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Failures, Repair and Protection of Cooling Towers

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Summary

The presented paper will attempt to summarise some conclusion from a comprehensive refurbishment program successfully implemented at one coal and one nuclear power plant with totally 12 cooling towers.
In practice we find that cooling towers have frequently experienced accelerated deterioration due to concrete deterioration, reinforcing steel corrosion, the temperature gradient and freeze-thaw cycling. The objective of the initial inspection and testing was to establish the extend of deterioration which will serve as a basis for service life prediction and repair methods of cooling towers.

Keywords: Cooling tower, corrosion, failures, protection, repair methods, strengthening

1 Introduction

Cylindrical-shaped structures occupy a special place in industrial structures. Chimneys, silos, cooling towers and water tanks fall under this category. These structures have in common that large wall surfaces are exposed to environmental factors, which can be quite substantial and have a great impact on the serviceability and durability. In practice, we find that cooling towers have frequently experienced significant deterioration due to reinforcing steel corrosion, the temperature gradient and the freeze-thaw cycling. The varying exposures often act synergistically to impose an increasingly aggressive attack on the concrete and reinforcing steel.

2 Analysis of the critical points

2.1 Thermal stresses

The following two operational cases can lead to vertical cracks which can impair the function of the cooling tower shell:

- Normal operation: Because of the heating up by steam and as a result of external weather influences like frost and solar radiation, temperature differences dT are encountered in the shell.

As a consequence, bending moments are produced which, starting approximately from dT = 15 K, leading to the formation of vertical cracks.

- Set out of operation: Sudden temperature decrease (from about 25°C) in the thinner parts leads to great temperature stresses in the lower part of the shell. Excessive crack formation in the tensile area is the consequence.

2.2 Freeze-thaw bursting

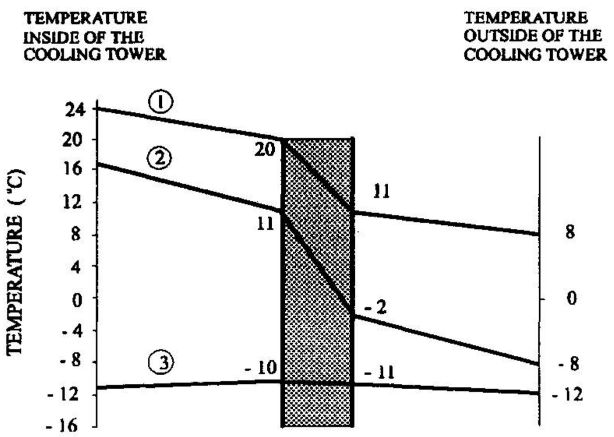

Fig. 1 Temperature profiles through reinforced concrete shell

Transition from water to ice involves an increase in volume by 9%. When cement paste is saturated with water this expansion of water on freezing can lead to disruption of the concrete if its strength is insufficient to resist the forces involved. The saturation need not be over the whole volume of the concrete and surface layers can suffer frost attack even though the main body is unaffected or vice versa. Figure 1 is a set of measurements made on the shell of a 125 m high cooling tower during a winter. Lines 1 and 2 were recorded at times when the tower was in normal operation. Line 3 was recorded when the tower was set out of operation. Note particularly that the freezing temperature of the outer shell surface was reached when the outside temperature was about - 8 °C. When set out of operation after 4 - 5 hours the temperature inside the shell decreased on the level of the ambient air. One episode of freezing is not enough to cause damage and major effects occur after a number of freeze-thaw cycles. The concrete surface in the middle European area is exposed to freeze-thaw cycles more than 100 times in a year. Since the exposed surface of the relatively thin concrete shell will be more susceptible to rapid cooling and thawing and because the surface is more likely to be saturated, the general effect of frost attack is a scaling or delamination of the surface.

3. Conclusions

1. Corrosion of reinforcement and climate induced cyclic thermal loads (temperature gradient or freeze-thaw cycling) are the most common sources of deterioration of cooling towers.
2. The selection of successful repair techniques should consider the causes of cracking and whether the cracks are dormant or active.
3. A long delay in repairs rapidly increase repair costs and ultimately imposes risks of structural failure. As an increasing amount of efforts is being spent on maintenance and repair of cooling towers, the industry has been going through a learning curve to achieve cost - effective repair and protection methods and materials.
4. Surface treatments should give an added protection against carbonation (R > 50 m) and at the same time decrease the water saturation of concrete under 92%.