tiles and slabs in accordance with EN 14411 [3] - Group B
- Extruded ceramic tiles and slabs in accordance with EN 14411 [3] - Group A

They should fulfil the following conditions:

- Side length of tiles and slabs between 8 and 30 cm
- Breaking force, F, in accordance with the stress group

The breaking force, F, of a tile or slab, which is defined as a measured quantity when determining the flexural strength in accordance with DIN EN ISO 10545-4 [1], incorporates the most important influencing factors of flexural tensile strength and thickness and is:

- linearly dependent on the flexural tensile strength,  $\beta$ , in N/mm<sup>2</sup>;
- dependent on the square of the thickness, h, in mm;
- independent of the format when square formats apply.

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When the flexural tensile strength of the tiles or slabs is known, the breaking force can be established by means of the following formula:

$$\text{Breaking force } F \text{ (N)} = 2 \times \beta \times h^2 \times b / 3 \times L$$

In which:

- $\beta$  flexural tensile strength of the tile or slab in N/mm<sup>2</sup>  
Minimum flexural tensile strengths:  
Split tiles in acc. with EN 14411 – Group A I  $\geq 23$  N/mm<sup>2</sup>  
Tiles in acc. with EN 14411 – Group B Ia  $\geq 35$  N/mm<sup>2</sup>  
Tiles in acc. with EN 14411 – Group B Ib  $\geq 30$  N/mm<sup>2</sup>
- h Tile or slab thickness in mm
- b Tile or slab width in mm;
- L Tile or slab length in mm

Figure 3 shows the breaking force, F, as a function of the tile and slab thicknesses and the actual flexural tensile strengths. Tiles or slabs with a greater breaking force, F, reduce the risk of damage.

### 3. Installation

The tiles and slabs are laid according to the thin-bed method in accordance with DIN 18157, Part 1 <5>, generally with hydraulic thin-bed mortars in acc. with EN 12004 [2] Class C2TE - on a previously produced cement floor of strength class CT-C25-F4 at least.

Cavities should be largely avoided when laying tiles and slabs. This can be achieved by means of the „combined method“ in accordance with DIN 18157 [5], Part 1, point 7.3.3, or by using the so-called „floating method“.

In order to produce composite flooring and coverings on separating or insulating layers, tiles may also be laid according to the thick-bed or „vibration method“ AK-QR [9].

With due regard to the tolerances of the tiles or slabs, the minimum possible joint widths are recommended. Height offsets and „projecting teeth“ should be avoided. Jointing is generally carried out with hydraulic jointing mortar; in the case of floor coverings which are additionally subject to chemical stress, e.g. in canteens or plants in the food industry, it may be necessary to carry out jointing with cold-curing resin jointing compounds, e.g. epoxy resin-based compounds.

#### References:

- [1] **DIN-EN ISO 10545-4** Ceramic tiles – Determination of modulus of rupture and breaking strength
- [2] **EN 12004** Adhesives for tiles – Definitions and specifications
- [3] **EN 14411** Ceramic tiles - Definitions, classification, characteristics and marking
- [4] **DIN 18 156** „Stoffe für keramische Bekleidungen im Dünnbettverfahren“- Teil 1: „Begriffe und Grundlagen“ / Teil 2: „Hydraulisch erhärtende Dünnbettmörtel“ / Teil 4: „Epoxydharzklebstoffe“ (Materials for ceramic coverings according to the thin-bed method) - Part 1: „Terminology and fundamentals“ / Part 2: „Hydraulically setting thin-bed mortars“ / Part 4: „Epoxy resin adhesives“)
- [5] **DIN 18 157** „Ausführung keramischer Bekleidungen im Dünnbettverfahren“ Teil 1: „Hydraulisch erhärtende Dünnbettmörtel“ / Teil 3: „Epoxydharzklebstoffe“ (Production of ceramic coverings according to the thin-bed method Part 1: „Hydraulically setting thin-bed mortars“ / Part 3: „Epoxy resin adhesives“)
- [6] **DIN 18560** Estriche im Bauwesen (Screeds for construction applications)
- [7] **Autenrieth** Bestimmung der Widerstandsfähigkeit von Industrie-Estrichen gegen mechanische Beanspruchung durch Flurfördermittel („Determination of the resistance of industrial screeds to mechanical stress imposed by industrial trucks“)
- [8] **ZDB-Merkblatt** Mechanisch hoch belastbare keramische Beläge („Hard-wearing ceramic coverings“)
- [9] **AK-QR** Verarbeitungsrichtlinien – Herstellung keramischer Bodenbeläge im Rüttelverfahren (Guidelines – Production of ceramic floor coverings according to the vibration method)

| Stress group | Breaking force F (N)EN ISO 10545-4 | Areas of application<br>Mechanical stress  |
|--------------|------------------------------------|--|
| I            | < 1,500                            | Private homes and floor coverings subject to similar mechanical stress, e.g. hotel bathrooms, health-sector premises   |
| II           | 1,500 – 3,000                      | Administrative, commercial and industrial premises (suitable for pneumatic-tyred vehicles), e.g. industrial kitchens, canteens, traffic zones, car showrooms and maintenance rooms, sales rooms, in each case without industrial trucks<br><b>Pressure up to 2 N/mm<sup>2</sup></b>    |
| III          | 3,000 – 5,000                      | Commercial and industrial premises (industrial trucks with Superlastik, solid rubber and Vulkolan tyres), e.g. in the food retail and wholesale sector, non-food, general retailing and wholesale, shopping arcades<br><b>Pressures of 2 to 6 N/mm<sup>2</sup></b>                     |
| IIII         | 5,000 – 8,000                      | Commercial and industrial premises; areas of application as for group III, but traversable with polyamide rollers<br><b>Pressures of 6 to 20 N/mm<sup>2</sup></b>  |
| V            | > 8,000                            | Commercial and industrial premises; heavy-duty areas used by industrial trucks with polyamide rollers. Rolling of metal parts, e.g. production, assembly and storage facilities, repair workshops for machinery and heavy-duty equipment<br><b>Pressures up to 20 N/mm<sup>2</sup></b> |

Figure 2: Classification of groups according to mechanical stress

| Stress group | Thick ness (mm) | Breaking force F (N)  |        |        |        |        |       |        |        |        |
|--------------|-----------------|---|--------|--------|--------|--------|-------|--------|--------|--------|
|              |                 | Porcelain stoneware tiles in acc. with EN 14411 Group B Ia – E $\leq 0,5\%$ (square format)<br>Flexural strength in N/mm <sup>2</sup> |        |        |        |        |       |        |        |        |
|              |                 | 27  | 32     | 37     | 42     | 47     | 52    | 57     | 62     | 69     |
| I            | 6.00            | 722   | 855    | 989    | 1,123  | 1,256  | 1,390 | 1,523  | 1,657  | 1,844  |
|              | 7.00            | 982   | 1,164  | 1,346  | 1,528  | 1,710  | 1,892 | 2,074  | 2,255  | 2,417  |
|              | 8.00            | 1,283   | 1,520  | 1,758  | 1,996  | 2,233  | 2,471 | 2,708  | 2,946  | 3,157  |
|              | 8.50            | 1,448   | 1,716  | 1,985  | 2,253  | 2,521  | 2,789 | 3,057  | 3,326  | 3,564  |
| II           | 9.00            | 1,624   | 1,924  | 2,225  | 2,526  | 2,826  | 3,127 | 3,428  | 3,728  | 3,996  |
|              | 9.50            | 1,809   | 2,144  | 2,479  | 2,814  | 3,149  | 3,484 | 3,819  | 4,154  | 4,452  |
|              | 10.00           | 2,005   | 2,376  | 2,747  | 3,118  | 3,489  | 3,861 | 4,232  | 4,603  | 4,933  |
|              | 10.50           | 2,210   | 2,619  | 3,029  | 3,438  | 3,847  | 4,256 | 4,666  | 5,075  | 5,439  |
|              | 11.00           | 2,426   | 2,875  | 3,324  | 3,773  | 4,222  | 4,671 | 5,121  | 5,570  | 5,969  |
|              | 11.50           | 2,651   | 3,142  | 3,633  | 4,124  | 4,615  | 5,106 | 5,597  | 6,088  | 6,524  |
| III          | 12.00           | 2,887   | 3,421  | 3,956  | 4,490  | 5,025  | 5,559 | 6,094  | 6,628  | 7,104  |
|              | 12.50           | 3,132   | 3,712  | 4,292  | 4,872  | 5,452  | 6,032 | 6,612  | 7,192  | 7,708  |
|              | 13.00           | 3,388   | 4,015  | 4,642  | 5,270  | 5,897  | 6,524 | 7,152  | 7,779  | 8,337  |
|              | 13.50           | 3,653   | 4,330  | 5,006  | 5,683  | 6,359  | 7,036 | 7,712  | 8,389  | 8,991  |
| IV           | 14.00           | 3,929   | 4,656  | 5,384  | 6,112  | 6,839  | 7,567 | 8,294  | 9,022  | 9,669  |
|              | 16.00           | 5,132   | 6,082  | 7,032  | 7,983  | 8,933  | 9,883 | 10,833 | 11,784 | 12,629 |
| V            | 18.00           | 6,495   | 7,697  | 8,900  | 10,103 | 11,306 | -     | -      | -      | -      |
|              | 20.00           | 8,018   | 9,503  | 10,988 | 12,473 | -      | -     | -      | -      | -      |
|              | 22.00           | 9,702   | 11,499 | 13,295 | 15,092 | -      | -     | -      | -      | -      |
|              | 24.00           | 11,546  | 13,684 | 15,823 | 17,961 | -      | -     | -      | -      | -      |

Figure 3: Breaking force, F, of tiles according to thickness and flexural strength