USE OF GEOTEXTILES AND GEOCOMPOSITES IN THE UNITED KINGDOM

By the ASCE Committee on Construction Equipment and Techniques

ABSTRACT: Geotextiles and geocomposites are relatively new materials in engineering and their developments have proceeded differently in different countries. This paper reviews the uses and developments in the United Kingdom. It covers a wide range of materials by type and composition in reinforcement, the impact of actions under patent legislation to protect the Reinfored Earth System, and a summary of some of the main trials carried out or still in hand. Examples of application in remedial and marine works are given. The types and use of geocomposites are covered together with biodegradeable materials. Future developments in the United Kingdom are then considered.

INTRODUCTION

A new group of materials worldwide is covered by the geotextiles and their various combinations. Design and application experience is growing and this paper considers the United Kingdom's work against the background of the 1982 Las Vegas Conference and the 1986 International Conference in Vienna, Austria.

> It is unfortunate that engineers and architects in England are so conservative, one might almost say prejudiced in their ideas, that many of them will not use this form of construction, even though their Continental and American confreres have proved to them, so clearly, its usefulness and economy, and above all, its safety; having shown that it may be employed with perfect confidence, and that by its use cheaper, lighter and more durable structures may be erected than those built employing the old methods.

Though the picture is changing slowly, this statement is very much an accurate summary of the situation in England in connection with reinforced soil and the use of geotextiles in construction generally. It speaks volumes that the quotation was written in 1904 by C. F. Marsh in his book *Reinforced Concrete*.

In the 1980s, the use in Britain of geotextiles and geocomposites (combinations of geotextiles with other geotextiles and/or geogrids and/or geomembranes) has consolidated. The dramatic breakthrough into sophisticated earth structures that R&D, field trials, and some pioneering structures led workers to believe was imminent, did not occur, nor is it likely to. Instead, progress is undramatically steady as the following major advantages of structures reinforced with geotextiles have been confirmed in practice:

1. Ease and speed of construction.
2. Ability to withstand differential settlement.

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3. Suitability for phased construction at restricted sites.

4. Ability to provide viable solutions to exceptionally difficult, otherwise intractable, construction problems.

5. Economy of construction.

Geotextiles

Generally, the acceptance of geotextiles has been led by site applications, mostly temporary ones, and also the subsequent impetus of research and trial work by laboratory academics and manufacturers. With a few exceptions, such as subgrade/subbase separation, applications of geotextiles and geogrids, etc., in Britain are still considered innovative. Though the situation has begun to improve over the last two years, most applications are still characterized by their small size and/or experimental nature. There are several reasons for this.

1. Lack of opportunity: the large volume of highway and other public works projects necessary to replace Britain's aging inventory of infrastructure works has not yet materialized. A sufficient level of construction activity did exist in the late '60s, and early '70s—but reinforced soil technology and the large range of geotextiles were not generally available.

2. Economic state: in the downturn of construction activity, unit construction costs, especially for all aspects of concrete structure work, have been squeezed by fierce competition—this has all but eliminated the economic edge of reinforced soil-retaining walls and abutments.

3. Legacy of the Vidal Reinforced Earth patent action.

Henry Vidal obtained his main patent for Reinforced Earth in the United Kingdom in 1967. This was challenged in the early 1970s by the Department of Transport on the grounds that the patents covered method rather than principle. After six years an out-of-court settlement was reached using a U.K. patent law which lays down that a patent does not apply to the Crown (i.e., the British Goverment) and whereby Vidal limited his patent to systems using strips. In addition, a single lump-sum payment, based on estimated royalties, was paid as legal compensation. Vidal went on to win two other actions in the United Kingdom, one for a prolongation of his patent (to recover time lost during his six-year action), the other against Soil Structures, Ltd. He has had similar success in defending his patents in Australia and the United States.

The vigor with which Vidal defended his monopoly in Britain effectively deterred all but the most persistent engineer from exploring the possibilities of Reinforced Earth and with it other aspects of reinforced-soil technology.

The situation is not entirely gloomy, though, and there have been positive influences in the adoption of geosynthetic reinforced-soil structures. As for all new construction techniques, acceptance of the use of geotextiles requires determined efforts on the part of enthusiastic engineers. They need a keen grasp of the subject to encourage acceptance by less-innovative design engineers and by contractors in their particular region or sector of the industry. Colin Jones of West Yorkshire Metropolitan Council (WYMCC; now abolished) and Miles O'Reilly and Richard Murray of the Transport and Road Research Laboratory (TRRL) have been prominent and successful in this

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pioneering role (Jones 1978; Murray and Bowden 1979).

Two small British companies, Soil Structures, Ltd. and Soil Structures International (SSIL), both led by Derrick Price, have been active and have been responsible for about 15 geotextile-reinforced soil structures in the United Kingdom using the Websol system.

Though economy was always one of the strongest reasons for adopting reinforced soil, some structures have been built despite being no cheaper than conventional ones. Typical reasons are the ease and speed with which small sections can be built (for example, at busy intersections), and, often, the opportunity to do this out of sequence.

A comparatively large number have been trials or developments of various systems including WYMCC's York, Anda Augmented Earth, WYMCC/Hoban's Linked-Tyre, SSIL's Websol, and, most recently, the NEW system. Although not marketed or promoted as part of any particular system, several trial walls incorporating Netlon Tensar polyolefine geogrids have been built by various organizations, often with the active design support of Netlon, Ltd. Three of the systems named previously, the Linked-Tyre, Websol, and NEW systems, all use another British-invented geotextile, Paraweb (or in loop form, Paraloop), a thin polyethylene-sheathed polyester fiber strap. A recent vertical-faced structure, designed by Geostructures Consulting, incorporated Stabilenka woven polyester geotextile.

Material Types

Current emphasis in Britain is on the use of geotextile-reinforcing inclusions manufactured from either one of the materials in Table 1 or one of the combinations shown in Table 1.

As more structured information is available from geotextile manufacturers and from independent testing, geotextiles are being selected by designers on an increasingly informed basis. Selection is primarily on the basis of index tests; i.e., on their strength and physical characteristics such as:

1. Failure strength at specified rates of strain, creep, and relaxation.
2. Durability of their constituent polymers in relation to the chemical properties of the project's fill and the groundwater regime.
3. For creep, more realistic assessments of test data are now proposed limiting extrapolation to a period no longer than 10 times the duration of the test program.

Industry conservatism towards new technology, and associated over-cautious bidding, has been a major restraint on the more extensive use of geotextiles in Britain. Until increased familiarity with the products enables construction companies, especially their estimators, to produce realistic assessments of the cost of installing geotextiles, then the real benefits of these materials including economy and ease of construction will not be fully appreciated.

The advantages geosynthetics offer as construction expedients; e.g., enabling edge-compaction of embankments without overfilling, thus creating savings in materials, labor, and plant costs, will not be realized until realistic responsible pricing of this new technique is made by contractors and, to a lesser extent, by designers. The experience of Georgia DOT (Godfrey 1984), where the conventional concrete gravity or cantilever wall has been replaced entirely by reinforced soil structures, has not been mirrored in Britain. It is unusual in the writer's experience to encounter a contractor with direct ex-

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TABLE 1. Materials

Polymer (1)	Typical products (2)
Polypropylene	Tensar SS1 and 2 geogrids, Geolon 15 and 200, Scotlay 120-300, Geotex Standard range wovens; Polyfelt TS needle-punched, and Typar spunbonded nonwovens, etc., Erolan random matrix erosion control material
Polyethylene	Tensar SR55, -80, and -110 and GM1 geogrids, Lotrak 10/7-45/45, Geolon 40, Geotex Hi-Flow range wovens, Tensar Mat multilayer erosion-control material
Polyamide	No longer much used as primary functional constituent of two-dimensional wovens; Enkamat random-thread matrix erosion-control material
Polyester	Geolon 70, Bidim nonwovens
Polyethylene and polypropylene	Terram 500-4000 nonwovens, Geotex, Lotrak MT wovens, Filtram drainage layer (polyethyelene grid faced with Terram nonwovens)
Polyethylene and polyamide	Lotrak needleweave
Polyester and PVC	Enka N33, Hatelit 20/9 and 30/13, and Terram 42A PVC-coated meshes
Polyester and polyethylene	Paraweb 50 and 100, Para-grids and other bundles of parallel-laid polyester fibers sheaved in a polyethylene coating, Para-products generally; Geotex Hi-flow
Aramid and polyethylene	Para-strip 150, Para-tie 150 and 300, Enka Twaron rope
Polyester and polyamide	Stabilenka 150-400 wovens (available to 1,000 grade; i.e., strength of 100 metric tons/m width), Enka Colbond PF

perience of geotextiles beyond the use of Terram as subgrade subbase separation and reinforcement layer.

As acceptance of reinforced concrete eventually became universal, so the picture in Britain is changing with regard to reinforced soil and the associated use of geosynthetics. One strong development is the increasing trend towards their use in association with:

1. Marginal (i.e., aggressive or low-cost waste) material.
2. Construction of highways, hardstandings, and low-rise buildings on poor soils.

This trend has led away from the extensive use of concrete-faced metallic strip reinforced soil structures.

Construction Categories

These systems are examples of a range of different construction forms which have been categorized (Jones 1978) according to the type of connection between the reinforcement and the wall facing, as follows:

1. Concertina—integral flexible wraparound facings.
2. Telescope—to fixed brackets; e.g., Reinforced Earth dowelled facing panels with horizontal compressible joints.
3. Sliding—to vertical elements; e.g., York system.

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In the following sections some examples of innovative use of geotextiles and geocomposites will be given. The majority of current activity both in Britain and overseas by British companies can be summarized thus:

1. Routine low-grade use such as reinforcement/separation at the interface of subgrade and road subbase and railway ballast—accounting for about 50% of geotextile applications in terms of area.
2. Intermediate technology applications such as asphalt reinforcement—the latter is a growing market now reaching almost 15–20%.
3. Embankment slope and base reinforcement—up to 20–30%.
4. Sophisticated reinforced soil structures—many designed in Britain for overseas projects—accounting for 5–10%.

Remedial Works

Following early Japanese work on slope reinforcement using Netlon grids, derivation of design methods for repairs for failed slopes of cuttings and for new embankments with Tensar geogrids has been carried out (Murray et al. 1982; Jewell and Woods 1984). These multilayer techniques with and without geotextile wraparound on the surface of the slope will be familiar to highway engineers in North America where the Tensar Corporation has been active in their promotion.

The trials referred to on both models and full-size structures (Bolton et al. 1978), are an important means to introduce a technique which at this stage is still based largely on empirical design procedures. Full-scale trials have been carried out in Britain on new construction techniques incorporating geotextiles. At Dewsbury an urban ring road embankment has been the subject of trials conducted jointly by the WYMCC and TRRL during 1985–1986.

Dewsbury Trials

The two problems of an acute shortage of suitable fill and of surplus (but highly alkaline [pH above 9]) pulverized fuel ash (PFA) from the local power station were solved after the trials confirmed the suitability of PFA as reinforced fill with both Fibretain, a glass-fiber strap, and Tensar SR2 geogrid as reinforcement. In addition, a section was constructed using Paraweb reinforcement.

For environmental reasons, the walls were faced by an expensive vertical multiple-layer skin up to 7 m high, comprising masonry in front of mass concrete and precast slabs slotted into H-piles. The Tensar reinforcement was passed through the horizontal joints between abutting precast slabs, and held by dowels slotted through them and cast into the mass-concrete. The other types of reinforcement were passed around metal connectors forming sliding "York-type" fixings only at the rear of the facing. Another similar Tensar SR2 geogrid reinforced PFA fill retaining structure has been built for the Stirling Inner Ring Road.

Other Field Trials

Another form of retaining wall construction tested by the TRRL and due to be built in 1987 on the A75 Annan bypass in Scotland is the Austrian NEW system. This consists of large precast concrete planter boxes stacked

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vertically checkerboard fashion, anchored back into an aggressive high-Redox fill by either Paraloops (in Britain) or Stabilenka looped straps (in Austria). The anchor loops slot through the back face of the front planter unit and around a semicylindrical concrete anchor block (in Britain) or curved plate (in Austria) buried in the fill.

Much emphasis is being placed in Britain on the use of reinforced PFA fill for embankments and retaining walls. Though PFA has a high pH, and is thus unsuitable for use with metal inclusions, it is favored as a fill material, since it is cheap and lightweight (unit weight of about 15 kN/m^3). As a result of the Dewsbury trials and Ring Road construction, PFA is now a proven material for use with polyolefine and shielded polyester reinforcements.

Chalk Fill

Another problem material, chalk, was not approved for use in reinforced soil construction when the British code for reinforced soil retaining wall, Department of Transport (DTp) Technical Memorandum (Bridges), BE 3/78 (Johnson 1985) was issued. Though this veto was withdrawn in 1984, a very low maximum saturation moisture content of 20% was set. This effectively prevented the use of chalk as a reinforced fill throughout the South of England. In this region soft chalk deposits appear near ground level at high natural moisture contents approaching saturation moisture content. These average about 30% and may reach over 35%.

In trials organized by Hampshire County Council and the TRRL in 1986 near Portsmouth, chalk fill with natural moisture contents well in excess of 20% has performed satisfactorily. Using controlled compaction techniques, two 5.5-m-high, 30-m-long, reinforced soil walls have been constructed back-to-back: one reinforced by metallic strips of the Reinforced Earth System and the other by Fibertain glass-fiber straps of the Anda Augmented Earth System. Both walls have 2 m of chalk fill surcharge: postconstruction monitoring has indicated insignificant face movements. There is a good chance that the success of this trial will lead to significant project cost savings being realized on the forthcoming extension of the M27 Motorway. It is likely that on-site chalk may now be used as fill in reinforced soil bridge abutments and retaining walls on the large number of road structures required.

Slope Failures

An area where there has been a considerable use of geotextiles has been in the repair of slope failures. In an interesting set of trials carried out under the guidance of the TRRL ("Technical" 1978) five repair techniques and two preventative techniques have been carried out on an embankment on the A45 Cambridge Northern Bypass. This 7-m-high embankment was constructed in the late 1970s from Gault Clay, an over-consolidated clay with 1(v)-on-2(h) sideslopes. In common with a large number of such earth fills of similar or greater age, it has been subject to a succession of shallow-seated translational slides. Further discussion on the possible failure mechanisms is beyond the scope of this paper (Greenwood et al. 1985).

Apart from the repair techniques using the Linked-tyre system and geogrid gabion toe wall, two other geogrid-based techniques were geomesh containment fill (contained in geogrid envelopes) as a repair geomesh plus anchors.

For the latter, a sheet of Tensar SS1 geogrid laid over the sideslope, an-

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chored in alternating rows at laps and midpoints at grid centers at 2.5-m centers up the slope. Anchors were Duckbill earth anchors attached to about 2-m-long cables (to reach beyond the critical slip plane) bolted to steel plates bearing on the grid: topsoil was placed over the grid to a depth of about 250 mm (perhaps an excessive amount). These last mentioned were the cheapest of the set of geotextile/geogrid repairs: the anchored geomesh offering perhaps the most promising solution to distressed slopes or to reinstated failures.

Geotextiles have been used in many temporary retention structures, usually with wraparound geotextile facings. Two typical examples are:

1. A near vertical 1-m-high bund along the centerline of a road pavement being regraded in two stages to permit one-way traffic flow during construction.
2. Steep sloped 6-m-high fill either side of an under-road culvert to be built through an embankment on soft ground to ensure maximum loading of the culvert foundation and maximize surcharge-induced primary settlement prior to its construction.

These are applications where the advantages of geotextiles are exploited to the full and creep, resistance to site damage, and durability are not an issue. Accordingly, a large increase in this category of use is to be expected.

Marine Works—Barking Creek

A marine reinforced soil retaining wall project that introduced several innovations was constructed in 1985 as part of a redevelopment program. It was carried out in London on the tidal River Roding (better known as Barking Creek), in which a small dock was reclaimed. The 15-m-wide entrance to the dock was closed by a 4-m-high by 5-m-wide reinforced soil retaining wall founded on a 0.6-m-thick reinforced granular mattress constructed on a 1.5-m-thick hardcore mound. This foundation rested on a 1-m-thick layer of gravel overlying London Clay. A 2-m-thick layer of alluvium covering the site was excavated locally under the area of the reinforced soil block.

The reinforced soil method of construction was chosen by the client, as previously sheet pile walls had experienced early corrosion. He was interested in evaluating the potential of this recent technique with its advantages of speed and economy for use in future quay wall reprovision in other parts of Barking Creek. While the short length of this wall has not realized these benefits in full, other features of the selected design contributed to its adoption:

1. Capability to accept economically a heavy design loading.
2. Avoidance of need to fill around and pile between long sheet pile tie rods and anchor piles of the sheet pile alternative.
3. Greater durability of the concrete facing panel compared with the sheet pile alternative.

Marine Works—Websol System

A range of marine walls has been built in Britain over the last 5 years using the "Websol" system marketed by Soil Structures Interntional, Ltd., taking advantage of the durability of Paraweb reinforcement in aggressive conditions. Paraweb is one of the large number of geocomposites manufactured by ICI's Para-products Division. It is corrosion-free and has a strength comparable to steel, though its modulus is of the order of 8 kN/mm^2 compared with steel at 210 kN/mm^2. In the Websol System the Paraweb strip is laid in a zigzag pattern between steel back bars, buried in fill, and horizontal toggles slotted into steel loops are cast into the rear of precast concrete facing panels. Three examples of such walls are:

1. Southampton (John et al. 1982)—4 m high, 20 m long, built on 2 m very soft clay overlying 3-m of compressed peat—minimum tidal range was 4 m.
2. Jersey (Kempton et al. 1985)—8 m high, 240 m long, built on a 5-m-high rock bund—a large tidal range of 11 m maximum occurs at this site.
3. Swansea—8 m high and 25 m long, seated on the floor of a former dry dock designed for rapid drawdown of 6 m/hr.

In another marine project where corrosion resistance is also of great importance, Tensar SS2 geogrids have been used to reinforce concrete cylinders cast around badly damaged concrete pier piles and columns. Geotextiles have been used as flexible concrete formers and as concrete and sand-filled erosion control mattresses. For the pier repairs, Dowsett Prepakt manufactured Fabriform polypropylene woven geotextile jackets fitted with plastic zips and rope end-ties. These were used to form 5-m-long cylindrical shutters for the concrete grout pours. Fabriform geotextile mattresses filled with microconcrete were used as anti-scour protection for some of the pier foundation blocks. The use of geotextile formwork for a large range of dry-land and underwater concreting operations is increasing generally.

Saline Soils

Many of Soil Structures International's "Websol" walls have also been constructed in the Middle East, where aggressive salts in the desert fills have favored the use of inert Websol strapping rather than metallic strips or meshes. A series of 50 bridge abutments and retaining walls totalling 35,000 m^2 in facing area and 60 structures totaling 80,000 m^2 have been erected in Oman and Kuwait, respectively. One pair of abutments in Oman exceeded 17 m in height and, as for all the Oman structures, have been designed for a high traffic-loading intensity.

Summary of Reinforced Soil Wall Construction in the United Kingdom

Though still small in world terms, the total area of reinforced soil retaining structures constructed in Britain at the end of 1986 is about 65,000 m^2 of which 44,000 m^2 used the Reinforced Earth system. About 30,000 m^2 have been erected over the last 2 years, showing that the use of reinforced soil is accelerating (although the greater proportion did not include geotextiles). It is appropriate to emphasize that the small take-up of reinforced soil in Britain illustrates the adverse affect which the prolonged patent litigation caused.

Other Applications

Recent developments in the use of geotextiles/geogrids include:

1. Highway and hardstanding subbase construction: progress is being made on developing design and empirical and construction techniques for subbase re-

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inforcement. The TRRL has been carrying out traffic trials on geogrid reinforced subbase as a followup to work done at Oxford University (Milligan and Love 1984).

2. Asphalt reinforcement: after a series of trials and research, geogrids are increasingly used within asphalt surfacing as in-layer tensile reinforcement and also sandwiched between existing concrete or asphalt surfacing and asphalt overlays as reflective cracking restraint. Lotrak geotextiles are also being used in the latter role after successful trials. Tensar AR1 geogrids are being used in trench repairs to reduce backfill settlement and reinforce edge joints of reprovisioned paving.

3. Concrete reinforcement: the conventional use of steel mesh reinforcement for concrete roads and scrim/fabric and metal mesh reinforcement for plasterwork has been augmented, in as yet only a few projects, by the use of Tensar SS1 and 2 geogrids as crack control in concrete slipways, thin precast concrete items, and external cement rendering to buildings. The corrosionless properties of polymer geogrids are used in these applications where concrete cover is small.

Geocomposites

A large range of synthetic geocomposites is now available in Britain. Many are listed in Table 1. Though most are prefabricated in the factory, one system called Trammel Fin Drain supplied by Don and Low, plc, is site-fabricated by sandwiching a central geogrid core between either polypropylene filter fabrics on both sides or a filter fabric on one side and an impermeable membrane (e.g., polyethylene sheet) on the other when used in a cut-off drain format. Another type of composite is the vertical strip drain used extensivley in the Great Yarmouth Bypass and the Stanstead Abbott's Bypass under high embankments on peat. On both projects geogrid base reinforcement was also used to restrict settlement (both differential and total) and prevent any failure mechanism. In both projects the geogrids were laid after drain installation was carried out on a 0.5- to 1.0-m-thick granular drainage blanket. Two vertical strip drains available in Britain include Mebra-Drain with a polypropylene fabric core and nonwoven filter jacket and Colbond CX 1000 with an Enkamat core and a Colbond polyester filter fabric.

Geocomposites for Erosion Control

Discussion of geotextiles in this paper has centered on the following four functions: reinforcement, separation, filtration, and drainage. A fifth important function (which can be regarded as a combination of the first three) is erosion control.

Britain is not generally subject to extremes of rainfall intensity or drought. Adverse combinations of slope steepness, slope length, rainfall intensity, soil erodibility, and plant cover do occur sufficiently often to create erosion problems. In addition, erosion of bare soils is caused by wind, freeze/thaw cycles, and stream flow. The costs of neglecting the effects of erosion in Britain in terms of scarring of the landscape, the loss of capacity of drains and ditches, and the work necessary to clear them, have resulted in a growing demand for erosion-control products including geotextiles. They all act as expedients to assist vegetation establishment by protecting bare soil pending the germination and rooting of newly sown seeds, the vegetation providing the long-

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term erosion resistance. Synthetic geotextiles are durable once shaded by vegetation and provide enhanced resistance against turf tearing due to water flow or traffic.

Biodegradeable Geotextiles/Geocomposites

Apart from the range of synthetic two-dimensional geotextiles, such as Enka N33, Hatelit grids, Landmesh polypropylene mesh, Terram 42A, Wyretex, etc., and three-dimensional geotextiles, such as Enkamat, Terram mat, Armater, etc., a range of biodegradeable geotextiles is now available in Britain. They consist of natural fibers either alone or with synthetic polymer threads or meshes woven or quilted together to form meshes or mats. All are essentially mulches prefabricated for ease of handling: they are all cheaper than synthetics consisting entirely or partially of waste or low-cost natural products. At present these products are all of foreign origin and include Enviromat, Geojute, Greenfix, and Hold-Gro. As well as the normal erosion-control functions of shielding, decreasing surface velocities, increasing soil moisture, and insulating soil against extremes of temperature, biodegradeable, geotextiles increase soil humus content as they rot.

As an example the Greenfix mats (similar to North American Green mats made in the United States) are available in a preseeded version, reducing the number of site operations necessary to establish vegetation. With appropriate treatment (i.e., addition of fertilizers and soil conditioning with alginates and lime as necessary), it has been established that topsoiling can be much reduced in thickness on newly formed earthworks slopes when this type of geotextile is used.

Though not well-documented, the demand for erosion-control products is estimated to be about 250,000 to 400,000 m^2 per year at present and is growing. The appreciation is also increasing that vegetation can often provide more than an aesthetic and erosion control role. Much valuable work reestablishing the role of vegetation as an engineering material has been done since the late 1940s in Austria (Schiechtl 1980). More recently, D. H. Gray (Gray and Leiser 1982) has investigated the relationship between landslips and clear felling of timber. This complements the research in the laboratory and the field by workers in Israel, the United States, and Canada. They have shown that root reinforcement and soil-moisture reduction can contribure significantly to the shear strength of soil strata in a slope, and thereby increase slope stability with respect to shallow-seated downslope movements.

The ability of vegetation to economically fulfill the aforementioned role as well as other bioengineering roles such as erosion control, shelter, catchment runoff modification, and dune stabilization appears to be gaining more widespread acceptance in Britain. The Construction Industry Research & Information Association (CIRIA) and Department of Environment (DOE) are sponsoring a research project on the use of vegetation as an engineering material. The role of geotextiles which assist in the establishment of all forms of vegetation is thus likely to increase in importance.

FUTURE DEVELOPMENTS

It is likely that there will be a continuation of the trend towards two major product types.

1. Cheap Construction Expedients—low-cost woven and nonwoven geotextiles and eventually geogrids available at about $0.40–$0.65/m².
Applications:
- Ensure that design geometry of road, pavement, embankment shoulder, etc., is maintained during construction processes.
- Temporary access roads and low-height reinforced soil retention structures.

2. High-Cost Multicomponent Geotextiles/Geomembranes—stitched, heat- or resin-bonded combinations of high-performance wovens, nonwovens, meshes, grids, matrices, and membranes sometimes incorporating natural materials such as timber or stone available at a wide range of prices which may start at $2 and reach over $50.
Applications:
- Marine reclamation/barrages.
- Embankment base reinforcement.
- Retaining soil structures.

In parallel there should be other developments resulting from experience:

1. Major applications
   - Steepened embankment slopes.
   - Asphalt reinforcement.
   - Marine/riverside reclamation/site formation.
   - Erosion control (particularly overseas).
   - Public health engineering—landfill.
   - Concrete reinforcement.
   - Temporary works as reinforced soil retention structures.
2. More discerning use with better specifications for and direct experience of materials.
3. Use of vegetated or lightweight precast fiber reinforced concrete panels as facing to vertical wraparound geotextile reinforced soil structures as more economical forms than the heavy "structural" concrete panels commonly used.
4. Realistic requirements should be set for durability—200 years has been "guaranteed" for the massive Oosterscheldt Barrier project in Holland. Many uses are short-term, however, such as embankment base reinforcement, typically 3–4 years. It has been reported that reinforced soil structures presently being built in Japan have a design life of 30–40 years only. Will the rest of the world follow?
5. New applications and better ways of detailing will evolve with the continued evolution of geotextiles, and of their application, as experience is accumulated. As with other new materials geotextile technology will develop its own style, and as with others it will inevitably involve failures. The progression of engineering design has been a series of steps between unforeseen disasters.

However, in the trend to acceptance of geotextiles as one of an engineer's many standard options, two obstacles remain:

1. Standard specifications and test methods are required.
2. There is general reluctance on the part of our profession to any new idea or product which does not have a well-established track record.

Conclusion

The increased acceptance of geotextiles in Britain and Europe is very much in the hands of the manufacturers. There is a strong need for geotextile manufacturers to provide full information to enable the designer to select the appropriate geotextile and to provide an organization to promote the optimum use of geotextiles.

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