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Repair of the Bascule Pier of the Oddesund Bridge

Réparation de la pile du pont mobile de Oddesund

Instandstellung des Klappfeilers der Oddesundbrücke

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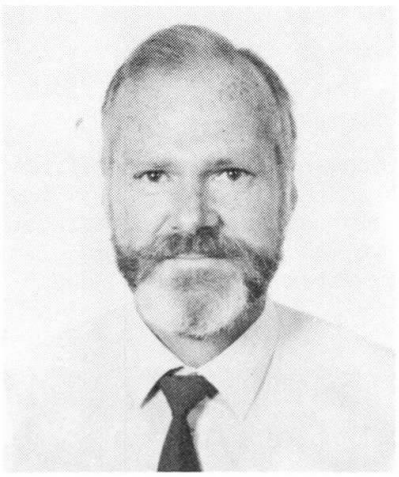

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SUMMARY

Throughout its fifty-year life the bascule pier of the Oddesund Bridge has suffered both from alkali-silica reaction in the concrete and from a slanting pile foundation. These primary defects have in the course of the years resulted in movements and settlements. Attempts have been made to repair these primary defects and the resulting defects in various ways. However, these makeshift solutions have not fully been successful. After a final analysis in 1986 it was decided in 1987 that a total renovation of the bascule pier pile foundation and pier itself should be carried out. The field work was started in March, 1989.

RÉSUMÉ

La pile du pont de Oddesund souffre, depuis 50 ans qu'il existe, de réactions alcalino-siliceuses du béton et d'une médiocre fondation sur pieux. Ces défauts primaires se sont manifestés sous forme de déplacements et de tassements. A intervalle réguliers il a été tenté d'y remédier, mais sans succès. A la suite d'une étude approfondie il a été décidé de rénover entièrement la pile, y compris la fondation sur pieux. Les travaux ont commencé en mars 1989.

ZUSAMMENFASSUNG

Der Klappfeiler der Oddesundbrücke hat Zeit seines Bestehens, d. h. seit 50 Jahren teils unter Alkali-Kiesel-Reaktionen im Beton, und teils unter einer schiefen Pfeilerfundation gelitten. Diese Primärschäden haben im Laufe der Jahre Bewegungen und Senkungen zur Folge gehabt. In regelmässigen Abständen hat man versucht, die Primärschäden sowie die Folgeschäden auf verschiedene Weise zu beheben. Diese Ausbesserungen haben jedoch das Problem der Klappfeiler nicht vollauf gelöst. Nach einer gründlichen Analyse des Schadenumfanges und der Ursachenkette wurde beschlossen, den Klappfeiler total zu renovieren, d. h. sowohl die Pfeilerfundation als auch den Pfeiler selbst. Die Bauarbeiten begannen im März 1989.

1. THE ODDESUND BRIDGE

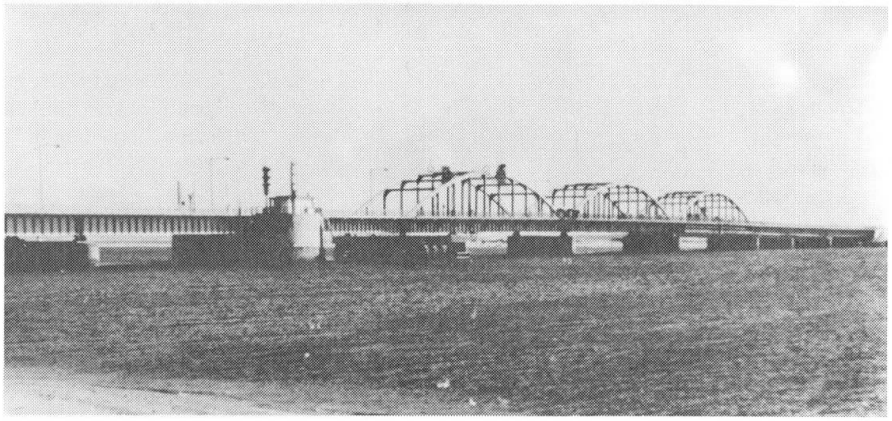


Fig. 1

The combined road and railway bridge over Oddesund was built in the period 1934-37. Fig. 1.

Its capacity for traffic is still considered sufficient, but with regard to road traffic the bridge is exposed to maximum utilization in the peak load period in the summer holiday season.

The navigation conditions seen in relation to the ships that pass the bridge are also acceptable.

Already shortly after the Oddesund bridge had been finished in 1937, settlements and cracks as well as deformations were found in the bascule pier (Fig. 2). Since then the bascule pier has been subjected to continued examinations, repairs and reinforcements. Likewise, it was the main object in connection with the work of the Danish Alkali-Silica Committee in the 1950's and the 1960's.

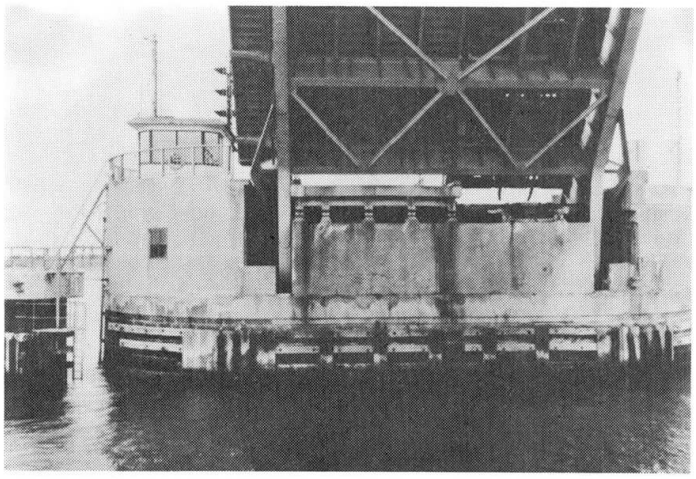
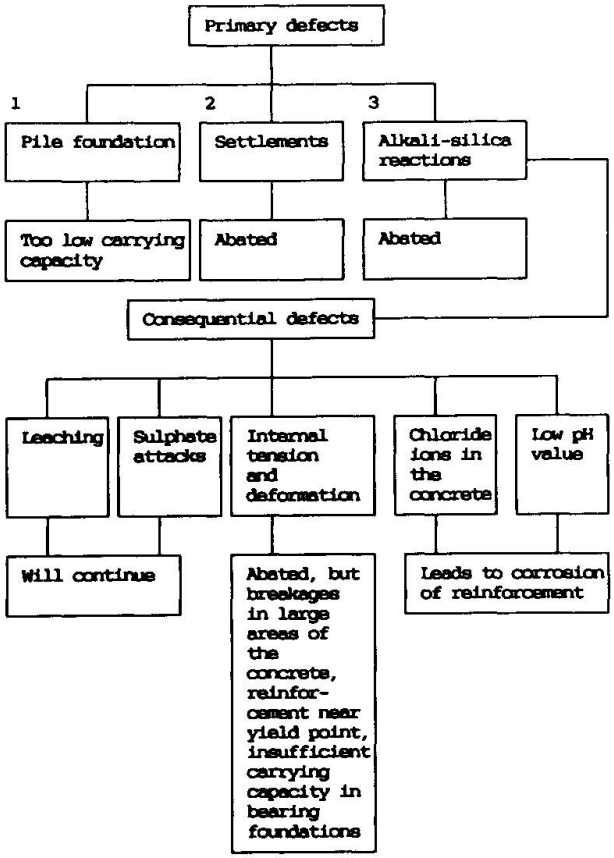


Fig. 2

2. SPECIAL EXAMINATION

In 1986 the Bridge Maintenance Department of DSB (Danish State Railways) carried out a special examination of the bascule pier in co-operation with Rambøll & Hannemann, Consulting Engineers A/S.

Registration of the condition of the pier was carried out as well as evaluation of its carrying capacity and structure, and the history of the defects was clarified. The history of the defects appears from the outline below.



The defects can be divided into three "primary defects":

1. The carrying capacity of the pile foundation is too low, especially with regard to the ability to absorb impacts from ships and the load of ice.

2. The pier has settled towards the channel and towards the west owing to different foundation conditions and different pile point levels, but the settlements have now abated, and the consequential damage has been repaired.

3. The concrete of the bascule pier structure is heavily affected by alkali-silica reactions resulting in expansion and differential expansions. As a consequence of this the concrete has become severely cracked, and changes in the original geometrical form of the bascule pier have occurred.

   Both the total expansion and the differential expansions have now abated.

As a consequence of the alkali-silica reactions three types of "consequential defects" have occurred:

3.1.a and 3.1.b

Through the concrete which is cracked all through, an entrance has been opened for sea water, which has leached the concrete and brought in sulphates.

These attacks will continue to disintegrate the concrete.

3.2.a and 3.2.b

Through the cracked concrete the sea water has brought in chloride ions in dangerous quantities, and the leaching has reduced the pH value of the concrete, which has led to/will lead to corrosion attacks on the reinforcement.

3.3

The expansion due to alkali-silica reactions has had the effects that the reinforcement is at or near the yield point everywhere, and that in large areas the concrete is in danger of breaking under compressive as well as tensile stresses.

The concrete in the bearing plinths is so seriously disintegrated that the carrying capacity of this structure is considered insufficient.

The carrying capacity of the bascule pier structure is sufficient with the exception of the abovementioned bearing plinths, but estimated on the basis of an elastical consideration the carrying capacity is too small. The elastic tension gives rise to large areas of breaks and cracks in the structure, and this in combination with the continued disintegration of the concrete and corrosion of the reinforcement implies that its durability cannot be secured.

The pile foundation of the bascule pier has had too low carrying capacity right from the beginning. For net weight alone the carrying capacity is approximately 85 % of the required value, and for ice load and impact from ships it is as low as approximately 35 % of the required value.

From the point of view: How can the bascule pier be renovated, or can it be renovated at all? - was it specially important to classify the observed movements of the bascule pier according to their nature as either settlements or total and differential expansions.

This was important in order to see whether these movements would continue or not, and in order to evaluate the strain in the very structure.

The differential expansions explain the cause of the many cracks, local breakages and deformations of the bascule pier.

The final report on the special examination dealt with four different possibilities of solving the problem:

1. Interim renovation (will not secure the carrying capacity of the pile foundation).
2. Total renovation.
3. New bascule pier.
4. Establishing of a passage span at the other end of the bridge and change of the existing passage span into a fixed span.

On the background of the report on the special examination the DSB decided in the autumn of 1987 to go in for a total renovation.

3. PROJECT PROPOSAL

3.1 Preliminary Conditions

. The bascule pier will be strengthened so much that its carrying capacity is sufficient according to the current load regulations and standards.

. It is the aim of the project that the total renovation shall have a life of 60 years, corresponding to the estimated remaining life of the rest of the bridge. This is achieved by:

  - making sure that the carrying capacity of the newly built structures and the entire structure will last 60 years.

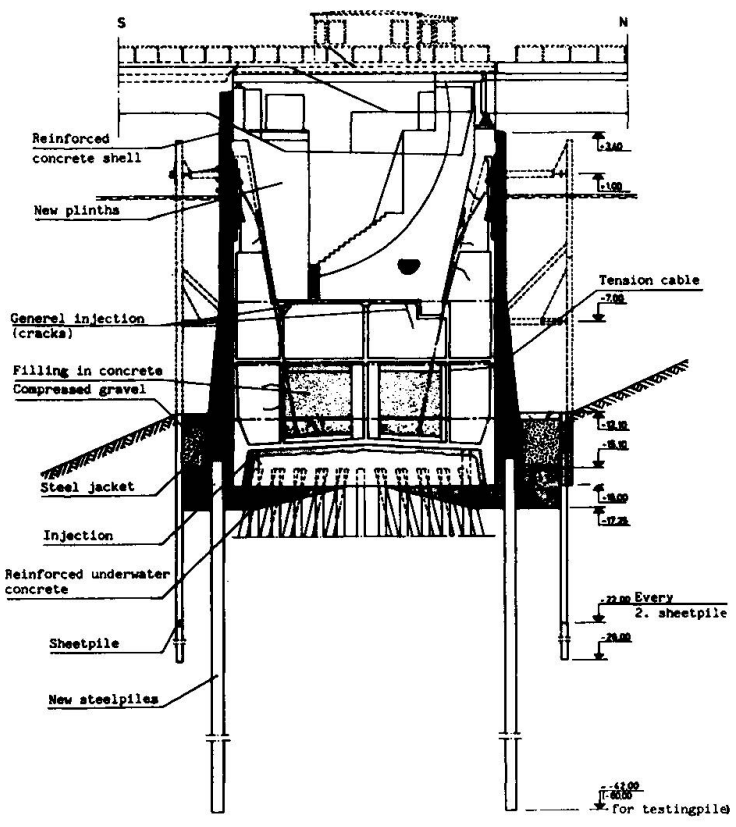
  - repairing the existing structures to such an extent as circumstances require, while at the same time precautions are taken to ensure that it will be possible later on to carry out replacements/repair in such a way that the desired life of 60 years is achieved.

. Impediments to operation (impediments to railway traffic, road traffic and navigation) in connection with the renovation will be minimized to the greatest possible extent.

. The risk in connection with work on the badly damaged pier will be minimized.

. The construction period will be spread over 3 years from 1989.

3.2 Description of the project



CROSS SECTION

The renovation project comprises an external strengthening of the pier in the form of a reinforced concrete shell around the pier, founded on new piles and connected with the old structure by means of transverse anchors. External the concrete shell provides with a steel jacket. Internal repair and tightening are made by injection. New bascule bearing plinths are concreted.

The work is carried out in a dry building pit behind a provisional steel sheet piling, which is driven into the ground around the pier. Traditional working methods can then be applied for the carrying out of uncovering, hewing, renovation of coarse cracks, establishing of transverse anchors, displacement locks and welding of steel jacket etc.

4. POSTSCRIPT

When the special examination of the bascule pier of the Oddesund Bridge is seen in relation to the main damage, which is alkali-silica reactions, it shows

that we have a fairly good knowledge of:

. How the concrete should be composed in order to prevent the occurrence of alkali-silica reactions.

. The chemical reactions that occur in connection with alkali-silica reactions.

. The types of external environment that promote/start alkali-silica reactions.

. Testing methods for the evaluation of the alkali-silica reactivity of aggregates.

that we have too little knowledge of:

. The temporal dependence of alkali-silica reactions (total expansion and differential expansion) on:

  - The external environment.
  - The composition of the concrete.
  - The particle size of the reactive particles in the aggregates.
  - Reinforcement percentage.
  - The geometry of the structure.

. The correlation between alkali-silica expansion in concrete in laboratory experiments (tests) and in concrete in the structures (in "nature").

. The strength of concrete that has been damaged by alkali-silica reactions:

  - Reinforced concrete.
  - Non-reinforced (plain) concrete.

. Repair methods.

. The optimal time for repair seen on the background of the fact that the temporal dependence of alkali-silica expansion is principally an S-shaped curve, where the expansion begins and ends slowly, but is violent in an intermediate period.

On this basis the DSB count on implementing an extended examination of several years' duration in order to clarify the lack of knowledge in this field.

The renovation has started on site March 1, 1989.