PROCEDURES FOR REPAIR OF PATHOLOGIES IN CERAMIC FACADE CLADDINGS

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ABSTRACT

Through a discussion of the factors involved in the occurrence of detachments in ceramic facade claddings, this work seeks to establish parameters for restoring this building subsystem. Through this investigation, subsidies are sought for applying a methodology developed for the repair of this type of pathological manifestation.

The work presents and analyses a case study in a residential building located in the city of São Paulo - Brazil. In this case study it is attempted to apply parameters based on actions of a preventive and corrective character, in defining an approach for repairing facades affected by detachments.

1. INTRODUCTION

This work is based on the methodology developed by CAMPANTE (2001) for diagnostics, prevention and repair of pathological manifestations in Ceramic Facade Claddings (CFCs) consisting of three different phases: diagnostics, treatment and prediction, of which the first two are described in this work. The studied case involves an intermediate type of residential building of 13 floors, located in a middle-class neighbourhood in the area west of the city of São Paulo. Figure 1 presents a view of the building.

Figure 1: View of the building.

This case originated in user claims that there were physical risks because of a problem of falling ceramic tiles in a pedestrian passage alongside the building. The builder was then called and after visiting the site concluded that specified repair work being carried out was not solving the problem.

2. DIAGNOSTICS OF THE PROBLEM

This stage comprises four different phases: inspection, interviews, *anamnesis* (establishing preceding history), analysis (establishing cause/effect relations), which are described below.

2.1 INSPECTION

The first action taken was an inspection *in situ*, upon which the building was characterised in regard to its surroundings, as shown in Figure 2.

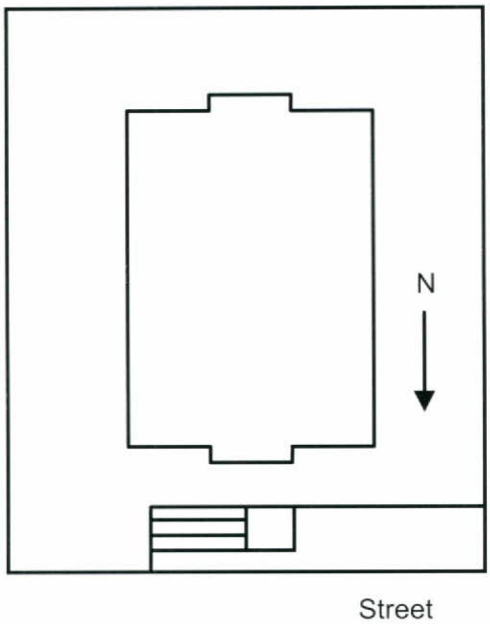

Figure 2: Location of the building.

It can be observed that the problem happened in the east facade of the building, as shown in Figure 3 and quantified in Figure 4.

Figure 3: Detachment event in the east facade of the building.

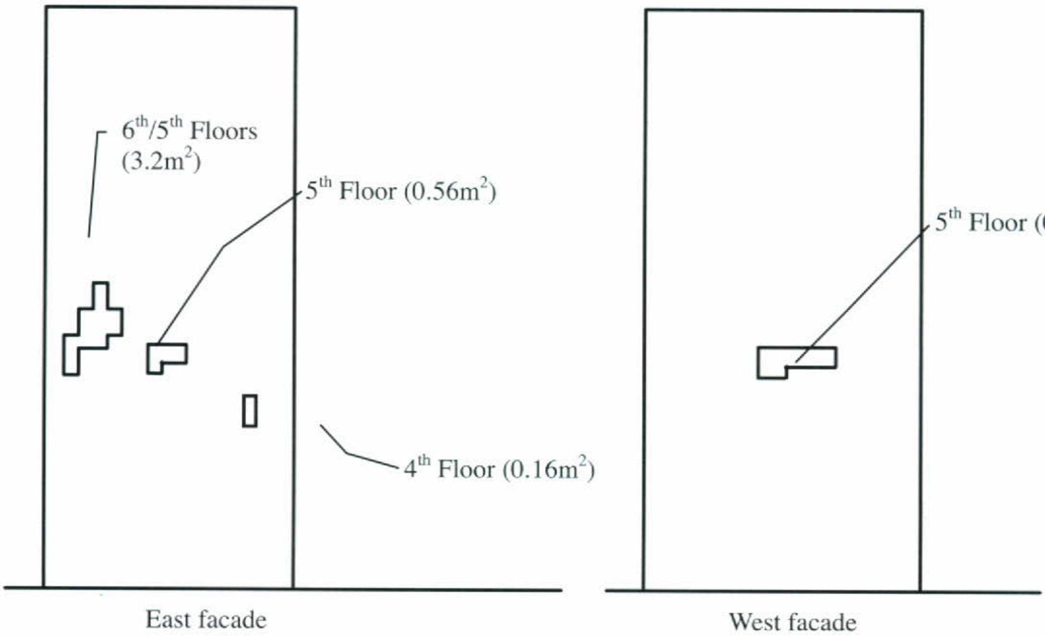

Figure 4: Views of the positions at which the detachments occurred and their respective areas.

The *in situ* inspection also highlighted the notable exposure to sunlight that affected the facade in two periods of the day, as shown in Figure 5.

Figure 5: Evidence of east facade exposure to sunlight.

Another fact demonstrated in the inspections was the lack of coverage on the back of the ceramic tiles that came off the facades, as shown in Figure 6.

Figure 6: Evidence of the lack of coverage on the back of the ceramic tiles.

Areas were also observed in which tiling swellings warned of the eminent risk of tiles popping, entailing great risks for the users and demanding urgent solution, as Figure 7 shows.

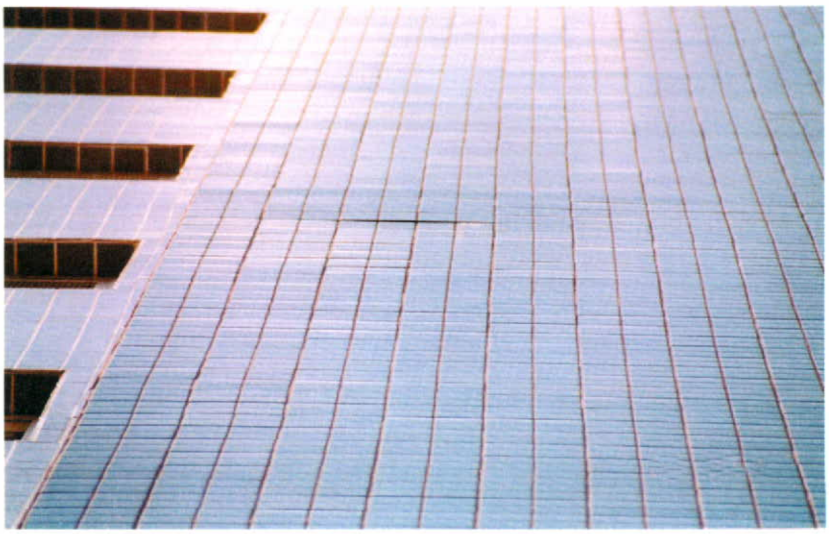

Figure 7: Appearance of swellings in areas of the west facade of the building.

2.2 INTERVIEWS

In a second phase of the diagnosis three interviews were held with the engineer responsible for the work, the building guard (who works in construction) and the building manager (one of the first residents). The information collected was used to draw up the preceding history of the building and of the CFC subsystem.

In the interview with the engineer, data was collected on the building: it was built in 36 months, using a reinforced concrete structure formed on site, filled in with ceramic blocks, with cladding on all facades of glazed pressed ceramic tiles in four different colours (white, ash grey, blue and green), measuring 20 x 20 cm (simulating size 10 x 10 through an accompanying division).

The builder's engineer reported that the building had been delivered at the end of 1998 (December), the first claims being filed in March of 1999, a fact confirmed by the manager. According to the engineer, the work had been performed without any big problems, each stage being completed within the set term, with all due care "as can be seen by the quality of the concrete structure, whose departures from plumb in the facades do not exceed 2 cm."

According to him, great care had been taken in rendering the facade and fixing the tiles, since it was done by a skilled pieceworker in installing ceramic tiles on facades, who had worked for the builder for over 20 years; this work had been accompanied by technicians of the company that produced the fixing mortar (type AC II), which had been recommended by the ceramic tile. manufacturing company. This care was necessary due to the lack of experience by the builder in using this type of facing (they had hardly made any facade claddings with small size pieces following the traditional method).

The information received from the guard did not confirm these statements, in truth it contradicted them. According to him, the facade render was done by a pieceworker (the one that had worked for over 20 years with the builder), different from the one responsible for the CFC subsystem, and this latter individual had ended up changing the team of workers three times. The two affected facades were executed at the same time with scaffold hoists (with mechanical and plank walkways) in all their extensions, adopting the following order: it descended executing the render, the team changed (this went to another facade) and they went up the hoist not in service (to leave "the render time to time to dry") and once up high, they came down fixing the ceramic tiles, one week after applying the render.

Furthermore, according to the guard, the back-up by the company producing the fixing mortar was restricted to a training one afternoon with the team that started the tile fixing service. The training explained how to stir the mortar powder in water, the proportion of the mixture, the need to let it rest a certain time and how to spread the plaster on the surface. This training was not repeated for the other members of the team that were changed.

2.3 ANAMNESIS

During the anamnesis phase of the building, the lack of a construction memory by the manufacturer became clear, which negatively affected the study of the building documentation (plans, briefs of structural calculation, specifications and tests of materials reception, chronograms and work logs). The lack of precision or even the inexistence of these data limited the Data Analysis phase of the proposed Methodology, since it was not possible to reconstruct the documentation of the building's previous history.

Records of accounting receipts of materials purchases were apparently not kept, which would have allowed tracking the products; only the receipts of ceramic tile purchases were found, but not of the fixing mortar. The explanation given by the builder was that as the amount spent on the ceramic tile purchase was high (since the tiles were bought in just three lots), these were easier to book.

Other important data sources would have been the work logs and physical chronograms, but these could not add any more information either, as the existing logs were not fully written up: they did not have complete records of the team responsible for the execution of the CFCs, how the quality of the performance of the work was controlled or its reception; events or even whole days were missing. As to the physical chronograms, which could accurately determine when work was performed, the rhythm of its implementation, as well as other information, could not be found.

2.4 ANALYSIS OF CAUSE-EFFECT RELATIONS

As access was unavailable to all the relevant information, based on the evidence established during the interviews and the *in situ* visit, it was sought to determine the **Nature** and **Origin** of the problem, following the approach developed by CAMPANTE (2001). Thus, starting at contact with the problem of ceramic tile detachment of the east facade, the 1st observation Level, the Immediate Cause, was reached, i.e., it was caused by lack of bonding between ceramic tiles and fixing mortar evidenced by absence of coverage on the back of the tiles.

Developing the analysis of the Nature of the problem led to factors such as:

- Installation after fixing mortar open time had expired;
- Installation without carrying out the floating and buttering adhesive procedure;
- Inadequate pressing down onto the bands of mortar and thumping of the tiles evidenced by the lack of tile rear profile impressed in the surface of the fixing mortar;
- Lack of care in cleaning the fixing surface;
- Installation on surfaces subject to severe climatic conditions, such as: high exposure to sunshine on the facades, high frequency of strong winds, high temperatures and rainfall in the period in which the facade was built (October, November, according to the building engineer), without appropriate protection;
- Installation under unfavourable working conditions, i.e., large installation areas provided by a scaffold hoist of 6,5 m (information obtained from the building engineer);
- Use of numerous work teams;
- Absence of person in charge of accounting for the work done on the scaffold and;
- Absence of resident engineers during the execution of the CFCs.

After analysing the factors involved in the **Nature** of the problem, it was then possible to go on to their Origins:

- Inadequate choice of fixing mortar (AC II) for the conditions of use, i.e., with a short open time;
- Deficiencies (or absence) in the execution procedure;

- Lack of training of fixers;
- Incorrect uses (or absence) of proper tools and;
- Deficiencies (or lack) of control criteria relating to the performance of services and acceptance of the work;

After having defined the probable diagnostics, the proposed Methodology attempts to arrive at a prediction of the likely evolution of the problem if it is not treated. This required mapping the facade to establish the real dimension of the problem. Mapping was conducted using a percussion instrument handled by a building worker, using a so-called 'seat'. Wherever this worker found a ceramic tile with a hollow sound, this point was marked.

The conclusion reached was that nearly 65% of the east facade was affected, and 55 % of the west facade exhibited local 'swellings'. In view of the risk for the users, it was decided to completely renew the subsystem.

3. DEFINING THE TREATMENT

As set out in the Methodology proposed by CAMPANTE (2001) the definition of the treatment to be adopted and its extent should be based on four initial aspects:

1. Extent of the problem, defined by the affected CFC area;
2. Risk for the users during use, if no action is undertaken;
3. Service life of the building and;
4. Costs associated with the type of proposed repair.fi

The decision matrix described by CAMPANTE (2001) can be used to determine the best repair procedure for this case. An application is given in Table 1.

Event	Level of impact
Affected Area	High
Risk for the user	High
Remaining service life	High
Repair cost x Value of the asset	Low

Table 1: Decision matrix for building D.

Analysis of the building situation based on Table 1 led to the conclusion that the best option would be complete renewal of the affected facades, i.e., complete removal of the ceramic tiles and installation of a new cladding (at this point in the discussion it was still unknown whether the cladding would be ceramic or not).

To reach this conclusion, first the probability of accidents was analysed, if no action were undertaken in areas as yet without detachments. It was established that approximately half of the facade area was already affected by 'swellings', making these areas quite unstable, with eminent risk of ceramic tiles coming off, which in fact ended up happening in the west facade, fortunately with no personal injury. It was thus decided to completely redo the facades and not carry out local repairs.

This decision was also confirmed on considering the remaining service life of the building which was 2.5 years old, i.e., it was a quite new building, still at the beginning of its actual service life. As discussed above, in cases such as these the only option is complete renovation of the subsystem.

Even without considering technical aspects, such as those discussed by CAMPANTE (2001), relative to the binomial Cost of Repair x Value of the Asset, the conclusion for the condominiums was reasonable. According to the proposed Methodology, even having CFC repair costs estimated at about US $300,000.00, the roughly calculated value of the building, based on the value of each unit (US $28,300.00) would be US $1,358,400.00 (4 units per floor x 12 floors x the value of each unit). Considering furthermore that the building was still at the beginning of its service life and that a change in the type of facade cladding could depreciate the value of the units, it was concluded that renewal of the CFCs would be the right decision.

Thus, in March 2001 renovation of the east facade was started. A pieceworker recommended by the tile manufacturer was hired (a company that seeks to be accredited by the tile manufacturer for installing its products) to carry out the repairs. The initially considered (and budgeted) procedure for the pieceworker was to be the complete removal of the ceramic tiles and the installation of new ceramic tiles, on the previous fixing mortar, with the opening of movement joints in the render, as shown in Figure 8.

Figure 8: View of the east facade during repair.

During the removal of the ceramic tiles, evidence was encountered of other problems hidden till then, such as, render apparently affected with regard to its mechanical strength and physical integrity in different points of the facade.

To determine the true extent of the problems in the render pointed out by the workers, it was decided to conduct field tests to determine the real conditions found in the facade. Table 2 gives the values found.

Scaffold hoist	Average stremgth (kgf/cm^2)	Adhesion Coef. Var. (%)	Average stremgth Média (kgf/cm^2)	Surface Coef. Var. (%)
1	3,46	32,54	14,59	38,48
2	4,06	53,91	10,31	37,73
3	2,60	45,51	11,21	67,93
4	3,43	35,38	15,44	40,08
5	3,99	83,69	11,84	40,82

Table 2: Summary of the values found during the field test in the facade under repair.

Based on these tests it was concluded that there were only some small areas (about 10% of the total area) of affected render; these were mapped and identified for repair. In most of the surface the fixing mortar still retained its surface strength, which allowed it to be used as a base for the new layer, just recommending sanding of its rough edges and regulating its surface with mortar of the AC II type.

In the regions in which the fixing mortar was removed, but the render was unaffected, it was necessary to apply a priming layer between the old render and the regulatory AC II mortar layer, using a cement slurry mixed with water and PVA Rodopas® 503 D resin in a proportion of 1:6, with application after 1 hour with a foam roller.

In the regions in which the render was affected, before reinstallation it was necessary to remove the adjacent areas. To do this, without causing further damage, it was necessary to cut out all the areas that presented a hollow sound with a circular diamond saw accompanied by checkerboard pattern, with horizontal and vertical cuts forming a checkerboard, in which later, the small pieces are removed using a chisel and punch.

On removing the whole area it is necessary to apply a primer similar to the one described previously. If the thickness of the render mortar is less than 5 mm, resin PVA Rodopas® 503 D should be added to the gauging water in a proportion of 1:6. After doing this, a new render should be applied with industrial mortar Cimpor® F 11.

In these areas of the render, levelling can be carried out with regulating mortar, without needing to apply this on the renewed render.

After regulation of the whole surface, ceramic tile installation can start using mortar of the AC III type (due to its larger open time) using the floating and buttering technique (owing to the impossibility installing movement joints, as shown below) and using the procedures set out in standard NBR 13755 (ABNT, 1996).

Due to the thinness of the render, in some areas movement joints could not be installed without removing and reinstalling the whole render coat. Though this is technically the most appropriate solution, factors of an economic nature (high cost), institutional nature (damaging the image of the company and interference in the use of the building) and of a technical nature (possibility of affecting internal coatings and interfering with other subsystems, squares, for example) do not allow implementing this repair approach.

5. REPAIR PREDICTION

In this application phase of the Methodology proposed by CAMPANTE (2001), it is necessary to evaluate the durability and reliability of the proposed repair, which it is difficult to do due to the lack of accurate data regarding the interfaces of the various subsystem components. Considering the options available before the repair (imminent collapse of large CFC areas), it is believed that the prediction for this repair can be considered satisfactory, though it cannot be quantified exactly, in terms of time.

The impossibility of opening movement joints represents a limiting factor to achieving a high degree of reliability, but again, means are unavailable for defining this. Another constraining factor on the reliability of the proposed repair is the absence of an executive project for the repair. It is considered that the application of the procedures described by MEDEIROS (1999) (as far as possible) can partly counteract this limitation. Accurate execution control procedures and the assurance that recommendations are followed up can ensure repair with an appropriate degree of reliability.

Another limiting factor concerning the durability and reliability would be the absence of a PPP to be used in their execution. Having such a project is very important, since this level of repair is almost like a new execution of the subsystem. Thus, a systemic approach is required in considering the various factors of influence involved in planning, execution and control. However, it is necessary to realise that performing this is already quite complex in the building stage, and even more so in a possible repair phase.

6. CONCLUSIONS

In the case study the negative effect was evidenced of the lack of availability of documents on the construction of the buildings, for analysing the factors of influence in the nature and causes of the problem, such as: structural projects, calculation briefs, work logs, etc.

In every case , one could observe the lack of systemic analysis in the diagnostics and in establishing treatment procedures. The lack of technical knowledge is also to be observed by the professionals employed by the builder, on conducting a diagnostics (drawing conclusions based on 'experience'), well as in ceramic tile installation (producing incorrect repairs).

Another fact highlighted by the interviews and inspections was a certain mistrust in supplying information by all those involved, in the case of the engineers, perhaps due to fear of criticism of the technical procedures adopted; in the case of the two users, the distrust possibly stemmed from the depreciation that their assets could come to suffer. In truth, the investigator often had the impression of being viewed as a 'criminal expert' rather than as a professional attempting to help solve a problem.

During the application of the proposed Methodology, it could be observed that the necessary variables for the decision-taking matrix mentioned in the case studies needed a quantitative determination to have a more accurate application for each specific case.

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