BRANTMAN B.P., KAZARNOVSKY V.D., POLUNOVSKY A.G. and RUVINSKY V.I.
Soyuzdornii, USSR

Experiments on the use of synthetic non-woven materials for road structures

Expériences sur l'utilisation de non-tissé synthétique dans les ouvrages routiers

RÉSUMÉ On a décrit les essais sur utilisation du non-tissé Bidim dans les ouvrages routiers, réalisés en 1975. On a construit trois planches d'essais: un remblais sur terrains marécageux, deux structures dans un déblai humide inclu une planche avec le sol enveloppé par le matériau traité au bitume. Cet essai a pour but l'assurance de résistance et de stabilité de la chausseé à l'utilisation du sol argileux local au lieu du sable d'apport et également l'amélioration de dimensionnement du sol de couche de forme du fait de l'elimination de son decompactage au cours de l'exploitation des routes. D'aprés les premiers résultats des observations sur la densité et la teneur en eau du sol, des performances des chaussées etc. on a pu constater que l'emploi des non-tissés pour les buts prévus était progressif. Toutefois, on ne peut tirer une conclusion définitive qu'aprés les études ultérieures.

In recent years difficulties in delivery of imported soil and the necessity in reducing the volume of earth works encounter more and more often in road construction. This fact concerns both the imported soils for embankment construction and the imported sands and sandy gravels for draining and frost-resistant layers, bases and temporary road pavements.

One way to reduce the volumes of imported soils needed is the use of non-woven synthetic materials. The latter are used: on sections with bases of low bearing capacity to provide the passage of vehicles; to prevent the granular materials and subsoil from mixing together; to prevent silting up the drainage structures and the frost-resistant and draining layers; and also as a toe-filter in structures of slope reinforcement.

Non-woven materials for road construction should have the following properties: mechanical tensile strength, sufficient permeability, capability to retain fine soil particles, resistance to chemical and biological attack.

One of the widely used materials meeting all these requirements is the non-woven synthetic material "Bidim" produced by the French company "Rhône-poulenc-textile".[X)] It was the very material that was used in experiments carried out by Soyuzdornii together with the company in 1975.

The aim of the experiments was to study the effectiveness of using the non-woven material for embankment construction under difficult soil and hydrological conditions.

[X)] MM. Godar I. and Kurashova T., representatives of the company, took part in this work.

For these experiments, some 10 000 m^2 of "Bidim", including the bitumen treated one (called "Coletanche NT" in this case), and 400 m of drainage pipes from PVC with filters of "Bidim" were supplied by the French company.

Grades "U-34" and "U-44" of the material 3.4 and 4.4 mm in thickness and 300 and 400 g/m^2 in mass, respectively, were used in the experiments. Tensile strengths of the materials were from 10 to 22 kgf/cm^2 and relative elongations at rupture were from 50 to 70 percent. Radial permeability was $3 \cdot 10^{-3}$ m/sec without load and from $4 \cdot 10^{-4}$ to $3 \cdot 10^{-4}$ m/sec under loads of 1 and 2 kgf/cm^2, respectively; normal permeability was from $5 \cdot 10^{-4}$ to $4 \cdot 10^{-4}$ m/sec under the same loads.

Permeability data show that the material has isotropic properties. The same may be said about the other characteristics.

Water absorption was equal to 0.4% at 65% relative humidity and 25^0C and to 0.6-0.8% at 100% relative humidity and 25^0C.

In trial tests "Coletanche" of 4 mm thick was used. It was made of non-woven fabric (about $300 g/m^2$) penetrated with bitumen of grade SM 2 ($4.5 kg/m^2$). This material has the following strength characteristics: ultimate tensile strength at 20^0C is about 25 kgf/cm, relative elongation at rupture is 48%, and resistance to penetration of a rod 6 mm in diameter is 80 kgf. Under normal pressure the seepage of water through the material is not observed. Only using special instrumentation made it possible to measure its permeability that proved to be less than 10^{-8} m/day.

"Coletanche" is practically impervious even at relative elongation up to 30-40%. It is not subjected rotting and is resistant to a number of chemicals, excluding hydrocarbons.

During experiments three test sections were built: one was on a temporary road crossing the swamp and two others were on a motorway within wet cuts. The subgrade structures are shown in Fig. 1.

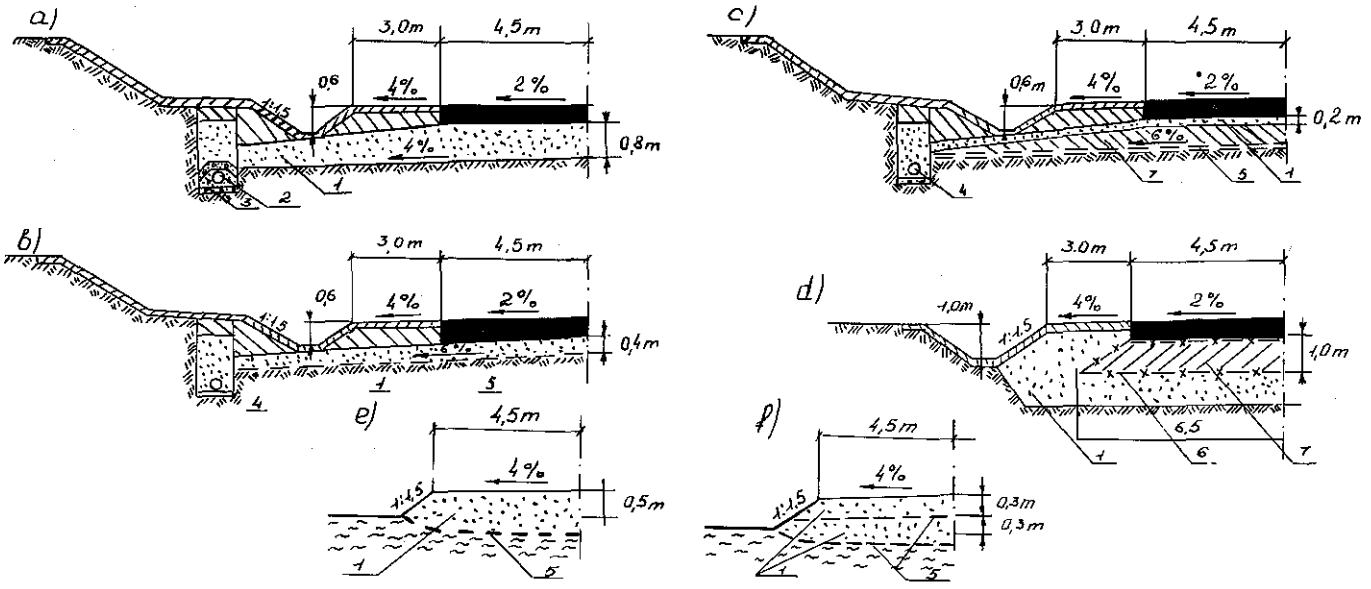

Fig.1 Subgrade and pavement structures with non-woven synthetic material: a - common structure with a frost-resistant layer; b- structure with non-woven material reducing the non-uniformity of soil heaving; c - structure with a capillarybreaking layer from non-woven material; d- structure with "soil in envelope" of bituminous treated material; e- structure on swamp with non-woven material in the subgrade bottom; f- structure on swamp with two layers of the material: 1- sand; 2- asbestos cement pipe; 3- crushed stone; 4- pipe of PVC; 5- non-woven material; 6- bitumen treated material; 7- loam

Construction was completed on the section on swamp in 1975 and on other sections in 1976.

The first section 172 m long was laid on the swamp of type 1 according to the engineering classiffication of swamp types. As to the nature of groundwater recharge this peat bog was the upland one. Due to extremely dry summer of 1975 the ground water level in the swamp and the moisture of peat somewhat decreased. The natural moisture of peat immediately before the embankment construction was 275 to 735%, the porosity was 83-93%, the degree of decomposition was 96% and the ash content was 30%. The relative settlement of the peat determined on data of compression tests under 0.2 kgf/cm^2 was 160 mm/m. The depth of the swamp mainly was 1.5m reaching sometimes 1.8 m

This section was a part of the access road to the sand-gravel quarry. On the test section as well as on the whole access road it was intended to construct an embankment 8m wide from sand gravel in order it can withstand traffic without any additional strengthening its upper part or laying a pavement. The test section was divided into six lengths according to the type of embankment structure: embankment 30 cm high with the material of grade U-34 in the bottom, 20 m in length; the same with the material U-44, 70 m in length; embankment 80 cm high with the material U-34 in the bottom, 32 m in length; the same with U-44, 20 m in length; embankment 80 cm high (with reserve for settlement) including two layers of U-34 (one in the bottom and another at 30 cm distance from the bottom), 20 m in length; the same with U-44, 20 m in length. The last two structures were in the middle of the section within the largest depth and highest moisture of peat. An excess of the embankment height was made to provide the reserve for peat settlement. In the case of the first two structures the depth of swamp was 0.5 to 1.2 m

For embankment construction a sand gravel with 30% gravel and about 99% of particles larger than o.1 mm was employed. The material has a fineness modulus of 2.52, filtration coefficient of 2.5 m/ day, total content of silt-clay particles not less than 1%, maximum density at standard compaction 1.88 g/cm^3, and optimum moisture 10.7%.

Recently upon completion, the access road was opened to heavy traffic with passage 150-200 trucks of the types "KrAZ" and MAZ" daily.

In accordance with a technology of the embankment construction the provision was made for removal of trees from a cutting, laying and stitching "Bidim" and its covering with sand gravel course of proper thickness.

"Bidim" was delivered on the site in rolls 5.2 m wide and 300 m long. Two sheets of "Bidim" were spread through the width of the embankment. Unrolling the sheets was performed manually, one sheet upon another, then the sheets were stitched together along one edge by longitudinal stitch and unfolded. Stitching was performed by means of portable sewing machine "Union Special" produced in FRG. A double chain stitch was used for this operation. The rate of sewing was 7-8 lin. m per minute.

The unrolling and stitching the sheets were performed by a crew of 4-5 operators.

On test sections in a wet cut the technology of laying the material was the same as above. The difference was in larger width of laying the material.

The sheet spread was covered with sand gravel. The sand gravel was delivered by dump trucks and leveled by a bulldozer. The depth of sand-gravel course was maintained within the range of 30 cm in compacted state. Compaction was performed by a self-propelled pneumatic-tired roller D-551 weightening 40 tons, wheel pressure being 4.25 kg/cm^2.

It should be noted that bursts of the material 1.5-2 m in length with peat bulging took place during compaction of the first layer at picket 2+53 along the axis of the road and at picket 2+86 at 2 m distance from the right edge.The bursted areas were cleaned from sand and peat, covered with the fabric with overlaps and then filled up again.

After filling-up and compaction of the first layer of sand gravel the second fill-up layer was laid by the same technology. On sections with two layers of "Bidim" each of them was separated by a fill-up layer. Observations on test sections have shown:the embankment quickly gained stability and good compactness under the action of traffic. The test section has a negligible tendency to rutting as compared with adjacent sections of the access road.Any significant differences between sections with U-34 and U-44 were not found. On the adjacent sections where the natural base was of overwetted clayey partially peaty soil the embankment was compacted worse and deep ruts appeared; traffic conditions were unfovourable.

Pit sampling through the full depth of the embankment has shown that fine peat particles do not penetrate the fill-up soil. Peat under the embankment consolidated and had a settlement of 30 cm.As the results of vane tests have shown the strength of peat beneath the embankment was $C_{cond.} = 0.4$ kgf/cm^2. The moisture content dropped from 275 % to 209 %.

A year after "Bidim" had been placed, during pit sampling the specimens of the material were cut from sheets and subjected to uniaxial tensile test. It was found that neither strength and deformability nor the appearence of "Bidim" had changed. Further observations on the section will permit the changes of bearing capacity, density and dynamic behaviour of the embankment with "Bidim" to be characterised more completely.

In wet cut two structures with "Bidim" ("b" and "c") were laid. The aim of the experiment is to reduce thickness of frost-resistant layer. To solve this problem a study is made of the possibility of using "Bidim" both for leveling the variability of pavement frost heave (type "b" in Fig.) and as a capillarybreaking layer (type "c" in Fig.). It is supposed that "Bidim" will also divert a free water to drainage structure with pipes (d=150 mm) of PVC. According to the aims of the study in the structure of type "b" "Bidim" was laid on the depth of 0.8 m immedeately beneath a sand underlayer of the road pavement whereas in the type "c" it was laid on the depth of 1.2 m from the pavement surface and covered with clayey (light loam) soil.For the type "b" the non-woven material of grade U-34 was used; it was laid in one layer on a half of the section(total length of the section is 50 m) and in two layers on another half. In the structure of type "c" the material of grades "U-34" and "U-44" was laid in three layers on two sections 30 m long, respectively. To determine the effectiveness of "Bidim" a structure meeting the existing design standards was constructed in the same cut (type "a" in Fig.).

A road pavement on the sections of test structures and of reference one was as follows: the upper pavement layer of sand asphalt 4-6 cm thick, the lower pavement layer of coarse asphalt concrete 5-9 cm thick, the base course of coated macadam 8 cm thick, the subbase of cement and slag stabilized soil 20 cm thick, the subgrade of sand 0-40 cm thick on sections with "Bidim" and that 80-90 cm thick on a section without "Bidim".

The results of soil tests have shown that "Bidim" is supported on heavy loam interbedded with watersaturated sand and morainic sandy loam. Stable groundwater level was marked on a depth of 1.3 m from the pavement surface.

Apart from the aim pointed above the efficiency of drainage pipes of PVC with fil-

ters from "Bidim" laid below trenches is studied.

In another wet cut on the same road a structure "soil in envelope" (type "d") with "Coletanche" was built. The length of this test section is 62 m.

The aim of this experiment is, first, to provide the strength and frost-resistance of road pavement using local clay soils instead of imported sand for subgrade construction and, second, to reduce a required thickness of a pavement by limiting the the losses of density inthe process of road service. To solve this problem study is made of using the "Bidim" treated with bitumen for a structure "soil in envelope".

In this structure the soil under a carriageway to a depth of 1 m from the bottom of the pavement is isolated by the material "Coletanche" from all the sides. The subgrade was constructed from heavy loam at 1-2 % optimum moisture content.

A road pavement on this test section is as follows: the upper pavement layer of fine asphalt concrete of the type "A" 3.5 cm thick, the lower pavement layer of coarse asphalt concrete 5 cm thick, the basecourse of coated macadam 8 cm thick, the subbase of cement stabilized soil 20 cm in thickness, the sand underlayer 5 to 10 cm thick on the section with "soil in envelope" and that 80 to 100 cm thick on the reference section.

The rolls of "Coletanche" (sheets 4.3 m wide and 70 m long) were also unrolled manually, however the sheets were not stitched but gas welded. To determine the effectiveness of using the non-woven synthetic material for reduction of frost-resistant layer thickness the following is kept under observation: traffic composition; deformations of pavement surface; density and moisture content of subgrade soil; temperature regime of road pavement and subrade.

Observations on pavement deformations include: leveling at 2 m intervals and measuring the irregularities 3 to 4 long on each traffic lane with straight edge of the types PKR-4 and PKR-6U as well as measuring the cross fall at 2 m intervals using a straight edge of the type PKR-3.

Observations on density and moisture content of the subgrade soil are carried out through the use of internal gamma densimeter (ITP-2) and neutron moisture indicator (NIV-2). During the autumn of 1975 bore holes for radioisotope measurements were drilled and equipped on the test and reference sections. At the same time measurements of density and moisture content of soils were performed with 03 m increments from the bottom of road pavement down to 2 m depth from its top.

A study of thermal regime of pavement structures is conducted by the method of hydraulic analogies using a calculator (hydraulic integrator of V. S. Lukiyanov's system) which is an analog device permitting numerical solution of the problems of unsteady process of heat transfer. This design method is based upon a principle of strict mathematical analogy between changes in water levels in the integrator tubes and those of the function in question. Thereby a space is considered in accordance with the finite difference method. The air temperature values in the region of test sections are accepted as boundary conditions.

Alongside with the observations on test sections, the study of effectiveness of using "Bidim" in road construction includes laboratory tests. In particular, a possibility of the use of "Bidim" for frost-heave protection is considered. Tests are conducted in an installation (1.2 x 2.7 m in plan and 1.0 m in height) containing soils with different susceptibility to frost heaving. The installation is put in a freezing chamber. Frost penetrates in the soil from the top (the soil has thermo-insulation).

Tests are carried out with water inflow the level of which is regulated. The installation operates in complex with soil temperature recorder "KSP-4".Measurements of pavement deformations on sections with "Bidim" and without it are performed during the test.

Beside the observations stated above, in 1977 it is planned to conduct measurements of pavement strength, state of drain pipes of PVC, settlement of an embankment on the swamp etc.

First results of observations on the test sections carried out in 1976 as well as the results of laboratory tests are indicative of the perspectivity of using non-woven materials to reduce the earthwork volume but any final conclusions may be drawn only after further observations.