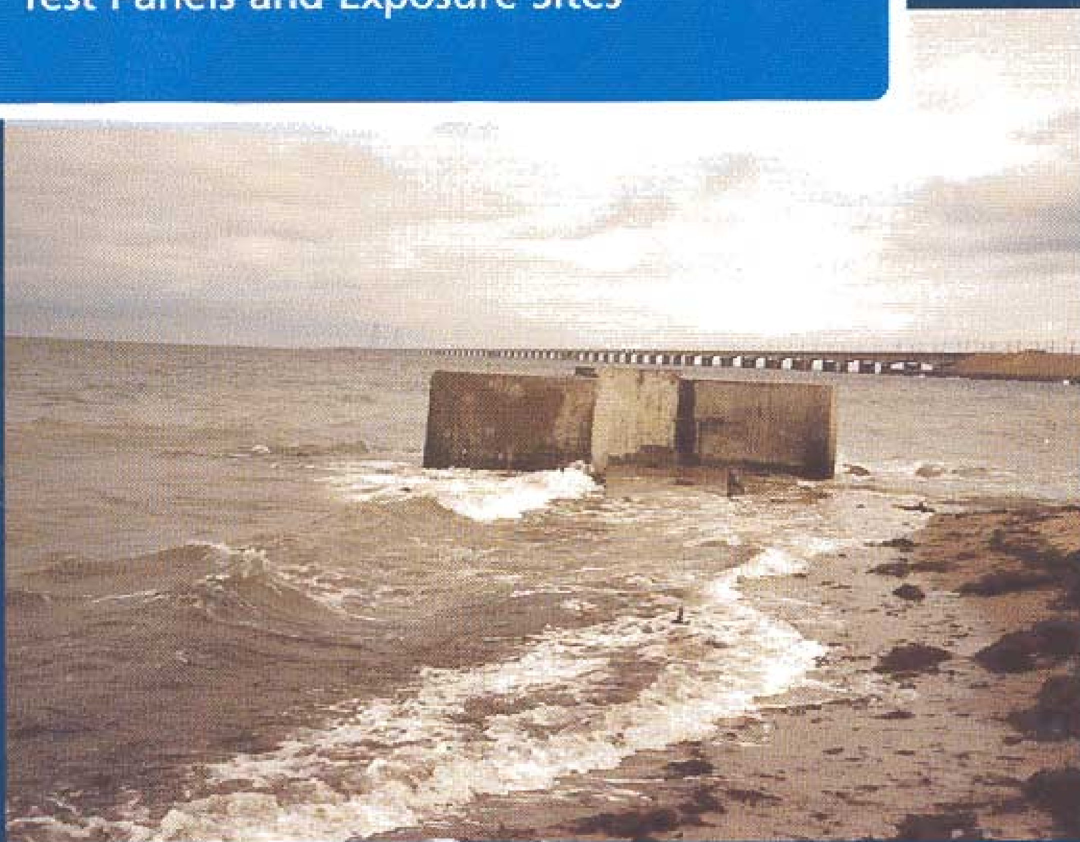
HETEK

Test Panels and Exposure Sites



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Abstract

This report forms a part of the Danish Road Directorate's research programme called High Performance Concrete - The Contractor's Technology (abbreviated to HETEK). HETEK is divided into eight parts where part no. 7 concerns Pre-testing of concrete, materials, composition and workmanship Prior to the casting of concrete structures a pre-testing shall be carried out. Usually a pre-test includes casting of a test panel.

The Danish Road Directorate is planning to establish some sites where the concrete test panels can be exposed to different environmental conditions.

This report describes the design of the concrete test panels, proposals for the test programme and lay out for the proposed exposure sites.

Front Page photo

The front page photo shows Storebæltsforbindelsens exposure site at Knudshoved, Denmark. The test panel has a total weight of approximately 40 tons.

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0. Preface

The research programme for pre-testing of concrete and concrete works forms part of a larger research programme called High Performance Concrete - The Contractor's Technology (abbreviated to HETEK).

The research programme, offered by the Danish Road Directorate, is financed by the Ministry of Industry - The Research Contract Committee. The technical management of the project is attended by the Danish Road Directorate by Erik Stoklund Larsen, in cooperation with the leaders of each part of the research project.

The research programme for pre-testing of concrete and concrete works is performed by a consortium composed of
Dansk Betoninstitut A/S
DTI-Byggeri
Unicon Beton I/S

Jens Frandsen (4K-Beton A/S) has performed consultancy services.

The consortium is managed by:

- Find Meyer, project manager, Dansk Betoninstitut A/S
- Christian Munch-Petersen, DTI-Byggeri
- Freddie Larsen, Unicon Beton I/S
- Jens Frandsen, 4K-Beton A/S

The present part of the programme: Pre-testing of concrete and concrete works, consists of following 5 phases:

1. State of the art
2. Graduation
3. Test panels and exposure sites
4. Incorporation of results from other parts of the research programme
5. Final report and elaboration of instructions

This report is about phase 3 concerning test panels and exposure sites.

The report has been reviewed and commented by Reidar Kompen, Statens Vegvesen, Vejdirectoratet Norge, who is a member of the technical committee of HETEK.

1. Introduction

The Danish Road Directorate intends to place test specimens, so called test panels, at specific exposure sites, where they are exposed in different environments. The goal is to be able to estimate the resistance of panels against erosion in the chosen environments. The test panels are intended to be produced either in connection with contractual testing of recommended types of concrete for specific works, or under a seperate contract possibly with other types of concrete mixes, construction methods and/or panel design.

The exposure sites will be chosen so that they correspond to the normal environment either along motorways or by road bridges in Danish sea water.

The expected extent of testing under this long-term testing programme must be taken into consideration when outlining the size and number of test panels. Possibilities of transportation to the exposure sites must also be evaluated.

The present report is concerned with the test programme, the design of the test panels and the layout of exposure sites. The report also gives an estimate of expences.

2. Test panel

2.0 Significant parameters for designing a test panel
The following must be taken in consideration when designing and constructing a test panel:

- Size and weight
- Geometrical design
- Reinforcement and concrete cover
- Surface available for testing
- Implementation

In principle there are a number of points that must be considered regarding panel design.

One point of view is that the panels must be representative for the actual constructions. The panels must therefore be designed according to typical construction details and they must be constructed as the actual constructions. If the panels are placed in the same environment as the actual constructions, the constructions will not be affected by drilling of cores because samples can be taken from the panels. This type of panel will in the following be called "CONSTRUCTION PANELS".

A second point of view is that it is primarily the concrete mix's resistance against deterioration which should be analyzed. Design and construction are of secondary importance. If the design and the construction are the same, comparison of different concrete mixes can be made on this basis. Therefore the panels do not have to be large. This type of panel will in the following be called "LABORATORY PANELS".

The third point of view is that the panels need only to a certain extent to be representative of the actual constructions. Such panels, which in the following are called "STANDARD PANELS", must be designed and constructed according to predefined procedures.

The geometry of a standard panel must be relatively simple, corresponding to a "Standard Construction". More complicated construction details are not examined, as they are for the construction panels. The implementation must correspond to "Standard Implementation" and will thereby reflect the actual implementation in a higher degree than for laboratory panels. The standard panels must therefore not be to small.

Each of the above mentioned types of panels is evaluated in the following.

CONSTRUCTION PANELS
The combination possibilities for design, reinforcement and construction of construction panels are numerous due to the fact that any specific construction is performed with a specific concrete mix. They contain complicated geometrical details and arrangements of reinforcement, and form materials and construction methods can be different.

For significant constructions, construction panels are often prescribed to weigh at least 40 ton. Transportation and placing of such panels is very expensive and not always possible.

Concrete cast in specimens with complicated construction details and heavy reinforcement has the disadvantage that it is almost impossible to examine the concrete by using the normally used methods for testing durability parameters. The reason for this is that testing is carried out on drilled cores, and in areas with heavy reinforcement drilling is very difficult. The cores break and do not contain enough concrete for further research. The concrete to be tested may also be under the influence of the complicated drilling process, which can result in notch effects and often failure when drilling and removing.

One must face the fact that destructive methods of measurement cannot be used in such complicated casting areas, even though it is these areas which are of the greatest interest. The advantage of construction panels is that they reflect real constructions. The disadvantages are that testing of complicated areas does not give reliable results and that testing cannot always be carried out. Construction and transportation are also expensive.

LABORATORY PANELS
With this type of panel it is possible to design small panels which entail minimal expenses for construction and transportation, especially if the panels are constructed with plain concrete.

Size, weight and geometrical shape can be chosen freely. However, the panels must be chosen so that they remain at the exposure site during the whole testing period. This means that the panels must be stabile against effects of waves or current, and that they must not be easy to remove by any attempt of vandalism or theft.
In accordance with the purpose of the laboratory panels, reinforcement is not required. The whole surface of the panel is thus available for taking samples.

Experiences from the plain concrete test panels of the State Bridge of the Great Belt (paragraph 3) show, however, that the subsequent testing would have been more successful if the panels had been reinforced.

Construction of test panels must be done under consistent conditions - preferably in a laboratory - so that comparison of durability results for different kinds of concrete mixes can be made on the basis of consistent panel construction.

The disadvantages of laboratory panels is that the influence of construction design and actual construction conditions is not examined. It is also obviously impossible to examine the state of reinforcement if plain concrete laboratory panels are used.

STANDARD PANELS

Standard panels are in principle designed and executed as something between construction panels and laboratory panels.

The geometrical shape is relatively simple and corresponds to commonly used construction elements such as walls, columns or beams. Size and weight is limited so that panels can be transported by a truck with a crane (approx. 2 ton with a range of 4 m).

Standard panels are executed with reinforcement. The amount of reinforcement can be chosen, e.g. corresponding to 100 kg/m³ concrete. The condition of the reinforcement can be followed during the testing period. The concrete cover can either be chosen identical to the actual construction or smaller. If the concrete cover is chosen as prescribed for the constructions (in Denmark typically 50 mm for constructions exposed to chloride on land and 70 mm for constructions in seawater), it is not expected to be possible to observe any corrosion of reinforcement during the first one hundred year test period. In order to obtain more information about deterioration of the reinforcement, the concrete cover can been chosen smaller, e.g. 15-25 mm. Thereby the construction conditions in the concrete cover are different (e.g. the amount of large aggregate), and the placement of some of the reinforcement with the prescribed concrete cover and the rest with reduced concrete cover should be considered.

The geometry and the reinforcement of the standard panel must be selected so that the surface area available for testing is as big as possible. However, the geometry and reinforcement must fulfill the structural conditions mentioned above, and in addition there may be other structural conditions to take in consideration. The geometric design and the placement of reinforcement will therefore be a compromise.

Based on an evaluation of the above mentioned types of panels, a decision has been made to perform panel design corresponding to "Standard panels".

2.1 Design of a standard panel

As mentioned earlier, the geometric shape is expected to be relatively simple corresponding to commonly used structural elements e.g. walls, columns and beams.

Figure 1 shows the chosen standard panel. The panel corresponds to a wall with a thickness of 0.6 m. The geometry is the same as the test specimen described in the instruction "Basic Construction Pretesting".

The standard panel weighes approx. 2 ton.

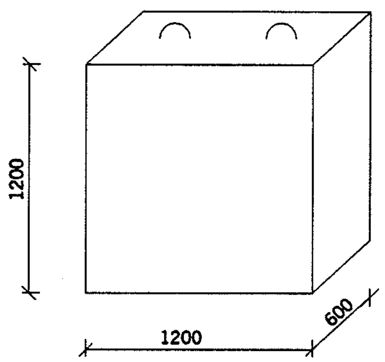


Figure 1, standard panel, geometry.

The reinforcement in the standard panel is the same as in the test specimen described in "Basic Construction Pretesting". The reinforcement is shown in figure 2. The degree of reinforcement is app. 100 kg/m³ similar to conventional reinforced constructions. The concrete cover is the same as in the actual construction. This means 50 mm for constructions exposed to chloride on land and 70 mm for constructions in marine environment. 50 mm concrete cover is illustrated in figure 2.

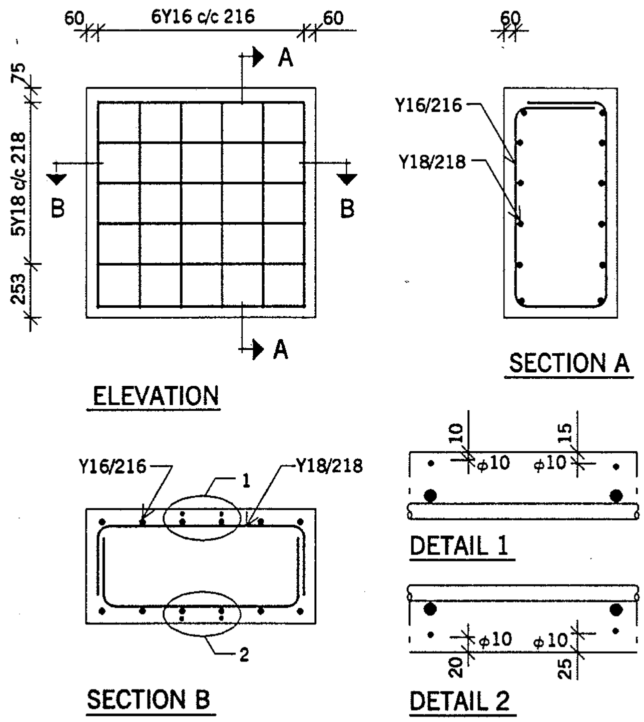


Figure 2, Reinforcement in standard panel.

With such a large concrete cover, no information about corrosion of reinforcement can be expected for the first 100 years. It should be noted, however, that the quality of the concrete in the concrete cover will reflect the conditions in the actual constructions. To obtain more information about corrosion, a few extra vertical rebars ø10 can be placed closer to the surface - similar to concrete covers of e.g. 10, 15, 20 and 25 mm. A proposal for their placement is shown in figure 2.

In connection with the long-term testing of the standard panels, it is primarily the concrete in the exposed surface area which is of interest. The standard panel illustrated, 0.6 m thick, has a relatively large amount of "inner concrete", which is of less interest as far as testing is concerned.

Standard panels with different design and a larger surface/volume - ratio are shown in appendix 1. Such panels have been constructed and placed at exposure sites in Norway.

Similar panels can of course also be used, but in this case the specimens made according to the regulations in the instruction cannot be used.

In the following the standard panels are presumed to be designed as shown in figure 1.

2.2 Test programme proposal

The long-term test programme must include testing of those parameters which are of greatest importance for calculating deterioration prognosis. Samples for examination of these basic parameters are expected to be taken from the inner of the panel. The deterioration mechanisms, with additional basic parameters, which should be included in the test programme, are

- Chloride penetration
  - Parameters of diffusion (bulk diffusion)
  - Capillary depression
  - Petrographic analysis

- Frost/thaw deterioration
  - Air void analysis

The long-term test programme also includes functional testing of the environmentally affected concrete surface, with the aim of being able to determine whether there is correlation between prognosis and reality.

The functional testings that should be included in the test programme are:

- Chloride penetration
  - Profile of chloride
  - Corrosion of reinforcement

- Frost/thaw deterioration
  - Freeze-thaw analysis

- Other deterioration
  - Petrographic analysis

The detailed test programme for basic parameters and the functional testing of the surface concrete must be planned according to the scope of the test.

There can, in principle, be 3 different scopes:

- Reference testing
- Comparison testing
- Research testing

REFERENCE TESTING

Reference testing implies that the standard panel is used as a reference for corresponding "Standard Constructions" performed with the same concrete and the same construction methods. The test programme for such a reference test should include examination of basic parameters (e.g. 28 days after casting), which can be used for the deterioration prognosis.

Functional testing of surface concrete will be dependent on the deterioration prognosis, e.g. after 10, 20 and 50 years.

COMPARISON TESTING

The purpose of comparison testing is, for standard panels with different concrete mixes (but otherwise identical), to examine resistance against deterioration by comparison.

The purpose could, for instance, be a selection on the basis of a 10 year test programme including:

- Examination of basic parameters, e.g. after 28 days and 10 years.
- Examination of functional testing, e.g. after ½, 1, 2, 5 and 10 years.

The comparison could also be related to implementation, e.g. vibration time or finishing treatment. In this case, the standard panels must be purpose-made, and concrete mixes must be the same for the panels that are compared.

RESEARCH TESTING

The purpose of research testing could be to test existing theories in practice and, if necessary, to revise them or develop new theories that utilise the results obtained from testing.

The test programme for such a research test should include the previously mentioned basic parameters and functional testings, and also be adapted to any wishes from other interested parties: Education institutions, research centres and consulting companies. A detailed plan can therefore not be given here.

DRILLING PLAN

The cores that are used for determing the basic parameters must have a length of approx. 200 mm. Figure 3 indicates the possible drilling areas on a panel placed in water with a depth of approx. 0.25 m. A total of 48 cores can be drilled between the rebars. If the panel is exposed on land, another 12 cores can be drilled in the lower part of the panel.

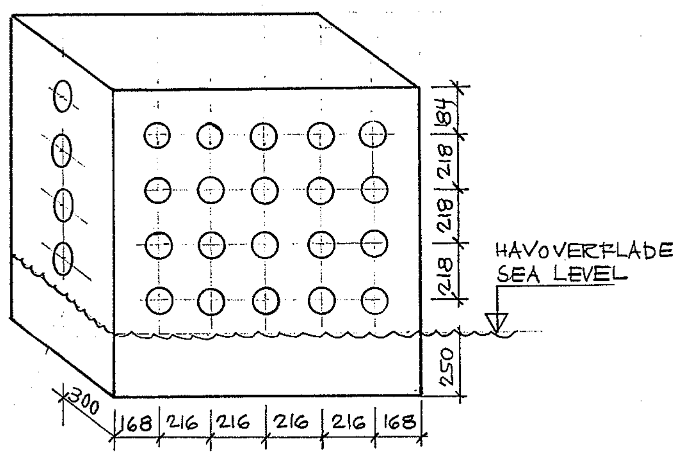


Figure 3, Drilling plan, 1:30, Cores ø100 x 200 mm for determination of basic parameters.

Only the outer part of the concrete can be used from the cores that are drilled for functional testing. The cores do not need to be longer than approx. 50 mm and can therefore be removed from areas where rebars cross each other. Figure 4 indicates a possible placement of these cores from a panel placed in app. 0.25 m water. It is possible to drill 92 cores. If the panel is exposed on land, another 28 cores can be taken from the lower part.

If the upper parts of the cores drilled for the determination of basic parameters, figure 3, are not used, they may be used in the test programme for functional testing. Examination of the state of the rebars (corrosion) can be done by cutting into the rebars with reduced concrete cover, see figure 2 and 4.

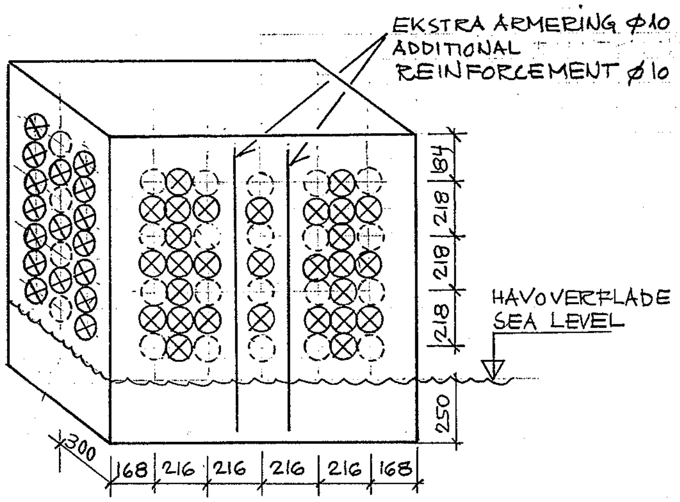


Figure 4, Drilling plan, 1:30, Cores ø100 x 50 mm for functional testing.

Holes must be repaired after removal of cores in order to insure that the influence of contined exposure is uniform on the entire surface. Repair can be done with concrete which is compatible with the concrete in the panel, and is suitable for manual casting. The material must be declared by REPTON.

The holes must be cleaned and moistened with fresh water so that the concrete is saturated and surface-dry before filling.

The holes must be protected against sea water until the repair is finished.

The holes are to be filled with the repair material in 50-100 mm layers. Every layer is compacted by stamping so that there is full bonding to the surface in the holes. The filled hole must be protected against saline infection and drying for at least one week.

A more detailed drilling plan can only be elaborated when the test program is finally determined.

For the panels placed in 0.25 m seawater, the drilling plan must take into consideration the fact that there may be differences in the degree of exposure of the 4 sides. This must be taken into consideration when comparing results. The same applies when panels are placed at the roadside.

2.3 Price estimate

The estimated price for making one test panel is approx. 10,000 DKK. Panels from projects where the instruction has been used can be used without any further costs.

In addition there are expenses for inspection, drilling of cores, repair of holes and the final testing.

The price for drilling one core and repairing the hole is dependent on the transport distance and the accessability of the exposure site, and is estimated at approx. 1,000 DKK.

Inspection, reporting and evaluation is estimated to cost 8,000 DKK per test panel if at least 10 test panels at the exposure site are examined at the same time.

Expenses for the testing mentioned in paragraph 2.2 are:

Basic parameters:		
Bulk diffusion	approx. DKK	6,000
Capillary suction	approx. DKK	2,500
Petrographic and air void analysis	approx. DKK	3,500
Total	approx. DKK	12,000
Functional testing:		
Analysis of chloride penetration	approx. DKK	1,500
Freeze-thaw analysis	approx. DKK	2,000
Petrographic and air void analysis	approx. DKK	3,500
Total	approx. DKK	7,000

The total costs per standard panel for the above mentioned test programme with additional testing periods for the basic parameters are in 1996 prices.

REFERENCE TESTING

Casting the panel	approx. DKK	10,000
Basic parameters, 3 samples after 28 days	approx. DKK	36,000
Functional testing, 3 samples after 10, 20 and 50 years	approx. DKK	63,000
Drilling of 36 cores and repair of holes	approx. DKK	36,000
Inspection and reporting	approx. DKK	8,000
Total	approx. DKK	153,000

COMPARISON TESTING

Casting the panel	approx. DKK 10,000
Basic parameters, 3 samples after 28 days and 10 years	approx. DKK 72,000
Functional testing, 3 samples after ½, 1, 2, 5 and 10 years	approx. DKK 105,000
Drilling of 63 cores and repair of holes	approx. DKK 63,000
Inspection and reporting	approx. DKK 8,000
Total	approx. DKK 258,000

RESEARCH TESTING

A detailed test programme must be available before a price calculation can be made.

The prices given above must be seen as estimated prices as the number of samples and periods for testing may vary.

All prices are excl. VAT.

3. Exposure sites in marine environment

3.0 Significant parameters and requirements to exposure sites
When chosing locations for exposure sites the following parameters must be evaluated:

- Chloride content in the seawater.
- Frost/thaw effects

Choice of exposure sites must also take into consideration:

- The site must be available for many years and must therefore not change appearance, e.g. caused by erosion or filling with any material
- The site must be undisturbed, so that any risk of vandalism is minimized
- The site must be easily accessable for transport of the 2 ton elements, and for further inspection and testing
- The chosen site must be affiliated to a certain structure, where inspection is carried out frequently in connection with the Road Directorates' inspection programme. Inspection of the exposure sites can therefore be carried out as a matter of routine.

Finally, the test panels must be placed at the exposure sites in a manner that:

- The distance between the panels must at least be 1.5 m, so that there is enough space to use the machine, which is used for drilling cores
- The lower part of the panels is approx. 0.25 m under normal water level. Drilling is thus possible - in calm weather - above sea level (see figure 2 and 3).
- The panels must be orientated in relation to the predominant wave and wind direction, so that the exposure of the 2 largest surfaces of the panel is as uniform as possible

3.1 Preliminary investigations/research
In order to elaborate a programme for exposure sites in marine environment, some preliminary investigations/research have been carried out on existing exposure sites and also of possible locations for future exposure sites administrated by the Road Directorate.

The following existing exposure sites have been analyzed:

- Storebæltsforbindelsens exposure site near Knudshoved, built in 1992
- The exposure site for Statsbroen Storebælt near Halsskov, built in 1979

As can be seen on the photographs, appendix 3, the test panels from the exposure site near Halsskov are in 1996 no longer exposed to seawater at normal water level. The panels were originally placed on the beach, but the coastline has now receded. The test panels were cast without any reinforcement. This is why it has not been possible to examine the influence of the penetration depth of chloride on the state of the reinforcement.

At the exposure site near Knudshoved - see appendix 2 - there has from the construction period in 1992 until today not been any analogous visible indications of displacement of the coastline, not by material sedimentation nor by erosion.

When doing preliminary investigations/research of the chosen possible locations for the Road Directorates marine exposure sites, it is important to form a correct estimate of erosion and material sedimentation. Preliminary investigations as to the placing of the panels on pontoons have been given up partly because of economical considerations, but principally because security against destruction under extreme weather conditions is not sufficient.

The following locations have been analyzed:

- Farø
- The Little Belt near the old bridge
- The Little Belt near the new bridge

3.2 Exposure site, location Farø

The proposed locations for exposure sites on Farø are directly under the bridge on the north or south side of the isle. Figure 5 shows the locations.

On the photographs, appendix 4, details of the locations can be seen.

The following should be noted:

Location

The north side of Farø is relatively undisturbed. The south side is often crowded by guests from the neighbouring cafeteria and exhibition centre.

Current and seabed conditions

Along the coast on the north and south side of Farø the current is moderat. There has been erosion on the south side by the cliffs. On the north side, east of the bridge, approx. 10 m of the area have eroded. This area was filled after the bridge was built in 1979-85. The coast areas are shallow. A rough estimate of the depth of water is less than 1 m within 15 m from land.

Transport possibilities

It is not possible for a truck to drive directly to the coastal areas. However materials and test panels can be lowered from the bridge by using a crane mounted on a truck. The truck must be placed on the shoulder on the bridge. The distance between the center of the shoulder to the edge of the bridge is approx. 3 m.

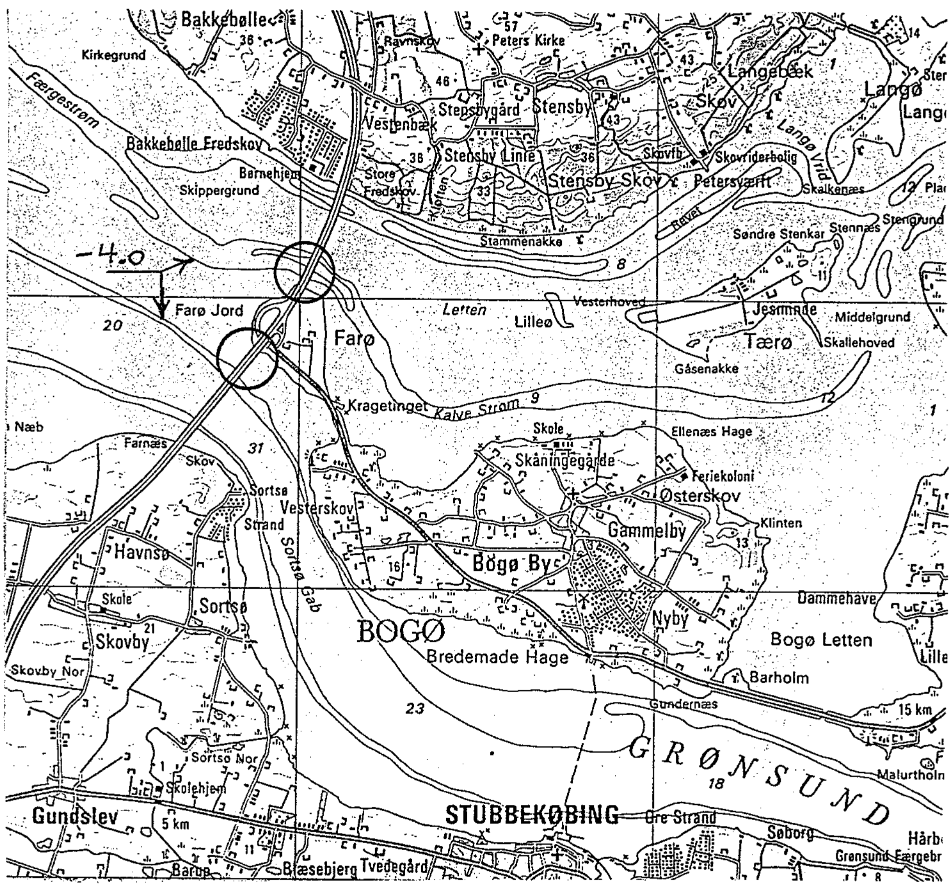


Figure 5 Plan, Farø 1:100,000.

Environmental conditions

The water in the coastal areas freezes during a hard winter. There is rarely any ice pack of importance in the near-shore areas. The Royal Danish Administration of Navigation and Hydrography has just begun measuring the chloride content in the water near Farø - see appendix 7. The results are as yet uncertain, but the salt content in the surface water is estimated to be approx. 10 mg/l on a yearly basis.

Layout

Figures 6 and 7 show a layout for an exposure site with 12 test panels on the north side of Farø.

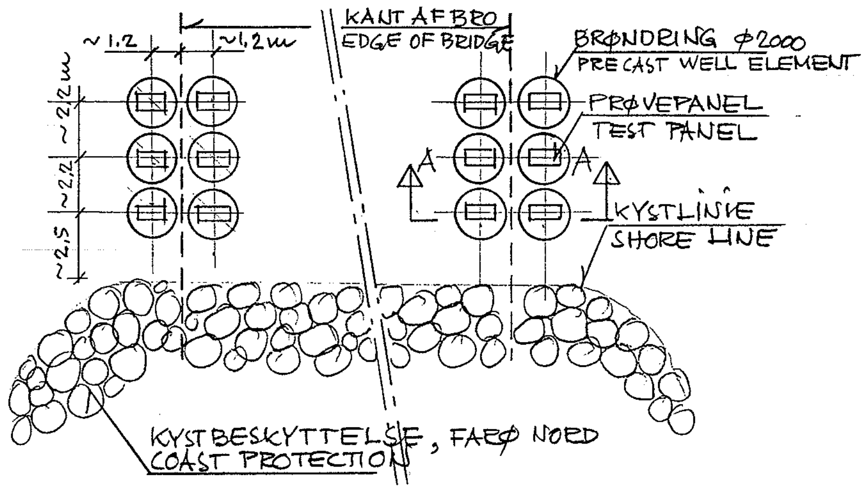


Figure 6 Exposure site, north of Farø, plane 1:300.

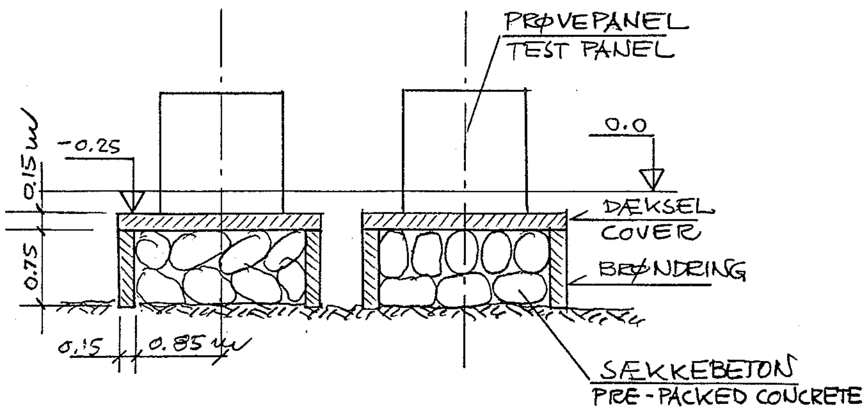


Figure 7 Exposure site, north of Farø, sectional view 1:75.

Price estimate

It is difficult to make a price estimate on the basis of the plans and sketches shown above as knowledge of soil conditions is not sufficient.

A rough estimate of the total cost of construction is 150,000 DKK.

Expenses for transportation and placing the test panels with a truck can be based on an hourly rate of approx. 500 DKK/hour.

If an estimated average time for transportation and placing the test panels is set to approx. 6 hours per test panel, the total cost would be approx. 36,000 DKK for 12 test panels. Furthermore there are expenses for signalling of road works.

3.3 Exposure site, location Little Belt, old bridge

The proposed exposure sites are located beneath the Old Little Belt Bridge, at the last pier shaft on land both on Jutland and Funen sides. Figure 8 shows where the exposure sites are located.

On the photographs, appendix 5, some closer details of the locations can be seen.

The following should be noted:

Location

The areas are relatively undisturbed.

Current- and seabed conditions

There is a strong current in the Little Belt. Erosion can be seen clearly at the old bridge on the Funen side. Any material sedimentation is unthinkable. From the coastline the seabed has a steep gradient - on a rough estimate with an angle of 30° until the waterdepth is approx. 2 m (see the contour lines in figure 8).

Transport possibilities

On the Jutland side, Snoghøj, transportation by truck is possible from Snoghøj and finally on the unpaved road to the concreted area in front of the bridge.

On the Funen side transportation by truck is not possible. Construction of an exposure site in connection with the existing glacis at the base of the pier shaft would be possible utilising transportation by ship as the water depth is sufficient.

Environmental conditions

The Little Belt is ice-free most winters due to strong currents. Measurements made by the Royal Danish Administration of Navigation and Hydrography, of the chloride content in the water near Æbelø, see appendix 7, show an average chloride content at approx. 15 mg/l in the surface water.

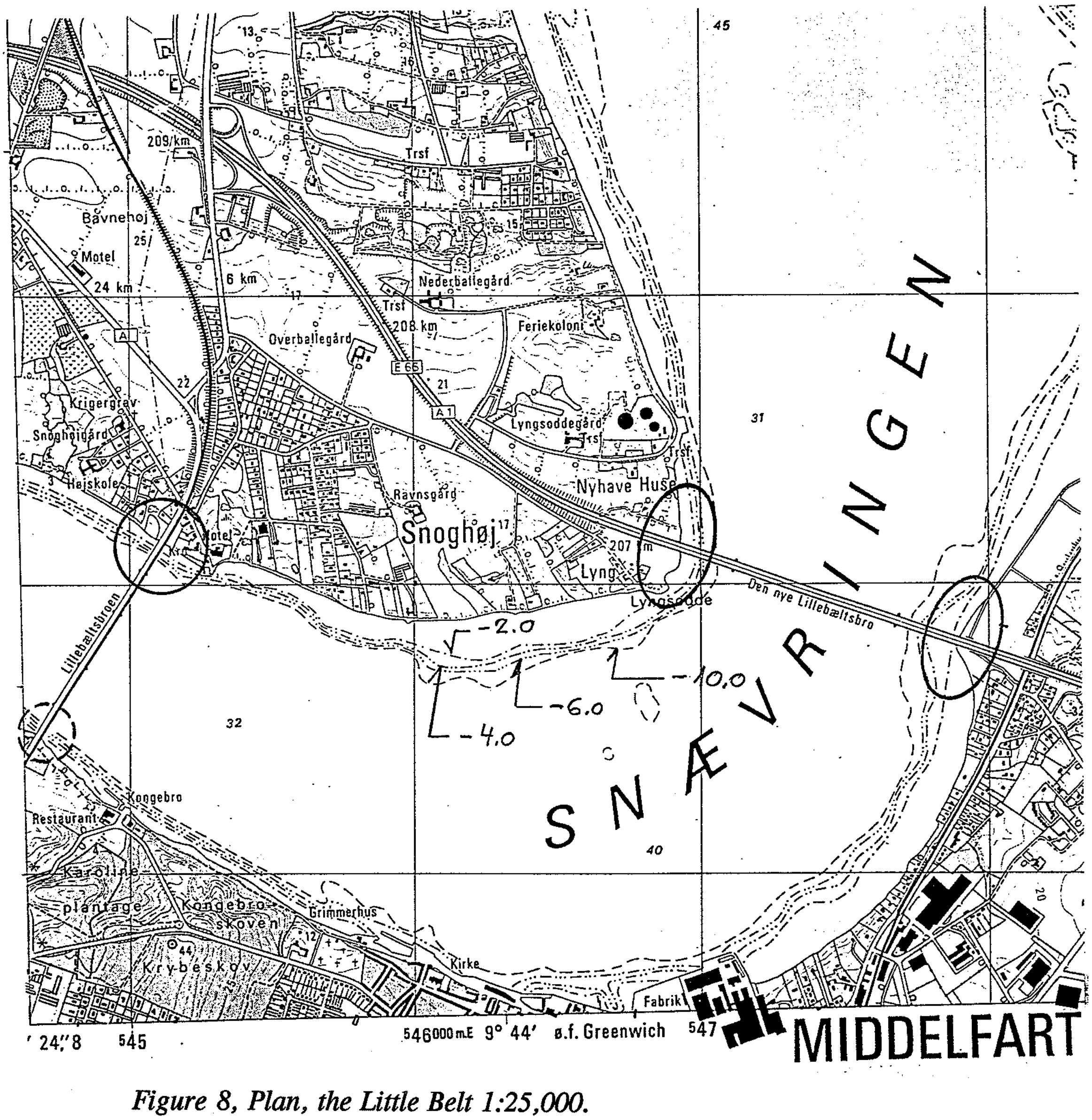


Figure 8, Plan, the Little Belt 1:25,000.

Layout

Figures 9 and 10 show a layout for an exposure site with 12 test panels on the Jutland side, Snoghøj.

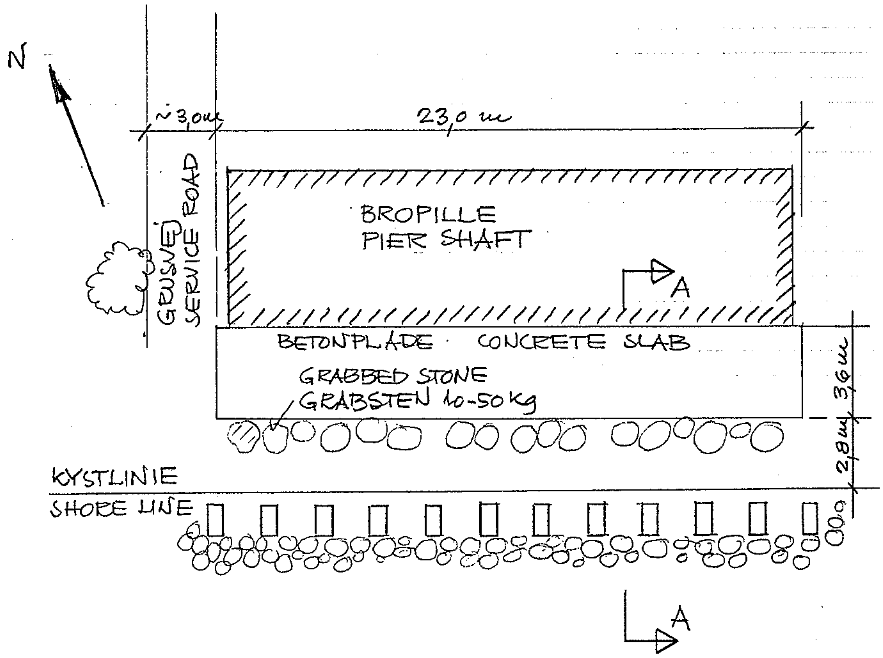


Figure 9 Exposure site, the Old Little Belt Bridge, Snoghøj, plan 1:300.

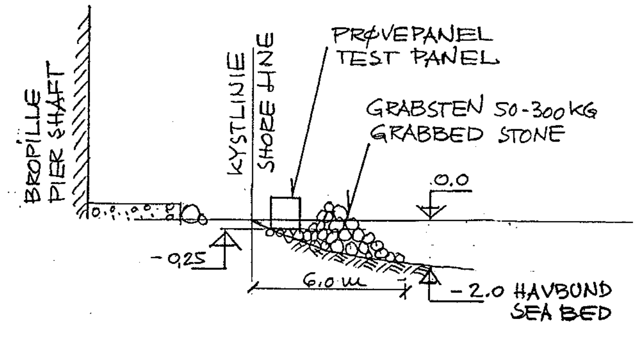


Figure 10 Exposure site, the Old Little Belt Bridge, Snoghøj, sectional view A 1:300.

Price estimate

It is difficult to make a price estimate on the basis of the plans and sketches shown above. Supply of materials from the land side would probably require repairs to the unpaved road and site conditions are complicated.

A rough estimate of the total cost of construction is 100,000 - 200,000 DKK.

Any exposure site on the Funen side is estimated to be more costly because of the difficult transportation conditions.

Expenses for transportation and placing the test panels by truck can be based on an hourly rate of approx. 500 DKK/hour.

If an estimated average time for transportation and placing the test panels is set to approx. 6 hours per test panel the total cost would be approx. 36,000 DKK for 12 test panels.

3.4 Exposure site, location Little Belt, new bridge

The proposed exposure sites are located beneath the New Little Belt Bridge, at the last pier shaft on land both on the of Jutland and Funen sides. Figure 8 shows where the exposure sites are located.

On the photographs, appendix 6, some closer details of the locations can be seen.

The following should be noted:

Location

The area on the Funen side is public and is used e.g. for angling. The area at Lyngsodde is located near to a public parking place, and is therefore also very often visited.

Current- and seabed conditions

The current is strong in the Little Belt.

The risk for erosion on the Funen side is very limited as grabbed stones have been placed along the whole public area. The water depth outside this erosion protection is approx. 2 m. From here, the seabed gradient is moderate as can be seen from the contour lines in figure 8.

On the Jutland side, Lyngsodde, the seabed gradient is even more moderate - estimated 1:4 until the water depth is 2 m. The shore has no coast protection and the risk for erosion is estimated to be very limited.

Transport possibilities

The transportation possibilities for access by truck are good on the Funen side as there is an unpaved road along the shore. However, the distance from the unpaved road to the suggested location of the exposure site is so large, that a temporary road would have to be made, otherwise it would not be possible to place the test panels with an ordinary truck-mounted crane. Alternatively a crane with longer reach can be used.

On the Jutland side the transportation possibilities are also good due to the public parking place. From here transportation can be made via the beach possibly by laying out steel plates.

Environmental conditions

Because of strong currents the Little Belt is ice-free most winters. The average chloride content in the surface water is on a yearly basis 15 mg/l - see appendix 7.

Layout

On the Jutland side, Lyngsodde, the conditions are quite similar to the ones at Snoghøj, see figure 9 and 10. The shore at Lyngsodde is a bit more shallow and the transportation possibilities are better, but the area is more disturbed by visitors than at Snoghøj. Figures 11 and 12 show a layout for an exposure site on the Funen side.

Price estimate

The exposure site on the Funen side is estimated to be more costly than the location at Snoghøj, because of the large water depth and the longer distance from the existing unpaved road to the exposure site - see figure 11 and 12.

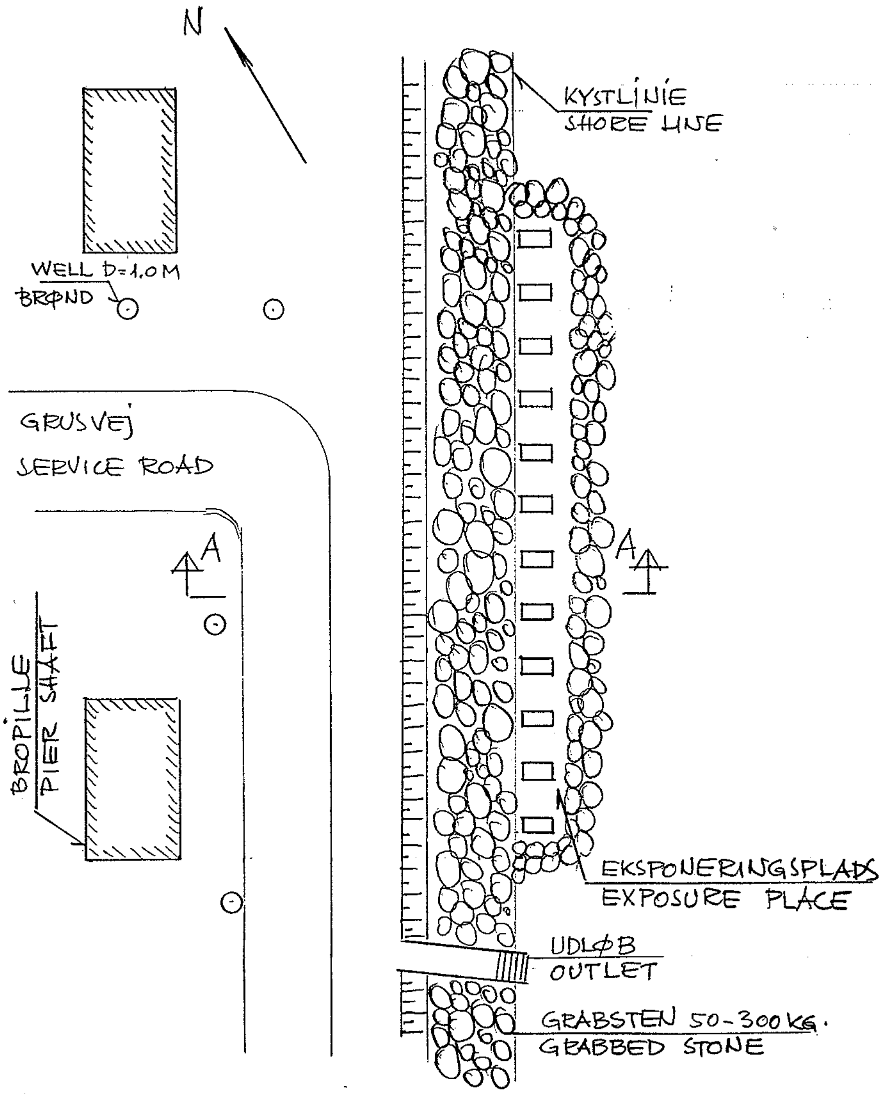


Figure 11 Exposure site, the New Little Belt Bridge, plan 1:300.

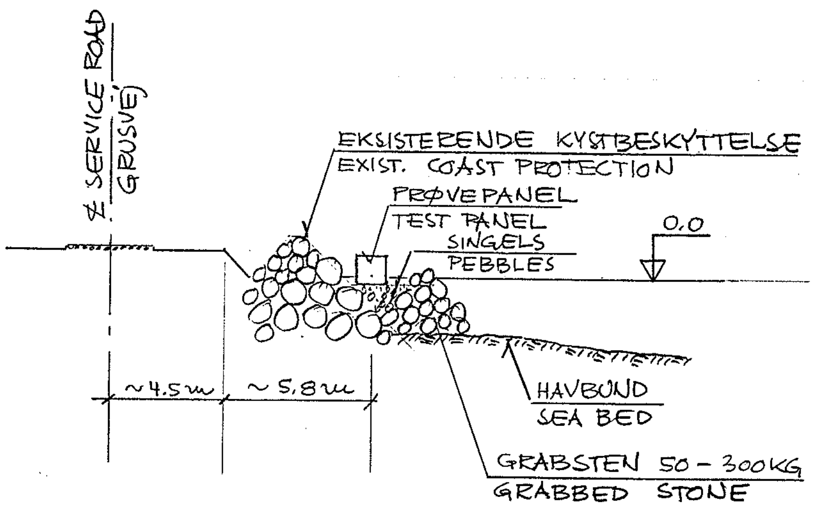


Figure 12 Exposure site, sectional view A 1:300.

An exposure site at Lyngsodde is estimated to be less costly than an exposure site at Snoghøj because of the good transportation possibilities and a relatively small water depth.

3.5 Conclusion and recommendation

Based on the preliminary investigations/research it is recommended that exposure sites in marine environment are constructed at two locations.

One is on the north side of Farø in the shallow area between the abutment and the first pier shaft. The area is undisturbed and transportation of materials and test panels can be done from the bridge.

The other location is beneath the Old Little Belt Bridge, on the Jutland side at Snoghøj. This location is also undisturbed and transportation of materials and test panels can be done from the landside.

The chloride content is different at the two locations and are continously measured by the Royal Danish Administration of Navigation and Hydrography. The preliminary measurements at Farø show a chloride content at approx. 10 mg/l, while the measurements at Æbelø, close to the Little Belt, show a chloride content at approx. 15 mg/l, both measured in the surface water. By selecting the suggested locations, the effect of different environments on the chloride penetration can be examined.

The estimated construction cost for the 2 exposure sites, both with space enough for 12 test panels, is in total 300,000 DKK in 1996 prices excl. VAT.

Transportation and placing 24 test panels is estimated to cost approx. 75,000 DKK in 1996 prices excl. VAT.

In comparison the testing programme for all 24 test panels would cost 3.5 - 6.0 mio. DKK in 1996 prices excl. VAT, see paragraph 2.3. The constructional cost is about 10% of the expenses for casting and testing the panels.

The extent of testing and the size of the exposure sites can of course be reduced, and the expenses will be reduced proportionally.

4. Roadside exposure sites

4.0 Significant parameters and requirements to exposures sites
When chosing roadside exposure sites, the following parameters must be estimated:

- The effect of chloride caused by salting
- Frost/thaw effect

Choice of exposure sites must also take into consideration:

- The site must be available for many years
- The site must be undisturbed, so that the risk for vandalism is minimized
- The site must be easily accessible for transportation of the 2 ton panels and for further inspection and testing
- The roadway next to the site must not be uneven, so that the influence of salt splashing from vehicles is uniform

Finally, the test panels must be placed at the exposure sites so that the internal distance between the panels is at least 1.5 m. This is to ensure that there is enough space to use the machine for drilling out cores.

Furthermore, the orientation of the test panels in relation to the predominant wind direction must be chosen so that the 2 largest surfaces on the test panels are exposed as equally as possible.

4.1 Preliminary investigations/research
In order to elaborate a programme for roadside exposure sites some preliminary investigations along selected motorway sections have been made. Though placing and testing will cause traffic problems because one traffic lane will have to be closed, the exposure conditions are perfect along motorways.

As the test panels are to be tested on all 4 sides, a uniform saline exposure on these surfaces is necessary. This can only be obtained if the test panels are placed in the central reservation.

With regard to road safety there must be at least 1.5 m between the test panels and the roadway. Therefore the exposure sites must be selected in sections with wide central reservations.

The motorway sections that have been inspected are:

- E45 Skanderborg - Århus
- E66 Halsskov - Amager

- E4 Køge - Farø
- A10 Hobro - Åbenrå

On the mentioned sections there are central reservations that are sufficiently wide at the following locations:

- E 45 on extensive sections between Skanderborg and Århus
- E 66 between Ringsted and as far as 7 km east of Kongsted - a total of approx. 15 km
- E 4 between Piperhus and Rønnede a total of approx. 5 km
- A 10 by the slip road towards Skanderborg N, north of the bridge across the bay of Vejle, south of Kolding and north of Åbenrå

The photographs in appendix 8 show the central reservation at Ringsted and Kongsted.

Differencs in saline exposure at the above mentioned sections can be analyzed on the basis of the County Road Department's (Amtsvejvæsenet) consumption of salt for a number of years.

4.2 Plan for exposure sites
Figures 13 and 14 show an outline for an exposure site with 12 test panels placed in a central reservation.

Exposure sites with the outline shown can be placed at any of the locations mentioned in paragraph 4.1.

In order to ensure uniform support, the panels are positioned on horizontally placed concrete piles.

Price estimate

The estimated price for the establishment of one exposure site with 12 test panels is 60,000 DKK. Furthermore there will be expenses in connection signalling during the construction period and when testing.

Expenses for transportation and placing the 12 test panels are estimated at approx. 36,000 DKK. This does not include any costs in connection with signalling of road works.

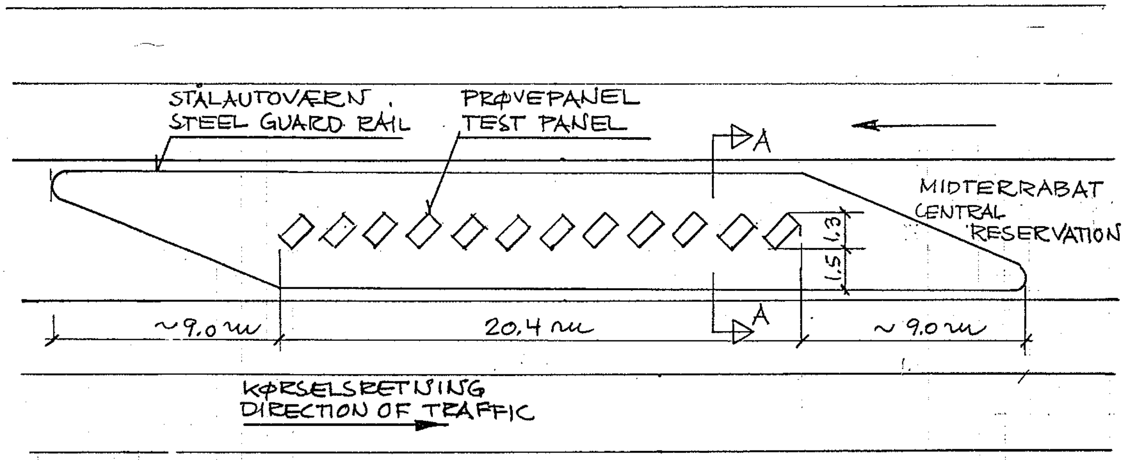


Figure 13. Exposure site in central reservation, plan 1:300.

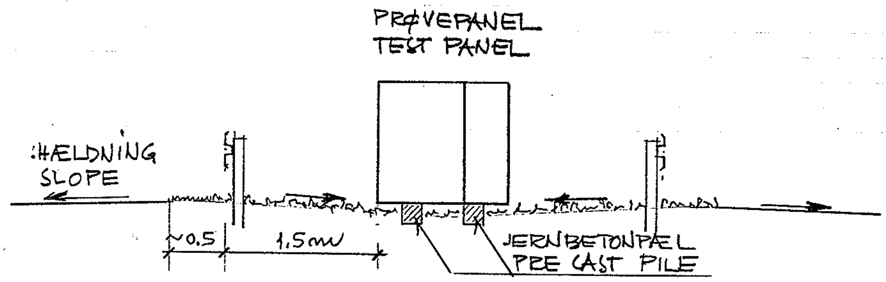


Figure 14. Exposure site in central reservation, sectional view A 1:75.

4.3 Conclusion and recommendation

Based on the pilot study, it is recommended that roadside exposure sites are constructed on a wide central reservation on the motorway.

Such sections exist on Sealand, e.g. between Ringsted and Kongsted. In Jutland analogous sections can be found, e.g. at E 45 Skanderborg/Århus and on A 10 by the slip road towards Skanderborg north and at the bridge across the bay of Vejle.

To limit the expenses for transportation, 2 exposure sites can be constructed, one on Sealand and one in Jutland.

The choice of locations must amongst other things be made on the basis of the County Road Department's (Amtsvejvæsenet) information about consumption of salt. This must be as varied as possible, and it must be registered during the testing period.

The road lanes alongside the selected sites must not be uneven throughout the whole testing period in order to ensure a uniform exposure of the test panels. If the road is on a gradient, the disadvantageous effects of uneven road surfaces are reduced.

The estimated cost of establishing 2 exposure sites - each with space for 12 test panels - is a total of approx. 120,000 DKK in 1996 prices excl. VAT.

Transportation and placing 24 panels is estimated to cost approx. 75,000 DKK in 1996 prices excl. VAT.

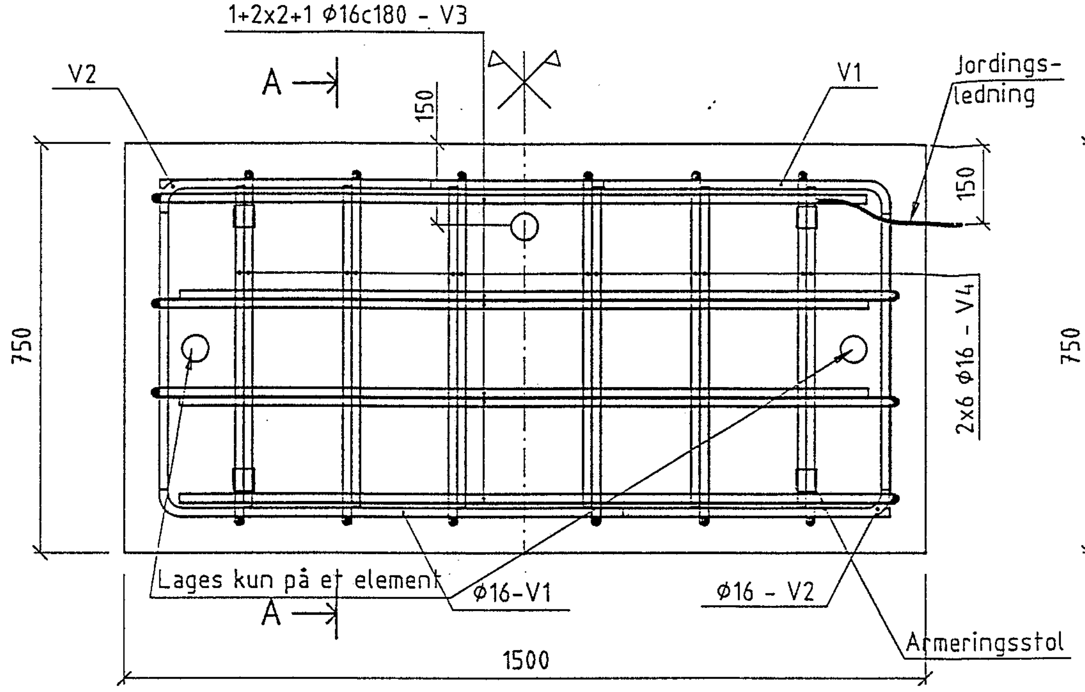
The above-mentioned prices do not include expenses for signalling road works.

The testing programme for all 24 test panels will cost 3.5 - 6.0 million DKK in 1996 prices excl. VAT - see paragraph 2.3.

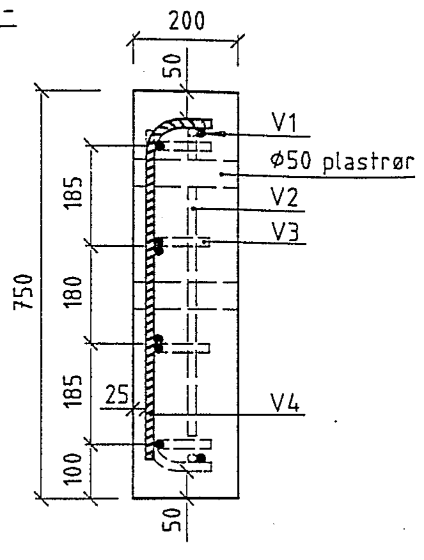
The construction costs of the exposure sites are thus approx. 5% of the expenses for producing and testing the test panels.

The extent of testing and the size of the exposure sites can of course be reduced, and the expenses will be reduced proportionally.

Appendix 1
Test panels from a Norwegian RdD programme (in Norwegian)

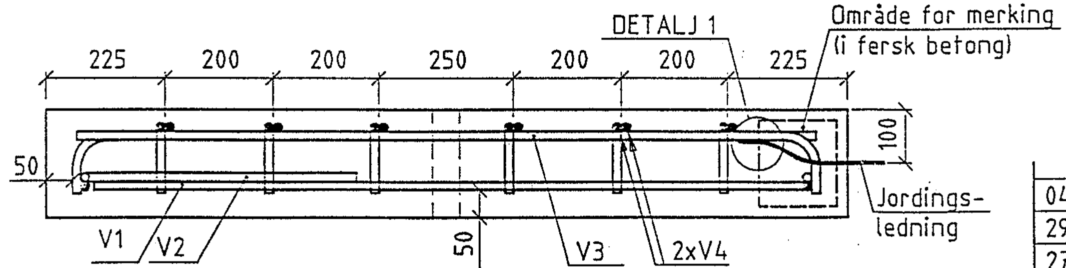


OPPRISS 1:10

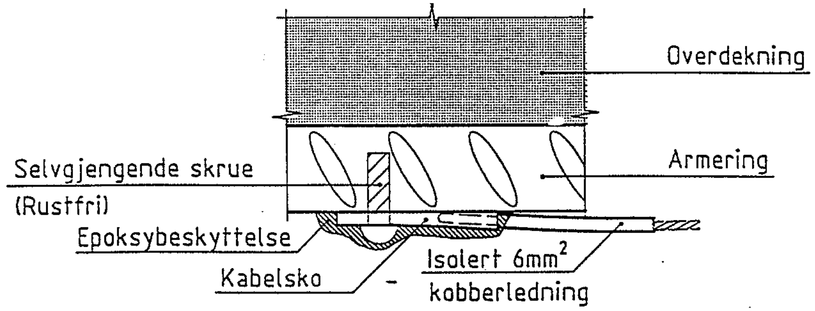


SNITT A-A

1:10



PLAN 1:10



DETALJ 1 Jordingspunkt

BEMERKNINGER

- Armeringen kan punktsveises. Det skal da sveises "innenfra" slik at sveisepunktene ligger innenfor overdekningen og det ytterste lag med armering.
- Elementet skal støpes ut stående
- Armeringsstoler spikres til forskalingen og bindes til V4.
- Alle hjørner avfases med 20mm trekantlist.
- Jordingspunktet plasseres på "innsiden" av armeringen, og bart metall på kabelskoen beskyttes med epoksy etter fastskruing. Den isolerte jordledningen føres gjennom endeforskalingen (ca.100mm).
- Hvert element merkes med prøveblanding (fortløpende bokstav), V for veggelement og elementnummer (1 til 5).
  F. eks. AV1.......AV5
  BV1.....osv.
  :
  osv.

Dato	Rettelse	Merke	Rettet	Kfr.
04.02.94	Endret staghull etter utførelse	C	Li	
29.10.93	Fjernet og flyttet staghull	B	Li	
27.10.93	Arbeidstegning	A	Li	

STATENS VEGVESEN

FoU-prosjekt:

Utvikling av kloridbestandig betong

TRINN 2

Målestokk			
1:10	Tegn.	10.93	Li
	Kfr.	10.93	HR
Mål i mm	Trac.	10.93	IMJ
	Kfr.		

Veggelement

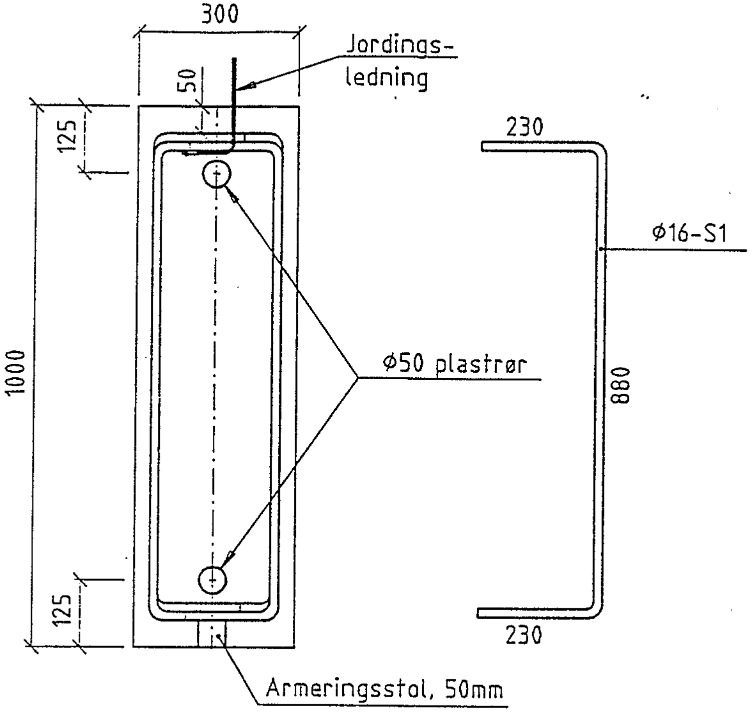
5 stk. pr. prøveblanding

Erstatning for/av:

142/93 C

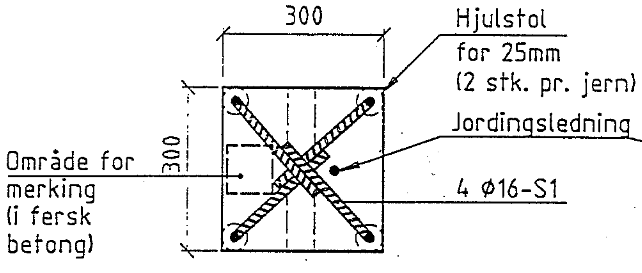
Ident: FOU-HILOE-1

Vegdirektoratets bruavdeling, Oslo, den



OPPRISS

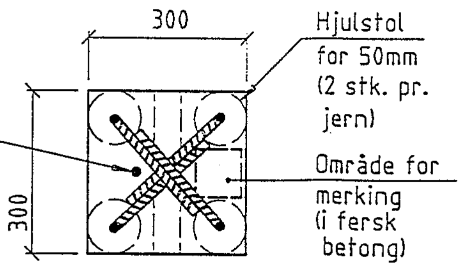
1:10



PLAN, type 25

(overdekning 25mm)

1:10



PLAN, type 50

(overdekning 50mm)

1:10

BEMERKNINGER

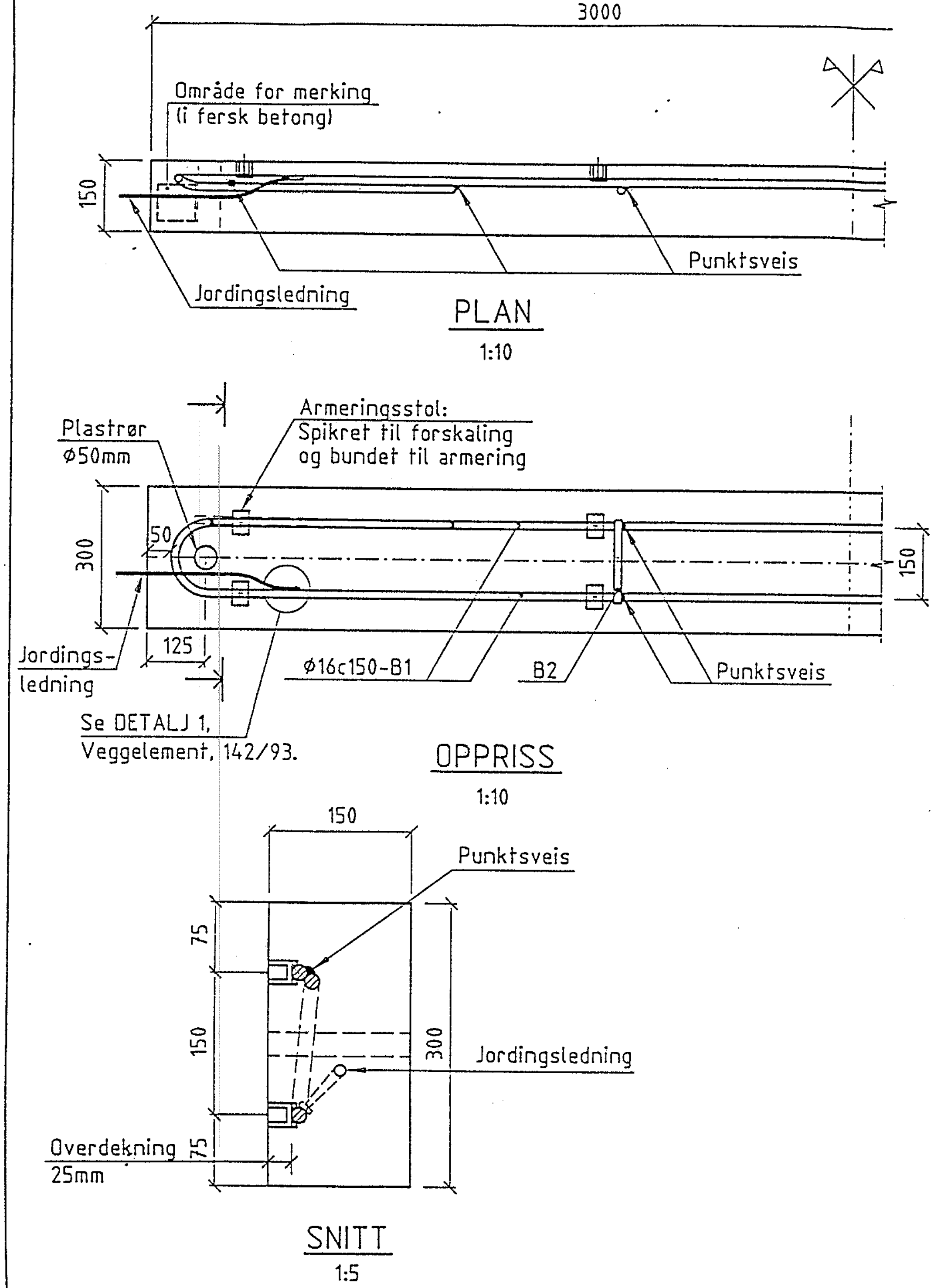
- Armeringen settes sammen av 4 stk. S1 pr. element (samme for type 25 og type 50)
- Armeringen kan festes sammen med punktsveising
- Elementet støpes ut stående.
- Hjørnene avfases med 20mm trekantlist.
- Jordingspunkt. $6mm^2$ isolert ledning føres ca. 100mm ut.
- Festing av kabelsko, se DETALJ 1, Veggelement, 142/93.
- Hvert element merkes med prøveblanding og type.

  F.eks. A25, A50
  B25 osv.
  :
  osv.

Dato	Rettelse	Merke	Rettet	Kfr.
27.10.93	Arbeidstegning	A	Li	

STATENS VEGVESEN FoU-prosjekt: Utvikling av kloridbestandig betong TRINN 2	Målestokk 1:10 Mål i mm	Tegn. 10.93 Kfr. 10.93 Trac. 10.93 Kfr.	Li HR IMJ
Søyleelement 2 stk. pr. prøveblanding	Erstatning for/av: 143/93 A Ident: FOU-HILDE-2		

Vegdirektoratets bruavdeling, Oslo, den



BEMERKNINGER

- Armeringen bør punktsveises som vist, og det skal sveises "innenfra" slik at sveisen ligger innenfor overdekningen og det ytterste lag med armering.
- Elementet skal støpes ut liggende på høykant.
- Armeringsstoler spikres til forskalingen
- Jordingspunkt. $6mm^2$ isolert ledning føres ca. 100mm ut gjennom endeforskalingen.
- Hvert element merkes med prøveblanding, B for bjelkeelement og elementnummer (1-4)

  F.eks. AB1 .... AB4

  BB1 ... osv.

  :

  osv.

Dato	Rettelse	Merke	Rettet	Kfr.
27.10.93	Arbeidstegning	A	Li	

STATENS VEGVESEN

FoU-prosjekt:

Utvikling av kloridbestandig betong

TRINN 2

Målestokk			
1:10 / 1:5	Tegn.	10.93	Li
	Kfr.	10.93	HR
Mål i mm	Trac.	10.93	IMJ
	Kfr.		

Bjelkeelement

4 stk. pr. prøveblanding

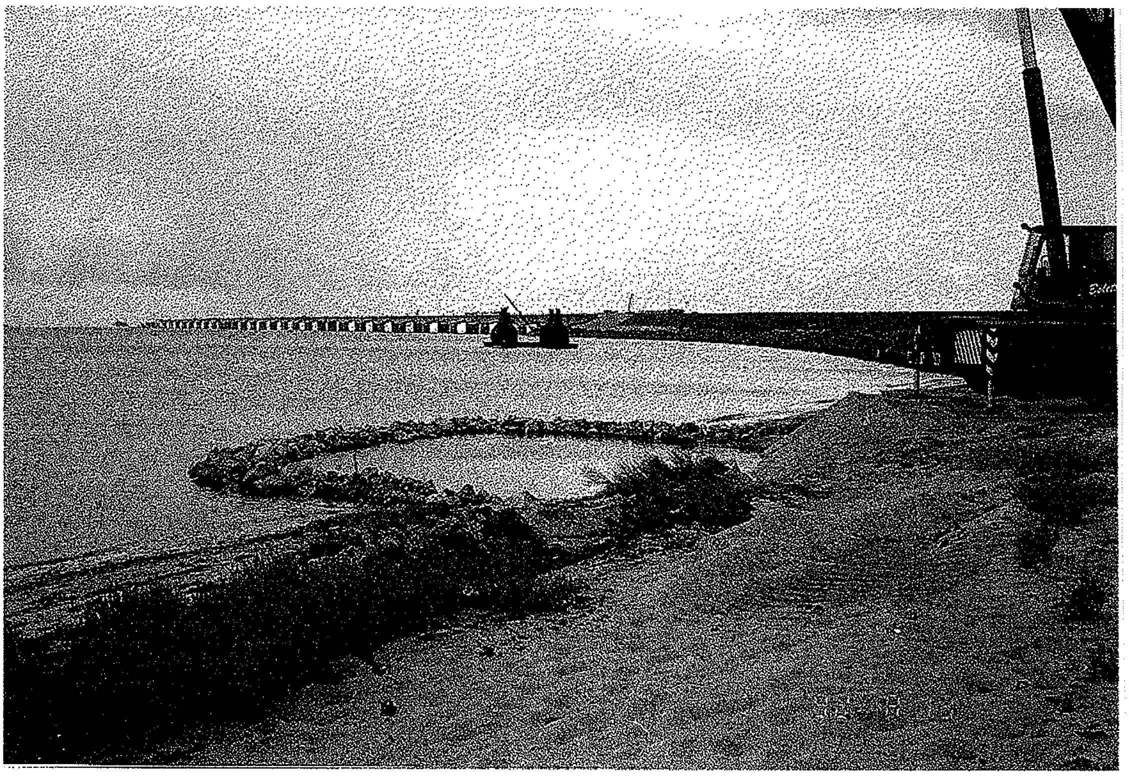
Erstatning for/av:

145/93 | A

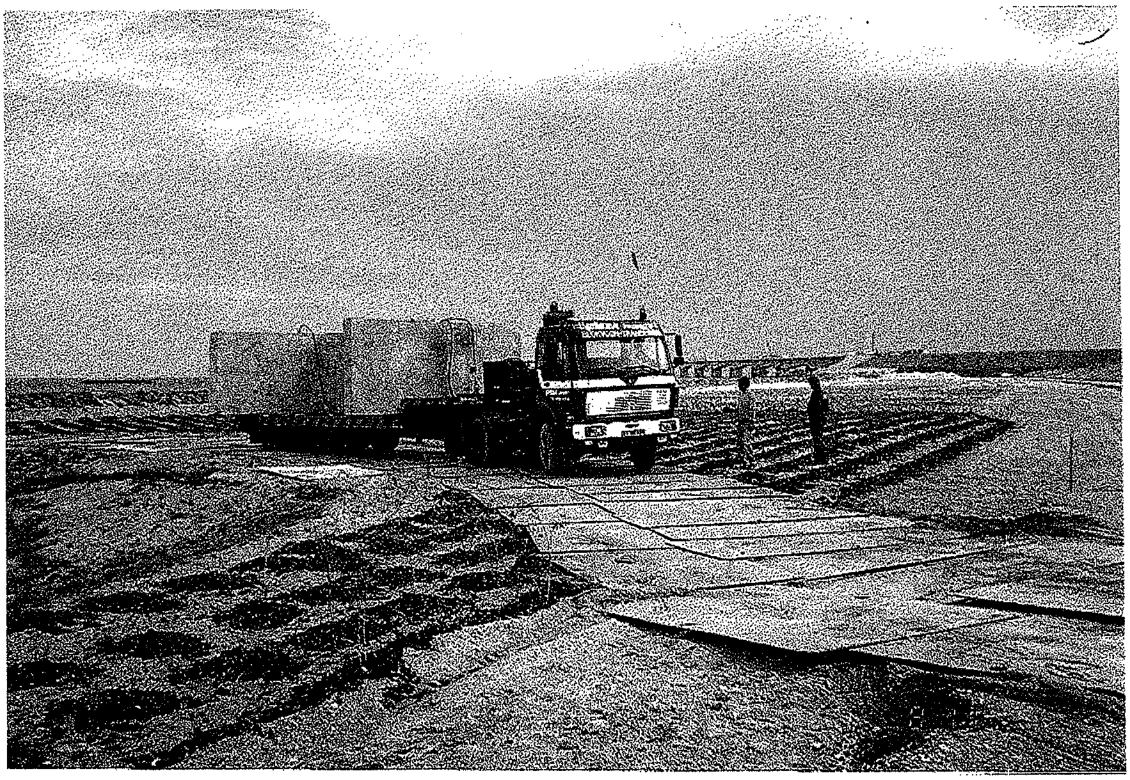
Ident: FOU-HILDE-4

Vegdirektoratets bruavdeling, Oslo, den

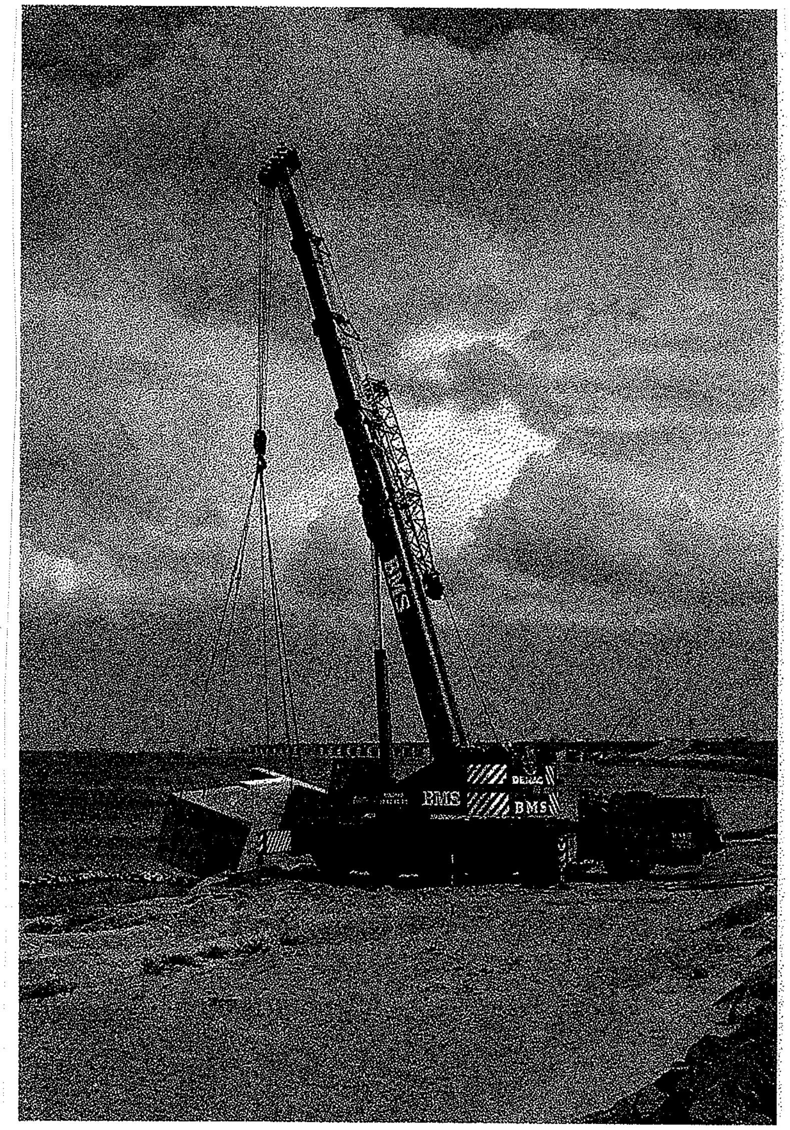
Appendix 2
Storebæltsforbindelsen's exposure site at Knudshoved



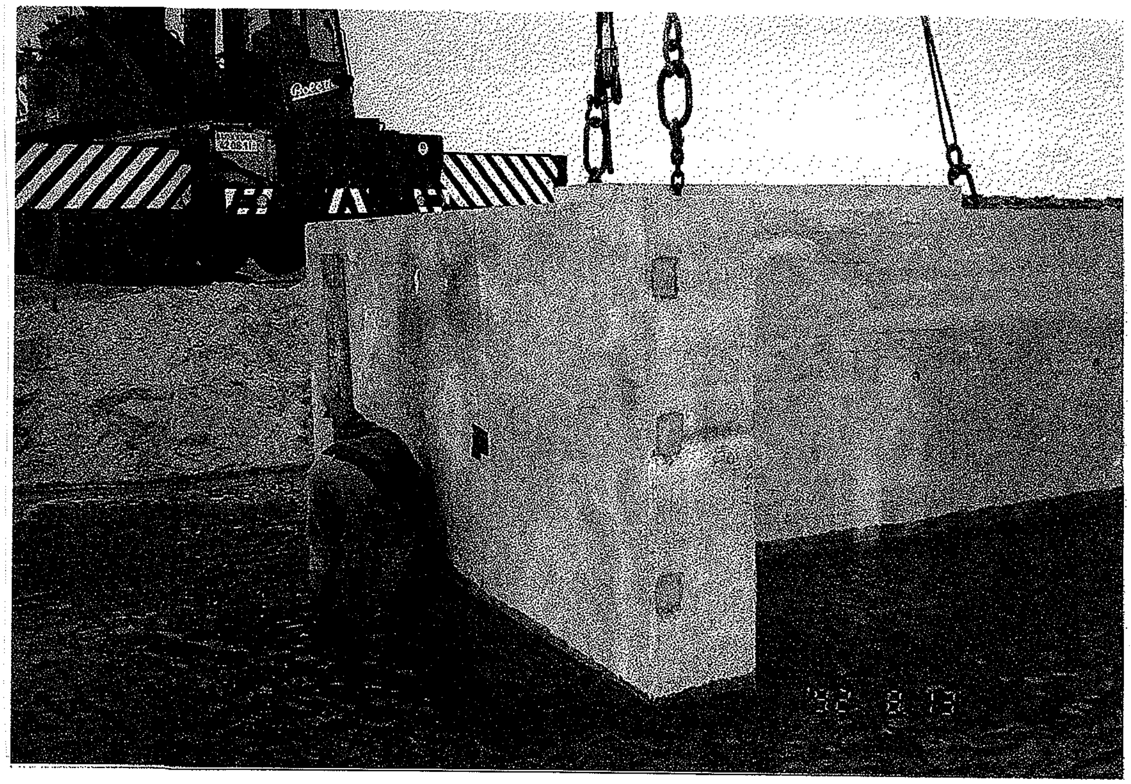
Storebæltsforbindelsens exposure site at Knudshoved. Erosion protection of stones 5-300 kg. August 1992.



Transport of the approx. 37 ton test element.



Placement of the test element.

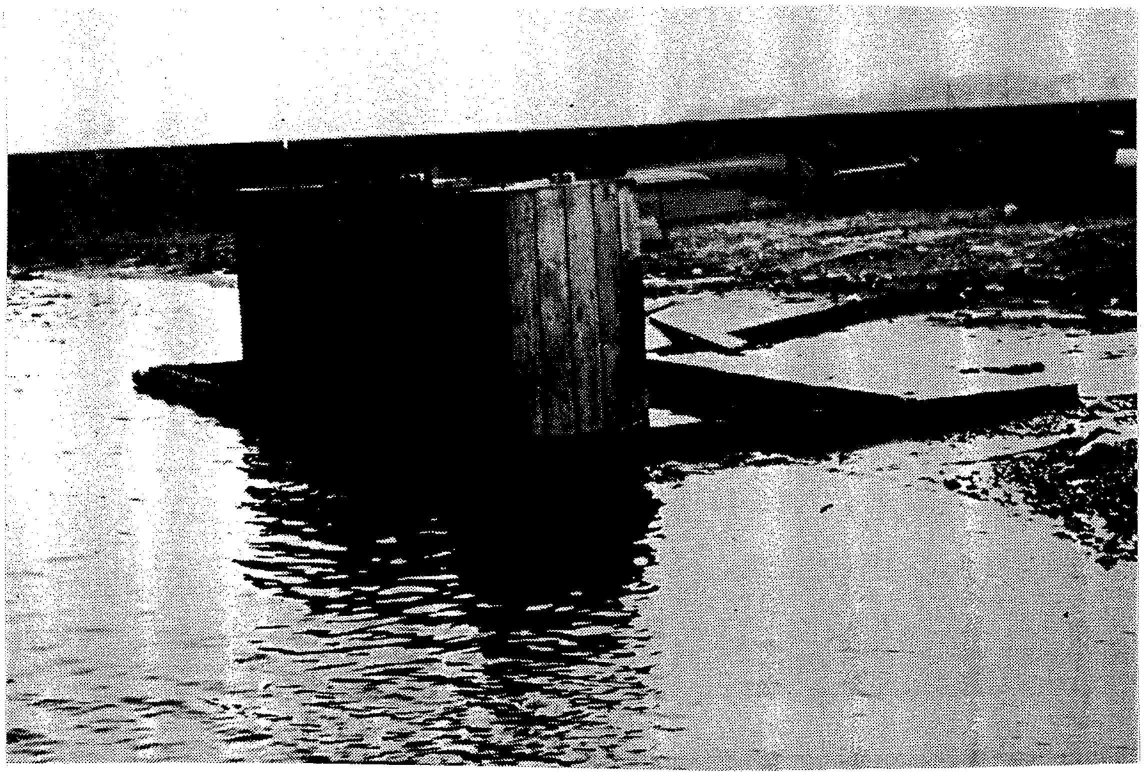


The base of the test element is placed approx. 0.30 m under water.

Test element. July 1996.

Test element. July 1996.

Appendix 3
Statsbroen Storebælts exposure site at Halsskov



Exposure site at Halsskov. 1979.
Test panels in seawater. From bkf-report R:094.

The same exposure site in 1996.
Test panels approx. 10 m from the waterline.