BUILDING FACADES WITH PORCELAIN STONEWARE TILES IN RECIFE - BRAZIL

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ABSTRACT

Porcelain stoneware tiles are widely used in Recife - one of the largest cities in Brazil - as a cladding material for tall building facade finishing, mainly for aesthetical and commercial reasons and, in some cases, together with dimension stone.

Since 1996 more than 50 building facades were finished with this material through directly adhered method and very few technical improvements have been added along the years. These buildings have some particular features in common such as: reinforced concrete framework, external wall rendered with cement-lime mortar and low productivity when compared with industrialized construction methods. Another important feature is that many of the buildings have more than 20 floors and some of them up to 45 floors.

Based on audits and on a field work where 25 out of the 50 buildings were studied, the following common features could be identified: (i) porcelain stoneware tiles are usually used together with other finishing materials (ceramic small format tiles and dimension stone); (ii) polished porcelain tiles products were used in 77% of the buildings; (iii) 30 x 60 cm was the largest format used and 30 x 30 cm was the most common; (iv) cracks in grouted joints and water leakage were the main defects found, (v) detachments occurred in 8% of the cases; (vi) Portland cement adhesive mortars (both dry set and latex) were used in 95% of the cases for setting the tiles, (vii) in 100% of the building facade, movement joints were used; (viii) less than 15% of the buildings could count on a formal engineered design.

This paper - based on the experience of the local construction market - shows not only the importance of research investments and national standards review in order to support the construction market to accomplish good results on new ceramic tile architecture but also make clear that good practice can stimulate the use of porcelain tile in facade with success.

1. INTRODUCTION

Recife is a 218 Km^2 city located in North-east Brazil with a population of 1,422,905 inhabitants, according to 2000 Brazilian official census. The weather in Recife is typically tropical, very hot and humid all over the year (Figure 1 and 2).

Local construction market is known by its high-rise building construction of very slender concrete structures (FONTE et al., 2005) and the use of high strength concrete (above of 30 MPa). Although pre-mixed concrete is a common practice all over the country, in Recife it is usual to mix concrete on the job site. Partition walls are built with ceramic blocks and most building practices feature a low industrialization level. Typical construction period for a building in the city takes about 40 months.

Some examples shows in the website www.emporis.com/pt/ and reproduced in Figure 3 show that Recife is the fourth city in the country in high-rise buildings (more than 35 m high) and has the highest percentage of buildings with more than 30 floors (13.57%) and the lowest percentage of buildings with less than 20 floors (76.36%). An increasing number of high-rise buildings can be observed. Considering those now under construction, about 43% have more than 25 floors and 28% more than 30, as shown in Figure 4.

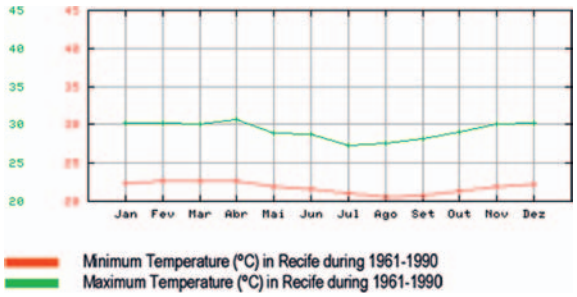

Figure 1. Variation of the maximum and minimum temperatures in Recife (http://www.inmet.gov.br/climatologia/combo_climatologia_I.html)

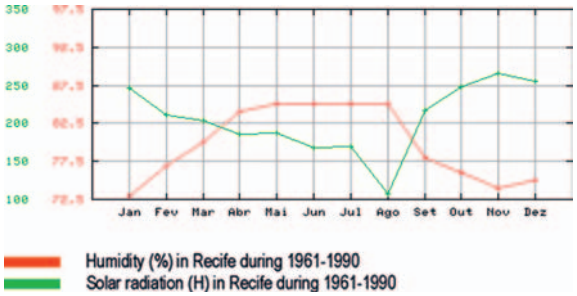

Figure 2. Variation of humidity and period of solar radiation in Recife (http://www.inmet.gov.br/climatologia/combo_climatologia_I.html)

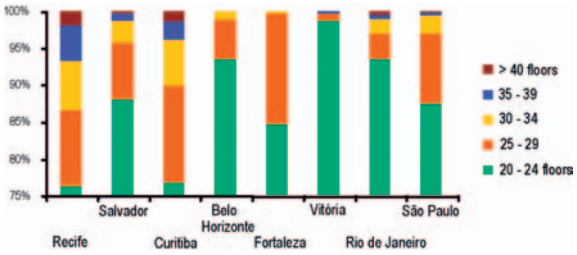

Figure 3. Buildings constructed in Brazilian cities according to their height. Source: Emporis 2003®

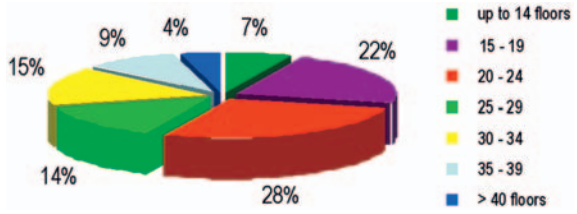

Figure 4. Buildings under construction in Recife according to their height. Source: Emporis 2003®.

2. FACADES IN RECIFE

Buildings in Recife are known for their facades covered with ceramic tile products. Other types of finishing methods such as painting, concrete and decorative renders are used in only 6% of the city buildings (Figure 5).

Throughout the years there has been a considerable increase in the use of ceramic tile on facades (Figure 6) and from the 1980's on this sort of covering became the most used in all kinds of buildings (Figure 7).

The most widely used ceramics tiles in Recife can be classified as group BIa (stoneware) and BIIb (semi-stoneware) according to their water absorption rate. Most common format is 10 x 10 cm.

It was from the 1990's on that the use of porcelain tile on facades started in the city. Since then, a continued increase in tile dimensions has been noticed.

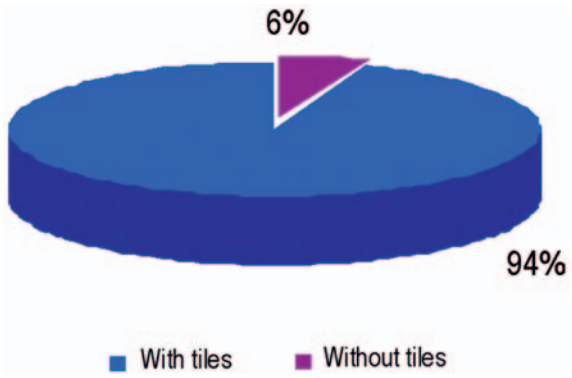

Figure 5 Ceramic tiles as facade covering in Recife in 2001. COSTA E SILVA (2001)

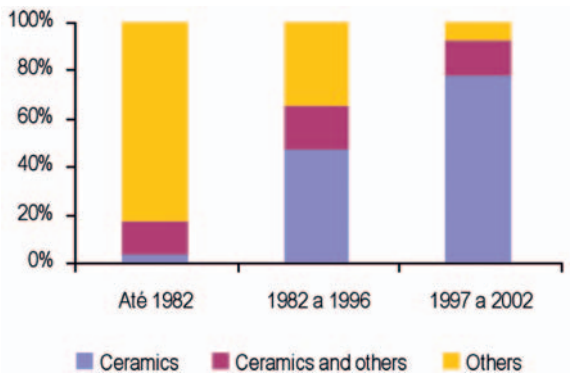

Figure 6 Increase of ceramic coverings usage in facades in Recife. COSTA E SILVA (2001)

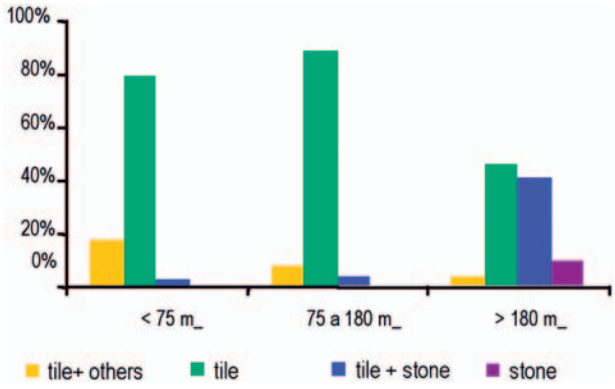

Figure 7 Materials types used for facade purpose in relation to area of apartments. COSTA E SILVA (2001).

The directly adhered installation method was used in all projects that have been studied. A great variety of adhesive mortar and plaster were applied. The plaster mortar type was mostly composed of cement, lime and sand, prepared in the construction sites. A study on similar construction sites by CARNEIRO; LIMA; ANTUNES (1995) showed that render cement content varied a lot. While one of the renders had only 5% of cement content, another reached 23% of the mass of dry material.

3. OBJECTIVES AND METHODOLOGY

The main objective of this work is to present the interesting experience of Recife in the construction of high-rise buildings facades with directly adhered porcelain tiling method. Based on a field research, the study also aims to:

- understand design solutions and materials used in the construction of facades;
- identify most common existing defects in tiling facades;
- evaluate directly adhered tiling performance when applied to porcelain stoneware facade in high-rise buildings.

The field research was based on audits to buildings where porcelain tiles were used on facades. A survey was carried out to identify and catalogue different kinds of projects. Constructors and designers involved in 25 different projects were interviewed in order to identify materials and products applied and better understand design details and defects found.

4. PORCELAIN TILE AS FACADE COVERING

There is not a precise record of the first building to use porcelain tiles directly adhered on facade in Brazil. However, the *Curitiba Trade Center* building finished in 1995 in Curitiba, state of Paraná, deserves credit as a landmark in the country (Figure 8) as one of the first usages. In this construction, tiles and latex adhesive mortar were imported - the national production of porcelain tiles began two years later in 1997.

The buildings *Planet Work* in Sao Paulo and the *Condominium Enseada dos Corais* in Natal are also important national landmarks of how porcelain tile is been used in the country since than. Both buildings were built in 2001 (Figure 8).

Figure 8. Important projects in Brazil where porcelain tiles where used in facades. From left to right: Curitiba Trade Center in Curitiba; Planet Work in Sao Paulo and Condominium Enseada dos Corais in Natal.

In Recife, the first important project where porcelain tiles were used on facade was the Principe de Marsala Building finished in 1996. In this project 30 x 30 cm polished tiles had been used in an area of about 10,000 m^2 (Figure 9).

Since then, an increasing number of construction companies have been using porcelain tile as facade covering of both residential and commercial buildings, normally together with other types of coverings such as stones and small tiles (see

Figure 10). About 65% of those projects are used for residential purposes and 35% are commercial projects.

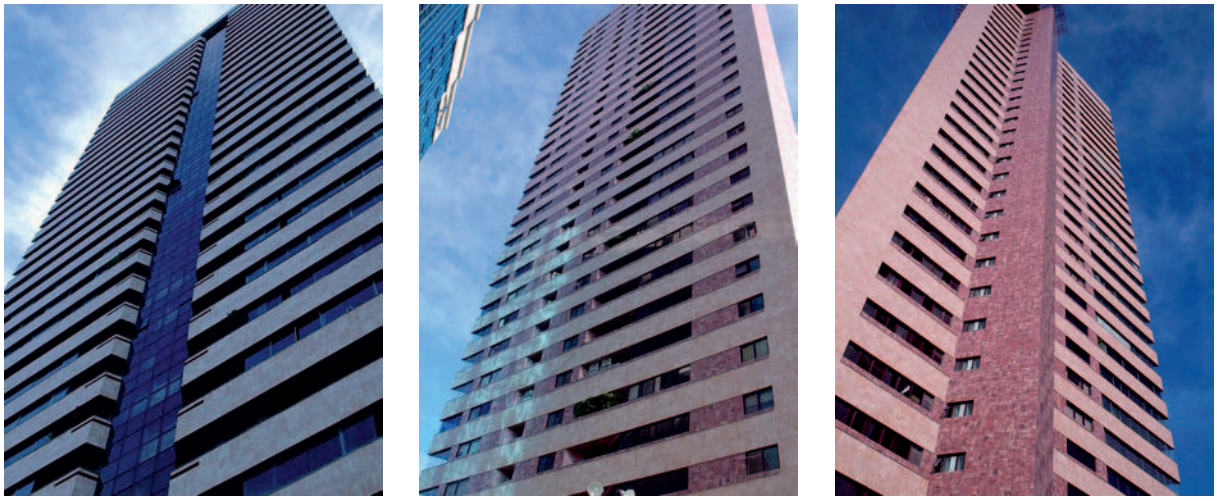

Figure 9. Facade overview of the first great project in Recife where 30 x 30 cm porcelain tiles were used.

Figure 10. Porcelain tiles building facades in Recife. Most buildings have more than 20 floors. Facades architecture put together ceramic tiles, dimension stone and structural glazing.

More recently, on the other hand, two other buildings facades with porcelain tiles have been built using curtain wall methods, one in Curitiba and another in Belo Horizonte. In both projects, individual metal inserts were used to fix the tiles through a technology based on the ventilated system found in Europe.

4.1. PORCELAIN TILES

Polished products porcelain tiles are a clear preference to cover facades of buildings in Recife. Taking into consideration all the buildings visited during the field work, it represents 77% of the total amount. On other 13% projects polished and non-polished products were mixed together and in only 10% used projects non-polished materials were exclusively used.

Concerning the dimensions of the tiles, 44% of facades used 30 x 30 cm format, while 40 x 40 cm was used in 40%. Tiles of 45 x 45 cm and superior formats were used in 16% of the cases. Obviously the kind of tiles specified to the facades studied was directly influenced by market availability at that moment. Tiles of 40 x 40 cm format and larger formats were introduced in the national market after 2000. The largest tile ever seen applied on a building facade in Recife was a 30 x 60 cm tile used in two of the visited buildings. However, there are 60 x 120 cm already directly adhered recently used in Florianopolis, in the south of the country.

4.2. MATERIALS AND INSTALLATION METHODS

100 % of buildings audited in the field research used directly adhered method to install tiles, 94% of them with industrialized adhesive mortar while only 6% of mortars were prepared in the job site. 85% of the adhesive mortar identified can be classified as dry site (mono-component) and other 15% as latex mortar (bi-components). The use of latex is more recent. First specification in the city was only in 2002.

In many cases, adhesive mortar was applied to the back of tiles previously and sometimes cement-polymer spatter dash was used. Simple wire anchorage (Figure 11) aiming to reduce the risk of future detachment was also used. This kind of preparation was used in about 28% of the facades until 2000. Afterwards, this technique was used only for repairing purposes.

Figure 11. Examples of simple wire anchorage to improve bond stability.
Back surfaces of tiles were previously prepared with adhesive mortar or spatter dash.

4.3. FACADE DESIGN

A small number of formal engineering designs were found (less than 15% of cases), which could guide the construction of the porcelain tile facades. Projects were supported by the construction companies themselves based on the experience of resident engineers and technical information provided by tile and mortar manufacturers. Most information does not cover movement joint positioning and reinforcement of the render layer as it should do.

Although formal design was not a practice, all facades have horizontal movement joints between floors and some vertical joints too.

4.4. FACADE DEFECTS

The main defects found on the facades were: water leak due to small interface cracks associated with efflorescence, seaweed and fungus proliferation, in grouted joints. The proliferation of seaweed and fungus and the spreading of efflorescence can seriously damage aesthetics, being both problems related to the water presence and bad specification of grout material.

Cracks and water leaks can put the facade tiling into stability risk since cyclic hygroscopic movement can significantly damage mortar and grout mechanical resistance, and stress accommodation ability as stated by HAROLD (1996); SU (1995), FRITZE (2002), OLIVEIRA (2005). It was not possible to identify all the reasons for water leakages, although some hypotheses can be advanced such as:

(I) interface cracks between grouted joints and tiles, observed in most inspected facades (see Figure 12);

(II) bond failures in joint sealant to the edges of tiles, associated to the inadequate positioning of the back rod and sealant section;

(III) tile cracks due to saw cut used to install wire anchorages at back of the tiles (Figure 13);

(IV) imperfections between window frames and porcelain tiles due poor detailing and workmanship.

Figure 12. Small cracks between grouted joint and porcelain tiles edges that happened in many facades that have been inspected during the field survey.

Figure 13. Example of crack observed where wire anchorages were attached to the back of tiles in order to improve bond stability.

Concerning bond problems, few cases were found and only in two cases severe detachment were found as seen in Figure 14. In Figure 14 regular cement and lime render was used and detachment happened all over facade due to insufficient bond and strength.

Lack of surface planarity has also to be taken into consideration on aesthetics. Slight curvature of porcelain tile can be a problem in facade depending on colour pattern. This is even more relevant when using polished porcelain tiles of large dimensions as observed in most inspected facades of the city.

Figure 14. Severe bond defects occurred in two cases. After six years tile facade was entirely repaired.

5. DISCUSSION ON THE USE OF PORCELAIN TILES FACADES IN RECIFE

Taken into consideration the evidence from the field research, some aspects can be pointed concerning the use of directly adhered porcelain tiles in facades of tall buildings. To allow a brief discussion, all the information available was condensed in six different items, presented below.

5.1. WHAT ARE THE REASONS THAT EXPLAIN THE CHOICE FOR PORCELAIN TILING IN SO MANY PROJECTS IN THE CITY?

Ceramic tiles have been used in building facades in Recife for many years. The city architectural scene has been influenced by glazed tiles imported from Europe since the XVI century mostly for religious and institutional building but also a sign of nobleness. Home owners considered ceramic tiles as material of high social standing.

During the last decades ceramic tile became the first choice to high-rise building facades too. This preference is so remarkable that very few projects can be seen with other kind of material besides tiles. Only dimension stone is well used too. Local construction market is strongly linked with regional culture and consumers also have a good value perception of ceramic tile advantages when compared to other types of coverings. Cleanability, low maintenance cost and durability are some advantages of great importance. It was only in the 90´s, however, that porcelain tiles became an important aesthetic alternative.

5.2. WHICH TECHNICAL CONDITIONS CAN BE CONSIDERED FAVOURABLE OR NOT TO PORCELAIN TILING USAGE?

Just as the majority of the North-eastern Brazilian cities, Recife has hot weather all year round. Air humidity and solar radiation are very high too. Although daily temperature gradient should not be considered a problem, high temperature and typical fresh rain can be responsible for quick expansions and contraction of adhered tiles.

Slenderness in many buildings in Recife is also a question of concern since porcelain tiles have been used in facades that are taller then 110 m but less than 10 m wide. Therefore it is not uncommon that these cast *in situ* reinforced concrete structures present relatively high displacements due to wind load as well as shortening due to fluency and shrinkage of concrete. These features are particular important when large-sized porcelain tiles are used. Because of this, on many projects tile is limited to 30 x 30 cm.

High-rise building featuring those particular architectural and structural conceptions is determinant to the right selection of tile, adhesive mortar, grout and cement render. Installation designer also must consider specifically those conditions relating to the detailing of movement joints and render reinforcement, even though official standards do not consider building typology as an important guideline.

5.3. ARE MATERIALS AND INSTALLATION TECHNIQUES WELL ADJUSTED TO LOCAL CONDITIONS?

A great variety of adhesive mortar was used and only in the last three years latex adhesive is been used too. According to GUAM; ALUM (1997), latex adhesive mortar has been using in Singapore since the 80´s. Higher flexibility when compared to local dry set adhesive as pointed out by AKIAMA; MEDEIROS; SABBATINI (1997) recommended latex adhesive mortars.

No meaningful modification was made in relation to render material or application to suit porcelain tiles. Render cement mortar used to have similar characteristics as those used as substrate for the small format tiles that are regularly used. MEDEIROS (2000), however, recommended extra surface strength to promote good bond with adhesive mortar. It is also recommended to use floating and buttering when laying tiles in order to improve bond surface contact.

Although specific design for facade tiling is still not a practice in Recife, it is strongly recommended to improve durability and guarantee better performance. Authors believe that it is exactly in the design step that it is possible to suit material characteristics and installing details to local building requirements.

5.4. HOW DEFECTS FOUND CAN BE EXPLAINED?

Porcelain tile is relatively new material for building facade purposes in Recife. The oldest project is now no more than 10 years old. Even though there are an expressive number of defects such as installation joint cracks, efflorescence and water leak problems only two cases of severe detachment were found. It is important to state that most part of these problems happened during the first three years after project conclusion.

All data and information collected allowed concluding that most part of the problems is related to inadequacy of materials used to fix tiles and grout joints. Therefore one of the aspects that should be investigated more thoroughly in order to minimize such defects is the correct specification of adhesive mortars and grouts. In most cases where cracks occurred other related defects also were identified, although the cracks in porcelain tiles shown in Figure 13 are related to the cuts made to fix the anchorage wires.

5.5. HOW LONG WILL THE TILES REMAIN ADHERED TO THE FACADES?

This is likely to be the most serious and important question under discussion, since its answer is imprecise and more research into the durability of directly adhered facade tiling needs to be undertaken. It seems to be quite relevant to investigate the adherence loss that may occur under cyclic movement which may result in material fatigue. This fatigue might cause the decreasing of adherence due to daily temperature changes and humidity, associated to the displacements due to wind action. FREITAS; VAZ SÁ (2005) studied these effects and found good evidence of adherence loss under temperature and humidity changes.

Loss in adherence along the years can also be associated with fungus and mould proliferation stimulated by water leakage though grouted joints cracks. This certainly deserves more attention from material manufacturers, construction companies and specifiers. It is not only important to avoid aesthetic problems such as dispigmentation, fading, darkening, stains but also necessary to reduce risk of stability problems as shown. SHOET; PACIUK (2004) evaluated the degradation of different types of facade coverings to conclude that ceramic tiling lifetime is situated somehow between 15 and 21 years. Therefore, it will not be a surprise if in the near future it becomes possible to observe a larger number of defects in building facades in Recife.

5.6. HOW TO PREVENT THE MAINTENANCE ACTIVITIES?

Maintenance routines are very important to prevent defect in multi-storey buildings and especially in high-rise projects. Although many problems could be avoid and lots money could be saved, very little attention is given to facade maintenance – residential building in particular.

It is also relevant that the ceramic tile market chain be involved together to promote facade maintenance. That includes improvements in standardization as a key factor. Experts, manufacturers and builders must establish some clearer criteria in terms of preventive maintenance. Besides developing engineered design and controlling installation process, builders must inform final users how to do the maintenance, and its importance.

6.0. CONCLUSION

Recife is not only a huge real scale laboratory for porcelain tiling facade installation. The city has a spectacular reserve of tall buildings where ceramic tile covering is used on a scale possibly unequalled anywhere in the world. These projects were put into practice through out many different construction techniques, materials and detailing for the last 10 years. This study tried to rescue such rich experience in order to point up important lessons very difficult to learn from theoretical research.

The use of porcelain tiles in facades in the city is entirely connected with consumer acceptance. Although the number of visible defects is meaningful, stability problems is clearly decreasing when same aged projects are compared. The most usual facade defect observed was water leakage due to cracks in grouted joints, associated with seaweed and fungus proliferation. Joint efflorescence also was identified. Tile detachments were the most important stability defect and occurred in two cases of the 25 studied.

Porcelain tiling facades in Recife plays a remarkable role in the city architecture and presents good results in general. Facades performance can be improved, however, if better detailing, material specification and installations quality control can be put into practice. Designing and installation should consider all the critical features of facades as discussed by MEDEIROS (2000), but also should include maintenance planning to achieve long lasting results.

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