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A Review of Novel Shore Protection Methods

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SUMMARY

This review is based on an analysis of gabions as a means of shore protection.

Gabions as a form of sea defence are now widely used on both sand and shingle beaches of the UK. The report concentrates on the three main types of gabion material; plastic covered wire mesh, galvanised welded steel mesh and heavy duty plastic mesh.

The main findings are that gabions are not suited for use in areas of high wave activity and their life expectancy is considerably shortened (by abrasion) when used on shingle beaches. The more flexible "maccaferri" type can more easily withstand deformation and can be effectively used on the upper foreshore as groynes, revetments and seawalls. The electrically-welded steel mesh gabions have proved to be effective as retaining walls and in the stabilisation of cliffs and beach ridges. There is too little information, however, to be able to assess their effectiveness as groynes, revetments, etc. The heavy duty plastic mesh type of gabion is not widely used and its usefulness as a coast protection material has yet to be proven.

This, the third of a series of reports on low cost and novel shore protection methods, was produced for the Water Directorate of the Department of the Environment under DOE contract No PECD 7/7/055.

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Note: Maccaferri, Netlon, Weldmesh, Gridweld, Intelok, Tensar and Terrafirma are registered trade names.

FIGURES

PLATES

1 INTRODUCTION

In 1981, the Water Directorate of the Department of the Environment, commissioned Hydraulics Research Limited, Wallingford to review low cost or innovative methods of shore protection and assess their potential for use on the open coastline.

This, the third report in a series of reviews, considers the use of gabions as a form of coastal protection. It describes the three main types of gabion construction material and how they are being used in both coastal defence and cliff or bank stabilisation. The methods employed in producing this report and the information contained in the summaries in Appendix 2 were by either:

(a) literature review, or

(b) a questionnaire sent to all the relevant local authorities who have responsibility for coastal protection and have used gabions previously, or

(c) site visits which, in a number of cases, included obtaining the views of the local site engineers.

Although gabions have been used as a form of sea defence and river bank protection for many years, there is little published information on their performance. The name is derived from the Italian word "gabbionni" which, literally translated, means "big cages". In their earliest form, traced back to the fifteenth century, gabions were usually constructed as cylindrical, open-ended, wicker baskets and when filled with stones, used as a military engineering device for fortification as well as for river and coast protection.

The modern gabion is basically a rectangular, prefabricated mesh box, assembled on site and then filled with large stones, rockfill or shingle. There are three main types in common use today:

(a) the "Maccaferri" type box and "Reno" mattress gabion. This is a rectangular basket, divided by diaphragms into cells and formed of galvanised woven hexagonal steel wire mesh onto which is extruded a PVC coating for extra protection in the marine environment.

(b) the "Weldmesh" or "Gridweld" type box or mattress gabions (also with diaphragms when required) are made from a high tensile steel wire mesh, electrically welded at each intersection and galvanised for use in coastal conditions. Gridweld gabions are now available in a PVC coated finish. This is a fairly recent introduction which we have not been able to examine in this report.

(c) the "Netlon" type gabion or mattress constructed from corrosion resistant heavy duty plastic mesh.

All three types are supplied in a collapsed form and are assembled on site where they can be wired together to form the desired structure. Depending on site conditions, it may also be necessary to cover the area beneath or behind the structure with a suitable filter to prevent leaching of the backfill by wave action.

Gabions are available in a variety of sizes and can be used for differing purposes, the most common coastal applications being for groynes, revetments, sea walls and retaining walls. The type most generally used is probably the "Maccaferri" gabion, manufactured mainly in Italy by Officine Maccaferri who also make "Reno" mattresses, the latter being gabions whose depth, compared to width and length, is small, individual cages being wired together to form the mattress.

Gabions are most often used on sand beaches but can also be used on shingle beaches providing they are only subjected to occasional wave action. If they are placed within the intertidal zone, movement of the shingle, pebbles etc can rapidly abrade the surface of the basket wire and thus enhance corrosion by exposing the metal to the salt water environment. In other words abrasion is not good for PVC or galvanised coating, nor is it good for already rusted surfaces which are themselves protected to some degree by oxidation. Having said that, there are a number of sites on the North-west coast of England where they are being used, seemingly successfully, on stoney and shingle beaches (see Plate 1) although with a limited life expectancy. In these areas regular maintenance is needed to prevent the gabions from deteriorating.

The other main type of metal gabion sometimes used on the coastline is constructed from high tensile, heavy duty, dipped galvanised wire mesh electrically welded at each intersection. They are normally made box shaped and can also be constructed mattress shaped if required. Manufactured in a range of sizes, they are less flexible than the "Maccaferri" gabion and have been used mainly for:

(a) sea walls, in the shape of sloping mattresses;

(b) retaining walls (stabilisation of cliff slips), built usually in stepped or pyramid form, as at Overstrand, Norfolk and for (see Plate 2);

(c) stabilising beach ridges, as at Chesil Bank, Portland (see Plates 3, 4 and 5).

These "Weldmesh" and "Gridweld" gabions are more rigid than the "Maccaferri" type but nevertheless can tolerate limited movement and change in shape when subsidence occurs.

The third type of gabion in use today is constructed in heavy duty polyethylene mesh. This material is very flexible and non-corrodible but whether it will withstand abrasion, long term creep and vandalism (or even general wear and tear) has yet to be proven. In a coastal environment one can only consider using these on the backshore to stabilise sand dunes, earth banks, etc., (see Plate 6).

For all gabion types the problem of vandalism (or even general wear and tear) can be a major one, especially on beaches that are easily accessible and heavily used. As the attached questionnaire summaries show, people have been known to use the gabions for shelter when holding beach barbeques and obviously fires can, on the "Maccaferri" type burn off the PVC coating exposing the metal to corrosion. This misuse would be very serious in the case of the polyethylene mesh type. Both the PVC coating and the polyethylene mesh are easily cut with pocket knives or other sharp objects and abrasion by beach material or the rockfill within the gabions (exacerbated by people walking on them) is also likely to reduce the expected lifespan. Broken or exposed wire can also be dangerous to children playing on the beach, so gabions need regular monitoring and repair to prevent them from becoming a hazard.

We have found, therefore, that gabions are structures which need regular maintenance, and without monitoring and repair, are likely to deteriorate in a relatively short space of time.

Strangely, although gabions have been marketed and used in Europe for many years, they are relatively new to North America, being widely used only during the last couple of decades. Gabions are, however, becoming more popular both in the UK and in other parts of the world. They are, for instance, widely used in Third World countries where labour is plentiful.

Plates 7 and 8 show plastic covered Maccaferri gabions at Ambo on Tarawa in Kiribati (formerly the Gilbert Islands) (Ref 7). They have been placed on the lagoon side of a causeway to protect the road from erosion. When constructed in July 1975 they were filled with coral boulders and adjacent gabions wired together for extra strength. Although they are sheltered somewhat from heavy seas by an offshore reef, they are nevertheless exposed to direct wave action and their life under these conditions is likely to be limited. Coral has sharp edges which will eventually cut through the plastic covering and thus enhance the corrosion process.

The installation of gabions is labour intensive and in regions where manpower is relatively cheap, they can be very cost effective.

In this country gabions are widely used as shore protection in areas as widely different as the shingle beaches of the Cumbrian coastline (see Plate 1) and the sandy beaches of East Anglia (Plates 9 and 10). In the following chapters, performance is considered not only in terms of the type of beach on which it is placed but also in relation to its position relative to the water line.

We have come across only one gabion breakwater in our review, this being on the shores of Lake Erie at Geneva State Park, Ohio (Ref 9). The structure, placed about 18m offshore, was designed to break up the wind induced waves before they reached the cliff. Although it seemed to work reasonably well during the monitoring period at this site, it would be unlikely to survive on the coastline of the United Kingdom. Indeed, any type of gabion structure subject to almost continuous wave activity is not likely to survive very long. Internal abrasion, under these conditions, will occur within the baskets due to movement of fill and maintenance would be extremely difficult. It is considered unnecessary to mention this further in this report.

2 FORESHORE PROTECTION

In the coastal strip there are two distinct zones; the foreshore where wave activity occurs regularly, and the backshore where wave activity is limited to the occasional storm. On the foreshore, gabions have been used as groynes, revetments and sea walls. It is often difficult to differentiate between the latter two and hence definitions used in this report are:

1. Groyne - a structure usually built perpendicular to the shoreline, to trap littoral drift or retard erosion of the beach. Located on the foreshore.

2. Retaining wall - a structure designed to retain or prevent sliding of earth fill, soft cliff material, etc. Usually located on the backshore.

3. Revetment - a sloping structure used to protect and stabilise earth or clay embankments, sand dunes and cliff faces. Used mostly on the foreshore but sometimes also on the backshore.

4. Sea wall - a vertical or near vertical structure built parallel to the coastline to prevent erosion or flooding. Usually located on the foreshore.

2.1 Groynes

Groynes are constructed with the aim of reducing the rate of littoral drift and so provide a protective mantle of beach material (such as sand or shingle) along the frontage. In a suitable environment, gabion groynes, well designed and installed, are an effective means of trapping this drift.

There are several distinct advantages when considering gabions as groynes. They are flexible and so conform to minor settlement. They are also permeable and thus to some extent wave absorbing. Individual gabion boxes can often be installed fairly quickly between tides. Another advantage is that the interstices can become filled with silt, sand and covered with vegetation, (wind or water borne) thus building up the beach so that the gabions gradually blend in with their surroundings. An example of this is at Holme next the Sea, Norfolk, where the Anglian Water Authority have installed "Maccaferri" type short gabion groynes to trap mainly wind blown sand plus an integral low sea wall to stabilise the sand dunes at the top of the beach (Fig 4 and Plates 9 and 10). The system, built on a wide sandy beach on the eastern edge of the Wash, was installed in stages starting about 15 years ago. Initially it comprised 21 gabion groynes 24 metres long and 25 metres apart together with 500 metres of revetment. This system was extended southwestward by 460m in 1975. There is little shingle present on this beach and the wave climate is not too severe. Plate 10 shows the importance of installing foundation pads, particularly at the seaward end of the groynes to prevent scouring and consequent settlement.

The gabions have proved effective, with only minor damage occurring after the surge of 1978. They have recently been extended by 380m toward Old Hunstanton (see summary sheet and Plates 9 and 10). To further stabilise the sand dunes to the rear of the structure, marram grass was planted on the sand backfill. A filter cloth was also used to retain backfill from leaching through the gabions. The good performance of this system stands in contrast to gabions installed on a nearby beach, where they were abraded rapidly by shingle and lasted only a few years.

Disadvantages, some of which have been given earlier, consist mainly of basket deterioration due to abrasion (by wave borne shingle and debris), vandalism and the need for good compaction of the rockfill (usually by hand) making it labour intensive. Gabions are flexible so in a mobile environment may work their way into the beach unless suitable foundation is provided.

Because of the cost of materials used in constructing traditional groynes there is clearly a need for examining innovative methods. To make a conventional groyne less costly for example, it is feasible to construct the landward end of the groyne with gabions, ensuring of course that the gabion baskets do not move out of position. This has been done on a sand and shingle beach on the south coast (see Plate 11). However, it is too early to say whether a hybrid groyne of this nature will prove to be a useful asset in terms of cost effectiveness.

In our opinion, the best groyne filling material for use on the foreshore is rounded large shingle or cobbles which will adjust to beach changes, have a good wave absorbing quality and will, if well packed, not settle in the same way as angular stone. The problem with angular rock in areas of wave activity where the fill is mobile is that the sharp edges tend to cut through any PVC coating exposing the metal to corrosion. However, many local authorities find that the use of angular rockfill can be more cost effective. These authorities, in most cases, have used angular fill for constructing walls at the top of the beach out of the reach of wave activity, or in areas of light pedestrian traffic. In such areas i.e. the backshore zone, gabions filled with rectangular blocks do keep their shape better than ones filled with rounded stone (see Plate 12). Therefore, gabions filled with angular stone appear to work well under conditions which do not lead to movement of the fill material. This generally precludes their use as groynes.

As far as the hydraulic design of a groyne system is concerned i.e. length, spacing, height, etc., some guidance can be found in a recent literature review by Hydraulics Research Limited (Ref 6). One should bear in mind that this survey was carried out mainly with conventional groyne systems in mind. For example, an effective groyne length might not be possible with gabions, since this may take them seaward into the zone of continuous wave activity. Under these conditions, the groyne ends will quickly deteriorate. Thus gabion groynes can really only be used to trap material efficiently on the upper part of the beach and cannot be expected to arrest a large part of the littoral drift. They may, however, help to trap wind blown sand.

As far as strucural design is concerned, the manufacturer's guidelines should be carefully followed. This is very important especially with respect to instructions about effective packing. Badly packed gabion groynes will deform and quickly lose their crest height. Stresses imposed by movement of the baskets can cause abrasion of the wires, with consequent breaking and loss of material.

2.2 Revetments

Usually constructed as a sloping apron designed to dissipate wave action, they are used to provide protection to earth or clay embankments, sand dunes or cliff faces. For reasons of stability, gabion revetments are usually constructed as mattresses laid on slopes no steeper than 1:1, with filter material, if necessary, laid beneath or behind them. With slopes steeper than this, a stepped form of revetment or sea wall using one metre high box gabions can be adopted with an overlap of perhaps half a metre. With both types of structures, adequate toe protection and anchorage must be provided. Another factor to be borne in mind is that shingle and coarse sand beaches are much steeper than those of fine sand and hence gabions, unless securely anchored, tend to slide or topple seaward more easily. The beach being steeper also means that wave energy is absorbed over a relatively narrow zone and the beach material will therefore be more mobile.

We have come across a number of locations where gabion revetments (and groynes) have been used in too severe a wave environment. Under conditions of large tidal range and severe wave action, beach material and indeed the gabion fill, is constantly in suspension causing rapid wear. At a number of sites, revetments laid on shingle beaches have become totally destroyed in only a few years. Attempts have been made to protect damaged lids by patching with concrete or grouting with bitumen. Concrete patching is generally used where gabions are subject to pedestrian traffic. On most sites visited, where bitumen was used, penetration of the grout was less than adequate and tended to spall off under hydrostatic pressure, sometimes tearing the gabion wire in the process.

It has to be said that problems of gabion revetment design, as with groyne design, have not yet been ironed out. The relatively thin mattress type of gabion construction can lead to problems at the interface between the basket and the underlying fill. Even the inclusion of a filter membrane does not necessarily resolve the problems associated with fluctuating wave induced pressures. The suction forces induced by wave rundown can be sufficiently high to drag the mattress out of alignment and cause structural failure unless securely tied back. Gabion mattresses, most commonly used in revetment construction, are generally too thin to withstand wave attack in all but very mild wave climates. There is clearly room for improvement in a number of aspects of design. However, before improvements in hydraulic performance are made, the problem of corrosion in an active wave environment still needs to be solved. More research needs to be carried out for example into the use of different plastics in order to protect the gabion wires more effectively.

A report published by the Water Research Laboratory of NSW (Ref 8) looks at the use of "Maccaferri" gabions and "Reno" mattresses for coastal revetments and highlights the problems of installing gabion mattresses on flat sandy beaches.

"Reno" type gabion mattresses were installed in two different thicknesses (230mm and 290mm) and with two different forms of filling material (crushed blue metal and rounded river gravel). "Terrafirma" was used as the filter fabric. The mattresses were lain on the beach face (composed mainly of sand). Stone grading, from a local quarry, was poor. Work proceeded well until the tidal zone was reached when rapid changes in beach level caused problems. In view of this, one mattress was placed in a pre-assembled condition but the stresses imposed by transporting it and repeated re-handling caused serious damage and distortion of the cages. Construction was therefore not attempted below low water. The last two seaward rows were very poor in appearance due to rapidly changing beach levels and the fact that it was impossible to complete a full row between tides. Construction began on 16 November 1976 and the five rows were not finished until 21 January 1977. The tests showed, not surprisingly, rapid loss of undersized material and the filling in several places disappeared after the first major storm. It was also noted that where there was more than 30% material loss, wear was extremely rapid, the PVC coating being entirely stripped from some wires, exposing the galvanised metal. No comments were made as to the suitablity of the different materials or about the different sized mattresses used in this project.

Maximum wave heights of one metre at the foot of the structure did not cause movement. However, sand level variations resulted in the frequent emergence of the panels which then acted as a low groyne, "accumulating sand on one side and eroding it on the other". Where filter cloth overlap was less than 500mm, leaching of sand took place, resulting in quite marked subsidence along the lines of overlap.

The project also showed that the method of lifting pre-filled mattresses was only partly successful giving rise to distortion of the mattress, stretching of the wires and splitting of the PVC coating. After the lift, the previously tightly filled mattress became extremely loose. After destroying one mattress during lifting, this method of laying was abandoned. It was concluded that pre-filling may be feasible but required substantial plant to achieve success as well as detailed supervision to maintain quality. Optimum results can be obtained with multipoint lifting but this requires specialised plant which may put the construction out of the low cost category.

2.3 Sea Walls

Sea walls are usually built parallel to the coastline to prevent erosion or flooding as a result of wave action. The manufacturers recommendations for gabion use include the following:

(a) the foundation must be protected against undermining by placing the footings below the lowest level to which the foreshore is likely to drop;

(b) vertically faced walls, even if stepped, should not be used where they are subject to heavy wave action;

(c) if the structure is subjected, at any time, to direct wave action of a height of one metre or more, the face must be sloped not steeper than 1:2;

(d) where leaching of fines from behind the wall is likely to be a problem, filter membranes should be laid under and behind the gabion cages themselves.

Few of the gabion sea walls that have been inspected could be said to be subject to high levels of wave activity. Those that were, showed a high level of damage due to wire corrosion, etc. Instability was also seen to be a problem, especially on steep shingle beaches, when gabion baskets tended to overturn in a seaward direction as a result of changing beach levels (see Plate 13). As with revetments, the effective use of gabions for sea wall construction, even in moderate levels of wave activity is not easily achieved. Despite the short life of these structures, gabions are often used in preference to conventional sea walls because of their low capital cost. It is difficult to assess the cost benefit of these structures because of their "uncertain" design life.

3 BACKSHORE PROTECTION

In this zone, subject to only occasional wave activity, all three types of gabion material are in use to stabilise cliff faces or to prevent the erosion of sand dunes, earth embankments, etc.

3.1 Retaining walls

Both the flexible "Maccaferri" type PVC coated gabion and the semi rigid "Weldmesh" or "Gridweld" type gabion are normally used for structures of this sort and can be built sloping, vertical or stepped, depending on conditions. Since these structures are permeable, problems with natural springs and water run off are also considerably reduced. At Overstrand in Norfolk for example, "Weldmesh" gabions were used to stabilise and repair a cliff slip (Plate 2). The cliff was protected with 12 rows of gabions rising at an angle of 45 degrees. It provides a 49 metre frontage at the base rising in pyramid form to an 18 metre width at a height of 5.5 metres. Built in 1966, the 245 gabions (75mm x 75mm x 5mm gauge) made up on site and filled with local stone, continue to be effective. A system of drainage pipes within the structure run off surplus water to the beach. An inspection in 1983 showed only minor corrosion had taken place since construction and the baskets appeared to be in good condition (see Plate 2) although one or two baskets were half empty, possibly the result of the rockfill splitting into smaller pieces (due to compression) and being washed out through the mesh by run off.

Another example of a gabion retaining wall can be found at Downderry in Cornwall (Ref 2). Here erosion of the cliff toe was threatening to cause a major slip and a stepped retaining wall was built to stabilise the cliff slope. This wall, built in 1971 is still performing effectively.

3.2 Revetments

All three types of gabion material described previously have been used as revetments with varying degrees of success.

At Aldeburgh in Suffolk, an extensive system of "Maccaferri" gabions was installed in 1966, incorporating an apron, groynes and sea wall, protecting a levee separating the sea from a navigable river with low lying ground beyond. This is used as a second line of defence behind a shingle ridge. To date the ridge is still intact and there has been no interaction between gabions, shingle and sea. The gabions look to be in good condition and there is no evidence of vandalism or of corrosion by salt water.

At the Chiswell end of Chesil Beach, Portland, a system of gabion mattresses, both Maccaferri and Weldmesh, straddle the beach crest in three layers. Installed in 1981 (see Plates 3, 4 and 5) they are anchored to gabion boxes set into the landward slope of the beach. As the attached summary indicates, both local beach pebbles and Portland capstone were used as fill material and some of the Maccaferri gabions had a lining of Netlon to prevent undersized fill from being drawn out by wave action. The mattresses are situated on the beach crest above normal wave activity and are subject to only occasional overtopping. Generally, the exposed baskets are in good condition although we believe that some damage has occurred to the Netlon lining.

At Brancaster on the Norfolk coast, a sloping revetment consisting of a "Netlon" mattress and incorporating "Tensar" short stub groynes (Tensar is another type of plastic mesh manufactured by "Netlon"), was built in 1981 to protect the seaward face of eroding sand dunes (see Plate 6 and Fig 3). As the attached summary indicates, this was an experiment to determine their usefulness compared with the "Maccaferri" type gabion. One problem encountered when the baskets were being filled from the top by machine, was that the fabric stretched and holes were punched through the cages. They thus had to be hand filled to ensure that the baskets kept their shapes. It would appear that this revetment, although cheaper, requires more attention than plastic coated metal gabions.

Netlon gabions were also installed about a year ago on the back of a promenade to the east of Hengistbury Head, Dorset. They consist of a layer of gabion boxes set into a concrete plinth to give protection to the base of the clay cliff. They are filled with either local gravel rejects or limestone angular rock and the front face is further protected by a layer of flat Tensar mesh (see Plate 14). The condition of the gabions is good on the more sheltered east side (limestone rockfill) although the more exposed western end some cases have settled requiring repacking and some have lost their shingle fill. There is evidence of vandalism, the cages being cut with a knife, which is always a problem with plastic mesh. Although only installed recently and therefore still being assessed, the gabions seem to be performing reasonably well but will require careful monitoring.

4 SUMMARY OF FINDINGS

Each installation mentioned in this review is "site specific" with its own exclusive parameters, i.e. wave climate, tidal conditions, beach configuration, etc. Care should thus be exercised when using the following general guidelines for a particular type of structure:

1. Well designed gabions can prove cost effective but cannot be described as aesthetically pleasing. This may be a factor to consider in areas visited by holidaymakers.

2. Gabions depend for their strength on the retention of a large number of small rocks within the enclosing mesh. If the fill is not tightly packed, wave action causes excessive flexing of the mesh which in turn leads to breaking of the plastic coating and galvanised surface, and the ensuing corrosion rapidly causes breaking of the wire. The more flexible gabions can accomodate, to some extent, small voids by deformation of the cages.

3. Regular monitoring and repair is essential, especially in the more popular holiday areas and in places where gabions are subjected to beach movement and wave activity is high. It is usually possible to repair the mesh type gabion quickly by rewiring if the damage is localised. Unless baskets are repaired quickly, broken wires can become a hazard to holidaymakers (see Plate 15).

4. Gabion structures are labour intensive and keeping costs down would depend on:

   (a) available manpower
   (b) availability locally of suitable stone or rockfill

(c) easy site access.

5. "Maccaferri" gabions are recommended for sandy beaches although they have been used, seemingly successfully, on shingle beaches with a probable shortening of their expected life span. Their use in this environment, however, should be restricted to the upper parts of the beach.

6. "Maccaferri" gabions are flexible and therefore can adjust to moderate beach profile changes without structural damage. The more rigid galvanised wire gabions, such as "Gridweld" and "Weldmesh", have been used less extensively in the foreshore zone. For this reason one can be less certain about their likely performance in this environment. It is likely, however, that only minor beach changes could be accommodated without structural damage.

7. "Maccaferri" baskets are woven and this places an upper limit on the size of wire that can be used. These restrictions would not apply to a welded basket.

8. Adequate burying of the first layer of baskets is important to avoid undercutting by the sea and thus causing displacement.

9. If not filled "in situ" then great care must be taken to ensure that the method of lifting mattresses does not:

   (a) distort the mattress
   (b) stretch the wires
   (c) split the PVC coating.

   Coupled to this, the plant and supervision involved in moving pre-filled mattresses may well prove to be very expensive.

10. If a gabion structure is to be subjected to direct wave action of one metre or more, the face must be sloped.

11. Opinion as to the lifespan of the metal gabions on the foreshore is divided but the general consensus is that in

areas subject to severe wave activity, gabions will succumb to rapid abrasion and as a result their lifespan can be as short as 2 or 3 years. On flat sand beaches subject to moderate or low wave activity the lifespan can be a decade or more. On the backshore, however, where gabion structures are not subjected to regular wave activity they can be expected to have a considerably longer lifespan. At Overstrand in Norfolk for example, a "Weldmesh" type retaining wall installed above HWMST, has been in existence for 18 years and still appears to be in good condition.

12. As far as the "Netlon" type of gabion is concerned, we know of sites where they are currently in use on the backshore, but as yet it is too early to assess their longevity on the foreshore. Clearly, however, they are more susceptible to vandalism than the other types of gabion.

13. All gabion structures can fairly easily be vandalised or damaged during construction. PVC coating for instance, can crack (with eventual rusting of the metal beneath) although looking intact.

15. Gabions have been used either with rounded stone or with angular rock. Rounded stone would appear to be a better solution in an active wave environment while angular rock keeps baskets in good shape in areas where beach movement is insignificant. Plate 16 shows how even very large stone sets can be used to fill gabion baskets. One should bear in mind however that these baskets will not conform to beach changes as easily as if they were filled with smaller stones.

16. Mattresses placed on a sloping surface are prone to sliding, (usually generated by wave forces) so provision of toe anchorage is essential when founding on a rocky sub-surface. Provision of an adequate thrust toe is also important on a sandy embankment. Mattresses due to their thin section can also be prone to buckling so an intermediate form of anchorage is important.

17. The provision of a filter membrane is essential where leaching of fines from beneath or behind a structure is likely.

18. Although bitumen grouting is sometimes used to provide additional protection, it is difficult to grout completely. In a lot of cases penetration has been less than adequate and bitumen has tended to spall off under hydrostatic pressure, sometimes tearing the gabion wire in the process.

19. It is possible to use gabions as a former and to provide full grouting. This method was used at the Dover Hoverport (using concrete) to provide a foundation for the Hoverpad.

20. Concrete capping, usually installed to allow pedestrian traffic but unless put in after all settlement has ceased, may crack and disintegrate.

21. Gabion baskets must be securely wired together. Diaphragms when used must be wired tightly to the gabion lid which in turn should be strongly secured. This keeps movement of the fill to a minimum and helps to retain the original shape of the gabions.

This is by no means an exhaustive list of "design criteria". It is essential that the manufacturers recommendations should be followed wherever possible.

5 CONCLUSIONS

1. It is not always cost effective to protect the coastline with conventional sea defence works, particularly in rural areas where there is little or no risk to property. Low cost structures such as gabions can be used, for example, to retard shoreline erosion or to give long term protection to those parts of the beach out of reach of normal activity. One of their particular strengths is that gabions are wave absorbing and hence generally are not detrimental to beach stability.

2. Understandably perhaps, it has been difficult to obtain information about gabion structures that have been quickly destroyed. One should therefore bear in mind that although the summary sheets point to a relatively long life of some structures, the average life span may be considerably less than these findings suggest. We know of instances where structures have been damaged beyond repair in a relatively short space of time and little evidence of gabion protection is left. It would therefore appear that the life span of a gabion structure can be as low as 3-4 years or less in an active wave environment, but when out of reach of normal wave activity can be as high as 18 years or more.

3. The most widely used material for gabion construction would appear to be:

   (a) Maccaferri (woven galvanised steel wire enclosed in a PVC coating for use in the marine environment). Used in basket or mattress form they are most useful on the foreshore because of their flexibility and ability to flex under changing beach levels.

   (b) Weldmesh or Gridweld (high tensile steel wire mesh, electrically welded at each intersection, galvanised and now obtainable with a PVC coating). Effective as rigid training walls, etc., where toe movement is not anticipated.

(c) Netlon (heavy duty plastic mesh). Used above any wave action, can be effective for cliff toe stabilisation as an absorbing splash wall and for stabilising sand dunes. This material however, has a tendency to stretch when being machine filled from the top of sloping revetments. It is also vulnerable to vandalism and general wear and tear.

4. Because of its "building block design" gabion structures can be widened, or heightened with relative ease. However, toe erosion problems cannot be easily remedied once the structure is constructed.

5. They also require a high level of maintenance, particularly when used in urban areas. For example, the wires can become broken when subject to heavy pedestrian traffic and this can be a hazard. Generally speaking maintenance, damage, etc., will be minimised if the manufacturer's recommendations (so far as the method of construction is concerned) are followed.

6. Gabion structures are not recommended for use in areas of high wave activity where movement of fill and beach material (particularly shingle) can cause rapid wire abrasion.

7. They are not recommended for shingle beaches when placed in the inter-tidal zone. Under these conditions wear and tear in an area under almost continual movement can reduce their effective life span dramatically irrespective of type of fill.

8. Where the fill is likely to be agitated by wave action, baskets should be <u>well packed</u> with rounded stone if possible. Angular stone, if moved internally by wave action, will tend to settle and result in basket deformation if stacked, or, because of relatively sharp edges, result in excessive internal abrasion if in mattress form.

9. Gabions are generally effective as revetment or training walls in the backshore zone, out of reach of normal wave activity and subject only to spray. In this zone block stone and angular fill has been used successfully as "dry stone walling". In this

position they can be as effective on shingle or sand beaches provided the gabion is well filled. Major wear and tear is however likely, due to pedestrian usage. In these conditions they can be strengthened by concrete capping, or repairs can be made by concrete or bitumen patching. Here the lifespan can, with regular monitoring, be in the order of two decades or so.

10. They can be effective on wide sandy beaches, especially above the high water line where they could eventually, being permeable, become covered by wind blown sand and in some cases become colonised by dune grasses. Under these conditions, the life span of the gabion material could be a decade or more.

11. It was found that the weldmesh type gabion, due to mechanical failure largely caused by corrosion, produced extremely sharp points and edges with obvious consequences for popular beaches.

12. Broken and empty gabion cages do tend to roll and in one case was found to have travelled several miles aided by the wind and waves along the beach.

6 REFERENCES

1. Anon (C H Dobbie & Partners) "Maritime and Riparian uses of gabions". Dock and Harbour Authority, December 1965.

2. Maccaferri Handbook.

3. BRC "Weldmesh" brochure.

4. "Gridweld" brochure.

5. "Netlon" brochure.

6. Hydraulics Research Station. "Groynes in coastal engineering - a literature review". IT 199, March 1980.

7. Hydraulics Research Station. "Gilbert Islands - Land reclamation, causeway construction and sea defences, EX 727. March 1976.

8. Brown, C T. "Some factors affecting the use of Maccaferri gabions and Reno mattresses for coastal revetments." University of New South Wales Research Laboratory (Report 156). October 1979.

9. US Army Corps of Engineers. "Low Cost Shore Protection. Final Report in the Shoreline Erosion Control Demonstration Program (Section 54)." Prepared by Moffat & Nichol, Engineers, 1981.

7 ACKNOWLEDGEMENTS

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Mobbs and English (Consulting Engineers)

The American summaries in Appendix 2 were obtained from the US Army Corps of Engineers final report on their "Shoreline Erosion Control Demonstration Program (Section 54). They are reproduced here by kind permission of the publishers Moffatt & Nichol, Engineers Long Beach, California, USA.

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APPENDIX 1

APPENDIX 1 - QUESTIONNAIRE

To discover how the local authorities view gabions as a means of shore protection we sent a questionnaire to all the Councils with coastal defence responsibilities and who are known to have used gabion protection at one time or another. The edited answers to the questionnaire (shown on page 26) are set out in this Appendix. We are most grateful to those local authorities who were kind enough to reply.

QUESTIONNAIRE

Do you agree with the following:

1. Gabion structures are more suitable for sandy environments and climates with mild to moderate wave conditions.

2. Gravel is likely to abrade gabions quickly if they are situated in the intertidal zone.

3. Gabions are useful in stabilising sand dunes, especially if they eventually become covered.

4. Gabions are prone to vandalism and therefore should be designed for an expected life span of no more than 10 years.

5. Gabions could be a hazard to holidaymakers when the baskets are broken, etc., and therefore must be monitored.

6. Gabions should be PVC coated rather than galvanised to be more resistant to corrosion especially if wetted by salt spray.

7. Whatever method or type of material is used, tight packing is essential, i.e. allow to settle and then, if necessary, repack.

8. In general gabions are more suited as sloping revetments on the upper beach than as groynes on the lower beach, i.e. placed where they will not be subject to continuous submersion and wave activity.

9. The flexible "Maccaferri" type gabions perform best when filled with large rounded stones.

10. The rigid gabion type boxes (such as "Weldmesh") will hold their shape better and last longer if packed well to avoid settlement.

11. The flexible PVC coated gabions are generally better than the nylon net or rigid type for use on the open coast.

12. Finally, any comments on your experience with gabions would be welcomed.

1. Agreed.

2. Agreed.

3. Agreed.

4. Very little vandalism experienced.

5. Agreed.

6. Agreed.

7. Agreed.

8. Agreed.

9. Agreed.

10. Agreed

11. -

12. My Council and the former constituent Councils have used gabions extensively with some degree of success. Groynes constructed with gabions have been a limited success only where the base was at least 2m wide and where the stone fill was angular.

Allerdale District Council

1. No comparative experience.

2. The above type of gabion is generally resistant to wave action but the PVC coated galvanised wire mesh wears away by abrasion with total breakdown after about five years.

3. -

4. Polypropylene polymer mesh type of gabion ("Netlon") prone to vandalism (pocket knife attack), so life span variable and uncertain.

   Expected life of the high tensile wire mesh type gabion ("Weldmesh") approx 10 years (on shingle beaches).

   For "Maccaferri" type gabions see 2 above.

5. The "Weldmesh" type due to mechanical failure, largely caused by corrosion, produced extremely sharp points and edges. This is not acceptable where the general public are free to roam. The plastic mesh will need careful monitoring.

6. -

7. "Maccaferri" type gabion packed by hand using old limestone kerbstones around three sides and then filled with beach cobbles and stones.

8. -

9. See 7 above.

10. Mechnically the strongest with the obvious advantage that it can be roughly handled and can resist direct loading using suitably sized rock or rubble.

11. Netlon type presently used to support cliff toe drainage and only occasionally subject to wave action. Currently under assessment.

12. "Maccaferri" type gabions, presently the most widely used, are particularly successful on a coastline subject to a severe wave climate with beaches comprising shingle, cobbles and rounded stones up to20mm in size. Due to rapid beach erosion they are now being asked to fulfill a purpose they were not designed for i.e. use in an increasingly severe wave exposure.

1. Agreed.

2. Agreed.

3. Experience has shown that the fence method is more effective and aesthetically pleasing, than gabion protection. Cheaper and easier to extend sand fences upwards as accretion progresses.

4. Not a problem but accept that it could be in the more metropolitan areas.

5. Agreed.

6. Agreed.

7. Agreed.

8 Agreed.

9. Have very little trouble with as dug granite or angular stone.

10. Agreed.

11. Agreed.

12. We have used "Maccaferri" gabions in the estuarial situation and as coast protection. This also includes Reno mattresses which have stayed in position even when laid flat on the top of a wave return wall which, with a Force 8-10 southerly gale, has thousands of gallons of water crashing down on it at high tide.

Carrick District Council

1. Properly anchored and designed gabion structures can provide economic coast protection, even in exposed tidal positions.

2. Unable to comment.

3. Agreed.

4. Heavily constructed and well designed gabions suffer no more than traditional structures from vandalism.

5. Broken and protruding ends of gabions are extremely dangerous and require regular attention.

6. No experience of PVC coated gabions, I would balance additional cost of metal thickness with cost of PVC cover in view of eroding of PVC by wave and stone filling movement.

7. Annual topping up of open top gabions occurs in this area.

8. Each area can be effectively protected by gabions. The gabions used on the lower beaches to trap tidal and windborn sand and the sloping type of revetment as a flexible protection to the coast or river bank.

9. This fill material not naturally available so cannot comment on the comparison.

10. Agreed

11. No comparative experience.

12. This Authority has a length of approx ¾ mile of coastal protection provided by a gabion structure and this has proved cost effective but would not be described as aesthetically pleasing in a resort situation. The ability to quickly create substantial barriers to enable the rapid build up of sand, working between tides with limited heavy construction plant gives the gabion structures a distinct advantage.

Cleethorpes Borough Council

1. -

2. -

3. -

4. -

5. Agreed.

6. Agreed.

7. -

8. Agreed.

9. Agreed.

10. Agreed

11. Agreed.

12. Experience has shown that adequate burying of the first layer of baskets is important to avoid undercutting by river or sea thus causing displacement.

Copeland Borough Council

1. Gabion structures should be limited to mild or moderate wave conditions.

2. -

3. Agreed.

4. Agreed even without vandalism.

5. Agreed.

6. Our preference would be galvanised as wire seems to rust under the PVC coating. Perhaps better to PVC coat the galvanised wire.

7. Agreed.

8 Agreed.

9. -

10. Agreed.

11. -

12. As a generalisation I think it fair to say that we have not used gabions as protection where they would be directly exposed to the action of the sea although they have been quite widely used along the coast for the protection of highways.

    For marine sites the normal use of this type of material is in the provision of mattresses for anti-spray protection of slopes.

Cornwall County Council

1. -

2. -

3. -

*4. -

5. -

6. -

7. Not always practicable especially where multilayers of gabions are used.

8. -

9. -

10. -

11. -

12. From my limited experience I cannot in general contend any of the points made except statement number 4 where I would question the 10 year life span.

Cumbria County Council

11. No experience, but on an exposed coast nylon net type might be particularly vulnerable to damage. I do experience considerable problems with barbeques which could be a real problem, probably more so with nylon net than PVC coated wires.

12. The gabions at this situation have been very successful and I believe that these sloping flexible type gabions are exceedingly useful particularly in conjunction with small areas of concrete as mentioned above and indeed in isolated positions where returns and "top" repairs can be carried out with concrete bag protection.

Lewes District Council

1. Agreed

2. Agreed

3. Agreed

4. We have "Weldmesh" gabions installed 18 years ago with no vandalism. We would hope for much more than 10 years of life as this would make them too expensive.

5. Agreed

6. Agreed

7. Time does not allow repacking especially where more than one layer of gabions has to be used. We find settlement to be a slow process. With PVC coated gabions the whole structure settles and repacking is considered unnecessary.

8 Agreed

9. Agreed

10. Settlement after a few years seems inevitable and repacking is not only very expensive but almost impossible if there are several courses of gabions. Topping up with small stones through the interstices is a very short term measure and will only last a very few storms.

11. Agreed

12. We have found that PVC covered gabions abrade quickly in the intertidal zone, and are useless within a few months where there is any shingle on the beach. "Weldmesh" gabions subject to storm waves will also disintegrate and must be kept above HWMST. Gabions not considered a 'low cost' method on the East Anglian coast where supply of large natural stone is limited. The labour element is high and any mechanical filling method is inferior due to the need for tight hard packing.

Mobbs & English, Consulting Engineers
to North Norfolk District Council

1. Maccaferri gabions located at rear of a steep pebbly beach, not subjected to waves under normal circumstances. Successful in forming a return wall supporting the land immediately behind the beach. First defences placed in position some 12 years ago, a further two courses added two or three years ago. The wall now provides an effective barrier against bank erosion and wave overtopping.

2. Agreed.

3. Agreed.

4. Gabions have not been particularly prone to vandalism. It is hoped that current life span will be considerably more than 10 years.

5. Agreed.

6. Agreed - PVC coated type used.

7. Agreed.

8. -

9. Local stone of an angular nature used, also flat faced stones on the front face largely for cosmetic purposes but also to retain the basket shape. Rounded stones considered unsuitable.

10. -

11. Agreed.

East Devon District Council

1. Agreed.

2. True, although the Council have installed trial gabions for a period of four years on an extremely abrasive flint beach founded into bedrock chalk and cut back into very soft and fragmented limestone cliffs. The structures are free standing and laid back between 55^0 and 25^0 to the horizontal with the area between the top edge of the gabions and the cliffs protected by a thin skin of concrete. Remedial work carried out annually.

3. -

4. Basically true although vandalism not experienced during four year trial period. The 10 year design life would be for structural integrity rather than for vandalism which is just as likely to be a problem in the short as in the long term.

5. A good case for battering back of gabions with the safety of holidaymakers in mind.

6. Agreed. There is a good case for the manufacturers to experiment with different types of plastic coating for use in other than sandy environments.

7. More essential for vertical gabions. When battered back they are better left to follow the new contour than being opened and repacked.

8. Agreed, although in our particular case they have been subject to considerable wave activity.

9. Kentish ragstone used, which gives some interlocking characteristics which I believe is useful. Very satisfied with this, it might just be that rounded stone may rather more quickly be drawn out of a damaged gabion.

10. Agreed. The avoidance of differential settlement is important in such a wall.

1. Agreed.

2. Agreed.

3. Agreed.

4. Vandalism extremely limited.

5. Annual monitoring should be undertaken with all structures and in the early years of design life I doubt that gabions are any more susceptible to maintenance than other defences.

6. -

7. Agreed - Hand packing also assists in construction.

8 Agreed.

9. Angular crushed stone has been most satisfactory.

10. Agreed.

11. Agree with comment but no experience.

12. In general it is a system that is supported because of its basic design element. The baskets do tend to blend in with the local environment more easily than a concrete construction and it would be my intention where suitable sites do occur that gabions will be used.

Penwith District Council

1. Gabions are most suitable for use in mild to moderate wave conditions.

2. -

3. -

4. If the correct sized stone is used and baskets are well tied together, the effects of vandalism can be minimised.

5. Gabions should be inspected regularly to make good the effects of vandalism and to avoid the risk to people using the beach.

6. While in general PVC coated gabions are more resistant than galvanised gabions, the PVC coating does get damaged during filling and any corrosion taking place may not be apparent until it is too late.

7. Agreed.

8 Gabions are performing adequately at a lower beach level.

9. -

10. -

11. -

12. Only flexible "Maccaferri" type gabions have been used.

Note: The gabions in (8) above are, we think, on a sandy beach and in a sheltered area.

Borough of Poole

1. -

2. No experience.

3. No experience of dunes but fines do pass easily through gabions.

4. Some vandalism experienced.

5. Agreed.

6. Gabions should be both galvanised and PVC coated.

7. It is desirable to have them as well packed as possible.

8 Have been used in both situations.

9. Certainly better when well packed with rounded rock than when filled with old broken paving slabs laid flat. The latter makes them too rigid and impervious.

10. No experience of "Weldmesh" type.

11. Only experience is with "Maccaferri" type.

12. It is not thought that one should anticipate gabions lasting much longer than 10 years. They are, however, a cheap and effective way of trying out a new defence system prior to doing more permanent works.

City of Portsmouth

1. Agreed.

2. Agreed.

3. Agreed - revetments are more likely to become covered by sand if sloping face is presented to the waves as opposed to a vertical wall.

4. Vandalism not experienced, however, 5mm ϕ wire is specified for the cages. Would hope for a longer life than 10 years.

5. Agreed - an annual maintenance inspection to rebind broken wires and refill with stones is done at the end of the tourist season and before the autumn gales.

6. PVC coated gabions when damaged can trap salt between the coating and the wire causing corrosion which is not readily seen.

7. Agreed - we specify that the exposed faces of the gabions are hand packed with semi-dressed stone in order to reduce the amount of fine material washing out, causing settlement.

8 Agreed - see 3 above.

9. No experience.

10. Agreed - see 7 above.

11.

12. The rigid type requires closer attention to the filling operation in order to prevent voids from settlement, the more flexible type can accomodate such voids by deformation of the cage.

The better solution is a combination of a rigid gabion wall, well filled, built off a flexible mattress base. This flexible base can accomodate any settlement preventing any undermining of the apron.

South Hams District Council

1. Agreed.

2. Agreed.

3. Not used for this purpose.

4. Agreed - also a popular shelter for lighting fires which melt the plastic coating.

5. Agreed - also time consuming to repair.

6. No experience of galvanised gabions but PVC is easily damaged.

7. Agreed.

8. Not used gabions as groynes.

9. Satisfied using cubical or angular igneous rock filling. Rounded stone suggests soft material and will therefore deteriorate through erosion.

10. Agreed although only been used successfully along a river bank.

11. No experience but PVC is easily damaged.

12. The flexible PVC coated "Maccaferri" gabions have, in general performed well and although distorted, remained an effective barrier. However, because of their vulnerability to vandalism and the resultant danger to holidaymakers, etc., I remain a little less than enthusiastic about them for coast protection.

Borough of South Tyneside

1. Agreed.

2. Agreed.

3. No experience.

4. Little vandalism expeienced. Life span in this environment substantially less than 10 years.

5. Agreed. A fairly severe hazard.

6. Gabions used were PVC coated but mechanical damage swiftly exposed the material to corrosion.

7. Agreed.

8 Agreed.

9. Gabion filled with large rounded pebbles but damage still occurred.

10. Agreed.

11. Agreed.

Torridge District Council

A P P E N D I X   2

B R E A K W A T E R S

REPLIES TO QUESTIONNAIRE

TYPE	Breakwater - gabion type
LOCATION	Geneva State Park, Ohio, USA (Lake Erie)

DESCRIPTION OF SITE

Position	Southern shore of Lake Erie
Coastal Topography	Cliffs approx 6m high (mostly silt and clay with sand)
Beach Alignment	North 70^0 east
Beach Material	Medium to very coarse grain lithic and quartz sand
Beach Width	0.6m to 18.3m
Intertidal slope	1 in 11
Offshore Topography	Thin layer of fine sand on bedrock
Maximum Wind Fetch	70 miles (from the west)
Wave Height (mean)	0 to 0.3m (LEO)
Wave Height (max)	1.2m (LEO)
Net Littoral Drift (direction)	Eastward
Net Littoral Drift (magnitude)	$80,000m^3$ over 4 months of wave records
Tidal range (mean)	None
Tidal range (spring)	
Tidal range (neap)	
Mean Level	0.91m LWD
Datum	Low Water Datum (LWD) = 172.4m IGLD
Problem	Cliff slumping aided by wave action

DESIGN DETAILS

The gabion breakwater consisted of wire baskets, half vinyl coated and the rest galvanised, filled with stones (0.13 to 0.23m). Filter cloth was laid along the bottom in all but the eastern one third of the structure. Mattress type gabions were placed along the lakeside toe at each end of the structure.

SITE LAYOUT

The breakwater was 30m long, 5.5m wide at the base and 1.8m wide at the top. Crest level was approx 1.0m above mean water level with the toe at approx 0.8m below mean water level. The structure was situated parallel to the shore and about 18m from the shoreline.

CONSTRUCTION DETAILS

Filter cloth was first laid along the bottom in all but the eastern third of the structure. The wire baskets, vinyl coated in the western half and galvanised in the eastern half of the breakwater were filled with stones graded in size between 0.13 and 0.23m.

The toe of the structure was protected against scour by a row of mattress type gabions that extended 2.1m beyond the main section.

COST AND COMPLETION DATE Approx $35,000 December 1978

PERFORMANCE

The part of the structure without filter cloth settled a few centimetres and during the monitoring the toe gabions were undermined and deflected downward. The galvanised baskets failed first and the PVC baskets followed. At the end of the first year all but the end baskets in the toe mattress had broken open and the stone washed away. The main section although deformed remained intact except at the east end where more than half the baskets were open and empty.

ANALYSIS

Despite the damage the structure performed well trapping littoral material behind it.

Comments and suggestions for future gabion breakwater installations:

1. Filter cloth or stone bedding must be used to prevent settlement
2. Stones must be tightly packed in the gabions
3. Toe protection is essential to prevent scour and settlement
4. This particular system should be reserved for milder wave climates and more resistant bottom formations
5. Place any toe protection mat in trench that has been excavated below the anticipated scour depth
6. Place rip-rap in front of the toe protection mat for additional protection.

CONCLUSIONS

REFERENCE

Low Cost Shore Protection. Final Report on the Shoreline Erosion Control Demonstration Program (Section 54) 1981. Published by the US Army Corps of Engineers.

G R O Y N E S

TYPE	Groyne - gabion type
LOCATION	Kotzebue, Alaska, USA

DESCRIPTION OF SITE

Position	Western coast of Alaska in the Chukchi Sea
Coastal Topography	Low lying gravel spit fronting a road at +1.83m MLLW
Beach Alignment	$N5^0E$
Beach Material	Fine to medium gravel
Beach Width	9m to 15m
Intertidal slope	1 on 8
Offshore Topography	Shallow and sloping with offshore bars (which break up the easterly storm waves)
Maximum Wind Fetch	
Wave Height (mean)	0 to 0.3m LEO
Wave Height (max)	1.15m (obs), 1.98m LEO predictions
Net Littoral Drift (direction)	Northward
Net Littoral Drift (magnitude)	
Tidal range (mean)	0.3m
Tidal range (spring)	0.33m
Tidal range (neap)	
Mean Level	0.17m above MLLW
Datum	MLLW
Problem	Erosion by wave action and ice floes

DESIGN DETAILS

The test devices along this 1000m stretch of shoreline comprise two groyne fields consisting of three groynes each, 61m of gabion revetment and 61m of steel barrel revetment placed downdrift of the groyne fields. The updrift (sothern) groynes were constructed of steel barrels and the downdrift groyne field comprised two gabion groynes and a sand-pillow groyne at its northern end.

This summary concerns the two gabion groynes in the downdrift groyne field.

Gabions are particularly suited to this site because of the relatively low transport costs of the baskets, their flexibility in conforming to scour holes and the multiple choices they offer as to the type of material with which they can be filled.

SITE LAYOUT

These two groynes, located in the more northern of the two groyne fields, were T-shaped with the groynes laid on the beach slope at right angles to the shoreline (the base of the T pointing seaward) and 16.5m long. The bulkhead built at the top of the beach was 11m long. The elevation of the groynes was from +1.83m at the top of the beach to below MLLW at the seaward end.

CONSTRUCTION DETAILS

The groynes were constructed as follows: (a) This was a PVC coated gabion groyne lined with Polyfilter-X filter cloth and filled with sandy gravel. It was built in the shape of an inverted T, laying the 1.8m x 0.9m x 0.46m gabion baskets flat in the foundation layer and then another layer on their sides (0.9m high) on top. (b) The other groyne was made of galvanised wire mesh gabions lined with a galvanised hardware cloth. This groyne was built in the same way and to the same dimensions as (a).

COST AND COMPLETION DATE September 1978

PERFORMANCE

October ice piling up against the south side of the groynes, as a result of tidal movement, shifted the seaward ends of the groynes northward by about half a metre. The updrift PVC groyne was not damaged and this was the only structural or material alteration recorded. The downdrift groyne suffered the same shifting but damage was more extensive. Its baskets were lined with galvanised wire screening which separated at its seams allowing the gravel fill to escape. However, this only occurred in two of the seaward baskets.

ANALYSIS

Both groynes worked well, causing sand fillets to form between them.

PVC coated gabions: After 9 months the depth of accretion on the south side was 0.3 to 0.45m while some scouring was evident on the north side.

Galvanised coated gabion: After 10 months an abandoned boat caved in the south side of one of the gabions. At this time accretion had reached 0.45m on the south side while erosion was observed near the landward gabions on the north side of the groyne.

CONCLUSIONS

Good performance but deterioration of the outer end exposed to high waves is a problem. The monitoring period was not long enough to determine long term trends.

REFERENCE

Low Cost Shore Protection. Final Report on the Shoreline Erosion Control Demonstration Program (Section 54) 1981. Published by the US Army Corps of Engineers.

TYPE	Groyne - gabion type
LOCATION	Port Sanilac, Lake Huron, Michigan, USA

DESCRIPTION OF SITE

Position	Sanilac section 26. 4 miles south of Port Sanilac.
Coastal Topography	10m high clay cliff sloping at approx 1 on 1.5 with less than 25% vegetative cover.
Beach Alignment	$N10^{0}W$
Beach Material	Thin mantle of sand and gravel covering clay.
Beach Width	3 to 30m depending upon lake level
Intertidal slope	1 on 100
Offshore Topography	Hard clay bed sloping at about 1 on 100
Maximum Wind Fetch	From north, 165 miles, from east, 40 miles
Wave Height (mean)	0 to 0.3m LEO
Wave Height (max)	1.2m LEO
Net Littoral Drift (direction)	Southward
Net Littoral Drift (magnitude)	
Tidal range (mean)	
Tidal range (spring)	
Tidal range (neap)	
Mean Level	175.8m LWD (IGLD)
Datum	International Great Lakes Datum (IGLD)
Problem	Beach and cliff erosion by wave action

DESIGN DETAILS

This 610m length of shoreline was selected for testing six different types of groynes including Longard tubes, gabions, sandbags, a rock mastic and rock filled timber crib.

The distance between each groyne was unusually large, three times the groyne length.

Evaluation of the groynes was concerned with their structural adequacy and the three to one space to length ratio.

The gabion groyne was the third most northerly of the six and situated 70.6m south of a Longard tube groyne.

SITE LAYOUT

The gabion groyne tip was inclined downdrift at an angle of 102^0 to the shoreline.

CONSTRUCTION DETAILS

Filter cloth was not placed beneath the baskets, nor was it used to line the galvanised gabion baskets when filled with large cobbles. In section the groyne consisted of three tiers of gabion boxes.

COST AND COMPLETION DATE October 1974

PERFORMANCE

Functionally the groyne performed well, sand was trapped and beach fillets formed between groynes protecting the bluff toe. Some scour beneath the seaward baskets facilitated the collapse of one of the baskets and subsequent loss of the cobble fill.

ANALYSIS

The groyne had deteriorated significantly at the six year inspection but till then had been effective in building a protective beach.

CONCLUSIONS

Good performance but deterioration of the outer end exposed to high waves is a problem.

REFERENCE

Low Cost Shore Protection. Final Report on the Shoreline Erosion Control Demonstration Program (Section 54) 1981. Published by the US Army Corps of Engineers.

R E T A I N I N G   W A L L S

TYPE	Retaining Wall - gabion type
LOCATION	Downderry, Cornwall

DESCRIPTION OF SITE

Position	On south coast ~ 10 kms west of Plymouth
Coastal Topography	Beach backed by cliff
Beach Alignment	East-west
Beach Material	Shingle with rocky outcrops
Beach Width	
Intertidal slope	
Offshore Topography	
Maximum Wind Fetch	Practically unlimited from S-SW
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	
Net Littoral Drift (magnitude)	
Tidal range (mean)	
Tidal range (spring)	
Tidal range (neap)	
Mean Level	
Datum	
Problem	Cliff erosion

DESIGN DETAILS

As the cliff is above normal high tide level it was considered sufficient to construct a stepped retaining wall of gabions rather than of more coventional form.

SITE LAYOUT

The stepped retaining wall is 6m high, typically 3m wide but 5m at point of max erosion. Slope of the front face is 1:2.

CONSTRUCTION DETAILS

Baskets filled with quarry stone.
Beach material as fill between structure and cliff.
Existing cliff faced with quarry waste.

COST AND COMPLETION DATE Circa 1971

PERFORMANCE

Quarry waste slope above retaining wall well vegetated.
Some vegetation in places on face of gabion wall.
No erosion evident at toe of wall when site was inspected in summer of 1983.
Structure appears to be in good condition.

ANALYSIS

CONCLUSIONS

This retaining wall has been in place for about 12 years and is still successfully protecting the cliff-face. Toe of wall is above the level of normal high tides and does not appear to have suffered from wave induced abrasion.

REFERENCE

Design details obtained from Maccaferri brochure (Ref 2).

TYPE	Retaining wall - gabion type
LOCATION	Whitehaven, Cumbria
DESCRIPTION OF SITE	
Position	South of the west pier
Coastal Topography	Cliffs fronted by shingle beach and rock ledges
Beach Alignment	NNE-SSW
Beach Material	Shingle and shale beach
Beach Width	Approx 100m between mean high and low water marks
Intertidal slope	
Offshore Topography	
Maximum Wind Fetch	
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	Northward
Net Littoral Drift (magnitude)	
Tidal range (mean)	
Tidal range (spring)	
Tidal range (neap)	
Mean Tidal Level	
Datum	
Problem	Foreshore erosion

DESIGN DETAILS

Retaining wall is probably three gabion boxes high set at the top of the beach possibly out of reach of wave and tidal action.

SITE LAYOUT

Length of wall is 200 metres, protecting a cliff of quarry spoil.

CONSTRUCTION DETAILS

Gabion boxes filled with dressed stone.

COST AND COMPLETION DATE 1978

PERFORMANCE

Wall in good condition in 1983
No signs of structural damage

ANALYSIS

The wall appears to be performing well and should remain in good condition for some years to come.

CONCLUSIONS

REFERENCE

Visit in August 1983

R E V E T M E N T S

TYPE Revetment - gabion mattress

LOCATION Aberdeen

DESCRIPTION OF SITE

Position

Coastal Topography

Beach Alignment

Beach Material

Beach Width

Intertidal slope

Offshore Topography

Maximum Wind Fetch

Wave Height (mean)

Wave Height (max)

Net Littoral Drift (direction)

Net Littoral Drift (magnitude)

Tidal range (mean)

Tidal range (spring)

Tidal range (neap)

Mean Level

Datum

Problem

DESIGN DETAILS

As a result of a new sea wall and a system of groynes installed on a 3 mile frontage, it was anticipated that terminal scour would occur where the scheme terminated in the sand dunes to the north of the River Don.

Weldmesh gabions were used as a revetment mattress with a concrete capping beam supported on double steel piles to retain the toe.

SITE LAYOUT

The revetment commenced at a slope of 1 in 2.5 at the seawall and flattened to 1 in 4 where it terminated at the sand dunes. Top of the slope is at +0.23m ODN.

1700 gabions (1.83m long x 0.91m wide x 0.46m deep) were used over a total length of 107m.

CONSTRUCTION DETAILS

COST AND COMPLETION DATE

PERFORMANCE

Performance not known.

ANALYSIS

CONCLUSIONS

REFERENCE

B R C "Weldmesh" brochure (Ref 3).

TYPE	Revetment & stub groynes - Plastic mesh type gabions
LOCATION	Brancaster, Norfolk
DESCRIPTION OF SITE	
Position	West of Brancaster golf club house
Coastal Topography	Sand dunes protecting low lying land
Beach Alignment	East-west
Beach Material	Sand overlying mud flats
Beach Width	Approx 200m at low water
Intertidal slope	
Offshore Topography	
Maximum Wind Fetch	
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	Westward
Net Littoral Drift (magnitude)	
Tidal range (mean)	
Tidal range (spring)	6.4m at Hunstanton
Tidal range (neap)	3.2m at Hunstanton
Mean Level	
Datum	OD (N)
Problem	Stabilisation of sand dunes

DESIGN DETAILS

See Plate 6

SITE LAYOUT

See Figure 3.

CONSTRUCTION DETAILS

The seaward face of the dune system was graded by machine to the required slope, and the empty cages, made up on site by hand lacing, were placed onto a sheet of non-woven fabric, to prevent subsequent scour of the sand backfill. "Wholestone" was packed largely by hand in the gabion mattresses, but by machine into the groynes. The lids were laced by hand.

COST AND COMPLETION DATE £5,000 (1980 prices). Completed in 1981.

PERFORMANCE

The Netlon plastic cages were used for the first time by this Authority, at Brancaster, as an experiment, to determine their usefulness compared with Maccaferri Gabions, which have been traditionally used. The Netlon cages were also considerably cheaper than Maccaferri.

In practice, they were more expensive to fill, because of their tendency to split whilst being laced, and the necessity to hand pack the wholestone by hand. Machine filling caused the stone to punch holes in the bottom of the cages. The "Tensar" material proved more durable during construction than Netlon.

ANALYSIS

Subsequent maintenance has been a liability, due to damage to the plastic strands, causing the whole stone to be lost. Subsequently, there has been differential settlement on the mattresses.

CONCLUSIONS

REFERENCE

Anglian Water Authority (Norfolk Division)

TYPE	Revetment - gabion type
LOCATION	Burry Port, Dyfed
DESCRIPTION OF SITE	
Position	East of entrance to port
Coastal Topography	Originally sand dunes
Beach Alignment	E-W
Beach Material	Sand
Beach Width	
Intertidal slope	
Offshore Topography	
Maximum Wind Fetch	
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	
Net Littoral Drift (magnitude)	
Tidal range (mean)	
Tidal range (spring)	
Tidal range (neap)	
Mean Level	
Datum	
Problem	Protection of reclaimed land (copper slag)

DESIGN DETAILS

Mattress designed to a 1:3 slope.

SITE LAYOUT

Extends over about 100m of foreshore.

CONSTRUCTION DETAILS

Gabion mattress filed with limestone. Toe protection consisting of 150mm dia limestone similar to that filling the mattress. Mattress underlain by filter cloth.

COST AND COMPLETION DATE 1978

PERFORMANCE

The PVC coating on the lower part of the revetment has, in areas, been badly abraded. Subsequent erosion of the galvanised wire has caused local failure. Repairs have been made by grouting the surface of the revetment with bitumen.

ANALYSIS

The slag which has spilled out onto the sand beach is very abrasive and has, in a relatively short time, damaged the toe of the gabion revetment. The bitumen has given some, but not total protection, to the revetment against abrasion by the copper slag.

CONCLUSIONS

REFERENCE

TYPE	Revetment - gabion type
LOCATION	Chesil Beach, Chiswell, Portland

DESCRIPTION OF SITE

Position	On crest of shingle bank
Coastal Topography	Steep pebble bank 0-13m AOD
Beach Alignment	Beach runs NW to SE and faces SW
Beach Material	Elongated pebbles (30mm-70mm long dia) 95% flint and chert
Beach Width	Approx 50m HWL to beach crest
Intertidal slope	1:4
Offshore Topography	Bed slope flattens to approx 1:10
Maximum Wind Fetch	4,000 miles
Wave Height (mean)	1.2m
Wave Height (max)	Inshore wave height = 6.5m (Ho = 9.0m)
Net Littoral Drift (direction)	
Net Littoral Drift (magnitude)	
Tidal range (mean)	1.00 - (-0.85) = 1.85m
Tidal range (spring)	1.80 - (-1.30) = 3.1m
Tidal range (neap)	0.80 - (-0.40) = 1.2m
Mean Level	0.23m AOD
Datum	Ordnance Datum Newlyn
Problem	Under prolonged SW storm conditions beach degrades and there is danger of breaching.

DESIGN DETAILS

Three layers of gabion mattresses in total of 16 bays each 8 metres long (measured along the beach crest).

Mattresses placed over the crest and anchored to gabion boxes set in the landward slope of the beach.

Within each bay each mattress is tied along each edge to the mattress below, alongside and above.

Mattresses of different manufacture, different construction and with different filling material are all being monitored.

See Plates 3, 4 and 5.

SITE LAYOUT

Flexible Gabion mattresses straddle beach crest in three pyramid layers: (148m x 18m), (144m x 12m), (143m x 6m), anchored to gabion boxes (2m x 1m) set into landward beach slope.

CONSTRUCTION DETAILS

Mattresses comprise:

1. BRC Weldmesh 6m x 2m basic unit in 5, 8 and 10 gauge galvanised wire at 50 x 25 and 75 x 75 mesh sizes.
2. Maccaferri Reno 6m x 2m basic unit in PVC coated wire with 6 and 10 compartments.

Filling Materials Comprise:

1. Local beach pebbles screened to omit material less tan 37.5mm.
2. Locally won Portland Capstone 100mm-200mm.

Gabions are laced together along all adjacent edges and between upper and lower layers to produce single structure. Wire diameters of 2.5mm, 2.0mm and 1.6mm galvanised and 2.2mm PVC coated used for tying and stitching at varying pitches.

COST AND COMPLETION DATE £140,000 13 November 1981

PERFORMANCE

To date the mattresses have been subjected to wave run up on approximately four occasions. The lower mattresses are covered in shingle and their physical conditions is unknown. Of the exposed mattresses, performance is good in all cases but some difficulties have been experienced with the Netlon lining to the Maccaferri mattresses - remedial action will be taken during 1984.

ANALYSIS

CONCLUSIONS

REFERENCE

C H Dobbie & Partners
Consulting Engineers

TYPE	Revetment/Breastwork - gabion type
LOCATION	Mudeford, Christchurch Bay
DESCRIPTION OF SITE	
Position	About 500m east of coastguard station
Coastal Topography	Embayed beach backed by low cliffs or seawalls
Beach Alignment	Northeast to southwest
Beach Material	
Beach Width	50 - 75m
Intertidal slope	About 1:100
Offshore Topography	Very shallow nearshore seabed. 10m contour about 3km offshore
Maximum Wind Fetch	200km to the southeast
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	West to east
Net Littoral Drift (magnitude)	
Tidal range (mean)	
Tidal range (spring)	1.49m
Tidal range (neap)	1.25m
Mean Level	
Datum	
Problem	Erosion at base of soft cliffs
DESIGN DETAILS	

SITE LAYOUT

Gabions placed on sandy beach at foot of extremely erodible low cliffs which are vulnerable to direct wave action.

CONSTRUCTION DETAILS

COST AND COMPLETION DATE

PERFORMANCE

At the present time (July 1983) no complete gabions visible on the beach. Only a few isolated strands of wire network are seen above sand level.

ANALYSIS

CONCLUSIONS

Gabions are thought to have been destroyed by wave action and subsequently removed.

REFERENCE

HRS photo albums dating from about 1976.

TYPE	Revetment - gabion type
LOCATION	Oak Harbor, Washington, USA

DESCRIPTION OF SITE

Position	Between Oak Harbor & Crescent Harbor facing the Saratoga Passage
Coastal Topography	9m high cliff
Beach Alignment	Approx east-west
Beach Material	Sand and gravel
Beach Width	6m to 60m (MHHW to MLLW)
Intertidal slope	1 in 16
Offshore Topography	
Maximum Wind Fetch	17 miles from SSE
Wave Height (mean)	0 to 0.3m LEO
Wave Height (max)	0.91m LEO
Net Littoral Drift (direction)	
Net Littoral Drift (magnitude)	
Tidal range (mean)	2.83m (semi-diurnal) 3.47m (diurnal)
Tidal range (spring)	
Tidal range (neap)	
Tidal level	Extreme high tide = +4.4m MLLW
Datum	MLLW (1.87m below NGVD)
Problem	Erosion by wave action. Not an immediate problem in this area.

DESIGN DETAILS

Four basic types of revetment were built at this site from locally available materials. The revetments were separated by timber groynes in order that the failure of one revetment should not affect the performance of adjacent ones.

The PVC coated gabion revetment was divided into four sections with a separation bulkhead between each section. Section 1 (the eastern end) had no filter. Section 2, had a gravel filter, Section 3 had a filter cloth behind it and Section 4 had no filter.

Gabions filled with 0.3m dia rock. Toe protection also consisted of 0.3m dia rock placed at the base of the structure.

SITE LAYOUT

Mattress type 0.5m thick sloping revetment
Sect 1 - 19m long, no filter, top elev +5.33m, toe elev +3.81m
Sect 2 - 19m long, gravel filter, top elev +5.33m, toe elev +3.81m
Sect 3 - 23.3m long, filter cloth, top elev +5.33, toe elev +3.66
Sect 4 - 23.3m long, no filter, top elev +5.33m, toe elev +3.66m
Structure slope 1 on 1.5.

CONSTRUCTION DETAILS

The beach was excavated to secure the toe of the revetment and the slope grading was prepared by loader and finished off by hand. An 0.3-0.4m deep gravel filter was placed under section 2 and a cloth filter placed under section 3. Final grading was done by hand and the lids shut with twists of wire also linking adjacent baskets at 0.15m intervals (to save time compared with the recommended continuous wire lacing method). Top soil (0.3m) was laid behind the crest and toe protection dumped at the base of the revetment.

COST AND COMPLETION DATE   Approx $14,000   June 1978

PERFORMANCE

Backfill was lost, apparently the result of being washed out from behind the gabions by overtopping waves.

All toe protection was displaced and many undersized stones were washed from the gabion baskets.

The two types of filter proved equally effective in stopping leaching of soil.

ANALYSIS

The monitoring period was too short to determine the longevity of the structures.

In an area of progressive long term recession, the flexibility of the gabions should improve their performance over a more rigid type of structure.

CONCLUSIONS

The mattress crest was too low, allowing overtopping and consequent loss of backfill material.

REFERENCE

Low Cost Shore Protection. Final Report on the Shoreline Erosion Control Demonstration Program (Section 54) 1981. Published by the US Army Corps of Engineers.

TYPE	Revetment - gabion type
LOCATION	Ravenglass, Cumbria

DESCRIPTION OF SITE

Position	Stubb Place, south of MOD range
Coastal Topography	Low lying land
Beach Alignment	N-S
Beach Material	Sand foreshore backed by shingle ridge. Rock platforms
Beach Width	600m between mean high and low water marks
Intertidal slope	
Offshore Topography	
Maximum Wind Fetch	
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	Northward
Net Littoral Drift (magnitude)	
Tidal range (mean)	
Tidal range (spring)	
Tidal range (neap)	
Mean Level	
Datum	
Problem	Protection of a shingle ridge

DESIGN DETAILS

Line of Maccaferri gabions set at top of shingle ridge at about high water level or a little above.

SITE LAYOUT

Length of revetment approximately 200 metres.
Set on top of shingle ridge

CONSTRUCTION DETAILS

Maccaferri boxes filled with angular rock

COST AND COMPLETION DATE 1979

PERFORMANCE

Satisfactory.
Gabion wall is in good condition with no serious displacement by wave action or structural damage.

ANALYSIS

Gabion boxes though not packed particularly well are in good condition structurally.

CONCLUSIONS

REFERENCE

Visit August 1983
River and Sea Gabions Limited (Personal Communication)

TYPE	Revetment - gabion type
LOCATION	Siddick, Cumbria
DESCRIPTION OF SITE	
Position	2km north of Workington
Coastal Topography	Reclaimed land
Beach Alignment	NE-SW
Beach Material	Shingle ridge on rocky foreshore
Beach Width	450m from mean high to low water marks.
Intertidal slope	
Offshore Topography	
Maximum Wind Fetch	
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	
Net Littoral Drift (magnitude)	
Tidal range (mean)	
Tidal range (spring)	
Tidal range (neap)	
Mean Tidal Level	
Datum	
Problem	Eroding foreshore backed by low lying land

DESIGN DETAILS

SITE LAYOUT

Gabion revetment over 500 metres frontage

CONSTRUCTION DETAILS

COST AND COMPLETION DATE 1972

PERFORMANCE

Gabion revetment constructed as part of a foreshore reclamation scheme. Breach occurred in the revetment and protection works were necessary within 12 months. Few gabions survived to 1983 site inspection.

ANALYSIS

One cannot determine the form of construction because only a few gabion boxes are still intact.

CONCLUSIONS

Too severe a wave environment for a gabion structure.

REFERENCE

TYPE	Revetment - stone filled gabion mattress overlying clay embankment
LOCATION	Winthorpe and Skegness, Lincs

DESCRIPTION OF SITE

Position	
Coastal Topography	
Beach Alignment	North-south
Beach Material	Sand
Beach Width	150m
Intertidal slope	1 in 30
Offshore Topography	
Maximum Wind Fetch	450 miles from NE. 250 miles from East
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	
Net Littoral Drift (magnitude)	
Tidal range (mean)	4.40m
Tidal range (spring)	6.00m
Tidal range (neap)	2.80m
Mean Level	0.21m ODN
Datum	Ordnance datum
Problem	Former dunes removed by tidal and wave action

DESIGN DETAILS

The design of the revetment is shown in Fig 2

SITE LAYOUT

Mattress type revetment
Top elevation +6m ODN. Toe elevation approx +2m ODN.
Structure slope 1 in 3.5 approx

See Figure 2.

CONSTRUCTION DETAILS

The sand beach was excavated to take the lower end of the revetment and the clay slope graded.

The "Reno" mattress was constructed on the slope with filter material placed underneath. The lower end of the revetment was re-covered with sand.

COST AND COMPLETION DATE   £350/m of frontage   1983

PERFORMANCE

This and similar lengths of bank suffered damage, both the actual materials used, and to the construction as a whole. Failures have occurred at the top, slope and toe of the bank, either in isolation or combination. These failures have involved both the destruction of the mattresses, or the filter sheet. The performance of the defence has been affeced by the failure of its components in that the top level has been lowered.

ANALYSIS

CONCLUSIONS

REFERENCE

Anglian Water Authority (Lincolnshire Division)

S E A   W A L L S

TYPE	Sea wall and groyne system
LOCATION	Dubmill Point, Cumbria

DESCRIPTION OF SITE

Position	2km north of Allonby
Coastal Topography	
Beach Alignment	N-S
Beach Material	Shingle ridge on sand/shingle foreshore
Beach Width	500m from mean high to low water mark
Intertidal slope	
Offshore Topography	
Maximum Wind Fetch	
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	Northward
Net Littoral Drift (magnitude)	
Tidal range (mean)	
Tidal range (spring)	
Tidal range (neap)	
Mean Level	
Datum	
Problem	Protection to road edge

DESIGN DETAILS

Sea wall at least two gabion boxes high
Groynes also appear to be two boxes high

SITE LAYOUT

Low gabion sea wall which is apparently back filled with soil. Gabion groynes also present and these extend seawards into the intertidal zone.

CONSTRUCTION DETAILS

Maccaferri gabion wall and groynes filled with angular stone.

COST AND COMPLETION DATE

1960's

PERFORMANCE

Crest of wall is partially vegetated. The wall has lasted very well, but the groynes are subjected to wave action and abrasion by shingle. Many of the groyne ends have been destroyed, the remainder showing severe abrasion. The landward end of the groynes are in a satisfactory condition.

ANALYSIS

The vegetative growth on the wall suggests that it is out of reach of normal waves and tides. Damaged gabion groynes are still retaining some beach material fairly effectively. This is a fairly remote area and damage by pedestrians does not appear to be a problem.

CONCLUSIONS

REFERENCE

Visit Summer 1983

TYPE	Seawall - gabion (maccaferri) type
LOCATION	Kiribati (formerly the Gilbert Islands)

DESCRIPTION OF SITE

Position	Ambo (lagoon side of island)
Coastal Topography	Coral outcrop
Beach Alignment	
Beach Material	Fine coral sand [D_{50} (0.44mm)] and shell
Beach Width	Approx 25m
Intertidal slope	Approx 1 in 10
Offshore Topography	Approx 1 in 300
Maximum Wind Fetch	Approx 12 miles from NW (to edge of lagoon)
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	
Net Littoral Drift (magnitude)	
Tidal range (mean)	1.2m
Tidal range (spring)	Approx 2.0m
Tidal range (neap)	0.5m
Mean Tidal Level	
Datum	
Problem	Causeway erosion by wave action

DESIGN DETAILS

Gabion seawall installed to protect causeway and road behind beach just above sea level. Gabions filled with coral rock.

Plates 7 and 8

SITE LAYOUT

Gabions laid directly on beach about 3m seaward of roadway (see Plate 7).

CONSTRUCTION DETAILS

The 2m x 1m x 1m maccaferri gabions were laid in a line as shown in Plate 8 and filled by hand with plate coral. It took eight man hours to fill one gabion and costs were broken down as follows:

baskets 69%, labour 15%, plant 15%.

COST AND COMPLETION DATE

$A52 (per gabion) i.e. £16/m^3 at 1975 prices.

PERFORMANCE

The gabions are working well and Plate 8 shows the beach build up over 3 years as compared with Plate 7.

ANALYSIS

It is emphasised that this is the lagoon side of the atoll. The ocean side is, in general, too exposed especially where the offshore reef is fairly narrow in width.

CONCLUSIONS

REFERENCE

Hydraulics Research Station
Report No OD18 by D W Holmes
January 1979

TYPE	Low sea wall/bulkhead - box gabions
LOCATION	Mablethorpe, Lincs

DESCRIPTION OF SITE

Position	To north of town centre's main beach access
Coastal Topography	Sand dunes behind a sandy beach
Beach Alignment	350^0
Beach Material	Sand
Beach Width	Approx 500m
Intertidal slope	Approx 1 in 100
Offshore Topography	
Maximum Wind Fetch	450 miles in a NE direction and 250 miles in an E direction
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	Southward
Net Littoral Drift (magnitude)	
Tidal range (mean)	4.40m
Tidal range (spring)	6.00m
Tidal range (neap)	2.80m
Mean Level	0.21m ODN
Datum	Ordnance datum
Problem	The seaward toe of the dunes being eroded by tidal action

DESIGN DETAILS

3m x 1m x 1m stone filled gabions laid in a saw-toothed line.

See fig 1.

SITE LAYOUT

Length - 600m
Top elevation +5m ODN
Toe elevation +4m ODN
Galvanised steel tubing driven in as anchorage

See Figure 1.

CONSTRUCTION DETAILS

COST AND COMPLETION DATE £55 per metre of fontage at 1978 prices.

PERFORMANCE

The actual materials from which the gabions are manufactured, and the stone fill have a life in the marine environment of 10 years or so.

At this particular site, the gabions trapped sand to the rear face and assisted in building up the dunes, but at other sites, the gabions have been undermined by lowered beach levels, or physically toppled by waves, even though the gabions are still intact.

ANALYSIS

CONCLUSIONS

REFERENCE

Anglian Water Authority (Lincolnshire Division)

TYPE	Low sea wall and groynes - Maccaferri gabions
LOCATION	Old Hunstanton, Norfolk

DESCRIPTION OF SITE

Position	Frontage to Golf Club
Coastal Topography	
Beach Alignment	East-west
Beach Material	Sand, overlying mud
Beach Width	Up to 400m at low water
Intertidal slope	
Offshore Topography	
Maximum Wind Fetch	
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	Eastward
Net Littoral Drift (magnitude)	
Tidal range (mean)	
Tidal range (spring)	6.4m at Hunstanton
Tidal range (neap)	3.2m at Hunstanton
Mean Level	Approx OD
Datum	Ordnance Datum Newlyn
Problem	Stabilisation of sand dunes

DESIGN DETAILS

See Fig 4 and Plates 9 and 10

SITE LAYOUT

See Figure 4.

CONSTRUCTION DETAILS

The beach profile was shaped to the required level, to achieve a top finished level on the gabions of +6.0m ODN. The cages were machine filled, internally laced and braced, with final packing carried out by hand. Reclaimed sand from the foreshore was dumped in behind the completed cages and consolidated. Marram grass, obtained locally was planted by hand.

COST AND COMPLETION DATE £100,000. 1983 Autumn

PERFORMANCE

The original revetment works to the East, at Holme, were constructed about 14 years ago. The latest works are a progression of these, spread over several stages over the intervening years. 500m was constructed in 1969, 460m in 1975, and the present extension of 380m was completed last year, to cover a recently scoured area of frontal dune.

ANALYSIS

The previous work has been very successful in halting the erosion of the frontage involved, with the original PVC coated galvanised wire showing no signs of deterioration. In fact much of this work is covered, with a good marram growth established. The groynes have raised the beach level to the point where they are partially covered.

CONCLUSIONS

REFERENCE

Anglian Water Authority (Norfolk Division)

TYPE	Seawall - gabion type
LOCATION	Parton, Cumbria

DESCRIPTION OF SITE

Position	Near railway station
Coastal Topography	Shingle beach on rock platform
Beach Alignment	NNE-SSW
Beach Material	
Beach Width	Rock ledges extend 250m at mean low water
Intertidal slope	
Offshore Topography	
Maximum Wind Fetch	
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	
Net Littoral Drift (magnitude)	
Tidal range (mean)	
Tidal range (spring)	
Tidal range (neap)	
Mean Tidal Level	
Datum	
Problem	Eroding foreshore

DESIGN DETAILS

Some of the Maccaferri gabions have been filled with pebbles and some with angular stone.

SITE LAYOUT

Frontage protected by gabion sea wall is 300 metres.

CONSTRUCTION DETAILS

COST AND COMPLETION DATE 1979/80

PERFORMANCE

Adequate in Summer 1983
Generally in good condition but breached at one point.

ANALYSIS

The gabion wall has held together but where it was filled with pebbles it has toppled seawards. Those parts filled with dressed stone remained upright.

CONCLUSIONS

REFERENCE

Visit in Summer 1983.

TYPE	Seawall - gabion type
LOCATION	Ravenglass, Cumbria

DESCRIPTION OF SITE

Position	Town frontage
Coastal Topography	Estuary fronted by extensive sand dunes
Beach Alignment	N-S
Beach Material	Sand and mud
Beach Width	
Intertidal slope	
Offshore Topography	Sand dunes protect frontage from wave action
Maximum Wind Fetch	
Wave Height (mean)	
Wave Height (max)	Wave action negligible
Net Littoral Drift (direction)	
Net Littoral Drift (magnitude)	Negligible
Tidal range (mean)	
Tidal range (spring)	
Tidal range (neap)	
Mean Tidal Level	
Datum	
Problem	Flood risk area

DESIGN DETAILS

Line of gabions protecting greensward just above the tide line.

SITE LAYOUT

Gabion wall about 0.75m high protects the greensward on the town frontage. The wall is just north of the confluence of the Rivers Irt and Esk.

CONSTRUCTION DETAILS

Maccaferri boxes filled with angular rock.

COST AND COMPLETION DATE 1980

PERFORMANCE

No signs of serious wear and tear in Summer 1983.

ANALYSIS

The wall is sheltered and appears to be performing satisfactorily.

CONCLUSIONS

REFERENCE

Visual inspection

TYPE	Seawall - gabion type
LOCATION	St Bees Bay, Cumbria

DESCRIPTION OF SITE

Position	South end of golf course
Coastal Topography	Cliffs to north and low lying land to south
Beach Alignment	NW-SE
Beach Material	
Beach Width	400m between mean high and low water marks
Intertidal slope	
Offshore Topography	
Maximum Wind Fetch	
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	
Net Littoral Drift (magnitude)	
Tidal range (mean)	
Tidal range (spring)	
Tidal range (neap)	
Mean Tidal Level	
Datum	
Problem	Eroding foreshore backed by low lying land. Cliff erosion at north end of frontage.

DESIGN DETAILS

Gabion seawall two boxes high over most of the frontage but three layers at south end. Toe of wall appears to be within reach of high tides.

See Plate 1.

SITE LAYOUT

Length of frontage protected by seawall is 300 metres.

CONSTRUCTION DETAILS

Maccaferri gabion boxes filled with angular rock.

COST AND COMPLETION DATE 1972

PERFORMANCE

Satisfactory in Summer 1983
Minor damage.
In surprisingly good condition at south end despite being littered with large stones from cliff slippage.

ANALYSIS

North end adjacent to eroding cliff line.
Worth monitoring in the longer term.

CONCLUSIONS

REFERENCE

Inspection in August 1983

TYPE	Seawall - gabion type
LOCATION	St Bees Bay, Cumbria

DESCRIPTION OF SITE

Position	Lowside, Nethertown
Coastal Topography	Shingle beach on rock platform backed by cliffs of glacial fill
Beach Alignment	NW-SE
Beach Material	Shingle beach with steep storm ridge, overlying rock platform
Beach Width	350m between mean high and low water marks.
Intertidal slope	
Offshore Topography	
Maximum Wind Fetch	
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	
Net Littoral Drift (magnitude)	
Tidal range (mean)	
Tidal range (spring)	
Tidal range (neap)	
Mean Tidal Level	
Datum	
Problem	Protection to chalets at crest of shingle ridge

DESIGN DETAILS

Maccaferri gabion boxes filled with large angular stone.
Sea wall is two gabion boxes high

SITE LAYOUT

Sea wall set on top of shingle beach, probably within reach of wave action at high tide.

CONSTRUCTION DETAILS

Gabion boxes filled expertly with large angular stone.

COST AND COMPLETION DATE Construction has been continuing since 1978.

PERFORMANCE

Gabion wall placed on top of an actively worked shingle beach. Abrasion does occur and boxes are destroyed and replaced. Parts of older gabion wall at northend of frontage overturned in a seaward direction.

ANALYSIS

The exposure of beach is severe and the shingle ridge is probably subject to large changes in level.

Once boxes are displaced seawards, damage is fairly rapid.

CONCLUSIONS

REFERENCE

TYPE	Sea wall - gabion type
LOCATION	Scrabster, Caithness, Scotland

DESCRIPTION OF SITE

Position	Gabions placed at toe of coastal boulder clay cliff at the Gill
Coastal Topography	Boulder clay cliffs
Beach Alignment	Beach runs NW to SE and faces NE
Beach Material	Clay with thin overlying layer of sand
Beach Width	-
Intertidal slope	1:20
Offshore Topography	-
Maximum Wind Fetch	900 km
Wave Height (mean)	Approximately 1.0 m
Wave Height (max)	3.0 m
Net Littoral Drift (direction)	-
Net Littoral Drift (magnitude)	-
Tidal range (mean)	-
Tidal range (spring)	2.3 - (-1.9) = 4.2 m
Tidal range (neap)	1.0 - (-0.6) = 1.6 m
Mean Level	-
Datum	Ordnance Datum Newlyn
Problem	Erosion at toe of boulder clay cliff with resultant instability of cliff slope

DESIGN DETAILS

SITE LAYOUT

CONSTRUCTION DETAILS

Gabion boxes constructed at toe of boulder clay cliff. Infill material placed behind boxes on slip surface in an attempt to obtain a stable slope.

COST AND COMPLETION DATE

1972 (Cost unknown)

PERFORMANCE

Completed in 1972; totally destroyed in 1980. This structure proved to be totally inadequate for its intended use.

ANALYSIS

CONCLUSIONS

REFERENCE

Highland Regional Council

TYPE	Sea wall and stub groynes - gabion type
LOCATION	Seascale, Cumbria

DESCRIPTION OF SITE

Position	Opposite railway station
Coastal Topography	Thin shingle beach overlying sand foreshore with rock out crops
Beach Alignment	NE-SW
Beach Material	Sand and shingle
Beach Width	400m between mean high and low water marks
Intertidal slope	
Offshore Topography	
Maximum Wind Fetch	
Wave Height (mean)	
Wave Height (max)	
Net Littoral Drift (direction)	
Net Littoral Drift (magnitude)	
Tidal range (mean)	
Tidal range (spring)	
Tidal range (neap)	
Mean Level	
Datum	
Problem	Foreshore erosion

DESIGN DETAILS

Protection to grassed amenity area and car park.
Maccaferri gabion wall and stub groynes.
Maccaferri wall appears to be two gabion boxes high and judging by grass growth in front of it, is above the normal high tides. At south end of the town frontage the gabion wall is just above the swash line. Also very short gabion groynes located at the south end.

SITE LAYOUT

Wall and gabions situated at top of rocky beach.

CONSTRUCTION DETAILS

Maccaferri boxes filled with mostly angular stone but also with pebbles.

COST AND COMPLETION DATE 1978/79

PERFORMANCE

Some groynes badly damaged and do not appear to have trapped littoral drift. Gabion wires showed little sign of deterioration, despite being packed rather irregularly in places. Damage is local. The freshly cut wires have not resulted in spillage of store out of the baskets as far as one can tell. Wall at southern end partly overturned but essentially intact.

ANALYSIS

The sea wall is in good condition and is performing well.
The stub groynes built on a rocky foreshore have, as one might expect, been subject to wear and tear. Local damage in the past evident by concrete patches. Probably due to pedestians walking along the top of the wall.

CONCLUSIONS

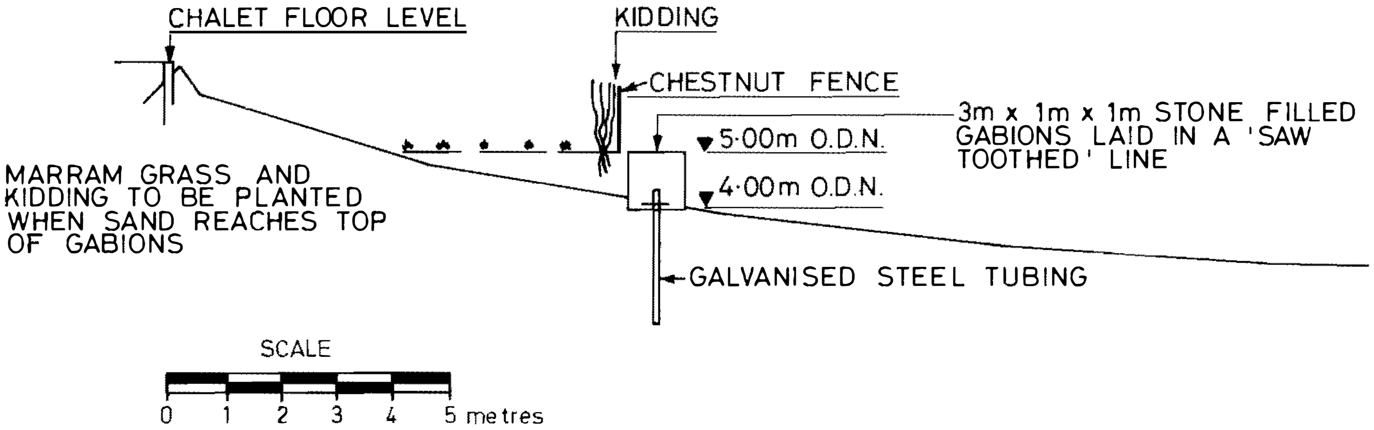
Performance variable. Gabion boxes intact but have lost their shape a south end of frontage. Wave inflicted damage?
Groynes not suitable in this position.

REFERENCE

Visit in August 1983

Figures

FIG.1 SECTION THROUGH BULKHEAD AT MABLETHORPE, LINCS.



TYPICAL CROSS SECTION

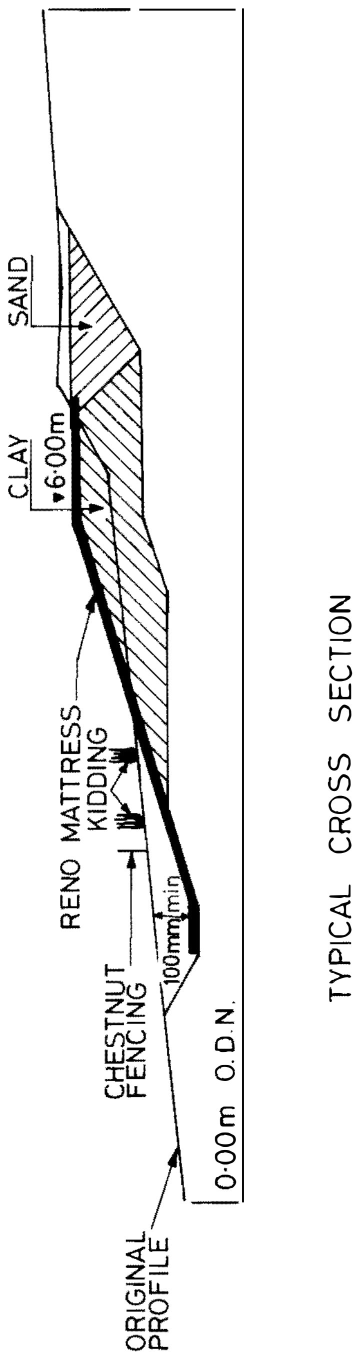
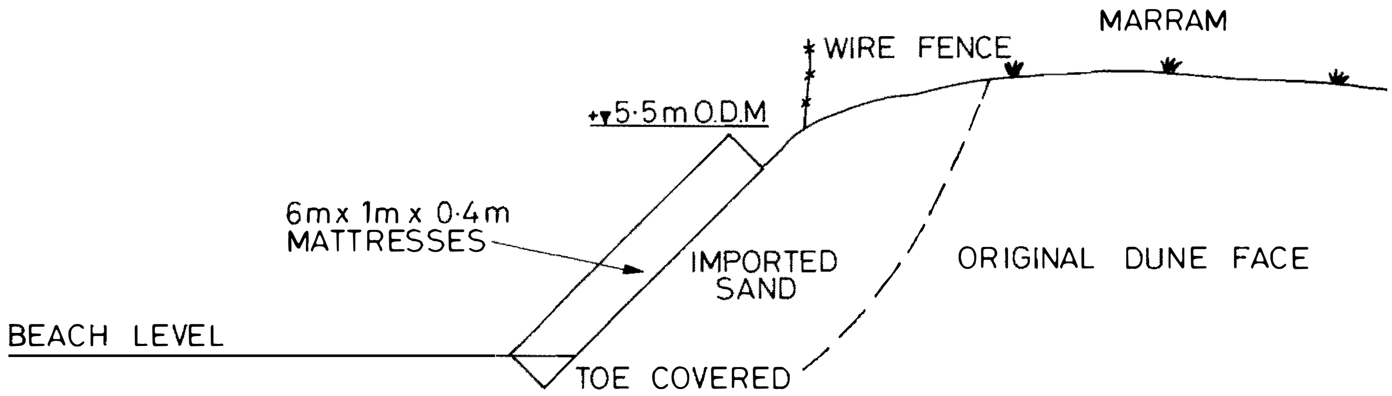


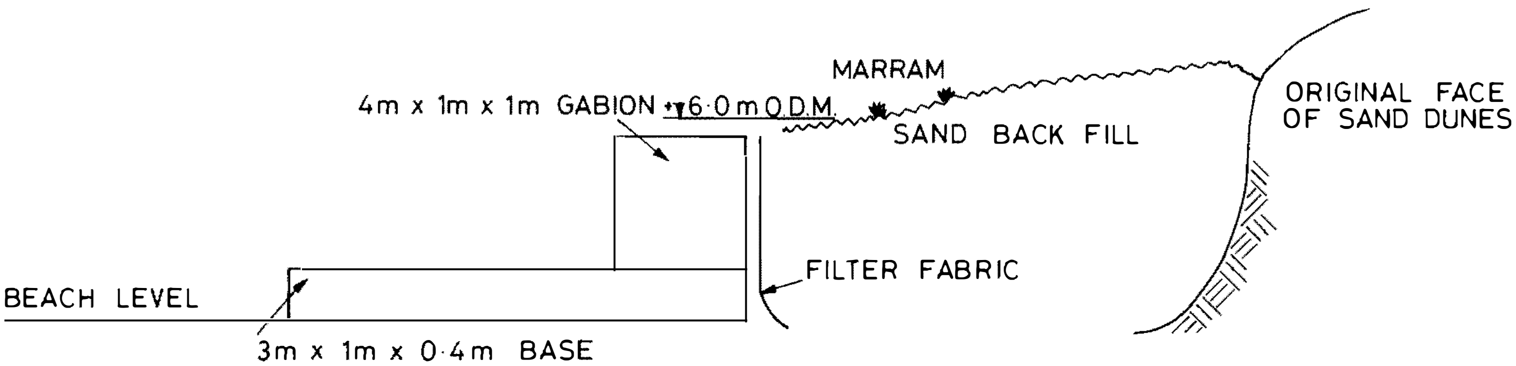
FIG. 2 SECTION THROUGH REVETMENT AT SKEGNESS AND WINTHORPE, LINCS.

FIG. 3 SKETCH OF STRUCTURE AT BRANCASTER, NORFOLK



TYPICAL CROSS SECTION

FIG. 4 SKETCH OF STRUCTURE AT OLD HUNSTANTON, NORFOLK



TYPICAL CROSS SECTION

Plates

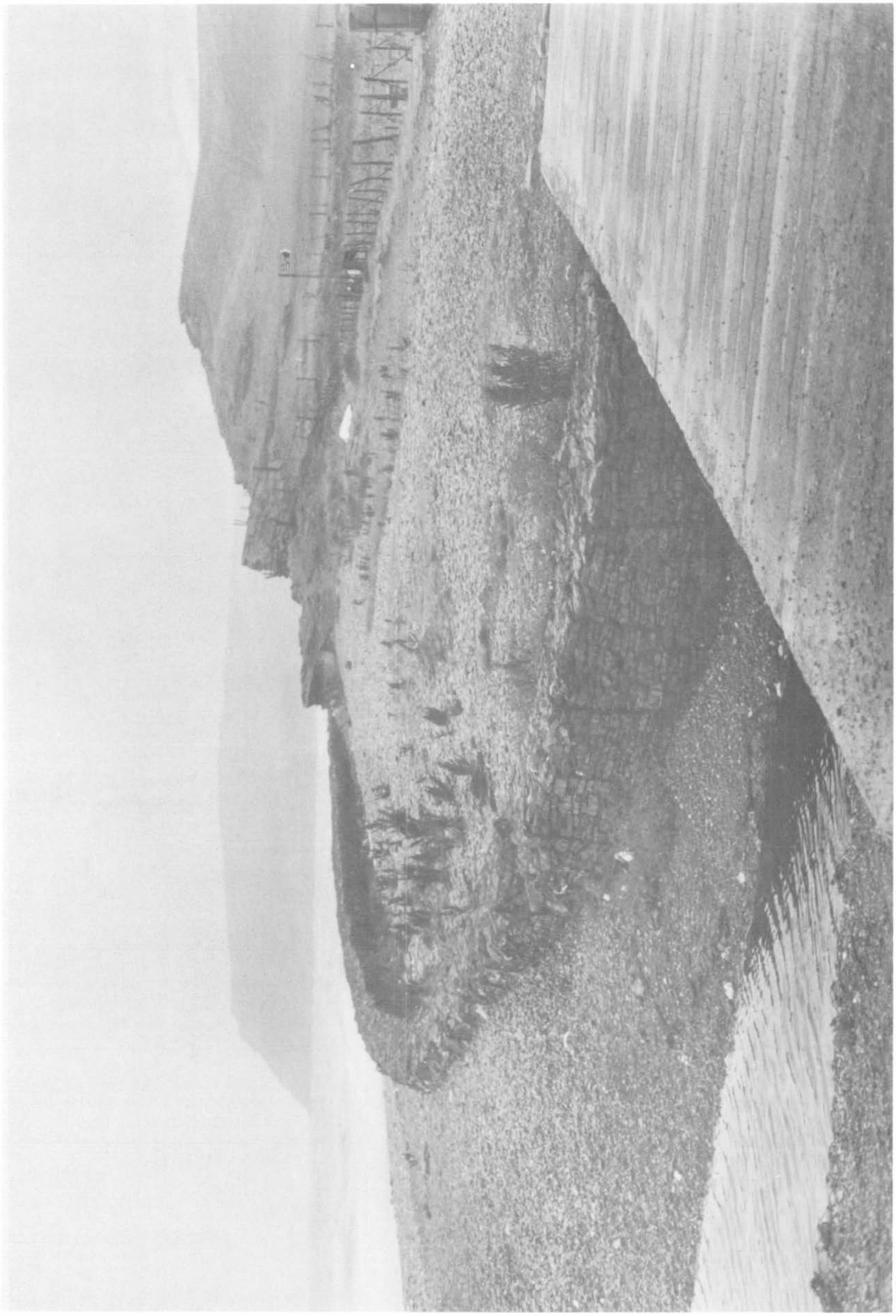


Plate 1 "Maccaferri" type gabion sea wall on shingle beach at St Bees Bay

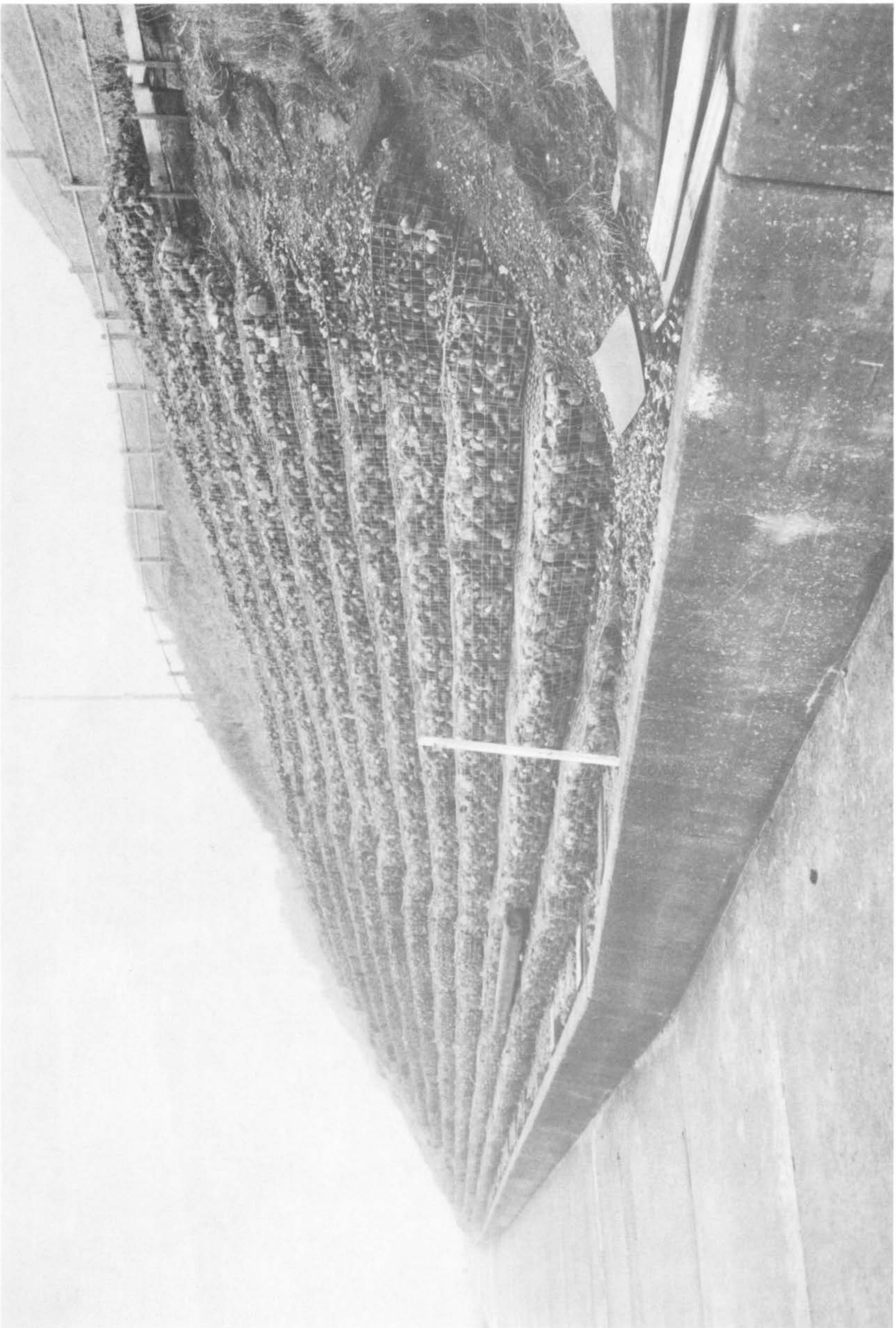


Plate 2 "Weldmesh" type retaining wall, Overstrand

Plate 3 Installing "Weldmesh" and "Maccaferri" gabions on Chesil Beach

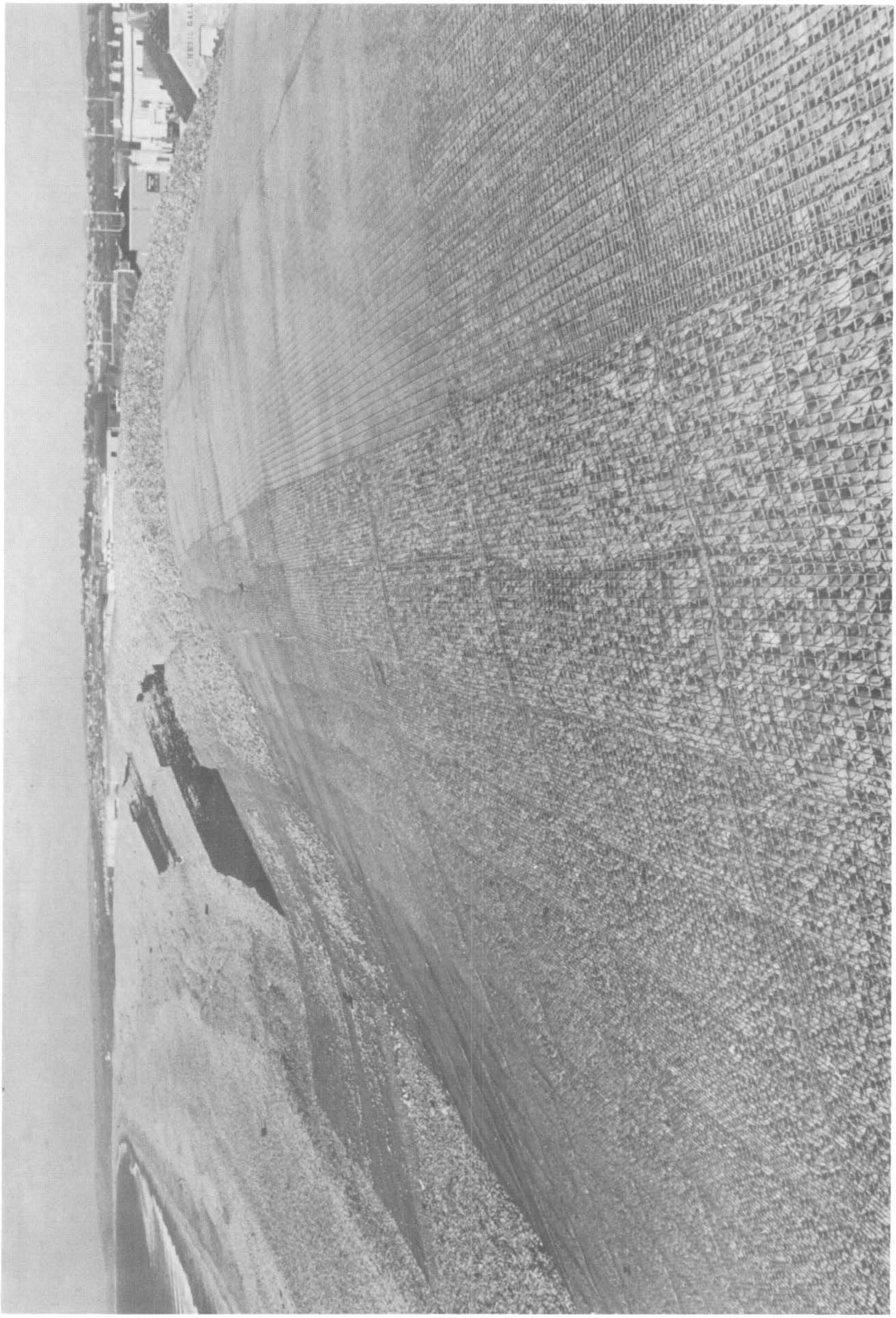


Plate 4 Gabions in position on shingle ridge at Chesil Beach (looking west)

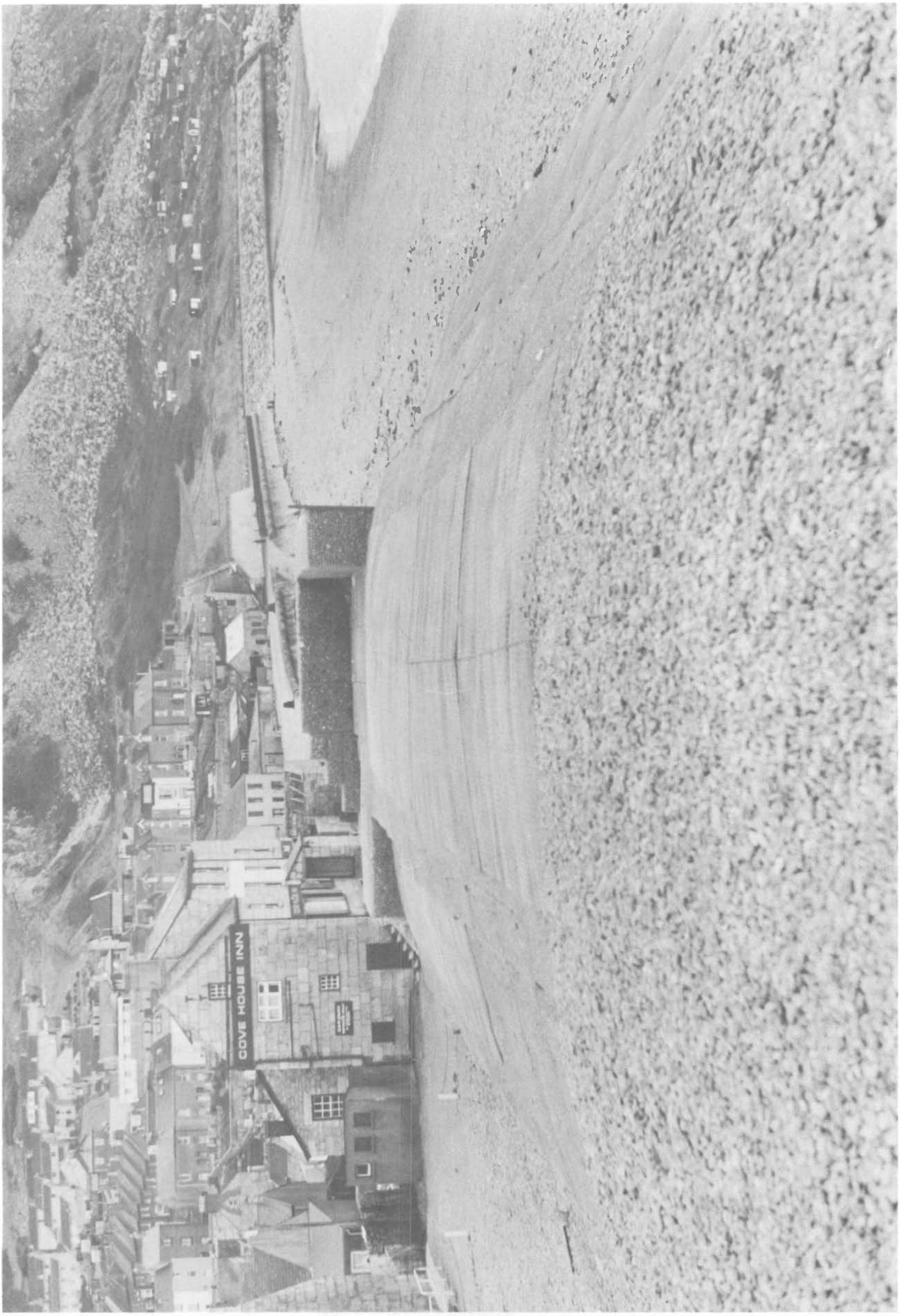


Plate 5 Gabions in position on shingle ridge at Chesil Beach (looking east)

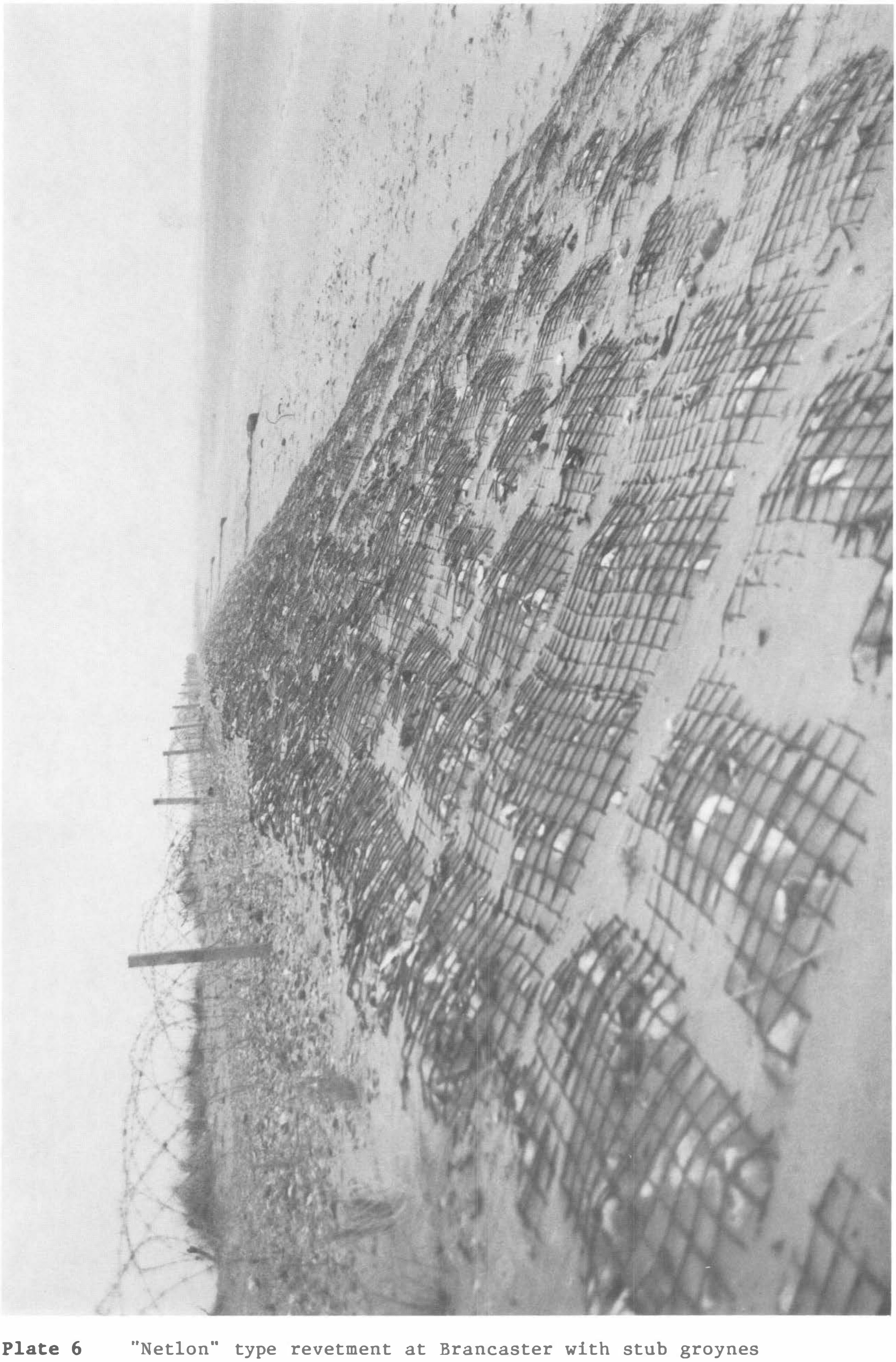


Plate 6 "Netlon" type revetment at Brancaster with stub groynes

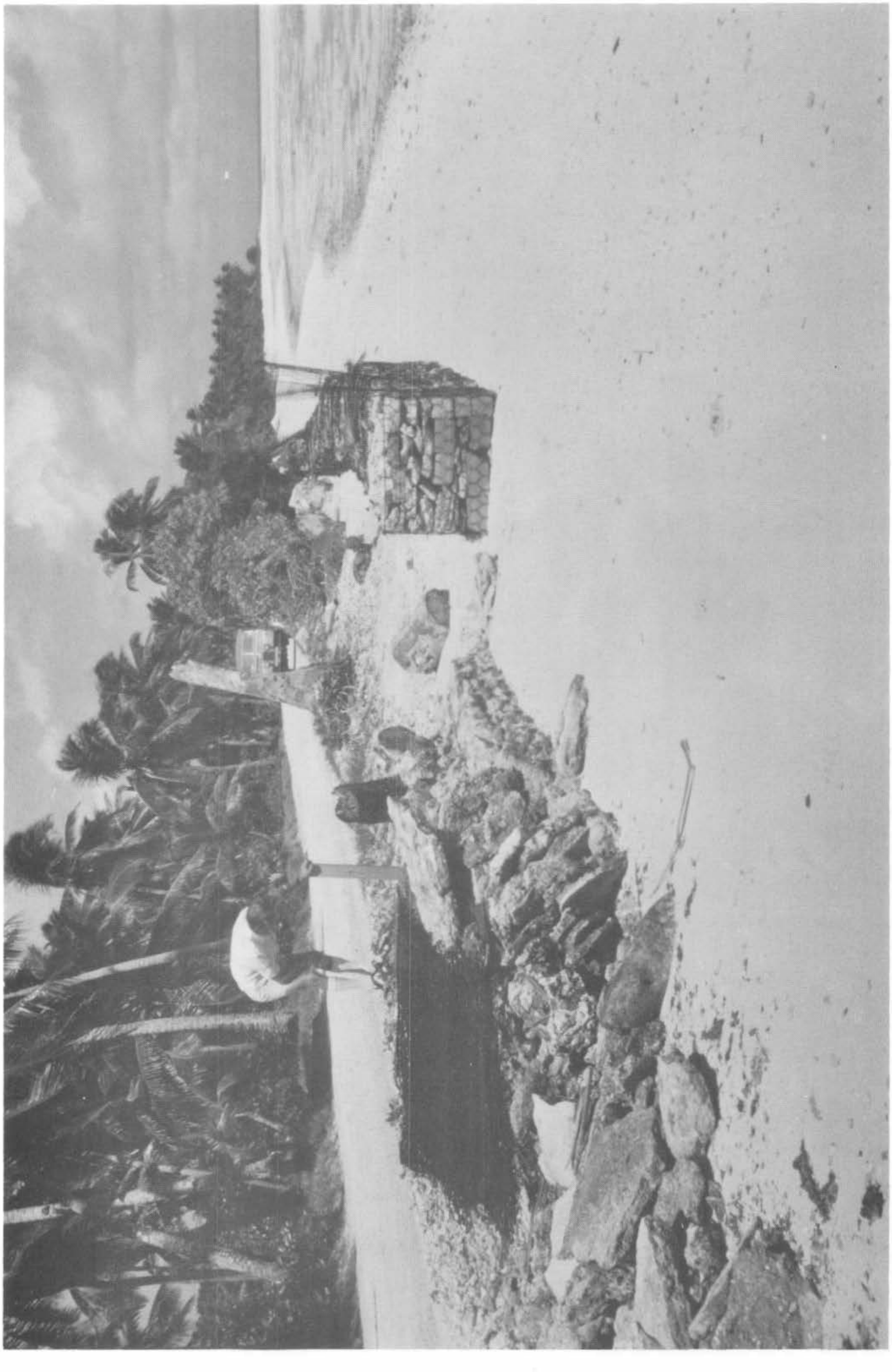


Plate 7 "Maccaferri" type gabion being installed - Ambo, Gilbert Islands, 1975

Plate 8 Beach build up at Ambo, Gilbert Islands, 1978.

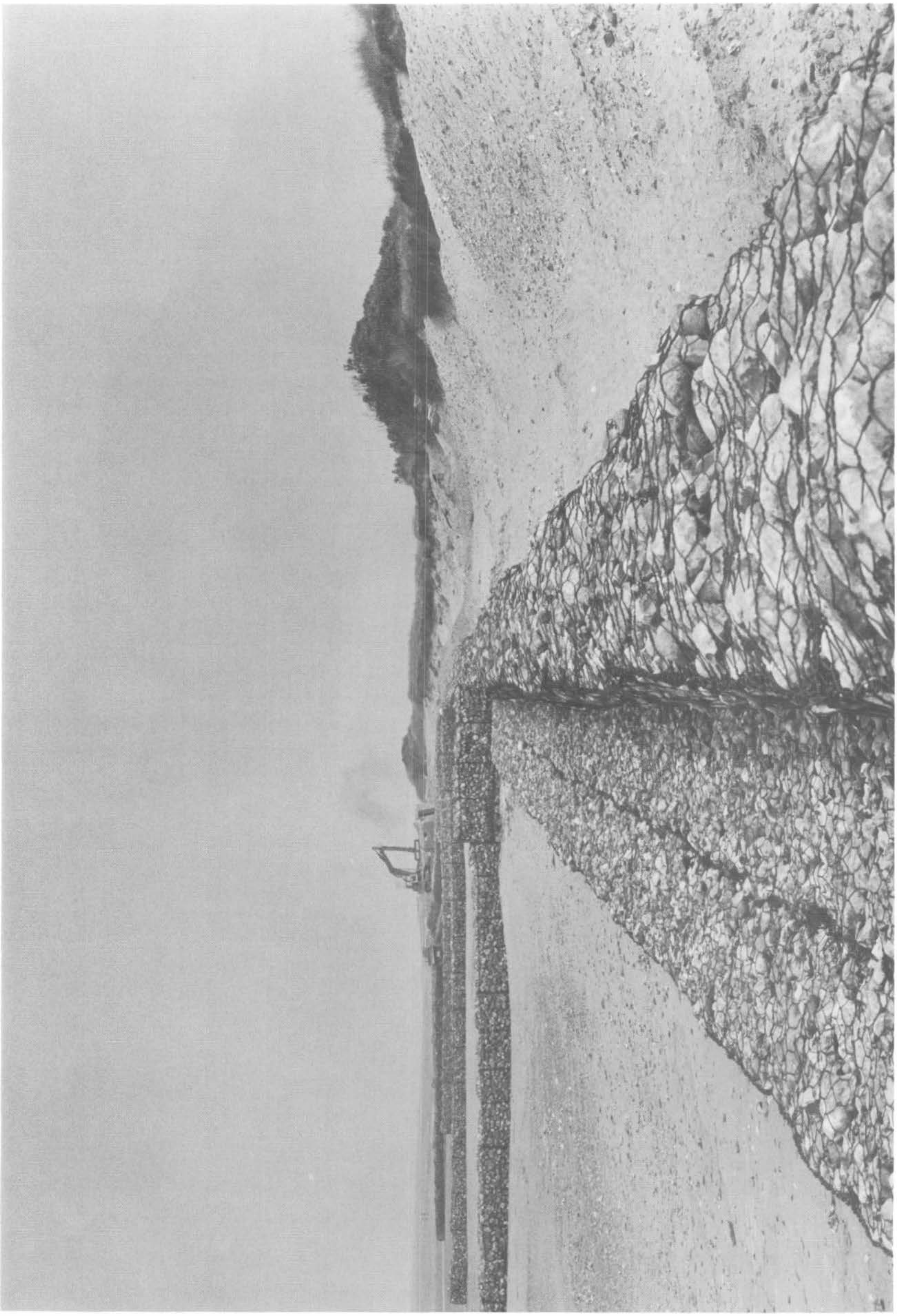


Plate 9 "Maccaferri" type sea wall at Old Hunstanton

Plate 10 "Maccaferri" type groyne showing foundation pad and scour hole, Old Hunstanton

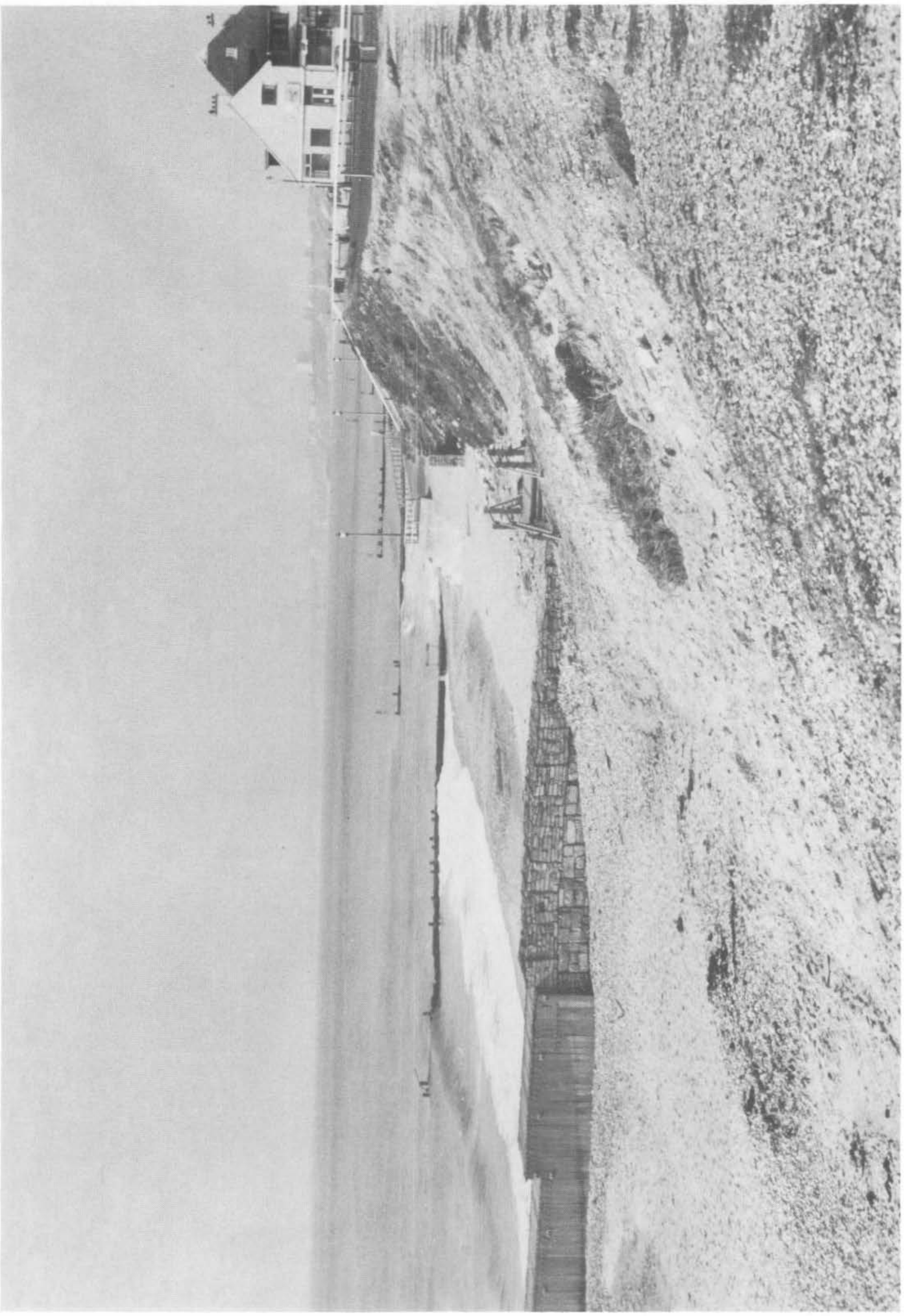


Plate 11 Hybrid groyne at Southbourne, Dorset

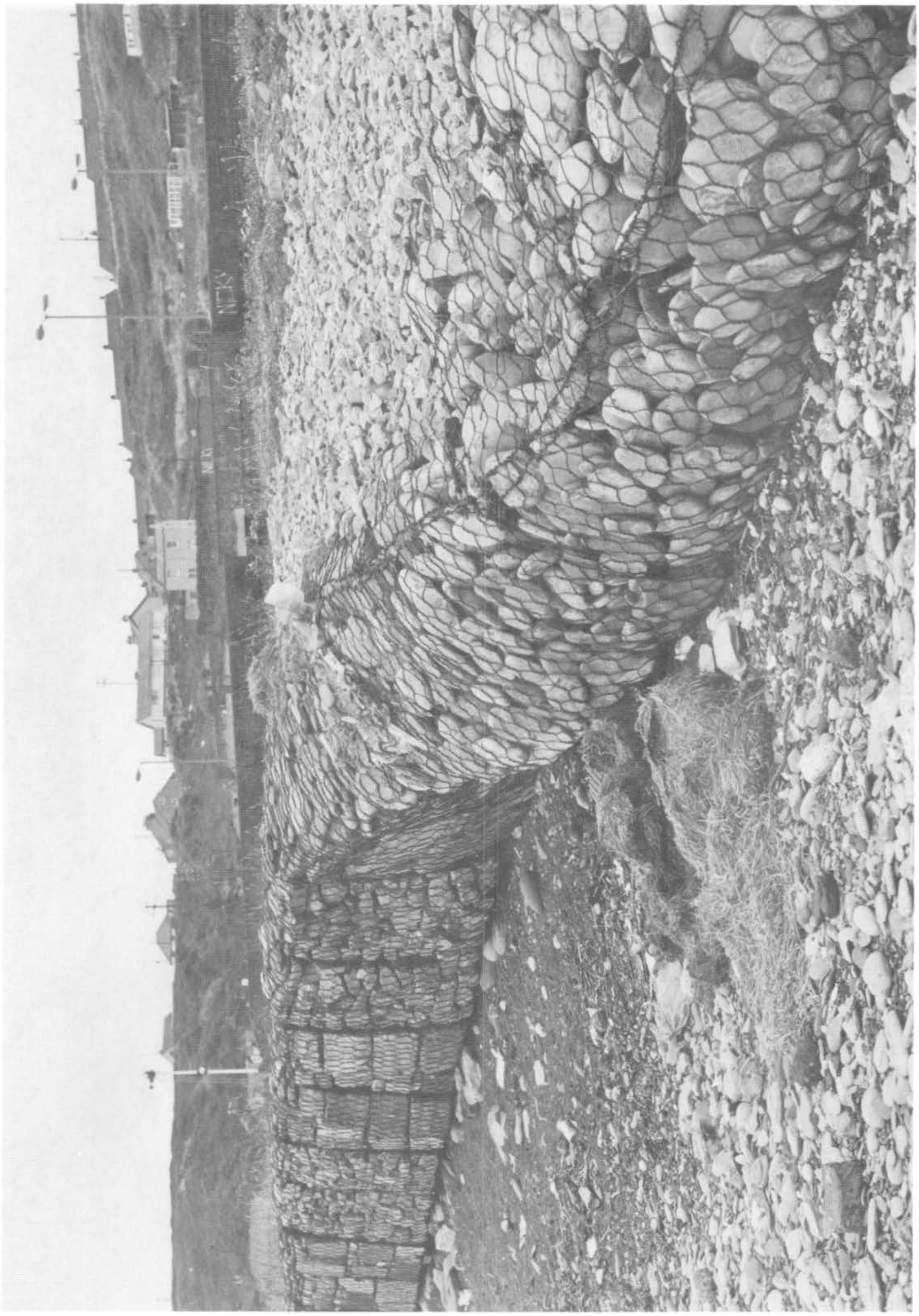


Plate 12 Sea wall - south of Workington, Cumbria

Plate 13 Damaged sea wall on shingle beach

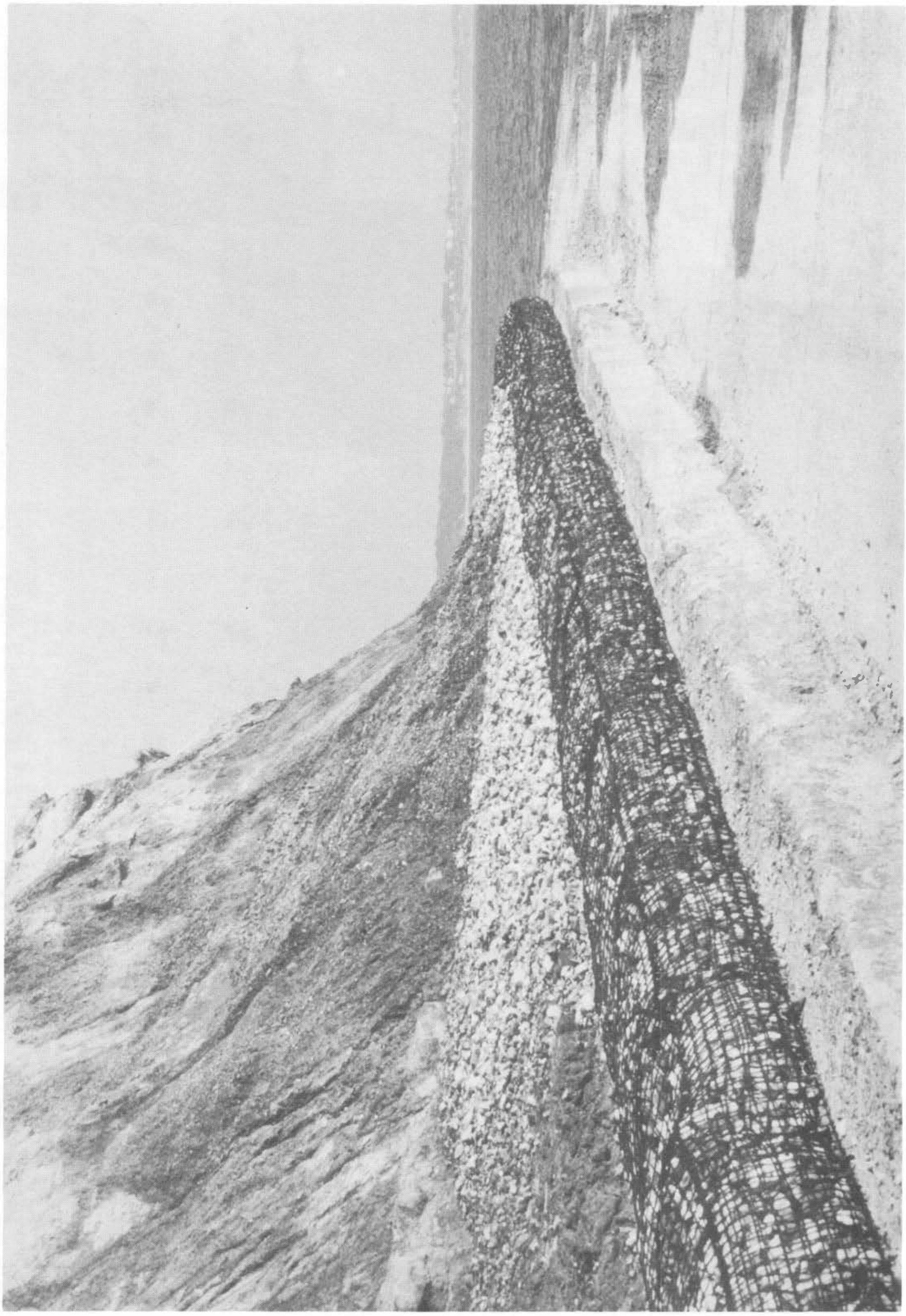


Plate 14 Netlon gabions protecting a cliff face - Hengistbury Head, Nr Bournemouth

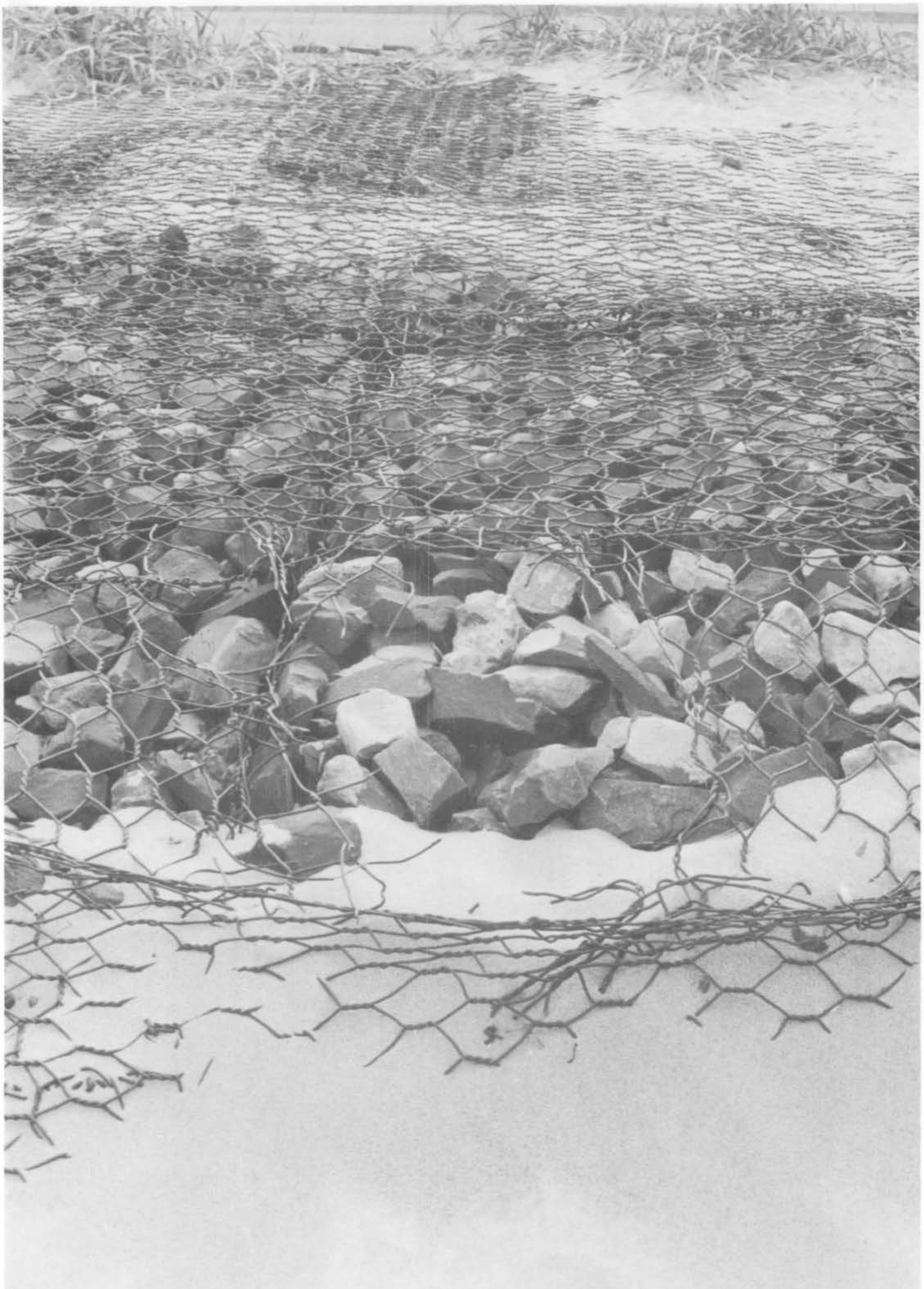


Plate 15 Example of damaged gabion revetment

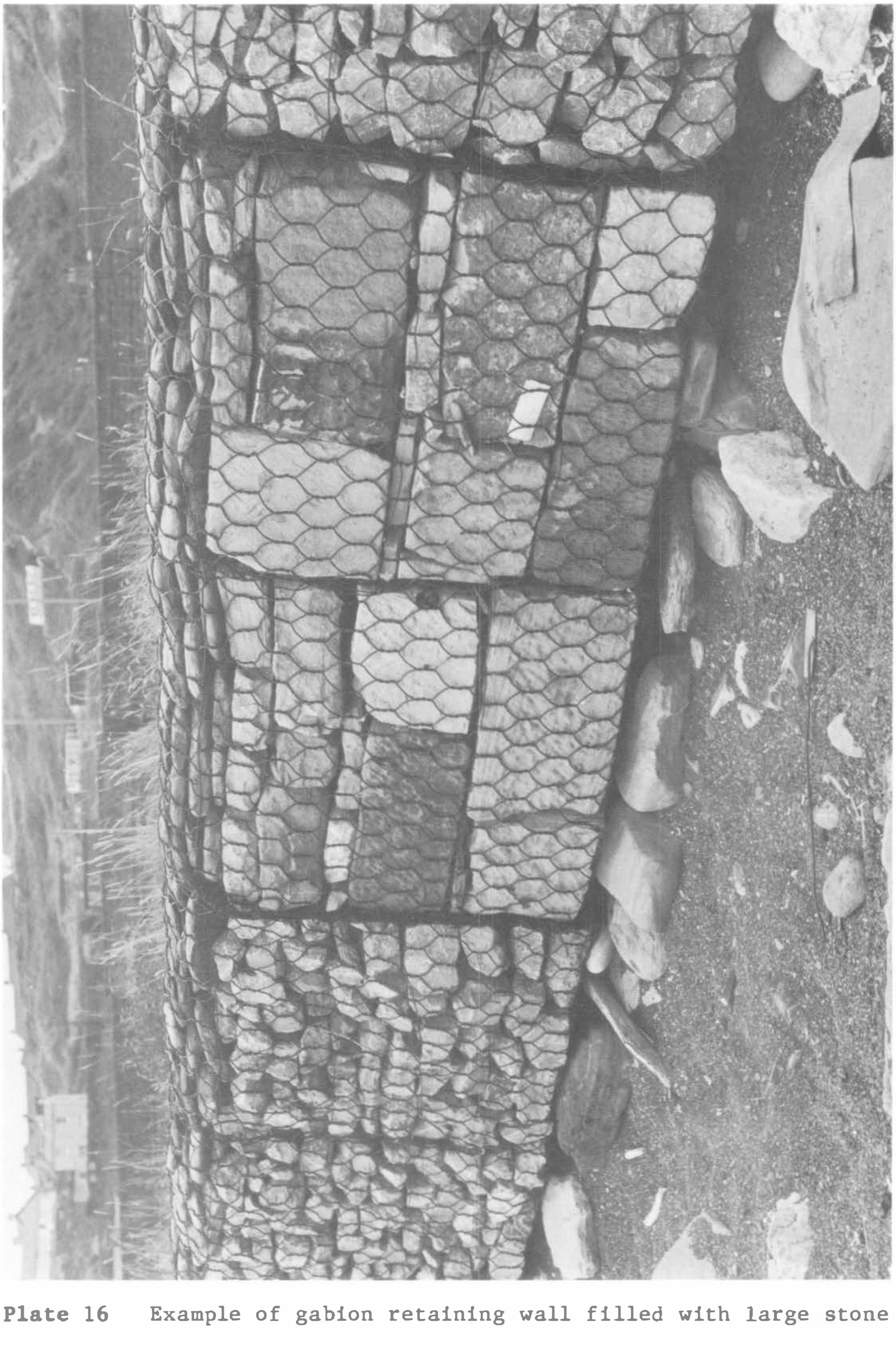


Plate 16 Example of gabion retaining wall filled with large stone sets