APPENDIX

APPENDIX 1

EN ISO 10545 - Part 1
Ceramic tiles
Sampling and basis for acceptance

❑ This standard applies to uninstalled ceramic tiles. It establishes the rules for the composition of a sample lot.

❑ The lot must consist of tiles produced under conditions and with properties that are assumed to be uniform. Thus every consignment, that is every quantity of tiles delivered within two days, must be divided into sub-consignments that are assumed to be homogeneous and can thus constitute inspection lots.

❑ The number of lots to be inspected and the choice of properties to be considered for inspection will be subject to agreement between supplier and consumer, as will be the choice of location where the sampling will be performed.

❑ The sampling will be performed by randomly taking samples from the inspection lot. Usually two samples are taken. Every sample must be packed, sealed and labelled.

❑ Every property will be assigned a "sample size", or a minimum number of tiles to be inspected as noted in a table, together with the basis of acceptance or rejection.

❑ Tests on the sample tiles must be performed according to the methods specified in the corresponding standards.

In regard to the preceding European Standards (EN163), the table setting forth the standards of acceptance and rejection has been modified to take into account:

❑ new added testing methods, and an eliminated method;

❑ modifications in product requirements: for all requirements which are not obligatory but which must be declared by the manufacturer, the table specifies that the basis for acceptance or rejection depends on the conformity (or lack thereof) with the manufacturer's declaration.

EN ISO 10545 - Part 2
Determination of dimensions and surface quality

❑ Method applicable to all ceramic tiles.

❑ For all measurements, 10 whole tiles are required.

❑ Instruments include vernier calipers, micrometer, screw gauges or other suitable apparatus. Tiles with surfaces of less than 4 cm^2 are excluded from all measurements other than thickness.

Measurement (Fig.1)

❑ Measurement of length and width. Each side of the tile must be measured 5 mm away from the corners. The average dimension of a square tile consists in the average of 4 measurements and the average size of the sample consists in the average of 40 measurements.

The average length and width of an oblong tile consists in the average of the measurements of two opposite sides, so that the average length and width of the sample consist in the average of twenty measurements of each dimension.

❑ Measurement of thickness. Thickness is measured by first tracing the two diagonals, then measuring the thickest point along each of the four segments obtained. In the case of extruded tiles, four lines perpendicular to the direction of extrusion are traced, and the thickness is measured at the thickest point on each line.

❑ Measurement of straightness of sides. The deviation from straightness of a side is measured at the center of that side, and the measurement must be taken for every side of every single tile.

❑ Measurement of rectangularity. This consists in the deviation of the outer corner of the side of the tile (5 mm from the corner) from the inner side of the calibrating plate. Deviation from rectangularity is expressed, in percentage terms, by the formula: $\delta/\mathbf{L} \cdot \mathbf{100}$ where **L** is the length of the adjacent side of the tile.

❑ Measurements of surface flatness. Surface flatness is defined by the 3 measurements described below which, for tiles smaller than 40 x 40 mm, are taken with metal straight edges and thickness feeler gauges.

• *Center curvature*: the departure of the center of the tile from the plane in which 3 of the 4 corners lie. For every tile, 4 measurements are taken. The maximum center curvature is expressed in mm or as a percentage relative to the diagonal calculated from the work size.

• *Edge curvature*: the departure of the center of a tile from the plane in which 3 of the 4 corners lie. The maximum edge curvature is expressed in mm or as a percentage of the relative work size.

• *Warpage*: the departure of the fourth corner of tile from the plane in which the other three angles lie.

The maximum warpage is expressed in mm or as a percentage of the diagonal calculated on the basis of the work size.

❑ Surface quality. This assessment requires a surface of at least 1 square meter and a minimum of 25 tiles.

The tiles must be placed under a light source of 300 lux and observed with the naked eye from a distance of one meter.

The quality of the surface is expressed as a percentage of tiles without defect.

Intentional surface effects must not be considered defects (see corresponding paragraph under product standards); cracks, nipped edges and nipped corners can not be considered intentional effects.

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EN ISO 10545 - Part 3
Determination of water absorption, apparent porosity, apparent relative density and bulk density

❑ Method applicable to all ceramic tiles.

❑ The test must be performed on 10 whole tiles in cases where the surface of each tile is less than 0.04 m^2; if greater than 0.04 m^2, 5 tiles will suffice. In any case, every test sample must weigh a minimum of 50 g.

❑ After tiles are brought to a constant weight through drying, they are weighed with a precision which depends on the weight of the tile. Tiles are then placed to be boiled in a container of distilled or de-ionized water, in such a way that they do not touch the bottom and are completely immersed. Container should be kept at boiling point for two hours. Then tiles should be left cooling for four hours immersed in water. Once the tiles have been removed from the container, excess water is removed with a chamois leather and tiles are then weighed, again as precisely as for dry weight.

❑ The absorption of water, expressed as a percentage of the weight of the dry material, is expressed in the formula:

$$[(m_2 - m_1)x100] / m_1$$

where:

m_1 = the mass of the dry tile

m_2 = the mass of the wet tile.

The average absorption of water of the sample is determined by the arithmetic average of the individual results, and results must be rounded off to a single decimal place.

The determination of water absorption, which is required for a product's assignment to a group, remains the same as that stipulated by the European Standards (EN 99); other properties have also been added for which no requirement exists (that is, these properties are not considered in the sections on product requirements) but which may be useful in typifying the structure of the tile's ceramic mass: for theses properties, water absorption is measured through water impregnation at a residual pressure of 100 ±1 kPa for 30 min.

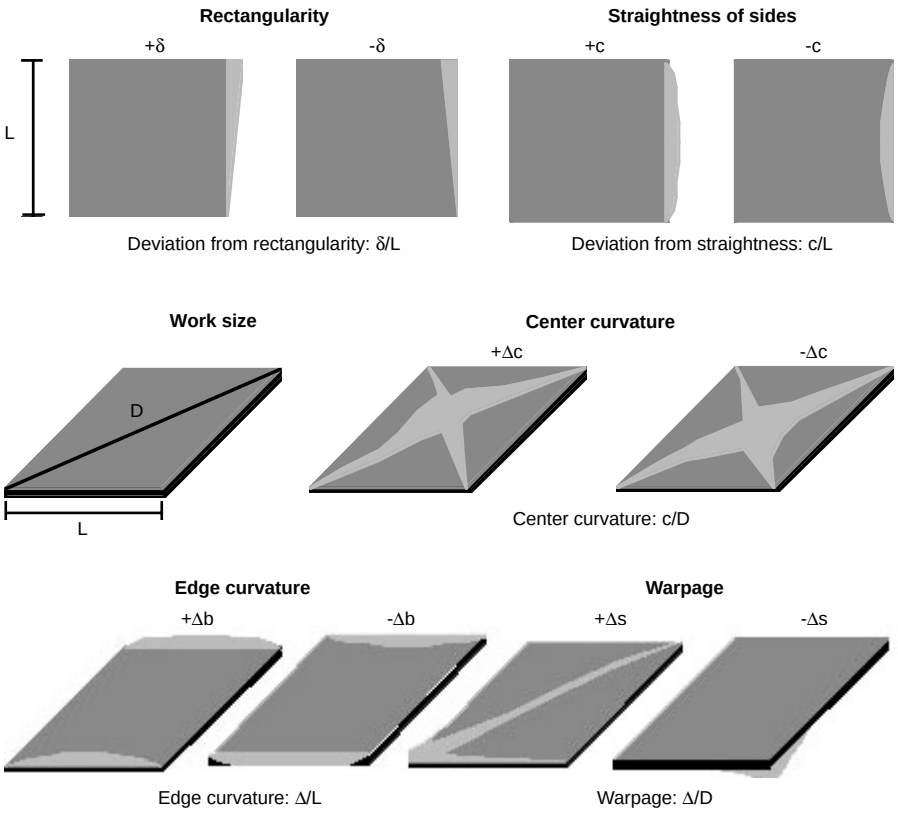

Fig. 1 Scheme of dimensional properties.

EN ISO 10545 - Part 4
Determination of modulus of rupture and breaking strength

❑ Method applicable to all ceramic tiles.

❑ The test must be performed on whole tiles whose number depends on the size of the tiles (Table 1). Only exceptionally large tiles, or tiles whose shapes make it impossible to insert them in the apparatus, may be cut.

❑ The tile is placed on two supporting rods with the proper surface uppermost (Fig.2) so that it protrudes by the length **1** beyond each supporting rod. The load is applied evenly at a constant rate of increase of stress (1 N/mm^2 s) by means of a third rod in contact with the proper surface, equidistant between the supporting rods. Extruded tiles must be so positioned that the direction of extrusion is perpendicular to the rods. For

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Table 1 Instrumental parameters for the measurement of modules of ruptures, according to the format of the tiles.

Dimension of tile (mm)	Diameter of rods, d (mm)	Thickness of rubber, t (mm)	Overlap of tile beyond the edge support, l (mm)	Minimum number of tiles for test
≥ 95	20	5	10	7
< 95 ≥ 48	10	2.5	5	7
< 48 ≥18	5	1	2	10

rectangular tiles, the longer side must be perpendicular to the support rods.

❑ The resistance to bending σ, expressed as N / mm^2, is given by the formula

$$\sigma = \frac{3FL}{2bh^2}$$

where :

F = breaking load (in N)

L = span between the supporting rods (in mm)

b = width of the tile at the broken edge (in mm)

h = minimum thickness of the tile (in mm) measured along the broken edge.

The average resistance to bending of the sample is the arithmetic average of the individual results.

The test method is the same as that described in the preceding European Standards (EN 100: the so-called "three-point method"). An important modification has been introduced: the test report must note not only the load F required to break the sample and the modulus of rupture from bending, but also the "breaking strength calculated S". The modulus of rupture σ is undoubtedly an important parameter, but it refers to an intrinsic property of ceramic material: in physical terms, it represents work per unit of volume, a value that may be useful for the specifier but that gives no information on the maximum load that a tile can bear. This last parameter depends on the dimensions of the sample: in fact, given the same level of water absorption (and thus the same intrinsic properties of the material), the value of the modulus of rupture from bending σ is the same, but the force F required to break the sample varies depending on the dimensions of the sample itself. Strictly speaking, then, within each group as defined in the product standards, different requisites would have to be established depending on tile format σ a virtually impossible enterprise. It was therefore decided to introduce a "recalculated breaking strength S ", obtained by multiplying the value of the force F (as read on the instrument) by the ratio between L (the distance between the supporting rods) and b (the width of the test sample). This makes it possible to obtain a value of the load which is independent of the format, and for which a requisite can be specified in the product standards.

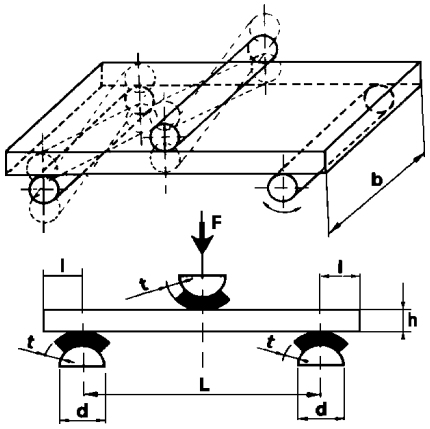

Fig. 2 Loading system in the measurement of modulus of rupture and breaking strength.

EN ISO 10545 - Part 5
Determination of impact resistance by measurement of coefficient of restitution

❑ Method applicable to all ceramic tiles.

❑ The test must be performed on at least five samples, sized 75 mm x 75 mm, cut from the tiles. The test samples are applied with a rigid epoxide resin adhesive to specially prepared blocks of conglomerate, sized 75 mm x 75 mm x 50.

❑ Testing apparatus (fig. 3) consists of:

• a steel ball with a diameter of (19 ± 0.05)mm;

• a device equipped with an electromagnet, and a guide tube to insure that the dropping steel ball falls on the center of the test sample which is placed on a rigid support;

• an (optional) electronic device that measures the time interval between the first and the second impact when the ball falls on the surface of the test sample.

❑ The sample is positioned horizontally on the instrument with the surface under the electromagnet so that when the ball is released from a height of 1 meter it hits it in the center. The height of the rebound is measured, or, alternately, the interval of time between two successive rebounds. Any damage visible from the distance of 1 meter must be noted, but may be ignored in classyfing tiles.

❑ The coefficient of restitution (e) is calculated using different formulas depending on the type of measurement selected (time or height).

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The test is recommended for tiles to be used in floors where impact resistance is considered especially important. A coefficient of restitution with a value of 0.55 is considered sufficient for normal low-stress levels of use; higher values are required in cases where greater stress is anticipated.

EN ISO 10545 - Part 6
Determination of resistance to deep abrasion. Unglazed tiles

❑ Method applicable to all unglazed ceramic tiles.

❑ The test must be performed on whole tiles or on samples of sufficient dimensions; at least 5 per type are required.

❑ The apparatus used, as illustrated in Fig. 4, consists of a rotating disk of standardized material and dimensions, a storage hopper equipped with a device for dispensing the abrasive material, and by a stand for the sample.

❑ The sample is placed on the instrument in such a way as to be tangential to the rotating disk, insuring that the abrasive material is uniformly dispensed (100 g / 100 revolutions).

After 150 rotations of the disk, the cord length of the groove made by the abrasive material is measured. The procedure must be performed on every sample in at least two different areas at right angles to each other.

❑ Resistance to deep abrasion is given by the expression:

$$V = \left(\frac{\pi\alpha}{180} - \sin\alpha\right)\frac{hd^2}{8}$$

where:

V = the volume of material removed (mm^3)

$\sin \alpha/2 = l/d$

d = diameter of the rotating disk (mm)

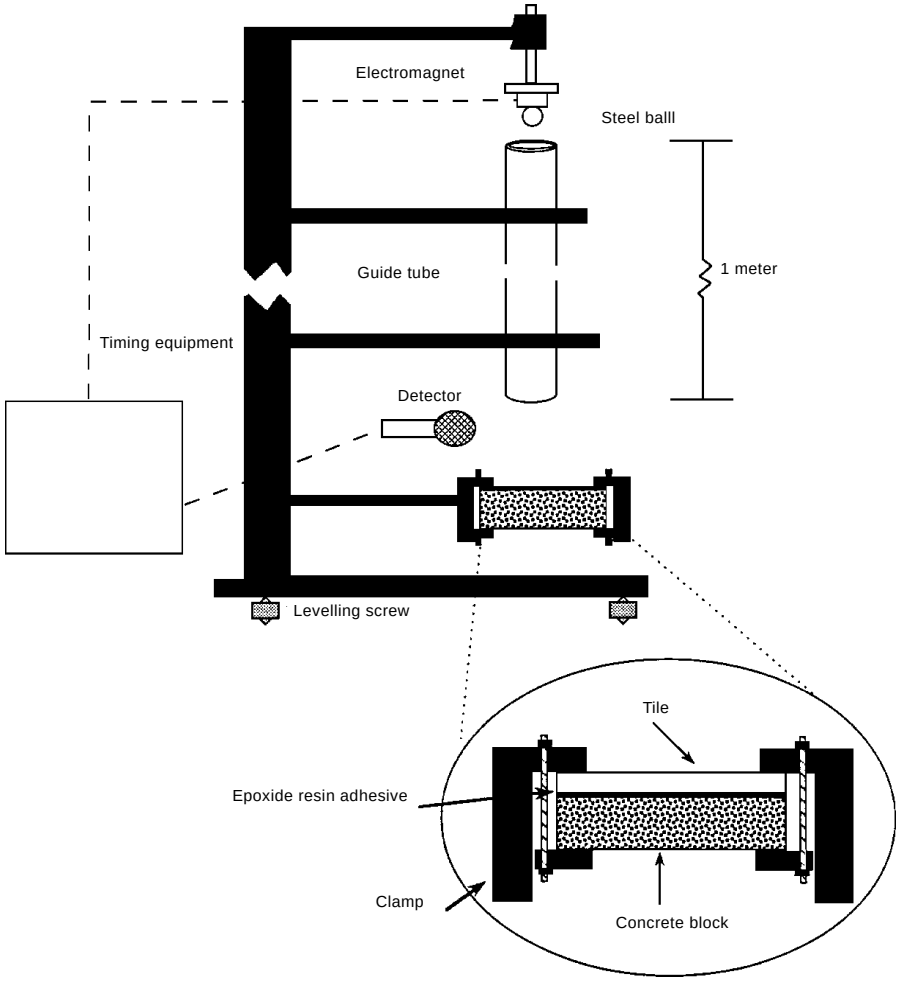

Fig. 3
Scheme of the measuring system of coefficient of restitution.

h = thickness of the rotating disk (mm)

l = lenghts of the chord

α = angle subtended at the center of the disk by the chord (in degrees).

The test method and the expression of the results are the same as those reported in the preceding European Standards (EN 102).

Only one modification was introduced, regarding the material to be used for the calibration of the instrument: rather than “Standard Austrian Granite” (a natural material that is difficult to obtain and of indefinite compositional properties), it was decided to make the primary standard a synthetic material, transparent fused silica, whose properties are well-known and clearly defined.

The procedure of calibration remains unchanged.

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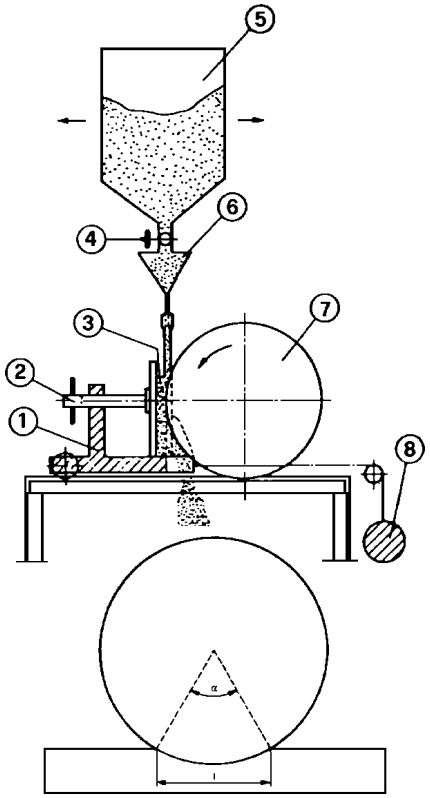


Fig. 4
Outline of abrasion measuring instrument for unglazed tiles.

1. Sample clamp.
2. Blocking screw.
3. Test sample.
4. Valve.
5. Feed fox for abrasive material.
6. Steady flow funnel.
7. Steel disc.
8. Counterweight.

EN ISO 10545 - Part 7
Determination of surface abrasion resistance of glazed tiles

❑ Method applicable to all glazed ceramic floor tiles.

❑ The testing apparatus is illustrated in Fig. 5.

❑ The abrasive load consists of steel balls of various diameters, white aluminum oxide F80 and water.

❑ The test must be performed on eleven samples of 100 mm x 100 mm, cut out of the tiles in such a way as to include the different colors and decorations that may be present in the proper surface.

❑ The number of revolutions for every stage of abrasion is: 100, 150, 600, 750, 1,500, 2,100, 6,000, and 12,000.

❑ After the abrasion, samples are rinsed, dried and placed under a light source (Fig. 6) capable of lighting the surface of the samples with an intensity of 300 lux: a test sample is determined to have not resisted a certain stage of abrasion when the area subjected to wear is clearly distinguishable. The classification system is set forth in Table 2.

Tiles whose abraded surface can still, after 12,000 revolutions of abrasion, be considered cleanable if subjected to the stain resistance test according to EN ISO 10.545 - Part 14, are considered to be in class 5.

After the "wet" test method (or so-called "PEI method") described in the preceding UNI EN 154 standard was chosen, the dry method (called MCC) disappeared. The monitoring system has been improved. Samples to be observed are placed in a box 61 cm wide (Fig.6), its interior painted a neutral gray (to prevent unwanted reflections); the light source, with color temperature of between 6000 and 6500 K (temperature is linked to wave length, and thus to the light's color) must be screened and there must be 300 lux on the sample to be observed. The major modifications regard classification:

❑ a "zero class" has been introduced: tiles for covering floors must withstand (that is, not show signs of abrasion from) at least 100 revolutions; otherwise, they must be considered wall tiles;

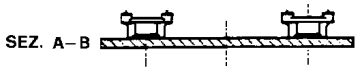
❑ the number of stages for each class of abrasion has been reduced in order to simplify test procedures, without depriving them of meaning;

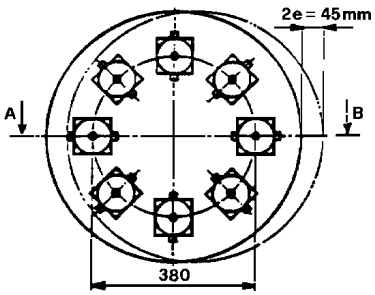
❑ a "class 5" of resistance has been added, to distinguish the new types of products that are usually described as "highly resistant." The definition of this new class of resistance considers resistance to abrasion not a sufficient condition, especially considering the severe conditions of use to which these tiles could be subjected; practically speaking, a surface's good mechanical resistance must be combined to a good resistance to stains. Thus the new definition takes into account both product innovations (the production of "technical" materials with great surface resistance) and also the consumer's need for a product that not only does not deteriorate aesthetically, but is also practical in its cleanability (that is, ease stain removal) and easy maintenance.

EN ISO 10545 – Part 8
Ceramic tiles
Determination of linear thermal expansion

❑ Method applicable to all ceramic tiles.

❑ To perform the test, two perpendicular





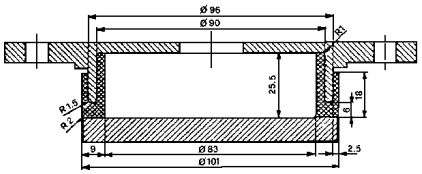


Fig. 5
Outline of abrasion measuring instrument for glazed tiles (PEI method).

samples must be cut from the center area of the tile. The length of the samples must be suitable to the measuring apparatus; the area of the cross-section must be greater than 10 mm^2 and the length of any side in cross-section must be less than 6 mm. In the case of glazed tiles, the glaze must be removed.

❑ After the samples are dried, their length is measured at room temperature with cursor calipers / gauge.

Every test sample is placed in an instrument capable of raising the temperature by 5 °C / min. Initially and throughout the heating procedure, the length of the sample is measured.

❑ The coefficient of linear thermal expansion (α) is expressed to the first decimal place x 10^{-6} per degree Celsius according to the formula:

$$\alpha = \frac{1}{L_o} x \frac{\Delta L}{\Delta t}$$

where:

L_o = sample length at room temperature

ΔL = increase in length of test sample

Δt = rise in temperature

EN ISO 10545 - Part 9
Ceramic tiles
Determination of resistance to thermal shock

❑ Method applicable to all ceramic tiles under normal conditions of use.

❑ Test must be performed on at least 5 tiles free from defects at the beginning of the test.

❑ The procedure consists in cycling sample tiles ten times between the temperature of cold water and a temperature slightly higher than that of boiling water, generally between 15 and 145 °C. For tiles with a water absorption of under 10%, the lowest temperature is reached by means of the total immersion of the tiles in an uncovered bath with a water temperature of 15 °C. In case of tiles with a water absorption higher than 10%, the water bath must be covered with an aluminum plate on which a layer of aluminum grains is placed; the glazed surface of the tiles must be placed in contact with this layer.

❑ In both cases, after 5 minutes at the low temperature, samples must be placed in an oven at 145 °C for about 20 minutes and then immediately transferred back to the low temperature conditions.

❑ At the end of 10 cycles, the samples are examined for visible defects.

EN ISO 10545 - Part 10
Ceramic tiles
Determination of moisture expansion

❑ Test method applicable to all ceramic tiles.

❑ 7 whole tiles are needed to perform the test. From the center of each tile, a specimen at most 10 cm long and 3.5 cm wide is cut. In the case of extruded tiles, the length of the test specimen must be in the direction of the extrusion.

❑ Specimens are refired in a kiln at 550 °C. and then returned to room temperature.

❑ The length of each specimen is determined with a micrometer, using reference bars of nickel steel (invar) of appropriate dimensions. This measurement is taken twice, at a 3-hour interval.

❑ Specimens are immersed in boiling water for 24 hours, ensuring that the level of water is higher than the specimens by at least 5 cm and that the specimens do not touch each other.

❑ The specimens are removed from the water and allowed to cool for an hour, after which their length is measured twice, at a 3-hour interval.

Stage of abrasion visible damage (revolutions)	Class
100	0
150	1
600	2
750, 1500	3
2100, 6000, 12000	4
> 12000(1)	5

(1) Must pass the test indicated in ISO 10.545-14 for stain resistance.

Table 2
Classification of abrasion resistance of glazed tiles (PEI method).

❑ Moisture expansion measured in mm / m is expressed by the formula:

$$\frac{l}{L} x 100$$

where:

l = the difference between the average of the measures taken after the treatment with boiling water, and the average of the measures taken before such treatment (mm)

L = initial length (mm).

EN ISO 10545 - Part 11
Ceramic tiles
Determination of crazing resistance. Glazed tiles

❑ Method applicable to all glazed ceramic tiles except those where crazing is an inherent decorative feature of the product.

❑ The test is performed on at least 5 whole tiles that may be cut only if they are

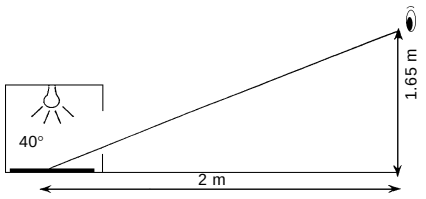


Fig. 6
Monitoring conditions of abrasion effects on glazed tiles (PEI method).

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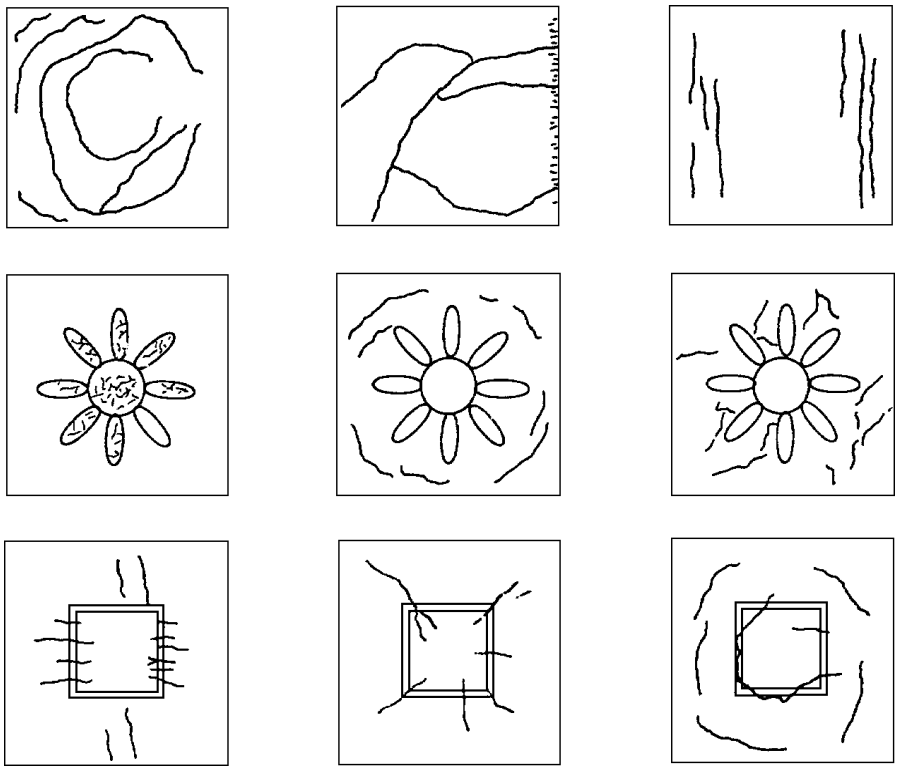

Fig. 7
Various types of crazing.

exceptionally large; at the start of the test, all samples must be free from crazes.

❑ Tiles are placed in a pressure-cooker, and pressure is raised gradually to 500 kPa (t=159 °C) and maintained at that level for 2 hours.

The pressure is then lowered as quickly as possible to room pressure and the tiles are allowed to cool, after which an aqueous solution of methylene blue is applied and then removed.

The purpose of this treatment is to make visible to the eye otherwise unperceivable crazing.

❑ The glazed surface of the tiles is examined for crazing, taking care to avoid confusing crazes with scratches, and disregarding cracks (Fig. 7).

EN ISO 10545 - Part 12
Ceramic tiles
Determination of frost resistance

❑ Method applicable to all ceramic tiles intended for use in freezing conditions in the presence of water.

❑ Test must be performed on a minimum area of 0.25 m^2, and on not less than 10 entire tiles that are free of defects.

❑ After drying to a constant weight, tiles are placed in a vacuum tank to a pressure of (60±4) kPa below atmospheric pressure.Water is introduced while this pressure is maintained for 15 minutes before returning to atmospheric pressure. In this way, the initial water absorption (before the cycles of freeze and thaw) is determined, as given by:

$$E_1 = [(m_2 - m_1)/m_1] \times 100$$

where:

m_1 = dry mass of each tile;

m_2 = wet mass of each tile.

❑ All the tiles are placed in a freezer in which the temperature is controlled, when possible, by inserting a thermocouple in a hole made in a typical tile of the sample under examination.

The cycle of freeze and thaw includes the following phases:

• cool the tiles to -5 °C at a speed of 20 °C / hour;

• maintain at -5 °C for 15 minutes;

• introduce water at (20±5)°C to raise the tiles to +5 °C;

• maintain at +5 °C for 15 minutes.

The described cycle must be repeated a minimum of 100 times, at the end of which the samples are weighed (m_3), and then dried until they reach a constant weight (m_4), and visually inspected.

❑ Final water absorption is calculated, as given by

$$E_2 = [(m_3 - m_4)/m_4] \times 100$$

and any damage visible on the proper surface and edges of the tile are noted.

Modifications of the EN 202 standard are intended to shorten the length of the test so that more repetitions of the cycle can be staged in a reasonable time. It is in fact recognized that frost damage is a function above all of the number of cycles (that is, of the shifts across 0 °C when water transforms to ice and vice versa) rather than of a low temperature. How quickly the temperature drops is also an important factor (especially in proximity of 0 °C), linked to the velocity of ice formation and the causing of tensions that may make the tile break.

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Aqueous test solutions	Low concentration (L)	High concentration (H)	Length of attack (GL)	Length of attack (UGL)
(4.1) Ammonium chloride	(100 g/l)	(100 g/l)	24 h	12 Days
(4.2) Sodium hypochlorite	(20 mg/l)	(20 mg/l)	24 h	12 Days
(4.3.1) Hydrochloric acid	3% (V/V)	—	4 Days	12 Days
(4.3.2) Hydrochloric acid	—	18% (V/V)	4 Days(1)	12 Days
(4.3.1) Citric acid	100 g/l	—	24 h	12 Days
(4.3.2) Lactic acid	—	5% (V/V)	4 Days(1)	12 Days
(4.3.1) Potassium Hydroxide	30 g/l	—	4 Days	12 Days
(4.3.2) Potassium Hydroxide	—	100 g/l	4 Days(1)	12 Days

(1) Only if requested

Table 3 Chemical resistance. Test solution and conditions for glazed (GL) and unglazed (UGL) tiles.

The standard dictates that one should "repeat the cycle a minimum of 100 times", implying that client and supplier may agree to measure resistance to a higher number of cycles, should particular weather conditions require as much.

EN ISO 10545 - Part 13
Ceramic tiles
Determination of chemical resistance

❑ Method applicable to all ceramic tiles to determine chemical resistance at room temperature.

❑ Each of the aqueous solutions set forth in Table 3 must be tested on at least 5 test samples that are:

• cut out (50 x 50 mm), in the case of unglazed tiles;

• entire or partial, in the case of glazed tiles.

Classification

❑ Unglazed tiles: samples extracted from unglazed tile are first partially immersed in the test solutions for 12 days and then subjected to running water for 5 days, then boiled in water for 30 minutes, dried and visually inspected for variations on the proper surface, on the cut edges and on the non-cut edges. The effects observed are the basis of the classification of Table 4.

❑ Glazed tiles: Test solutions are maintained in contact with the glazed surface of the tiles for the length of times noted in Table 3, after which the surface is cleaned and dried and the effects created by the solutions are assessed according to the diagram of Fig.8.

Should the pencil test not be applicable, the tiles are indicated as "Normal classification not possible", and classified on the basis of the visual inspection according to Table 5.

EN ISO 10545 - Part 14
Ceramic tiles
Determination to stains resistance

❑ Method applicable to the proper surface of ceramic tiles to determine stain resistance.

❑ Each of the staining agents listed below must be maintained in contact with at least 5 test samples (whose proper surface has first been cleaned and dried) for 24 hours. Stains are removed in stages through the use of different cleaning agents and procedures (Fig.9).

Classification of the results follows visual inspection: class 1 tiles are the easiest from which to remove a given stain, while with class 5 tiles, such stains cannot be removed

Test solutions	No visible effect (A)	Visible effects on cut edges (B)	Visible effects on cut and uncut edges and on proper surface (C)
Ammonium chlorid / Sodium hypochlorite	UA	UB	UC
L Solutions	ULA	ULB	ULC
H Solutions	UHA	UHB	UHC

Table 4 Unglazed (UGL) ceramic tiles: classification of chemical resistance.

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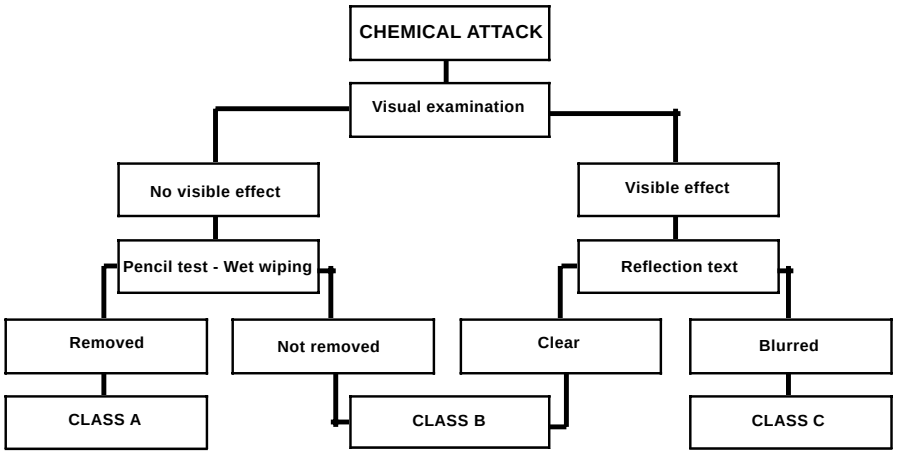


Fig. 8 Classification scheme for chemical resistance of glazed (GL) ceramic tiles.

and the proper surface has been damaged irreversibly.

Stains

1) Green staining in light oil (red staining for green tiles).
2) Iodine alcohol solution.
3) Olive oil.

Cleaning agents

1) Hot water.
2) Weak commercial cleaning agent.
3) Strong commercial cleaning agent.
4) Solvents (hydrochloric acid, potassium hydroxide, acetone, others to be specified)

Cleaning procedures

A) Running hot water.
B) Manual cleaning with weak commercial cleaning agent.
C) Mechanical cleaning with strong commercial cleaning agent.
D) Immersion in suitable solvent (hydrochloric acid, potassium hydroxide, acetone, others to be specified).

EN ISO 10545 - Part 15
Ceramic tiles
Extraction of lead and cadmium from glazed tiles

❑ Method applicable to proper surfaces of all glazed ceramic tiles. This method was not included in the EN standards, deriving rather from the American ASTM C-895 system; it regards the determination of the amount of lead and cadmium that may be released into an acetic acid solution by a glaze, in the case of tiles used in food-preparing areas (like tiles installed on kitchen counters).

❑ The determination must be made on at least three whole tiles whose surface has been first cleaned and dried. Each tile is then prepared as shown in Fig.10.

❑ The extraction is effected with a 4% (V / V) acetic acid solution for 24 hours; the amount extracted is determined in the appropriate manner, such as by means of atomic absorption spectrophotometry.

EN ISO 10545 - Part 16
Ceramic tiles
Determination of small color differences

This method was not included in the EN standards, but appears as part of the U.S. standards. The test method used is the one described in the standard ASTM C-609, and measures small differences in color between an unknown sample and a reference tile; the standard specifies that this method should be used to measure only tiles that are solid color and smooth; with other tiles, the results may not be valid. The test is based on the use of a colorimeter; any colorimeter on the market may be used, so long as it gives values that can be mathematically transformed into the tristimulus values X,Y and Z (according to CIE).

The instrument is first calibrated using a primary standard (magnesium oxyde) or a secondary standard, depending on the indications of the supplier of the instrument.

Measures are then taken of the unknown sample and the reference sample,

Table 5 Glazed (GL) ceramic tiles: classification of chemical resistance.

Test solutions	No visible effect (A)	Visible difference in appearance (B)	Partial or complete loss of original surface (C)
Ammonium chloride - Sodium hypochlorite	GA(V)	GB(V)	GC(V)
L Solutions	GLA(V)	GLB(V)	GLC(V)
H Solutions	GHA(V)	GHB(V)	GHC(V)

APPENDIX 1

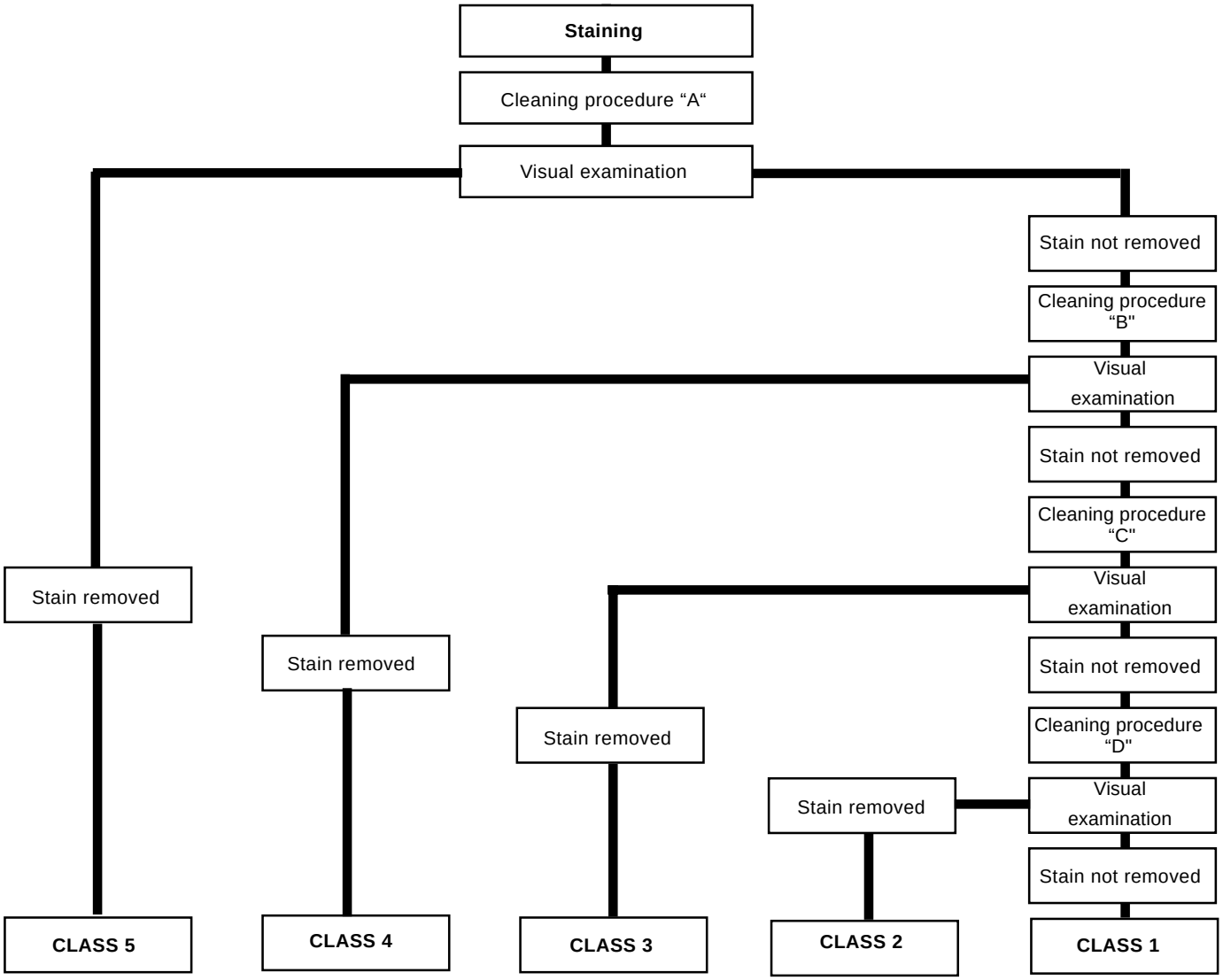


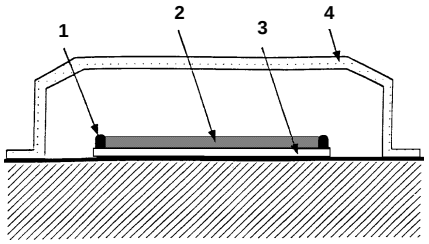
Fig. 9 Classification scheme for resistance to stains.

alternately, until three readings have been taken of every tile.
Finally, the standard specifies the method to be followed to calculate differences of color, specifically as regards instruments that give the values in L, a and b (which are transformed into X, Y and Z).

EN ISO 10545 - Part 17
Ceramic tiles
Determination of coefficient of friction

❑ Method applicable to glazed and unglazed ceramic tiles for floor covering. This method (not included in the EN) is particularly important for the safety of the final user, since the coefficient of friction relates directly to the slipperiness of a floor. Remember that the coefficient of friction is defined as the ratio between the tangential force and the vertical load on a body moving over a surface. The standard sets forth methods for measuring both the

APPENDIX 1



1. Silicone rubber
2. Solution
3. Tile
4. Dome

Fig. 10
Extraction of lead and cadmium: sample assembly during test.

dynamic coefficient of friction (associated with an element moving over a surface) and the static coefficient of friction (associated with an element that must move from a position of rest).

❑ Method A: this method, of English origin (BCR-Tortus), measures the dynamic coefficient of friction with a portable mobile apparatus, a moveable device with an electric motor that moves at a constant velocity over the surface of the tiles to be tested. The apparatus measures the coefficient of friction created between the tiles and a contacting element (slipping element) that is covered in standardized rubber (4S) and bears a predetermined load. The dynamic coefficient of attrition, both average and precise and under all surface conditions (dry, wet with water, etc.), are measured. This method can be used either in the laboratory or on floors in service.

❑ Method B: this method, originated in the United States (ASTM C1028) measures the static coefficient of friction with an apparatus that uses a dynamometer to determine the maximum horizontal force needed to initiate movement between the slider (covered in standardized 4S rubber and loaded with a known weight) and the tile surface, when dry and also when wet. This method, too, may be used in the laboratory and on floors in service.

❑ Method C: this method is modeled on the German standard DIN 51130. A person walks back and forth on a panel covered with ceramic tiles. The inclination of the test area is increased at a constant rate until the angle is reached at which the person finds it difficult to walk (and begins to slip).
The test is then interrupted and the angle of inclination of the panel at this point is measured; remembering that in this case, the coefficient of friction is equal to the geometrical tangent of the measured angle.
The test is conducted by applying oil to the test surface, and the testing person wears works shoes with standard soles. This test can be conducted only in the laboratory and not in the field.

❑ Method D: this method requires the use of a pendulum to whose arm a slippery element covered in standardized rubber (4S) is connected. The pendulum is made to swing and the amount of energy absorbed when the slider comes into contact with the test surface, be it either dry or wet with water, is then measured. This method too can be used both in the laboratory and in the field.

EN ISO norms for ceramic tiles - **Requirements**

APPENDIX 2

Properties	Group AI ISO13006 Annex A		Group AIIa P.1 ISO 13006 Annex B		Group AIIa P.2 ISO 13006 Annex C		Group AIIb P.1 ISO 13006 Annex D		Group AIIb P.2 ISO 13006 Annex E		Group AIII ISO 13006 Annex F	
	Precision	*Natural*	*Precision*	*Natural*	*Precision*	*Natural*	*Precision*	*Natural*	*Precision*	*Natural*	*Precision*	*Natural*
Length and width												
Allowable % deviation of the average dimension of each tile (2 or 4 sides) from work size W	±1.0 up to a max. ± 2 mm	±2.0 up to a max. ± 4 mm	±1.25 up to a max. ± 2 mm	±2.0 up to a max. ± 4 mm	±1.5 up to a max. ± 2 mm	±2.0 up to a max. ± 4 mm	± 2.0 up to a max. ± 2 mm	±2.0 up to a max. ± 4 mm	±2.0 up to a max. ± 2 mm	± 2.0 up to a max. ± 4 mm	± 2.0 up to a max. ± 2 mm	± 2.0 up to a max. ± 4 mm
Allowable % deviation of the average size of each tile (2 or 4 sides) from the average of 10 test specimens (20 or 40 sides)	maximum ± 1.0	maximum ± 1.5	maximum ± 1.0	maximum ± 1.5	maximum ± 1.5	maximum ± 1.5	maximum ± 1.5	maximum ± 1.5	maximum ± 1.5	maximum ± 1.5	maximum ± 1.5	maximum ± 1.5
Thickness	Thickness must be indicated by manufacturer											
Allowable % deviation of the average thickness of each tile from the work size	± 10											
Straightness of sides (Proper surface)												
Maximum % deviation from straightness related to the corresponding work size	± 0.5	± 0.6	± 0.5	± 0.6	± 1.0	± 1.0	± 1.0	± 1.0	± 1.0	± 1.0	± 1.0	± 1.0
Rectangularity												
Maximum % deviation from rectangularity related to the corresponding work size	± 1,0											
Surface flatness												
Maximum % deviation from flatness in surface a) center curvature related to the diagonal calculated from work size	± 0.5	± 1.5	± 0.5	± 1.5	± 1.0	± 1.5	± 1.0	± 1.5	± 1.0	± 1.5	± 1.0	± 1.5
b) edge curvature related to the corresponding work size	± 0.5	± 1.5	± 0.5	± 1.5	± 1.0	± 1.5	± 1.0	± 1.5	± 1.0	± 1.5	± 1.0	± 1.5
c) warpage related to the diagonal calculated from work size	± 0.8	± 1.5	± 0.8	± 1.5	± 1.5	± 1.5	± 1.5	± 1.5	± 1.5	± 1.5	± 1.5	± 1.5
Surface quality												
% of acceptable tiles in the lot	95 minimum											

Group A
Dimensional and aspect properties - Test according to ISO 10545-2.

APPENDIX 2

Group A
Physical properties.

Properties	Group AI ISO 13006 Annex A		Group AIIa P.1 ISO 13006 Annex B		Group AIIa P.2 ISO 13006 Annex C		Group AIIb P.1 ISO 13006 Annex D		Group AIIb P.2 ISO 13006 Annex E		Group AIII ISO 13006 Annex F	
	Precision	*Natural*	*Precision*	*Natural*	*Precision*	*Natural*	*Precision*	*Natural*	*Precision*	*Natural*	*Precision*	*Natural*
Test method ISO 10545-3 Water absorbtion % by weight Average value Individual value	≤ 3 3.3 maximum		3 < E ≤ 6 6.5 maximum		3 < E ≤ 6 6.5 maximum		6 < E ≤ 10 11.1 maximum		6 < E ≤ 10 11.1 maximum		6 < E ≤ 10 11.1 maximum	
Test method ISO 10545-4 *Breaking strength, in N* a) thickness ≥ 7.5 mm b) thickness < 7.5 mm *Modulus of rupture, in N/mm²* Not applicable if the breaking strength is ≥ 3000 N Average value Individual value	not less than 1100 not less than 600 minimum 23 minimum 18		not less than 950 not less than 600 minimum 20 minimum 18		not less than 800 not less than 600 minimum 13 minimum 11		not less than 900 not less than 900 minimum 17,5 minimum 15		not less than 750 not less than 750 minimum 9 minimum 8		not less than 600 not less than 600 minimum 8 minimum 7	
Test method ISO 10545-5 Impact resistance	test method available											
Test method ISO 10545-6 Resistance to deep abrasion of unglazed tiles V mm³	max 275		max 393		max 541		max 649		max 1062		max 2365	
Test method ISO 10545-7 Resistance to surface abrasion of glazed floor tiles	report the class of abrasion and the number of cycles passed											
Test method ISO 10545-8 Coefficient of linear thermal expansion from room temperature to 100°C	test method available											
Test method ISO 10545-9 Resistance to thermal shock	test method available											
Test method ISO 10545-10 Moisture expansion of unglazed tiles (mm/m)	test method available											
Test method ISO 10545-11 Crazing resistance of glazed tiles	requested											
Test method ISO 10545-12 Frost resistance	test method available											
Test method ISO 10545-16 Small color difference	test method available											
Test method ISO 10545-17 Coefficient of friction	For floor tiles, report value and test method adopted											

APPENDIX 2

Group A
Chemical properties.

Properties	Group AI - ISO 13006 Annex A Group AIIa - ISO 13006 Annex B-C Group AIIb - ISO 13006 Annex D-E Group AIII - ISO 13006 Annex F
Chemical resistance **Test method ISO 10545-13**	
Resistance to low concentrations of acids and alkali a) glazed tiles b) unglazed tiles	**report the class of chemical resistance**
Resistance to high concentrations of acids and alkali	**test method available**
Resistance to chemicals for home use and pool chemicals a) glazed tiles b) unglazed tiles	**min. GB** **min. UB**
Test method ISO 10545-14	
Stain resistance a) glazed tiles b) unglazed tiles	**min. Class 3** **test method available**
Test method ISO 10545-15 **Lead and cadmium release**	**test method available**

APPENDIX 2

Group B
Dimensional and appearance properties - Test according to ISO 10545-2.

Properties	Group BIa - ISO 13006 Annex G				Group BIb - ISO 13006 Annex H			
	Area S of product (cm^2)				Area S of product (cm^2)			
	S ≤ 90	*90 < S ≤≤190*	*190 < S ≤ 410*	*S > 410*	*S ≤ 90*	90 < S ≤ *190*	*190 < S ≤410*	*S > 410*
Length and width								
Allowable % deviation of the average dimension of each tile (2 or 4 sides) from work size W	± 1.2	± 1.0	± 0.75	± 0,6	± 1.2	± 1.0	± 0.75	± 0.6
Allowable % deviation of the average size of each tile (2 or 4 sides) from the average of 10 test specimens (20 or 40 sides)	± 0.75	± 0.5			± 0.75	± 0.5		
Thickness	Thickness must be indicated by the manufacturer							
Allowable % deviation of the average thickness of each tile from the work size	± 10		± 5		± 10		± 5	
Straightness of sides (Proper surface)								
Maximum % deviation from straightness related to the corresponding work size	± 0.75	± 0.5			± 0.75	± 0.5		
Rectangularity								
Maximum % deviation from rectangularity related to the corresponding work size	± 1.0	± 0.6			± 1.0	± 0.6		
Surface flatness								
Maximum % deviation from flatness in surface a) center curvature related to the diagonal calculated from work size	± 1.0	± 0.5			± 1.0	± 0.5		
b) edge curvature related to the corresponding work size	± 1.0	± 0.5			± 1.0	± 0.5		
c) warpage related to the diagonal calculated from work size	± 1.0	± 0.5			± 1.0	± 0.5		
Surface quality								
% of acceptable tiles in the lot	95 minimum							

APPENDIX 2

Group B
Dimensional and appearance properties - Test according to ISO 10545-2 (cont.).

Properties	Group BIIa - ISO 13006 Annex J				Group BIIb - ISO 13006 Annex K			
	Area S of product (cm^2)				Area S of product (cm^2)			
	S ≤ 90	*90 < S ≤ 190*	*190 < S ≤ 410*	*S > 410*	*S ≤ 90*	*90 < S≤ 190*	*190 < S ≤ 410*	*S > 410*
Length and width								
Allowable % deviation of the average dimension of each tile (2 or 4 sides) from work size W	± 1.2	± 1.0	± 0.75	± 0.6	± 1.2	± 1.0	± 0.75	± 0.6
Allowable % deviation of the average size of each tile (2 or 4 sides) from the average of 10 test specimens (20 or 40 sides)	± 0.75	± 0.5			± 0.75	± 0.5		
Thickness	Thickness must be indicated by the manufacturer							
Allowable % deviation of the average thickness of each tile from the work size	± 10		± 5		± 10		± 5	
Straightness of sides (Proper surface)								
Maximum % deviation from straightness related to the corresponding work size	± 0.75	± 0.5			± 0.75	± 0.5		
Rectangularity								
Maximum % deviation from rectangularity related to the corresponding work size	± 1.0	± 0.6			± 1.0	± 0.6		
Surface flatness								
Maximum % deviation from flatness in surface a) center curvature related to the diagonal calculated from work size	± 1.0	± 0.5			± 1.0	± 0.5		
b) edge curvature related to the corresponding work size	± 1.0	± 0.5			± 1.0	± 0.5		
c) warpage related to the diagonal calculated from work size	± 1.0	± 0.5			± 1.0	± 0.5		
Surface quality								
% of acceptable tiles in the lot	95 minimum							

APPENDIX 2

Group B
Dimensional and appearance properties - Test according to ISO 10545-2 (cont.).

Properties	Group BIII - ISO 13006 Annex L	
	Non-spacer	*Spacer*
Length and width	Side ≤ 12 cm: ± 0.75 Side > 12 cm: ± 0.50	+ 0.6 - 0.3
Allowable % deviation of the average dimension of each tile (2 or 4 sides) from work size W		
Allowable % deviation of the average size of each tile (2 or 4 sides) from the average of 10 test specimens (20 or 40 sides)	Side ≤ 12 cm: ± 0.50 Side > 12 cm: ± 0.30	± 0.25
Thickness	Thickness must be indicated by the manufacturer	
Allowable % deviation of the average thickness of each tile from the work size	± 10	
Straightness of sides (Proper surface)	± 0.3	
Maximum % deviation from straightness related to the corresponding work size		
Rectangularity	± 0.5	± 0.3
Maximum % deviation from rectangularity related to the corresponding work size		
Surface flatness	+ 0.5 -0.3	+ 0.8 mm - 0.2 mm
Maximum % deviation from flatness in surface a) center curvature related to the diagonal calculated from work size		
b) edge curvature related to the corresponding work size	+ 0.5 - 0.3	+ 0.8 mm - 0.2 mm
c) warpage related to the diagonal calculated from work size	± 0.5	0.5 mm for sizes ≤ 250 cm^2 0.75 mm for sizes > 250 cm^2
Surface quality	95 minimum	
% of acceptable tiles in the lot		

APPENDIX 2

Group B
Physical properties.

Properties	Group BIa ISO 13006 Annex G	Group BIb ISO 13006 Annex H	Group BIIa ISO 13006 Annex J	Group BIIb ISO 13006 Annex K	Group BIII ISO 13006 Annex L
Test method ISO 10545-3 Water absorbtion % by weight Average value Individual value	≤ 0.5 0.6 max	0.5 < E ≤ 3 3.3 max	3 < E ≤ 6 6.5 max	6 < E ≤10 11 max	E > 10 minimum 9 When the value exceeds 20% this shall be indicated by the manufacturer
Test according to ISO 10545-4 *Breaking strength, in N* a) thickness ≥ 7.5 mm b) thickness < 7.5 mm *Modulus of rupture, in N/mm²* Not applicable if the breaking strength is ≥ 3000 N Average value Individual value	not less than 1300 not less than 700 minimum 35 minimum 32	not less than 1100 not less than 700 minimum 30 minimum 27	not less than 1000 not less than 600 minimum 22 minimum 20	not less than 800 not less than 500 minimum 18 minimum 16	not less than 600 not less than 200 Thickness ≥ 7.5: min.15 Thickness < 7.5: min.12
Test method ISO 10545-5 Impact resistance	test method available				
Test method ISO 10545-6 Resistance to deep abrasion of unglazed tiles V mm³	max 175	max 175	max 345	max 540	—
Test method ISO 10545-7 Resistance to surface abrasion of glazed floor tiles	report the class of abrasion and the number of cycles passed				
Test method ISO 10545-8 Coefficient of linear thermal expansion from room temperature to 100°C	test method available				
Test method ISO 10545-9 Resistance to thermal shock	test method available				
Test method ISO 10545-10 Moisture expansion of unglazed tiles (mm/m)	test method available				
Test method ISO 10545-11 Crazing resistance of glazed tiles	requested				
Test method ISO 10545-12 Frost resistance	requested		test method available		
Test method ISO 10545-16 Small color difference	test method available				
Test method ISO 10545-17 Coefficient of friction	For floor tiles, report value and test method adopted				

APPENDIX 2

Group B
Chemical properties.

Properties	Group BIa - ISO 13006 Annex G Group BIb - ISO 13006 Annex H Group BIIa - ISO 13006 Annex J Group BIIb - ISO 13006 Annex K Group BIII - ISO 13006 Annex L
Chemical resistance **Test method ISO 10545-13**	
Resistance to low concentrations of acids and alkali a) glazed tiles b) unglazed tiles	**report the class of chemical resistance**
Resistance to high concentrations of acids and alkali	**test method available**
Resistance to chemicals for home use and pool chemicals a) glazed tiles b) unglazed tiles (Group BIa-BIIb)	**min. GB** **min. UB**
Test method ISO 10545-14	
Stain resistance a) glazed tiles b) unglazed tiles	**min. Class 3** **test method available**
Test method ISO 10545-15 **Lead and cadmium release**	**test method available**

APPENDIX 3

The term "certification" is defined in the UNI CEI 70001 standards, paragraph 13.5, as follows: "Certification of conformity – *action by means of which an independent third party testifies that, with reasonable dependability, a given product, process or service is in conformity with a specific standard or another official document.*"
The term "certification" refers to the complex of procedures including testing, inspection and verification by means of which it can be concluded that a product not only conforms with established technical standards, but is subject to sufficient self-monitoring during all phases of production so that, even though all tests cannot be conducted "on line", a constant quality of production can be reasonably guaranteed. This requires that the manufacturer be equipped with an adequate system of quality control, complete with a manual, a laboratory with specialized technical personnel and an adequate system of data registry so that, in cases where products are not in conformity, the original causes of the defect can be traced. All these indications are specified in the ISO 9000 standards.

Let us consider the specific case of ceramic tiles.
The EN ISO standards, prescribing quality requirements for first-choice materials and describing the corresponding test methods, are presented in section 2.2, and described in detail in Appendices 1 and 2. Some of these tests (like the evaluation of surface quality) constitute an integral part of normal production lines (grade sorting lines); while others (like chemical and abrasion resistance, etc.) are destructive, and hence cannot be performed "on line" but rather "on samples". In the case of the latter type, the manufacturer must perform them (or have them performed) periodically, with a frequency that depends on the importance of the test to quality control. If a test's results are negative (that is, if the product is found to be not in conformity), the manufacturer identify the possible cause or causes, analyzing the characteristic parameters of the various phases of the production cycle and making the required corrections; finally, products that are not in conformity must be identified and carefully isolated from normal production.
All this is part of the so-called "quality control system", which requires:
- ❑ a quality control manual, describing the various operational procedures and noting standards of evaluation and interpretation of results;
- ❑ a quality control laboratory complete with sufficient equipment and specialized technical personnel;
- ❑ documentation of the results of examination as effected at the various phases of the production cycle: raw materials, grinding, pressing, drying, glazing, firing;
- ❑ documentation of examination effected on finished product.

As regards the preparation of the quality control manual, the organization and management of the laboratory and the tests on raw materials and partly finished products, manufacturers are referred to the EN ISO 9002 standard which offers general guidelines modifiable to specific cases. Examination of finished products, instead, must be performed in conformity with the EN ISO standards for ceramic tiles.
Although these procedures are complex, each manufacturer will already have its own internal quality control system, and it will be sufficient for such a system to be modified to meet the aforementioned requirements of the EN ISO standards.
Companies already equipped with a

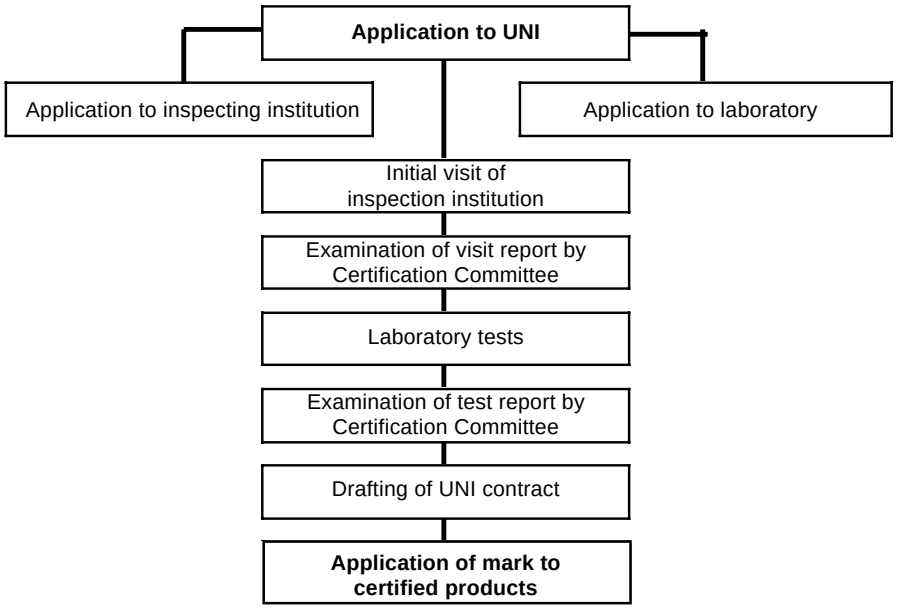


Fig. 1
Flow-sheet for the application of the UNI Mark.

APPENDIX 3

Fig. 2
The UNI Mark logo.

sufficient quality control system are the first to request the mark. As noted above, they may request it but are not obligated to; the mark for ceramic tiles is optional. Nevertheless it is important, and its importance is sure to increase in the near future since it constitutes an official recognition of sound production management, as well as an excellent form of self-presentation to consumers in all the European markets. (It must be remembered that a quality mark is also in use in other European countries).

In Italy, the quality mark is conferred by UNI, Italian Standardization Body, which is its proprietor and grants the right to use the mark to any requesting company that demonstrates, first, that it has an adequate system of quality control (as described above); furthermore, the type of product for which the mark is requested must meet the requirements established by current standards.

The procedure to be followed is described in a UNI publication on the subject. Fig.1 presents a brief flowchart for the attribution of the mark. The main steps in the procedure to be followed are summarized below.

First, the mark is requested by the manufacturer, that is by "*the company that produces ceramic tiles and/or offers them on the market, under its own name, assuming complete responsibility for the product*." Thus the mark may be requested even by a company that does not directly produce the tiles, but only distributes a product (for which it assumes complete responsibility) that is manufactured and packaged in its name by a third party.

The mark is requested for a **c**ommercial series: that is to say, for tiles

- ❑ that belong to the same product Group, as established by the EN ISO standards (see section 2.2);
- ❑ that have the same body and the same thickness, and are grouped into a certain number of formats and colors.

The mark (Fig.2) is indelibly stamped onto the series which has acquired the right to use it: it is important to be able to distinguish the series that carries the mark from that same company's other production, so as to avoid any misunderstandings or imitations.

The mark is also featured in catalogs, brochures, advertising flyers: since it represents a distinction of quality, it is in the manufacturer's interest to guarantee its broadest possible exposure through individual and group advertisements.

The mark is the property of UNI, which grants a manufacturer the contractual right to use it for four years, at the end of which the contract is tacitly renewed unless it has been revoked by either of the contracting parties.

Once the application is sent to UNI complete with required documentation, the procedure for receiving the permit for the mark begins; the procedure includes, first, a visit by the Inspection Institution designated by UNI (Centro Ceramico Bologna). The main purpose of the visit is to verify the existence of an adequate internal system of quality control, as indicated above: the producer must indicate how the quality control inspections are conducted, submitting all pertinent data. The frequency and nature of the inspections on semi-manufactured goods and on the stages of the technological process are at the discretion of the manufacturer: for example, for raw materials, it is sufficient to include in the documentation a technical form completed by the supplier.

Inspections on finished products, by contrast, are stricter. First, sampling is quite regulated: for each commercial series, it must be substantial, as regards formats as well as glazes and colors: details regarding sampling must be specified in the visit report. Control tests must be performed following EN ISO standard test methods; other test methods may also be used, so long as their correspondence to standard methods has been verified. Frequency of testing is set forth in Table 1; all the colors of a series must be monitored periodically, and after a year of on-going production inspections, the entire range of tests required by EN ISO standards must have covered the totality of production. A-type tests must be performed at the production site; B- and C-type tests may be effected partially or totally at an external laboratory (such as the manufacturer's laboratory, or an external laboratory).

All test results must be properly documented and presented by the manufacturer at the time of the visit. Samples are also selected at this time and sent to the official testing laboratory (Centro Ceramico Bologna) for testing.

The Inspection Institution sends the report of its visit to the Certification Committee, which evaluates the report. If that report

APPENDIX 3

receives a positive evaluation, the Certification Committee commissions the testing laboratory to perform all tests required by the EN ISO standards on the series for which the use of the mark is being petitioned. The laboratory sends out test reports to the Certification Committee, which is empowered to give final approval, based on which UNI draws up a contract with the manufacturer for the granting of the permit to use for the mark.

During the life of the contract, the Inspection Institution must visit the production plant annually to verify the proper management of quality control (and especially of the registers in which test results are documented). Furthermore, samples are drawn to be sent to the designated laboratory for testing: obviously, fewer tests are required than for the initial application for the mark, since this is a sample-based evaluation, performed on materials selected on the basis of their significance. UNI can then commission the test laboratory and the inspection institution to perform unscheduled sampling of tiles both from the manufacturer and on the market, so as to conduct tests to ascertain if these samples conform to those submitted for the initial testing.

Obviously, violations of contract will merit sanctions of varying gravity, as listed in the relevant UNI publication.

Type of test	Frequency	Property tested
A	daily	dimensions and surface quality water absorption modulus of rupture
B	monthly	abrasion resistance chemical resistance crazing resistance Mohs hardness
C	yearly	linear thermal expansion thermal shock resistance moisture expansion frost resistance

Table 1
Quality control scheme.

APPENDIX 4

EN ISO standards establish quality requirements only for first choice materials, or materials "of the best commercial quality" (as stated in the EN 87??? standard). All materials of lesser quality have no classification requirements. Currently, every company uses its own standards of selection, using such terminology as ""first", "second", "third", "first commercial", "kiln output", "discard", etc., creating confusion on the market.

At a meeting in Brussels on November 16, 1990, the CET (European Federation of Manufacturers of Ceramic Tiles) reached an agreement regarding the definition of quality grades of ceramic tile, and specified a labelling system for boxes. This agreement establishes no official norm but does nevertheless represent true progress in the distribution of ceramic tiles.

As regards the labelling of boxes and packages, only general suggestions were provided. Quality classification must be clearly and legibly noted, in Arabic numerals; companies must label in whatever way is most effective, depending on corporate requirements and technical means available.

Since the first choice classification has already been defined (as materials that conform with EN standard requirements[(1)]), it was sufficient to define second choice in order to automatically generate the definition of third choice.

Factors that determine a tile's classification are, first, aesthetic defects (stains, flecks, defects in decoration, etc.) that are detrimental to the appearance of the proper surface. For second-choice tiles, the established distance from which these defects are visible is greater, but the maximum allowable percentage of defective tiles (5%) is the same. If this percentage is exceeded, tiles are considered third-choice. As for functional properties, the limits established for first-choice have been slightly increased, while guidelines regarding physical and chemical properties are more complex and detailed.

For some of these properties(abrasion resistance of the surface of glazed tiles, and resistance to acids and bases, also of glazed tiles) the requirement of first choice depend on the manufacturer's statement, and likewise for second choice. For other properties, requirements have remained unaltered, since said properties are considered peculiar to ceramic tiles, or in any case fundamental to the performance required: such is the case with thermal shock resistance and crazing resistance (even if manufacturers may declare that glazes used to achieve aesthetic affects may craze), as well as with resistance to stains, home-use chemicals and pool chemicals.

Finally, for the remaining properties, it was accepted as a general principle that for a material of second choice, an acceptable value-limit is the first-choice requirements of the group immediately following it. For example, requirements for second choice of group BI are those for the first choice of group BIa. Obviously, this general standard has required adaptations due to some incongruities in the system. The results are set forth in Table 1. It should be noted that though the data in this chart are the result of several elaborations and detailed discussions, it has yet to be perfected: nevertheless, it is a sound point of reference in a confused situation that has persisted for years and was in urgent need of regulation.

It has been established that the standard constitutes a strong recommendation, especially for tiles for the export market.

The complete text of the agreed-upon regulations follows.

Affixing of the quality grade on boxes and packaging

For products in conformity with the requirements established by the EN standards, the first-choice designation must be specified, as prescribed by said standards.

Likewise, for products that do not satisfy the requirements established by the EN standards, the designation of 2nd and 3rd choice must be specified.

These indications must be entirely clear and legible on the boxes and packages, using Arabic numerals of a size and form that may vary depending on the technical means and corporate requirements of the manufacturer.

Standards of selection: aesthetic and functional

❑ *Aesthetic standards*

• 1st choice

The proper surface of the tiles must appear intact in all its parts; an aesthetic assessment will require the testing of at least a sample of 1 m^2 and a minimum of 30 tiles, as established by the EN 98 standard.

The assessment is effected by observing the proper surface of the tile at a distance of **1** meter under a light of 300 lux.

The result is expressed as a percentage of tiles with defects.

• Requirements for 1st choice

Percentage of defective tiles < 5.

• 2nd choice

A sample of at least 1 square meter and a minimum of 30 tiles must be tested. The assessment must be effected by observing the proper surface of the tiles at a distance of 2 meters and under a light of 300 lux.

The result is expressed as a percentage of tiles with defects.

• Requirements for 2nd choice

Percentage of defective tiles < 5.

(1) The Cet agreement refers to EN norms in force at the time it was signed (1990). The EN ISO norms described and used in this guide (see §2.2. and Appendices 1 and 2) are an updating of those norms. The values included in Table 2 will be updated using as a reference the requirements listed in Appendix 2.

APPENDIX 4

Properties	AI	AIIa-1	AIIa-2	AIIb-1	AIIb-2	AIII	BI	BIIa	BIIb	BIII
Modulus of rupture (EN 100) • Average value	*≥ 20* **≥20**	*≥20* **≥17.5**	*≥10* **≥8**	*≥17,5* **≥8**	*≥8* **≥8**	*≥8* **≥8**	*≥27* **≥22**	*≥22* **≥18**	*≥18* **≥15/12**	*≥15/12* **≥8**
• Individual value	*18* **18**	*18* **15**	*9* **7**	*15* **7**	*7* **7**	*7* **7**	— **20**	*20* **16**	*16* **7**	*7* **7**
Mohs hardness (EN 101) • Glazed • Unglazed	*≥5* **≥5** *≥6* **≥6**	*≥5* **≥5** *≥6* **≥6**	*≥5* **≥4** *≥5* **≥4**	*≥5* **≥4** *≥6* **≥3**	*≥4* **≥4** *≥3* **≥3**	*≥4* **≥4** *≥3* **≥3**	*≥5* **≥5** *≥6* **≥6**	*≥5* **≥5** *≥6* **≥6**	*≥5* **≥5** *≥6* **≥4**	*≥5 f* **≥3 w** *≥4 f* **≥3 w**
Deep abrasion (EN 102)	*≤300* **≤393**	*≤393* **≤649**	*≤771* **≤1419**	*≤649* **≤2365**	*≤1419* **≤2365**	*≤2365* **≤3174**	*≤205* **≤345**	*≤345* **≤540**	*≤540* **≤2046**	— —
Linear thermal expansion (EN 103)	*4÷8* **≤10** *5÷13* **≤12**	*≤10* **≤10** *≤12* **≤10**	*≤10* **≤10** *≤12* **≤10**	*≤10* **≤10** *≤10* **≤10**	*≤10* **≤10** *≤10* **≤10**	*≤10* **≤10** *≤10* **≤10**	*≤9* **≤9**	*≤9* **≤9**	*≤9* **≤9**	*≤9* **≤9**
Thermal shock (EN 104)	*Required for all groups* **Required for all groups**									
Crazing (EN 106)	*Required for all groups* **Required for all groups**									
Chemical resistance unglazed (EN 106) • Household chemicals and pool chemicals • Acid and alkalis	*req'd* **req'd** *req'd* **req'd**	*req'd* **req'd** *req'd* **req'd if agreed**	*req'd* **req'd** *req'd if agreed* **req'd if agreed**	*req'd* **req'd** *req'd if agreed* **req'd if agreed**	*req'd* **req'd** *req'd if agreed* **req'd if agreed**	*req'd* **req'd** *req'd if agreed* **req'd if agreed**	*req'd* **req'd** *req'd* **req'd**	*req'd* **req'd** *req'd* **req'd**	*req'd* **req'd** *req'd* **req'd**	*req'd* **req'd** *req'd* **req'd**
Chemical resistance glazed (EN 122) • Stains • Household chemicals and pool chemicals • Acid and alkalis manufacturer	*Min. class 2 for all groups* **Min. class B for all groups** Min. class 2 for all groups **Min. class B for all groups** *Requested if agreed upon. According to class of chemical resistance indicated by manufacturer* **Requested if agreed upon. According to class of chemical resistance indicated by manufacturer**									
Surface abrasion (EN 154)	*According to class of abrasion indicated by manufacturer* **According to class of abrasion indicated by manufacturer**									
Moisture expansion (EN 155)	— —	— —	— —	*≤0.6* **≤0.6**	*≤0.6* **≤0.6**	*≤0.6* **≤0.6**	— —	— —	*≤0.6* **≤0.6**	— —
Frost resistance (EN 202)	*req'd* **req'd if agreed**	*req'd if agreed* **req'd if agreed**	*req'd if agreed* **req'd if agreed**	*req'd if agreed* **req'd if agreed**	*req'd if agreed* **req'd if agreed**	*req'd if agreed* **req'd if agreed**	*req'd* **req'd if agreed**	*req'd if agreed* **req'd if agreed**	*req'd if agreed*	— —

Table 1
Requirements for quality grades.

1st choice: italic;
2nd choice: bold.

f = floor
w = wall

• 3rd choice
Tiles in this group include all those that do not satisfy the requirements established for 1st and 2nd choices.

❑ *Functional standards*
• Requirements for 1st choice
Tiles must satisfy 1st choice requirements, as established by the specific EN product standard for the group to which it belongs.

• Requirements for 2nd choice
- *Dimensions*
Tiles must satisfy the requirements established by the specific EN product standard for the group to which it belongs, with a maximum allowable deviation of 25% from the tolerances indicated in the aforementioned standard.
- *Physical and chemical properties*
Tiles must satisfy the requirements set forth in Table 1.

• Requirements for 3rd choice
Tiles in this group include all those which do not satisfy the requirements for 1st and 2nd choice.

APPENDIX 5

CENTRO CERAMICO - BOLOGNA

Italian Center for the Research and Testing for the Ceramics Industry

International denomination:
ITALIAN CERAMIC CENTER

Headquarters:
Via Martelli, 26 - 40138 Bologna
Tel. (051)534015 - Fax (051)530085

Branch Unit:
CERTI.CER
Via Valle d'Aosta 1- 41049 Sassuolo (Modena)
Tel / Fax (0536)802154

Internet: www.cencerbo.it
e-mail: centro.ceramico@cencerbo.it

The Centro Ceramico is managed by a University Consortium, whose members are:

UNIVERSITY OF BOLOGNA

ERVET
Regional Organization for Economic Development

EMILIA-ROMAGNA CHAMBERS OF COMMERCE ASSOCIATION

ASSOPIASTRELLE
Association of Italian Ceramic Tile and Refractories Manufacturers

ANCPL
Italian Association of Manufacturing Cooperatives

ENCS
Italian Institute for Ceramics and Silicates

ANDIL
Italian Association of Heavy Clay Products Manufacturers

FEDERCERAMICA
Italian Association of Ceramics and Abrasives Manufacturers

Acknowledgement of the legal status of the University Consortium:
DPR 10 / 4 / 1978, n.806

National and international accreditations

Laboratory listed in the register of the "Highly Qualified Private and Public External Laboratories" Ruling of the Ministry Of Scientific Research 6/16/1983 (G.U. 7/6/1983, n.183)

Laboratory authorized to monitor atmospheric pollution L.7/13/1966, n.615 - Ruling of Ministry Of Health 8/10/1974 (G.U. 9/1/1974, n.240)

Italian reference Ceramics Laboratory for the "Mutual Recognition Agreement of Test Reports" of the CEN Certification Committee N.5

Italian reference Ceramics Laboratory for CERLABS - World Network of National Ceramic Laboratories

Inspection institution and official test laboratory designated by UNI for granting the Quality Mark for Ceramic Tiles

Inspection institution and official test laboratory designated by UNI for granting the Quality Mark for Bricks

Test laboratory accredited by SINAL, according to UNI CEI EN 45001 (Accreditation N. 0058, 10/21/1997)

Laboratory designated by ENCS (Italian Institute for Ceramics and Silicates) for granting the ENCS Mark for sanitary articles

Recognized official laboratory for the exportation of ceramic tiles and sanitaryware in Saudi Arabia, according to S.A.S.O

Test laboratory accredited by P.C.B.C. (Poland) according to ISO/IEC 25

Official laboratory acknowledged by ZAG-ZRMK (Slovenia) for the exportation of ceramic tiles.

Official laboratory recognized by the Ministry for the Defense for the monitoring of the consignment of earthenware

Laboratory with Qualified Personnel according to EN 30011 for assessing quality systems according to EN ISO 9000

CERLabs **- World Network of National Ceramic Laboratories**

APPENDIX 5

Activities

❑ Applied research
❑ Assistance to industry, certification, consultation
❑ Professional training
❑ Distribution of information

in the following areas:

❑ **Chemistry and raw materials**
❑ **Industrial ceramics** (tiles, bricks, sanitaryware, earthenware, refractories, etc.)
❑ **Advanced technical ceramic**
❑ **Environment**
❑ **Processes and energy**
❑ **Product and system quality**

Tests, analyses, services

❑ Tiles, Sanitaryware, Refractories, Bricks, Pipes for building, Adhesives for building, Dinnerware, Cements and Concrete:
• quality assessment according to test methods established by respective standards, national (UNI) and international (EN, ISO)
• microstructure characterization (SEM,EDS).

❑ Defects in tiled floors and wall coverings: on-site inspections, technical assistance, etc.

❑ Ceramic raw materials, glazes, frits, etc.; execution of:
• chemical analysis and chemical determination
• mineralogical analysis
• microscope examinations
• thermal analysis (DTA,TG, dilatometrics, firing tests)
• granulometric analysis
• heating microscope.

❑ Chemical analysis of waters (waste water, processing water) and of production and purification waste / residues.

❑ Characterization of gaseous emissions.

❑ Measurement of exposure to pollutants in the workplace.

❑ Energy Auditing: measurement of thermal and electric consumption, and assistance in energy conservation.

Manuals for ceramic tile professionals

Ceramic tile professionals may request the following manuals on ceramic tile. They include the results of research projects, or they were published to cover topics of particular interest in easy and readable format.

APPENDIX 6

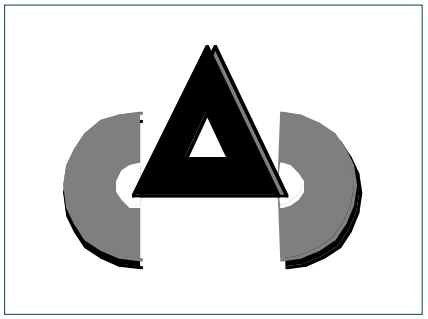
Constitution

Art. 1
1.1. The Arbitration Board has been established under the auspices of the Centro Ceramico for the purpose of offering services of arbitration (basic and extraordinary), conciliation and contractual appraisal in the interest of promoting the friendly resolution of disagreements and/or controversies regarding ceramic materials.
1.2. Said services are regulated by the Rules of Procedure which are attached to the present Constitution and are an integral part of same.
1.3. The Arbitration Board is located within the Centro Ceramico.

Art. 2
2.1. The Arbitration Board is directed and administered by a Council.
2.2. The Council has full authority to pursue the achievement of all the aims of the Arbitration Board.
2.3. In particular, the Council:
a) creates and maintains a list of arbiters and experts;
b) assigns arbiters and experts;
c) stipulates the amount parties must pay for reimbursement of administrative expenses;
d) resolves challenges to arbiters and experts;
e) resolves claims against fees to arbiters and experts;
f) provides opinions on procedures to arbiters and experts.

Art. 3
3.1. The Council is composed of seven members including the President.
3.2. The President of the Centro Ceramico is by rights the President of the Council.
3.3. The Board of Directors of the Centro Ceramico nominates the members of the Council of the Arbitration Board, selecting them from among the pool of persons of proven experience in the law or in ceramics, and of clear moral integrity.
3.4. The Council's tenure lasts 4 years and its members may be reinstated.

Art. 4
4.1. The Council is convened by the President whenever he deems it appropriate, and when at least 3 of its members request it.
4.2. The Council is presided over by the President or, in case of his absence of inability to serve, by the oldest member of the board.



4.3. The Council deliberates with the presence of at least half of its members.
4.4. Decisions are made by a majority vote of members present.
4.5. In the case of a tie, the vote of whoever has convened the union will be decisive.

Art. 5
5.1. The Council nominates the Secretary of the Arbitration Board.
5.2. The Secretary executes the decisions of the Council, draws up the minutes of its meetings, reports to the Council on the functioning of the administration and of services rendered to the Arbitration Board.

Art. 6
The functioning of the Arbitration Board is assured by the payment of expenses by the users of the services and, in cases where such payments do not suffice, by the Centro Ceramico.

Art. 7
This Constitution may be modified following deliberation of the Council, ratified by the Board of Directors of the Centro Ceramico.

Rules of Procedure

Art. 1 - Arbitration services
1.1. Arbitration services consist in providing one or more arbiters to parties for the resolution of conflicts.
1.2. Conciliation services consist in providing the parties with one or more conciliators who will promote an agreement among parties.
1.3. Services of contractual appraisal consists in providing parties with one or more experts responsible for formulating a technical evaluation.
1.4. Recourse to arbitration services entails unconditional acceptance of the Constitution of the Arbitration Board, of its Rules of Procedure, and of the decision that will be made, exempting the Board from any responsibility.
1.5. Parties have a joint obligation to pay the fee of the arbiter and/or the expert.

Art. 2 - Arbitration agreement
2.1. Reference is made to one of the aforementioned rules of procedure when an arbitration agreement exists between parties or when, despite the absence of an arbitration clause or compromise, the parties jointly request it of the Arbitration Board.

2.2. When the parties agree in writing to avail themselves of the services of the Arbitration Board, and specify no further details, this will be understood to signify: a single arbiter rather than an arbitrating body; an outside arbiter rather than a Board one; a judgement based on fairness rather than on jurisprudence.
2.3. In the case of several parties, a single arbiter will pass judgement, regardless of the arbitration agreement.

Art. 3 - List of arbiters and experts
3.1. The Council draws up and updates the list of arbiters and experts, including individuals of proven experience in the legal and/or ceramics field and of uncontested moral integrity.
3.2. Whenever it is deemed appropriate, the Council may designate people who are not on the list, but possess the aforementioned requirements.
3.3. Either part may reject in writing the designated arbiter or expert, citing reasons for doing so.
3.4. Following such a rejection, the Council will confer with the interested parties and then make its decision without appeal.

Art. 4 - Request for arbitration
4.1. The party that wishes to promote arbitration presents a written request to office of the Arbitration Board, notifying the opposite party by registered mail.
4.2. The request must indicate:
a) name and address of the parties;
b) type of arbitration requested: standard or extraordinary, arbitration body or single arbitrator;
c) exposition of facts and legal issues on which the request is based;
d) summary of the arguments which the requesting party means to use;
e) in the case of an arbitration body: full name and address of the arbiter in the field.
4.3. Together with the request, the requesting party must submit to the office of the Arbitration Board:
a) a copy of the compromise or of the compromise clause;
b) the original letter of attorney, if said party intends to be represented and defended in the proceedings;
c) the receipt of the registered letter noted in comma 1 above;
d) the compensation owed to the office of the Arbitration Board, as estimated by the Council.
4.4. The office of the Arbitration Board registers the request in the appropriate chronological register, opens a file and assigns it a number.

Art. 5 – Integration of the lawsuit
5.1. Within thirty days of being notified of the request, the defendant party must submit to the Arbitration Board a written response to the pertinent questions, indicating the arguments it intends to use and, in the case of an arbitration body, designating the special arbiter.
5.2. If he intends to seek legal representation and defense, said party must also present the original of the letter of attorney.
5.3. Within ten days from the expiration of the term in the above sub-section, the office must submit the file to the council.
5.4. Depending on need, the Council designates a single arbiter and the president of the arbitration body. In cases where the parties do not designate an expert arbiter, the Council designates him / her as well.
5.5. The Council also determines the arbiter's advance payment.
5.6. The office of the Arbitration Board immediately communicates the results of said deliberation to the arbiter and to all parties by registered mail.

Art. 6 - Procedures
6.1. Once the arbiter's advance payment has been paid as per the above art. 5.4, the process begins.
6.2. Within ten days of said payment, the arbiter communicates to the parties, by registered letter, the date and hour of the first meeting to be held within the next twenty days.
6.3. Arbitration takes place at the offices of the Ceramics Arbitration Board.
6.4. The arbiter takes the minutes of the meeting which he undersigns.
6.5. The arbiter attempts to reconcile the parties.
6.6. If the parties are reconciled, they draw up and sign a statement of reconciliation, under the guidance of the arbiter, indicating among other things who will be responsible for paying the fee of the arbiter, whose responsibilities conclude with the signing of this document.
6.7. The arbiter conducts the inquiry using his best judgment and respecting the principle of cross-examination.

Art. 7 - Decision
7.1. The arbiter issues his decision within three months of the first meeting, unless otherwise agreed by the arbiter and parties involved.
7.2. The decision is issued in written form and is signed by the arbiter.
7.3. When there are multiple arbiters, the decision is arrived at by a majority vote.
7.4. Should one arbiter refuse to sign the decision, the other arbiters note this fact in the ruling itself.
7.5. The decision must contain the claims of the parties involved, the course of the proceedings, the motives and the final verdict.
7.6. In his decision, the arbiter caps his fee and the expenses for the defense of the parties involved, charging them to one or

the other party according to the principle of loosing party.
7.7. A written claim against the payment of the arbiter's fees may be submitted to the Council of the Arbitration Board within thirty days of notification of the arbiter's decision.
7.8. Said claim does not suspend the deadline for the execution of the other points of the decision.
7.9. The Board makes an irrevocable decision regarding the claim against the payment of the arbiter's fees.
7.10. The arbiter sends an original copy of the decision to each of the parties by registered mail, and files another original copy with the Arbitration Board.
7.11. In the case of legal arbitration, the arbiter must also observe the formalities established by the code of civil law.

Art. 8 - Execution
Statements of reconciliation or decisions must be implemented by the parties within thirty days of their notification, unless another deadline is indicated in the decision.

Art. 9 - Applicability of procedures
The preceding procedures also apply to the process of reconciliation and contract appraisal, to the extent that they are relevant.

Compromise clause

Any question regarding the assessment of the rights, the determination of damage and its quantification that cannot be amicably resolved between the parties, will be referred to the outside arbitration of a single arbiter to be appointed according to the Rules of Procedure of the Arbitration Board instituted within the Centro Ceramico Bologna, which the parties declare they know and accept unconditionally.

Sources:

All pictures in this guide have been provided by Assopiastrelle, Edi.Cer. and Centro Ceramico Bologna.

The following pictures are included in the book Cer-Architect (Edi.Cer. 1999). They display projects, in Italy and other countries, made with Italian ceramic tile.

P. 19 Museo Leonardesco, Vinci (Firenze) - Italy.
P. 22 “St. Lawrence Square” Shopping Centre, Toronto - Canada.
P. 50 Lycée du Granier, La Pavoire - Francia.
P. 53 S. Rocco Clinic, Brescia - Italy.
P. 60 Oasi Congress Center, Acireale (Catania - Sicily) - Italy.
P. 74 Metro Bisolidos Centre, Water Treatment Department, San Diego - USA
P. 103 Palazzo Ducale, “Salone d’Onore”, Sassuolo (Modena) - Italy.
P. 112 Banca Popolare di Lodi - Italy.
P. 123 left: outdoor portico, private residence (Italy)
P. 123 right: National Insurance Institute, Budapest - Ungheria
P. 124 Piazzale della Chiesa di Santa Chiara, Assisi - Italy.
P. 127 Flooring, cheese production plant, Modena - Italy.
P. 130 left: antique Italian pharmacy
P. 135 top left: bedroom, private residence
P. 135 bottom left: Hotel Fortino Napoleonico, Ancona - Italy.
P. 143 top: Fashion Cafe, London - U.K.
P. 143 bottom - Montreal Station (Quebec) - Canada
P. 145 Heart Hospital, Rancho Mirage, California - USA
P. 146 Indian Mound - USA
P. 148 top: “Water Treatment Department, San Diego - USA
P. 148 bottom: Le Torri Company, Modena - Italy.
P. 154 left and top right: Piazzale della Chiesa di Santa Chiara, Assisi - Italy.
P. 156 left: Shopping Town Hotel, Melbourne - Australia
P. 158 flooring, private residence
P. 164 Golda Meir Center, Tel Aviv
P. 175 flooring, antique Italian palace
P. 179 Heart Hospital, Rancho Mirage, California - USA
P. 180 industrial plant, Dongen - Netherland
P. 181 Australian Institute of Science and Technology, Canberra - Australia
P. 186 flooring, private library
P. 197 Raffles Hotel, Singapore
P. 204 a square in S. Gimignano (Siena) - Italy.