The Øresund bridge-tunnel: assessment of the environmental impact

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The Øresund Bridge-Tunnel. Assessment of the Environmental Impact

La liaison fixe sur l' Öresund. Impact sur l' environment.

Die feste Verbindung über den Öresund. Umweltverträglichkeit

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SUMMARY
Today it is considered very important that before the start of large construction projects a thorough analysis is made of the effects of the construction on the external environment. The environmental investigations normally have to be carried out in several steps, for the actual environmental assessments, which are an important prerequisite for the final decision to go ahead with construction, has to be followed by an environmental optimization in the design stage and by surveillance during and after the construction stage to ensure that the assessments hold good. In the article the bridge-tunnel across the Øresund between Denmark and Sweden is used as an example of construction that has been subject to a careful assessment.

RÉSUMÉ
Aujourd'hui, avant de mettre de grands travaux en chantier, il est important de procéder à des études approfondies de compatibilité avec l' environnement. Ces études sont effectuées par étapes, étant donné que les véritables évaluations environnnementales, dont dépend largement la décision de réaliser les travaux, doivent être suivies d'une optimisation environnementale dans la phase de conception et dans la phase de réalisation. Une phase de surveillance doit suivre pour vérifier le fondement des évaluations. Dans le présent article, le liaison fixe sur le Sund reliant le Danemark à la Suède est donné comme exemple d'une construction dont l'impact sur l'environnement a été très soigneusement étudié.

ZUSAMMENFASSUNG
Vor der Ingangsetzung von grösseren Bauprojekten wird heute grosser Wert auf eine gründliche Prüfung der Umweltverträglichkeit gelegt. Sie wird in der Regel in mehreren Etappen durchgeführt, wobei auf die eigentlichen Umweltbeurteilungen als Voraussetzung für die Entscheidung zum Bau der Anlage in der Planungsphase eine Umweltoptimierung folgen muss. Ebenso ist während und nach der Bauphase festzustellen, ob die Einschätzungen Bestand haben. Im Artikel wird die feste Verbindung über den Öresund zwischen Dänemark und Schweden als ein Bauvorhaben angeführt, das im Hinblick auf die Umwelt beispielhaft untersucht worden ist.

In step with the increasingly accentuated focus in recent years on the importance of environmental aspects, the environmental assessments in respect of major construction works have been carried out with increasing thoroughness. The following is a description of the environmental assessment carried out for the bridge-tunnel across the Øresund (the Sound) between Denmark and Sweden. This is followed by a description of the manner in which the assessments will be followed up in a later stage of the project. /1/ contains a detailed description of the effect of the Øresund bridge-tunnel on the marine environment. The major conclusions from that report are included in this presentation.

The environmental analyses in respect of the Øresund bridge-tunnel were the work of a project group with representatives from all directly involved environmental and construction authorities. The work was successful and fruitful, and it proved important that the environmental authorities both selected the problem areas to be investigated and approved the investigations carried out. One result of this was that questions to the environmental report could be treated by responsible experts who had participated in the preparation and approval of the report.

The bridge-tunnel across the Øresund

For many years a bridge-tunnel between Denmark and Sweden across the Øresund has been planned. Environmental assessments of several proposed constructions have been carried out, most recently in 1990/91 when a very thorough environmental assessment was carried out on two alternative alignments of the fixed link.

On the basis of, inter alia, the environmental report a governmental agreement between Denmark and Sweden was signed on 23 March 1991. The fixed link was adopted by act of law in Sweden in June, and in Denmark the Act was adopted on 14 August 1991. The Agreement was ratified on 24 August 1991.

The link between Denmark and Sweden will consist of a four-lane new motorway and a double-track electrified railway between the cities of Copenhagen in Denmark and Malmø in Sweden. The section on land in Denmark is about 15 km long. The section from coast-to-coast is about 16.2 km. From the Danish coastline it is designed via a 2 km long man-made peninsula, an approximately 2 km long submerged tunnel under the Drogden channel, and then up across a 2.5 km long man-made island. East of the island follows a 2.3 km low-level bridge and 7.4 km long high-level bridge across the Flinterenden and Trindelrenden channels to reach the shore just south of Malmö in Sweden.

The bridge-tunnel and the environment

The environmental propriety of the Øresund bridge-tunnel will be ensured in three steps:

Step 1. Environmental investigation in the spirit of the EC EIA Council Directive (EIA=Environmental Impact Analysis) /2/.

Step 2. Environmental optimization.

Step 3. Environmental surveillance.

Step 1 was almost completed with the issue of /1/, and Step 2 has now been started, after the adoption of the Act. At the same time the considerations about the environmental surveillance under Step 3 will be intensified. The three steps will be described in the following three sections of this paper:

1. Environmental investigations

The following environmental investigations in respect of the Øresund bridge-tunnel have been completed at present:

1.1. Visual character of the fixed link

The envisaged design of the construction was analysed to describe how the fixed link could be given the highest possible aesthetic value.

1.2. Geology and its importance for the construction's environmental effects

Based on existing knowledge a geological model has been constructed which covers conditions both under the land section on the Danish side and under its coast-to-coast section.

The geology of the area raises the following environmental problems:

1.2.1. Groundwater conditions under the land section

Denmark is enormously dependent on her groundwater resources. 98% of the country's total consumption of water is covered by pumped-up groundwater. Water consumption in Copenhagen is at present about 7.8 million m^3, of which about 1.5 million m^3 is extracted from borings placed in Amager near the construction. In Amager the construction has been dug up to 6 m down below ground level, and the groundwater level is at a depth of about 1 m.

The construction will reduce the availability of water. This can be remedied by arranging the necessary lowering of the groundwater in such a manner that polluted water is separated from high quality water and that the high quality water is led to the waterworks.

1.2.2. Earth pollution

The land section will pass a number of areas known for or suspected of containing polluted earth. They are industrial areas and oil/petrol installations.

The polluted earth may present problems in connection with handling and treatment. Moreover, it is expected that the lowering of the groundwater level will activate occurrences of polluted groundwater, which will more rapidly seek down towards the primary groundwater level.

It has been decided that a mapping must be carried out and followed by a detailed examination of all suspect areas near the construction. Through this investigation it must be determined where there will be a need of taking measures to prevent earth pollution.

1.2.3. Earthquake risk for the construction

Denmark is situated in a low-seismic region. There have been no known examples of constructions that have been damaged or destroyed by earthquakes, and there is no tradition of earthquake assessment of planned constructions.

As the Øresund bridge-tunnel will be close to a main fault between the Fenno-Scandinavian bed-rock area and the Danish/German basin it was decided that the earthquake risk for the construction should be assessed. By using the method recommended in Eurocode 8 (draft 1990) it was found that the worst imaginable earthquake within a 300 by 150 km area along the main fault will have its epicentre at a depth of 9 km and a magnitude of 5.3 on the Richter scale. For other reasons the bridge-tunnel will have to be constructed so that it can resist such an earthquake without problems.

1.2.4. Raw material requirements

The construction will need 1.5 million m^3 gravel and 1.1 million m^3 stones for embankments, casings, etc. Another 0.7 mill. m^3 of sand and 1.3 mill. m^3 of gravel are needed for concrete. The gravel for concrete will be extracted from quarries in neighbouring countries or in the small Danish island of Bornholm, and the sand for concrete will probably be extracted from special sand occurrences in or near Bornholm. The other material will be extracted from the sea bottom in the neighbourhood of the construction, and the environmental investigation showed that there are very large amounts of sand/gravel available.

Finally it was estimated that material extracted through digging for the construction can be contained within the man-made island and peninsula. Consequently, no problems are expected in finding space for depositing dug-up materials.

1.3. Historical interest

The sea level in the Øresund area is now a couple of metres higher than in the Stone Age, and in the areas which were then land but are now covered by sea it is possible to make important finds of villages, etc., from the Late Stone Age.

For many centuries the Øresund has been one of the world's busiest waters, and numerous ships have been wrecked in the Sound. We have information about a large number of new and old shipwrecks, but presumably the bottom of the Øresund can disclose many more wrecks whose existence is not known from the files.

A registration has been made of the locations of known Stone Age finds and of wrecks. Test samples have been taken from the sea bottom at especially promising points, and reconnaissance by air has been used to find wrecks.

1.4. Marine environment

In the environmental investigations every effort was made to create a reliable basis for an assessment of the effect of the construction on the marine environment. The investigations, described in detail in /3/, were carried out by simulation in computer models in which all collected data on topography, hydrography and the addition of matter were incorporated.

1.4.1. Marine environment in the Baltic Sea

The distance between the construction area and the Baltic Sea is quite considerable. That none the less the construction can affect the environment in the Baltic Sea is due to the special hydrographic conditions in the area. The Baltic Sea, with its 375,000 km^2 the largest brackish water area in the world, can be viewed as a ligated bay with connection to the North Sea/Kattegat through the 3 belts Lillebælt, Storebælt and Øresund. Some 470 km^3 fresh water annually flows from the rivers into the Baltic Sea, but far larger volumes of water move, depending on weather and wind conditions, northward or southward through the three belts. The water masses pass through Lillebælt-Storebælt-Øresund in the proportions 1:7:3, respectively.

The influence of the construction is amplified by its location on a very important threshold with a water depth of only 7-8 m. North, and often also south, of the threshold the water column is divided into layers with a salt bottom layer and a fresher surface layer. In calm weather the salt bottom layer is prevented by the threshold from reaching the Baltic Sea, and only in cases of sustained southward current does the saltier bottom water get carried across the threshold.

The fixed link will reduce the water-flow through the Baltic Sea by about 3% but the model simulations showed that this has only a very limited effect in the Baltic Sea. The absolute salt content in the surface layers and in the bottom layers in the Bornholm basin will be reduced by only 0.002 and 0.003%, and this should be compared to the natural variation in the same salt content, which is of the order of 0.15% within a period of a few years. Correspondingly, the relative oxygen content will be reduced from 100% to 99.63%.

When digging in the sea bottom it will be possible to avoid these effects entirely, but in order to achieve a true zero-effect more than 11 mill m^3 bottom matter has to be removed from the construction area.

The change in salinity and oxygen might have an influence on flora and fauna. This question will be subject to further analyses which will be initiated in the near future.

1.4.2. Permanent changes in the environment near the construction

The environmental investigations pointed out a number of permanent changes that must be expected in the areas close to the construction. The most important are:

a. The Sound between the man-made island and Saltholm will have a slight tendency to sand up. This must be avoided to prevent foxes and rats to reach Saltholm, where the rich bird-life today depends on the absence of these species.

b. the beach quality north of the man-made peninsula may deteriorate. It will be investigated how a changed coastline can minimize or prevent this problem.

c. A minor worsening of ice conditions in the Drogden in hard winters must be foreseen.

d. Fear has been expressed of increased risk of flooding on South Amager as a consequence of the construction. However, an analysis of this problem showed that the water level increase in the worst case of flooding will be less than 2 cm.

e. Conditions for a small seal colony and a considerable population of moulting swans in the summer months will be poorer.

1.4.3. Temporary changes caused by the construction

A great environmental problem in the building stage may be sediment vanes created by waste from digging processes on the sea bottom. These may destroy or reduce the large common mussel banks, which are basic food for the eiders. The widespread grasswrack water-meadows, spawning and maturing ground for almost all the species of fish that are of interest to the fishing industry, could be damaged. Finally there is a fear that very large occurrences of herring on spawning mission to the Baltic Sea in the spring months will be disturbed by the sediment vanes.

In order to minimize these problems the digging tools for digging on the sea bottom will be tools that can work with a minor waste, and digging will not take place on both sides of Saltholm at the same time in the spring months.

1.5. Noise

A number of assessments have been made of the effect for neighbours of noise from the four-lane motorway and the double-track railway. The assessments have been updated in 1991 from the newest prognoses for traffic across the construction in the year 2010.

A large part of that traffic will be existing traffic which is led from other railways and roads to the construction. Therefore many homes will be relieved of noise while a number of neighbour homes will be exposed to new noise. By placing the construction in a deep excavation an effort has already been made to minimize the noise problems.

1.6. Emissions

Also the emissions from the traffic across the construction have been evaluated, based on the 2010 prognosis, and they were compared with the emissions from traffic without the bridge-tunnel. Assessments were made for the "globally" effective CO_2, and for the more locally problematic CO, NO_x, SO_2, and HC and particles. It has been proved that the emission will be systematically reduced when the fixed link comes into being.

2. Environment optimization

Section 1 of this paper has given a review of the environmental investigations carried out. During the months to come the detailed planning and design will be implemented, and at the same time the environmental work will be continued. The design will be giving the environment maximum consideration, and especially the two main aspects:

The shape of the man-made island and peninsula must be optimized. So the increase in resistance to the water-flow in the Øresund will be down to a minimum, that is the effects in the Baltic Sea, or alternatively the volume of material removed in the compensatory digging, will be small.

To test the amount of waste from the digging tools, test digging must be carried out in the lime underground in the Øresund as support for the choice of optimum digging tools for the work in the hard lime.

3. Surveillance of environment

As mentioned, the environmental authorities have participated actively and in a positive spirit both in the selection of the main aspects of interest and in the work of assessing possible environmental problems. In the optimization stage the environmental influence of the construction will be minimized, but it cannot be entirely avoided that a construction of this size will have both temporary and permanent environmental effects. Therefore a set of rules must be laid down for permissible effects during and after the construction stage, respectively, and a surveillance programme must be prepared to ensure that this set of rules is observed.

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/1/ The Øresund Environment 1991

/2/ The EC Directive 337, 1985: Environmental Impact Analysis (EIA)

/3/ "Assessments on the Effects of the Øresund Bridge-Tunnel on the Environment" by Kurt Lykstoft, the IABSE Conference, Nyborg, Denmark, May 1991