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Concrete for the Øresund Tunnel

A comprehensive concrete specification has been prepared to control the quality of the concrete for the Øresund Link. The required service life of the structure is 100 years in environmental conditions that are aggressive to concrete; marine environment, deicing agents, freeze-thaw action, water pressure etc.

This paper gives a short review of the most important requirements for the concrete to be used for the 3,510 m long immersed tunnel from Amager (outside Copenhagen Airport) to an artificial double island south of Saltholm (in the middle of Øresund). The basis for the requirements is shortly commented.

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The Øresund Fixed Link

The construction of the Fixed Link across Øresund - following the 1991 agreement between the Swedish and Danish governments - is now well under way.

Aimed at improving transport connections between the two countries and thereby strengthening cultural and economic co-operation, the link is expected to stimulate the development of a joint labour and housing market on each side of Øresund. In short, the link is expected to further the integration of the Øresund region, paving the way for successful competition with Europe's other major regional centres.

One of Scandinavia's largest investments in infrastructure, the Fixed Link across Øresund will be financed through international capital market loans, guaranteed by the two governments. The users - motorists, freight operators and railways - will pay to cross the Fixed Link.

The Fixed Link consists of a combined twin track railway and a four-lane motorway and its financial structure has been devised so that road users carry the major share of the rail link's construction costs. This solution has been designed to allow the railway to absorb a significant share of the expected increase in freight and passenger traffic thus avoiding negative effects on the environment.

With imports and exports between the two countries accounting for more than 10 pct. of their respective foreign trade, economic co-operation between Sweden and Denmark has traditionally been extensive. A significant part of Denmark’s trade with other Nordic countries takes place via Sweden and Denmark itself rates as an important transit route for Scandinavian trade with Europe.

With an annual GNP of DKK 500 billion, the future Øresund region is therefore poised to become an economic power centre in Europe. In comparison, the combined GNP of Sweden and Denmark totals DKK 2,400 billion.

The area’s total urban population is 2,3 million. If the population in the surrounding areas is included, the figure is 3.2 million of which the overall workforce is 1,5 million.

Measured by GNP, the region counts as the eighth largest in Europe while in terms of educational institutions and research, the region ranks fifth. As an air traffic hub, the region is sixth in Europe.

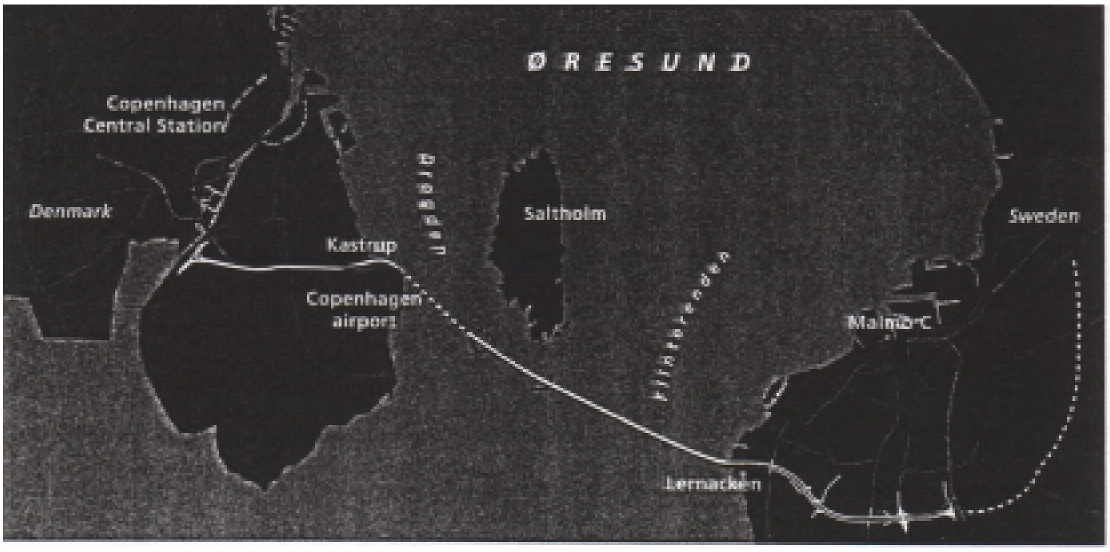
In itself the Fixed Link will not provide growth and development. Yet already today, years before the link opens to traffic, significant trends within culture, education, research and business indicate that hopes for integration will be fulfilled and that the foundation for a major region is being established. The results measured in greater economic activity, better exploitation of resources, greater research capacity and a favourable investment environment will benefit millions in years to come.

Technical description

The fixed motorway and railway link across Øresund will extend just under 16 km between Kastrup on the Danish coast and Lernacken on the Swedish coast.

The link’s elements are:

- An artificial peninsula extending 430 m from the Danish coast at Kastrup
- An immersed tunnel 3,510 m long under the Drogden navigation channel
- An artificial island 4,055 m long south of Saltholm
- A western approach bridge 3,014 m long between the island and the high bridge
- A cable-stayed high bridge 1,092 m long across the Flinte navigation channel
- An eastern approach bridge 3,739 m long from the high bridge to the Swedish coast at Lernacken
- A terminal area with toll station and Link Control Centre located on the Swedish coast at Lernacken.



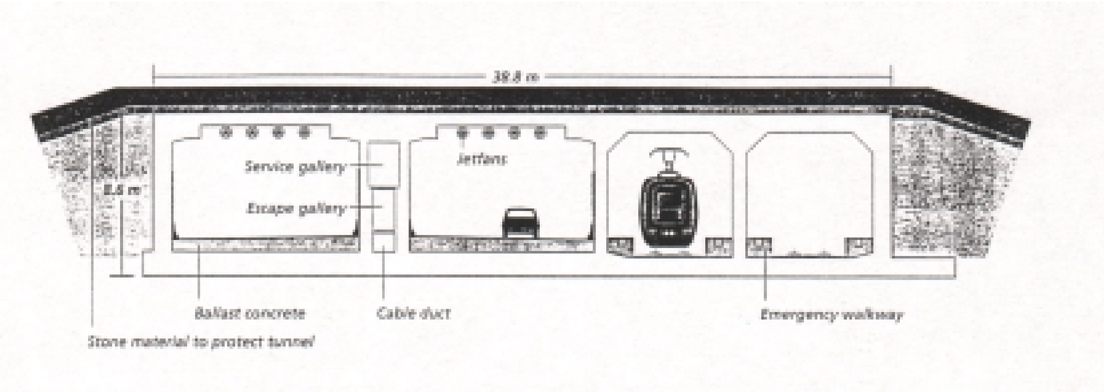
The immersed Tunnel

The western part of the Øresund Fixed Link consists of an approx. 3.8 km long tunnel between the artificial peninsula and the artificial island. The tunnel project comprises three main components:

- Ramp and portal building on the peninsula
- Immersed tunnel under the Drogden navigation channel
- Ramp and portal building under the artificial island

The portal structures accommodate underground service buildings with rooms allocated for tunnel installations, i.e. road lighting, ventilation, drainage, communications and energy supply. These installations constitute an essential part of the overall tunnel performance as experienced by the users.

The immersed part of the tunnel consists of 20 elements, each app. 175 m long, resulting in a total immersed tunnel length of 3,510 m. Each element is made from 8 sections, joined together by temporary prestressing. The outer cross-sectional dimensions are 8.6 m by 38,8 m, enclosing two railway tubes, two motorway tubes, and a central escape and installation gallery.



Cross section of tunnel placed in trench

The elements are placed in a pre-dredged trench, and founded on gravelling sand. Backfilling along the sides and on the roof is designed to offer a permanent cover and protection of the tunnel in all situations. The final tunnel profile is in general below seabed level, and at the Drogden navigation channel the top of the cover is 10 m below water level.

The motorway tubes are equipped with New Jersey safety barriers, wall paneling, and a central sump. Lighting is continuous throughout, with transition zones at either end to enable road users to adjust to the difference in light intensity. A special feature are the daylight screens above the tunnel entrances, which reduce the black hole effect, and give motorists time to adjust to the lighting difference.

The roofs and walls of all tubes are protected with fireproof insulation material, and emergency installations containing fire-fighting equipment and telephones are placed at approx. 100 m intervals. Safety doors are provided approx. every 50 m between the two railway tubes. Approx. every 100 m between the railway and the motorway tube, and approx. every 100 m in the walls giving access to the escape gallery, which constitutes a safe exit for all tunnel users in case of emergency.

The concrete volume in the immersed Tunnel is approximately 445,500 m^3 plus 57,000 m^3 of ballast concrete.

Concrete strategy

Concrete Strategy

Background

The Owner - Øresundskonsortiet - has decided to follow a formulated strategy when preparing the concrete specification.

The strategy was useful when general discussions occurred during the formulation of the requirements.

Strategy

The Owner, ØSK, wants to define and control the concrete quality.

The quality is defined by the requirements to

1) production of concrete including mix design (Materials)
2) requirements to the execution including curing (Workmanship).

The quality is controlled by requirements to inspection, testing and documentation as a part of a quality system in accordance with EN ISO 9001.

The requirements have been established by the Owner and their consultants. The requirements shall be based on well-known technology and they shall secure a service life of 100 years with proper maintenance, but without any major repair works.

The strategy is enforced by the preparation of a comprehensive concrete specification as a part of the tender documents.

The Owner wants an open competition between contractors, but it shall be ensured that the contractors do not compete on quality.

The specification shall leave as much freedom as possible to the contractors in the choice of concrete mix design, but thorough attention shall be given to the risk of failing to obtain the defined quality.

Format

The concrete specification consists of two parts belonging together:

- Production of concrete (Materials)
- Execution of concrete (Workmanship)

In each individual section requirements, inspections, testing and documentation are gathered for each individual subject.

Reference documents

The general reference document for the specification is Eurocode 2: "Design of concrete structures".

ENV 206: "Concrete performance, production, placing and compliance criteria" shall not be used as a reference document.

In general European Standards for constituents and testing shall be used whenever possible. If it is not possible to refer to a European Standard, reference should be made to other international Standards or to Danish or Swedish Standards.

Definition of life time

100 years service life shall be ensured for all concrete structures. Easy replaceable concrete components (e.g. crash barriers) can have a service life of only 50 years.

The service life is defined as the period within which full function is maintained.

Reinforcement corrosion is not allowed to start within the 100 years service life.

Maintenance shall be performed, but major repair-work or replacement shall be avoided. The structures shall be prepared for cathodic protection, but the service life shall be obtained without taking the cathodic protection into account.

Definition of well-known technology

Well-known technology is defined as technology well-tried with positive results under similar environmental conditions.

The Owner will rather use well-known technology with the above definition than use a new (and maybe unsafe) technology in order to try to save costs.

When preparing the specification questions about this principle arose. Which technologies are well-known and by whom. If the common and "well-known" technologies are regarded as unsafe by experts, it may be sensible to use a new but safe - according to experts - technology. This is called an **innovation**.

The main innovations in the specifications are:
- European constituent standards
- Defined Conformity procedures
- Stress calculations for early age cracking
- Service life calculations including the workmanship

Formulation of requirements

The specification is because of the strategy formulated according to the following directions:

a. Restrictions on the concrete mix design only to ensure the use of well-known technology
b. The concrete mix design chosen by the contractor is evaluated whenever possible through performance tests.
c. Restrictions on the type of constituents and the corresponding detailed requirements are used to ensure the use of well-known technology and constituents of high quality.
d. Specific requirements to the execution are used according to experience.
e. The calculation methods and test methods are defined in any case (with appertaining conformity criteria) in order to demonstrate the quality.

In accordance with the strategy the concrete specification comprises requirements that ensure the use of highly classified and tested constituents.

The composition of concrete is controlled by a small number of detailed requirements and when possible by performance tests which give an evaluation of the concrete durability.

In addition a comprehensive pre-testing programme is required. One or more major realistic full scale trial castings shall be performed and the contractor shall state how his execution methods have influenced the mix design and selection of constituent materials.

Performance tests are used to the extent that the test methods applied can divide concrete mixes in acceptable and not acceptable mixes or can reflect reality. Most of the methods are carried out as an accelerated version of reality, where measures such as increased temperatures, pressure or concentration are used to get a quick reply to a question that can only be answered by waiting for a 100 years.

As all the mechanisms that deteriorate concrete are not known in details and can not be formulated in exact mathematical terms, the acceleration factor can not be calculated correctly and it is not even possible to remain on the safe side. Durability calculations can therefore not be left to the contractor.

As the Owner wants to be in control, the calculations and evaluations must be performed by the Owner's consultants and the results (detailed requirements and performance tests) are written in the specifications.

Basis for Decisions

Based on the state of the art of concrete technology and experience from similar major concrete constructional works, a number of subjects were identified which have to be evaluated before writing the final version of the specification. For each of these subjects a technical note were prepared.

Each technical note comprise a state of the art of the subject concerned and a critical analysis of previously formulated requirements. All technical notes include a conclusion containing the recommended set of requirements.

Technical notes are prepared about the following subjects:

- Frost Resistance
- Temperature and stress requirements
- Protection against evaporation
- Conformity procedure
- Comparison of concrete requirements with similar requirements and properties for other structures
- Chloride penetration in concrete
- Alkali-silica-reactions
- Blast furnace cement
- Casting methods
- Crack investigation
- Fire resistance

Environmental zones and main types of concrete

The immersed Tunnel is divided into different *environmental zones* based on the aggressiveness of the environment. Between the various zones different requirements for the concrete quality, concrete cover and cracking are formulated. Within each zone a minimum concrete quality is required, which is expressed as a specified concrete type. Two main types of concrete are defined:

Type A: with a maximum water-cement ratio of 0.40

Type B: with a maximum water-cement ratio of 0.45

Please refer to fig. 3 below.

Fig. 3:
Principles of environmental zone classification of the immersed Tunnel

Zone	**Environment:** Examples of construction elements	**Type of concrete**
1.	**Severe marine environment**: External walls, floors and roof in the immersed Tunnel	A
2.	**Non-marine environment:** Internal walls in the Immersed Tunnel. Parts of portal buildings	B
3.	**Frost environment:** Ramps, parts of portal buildings	A with air
4.	**Marine environment:** Non-structural concrete Ballast concrete	B

Water-cement ratio

100-years required service life is identical to require a balanced combination of dense concrete and a thick concrete cover. In principle the denseness increases when the water-cement ratio (w/c) is lowered. The Owner can therefore be tempted to require a very low w/c, with the purpose of allowing use of a normal concrete cover. However even if this should be possible in theory, it is not a well-known technology, that a very low w/c will have a water-proof concrete as result.

The reason for this is that a very low w/c often is followed by a number of negative aspects, which in return will have negative effects on the denseness and waterproofness:

1. At a low w/c the tendency of internal micro cracking caused by the cement reactions is increased. The lower w/c, the higher the tendency of cracking.

   When the w/c decreases from 0.40 the tendency of cracking increases significantly. The risk of cracking seems also to increase with increased content of mineral additions and primarily by the amount of silica fume (micro silica).

It is, however, not scientific clarified in which way these internal micro cracks reduce the denseness. Maybe they have “micro”-importance. But, however, they can hardly be positive.

2. At a very low w/c you can risk ending up with a concrete-mix that is difficult to cast. Even with a normal slump the vibration time before the concrete is compacted can increase heavily and form vibration can become impossible.

   Furthermore, the concrete can be very difficult to finish in an ordinary way.

   To compensate for these negative effects it is often necessary to use an extremely high dosage of admixtures such as melamine-superplastizicers. The resulting prolonged setting time can result in production problems such as casting by day and finishing and curing by night and a with a lower quality of the final product as consequence. Crust-formation on surfaces are also observed in some occasions.

3. The prolonged setting times, often in connection with concrete with low w/c together with a high dosage of plastizicers, involve the risk of getting an unstable air-entrained system in the concrete.

   The frost resistance of the concrete can be reduced considerably. This is nevertheless no problem for the immersed parts of the Tunnel, which is not exposed to frost.

Taking all these potential risks with very low w/c into consideration, it is concluded that an optimum concrete quality is obtained using a concrete with a w/c maximum of 0.40, but not much lower. Experience from Swedish and Danish bridge construction shows, that concrete of this quality in general fulfills very large demands for quality.

In the concrete specification for the Öresund Tunnel the requirement for w/c is that it must not exceed 0.40 in the most exposed construction elements, i.e. the external walls of the Tunnel. Because this is a maximum value, the mean value (“the target value”) will be approximately 0.38.

This is a reasonable requirement, which should not involve any problems in the construction phase. No requirements are stated about the highest allowable water content or cement content, demands, which could involve restrictions for the contractor selecting his optimum mix. The primary requirement for well-known technology is therefore satisfactory fulfilled.
In the more moderate environmental zones a maximum w/c of 0.45 is required (the mean value is 0.43) which also is a concrete of a very high quality.

Concrete cover

On basis of the w/c requirements as stated above a sufficient concrete cover for the reinforcement bars should be determined. Or to put it another way: Which cover shall be required taking the required w/c and the overall requirement of 100-years of service life into account?

Previously it had been a widespread opinion among scientists that it is hardly impossible to cope with a desired service life of 100-years in a marine or deicing environment, unless the concrete cover is very big.

It is important to realize that this thesis was based on <u>laboratory</u> measurements of chloride diffusion and the critical chloride content (before corrosion starts). The question was, what will happen in the real life?

To clear this picture comprehensive field surveys have been carried out during the last years in Sweden and Norway. Chloride diffusion in concrete in marine environment has been examined under real life conditions. It appears from the results that laboratory tests often overestimate the real diffusion speed with a factor of 20 or more.

Furthermore it appears that the normal accepted critical chloride content often is much too low, especially for concrete with pure Portland cement. This means that the chloride content in the concrete near the reinforcement can be higher than normally believed without corrosion.

Measurements of chloride penetrating into the repaired piers on the Öland Bridge in Sweden, together with measurements of samples from the field station run by SP in Träslövsläge in Sweden, shows that a service life in sea environment of 100-years with almost certainty is obtainable in a crack free concrete with w/c of 0.40 and with pure Portland cement, if the concrete cover is around 75 mm.

This even includes a pessimistic assumption about the critical chloride content.

In less chloride aggressive environment the concrete cover can be reduced to less than 75 mm.

Please refer to fig. 4 below, which is identical to fig. 3 for the first three columns.

Fig. 4:
Requirements for w/c and cover in the immersed Tunnel

Zone	**Environment:** Examples of construction elements	**Type of concrete**	**Water/ cement ratio**	**Cover in mm**
1.	**Severe marine environment**: External walls, floors and roof in the immersed Tunnel	A	0.40	75
2.	**Non-marine environment:** Internal walls in the Immersed Tunnel. Parts of portal buildings	B	0.45	50
3.	**Frost environment:** Ramps, parts of portal buildings	A with air	0.40	75
4.	**Marine environment:** Non-structural concrete Ballast concrete	B	0.45	Not relevant

A concrete cover of 75 mm is rather high according to normal Swedish and Danish practice. Possibly a smaller concrete cover could also give a 100-year service life. However, it is a fact that based on today's level of knowledge it is not possible to safely calculate a 100-year service life with a concrete cover less than 75 mm in a very aggressive chloride environment - if the w/c requirements shall be within limits where the concrete is workable.

One should also take into consideration that the service life of a structure made with a specific mix-design is almost proportional to the square of the concrete cover. A decrease in cover from 75 mm to 60 mm resp. 50 mm will therefore reduce the service life with a factor of $(60/75)^2$ = 0.64 resp. $(50/75)^2$ = 0.44 resulting in a service life of 64 resp. 44 years. This calculation also shows the importance of securing the required cover during the construction.

Crack free concrete

The external walls of the Tunnel are exposed to a very heavy environmental load. No membrane is placed at the outside of the concrete with the consequence that a high water pressure (around 20-30 meters) will constantly be applied to the concrete which means that a small but constant flow of salt water will penetrate in through the concrete.

When - or if - the water arrives at the inside of the Tunnel it will evaporate and leave the chlorides in the concrete surface. The chloride content in the cover of the inside of the Tunnel must not during the whole service life reach a level that is so high that the reinforcement corrosion starts.

The water and subsequent chloride flow should therefore be limited as much as possible. This process is mainly controlled by the w/c and the amount of cracks, and with the required w/c in practice only the cracks. This statement shall be somewhat elaborated below.

Measurements of the transport of water through concrete which has been performed at Lunds Technical University show that the water flow is very little in a concrete with w/c 0.40 and a thickness of 1 m. You can therefore expect that the total amount of water passing the concrete during 100 years is so low that chloride concentrating to a risky level would not take place if the chloride ions were transported at the same speed as water. Even that is a pessimistic assumption because transport of chlorides is slower than transport of humidity.

At the outside of the Tunnel walls the chloride concentration is high all the time corresponding to the chloride concentration in Öresund, i.e. less than 1,6 weight-%. This concentration is nevertheless so low that it probably cannot initiate corrosion in the reinforcement. Even if corrosion should start the speed of corrosion will be low and of little practical importance because the concrete is permanently water-saturated.

If the concrete cracks, very large amounts of water and chlorides can be transported through the concrete. A 1 m long crack with a width of 0,1 mm in a 1 m thick concrete wall can theoretically transport 100.000 tons of salt water during 100 years when the water pressure corresponds to 30 m depths of water. A crack width of 0.001 mm transports only 110 kg water during the same time.

Therefore, very strict requirements to crack free concrete are specified. For the construction elements most severely exposed to the environment a total crack free concrete is required.

Early-age crack control

Temperature difference requirements have traditionally been used as means of preventing early-age cracking. Temperature difference requirements do not reflect the influence of the restraint conditions and the mechanical concrete properties (for example early-age shrinkage, which depends on the mix-design). If the risk of cracking should be transformed to a temperature difference requirement it therefore has to be very conservative requirements to cover all restraint conditions and concrete types.

As a consequence the requirements to early-age crack control are based on stress calculations making it possible to take into account the actual restraint conditions and concrete properties.

The requirements are stated as a double requirement where the Contractor shall 1) make a calculation (simulation) of the crack risk (P) and document that P is lower than the limit and 2) inspect the structures for cracks and measure any crack widths (w) and document that w is lower than the limit.

We shall be less than 0.20 mm except for the water retaining parts of the tunnel and the splash zone on the bridge where no cracks are allowed.

The calculation of P shall be performed using a Finite Element Method on a computer. The input data shall be the properties of the hardening concrete as determined mainly by testing and other data necessary to describe the contractors planned execution and the environmental conditions (wind, temperature, etc.). The stresses calculated by the program shall be divided by the axial tensile strength to form the cracking risk, P.

The acceptable risk of cracking (P) is specified as 0.7 for all water retaining structures and 1.0 for all other structures.

As in-situ measurements of stresses and strains are almost impossible, the monitoring of the hardening process shall be based on temperature measurements.

All work methods, inspection methods and equipment for temperature control shall be tested during pretesting or in trial castings. The work methods and equipment shall be evaluated by temperature measurements, which shall be compared to calculated temperatures.
In production testing the temperature shall be monitored in a number of locations. These locations shall be selected on the basis of the planning calculation where critical cross sections are identified.

Cement and additions

Pure Portland cement and Slag cement (more than 66% slag) are allowed to be used in all parts of the Tunnel. Fly ash and silica dust may be used in restricted quantities together with Portland cement. The same w/c applies for concrete with mineral additions as for concrete with pure Portland cement or Slag cement.

The additions are allowed taken into calculation of the w/c by multiplying the amount of addition with an efficiency factor and add the result to the cement content. The efficiency factors are fixed corresponding to how many kilograms of pure Portland cement one kg of addition can replace from a durability point of view.

Portland cement must be of the low alkali type considering the risk of alkali-aggregate reactions. The C_3A-content is allowed up to 5% considering the need of sulfate resistance in the marine environment. A minimum value of C_3A has not been required because modern field surveys have not been able to show that the C_3A-concentration influences the risk of reinforcement corrosion.

No requirement for maximum heat development is stated but the requirements to early-age crack control do that low heat cement in general will be the best choice.

Slag cement shall be sulfate resistant and therefore it shall have a very high slag content. Cement of this type was developed in Sweden in the end of the 1970's and the beginning of the 1980's. It was sold under the name of “Massivcement” and contained 65% granulated ground blast furnace slag.

Slag cement concrete does often have a relatively low heat development, which in principle should be useful to reduce the risk of cracking. During practice and laboratory tests it has been shown that concrete with slag cement can be more brittle and therefore more sensitive of early-age cracking than Portland cement concrete with the same heat development.

It can be mentioned that concrete with Slag cement has been used successfully in a number of immersed tunnels in the Netherlands in spite of a considerably higher w/c of 0.55.

Silica fume (micro silica) is allowed in an amount of maximum 5% of the total binder content but only in concrete with Portland cement. The efficiency factor shall be 2 and this value is equal to Danish but higher than the Swedish standards. The size of the efficiency factor does, however, only have a limited influence considering the allowed content.

Fly ash is allowed but only in concrete with Portland cement with or without silica fume. The maximum allowed fly ash amount is 15% of the total binder content, and the efficiency factor is 0.3, i.e. the same value that has been used in Sweden but lower than the Danish value of 0.5.

Aggregate must be “pure and healthy”. All aggregates including sand and fines must pass a comprehensive pre-testing focused on the alkali reactivity. Many of these test methods are very time consuming wherefore the tests must be started early.

Frost resistance shall be guaranteed by selecting a concrete mix with an air-entrained system of high quality and stability. Through comprehensive pre-testing of the concrete, the necessary air content shall be determined in the fresh and in the hardened concrete.

The pretesting includes salt scaling tests according to the Swedish method, “Boråsmetoden”, as well as tests of the internal frost resistance with the so-called dilation method. Here concrete is water saturated for half a year followed by one freeze-thaw cycle. No formation of cracks inside the concrete must take place.

Production control will be carried out through frequent testing of the air-content of the fresh concrete. Tests must also be carried out of the air content of the hardened concrete and of the salt scaling test on drilled cores.

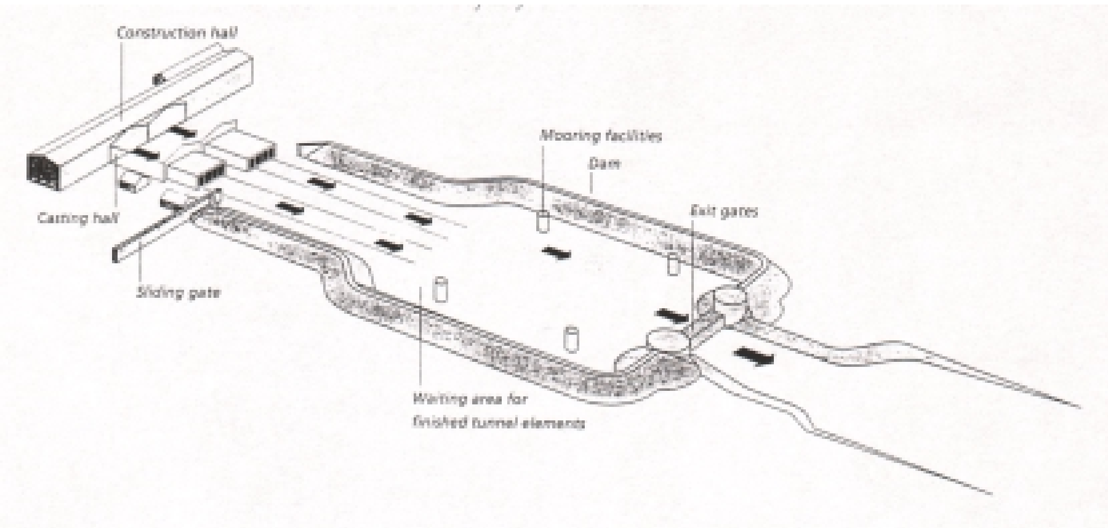
Full-scale trial castings

An important link between the completed pretesting and the production is the full-scale trial castings. Here the contractor shall prove that the intended concrete mix corresponds to the selected production method. A full-scale trial casting is a major casting performed under almost full-scale conditions with regard of transportation, casting and curing methods. These full-scale trial castings must be carried out for every new type of construction element.

Element fabrication

All 20 tunnel elements are fabricated in a purpose-built casting yard at the Nordhavn area of Copenhagen Harbour. A novel concept based upon a very high level of factory production is used. An element is prefabricated in 8 segments of 22 m. Each 22 m segment is cast in one single pour of 2,700 m^3 of concrete over an approximately 24-hour period. By casting an entire section in one single operation, production is speeded up, and thermal problems in the concrete during the curing are reduced considerably.

Factory conditions are achieved by the erection of sheds where the reinforcement is assembled and prefabricated. A central shed covers two production lines, where two segments are produced simultaneously per week, in order to meet the time schedule. Each section is produced on specially prepared formwork.



After three days of curing the segments are ready for the next step. The base formwork is released, and the segment is jacked forward with the formwork remaining in place. Once the elaborate formwork is released, the segment is resting on six skidding beams, positioned underneath the tunnel walls. These supporting concrete beams are continuous over 300 m, and provided with stainless steel plates on top. Six bearing pads per section are placed on each beam, so that a total of 36 pads carry one segment. Jacking forward is performed by pressing against the segment joint, moving the pads along the steel plate.

Now the following segment can be made, starting with the placing of the prefabricated reinforcement on the base formwork. Later the formwork for the inner and outer walls is placed in position, and the segment is cast against the previous one, giving a perfect match.

When the last segment is ready and joined with the previous segments, an 8-segment tunnel element is formed. The element is then jacked out of the shed.

The joints between the segments are provided with a continuous water stop in each face, containing groutable tubes to ensure watertightness. The segments of a tunnel element are held together with temporary prestressing cables until the tunnel element has been backfilled in the trench.

Both ends of the tunnel element are equipped with a steel frame for the immersion joint, including a GINA Rubber profile for initial watertightness. Completion of the tunnel elements for the immersion includes placing of ballast concrete, water ballast tanks, and temporary end bulkheads.

Two tunnel elements are produced in parallel and when finished they are jacked to the end of the skidding beams, and the sliding gates to the production facility are closed in preparation for flotation of the elements inside the basin.