TILE INSTALLATION PROJECT
A Spanish initiative for quality tiling

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....tile is excellent in artistic efficiency, functionality, durability and economic efficiency. I believe that ceramic tile will become an increasingly important material for future cities and architecture.

SHOZO UCHII (Qualicer'92)

ABSTRACT

A project is presented, aimed at improving ceramic tile installations in a country with high tile consumption, a long tradition in tile applications, but with notable shortcomings that affect all the links of the chain involved in tile distribution and use.

After describing the context of this action model, the contents of a unitary document are set out on tile installation techniques: selection of the ceramic tile, bonding and grouting materials, diagnosis and treatment of backgrounds, installation techniques and systems, and other complementary contents.

The project includes a training model directed at the various professional figures that intervene in the marketing and use of ceramic tiles, with a methodology design for assessing professional competence and trainer training, as well as the use of multimedia tools.

THE FUTURE OF CERAMIC TILE IN TERMS OF QUALITY

Since the introduction of the porous-single firing process and the current production structure in tile manufacture, as well as raw materials preparation by the wet method, this industrial branch has undergone significant transformation as a result of innovations in the production process, propitiating innovation in ceramic tile, both in its fundamental technical and aesthetic characteristics. As **Table 1** sets out, in the 80s we entered a stage, in which not only was technical and aesthetic diversification in tile consolidated, but a specialised product offer was recovered, which can aspire to uses other than purely residential applications.

CERAMIC TILES AND ARCHITECTURE		
Industrial Sector	**Building Construction**	**Tile installation**
Fully automated manufacturing process	Industrialised construction	Design of ceramic tiling
Product innovation	Prefabrication and new materials	Fit to functional requirements
Offer diversification	Comfort and energy saving	High performance deformable adhesives
Quality management	Functional requirements	and grouting materials
Technical marketing	Maintenance cost	Durability
	Respect for the Environment	Quality assurance

Table 1.

However, the ceramic tile industry has practically centred all its efforts on the industrial area and product innovation, without attending to tile destination, with regard to possible new or recovered uses, or the need to offer a service that could provide greater added value or consolidate an existing value. The success of the designer tile, growth of the rustic tile range, notable advances in tile decoration led by a powerful auxiliary industry of frits and glazes, low temperature decoration, as well as the emergence of porcelain tile, have together given rise to an impressive offer that can comfortably attend to interior decoration demands. The offer does however present some important gaps when products destined for non-residential applications are to be promoted, in which functional requirements outweigh aesthetic needs. This is where the branch has until recently exhibited a certain contradiction: suitable products are available, but an appropriate technical marketing policy has not been developed for promoting these non-residential products.

This development, shared by the major tile producing nations, parallels that of building construction, an evolution characterised by fast tracking, new materials, and of late, considerations relating to comfort, energy saving, maintenance costs, and environmental interaction. With regard to finishes in building construction, constructional solutions and materials tend to be preferred, which favour the obtainment of the above objectives[1].

Within the context of these objectives of today's Architecture, ceramic tiling represents an option for the future in economic, functional, aesthetic and environmental terms, as the Japanese architect Shozo Uchii so masterfully stated in this very same international forum[2]. A rapid review of the architecture found in the Pacific area, with widely differing countries and cultures in which tiles were not generally used in building construction until recently, reveals that a spectacular growth has taken place in tile applications in exteriors, both in curtain walls and in softer versions where texture, combinations of materials and light effects are allowed to play a role. This is a major phenomenon, and is a consequence of the positive aesthetic and functional evaluation that ceramic tile deserves when a satisfactory tile installation has been assured. It is precisely the assurance of the durability and low maintenance of ceramic envelopes[3], and the incorporation of prefabricated panels that meet all the stipulated functional requirements[4], which can be rapidly and easily installed, which have been decisive factors in this widespread boom in ceramic applications.

In the face of growing tile use, taking into account the product's high technical and aesthetic levels, it would be convenient to focus on promoting technical marketing, especially in disseminating selection criteria and fostering ceramic floor and wall tile applications beyond the residential environment, based on an innovated tile installation technology. This would be supported by:

* Setting clear tile and installation materials selection criteria, considering the compatibility of the background, functionality and performance requirements in terms of environmental conditions.

* Considering floors ands facings as multilayer systems in which the ceramic tiling forms the epidermis, behind which adaptation is needed to the backgrounds or backing materials, or to one or more specific material functions (vapour diffusion capacity, sealing, thermal insulation, soundproofing, electrical conductivity, etc.).

* The combined relationship of characteristics and behaviour of the installation background and the tile itself with the bonding and grouting materials, setting clear selection criteria for these materials, favouring those that assure optimum adhesion strength and deformability, even in the most unfavourable situations.

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[1]. The wall of the future. MASSIMO COLOMBAN. Proceedings of International Conference of Building Envelope Systems and Technology (ICBEST'97) pages 17-25. University of Bath (United Kingdom). April 1997

[2]. The role of the ceramic tile in contemporary architecture. New expressions in design. SHOZO UCHII. Qualicer'92, pages 23-28

[3]. Durability of the facade. DIEGO ALVES. Proceedings of International Conference of Building Envelope Systems and Technology (ICBEST'97) pages 281-286. University of Bath (United Kingdom). April 1997

[4]. Evolution of curtain wall design against water infiltration. RAYMOND TING. Proceedings of International Conference of Building Envelope Systems and Technology (ICBEST'97) pages 217-222. University of Bath (United Kingdom). April 1997.

* Intervention in tiling design, especially by incorporating elements that will together avoid producing rigid systems: movement joints and tiling joints.

* Research and development of new materials for those flexible elements of the tile finish, which constitute the complement of the epidermis, whose sealing, resistance to UV rays, chemical resistance, and optimum behaviour generally on ageing needs to be assured[5].

* Growing attention to prefabricated products capable of being tiled, especially those destined for use as envelopes and partitions.

CERAMIC TILES IN SPAIN: MANUFACTURE, MARKETING AND USE

The Tile Installation Project appears at a time of important changes in the materials and processes involved in tile installation, almost at the end of a period that has produced a considerable rise in non-quality in tile finishes. These changes have almost equally affected all the sectors and trades that intervene in tile installation, precisely at a time when the future European standards on bonding and grouting materials are being defined, as well as the *European Guide for the design and installation of ceramic tiling*. Let us briefly examine the various industrial, commercial and professional sectors involved:

CERAMIC TILE MANUFACTURING INDUSTRY

The thorough technological upgrading that started in the mid eighties not only provided a substantial rise in production but also allowed implementing technological innovation in the processes and production of a wide range of products, which differed technically and formally from products belonging to the pre-upgrading period. Specifically, raw materials preparation processes by the wet method (spray drying), the optimisation of forming by semi-dry pressing, and current firing processes in single-deck kilns have allowed:

* Obtaining tiles with enhanced technical performance, widening the product range by **diversity and specialisation.**

* Producing **less porous tiles**, ranging from semi-vitreous to highly vitrified products, with a water absorption capacity of less than 0.1%.

* **Ever larger sizes**, almost without constraints on dimensions or geometry, accompanied by strong promotion efforts devoted to exclusively using sizes exceeding 20 x 20 cm.

* Considerable increase in the offer of finishes and decorations, with the incorporation of new generations of glazes and low temperature decoration techniques, with an added diversification for technical and formal tile characteristics.

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[5]. The evolution in joint sealing. PAUL DURHAM. Proceedings of International Conference of Building Envelope Systems and Technology (ICBEST'97) pages 223-228. University of Bath (United Kingdom). April 1997

If the spectacular production hikes of recent years have considerably stimulated exports, there has been a noticeable effect on the domestic market. Spain currently tops tile consumption per capita in the European Union, with a domestic consumption that lies at around 200 million square metres yearly. Even without statistically reliable data on the domestic market, a large part of domestic consumption is known to go to residential tiling applications, and to the large market in renovation/restoration; however, a growing part is intended for non-residential applications, both in interior decoration design and building exteriors. The manufacture of high performance tiles suggests uses in non-conventional areas, and this proposal is intrinsically linked to a non-conventional tile installation.

Finally, tile distribution and sales have undergone considerable structural transformations, going from great wholesale distributors to retail sales through specialised tile stores and showrooms, in an attempt to unite tiles with sanitary ware, bathroom and kitchen furnishings. This capillary diffusion in tile marketing has also led to a growing lack of technical competence in sales staff, which already exhibited notable shortcoming in the preceding period, especially in technical marketing.

The diversification of the product offer, and desire to include tile in non-residential domains with concrete service requirements, have led to an urgent need for information and product selection specifications. Given the high sales volume through retail sales outlets, such information must necessarily also be available at the sales outlets. Both variables highlight the general absence of information on the ceramic product and selection criteria for given uses in specific architectural contexts, information that is hardly covered by the technical marketing departments of a handful of ceramic companies.

INDUSTRIAL SUPPLIERS OF TILE INSTALLATION MATERIALS AND EQUIPMENT

The high tile consumption, expectations with regard to changes in tile fixing techniques, and appearance on the market of new products have led to a substantial change in the offer of bonding and grouting materials for tile installation by some companies, which have come to establish themselves in Spain, and by others that were already established and have diversified their production. This phenomenon, which in principle is positive in widening and diversifying the offer in bonding and grouting materials, has had quite varying repercussions as there are no regulations available in Spain to regulate the quality and performance of these materials. The sales of low quality adhesives with the same references as high-performing ones have given rise to innumerable problems relating to quality, especially when tiles with low or very low apparent porosity are used together with non-stable or rather unsuitable substrates for encouraging the formation of a mechanical bond with cementitious adhesives.

On the other hand, the prefabricated product, special tile installation materials and equipment branches, though having a stable presence in Spain, have only achieved slight penetration into the markets as a result of their restricted promotional capacity, so that at present, specifiers are still largely unaware of the scope, in terms of quality and durability of tiling installed with these types of materials.

SPECIFIERS: ARCHITECTS AND TECHNICAL ARCHITECTS

The almost general absence of any specification is to be highlighted both in the planning and execution of the work, as a result of not having any updated regulations on the subject. To be added is furthermore the relative unacquaintance with tiles and even greater unfamiliarity with installation technology. If we also add the absence of any control on finishes we gain an impression of insecurity in tile use, and at times of a move towards alternative, *less problematic* products. This has led to problems of aesthetic and functional quality in tiling, especial in special applications, as well as a significant rise in pathologies and complaints regarding tile products and installations.

THE BUILDING INDUSTRY

The quality of building finishes generally tends to improve, with new functions being assigned to facings whether clad or not with tile. Such is the case of sealing materials, thermal insulation, soundproofing, underfloor heating, etc. However, this increase in functional quality goes together with new requirements for the materials used, requirements that also extend to tile and tile installation systems.

On the other hand, industrialised building construction has led to using new backgrounds and sharp drops in construction times, involving substrates with different behaviour to traditional backgrounds for tile fixing. The unfamiliarity with these backgrounds and absence of correcting measures usually entail the risk of a good many problems relating to the proper functioning and quality of the ceramic finish.

Last but not least, the lack of professional competence in the installation, mainly encountered with a certain type of subcontracting at low prices involving piecework, underlies most of the problems currently found in ceramic tile installations.

There thus often arises a disappointing gap between expectations and results in ceramic tilings. The need to apply new tile installation methods and use of suitable materials does not match the professional skills available or budgets involved, and problems relating to non-quality surface again.

TILE FIXERS

A general shortage of competent tile fixers has been observed in Spain. This conclusion was arrived at after meetings with the distribution branch, tile manufacturers, and experts from the adhesives and tile installation materials branch. Basically three types of tile fixers are found:

* Subcontractors, of recognised prestige in their geographical area, who undertake assignments on a non-piecework basis, with a good level in conventional applications and more or less successful forays into special installations. They preferably work in the free-rent housing sector, single-family housing and large budget renovations.

* Self-employed tile fixers who are self-taught or have received training in some tile

fixing course. They undertake fast, quality installations in conventional applications using thick-set fixing in cement mortar. They hardly have any experience however in thin-set installations, and represent the most qualified group doing piecework or who take on work according to an estimate, in medium-level building construction.

* Versatile masons who individually or in groups take on tiling jobs as piecework or by the square metre, without any quality reference unless this be that the tiles do not fall off straightaway.

As a result of the above remarks on the shortage of competent tile fixers and differences in the ways of working of the various groups described, a great price difference can also be inferred amongst them, without of course any reference prices being available either.

In the face of no regulated training (at the moment), and the scatter in non-regulated training, but especially considering the absence of any trade regulations or recognition of trade status, every imaginable situation can arise according to the professional practice of each territory, and the quality levels which, be they well or badly understood, are expected there.

The inadequacy of the available training, centred on traditional floor and wall tiling methods with thick-set tile installations, for the profession's current needs, makes it virtually impossible for competent tile fixers to accede to the trade, who can satisfy the need for qualified tile fixers, and can undertake any type of tiling job with the necessary guarantees.

The further non-existence of any trade associations or groupings, except for a few isolated cases, considerably hamper any type of communication with this professional group.

In view of the foregoing, it may be concluded that:

- There is a important shortage of competent tile fixers for special applications (exterior tiling or tiling that is to perform specific functions). This involves a clear constraint on product uses outside the residential environment, and limits possible future uses that had such a high profile in the past (sanitary architecture with public access, facades, urban furnishings, etc.).

- The non-existence of suitable training to meet current requirements in tile installation quality also acts as a constraint on product growth, while involving a significant rise in prices, with price levels being reached resembling those in the major European countries without the counterpart quality assurance.

- The lack of specifications and control on finishes also foster professional incompetence and low cost piecework without any kinds of restrictions, as there are no legally enforceable standards. In most cases, regardless of the existence of any complaints, user dissatisfaction is the result. The greater the expectations raised by the ceramic tile, the greater the disappointment at the result.

Table 2 presents an overview of the context in which the present training project is to be situated, in terms of the various branches involved in tile installation.

TILE INSTALLATION PROJECT CONTEXT			
Industrial/ professional sector	**Characterisation**	**Effect**	**Result**
Ceramic tile manufacturers	Technological innovations in processes and products Strong domestic market (≈200 10^6 m^2/year) for new housing and renovation. Forays into non-conventional applications. Drastic changes in distribution and sales	Less porous tiles Larger sizes Offer diversification and specialisation Interior decoration and consumption product Inadequate after-sales service Retail market Low professional competence in sales	• Need for information and specifications for product selection • Non-quality stemming from unsuitable product selection • Unsuitable tile selection and installation
Tile installation materials and equipment suppliers	Expanding adhesives and grouting materials sector Distortion in product offer stemming from lack of regulations Scarce penetration of prefabricated products Low level of equipment in tile installation	Unfamiliarity with available materials Purchase by price instead of suitability or quality Scant use of prefabricated products Low quality finishes	• Problem of quality in ceramic tiling • Low functionality of tile claddings • Defective finishes
Specifiers: Architects and Technical Architects	• Absence of specifications stemming from absence of regulations • Little familiarity with ceramic tile and tile fixing technology Absence of quality control	Absence of tiling design Lack of product selection criteria Lack of guidelines in directing building construction Tile fixers have no interlocutors No consideration for finish quality	• Problems of aesthetic and functional quality in ceramic tiling • Pathologies • Complaints • Uncertainty and move towards alternative products
Building construction	Greater quality demands on finishes New functions *versus* new requirements Tiles in special applications Industrialised building construction Professional incompetence Piecework in tile installation	Technically and aesthetically improved finishes Multilayer systems for tile claddings New substrates and different behaviour Deficient technical and aesthetic quality of ceramic tilings	• Gap between expectations and results • Need to apply new technologies • Pathologies • Complaints
Tile fixers	Absence of regulated training and scatter in non-regulated training Absence of regulation and recognition of trade competences Distortion in work demand/supply Absence of trade associations	Mismatch between training and trade requirements Non-existence of a recognised trade profile Productivity versus quality No interlocutors	High cost of quality Shortage of competent tile fixers Shortage of specialists Problems of quality in finishes

Table 2.

TECHNICAL GUIDE FOR CERAMIC TILE INSTALLATION

The diagnosis of tile installation in Spain led to creating a full documentation on tile installation technology, under the following premises:

- It was to cover the whole tile installation process, from the selection of the materials and work planning to actually performing the tile installation, on the basis of an experience already undertaken at the Instituto de Promoción

Cerámica in 1987, which led to the publication of a technical manual and guide on tile installation[6].

- All the industrial and professional branches and parties involved in manufacturing and marketing the materials used (tiles, adhesives, prefabricated products, etc.), as well as those actually responsible for tile installation, were to participate in drawing up the documentation, and reaching a consensus on the result.

- The documentation was to include the latest advances in tile installation technology, ensuring quality and optimum yield.

- The contents were to be harmonised with international standards.

- Dissemination of the results was to be tailored to user needs, the users being a heterogeneous group with different professional levels and backgrounds.

- The documentation was to be prepared in a very short time since its availability was a basic requisite to starting the following programmes envisaged in the Project.

Amongst the above premises, the intention of preparing an opera *omnia* on tile installation compatible to all end users was a major challenge to all involved in drawing up the documentation. We believe that this has been achieved by dividing the subject matter into blocks and providing step-wise detail on the information required. The first option enables the user to select the information that is needed; the second allows establishing the appropriate level of consultation for his needs. The first edition of the documentation in CD-ROM format permits this objective to be met with relative simplicity. T**able 3** sets out an overview of the documentation structure.

The first level of consultation provides well-structured, elementary information in an easy language, which is directed at the various professional groups of users as well as the consumer, who is not required to have any prior knowledge of the subject matter. The contents belonging to this first level comprise:

Criteria for selecting the materials backed up by orienting tables and charts.

Succinct description of tile installation processes and techniques.

Simple characterisation of fixing surfaces.

Questionnaires to facilitate the selection of techniques and materials.

The second level of consultation links the selection and characterisation of materials to technological parameters, in most cases associated with international standard test methods. On the other hand, further information is provided on tile installation processes and techniques, with a view to presenting enough information to allow producing quality tiling. This is a level of consultation directed at sales staff and travellers engaged in tile marketing and application. The documentation contents associated with this level of consultation are essentially technical and are intended to meet the needs of the above users.

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[6]. Manual-Guía Técnica de los Revestimientos y Pavimentos Cerámicos. VV.AA.. Instituto de Promoción Cerámica. ISBN 84-505-6189-2. Castellón, 1987

BLOCKS OF SUBJECT MATTER	LEVEL OF CONSULTATION (*) 1	2	3	TARGET GROUPS FOR THE DOCUMENTATION (**)
CERAMIC TILES				• After-sales service staff of ceramic companies. Technical marketing departments (3)
• Criteria for product selection in terms of service application. **Functional classification**				• Ceramic company sales representatives (2)
- Classification of building domains	✓			• Retail outlet sales staff (2)
- Specifications questionnaire for ceramic tile selection	✓			• Technical sales representatives for tile installation materials (2)
- Technological parameters associated with the functional classification		✓		• Tile fixers (2)
• **Typology classification** associated with commercial product groups	✓	✓		• Specifiers (Architects, Technical Architects, Quantity Surveyors) (2)
• **Technological parameters** of ceramic tile			✓	• Consumer/End user (1)
• **Reception control**		✓		
• **Handling specifications**		✓		
• **Reference to quality marks**			✓	
• **Contribution to the Art of Cladding Architecture**		✓		
• **Functional and aesthetic considerations**		✓		
• **Ceramic tilings and alternative products**		✓		
TILING BACKGROUNDS				• Tile fixers (1)
• **The base**				• Subcontractors (2)
- Physico-chemical stability		✓		• Specifiers (2)
- Types of bases		✓		• Technical sales representatives for tile installation materials (2)
• **Intermediate layers**				• Retail outlet sales staff (1)
- Compressibility		✓		• After-sales service staff (1)
- Layers with functions in the system		✓		
- Layers with complementary functions to the ceramic tiling system		✓		
• **Tile fixing surface**				
- Parameters involved	✓			
- Types of surface		✓		
• **Diagrams for analysing tiling backgrounds**	✓			
• **Orienting questionnaire for diagnosing the state and preparation of the background**	✓			
BONDING AND GROUTING MATERIALS				• Technical sales representatives for tile installation materials (3)
• **Definitions**	✓			• Tile fixers (2)
• **Composition of the materials**			✓	• Subcontractors (2)
• **Bonding materials.** Description and classification	✓	✓		• Specifiers (3)
• **Grouting materials.** Description and classification	✓	✓		• Retail outlet sales staff (2)
• **Additives for concrete and mortars**			✓	• After-sales service staff (1)
				• Consumer/End user (1)
TILE INSTALLATION TECHNIQUES				• Tile fixers (2)
• **General**	✓	✓		• Subcontractors (3)
• **Tile installation techniques in conventional applications**. Integral tile installation system	✓	✓		• Specifiers (3)
• **Tile installation techniques in special applications**				• Technical sales representatives for tile installation materials (3)
- General	✓			• Retail outlet sales staff (2)
- Types of applications	✓	✓	✓	• After-sales service staff (1)
• **Movement joints**				• Ceramic company sales representatives (1)
- Function and types of joints	✓			• Consumer/End user (1)
- Joint design		✓		
- Installation materials and techniques		✓		
- Special joints		✓		
• **Tile installation equipment**				
- Tile installation tools and accessories		✓		
- Cutting technology		✓		
- Scaffolding		✓		
- Cleaning, protection and maintenance of ceramic tiles		✓		
• **Safety and health** (risks and risk prevention, basic standards and protection measures)		✓		
GUIDE FOR DIAGNOSING PATHOLOGIES IN CERAMIC TILINGS				• Tile fixers (2)
• **Attribution of the nature of the pathology**				• Subcontractors (2)
• **Questionnaire for identifying pathologies**	✓	✓		• Specifiers (2)
		✓		• Technical sales representatives for tile installation materials (2)
				• Retail outlet sales staff (2)
				• After-sales service staff (1)
				• Ceramic company sales representatives (1)
				• Consumer/End user (1)
LEXIS	✓	✓		
STANDARDS		✓	✓	

(*) **Level 1**: Elementary information without prior knowledge of the subject maater; **Level 2**: Easily understandable technical information; **Level 3**: Specialised technical information.
(**) Targeted professional group and level of recommended information.

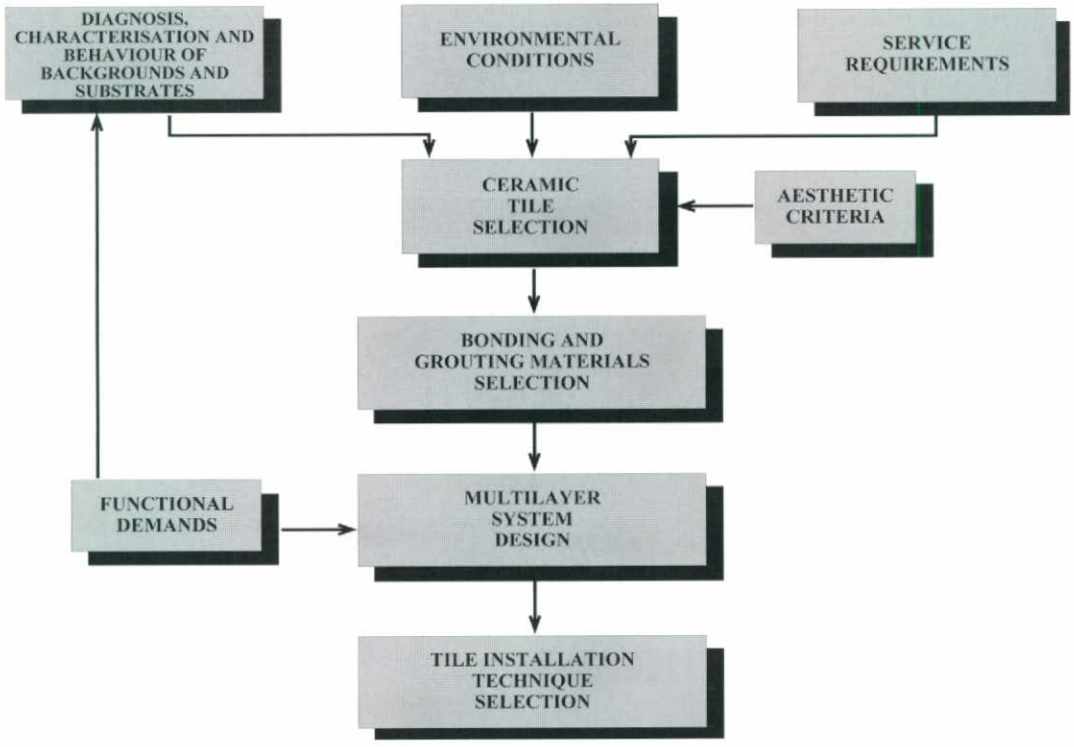
Table 3.

Both at the first and at the second level of consultation, there is constant linking of the information in terms of corresponding files on *lexis* and *standards*, taking into account the innovative character of the documentation that has been produced, and the shortcomings on this subject matter in Spain.

The third level of consultation is intended to provide an informative response to specialised documentation, at least in matters that appear to be essential in Spain for advancing in proper tile use and tile installation:

- Technological parameters associated with the technical characterisation of ceramic tiles.
- Composition of bonding and grouting materials, because of their special contribution to tile installation.
- Special applications in the context of greater functional demands than current architectural requirements.

The intended *unitary* sense of the documentation that has been drawn up, and its division into blocks of subject matter to facilitate consultation, required keeping to a tree scheme that provided an *overall view* from any angle at all times. This tree leads to the selection of the tile installation technique as depicted in the schematic, in which the box on *tile installation techniques* forms the beginning and end of the whole documentation.



CERAMIC TILES

Until a little over a decade ago, the Spanish tile market basically involved wall tile (around 75%). Since then it has developed in two directions, with a rise in the consumption and presence of ceramic flooring, besides broadening the range of products, first with glazed stoneware and subsequently with porcelain tile. Spain is currently the leading nation in tile consumption per capita (about 5 m^2 per inhabitant/year).

The deficiencies detected in the marketing and sales chain, diversification of the offer and need to consolidate the domestic market as closest destination for Spanish tile, required setting product selection criteria and providing accessible information for all parties involved in marketing, selling and using tiles, moreover taking into account that:

- The spectacular export growth may hit a ceiling and no longer absorb production increases.
- Average export product prices and domestic market prices weigh in favour of the latter.
- The evolution of the building construction branch exhibits positive trends, both in renovating and new construction.

LINKING OF PARAMETERS WITH PHYSICO-CHEMICAL CHARACTERISTICS		
PARAMETER	PHYSICO-CHEMICAL CHARACTERISTICS	TEST METHOD
FLOOR OR WALL TILE (trafficked or non-trafficked) **P/R**	**Breaking load on whole tiles**	**ISO 10.545-4**
	Resistance to loss of surface quality (1)	
	* Surface abrasion (glazed tiles **GL**)	**ISO 10.545-7**
	* Deep abrasion (unglazed tiles **UGL**)	**ISO 10.545-6**
	* Cleanability (stain resistance), after applying the surface abrasion method	**ISO 10.545-14**
	* Mohs scratch hardness	**UNE 67-101-92**
	* Gloss loss (2)	**ISO 2813**
	Slip resistance (1)	**ISO 10.545-17**
	Dimensional characteristics	**ISO 10.545-2**
INTERIOR OR EXTERIOR **i/e**	**Same characteristics as P/R**	
	Resistance to freeze/thaw cycles	**ISO 10.545-12**
TRAFFIC INTENSITY $I_A/I_B/I_C$	**Resistance to loss of surface quality** (Idem P/R)	
ABRASION RISK	**Resistance to loss of surface quality** (Idem P/R)	
SLIP RISK **A**	**Slip resistance**	**ISO 10.545-17**
FROST RISK **E**	**Resistance to freeze/thaw cycles**	**ISO 10.545-12**
CHEMICAL ATTACK **H**	**Resistance to household detergents and swimming pool salts**	**ISO 10.545-13**
	Resistance to low concentrations of acids and alkalis	
	Resistance to high concentrations of acids and alkalis	
TILING JOINT J_C/J_A	**Dimensional characteristics**	**ISO 10.545-2**
SPECIAL CHARACTERISTICS	**Electrical conductivity** (Ω)	**ASTM C483-66 (R1990)**
	Slip resistance (AA)	**ISO 10.545-17** **AS 3661.1** **DIN 51097 (11/1992)** **DIN 51130 (11/1992)** **RG ZH 1/571** (3) **ASTM C-1028**
	Chemical resistance to specific products (HE)	**Established by agreement**
	Controlled gloss (BR)	**DIN 67570 (1/1982)** **ASTM C584-81 (R1988)**
	Resistance to sharp temperature changes (FC)	**ISO 10.545-9**
	Special mechanical performance (7)	
	* Breaking load	**ISO 10.545-4**
	* Impact resistance	**ISO 10.545-5 or** **CSTB C-2898 (Annexes 7 and 8)**
	* Resistance to rolling	**CSTB C-2898 Annex 6 (1996)**

(1) Only applicable to flooring
(2) Measurement by standard reflectometer at 60° on tile abraded at 600 revolutions according to the gloss loss method
(3) **RG ZH 1/571** is not a test method. It is a classification of building domains in terms of slip resistance on the basis of standard **DIN 51130** and the classification of tiles with a profiled fair face, in accordance with the relationship between displacement space and minimum volume.

Table 4.

- The quality and diversity of the range of products offered require tile promotion beyond the residential environment.
- The growing consumer culture warns against disappointing the expectations raised by tile promotion. An effort also needs to be made to *facilitate* the selection and proper use of the product, both in *conventional* and in *special* applications.

Considering the tile end user, and before him, the whole tile marketing and sales chain, it was necessary to structure the information so as to allow:

- Selecting tiles for a given application, in terms of recognisable parameters by a non-professional user, who was not even familiar with the product and its application. At the same time the selection process was to be facilitated by responding to simple questionnaires or consulting tables or charts.
- Linking these parameters that were recognisable by the *general public* to technological parameters associated with standard international test methods for ceramic tiles **(Table 4)**.
- Establishing certain levels for these technological tile parameters (physico-chemical characteristics), which permitted drawing up a **functional tile classification**, setting minimum requirements that ensure optimum performance in a given application, throughout a tile installation's life cycle. As an example, **Tables 5, 6, 7** and **8** set out the levels of mechanical strength and resistance to loss of surface quality.

APPLICATIONS	BREAKING LOAD (F)
Flooring exclusively for pedestrian traffic	$F \geq 900$ N
Flooring not exclusively for pedestrian traffic	$F > 2{,}000$ N
Wall tiling	$F \geq 450$ N

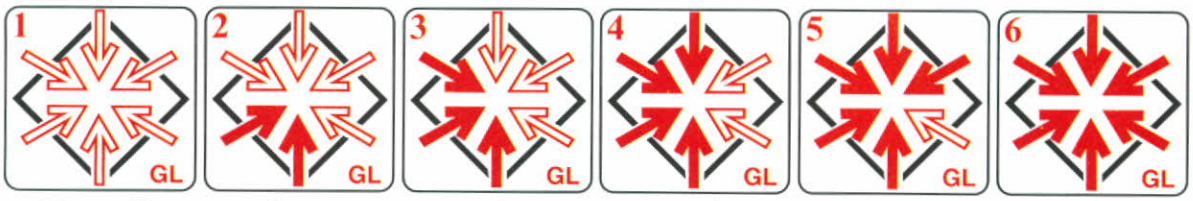
Association of **mechanical strength** with **breaking load (F)** applied to whole tiles according to test method **ISO 10.545-4**.

Table 5.

LEVELS OF RESISTANCE TO LOSS OF SURFACE QUALITY IN TERMS OF TRAFFIC INTENSITY AND ABRASION RISK		
LEVEL	**TRAFFIC GROUP**	**DESCRIPTION**
1	No traffic	For tiles not subject to traffic and destined for use as non-trafficked floor or wall tiling
2	Low	Low frequency traffic is found together with the non-entrance of abrasive materials (interior building domains without direct access from outside)
3	Medium	Low frequency traffic is found together with the entrance of abrasive materials (interior or exterior building domains with direct access from outside)
4	High	Medium frequency traffic is found together with the non-entrance of abrasive materials (interior building domains without direct access from outside)
5	Intense	Medium frequency traffic is found together with the entrance of abrasive materials (interior or exterior building domains with direct access from outside)
6	Severe	High frequency traffic is always found together with the entrance of abrasive materials (whatever the type of building domain and location)
7	Not exclusively pedestrian	Associated with level 6 severe traffic, with a minimum breaking load exceeding 2,000 N and the possibility of requiring special mechanical performance such as **resistance to rolling, resistance to light and heavy impact** with the added recommendation of using tile sizes smaller than 33x33 cm and greater than usual thickness.

Table 6.

RESISTANCE TO LOSS OF SURFACE QUALITY IN GLAZED TILES (GL)

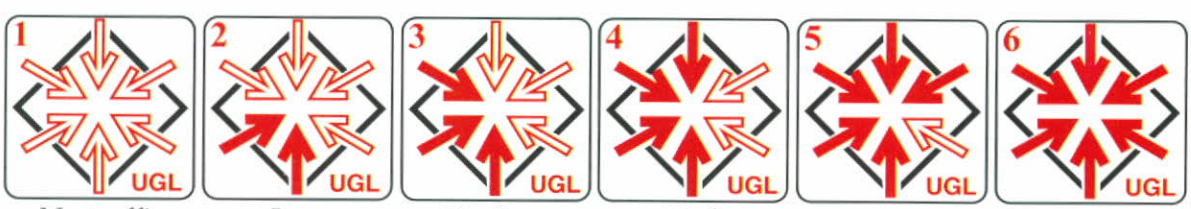


No traffic Low Medium High Intense Severe

MINIMUM LEVELS OF RESISTANCE TO LOSS OF SURFACE QUALITY	1	2	3	4	5	6
Resistance to surface abrasion according to ISO 10.545-7 (Class and visible stage ≥)	-	II 600 rev	II 600 rev	III 1500 rev	IV 2100 rev	IV 6000 rev
Stain resistance after surface abrading (visible stage) according to ISO 10.545-14	-	3	3	3	3	3
Stain resistance according to ISO 10.545-14	3	-	-	-	-	-
Mohs scratch hardness (UNE 67-101-92)	-	-	4	4	6	6
Mean gloss difference value at 60° at 15 positions on the test specimen before and after abrading at 600 revolutions according to the method for determining gloss loss by a standard reflectometer (ISO 2813)	-	-	-	<15	<15	<15

Table 7.

RESISTANCE TO LOSS OF SURFACE QUALITY IN UNGLAZED TILES (UGL)



No traffic Low Medium High Intense Severe

MINIMUM LEVELS OF RESISTANCE TO LOSS OF SURFACE QUALITY	1	2	3	4	5	6
Maximum volume removed (in mm^3) in deep abrasion according to ISO 10.545-6	-	<2365	<1419	<649	<393	<175
Stain resistance according to ISO 10.545-14 after subjecting the tiles to surface abrasion according to ISO 10.545-7 up to the 600-rev. stage	-	3	3	3	3	3
Stain resistance according to ISO 10.545-14	3	-	-	-	-	-

Table 8.

As a result of the foregoing points, it has been possible link the parameters characterising building domains to the physico-chemical characteristics of the tiles to be used in these domains. Having drawn up a functional tile classification, tables and questionnaires could then be prepared, which facilitate tile selection in terms of its service application. **Table 9** is presented as an example.

CERAMIC TILE FUNCTIONAL CLASSIFICATION
SPECIFICATIONS QUESTIONNAIRE

Flooring	
Wall cladding	

Tiling joint	Open joint (width ≥ 3 mm) **JA**	
	Butt joint (1.5 ≤ width ≤ 3 mm) **JC**	

Interior	
Exterior	

Size selection	L < 200 mm	
	L ≥ 200 mm	

Type of ceramic tile	Glazed (GL)	
	Unglazed (UGL)	

Traffic type and intensity	Exclusively pedestrian	Intensity	I_A High frequency traffic	
			I_M Medium frequency traffic	
			I_B Low frequency traffic	
	Not exclusively pedestrian			

Abrasion risk	Risk (Exterior floring, interior flooring with direct acces from outside and special situations)	
	No risk (Interior flooring without direct access from outisde)	

Frost risk	Yes	
	No	

Presence of water	Yes	
	No	

Chemical resistance	Yes	
	No	

SPECIAL CHARACTERISTICS		
Characteristics	Requirements	Test method
Special mechanical strength and loss of surface quality		
• Breaking load		Test method
• Size		
• Thickness		
• Impact resistance		
• Resistance to rolling		Annex 6 CSTB C-2898
• Others		
Special slip resistance		
• Method A: Wet coefficient of friction		ISO 10.545-17
• Ramp for bare feet		DIN 51097
• Ramp for special conditions		DIN 51130
• Combination profile/ramp		Classification ZH 1/571
• Others		
Electrical conductivity		
Controlled gloss		
Extreme temperature changes		ISO 10.545-9
Chemical resistance to specific products		
• Specify products and concentrations		
1-	HA	As agreed between parties
2-	HA	As agreed between parties
3-	HA	As agreed between parties
4-	HA	As agreed between parties

Table 9.

We are however aware that there remains a certain lack of sharpness in two essential parameters in the proposed functional classification: *resistance to loss of surface quality and slip resistance*. This imprecision is a consequence of the current standards themselves, which are necessarily to be followed.

With regard to *resistance to loss of surface quality*, the lack of precision is a consequence of the limitations of the test methods for abrasion resistance (ISO 10.545-6, ISO 10.545-7) and scratch hardness (UNE 67-101-92), for establishing a clear correlation between the levels of wear in a tile after installation under service conditions, and the abrasion stages and scratch hardness proposed in these standards. By adopting the measure of gloss loss and stain resistance of abraded tiles, together with abrasion resistance and scratch hardness, we believe that the margin of uncertainty or imprecision regarding the tile's real behaviour has been reduced.

With regard to *slip resistance*, there is greater uncertainty, as a result of the current state of the technique. In ceramic flooring where special non-slip requirements are to be met, the German standards **DIN 51097** and **DIN 51130** are to be directly applied together with the building domains classification proposed in **ZH 1/571**.

In ceramic flooring with lower non-slip requirements, one of the methods can be used contained in draft standard ISO 10.545-17 (Method A, with a dry and wet coefficient of friction equal to or larger than 0.4), while awaiting results from the ongoing various researches, and revision of national standards on tile installations to provide a more accurate tile classification in terms of non-slip requirements[8], [9], [10].

TILING BACKGROUNDS

The problems relating to defects in tile installations, attributable to the nature, state and behaviour of the backgrounds or substrates have acquired notable importance in Spain, although new construction materials and innovative technologies in decks, envelopes and partitions are not yet being widely used, as is the case in other countries. Currently, horizontal decks basically consist of concrete slab, while vertical backgrounds usually involve masonry walls, brickwork or concrete envelopes, and brickwork partitions. Gypsum board, plasterboard, or plastered clay brickwork have only managed minor penetration in residential building construction, to varying degrees according to the geographical areas involved.

The problem of tile installation backgrounds basically stems from defective quality in installing them, structural movements and movements arising in the substrates themselves as a result the type of construction involved, or fast-track construction systems. The absence of any specifications regarding tile installations and backgrounds (diagnosis, anticipation of background behaviour), fixing surface

[7]. Cleanability and hygiene of ceramic tile surfaces. G. TIMELLINI, G. CARANI. Centro Ceramico de Bologna (Italy). Qualicer'96, Vol. I, pages 43-59
[8]. The measurement of floor slip resistance. Guidelines recommended by the UK Slip Resistance Group. Issue no. 1, June 1996. United Kingdom
[9]. Resolving the grey areas of slip resistance. RICHARD BOWMAN. Architectile, November 1996-January 1997, pages. 62-66
[10]. Confusion continues to reign over slip-resistence. JESS MCILVAIN, TCA. Tile & Decorative Surfaces, February 1997, pages. 38-40, 94.

preparation treatments or mitigation of background movement, lie at the origin of many tile installation pathologies, which we presume to be a major cause compared to other sources of problems, especially when combined with butt-jointed tiling without movement joints.

It was vital to prepare a documentary block that could serve as a guide to the user, in diagnosing the state and behaviour of a background and allow acting accordingly before actually proceeding with the tile installation.

When we started preparing the documentation, we thought that the advance in the work of Working Group CEN/TC67/WG4 would allow adopting a quite defined model in this matter, especially considering the very title of the draft standard that was to be developed by this Group: *Guidelines for the design and installation of ceramic tiling*. Spain has also been taking part in the Group since May of 1996, but to date a unitary document has not yet been produced on the characterisation of backgrounds, at least not at the level required in Spain. This is a result of the general approach that will foreseeably dictate the final draft, as a result of the discrepancies that have arisen amongst Group members, and the diversity in the various types of substrates and tile installation techniques that have been put forward by the countries participating in draft preparation.

As it was thus impossible to incorporate a complete documentation on the subject, which was fully harmonised with this draft standard, it was decided to draw up a document of our own, which, respecting the criteria already approved by CEN/TC67/WG4, would serve as an effective consultation tool for all the professional branches involved in tile installation in Spain, particularly for the tile fixers and technicians, sales staff and travellers in tile installation materials supply. This document was to satisfy the following requirements:

- Separating the constituent layers comprising the multilayer system usually involved in tiling backgrounds i.e. the structural element that supports the tiling, which we will term **base** (decks, envelopes, rough partition walling, etc.), the existing intermediate layers or those that are used as a result of functional requirements, or are needed for preparing the tile installation, especially in thin-set fixing (levelling layer, screed, load distribution, sealing, insulating layers, etc.), and finally the **fixing surface**.

- To this elementary division of the multilayer system we associated certain technological parameters that allow evaluating the state and behaviour of the background with regard to the tile installation, and allow predicting required safety margins for characterising the backgrounds, and acting on them in an intermediate stage between the design and installation of a ceramic tiling. With a view to simplifying the association of these parameters to the multilayer system, it was decided to:

– Associate a stability parameter with the base, as far as predicting foreseeable movements was concerned which stemmed from dimensional stability and stability of a physico-chemical type (corrosion of metals and concrete).

– Associate a compressibility parameter with the intermediate layers.

– Associate parameters of planarity, cohesion, water absorption/suction, behaviour

under water/moisture action, surface texture and chemical compatibility with the fixing surface.

- After defining the multilayer system and the parameters associated with the nature, behaviour and compatibility of the background for the tile installation, it was necessary to provide the user with an instrument that would allow him to perform the diagnosis and act accordingly. This was done by incorporating certain diagrams for background analysis, and as an alternative or complement, answering a questionnaire that enabled defining the tile installation, including the intermediate layers.

- As an alternative to the foregoing point, the documentation files associated with each type of background can be directly consulted, separately considering the base, intermediate layers, and fixing surface.

Tables 10 and **11** are presented as examples.

RELATION BETWEEN GLOSS DISAPPEARANCE TIME AND ESTIMATION OF FIXING SURFACE ABSORPTION-SUCTION	
Gloss disappearance time. (In seconds)	Absorption/suction
< 10	Very high
10 to 20	High
20 to 60	Medium
>60	Low
No suction	None

EFFECTS AND RECOMMENDABLE CORRECTIONS WITH REGARD TO FIXING SURFACE POROSITY				
Absorption /suction	**THICK-SET FIXING (MC)**		**THIN-SET FIXING**	
	Effects	Corrections	Effects	Corrections
Very high	• Possible dehydration of the mortar • Inadequate bonding	• This tile fixing system is not recommendable	• Possible dehydration of the cementitious adhesive • Inadequate bonding • Reduced open times and adjustability	• Application of pore-sealing primers **I1**
High	• Possible dehydration of the mortar • Risky bonding	• Previous wetting of the fixing surface	• Reduced open times and adjustability of adhesives	• Reduction of adhesive spread surface area
Medium				
Low	• Very low adhesion strength	• Thick-set fixing is unfeasible	• Low adhesion strength with resin-free adhesives (**A1** and **A2**)	• Fixing with adhesives **C1**, **C2**, **D** and **R** is recommended
None	• No adhesion strength	• Thick-set fixing is unfeasible	• No adhesion strength with resin-free adhesives (**A1**, **A2**) • Low adhesion strength with adhesives containing a low resin proportion (**C1**)	• Bond bridge primer (**I3**) if adhesives **A1**, **A2** and **C1** are used • Fixing with adhesives **C2**, **D** and **R** is highly recommended

Estimation of the water absorption/suction of a fixing surface and correcting measures in terms of fixing technique.
I1: pore-sealing primer.
I3: bond bridge primer.
A1, A2, C1, C2, D an R: see Table 12.

Table 10.

CERAMIC FLOORING BASE ANALYSIS DIAGRAM

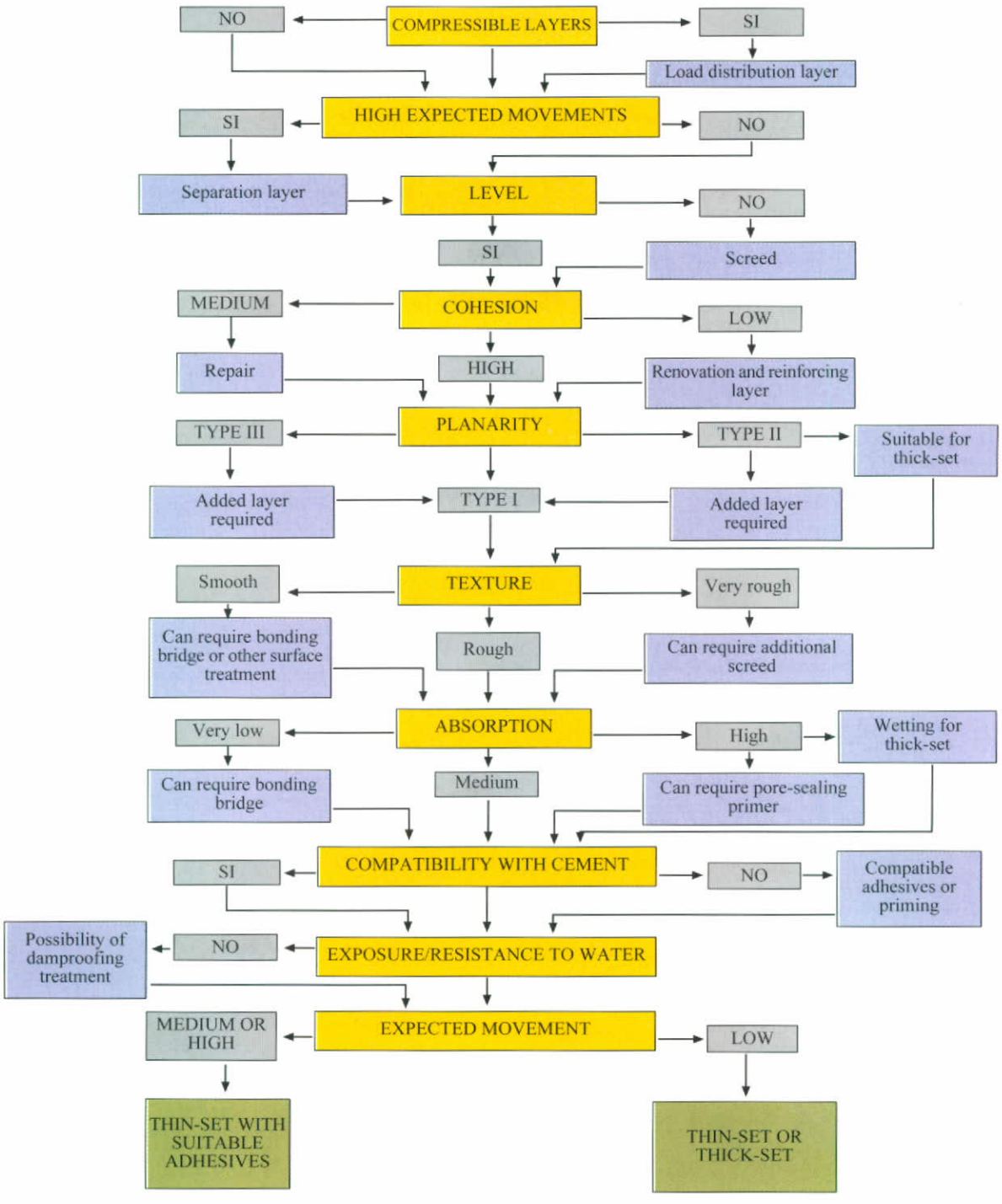


Table 11.

The user can consult individual files that characterise the various bases and fixing surfaces, with a view to complementing the information to be found in the previous tables with factors that could not be classified, such as the chemical action of moisture or the chemical compatibility between bonding materials and fixing surface. The foregoing files are extended with further information on bases, intermediate layers and fixing surfaces, which allow identifying which action should be taken on the backgrounds, as well as the actions to be carried out prior to tiling. In every case the striving was to ensure the satisfactory behaviour of the tiling throughout its useful life with a sufficient tolerance margin.

BONDING AND GROUTING MATERIALS

The bonding and grouting materials market for tile installation has in the last few years gone through a *crisis of identity* (not for the manufacturer of these products, but for the user). Until well into the 80s, tile installation in Spain involved thick-bed installations with cement mortars prepared on site and neat cement slurries for grouting, always with butt jointing. A technique and materials were involved, which were more or less compatible with a medium/high porosity ceramic tiling on more or less stable backgrounds, since ceramic flooring had quite a minor presence.

This situation changed considerably when glazed stoneware floor tile began to be marketed. Since then a market for ceramic flooring has been created especially in residential applications. Perhaps as a result of copying foreign tile fixing systems and also as a reaction to the first great pathologies that appeared in residential ceramic flooring, bonding materials began to marketed for thin-set fixing, under various names, which became naturalised in the 90s (cementitious adhesives, adhesive mortar, cement containing additions for wall tiling, mastics, etc.). Although at present UEAtc guidelines are already applicable for evaluating adhesive techniques in tile installations, there are few references in Spain regarding the marketing of such products, and even less information for the specifiers to be included in the technical requirements of tiling designs. This situation became even more complicated by the spread of thin-set fixing with tiles that were becoming less and less porous, having larger sizes, though it is still a minor fixing technique in wall tiling.

The need to partially or totally replace mechanical adhesion strength by a chemical type of bonding in installing tile with a low to very low apparent porosity, the necessary deformability of bonding materials to adapt to less stable substrates than in the past, and finally the peculiarities of thin-set fixing, specifically with the open time parameter, have led to innumerable problems in floor and wall tiling, on using materials with the same trade name but exhibiting different compositions and performance. The documentation prepared in the block on this subject matter was intended to clear up the situation regarding bonding and grouting materials in Spain, helping the user in his selection and offering suitable information for a better understanding of the essential role that these materials play in the tile installation process.

In this case, the advanced situation of the work of Working Group CEN/TC67/WG3 has allowed establishing classifications that are in harmony with the European standard on adhesives for ceramic tiles, especially taking into account draft standard prEN 12004, which represents an important advance for countries such as Spain compared to the foregoing situation, since it establishes:

* Basic definitions on tile installation methods and tools, classification of bonding and grouting materials and the properties that they are required to exhibit on the basis of standard test methods.

* Certain compulsory characteristics to be met by all adhesives, both of the normal and fast-setting cementitious type, and of the adhesives and grouting materials in dispersion and of the reaction type.

* Optional characteristics (additional and special) for special performance bonding and grouting materials.

In particular draft standard prEN 12004, pending survey and final voting in its September 1997 version, establishes terminology, specifications and conformity evaluation of cementitious bonding materials, as well as dispersion and reaction resin adhesives, with singularly important sections such as the definition of the application properties of these materials (shelf time, adjustability, shear and tensile adhesion strength, deformability, and transverse deformation), as well as a table of characteristics (compulsory, additional and special), which establish minimum values for adhesion strength and open time for the various types of adhesives.

Taking the draft standard and the other work prepared by Group CEN/TC67/WG3 as a reference, while also taking into account the peculiar situation of tile installation in Spain, and the marketing of bonding and grouting materials, a classification was drawn up of these materials as set out in **Tables 12** and **13**, which are intended to:

* Establish a suitable bonding and grouting materials classification for the current Spanish market, including economic bonding and grouting materials (**A1**, **A2** and **J1**), which may be compatible with conventional applications (interior residential).

* Distinguish cementitious adhesives and grouting materials with a low polymer resin content (setting the limit at 2% by weight of the composition), from those exhibiting larger contents (**C1** and **C2**, **J1** and **J2**).

* Include dispersion and reaction resin adhesives in (**D** and **R**), as well as primers **(I)** for fixing backgrounds.

These classifications allow linking the various bonding and grouting materials to types of application and requirements, essentially relating to adhesion strength and deformability.

On the other hand, the documentation drawn up goes further into considering the role of water-soluble polymers and thermosetting and elastomeric polymers in the behaviour of bonding and grouting materials. The former because of their positive effect on *workability* and *open time* of these materials: open time is a key parameter in our country, especially in the regions with a warm, dry climate. The latter because of their effect on adhesion strength and deformability. Having explained their importance, the different types of adhesive are explicitly mentioned according to the application involved, particularly in special applications (exteriors or where specific functions are required), in which the parameters indicated are vital to achieving suitable tile installation quality. Making the assumption that the bonding and grouting materials (**C1** and **C2**, **J1** and **J2**) are going to meet the minimum adhesion strength requirements set in draft standard prEN 12004, the *deformability* parameter is stressed, and even extended to reaction bonding and grouting materials for certain special applications.

BONDING MATERIALS				
BINDERS	**DEFINITION EN 12004**	**CODE**		**CURRENT NAME**
Cement	Cementitious adhesive	A1		"Mortero cola convencional[5]"
Cement	Cementitious adhesive	A2		"Mortero cola con caseína"
Cement+resin[1]	Cementitious adhesive	C1		"Mortero cola de altas prestaciones[5]"
Cement+resin[2]	Cementitious adhesive	C2		"Mortero cola con ligantes mixtos[5]"
Cement+resin[3]	Cementitious adhesive[4]	C2		Mortero cola con ligantes mixtos[5]"
Resin	Dispersion adhesive	D		"Pasta adhesiva"
Resin+hardener	Reaction resin adhesives	R		"Adhesivo de resinas de reacción[5]"
Resin and/or cement	Primers	I		"Imprimaciones"

[1] Powdered resin low proportion (≤2%).

[2] Powdered resin high proportion (>2%).

[3] Liquid resin.

[4] With separate components.

[5] All these adhesives may be available in a fast-setting version.

Table 12.

GROUTING MATERIALS				
BINDERS	**DEFINITION EN 12004**	**CODE**		**CURRENT NAME**
Cement	Cement grout	JC		"Lechada"
Cement+resin[1]	Cementitious grouting material	J1		"Mortero para juntas[5]"
Cement+resin[2]	Cementitious grouting material	J2		"Mortero para juntas[5]"
Cement+resin[3]	Cementitious grouting material[4]	J2		"Mortero para juntas[5]"
Resin	Dispersion grouting material	JD		"Pasta para juntas"
Resin+hardener	Reaction resin grouting material	JR		"Morteros para juntas de varios componentes.[5]"

[1] Powdered resin low proportion (≤2%).

[2] Powdered resin high proportion (>2%).

[3] Liquid resin.

[4] With separate components.

[5] All these adhesives may be available in a fast-setting version.

Table 13.

TILE INSTALLATION TECHNIQUE

Taking into account the peculiarities of tile installation in Spain, this documentation block was to cover all the stages that comprised the general planning of the tile installation process, linking materials selection criteria and background treatments. Both types of tile fixing found in Spain were however to be included,

traditional thick-bed fixing with cement mortar prepared on site, and thin-bed fixing with different types of adhesives. Finally, all the technical subjects inherently involved in movement joints and special applications were to be dealt with in detail, given their scant implementation in tile installation, and the low level of professional competence of most of the professional players party to the process, from specifiers to tile fixers.

The delay arising in the development of the work of Working Group CEN/TC67/WG4 and the foreseeably general character of the final document to be submitted for approval by CEN/TC6, make it unfeasible to use the various drafts prepared by this Group. Instead, countries like Spain, Italy and Portugal, should aspire to having a *manual for the design and installation of ceramic tiling* that regulates this activity under all its aspects, as these nations have the added difficulty of not being able to count on organised trade groups or associations as interlocutors, with homogeneous criteria in performing their trade. For this reason, even while attempting to include draft documents prepared by Group WG4, we have had to draft a complete, unitary documentation on the whole tile installation process. This has also been structured according to levels of consultation that would satisfy the information needs of the different parties to the tile installation process. The documentation produced according to its various levels, comprises the following sections:

* Detailed description of the general tile installation process, highlighting the essential features that lead to technical and aesthetic quality assurance of the tiling, raising the work yield, suppressing improvisation, downtime and unforeseen contingencies, all of which are set out according to the schematic presented at the beginning of this section.

* Technical description of tile installation by the thick-set method, its main features and the compatible applications with this tile installation method.

* Full technical description of tile installation by the thin-set method as an alternative to traditional tile installation and as a quality solution to a considerable number of tile applications, with extensive information on materials preparation and application, use of suitable tools and the peculiarities of this technique in accordance with the different applications, including recommendations for quality control of materials and the tile installation process.

* After describing the various technical options for tile installation, certain systems are established for fixing in conventional applications, following an elementary classification of substrates (expected movements and planarity), and tiles (water absorption capacity), as set out in **Tables 14** (floor tile installation) and **15** (wall tile installation).

* A documentation block is specifically devoted to movement joints, from an elementary classification in accordance with the WG4 proposal to specifications on materials and the installation technique, taking into account the most advanced international standards on the subject.

* Finally specific documentation blocks are established for each and every special application.

FLOOR TILING						
BASE		Integral system	CERAMIC TILE			Special requirements
CLASS (expected movement)	TYPE (planarity)		Absorption >3%	Absorption from 1-3%	Absorption <1%	
			TYPE OF ADHESIVE			
1	I	SD_1[b]	A1	C1	C2	
	II	SD_2	A1[c]	C1[c]	C2[c]	
		SD_3	A1	C1	C2	
		SG_2	MC	N/A	N/A	
	III	SD_3	A1	C1	C2	
		SG_1[b]	MC	N/A	N/A	
2	I	SD_1[b]	C1	C1	C2	
	II	SD_2	C1[c]	C1[c]	C2[c]	
		SG_3	MC	N/A	N/A	with separating layer
	III	SD_3	C1	C1	C2	with screed
		SG_3	MC	N/A	N/A	with separating layer
3	I	SD_1[b]	C2	C2	C2	
	II, III	SD_2	C2[c]	C2[c]	C2[c]	
		SD_3	C2	C1	C2	
4	I, II, III	SD_3	A1	C1	C2	
		SG_3	MC	N/A	N/A	
5[a]	I, II	SD_3	C1	C1	C2	with load distribution layer
		SG_3	MC	N/A	N/A	with load distribution layer

(a) Type III is unacceptable
(b) Pretreatment of fixing surface absorption
(c) Adhesives can be used up to 15 mm thick
N/A: Not applicable

Table 14.

WALL TILING					
BASE		Integral system	CERAMIC TILE		
CLASS (expected movement)	TYPE (planarity)		Absorption >3%	Absorption from 1-3%	Absorption <1%
			TYPE OF ADHESIVE		
1	I	SD_1[a]	A1/A2	C1	C2
	II	SD_2	A1[b]	C1[b]	C2[b]
	III	SD_2	A1/A2	C1	C2
		SG_1[a]	MC	N/A	N/A
2	I	SD_1[a]	C1/D[c]	C1/D[c]	C2/D[c]
	II	SD_2	C1[b]	C1[b]	C2[b]
3	I	SD_1[a]	C2/D[c]	C2/D[c]	C2/D[c]
	II	SD_2	C2[b]	C2[b]	C2[b]

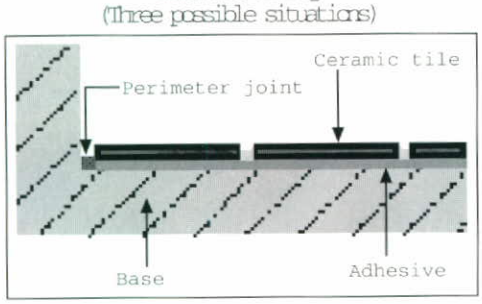
(a) Pretreatment of fixing surface absorption
(b) Adhesives can be used up to 15 mm thick
(c) With ceramic tiles up to 900 cm^2
N/A: Not applicable

Table 15.

FLOOR TILING

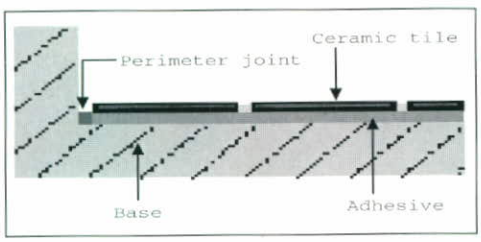
Thin-set fixing
(Three possible situations)

SD_1



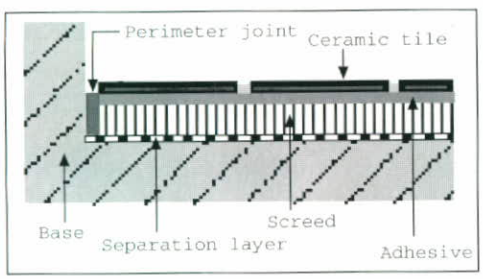
SD_1: Adhesive tile fixing directly on the base up to 5 mm thick

SD_2



SD_2: Adhesive tile fixing directly on the base up to 15 mm thick

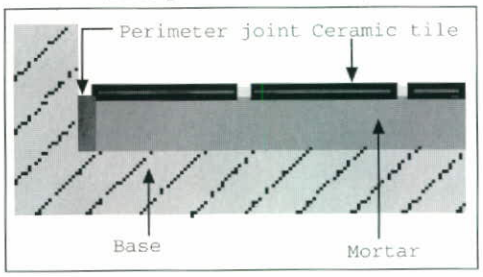
SD_3



SD_3: Adhesive tile fixing on a screed or load distribution layer, according to the specific case, previously installed on the existing base with a separation layer.

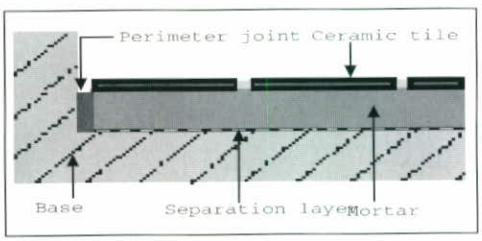
Thick-set fixing
(Three possible situations)

SG_1



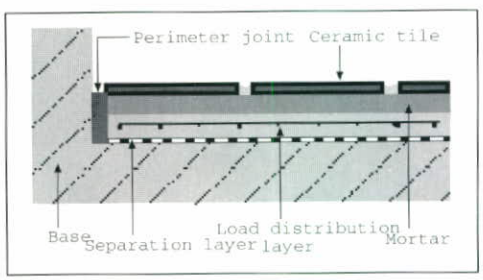
SG_1: Tile fixing directly on the base with mortar

SG_2



SG_2: Tile fixing directly on the separation layer with mortar

SG_3

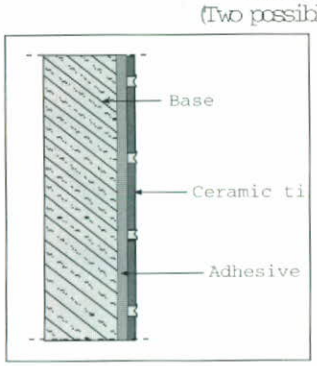


SG_3: Tile fixing on a screed or load distribution layer with mortar, according to the specific case, previously installed on the existing base with a separation layer

WALL CLADDING

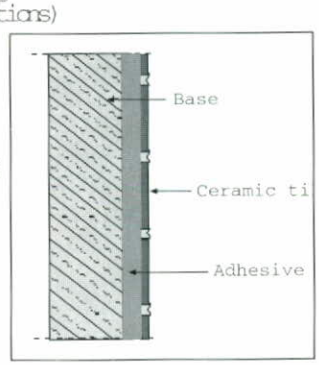
Thin-set fixing
(Two possible situations)

SD_1



SD_1: Adhesive tile fixing directly on the base up to 5 mm thick

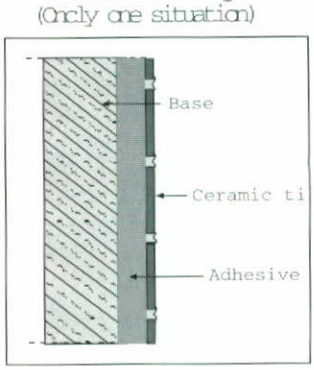
SD_2



SD_2: Adhesive tile fixing directly on the base up to 15 mm thick

Thick-set fixing
(Only one situation)

SD_3



SD_3: Tile fixing directly on the base with mortar

The effort made deserves highlighting, which attempted to communicate the need to incorporate *movement joints* in every design, by facilitating detailed information on materials and tile installation techniques, extending these to prefabricated products for this type of joint. The best guidelines were consulted, set out in the various national standards (BS 5385, AS 3958.1, AS 3958.2, American Tile Installation Manual by the TCA), on installing movement joints and also on classification and test methods for the materials involved (DIN 18540, ASTM C920, BS 6213, ASTM D-1564-71, ASTM D-624-71, ASTM D-624-73 and DIN 53495). This has led to an abundance of tables for the correct selection of materials and most suitable techniques, even taken from trade catalogues to facilitate the work for specifiers and tile fixers. The written documentation is supplemented by a great many construction diagrams and graphic materials that can serve as references for the user.

In attempting to set out a suitable technology for the tiling with the greatest possible detail, a great effort has been made in the chapter on special applications. On the one hand, it has been attempted to cover all applications in exteriors and/or tile installation process performing specific functions; on the other hand, specific information has also been covered for tile installation as well as informative aspects relative to multilayer systems (sealing, insulation, etc.).

At a first level of consultation, through a technical file, a description is provided of recommended uses, tile requirements, materials involved, tile installation methods, grouting operations, movement joints, and a list of reference international standards.

At the second level of consultation, a detailed description is provided of the tile installation process, with construction details, charts for materials selection, and abundant photographic material to supplement the description of the technique.

At the last level of consultation, specially directed to specifiers, extensive information is provided on the functionality of the special application in all the aspects involved; characterisation of the main and derived functions of the tile installation, description and criteria of the available materials for achieving this function, tile installation process, and constructional peculiarities of these materials that are subsequently to be tiled. Thus for instance, for ceramic flooring with soundproofing, the concept of soundproofing in construction is incorporated, by introducing a parameter that measures the soundproofing (standard weighted sound of footfall or sound of impact), soundproofing materials, and the parameter of dynamic rigidity, as well as the design and installation of soundproofing for subsequent tile fixing.

This documentation block contains other auxiliary sections on the tile installation process: one is devoted to the technology of tile cutting, with an extension to all the equipment involved (tools, measuring instruments and machinery) for tile installation; another is devoted to safety and health in the workplace, specifically with trade-related materials; finally a third section sets out to guide the user in diagnosing tile installation pathologies, classifying these according to their origin. This last option goes together with a questionnaire that the user can fill in as an aid in the diagnosis of the pathology.

THE TRAINING PROJECT

An analysis of tile installation in Spain implicitly involved diagnosing the

professional competence of all the industrial and commercial branches involved in the process, ranging from tile manufacture to actual tile installation.

A training model was required, which would make good the shortcomings detected in professional competence in the various groups involved or simply raise the specialisation or trade competence. From September 1996 to June 1997, an overall project was developed, aimed at answering professional training needs in terms of the following figures:

* *Tile seller*, both the travellers that attend to the distribution and sales of the product from the manufacturer as well as sales staff at more or less specialised sales outlets and showrooms.

* *Technical salesperson of tile fixing materials*, including a wide range of professionals devoted to selling tile installation materials, especially bonding and grouting materials and additives.

* *Tile fixer*, as the professional with basic trade status, able to install any type of tile independently in conventional applications, working under supervision in special applications.

* *Master tile fixer*, corresponding to the figure of the subcontractor, recovering the concept of mastery (in the old professional trade structure), with regard to the degree of specialisation and autonomy in tile installation, under premises of quality and high yield with innovative materials and techniques.

* *Technical specialist in ceramic tiling*, a figure that is necessary for quality control in finishes, in special tile installation applications, and exceptional projects, which as a result of their magnitude or characteristics require a technical director. This professional figure has yet to be created among the professional group currently in charge of technically supervising building construction in Spain (quantity surveyor or technical architect).

Although the primary training needs of some of these figures can be attended by seminars or specific individual training actions, an overall project needed to be designed, covering all the variables that would ensure quality training:

- Defining the various professional figures, as well as their competences, skills, responsibilities and autonomy.

- Providing training contents for each figure and fitting these contents to a specific training project.

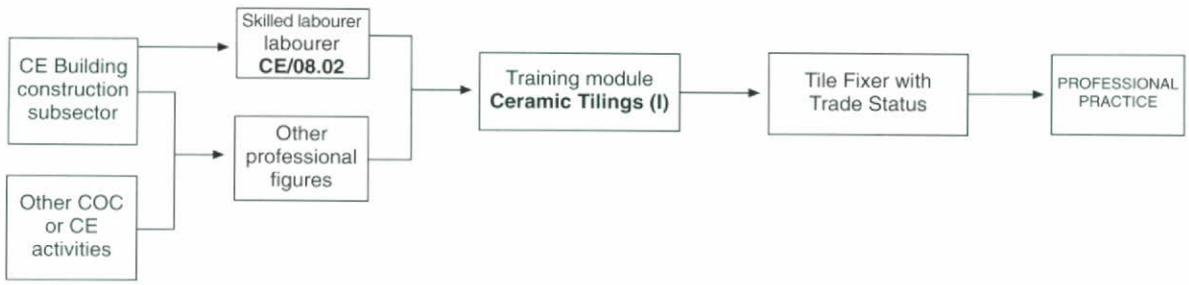
- Using multimedia tools for imparting the training contents.

- Creation of a methodology for assessing professional competence, which would serve in preselecting the trainees and evaluating the training result.

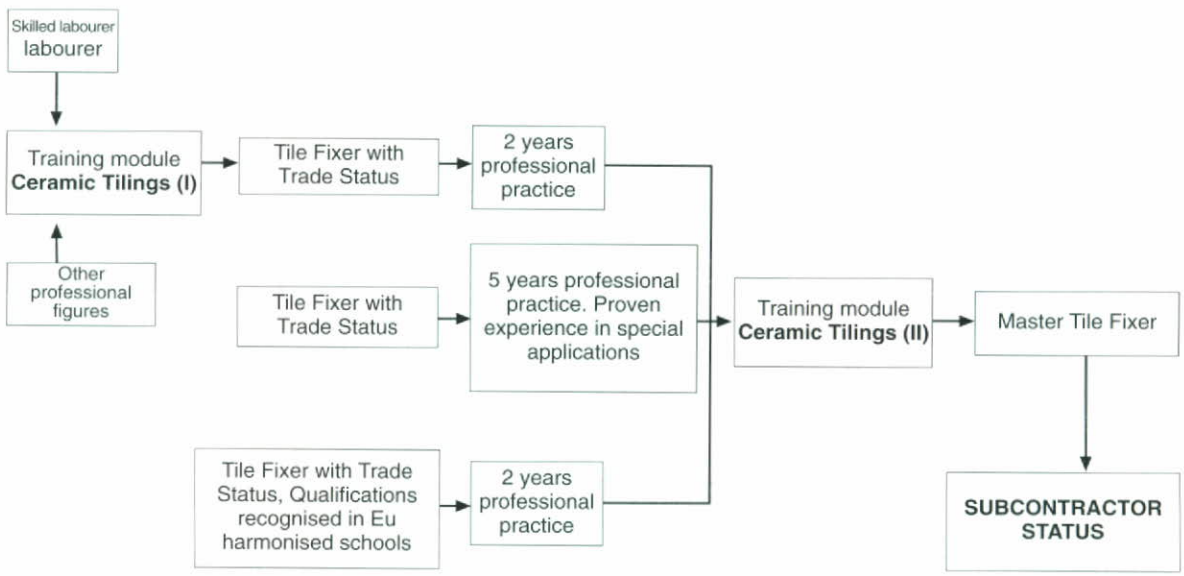
- Specifically for tile fixer training, availability of a methodology for training trainers, focusing on pedagogical training as well as specialisation of these prospective instructors in new tile installation technologies.

Although the training project establishes the professional competence and skills of each of the above figures, training modules have been specifically designed for the tile fixer trade, which are intended to cover the future training of the figure of the tile *fixer with official trade status and the master tile fixer with official trade status.*

In the first case, a training module is to be put in place directed at the installation of finishes, in terms of the professional figure of the *tile fixer* (known as "instalador de revestimientos" (CE/08.02) according to building construction nomenclature), which coincides with Level 2 training modules, as defined by the Instituto Nacional de Empleo. Access will be had to this module according to the following schematic for ongoing training or after a previous course in masonry, with minimum contents of a theoretical and practical nature, to ensure that the tile fixer module will be profitably imparted.



In the second case, the training module is aimed at the *subcontractor* or Level 3 "instalador de revestimientos". Access is had to the module after achieving official tile fixer status with a certain experience, depending on the background of the candidates and number of years of practice in the trade, as set out in the accompanying schematic.



For the two foregoing modules, and especially for *Ceramic Tilings I*, directed at training tile fixers with trade status, quality training is targeted based on the following characteristics:

- A clear innovation in contents (materials, techniques and new applications for ceramic tiling), and new related methodologies, prioritising the techniques and working methods that provide greater quality and better tiling yield.
- Adaptation of theoretical knowledge to practical knowledge.

- Parallel elucidation of theoretical and practical knowledge, based on the distribution of teaching hours and training process stages, with the clear objective that the trainee feels that he is engaged in a task and not just a passive individual in a class.
- Compatibility and complementarity between techniques and practical knowledge.
- Restriction of the number of teaching hours for each vocational module, which is never to exceed 450 teaching hours, with a view to making quality training compatible with short-term professional expectations.
- Provision of a distribution of teaching time between the acquisition of practical knowledge and skills versus theoretical knowledge in favour of the former in a ratio of at least 80%.
- Detailed training programme, with teaching time developing towards progressively increased autonomy of the trainee, so as to prepare the trainee for professional practice and motivate him by skills acquisition. Three stages are programmed: pure training, mixed training with supervised practices, and actual work at a building site with periodic updating of theoretical and practical knowledge.
- The systematic application of a methodology for evaluating professional competence prior to training to achieve the necessary basic uniformity among the prospective trainees and *customise* the contents to the needs of the professional grouping.
- Emphasis on visual communication methods rather than oral, and oral rather than written, for delivering the informational contents, systematically using multimedia tools, such as CD-i, video, slides, diagrams, hardcopy graphics, trade catalogues, and in every case physical samples.
- With regard to the skills acquisition hierarchy: first quality installation, and then high yield installation, attempting to achieve the second with time and practice after consolidating the first step. The trainee shall first acquire confidence and then find motivation with growing responsibility, rapidity and productivity.
- Specialist instructors that systematically apply the methodology of the module for trainer training.
- Activation of vertical and horizontal communication amongst instructors/trainees.
- Prioritise practices and skills in the most common applications, using techniques that represent a rise in quality and yield.
- Prior to starting the training modules, it is vital to foster trainee motivation by underscoring the nature of the specialty and vocational opportunity that the tile fixer trade offers in highly industrialised quality building construction.
- Subsequent to the training module that trainee shall be monitored in the first few months of his professional practice to evaluate his post-training and achieve the ultimate objective, which is the incorporation in the workforce of a trained worker.

The above characteristics involve a change and an effort in drawing up, programming and effecting the training. This represents a qualitative and quantitative change in the current field of vocational and ongoing professional training in this subject matter, far from the average levels found in other European countries with a tile consumption that is much lower than in Spain. The effort is assessable not just by the methodology and contents of this training module but also by the use of suitable media and the need to count on specialist, highly motivated instructors for carrying out the work.

For the pre- and post-training evaluation methodology, various models were taken into account, which could more or less easily be adapted to training in the Spanish building construction sector, the model presented by Mr. Colin Cass in Qualicer '94[11], being the one closest to ours. On the other hand, training contents in Germany were a major technical reference, except for the substantial differences involved in a long-term training model, developed in a different context from the training needs of the Spanish building industry. The specialisation and ongoing training of the instructors or trainers was another key issue in this project, considering the serious shortage of qualified teachers that threatens to occur when this training programme is to be widely implemented.

Tables 16 and **17** set out the teaching units and skill acquisition of the training module designated *Ceramic Tilings I*.

Teaching units	Hours
1 - General theory (I): Units and measures. Lexis	25
2 - Theory applied to practice (II): Measuring up and setting out	25
3 - Ceramic tiles	15
4 - Tiling backgrounds/substrates	30
5 - Work planning	25
6 - Materials	25
7 - Conventional applications	200
8 - Introduction to non-conventional applications	65
9 - Movement joints	10
10 - Cost estimates and work reports. The self-employed tradesman	10
TOTAL	**430**

Table 16.

The training module designated *Ceramic Tilings II* directed at the professional figure of the Subcontractor or Master Tile Fixer is intended to cover the following professional competencies.

- Installing complete ceramic tiling designs based on plans and specifications issued by the relevant direction or, in general the client/contractor.
- Drawing up work estimates that include materials and multilayer systems to be installed prior to tiling.
- Directing, programming and coordinating the work of the tile fixers.
- Directing and/or carrying out all the special applications.
- When specifications are lacking, possession of the necessary criteria and methodology to foresee the required technique, materials and collateral tasks.

These competencies correspond to specific tasks of the ceramic tiling subcontractor, as set out in **Table 18**. These specific tasks are linked to teaching units

[11]. Tile fixing skills: an Australian approach to quality control. COLIN CASS. TAFE Commission of N.S.W. Sydney Institute of Technology (Australia) Qualicer'94, Vol.II, pages. 217-229

presented in **Table 19**, anticipating an assessment system and skill acquisition as shown in **Table 20**. This training module project, aimed at recovering the figure of the Master Tile Fixer, is to be implemented after running the training module *Ceramic Tilings I*, thus ensuring adequate professional experience for the group targeted by this specialised training, which represents the climax of the whole process.

BASIC CONTENTS	ACQUIRED COMPETENCE	EVALUATION
Theoretical knowledge (theory)	A	EC
• Basic arithmetic: calculation, measurements, percentages		
• Basic geometry: interpretation of surfaces, calculation of areas and volumes, calculation of slopes, understanding tiling systems		
• Physical magnitudes related with the profession		
• Basic chemistry of materials		
Background knowledge (theory and practice)	B	EC, EP
• Introduction to backgrounds/substrates		
• Cement mortar		
• Adhesives		
• Grouting materials		
• Other materials: primers, sealers, cleaning agents, etc.		
Ceramic tiles (theory and practice)	B	EC, EP
• Types of tiles, identification and characteristics		
• Tile selection in terms of use		
• Information supplied by the manufacture and its interpretation		
• Ceramic tiling systems		
• Introduction to tile cutting		
• Surface treatments		
• Pre-installation controls		
Backgrounds/substrates (theory and practice)	C	EC, EP
• Identification and characterisation		
• Background/substrate controls		
• Actions undertaken on backgrounds/substrates		
• Preparation for tile installation		
Work programming (theory and practice)	C	EC, EP
Materials (theory and practice)	B	EC, EP
• Specifications and controls		
• Preparation and handling		
• Application		
Tiling in conventional applications (practice)	C	EP
Tiling in non-conventional applications (theory and practice)	B	EP
Movement joints (theory and practice)	B	EP
Equipment (theory and practice)	B	EP
End operations (theory and practice)	B	EP
Reports and cost estimates (theory and practice)	A	EC, EP

EC: ongoing evaluation (apprehension of theoretical knowledge)
EP: evaluation on carrying out a programmed assignment or hypothetical practical case linked to a skill Acquired Competence
LEVEL A: Understanding and being able to explain theoretical information.
LEVEL B: Also being able to select materials and techniques and carry out a set assignment.
LEVEL C: Also being able to diagnose difficult situations and take fast, efficient decisions to solve them.

Table 17.

In the first stage, the following objectives are set:

- Full development of the training module *Ceramic Tilings* I, prioritising its implementation in the geographic regions exhibiting the greatest imbalance between demand and supply of competent tile fixers, and where there is a greater predisposition towards quality training.

SPECIFIC TASKS OF THE MASTER TILE FIXER
* Analysing all the conditioning factors of a design and measuring to plan on site. Interpretation of design plans.
* Knowing and being able to interpret quality standards on tiling materials and equipment, as well as their guarantee or quality marks.
* Directing and doing the necessary measuring up and setting out on site.
* Selecting and stockpiling materials and organising work teams.
* Coordinating the performance of the work with the person in charge of construction
* Directing and coordinating work teams.
* Knowing and ensuring health and safety regulations of the building sector are applied. Observing and ensuring tile installation specifications are met.
* In the absence of specifications, designing and carrying out a full tile installation even in non-conventional applications.
* Knowing and having selection criteria relative to the quality and suitability of tools, equipment and machinery for a tile installation.
* Being able to select, design, and install scaffolding according to functionality and safety criteria.
* Knowing and being able to select the most innovative materials involved in multilayer systems.
* Knowing and being able to apply quality control plans in installing ceramic tilings.
* Knowing and being able to diagnose non-quality situations in tile installation, ranging from materials to finishes.
* Drawing up detailed cost estimates.
* As a subcontractor, directing a tiling company, based on updated knowledge of company management, fiscal and legal requisites.

Table 18.

Teaching units	Hours	Blocks Week*
1 - Review of tile installation technology (I) (**)	30	1-2
2 - Review of tile installation technology (II) (**)	30	2-3
3 - Review of tile installation technology (III) (**)	30	3-4
4 - Review of tile installation technology (IV) (**)	30	4-5
5 - Introduction to multilayer systems	30	5-6
6 - Special applications (I). Flooring with soundproofing	20	7
7 - Special applications (II). Flooring with thermal insulation	20	7-8
8 - Special applications (III). Flooring with thermal insulation and soundproofing	20	8-9
9 - Special applications (IV). Flooring with underfloor heating	20	9-10
10 - Special applications (V). Raised flooring	20	10
11 - Special applications (VI). Ceramic tiling with sealing	50	11-12
12 - Special applications (VII). Exterior tiling	50	13-14
13 - Special applications (VIII). Swimming pools and wet environments	30	15-16
14 - Special applications (IX). Flooring with high mechanical strength	30	16-17
15 - Special applications (X). Highly resistant ceramic tiling with chemical sealing	30	17-18
16 - Special applications (XI). Conductive ceramic flooring	10	18
17 - Special applications (XII). Ceramic tiling in renovation programmes. Special applications	40	19-20
18 - Safety and health	10	20
19 - Designing, planning and programming the work	40	21-22
20 - Drawing up reports and cost estimates	10	22
21 - Management of a tiling company	10	23
22 - Fiscal and legal requisites relating to a tiling company	40	23-24
SUBTOTAL	**600**	**24**
END OF COURSE PROJECT	**40**	**2**
TOTAL	**640**	**26**

* The proposal recommends giving a week's hours of lessons per month
(**) A detailed overview is involved (theory and practice) of the contents of the training module Ceramic Tilings I

Table 19.

- Programming and holding seminars at the Official Colleges of Quantity Surveyors and Technical Architects, which will also serve as the basis for designing the training of specialists in ceramic tile installations.
- Dissemination actions with the new training module in centres at which tile fixer training courses are already being held.
- Persuading the Administration in general, and the individual Bodies that are officially competent in matters of training in the building construction branch, to provide funding for tile fixer training under the set premises.
- Establishing a public service providing technical information and advice on the correct selection of materials and tile fixing techniques in conventional and special applications.

BASIC CONTENTS	ACQUIRED COMPETENCE	EVALUATION
Review of tile installation technology (theory)	**C**	**EC, T**
• **Interior decoration. Design theory**		
• **Drawing up and interpreting designs and plans**		
• **Measuring up, setting out and programming work**		
• **Ceramic tiles**		
• **Tiling backgrounds/substrates**		
• **Bonding and grouting materials**		
• **Movement joints**		
• **Cutting technology and equipment for tile installation**		
• **Other tile installation materials**		
Multilayer systems	**C**	**EC, T, P**
• **Constructional solutions**		
• **Soundproofing and soundproofing materials**		
• **Thermal insulation and thermal insulation materials**		
• **Sealing and draining.**		
• **Ceramic tilings with high mechanical strength and chemical resistance**		
Special applications	**C**	**EC, T, P**
• **Ceramic flooring with soundproofing**		
• **Ceramic flooring with thermal insulation**		
• **Ceramic flooring with thermal insulation and soundproofing**		
• **Ceramic flooring with underfloor heating**		
• **Raised ceramic flooring**		
• **Ceramic tilings with sealing**		
• **Ceramic flooring over large surface areas**		
• **Exterior tiling**		
• **Swimming pools and wet environments**		
• **Ceramic flooring with high mechanical strength**		
• **Highly resistant ceramic tilings with chemical sealing**		
• **Conductive ceramic flooring**		
• **Ceramic tiling in renovation programmes. Special applications**		
Safety and health	**B**	**EC, T**
Work programming **(theory and practice)**	**C**	**EC, T, P**
Management of a tiling company	**A**	**T**
Fiscal and legal requisites relating to a tiling company	**A**	**T**
Work reports and cost estimates	**A**	**EC, T**

EC: ongoing evaluation (apprehension of theoretical knowledge)
T: evaluation through a test or examination on theoretical knowledge and theoretical/practical suppositions
P: contents susceptible of forming part of an end of course project, to be evaluated by a board of examiners

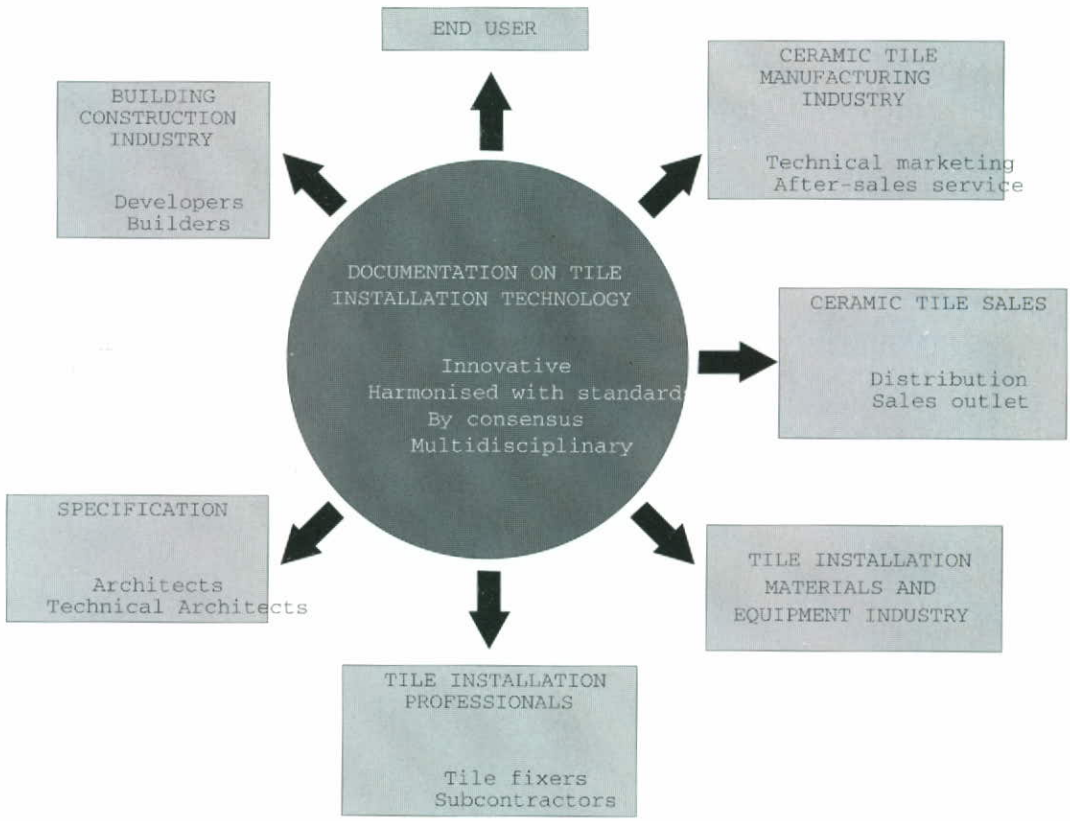
Acquired Competence

LEVEL A: Understanding and being able to explain theoretical information
LEVEL B: Also being able to select materials and techniques and carry out a set assignment
LEVEL C: Also being able to diagnose difficult situations and take fast, efficient decisions to solve them.

Table 20.

SUMMARY

A model has been presented setting out a course of action for improving tile installation quality, which can be characterised as follows:



* It is applied to a territory with high tile consumption and notable shortcomings in tile installation.

* All the industrial and professional parties involved in manufacturing, marketing and selling, and using tiles have participated.

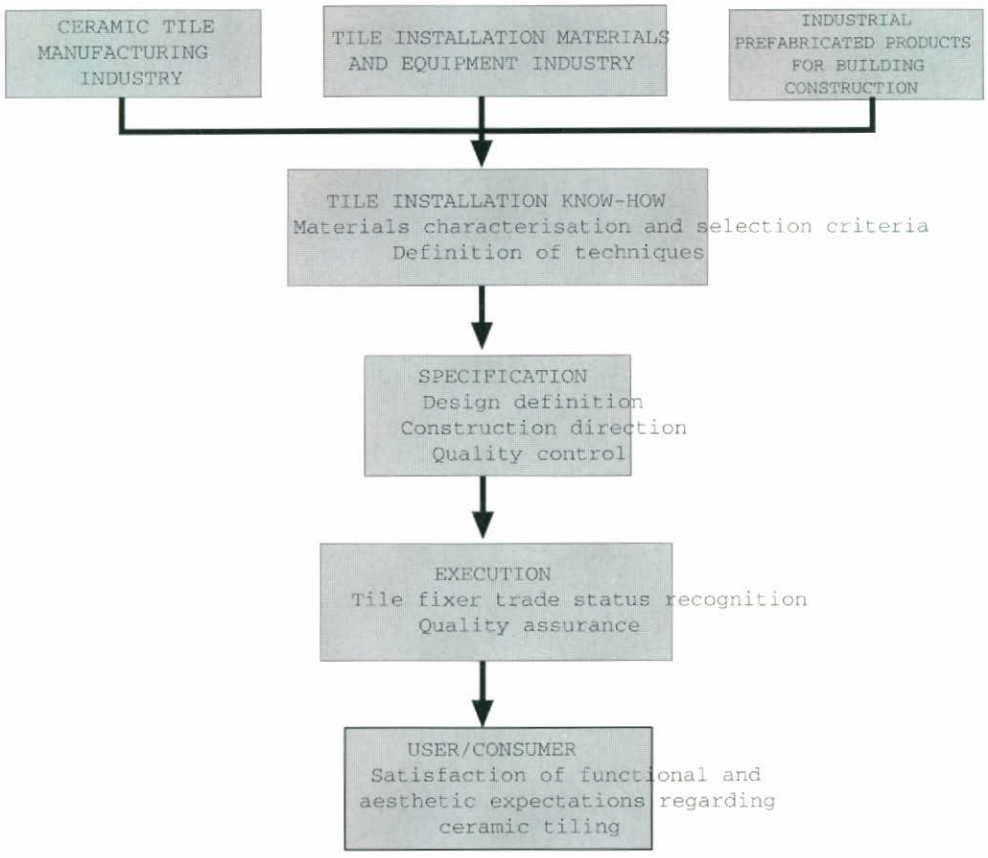
* t includes a unitary documentation on tile installation technology, as an instrument of universal dissemination. The documentation also served to define basic training contents. It is also a key instrument in selecting the most suitable materials and techniques for quality tile installations.

* A training model is proposed, which can progressively raise tile fixer competence and mitigate the current lack of specialists. The training model is characterised by including innovative contents, the latest technical resources, participation of specialists, and application of a new training methodology.

* Other promotional actions are foreseen to foster good practice in tile installation, especially aimed at the professional groups involved in designing and directing tiling projects in building construction.

The model is intended to disseminate the proper selection and use of tiles, creating a positive approach to ceramic tilings from functional as well as aesthetic points of view.

It also aspires to starting a standardisation process for tile fixing in Spain, which requires providing trade status criteria and competence, specialist training, and in sum should lead to a *recognised trade status* and *specification* for the activity.



Another priority objective is promotion of innovative materials and technique, especially high performance bonding and grouting materials, to ensure quality, durability and optimum behaviour if the tile installation, as well as extending the use of tile to a set of special applications that undoubtedly represent the potential future growth of this product and the industrial sector that produces it.

We believe that the model can be exported to other countries with a similar economic situation, after suitable adjustments, in which the potential use of ceramic tiles is conditioned by similar tile fixing constraints. Hence its presentation in this international forum.

ACKNOWLEDGEMENT

To the groups of experts from the various industrial sectors, who made drawing up a unitary documentation on Tile Installation Technology possible.

To the Companies and Bodies that have cooperated in carrying out the first stage of the Tile Installation Project.