GOVERNMENTAL SERVICE OF AUTOMOBILE ROADS OF UKRAINE
(UKRAVTODOR)
State Road Scientific and Research Institute named after M.P.Shulgin
DerzhdorNDI

REPORT ON SCIENTIFIC AND RESEARCH WORK

under Contract No. 46-09

"Determination of physical and mechanical properties of soils treated by the stabilization agent SoilBind SBT11-W for the construction of road facings under conditions of Ukraine " (interim report)

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INTRODUCTION

The work is carried out according to Contract No. 46-09 of 22.01.09 with the "Infox" Limited Liability Company. The work topic is "Determination of the physical and mechanical properties of soils treated by the stabilization agent SoilBind SBT11-W for the construction of road facings under conditions of Ukraine".

The main disadvantage of the soils, which are strengthened by the mineral viscous materials, is their extreme friability. When developing different methods of strengthening soils there were sought new effective decisions regarding a convincing improvement of their structural and mechanical properties.

It has been established and confirmed on the basis of long-term observations under production conditions that when strengthening soils by two different viscous materials, which are characterized by sufficient different, but non-antagonistic properties and structure, they assume a high landslide, frost and temperature resistance, and, if needed, they can be less rigid and more deformable materials.

The methods, which are combined when strengthening soils by means of adding additive compounds of two viscous materials or one viscous material and a surface-active additive (SAA) or an active agent of water-repellent type, got the name of complex methods. The development of such methods opens broader possibilities with regard to a directional regulation of structure formation processes, the creation of a high strength and other properties of the strengthened soils depending on the area of their use under different natural conditions. When studying the advantages laid in the complex strengthening methods, it has been established that upon this there are formed the earlier unknown types of complicated three-dimension structures of a combined type.

According to a planning calendar in the first stage there were carried out the investigations of the physical and mechanical figures of the soil mixtures treated by the stabilization agent SoilBind SBT11-W and in a complex way by the stabilization agent SoilBind SBT11-W and cement.

1. Analysis of the technical information and compilation of a research program

On the basis of information provided by the customer a conclusion was made that the use of the stabilization agent SoilBind SBT11-W allows solving issues such as avoiding the washout of the road after rains, the appearance of potholes, the washout of separate fractions of the filling aggregate from the surfacing, the appearance of tracing ruts as well as the reduction of a harmful influence on environment.

The essence of the use of the stabilization agent SoilBind SBT11-W lies in the fact that the treatment of soils by the water solution of the stabilization agent results in the formation of solid water-resistant structures that can be used in the construction of roads as the main and only layer of the road facing.

According to the data of the developer the material SoilBind SBT11-W is a milk-white liquid that is able to create foam when shaking it up. The material has a water base, is non-toxic, non-combustible, non-hazardous for environment, resistant to tinning, and has an admissible safe level of volatility of the organic substance. It can be broken down with fresh, sea and hard water. /**brackish water but not containing any humus/algae.**

The roads, which are arranged by using the polymeric soil stabilization agent SoilBind SBT11-W, cannot be washed out by rains, reserve their resistance to mechanical loads, their strength and stability in a temperature range from minus 20 0C till plus 1400C, are resistant to the action of oils, petrol and most acids (when Fully cured). The soil, which is strengthened by the polymeric stabilization agent SoilBind SBT11-W, does not burn away (does not char at a temperature of plus 2970C).

This material can be used for the construction of rural roads (soil + stabilization agent), of roads of a general use (soil + stabilization agent + asphalt), take-off and landing runways, thoroughfares (soil + stabilization agent + cement- concrete surfacing). Such surfacing can stand a load of over 40 t.

The material SoilBind SBT11-W can be used when strengthening clay, sand, rubble, **limited** volcanic **material**, **not** peaty soils as well as shredded industrial waste, construction waste, and industrial (mine) waste. Works can be carried out under conditions of a high humidity, drought, **not in frosts and floods or when the bottom of layer being treated is less than 3 degrees C**

To build roads by using the soil stabilization agent SoilBind SBT11-W there can be used the breaking machine, the recycling instrument, grader, spray-type equipment, and slot.

The technology of carrying out works on arranging the layer of the road facing strengthened by the soil stabilization agent SoilBind SBT11-W consists of certain stages.

The stage of preparation works includes the examination of geology, topography, angles of slope, reference marks, drainage systems, water levels (including the rain season). It's needed to be checked that the base is homogeneous, the water is not stagnated and not collected under the road, it has a functional drainage system, the big tree roots under or above the road surface are absent, the base rubble should have a size not more than 20 % of the thickness of the pressed layer. A soil test should be carried out: you should assure yourself of the fact that the contents of clay parts do not exceed 30% of the mixture composition for the roadway surfacing, you should determine the granulometric soil composition (30-35% of small fractions are to be sifted by means of the sieve with a hole of 0,063 mm).

The main works include the removal of the upper soil layer (Drawing 1) and the aligning in depth up to 300 mm. Then the soil aeration (Drawing 2) and the polymeric compound pulveration (Drawing 3) by using a water-jetting vehicle producing an even distribution of liquid. Afterwards when using a harrow the polymeric compound solution is mixed with the aerated soil (Drawing 4). The grader is used prior to and during the stamping for leveling a correct road profile, the layer consolidation is carried out by means of a turbine-type vibratory twin drum roller (Drawing 5).

The last ones are the final polymeric compound pulveration and the stamping of the layer surface without any vibration. To check the surfacing state one should carry out a «penetrometer test», with a clegg/ nulclear density equipment which will show soft points.

According to customer's data a specimen compression test will show that the pressed layer, which is arranged by using the polymeric soil stabilization agent SoilBind SBT11-W, stands the load of transport vehicles with a weight of up to 100 t. when fully cured after 28 days

Moreover, when using such technology the cracks can be repaired as the polymer has a 'bond back' capability.

According to Contract No. 46-09 there was planned the fulfillment of the program of investigating soils and prepared specimens that is specified in tables 1.1 and 1.2.

Table 1.1 – Compositions of soil mixtures that will be investigated

Material that is investigated
Soil that is treated by the stabilization agent **Sieve analysis**
Soil that is improved by the stone material and treated by the stabilization agent **Sieve Analysis**
Soil that is improved by the stone material and treated by the stabilization agent and cement **Sieve Analysis**

Table 1.2 – Figures of the physical and mechanical properties to be examined

Figures of the physical and mechanical properties
Compression durability limit of the water-saturated samples
Compression durability limit of the non-water-saturated samples
The average density of the pressed material
Water resistance
Water saturation **(Water uptake test not submersion)**

2. Selection of soil samples for conducting their examination and determining their properties

In January 2009 a representative of the DerzhdorNDI executed a visual examination of the road facing state on the automobile road – «Access route to the plant of the «Infox» LLC.

The specified automobile road is on balance of Vodokanal (Water channel) and assigned for the local transportation of loads and the drive to enterprises in the industrial zone.

The drive length comes to approximately 2 km. The width of the traffic area totals 4-6 m. The roadway surfacing includes cement-concrete slabs with different dimensions (rectangles with their sides of 1-3 m), and a thickness of 10-12 cm.

The borders on the road are practically absent, the longitudinal and cross sections have ground or negative marks, the water drain is complicated on a considerable distance and absent in some places (the water is on the road). **Drainage problem must be resolved as this can undermine the integrity of the road. The road should be graded to prevent water gathering on the surface.**

In the period of the road operation the concrete slabs gave under and were partially destructed under the action of the heavy-load vehicles and under conditions of a steady over-watering of the earth bed.

On either road side there is an industrial zone (supply lines) or a wagon with humid soil, which is overgrown with grass, reed, shrubs and trees.

According to the examination results it was established that the most characteristic destructions of the road facing are flaking (Drawing 2.1), cracking (Drawing 2.2), subsidence (Drawing 2.3) and potholes (Drawing 2.4) of cement- concrete slabs on a considerable area. The deformations of the road surfacing reach a depth of 20-40 cm and a length of the road surface of up to 6 m. The defects are filled with water.

The existing automobile road was built about 40 years ago by using the method of laying aerodrome cement-concrete slabs on the pressed sand “bed” (earth bed). The selection of soil samples was carried out in order to conduct investigations and determine their properties under laboratory conditions.

The laboratory of the DerzhdorNDI determined the soil parameters:

- Limit of liquidity $W_L = 31\ \%$
- Limit of plasticity $W_P = 17\%$

The soil plasticity number makes up 12. Due to the classification the soil can be determined as heavy clay loam.

3. Determination of the physical and mechanical properties of soils treated by the stabilization agent SoilBind SBT11-W

Methods of the preparation of samples

The samples of a cylindrical form for determining the physical and mechanical properties of mixtures are made by means of pressing mixtures that are prepared under laboratory conditions.

The consolidation of samples from the strengthened soils was made in cylindrical forms with a size of 50 mm according to the standard ДСТУ Б В.2.7- 89-99. The soil mixture with the viscous material is poured into the mould. It is rodded (poked) with the help of a spatula for a regular distribution of the mixture, and then the upper follower (liner or filler) is inserted into the mould. The mould with the mixture is put on the lower press slab, the upper slab is connected with the upper follower, and the press is released. The compression of samples from soils, which are strengthened by the stabilization agent or the stabilization agent with the mineral viscous material, was conducted under loads that correspond to the compression conditions on the device of standard compression. (**Is the pressure with or without any vibration)**

The curing time of the mixture under loads totaled (3,0±0,1) minutes, then the sample is taken out of the mould and measured by means of a beam compass. The pointing error of the specimen height made up 1 mm.

The samples of mixtures and strengthened soils, which contain over 4% of the mineral viscous materials in their composition, are stored in the bath with a hydraulic gate at a temperature of (20±5)°C.

The samples of mixtures with the liquid and emulsified viscous materials, which have water in their composition and are strengthened by the stabilization agent, were tested after 14(**The curing period for polymers is also 28 days**; the samples of soils, which are strengthened by the stabilization agent together with cement, were tested after 28 days.

The solution of the stabilization agent SBT11-W with water is used for strengthening soils.

Specimen testing results

According to the program of investigations (chapter 1) the DerzhdorNDI conducted the determination of figures of the physical and mechanical properties of soil mixtures with the composition specified in table 3.1.

Table 3.1 – Composition of soil mixtures

Series number	Mineral composition, % due to mass **Volume (we need a sieve analysis for each mix)**	Concentration of the stabilization agent SBT11-W in water solution, %
1	Soil - 50 %, stone material, fractions 0-10 mm - 50 %	14,2
2	Soil - 50 %, stone material, fractions 0-10 mm - 50 %	17,8
3	Soil - 50 %, stone material, fractions 0-10 mm - 50 %	21,4
4	Soil - 50 %, stone material, fractions 0-10 mm - 45 %, cement - 5 %	14,2
5	Soil - 50 %, stone material, fractions 0-10 mm - 45 %, cement - 5 %	17,8
6	Soil - 50 %, stone material, fractions 0-10 mm - 45 %, cement - 5 %	21,4
7	Soil 100 %	14,2
8	Soil 100 %	17,8
9	Soil 100 %	21,4

The determination of indicators of the physical and mechanical properties of soil mixtures was carried out according to the requirements of the standards ДСТУ Б В.2.7-89-99 and ВБН В.2.3-218-002-95. The testing was executed on the equipment of the certified testing center DerzhdorNDI.

Table 2.2 – Figures of the physical and mechanical properties of soil mixtures treated by the stabilization agent SoilBind SBT11-W or the complex viscous material (SoilBind SBT11-W and Portland cement of grade 400)

Series number	Compression strength on a dry basis, MPa	Compression strength on a water-saturated basis, MPa	Water saturation, %	Density, g/cm^3
1	3,50	0,40	24	1,73
2	3,72	0,40	22	1,75
3	5,16	0,40	22	1,76
4	5,12	4,35	17	1,77
5	5,23	3,60	17	1,77
6	6,09	4,28	16	1,79
7	7,20	0,40	29	1,66
8	8,09	0,40	32	1,62
9	9,17	0,40	29	1,68

The lower densities in 7,8.9, indicate insufficient fines of 0.063 material.

Due to the testing results of the physical and mechanical properties of soil mixtures it has been established that the stabilization agent SoilBind SBT11-W efficiently affects the figure – compression strength of soils in a dry state. Due to the data of table 2.2 one can see that the compression strength of samples in a dry state is high enough - from 7 to 9 MPa. At the same time the testing of samples from soils stabilized by SoilBind SBT11-W in a water-saturated state showed an essential strength reduction. **The international ASTM standards recommend that a water uptake test is employed for stabilized soils, NOT A**

SUBMERSION TEST. In situations where flooding or water ingress is anticipated then the surface of the layer below the layer being treated would be sealed first with polymer and the surface of the treated layer would also be sealed with polymer. Laboratory samples are normally sealed first and allowed to dry before a water uptake test to simulate the above conditions.

The testing of soil mixtures with the added stone materials treated by the stabilization agent SoilBind SBT11-W showed a strength growth of the material in a dry state, but at this the figures in a water-saturated state are low enough. The figure value of the water saturation should be stated as well, which amounted to over 20% for all samples.

The comparative analysis of the physical and mechanical properties of soil mixtures treated by the stabilization agent SoilBind SBT11-W and of soil mixtures with an improved grain composition by adding stone materials and treated by the stabilization agent SoilBind SBT11-W allowed establishing that the soil mixtures, which are treated by the stabilization agent and are in a dry state, have a higher strength than soil mixtures that contain stone materials. **This enables to state that the stabilization agent creates effective connections between colloidal soil fractions.** This can be effected if there are insufficient fines.The total aggregate of connections in soil mixtures is larger than in soil-rubble mixtures that become apparent when determining a compression strength limit.

Due to the work character of layers from soils in the road constructions it should be noted that the soils are under conditions of a periodical watering owing to a water-and-thermal regime of the object (influence of surface waters, concentration of stream wetness, capillary moisture etc.).

The testing results of the strength limit in a water-saturated state (the capillary water saturation was carried out according to the standard ДСТУ Б В.2.7- 89-99) demonstrated an essential strength reduction of the samples treated by the stabilization agent SoilBind SBT11-W. The strength of the samples was almost a next lower order practically in all cases.

The testing of the polymer treated samples after 14 days, instead of 28 days, and the fact that the samples were not sealed are probably responsible for this result.

This gives evidence of an insufficient strength of structural connections that is created by the stabilization agent with soil fractions under the influence of moisture.**(This also indicates too many voids possibly created by a shortage of fines.)** The established result can be explained by the influence of water on soil fractions, namely the processes of water saturation and swelling of the soil mass. Probably, the thin polymeric films, which are created by the stabilization agent SoilBind SBT11-W, are unable to effectively contradict the division of stages between the mineral filler (soil fractions) and water. **This action is unusual as we normally coat all the soil particles during the mixing process and this in effect seals them and prevents water ingress.**

The testing of samples, which are treated by a complex viscous material, namely by the stabilization agent SoilBind SBT11-W and cement of grade 400, showed high figures of the physical and mechanical properties of soil mixtures. For all compositions of mixtures the compression strength in a dry state made up more than 5 MPa. The strength in a water-saturated state was equal to from 3,6 MPa to 4,5 MPa. The water-saturation of samples strengthened by a complex viscous material is by 20-30 % less than that one of samples treated by the stabilization agent only.**This again indicates that the cement compensated for the shortage of fines and reduced the void ratio.** The water resistance
established by means of the stability coefficient is over 0,7 for all mixtures. The average density of all samples comes to 1,8 g/cm$^{3.}$

CONCLUSION

One can conclude that the stabilization agent SoilBind SBT11-W is a stabilization agent of soil masses, but no viscous substance. This stabilization agent is effective when treating soils that at a later stage do not undergo long-term water saturation.

The determined figures of the physical and mechanical properties of soil mixtures, which are strengthened by a complex viscous material, enabled to establish a high efficiency of the stabilization agent SoilBind SBT11-W for strengthening sand and clay soils. Owing to the combination of the viscous materials (stabilization agent SoilBind SBT11-W and cement) one manages to reach high compression strength both in non-water-saturated and water-saturated materials (from 6 MPa to 3 MPa). Such strength figures ensure that the road- building materials have a high strength, frost and temperature resistance as well as are less rigid and more deformable materials.

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4. ГОСТ 5180-84 Soils. Methods of a laboratory determination of the physical properties
5. ГОСТ 12536-79 Soils. Methods of a laboratory determination of the granulometric (grain) and micro-aggregate composition
6. СН 25-74 Instruction on using soils strengthened by the viscous materials for arranging the bases and facings of automobile roads and airports. Gosstroy of the USSR, Moscow-1975
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Road building technology to “СПТ” factory.

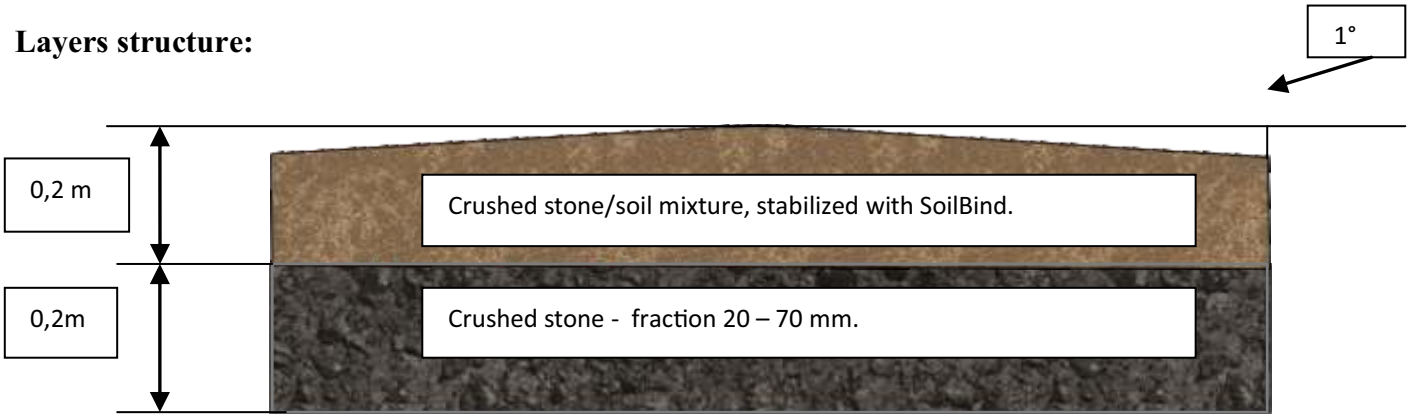
Location: Odessa city.Ukraine. Reinforced-concrete slab road. The territory is slightly waterlogged because of the heavy rains.

Soil: loam.

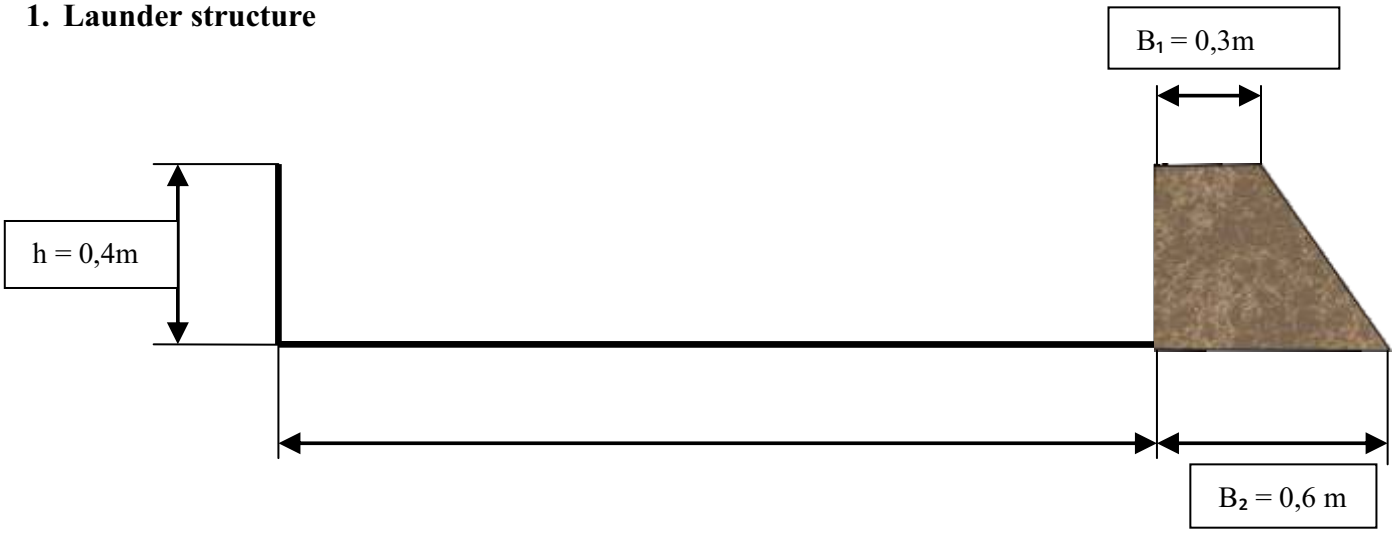
Road destination: local importance road for heavy-load trucks.

Ground characteristics of the site: L = 1200 meters; B = 6 meters; h = 0,4 meters; S = 7200 sq. meters, V = 2880 cubic meters.

Layers structure:



1. **Launder structure**

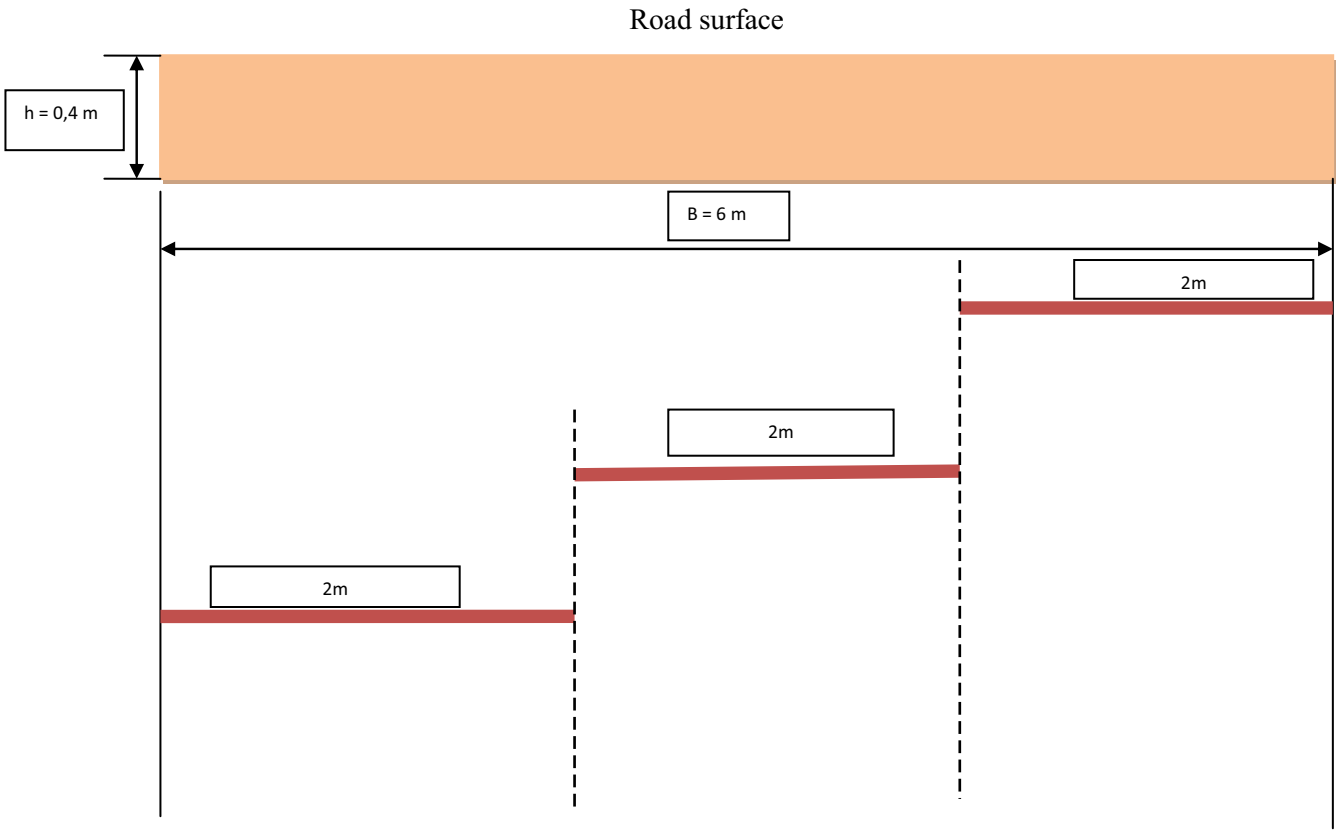


- Slope is planned by the grader: h = 0,4m; B_1 = 0,3 m; B_2 = 0,6m on the whole length of road to be repaired.

2. **Broken Stones Layer Structure.**
   - Broken stones layer installation on the whole length of road to be repaired.
   - Broken stones, 40 – 70mm fraction are pouring out for h=0,15meters height.
   - Making even with a help of grader.
   - Broken stones, 10 – 20mm fraction are pouring out for h=0,05meters height.
   - Making even with a help of grader.
   - This layer is moistened by sprinkler with 2,4 ltrs. of water per sqr. meter.
   - Getting smooth by vibration roller in accordance with jamming (blocking) method, till there will be no waves in the front of the rollers shaft.

3. **Site basic surface structure.**
   - The whole road is divided on 6 divisions 200 meters each. Following activities complex will be fulfilled step by step. First division will be worked out in 3 drivings. Surface strengthening should be fulfilled after soil mixture stabilization on one of the road divisions.
   - Sand filling (sifting), h=0,1meters**.**
   - Profiling.
   - Crashed stones, 10 – 20mm fraction, are pouring out for h=0,088meters height.
   - Surface profiling by grader.
   - Portland-slag cement type 400 h=0,012meters is pouring out, then, making the surface even.
   - Careful blending of sand, cement and crushed stones by special rigging equipment.
   - Blended mixture is profiled by the grader.
   - Surface is moistened by sprinkler with 13% Soilbind water solution. Consumption comprises up 30 liters per cubic meter.
   - Surface dries off up to the needed moisture content.
   - Grader profiling, roughness' are smoothed out. Filling up can take place.
   - Surface is compacted by the vibration roller, till there will be no waves in front of the roller shaft (Roller shaft have to move after the wheels, in order to avoid wheels profile on compacted surface).
   - Surface dries off, till the moment when soil won't stick to roller shaft.
   - Compacted surface is moistened by the sprinkler with 25% Soilbind water solution. Consumption comprises 0,9 liters per sqr meter.
   - Roller makes the final compaction in ordinary mode, after the stabilized layer is dried out (roller shaft have to move after the wheels in order to avoid wheels profile on compacted surface).

4. **Soil-mixing machine passage succession (considering that the width of the rigging equipment is 2 meters).**



NOTES:

1. **Stabilizing solution preparation**:
   - Sprinklers tank should be filled with 1000 liters of water.
   - Soilbind polymer should be poured into the tank in the amount of 800 liters (4 barrels x 200liters).
   - Each barrel should be washed out by the water until it will be pure. Everything washed our from barrels should be added to the polymer solution into the sprinkler's tank.
   - After fulfillment of the mentioned above operations, tank should be filled with water till 6000 liters level.
2. **Fixing solution preparation**:
   - Sprinklers tank should be filled with 1000 liters of water.
   - Soilbind polymer should be poured into the tank in amount of 1600 liters (8 barrels x 200liters)
   - Each barrel should be washed out by the water until it will be pure. Everything washed out from the barrels should be added to the polymer solution into the sprinkler tank.
   - After fulfillment of mentioned above operations, 2600 liters of water should be added into the tank
3. **Polymers residuals have to be washed out from the tank, sprayers, stop valves and sprinklers pumps.**

2009 Ukraine cement/polymer/construction waste factory