INJECTIONS OF MICROCEMENT IN PILE CAPS CRACKED BY ALKALI-AGGREGATE REACTION

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Abstract

The alkali-aggregate reaction affects durability and mechanical resistance of concrete structures provoking cracks. Despite these pathological manifestations it cannot be said that the final stage cannot be reached even if reaction is slow. The occurrence of such phenomena on foundation blocks is rarely described in the literature and it was recently identified in foundations of buildings in the metropolitan region of Recife, constituting a cause for concern for the community of technicians and the civil construction industry. Pile caps affected by the AAR may suffer interventions with adequate recovery techniques for each situation. Thus, microcement injection in cracks on foundation blocks affected in the metropolitan region of Recife has been studied and services have been monitored with a view to inspecting the procedures adopted. The collection of cores, cleaning procedures and the closing of cracks filled superficially with epoxy, the application of the microcement and coring after the injections made it possible to verify if the cracks were totally filled with the injected material. The results in this study are expected to be a source of reference for future crack reparation procedures in pile caps affected by the AAR.

Keywords: alkali-aggregate reaction; injections in pile caps; pile caps; microcement; concrete.

1 INTRODUCTION

The identification of the alkali-aggregate reaction phenomenon in pile caps of residential and office buildings in the metropolitan region of Recife, Brazil, was first evidenced in 2005. Until then, this phenomenon had rarely been described in the literature with relation to foundation blocks. In Brazil, it is the first time that this phenomenon has been identified in building foundations. It is therefore a new challenge to Brazilian state of the art and engineering since it is an unpublished problem [1].

In Brazil, the granitoid aggregates widely used in concrete building construction comprise quartz-feldspathic rocks such as granites, gneiss, and, which are found broadly across the country. The quartzites essentially constitute quartz rocks of restricted use as aggregates for concrete.

Tectonic efforts of varying intensities and active at different geological periods affected a large part of those "granitoids" and were responsible for the development of some textural characteristics capable of rendering the aggregate potentially reactive with cement alkalis.

AAR actions in foundation blocks were only recently verified in the metropolitan region of Recife. Those structures affected by the AAR constitute cases where those granitoid reagents were employed.

The importance of the damage resulting from the alkali-aggregate reaction already verified in about 29 buildings of the metropolitan region of Recife shows the need to avoid isolated decisions and adopt properly organized and coordinated ones.

After the collapse of the Areia Branca Building on October 10, 2004 due to the rupture of the underground pillars, there was a great concern to inspect the already existing building foundations. Upon conducting these inspections, cracking problems resulting from the AAR were identified. This diagnosis was provided after identifying map cracking in the blocks and in the laboratory results of drilled cores [1].

Once the existence of AAR in the foundation blocks of the buildings was verified, attention turned to recovering the cracks as these may facilitate the entry of aggressive external agents leading to

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structure deterioration. Although some researchers state that the AAR alone cannot lead a concrete structure to a sudden collapse as it is a phenomenon that develops through the years, it cannot be said that the limit state rupture will not be attained in spite of the delayed reaction. Therefore, concrete elements affected by the AAR must suffer interventions with appropriate recovery techniques for each situation.

2 MATERIALS AND METHODS

2.1 General

Since it is a problem not yet addressed in the literature and as there is no case of recovery on this type of structure with such a pathology, a case study was carried out at an important public building in the metropolitan region of Recife, Brazil, aiming to recover the blocks affected by the AAR. This was done by injecting microcement inside the cracks preventing external agents from further aggravating the damage already affecting the foundation blocks.

The building studied is eleven stories high, features rectangular architecture, with approximately 80 meters in length and 24 meters in width. Its structure was entirely conceived in apparent reinforced concrete, and is subdivided in three modules separated by dilatation joints. The central module (1) is 30 meters long and 34 meters wide, where the elevators and the staircase to the upper floors are located. The other two modules (2 and 3) are identical in length (25 meters) and width (24 meters) and are symmetrically located in relation to the central module. Concrete used in the building construction was manufactured in the 90's [2].

Pile caps of varying dimensions and shapes were used in the building foundation, featuring diverse volumes and numbers as described in (Table 1) [3]. The piles are made of centrifuged concrete of diameters ranging from 40 to 70 cm.

Except for the blocks situated in the elevator shaft, all blocks are located with a capping quota at the level of the first floor slab.

2.2 Materials and mix designs

The following materials were used to close the cracks caused by the AAR expansion phenomenon in the foundation blocks of the building studied:

- Kaolin and epoxy resin , materials that were mixed and used jointly to reduce epoxy fluidity. The mix proportion of those materials is on average 0.20 kg kaolin for each kilogram of epoxy resin. The mixture aims to superficially close the cracks of up to 1 cm in thickness.
- Grout, to close cracks thicker than 1 cm. The water used in the preparation of grout should be enough to render the mortar thixotropic.
- Water from the local public supply network..
- Microcement graded below 8 μm, ultra-fine cementitious material.
- Appropriate superplasticizer for microcement grout, material used for increasing microcement fluidity.

The microcement, the water and the superplasticizer are the components of the injected microcement grout responsible for filling the cracks inside the block. In mixing these materials for the injection grout, a water/cement ratio of 0.50 was employed and 2% of superplasticizer measured in relation to the microcement weight (to ensure fluidity) was used.

2.3 Methods for assessment and analysis

General

Once the laboratory analyses confirmed that the building's foundation blocks had cracked due to the alkali-aggregate reaction phenomenon, a recovery plan was devised aiming to recover their integrity and reestablish the useful life of the construction.

To this end, the recovery plan comprised two stages: the first one consisted of closing the cracks with microcement grout to prevent the entry of aggressive agents and humidity inside the element and the second stage involved the encapsulation of the blocks thus restricting the expansion of the AAR. However this second stage will not be presented in this paper.

To ensure higher efficiency of the expected results, a sequence of procedures was adopted in the injection of the microcement in the cracked blocks.

Excavation and Cleaning of the Blocks

This type of procedure is one of the first steps performed on the foundation blocks. In spite of not involving great technique or using state-of-the-art technologies, this stage is of fundamental importance in the recovery plan.

Excavation must be performed according to recommendations and safety standards to prevent landslides on the workers and ensuring enough space for superficial cleaning of the external faces of the blocks using a high pressure washer (Figures 1 and 2) for better visualization of the cracks

Holes below the Main Crack and Placement of Purges

The procedure of opening 2-inch diameter holes below the main crack (Figure 3) - common to all the blocks - was extremely important to remove materials (sand, clay and other materials originating from the embankment) from inside the cracks.

It is important to emphasize that the execution of those holes was adopted after several frustrated attempts to remove materials which were seated deep into the cracks. With the presence of embankment materials inside the cracks the microcement grout injection was compromised by the lack of space.

To perform the washing procedure inside the cracks and the microcement grout injection it was necessary to install 3/8-inch diameter pieces of hose (which will be named purges) around the border of the cracks. Because some of those cracks were not wide enough for the purges to be directly installed, holes of 1/2 inch in diameter and with approximately 4 inch in length were made using an impact drill (Figure 4).

Fixation of Purges and Superficial Closing of the Cracks

Despite its apparent simplicity, the accomplishment of this stage required plenty of ability, especially regarding the superficial closure of the cracks. Cracks thicker than 10 mm had to be closed with with non-fluid grout where this mortar penetrated up to 20 mm (Figure 5). The application of this mortar aimed to minimize the use of great amounts of epoxy resin due to its high market price.

Epoxy Resin was also used for the superficial closure of cracks provided they were not larger than 10 mm. Fixation of the purges was also performed using this type of material (Figure 6) to prevent air escape when the water used for washing or the cement grout were injected through the purges.

Washing and Checking the Effectiveness of the Cleaning of the Cracks

Twenty-four hours after performing the superficial closure of the cracks the internal washing of the cracks was carried out by injecting water under pressure. This procedure is performed using a compressor and a 10-liter tank prescribed for the injection of resins, laitance, mastic and grout.

The internal washing of the cracks resulting from the AAR consisted in injecting water through the purges until all the material was removed from their interior. The removal of sand and clay from the bottom of cracks was only possible thanks to the 2-inch holes previously made for this purpose.

To this end, it was necessary to force the water injected under pressure to flow through the 2-inch holes, while closing all the purges placed on the block face (Figure 7).

With a view to ensuring that the washing procedure was effective 2-inch diameter cores were drilled before and after washing (Figures 8 and 9).

Procedure Adopted in the Injection of the Microcement Grout

The microcement injection was the last procedure adopted, as the microcement can only be injected in the cracks after all procedures (closing, washing and drying of the cracks) have been satisfactorily performed . The success of the microcement grout injection is directly related to the proper execution of the other procedures.

When injecting the microcement, some care must be taken to avoid emptying the interior of the cracks. Therefore, the microcement injection must always start from the lowest points. If this procedure is adopted the interior of the cracks is more uniformly filled in, thus minimizing the emptying of spaces.

The filling in of the cracks must be performed from the lower side as shown in Figure 10, since the material entering expels the air from the higher purges enabling the microcement grout to fill all the voids inside the cracks.

3 RESULTS

In order to prove that the cleaning procedure was satisfactory performed, rendering the cracks totally free to be filled with microcement, cores were drilled from all the blocks after a period of 28 days when the injection of cementitious material was concluded.

The coring aimed to verify whether the cracks provoked by the AAR expansion had been filled by the injected material. As expected, at the points from which 2-inch diameter cores were drilled (totaling four units per block, corresponding to one core for each face), all the cracks were filled with the injected microcement and featured consolidated crack faces (Figure 11).

4 DISCUSSION

The application of the microcement injection method inside the blocks cannot be classified as structural reinforcement of the concrete structure affected by the alkali-aggregate reaction; this procedure is a palliative measure before the appropriate structural reinforcement.

It is difficult to guarantee that the filling of the cracks will be perfect and thorough. In spite of all the care taken in the washing, it is safe to say that not all the material was removed due to the great amount of clay and sand deposited through the years which solidified in the inner face of the cracks.

Even knowing that the transmission of efforts will not be totally guaranteed, the filling of the cracks is necessary to prevent the appearance of new pathologies such as reinforcement oxidation and water penetration, which would favor new expansions.

The use of the microcement in the blocks to close the cracks provoked by the expansion reaction proved quite satisfactory. Another material that could also be applied in this case is epoxy resin. However this material was not recommended due to humidity present in the inner faces of the cracks which prevents the connection and bonding of the faces in addition to posing other disadvantages if compared to microcement.

5 CONCLUSIONS

According to the laboratory tests, the aggregate used in the construction is of good quality as far as its physical-mechanical characteristics are concerned. However, from the mineralogical point of view this type of aggregate is responsible for developing expansive reactions of alkali-silicate type due to the presence of quartz and feldspar in its mineralogical composition [4], [5], [6].

Besides the latter, coarse aggregate features a mylonitic texture. According to some authors this type of texture is highly reactive in the presence of cement alkalis.

Proper microcement injection depends on the removal of materials inside the cracks (sand, clay, etc.); proper installation of the purges at the endpoints of the cracks; the washing process through water injection under pressure using a compressor; air-injection drying inside the cracks using a compressor after the washing is concluded; the drilling of cores to identify the effectiveness of the cleaning; cleaning and drying processes before the microcement injection; and the drilling of cores to confirm the effectiveness of the filling.

6 REFERENCES

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TABLE 1 – Characteristics of foundation blocks.

Blocks	Quantity	Section	Height	Block volume	Total volume	Number of piles/ block
BP 03 – BP 13 BP 12 - BP 22	04	trap./ tectang.	1.75	40.1	160	09
BP 04 – BP 14 – BP 11 BP 21 – BP 17 – BP 18	06	rectangular	1.75	31.8	191	08
BP 5/6 – BP 15/16 BP 9/10 – BP 19/20	04	rectangular	1.75	31.8	128	08
BP 07 – BP 08	02	hexagonal	1.75	38.2	76	08
BP 01 – BP 02	02	rectangular	1.75	4.3	9	02
B 1	20	square	1.75	6.4	128	01
B 2	10	square	1.75	6.4	64	01
total	48	-	-	-	756	-

Figure 1: Start of excavation around the AAR-affected foundation block.

Figure 2: Cleaning of the block face using high-pressure washer, with a capacity of 400 kilopascal and flow of 360 liters/hour.

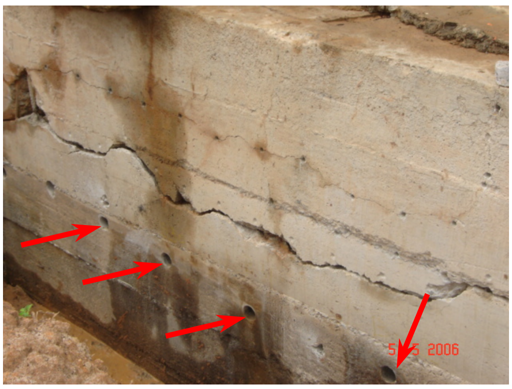
Figure 3: 2"-diameter holes (arrows) under the main crack for removal of materials deep in the the cracks.

Figure 4: 1/2"-diameter and 4"-length holes using impact drill in cracks with smaller openings.

Figure 5: Non-fluid grout application in the cracks with opening larger than 10 mm and fixation of purges.

Figure 6: Superficial closure of the cracks and fixation of the purges using epoxy resin mixed with kaolin. The cracks closed with grout were also covered with epoxy (arrow).

Figure 7: Washing of cracks using water injected under pressure and exit of dirt from the 2."-holes.

Figure 8: Removal of specimen before washing with the inner face of the crack soiled by clay material.

Figure 9: Specimen taken after washing of cracks showing the inner face of the crack free of material originating from the embankment.

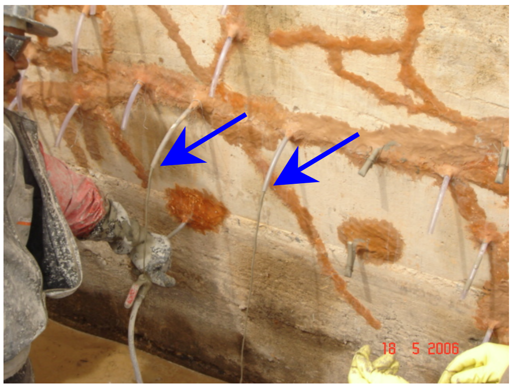

Figure 10: Grout injection through lower purges, where the arrows show the exit of the grout indicating that the cracks were filled.

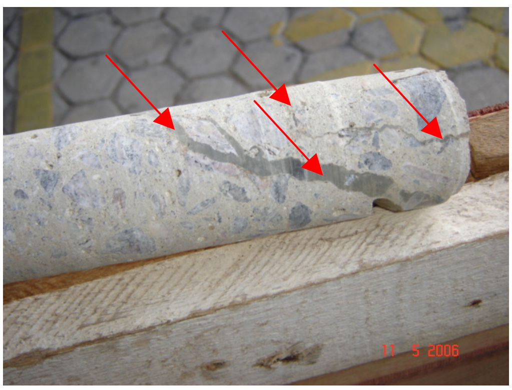

Figure 11: Specimen extracted after microcement injection and with all the cracks filled (arrows).