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A REVIEW OF NOVEL SHORE PROTECTION METHODS

Inspection of sea defences in Holland
and Belgium
17 to 21 September 1984

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ABSTRACT

This short report summarises a visit to Holland and Belgium to examine methods of sea defence not commonly used in the United Kingdom.

What was immediately obvious was the predominance of asphaltic type constructions which appear to have considerable promise as an alternative to the more traditional forms of coast protection used in this country.

Some of these schemes have been in place for several decades and have therefore withstood the test of time.

We consider that several of the asphaltic forms of construction inspected, including Fixtone (gap graded stone keyed together with asphalt), dense gap graded stone asphalt and asphaltic concrete have potential for use in the marine environment of the United Kingdom and warrant a more detailed study.

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1 INTRODUCTION

The purpose of the visit was to examine methods of sea defence not commonly used in the United Kingdom. In particular we were interested in assessing the use of bitumen in the marine environment and gaining some insight into its potential for use in coast protection works in the United Kingdom. Bitumen has been widely used in the low countries in constructing sea dykes, revetments etc. especially with the rise of the petroleum industry in these countries. In the United Kingdom, on the other hand, asphaltic concrete and other forms of bituminous mixes have largely been restricted to the construction of pavings etc. Its use in the marine environment has been primarily as a jointing medium.

We are grateful for the kind hospitality received during our visit, particularly from Messrs H Roos and A J Woestenenk of Bitumarin BV. We would also like to thank Mr P Broun of Bitumar, and Mr Van Damme of the Ministry of Public Works, Belgium for showing us the construction of the new harbour at Zeebrugge and the adjacent sea defences. Finally we would like to thank the Water Directorate of the Department of the Environment for making this visit possible. The visit was made within our contract PECD 7/7/055, concerned with low capital cost protection. The observations made and conclusions drawn during this visit will be viewed in context with our wider studies and incorporated in our series of reports on the subject of low cost coast protection.

2 DESCRIPTION OF SITES INSPECTED

Vlissingen
17 September

After travelling overnight from Sheerness to Vlissingen (Fig 1) we were met by Mr Roos and proceeded to inspect the sea defences at the De Ruyter Boulevard west of the port entrance. At the south east end of the Boulevard an asphaltic concrete revetment was built to protect a vertical sea wall which had become increasingly prone to overtopping during gales. Apparently one of the principal navigation channels to the port had been moving towards the shore causing beach levels to fall and wave action to become increasingly a problem. During exceptionally severe storms waves were hitting the sea wall with such force that water was at times thrown up above roof top height. A "hog backed" revetment was constructed in front of the sea wall in 1958/9 to reduce wave overtopping and further deterioration of beach levels. Since its construction normal wave activity does not impinge upon the vertical sea wall but is dissipated on the revetment slope. The wetted area seen in Plate 1 shows the height to which the water level rose at the previous high water (approximately mid-way between neap and spring tides).

A cross-section of the revetment is shown in Fig 2. Essentially this consists of a sand core covered by an asphaltic concrete skin. The skin has two layers, the bottom one including gravel and the top one crushed stone. The two asphaltic layers are bonded together with a bituminous emulsion.

Below the mean water line the revetment is faced with basalt blocks which are asphalt grouted. Waves at this site are limited in height by a horizontal berm of asphalt grouted rubble at a level of -1.0m. (MLWST is -2.05m and MHWST is +2.27m). At the junction with the old wall the revetment is at about the level of the highest recorded water level i.e. +4.55m.

When we inspected the revetment it was clear from the position of the trash lines that wave run up does reach the base of the wall during storms, see Plate 2. The asphaltic concrete surface was in good condition, although some separation of the two asphaltic concrete layers had taken place locally. Because of the relative ease of repair it was difficult to determine how much wear and tear the surface had been subject to over the years. Also the surface had a blinding coat of crushed gravel. This tended to make it even more difficult to spot any repairs that may have been made. The hand pitched basalt set on the lower part of the revetment had obviously been damaged by wave action. Maintenance was in fact being carried out at the time of the visit (Plates 1 and 2). Because of the state of the tide it was not possible to inspect the rubble base of the revetment. Since the revetment has been protecting the sea wall for about 25 years one would assume that the coast protection authority has been satisfied with its performance. Although our assessment was quite clearly subjective, this type of construction looked impressive. It would be useful to know more about the history of maintenance of this revetment and its hydraulic performance from the authority responsible for coast protection in this area. We feel that further gathering of information is vital, particularly in view of the fact that a not too dissimilar scheme is now under construction at Porthcawl. The Porthcawl revetment will also need to be monitored carefully. The performance of these two schemes should indicate whether this type of revetment is a viable alternative to the more traditional methods of construction used in the United Kingdom.

At the northern end of the De Ruyter Boulevard there is a wide sand beach on which there is a permeable groyne consisting of two lines of timber piles driven into the beach. Only the top 300mm or so of the groyne was visible above the sand surface so it was not possible to determine whether the poles were interconnected. The groyne was in good condition. Because of its permeability and low height the groyne did not appear to be affecting the beach adversely! There was no evidence of downdrift erosion, nor indeed of tidal scour adjacent to the groyne timbers.

Westkapelle

Westkapelle is a village some 20 km northwest of Vlissingen, on the west coast of the island of Walcheren, see Fig 1. As a result of bombing raids prior to the liberation of the island by the Allies during World War 2 a number of revetments were badly damaged. The worst damage was to the Westkapelle wall, which protects the most exposed part of the island. Due to a shortage of stone and the urgency for repair much of the material was reused from the damaged traditional revetments. For example, basalt blocks which were too damaged for relaying as blockwork revetments were used to construct an asphalt grouted rubble facing to the dyke at the north-west corner of the island. The grout was "bulked up" with gravel in order to reduce the cost of the mix since large voids in the rubble facing had to be infilled. By 1947 when the situation had become more normal, parts of the Westkapelle revetment were rebuilt by resetting basalt blocks by hand and by jointing them with asphalt grout. This operation must have been extremely labour intensive but has proved to be very long lasting since those parts of the jointed block revetment which we inspected were still in serviceable condition. The structure exhibits admirable qualities of workmanship, however this type of construction is labour intensive and dressed basalt stone is by no means cheap, so the method is unlikely to be an economical form of sea defence today.

There are also a number of short, high crib type wooden groynes at Westkapelle which we believe were originally filled with stone. This presumably has now been lost and the groynes remain as two rows of vertical wooden piles. With the loss of fill the groynes are now structurally less than sound and require, we would think, continual maintenance. (The groynes at Vlissingen were similar in design but projected less above the mean beach level and hence were less prone to damage.) Because of the state of the tide it was not possible to assess whether the groynes fronting the basalt block revetment were having any effect on the littoral regime. In the embayment immediately to the south of the revetment there were two long low groynes of a similar design, but which appeared to be trapping sand more effectively than the shorter high groynes.

The Dutch Authorities are in the process of building up their coastal defences along the entire coast to the level of the Delta project. This means that this area will be re-instated in the near future (to the extent of demolishing houses behind the original revetment to make space for the enlarged sea defences). It would be worth keeping in touch with these developments if only to monitor the performance and type of the new coastal protection.

Veersegat Dam

The Veersegat dam is situated at the north end of Walcheren and forms a connection to the island of Noord-Beveland. It is one of the main dams of the Delta project which was begun after the disastrous 1953 winter flood. The aim of the project is to strengthen the sea defences of the country and to shorten the coastline of the southern part of Holland. Veersegat dam consists essentially of a core of sand, dredged from the adjacent sea bed, with an asphaltic concrete skin, see Fig 3. The surface has been "blinded" by applying a course of shells and fine gravel and rolling these in while the asphaltic surface was still hot. The dam was finished in the late fifties and a wide sand beach and dunes were established to the seaward by artificial nourishment. As far as we can tell the concrete surface has not been exposed to wave action; it shows little sign of deterioration.

Oosterschelde Barrier
18 September

The storm surge barrier between the islands of Noord-Beveland and Schouwen-Duiveland is now nearing completion. Two artificial islands have been constructed at the mouth of the Oosterschelde incorporating a ship lock on the larger of the two, to allow access from the hinterland to the North Sea. Three deep water channels separate these two islands from the shoreline and they are designed to remain open to tidal flow except during exceptionally high tides. Sixty five prefabricated concrete piers have now been placed in the three channels and massive steel gates will be suspended and when necessary slid vertically down onto a sill beam connecting each pier. The southern of the two islands, Neeltje Jans, includes a dock complex on its sheltered eastern face, a ship lock, a power plant and the control centre for the operation of the gates. A number of harbour arms and jetties in this vast complex are of bituminous construction. The facings to the revetments include asphaltic grouted stone, asphaltic concrete and

Fixtone laid in situ and in mattress form (see glossary). A typical section of one of the breakwaters is shown in Fig 4. All these revetments are of recent construction. They will be subject to varying degrees of exposure, facing both into the North Sea and into the more sheltered waters of the Eastern scheldt. The whole island is to be a showpiece of Dutch engineering expertise. It should not, therefore, prove to be difficult to obtain details of the performance of the various types of revetment from the Rijkwaterstaadt who will be maintaining these defences.

Westenschouwen

The south-west facing coastline of the island of Schouwen-Duiveland has a number of basalt groynes which have clearly been in place for several decades, see Plate 3. These groynes cross a wide sand foreshore and appear to be partially arresting littoral drift which in this area is in a net north-west to south-east direction. Because of their low profile they do not appear to have trapped large quantities of sand but seem to have been effective in maintaining stable beach levels. The dunes are protected by a sloping asphaltic concrete revetment with a toe of grouted stone, see Plate 4. The asphaltic concrete is beginning to show signs of deterioration. Further north-west, where the dunes face the open sea and where the foreshore increases in width beach protection consists of groynes but the dunes are unprotected. Attempts are being made (by means of brushwood fencing) to make good wind induced erosion. Erosion is slight and the dune stabilization measures stand a fair chance of success.

At the approaches to the bridge connecting the artificial island to Shouwen-Duiveland there is also asphaltic revetment protection, but of recent construction. It consists of an upper slope and horizontal berm made of asphaltic concrete with a grouted stone apron down to beach level. These revetments are as yet undamaged.

Brouwersdam

This is an enormous and impressive dam which is essentially a sand dyke covered with a skin of asphaltic concrete, see Fig 5 and Plate 5. The seaward toe of the dam is protected by a wide grouted stone revetment with gabions set into the toe for drainage (Plate 6). The dam connects the islands of Schouwen-Duiveland and Goeree-Ovevflakkee. Here again, as at Veersegat there is a belt of sand dunes on the seaward face. The belt is not continuous but where it disappears the foreshore is nevertheless wide and very flat and hence shelters the dam against severe wave activity. The toe of the dam is in very good condition some 15 years after being built, although exposure to wave attack in this area is not severe. (The toe of the dam being 1m above mean sea level.) At the time of our visit, sand was being transferred from south to north through a permanently installed pumping system (Plate 5). The length of the dam is about 7km and the distance that the sand was being pumped was of a similar order of magnitude.

Ouddorp

The promontory at the western extremity of Goeree-Ovevflakkee consists of a narrow sand dune belt which has been eroding for several centuries. Since the middle of the nineteenth century the foreshore has been groyned in an attempt to reduce erosion and a number of long, low profile groynes can be found in this area. The rate of littoral transport of sand on the upper foreshore appears to be quite large but the groynes are too low to trap this effectively. There are a number of very wide sand bars and gullies whose alignment suggests a northerly net drift of sand along this frontage.

The sea defences in this area are being upgraded and an asphaltic concrete revetment is being constructed over a sand core, see Plate 7. For protection against wave attack during the construction stage a line of temporary bunds were built some distance to the seaward. Shortly before our visit the bunds were overtopped by wave action although no damage, as far as one could tell, was done to the revetment. The area will clearly be subjected to wave attack, unless massive sand nourishment is carried out on the foreshore. The performance of the asphalt grouted stone at the toe of the revetment (Plate 8) will be well worth monitoring in future years.

Rotterdam Harbour

A number of bituminous revetments line the canals to the south of the main Rotterdam waterway. These include revetments of stone grouted with asphalt, sand asphalt berms and rubble mound revetments incorporating a layer of Fixtone above the mean water line, see Fig 6. Most of these have been constructed in the last 7-8 years. Although our tour of these was brief we nevertheless obtained a strong impression that bitumen in one form or another is used extensively for protecting banks in inland waterways in this part of Holland. We were struck by the ease with which this material can be used for upgrading existing canal protection, constructing features such as access ramps, berms and walkways for public use. Plate 9 shows how easily a berm can be constructed using sand asphalt, and the toe of the berm protected by asphalt grouted stone.

Hoek van Holland
19 September

Hoek van Holland (Hook of Holland) is on the north side of the entrance to Rotterdam Harbour. We inspected the north breakwater, a rubble mound structure which has been extended in recent years. The landward end has a concrete "promenade" with a wave return wall on the north face. The surface layers of rock on both the northern and southern faces of the older part of the structure were asphalt grouted about 10 years ago. On the exposed north face of the breakwater there is added protection in the form of a reef of large stones laid parallel to the breakwater axis, see Plate 10. This reef causes waves to break and reduces the amount of wave overtopping into the navigation channel. Large scale dredging has taken place in the approaches to the harbour and much of the dredged material (sand) pumped onto the northern beaches. This has accumulated to form a wide buffer zone between the beach and the low lying hinterland.

The asphaltic grout of the breakwater shows surface deterioration, but it still seems to be performing satisfactorily. The seaward end of the breakwater is in relatively deep water and wave attack is such that the rock core has had to be protected by armouring with very large precast concrete cubes. These are randomly placed and their movement subsequent to construction is being monitored. Monitoring consists of recording the position of a number of the blocks which have been painted so as to resemble giant dice! Presumably their position is determined by means of aerial photography.

Scheveningen

Scheveningen is a tourist resort north of Hoek van Holland which lies at the southern end of a wide belt of sand dunes which extend northwards almost to Den Helder. This area is probably the most widely used stretch of coast in Holland so far as bathing and other water-based recreational activites are concerned. It has a number of towns including Scheveningen, which resemble British resorts, that is to say the wide sand beaches are groyned and are backed by concrete sea walls. At Scheveningen, the sea wall is situated well up the beach and the groynes (Plate 11) are of the low profile type. The impact on adjacent beaches (downdrift erosion, updrift accretion, scour in front of sea walls) is much less marked than at many United Kingdom resorts. The lower part of the beach is quite flat and the wave breaker zone very wide. Strong offshore currents evidently develop and bathers are warned not to swim in the vicinity of the groynes. The groynes consist essentially of basalt blocks grouted with asphalt.

They were first built in this part of Holland in 1938 and appear to have been maintained in this form ever since. The method of construction would now probably be prohibitive in cost and it is quite likely that all the groynes that we have seen in Holland are several decades old. Groynes of this type while having an initially high capital cost are much cheaper to maintain and probably last a lot longer than the traditional wooden groynes found along the coastline in the United Kingdom.

Bergen aan Zee

Bergen is to the north of Scheveningen, near the northern end of the wide belt of sand dunes mentioned above. Although it appears to be a small holiday resort it is obviously heavily used in the summer. During our inspection the havoc wreaked by pedestrians was being made good (see Plate 12). The toe of the sand dunes was being protected by a form of fagotting not seen in this country. It consisted of clumps of rushes or dried grasses placed in rows, presumably with the intention of trapping sand. This area is exposed to winds blowing from the north-west over the North Sea. Judging by the steep seaward face of the dune line it would appear that set up of the water level brings wave action up to the toe of these dunes. The protection measures appeared to be somewhat half hearted by comparison with the scale of the erosion problem.

Ijmuiden

The port of Ijmuiden is one of major importance in that it affords direct access from the North Sea to the industrial areas of Amsterdam, via the Noordzee Coral. It also give access to inland waterways including the vast tract of water called Ijssel meer (the Zuider Zee). The breakwaters at the entrance to Ijmuiden have been extended seaward several times while the dock complex has expanded to cope with the very rapid growth of petroleum related industries in this area.

We were shown around the south breakwater by Mr Woestenenk, Managing Director of Bitumarin BV. Both the north and the south breakwaters have a core of rock, covered with a 2.5 metre layer of heavy stone asphalt, see Fig 7. The placing of the asphalt was a major achievement by Bitumarin in that the mix included stones up to 34 kg in weight and that about 700,000 tonnes of this were used to provide armouring for some 3200 metres length of breakwater. A large proportion of this mix was laid underwater. Since that time the breakwaters have been extended seawards and upgraded, and the primary protection on the seaward face now consists of 20 - 50 (?) tonne concrete cubes. (The cube size used depends on the relative exposure to wave action along the length of the breakwater.) Plate 13 shows cubical armour blocks protecting a spur breakwater on the south side of the harbour.

Zeebrugge
20 September

At Zeebrugge we were introduced to Mr L V Van Damme, Principal Engineer for the Ministry of Public Works, who is responsible for development of the port of Zeebrugge. We also met Mr P Broun of Bitumar, Belgium, a sister company of Bitumarin BV of Holland. We were shown the west outer harbour breakwater the seaward face of which is protected by two layers of cubical "fluted" concrete blocks weighing 25-30 tonnes, see Plate 14. These are lain on heavy quarry stone, which itself provides a cover to the rock core of the breakwater. The new outer harbour at Zeebrugge is a massive project, with the outer breakwater being scheduled for completion in 1985. Equally impressive is the nourished beach between Zeebrugge and Zwin to the east. Over 9 million cubic metres of sand have been dredged offshore and pumped along a frontage of about 9 kilometres to form a beach about 100 metres wide at high tide. Unfortunately little information is available on the performance of this beach since nourishment some 6 years ago. It is intended to nourish this frontage with a further 1 million cubic metres of sand in the near future, and we intend to obtain details about this operation in due course.

It was also interesting to see the use of Fixtone and asphaltic concrete for "inner" breakwater protection in the work harbour on the east side of the new harbour at Zeebrugge, see Figs 8 and 9 and Plate 15. All the asphaltic protection is of relatively recent date, the construction of the new harbour having only been begun in 1977. In relatively sheltered conditions Fixtone appears to be an alternative to rubble mound protection and is probably a cheaper protective covering than say a concrete or masonry revetment. Fixtone has the advantage of being able to be easily maintained and quickly constructed. Its ease of use is a positive advantage over many of the traditional methods of revetting used in the United Kingdom. (One must remember, however, that since it is permeable it requires a filter to prevent the leaching out of fines.) We feel that monitoring of the newly built Fixtone revetment would be useful since it may provide an alternative method to protecting embankments, the upper parts of sea walls, etc., in the UK.

Knokke-Heist

The Belgian beaches between Zeebrugge and the Dutch frontier had been eroding for some years when the decision was made to improve existing groynes and build a total of 25 new ones to try and reduce the rate of beach recession. The groynes, of asphalt grouted stone sets, built during the period 1952 to 1960, are in very good condition for their age. Some damage has taken place where boulders have subsequently been used as an abutment to the stone sets. This is not surprising in view of the fact that maximum wave heights of up to 7 metres have been observed here. At present the groynes are too low to be effective in retaining the massive artificial sand fill and large boulders are being imported to increase their effective height.

Ostende to Middlekirke

From Ostende westwards to Middlekirke protection against encroachment by the sea is similar to United Kingdom practice, the defences consisting of sloping masonry or concrete walls and groynes. The groynes, however, are of the low profile type. They are ubiquitous on both the Belgium and Dutch coasts and all appear to be fairly old. The cost of constructing new groynes of this type must be high and there may well be a policy to maintain such groynes rather than construct new ones. While this visit was not intended as an inspection of groyne behaviour we feel that much could be learnt by finding out about the coast protection philosophy in these two countries with respect to groyne design.

3 CONCLUSIONS

During this visit we were given the opportunity to inspect, albeit briefly, a wide range of coast protection methods and in particular those incorporating asphaltic mixes of one type or another. At some sites the exposure to wave action was similar to that encountered on the east, south and Irish Sea coasts of the United Kingdom. Some schemes have been in place for two to three decades and have therefore withstood the test of time. Other schemes which, although of recent construction clearly have potential for use in the marine environment.

The following types of asphaltic construction appear to have considerable promise as an alternative to the more traditional forms of coast protection used in the UK. However, at present, scant information about maintenance costs, cost of construction, etc., has been published. Such information will need to be obtained before firm guidelines can be drawn up about the use of asphalt as a coast protection material.

Of the methods of revetment protection examined we were particularly impressed by Bitumarin's "Fixtone", a patented mix of gap graded stone keyed together with asphalt, but maintaining a very high porosity. Fixtone has the advantages of not needing compaction and can also be used above or below the water line. As with many other forms of asphaltic construction it retains its visco-elastic properties and can therefore adjust to minor changes in profile without damage. Although we did not inspect any Fixtone revetments subject to a moderate or severe wave action we know that this type of protection has performed well under full scale laboratory conditions. The Delft Hydraulics Laboratory report M1942, dated June 1983 and entitled "Fixtone. Stability under wave attack" describes these tests, and although they were carried out using regular waves they demonstrated that a Fixtone revetment laid at a slope of 1:3 can withstand waves of up to 2.65 metres (with a periodicity of 3 to 5 seconds) without damage. Such a revetment appears to have considerable potential, for example, as a facing to the upper part of a seawall or earth embankment. Because of its porosity a Fixtone revetment usually requires to be lain over a filter to prevent leaching out of fines from the embankment core. Fixtone is widely used in the Low Countries as revetment protection in harbours, canals and other semi-sheltered waters. Its use on the open coast, where it will be subject to the full force of storm waves, has yet to be proven.

Dense gap-graded stone asphalt has been used widely in the Netherlands. At Ijmuiden, for example, it forms a protective layer to the core of two massive breakwaters. Asphalt has also been used as a grout to stabilise and protect the stone armouring on both faces of the north breakwater at the entrance to the Rotterdam waterway at the Hook of Holland. This form of grouting appears suitable for areas subject to continuous wave activity and can be used both above and below the water line. Its use need not be restricted to breakwater and sea wall construction. For instance grouting of relatively small rock may well provide a viable alternative to the use of concrete or timber groynes or heavy rock bastions on sandy beaches. However, it could prove aesthetically displeasing and may therefore not be suitable for use on tourist beaches. It has the very real advantage over rigid structures in that it can deform or conform to minor settlement (as a result of beach scour for example) without losing structural integrity.

Asphaltic concrete when laid as a membrane over rock or sand fill appears to have potential as a revetment form. In Holland, asphaltic concrete is widely used for dam or dyke protection above the water line, while grouted stone aprons give the necessary added protection against wave action below this level. The revetment at Vlissingen has been in place for some 25 years while Brouwersdam is now some 15 years old. The Vlissingen revetment is more exposed than Brouwersdam and has required maintenance, as can be seen in Plates 1 and 2 of this report. The profile of the Vlissingen revetment was tested in the hydraulics laboratory at Delft using regular waves. It is now generally accepted that regular waves do not represent the real sea state at all well. The asphaltic revetment presently under construction at Porthcawl, South Wales, was tested in the laboratory using random waves, albeit at a small scale. In our opinion assessment of the hydraulic performance of asphaltic structures is better made from site inspection of structures already in existence. There are also "structural" problems in the design of new asphaltic revetments. The two course form of construction used at Vlissingen is not recommended and at Porthcawl the asphaltic concrete is being laid as a single layer. While there are now more efficient binders to seal adjoining layers, the single course construction avoids problems such as the intrusion of water or wind blown sand which can destroy inter layer cohesion. For fast, effective laying down and compaction of an asphaltic concrete surface in the temperate climate of Europe single layer construction where possible is strongly recommended.

The use of lean sand-asphalt should perhaps be restricted sheltered sites or to areas of low wave activity. The percentage of bitumen in sand asphalt is usually low, of the order of 5%. It can therefore provide a relatively cheap means of stabilising the core of sand or earth embankments. It can also be used as a filter layer to heavier armouring. Overfilling the voids in the sand filler results in what is commonly referred to as sand mastic. The composition of sand mastic can vary within wide limits and hence can be put to various uses. It has been used as a grout or laid in mattress form for toe protection under water. We feel that the full range of uses for this material has not perhaps been adequately explored or tested under controlled conditions.

In conclusion, most of the asphaltic forms of construction which we examined have potential for use in the marine environment of the United Kingdom. Which are effective in terms of capital outlay and subsequent maintenance costs remains to be seen, but in our opinion the use of asphaltic forms of construction certainly warrants more detailed study.

It would be extremely useful to tap this source of expertise to enable UK contractors to make full use of this largely untried form (at least in this country) of coastal protection.

Some asphaltic forms of construction may look a little harsh aesthetically but there must be some sites in the UK where this would not be a serious problem. On parts of the east coast for instance, slag from local steel mills has traditionally been used in coastal protection. This material is now getting in fairly short supply and as there are no natural sources (large rock from stone quarries, etc) close at hand, asphaltic protection may well prove to be a viable alternative to traditional construction techniques.

4 GLOSSARY

Asphaltic Concrete — A mixture of stone, sand, fines and bitumen. It should have voids ratio of 3 to 6% after compaction and is then virtually impermeable. Used as a watertight revetment above high water, or as lining for dams, canals etc. Must be laid and compacted in the dry.

Asphaltic Grout — A mixture of sand, fines and with bitumen in sufficient quantity to overfill the voids. Applied hot, by pouring or hand-floating into place. Stone can be added to bulk up the mix, i.e. when filling in large voids.

Fixtone — A proprietary name for a permeable, so called "open stone" asphalt, developed by Bitumarin BV. The gap graded stone (usually 20/40 mm limestone) is bonded with mastic. It is very much an underfilled mix and hence very permeable. Fixtone can be prefabricated in mattress form, and hence can be laid below the water line, for example, and used as protection against scour. Commonly used as bank protection in canals etc. Also used as a revetment, generally above the water line.

Mastic — A mixture of sand, fines and with bitumen in sufficient quantity to overfill the voids. It is naturally dense and requires no compaction. Apart from its use as a lining material above and below water level it is often used as a grout.

Sand Asphalt — A mixture of sand with some 3 to 5% of bitumen. It has a permeability very similar to the sand constituent. Can be used as a core material for reclamation bunds, as a filter, or as an underlayer for heavier revetment protection.

Dense stone Asphalt — A gap graded mixture of stone, sand, fines and bitumen. The bitumen slightly overfills the voids and hence the material is impermeable. First used at Ijmuiden with very large stone (70 kg max) for breakwater armouring. When lighter stone is incorporated the asphalt can be used as a grout.

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Figures

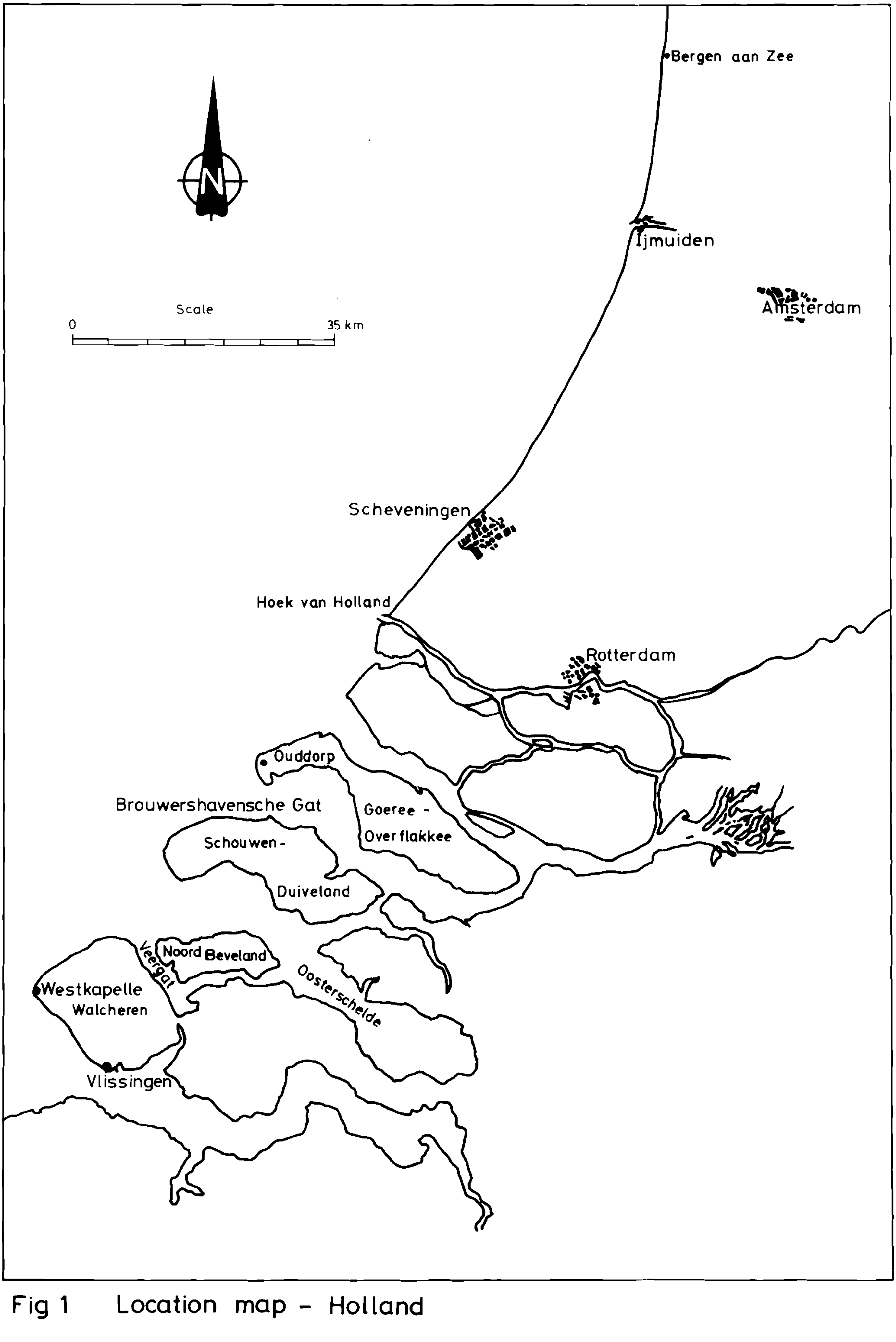

Fig 1 Location map - Holland

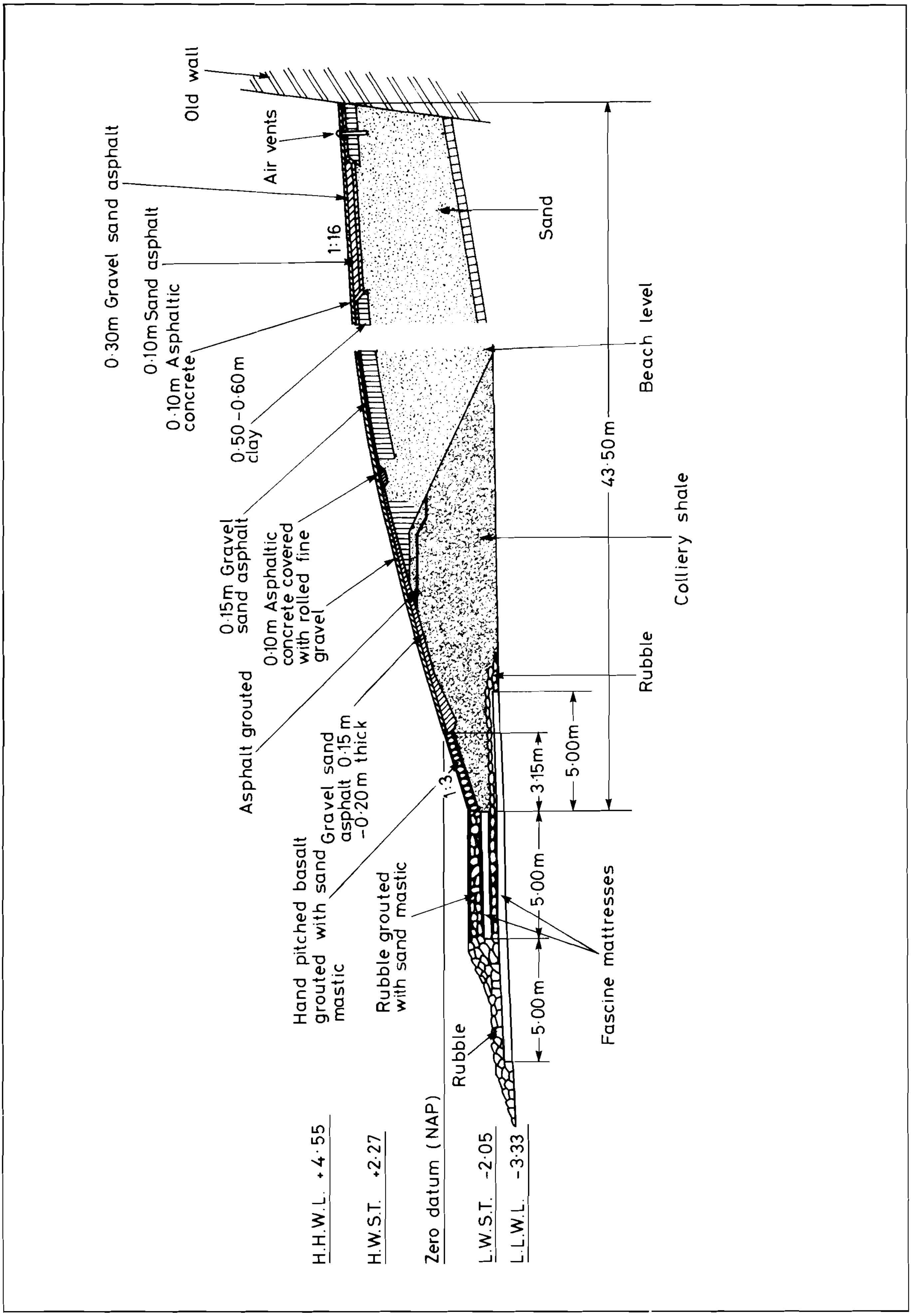

Fig 2 Asphaltic revetment, Flushing, Holland

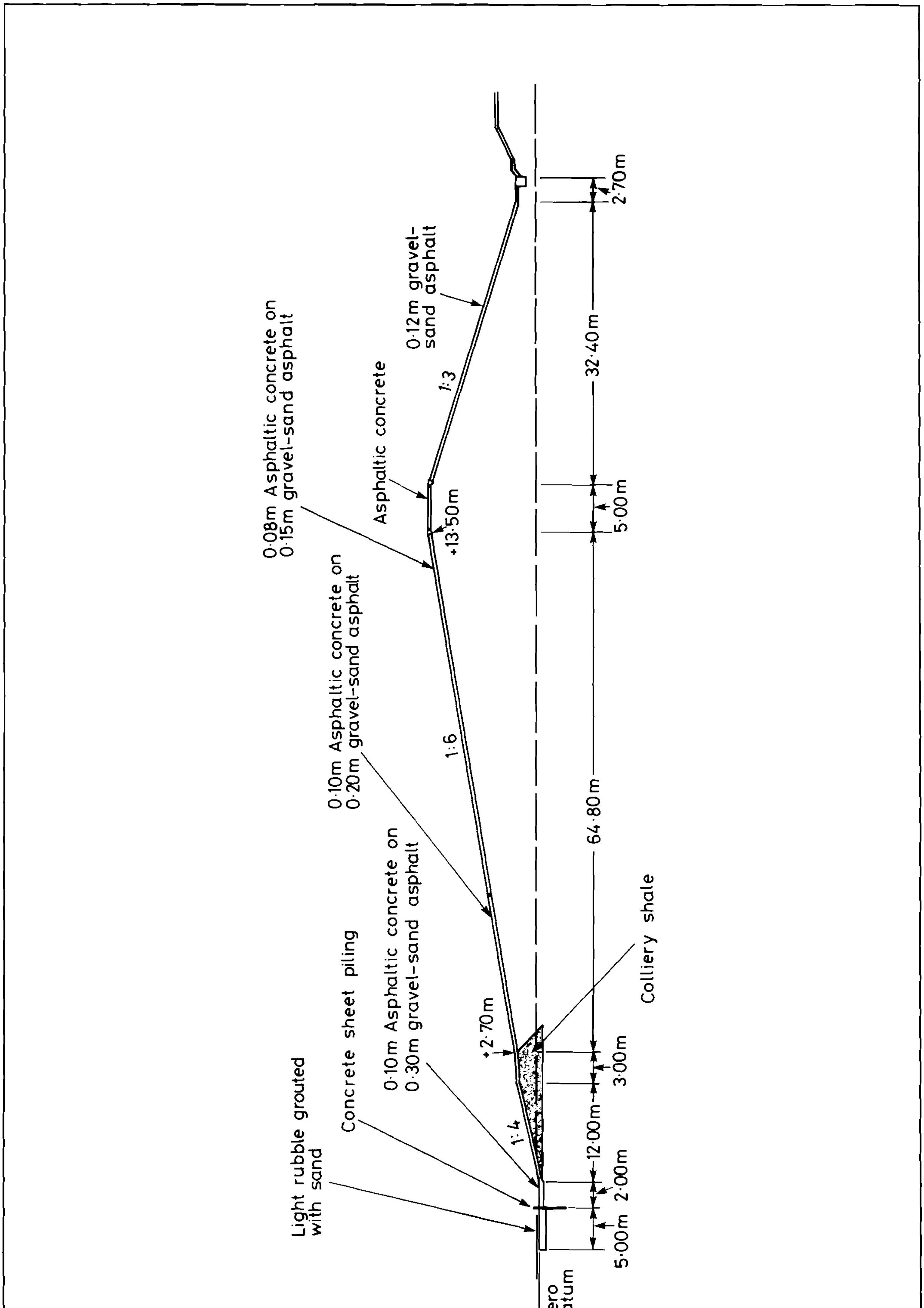

Fig 3 Section through Veersegat Dam, Holland

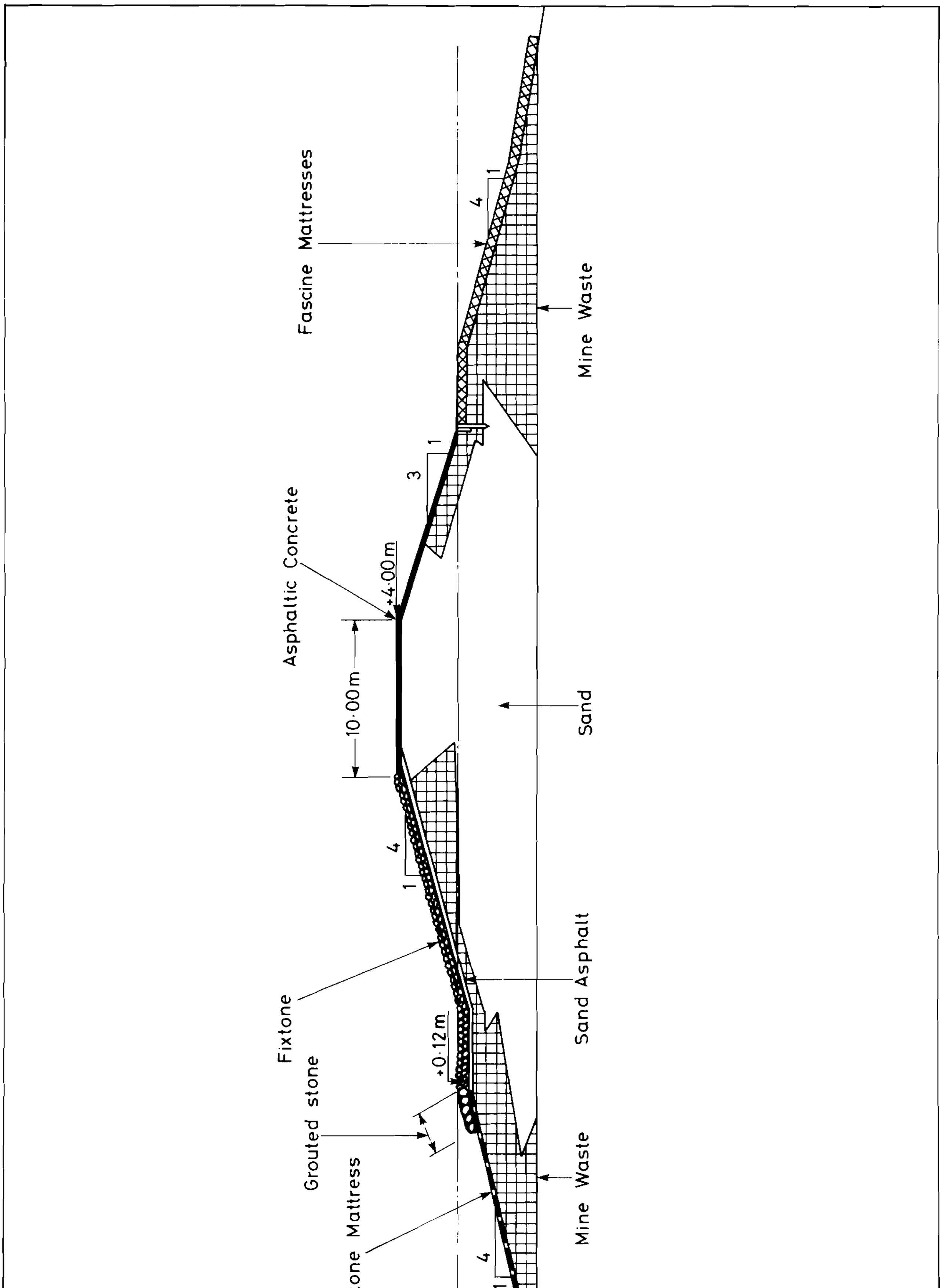

Fig. 4   Typical breakwater of the Eastern-Scheld, Holland, built in 1979

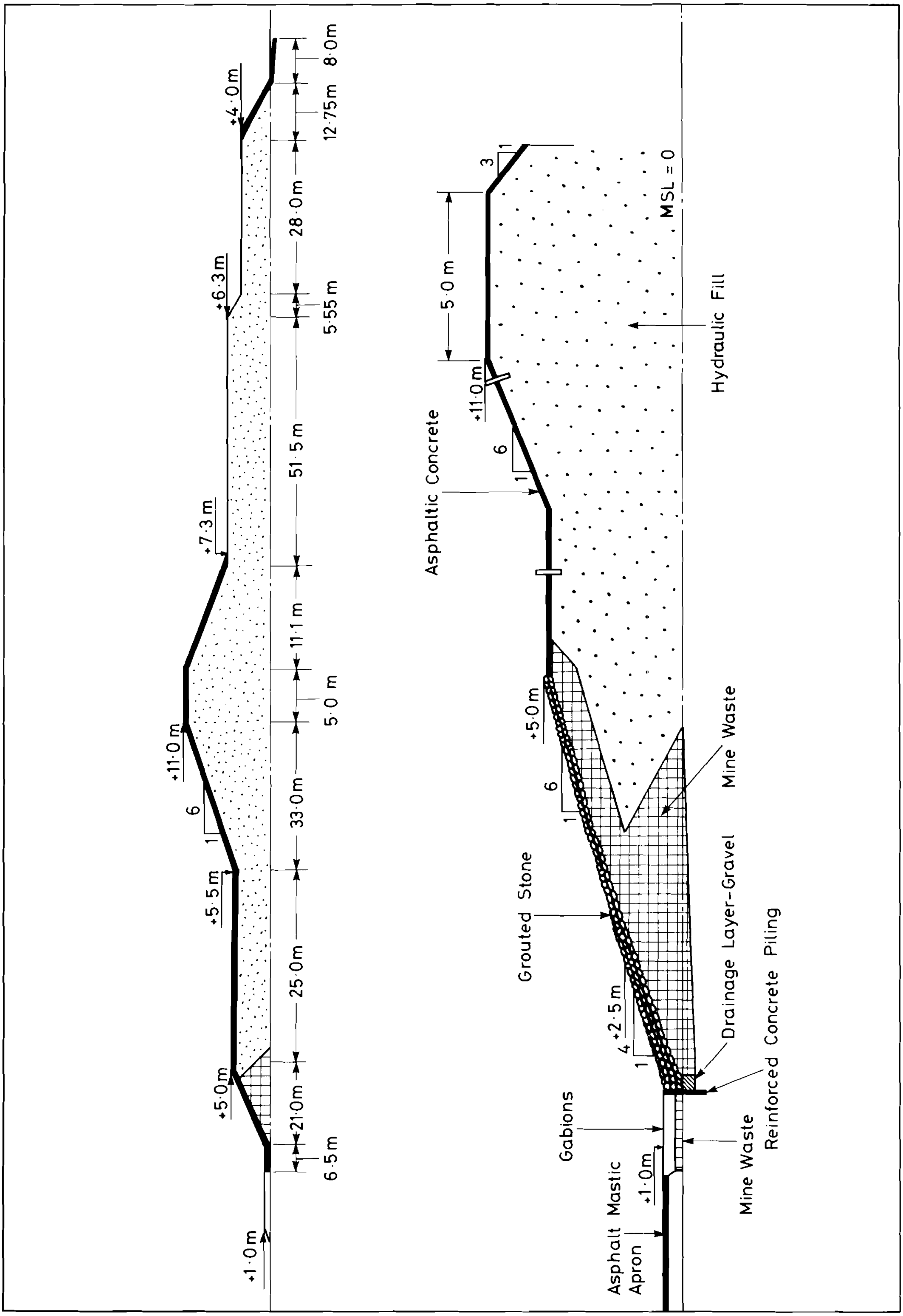

Fig. 5 Cross section through closure dam at Brouwershaven, Holland

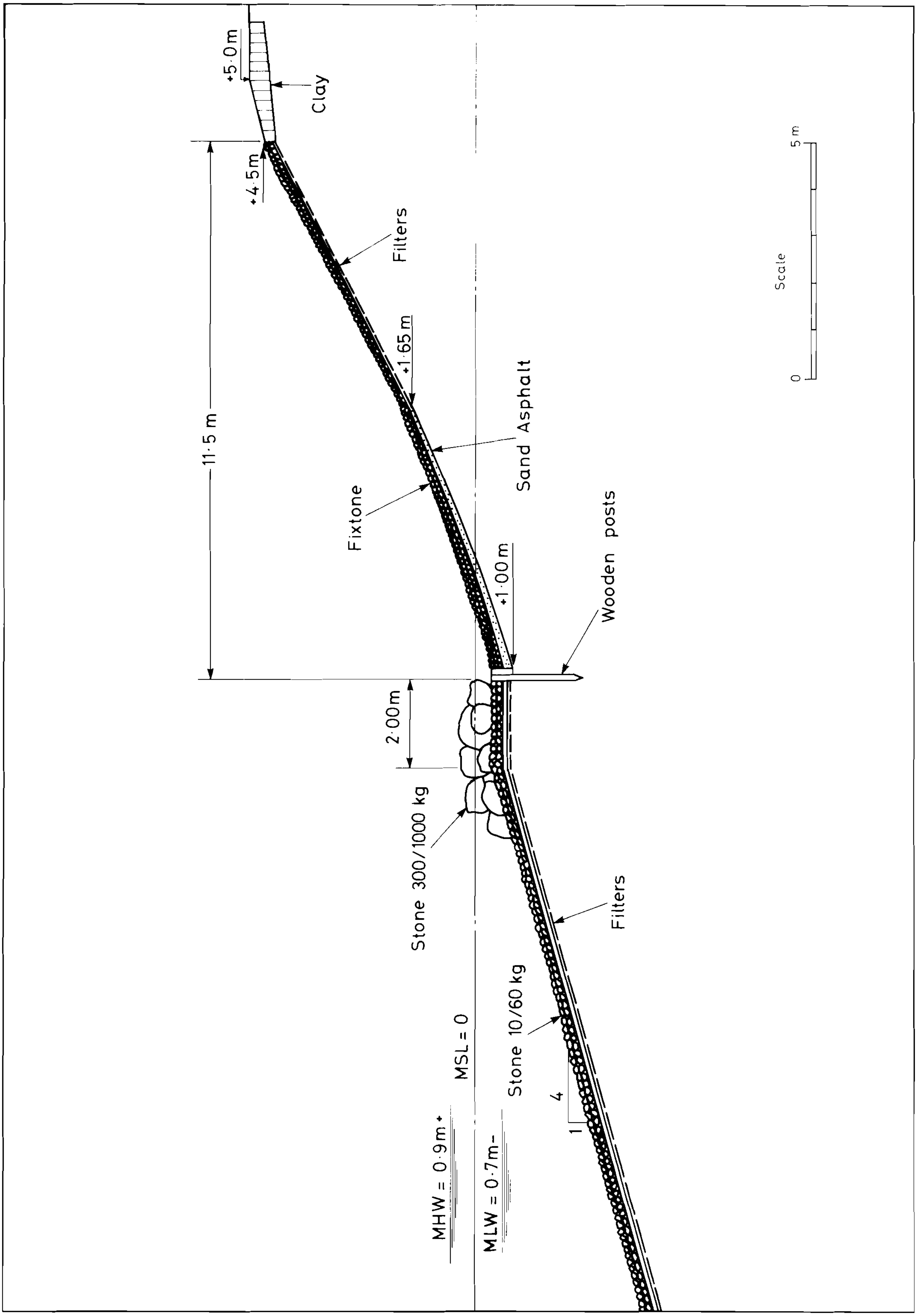

Fig. 6 Fixtone revetment in waterways at Rotterdam

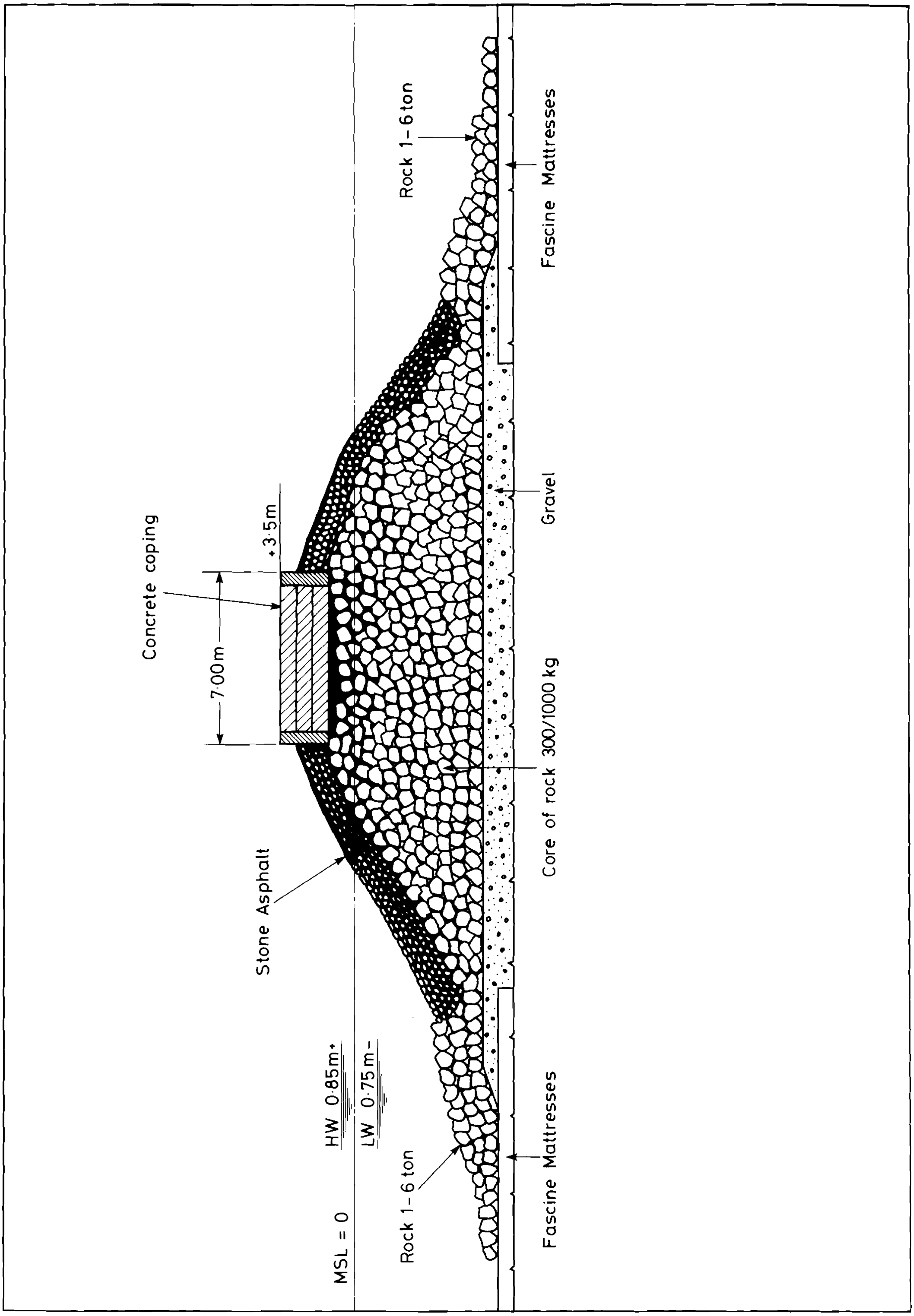

Fig 7 Ijmuiden Breakwater, Holland, built 1962-67

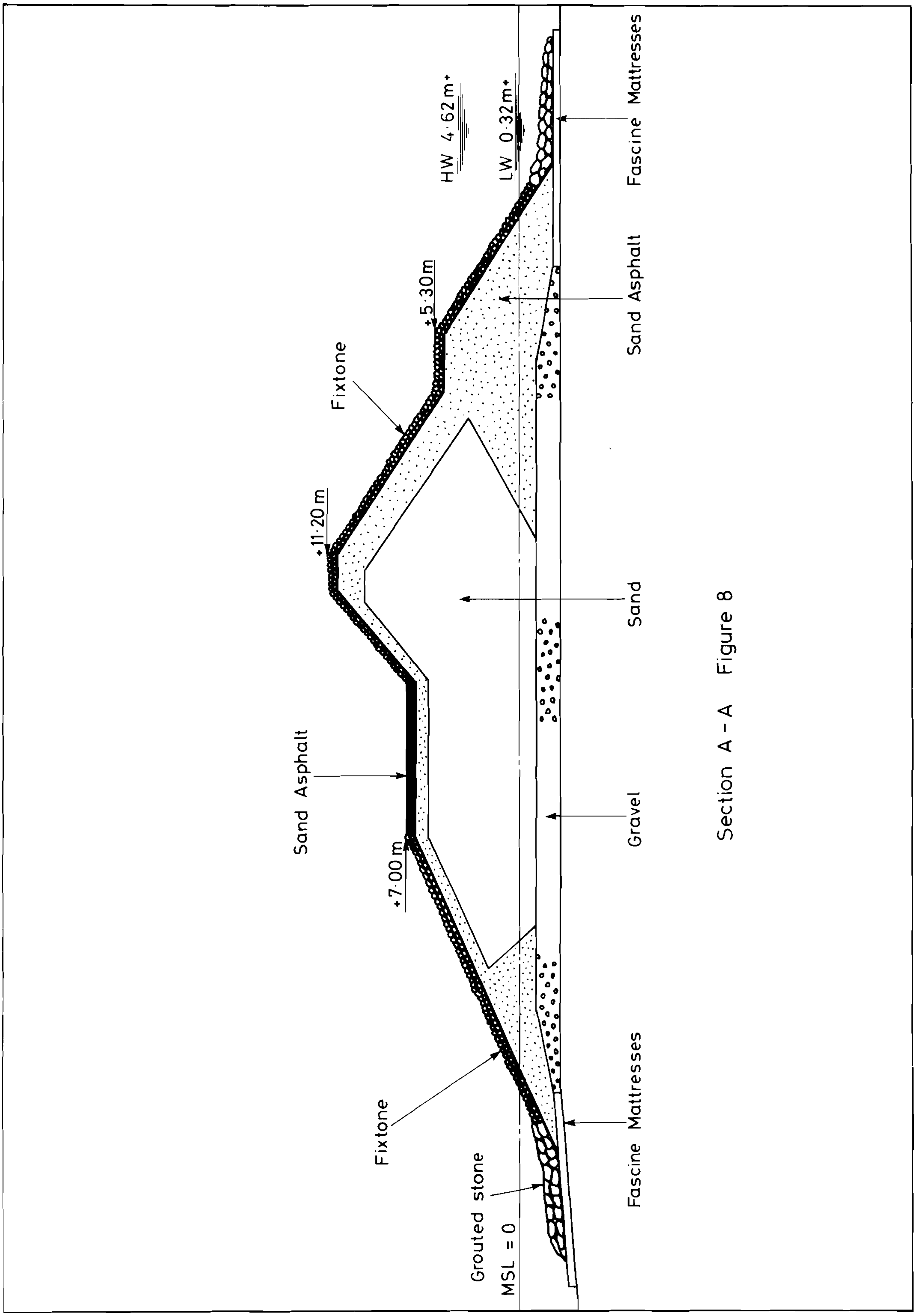

Fig. 8 Breakwater at Zeebrugge, Belgium, built 1979

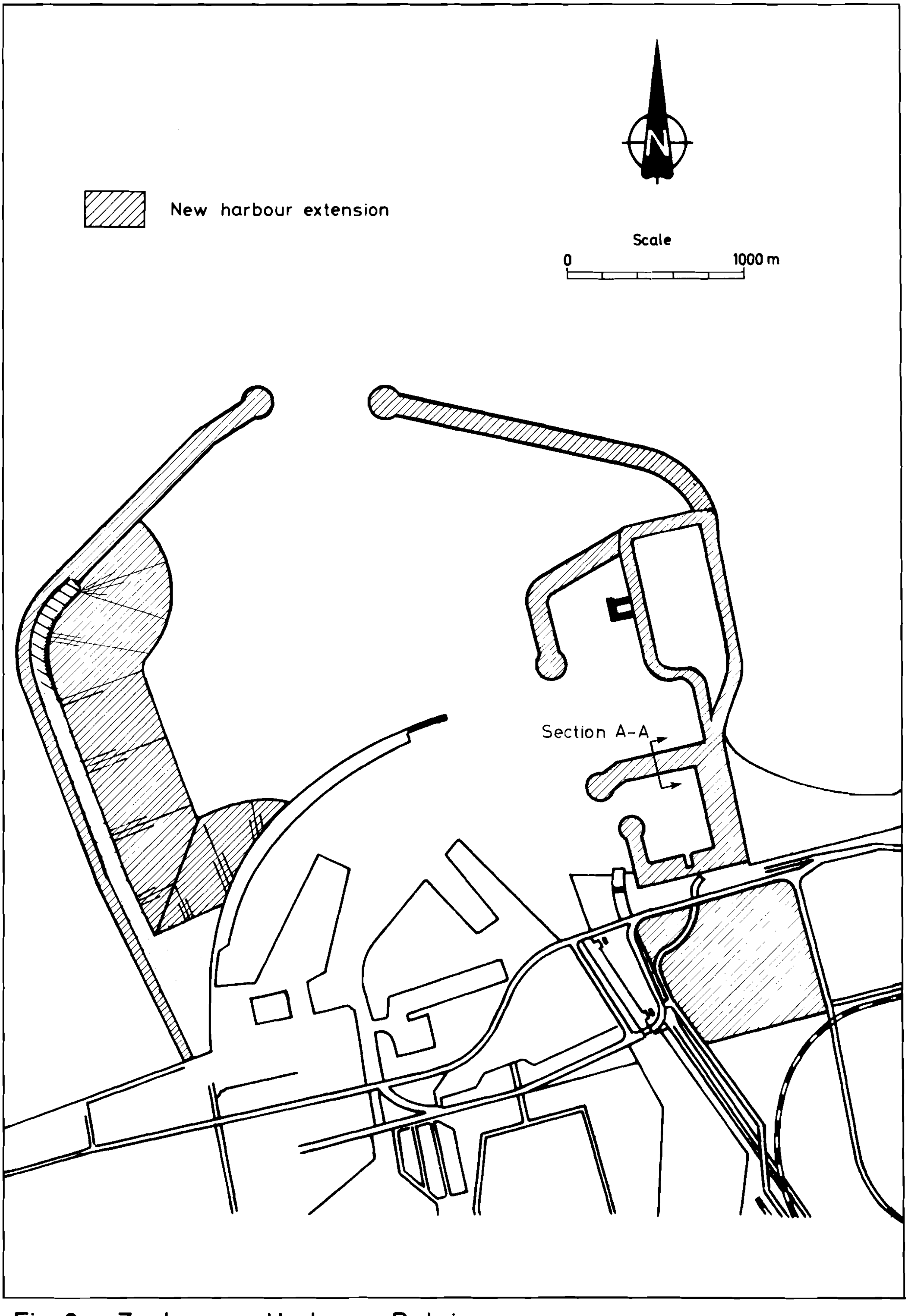

Fig. 9 Zeebrugge Harbour, Belgium

Plates

Plate 1 Vlissingen. Brick sea wall protected by a wide asphaltic concrete revetment.

Plate 2 Vlissingen. Repairs to asphaltic concrete revetment.

Plate 3 Westenschouwen. Low profile type stone groyne.

Plate 4 Westenschouwen. Asphaltic protection to toe of dunes.

Plate 5 Brouwersdam. Southern end. Artificial sand nourishment and dune development seaward of dam.

Plate 6 Brouwersdam. Northern end. Asphalt grouted stone armouring, gabion drainage layer and flexible sand asphalt toe.

Plate 7 Ouddorp. Surfacing of the landward face of the sand dyke using asphaltic concrete.

Plate 8 Ouddorp. Asphalt grouted toe to seaward face of dyke.

Plate 9 Rotterdam Waterway. Small scale bank improvements using asphalt grout and sand asphalt.

Plate 10 Hoek van Holland. North breakwater protected by asphalt grout and by a reef of large rocks.

Plate 11 Scheveningen. Low profile basalt groyne.

Plate 12 Bergen aan Zee. Dune stabilisation.

Plate 13 Ijmuiden. Spur breakwater armoured with large concrete armour units.

Plate 14 Zeebrugge. Concrete armour units protecting the new south breakwater.

Plate 15 Zeebrugge. Construction of Fixtone revetment over a sand asphalt core.