Extended Abstract

Quality Control of Ceramic Tiles Application

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1. Introduction

The opening of borders between countries of the European Union associated itself with the technological evolution since the mid-twentieth century, increased competition between companies in the construction sector. This aspect made the companies in this industry proceed to a review of the methods and systems of production in search of higher productivity and quality on its services and building products.

Ceramic tiles are items that have significantly evolved over the years due to an increase of technological innovation in the manufacturing industry. The importance of the complex behavior of ceramic tiles and their methods of application, implies a greater systematization and specifications of material and procedures to adopt on the coating application. Currently, there are available commercially ceramic materials of different porosities, shapes and sizes for use on different environments, inside and outside of buildings, on a wide range of extreme weather conditions.

Considering these facts, is of great importance to develop a systematic methodology, analysis tool of the various elements that exist and are adopted in the market, according to the applicable standards and legislation. Considering the diversity of the existing ceramic tile features, and techniques of application of these materials, we try to develop a proposal for a quality control methodology that allows systematization and monitoring of the implementation method of ceramic tiles, in order to ensure a greater longevity and quality of workmanship.

Therefore, the main research topic of this study is to develop quality control methodology for application in work of ceramic tiles for walls and floors.

2. Ceramic tiles

2.1. Material properties

The ceramic coatings characteristics depend on the management of the manufacturing process and the technical specificities of the product, which allows the correction or manipulation of the majority of characteristics such as brightness, color, porosity, mechanical resistance, chemical resistance, among others.

In order to optimize the final product it is necessary to consider some characteristics associated with, among other factors, the proportion and type of raw materials used, the conditions of manufacturing processes and its specific features, allow the control and optimization of the following specific properties [1]:

- Bending resistance / Compression resistance / Mechanical strength / Shock resistance;
- Absorption / water by capillary action (depending on the amount of water used and respective compactness of the part) / Opened porosity;
- Thermal linear expansion coefficient (relevant to high temperatures or large differences in temperature ranges in abroad applied coatings);
- Resistance to frost (testing the freeze-unfreeze action, highly relevant in environments with aggressive atmospheric conditions);
- Resistance to abrasion (for floors with heavy traffic);
- Thermal and electrical conductivity / Melting point;
- Chemical resistance against aggressive agents (such as wind or rain);
- Esthetic solutions.

2.2. Types of tiles and their functional requirements

2.2.1. System ceramic tiles contitution

A floor or wall covering is constituted by resistant element (support), regularization layer, it may have a waterproofing layer and an insulating layer, in case of glued ceramic, de settlement layer e joint filling layer, or mechanical fixation and ceramic coating. For its definition is essential the specification of use, the type of material that will get the loads to be transmitted, the construction techniques and methods of fixing between elements. The layers of a coating system and its function are constituted by:

Beyond the traditional application of adherent ceramic coating described, there are also independent applications, or ceramic coatings that are not applied directly to the building but in a metal bearing structure fixed to the support, where the ceramic pieces are fixed to the support by clips.

Ceramic tiles, according to Lucas [2] can be essentially on the following items:

- **Traditional adherent tiling,** where the tiles are applied directly on the supports with traditional thick mortars;
- **Adhesive ceramic tiling** where the tiles are glued directly to supports with thin mortars (nontraditional), obtained from products prepared and pre-dosed created in factories;
- **Separated/detached tiles,** or coverings that are separated from the support by the interposition of a membrane or a separating layer;
- **Independent support coatings,** in which the tiles are fixed mechanically through a support structure of wood or metal which therefore, makes it independent of the supports.

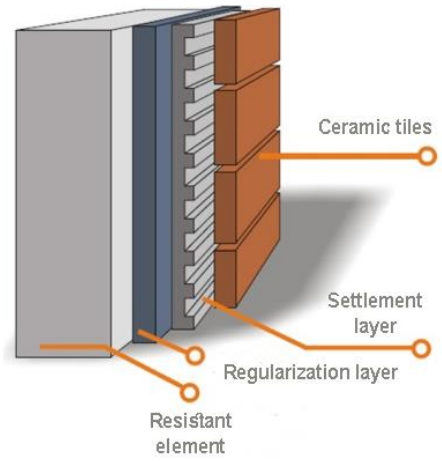

Figure 1. Ceramic tile adherent

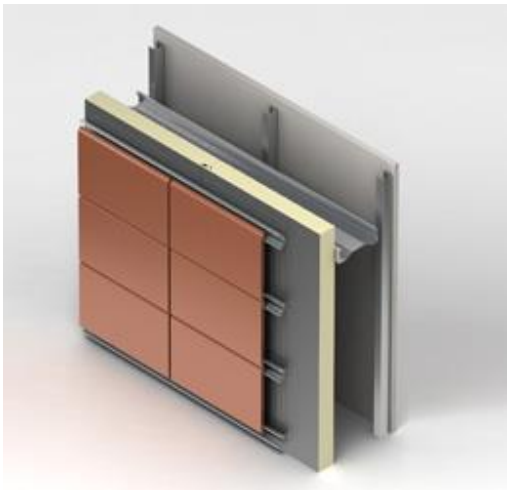

Figure 2. Ceramic ventilated façade

There are several types of ceramic tiles coatings such as:

- Tiles: tiles (white base), in which the outer face is covered by a glaze or enamel, which confers impermeability, wear resistance and decorative or textures. It is used on interior or exterior walls;
- Clay tiles red: with shades of red due to the presence of iron oxide. And they are mainly used in floors;
- Ceramic sandstone: it is a product that after molding, is applied a glaze and subjected to cooking. Applies on both walls and floors;
- Porcelain tiles: it is a vitrified product in all its mass and uniform color. These characteristics give it great resistance to bending and wear, chemical attacks and aggressive atmospheric conditions resistance. Can be applied to walls and floors, interior or exterior.

2.2.2. Functional requirements of the ceramic tiles

The ceramic tiles should be selected regarding its function and where it will be applied. The exterior wall coverings and floors have to ensure the protection of the support, the tightness of the building and aesthetic performance. The interior coating performs the functions of regularity, aesthetic appearance, comfort and adds to the acoustic performance.

There are four basic requirements that these coating materials have to meet in terms of security, livability and durability, which are set out below [3]:

- **Safety requirements;**
- **Habitability requirements;**
- **Requirements to adapt to normal use;**
- **Durability requirements.**

2.3. Manufacturing processes

In a general way, the ceramic materials manufacturing processes include molding, drying and firing, based on the pressing shaping, forming by extrusion (the mixture to obtain the ceramic slurry may be by dry or by wet) or manual molding.

In the **method of forming by dry pressing**, the cast powder is compressed in a mold which is pressed to obtain a compacted product, homogenous, raw and with low porosity. In this procedure, there is a reduction of the volume occupied by the pores, giving rise to a particle readjustment, and therefore a compact product with higher density.

Figure 3.Dry pressing process

In the **forming process by extruding** the plastic ceramic material is forced through a matrix of constant cross section. Extrusion is a technological process of plastic deformation of the mass, wherein the material is subjected to high pressure and is forced through the orifice of a matrix, to reduce or modify the cross-sectional shape. The ceramic coating comes in the form of continuous tape and is cutted according to the specified size coat.

After the conformation, the thermal processing is followed in order to achieve the consolidation required for the final product, consisting of drying, sintering and vitrification. Depending on the type of ceramic coating, there may be a stage for glazing, applied by bell or by spraying, and decoration, this is applied by screen printing, roller printing or more recently by digital printing. It is concluded with the firing of the tiles, so that the particles are consolidated by heating to high temperatures.

3. Standardization

In the case of construction materials, wall and floor tiles, have the regulatory framework **Regulation (EU) No 305/2011** [4], which lays down harmonized conditions for the marketing of construction products.

The standards used in the application of ceramic tiles are the **European standard NP EN 14411: 2008** [5] and the **CE marking,** to ensure the conformity of the construction product. Getting the definition of terms, classification of products and packaging, criteria, characteristics and marking of ceramic tiles, as well as the manufacturing specifications, ensuring the ability to perform its function

according to the performance levels reported for both ceramic products first choice as for the rest. Thus, the essential requirements are assured of ceramic materials used in work throughout their working life, in terms of mechanical resistance and stability, safety in use, hygiene, health and environment and energy saving.

4. Anomalies

The classification of anomalies in the performance of ceramic tiles is understood as pathological problem, that is, a situation that does not display the expected performance. In this way, a pathology analyzes aspects of an abnormality and its cause, origin and nature of problems.

The different types of anomalies may arise both inside and outside the building, although it is more suitable for outdoor locations or areas subject to adverse actions, such as humid places or subjected to water vapor, temperature variations, or subjected to excessive loads for which they were not dimensioned.

In case of anomalies in a ceramic tile system, we can found anomalies like detachment of the ceramic tiling, deterioration of the tiles, deterioration of the joints, deterioration of the tile bed, cracking of the tile, crushing of the borders, detachment, cracking of mass within the joint material, efflorescence, change of colour/brightness, vegetal organisms.

The diagnostic techniques are constituted by four groups according to the type of execution and functioning of the equipment used, which is visual observation, electrical techniques, thermo-hygrometric techniques and ultrasonic techniques [6].

The repair of anomalies and the elimination of their causes must be in one of the diagnostic techniques, privileging the visual observation because some anomalies are detected at this stage and can be obtained an effective solution not having to resort to other deeper methods.

The inspection of the system is the main method to follow, in order to prevent future anomalies, so it should ensure the maintenance and periodic inspections.

5. Quality control

Guidelines are proposed for the development of a methodology of quality control on the construction site for the application of ceramic coatings in terms of monitoring and verification of the construction process. Quality control will ensure a recommended methodology for this type of coatings in order to ensure the optimization of the application, maintenance and use of the coating system over the expected useful time, ensuring compliance with applicable legal and regulatory requirements.

5.1. Constructive methods, equipments and construction products

The constructive methods can be decomposed into a set of specific activities that must guarantee the quality parameters of each method of application of the ceramic materials associated to the following time spaces:

- Before the beginning of the construction work;
- Materials / equipment reception;
- Application reparation;
- Aplication;
- After the coating application.

In the different activities related to the application of ceramic coatings, some procedures that must be followed in the development of the application works should be considered, such as:

- You should only initiate the replacement of the tiles after the support and the foundation layer are treated and, when possible, after the elimination of the causes of diseases. If not, the necessary precautions must be taken so that the coating system will not be affected by such defects or has the capacity to resist them;
- The replacement of tiles must be done in well defined areas, in a rectangular shape;
- The rehabilitated zones should be bounded by joints square cut with waterproof fill and little hard padding;
- The reuse of tiles implies its prior full cleaning, removing all traces of glue products or repointing;
- The support or foundation layer must be free of any glue products, dust or other waste resulting from detachment of the tiles or its exposure to weather conditions, before rehabilitation;
- The final aspect of the rehabilitated area should be as similar as possible to the neighboring areas, which isn´t an easy goal to achieve, either by staining the tiles, either by the joint appearance;
- It must be given a special attention to the flatness of the new coating and its alignment with the wall face, since the new tiles are often more prominent due to the irregularities of the support and the difficulty of placement.

The work equipment used for the application of ceramic coatings is essentially scaffolding, cutting and drilling equipment, mixing equipment, trowel or trowel for manipulating mixtures, gluing (for placement of the laying layer), rubber hammer (allows pressing ceramic plates), spacers, nylon tapes or wooden slats (allow the first row of facing boards to be aligned), profiles that allow the connection of two uneven areas, level ruler and tape measure.

When receiving ceramic tiles, it is necessary to take into account the designation of the product, size and lot (caliber and tonality, if they are certified.) In relation to laying and filling materials, it is also advisable to verify the designation but also the expiration date, storage conditions, instructions and care required for the application, the amount of kneading water and the rest time.

5.2. Occupational, health and safety management

Safety and health at work specifies the minimum requirements to be implemented on site in order to ensure adequate conditions of safety and health of workers. It arises as a continuing need for prevention and control, so as to minimize human failures or material failures.

There are several safety and health risks associated with the application of ceramic coatings, from equipment handling, material collapses, soil instability, additional risks to hygiene, incorrect posture and health (exposure to noise or hazardous agents) which can be avoided with prevention and control measures such as:

- Checking the safety and maintenance status of the equipment;
- Checking the materials condition to be applied;
- Application of collective protections, such as signaling, or distribution of personal protective equipment.
- Checking if the training of each employee is appropriate to the role they play;
- Make available to all workers all information concerning occupational safety and health, including records or Specific Safety Plans.

5.3. Environmental management of the work

The environmental management system, associated to the application of ceramic tiles, with construction works, must be implemented in project planning, work preparation, construction, maintenance, operation and exploitation, particularly at the end of the life cycle of the ceramic tiles, and the materials necessary for its correct application, where it must be done his referral (recycling, new appropriate use or disposal). However, in order to minimize any unused solid waste, it is advisable to use them in constructions, materials that are ready to be applied, and that is only necessary their application. The legislation sets guidelines, criteria, and ecological and sustainable procedures at all stages, varying depending on the specialty, the work dimension, and the activities duration (Decree-Law No. 46/2008, of March 12, as amended by Decree-Law No o 73/2011 of 17 June).

The implementation of prevention and minimization of environmental impacts actions, should be considered in order to minimize the disturbance to the population and the environment.

In this follow-up, when we analyze the standards, continuous improvement of environmental performance is found to be established, defining requirements and implementing tools to minimize environmental impacts through the European Standard **NP EN ISO 14001: 2004,** allowing:

- Continuous improvement of environmental policy;
- Reduced consumption of energy and raw materials;
- Reduction of waste and reuse of resources;
- Pollution prevention;

- Cost reduction and optimization of their control;
- Ensure compliance and compliance with legal requirements;
- Development and sharing of environmental solutions.

Therefore, in order to complement the NP EN ISO 14001: 2004, a construction work, it is necessary a compatibility with the implementation of a Quality Management Systems (ISO 9001) and safety (OHSAS 18011).

5.4. Non-conformities Management (Anomalies Prevention)

Nonconformity management allows establishing and implementing different methods that identify, correct and prevent nonconformity, actual or potential, through corrective and preventive actions. The European Standard EN ISO 9001: 2008, which refers to the Design and Implementation of the Management System is the reference standard for the management "of a" non-conformity, and defines it as non-compliance with a requirement or procedure quality management system. Concomitantly, in order to deal with non-compliance that appears in the application of a ceramic coating, develops corrective action to identify the causes of the appearance of non-compliance and are applied to eliminate these same causes.

It is essential to evaluate the effectiveness of actions implemented in order to be reviewed by the Quality Management System (QMS) whenever necessary, so a way to prevent the occurrence of potential nonconformities is through the implementation of preventive actions. Present normalization identifies procedures for the implementation of these actions, to prevent the emergence of non-conformities:

- Identify the circumstances of potential non-conformities and their effects on quality management;
- Develop and implement preventive actions, such as statistical control or planning periodic maintenance, keeping your registration and control;
- Evaluate the results of the actions implemented, estimating their effectiveness or possible need for QMS review.

It is extremely important that the records of conformity assessment and the monitoring of the implementation of corrective and preventive actions are maintained, amended and updated whenever the QMS check this need.

These records shall include indications of training, monitoring, inspections, maintenance, identification of applicable legal requirements, quality management reviews, or records in accordance with applicable standards. In addition to the registration effected also defines the necessary resources, deadlines and responsibility for their implementation and monitoring.

A systematic process nonconformance management is to identify and investigate non-compliance (or potential nonconformities) and their probable causes, implement corrections to rectify

non-compliant situations, implement actions to prevent their recurrence and mitigate its environmental impacts and analyze the factors that influence the quality management system.

The use of integral procedures of the systematic process of nonconformities management, leads to continuous improvement of quality management system "in order to increase capacity to meet requirements," according to Portuguese Standard EN ISO 9000: 2005 "Management Systems quality - Fundamentals and vocabulary ".

5.5. Document management

The management and control of documents and records aims to implement a documented methodology in the monitoring of the activities performed on site in accordance with applicable legislation. According to the Portuguese Standard EN ISO 9001: 2008 "Quality Management Systems" sets "the guidelines and responsibilities for verification, approval, issuance, control, distribution, review, collection, archiving and destruction of the management system documents quality.

All documentation must be correctly identified (containing your designation, coding, revision number, date, requirement of the standard to which it relates), filed, and have their access controlled with a proper distribution by the workers, and available on site and when it is required. An update to the current version, must be made whenever there are changes. After these changes are reviewed periodically, and external source documents must be properly identified and implemented taking into account its impact on quality management.

In the present study, we highlight the records made during the application of ceramic coatings:

- Registration of training activities / Work instructions;
- Registration of distribuition of equipments for individual safety;
- Registration or lists of materials and equipment on site checks, including its periodic maintenance / Registration markings EC of materials and equipment;
- Environmental monitoring reports / Registration of waste management;
- Registration of non-compliance and the implementation of mitigation actions.

6. Conclusions

Given the excellent characteristics of ceramic tiles, including their durability, different behavior of technical characteristics and aesthetic diversity, there has been a wide range of building materials options and the exploration of new application solutions tiles. The remarkable evolution of the development of construction products and their application methods allowed that, currently, we face not only with new construction works, but mainly to an increase in repair and maintenance works on all elements of construction.

In order to meet the optimization of the durability of an application solution for ceramic coatings over its lifetime, it has been found that it is necessary to define procedures and requirements

of quality control methodology for applying these coatings in order to optimize all steps in the application of ceramic coatings since its conception to its use in subsequent service and maintenance.

It was understood through this study, the characterization and analysis of various types of ceramic coatings, applied in different environments, walls or floors, inside or outside under a wide range of different conditions. It was described the procedure of the methods of applying ceramic coatings solutions, considering the regulatory framework and established an approach of a methodology for quality control in the work context.

It has been defined a strategy for safety management, hygiene and health for the work the construction, concluding that this management is extremely important, because when applied, provides benefits in the health environment, safety and welfare of workers, contributing to productivity. The optimization of health and safety at work planning minimizes human errors and / or failures materials that give rise to accidents. It can be understood, that at all stages of a construction project there are risks or dangers that must be advised that indicate an ongoing need for the prevention and control. The risks may be associated with falls of material, risks related to construction machinery, unstable soil or aggregate risks to hygiene, to incorrect postures (like forced postures and intense or repetitive physical efforts) and health (physical, caused by noise, vibration, extreme temperatures, weather conditions, dust, or chemical and biological hazards).

To minimize the risks referred to above, and hence the accidents, it is advisable the implementation of preventive and control measures involving the verification of security status and maintenance of equipment; the verification of the safety data sheets of the chemical agents and how should be controlled; the application of collective protection measures, in particular through the Collective Protective Equipment; the distribution of Individual Protective Equipment; verification of training of each employee all the information relating to safety and health at work must be available to all the workers. The environmental management system, associated to civil works, must be implemented in project planning, work preparation, construction, maintenance, operation and exploitation, particularly at the end of the life cycle of each material, where to make its routing (recycling, new appropriate use or disposal).

Bibliographic references

[1] C. Rebelo, design and execution of ceramic coating - internal. Specialization in Construction Engineering. UFMG: School of Engineering, 2010.

[2] Lucas, J. A. Carvalho, Ceramic tiles – general description, normative requirements, functional classification. ITMC-33. Lisbon: LNEC, 2003.

[3] Lucas, J. A. Carvalho; Abreu, Miguel Mendes - Ceramic Coatings Glued - Detachment, ITPRC 4. Lisbon: LNEC, 2003.

[4] EU Regulation No 305/2011 of the European Parliament and Council of 9 March 2011.

[5] European Standard. NP EN 14411: 2008 (Ed. 2) - Ceramic tiles - Definitions, classification, characteristics and marking. Lisbon: IPQ, 2008.

[6] Cóias, V., Inspections and tests in the rehabilitation of buildings. Lisbon: IST Press, September 2006. ISBN 972-8469-53-5.