GEOSYNTHETICS IN COASTAL APPLICATIONS: PROTECTION, FILTRATION AND PLACEMENT ISSUES

D SHERCLIFF BSc CEng MICE MIHT CMIWM

GEOFABRICS LTD, Stourton, Leeds, England, LS10 1RD

SUMMARY: Geotextiles are often used in coastal defence works and whilst a great deal of excellent work was carried out by the Dutch and others from the late 1950's to the 1980's it would appear that whilst geotextiles have continued to develop, the specifications have become standardised, often defaulting to the geotextile used in the last installation. Engineers can loose sight of the reason for the use of the geotextile and the impression is that the geotextile is relegated to an afterthought and certainly does not gain the attention it deserves. There has been much development of geotextiles in the last 20 years and certain characteristics in the new geotextiles have been somewhat overlooked. The primary use of a geotextile in hydraulic engineering is that of a filter/separator under armour layers and the secondary use is as a reinforcement to enable embankment stability or for the wrapping of soils such as hung toe constructions or in the form of bags. This paper attempts to fill some of the gaps in knowledge for geotextiles used in their primary role as filter/separators by tackling various issues that have arisen. A modern specification is offered with engineering reasons for each clause utilising the key characteristics for a geotextile. Some guidance is given to the engineer on practical considerations for selection, placement and the often neglected quality assurance, giving a real engineering value to these specialist engineering materials.

1. INTRODUCTION

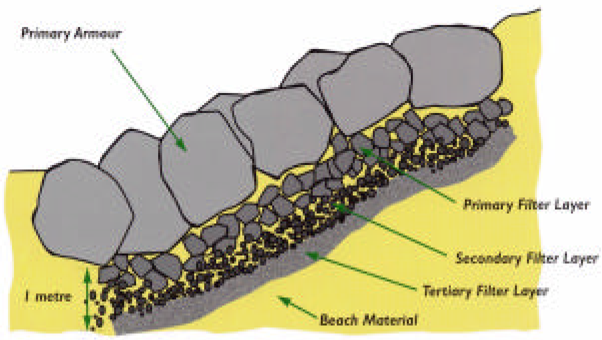
The storm surge of the 1950s affecting both the Dutch and UK coasts caused such disasters as the Lynmouth flood in Devon UK and the breaching of the dykes in Holland gave birth to the use of modern synthetics in coastal defence. The breaches particularly needed a quick solution and large four tonne capacity bags were filled with locally won material and where dumped into the breach. The expertise the Dutch have in weaving was fully utilised in producing good reinforcing fabrics which could be adapted to allow certain filter characteristics. Naturally as the dykes were restored, raised and extended these geotextiles were adapted from just reinforcement materials to filter/separators. Various weaving techniques and the mixture of different types of yarns meant that the designer could create a special woven which could have a specific characteristics for the given soil and water conditions present on a particular site. This reached a peak with the construction of such projects as the Delta Project where large multilayer mattresses were rolled onto massive barrels and rolled onto the sea floor to prevent scour between sluice gates. In UK engineers in general followed the good practice performed by Dutch engineers. In some instances the Dutch assisted with some of the projects especially on the Norfolk coast. This spawned much research work in the hydraulics laboratories and on specific test sites comparing revetment types on the dykes. Various design filter rules were published for various soil types and cover systems and guidance notes in publications in the 1980s. Since then development has been mostly concentrated on the revetment design via CIRIA (1) and a long awaited review of the "Rock Manual" which acts as a guide for all types of revetment design. Since the 1980's however there have been new developments in geotextiles which need to be taken account of in designs. Concepts such as risk assessment design have been introduced and used for revetments but not been applied to the use, or not, of the geotextile. This omission heavily implies that engineers consider the geotextile as an "after thought" in the design. In some instances assumptions on the ability of a geotextile to take installation damage are based on tests carried out over twenty years ago. Since then whole new types of geotextiles have been invented and introduced to this application. The main concept change is the idea of using high strain geotextiles as opposed to high stress textiles. Flexible geotextiles for flexible revetments. For instance thick needle punched non woven fabrics.

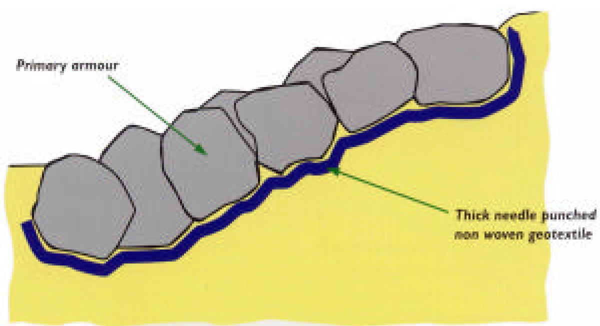
2. WHY USE A GEOTEXTILE IN COASTAL DEFENCE?

This may seem an unnecessary question but on reading the various non geotextile centred coastal defence manuals and design guides associated with rock armour the impression given is that the geotextile is an annoying addition which it would be so much easier to do without! The danger is that the geotextile can be reduced to the status of an afterthought and not adequately designed. In some instances has lead to the failure of the whole embankment. However when designed and placed correctly it can not only be the saviour of an embankment when an event occurs it can be have many other advantages as well.

2.1 Advantages

- Replacement of underlayers saving in material, material transport and placement costs. In some instances where transport of small stones is virtually impossible, say in shallow tidal waters at the base of a cliff where barges cannot manoeuvre close enough to dump. Whereas large primary rock armour can be beached and rehandled into place by excavators.





- Minimises the amount of "lost" material at the toe where rock buries itself into a soft subsoil
- Due to its sheet like qualities reduces differential settlement helping with long term maintenance of alignment of a revetment or breakwater.
- Establishing a hung toe on long shelving embankments where soft alluvial silts prevent the establishment of passive resistance for the rest of the revetment to build off. Reinforcing geotextiles and grids can be made into bags or gabions and "hung" from an anchor trench higher up or at the top an embankment.

2.2 Disadvantages:

- It maybe impossible to place geotextiles flat, in position and overlapped in turbid, turbulent water. Whilst there are a number of good installation techniques available there are limits to placing geotextiles in unprotected wave environments or strong currents. Some of the techniques for laying are discussed later.
- Poorly positioned geotextile which has not been properly covered can results in flaps of geotextile being exposed and can cause a danger to shipping by fouling propellers. If it is impossible to mark the edge of the geotextile reasonably accurately to ensure coverage and proper overlapping then geotextiles should be avoided.
- Whilst geotextiles have a wide range of permeabilities they should not be used where the core material of an embankment is made up of coarse boulders or shingle. It is most important not to place a geotextile over a highly permeable core material under revetment armour. In wave attack and high currents the underlying water pressure will cause uplift on the geotextile resulting either the tearing of the geotextile with consequent loss of core material or dislodgment or even removal of the primary armour.
- Where frequent rock outcrops occur under water. Placement of cover stone will inevitably pinch and damage the geotextile causing a hole to form and the consequent loss of fines form adjoining soft areas. For ‘dry’ installation with care and proper anchoring adjacent to outcrops geotextiles can be shaped to fit with these.

3. FILTRATION BY A GEOTEXTILE

3.1 Balancing “sand tightness” with high permeability

The concept that a geotextile allowing adequate passage of water whilst retaining sufficient particles to maintain soil structure is nearly as old as geotextiles themselves. In the wave environment the conditions are distinctive as there is a reversing flow and often a high flow in either direction. When a wave strikes the surface of a revetment, water rushes into the structure aided by the stored energy of the wave. When the wave draws down it causes an even more damaging uplift suction pressure on the surface. The pressures involved have been studied in detail in laboratories such as the Hydraulics Research Laboratories in the UK and the Delft wave flume in Holland. Advice on the stability layers required to dissipate the energy of a wave is well documented. The area sometimes neglected is the critical role that the geotextile can play. In a reversing flow it must be appreciated that the usual assumed Terzaghi filter build up associated with single directional filters may not apply as water flows in all directions within an embankment undergoing wave action. Problems associated with particulate clogging of thicker fabrics in single flow tend to be overcome as particles lodged in the centre of these fabrics are flushed out. The advantage of these thicker materials is that they combine good “sand tightness” with high permeability.

3.2 Consistent permeability at all strains

More importantly this can be maintained at all levels of strain. Experiments (2) were carried out in the laboratory where a needle punched non woven was clamped in two O rings and failed using a ball plunger in a standard puncture test rig. The maximum failure strain was recorded and then similar virgin samples were clamped and strained to various percentages of ultimate strain. These clamped strained samples were then remounted in a permeability rig and the resultant flow measured. The result was unchanged flow until approximately 80% strain had occurred where flow rates went markedly upwards. At 80% the structure of the fabric is starting to break down and fibres have started to disengage. This would be far beyond the design strain. For all working strains the conclusion is that permeability remains constant and at significantly high levels. From experience it is estimated that a geotextile should have a design strain of 40% elongation without break to allow for the rock intrusion into soft subsoil.

3.3 Relative permeability between filter layers

Van der Meer (1988) proposed a series of permeability factors to be used in stability calculations for rock armour revetments. The factors varied according to the armour layers, filter layers and core permeability. The idea is to make the engineer think of the relative permeability of the discreet layers with a view to avoiding the mistake of having materials of a low permeability placed on top of a high permeability material. If this occurs then any water trapped beneath the low permeability layer will cause uplift to that layer causing differential settlement at least. In the worst instance the surface could be blown off. One of the layers is of course a geotextile. The permeability factor recommended by Van de Meer for **all** geotextiles is a very conservative P = 0.1 almost describing the fabric as impermeable. It occurs to the author that with the vast range in permeability of different geotextiles of up to a factor of 100 this factor is very conservative and restricts the use high permeability geotextiles. As a rule of thumb it is at least advisable to ensure that the geotextile has a permeability at least 10x that of the underlying materials. An example of a site where this was not observed is shown below.

Picture 1: Damage of needle punched non woven due to high permeability 6F stone beneath geotextile instead of on top of it. Geotextile burst and tore in storm event which occurred during construction. The original design did not take into account the fact that the contractor was to build a haul road onto the beach using the Highway specification 6F material.

4. DURABILITY AND PLACEMENT ISSUES

4.1 Installation damage

The coastal defence environments by their very nature is fairly coarse variable and flexible. Much effort has been put forward in the past to protect rather fragile filter geotextiles from damage by placing a layer of gravel over the surface. A delicate filter fabric especially made in the factory does not match this rough environment and in turn puts heavy demands on the installer to place it without damage and then for it to survive in service with differential movements throughout its life. A carefully designed filter opening size and filter rate is all null and void if the fabric is peppered with large holes where large amounts of material can be sucked out!

Picture 2: Damage to a woven geotextile partially constrained and small rock dumped directly onto surface causing local puncture. This could repeated many times over the whole revetment.

Picture 3: Damage to a thin heat bonded non woven due partially to burst, surface abrasion and lack of cover layer protection

Rarely are their site damage tests on the geotextiles establishing if the specified geotextile can be practically placed without damage. A series of on site damage tests were carried out on the North Wales coast about 20 years ago where granular material was tracked over the various woven and non woven fabrics to see their ability to withstand installation damage. The conclusion was that all geotextiles need some sort of protection by a fine granular material to prevent puncture from upper armour units. To bring this experiment up to date a similar trial was held in 1998 on the Kimnel Bay beach witnessed by 30 coastal engineers from Wales and Ireland. A number of "rock drop" tests were carried out on the weakest in a range of needle punched non woven geotextile not previously tested. Rocks of 2 tonnes were dropped from a height of 4m onto the restrained geotextile. On removal of the rocks by grab observations showed little of no damage to the surface of the geotextile although it had been strained considerably no holes were visible. The conclusion by all witnesses was that these type of geotextiles could be used in more exacting installations than previously envisaged.

4.2 Rock drop design charts and site damage testing

The author and colleagues in fact set up a series of tests (3) on the Cardiff Bay Barrage site where a number of rock sizes and non woven needle punched staple fibre geotextiles were tested and an assessment a criteria for failure based on criteria such as an of actual hole and then obvious surface damage to produce a series of design curves enabling Engineers to select different grades based on an installation damage likely on their particular site.

Picture 4: Rock drop test ay Cardiff Bay Barrage. Note that fabric is constrained to create "drum" effect likely to occur in worst case on site.

For instance a 3.5 tonne rock dropped a distance of 1.5m has an energy of 3500 x 1.5 = 5250kgm. A graph was developed from these tests enabling the engineer a guide based on experiment to select a suitable robust geotextile (4). From the graph this would suggest a 14000N puncture resistant geotextile would give sufficient resistance to damage. If such data is unavailable for other types of geotextile or the site has some unique conditions it is advisable for Engineers to require a site specific rock drop test to try to simulate actual site placement conditions as part of the specification and geotextile selection process.

Once the true nature of the chosen geotextile is established this leaves the installer free to exploit the characteristics of the textile to its full in the installation method chosen. (See section?? for some laying techniques)

5. SPECIFICATION AND QUALITY ASSURANCE OF COASTAL GEOTEXTILE

5.1 Guidance from the European Standards

The measurement of the various basic properties is carried out in the laboratory using specially designed tests to give the designer the index values for comparison of one geotextile to another and to ensure consistency of product delivered to site. The European (CEN) and International standards (ISO) committees have devised these tests and the relevant tests should be used to define the properties required for the application. In Europe generic recommendations are given in the standard "Geotextiles and geotextile related products: Characteristics required for use in erosion coastal works (Coastal protection, bank revetments) EN13253:2001"

5.2 Relevant index tests for filter/separation

The relevant index tests should be matched to the function required both from an in service and an installation perspective. For a filter/separator the following functions should be considered in order of priority:

Permeability. Classic filter rules state that each layer of a filter system must be more permeable than the layer beneath being filtered. Similar rules developed for geotextiles suggest a coefficient of permeability 10 to 100 times greater than that of the filtered soil, especially in wave environments. It is important that the geotextile should maintain or exceed its index permeability whilst under load i.e. any re-orientation of the fines should not decrease permeability. When considering drainage elements such as in dams, filtration systems and slope protection in rivers where single directional flow is likely the permittivity of the geotextile should be considered. The permittivity is the discharge perpendicular tot the geotextile per unit pressure head difference and per unit area, expressed in s^{-1}. Blocking and clogging in single directional flow due to biological or chemical build up (residues) can reduce the permittivity considerably. As a general rule the correct geotextile is used where there is no significant pressure drop over the geotextile (taking into account possible blocking or clogging).

Filtration. The characteristic pore size of the geotextile has to be less than the average grain size of the soil to be filtered to prevent loss of material through the geotextile. Established design rules for reversing flow applications and for a typical geotextile state the O_{90} of the geotextile should be less than the D_{50} of the soil to be filtered. However there are variations for different geotextiles and should be checked against recommendations made in EN ISO 12956

Extensibility Rock armour functions by virtue of its dead weight being transmitted over as wide an area as possible to consolidate the underlying soil and minimising particle movement. The load imposed on the geotextile by the overlying rock is not evenly distributed. The highest stress concentration will be underneath the part of each rock in contact with the geotextile, which in turn will impose high localised strains. The geotextile needs to have a high strain capacity to allow it to deform around the rocks without rupturing and without loss of hydraulic properties. Whilst on the drawing the geotextile is shown in a single plane in reality it is forced to take up a highly deformed shape.

Puncture resistance. The geotextile must be able to withstand puncturing loads imposed both during installation and then during service. The weight, angularity and drop height of the rock being placed directly on the geotextile together with the haste with which the contractor has to work in the short tidal windows available to him all contribute to the puncturing load the geotextile will experience. In service the wave action on the overlying rocks may cause puncturing or where due to differential settlement in the subsoil extra strain is placed locally on the fabric.

Thickness. Thickness is required to cushion penetrating loads under the angular points of the overlying rock and also to provide a lateral drainage path where the surface is occluded by the overlying rock. The lateral drainage capacity is defined by the geotextile's transmissivity under load.

Durability. Strength and puncture resistance reduce over time by oxidation and in some instances hydrolysis. Durability may be influenced by temperature, UV-radiation, pollution in the water, air or soil.

The relevant index tests, which match closest to these requirements and shown in the typical specification in Appendix 1.11, are:

Water flow normal to the plane EN ISO 11058 – closely linked to permeability. Water is passed through the geotextile under a constant head of water.
Pore size EN ISO 12956 – Defines the opening size of a geotextile and its ability to trap particles and prevent passage. The geotextile is clamped and measured sand particles are washed through the fabric and the % passing is calculated.
Minimum tensile extension EN ISO 10319 – defines the total extension at break in all directions allowing differential movement without break under the rocks.

Tensile strength EN ISO 10319 – simulates the geotextiles ability to be handled on site using heavy excavators or equipment. The geotextile is clamped between two jaws and stretched until break and the tensile strength and elongation (above) is recorded.
Cone drop perforation EN 918 – Simulated the dynamic impact of dropped stones into the surface during installation. A metal cone is dropped onto a sample clamped in O rings and the resultant hole is measured.
Static puncture test (CBR) EN ISO 12236 – Simulates the biaxial strain of a rock attempting over time under heavy load to push through the fabric. A sample is clamped in O rings and a plunger is pushed through it, break strength and displacement recorded.
Thickness and thickness reduction under load – This simulates heavy localised compression of a thick geotextile which has been designed to retain some in plane flow to relief pore water pressures. Thickness is measured under loads of 2kPa and 200kPa.

5.3 Different priorities for reinforcement applications

Where a geotextile is primarily used as reinforcement for instance as a basal reinforcement to the underside of a breakwater constructed on soft silts different characteristics predominate such as material stiffness. Whereas extendibility is a benefit when used as part of a flexible revetment system obvious high tensile strength, low creep and low extension become the key characteristics where reinforcement is concerned. Reference should be made to the many guides for reinforced embankments for high strength wovens and grids.

Usually there is a requirement for high tensile strength with low extension where the geotextile is expected to be placed under high load and will prevent spread or slip in the embankment. When a geotextile is subjected to high load over a period especially in saline conditions the long term creep (elongation over time under constant load) should be considered.

5.4 Quality Assurance and Construction Quality Assurance

Most index tests are short term, low cost and repeatable and ensure consistency of product in production. Each manufacturer must have a recognised and independently audited Quality Control system. Tests relevant to the application should be carried out at regular agreed intervals on batches of geotextiles. Certificates should then be produced to confirm consistency of the product supplied. A recognised standards regulator, such as UKAS, should regularly monitor the laboratory, either in house or external. In addition the designer should request samples taken from materials delivered to site for additional testing if required.

In most European countries geotextiles are required to be CE marked for the application. It will, for instance, certify the geotextile for F filtration applications and R reinforcing applications specifically for coastal and river applications. A CE mark certificate is supplied which guarantees the geotextile meeting published values. Independent laboratories monitor testing carried out by any manufacturer with CE marked products.

5.5 Durability

To establish durability requirements there are a series of abrasion, UV resistance, oxidation and chemical immersion tests defined in EN and ISO testing selected for the specific site conditions considered. The most common is exposure to UV light and the designer is advised to specify a proven method of protecting the fibres, such as a certain percentage of carbon black in the fibres. The polymers used in the geotextile have certain properties at certain temperatures in say salt water or polluted water in the short and long term. Tests to prove the stability of these textiles in the short and long term should be undertaken.

It should be stressed that each geotextile has certain characteristics and it is up to the designer to choose a generic type based on sound engineering judgement. The Engineer should then specify the basic material type and the raw materials that it is made from including specific characteristics such as the optimum UV protection the type of raw material can sustain.

5.6 Polymer types – sinking or floating?

One characteristic of all oil-based polymers is that they have a specific gravity less that 1. Pure water, of course, has an S.G. of 1 and salt water has an S.G. of around 1.03 dependant on salt content. This means that by their nature geotextiles float and therefore gives the installer the basic challenge of holding this material down flat on the sea bed. There are some exceptions with polymers such as polyester which have an S.G. > 1 suggesting that this material will naturally sink, implying an easier time for the installer. The benefit is marginal for a number of reasons. Firstly in salt water the ability to sink can be reduced to zero and the fabric if not positively placed with a sinking system will "wallow" just beneath the surface and will neither sink or float making the task even more difficult. The thicker needle punched non wovens tend to have air trapped in them which gives them extra buoyancy initially and takes some time and agitation to remove the air bubbles. The recommendation for installers is therefore is to treat all polymers as floating especially in seawater.

The designer should also be extra careful to check the quality of polyester used as these materials can be susceptible to hydrolytic attack especially in warm saline conditions. This causes break down of the fibre and eventual break up of the geotextile. The most commonly used polymer is polypropylene, which is virtually inert in all marine environments. It is worth noting that some of these thick geotextiles are also used at the base of landfills where, in some instances there are toxic leachates at temperatures up to 60^{o}C. An on going test immersing polypropylene needle punched geotextiles in leachate at 60^{o}C shows no loss in strength in 10 years.(5)

5.7 Model specification for a filter/separator

As an example there follows a model specification for a needle punched non woven staple fibre geotextile commonly used in coastal defence.

Filter/separator geotextile for use beneath rock armour

The geotextile to be used as a filter/separator beneath the rock armour shall be a non-woven fabric manufactured by needle punching virgin, staple fibres of polypropylene incorporating a minimum of 1% by weight active carbon black. Geotextiles manufactured from fibres of more than one polymer will not be permitted.

The geotextile shall have the following properties:

Test description	Approved test method	Units	Typical value	Allowable tolerance for typical value
Water flow normal to the plane of the geotextile @50mm head	EN ISO 11058	$l/s/m^2$		-10%
Coefficient of permeability	EN ISO 11058	m/s		-10%
Apparent pore size - 90% finer [O_{90}]	EN ISO 12956	μm		+10%
Tensile extension	EN ISO 10319	%		-10%
Tensile strength	EN ISO 10319	kN/m		-10%
Cone drop perforation hole diameter	EN 918	mm		
Static puncture strength (CBR)	EN ISO 12236	kN		-10%
Push-through displacement	EN ISO 12236	mm		-10%
Thickness reduction for pressure increase from 2kPa to 200kPa	EN 964	%		+10%
Thickness @2kPa	EN ISO 964-1	mm		-10%

Geotextiles shall be delivered to site in packaging, which will protect the rolls from ultra-violet light degradation. The labelling shall clearly identify the product supplied in accordance with EN 30320: 1993. Geotextiles shall be protected at all times against physical or chemical damage. Geotextiles shall be kept in the wrappings provided by the manufacturer until required for use in the works.

The geotextile manufacturer shall provide production test certificates at the rate of one set of certificates per 6,000m^2 delivered to site and a minimum of one set per contract. Test methods employed shall be in accordance with the requirements of EN or ISO and be accredited by UKAS or similar recognised accreditation service to carry out the required tests. Certificates relevant to a batch of geotextile shall be furnished to the Engineer prior to that batch of Geotextile being incorporated in the works.

The rolls of geotextile shall be stored on level ground and stacked not more than five rolls high and no other materials shall be stacked on top of the geotextiles.

The geotextile shall not be exposed to direct sunlight for longer than thirty days.

The geotextile shall be laid and installed in the positions and to the line and levels described on the drawings. Material, which will be in contact with the geotextile shall not have protrusions, which are likely to damage the geotextile during installation or in service. Construction plant must not operate directly on the geotextile.

Joints shall be formed by overlapping by a minimum of 1000mm. A reduction in overlap to 300mm may be considered by the Engineer where the sub-layer is firm and above water level.

Prior to incorporation in the works samples of the geotextile shall be taken in accordance with the requirements of ISO 9862, 1990 at the rate of one set per 20 number of rolls. The Contractor shall retain half the samples and half shall be furnished to the Engineer. Both sets of samples shall be stored in light tight bags at ambient temperature until required for testing or disposal at the direction of the Engineer.

Provision shall be made should the Engineer so wish for a site “rock drop” test to be carried simulating the installation method to be used on site and using the relevant primary and/or secondary rock types supplied to site. A pad will be prepared on the beach material where a 6m x 6m piece of geotextile will be laid out and restrained in a taught manner by a minimum of 9 armour units greater than 1 tonne each placed around the perimeter of the fabric. A typical primary armour unit will be lifted to a height of 2m and dropped onto the surface of the geotextile (or onto the secondary rock over lying the geotextile) The rock(s) will be carefully removed exposing the geotextile. The test will be deemed successful if no visible holes are observed.

The following definitions shall apply when considering test results:

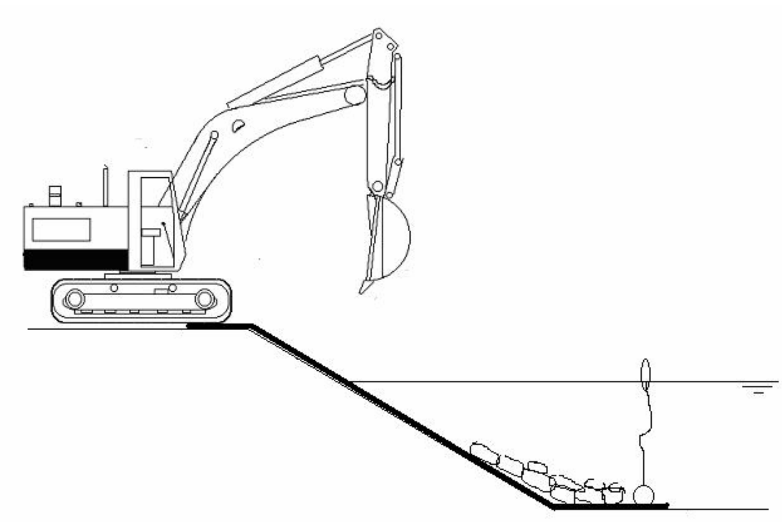
A *set of test results* shall be those results derived from specimens cut from one sample.

The *mean value* for any set of test results shall be the arithmetic mean of that set of results.

The *characteristic value* is the value below which not more than 5% of the test results may be expected to fall. This represents the value at 1.64 standard deviations below the mean value.

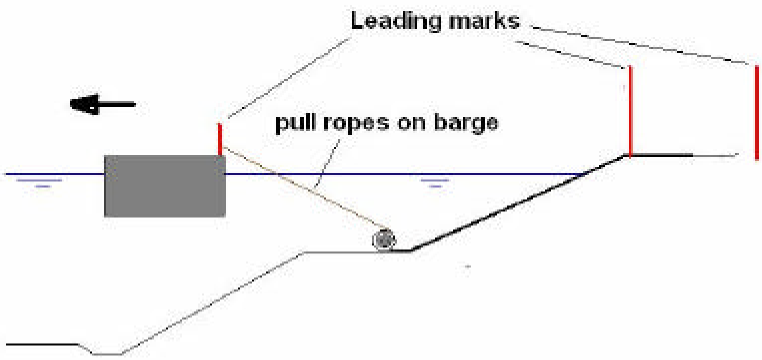
6. INSTALLATION ISSUES AND METHODS

Once the limiting characteristics of the geotextile have been established in conjunction with the installer the installation method can be finalised. If the designer has taken advice from an installer on the feasibility of construction this should be a straight forward process. Often, however, the installer is faced with a vague specification for an unsuitable geotextile to be placed in an impossible location at tender stage the responsible installer will point this out. This results in either the removal of the geotextile or a rushed alternative being used. An experienced installer will have good contacts with quality manufacturers who will offer suggestions or even adaptations to the basic geotextile. For instance woven manufacturers can produce materials with special loops woven onto the fabric to assist with connection to installation rafts or fascines. Folds of fabrics can be introduced by sewing over flaps of fabric to contain weights such as sinking poles or handling ropes. The challenge for most geotextile installations is the fact that oil based polymers float and when working in water depths over 5 meters in open water this can prove difficult. Some methods amongst many that can be used in placement underwater:



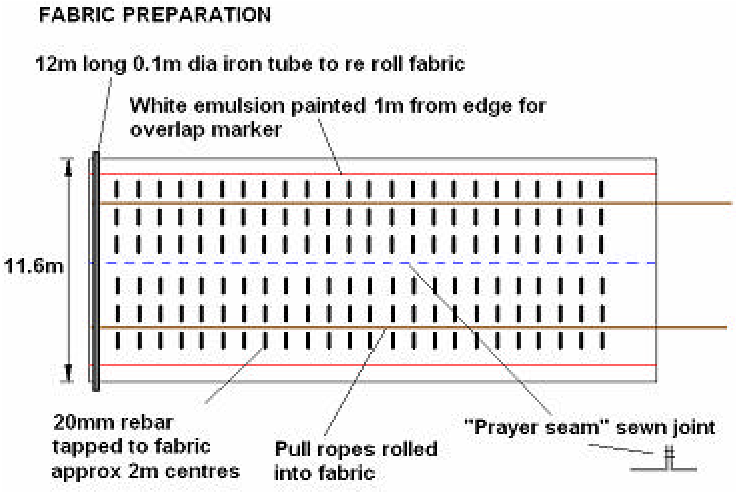
Picture 5a: Trap geotextile with tracks of excavator lower metal pole wrapped in geotextile. Leave pole till fabric weighted by initial stone placement. Retrieve pole by pulling on buoy ropes at ends of pole.

Picture 5b: Initial placement of rock to hold fabric in position. Note divers on hand to help with positioning and retrieval of pole



Picture 6a: Longer slopes using steel pole and pre weighted fabric (see preparation below). First slope uses first method then barge takes over handing ropes from shore to barge continues down slope. Additional barge may be used for rock dumping

Picture 6b: Barge manoeuvring pulling the submerged roll out to sea



Picture 6c: For deep remote placement. Geotextiles are unrolled remotely using pull ropes which are pre-rolled into a prepared roll. The roll is rolled out sewn to produce wide roll then rebar taped at intervals to the fabric. White markers on the black fabric show the overlap width to the divers at depth.

Picture 6d: Preparation of roll. Rebar being attached to fabric before being rerolled onto 12m steel bar. Note pull ropes to enable unrolling at depth.

Picture 7a: Fascine mattress preparation. Note the multi width mattress approximately 25m wide sewn together. Holes are made in fabric with a push rod the same diameter as the twine used to tie fascine to fabric. Note prepared giant fabric in background.

Picture 7b: Fascine mattress in and guide barge in position ready for stone dumping. The bamboos are tied at 1m centres in a latticework making the whole structure semi stiff. As the stones are placed the mattress lays down flat on the bed. The fascines have the advantage of trapping the rocks thus holding them in position and preventing them from rolling down the slope.

8. CONCLUSIONS

It is hoped that with the review of the major design guides that information given to engineers will be updated to take into account not only the traditional woven fabrics used in coastal engineering but the particular benefits of the more modern flexible geotextiles available. It is pleasing to note that these non wovens are commonly used because of their obvious benefits in filter/separator applications. It is up to the geosynthetics community to influence the coastal engineering community by raising the status of geotextiles in the design process. It would be significant with the new risk based analysis if the geotextile was referenced as a vital component of the revetment design and an actual risk value was given to the performance of the geotextile. In many ways the fact that the cost of a geotextile is many times lower than its value. The incorrect design or placement of a geotextile could cost the life of the revetment and there have been some notable costly examples of this around the world. Greater value will be placed on the geotextile when it is quality assured raising its profile on the site and in the design office. However when properly used they save large amounts of money and in some instances make construction possible where otherwise it would be impossible. Proper consultation with installers and manufactures for ideas on installation can often yield novel and practical adaptions to geotextiles to aid placement. It is hoped engineers will recognise this in both the design and the installation of these valuable materials.

REFERENCES

(1) CIRIA Special Publication 83/CUR Report 154 (1983)
(2) Report: Permeability of GEOfabrics non woven geotextiles at all strains Pub. GEOfabrics (1998)
(3) Rock drop tests carried out on the Cardiff Bay Barrage Pub. GEOfabrics (1996)
(4) Maritime and waterways revetment underlayers. Pub GEOfabrics (2005)
(5) Long term leachate immersion test on polypropylene needle punched non woven geotextiles. Interim report Pub GEOfabrics (2002)

BIBLIOGRAPHY

Schiereck, Gerrit J. (2004) Introduction to Bed, Bank and Shore Protection ch.13 Construction pp 315 – 330 Pub Spon Press

Wewerka, M (1984) Theortetical basis and practical experience – geotextiles in hydraulic engineering. Proceedings Institution of Civil Engineers, Flexible Armoured Revetments incorporating geotextiles. Pub Thomas Telford Ltd, London

VeldhuijzenVan Zanten, R. (Ed.) (1986) Geotextiles and Geomembranes in Civil Engineering Bank and Bed Protection pp 263-345 Pub. A.A. Balkema