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Natural materials for soil reinforcement

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ABSTRACT : The paper presents results of recent research on use of natural materials for soil reinforcement. The most promising protection methods are described e.g. coating by low density polyethylene (LDPE) melt of composite fabrics of natural fibre/ high density polyethylene (HDPE) slit tapes and ferrocement coating for small timber. Details of reinforcement are furnished.

1 NATURAL MATERIALS FOR SOIL REINFORCEMENT

In the past, natural materials have been looked upon as low cost substitutes for synthetics to be used in noncritical applications. The general belief has been that their strengths are uncertain and variable and the hazard of biodegradation renders them unsuitable for important structures.

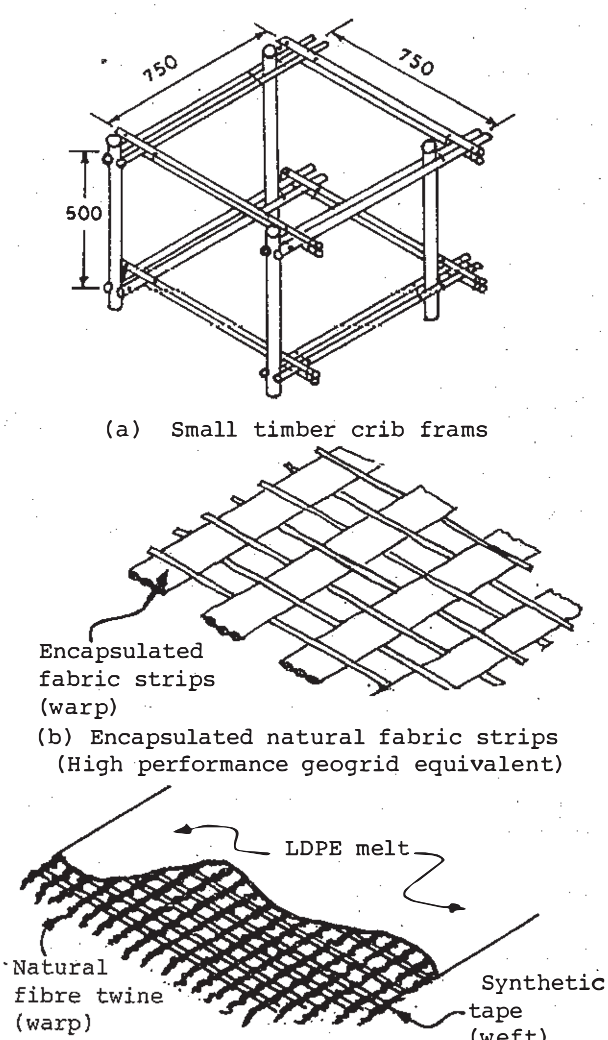
Studies of material characteristics carried out by various researchers [Pama (1978), Fang (1981), Mwamila (1983), Yamanouchi (1986)] in the past have already established that fairly consistent characteristics are realised by judicious choice of natural materials.

Traditionally natural materials have been extensively used in the past for soil reinforcements. But these were not engineering applications i.e. no specific requirement regarding materials were stipulated nor was any scientific evaluation made of their performance.

Recent studies have brought out clearly that strength and deformation characteristics of several natural materials such as bamboo, timber and fibres compare very favourably with synthetics. In fact, with regard to the deformation modulus and creep, the natural materials are superiror to synthetics.

The main problems are the protection from biodegradation and attack from organisms. It is also necessary to develop suitable forms of reinforcement for various applications. These are illustrated in figure 1.

Various treatments were evaluated such as:



(a) Small timber crib frams

(b) Encapsulated natural fabric strips (High performance geogrid equivalent)

(c) Natural woven fabric (stabilenka equivalent)

Fig. 1 : Forms of reinforcement

- Impregnation with water and oil borne preservatives.
- impregnation with synthetic polymers
- coating with cold setting liquid resins
- coating with synthetic melts
- encasement in concrete or cement composites e.g. ferro cement.

In the following paragraphs the most promising techniques are described and information presented regarding the techniques which have been tested on a small scale by fabricating trial pieces and using them in the field.

2 WOVEN FABRICS WITH NATURAL FIBRES

The fabric is made by weaving natural fibre twines in warp direction with HDPE slit tapes in weft direction. So far mechanised weaving on power looms has not been successful as the slit tapes have a tendency to get warped and twisted. Handlooms have been used successfully and the handloom weaving technique is cost effective in India. In fact, it helps to optimise the fabric design for specific use as range of applications is wide and a variety of products could be manufactured such as narrow tapes, wide strips and fabric rolls. Synthetic melt application is made possible by use of synthetic slit tapes in the weft direction. The melt provides a tough encapsulation, which would adequately protect the fabric against moisture ingress. Water soluble preservatives and fungicides successfully used in the past for treatment of timber, bamboo and thatch can effectively be used for treatment of the natural fibre. Further improvement can be achieved by coating the natural fibre with water repellants such as silicone and PVC emulsions.

Characteristics of the composite fabrics are compared with some of the high performance synthetic woven fabrics in table 1. The cost advantages are evident, the material characteristics are superior with regard to the deformation modulus and the composite fabric of the proposed design have good potential for manufacture in developing countries. It must be emphasised here that the manufacturing process involves a technology blend i.e. the natural fibres made in small units are combined with synthetics, woven again by small industrial units, but the final processing is done through an organised industrial unit where by necessary quality control and design optimisation can be achieved.

There is another avenue i.e. use of natural fibres coated by tough impermeable resins such as polyurethane. The manufacturing trial and experimental work is in an initial stage. The process seems to be promising but it is premature at this stage to arrive at a firm conclusion regarding the suitability of woven fabrics constituted of natural fibres coated by resins. There is an attractive prospect of using fabric of natural woven material for the geocells. The geocells by virtue of their higher modulus are expected to perform better than synthetic geocells as would be evident from table 2.

3 SMALL TIMBER FOR SOIL REINFORCEMENT FACING & CRIBS

The designs are based on use of pieces of 40 to 60 mm diameter small timber

Table 1. Comparison of costs and characteristics of synthetic and natural woven fabric for reinforcement

Description	Material	Weight (gm/m^2) & material price (Rs/Kg)	Ultimate tensile strength KN/M & strain at break (%)	Modulus at break (KN/M)	Cost/m^2 (Rs)
Synthetic woven (Stabilenka 200)	Polyester yarn	. 460 @ 120	200 (10)	2000	55 IE
Natural woven	. Sisal fibre . HDPE slit tape . LDPE melt	. 528 @17 . 50 @70 . 120 @60	200 (4)	5000	20 LE

IE - Estimated at current international prices
LE - Estimated at current local prices
1 US $ = Indian Rs. 12.8

Table 2. Comparison of costs and characteristics of synthetic and natural geocells

Material	Geocell Description & seam type	Tensile stregnth (Kn/M) & strain (%)	Modulus (KN/M)	Material requirement (kg/m^2) & unit price (Rs/kg)	Cost of geocell ($Rs./m^2$)
Unreinforced HDPE (after Koerner-'86)	200 mm (d) x 230 mm cell size, Ultra-sonic welding	110¢ (13)	846	3.0 @ 70	210 IE
Woven Natural Fibre	100 mm (d) x 200 mm cell size, Mechanical stitching	110 (2)	5500	. Sisal-0.96 @ 25 * . HDPE- 0.06 @ 70 . LDPE- 0.04 @ 60	31 LE

¢ From Gundle H D specifications ; * includes cost of polyurethane coating
IE - Estimated at current international prices, LE - Estimated at current local prices
1 US $ = Indian Rs. 12.8

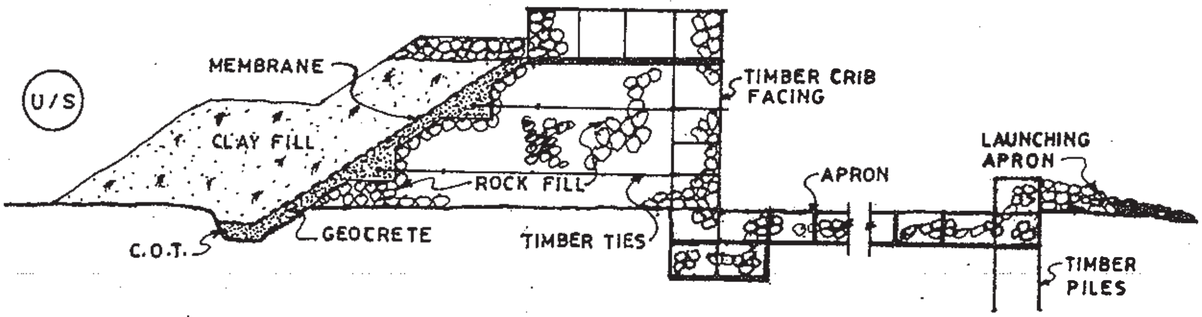
in lengths of 1.5 to 3 m. The use of small timber is made possible by development of a shear connector design. This design has been tested in the field over the last two years. One overflow crib dam has been built which has been performing satisfactorily for one year. Numerous tests have been carried out on samples fabricated in small workshops. The joint strength in single shear is found to be at least equal to the yield load of bolt and thus an allowable joint strength of 1200 kg has been realised for 40 mm dia timber. As the bolts are fixed in oversized holes cracks are neither initiated nor propagated along the bolt holes. The geometry of the contacting surfaces where the load transfer is achieved is such that stress concentrations are avoided; there are no sharp corners or notches and the confining forces mobilised by the bolts ensure that minor cracks and defects would not compromise the joint strength. The studies have substantiated the feasibility of manufacturing the small timber reinforcing elements to get consistent performance, using very simple tools. The confirmatory tests are underway and the results would be presented at the International Conference on timber engineering, Seattle, U.S.A. in Sept. '88.

The small timber cribs would be cost effective as compared to concrete cribs. Potential application of small timber cribs are illustrated in Fig.2. By judicious design, a combination of small timber ties and crib facings would replace gabions. The small timber reinforcements are eminently suitable for anchored wall constructions such as those developed by Fukuoka et al 1986 (Fig. 3). The extensions would be small and the form of joints used would impart adequate flexibility. Timber reinforcements would compare very favourably with high performance synthetic grids such as Signode, table 3. They can also replace steel rods and short pile reinforcements for bases of embankments on soft soils such as those described by Broms (1987).

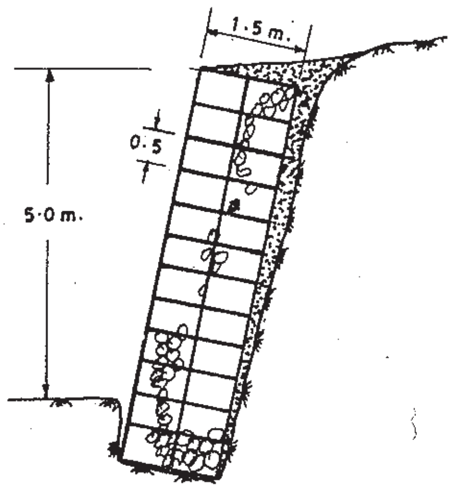
Protection of timber members by ferrocement is a very worthwhile and workable system. By using colloidal silica admixtures very tough and durable cement mortar coats of 6 to 8 mm thickness can be produced. Corrosion resistance can be achieved by use of galvanised iron, aluminium or high modulus synthetic meshes. By using a suitable coating and providing joints in the protective annulus, it could be ensured that the coating would be relieved of stress and therefore cracking would be avoided.

4 CONCLUDING REMARKS

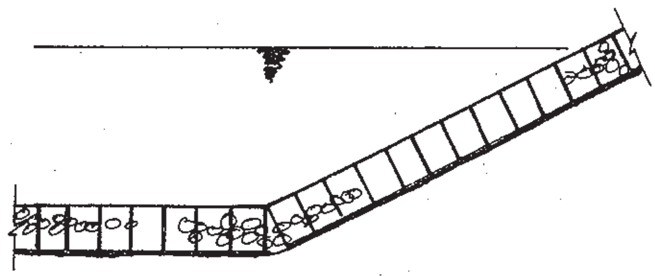
Many researchers have recognised the superior deformation characteristics of natural reinforcement materials; their energy saving potential and economic benefits are self-evident. Yet engineering applications on a significant scale have not so far been possible. This paper describes application details and suggests cost effective preservation techniques which aim at overcoming the deficiencies of natural materials.



(a) Overflow Dam



(b) Retaining wall



c) Flexible revetment

Fig. 2 : Applications of small timber crib

Table 3. Comparison of costs and characteristics of synthetic and natural geogrids for reinforcement

Description	Material & price (Rs/kg)	Weight (gm/m^2)	Strength at 2% strain (KN/m)	Modulus at 2% strain (KN/m)	Approximate cost (Rs/m^2)	Cost at Equivalent strength (Rs./m^2)
Signode TNX-5001	Polyester (PETP) @ 164	550	46	2300	90 IE	90
Tensar SRI	HDPE @ 75	872	23	1150	65 IE	130
Timber (40 mm Ø)	Treated timber @ 4.0	1430	25 ¶	1250*	11.5 ¢	21

IE - Estimated at current international prices, LE - Estimated at current local prices
¶ - Allowable stress (100 kg/cm^2) governs
* - Strain at allowable stress is less than 0.1%
¢ - Including fixture & mortar coat which are 40% and 60% respectively of the cost of treated timber.
1 US $ = Indian Rs. 12.8

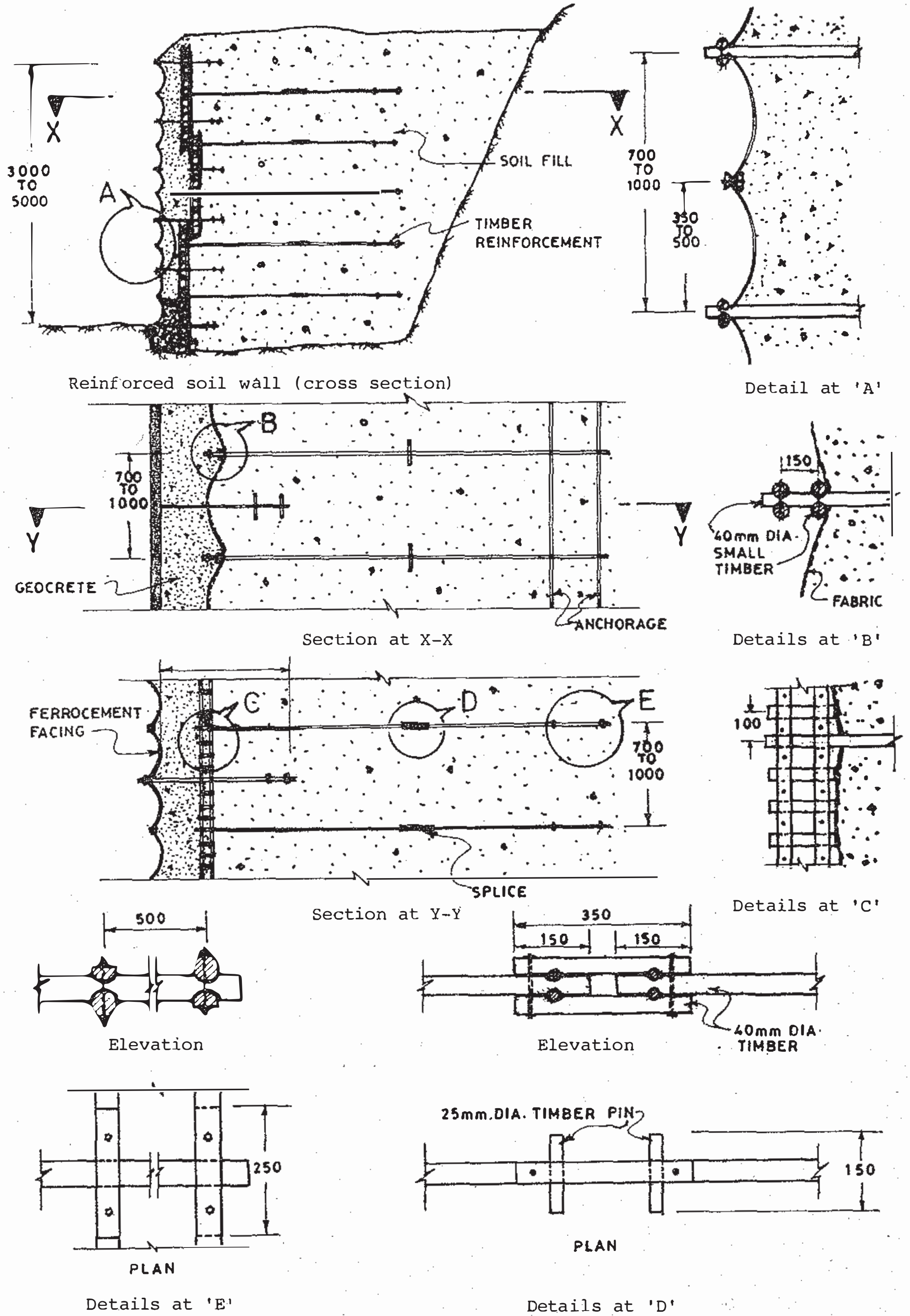


Fig. 3 : Timber reinforced soil wall

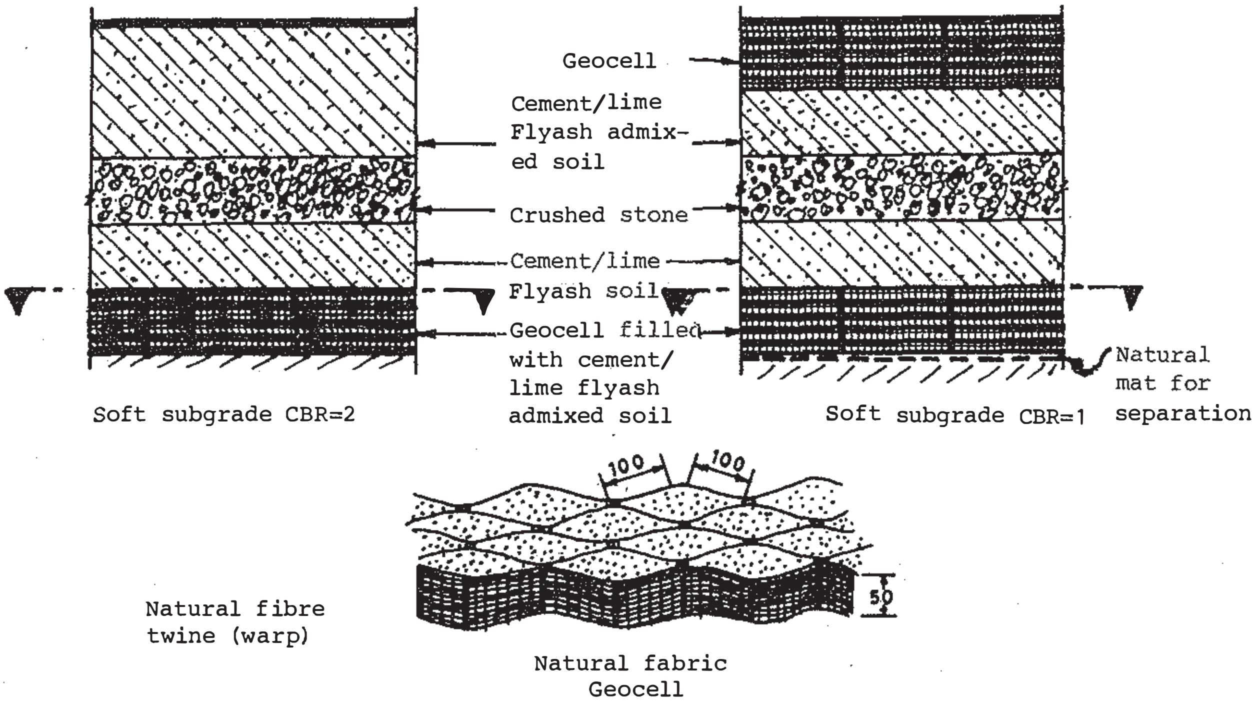


Fig. 4 : Geocell reinforced road base

It is suggested that the proposed protection methods should be subjected to extensive field evaluation. This could best be done without any risk, in applications such as timber cribs for erosion control, soil conservation structures (Fig. 2) and geocells for road bases (Fig. 4), where periodic replacement of the reinforcement is possible.

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