A METHOD FOR THE DESIGN OF CERAMIC TILING FACADES

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ABSTRACT

This work proposes a design method taking under consideration that appropriate design is a key factor to the performance of ceramic building facade claddings. The main phases and steps of the design process are discussed, including de description of the guidelines and criteria related to: exposure to environment and facade differential movements, compatibility of backgrounds and substrates, selection of tile, selection of adhesives and grouts and control joint positioning. The advantages and disadvantages of starting the designing process in different phases of the building project are also considered.

The proposed method is developed in fifteen different steps grouped in three phases. Phase 1: Initial analysis and definitions; Phase 2: Specification and Detailing and Phase 3: Installation and Control.

The guidelines are not only based on the available state-of-the-art literature and standardization, but also on several applications conducted by the author, two of which are presented in this paper.

The work concludes that the domain of tile manufacture technology is not a sufficient condition to achieve satisfactory results in ceramic tiling facade. Research on ceramic tiling design and application is vital to the future of tiling use. The need for development is shown with regard to several different aspects, including materials, installation methods and establishment of design criteria.

1. INTRODUCTION

1.1. THE IMPORTANCE OF DESIGN TO THE PERFORMANCE OF FACADE CERAMIC TILING.

From a practical point of view, design can be understood as thinking or planning in advance (before construction) in order to set out exactly what has to be done and how it should be done. Beyond being a management and control tool, design must allow improving constructibility and reducing costs.

When a technical decision cannot be made through standardized considerations, the designer has to consider not only the feasibility of conducting testing to validate his decision, but also the need for controlling the application of his decision on site, so that mistakes and misunderstandings can be avoided.

This vision of design can be used in practice when there is a commitment between the designer and the construction company to allow implementing a number of control actions. From this point of view, ceramic tiling design and application must be considered an engineering process of problem solving where empirical based decision-taking should be avoided.

Design is a key factor to the performance of ceramic tiling. Several experiences have shown that a correctly designed and planned ceramic tile application can reduce costs when compared to tradition applications, especially when maintenance costs are not considered.

1.2. DESIGN GUIDELINES AND CRITERIA.

Ceramic tiling systems must be a considered as a monolithic group of adhered layers of different materials, including the substrate. The system is applied over a background where the exterior layer is made up of ceramic tiles set and jointed by adhesives (cement or polymer based). The layers and materials generally used in facade ceramic tiling systems are shown in Figure 1.



Figure 1. Materials and layers of facade ceramic tiling. The background does not belong to the system but plays an important role in its performance.

Two main guidelines arise as being the most important to the design of facade ceramic tiling: life-time performance and avoidance of defects and pathologies. In order to consider these guidelines in the design process, five groups of requirement must be considered:

- dampness and protection of building exterior;
- constructibility;
- costs and market;
- aesthetics and culture;
- use and maintenance.

The consideration of all the variables and parameters involved in these groups of requirements make the process of ceramic tiling design complex, especially because many points of the application technology are still not well understood.

Design should also aim for the best cost-benefits relationship, adequate for a specific period of time. The clearer the design aims, the better are the result that can be obtained.

The design process must set out not only **what** should be but also *how* it could be done, including *when* each decision might arise. This should include specification of materials, application methods and techniques, detailing and control features. It also must allow continuous improvement of quality and productivity.

2. DESIGNING CERAMIC TILING FACADES STEP BY STEP

As mentioned before, the method proposed here is based on the need to avoid ceramic tiling defects and pathologies. Therefore, the design must create the necessary conditions for the improvement of the ceramic tiling application as a whole system.

The method must be carried out so that a satisfactory performance can be ensured in use. It must allow continuous improvement through feedback mechanisms among the different phases and steps of the process. The flow chart in Figure 2 proposes an organization of theses steps into three phases.

The facade ceramic tiling design process should be coordinated with other building designing processes as a whole. Sometimes steps are carried out simultaneously, but sometimes it is necessary to wait for previous information. Although architecture, structure, infillings, windows and finishing systems are involved, it is not necessary to develop the entire ceramic tiling design right from the beginning. On the contrary: what really matters is to the take the right decisions at the right time.

Taking this into consideration, a very simple question arises: *who* should develop the facade tiling design? A multi-disciplinary team can develop it, but a single coordinator is required. This coordinator is normally the architect leading the project but a specialist is often needed. The design process can be carried out inside the organization or instead, by an engineering consultant. In any case, a director is needed to carry out the process.



Figure 2. Phases and steps of the facade ceramic tiling design process.

2.1. DESIGN PHASE 1: INITIAL ANALYSIS AND DEFINITIONS.

The definitions before starting the design process are taken in this phase. This phase includes an analysis of the other parts of the building in order to guarantee considering every important variable.

The local exposure conditions that can interfere with the performance of the system are considered here, as well as the characteristics of the building structure, infilling walls and facade architecture. Because of this, concrete structure and masonry specialists may be involved. The architecture or design coordinator is normally in charge of this phase. Decisions include the selection of ceramic tile, number and thickness of the layers.

2.2. DESIGN PHASE 2: SPECIFICATION AND DETAILING

This is a phase of detailing definition and material specification. Typically the following steps must be carried out:

- specification of background preparation techniques and materials necessary for the application of substrate rendering or direct application of tiles;
- specification and detailing of control joint and required reinforcements in order to guarantee stability and stress concentration. This can include: vertical and horizontal joints to avoid cracks which come from the background or stresses due to thermal movements, steel reinforcement of rendering and background crack suppression membranes;
- selection of adhesives, joint fillers and sealants;
- construction detailing;
- specification of the application method;
- specification of application control criteria and tolerances.

Phase 2 is the most important of all because there are a large number of important variables to be considered and it requires very well organized data to allow establishing adequate communication tools with the job site.

Tables 1 and 2 propose classification and selection criteria that can be use both for adhesive and joint material. Table 2 considers tile size, building height and structural deformation.

CLASS OF ADHESIVE	OPEN TIME (min)	PULL OUT RESISTANCE (Kgf / cm ²)	FLEXIBILITY (mm)	
1	15 to 20	5 to 7,5	1,5 to 2,0	
2	20 to 25	7,5 to 10	2,0 to 2,5	
3	25 to 30	10 to 12,5	2,5 to 3,5	
4	30 to 40	12,5 to 15	3,5 to 4,5	
5	> 40	> 15	> 4,5	

 Table 1. Classification of adhesive mortar for exterior application

 based on open time, pull out resistance and flexibility.

Notes:

- **Open time** determined according to NBR 14083 (ABNT, 1998) and verified on the job site on the substrate and background of the application;
- **Pull out resistance** determined according to NBR 14084 (ABNT, 1998) under air curing at 14 days;
- Flexibility classification is based on more 500 tests carried out in the work of MEDEIROS (1999), MANETTI, MEDEIROS, SABBATINI (1999) and MEDEIROS, SABBATINI, AKIAMA (1998). Testing is according to UEAtc (1990) procedures.

	TILE SURFACE (cm ²)						
	S < 100		$100 \le S \le 300$		300 < S ≤ 900		
BUILDING HEIGHT	< 28 m	>28 m	< 28 m	>28 m	< 28 m	>28 m	
LOW DEFORMATION FRAMEWORK	1	2	2	3	3	4	
AVERAGE DEFORMATION FRAMEWORK	2	2	3	3	4	4	
HIGH DEFORMATION FRAMEWORK	3	4	4	4	4	5	

Table 2. Adhesive mortar selection for exterior application based on tile surface, building height and framework long-term expected deformation. The number indicates mortar class according to Table 1.

Notes:

- Tile surface and building height are the same as proposed by CSTB (1988).
- In order to feature the different levels of structure deformation, simplified criteria are proposed based only on the material and relationship between height and span of beams and height and thickness of slabs, as described below. However other features such as speed of construction and curing method may be considered.

LOW DEFORMATION:		Structural masonry;
	2)	Free span of BEAMS (L) up to 6 m and height (h) minimum of 50 cm;
AVERAGE DEFORMATION:		FLAT SLAB non pre stressed with span up to 6 m;
	2)	Free span of BEAMS (L) up to 9 m and relation height / span (L / h) up to 12;
	3)	Span of CANTILEVER BEAMS (L) up to 1,5 m and relation height / span (L / h) up to 3;
	4)	Span of CANTILEVER SLABS (L) up to 1,5 m and relation thickness / span (L / h) up to 12.
HIGH DEFORMATION:		Pre cast reinforced concrete frameworks with beams and slabs simply supported.
	2)	FLAT SLAB non pre stressed with span above 6 m;
		Free span of BEAMS (L) above 9 m and relation height / span (L / h) above 12;
		Span of CANTILEVER BEAMS (L) above 1,5 m and relation height / span (L / h) above 3;
	4)	Span of CANTILEVER SLABS (L) above 1,5 m and relation thickness / span (L / h) above 12

2.3. DESIGN PHASE 3: INSTALLATION AND CONTROL

This is an *on-site phase*. Steps include actions necessary for the implementation of the design in practice. During this phase, the designer must be involved directly with construction tasks so he can verify the applicability of details, materials and methods specified *in situ*. Here the following steps must be carried out:

- construction planning of facade ceramic tiling application;
- contractor, supervisors and workmanship training;
- quality control of design applicability on the job site.

Throughout this phase, the design process can be continuously improved, so that it can really work in practice.

3. RESULTS AND APPLICATIONS OF THE METHOD

The method presented has been used in the last four years in several projects. It has been improved several times to incorporate the practical results and latest research conducted.

Figure 3 shows three building (19 floors) where 2 x 2 cm porcelain tesserae was used. Long term deformation (creep) of concrete framework was critical. Adhesive mortar and joint filler Class 2 and 4 was used through double fixing technique.

Figure 4 shows two towers (24 floors) where 10 x 10 cm extruded tile was used (6 % absorption). Creep of concrete was expected to be critical here too. High productivity application was also an important requirement. Adhesive mortar and joint filler Class 4 were used. Control joints were sealed with polyurethane mastic. Figure 5 and Figure 6 show examples and details of joints in the same project.



Figure 3. Porcelain tesserae were used in the project. The combination of colours allows a harmonic composition. Concrete framework long-term deformation requires joints and high performance adhesive mortar.



Figure 4. Controls joints are shown in this facade where tile Group AIIa was used. High performance adhesive mortar was also used



Figure 5. The cantilever beam requires vertical control joint to avoid cracking along the interface of the masonry infilling walls. Notice the horizontal joints at every floor level, following the line of the bottom of the beam.



Figure 6. Accurate application of sealant of control joints is crucial to performance of a ceramic tiling system. Note the thickness of the installation joints. Open joints are necessary to control the deformation of the panel and accommodate dimension tolerances of tile.

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4. CONCLUSIONS

The building construction industry requires ceramic tiling systems that include materials supply, design and planning integrated in the building project and its other systems. They should also include workmanship and terms of guarantee so that risks and responsibilities are clearly identified.

These systems should be developed throughout a systematic approach in order to achieve satisfactory results. This is perhaps the only feasible way to get actual efficiency.

Although many aspects of the application technology of facade ceramic tiling are still not well understood, therefore urgently demanding research, a number of actions can be put into practice in order to avoid problems. PERRY, WEST (1994) proposes, for instance, that we need to undertake research to develop an appropriate theoretical model and adopt an appropriate safety factor to ensure satisfactory performance in use. The design method described in the present work is an example of this kind of action, although it is limited to the current codified limits until research can improve it.

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