GOVERNMENT OF PAKISTAN
MINISTRY OF COMMUNICATIONS
NATIONAL TRANSPORT RESEARCH CENTRE
****

A PRELIMINARY REPORT ON USER TRIALS OF GEOGRIDS IN ROADS CONSTRUCTION IN PAKISTAN

NTRC-174

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CHAPTER - I

Introduction:

Water is the major enemy for any road. The influence of water on the properties and performance of highway pavement foundation is profound. More than 150 years ago, Macadam, a pioneer in road building wrote that water can enter the pavements through various ways. Once it get access to the pavement, the pavement gets weakend and gets much more susceptible to damage by traffic. Water can enter the road as a result of rain penetrating the surface or as a result of the infiltration of ground water. The road surface must be constructed with a camber so that it sheds rain water quickly and formation of the road must be raised above the level of the ground water table to prevent it being soaked by ground water.

The roads can never be rendered thus perfectly secure until the following principles be fully understood, admitted and acted upon: namely, that it is the native soil which really supports the weight of the traffic and that while it is preserved in the dry state it will carry any weight without sinking and that if water passes through a road and fills the native soil, the road, whatever may be its thickness, losses support and disintegrates. In Pakistan, in some areas water table has risen quite close to the ground surface. This has resulted in failure of many existing roads which now require rehabilitation/reconstruction. However, proper rehabilitation of such roads is not an easy task. Roads rehabilitated in some of the water logged areas have again and again been subjected to deterioration soon after their completion. The problem of construction of new roads and rehabilitation of existing roads in water logged areas capable of coping with the ever-increasing traffic loads and severe environmental conditions in our country demands due attention to be paid to the problem. One of the solutions which has been successfully demonstrated and vastly used in developed countries is the use of geogrids. The suitability and economic viability of the use of this alternative is yet to be checked in our country. A demonstration project in this regard was thus prepared.

1.2 Objective of the Project:

The objective of the trial and study was to check the structural suitability and economic viability of the use of GEOGRIDS in road construction in Pakistan specially where the subgrade material being used is weak and the area is water logged viz-a-viz of conventional types of pavements presently being used in Pakistan. It was proposed that the GEOGRID material be tried on a stretch of a road section where the subgrade material is very weak i.e., the CBR value is less than 5.

1.3 Methodology:

The approach adopted for the study was to select a road section where the GEOGRID could be used for trial and demonstration purposes in order to check its suitability for water logged road construction projects in Pakistan.

It was decided that half a kilometer of the road stretch would be constructed for trial and demonstration purposes. The proposal envisaged construction of five different types of pavement sections, each of 100 meters length as detailed below:-

i) Conventional Pavement using granular sub-base, crushed aggregate base course and asphaltic concrete wearing course using GEOGRID material obtained from Messers Netlon/Tensar Limited UK over the subgrade top. The existing pavement was to be removed upto the subgrade top.

ii) Conventional Pavement as proposed above minus the GEOGRID to check the difference between the performance of the two pavements.

iii) Conventional Pavement as designed by the NWFP Highway department for this section using granular sub-base, crushed stone base and tripple surface treatment as surfacing layer keeping the existing pavement structure intact.

iv) Conventional pavement as proposed by consultants (NESPAK) for this section using asphaltic concrete also as a part of base course layer alongwith AC as surfacing layer.

v) Rigid pavement using cement concrete.

However, till todate the first two sections have been completed. The first one involves GEOGRID over subgrade top while the second is without GEOGRID, all other structural components being the same. Although the construction of the remaining sections is still to be done, the construction of the two sections met the basic objective of the study i.e., to check the suitability and effectiveness of the GEOGRID material in the water logged areas. The subgrade material of the trial section has a soaked CBR value of 4% and the water table depth is only 4 feet, which still rises to about ground surface level during rainy season.

Several foreign manufacturers of geogrid and geofabrics for road construction were contacted for the supply of the requisite GEOGRID/geofabrics material free of cost for demonstration purposes. M/s Netlon Limited of UK finally agreed to supply the same. However, to enable them to supply the most appropriate type of the GEOGRID material for the final section, M/s Netlon Limited, UK asked for certain data about the section such as soil characteristics, depth of water table, existing and projected traffic volume and axle loads etc which was collected and supplied to them. On receipt of the information, the M/s Netlon Limited, UK provided grates, delivered at Karachi, 100 meter of the GEOGRID material for 7.3 meters width of road section.

The present position is that the two sections already completed have been opened to traffic since their completion. The first section suing GEOGRID was opened to traffic in March, 1993 while the second one is in operation since June, 1993. The performance of these sections is being monitored. The section using GEOGRID is behaving perfectly well. It may be too early to make any positive statement regarding the comparative performance of the two sections. After completion of the remaining sections and monitoring of these, it would be possible to draw definite conclusions in this regard. But to date, almost after nine months of use all reports and observations confirm that the road section of 100 meter using GEOGRID is free from all defects such as subsidence of subgrade, rutting or vibrations or movements in asphaltic concrete surface.

CHAPTER - II

USE OF GEOGRIDS IN ROADS CONSTRUCTION

2.1 General:

In road construction, fabrics have been used since ancient times. Early man knew how to weave mats out of reed and how to compose matresses out of fascines. These matersses were spread out over marshy grounds as a base layer. On this layer he put stones to obtain a solid road. A second ancient technique for road construction on soft soils was laying down tree trunks. In this way wooden tracks were built up to lengths of several kilometers. So the use of polypropeen-techniques has a long history. The recent reveolutionary development of which present GEOGRIDS/ GEOFABRICS is the outcome should not make us forget that its typical function has been known for centuries.

The world "Geotextile" was coined awkwardly from the Greek and Latin to describe woven materials used in conjunction with soils as part of a construction project. Today a large range of GEOGRIDS and fabrics and sheet materials are available. These differ widely in appearance, manufacture and function. With one or two exceptions, geotextiles are made from synthetic polymers developed since the 1940's.

An analogous but distinct type of membrane is available in the form of GEOGRID. GEOGRIDS are formed by extruding the polymer not in the form of filamet but rather as a sheet; holes are then punched in the sheet which is subsequently drawn both parallel and perpendicular to its major axis, the effect being to produce a rectangular grid which due to the molecular orientation taking place during the drawing process, exhibits a high resistance to further deformation.

2.2 <u>Tensar Geogrids:</u>

"Tensar" geogrids are high tensile strength, integral polymer grid structures specifically produced for applications within the civil engineering industry. When placed within a medium such as a soil or asphalt, the bars or ribs transverse to the direction of primary loading provides a series of bearing points or anchorages. As a result, stress is transferred to the reinforcement not mainly by surface friction, as with strip reinforcement, but by grid interaction. This provides a highly efficient mechanaism for stress transfer which mobilises the maximum benifit from the reinforcement and minimises an charge lengths.

A range of "Tensar" SS geogrids have been developed, each with differing strengths and as per ture sizes, for the reinforcement of granular sub-base, capping layers and railway ballast placed over weak or variable soils.

2.3 <u>Uses of TENSAR GEOGRIDS:</u>

The general applications of the GEOGRIDS as used by the Highway Engineers in many parts of the world, specially USA and UK as part of the pavement or associated works are:

2.3.1 Embankment Foundations:

Geogrids can solve problems associated with the construction of embankments over poor foundations, in many cases avoiding the need for piled viaducts, or excavation of the weak foundation soil and substitution with a granular fill. They can also allow acceleration of fill placement often in conjunction with vertical band drains.

The grids may be employed in a number of ways:

a) Layers of grid near the base of the embankment to intersect deep potential failure surfaces. With Tensar geogrids it is possible to place the reinforcement where it is required without the need to have continuous layers across the full width of the embankment.

b) Encapsulation of a granular drainage layer with Tensar geogrids to reinforce and stiffen the base of the embankment, in addition to reducing and regulating differential settlement.

The low cost, high strength grids are ideal for cases (a) and (b) above.

c) The Tensar Geocell Mattress is rapidly asesmbled on site to form a deep, open cellular structure which is then filled with granular material. The filled Geocell creates a rigid, high strength foundation for the embankment, a construction platform for earthwork plant, and in addition it acts as a drainage layer.

The Geocell intersects potential failure planes and its rigidity forces them deeper into firm strata. The critical failure mechanism becomes that of plastic failure of the soft layer. The rough interface at the base of the Geocell ensures mobilisation of the maximum shear capacity of the foundation soil and significantly increases stability. Differential settlement and lateral spread are also minimised.

2.3.2 Reinforcement of Unbound Aggregate:

When granular material is compacted over Geogrids it partially penetrates and projects through the apertures creating an interlocking action between the stone and the grid. This interlock enables the grid to resist horizontal shear from the fill and thereby mobilise the maximum bearing capacity of the soft subsoil. Savings in fill thickness of 40% are regularly achieved.

Mechanical interlock creates a flexurally stiff platform which distributes load evenly, reduces rutting and minimises differential settlement.

Interlock between the grid and a well graded aggregate prevents lateral movement of particles at the base of the fill layer. This in turn prevents upward movement of subgrade fines by pumping.

Geogrids are used to reinforce granular sub-bases, capping layers and railway ballast placed over weak and variable soils.

When building over variable subgrades such as landfill, expensive ground treatment such as piling or excavation and replacement with an imported fill can be avoided by the use of several layers of geogrid within a granular capping layer. To achieve maximum reinforcing effect, the vertical spacing between grid layers should not be greater than 500 mm. Multiple layer systems are possible since by interlocking with the sub-base particles, the grid does not create a weak shear plane.

When pilling is considered necessary, several layers of Geogrid can be used with granular fill to form a stiff layer capable of transferring embankment loads onto the piles. This avoids expensive reinforced concrete pile caps and ground beams.

2.3.3 <u>Retaining Walls and Bridge Abutments:</u>

Geogrids permit the use of a wide variety of fill materials and facing details in the construction of reinforced soil retaining walls.

The horizontal grid layers provide the structural stability whilst the facing contains the fill and provides a suitable aesthetic appearance.

Reinforced soil structures have a high tolerance to differential settlement thereby avoiding the requirement for expensive foundations.

Wall facings can be hard, such as full height concrete panels, smaller modular concrete elements, timber, brick, stone or gabions. Alternatively, low cost soft facings can be formed by wrapping the grid layers up the face around successive lifts. The face can be detailed to provide vegetation.

2.3.4 <u>Steep Slopes:</u>

Rising land prices, the scaracity of good quality fill and the need to widen existing highways provide incentives to steepen slopes and to utilise marginal fills. Geogrids could be used to steepen embankment slopes up to 90 . A face support is required for slope angles between 45 and 90 . The grids can be wrapped around successive lifts of fill, removing the need for rigid facings.

Steep reinforced slopes for blast traverses around ammunition stores and environmental/noise bunds adjacent to roads have been constructed using this technique.

2.3.5 Repair of Slips and Landslides:

Traditionally, engineers have reinstated slips by excavation and disposal of the failed cohesive soil and substitution with a granular fill. Re-use of the slipped soil, reinforced with Tensar geogrids to intersect potential failure surface, has enabled repairs to be carried out at a quarter of the traditional cost and with the minimum of disruption to traffic.

Granular drainage layers may be incorporated within the repair to further enhance stability. The addition of lime will aid handling of particularly wet clay fills without affecting the performance of the grid.

2.3.6 Reinforcement of Asphalt Pavements:

a) Reinforcement of Asphalt Pavements:

Geogrids have also been developed specifically for the reinforcement of asphalt pavements.

The open grid structure enables the asphalt pavement layers above the reinforcement to mechanically interlock with the grid and bond to the bituminous layer or concrete below, through the grid apertures. In this way Geogrids differs from continous sheets of fabric materials.

b) Extended Fatigue Life:

The use of Tensar grid has been shown to increase the fatigue life of all bituminous pavements significantly. With dense bitumen macadam which is often susceptible to fatigue failure, the fatigue life may be increasd by a factor of 10.
This benefit is achieved because the grid reduces the rate of crack propagation.
The optimum position for the grid to extend fatigue life is at the base of the asphalt layers.
Immediate cost savings can be achieved by reducing pavement layer thickness which may be preferable to extending the life of the pavement.

c) Reflection Cracking:

When overlaying pavements with existing cracks or joints, Tensar grid reinforcement located at the base of the overlay will prevent the propagation of reflection cracks, greatly increasing the life of the overlay.

ideally suited for overlaying of:

i) Cracked pavements.

ii) Jointed concrete pavements.

iii) Lean mix concrete road bases

d) Rutting:

When overlaying areas where rutting is a problem, Tensar grid reinforced asphalt provides a simple alternative to modified asphalt mix design.

The optimum position for the grid is generally below the wearing course.

This solution is particularly suitable for:

i) Pavements subjected to high ambient temperatures

ii) Areas subjected to high contact pressures such as aircraft taxiways and container terminals

iii) Bus lanes

iv) Approaches to traffic lights

2.3.7 Erosion Control:

Tensar Mat is a robust, high tensile strength, three-dimensional structure with outstanding drape qualities which enable it to conform to and maintain intimate contact with the soil profile. With the mat completely filled with soil, and with an established grass root system, a tenacious and permanent erosion resistant cover is provided to slopes, banks and bunds.

a) Dry Slopes:

Having ensured the geotechnical stability of a slope, there is often a need for surface applied erosion protection. The natural solution is vegetation cover reinforced by Tensar Mat.

The mat mechanically stabilises the surface layer of soil pending the establishment of vegetation and ultimately improves the lateral continuity of the root system. In some circumstances, there is a need to create an instant grass cover so Tensar Turf Mat, i.e. Tensar Mat incorporating pre-cultivated grass, can provide this immediate engineered yet aesthetic solution.

b) Intermittently Wetted Slopes:

For slopes which are subjected to wave run-up or are intermittently wetted (such as auxiliary spillways to dams and flood bunds), both Tensar Mat and Tensar Turf Mat provide quantifiably enhanced erosion resistance to vegetation cover. If there is the possibility of soil erosion from the Mat prior to the establishment of grass then Turf Mat would be selected.

c) Permanently Wetted Slopes:

For areas which experience long-term inundation, such as the lower slopes and inverts of open channels, then Macdamat, (i.e. Tensar Mat incorporating bitumen bound gravel) provides the required protection layer whilst also supporting vegetation immediately above normal water level.

Where a building block or armour layer is required Tensar Gabions and Tensar Mattresses can be used in many combinations to create structures such as training walls, channel linings, control structures, revetments and aprons.

It is often the case that a range of exposure conditions prevail on a site and a combination of various geogrid products can be applied in appropriate and cost-effective ways.

CHAPTER - III

THE PROJECT

A presentation with the aid of video, slides and technical literature was made by Mr. Noor A. Husain of Transcontinent Traders, Rawalpindi, sole representative of Netlon Limited, UK in Pakistan, in NTRC regarding the possible uses of the Tensar/Netlon geogrid reinforcement system on roads in Pakistan. Out of various uses of the geogrid materials, one of the uses mentioned was that the Netlon geogrids could effectively be used in water logged areas over weak sub-grades and that it could result in tremendous savigs in construction cost of the project. It was also informed that the inclusion of Netlon geogrids within the granular layers of a pavement has been proved to be very effective method of reducing the thickness of granular material required by upto 40%.

The Netlon representative also indicated during the presentation that they were ready to assist in the application of the design methods incorporating Tensar/Netlon geogrids to projects in Pakistan. However, to do this, information that would be required by them to carry out any assessment would be:

1. The subgrade strength in terms of CBR or undrained shear strength (Cu).
2. The traffic loading in terms of equivalent standard axles (ESA's).
3. Water table position relative to the formation level.
4. Costs of materials.

Mr. S.M. Suleman from TENSAR/NETLON in USA & UK alongwith Mr. Noor A. Husain of TENSAR/NETLON Ltd. in Pakistan, in a meeting with the Senior Chief, NTRC discussed the possibility of using Tensar geogrid for road projects in Pakistan. In the meeting, it was decided that NTRC in consultation with concerned local agencies, shall select two locations namely; one for the road project and one for the land slide section. The NTRC would provide to M/s Netlon/Tensar Ltd. the requisite data regarding a) soil properties b) water table c) traffic volume and its composition d) axle load e) geometric parameters of road as well as for land slide section. On the receipt of information from NTRC, M/s Tensar would despatch material adequate for one kilometer each for road and the land slide area, which was finally reduced to 100 meters gratis for road surface.

3.1 Selection of Trial Section:

In order to obtain requisite information in respect of a road project, concerned agencies were contacted. First the National Highway Authority was contacted who informed us that at the time they did not have any such section under construction on which it's use could be tried. On subsequent consultation with the C&W Department - NWFP, it was finally decided to try this material on Jehangira - Swabi road. The C & W Department, Government of NWFP informed us that they were facing severe chronic water logging problem on a section of Jehangira - Swabi road and the existing road is unable to cope with the ever increasing heavy loads. They intended to improve the road so that it could cope for another 20 years.

The Jehangira - Swabi road was visited by the NTRC concerned officials and it was found that the section between Km 9+000 to Km 11+000 was worst as regards high water table and the nature of the subgrade material. The requisite information in respect of section Km 9+000 - Km 10+000 was collected from the records of KAMPSAX and the C&W Department officials. The information was sent to M/s Netlon Ltd. UK with the request that as agreed, 1 Km length of geogrid material appropriate for the section be sent to NTRC. Details of the information sent may be seen at Annex-A. In response to this information, M/s Netlon Ltd. UK sent an appropriate 100 meters length gratis of the Netlon geogrid material.

Section Details:

Type of Soil:

According to Kampax report who had earlier carried out study for improvement of this road, the soil type from Km 7+935 to Km 10+285 is very poor and as per AASHTO classification it is rated as A-6(9) to A-6(10). The soil has a soaked CBR of only 4%.

b) Traffic:

As per traffic counts conducted by the C&W Department in 1988, the traffic volume on the section was 2477 vehicles/day. NTRC has carried out traffic counts at the completion of the section in August, 1993. According to these counts, the traffic volume is 3498 vpd and 3393 vpd on 08-08-1993 and 04-08-1993 thus giving an average figure of 3448 vpd.

For the construction of the experimental section, several meetings were held with the C & W Department officials. Options like construction of the experimental section by NTRC on its own was also considered. On 10-10-1991, the project was again discussed in the meeting with the C & W Department's Officoials, Consultants (NESPAK) and contractor which was held under the Chairmanship of the Secretary C & W. Several other meetings were held with the C & W Department Officials regarding the initiation of the project. C & W Departments Officials were of the view to take up the entire project length of the Jehangira - Swabi road including the NTRC experimental section at the same time.

However the C & W Department, extending full cooperation agreed to bifurcate the tender and take up the construction of the experimental section of 1/2 Km length first.

3.3 Pavement Design for the Trial Section Using Geogrid:

Five different pavement sections using different materials were designed for the trial section. The design was based on AASHTO

Interim Guide, 1986. Also the New Road Note 31 of TRRL, UK 31, 1993 edition was consulted. The section using the GEOGRID material comprised of the following layers.

i) Placement of GEOGRID on top of the existing subgrade.

ii) 8" thick lift layer of granular material over the existing top of the GEOGRID.

iii) 12" thick granular sub-base.

iv) 12" thick base course.

v) 2-1/2" thick asphaltic wearing course.

The actual construction of experimental section using GEOGRID material on site was taken in hand in November, 1992 by the C&W officials.

3.4 <u>Detour for the Experimental Section:</u>

The initial detour constructed could not cope because of the heavy traffic and the marshy ground conditions. Keeping in view the heavy traffic and poor supporting conditions, for the construction of the detour NTRC provided specifications incorporating crushed stone with khaka material on top.

The details of the specifications are as under:-

a) Relaying 6" thick pitrun gravel previously used as base course of the existing pavement.

b) 4" thick layer of sand.

c) 6" thick well graded crush.

d) Stone-dust (Khaka) properly watered to fill the voids.

The detours constructed according to the specifications performed well even under heavy rains.

3.5 Construction of Experimental Section:

After several days of succesful operation of the detours, the excavation work of the existing pavement upto the subgrade level was taken in hand. Due to the poor subgrade conditions and high water table it was not possible to carry out any rolling of the existing subgrade. However, it was tried to level it as much as possible.

The GEOGRID material was finally laid on the subgrade on 03-03-1993 in the presence of Mr. Noor A. Husain, Netlon representative, Mr. Zia-ur-Rehman, SDO, NWFP Highway Department. Officials from various construction agencies like consultants NESPAK, Punjab Highway Department, Frontier Works Organization, etc, also visited the site during laying operation of the GEOGRID material and to observe the existing conditions of the subgrade. Photographs taken at the time of laying the material may be seen from Fig. 3.1 to 3.4.

On the top of the GEOGRID material, 8" thick gravel material was laid as a lift layer. On top of it, sub-base material 12" thick was laid in two layers of 6" each. The top sub-base layer was compacted to the required density of 98%. Over the sub-base layer, 12" thick water bound macadam base course was used. The

12" thick base course material was laid in two equal layers and each layer was compacted to 100% modified AASHTO density. Over the base course material, 2-1/2" thick asphaltic concrete wearing course material has been laid.

The quality control of the work was supervised by the NTRC itself. A Laboratory inspector was deputed full time on site to supervise the work and guide the contractor in execution of the work. The material testing was carried out by the NTRC laboratory staff. The field tests such as density, DCP, etc were also conducted by the NTRC laboratory men who visited the site alongwith the equipment to perform the tests.

The construction of the second section was taken in hand on 01-06-1993. The specifications adopted for the section were exactly same as these of the first one minus the geogrid material. As per information provided by the contracter and confirmed by our staff at site, the quantity of lift layer of granular material used was about 50% more than the first section as much of the material of this layer got embedded into the subgrade.

.6 Monitoring of the Section:

The first section was completed on 29-05-1993 and soon after its completion, it was opened to traffic. The second section was completed on 01-08-1993. Both the sections are now open to traffic. The section are performing quite well.

Fig.3.1 Geogrid material being unrolled on the top of the subgrade.

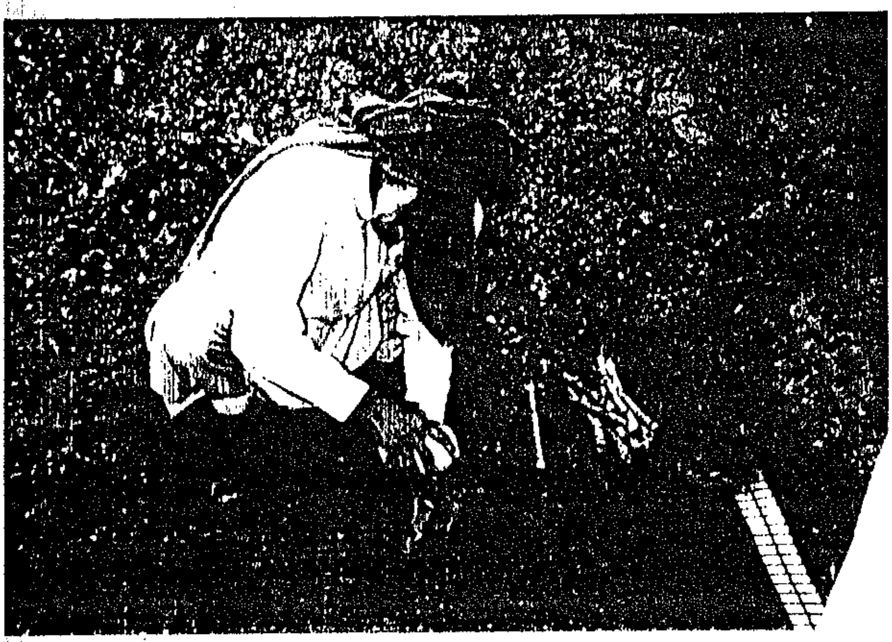


Fig.3.2 Geogrid material being fixed on the subgrade.

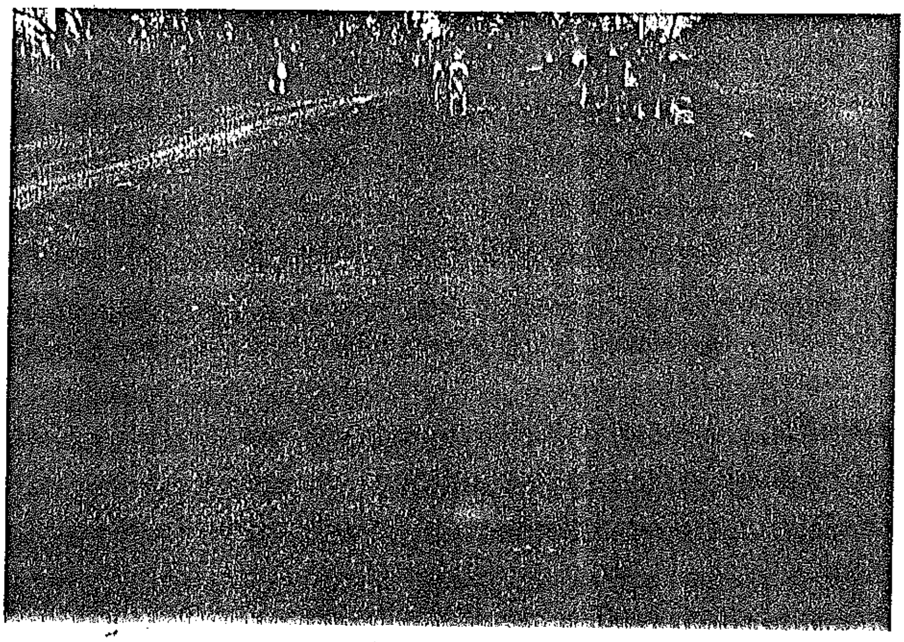


Fig.3.3 Geogrid material placed in position. One meter overlap of the two rools to give a total width of 7.3 meters.

Fig.3.4 Lift layer of material being spreaded on the geogrid.

The roughness of the surface of the first section was measured on [illegible]7-07-1993 using MERLIN machine. Two sets of readings were taken, one for each direction. The roughness obtained on Merlin scale (D) in mm from the two readings are 70 mm and 65 mm giving an average of 67.5 mm. The roughness in mm/km in terms of BI was obtained using the equation for asphaltic concrete surfaces:

$$BI = 574 + 29.9D$$

$$= 574 + 20.9 \times 65.5 = 2332 \text{ mm/km}$$

which shows that the road has quite good riding quality as the roughness of the asphaltic concrete surfaces varies from 1270 mm/km to 5370 mm/km.

The surface was also checked at several locations using striaght edge. There were no signs of any rutting or plastic movement in the asphaltic concrete wearing course. Also, there were no signs of any cracks on surface.

The sections were again visited on 12-01-1995. Physical conditions of the road section, with geogrid and the section without geogrid was observed. Benkleman beam tests and rut depth measurements were also made on the two sections. The results may be seen at Annexure-B. As far as physical condition of the road sections is concerned, the section with geogrid was in perfectly good shape with no cracking on the surface and having good riding quality. However, on section without geogrid, the condition were far below satisfactory showing high rut depths, alligator cracking and giving poor riding quality. The average rut depth of the section without geogrid was found 5 times more than the section having geogrid.

3.7 Conclusion:

To draw definite conclusions regarding the use of the GEOGRIDS in the water logged areas, monitoring of the sections using GEOGRID is required for a long period. However, its performance since its completion and opening to traffic on 25-09-1993, has been perfectly well. It could be concluded from the initial performance of the section, that the GEOGRID material is a very cost effective long term, permanent solution for the construction of roads in the water logged areas of Pakistan.

3.8 Recommendations:

In view of trial results so far, and their cost effective, permanent long term benefits, the following recommendations are made:-

a) The NHA may be requested to carry out further trials on their chronic problem sections of roads in their various national projects.

b) GEOGRIDS could also be tried for erosion protection of faces, and slopes in chronic areas like Kokala - Muzzaffarabad road, Karachi - Ormara road, 500 miles of K.K.H, some sections of Rawalpindi - Murree Road, and elsewhere in some areas of Kashmir, Northern Areas, NWFP and Baluchistan Mountainous areas, by respective national and provincial agencies. Annexures B & C attached for two case studies of protection of slopes and faces against erosion.

ANNEXURE - A.

DESIGN PARAMETERS FOR JEHANGIRA - SWABI ROAD

i) Soil Test Results:

a) Type of Soil

Sand	15.00%
Silt	43.00%
Clay	42.00

b) Plasticity

L.L	28.4
P.L	16.3
P.I	12.1

c) Moisture Content	12.63%
d) Classification (AASHTO)	A-6(9)
e) CBR (Soaked)	4%
ii) Depth of Water Table	4 feet

iii) Traffic Volume and its Composition:

Year of Count	No. of Counting Days	Pass Buses	Heavy Trucks	T-T Units	N.L.C Trucks	ADT Vehicle/ Day
1985	2 Days	313	367	173	0	2262
1986	2 Days	294	331	223	6	2290
1987	4 Days	363	306	115	4	2398
1988	3 Days	339	383	170	4	2477

iv) Axle Load:

Equivalent standard axle factors as recommended by Kampsax on the basis of survey carried out in 1986 for this road are as follows:-

Lorry Group	Bus	Trucks 2 Axle	Trucks 3 Axle	Trucks 4-6 Axle
Equivalence Factor	0.35	2.87	19.74	30.26

v) Geometric Parameter: = 7.3 m

Pavement Width = 1.82 m

Embankment Height = 1.5 to 5.00

vi) Proposed Pavement Design:

Asphaltic concrete wearing course = 3 cm

Asphaltic concrete base course = 7 cm

Crushed stone base course = 20 cm

Annexure-B.

TRANSENT DEFLECTIONS AND RUT DEPTH MEASUREMENTS MADE ON 12-01-1995

a) TEMPERATURE IN (^{o}C)

i)	AMBIENT TEMP	=	16.5
	1/2" TOP TEMP	=	22
	MID TEMP	=	21
	BOT TEMP	=	19
ii)	AMBIENT TEMP	=	
	1/2" TOP TEMP	=	23
	MID TEMP	=	21
	BOT TEMP	=	20
iii)	AMBIENT TEMP	=	19.5
	1/2" TOP TEMP	=	23
	MID TEMP	=	22
	BOT TEMP	=	20
iv)	AMBIENT TEMP	=	19.5
	1/2" TOP TEMP	=	23
	MID TEMP	=	21
	BOT TEMP	=	20

b) TRUCK LOAD

FRONT AXLE	=	2.99	TONS
REAR AXLE	=	6.68	"
GROSS	=	9.67	"

LOAD

LEFT WHEEL	=	2.94	TONS
RIGHT WHEEL	=	3.10	"
TOTAL	=	6.04	"

TRANSIENT DEFLECTIONS

ANGIRA - SWABI SECTION
H GEOGRID

S.No.	Dial Guage Reading	Deflection (mm)
[illegible]	43.00	0.86
[illegible]	47.00	0.94
[illegible]	43.00	0.86
[illegible]	47.00	0.94
[illegible]	50.00	1.00
[illegible]	46.00	0.92
[illegible]	41.00	0.82
[illegible]	42.00	0.84
[illegible]	39.00	0.78
[illegible]	42.00	0.84
[illegible]	30.00	0.60
[illegible]	39.00	0.78
[illegible]	40.00	0.80
[illegible]	35.00	0.70
[illegible]	35.00	0.70
[illegible]	45.00	0.90
[illegible]	38.00	0.76
[illegible]	39.00	0.78
[illegible]	42.00	0.84
V.	41.21	0.82
D	4.70	0.09
AR	22.06	0.01

JEHANGIRA - SWABI SECTION
WITHOUT GEOGRID

S.No.	Dial Guage Reading	Deflection (mm)
1.	58.00	1.16
2.	56.00	1.12
3.	51.00	1.02
4.	55.00	1.10
5.	57.00	1.14
6.	59.00	1.18
7.	58.00	1.16
8.	55.00	1.10
9.	53.00	1.06
10.	56.00	1.12
11.	62.00	1.24
12.	56.00	1.12
13.	55.00	1.10
14.	62.00	1.24
15.	59.00	1.18
16.	55.00	1.10
17.	56.00	1.12
18.	55.00	1.10
19.	60.00	1.20
AVG.	56.74	1.13
STD	2.75	0.05
VAR	7.56	0.00

RUT DEPTHS

JEHANGIRA - SWABI SECTION WITH GEOGRID

S.No.	Rut Depth
[illegible]	0.40
[illegible]	0.40
[illegible]	0.50
[illegible]	0.80
[illegible]	0.60
[illegible]	0.80
[illegible]	0.90
[illegible]	0.90
[illegible]	0.40
[illegible]	0.20
[illegible]	0.30
[illegible]	0.20
[illegible]	0.20
[illegible]	0.50
[illegible]	0.70
[illegible]	0.80
[illegible]	0.20
[illegible]	0.90
AVG	0.54
STD	0.26
VAR	0.07

JEHANGIRA - SWABI SECTION WITHOUT GEOGRID

S.No.	Rut Depth
1.	0.50
1.	0.60
3.	2.40
4.	4.00
5.	3.60
6.	2.50
7.	1.60
8.	1.90
9.	2.50
10.	1.60
11.	3.60
12.	3.90
13.	2.50
14.	2.60
15.	3.80
16.	2.10
17.	2.60
18.	2.50
AVG	2.49
STD	1.00
VAR	1.01

ANNEXURE - C.

Engineering Department

Case Study

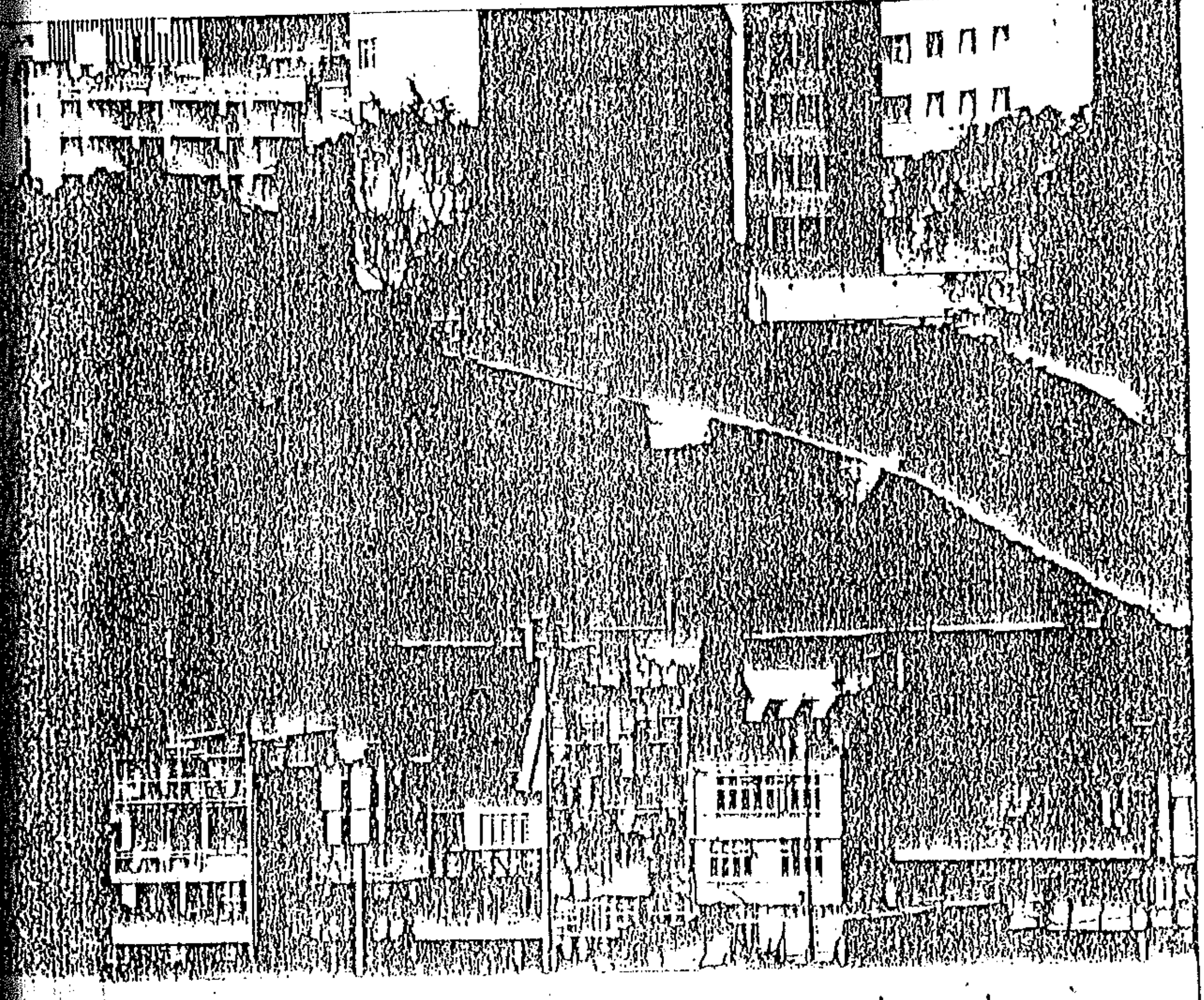
Tensar

ct: Erosion protection to 45° slope
Leighton Hill – Hong Kong

eifier: Geotechnical Control Office (G.C.O.) Hong Kong

uct employed: 'Tensar' Mat

te: March 1987



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Introduction

In March 1987 a large area of steeply sloping ground was regraded to 45° in order to improve stability. The newly exposed face required erosion protection to prevent the formation of deep gullies and to improve the long-term appearance. 3,015m² of 'Tensar' Mat was installed on the slope. Grass was quickly established and the performance during the first year has been satisfactory.

Site Description

The site is located adjacent to Wong Nai Chung Road on the west side of Leighton Hill in the northern part of Hong Kong Island.

The original slope angle varied from 60° to 85° supported at the toe by a 2m high masonry retaining wall. The slope comprises decomposed granitic material, with some slope-wash deposits. The surface was very uneven, reflecting the numerous small slip failures that had taken place.

A network of disused tunnels constructed over 40 years ago underlies the site.

At the top is a Government housing estate, with garage blocks located close to the slope. At the bottom there is a row of apartment blocks.

As part of their on-going investigation of slopes in Hong Kong, the G.C.O. carried out an extensive site investigation and determined that the slope stability was below the required standard. Remedial measures were therefore proposed.

Design Proposals for Remedial Works

A 14m high retaining wall was proposed to support the lower part of the slope. Above this the slope was to be re-profiled to a gradient of 1:1 and surface drainage would be installed.

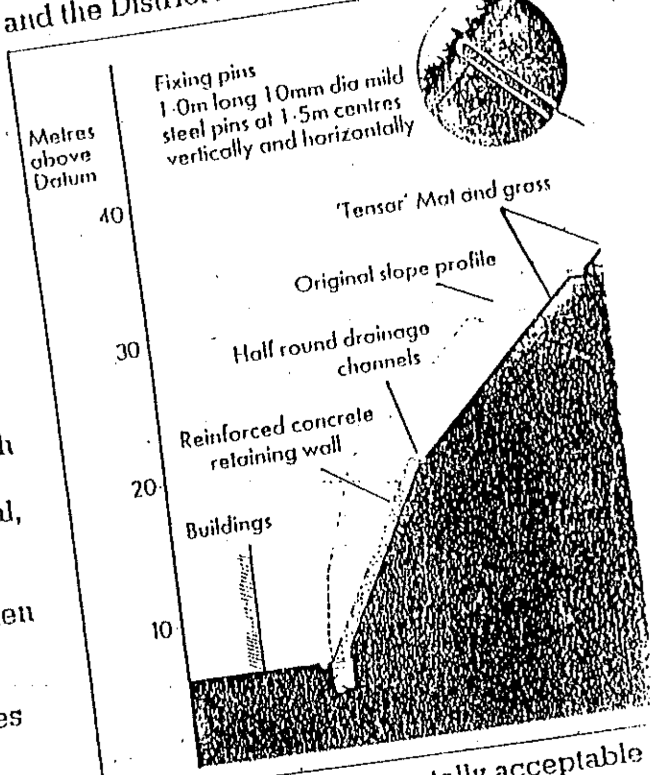
Remedial Works

The slope at the toe was cut back to an angle of 62° and a 14m high retaining wall was constructed against the newly cut face. Above this the slope was re-profiled ... (Fig. 1).

The exposure of very loose fill c… to the top led to the upper part of the sl… being reduced to 35°.

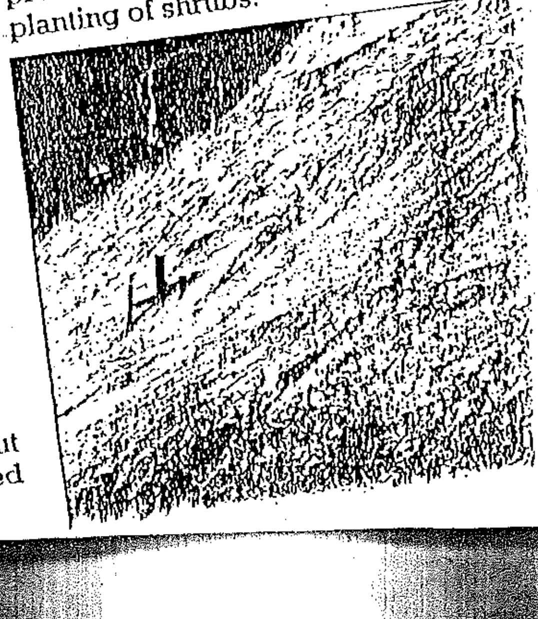
Erosion Protection to 45° and 35° Slope…

The conventional treatment of steep slopes in Hong Kong has for many years consisted of rendering the face with mortar, or chunan, as it is known locally. The Leighton Hill slope is highly visible and the District Lands Office had insisted



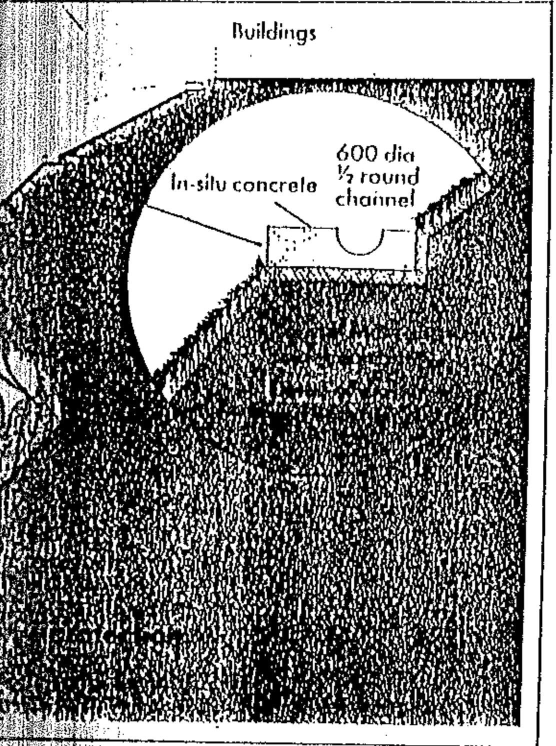
that a more environmentally acceptable solution be found.

The original slope had been well vegetated with a good tree covering an… was proposed that the slope should be re-planted if possible. G.C.O. proposed hydroseed the slope to provide erosio… protection and to follow this with the planting of shrubs.



During construction of the slope, G.C.O. engineers became concerned that the decomposed granitic soil was highly erodible (Fig. 2). They decided to amend the design to include some form of improved erosion protection.

A number of products were considered including open concrete lattice systems and various erosion protection mats.



'Tensar' Mat was finally chosen on the basis of its low cost and ease of installation compared to the concrete systems, its long-term durability and very important in this case, the natural appearance of the finished slope. The high strength of the mat would enable it to be installed on the steep slope without risk of tearing. The flexibility or drapability of the mat would ensure that it maintained intimate contact with the re-profiled slope since close contact with the slope face over the entire area is critical to prevent wash out of soil beneath the mat.

Installation of the 'Tensar' Mat

For this project G.C.O. chose to apply a double spray of hyrdoseed. The first spray was applied to the re-profiled slope prior to placing the 'Tensar' Mat.

Figure 2. Severe erosion of the re-profiled slope and led to the decision to adopt 'Tensar' Mat

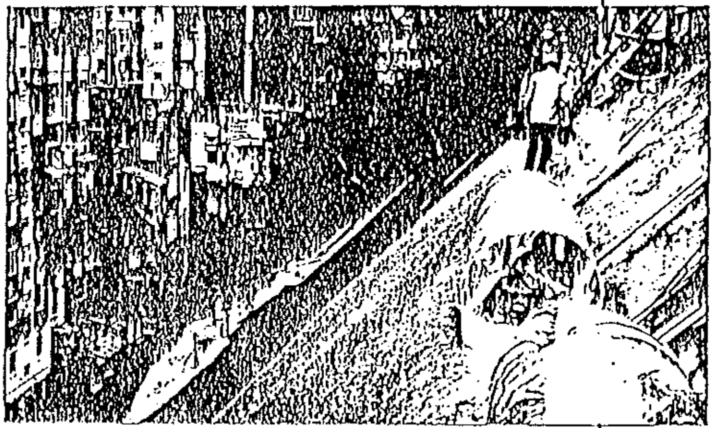


Figure 3. After hydroseeding the re-profiled slope, 'Tensar' Mat was rolled down the slope.

The mat was unrolled down the slope face (Fig. 3). Steel staples were used to fix the mat at the top of the slope and at 1.5m vertical and horizontal centres. This work was made easier by the use of ropes and ladders for access (Fig. 4). Owing to the soft nature of the soil G.C.O. specified 1.0m long staples fabricated from 10mm diameter ribbed reinforcing bar.

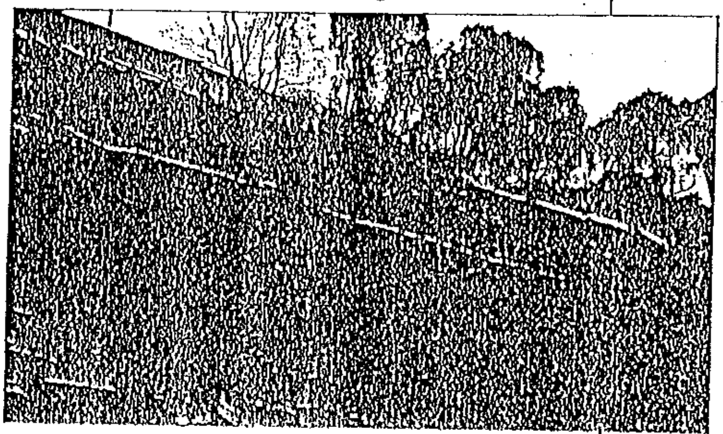


Figure 4. Fixing the mat to the 45° slope was made easier by the use of ropes and ladders

The 'Tensar' Mat was continued under the concrete support to the surface drains installed across the slope face. (See detail on Fig. 1).

After fixing the mat in position, topsoil was tipped down the slope and brushed into the mat, filling it to its full depth.

The second spraying of hydroseed was then carried out. Each application of hydroseed consisted of:-

	g/m^2
Bermuda grass seed	12.5
Bahia grass seed	12.5
Cellulose fibre mulch	170
Fertiliser	100

Performance

Most of the 'Tensar' Mat was installed in March 1987. A good lush grass growth was established by the end of April when the rainy season commenced.

The quilted mesh structure of 'Tensar' Mat succeeded in retaining the topsoil and newly rooted grass throughout the period of heavy rain in April/May.

One section of the 45° slope was left without 'Tensar' Mat during this period to allow for additional profiling. By the end of May this section had no grass growth and was highly eroded, with deep scouring (Fig. 5). By comparison the section with 'Tensar' Mat had achieved good grass growth with negligable soil loss.

The entire slope has now been completed using 'Tensar' Mat and is fully grassed (Fig. 6).

Figure 5. Severe erosion had occurred on the section without 'Tensar' Mat after one period of rain

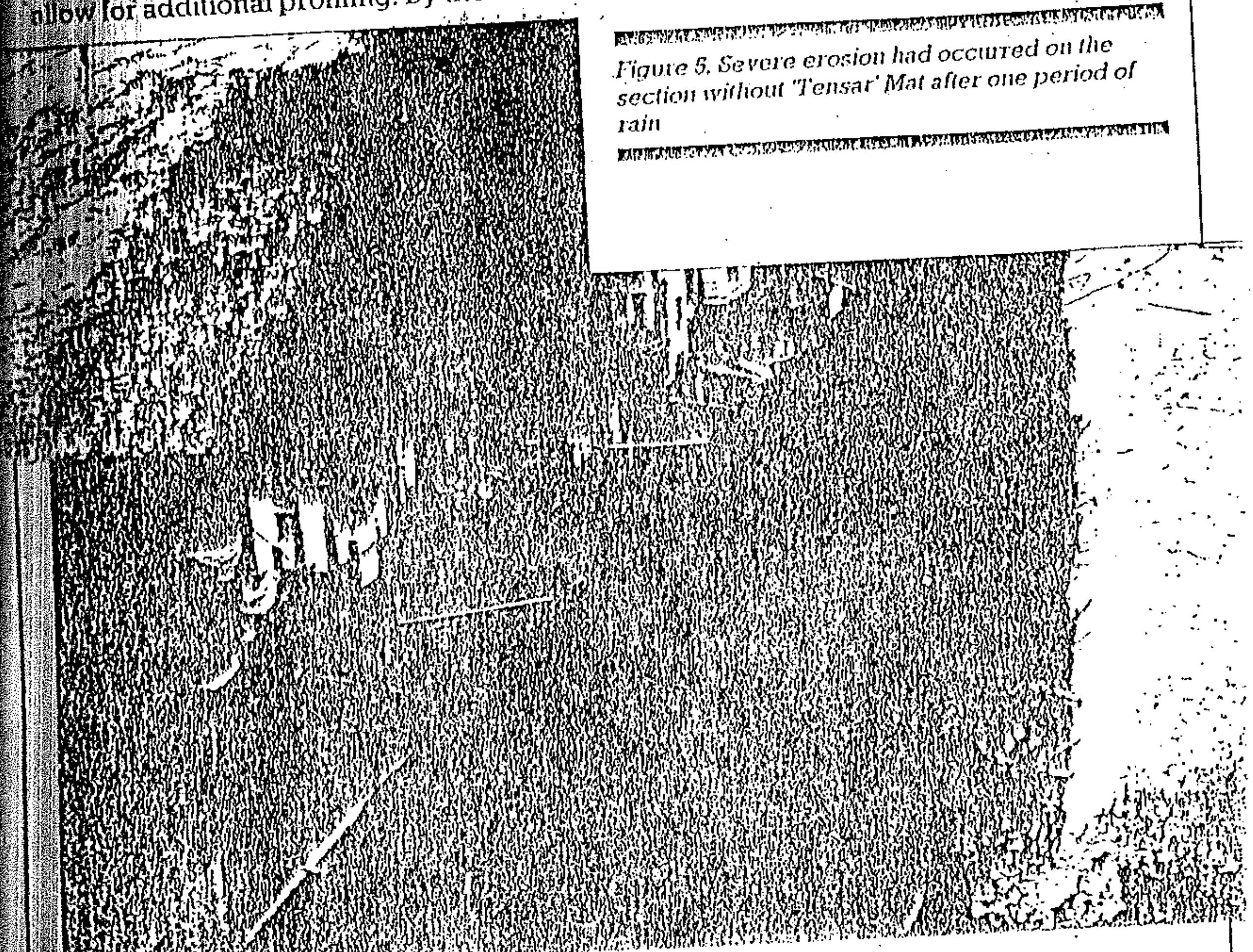


Figure 6

Additional literature for design and construction is available for

- Reinforced soil walls, slopes, slip repairs and embankment foundations
- Reinforced sub-base layers, asphalt layers and turf for paved and unpaved roads, airfields and other loaded areas
- Reinforced grass, revetment underlayers, gabions and mattresses for maritime and waterway engineering
- Waste management, drainage and protection to membranes and pipe coatings

The literature, together with other case studies, specifications and technical advice can be obtained from The Civil Engineering Division, Netlon Limited.

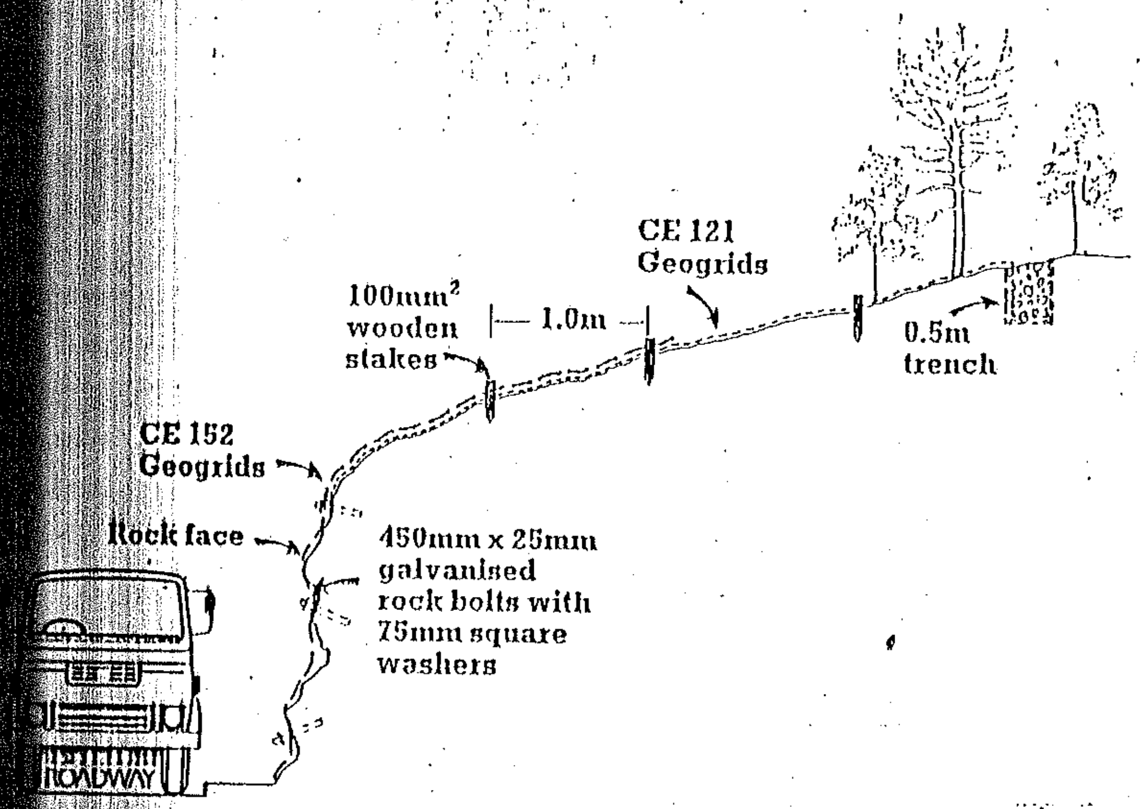
Tensar

Civil Engineering Department

A Case Study

Tensar

Project:	Protection of faces & slopes — Date: April '79
Client:	Avon County Council
Specifier:	Mander Raikes & Marshall
Contractor:	Nott Brodie
Product employed:	'Netlon' CE121 & CE152
Acknowledgements:	



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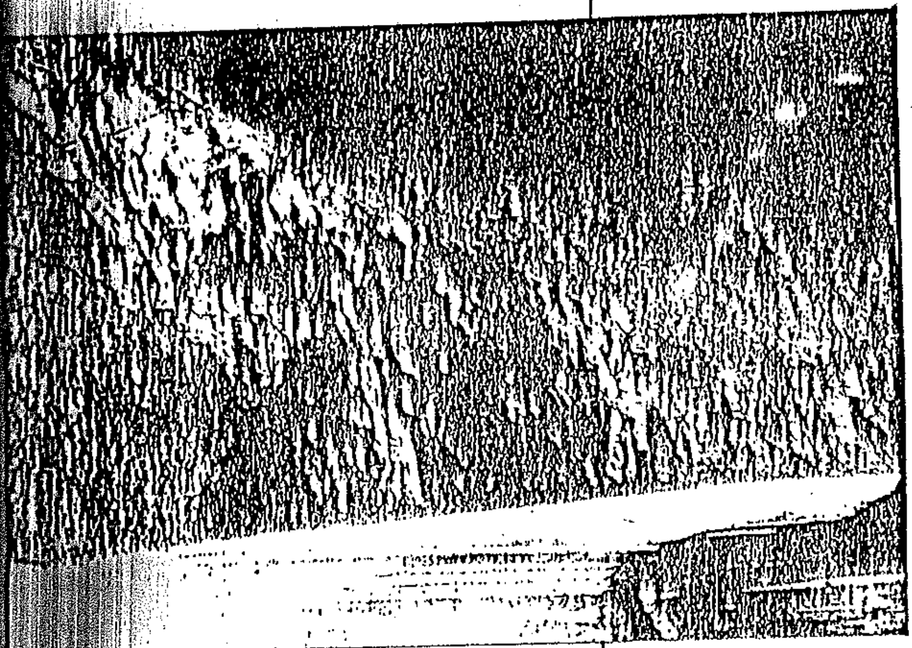
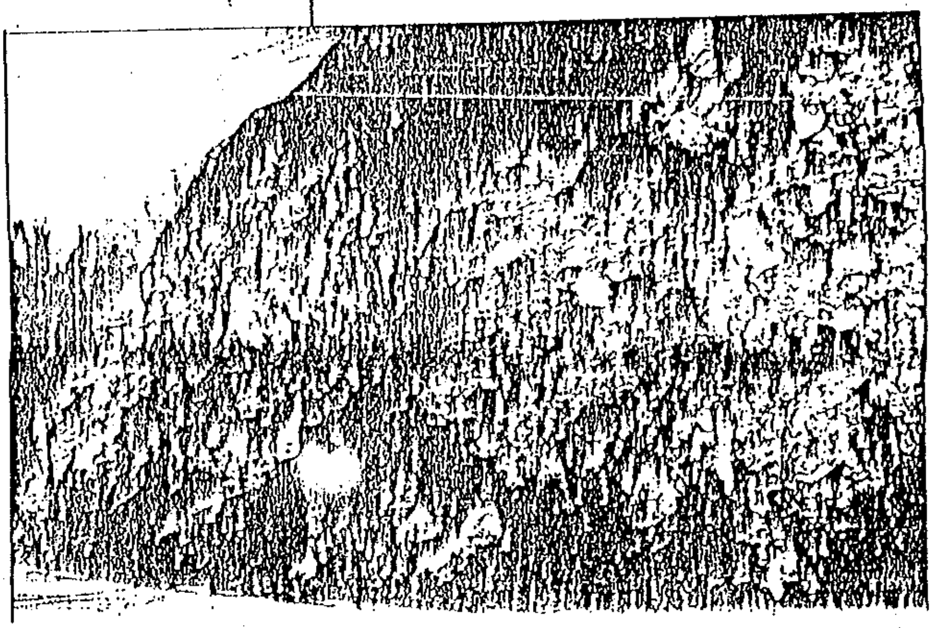
Following inspections of certain ck faces overlooking the A4 trunk ad which passes through the Avon orge at Bristol, the dangerous nature of rts of these faces and slopes was ought to the attention of the Avon ounty Council. As a result, the road as closed from February 1977 when medial work began, terminating in pril 1979 (see photographs 1 & 2).

In addition to its importance as a oute for the A4, known locally as ortway, the Gorge is an area of great atural beauty and provides a natural habita. fo: very rare plant species. In this respect the area is perhaps unique in Great Britain.

When preparing their proposals for the project, the consultants, Mander Raikes & Marshall, gave careful consideration to the choice of ma erials to be used on the face, in order that the visual appeal and the unique habitat should remain unimpaired. For this and other reasons, 'Netlon' polymer grids were selected to provide unobtrusive stabilisation to help contain rock falls (CE152) and prevent soil erosion (CE121).

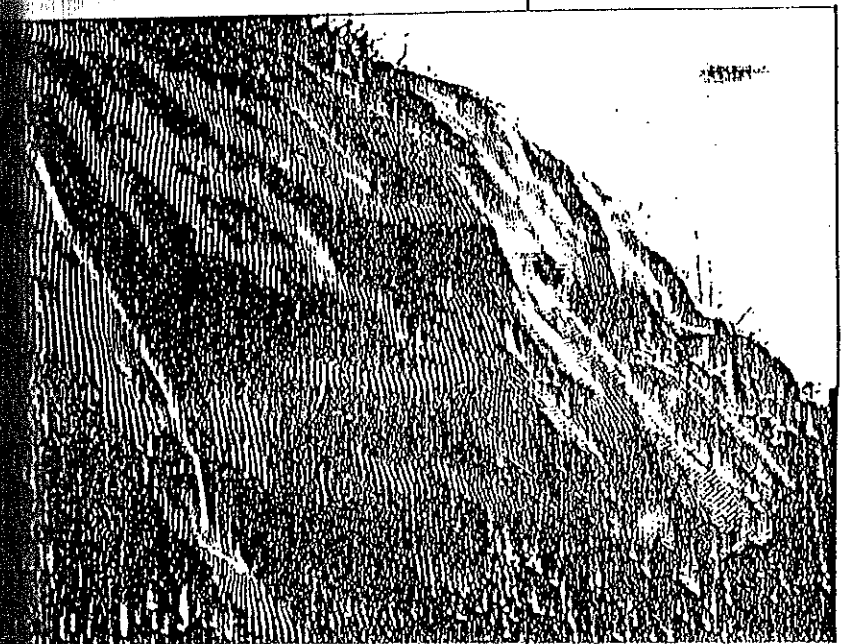


Photograph 1

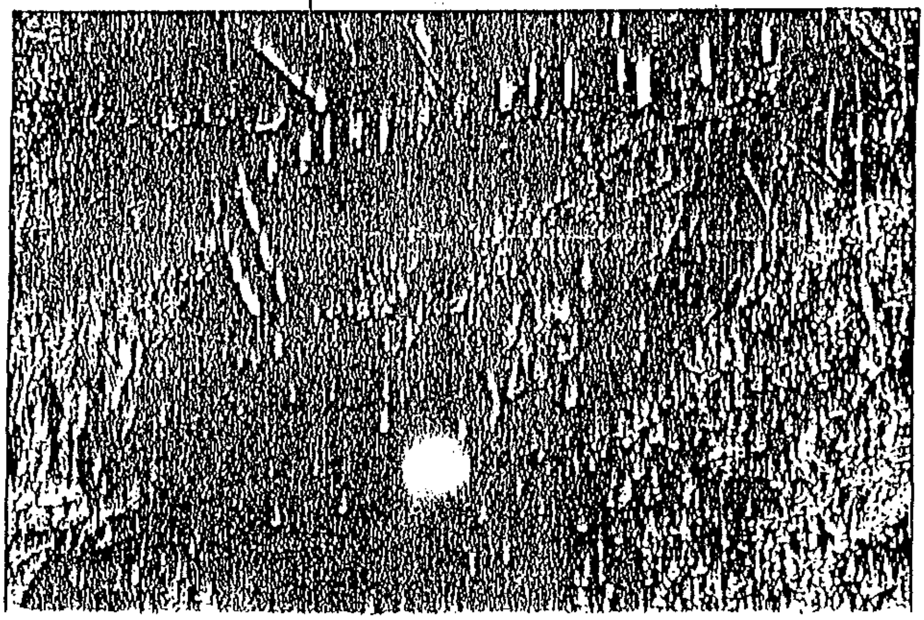


Netlon CE152 and CE121 proved to be sufficiently strong, yet flexible enough to conform to the sharp angles (see photograph 3) and hollows remaining after the very loose rock and a number of overhangs had been removed. Apart from the more obvious benefits, the grids afforded protection from rain water run-off to seeds and seedlings. They have also retained soil, reduced weathering and protected both roots and rock face from frost damage. When the vegetation mat is fully developed they will also reinforce the root mat and the support grids.

Two different methods of top fixing were used. In areas where there was sufficient soil, the grids were buried in a trench about 0.5m deep. In other more rocky areas, wooden posts of 100mm square section were driven into the cliff top at 1 metre centres. The grids were holed at suitable intervals and fitted over the posts (see photograph 4). Additional fixing was provided by plastic coated steel wire threaded through the grids and bound to the posts.



Photograph 3



...ilar wire was also used to link lengths at the overlaps. In all ...s intermediate fixings to the ... part of the face were of 450mm x ... diameter galvanised rock bolts ... with heavy square washers.

...itional labour was required due to ...weight nature of the 'Netlon' ... and it was considered much safer ... with than other mesh types – an ...tant consideration where ...erous cliff faces are involved.

The part played by 'Netlon' grids ...e Avon Gorge project illustrates ... effectiveness in providing long-... solutions to erosion and instability ...ock faces.

Tests have indicated that the development of vegetation would enhance the durability of 'Netlon' grids in such environments, as this would exclude the harmful ultra-violet light.

In areas of total exposure to sunlight, the inclusion of UV absorbers is sufficient to combat these adverse effects.

By February, 1979 a large proportion of the grids was already obscured by new growth at Avon Gorge.

Additional literature for design and construction is available for:

* **Vertical Retaining Walls**
* **Embankments**
* **Maritime & Waterways works**
* **Reinforced soil structures**
* **Paved roads and loaded areas**
* **Gabions and Mattresses**

This literature, together with case studies, specifications and technical advice can be obtained from the Civil Engineering Department, Netlon Limited.

Tensar.