Mud-pumping prevention of railway subgrade by using geotextile

La prévention du pompage de la boue dans les couches d'assise des voies ferrées par l'emploi de géotextile

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SYNOPSIS In this paper, the results obtained from a systematic study on the subgrade mud-pumping prevention and rectification by using geotextile are reported. Both laboratory and field performance tests on different geotextiles subjected to the condition under which subgrade mud-pumping may generate were conducted. It is point out that the compound structure formed by geotextile and thin sand layers fills the role of fine grain retention and filtration under hydrodynamic flow condition so as to prevent the railway subgrade from mud-pumping. Also the main technical requirements of the compound structure layer are suggested.

INTRODUCTION

Mud-pumping is one of the most common subgrade defects occurred on the existing railway lines in China. It seriously affects the safety of railway transportation and hinders the increase in traffic capacity. Therefore we have conducted a systematic research on mud-pumping prevention and rectification by using geopolymer since 1981. The research work involves: survey of conditions under which subgrade mud-pumping may generate; tests of different soils and geotextiles subjected to these conditions, including the filtration and retention behavior under simulated train dynamic conditions. And at the same time a long term observation over a series of test sections were also carried out in this condition.

CONDITIONS CAUSING SUBGRADE MUD-PUMPING

On-site survey and investigation show that the subgrade mud-pumping is caused by the poor combination of formation soil, water state and train dynamic load. These kinds of soils like the silty clay with high density, and the rocks susceptible to weathering to be turned to clay, as well as the overconsolidated fissured clay may be liable to cause mud-pumping under the following specific conditions:

(I) The content of grain size less than 0.05 mm is more than 80 , the liquid limit W_L>32 , and the plasticity index I_p>12;

(II) There is a thin soft layer under which the soil is rather hard with high strength, the number of blows of small penetrometer is more than 4 and the unconfined compression strength is greater than 130 Kpa. Besides, there is plenty of rainfall at the territory concerned and the surface drainage of the subgrade is not well;

(III) The formation soil when saturated may easily become slurry under repeated impact and vibration of train dynamic loads.

LABORATORY TESTS

The basic properties of the tested soils and the tested geotextiles are listed in table I.(a),(b) and (c).

TABLE I

(a) Physical Properties of Tested Soils

Place of Sampling and Signation of Soil		W_L %	I_p	Specific Gravity G_s	γ_d KN/m^3
Changsha	SI	31.0	I3.0	2.70	17.0
Chengdu	S2	34.7	17.0	2.71	17.3
Beipei	S3	30.6	I3.3	2.70	17.3

(b) Grain Size Distribution

Soil	> 2 mm	2-0.25 mm	0.25-0.05 mm	0.05-0.005 mm	<0.005 mm
S1	0.4	9.6	18.0	72.0	0
S2	0.4	3.6	6.0	65.0	25.0
S3	0.2	17.8	48.0	23.5	I0.5

Test for Slurry-Separation Capability of Geotextiles

The layout of the test is shown in Fig. 1. The geotextile is in direct contact with slurry and not protected by sand layer. During the test, the prepared slurry was subjected to a repeated dynamic impulse with porepressure of 7-18 Kpa (this is the same as that measured on Chengdu-Chongqing railway line).

Table II shows the test results obtained after the application of 5000 cycles of impulsing load (51 Kpa, 1 Hz).

The test results indicate that the slurry with grain size less than 0.02-0.004 mm were migrated through all of the three kinds of geotextiles in varying degree, which demonstrates that the geo-

Table I (c) Characteristics of the Tested Geotextiles

	Type and the Signation of Geotextile		
	3601 T1	400R T2	SH-2 T3
Raw material, pp.	long fiber	long fiber	short fiber
Weight g/m^2	204	400	635
Thickness mm	0.48	3.56	4.8
Equivalent open size μm	155	149	110
Tensile strength KN/cm	0.21	0.25	0.23
Elongation rate	63	160	80
Puncture strength KN	1.82	2.44	4.13
Tear strength KN	0.848	0.92	0.545
Permeability coefficient cm/s	1.4×10^{-2}	3.0×10^{-2}	2.0×10^{-2}

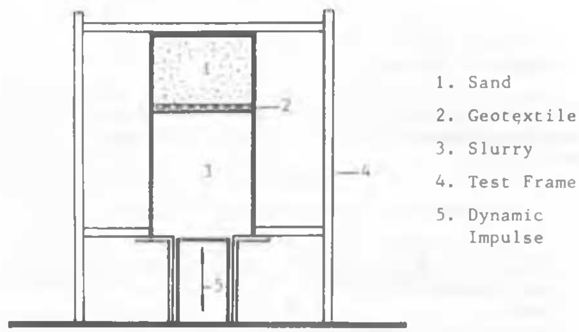

Fig.1 Layout of Slurry Separation Test

Table II
Test results of slurry separation

Type of geotextile	Grain size of slurry mm	Dynamic pore water pressure Kpa	Weight of slurry migrated %
T-3601	0.023	13.8	0.28
400R	"	6.9	0.60
300R	"	12.7	1.6
T-3601	0.004	13.8	0.89
400R	"	16.1	1.8
300R	"	10.4	2.0
T-3601	0.007	18.4	0.33
400R	"	13.3	1.4
300R	"	13.8	1.5

textile directly in contact to slurry and not protected by sand layer was hardly capable to prevent mud from bing pumped up. And this is in agreement with the actual field conditions.

Dynamic Model Test for Mud-pumping by Geotextile

The schematic diagram of the apparatus for the dynamic model test is shown in Fig.2. The dynamic load of 3±0.5 KN with a frequency of 1.6 Hz was applied, under which the dynamic stress actually measured on the surface of soil was 50-70 Kpa. The maximum loading cycle was 320,000. At the same time, the contamination rate of the sand was determined by sampling according to the predetermined cycle of loading. The typical results are shown in Fig.3 (a), (b) and (c).

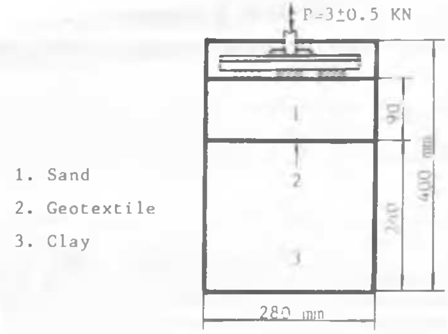

Fig.2 The Schematic Diagram of Dynamic Model Test

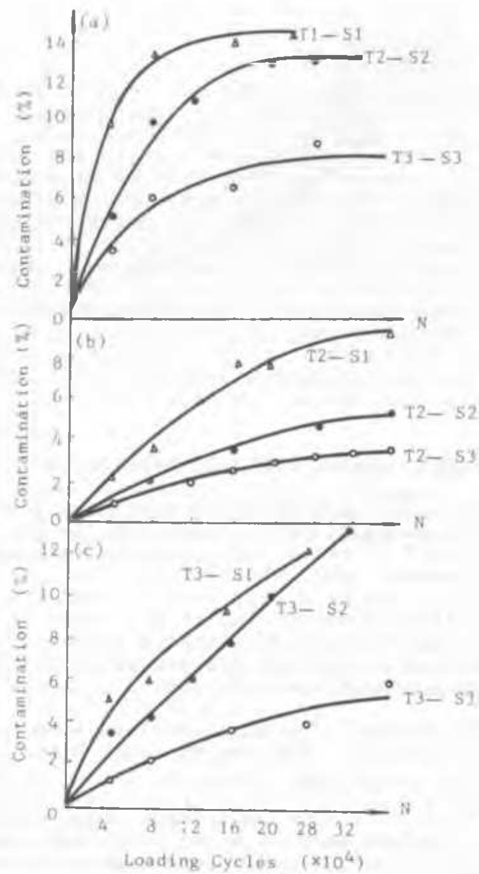

Fig.3 Contamination Percentage Varing with Loading Cycle
(a) Geotextile T1—Soil S1, S2, S3
(b) Geotextile T2—Soil S1, S2, S3
(c) Geotextile T3—Soil S1, S2, S3

The test results show that:

(I) The content of silt in soil has a considerable effect on the contamination of sand, The more the content of silt, the higher the contamination percentage would be. If the contents of silt in the two kinds of soils are nearly the same, then the more the content of clay in the soil, the lower the contamination rate would be.

(II) For the three types of tested polypropylene nonwoven geotextiles, their capability of retaining fine grain is shown as below: the type T2 (400R) needle punched continuous long fiber is higher than the type T1 (3601) heat bonded long fiber. Type T2 is also more capable than that of T3, the needle punched short fiber. Although T3 is thicker than T2, its retention capability is still inferior as compared with the later.

(III) As for the two materials of T1 and T2, after the loading cycles reached a certain value, the contamination rate slowed down gradually until no further increase of the total contamination precentage. But the contamination rate of T3 was not remarkably reduced at 320,000 loading cycles. This coincides with the results observed on site.

Effect of the Addition of Fine Grains on the Shear Strength and Permeability of Sand

Samples for shear and permeability test are prepared by a mixiture of medium and coarse sand with silt and clay taken from the investigation sites according to a specific proportion. The testing results (see Fig.4 and Fig.5) obtained proved that the contamination of fine grains had a certain dgree of effect on the shear strength of sand and the permeability of geotextile.

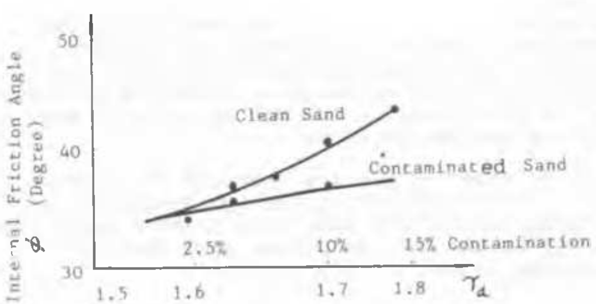

Fig.4 Variation of Ø of Contaminated Sand and Clean Sand

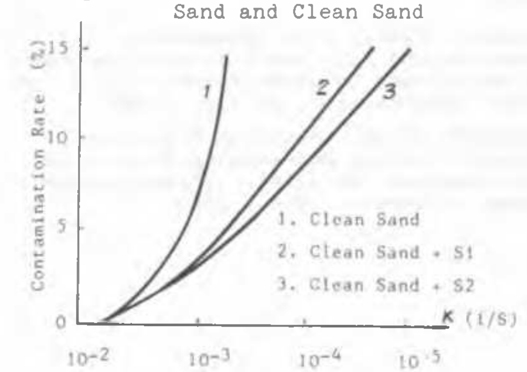

Fig.5 Variation of Permeability Coefficient K of Clean Sand and Contaminated Sand

MUD-PUMPING RECTIFICATION BY USING GEOPOLYMER

To carry out an all round on-site test of various geopolymers for the prevention and rectification of mud-pumping, 22 test sections on 16 railway lines have been established in recent years. They include embankments, cuttings, tunnels, stations and yards etc. Up to the end of 1985, about 64800 linear meters (approximate 260,000 m^2) of various kinds of geopolymers had been used on Chinese railways, of which about 7921 linear meters (approx. 35,000 m^2) were different types of geotextiles. These test sections have been periodically excavated for inspection and sampling. The results of these tests demonstrated that:

(I) The practices of mud-pumping prevention and rectification by using geotextile had shown distinct achivement, with only 5% of failures caused by unqualified construction or maintenance, etc;

(II) A survey of the test section with sand layer on Xiangfan-Chongqing railway line showed that no contamination was observed on the ballast where sand layer was layed above and below the geotextile, while at the same site where there was no sand layer used with the geotextile, the ballast was polluted quite rapidly (see Fig.6).

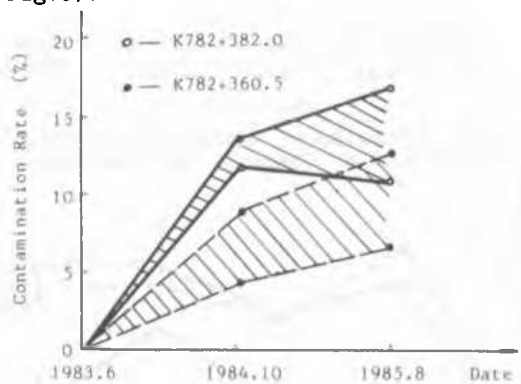

Fig.6 Variation of Contamination Hight with Time in Case No Sand Layers

(III) Geotextile might be somewhat polluted during a short period after installation. According to the analysis of the sand samples taken from the excavation, the content of grains of

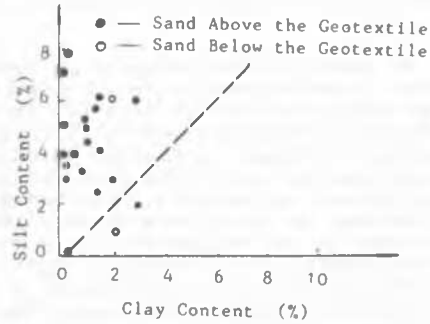

Fig.7 Content of Silty and Clay in Polluted Sand

less than 0.1 mm in the unpolluted sand was fairly low (normally at about 2%); which in the polluted sand it increased remarkably. The fine grains were silt and clay, in which silt predominated (see Fig.7). The maximum contamination percentage during the past 2-4 years was normally less than 10%

(VI) According to the information obtained from two test sites, if the sand layer under the geotextile was appropriate, the contamination would remain stable after it reached a certain height, and also showed (Fig.8 and 9) that T1 and T3, after being used for 1-2 years, were quite different in pollution height. Although the thickness and weight of T3 were far bigger than that of T1, the thickness and weight of the geotextile material itself is not a decisive factor in terms of mud-pumping prevention and rectification. Therefore one should not expect to prevent and rectify mud-pumping defect only by increasing thickness and weight of the geotextile.

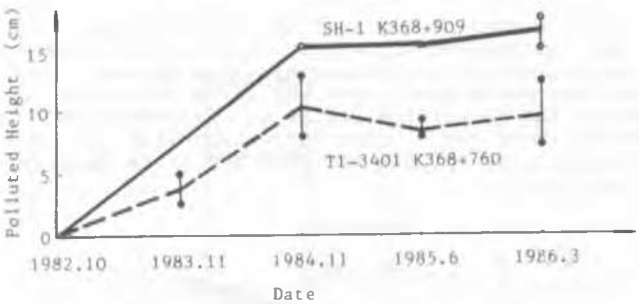

Fig.8 Variation of Contamination Height with Time at Changsha Testing Site

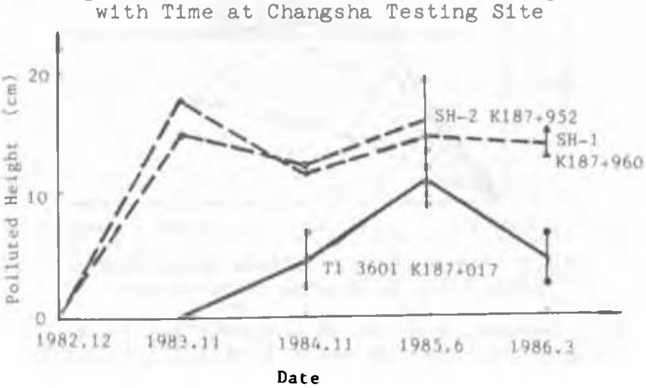

Fig.9 Variation of Contamination Height with Time at Yueyang Testing Site

(V) It can be seen from the excavations that the structural layer formed by both the geotextile and the sand layer serves as a key factor for the effective prevention and rectification of mud-pumping. To prepare a certain thickness of sand (10-20 cm) on top of the geotextile may effectively protect the material from being damaged by ballast or other hard objects and the appriciated sand below the geotextile is quite important for forming the filtration layer. This sand layer could be 5-10 cm thick based on the traffic conditions of Chinese railways. The sand should be of well graded medium and coarse sand containing less than 3% of 0.05 mm grains and no grain bigger than 5 mm. The match between the actually used sand and the geotextile satisfies the following conditions:

Preventing piping: $O_{95}<1\times D_{85b}$ (1)

Ensuring permeability: $O_{95}>1\times D_{15b}$ (2)

Uniform filtration: $O_{95}<2\times D_{50b}$ (3)

Where: O_{95} is the equivalent open size of geotextile; D_{85b}, D_{15b} and D_{50b} are D_{85}, D_{15} and D_{50} of the sand in contact with geotextile.

(VI) Since the subgrade soils of the railway sections where mud-pumping usually occures possesses high strength and the geotextile material in its application with sand layer usually flatten with a little deformation due to tension. Therefore it is not the key important issue in terms of the strength and elongation rate of geotextile used for preventing mud-pumping, but the permeability K_v/b and O_{95} of the geotextile are very important factors. In accordance with the experience gained in geotextile application, $K_v/b=1.0\text{-}5.0\times10^{-2}$ (1/s) (b is the thickness of geotextile), $O_{95}=0.08\text{-}0.15$ mm can satisfy the requirements in terms of mud-pumping prevention and rectification of the Chinese Railways.

CONCLUSIONS

(I) It has been proved through practice that the adoption of geotextile to prevent and rectify subgrade mud-pumping is an effective method.

(II) Laboratory and field research works proved that the filtration and separation of geotextile in preventing mud-pumping are very important. The technical key point is to form a compound structural layer on the surface of subgrade formation by laying sand above and below the geotextile. In other words, mud-pumping preventing and rectification can not be achiveed only by using geotextile alone.

(III) In order to get the compound structural layer, it is necessary to design specifically the thickness of the sand layers above and below the geotextile and the proper sand grading according to different geotextiles.

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