# STABILISATION OF SOILS USING RANDOMLY DISTRIBUTED FIBRE REINFORCEMENT: A REVIEW

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## AN IMPORTANT NOTE FOR THE READER

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# EXECUTIVE SUMMARY

A review of international literature covering the use of fibre reinforcement in cohesive and non-cohesive soils as a means of strengthening these materials was begun in 1992. The focus of the available literature was on the potential use of fibre–soil mixtures as a stabilised road pavement material and in earthworks construction.

The manner in which fibres work, and a range of different fibre types and their applications are described. Comparisons based on material costs are presented but in-place costs were not available.

While most data have been derived from laboratory testing, it is nevertheless clear that fibre–soil mixtures provide superior strength and deformation characteristics under static and dynamic loading conditions. However, more work is required to provide specific and practical information before fibre-reinforced soil is a viable method available to practitioners.

Recommendations are to:

- Review international literature (and also experience) in three to five years time, paying particular attention to quantitative design and construction methods.

- Alternatively, consider carrying out further research on the practical application of fibre-reinforced soil, which would be a significant undertaking, as follows:

    (1) Quantitatively evaluate the resilience and fatigue behaviour of fibre-reinforced soil under both static and dynamic (traffic and seismic) loading.

    (2) Determine methods for mixing, shaping and compacting fibre-reinforced soil.

    (3) Produce technical guidelines for practitioners on the design and construction of fibre-reinforced soil.

    (4) Undertake comparative studies between pavements which include fibre-reinforced soil and those pavements which include materials stabilised by traditional methods such as the addition of lime or cement.

# ABSTRACT

A review of international literature covering the use of fibre reinforcement in cohesive and non-cohesive soils as a means of strengthening these materials was begun in 1992. The contribution of fibres to the characteristics of mixtures of soil and fibre is presented and, in particular, the effect of the fibres on the mixture's strength and ductility under both static and dynamic loading is examined.

A range of potential fibre-reinforcing materials is outlined, and the application of them in improving the performance of road pavement materials and in earthworks construction is discussed. Comparative costs for soils stabilised using fibre, lime and cement are also presented. Recommendations for the use of this technique and for future investigations are presented.

## 1. INTRODUCTION

This review of the use of fibre-reinforced soil for its potential use in stabilising road pavement materials and in earthworks construction was begun in 1992.

Reinforcing soil by the addition of fibrous material is not new. Historically straw was used in brick making, while straw or horse hair was mixed with soil for use in the cob construction of early settlers' homes in New Zealand.

Since the 1980s, the use of steel reinforcing strips or polymer geogrids in New Zealand has increased, especially as their performance and durability characteristics are now becoming better known. These materials have found wide application in the reinforced earth construction of retaining walls and embankments. In these applications such reinforcing elements are placed in fixed positions and orientations.

# 2. FIBRE-REINFORCED SOIL

## 2.1 Introduction

The principle of using randomly oriented discrete fibres to reinforce soil is analogous to the fibre reinforcement of cementitious materials and other binders. When used to reinforce soils, fibres are introduced to the soil and mixed to a uniform distribution before compacting the mixture in place. However, this technology has not been applied as much as the reinforcing technologies based on geogrids that have led to the process known as reinforced earth. Of the studies reported, most are limited to laboratory investigations of fibre–soil mixtures, and the only commercial application is for TEXOL, a patented continuous fibre-reinforcement technique developed in France (Leflaive 1988).

## 2.2 Mechanism

The performance of a fibre–soil mixture is primarily influenced by:

- confining pressure;
- soil grading and particle shape;
- fibre aspect ratio (length to diameter ratio), modulus and surface characteristics (surface area, texture);
- reinforcing content, usually expressed as % by weight irrespective of different fibres having different densities.
- compactive effort required to achieve appropriate density.

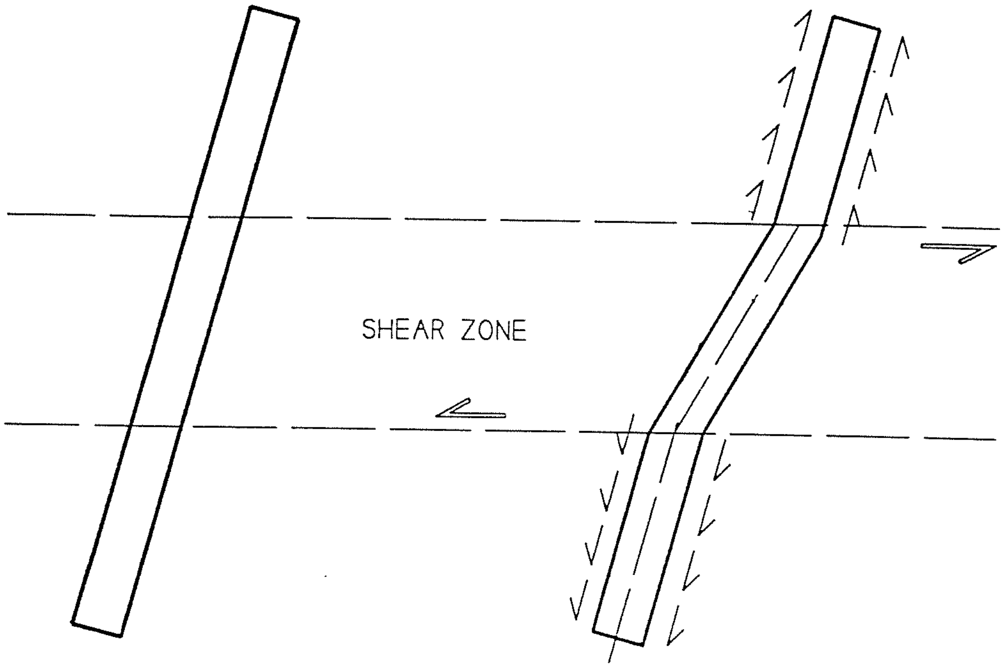
When fibre–soil mixtures undergo deformation, tensile forces develop in the fibres caused by friction at the surface of the fibre. The tensile forces resolve into a force normal to direction of shear, increasing the confining pressure on the shear plane, and a tangential force which acts to oppose the shear force. This mechanism is shown schematically in Figure 1. Fibre reinforcing contributes to shearing resistance when the fibres lie at some angle to the direction of maximum strain. Their effectiveness increases as the angle to this direction increases.

## 2.3 Mixing and Compaction

Mixing the fibres into the soil can be difficult. The mixing process has to evenly distribute the fibres without the fibres balling or segregating. It appears that, in the laboratory, the most efficient method for mixing is to use a mixer that has a kneading or helical action. Mixing fibres in cohesive material is more difficult and therefore more complicated than mixing with less cohesive soils.

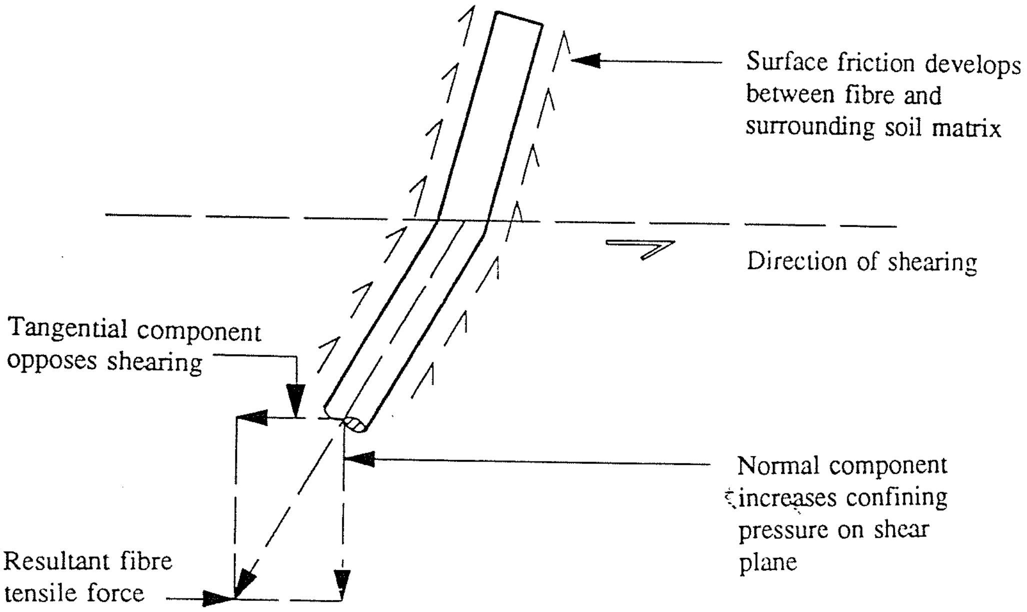
With the addition of reinforcing elements, the soil mixture becomes more resilient and, as the proportion of fibres increases, the compactive effort required to achieve a specified density condition also increases. As the fibre content continues to increase, a point is reached where "diminishing returns" will result in no further improvement in composite strength and possibly even result in strength reduction.

Figure 1. Diagram of mechanism by which fibre reinforcing contributes to soil shear strength.



Undeformed fibre

Fibre under shearing action



## 2.4 Static Load Response

Unlike the technologies of reinforced earth, geotextiles and geogrids, surprisingly limited information about the effects of randomly distributed fibres in soil is available. However, the studies that have been reported have generally touched upon most aspects of the behaviour of the fibre–soil mixture and the key parameters influencing its behaviour, and the results obtained are generally in agreement.

Satyanarayana et al. (1979), in an experimental programme, explored the effect of adding asbestos and glass fibres to a soil–cement mix. The programme involved cylindrical split testing (tensile strength) and unconfined compression testing of samples with differing proportions of cement and reinforcing. Addition of fibrous reinforcing provided additional strength gains over that afforded by the addition of cement alone. The combined effect of the fibres and cement was to provide significant increases in the strength of the composite over that of the unmodified soil.

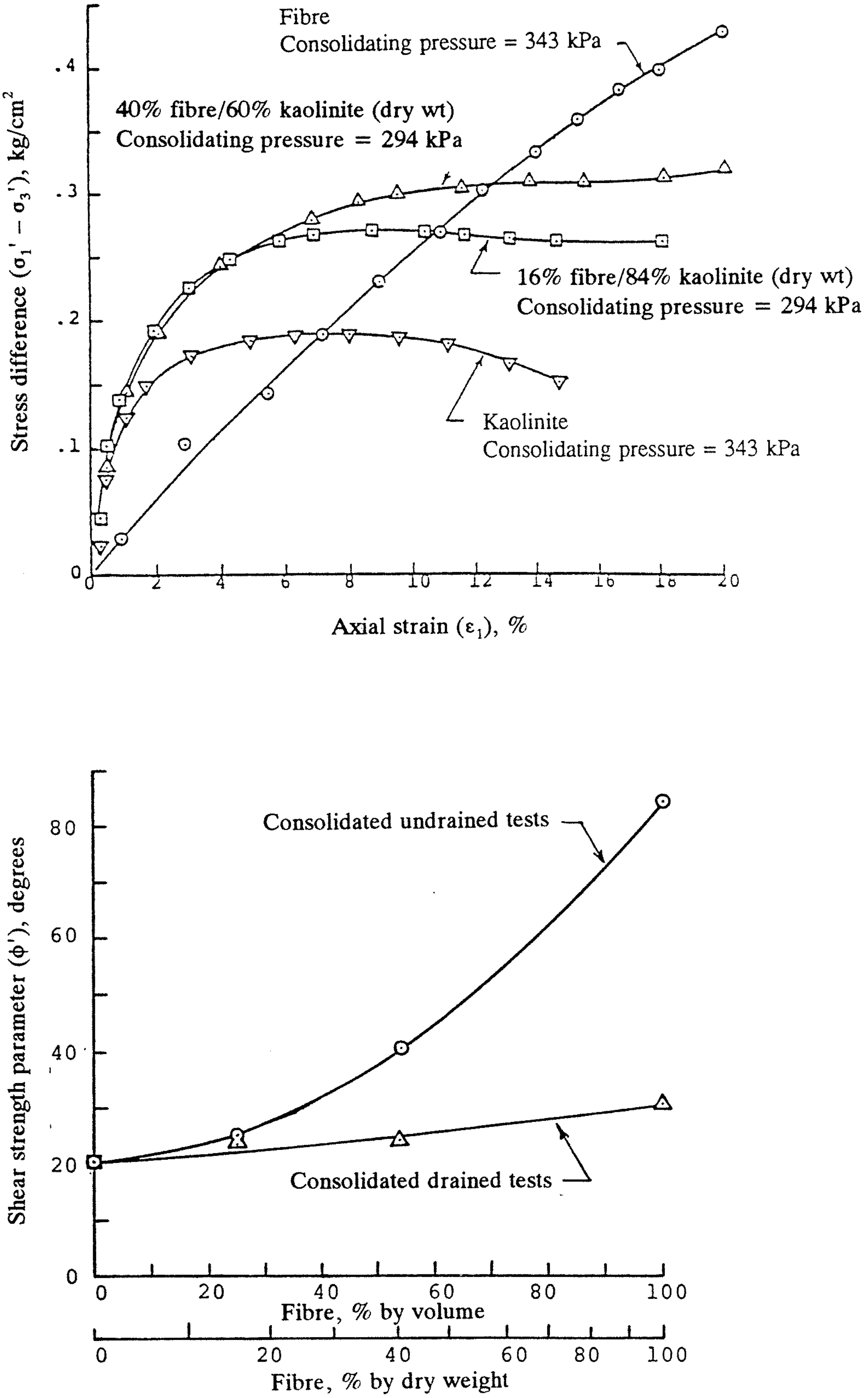
Hoare (1979) carried out a series of compaction and triaxial tests to evaluate the effect of fibre reinforcement (chopped geotextile and polypropylene fibres) on the characteristics of dry, sandy gravel. The compaction testing involved several different methods, and therefore different compactive efforts. The porosity of the compacted samples was evaluated and a positive relationship between porosity and reinforcement content was found. Thus, given constant compactive effort, the porosity of the fibre–soil mixture increased with increasing fibre content.

The stress–strain response of the fibre–soil mixtures was evaluated in a triaxial test programme in which, if porosity was kept constant, significant strength increases were obtained with increasing reinforcement content. However, if porosity increased with reinforcing content, and a consistent compactive effort was applied, these strength gains were not achieved. In some cases, the increasing fibre quantities reduced the strength to that of the unreinforced soil. The testing also showed that the strain required to reach peak strength increased with increasing reinforcement content. This increase in strain needed to reach peak strength can be attributed to the need for the fibre–soil sample to deform slightly to develop surface friction on the fibre so that loads are transferred to the fibres.

Hoare (1979) also noted that, when forming the fibre–soil samples, a kneading action was much more effective than vibration in achieving the required level of compaction.

Andersland and Khattak (1979) investigated the response of kaolinite–fibre mixes. The fibre reinforcing used in this study was wood pulp (cellulose) fibres, and the test mixes ranged from pure kaolinite through different proportions of kaolinite and fibre to pure cellulose fibre samples. Again it was found that the composite fibre–soil mix was stronger and more ductile than the unmodified kaolinite, as shown in Figure 2. As the fibre content increased, both the undrained and drained shear strength increased with increasing fibre content (Figure 2). The undrained shear strength showed a much greater increase (by 4 times) than the drained shear strength (which increased by only 1.5 times).

Figure 2. Stress-strain response of kaolinite–fibre composite(s) and effect of fibre content on the shear strength of the composite(s) (from Andersland and Khattak 1979).



Gray and Al-Refeai (1986) produced a comparative study of geotextile fabric versus fibre reinforcement of soil. Fabric layers contribute to the soil mass strength, with the level of contribution depending upon the fabric's tensile resistance and spacing. Fibres contribute to shear strength as a function of their concentration, orientation to the shear plane, and because the shearing action distorts the fibres. The resulting tensile forces which develop in the fibres provide additional resistance to the external applied load. The comparisons in Table 1 were made as a result of this study.

Table 1. Comparison of characteristics of fabric-reinforced soil with fibre-reinforced soil (from Gray and Al-Refeai 1986).

| **Fabric** | | **Fibres** | |
|---|---|---|---|
| 1. | Increases ultimate strength | 1. | Increases ultimate strength |
| 2. | Increases failure strain | 2. | Increases failure strain |
| 3. | Reduces post-peak strength loss | 3. | Reduces post-peak strength loss |
| 4. | At low strains of < 1% sample stiffness reduces (relative to unmodified soil) | 4. | Sample stiffness greater for all strains |
| 5. | Fabric spacing to sample diameter ratios > 1 gave no benefits at all | 5. | Strength increases linearly to 2% fibre content (by weight), then tended to an asymptotic upper limit for samples prepared at a constant density |
| | | 6. | For constant aspect ratio, confining pressure and reinforcing content, rougher (not stiffer) fibres were more effective |
| | | | See also Figure 3 |

Maher and Gray (1990b) carried out a laboratory based parametric study of the static response of sand (including glass spheres)–fibre (rubber, reed, plant fibre, glass filament) composites to investigate the influence of different fibre and soil parameters on soil behaviour. In addition, a theoretical model was proposed to allow the evaluation of the contribution of the fibres to the strength of a composite, and the experimental results were used to verify the model.

The test programme produced the following results:

- The fibres provided an isotropic reinforcing action, and the observed failure surfaces were generally planar and oriented as predicted by the classic Mohr-Coulomb failure criteria (45° + $\phi/2$).
- Principal stress envelopes were either curved-linear (uniform sands) or bi-linear (well graded sands). The transition occurred at a point defined as the "critical confining stress" ($\sigma_{crit}$) (Figure 4).
- The critical confining stress is quite sensitive to fibre aspect ratio, grain shape and soil grading, and it reduces with increased aspect ratio (fibre length/diameter) and better grading, but increases with particle sphericity.
- The maximum relative strength gains for the fibre–soil composite occur at confining pressures less than the critical confining stress.
- Shear strength was positively influenced by increasing fibre aspect ratio, fibre content, and better soil grading. Factors such as increasing particle sphericity and $D_{50}$* tended to reduce the fibre contribution to shear strength. Low modulus fibres such as rubber were found to contribute little to the shear strength although they retained better bonding within the soil mass compared to other fibres.
- Shear strength increases nearly linearly with fibre content until it approaches an asymptotic upper limit defined by the confining pressure and fibre aspect ratio.

These studies clearly show that the response of a fibre–soil composite under static loads is strongly influenced by the stress state, soil and fibre characteristics outlined in Section 2.2, and that the introduction of reinforcing fibres to the soil matrix will result in:

- increased peak strength;
- increased strain to reach peak strength;
- reduced degradation of post-peak strength at large strains;
- increased soil stiffness (Figure 3).

Fibre strength is not a critical parameter in terms of the behaviour of the composite material. Of far greater significance are the aspect ratio, elastic modulus, specific surface area and surface texture of the fibres. The fibres increase the resilience of the soil and therefore, to achieve a dense condition, greater compactive effort is required. Once this is achieved, however, the composite material behaves in a superior manner to that of the unmodified soil.

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* $D_{50}$ - sieve size for which 50% by weight of the sample passes.

Figure 3. Stress–strain response of sand reinforced with common basket reed fibres *(Phragmites communis)* (from Gray and Al-Refeai 1986).

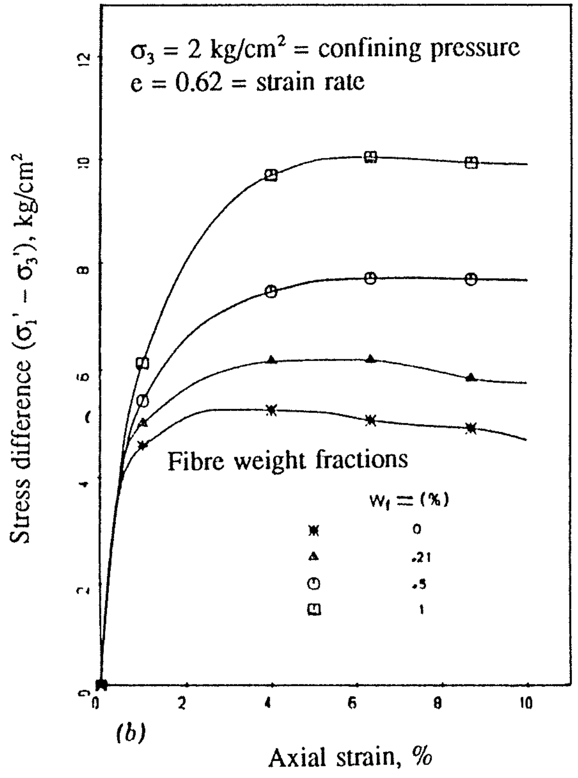
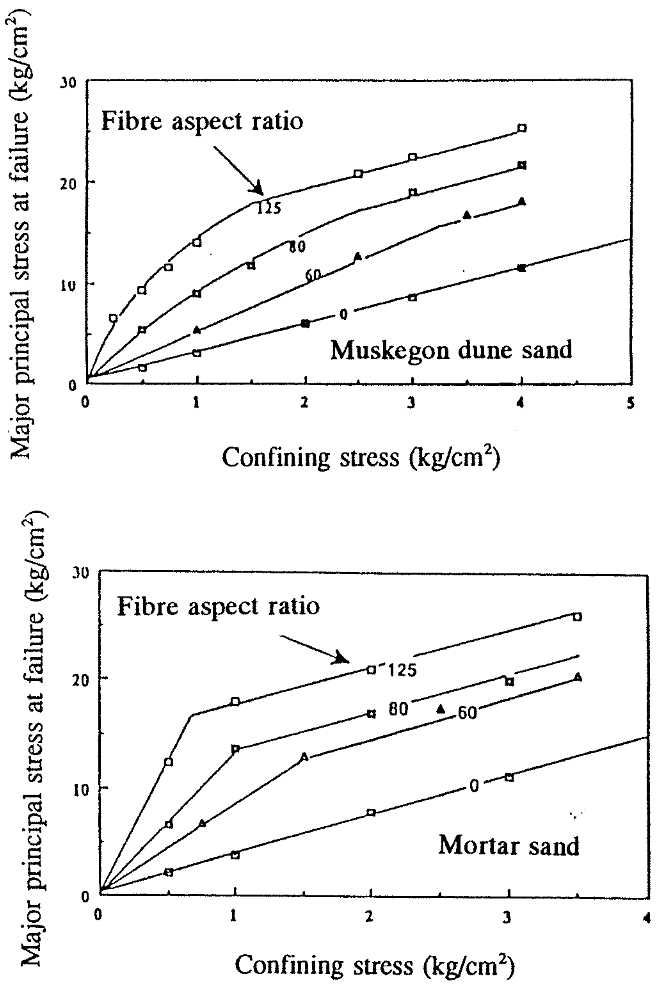


Figure 4. Principal stress envelopes for sand, demonstrating the effect of confining stress and fibre aspect ratio on major principal stress at failure, and the location of "critical confining stress" (from Maher and Gray 1990b).



## 2.5 Dynamic Load Response

The effect of randomly oriented fibres on the response of the composite material to dynamic loading has been assessed in terms of their effect on liquefaction resistance (Noorany and Uzdavines 1989) and of their effect on shear modulus and damping ratio (Maher and Woods 1990a).

### 2.5.1 Liquefaction Resistance

The work reported by Noorany and Uzdavines (1989) demonstrated that the introduction of randomly oriented fibres (0.38% by weight of polypropylene fibre) into a saturated uniform sand of a relative density of ~50%, and tested at cyclic stress ratios between 0.30 and 0.54 until liquefaction occurred, resulted in the following:

- for a given stress ratio the presence of reinforcement increased the number of cycles to liquefaction, particularly for the high stress ratios (Figure 5);
- the amount of strain developed in the reinforced soil was significantly less than that developed in parent soil samples tested under the same conditions;
- following initial liquefaction, the reinforced samples were able to resist several more high stress ratio cycles compared to their unreinforced equivalents.

The same process which serves to increase the required compactive effort in preparing the fibre–soil composite serves to increase the sample's resilience under dynamic loads. This process results in reduced accumulation of strain in each load cycle, and greater recovery of strain between load cycles. As a result of this behaviour the pore pressure increases at a much slower rate, and hence liquefaction resistance is higher when compared with an unreinforced soil specimen.

### 2.5.2 Response Parameters

A parametric laboratory study involving resonant column and torsional shear testing of composite fibre–soil samples was carried out. The effect of dynamic loadings on the shear modulus and damping ratio of the samples is reported by Maher and Woods (1990a). The conclusions made in this study are summarised in Table 2.

In general terms, the presence of randomly oriented fibre reinforcement in granular soils appears to improve the ability of the soil to resist dynamic loading. The resilience of the composite material, i.e. its ability to restrict strain accumulation (accumulated unrecovered deformation, as for example in wheelpath rutting) through the fibre–soil interactions, will be particularly important when assessing the use of this method of soil improvement in pavement construction.

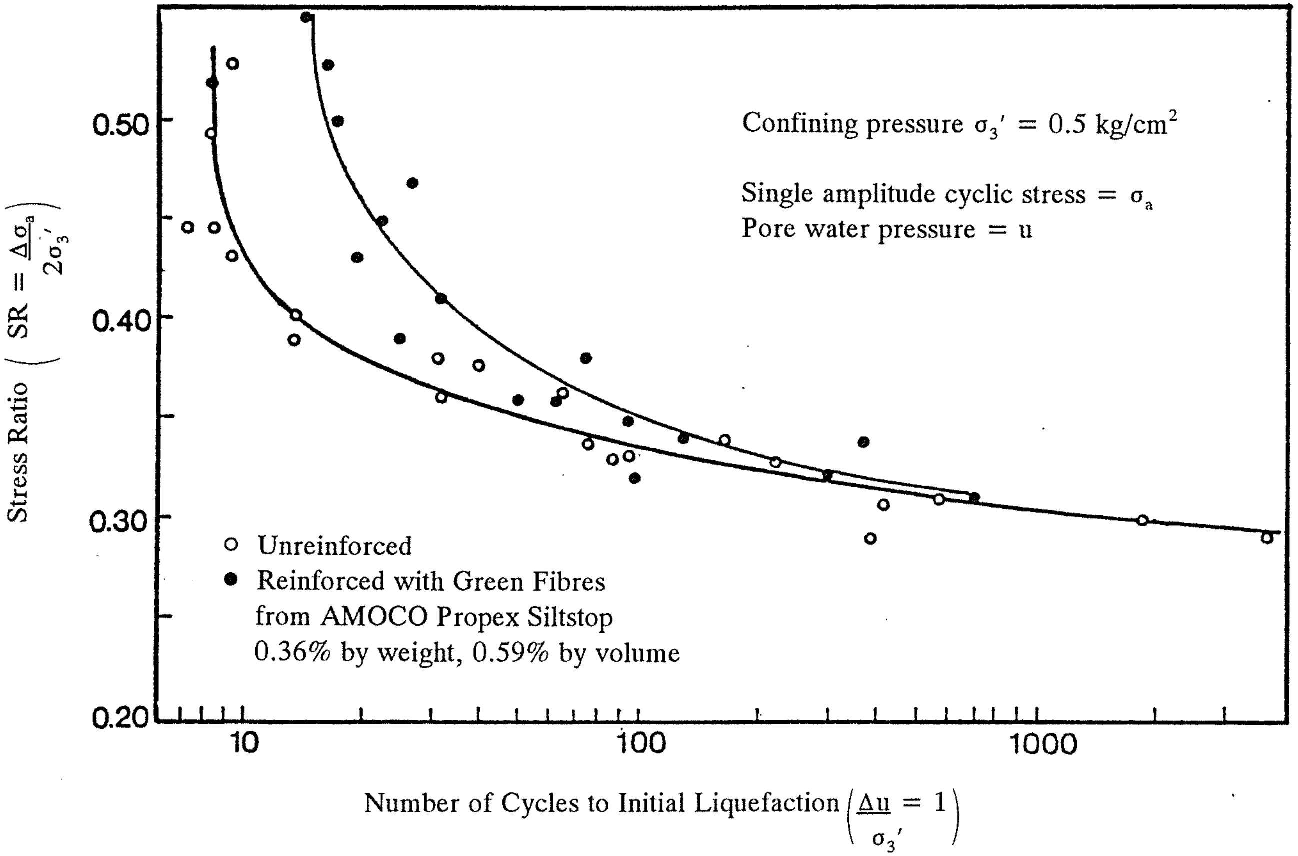
## 2.6 Field Applications

To date (1992), most published studies relating to fibre-reinforced soil have involved only laboratory investigation of the behaviour of the composite material. In this review of international publications, only two papers reported use of fibre reinforcement in a field application.

Table 2. Effects of parameters upon the dynamic response behaviour of fibre–soil composites (from Maher and Woods 1990a).

| Parameter | Effect of Fibres on Shear Modulus | Effect of Fibres on Damping Ratio |
|---|---|---|
| Strain amplitude | Reinforced soil stiffens relative to unreinforced soil as strain amplitude increases. | Reinforced soil has significantly greater level of damping at low strain levels, but approaches that of unreinforced soil with increasing strain amplitude. |
| Confining stress | Stiffens sample. However, contribution from fibres to overall sample stiffness reduces with increasing confining stress as soil particles interlock more effectively. | No effect. |
| Cyclic prestraining | Usually increases sand stiffness. However, resilient nature of composite fibre–soil mix means that effect is reduced because of reinforcing. | |
| Number of prestrain cycles | No effect. | No effect. |
| Fibre content | Increases shear modulus of sample (as for static loading) with a limiting fibre content of around 5%, after which no further improvement is observed. | Effect of fibre content on damping more noticeable at low strains, and diminished with increasing strain amplitude. |
| Fibre orientation (randomly oriented sample tested and compared with sample prepared with fibres parallel to sample axis) | No effect on shear modulus. Statistically the randomly oriented fibres have an expected orientation matching that of the prepared sample (i.e. perpendicular to the shear plane). | No effect on damping ratio. Statistically the randomly oriented fibres have an expected orientation matching that of the prepared sample (i.e. perpendicular to the shear plane). |
| Fibre aspect ratio | Stiffens composite fibre–soil mixture. Higher aspect ratio gives higher fibre surface area, and hence improved fibre–soil interaction. | Increased contribution by fibres but to a lesser extent than for shear modulus. |
| Fibre elastic modulus | Increasing fibre modulus contributes to shear modulus of composite material. More noticeable at lower strain levels. | Damping not affected in fibre modulus range tested. |

Figure 5. Effect of fibre reinforcement on the liquefaction potential of saturated sand (Noorany and Uzdavines 1989).



### 2.6.1 Use in France

TEXOL is a patented product and involves the mixing of a continuous polymer yarn with soil (Leflaive 1988). Although the reinforcing elements are not discrete, the yarn provides tensile resistance in the composite product. Developed in France, most of the field applications have been made there as well. Half of these applications have been in retaining structures where space constraints have precluded more traditional solutions. Other applications included the construction of levees and as energy absorbing barriers protecting roads and construction sites from rock falls. Laboratory and test track evaluations of TEXOL have been carried out to examine its performance under trafficking (both road and rail) loads, the initial results of which have been favourable.

### 2.6.2 Use in Sweden

The Swedish Road and Traffic Research Institute has carried out a study that involved developing methods for the use of sand in road pavements (Lindh and Eriksson 1990). Various methods for stabilising the sand were investigated and test strips were constructed. Included in a field study were two test strips using plastic fibres to stabilise a sand layer. The test strips were constructed on a road which has low traffic volume. The pavement was constructed with a 100 mm layer of sand, stabilised with 48 mm long plastic fibres at 0.25% and 0.5% by weight respectively for each section, and a 100 mm layer of basecourse gravel.

During construction they found that normal shaping methods could not be used in finishing the pavement surface. For this study, final trimming and shaping was carried out using hand tools. However, Lindh and Eriksson (1990) noted that with the addition of suitably modified tools a grader could be used successfully. Compared with an unreinforced sand layer, the fibre-reinforced layer exhibited superior stability, with no rutting of the surface when trafficked. Materials were mixed on site with a concrete mixer.

In the post-construction monitoring period (1988-89), neither pavement had shown any signs of distress. The pavements were to be monitored for a further three years according to the report which was published in 1990.

In stepping from the laboratory to the field, some study will be needed of the preparation of materials, laying, shaping and compaction. Clearly the method could only be considered viable if standard equipment could be used with minimal modifications. More study is required of this consideration.

# 3. IMPLICATIONS IN PRACTICE

## 3.1 Typical Reinforcement Materials

The papers reviewed in the previous section used a wide range of both natural and synthetic fibres (Table 3) in their studies of fibre–soil mixtures.

Table 3. Summary of fibre types referred to in the literature.

| Natural Fibres | Synthetic Fibres |
|---|---|
| • Asbestos | • Glass fibre |
| • Cellulose | • 66 x 7 mm strips of Terram 140 |
| • Reed/cane[1] | • Spun nylon string |
| • Bamboo | • Polypropylene<br>- rope fibre/thread<br>- olefin fibre, "Fibremesh"<br>- "Amoco Propex Siltstop"<br>- "Forta-Fibre Type A-5"<br>- monofilament fibres<br>- fibrillated fibres |
| • Palmyra (palm fibres)[2] | |
| • Rubber (Buna-N)[3] | |

[1] Common basket reed *(Phragmites communis)*
[2] *Borassus flabelliformis*
[3] ASTM D2000

A material that is suitable for reinforcement needs to be durable and inert to survive through the design life of the soil structure in question, which exceeds 25 years for a typical road pavement. Many commercially available synthetics meet this requirement because both geotextile and geogrid manufacturers have carried out extensive investigations to prove the durability of their products.

Natural materials will be less durable and will biodegrade with time. Some of these materials may prove to be suitable either in their natural state for short term applications, or with some form of treatment for longer term applications. Further, natural materials may prove extremely useful in areas where synthetics are unavailable and low technology solutions are required.

## 3.2 Use in Road Pavement Construction

The studies reported in Section 2 dealt with the characteristic properties and response under load of fibre–soil composites. The properties of the unmodified soil were found to improve by the addition of randomly distributed fibre reinforcement.

Fletcher and Humphries (1991) report a comparative laboratory assessment of the effect of silt to which polypropylene fibres had been added, at 0.5, 1.0 and 1.5% by weight, on the California bearing ratio (CBR).

They used three fibre forms. Two monofilaments 0.76 mm dia. x 25 mm long (l/d = 33) and 0.38 mm dia. x 19 mm long (l/d = 50) were used. A fibrillated filament that was also used was a flat rectangular tape, 0.38 mm dia.[**] x 19 mm long, made up of individual monofilaments of a smaller diameter. Results showed a significant increase in the relative CBR values of the modified versus the unmodified soil. There appears to be an optimal fibre content which maximises the CBR gain. While an indicator of increased performance, the CBR gain is unlikely to be directly applicable to current design methods, and more work would be required to assess the significance of the CBR gain.

During the testing, Proctor curves for densities were determined for each fibre–soil mixture. The results indicated an increase in maximum dry density with increasing fibre content under a standard compactive effort. This is contrary to the results reported by Hoare (1979), outlined in Static Load Response, Section 2.4. The reason for this is unclear but may be attributed to the type of fibres or the manner in which the samples were prepared. This aspect warrants further investigation to clarify it.

Given the reported superior properties of soil when reinforced, both in terms of the CBR and the dynamic response characteristics, fibre reinforcing of soils may have useful applications in pavement construction activities.

Further investigation of the dynamic, resilient and fatigue behaviour of fibre–soil mixtures is warranted, as are details relating to construction and economics when compared to currently (1992) used techniques. The system could have benefits where methods such as lime and cement stabilisation are precluded because of environmental problems, property damage, or the negative publicity sometimes generated by these methods.

## 3.3 Use in Earthworks Construction

The improvement in soil properties resulting from fibre reinforcement means that earthworks could be constructed with steeper batters. Materials previously deemed unsuitable may be modified, precluding the need to import expensive quality fill.

In addition, fibre-reinforced soils appear to display larger post-peak strengths under larger deformations than unreinforced soils. This would provide increased safety against sudden large scale failure of soil-filled batters.

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[**] Composite diameter comprised of 0.11 mm stems and 0.08 mm webs.

## 3.4 Cost Comparison

Usually cost will be the overriding factor in deciding upon the viability of this technique when compared with more traditional methods. Synthetic materials are quite expensive, though the purchase of bulk quantities will provide some economies of scale.

The specific advantages of fibre-reinforced soils could warrant their use in special circumstances. Table 4 provides a cost comparison for the synthetic fibrous materials and traditional soil stabilising agents used in pavement construction. The cost in place will depend upon several factors, including rates of addition and construction costs.

Table 4. Costs of stabilising agents compared with fibre reinforcement.

| Reinforcing/stabilising agent | | Material cost per tonne |
|---|---|---|
| Synthetic fibres: | - recycled plastic<br>- chopped polypropylene fibre | \$1,000[1]<br>\$8,000[1] |
| Lime | | \$150 |
| Cement | | \$200 |
| KOBM (slag) | | \$50 |

[1] These figures are those for bulk purchase, e.g. the chopped polypropylene fibres are supplied in 5 kg boxes at the rate quoted, and this cost could be expected to drop dramatically for the large quantities required in a construction application.

For the reinforcement of soil-filled batters, localised patching works, etc, many other factors will decide the economics of using the material being considered.

# 4. CONCLUSIONS

The following conclusions have been drawn from this project:

- Fibre-reinforced soil is considered to have two distinct but related potential uses, namely earthworks stabilisation and pavement stabilisation.

- Under static loading conditions, fibre-reinforced soil exhibits superior strength and deformation characteristics compared to unreinforced soil .

- Under dynamic loading conditions fibre-reinforced soil exhibits a markedly improved behaviour compared to unreinforced soil, particularly in terms of its liquefaction potential at high stress ratios.

- It would appear that knowledge and experience of fibre-reinforced soil is limited to date (1992), particularly of cohesive (non-granular) soils and of field applications outside the laboratory.

- This project has shown that fibre-reinforced soil is worthy of further consideration but it has not yet been shown that fibre-reinforced soil is a practical and economic alternative to traditional methods of soil stabilisation.

  Further knowledge is required before fibre-reinforced soil is a viable method available to practitioners. Transit New Zealand could at some future stage review international literature (and experience) again, paying particular attention to quantitative design and construction methods.

- Alternatively, Transit New Zealand could consider carrying out further research on the practical application of fibre-reinforced soil, which would be a significant undertaking.

  Such further research should include the following inputs for both earthworks and pavement stabilisation:

  - methods to determine optimum fibre dimensions and percentages (by weight) for specific applications;
  - optimum fibre types and their durability;
  - quantitative effect of soil moisture content and compaction;
  - quantitative effects of soil gradation and cohesion;
  - construction methods (including mixing) and equipment, and
  - construction costs.

  After the above outputs have been determined, meaningful comparisons could be made between fibre-reinforced soil and traditional soil stabilisation methods.

## 5. RECOMMENDATIONS

The recommendations are that Transit New Zealand should:

- Review international literature (and also experience) in three to five years time, paying particular attention to quantitative design and construction methods.

- Alternatively, consider carrying out the following further research on the practical application of fibre-reinforced soil, which would be a significant undertaking, as follows:

(1) Quantitatively evaluate the resilience and fatigue behaviour of fibre-reinforced soil under both static and dynamic (traffic and seismic) loading. This evaluation should consider:

  - various types of soils, including cohesive (non-granular) soils;
  - various types of fibres and optimum fibre percentages and dimensions; and
  - both earthworks and pavement stabilisation.

  For pavement stabilisation, fibre reinforcement of cohesive soils is expected to be more worthwhile than that of granular soils. This is because it is considered unlikely that fibre-reinforced granular soils would be more cost-effective than simply increasing the thickness of the unreinforced granular soil.

  Consideration should be given to commercially practicable pavement configurations before extending research to New Zealand laboratory work, trials by CAPTIF, or direct field construction.

(2) Determine methods for mixing, shaping and compacting fibre-reinforced soil. These methods should identify the most appropriate equipment to be used.

(3) Produce technical guidelines for practitioners on the design and construction of fibre-reinforced soil. These guidelines should cover the use of fibre-reinforced soil in both pavements and earthworks..

(4) Undertake comparative studies between pavements which include fibre-reinforced soil and pavements which include materials stabilised by traditional methods such as the addition of lime or cement. Generally the objective of fibre reinforcement would be to produce an improved layer in an otherwise standard pavement.

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