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Evaluation Prior to Repair of Industrial Reinforced Concrete Structures

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Summary

Tall and large-size reinforced-concrete structures, like high chimneys, cooling towers, silos, and other similar industrial buildings, need periodical diagnosis and repair, particularly when used in hard industrial conditions. Many kinds of damages result from technological reasons but, as a rule, the attack of polluted atmosphere from outside and/or from inside is always significant. As repair works on large and hardly accessible surfaces are costly the role of proper diagnosis, damage classification and, consequently, selection of repair methods is particularly important. In the paper, some examples of procedures are presented, as well as results of the investigations.

Keywords: concrete structures, concrete chimneys, cooling towers, corrosive actions, destruction of concrete, diagnosis of structures, concrete silos.

1. Introduction

Tall reinforced-concrete structures for heavy industrial use were usually erected without any finishing of concrete surfaces. Rough surfaces exposed for long time to direct influences of polluted atmosphere were step-by-step chemically and/or mechanically damaged. Statistically, the chemical destruction is dominating and the physical, mainly temperature effects are in the second row. In many situations, the walls for long time have been attacked from both sides, by external atmosphere and by destructive actions from inside. The speed and the range of deterioration depended on the intensity of corrosive actions but even more so on quality, mainly tightness of concrete, and the size of concrete cover over reinforcing bars.

Now, we know that maintenance and inspection of concrete structures should be regular and preventive but, as recently as 20 - 30 years ago the opinion about indestructibility of concrete was very common. Today, we also know the reasons of deterioration, and - more or less - we know how to eliminate these actions. Nevertheless, we are still looking for simple and objective methods of diagnosis, relatively not expensive tests, and selection of effective repair methods.

2. Evaluation of the state of structures

Unlike in bridges and road structures or marine structures, where the chloride penetration is the main corrosive agent, in industrial structures carbonation and sulfation processes are the most common problem. In real structures, the chemical test of carbonation degree and depth is the main indication how far is corrosive process, and what kind of protection is necessary to extend the lifespan of concrete structure. The most popular is determination of pH-reaction and the values pH≤9.0 are considered as unsafe degree of destruction process. Second step of chemical investigation includes more precise tests, e.g. determination of sulfate ions (SO_4^{2-}). The content of these ions over 1.5% of concrete mass is recognised as dangerous. To assess the thickness of layers with advanced carbonation and sulfation the drilled cores from a structure should be taken, (best of all throughout the full thickness of a wall), and cut into slices to be chemically tested.

In tall and large structures such tests are difficult, and sometimes even impossible, during the normal use of buildings. On the other side, the tests have to be done in many places, particularly along the whole height of walls. Unfortunately, in the same structure we may find places with carbonated layer of about 3-5 mm only, while few metres higher this layer is even 30 mm thick. It depends on the quality of concrete, particularly permeability of surface. As the number of drilled cores is limited, the specimens should be taken from characteristic places indicated on the basis of analysis of the course of erection and history of the structure use.

3. General description of typical cases

Large reinforced-concrete structures used for many years and not controlled properly are in majority damaged due to various external and internal influences. Each case requires exact diagnosis, classification of damage degree and selection of adequate repair methods.
In some kinds of structures the corrosive influences are typical (chimneys, cooling towers) while in others (containers, silos, tanks) the destructive actions and their results are much more individual. Generally, apart from careful inspection, the diagnosis should be supported by chemical tests. Particularly, the effect of deleterious industrial environment on carbonation rate and acid attack should be tested, as well as other technological internal pollutions.

High chimneys for large power plants were usually designed in the past as a single tube with the diameters chosen for the maximum emission from all boilers working with full rating. In reality, such a situation happened seldom or never. As a result, chimneys originally designed as "hot" were exploited all the time as "cold". Sometimes, additional reasons, like introduction of more efficient filters, seriously reduced the temperature of combustion gases previously expected.
It was the common reason of serious attack of aggressive agents, but the degree of corrosion varied significantly along the height of internal surface. The results of comparative tests of six chimneys, with height from 120 m to 300 m were the experimental material for the conclusions.

The characteristic shape of hyperboloidal cooling towers and relatively thin walls influenced on specific damages in these structures. Continuously wet atmosphere inside and high humidity outside the shells, in presence of aggressive gases (CO_2, SO_2) are the main reasons of concrete destruction. As a result of carbonation of $Ca(OH)_2$ and washing out of $CaCO_3$ (visible white outflows on the surfaces) the reduction of pH-reaction is a common phenomenon. The tendency of higher degree of calcium crystallisation in concrete (reduction of CaO) at internal surface is typical for the upper parts of shells. The results from tests on three cooling towers with heights 75 m, 90 m, and 96 m gave the experimental data for the general assessment.