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# FIRE RESISTANCE

The fire performance of most construction materials is a fundamental requisite in the *CЄ marking.*

According to European Commission decision 96/603/EC, all ceramic tiles that have received no organic treatment are classified, without any need for testing, in **class A1** of **reaction to fire**. As a result, the following codes appear in the *CЄ marking*:

- **A1** in ceramic tiles intended for wall tiling
- **$A1_{fl}$** in ceramic tiles intended for flooring

Ceramic tiles which, after the manufacturing process, have received a treatment that involves the presence of organic matter in a percentage exceeding 1% (for example, in protection primers for terracotta or fired clay tiles, or in anti-slip treatments applied on to porcelain tile or glazed stoneware tile), shall display the following codes in the *CЄ marking*:

- **F** in tiles intended for wall tiling
- **$F_{fl}$** in tiles intended for flooring

To be noted are the excellent properties of ceramic tile with respect to fire and fire propagation. The ceramic cladding of a construction element does not burn or produce toxic combustion gases; in addition, it inhibits fire propagation and, for a certain time, slows down heat propagation.

## Fire resistance according to EN 13501-1

This wide-ranging standard, published in February 2002, sets out in its first part the classification of materials, with their corresponding codes, based on the data obtained in the **fire reaction** tests. It includes the definition of terms and symbols, test methods, principles for test and sample preparation, testing of materials depending on whether they are applied to floors or not, criteria, and presentation of the classification.

The test methods envisaged in the standard include the following:

- *Non-combustibility test* (according to prEN ISO 1182) to identify materials that will not contribute to fire propagation, or that will do so in a negligible way. This is a pertinent test for classes A1, A2, $A1_{fl}$, and $A2_{fl}$.
- *Test for the determination of the heat of combustion* (according to prEN ISO 1716), which determines the maximum heat given off by a product when it burns completely, independently of its final use. This is appropriate for the same classes as the foregoing test.
- *Single burning item test* (according to EN 13823), which evaluates the potential contribution of a product to the development of a fire, under a fire situation that simulates a single burning item in a corner of a room near that

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product. It shall be applied for classes A2, B, C, and D; also for class A1 in certain cases.

- *Ignitability test* (according to prEN ISO 11925-2), which evaluates the ignitability of a product exposed to a small flame. It is applied to classes B, C, D, E, $B_{fl}$, $C_{fl}$, $D_{fl}$, and $E_{fl}$.
- *Reaction to fire tests for floor coverings. Determination of the burning behaviour of floor coverings using a radiant heat source* (according to prEN ISO 9239-1), which determines the critical radiant flux below which flames are not propagated on a horizontal surface. This is used to assign classes $A2_{fl}$, $B_{fl}$, $C_{fl}$, and $D_{fl}$.

The standard includes individual tables that set out the classes, the requirements for each class, as well as additional classifications in certain parameters, and the test methods applied to evaluate those requirements. The classification and codes are applied to all types of building materials, excluding those intended for floor coverings (**Table 1**), and those intended for floor coverings (**Table 2**). A qualitative description of the different codes is provided below.

The second part of the standard (UNE-EN 13501-2) is devoted to the characterisation and classification of construction elements in relation to their fire performance, based on the **fire resistance** test, which will be applicable to modular rigid coverings that adopt protective functions for load-bearing elements or act as separation membranes.

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| CLASSIFICATION OF CONSTRUCTION MATERIALS, EXCEPT THOSE INTENDED FOR FLOOR COVERINGS, ACCORDING TO THEIR REACTION TO FIRE (UNE-EN 13501-1) | |
|---|---|
| **Class** | **Description** |
| **F** | Products for which reaction-to-fire performance has not been determined or which cannot be classified as **A1**, **A2**, **B**, **C**, **D** or **E**. |
| **E** | Products capable of resisting, for a short time, small-flame attack without substantial flame propagation taking place. |
| **D** | Products that satisfy the criteria corresponding to class **E** and that are able to resist, for a longer time, small-flame attack without any substantial flame propagation taking place. In addition, they shall also be able to withstand thermal attack by a single burning item with sufficient delay, while giving off limited heat. |
| **C** | Like class **D**, but satisfying more stringent requirements. In addition, under thermal attack by a single burning item they shall provide lateral propagation of the limited flame. |
| **B** | Like class **C**, but satisfying more stringent requirements. |
| **A2** | They must such satisfy the same criteria as class **B** according to standard EN 13823. In addition, under conditions of fully developed fire, these products shall not contribute in any important way to fire loading and fire growth. |
| **A1** | The products of class **A1** shall not contribute to any phase of the fire including the one corresponding to the fully developed fire. For this reason, it is assumed that they are able automatically to satisfy all requirements of all the lower classes. |
| **Additional classification according to smoke production** | |
| **s3** | No limitation of smoke production is required. |
| **s2** | Total smoke production, as well as the rate of increasing smoke production, is limited. |
| **s1** | Stricter criteria are satisfied than those of class **s2**. |
| **Additional classification according to the production of drops/particles** | |
| **d2** | There are no limitations. |
| **d1** | No burning droplets/particles persisting beyond a given time are produced. |
| **d0** | No burning droplets/particles are produced. |

**Table 1**

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| CLASSIFICATION OF CONSTRUCTION MATERIALS INTENDED FOR FLOOR COVERINGS, ACCORDING TO UNE-EN 13501-1 | |
|---|---|
| **Class** | **Description** |
| $\mathbf{F_{fl}}$ | Products for which reaction-to-fire performance has not been determined or which cannot be classified as $\mathbf{A1_{fl}}$, $\mathbf{A2_{fl}}$, $\mathbf{B_{fl}}$, $\mathbf{C_{fl}}$, $\mathbf{D_{fl}}$, or $\mathbf{E_{fl}}$. |
| $\mathbf{E_{fl}}$ | Products capable of resisting small-flame attack. |
| $\mathbf{D_{fl}}$ | Products that satisfy class $\mathbf{E_{fl}}$ requirements and that are also able to resist, for a given time, attack by heat flux. |
| $\mathbf{C_{fl}}$ | Like class $\mathbf{D_{fl}}$, but satisfying more stringent requirements. |
| $\mathbf{B_{fl}}$ | Like class $\mathbf{C_{fl}}$, but satisfying more stringent requirements. |
| $\mathbf{A2_{fl}}$ | Products that such satisfy the same requirements as class $\mathbf{B_{fl}}$ in relation to heat flux. In addition, under conditions of fully developed fire, these products shall not contribute in any important way to fire loading and fire growth. |
| $\mathbf{A1_{fl}}$ | The products of class $\mathbf{A1_{fl}}$ shall not contribute to any phase of the fire including the one corresponding to the fully developed fire. For this reason, it is assumed that they are able automatically to satisfy all requirements of all the lower classes. |
| **Additional classification according to smoke production** | |
| **s2** | There is no limitation. |
| **s1** | Total smoke production is limited. |

**Table 2**

## Scientific-technical aspects of heat, flames, and their propagation in a fire

In order to understand the relative importance of the nature of the construction elements in relation to the development and consequences of a fire, it would be interesting to establish the general phases in which this phenomenon takes place.

Thus, if temperature is plotted as a function of fire development in a diagram, three different phases may be distinguished:

- An initial or ignition phase in which temperature increases slowly, since most of the heat is used in generating combustion and in evaporating the water contained in the materials.

- An intermediate phase in which temperature increases very quickly up to 800–900 ºC, as a result of heat build-up, flame irradiation, and the greater quantity of combustible material involved.

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- A final extinction phase in which heat loss through the walls, the effect of smoke, lack of oxygen, and air entry exceed the combustion heat.

Certain studies aimed at analysing materials and the parameters that define how these materials behave in relation to fire have been conducted[(1)]. Thus, the following may be distinguished:

*Material constituents of load-bearing structures*

Reinforced concrete has always been considered a safe material in relation to fire. However, the improved mechanical properties of cementing agents and steel, as well as the increased use of pre-compression treatments and prefabrication have led to lighter structures with a smaller cross-section, which display the same mechanical performance features.

In the case of fire, these structures reach more quickly the critical temperature at which their mechanical performance decreases. For that reason, with a view to avoiding or preventing the risk of structural failure, legislation on materials envisages different measures in regard to the coverings of load-bearing structures (use of insulation such as gypsum and vermiculite, renderings of different thickness, etc.).

*Material constituents of non-load-bearing structures*

The fire performance of flooring and wall cladding materials (including ceramic tiles) may be evaluated on the basis of the following parameters:

1. **Heating power**: Defined as the quantity of heat developed in the burn-up of a substance. According to this parameter, ceramic floor and wall tilings display complete inertia to combustion, in the range of temperatures that usually occur in a fire.
2. **Oxygen index**: This is the minimum required oxygen concentration to keep a material burning. Ceramic materials are fireproof at any oxygen concentration.
3. **Ignition or spontaneous combustion temperature**: These are temperatures at which a material starts to burn in the presence or absence of a flame, respectively. Once again, ceramic materials are fireproof.
4. **Development of the flame**: This corresponds to the rate of advance of the flame front.
5. **Flammability**: This is defined as the rate at which the flame travels from one side of the material to the other.
6. **Length of the flames**.
7. **Combustibility**: Parameter that considers the heat produced by combustion of the material and the speed at which this takes place.

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(1) *Behaviour of building materials in a fire.*
C. PALMONARI AND F. VAUGHAN.
CEC, European Ceramic Tile Manufacturers' Federation. Published in 1979.

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*In regard to these last four parameters, ceramic floor and wall tiles are also completely inert to combustion.*

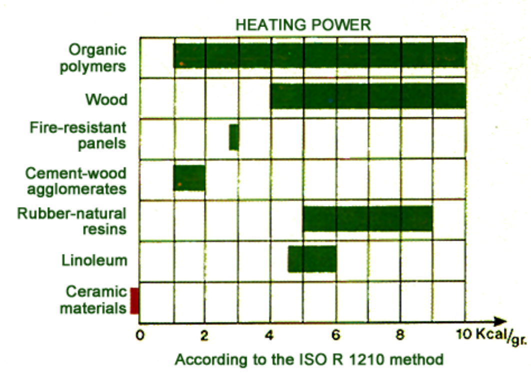
8. **Density and toxicity of smoke**: Many materials used in non-load-bearing structures produce smoke emissions. Smoke density is measured according to the standard of the National Bureau of Standards. Smoke is hazardous in itself, since it reduces visibility, hindering possible escape from a building in flames. However, in addition, it entails a risk of asphyxia and poisoning, since carbon monoxide is present in larger or smaller quantities in all combustion smoke. On the other hand, the use of organic materials of a petrochemical nature (PVC, polyurethane foams, and acrylic fibres) leads to increased concentrations of hydrocyanic acid and other toxic substances.

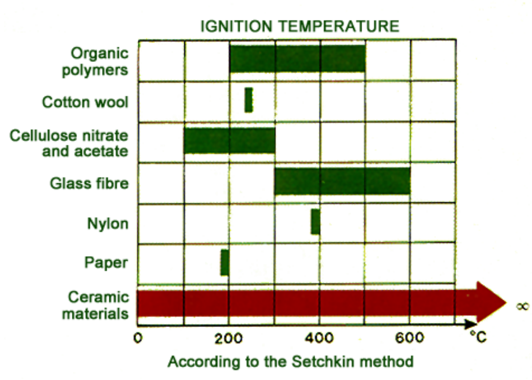
*Ceramic floor and wall tiles produce absolutely no toxic smoke or gas emissions*, which is why they are the most appropriate materials – together with their positive response in the other parameters for use in housing, and public buildings frequented by many people, such as hotels, offices, hospitals, service and commercial areas, theatres, etc.

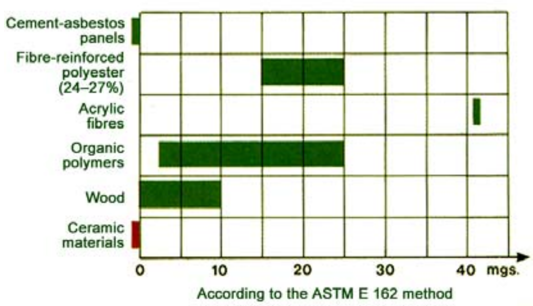
The enclosed figures present some of the results mentioned in the foregoing paragraphs.

A factor that needs to be taken into account, when it comes to evaluating ceramic tiling performance in relation to fire, is the fire response of the bonding and grouting materials used in tile fixing.

The tests conducted by the Rubber and Plastic Research Association of Great Britain, Shawbury, on panels of ceramic tiles installed with different materials, led to the following results:




*Production of smoke and toxic gases*

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- Solvent-based adhesives are hazardous in tile installation owing to their risk of flammability and toxicity; however, once the solvents have evaporated they are safe adhesives even under extreme conditions (flame in direct contact with the tile and glazed surface temperature of 535 ºC), and do not catch fire or lose their bonding properties.
- Polyvinyl acetate adhesives display no alterations at a surface temperature of 350 ºC. At higher temperatures they exhibit adhesion loss, though they remain fireproof.
- Latex adhesives are least resistant to fire, displaying considerable adhesion loss at 350 ºC and emitting non-toxic smoke. Their fire resistance increases when they are mixed with cement.
- Thin-set cementitious adhesives perform satisfactorily, though breakage occurs in tiles under the most unfavourable conditions. In thick-set beds, the results are less satisfactory above 350 ºC.
- Adhesives made from epoxy resins evidence no alterations below 400 ºC, whereas fracture and detachment phenomena appear at higher temperatures.

In short, it may be concluded that the bonding materials used in ceramic tile installation display very satisfactory fire performance, demonstrate good mechanical strength, and produce hardly any emission of fumes or potentially toxic substances.

It may be noted that analysis of laboratory tests and actual experience indicate that non-load-bearing building structures contribute most to the intensity and spread of flames, as well as to the formation of smoke and toxic gases. Therefore, appropriate selection of these materials represents the most effective prevention measure.

In view of the above, it may be concluded that ceramic floor and wall tiles are the most appropriate preventive coverings in the case of fire, given their incombustibility, inhibiting capacity for flame propagation, and absolute innocuousness in relation to the production of smoke and toxic gases. In addition, their delaying action in fire propagation can be useful for protecting the load-bearing structures, in addition to the temperature differential that their insulation capacity can establish between the fair face of the tiling and the base of the structure.

| Standard Heating Source Distance to the Clad Surface (in mm) | Temperature of the Fair Face of the Tiles (ºC) | Temperature of the Back of the Tile (ºC) |
|---|---|---|
| 152 | 350 | 80 |
| 76 | 460 | 90 |
| 0 | 535 | 100 |