CERAMIC TILING AS A SYSTEM. CODING PROPOSAL FOR APPLICATION IN INTERNAL TILING IN BUILDING CONSTRUCTION.

Julián Pérez Navarro[1], Francisco García Olmos[2]

[1]Director of the Technical Office of the Colegio Oficial de Aparejadores y Arquitectos Técnicos of the Murcia Region, [2]Director of Quality of ACE Edificación S.L.

1. INTRODUCTION

Ceramic tilings in building construction are often considered traditional work units, which in fact they are, given the antiquity of their use in buildings. However, the evolution of aspects relating to ceramic tiles and the backgrounds on which tiles are fixed sometimes makes it necessary to resort to the application of techniques and products that have nothing to do with traditional practices. At present, there is a wide range of types of tiles, bonding materials, grouts and other complementary products for tilings. All these items are however not necessarily mutually compatible, or can be equally applied onto any background, as all kinds of reciprocally conditioning factors can occur between these elements. The conditioning factors at issue therefore need to be determined, or the limits of application established, which reduce the risk of inappropriate arrangements. Knowledge of the characteristics of these components needs to be disseminated to all the parties involved, in addition to providing practical and coherent criteria for the correct design of the tiling system.

2. SOME CURRENT ERRORS

Two "misdirections" exist, without a doubt, in current practice when it comes to specifying ceramic tilings. The first is to consider the ceramic tile as the sole feature of the system, trusting tile manufacture to ensure the success of the system. On many occasions, when it comes to specifying, the only thing that is relatively defined is a certain type of tile of a concrete size. The tile installation technique is solved with traditional cement mortar or for the cases in which higher quality is desired, "cementitious adhesive" is specified. Besides this, little else is specified and what is worse, not much else is installed.

The second of these misdirections is, from our standpoint, of greater concern, since it means a head-on collision between the knowledge of materials and their operation in buildings, and the arrangement of elements in clear mutual incompatibility. In daily practice, from the point of view of the ceramic tilings, the only accepted deformation movement is that of the decks. Nobody questions the arrangement of decoupling layers for tilings on decks; thus layers of sand or gravel to achieve a relative independence that accommodates, as far as possible, the stresses in the tile layer deriving from the strains of structural elements. No other type of influence in respect of the deformations of the background is taken into account in everyday practice, with the sole exception of the qualitative consideration of thermal expansion in exteriors. Therefore, no other type of mechanism is considered nor constructed to this end, either inside or outside the tiling system. The movements stemming from compression stresses in the backgrounds, shrinkage of the substrates made of cement derivatives or even those of moisture expansion of the tiles themselves are systematically forgotten when it comes to conceiving and constructing ceramic tiling.

A simple reflection can enable us to understand the reach of these misdirections. Ceramic tilings are not a commonplace work unit in building finishes. The high mechanical properties of present ceramic tiles can cause their modulus of elasticity to far exceed that of the surrounding materials, for example, sometimes duplicating that of concrete, undoubtedly a reference material in the make-up of present buildings. As a result, a tiling panel with "butt" joints (absence of a tile-to-tile joint) forms a very thin sheet, however of tremendous rigidity with respect to the elements that habitually surround it. In these circumstances any strain imposed on the tiling entails strong

tensioning of the tile panel, which may be withstood by the bonding material or may sometimes give rise to bulging (buckling in mechanical terms), and therefore the ruin of the system. These and other considerations make correct and full specification an urgent need as an essential premise for a quality job.

3. COMPOSITION OF THE TILING SYSTEM

Ceramic tilings, in this case wall claddings on vertical facings, need to be conceived and specified as a system in which each part plays a certain role and is interrelated with the rest. This interrelationship is the basis on which success or failure in the performance of the tiling as a constructive element depends.

Basically a tiling system is made up of elements that form the tile panels, which generically have a surface character, and elements that serve as connections between the different panels, i.e., a subsystem of movement joints of a linear character.

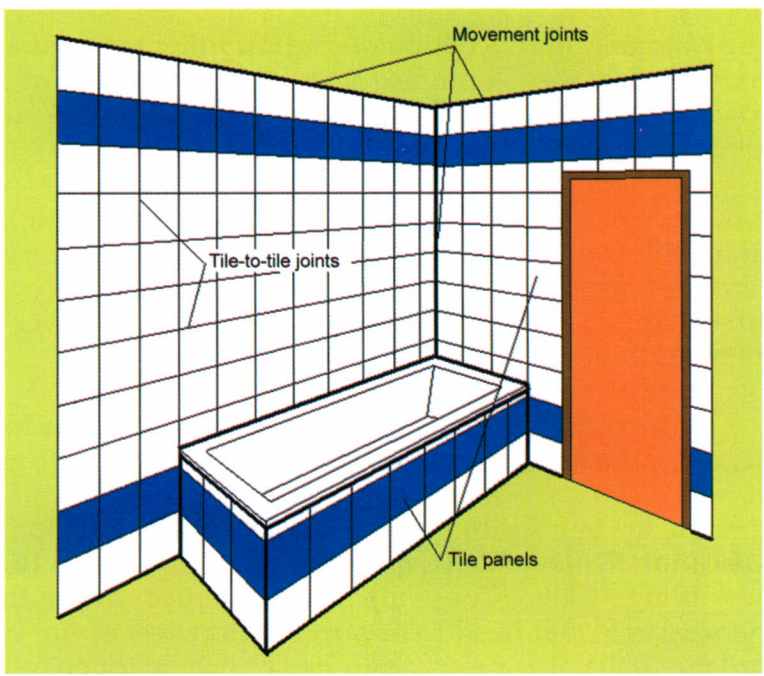

Figure 1. Schematic illustration of the "fair face" of a tiling system on a vertical facing

3.1. TILE PANEL

The elements that make up this subsystem are: the substrate which is the constructive element to be tiled; the surface to be tiled, which is the surface of this element which, with or without preliminary treatment, will be in contact with the bonding material; the bonding material itself and the final layer, consisting of tiles and tile-to-tile joints, which are in turn filled with grouting material.

3.2. MOVEMENT JOINTS

The movement joints are a fundamental part of the tiling system and serve as features that accommodate and act as safeguards for the stresses in the tile panel. These joints border the tile panel and are further designated in three ways:

- Perimeter movement joints that border the panel when there is a change of plane in the substrate.
- Intermediate movement joints that delimit the tiling panels in the same plane.
- Structural movement joints that carry the joints of the building structure into the tiling.

Except for the perimeter joints, which are generally present in any tiling, the intermediate and structural joints may appear or not, depending on the special circumstances that concur in a given tile panel.

4. SPECIFICATION OF THE TILING SYSTEM. PROPOSAL OF A CODE FOR TILE INSTALLATION.

The tiling system has to be suitably specified, both as regards the aspects that materialise in the specific tile panel and the system of movement joints.

In this sense of an integral conception of ceramic tiling as a system, it is proposed to establish a code that serves simultaneously as an instrument to describe the composition and, together with the characteristics of the tile, to complete the specification of the system.

In the composition of a tiling system, two elements occur as independent variables: the ceramic tile, which is chosen in terms of criteria that are not exclusively technical, and the background to be tiled, which is normally not specifically constructed to fit the tiling system. These two variables, however, will decisively influence the composition of the tiling system.

The code that is proposed here in fact brings together the characteristics of the rest of the components of the system, beside the ones mentioned, i.e., tile and substrate.

The code is made up of a series of five fields, four specification that are termed compulsory specification fields, which gather the necessary minimum features for the specification of any tiling system. These are complemented with a fifth specification field, which gathers aspects that need to be specified in view of the singularity of the case at point. Fundamentally, this field would be applicable for characteristics related to preliminary treatments of the background, certain conditions of interest relative to the installation, etc.

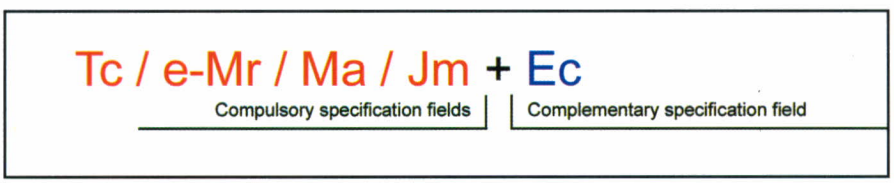

Figure 2. Code format for the ceramic tiling system

In addition to reflecting the greatest amount of information on the system in a rapid form, this coding approach tries to contribute to tiling system design by not leaving out any fundamental aspects that should be taken into account.

5. DEVELOPMENT OF THE CODE

5.1. COMPULSORY SPECIFICATION FIELDS

The following table sets out the various variants for each compulsory specification field, which occur in practice in internal wall tilings.

Compulsory specification fields			
Fixing technique **Tc**	**Thickness and grouting material** **e-Mr**	**Bonding material** **Ma**	**Movement joint system** **Jm**
G	e-JL	M	Mc
F	e-CG_1	A	Me
FF	e-CG_2	C1	
	e-RG	C2	
		D	
		R	
		Rd	

Figure 3. Schematic table of the compulsory specification fields.

The following sections briefly describe the different boxes of the table.

5.1.1. Fixing technique Tc

The first section, **Tc**, refers to the tile fixing technique, specifically to the following types:

G. *Thick-bed fixing* by applying traditional mortars. Mortar is applied with trowel on the back of the tile that is installed in its definitive place on the facing by tapping on the fair face of the tile.

F. *Thin-bed adhesive fixing on flat surfaces*. The adhesive one is normally applied with a trowel to produce a regular layer and is then combed with a notched trowel to obtain the appropriate thickness and the flatness.

FF. *Buttering and floating*. This consists of fixing a tile in a thin layer by means of two layers of adhesive: one applied onto the substrate and the other onto the back of the tile.

5.1.2. Tile-to-tile joints e-Mr

The second field, **e-Mr**, is reserved for the width of the tile-to-tile joint in mm-grouting material.

e *Width of the tile-to-tile joint*. It is recommended to set out tile-to-tile joint widths starting at 3 mm, although in some cases, for aesthetic reasons and always in the presence of stable backgrounds, this width can be reduced to 1.5 mm.

JL *System of traditional grouting with cement grout*. Mixture of cement, water and possible additions.

CG *Cementitious grouting material.* Mixture of hydraulic binders, mineral fillers and organic and inorganic additives, which only need to be mixed with water or a liquid addition prior to use.

By incorporating a liquid latex addition (special aqueous polymer dispersion), which can be mixed on site with the cementitious grout, an improved cementitious grouting material is obtained with additional characteristics. (Ar: high abrasion resistance and W: low water absorption). This then yields the following classes:

- CG1: Standard cementitious grouting material.
- C21: Cementitious grouting material with additional characteristics.

Standard UNE 83.800-94 establishes additional conditions for mortars for tight joints.

RG *Grouting material with reactive resin.* Mixture of synthetic resins, mineral fillers, organic and inorganic additives, which hardens as a result of a chemical reaction. These are available in the form of one or multiple-component systems.

5.1.3. Bonding material, Ma

The type of bonding material, **Ma**, features in the third field

M *Traditional mortar.* Mixture of cement and aggregate with water, in an appropriate proportion until obtaining a homogeneous mass.

This type of bonding material is customarily used for thick-bed fixing. The mortars used shall meet the requirements of standard "UNE 83.800-94. Masonry mortars."

The recommended classes of cement mortar or bastard mortar, based on their compressive strength are set out in standard UNE 83,800-94 (M-2, M-4 and M-8).

The water content shall be the quantity needed to reach the desired consistency; it is recommended not to exceed a cement/water ratio of 0.60.

C0 *Conventional cementitious adhesive.* So-called conventional mortars are cementitious adhesives that do not meet standard UNE-EN 12004 but do conform to the CE mark requirements (UNE-EN 12004/A1:2002)

These adhesive ones are not recommended for:

- external flooring
- large size tiles
- tiles with water absorption below 3%.

C1 *Cement-based adhesive.* Mixture of hydraulic binders, mineral fillers and organic additives, which only needs to be mixed with water or a liquid addition just before use. They meet the compulsory characteristics of UNE-EN 12004. They contain synthetic resin additions that assure medium-high adhesion.

These adhesive ones are not recommended for use with tiles of water absorption below 1%

C2 *Cement-based adhesive.* As in the foregoing, this is a mixture of hydraulic binders, mineral fillers and organic additives, which only needs to be mixed with

water or a liquid addition just before use. They meet the compulsory and optional characteristics of UNE-EN 12004. They contain synthetic resin additions or separate components that assure high adhesion.

5.1.4. Deformability

It would be necessary to add deformability to this coding of cement-based adhesive, according to UNE-EN 12002; i.e., **S1** and **S2**, as special characteristics in the sense of including medium or high deformability or not.

Thus, we could have a cementitious adhesive **C1 S1** of medium adhesion and medium deformability, **C1 S2** of medium adhesion and high deformability and **C2 S1** of high adhesion and medium deformability.

D *Dispersion resin adhesives.* Mixture of organic binder(s) in the form of a polymer in aqueous dispersion, organic additives and mineral fillers, which are supplied ready for use.

- **D1** for dispersion resin adhesives that meet the compulsory characteristics of UNE-EN 12004 .
- **D2** for dispersion resin adhesives that meet the compulsory and optional characteristics (adhesion at high temperature and after water immersion) of UNE-EN 12004.

The use of this type of adhesive is not recommended for floor tiles.

R *Reactive resin adhesive.* Mixture of synthetic resins, organic additives and mineral fillers, which hardens as a result of a chemical reaction. They are available in the form of one or multiple components. (UNE-EN 12004).

- **R1** for the reaction resin adhesives that meet the compulsory characteristics of UNE-EN 12004
- **R2** for the reaction resin adhesives that meet the compulsory and optional characteristics (adhesion after thermal shock and resistance to specific chemical products) of UNE-EN 12004

Rd *Deformable reactive resins adhesives.* Mixture of synthetic resins, organic additives and mineral fillers, which hardens as a result of a chemical reaction. They are available in the form of one or multiple components. Unlike the foregoing adhesive, they have the capacity to deform after hardening without significant loss of surface adhesion.

5.1.5. Movement joints, Jm

Mc *Conventional system of movement joints.* System of movement joints set out solely with perimeter joints

Me *System of movement joints* that includes intermediate joints in addition to the perimeter joints. Intermediate joints are generally positioned in such a way as to avoid having tiling panels longer than 8 m.

Independently of which joint system is selected, the movement joints that exist in the background shall be carried though into the tiling system, by installing the corresponding structural joints.

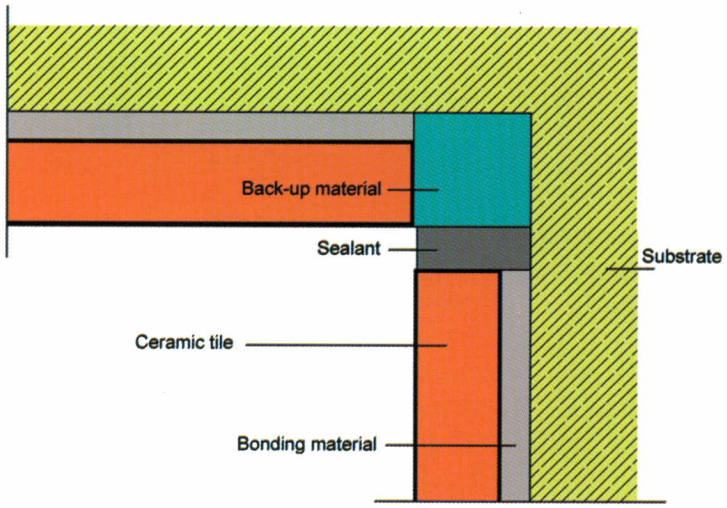

Figure 4. Scheme of a perimeter joint

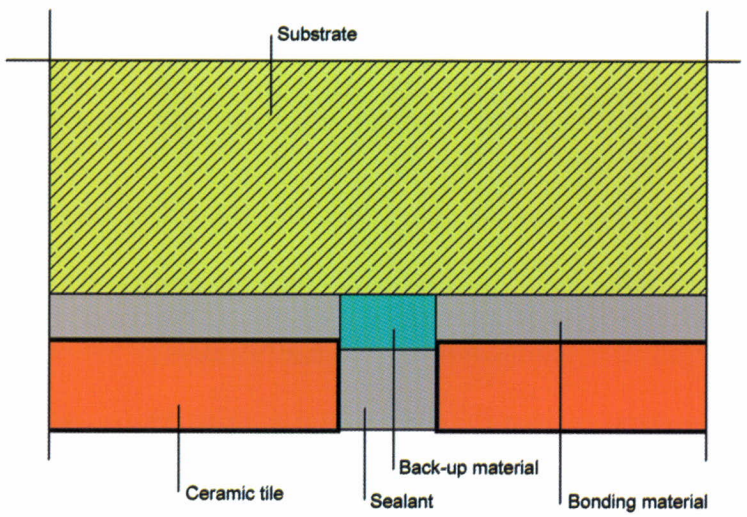

Figure 5. Scheme of an intermediate joint

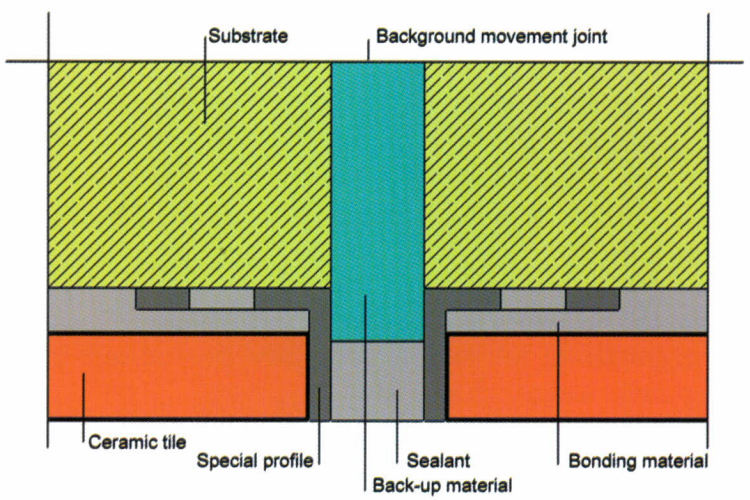

Figure 6. Scheme of a structural joint

5.2. COMPLEMENTARY SPECIFICATION FIELD

The following table sets out various possibilities for the use of the complementary specification field, which can include any circumstance of interest, to make the tiling system complete.

This can refer to preliminary treatments of the substrate to achieve an appropriate surface for tile installation, or circumstances to be taken into account during the tiling process. The table details some of these possible considerations.

Note that on many occasions, the content of this field will not materialise until the definitive characteristics of the substrate are known.

Description	Example of coding
Aplication of regulatory layer to the substrate	**Reg**
Treatment of the substrate with a consolidating primer	**Con**
Treatment of the substrate with a pore-sealing primer	**Tap**
Preliminary wetting of the substrate	**Hum**
Treatment of the substrate with a bonding primer	**Adh**
Requirement of specific lighting	**Lux**

Figure 7. Table schematically detailing the field of complementary specification.

Reg. *Application of regulatory layers*. Sometimes the substrate does not display sufficient planarity for direct application of the bonding material, making it necessary to apply a regulatory layer, usually consisting of cement mortar.

Con. *Application of a consolidating primer*. On some substrates with little cohesion, this type of treatment with a specific primer is advisable, which manages to recover a sound tile installation surface, even having a certain impermeability.

Tap. *Sealing by means of a pore-sealing primer*. Appropriate treatments for excessively absorbent substrates.

Hum. Traditional technique of watering the substrate prior to tile installation

Adh. *Bonding primer*. This treatment is applied to substrates with zero water absorption

Lux. *Conditioned lighting*. Sometimes the tiling panel has to be illuminate during its execution, in a similar way to the definitive lighting, with a view to controlling certain effects. This condition is important for example in the case of lighting set flush with the tiling .

6. DESIGN OF A TILING SYSTEM

This section sets out the criteria for the design of tiling systems, methodically completing the corresponding code.

In the first part, the parameters are established that are to be taken into account from the point of view of the ceramic tile, already chosen, and of the substrate. The following section relates these parameters to the elements to be selected for each specification field.

6.1. PARAMETERS OF INFLUENCE

6.1.1. Influence of the ceramic tile

Tile size

Based on size and the effects that are dealt with here, ceramic tiles can be classified in tiles of normal size and large size according to the criteria in the following table:

Tile surface area in cm^2.	Size
Up to 900	Normal
Above 900	Large

Figure 8. Table for tile classification based on size.

The influence of tile size can be found at times in the lack of total contact of the back of the tile with the adhesive when tiles of a certain size are used with thin-bed fixing. In general it is recommended to use the buttering and floating method when the tile surface area exceeds 900 cm^2.

Analogously, it is recommended not to use dispersion adhesives (D) for the tiles that exceed the mentioned size, in view of the difficulty of evaporating the water used in dispersing these adhesive and therefore attaining the "setting" process.

Texture on the tile back

The texture on the tile back can influence the selection of the tiling system. To this end, ceramic tiles are classified as tiles with or without projections on their back.

Thus, tiles sometimes display projections on their backs (dovetails, for example), which hamper the surface contact coverage with the bonding material when this is applied onto the substrate. In such cases, buttering and floating is recommended, i.e., the application of adhesive onto the back of the tile prior to installation.

Ceramic tile water absorption

Based on this parameter, tiles can be classified in terms of high or low absorption, which in turn conditions the type of bonding material that can be used. The following table contributes criteria for classifying ceramic tiles based on water absorption.

% absortion	Absortion class
>3%	High
≤3%	Low

Figure 9. Table for classifying tile based on water absorption.

One of the classic ways of interpreting the adhesive capacity of a tile is to have data on its water absorption. The most absorbing tiles have a greater capacity for anchoring as a result of the bonding material entering the tile pores, obtaining a better physical connection.

Moisture expansion

The potential moisture expansion of ceramic tiles can condition the selection of some elements of the system and in particular the bonding material, in view of the foreseeable appearance of shear stresses. These stresses, should they occur, grow in proportion to the tile size and gain in magnitude as they approach the tile perimeter. In daily practice, it is common not to have data on tile moisture expansion, especially when designing the projected tiling system. It is advisable, however, to select deformable bonding materials whenever a large tile size is involved.

6.1.2. Influence of the substrate

Substrate stability(*)

In the context of this study, by stable substrates are meant the constructive elements that do not exhibit movements of importance such as shrinkage, deflection or vibrations. Examples of this type of substrate are external and internal masonry walls, brick partitions set on a sound base, sufficiently mature concrete walls, etc.

Examples of unstable substrates could be recently made concrete walls, brick partitions placed on a non-rigid deck (small ratio edge/span), thin plasterboard panels, wood, etc.

Cohesion of the fixing surface(**)

Tiling systems need a sound substrate. Therefore, in the case of non-cohesioned substrates, cleaning and replacement treatments have to be applied by means of complementary layers, or by using consolidating primers.

Chemical nature of the fixing surface

The chemical nature of the fixing surface can condition the selection of the bonding material. In general the usual surfaces in construction display no problems in this sense, except when the surface consists of gypsum or its derivatives. In these cases there is mutual incompatibility with the cement-based adhesive in view of the possible reaction between the sulphates and cement aluminates. However, these reactions need the presence of water, so that one of the solutions, if this type of

(*)By substrate is meant the constructive element to be tiled: wall, partition, etc.

(**)By fixing surface is meant the surface of the constructive elements that will receive the tilling system.

adhesive is to be used, is to prime the substrate to establish an impermeable layer. Sometimes special adhesives with casein are used.

Planarity of the fixing surface

In general, for conventional tilings, a certain planarity of the fixing surface is required, which can condition the composition of the system.

The flatness of a substrate is generally measured in relation to its deviation in respect of the straight line marked by a 2-m long ruler.

Measured deviation in 2-m ruler	Planarity class
Less than 3 mm	High
From 3 to 8 mm	Mean
Above 8 mm	Low

Figure 10. Table for the classification of the fixing surface based on planarity.

Water absorption-suction of the fixing surface

Just as in the case of the ceramic tile, the water absorption of the fixing surface conditions the adhesion of the bonding material. A practical way of evaluating this parameter is to sprinkle the fixing surface with water and to observe the time it takes for the shine to disappear. The table details criteria for the classification of water absorption-suction.

Time in seconds	Absorption class
Less than 20	High
20 to 60	Medium
Above 60	Low

Figure 11. Table for fixing surface classification based on water absorption-suction.

6.1.3. Other parameters of influence

In addition to the parameters dealt with above, circumstances can appear that advise a more fine-tuned selection of some of the elements in the system. Without any doubt, the most important are associated with the appearance of significant tangential stresses, which usually stem from thermal swings. If such is the case, it becomes necessary to select solutions that provide the system with the capacity to dissipate any induced stresses. In this sense, the specifier has at his disposal a series of mechanisms: consideration of deformable bonding materials; study of the location and nature of the movement joints, or the use of grouting materials with low moduli of elasticity together with a greater joint width. In any case, these effects are usually unimportant in the conventional field of internal wall tiling considered here.

6.2. SELECTION OF THE FIXING SYSTEM

With a view to establishing criteria, albeit generic, which are valid for most internal ceramic wall tilings, the following tables have been drawn up, which set out the suitability or unsuitability of the different components as a function of the conditioning factors of the ceramic tile and substrate.

Suitability as a function of the conditionng factors of the ceramic tile							
Specification field	Key	Size		Absorption		Back texture	
		Normal	Large	High	Low	No projections	With projections
Fixing tchnique	G	A	A	A	NA	A	A
	F	A	NA	A	A	A	NA
	FF	A	A	A	A	A	A
Bonding material	M	A	A	A	NA	A	A
	C0	A	A	A	NA	A	A
	C	A	A	A	A	A	A
	D*	A	NA	A	A	A	A
	R	A	A	A	A	A	A

*A.- Appropriate / NA.- Inappropriate *Inappropriate for systems in contact with moisture*

Suitability as a function of the conditioning factors of the substrate									
	Key	Stability		Planarity			Absorption-suction		
		Stable	Unstable	High	Medium	Low	High	Medium	Low
Fixing technique	G	A	NA	A	A	A(1)	A	A	NA
	F	A	A	A	A(1)	A(1)	A	A	A
	FF	A	A	A	A(1)	A(1)	A	A	A
Tile-to-tile joint system	JL	A	NA	-	-	-	-	-	-
	CG	A	NA	-	-	-	-	-	-
	RG	A	A	-	-	-	-	-	-
Bonding material	M	A	NA	-	-	-	A(2)	A	NA
	C0	A	NA	-	-	-	A(3)	A	NA
	C	A	A*	-	-	-	A(3)	A	A
	D	A	A*	-	-	-	A(3)	A	A
	R	A	NA	-	-	-	A(3)	A	A
	RD	A	A	-	-	-	A(3)	A	A

***A(1).-** Appropriate with regulatory layer **A(2).-** Appropriate with surface preparation by wetting **A(3).-** Appropriate if precautions are taken with regard to the size of the area of adhesive application *Consideration of the deformability of the adhesive in cases of particular instability of the substrate*

7. FINAL REMARKS

To conclude this communication we wish to highlight the well-known functional characteristics of ceramic tiling, some of which are intrinsic to tile itself (hygiene, low maintenance, etc.), while others can be readily linked to tile (waterproofing, thermal and acoustic insulation, etc). Thus for a moment, we have just wished to leave aside the existing disenchantment, when we think about the failures of this type of cladding. These as we all know are due to many factors that are not always under our command (little standardization, lack of professional qualification, reduced implementation of the thin-bed system, etc.).

We therefore hope that with this attempt to establish a possible coding or registration of the different internal ceramic wall tiling systems, we have contributed a wisp of encouragement to this dear profession.

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