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FABRIC REINFORCED UNPAVED ROAD DESIGN METHODS—PARAMETRIC STUDIES

ETUDES PARAMETRIQUES DE CALCUL DE CHAUSSEES NON REVETUES RENFORCEES PAR DES NAPPES SYNTHETIQUES

PARAMETERSTUDIEN VON BEMESSUNGSVERFAHREN GEOTEXTILVERSTÄRKTER UNBEFESTIGTER STRASSEN

SUMMARY

Using geotextiles for building roads on soft subgrade is now a well accepted construction technique. Besides providing separation, filtration and possibly drainage, the fabric acts as reinforcement by increasing the subgrade bearing capacity, restraining subgrade and aggregate and supporting the load with membrane action. According to most design methods, the aggregate height required is a function of the subgrade strength, permissible rut depth, wheel load, traffic, fabric modulus and load spreading capacity. Results presented show the relative importance of these input parameters and demonstrate that a significant increase in modulus is required in order to benefit from the membrane effect.

ZUSAMMENFASSUNG

Der Gebrauch von Geotextilien in der Konstruktion von Erdstrassen auf weichem Grund ist nun gut anerkannt. Neben Separation, Filterwirkung und moeglicherweise Entwaesserung, geben die Textilien eine Erhoehung der Tragfaehigkeit des Untergrundes, eine Versteifung der Tragschicht und Entlastung des Untergrundes durch M mbranwirkung. Die meisten Berechnungsmethoden geben die Dicke der Tragschicht als Funktion der Scherfestigkeit des Untergrundes, erlaubte Fugentiefe, Radlast, Verkehr, Verformungsmodul des Gewebes und Lastverteilungsfaehigkeit. Die Ergebnisse dieser Untersuchung zeigt die relative Wichtigkeit der Rechnungsannahmen und zeigt dass eine grosse Erhoehung des Verformungsmoduls noetig ist um von der Membranwirkung zu profitieren.

INTRODUCTION

Geotextiles are now an accepted construction material in the establishment of trafficable surfaces on soft clayey, silty and organic soils. The fabrics may serve a temporary role in the development of a sealed pavement structure or they may be used for longer term performance as an integral part of unpaved roads in country areas or as haul roads for civil or mining projects.

As is the case in many other applications, geotextiles in unpaved roads often fulfill more than one of the basic functions of separation, filtration, drainage and reinforcement.

This paper presents comparative results obtained with a number of fairly wellknown design methods. These methods all concentrate on the role of the fabric as structural reinforcements and aim at determining the aggregate height required given the subgrade strength and fabric modulus and allowable tension.

Other geotextile selection criteriae are also important considerations in the overall design process, but will not be discussed here: E.g. those related to opening size, permeability, durability, survivability, workability and other properties.

PERFORMANCE REQUIREMENTS

The overall design of an unsurfaced road must take into account a whole range of factors: bearing capacity, deformation, traffic, climate, drainage, construction problems, geometry etc. The aim of the structural design of unpaved roads is to provide adequate selected cover material in order to prevent bearing failure due to wheel loads and excessive rutting under traffic. Additional problems may be faced during construction, such as general shear failure of the subsoil due to the weight of the fill, impaired mobility of construction equipment, lack of suitable aggregate and excessive settlement.

Design methods as discussed here are only concerned with a rational assessment of the bearing capacity of the soil below the aggregate layer and an estimate of the surface deformation under static and repeated loading by vehicular traffic. The assessment of the overall stability and settlement of the fill during and after construction is expected to be treated as a separate problem according to standard soil mechanics principles.

The design procedures discussed also assume that good aggregate quality (CBR>80) is preventing failure within the base course and that the fabric is effective as a separator.

UNPAVED ROADS WITHOUT FABRICS

Hammit (5) proposed a formula for determining the thickness of aggregate required for unsurfaced roads and airfields so as to produce a rut depth less than 3 inches (or 75mm). According to Hammit, the design thickness is a function of the number of coverages N of an equivalent single wheel load and the tyre contact area. Based on Hammit's empirical relationship and work by Webster and Alford (13), Giroud an Noiray (3) suggested a similar but simpler formula, which they proceeded to modify so as to allow design for other than standard axle loads and for different rut depths. Hammit's design will be referred to as Method H, and if amended according to Giroud and Noiray as Method HG. Details of these and other methods are given by Hausmann (6).

UNPAVED ROADS WITH FABRICS

The reinforcing action of fabrics on the unpaved road structure is interpreted in one or more different ways, referring to bearing capacity, aggregate and subgrade restraint and membrane action.

Firstly, the fabric is seen to influence the failure mode. Terzaghi already recognized that in very soft soils excessive deformation can occur at stress levels below that indicated by the traditional bearing capacity formula. He then proposed to differentiate between local shear failure, where plastic flow or densification of the soil cause large settlement without noticable bulging at the surface, and general shear failure, characterized by recognizable failure planes extending from the edge of the loaded area to the ground surface. The placement of a fabric on soft subgrade appears to have the effect of forcing a general shear failure where otherwise a local or punching type failure would occur. This has the effect of increasing the bearing capacity factor N_c from about 3 to 5 or more. Different authors may not agree as to its physical interpretation, but the fabric induced increase in bearing capacity seems to be well accepted.

Secondly a fabric is seen to provide restraint of the aggregate and the subgrade, if placed at their interface. Design procedures may take this effect into account by an improved load distribution capacity, sometimes referred to as slab effect. The tangent of the angle of spreading the surface load through the aggregate is referred to as the load distribution factor. It is of course also a function of the integrity of the aggregate itself.

Thirdly, subsidence associated with wheelpath rutting can develop tension in a fabric built into the road structure. This is particularly the case with high modulus fabrics with sufficient soil-fabric friction to develop an anchorage zone outside the loaded area. The upward resultant of the tensile forces in the deformed geotextile partially supports the wheel load and reduces the stress on the subgrade. This kind of reinforcement is termed "membrane support".

Fabrics are rarely placed within the subgrade itself. The reinforcing effect of fabrics within the subgrade would be small, because of the necessary disturbance of the soil before placement and the low soil/fabric friction and adhesion which could be expected in soft soils. Most common is the placement of the fabric at the aggregate-subgrade interface, in order to take advantage of all fabric functions. But if reinforcement of the aggregate is critical, an additional fabric layer may be placed within it. This may be economical where aggregate is expensive or of doubtful quality.

SELECTED METHODS OF DESIGN

One of the first design methods (1975) was Barenberg et al's (2) original approach, based on laboratory studies using non-woven fabrics. It relied on the observed improvement of the bearing capacity of the subgrade and a reduction of subgrade stress levels due to the presence of the geotextile.

Steward et al (11) of the U.S. Forest Service studied the performance of non-woven fabrics in a test road and concluded, like Barenberg, that there is an increase in bearing capacity and reduced severity of rutting with the use of geotextiles.

The analysis of full scale tests conducted by the U.S. Army Engineer Waterways Experiment Station (12, 13) with non-woven and woven fabrics indicated better performance of high modulus (woven) fabrics than low modulus (non-woven) fabrics with respect to rutting under traffic. This finding was verified by laboratory studies and theoretical analyses by researchers such as Kinney (7) and others and led to the inclusion of the membrane effect in design procedures. Initial methods such as proposed by Barenberg in 1980 (1), Giroud and Noiray in 1981 (3) and Raumann in 1982 (8) assume a particular shape of the deformed geotextile and incorporate various empirical findings. Rather than assuming the geometry of the fabric deformed by rutting, Sellmeijer, Kenter and Van den Berg (10) derived an analysis based on structural membrane theory. Their solution satisfies equilibrium of both, the membrane as well as the subgrade.

Ignoring membrane support and emphasizing correct location of the fabric for maximum lateral restraint, is the design method proposed by Haliburton and his co-workers (4).

For a detailed discussion of these methods, refer to Hausmann (6).

COMPARATIVE RESULTS

Microcomputer programs were written for a number of the above mentioned design methods in order to compare their results and assess their sensitivity to changing input parameters. It was attempted to analyze the case of a standard axle load of 80 kN using different methods of analysis. Dual wheel assemblies were assumed, with a tyre pressure of 480kPa, giving an effective contact pressure of 340kPa. A range of additional variables had to be determined for some of the design methods which may make the problems solved not exactly equivalent, but near enough for a valid comparison. In the following discussion, the effect of varying load, number of passes, load distribution factor and fabric modulus is looked at in detail for specific cases of fabric, soil properties and loading.

In the figures letters denote particular design methods as follows:

- H - Hammit (no fabric)
- HG - Hammit, as modified by Giroud & Noiray
- B - Barenberg (incl. membrane support)
- GN - Giroud and Noiray
- S - Sellmeijer et al

Figure 1 shows a typical design graph produced by the computer. It gives the aggregate height required for a subgrade strength expressed in terms of cohesion, for a rut depth of 0.075m. Note that the undrained strength of clay is approximately equal to 30 times the CBR (California Bearing Ratio). Curve H gives the aggregate height necessary without fabric. Curves S and GN are both based on a load distribution factor of 0.6, which is equivalent to an angle of load spreading of 31 degrees. The fabric assumed is a typical non-woven with a modulus of 20 kN/m. Preparing a number of design graphs for 100 passes of a load of varying magnitude but with the same overall configuration, allowed to plot Figure 2; a cohesion of 20 kPa was chosen for comparing the results. It illustrates a very strong influence of the magnitude of the load on the required aggregate height. With increasing load the relative difference between the design methods decreases.

Figure 3 shows the effect of the number of passes of the standard axle load. Input data includes a rut depth of 0.075m, a cohesion of 20kPa and for Methods S and GN a medium fabric modulus (192 kN/m). Curve S is assuming a very conservative load distribution factor of 0.5 and thus gives aggregate heights in excess of Hammit (H). A load distribution factor of 0.6 is standard for Method GN.

Figure 4 shows the effect of varying the load distribution factor in the Giroud and Noiray analysis. This is not as recommended by these authors, but it is of interest to compare these results with those obtained according to Sellmeijer et al in Figure 5. A rut depth of 0.075m, 100 passes and a modulus of 1400 kN/m are assumed. Both methods, but particularly Method S show a highly significant effect of the assumed load distribution factor. Experimenters and theoretical analysts have so far paid relatively little attention to the importance of load distribution, or the so called slab effect.

Figure 6 gives the design curves for the case of a fabric with a modulus of 800kN/m, 100 passes of the standard axle load and a rut depth of 0.15m, the latter being relatively large for design purposes, but chosen to accentuate the effect of the fabric modulus. Method S assumes a load distribution factor of 1. It can be seen that the results obtained according to Barenberg, Sellmeijer et al and Giroud and Noiray are very similar for a large range of subgrade values.

Finally, Figure 7 illustrates the effect of modulus on the required aggregate height for conditions as used for Figure 6. Despite theoretical differences, the membrane effect appears to be of similar magnitude in all three methods. It is apparent that a very large increase in modulus is required in order to make the membrane effect significant in relation to the effect of other variables.

CONCLUSIONS

The structural reinforcing effect of fabrics is not the only aspect to be considered in the design of unpaved trafficked areas, but currently available design methods provide a useful guide in the endeavour to provide adequate bearing capacity and resistance to excessive rutting under traffic. It was shown that several of the design methods give comparable results for certain conditions, yet some of the basic assumptions to be made, such as the load distribution factor, have a very significant effect of the results of the computations. Assumed axle load and number of passes chosen for the design are also most important, while a large change in fabric modulus is required to significantly affect road performance, even at a relatively high rut depth.

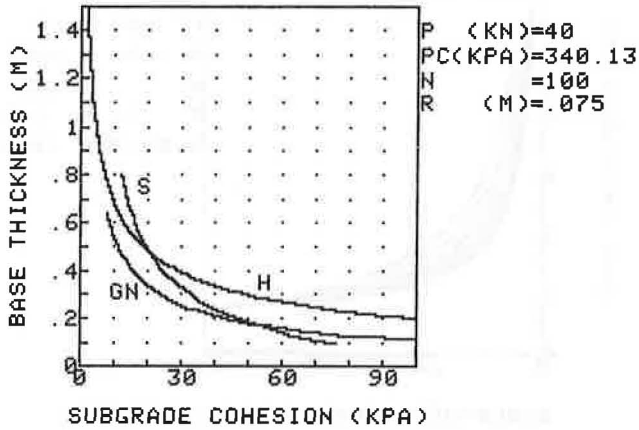

Fig.1 Aggregate thickness design charts

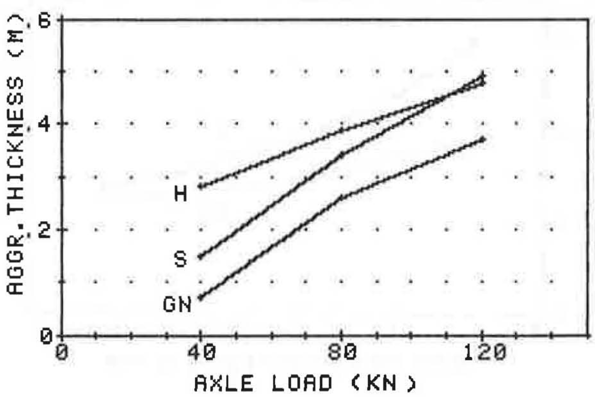

Fig.2 Effect of axle load on aggregate thickness

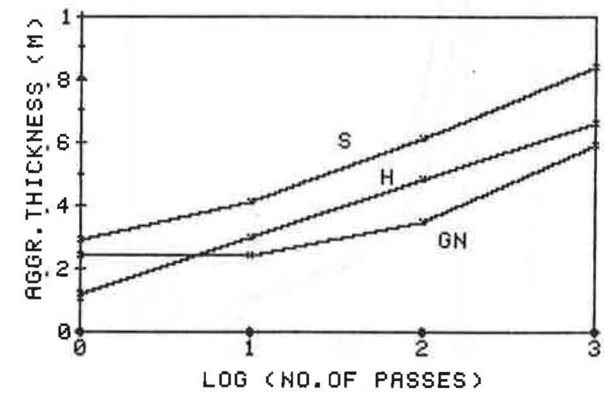

Fig.3 Aggregate thickness as a function of the number axle loads passing

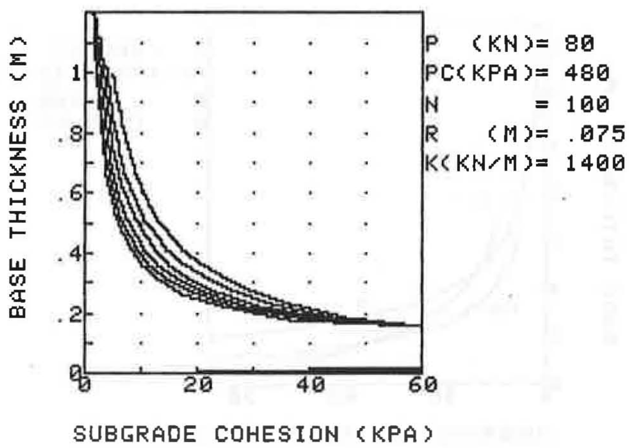

Fig.4 Giroud and Noiray design charts for various load distribution factors

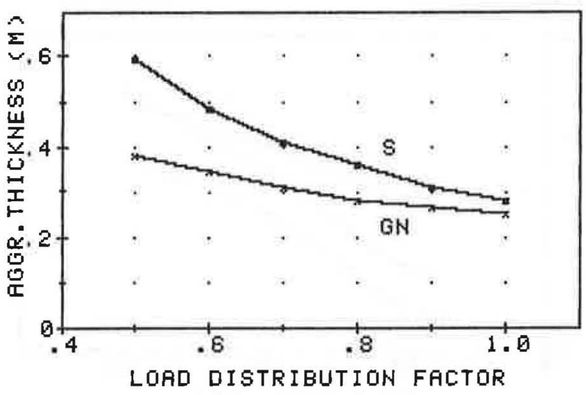

Fig.5 Aggregate height vs. load distribution factor

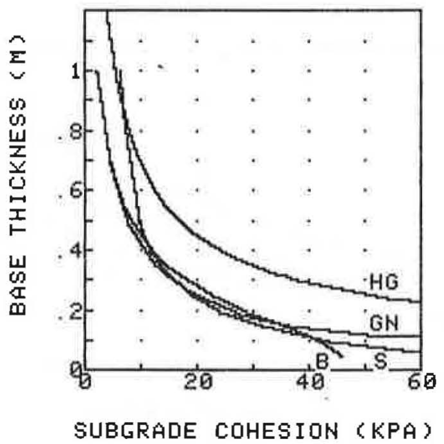

Fig.6 Design charts for fabric modulus of 800 kN/m

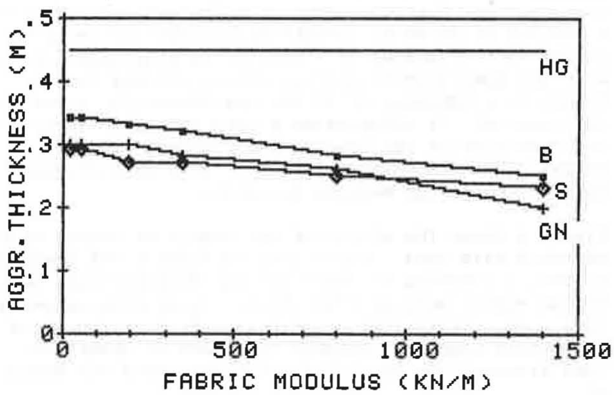

Fig.7 Effect of modulus on required aggregate height (rut depth 0.15m)

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