A SWIMMING POOL DETERIORATED BY ALKALI-AGGREGATE REACTIONS.

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1. ABSTRACT

Investigation of the deteriorated concrete of a swimming pool and the repair is described.

Keywords: Alkali-aggregate reactions, swimming pool.

2. BACKGROUND

In Denmark it has been common use to add salt (sodium chloride) to swimming pool water in most of the public indoor swimming pools. This is considered a major factor in the deterioration of a number of concrete swimming pools due to alkali-aggregate reactions.

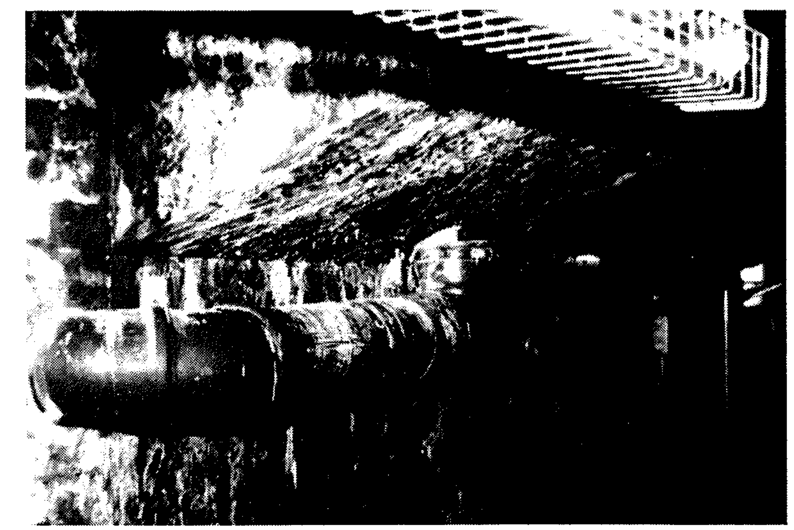

Fig. 1: Deteriorated concrete wall in the swimming pool.

3. CASE

A swimming pool constructed in 1976 was so deteriorated in 1981 that immediate repair was necessary.

Shortly after the opening there were problems with water penetration through the precast concrete slabs above the underground inspection corridor running all the way around the pool.

Also the walls of the pool caused problems due to cracks and water penetration, which created abundant stalactite formations and resulted in corrosion of the operation installations in the inspection corridor.

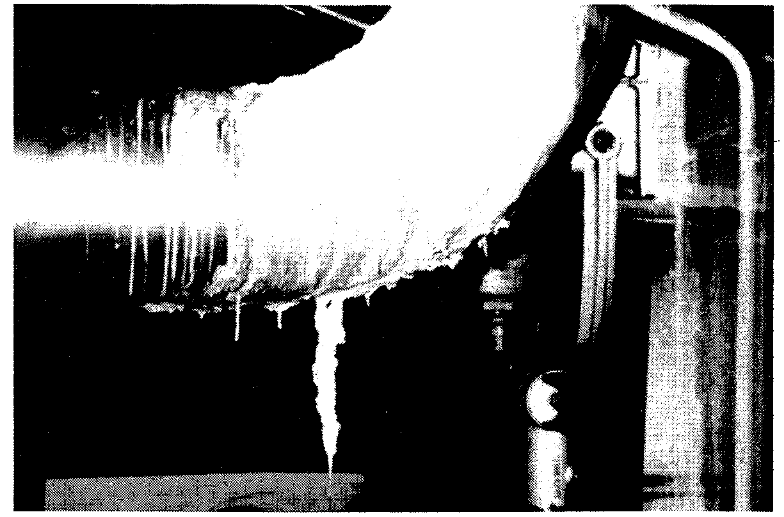

Fig. 2: Stalactites on the installations in the inspection corridor.

The cracks were several times injected with epoxy from outside, but new cracks continued to appear. After a couple of years brown or colourless exudations of gel were observed on the outside surface of the vertical concrete walls of the pool. The gel was mostly accompanyed by map cracks. The gel was relatively thin, being even able to flow through the pores of the concrete. Gel was observed on the surfaces also at places without visible cracks.

Concrete cores were drilled out both from the inside and from the outside of the vertical walls while the pool was still in use. The microscopic examination of thin sections made of the concrete of the cores confirmed that the concrete was severely attacked by alkali-aggregate reactions. The reactions were even observed in dense flint particles in the coarse aggregates. This is considered unusual and demonstrates that the exposure conditions are very aggressive.

The reasons for the very extensive reactions are due to the unfavourable conditions that prevailed when the concrete was cast, and to the unsuitable selection of the sand aggregates for the concrete. Cracks due to insufficient reinforcement undoubtedly aggravated the reactions.

The concrete for the pool was cast in situ during a cold winterseason. It was protected with insulation, and warmed with heat guns. This combined with insufficient reinforcement caused numerous initial cracks in the concrete surface.

When the pool was filled with water, the water penetrated through the cracks into the concrete and caused alkali-aggregate reactions with the sand aggregates containing flint. The alkali-aggregate reactions in the walls of the pool were accelerated by the heat in the swimming bath, the poolwater being 27°C and the air in the surrounding inspection corridor about 30°C.

Examination of the concrete in the bottom of the pool also showed alkali-aggregate reactions, but the extent of deterioration was much less than that of the walls.

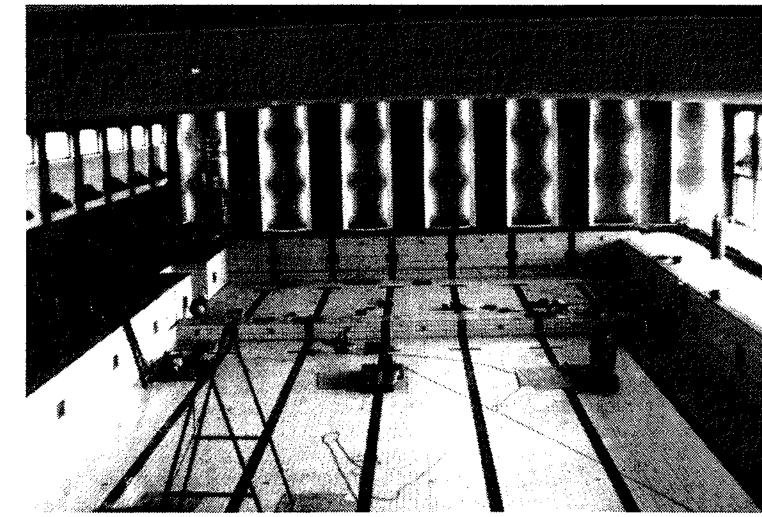

Fig. 3: The empty pool.

The 50 m long and 1.8 to 4.0 m deep swimming pool was emptied for further investigation. Shortly after it was found that a thin, viscous alkali-silica-gel was pressed out on the inside walls of the pool through microscopic cracks in the ceramic cladding.

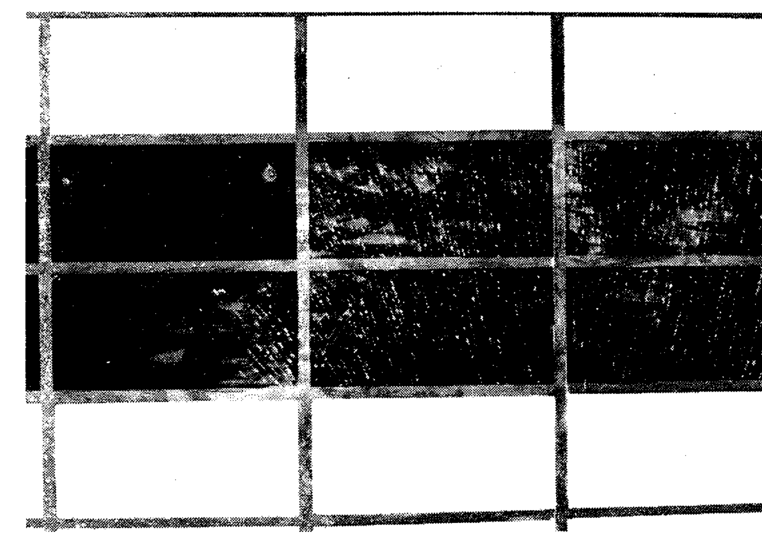

Fig. 4: Gel on the ceramic cladding.

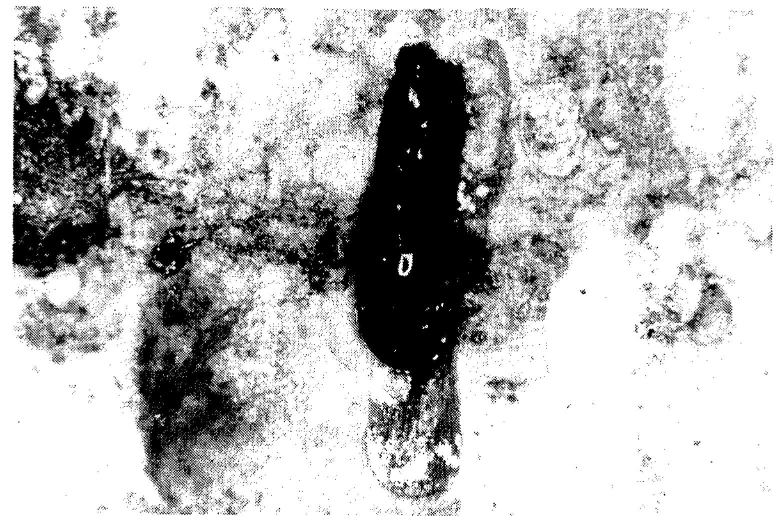

Fig. 5: Alkali-silica gel on the outside of the wall.

Figure 5 shows 3 generations of alkali-silica gel. In the bottom of the picture an old precipitation drying to a white lump is found. Above this a younger drop, and at the top a fresh adhesive precipitation is seen.

4. REPAIR

4.1 Choice of repair method

A number of repair methods were examined from a technical and economical wiew-point. The suggestions were ranging from filling the pool with sand and exchanging the swimmers with badminton players, to condemnation and rebuilding of the whole construction and its surrounding floors etc.

However a third solution was chosen /5/, considering that alkali-aggregate reactions require the presence of the following three reactants: silica, alkalis and water /1/, /2/, /3/.

As the concrete contained both silica and alkalis, and alkalis were available from the pool water, the only possible way to stop the deterioration and save the construction was to avoid contact between the saline pool water and the concrete by applying an impermeable membrane to the inside of the wall. During the subsequent drying of the concrete the alkali-aggregate reactions might become more deleterious since the actual concrete-mix might reach a pessimum proportion for humidity, like it has a pessimum proportion for silica content. However, examination of other similar concrete constructions, which have been repaired, did not indicate the presence of such a pessimum.

4.2 Solution

The main features of the chosen solution were as follows:

The whole ceramic cladding was removed and the installations were removed to the necessary extent. The concrete surface was cleaned and patched and coated with a bitumen membrane. The watertightness at all inlets and outlets through the membrane was established by steel flanges.

In order to protect the membrane against mechanical damage and to create support for a new ceramic cladding, the membrane was covered by 10 cm reinforced concrete. The concrete was connected to the existing construction by steel anchors with flanges.

The pool construction locally had to be reinforced by an internal concrete construction due to insufficient reinforcement, before the membrane was applied.

All inlets and outlets therefore had to be prolonged and equipped with flanges.

The internal layer of concrete was connected by steel anchors (plateanchors) to the existing construction. The principles in a plateanchor is illustrated in Figure 6.

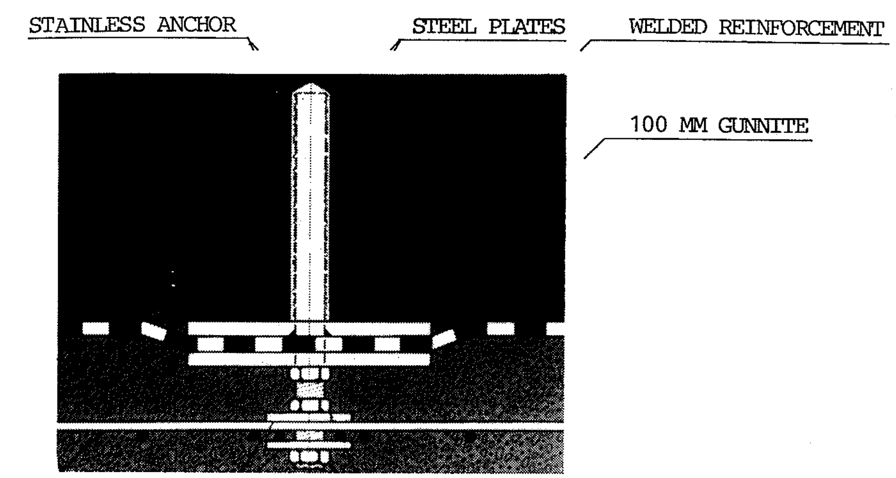

Fig. 6: Principles of plateanchor.

The application of the membrane had to be done very carefully. At all places where tubes, windows, etc. are going through the membrane, the principle with two flanges was used, and at every place the membrane had to be carefully adjusted to the inlet.

As an additional control the pool was filled with water as soon as the membrane had been finished, and proved to be watertight.

4.2.1 Concrete

The heavy reinforced concrete which was added for protection of the membrane, was cast in situ on the bottom of the pool and applied by gunniting on the vertical sides.

In order to secure the new concrete against alkali-aggregate reactions when it was exposed to warm pool water with sodium chloride, the aggregates for the concrete mix had to be transported from distant locations:

Coarse aggregates were crushed granite from the island Bornholm in the Baltic, and the sand was transported from Jutland. The sand was pure quartz with maximum 0.15% flint. These aggregates had not shown any expansion during tests according to ASTM morter bar method (C227-81).

The cement was special danish cement with low alkali content.

In order to improve the strength and watertightness 35% flyash was added.

The water/cement ratio was 0.4.

Also the mortar for the new ceramic cladding was mixed with pure quartz sand as aggregate.

The arrangements in connection with the repair af the swimming pool should thus ensure

- -that the new concrete is resistent to alkali-aggregate reactions, and
- -that the old concrete is no longer exposed to imbibition and percolation of the water with sodium chloride, and thus secured against further alkali-aggregate reactions, as soon as the water content in the old concrete has dryed out below the critical level.

5. ACKNOWLEDGEMENTS

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Some of the investigations were performed in cooperation with dr. G.M. Idorn, DK.

6. REFERENCES

(1) SBI: Alkaliudvalgets vejledning 1, Forløbig vejledning i forebyggelse af skadelige alkalikiselreaktioner i beton, Copenhagen 1961. (In Danish).

(2) IDORN, G.M.: Durability of concrete structures in Denmark, Copenhagen 1967. Danish Concrete Institute, Holte Midtpunkt, 2840 Holte, DK.

(3) Cementfabrikkernes tekniske Oplysningstjeneste, Betonteknik no 3/02/1973: Alkalireaktioner i beton, Aalborg 1973. (In Danish).

(4) Cementfabrikkernes tekniske Oplysningstjeneste: Betonbogen, Copenhagen 1979. (In Danish).

(5) MØRUP, H. and NIELSEN, F.: Renovering af Hillerød svømmehal, Byggeindustrien no 2, p 24 ff, 1983. (In Danish).

DAMAGES TO SWIMMING POOLS DUE TO ALKALI SILICA REACTIONS

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1. INTRODUCTION

Serious damages have appeared in a number of Danish swimming pools during the last few years. Alkali silica reactions play an important role in the deterioration proces and lead to serious consequences as to repair.

Improved future practice and development of preventive and remedial measures should be based on thorough knowledge of what went wrong and why.

In the following is first given a record of yesterday's Danish design practice for swimming pools and secondly a report on a couple of pools with serious damages. Proposals for future practice, and for preventive as well as remedial measures, supported by test results, conclude the paper.

Key words: Alkali silica reactions, swimming pools, damages, repair.

2. DANISH SWIMMING POOLS CONSTRUCTED IN THE 1960'ties AND 1970'ties

Construction of outdoor swimming pools was booming in the late 50'ties and the 60'ties whilst the construction of public indoor pools gained momentum in the late 60'ties and continued through the 70'ties.

It is noticable that design and construction practice for the concrete pools was developed for the outdoor pools and later used for the indoor pools although significant differences between the conditions, to which the concrete is exposed, are present. A typical cross section of an outdoor and an indoor swimming pool are shown on fig. 1.

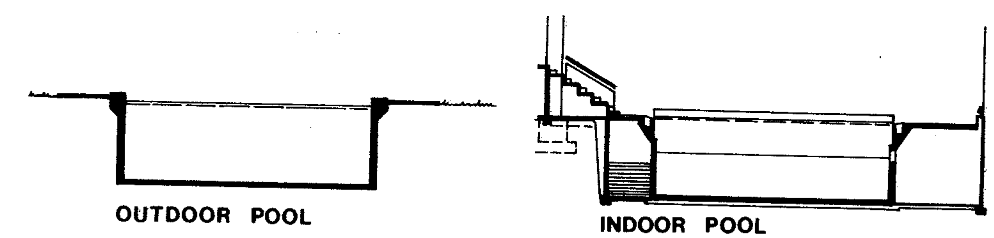

Fig. 1

Both are typically supported on the ground but whilst the outdoor pool has earthfill along its walls, the indoor pool is usually surrounded by a corridor used for piping and as inlet duct for the ventilation system of the swimming hall.

The common design and construction practice may be deducted from two lectures held by techn.dr. Anders Nielsen and myself, in the Danish Concrete Assosiation in 1978, published as a Danish Concrete Assosiation Publication No 5, 1978 /1/. In this paper you will find a recipe for construction of a water tight concrete swimming pool - formulated as ten commandments (fig. 2).