C.R. Coll. Int. Sols Textiles. Paris 1977

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The use of plastic fabric for pavement protection during frost break

Kunstoffgewebe als Belagschütz während des Auftauens.

In diesem Rapport werden behandelt numerische Analyse, eine Modellstudie im Laboratorium und eine Untersuchung in einem Versuchsgrübchen im vollen Maßstab. Verschiedene zweischichtige Systeme, mit dem Untergrund aus frostgefährdetem Material und darüber eine Schicht Reibungsmaterial, dazwischen ein Kunststoffgewebe, wurden dabei untersucht. Gegen jede Kombination stand ein Kontrollsystem ohne Gewebe.

Die Modellsysteme wurden mit einer dynamischen Plattenbelastung mehrere hunderttausend Male belastet. Der Lastmodul und das bestehende Einsinken wurden vermessen. In dem Versuchsgrübchen, wo die Oberfläche von einer dünnen Bitumendecke geschützt war, wurde jeder Ansatz zu Rissbildung notiert. Nach der Belastungsphase wurde die Grenzfläche zwischen den zwei Schichten analysiert um Wanderungen der Feuchtigkeit und des Untergrundmaterials festzustellen.

Ganz genommen haben die Ergebnisse keinen eindeutigen Einfluss des Kunststoffgewebes auf den Lastmodul erwiesen, dagegen wurde bedeutender Einfluss auf die Dauerfestigkeit beobachtet. Das Gewebe erwies einen gewissen Einfluss auf die senkrechte Wasserbewegung und bedeutenden Wiederstand gegen die Wanderung des Untergrundmaterials.

Introduction

The present report gives a brief review of work done by the author and coworkers on various aspects of the use of plastic fabrics in road building. The aspects treated are

- bearing capacity, including endurance under repeated load
- subgrade soil migration
- subgrade dewatering.

Studies have been conducted in three phases: computations of different bearing capacity parameters using multilayer elastic theory, laboratory model studies and a pilot study using full scale thicknesses of layers.

In Sweden fabric of different types and from different manufacturers have been used for several years in temporary transportation applications, where the surface of the ground has not been trafficable without special treatment. In road design the potential use of protective fabrics is for protection of soft subgrades during the frost break period. During this period frost susceptible subgrade materials are heavily enriched in liquid water, which reduces their bearing capacity to a fraction of normal, and the softened subgrade material may easily migrate into adjacent pavement layers, thereby rendering the invaded regions frost susceptible.

The standard procedure for protection against soil migration is to give the lower part of the subbase layer filtering properties. This usually implies insertion of a 15-20 cm protective sand ifilter layer. This sand layer gives some contribution to the bearing capacity of the road, but this is not accounted for, since soil particle migration will result in increased water content and consequently reduced bearing capacity of the protective layer during frost break. The report discusses to some extent substitution of fabric for this sand filter layer

Analytical approach

In the analytical approach the following four multi-layer elastic models were analysed.

Layer number	Model number			
	1	2	3	4
1	bit stab layers	=1	bit stab layers	=3
2	gran base	=1	crushed rock	=3

(continued)

Layer number	Model number 1	2	3	4
3	subbase 1	=1	–	–
4	subbase 2	fabric	filter layer	fabric
5	subgrade	=1	subgrade	=3

The thickness (cm), and elastic modulus (MPa) of the various layers are given in the following table:

	1	2	3	4
1	25,1000	25,1000	10,1000	10,000
2	10, 500	10, 500	50-60,500	50, 500
3	20 200	20, 200		
4	25 120	0.2 5000 10000	15, 200	0.2 varied
5	inf 80	inf 80	inf 80	inf 80

The ordinary layers were assigned a Poisson's ratio of 0.35, and the fabric was nominally given a value of 0.4, this strictly being meaningless but nevertheless required by the computer program. The two values of elastic modulus of the fabric were suggested by the manufacturer. The value 80 MPa of the subgrade modulus does not reflect frost break but rather the dry part of the year, which bears the majority of the traffic.

The load was set at 50 000 Newtons (5 tons) which would correspond to one wheel in a 10 ton axle arrangement. The tyre pressure was set at 0.6 MPa (six times atmospheric) which is fairly common in Sweden. Computations were made by using the BISTRO program, and the parameters recorded were horizontal strain at the lower interface of the bitumen bound layers and the vertical compressive strain on top of the subgrade.

Model 1 is a pavement structure built according to Swedish standard specifications, and model 2 is the same structure, but the sand layer on the subgrade being replaced by the fabric. The result of the analysis of these two models is shown in table 1.

The strains listed in the table are given in units of microstrain, i e one millionth (1% of strain = 10 000 microstrain). All the strain values displayed in the table are from critical, i e they would allow several million passages, if interpreted in terms of fatigue of road structures. Absolute values are however of secondary interest in the present study, whose purpose was comparison between systems with and without protective fabric.

It is seen that the horisontal strains in table 1 are practically influenced by the substitution of a fabric. The vertical subgrade strains increase from 238 microstrains under the conventional construction to 342 and 370 microstrain respectively after the introduction of a fabric with the properties assumed. This increase in strain is according to known data equivalent to a decrease in the number of passages to fatigue failure by nearly one order of magnitude, all other properties being assumed equal. This decrease in fatigue strength of the structure could easily be compensated for by assuming a slightly increased thickness of the subbase or by disregarding part of the thickness of the sand layer, which is most probably infiltrated by subgrade material. This line was however not pursued, since the main interest is the protection of crushed rock layers. The result of this analysis is shown in table 2, which also shows the horizontal tensile strain in the upper face of the subgrade.

This table also shows a negligible influence upon the strain of the bitumen bound layer, when the protective sand layer is replaced by fabric of quite different assumed moduli. Obviously the choice of protective layer has quite limited influence upon this tensile strain and can therefore be neglected.

The compressional strain of the subgrade shows a more pronounced variation with the properties of the protective layer, including different fabrics. On the other hand the simplified model has its greatest deviation from relaity in this region, the interface being far from a mathematical plane. In reality the subbase stones will penetrate into the sand layer and make its real thickness at many points smaller than in the model, thus jeopardizing its contribution to bearing capacity. The fabric on the other hand, if not punctured by the stones, will suffer very little change in thickness under the influence of the stones.

The radial strains shown in the table are quite small, but tensile. These strains may in actual fact have a much more destructive action in fatigue cracking of the subgrade than the vertical compressional strains. The fabric on the other hand will not be impaired by these tensile strains, and they may have a protective action in preventing cracks from propagating across the subgrade/subbase interface. This can be considered as a reinforcing effect of the fabric, which has been observed in other applications.

Laboratory model study

In this study a two-layer system, compacted in CBR-cylinders was subjected to repeated loading in a laboratory fatigue tester. Two CBR-cylinders were placed on top of oneanother, the bottom cylinder being filled with a subgrade material, and the top cylinder containing a standard subbase material up to a level of 10 cm. A fabric was clamped between the two cylinders. Each system tested was accompanied by a dummy system, having an ordinary fishnet clampled between the cylinders for indication of the position of the boundary layer.

The load was applied to a 50 mm diameter circular plate located at the centre of the free subbase surface. The load pulses were approximately rectangular and had a frequency of 10 Hz. The load amplitude was given a value which produced a computed vertical pressure of 0.08 kp/cm² on the subgrade surface. To each model system about a quarter of a million load pulses were applied, and instantaneous and permanent deflections were measured, while the load amplitude was monitored.

The subgrade material was a silty material known to be very frost susceptible, figure 1. Four different experiments were run, corresponding to four different subgrade water contents, each being accompanied by a dummy test with a fishnet instead of the fabric. The fabric used was one of the ICI products named Terram. After completion of loading the water content and the fine material content (< 0.074 mm) in the subbase layer adjacent to the subgrade interface was measured. In order to make possible computation of the total water transport, the subbase layer was divided into three layers for analysis of water content.

The results of this preliminary study are concensed in table 3. Tests were made at 4 different subgrade water contents: 20, 23, 26 and 30 %. Judging from the measurements of permanent deflection the system retained its original state at the three lower subgrade water contents, whereas at 30 % the system yielded after a certain number of load repetitions. The unprotected subgrade (8) yielded after 108000 load repetitions, whereas the fabric protected system endured to 216000 repetitions. In the pre-yield region represented by the four lower water contents the permanent deflection was quite limited, the differences recorded probably being due to experimental variations rather than the presence of the fabric. The rebound deflection, not recorded in the rable, showed no significant difference due to the presence of the fabric, illustrating the previous finding that in the pre-yield region the fabric has very little influence upon the deflection properties of the system

The water migration was obviously somewhat delayed by the fabric. Comparison with the filtering properties of the subbase material would have required a more detailed analysis of the mousture gradient in the subbase than was reasonable within the scope fo this study.

The migration of fine material was in most systems higher without fabric, in the yielded state (systems 7 and 8) considerably higher, quantifying the filtering action of the fabric.

The actual reason for the earlier failure of the non-protected system (8) cannot be deducted from the present study, but it was probably due to infiltration of water and subgrade material into the subbase, thus reducing the resistance of the system against loading, especially the subbase layer. The results obtained suggest further experiments along the same lines, based on the experience gained in this preliminary study.

Pilot study

The pilot study was carried out in a test pit at Stockholm Domestic Airport. Five test sections, 2 1/2 by 2 1/2 meters horizontally and vertical extension according to standard specifications were built. On a common imported subgrade of the silt material shown in figure 1 three road structures were laid

1. Conventional pavement with subbase and granular road base
2. Pavement with brushed rock base layer
3. Simulated gravel road strengthened by a 15 cm overlay.

Structure 1 had a fabric on the subgrade, structure 2 was built in two versions, one with a 15 cm protective layer and the other with a fabric on the subgrade. Structure 3 was also built in two versions, one with a fabric on the gravel road surface and one without any protective layer. Structure 3 was ment to find the protective action of the fabric in gravel road strengthening, i e protection against infiltration of the overlay from the small particle fraction of the road gravel and the existence of a possible reinforcing effect of the fabric under repeated loading. The intention was thus to study the effect of the presence of a fabric in conventional structures. Due to lack of space structure 1 could not be compared with a dummy structure without fabric.

The subgrade material was laid on a drainage layer, which was connected to a water pit, providing a constant water table 90 cm below the common road surface. All the test sections had a common wearing course: asphaltic concrete HAB 16 according to Swedish standard specifications. A longitudinal section and a horizontal view of the test pit are shown in fig 2.

The sections were provided with frost depth meters, settlement meters and temperature gauges, and the whole system was heat insulated in all directions except upwards. The road surface was subjected to freezing by blowing a stream of cold air from a refrigeration machine along the road surface for a period of several months. The temperature of the cold air was -12°C and the frost situation was monitored continually. As soon as any section had its frost limit at a depth of 40 cm below the subgrade surface, foam plastic was inserted in order to prevent frost penetration at any deeper level.

When the frost level was reached in all sections, the stream of cold air was replaced by a stream of hot air for thawing, and as soon as all sections had reached a temperature well above freezing point measurements were started. During this time there arose a heat wave in central Sweden, and the whole system reached a temperature of nearly 20° centrigrade in a short time. All the sections were subjected to static loading for measurement of plate bearing capacity and also to dynamic plate loading for measurement of rebound modulus under cyclic load at 16 Hz. Then all sections were subjected to dynamic loading at 16 Hz for a considerable time, and the permanent as well as the rebound deflection were recorded.

Permanent deflection plotted against time using logarithmic scales usually gives an inflexion point in this type of experiment. This inflexion point precedes an accelarated rate of permanent deflexion and is therefore taken as an indication of a change of the nature of the deflection mechanism, for simplicity denominated as "yield". After finished repeated loading the road surface was inspected, and at all test points subjected to repeated loading cracks had developed near the edge of the loading plate. Repeated loading was exerted by a heavy vibrator applying a sinusoidally varying force to a circular plate of 30 cm diameter on the road surface.

The results of the deflection measurements are condensed into tables 4 and 5, showing the dynamic and static moduli and the number of load repetitions to yield. Comparison of the moduli found in table 4 should be made by comparing sections 1 and 2 mutually and sections 3 and 4 mutually. Considering the standard deviation that actually occurred the differences are not significant. The static moduli would indicate a higher bearing capacity in the structures without fabric, which could make sense in the case of sections 3 and 4, one having a 15 cm sand layer, but definitely not in the case of sections 1 and 2, where the only difference is the presence of a fabric, which could not possibly cause a decrease in the static modulus. The differences observed have to be ascribed predominantly to structural variations.

Considering table 5 there is a definite increase in life time when comparing sections 1 and 2, the section with the fabric having more than doubled life time, which was confirmed by making measurements at two points in section 2. Comparison of sections 3 and 4 shows equal life time, but the dynamic load amplitude was higher in section 3 which contained the fabric. The difference in amplitude is due to a limitation in the loading equipment, which did not allow continuous variation of the amplitude.

Praticle size analysis of the layers adjacent to the subgrade showed no migration through the fabrics. Section 1 indicated migration from the gravel road, whereas in the other sections no migration was found. After the thaw period the water table had migrated through the subgrade level in all sections, which proved that no clogging had occurred.

Conclusions

From this review it can be concluded that

1. The influence of the fabric on the elastic deflection of multi-layer road pavement systems is limited or negligible
2. The influence of the fabric upon the occurence of failure is considerable
3. The fabric allows water migration from a wet silty subgrade material, although less than in the absence of any filtering material
4. The fabric has a considerable filtering effect in preventing the migration of fine particles, even smaller than 0.074 mm.
5. It is possible to study some of the important mechanisms of the filtering action and its consequences on deflection properties using simple laboratory models.

These conclusions are of course limited to the product studied, but certain extrapolations could be made to similar products and similar soil materials.

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Table 1

Analysis of models 1 and 2: conventional structure

Thickness of subbase lower layer	Modulus of subbase lower layer	Thickness of fabric	Modulus of fabric	Hor strain at bottom of bit stab layer	Vertical compression at top of subgrade
Millimeters	Megapascal	Millimeters	Megapascal	Microstrain	Microstrain
250	120	-	-	168	238
-	-	2	10 000	168	342
-	-	2	5 000	170	370

Table 2

Analysis of models 3 and 4: crushed rock structure

Elastic modulus of fabric	Thickness of macadam layer	Horizontal strain at bottom of bit layer	Vertical compression at top of subgrade	Tensile strain
Megapascal	Millimeters	Microstrain	Microstrain	
5 000	500	182	318	113
3 000	"	181	328	119
2 000	"	181	332	123
1 000	"	181	338	1 6
500	"	181	340	1 8
300	"	181	342	129
200	"	181	342	129
0	"	181	342	129
3 000	600	185	248	91
2 000	650	186	222	82
1 000	650	186	226	84
-	550	183	222	87
-	500	184	250	98

150 mm sand layer on subgrade

Table 3

Summary of results of laboratory model study

System number	1	2	3	4	5	6	7	8
Subgrade water content %	20	20	23	23	26	26	30	30
Fabric/No fabric	F	N	F	N	F	N	F	N
Number of load applications (thousands)	216	216	216	216	252	252	216	108
Computed pressure on subgrade, Kp/cm²	0.08	0.08	0.08	0.08	0.08	0.08	0,08	0.08
Fine material (<0,074 mm) content before and after loading (%) change	2.2 3.8 1.6	2.0 3.3 1.3	2.3 3.5 1.2	2.3 4.4 2.1	2.3 4.0 1.7	2.2 4.0 1.8	2.4 3.9 1.5	2.3 5.8 3.5
Permanent deflection, mm	1.0	0.5	2.0	1.0	3.5	2.4	24	38
Water migration to subbase, ml	0	0	13	17	17	30	42	72

Table 4

Dynamic and rebound static deflection at frost break. Static load 11.6 kN, frequency 15 Hz. Pavement temperature 18.4°. Water level 260 mm below surface.

Section	Fabric	Cyclic load kN	Cyclic defl mm	Modulus N/mm²	Static rebound deflection			
					First load		Second load	
					defl	modulus	defl	modulus
1		8.9	1.05	27.0	0.87	42.5	0.86	43.0
2	F	7.4	1.00	23.5	1.19	31.1	1.19	31.1
3	F	9.5	1.00	30.3	0.65	57.0	0.63	58.5
4		9.0	0.85	33.9	0.56	66.0	0.40	75.5
5	F	0.80	0.80	27.9	0.42	88.0	0.43	86.0

Table 5

Repeated loading at frost break. Number of loads to yield, characterized by deviation from linearity of the log deflection/log number of loads curve.

Section	Fabric	Dynamic load ptp kN	Thousands of load applications	Temperature °C
1		9 - 12	60	18.4
2	F	10 - 11	140	18.4
2	F	10 - 11	140	15.4
3	F	9 - 10	190	15.4
4		6 - 7	190	15.4
5	F	7 - 10	30	

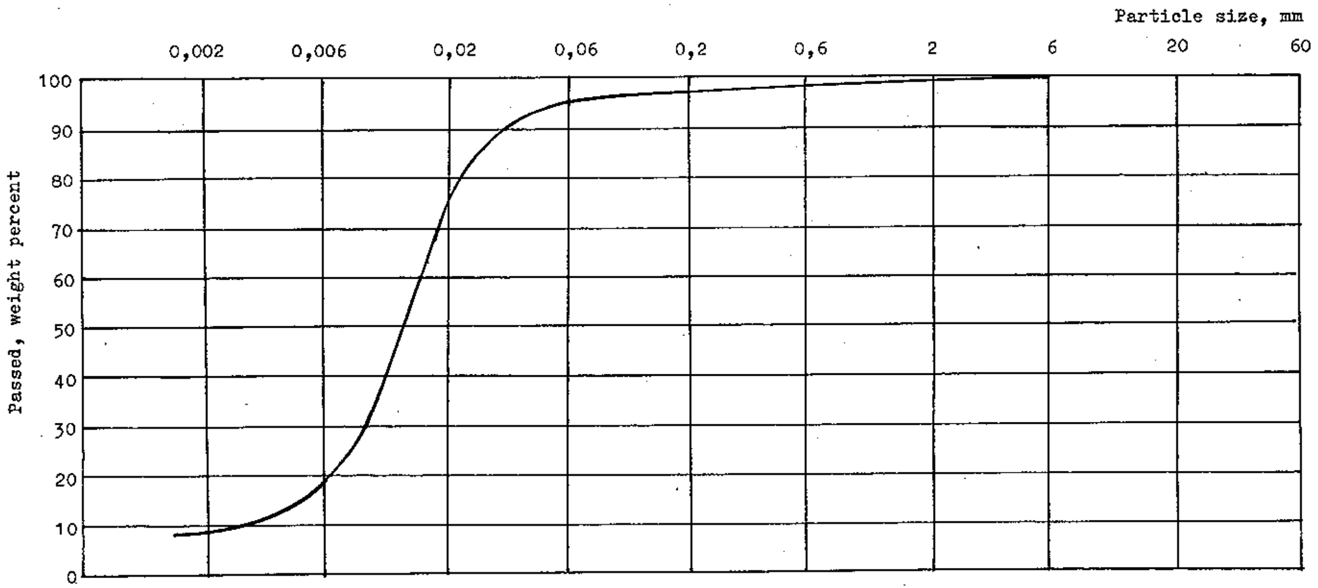

Fig 1: Grading curves of the material used in the artificial subgrade

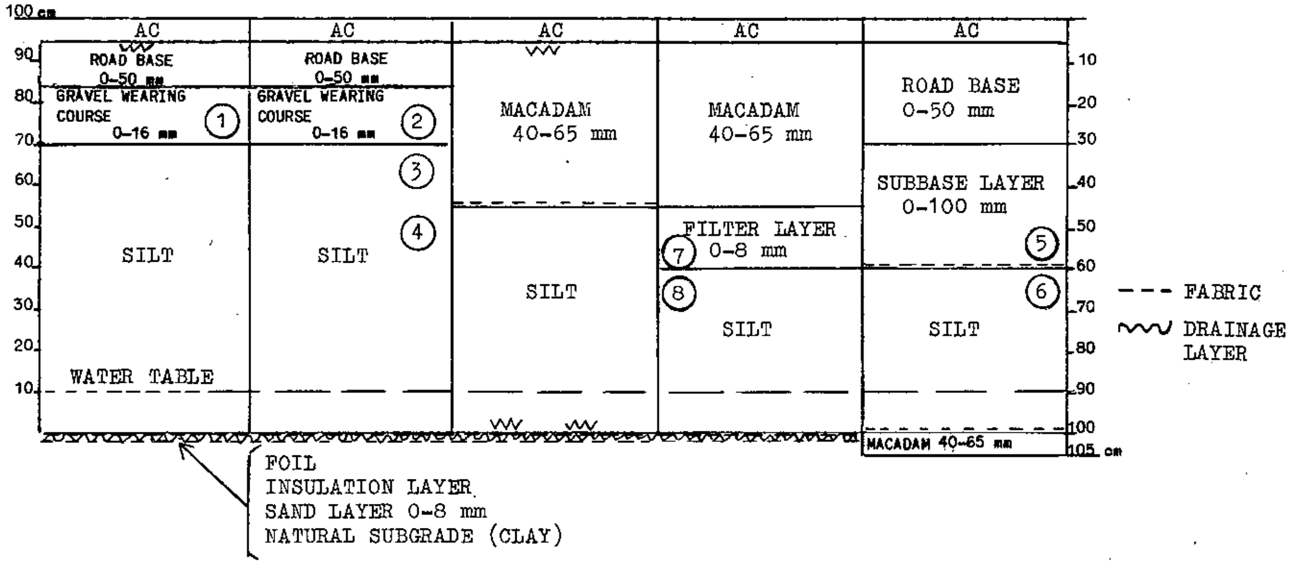

Fig 2a: Longitudinal section of test pavements. Figures in circles indicate samplingspoints.

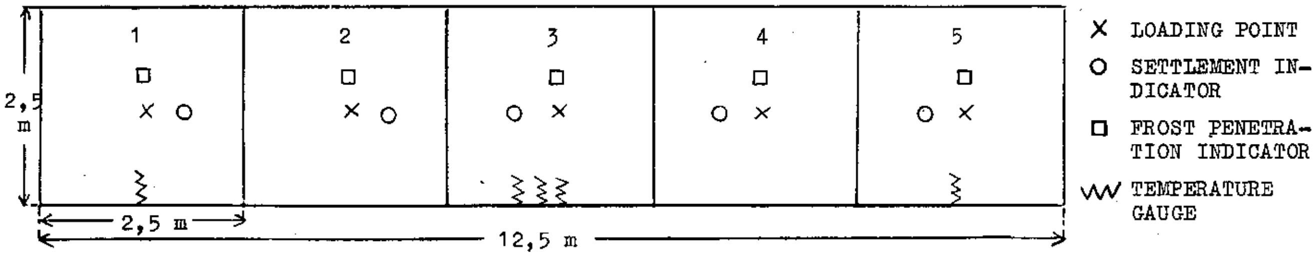

Fig 2b: Plan of test pavements.