ABSTRACT

This work shows the importance of the designs for ventures in the field of construction of buildings, with a focus on the stone coatings. The text is divided into four main parts describing the context of design development; basic recommendations for the development of facade coating designs, the positive impacts of the development of these projects for the construction and other sectors involved, and finally, draws some conclusions about the subject.

Much has been said about building pathologies (an allusion to the terminology adequate of biological areas) as visible defects and / or invisible that can cause damages in the enterprise, and that its origins can be found out in the stage of design, because the correct specification of materials has vital importance in the performance of the system for coating the facades. Faults in the specifications of the various materials that make up the system of coating can be capital in the emergence of “defects” such as debonding of coatings, efflorescences, etc.. Some cases of pathologies are presented as well as discussion of how they could have been avoided.

KEYWORDS

Ornamental stones; Pathologies; Facades; Mortars.

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1 INTRODUCTION

Much has been said about pathologies of buildings (in a reference to the terminology itself of biological areas) as visible and/or invisible defects that may affect the enterprise, as can be found in Ripper [1984].

During the process of design development, the designer must address some basic requirements such as: parameters for the functioning and overall quality of the work, the interactions between different parts of the building, and constructability. Thus, it is often the emergence of so-called congenital defects, i.e. construction defects generated at the design stage, by failure to comply with the established rules or accepted practice of building design (NBR 13531/95 and 13532/95)

Grunau [1981] presented statistics showing that in European countries, over 40% of all defects presented in constructions originate in deficiencies related to the design of buildings. An example can be seen in Figure 1.

![Stained marble.](image)

In Brazil, often, defects attributed to errors of execution actually originate in the design stage.

Furthermore, the supply chain for the civil construction sector has a wide range of actors and agents of partial products, created during the production process. The various players have incorporated different quality standards and that will affect the quality of the final product. Some of the actors involved are:
-- Users, the regions of the country and the specifics of the work;
-- The agents responsible for the planning of the venture;
-- Those responsible for the preliminary studies;
-- The designers of each specialty;
-- Manufacturers of construction materials at all stages;
-- Those involved in the stage of implementation of the works; and
-- Those responsible for the in-use operation and maintenance of the buildings.

2 THE VARIOUS DESIGNS IN CIVIL CONSTRUCTION

It is common practice in building construction that architectural design is the starting point for the development of several others that are needed for an enterprise, and after receiving the approval from the municipality, it becomes an important factor of technical decisions.

According to Melhado [1992] "the design should have its development led to aggregate maximum efficiency and construction technological rationalization, given the performance and functionality requirements of the building."

Meanwhile, activities that relate to the quality of a product range from the initial contractor’s needs
identification to the satisfaction of the end user. In the construction continuum that is the activity of construction, is another customer (known as intermediary), which should also have their needs addressed. But if the quality depends on several projects, materials and professionals, we recommend, as pointed out by Juran [1992], that a series of qualities can be understood as “a conceptual model of the interaction of the activities that affect the quality of the product or service in various stages, covering the identification of needs through to the assessment of whether those activities are being met.”

There are already mechanisms for ensuring the quality of materials and designs, where the application of the ISO 9000 series of standards has become routine. But there are new products coming to market daily that consumers often the pressure designers to specify. When a particular product is identified in specifications or construction documents there is often an additional “or similar”, leaving the buyer to decide on the best option. What must be transferred, from a strictly technical perspective, are the performance characteristics and properties of the product. The product selections should not be done in isolation, but must take into account the global knowledge of the performance parameters as well as the requirements of the building as a whole.

Specifically on the art of designing, Thomaz [2001] says that, amongst other questions, it is necessary to "know the most frequent defects of the item under study, seeking to avoid those problems in details and construction specifications." So when the designer ceases to observe basic requirements relating to function, overall quality of the work, and interactions between the phases of construction and constructability, there is and increased frequency of so-called congenital defects, that is, constructive pathologies are more likely to be generated even at the design.

As to the planning system, the most difficult and arduous task requires recognition that integrated design and construction planning be done by various professionals from different positions within the organization and in various stages of the design. This high planning must focus on the overall goals and limitations throughout the design. These goals drive the lowest level of the planning process.

The primary benefit of improved performance of the planning system will be to enhance the production unit’s quality of outputs of data, or the quality of the final design produced.

In order to improve performance of the planning system, it is essential to analyze non-conformities leading to the identification of root cause(s) and then recommendations to make improvements in future performance.

The root cause of poor quality or failures in the implementation of the planned work can be found at any organizational level, process or function.

3 THE FACADE COATING DESIGN

The failure to comply with existing technical norms and recommendations relating to material specifications and construction techniques, too often, leads to defects in the buildings, which in addition to becoming a great inconvenience to the parties involved (and condominium construction) become matters of easy challenge by experts in lawsuits (since the basic documents in the case, technical standards, were not followed).

On several occasions the Department of Materials and Civil Construction of EE.UFMG, through its group of teaching, research and extension in the area of finishing the construction, has been called to intervene with construction and condominiums to develop laboratory tests and designs, and the restoration of facade coatings. In a significant number of cases, design deficiencies have been identified as the main factor in the occurrence of defects.

According to Silva [2003], several measures should be taken for facade coatings to have satisfactory in service performance. Among them there is a need for preparation of a design for implementation of the
A facade on which is a series of detailed information relating to the specification of materials and execution techniques, as well as the positioning and sizing of the movement and control joints. Moreover, you should exercise strict control over the quality of the substrate material, mortar settlement, as well as the very material used in the coating. Construction companies in Belo Horizonte (third largest city of Brazil), especially those engaged in medium and high quality residential building construction, are constantly faced with the need to construct ceramic coated facades (coating noble and high acceptance by the consumer market, usually used in conjunction with other coatings, high standard, such as granite and aluminum).

The remaining text of this section outlines the recommended procedures and considerations for preparation of the executive design, specification of materials, and the installation of the facade coatings using ceramic and/or ornamental stone material.

A - Stage of elaborating the executive design
In constructing facades coated with ceramic tile and/or ornamental stone, it is of paramount importance that the executive design provide adequate detailing of the dilatation, movement and control joints [Carvalho Júnior 1999]. The absence or incorrectly sizing these joints are design flaws that can cause the detachment of the ceramic tile or ornamental stones facades.

The joints should have sufficient width to be absorptive and remain resilient (i.e., in the elastic regime) during thermal and hygroscopic events. The movement joints should be positioned in a staggered pattern over the coating (preferably located in regions of transition structure / masonry) and should be full-depth, from the outer surface to the back of the assembly, filled with resilient materials, able to release the tensions generated by movements of the structure and ceramic/ornamental stones ranges they delimit. Figure 2 illustrates this kind of joints.

![Figure 2 – Example of movement joint.](image)

Control joints are used on the changes of direction (such as corners and protrusions), as well as at the transition between different coatings, also with the task of absorbing the tensions that arise in these places. Figure 3 illustrates this type of joint.

![Figure 3 – Examples of control joints.](image)
B - Stage of specification of materials
The correct specification of materials is vital in the performance of the coating system used on the facade. Failure to properly specify the various materials that make up the coating system can be capital in the emergence of defects such as tile debondings.

The spatterdash is a layer of mortar to ensure greater plaster anchor of the masonry / structure [Carvalho Júnior 1999]. The spatterdash used on masonry is usually composed of cement and sand (materials proportions 1:3) with fluid consistency. The surface of concrete should typically be treated with an industrialized spatterdash or the addition of a resin (preferably acrylic-based) to conventional spatterdash mentioned earlier for use on masonry.

The plaster is a layer of regularization, applied directly over the base, with the task of defining the vertical plane and giving support to the next layer, the ceramic and/or ornamental stone coating itself. The plaster must meet the recommendations for resistance and bond strength in accordance with standard ABNT NBR 13749 (Coating of walls and roofs with inorganic mortars- Specification (1996)). This document stipulates that in the trial, to determine the bond strength by pull-off tests, the least 04 values of 06 cps tested should be greater than or equal to 0.30 MPa.

The dry-set mortar (used to set the tiles) must be at least of the type AC-II (also known as flexible polymeric dry-set mortars). For tiles and / or ornamental stones of low water absorption (such as porcelain stone-ware tile and / or granites) it is recommended to use dry-set mortar type AC-III. The resistance and bond strength requirements in the standard ABNT NBR 13755 (Coating of external walls and facades with tiles and the use of dry-set mortar - Procedure (1996)) for tiles set in facades, using dry-set mortar, state that in the trial to determine the bond by pull-off tests at least 04 values of 06 cps tested should be greater than or equal to 0.30 MPa.

The tiles to be used as facade coating must also fulfill specific characteristics [Neto 1999]. The ANFACER (National Association of Manufacturers of Ceramics) recommends that ceramics pieces to be used in facades present water absorption less than or equal to 6.0%. For pressed tiles, with water absorption of between 3 and 6%, standard ABNT NBR 13818 (Ceramic plates for coating - Specification and methods of testing (1997)) recommends that the plates have an hygroscopic dilation less than or equal to 0.6 mm / m. There is still, as positive features, the use of clear colors, small dimensions (e.g. 10cm x 10cm) and poly-oriented claws in back.

Concerning grouting of mortars, the standard ABNT NBR 14992 (Mortar the basis of Portland cement to grouting of tiles - requirements and methods of testing (2003)) recommends, for use in facades, the grout type II, which can be applied to tiles with absorption of water less than 3% and in areas whose extensions should use movement joints.

C - Implementation stage
The setting of the coating system itself must also be done with care because, flaws in this step will probably lead to a premature detachment of the plates.

The dry-set mortar used in to place tiles or ornamental stones requires a minimum time from the mixing of the product with water (usually of the order of 15 minutes). Open time, corresponds to the time that the dry-set mortar can be applied to the plaster without any loss of adhesion. For dry-set mortar type-II open time should be no more than 20 minutes (reference value, taken in the laboratory), and this should be verified on site for the setting ceramic tile and/or ornamental stone coating. The presence of any of the following conditions indicates that the open time has been exceeded: i) bright whitish film on the surface of the dry-set mortar; ii) lack of tackiness or no transfer of dry-set mortar when touched with the fingertips; and iii) inadequate adhesion to the mortar bed, as verified by a pull-off inspection of a newly set ceramic or ornamental stone.

It is also important that the mortar mixture be used in a period less than 2 ½ hours after first contact with water. When setting ceramic or ornamental stone pieces larger than 20 cm x 20 cm, it is
recommended to also apply mortar to the back of the work piece (beyond that already applied on the plaster with the use of appropriate tool).

Thus, there are three distinct and important steps toward the development of any specific facade coating design: executive design, material specification and implementation. Of course designers, responsible for the first two steps, should also contribute significantly to the stage of implementing the so-called generating design for production, which, according to Aquino and Melhado [2002] should provide enough detail to direct the execution activities.

4 POSITIVE IMPACT ON DEVELOPMENT PROJECT IN FACADES COATINGS

Observe that the development of specific design for implementation of the facade coatings contributes enormously to the reduction of possible defects from the non-observation of details exposed in the previous item.

Furthermore, in the current scenario businesses also have a social role in ecological and should become more in step with society, the general population and the workforce. As is happening with companies in other product sectors, the building industry needs to change the aims, focusing actions toward workers and the surrounding environment.

The construction industry must invest in improvements to human resource potential, recognizing itself as part of society and its problems. As well, the sector should focus on the environmental interactions and loadings when considering putting a building in-place; impact of time of implementation, addressing the issue of waste (such as consumption of materials and time beyond what is necessary) and generation of pollution.

The experience of the Department of Materials and Civil Construction of EE.UFMG, through its group of teaching, research and extension in the area of construction finishing, has clearly shown that, since 1996, works that were implemented with the use of an executive design have provided satisfactory performance relative to loads that facades routinely encounter (wind, sun, rain, humidity, among others).

Some of the benefits for construction and users that comes from this procedure are:
• Significant reduction in defects such as infiltration of moisture and water from rain, debonding and falling of the coatings;
• Identification of well performing designs and construction techniques that require less repair later in the facade service life; (This is in contrast to the frequently occurring situation since 1996, where the Department of Materials and Civil Construction of EE.UFMG has investigated, proposed improvements to, and reported on several poorly performing buildings that had not had executive facade design and installation plans.)
• The absence of rework (come from the need to repair facades with infiltration or collapse of coatings) means the absence of the nuisance to users of buildings (natural when performing repairs to the building occupied), maintaining the good image of the construction in the market, in addition to lower costs of maintenance of buildings; and
• Reduction in material waste in the form of rubble generated by the corrective actions during construction and subsequently because, in most cases, several layers of the coating system are not reusable, generating a significant amount of rubble and various types of pollution and costs (noise, dust generation, obstruction of flow of water courses, proliferation of vectors of disease, destruction of layers of soil nutrients, in addition to the cost of materials, transmission and deposition).

To be sure that pathologies can be avoided by correct techniques; some pathologies are shown in sequence. In the Figure 4, mortar is not appropriate because of low plasticity; Figure 5 shows improper use of granite in a facade; Figure 6 shows an inadequate sealant in a joint. To avoid these and many other cases, the technological characterization of the ornamental stones is highly recommended before use.
5 CONCLUSION

As observed, there is a significant influence of the executive design (involving specification of materials and techniques) upon the performance of facade coatings. This, therefore, denotes a fundamental importance of carrying it out.

The preparation of a detailed, consistent and feasible design will be possible provided that it is consistent in adequacy of transferring theory to practice, as well as in its recommendations, taking the significance of quality of workmanship (direct and indirect), as found in civil construction, into account.

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