REHABILITATION OF CONCRETE INDUSTRIAL BUILDING FACADES ATTACKED BY ACIDS

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ABSTRACT

This case study was based on the project for rehabilitation of sealing of facades, built in precast concrete, an industrial plant galvanizing of steel structures. Analysis of the Brazilian Standard NBR 6118 (design of reinforced concrete) was taken as well as review of literature on durability to identify causes of pathologies and prescribe the best therapy with the most appropriate materials and techniques. It was noticed that the main agents are aggressive chlorides and epoxy is the most suitable material that recovery.

Keywords: Pathologies; Durability; Facades; Epoxy.

The recovery of structures in reinforced concrete should be performed using the most modern techniques available in an appropriate manner, following the technical specifications indicated, that were drawn from a careful evaluation.

Initially we shall make a detailed study of existing conditions clearly identify the causes of them, make a precise diagnosis of pathologies encountered and finally set up the project for the rehabilitation of structures containing this all necessary technical specifications, such as:

- •Methodology of execution;
- •Materials to be used;
- •Equipment needed;
- •Skilled labor for execution of the works ;
- •Operational and safety procedures;
- •Time line for implementation;
- •Monitoring and maintenance of the structures after the interventions.

This case study was prepared based on the project for rehabilitation of facades, built in precast concrete panels, in an Industrial Plant of galvanizing. The object of this study was to identify the existing conditions and causes of the pathologies and prescribe the best therapy with the best materials available using the best techniques.

This paper describes the pathological manifestations observed in an industrial plant of galvanizing , built in 1999, using precast concrete panels and the methodology used for the recovery and rehabilitation of structures. The fence panels with double “T” geometry have the following dimensions; height 14 meters width 2.5 meters. Various pathologies were observed in the concrete panels and a photographic record of them was made for more detailed study. Initially ,fronts of carbonation, attack by chloride ions, reinforcement corrosion, spalling and leaching of concrete and several cracks were identified .

Fig. 1 Pathologies presented by fence panels .
Source: Setaviso Engineering [2013]

IDENTIFICATION OF PATHOLOGIC AGENTS

There are different types of galvanization, one of the oldest and most effective is hot-dip galvanizing. The galvanizing process consists of cleaning of steel parts with subsequent immersion in bath of melted zinc . This process is a versatile and economical way to protect structures, steel parts and equipment against corrosion. This process comprises seven steps (baths) important for the cleaning and soaking of parts. The process of cleaning and galvanization generates various pathogenic agents that can cause severe damage to concrete structures. The following agents were identified:

Originated from degreasing:

•Organic solvents:
•alkaline solvents;
•Emulsifier;
•Electrolytes in general;

Originated from pickling:

•hydrochloric acid;
•sulfuric acid;
•Nitric Acid;

Zinc electrolytes may be acidic or alkaline, of which the main ones are:

•Sulfur electrolytes.
•Chlorine electrolytes.
•Cyanide electrolytes.

As a general rule, the main contributors to a galvanization's final effluent are the following:[Source: CETESB]

1. The spillways of the metal surface's preparation and cleaning tanks (degreasing and pickling), where organic solvents are used to remove oils and greases, as well as acid and alkaline baths, for removal of slag, rust etc;

2. Waste from the electrolytic bath tanks, after several weeks or months of use

3. . Splashes from parts removed or transferred from their electrolytic tanks and leaks from tanks and pipes.

4. The waste usually consists of solutions of sulfuric acid, hydrochloric acid, nitric acid and hydrofluoric acid, essentially acidic electrolytes from baths. The PH of these wastes are often below 2.

IDENFICATION OF THE PATHOGIES

Although the Company has modern and efficient system for collection and treatment of gases and waste , from its manufacturing process is inevitable that many of the agents mentioned above are capable of acting and damage the concrete structures of the fence panels.

This action of pathogens plus the age of the building ,15 years, caused a several damage to concrete structures. It is noteworthy that the facade in question is oriented from east to west, so getting heat stroke during the entire period of the day, the damage becomes worse because at night the structure receives vapors from the fumes of hydrochloric acid and condensed on the surface. During day there was drying and evaporation, in a continuous process of wetting and drying. Due to the industrial atmosphere there was also acting on the structures a carbonation fronts. The consequences of carbonation reflect on the corrosion process allowing the penetration of chloride ions, part of the chloride ions are free to act. [ANDRADE2001], due to the higher solubility of the Friedel salt caused by reduction of pH [KULAKOWSKI, 1994]. Thus, the critical armature passive layer disruption limit is achieved by the free chloride ions in the concrete, even with a lower total of chlorides contents.

MONTERIO and NEPOMUCENO (1996) add that the efficiency of the additions used in cement as a factor in the reduction of chloride ions is reduced when the concrete is carbonated. According to [BAKKER, mentioned by FIGUEIREDO 2005], the combination carbonation and chloride is the most commonly cause severe corrosion problems.

Fig.2 Hydrochloric acid tanks for pickling
Source: Setaviso Engineering [2013]

One of the mechanisms of penetration of pathogens chloride ions in the concrete are through the concrete pores microstructure. The driving forces of the transport of these substances in the concrete can be the difference in concentration, pressure, temperature, density, electric potential and capillary suction [NEPOMUCENO, 2005].

There are four basic mechanisms of transportation of aggressive fluids and ions into the concrete permeability, capillary suction, diffusion and migration, which may act simultaneously or successively over time according to the exposure conditions that the concrete is subjected, [CALÇADA, 2004].

The penetration of chloride ion is possible only when there is water in the pores of the concrete. If the water is stagnant, the displacement of chloride ions takes place by diffusion. When the concrete undergoes cycles of wetting and drying, the penetration of these ions becomes by capillary force of water that are present [GUIMARÃES, 2000]. The penetration depth of the ions depends on the duration of periods of wetting and drying, as well as the permeability of the concrete surface [BAKKER and FIGUEIREDO, 2005].

According to [HELENE 1997], the four basic mechanisms are governed by three main parameters, as well as the mechanical properties of concrete, which are: the ratio W / C, healing and the degree of hydration - responsible for the quality of the concrete.

Mechanisms can occur simultaneously both in real situations and in testing procedures. [NEPOMUCENO 2005] presents some of these combinations:

•Capillary Absorption, convection and diffusion: the initial period depending on the moisture content, the inflow of ions will occur by capillarity, and then through diffusion;

•Diffusion and migration: may occur in migration tests, where an electrical potential is applied to determine the diffusion coefficient of chlorides;

•Permeability and convection: occur when agents are contained in the fluid that penetrates the structure.

Corrosion of reinforcement in concrete has two important effects on the concrete and produces spalling , decreases the section of the rebars [CANOVAS, 1988]. These two problems have been identified in almost all the panels, with the corrosion of the diameter of the rebars there was an increase in volume of up to 6 times . Internal stress in the section was generated , so that there is a loss of adhesion between the concrete and the reinforcement occurring “spalling” of concrete.

According to [THOMAS 1989], the fissures and cracks are the most important anomalies due to three aspects: the acknowledgment of a serious problem in the concrete structure, compromising the performance of the structure in service and psychological embarrassment that crack has on its users . The pathogens were identified after careful inspection, the experience also contributed to the diagnosis, allowing location correct identification of pathogens and the effects of each of the structures.

During the inspection were found a high concentration of reinforcement on the panels section. The covering thickness was below the NBR6118 and NBR9062 specifications. It was found many situations with 4 θ ¾ rebars concentration on the 100mm pillar section .

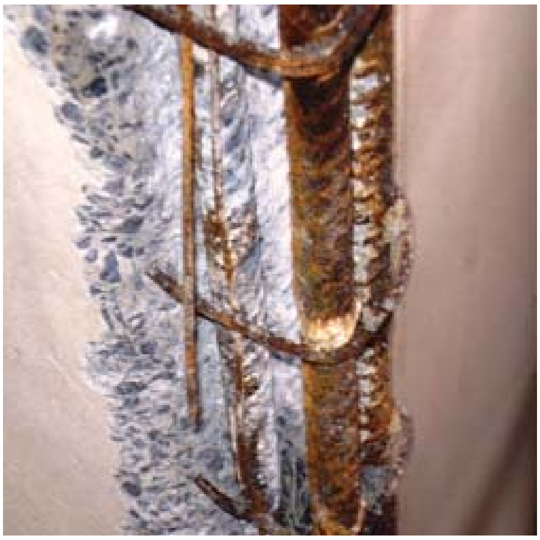

Fig. 3 High concentration of reinforcement, 4 rebar θ ¾ and low reinforcement coverings (6mm) The structure is already attacked by hydrochloric acid vapors. Source: Setaviso Engineering [2013]

The ABNT NBR 6118 indicates the following situations to fix the coverings (item 6.4) :

Environmental classification	Aggressiveness	Project classification environment	Risk of deterioration
IV	Very Strong	Industrial	High

Fig. 4 ABNT NBR 6118 Environmental Classification

Structure Type	Structural Element	Environmental classification: IV Nominal Coverings (mm)
Reinforced Concrete	Bean /Pillar	50 mm

Fig. 5 ABNT NBR 6118 Coverings Specification

The ABNT NBR 9062 prescribes:

“ 9.2.1.1 Coverings

“In the elements of precast concrete, as defined in Chapter 3, with not less than 25 MPa and minimum consumption of 400 kg of cement per cubic meter and W/C factor less than or equal to 0.45 characteristic strength fck, any reinforcement, including distribution, connection , must not have covering less than :

D) - For concrete in highly aggressive environment covering of 3.5 cm, as follows:

“- For more than 6 cm covering, should put an reinforcement skin supplement, whose coverings must not be less than the limits specified in this paragraph;”

Thus the low covering was also a major factor to allow chloride ions penetration and accelerate the corrosion of reinforcement. “

THERAPY PROPOSAL

For the rehabilitation of structures of fence panels was proposed the following solution:

•Wash all the structures with pressurized hot water 4,000 PSI (281kgf / cm²);

•Demolition of all points where the concrete showed signs of deterioration;

•Washing of structures with alkaline-based anionic surfactants, alkalis, solvents and emulsifiers concentrated detergent PH 14;

•Wash with mild biodegradable detergent and hot pressurized water 4,000 PSI;

•Treatment of armor using needle gun, wire brushes to remove all corrosion points;

•Replacement of armor that had loss of greater than 5% nominal section;

•Treatment of armor with zinc rich epoxy two component polyamide cured to provide cathodic protection to the carbon steel;

•Application of adherence to structural thixotropic epoxy adhesive slowly picks bridge;

•Restoration of damaged and demolished structural grout areas;

• Application of Structural Polymer mortar for repairs to concrete structures with thickness 0.5cm 2.5cm deep application system “dry-pack”;

•Application of cementitious mortar for structural repairs to concrete structures with thickness 3.0 cm to 7,0cm depth application system “dry-pack”;

•Application of Grout for larger repairs, application system “dry-pack”;

•Application of the sealing epoxy varnish, polyamide cured with appropriate viscosity to allow good penetration into concrete surfaces, plaster, masonry, cement asbestos seals these surfaces prevents excessive absorption with a dry film thickness of 50μ;

•Application of two intermediate coats with bi cured epoxy polyamide component, high-build, fast drying, developed to protect carbon steel and concrete in industrial exposures environment , applied dry film thickness of 150μ;

•Apply a finish coat of acrylic aliphatic polyurethane high build, bi component with a low content of volatile organic compounds (Low VOC). Paints in acrylic aliphatic polyurethane has excellent weathering resistance, excellent flexibility and toughness to withstand the harshest working conditions, with dry film thickness of 100μ

Fig. 6- First step of cleaning: washing with hot water
Source: Setaviso Engineering [2013]

Fig. 7- Second step of cleaning: washing with pressurized water and alkaline detergent pH14.
Source: Setaviso Engineering [2013]

Fig. 8- Reinforcement cleaning using needle gun.
Source: Setaviso Engineering [2013]

Fig. 10- Application of epoxy rich zinc for reinforcement protection.
Source: Setaviso Engineering [2013]

Fig. 9- Reinforcement cleaning using steel rotating brush.
Source: Setaviso Engineering [2013]

Fig. 11-Application of structural cementitious mortar for repairs up to 7cm deeper.
Source: Setaviso Engineering [2013]

Fig. 12- Application of epoxy varnish sealer and application of intermediate coat in epoxy two component polyamide cured.
Source: Setaviso Engineering [2013]

Fig. 13-Application of final coat in acrylic aliphatic polyurethane low (VOC).
Source: Setaviso Engineering [2013]

CONCLUSION

The recovery and rehabilitation of reinforced concrete structures is extremely expensive due to the need for specific treatment materials skilled labor plus the cost of partial or total interdiction of structures. The identification of services conditions that the reinforced concrete structures are subjected is a essential factor for it to have a long and healthy life. The constant maintenance and conservation allow the structures to remain in service for long periods.

In our case study we found that the extreme condition in what the structures were subjected (fronts combination of carbonation and chloride attack) and the low thickness of coverings was essential for degradation of them.

After the structural recovery and rehabilitation of structures, it was prescribe a protection system with the combination of epoxy and polyurethane paints. The system has an estimated useful life of 15 years and may have its life extended with specific periodic maintenance without the need for major interventions.

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