Disintegration of Concrete in Foundation and Anchorage Blocks for an Aerial Mast

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Alkali-aggregate reactions were found to be one of the causes of deterioration of the concrete in foundation and stay anchorage blocks for an aerial mast. Freezing-thawing and vibrations transmitted to the foundation and blocks from the stays were probably contributing factors in the disintegration process; the question is still open as to which of the three factors was primary and which secondary. The risk of deleterious alkali-aggregate reactions in concrete containing reactive aggregates is increased when the structure of which the concrete forms a part is carrying relatively heavy dynamic loadings or is subject to the action of other disintegrative forces such as frost action.

•THE PAPER describes an investigation aimed at clarifying the causes of heavy disintegration of concrete as observed in foundations for an aerial mast.

The structure consists of a steel mast, 230 m high, supported on a concrete foundation and fixed in a vertical position by 15 steel cables. The stays lie in three vertical planes forming angles of 120 deg between each other with five stays in each plane. At one end the stays are attached to the mast, at the other end they are attached to large bent steel bars anchored in reinforced concrete foundations (Fig. 1). The arrangement of the foundation and anchorage blocks is shown in Figure 2.

Each anchorage block is about 3 m long, 1.5 m wide, and 2.5 m high with about 1 m visible above ground level.

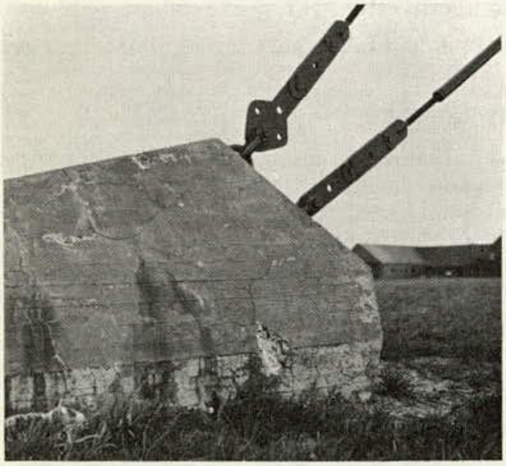

Figure 1. Anchorage block 8 (Fig. 2) with coarse cracks and map-cracking.

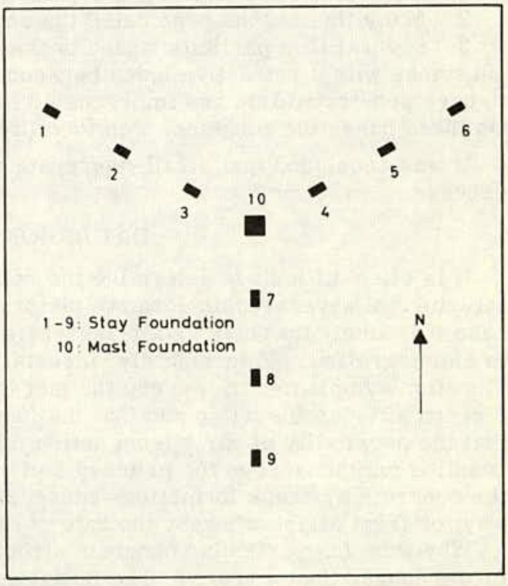

Figure 2. Arrangement of anchorage blocks and foundation (not in scale).

Figure 3. Close-up of mast foundation (10 in Fig. 2) showing extensive map-cracking and pop-outs.

Few and incomplete data were available on the materials and mix proportions used for the concrete in the foundations. However, it could be ascertained that ordinary portland cement, ordinary Danish pit aggregates, and "foundation concrete", with a relatively low cement content (usually about 150 kg/cu m) and a relatively high water content, had been used. Danish pit aggregates usually contain 10 to 30 percent weak, porous flint and limestone. The average content of alkalies in ordinary Danish portland cement is about 0.7 percent.

The foundation and anchorage blocks are situated in agricultural fields. They are subject to the action of the weather, which in Denmark is characterized by a rather high relative humidity during the whole year and a great number of freezing-thawing cycles during the winter.

INVESTIGATION OF STRUCTURE

After 3 years of service (the blocks and foundation were cast in the summer of 1957), cracks began to appear in the foundations. After 5 years of service, the foundations were extensively cracked, with map-cracking, single coarse cracks, and pop-outs (Figs. 1 and 3). Disintegration was most pronounced in foundations 7, 8, and 9 (Fig. 2).

During the field inspection, samples of the concrete were taken for laboratory investigation. The samples were examined by microscope and the findings were as follows:

1. The outer surface of the samples was map-cracked;
2. Many fine cracks penetrated the cement paste; and
3. Several flint particles at the broken faces were coated with a glassy, isotropic substance with a refractive index between 1.45 and 1.48. The same substance seemed to have penetrated into and impregnated the mortar surrounding the flint aggregates. On these bases the substance was identified as alkali-silica gel.

It was concluded that alkali-aggregate reactions had taken part in the disintegration process.

DISCUSSION OF RESULTS

It is often difficult to determine the relative influence on the durability of a concrete structure of several disintegrative factors acting at the same time. In the present case it is likely that both alkali-aggregate reactions and frost action have contributed to disintegration. Unfortunately, no detailed description exists of the very first deterioration symptoms. However, the fact that visible deterioration did not occur until 3 years after construction and that the foundations were cast during summertime, so that the possibility of early frost action may be ruled out, indicates that alkali-aggregate reaction may have been the primary factor. An opening up of the interior structure of the concrete by crack formations caused by alkali-aggregate reaction would prepare the way for frost attack whereby the rate of disintegration would be increased.

Why was this particular concrete structure not able to withstand the disintegrative forces longer than 3 years? The initial quality of the concrete for the exposure conditions is believed to have been inadequate, as is often the case. However, one other factor should be noted: Dynamic loadings caused by wind forces acting on the mast are transmitted through the cables to the anchorage blocks and through the base of the mast to its foundation. These dynamic loads, such as vibration and impact, create tensile stresses in the concrete and contribute to the formation and extension of cracks. This point of view is supported by the fact that southern winds prevail most of the year in Denmark. Thus anchorage blocks 7, 8, and 9 in the north-south oriented row would be expected to be most damaged, which was actually the case. A similar case of anchorage block deterioration caused by alkali-aggregate reaction has been described by Plum, Poulsen, and Idorn (1).

Observations on other structures—e.g., a crane bridge, particularly the parts where braking of the crane takes place, and road curbstones frequently subjected to collision with cars—also indicate that dynamic loadings may sometimes be a contributing factor of deterioration.

CONCLUSION

Combined action of alkali-aggregate reactions, freezing and thawing, and dynamic loading were found to be the cause of rather heavy and rapid deterioration of anchorage blocks and foundations for an aerial mast. The initial quality of this concrete was not adequate for the exposure conditions present.

Recommendations for repair constituted (a) removal of all disintegrated concrete to a depth of at least 15 cm from the surface; (b) careful cleaning of the new surface; (c) casting of a covering of high-quality reinforced concrete on top of the old concrete, the high-quality of the concrete being attained by using nonreactive aggregates, a water-cement ratio not higher than 0.55, and a cement content not less than 400 kg/cu m; (d) careful compaction; and (e) wet curing for at least one week after casting.

No new damage has been reported thus far.

REFERENCE

1. Plum, N. M., Poulsen, E., and Idorn, G. M. Foreløbig oversigt over alkalireaktioner i beton i Danmark. Ingeniøren, No. 27 and 28, Oct. 1957.