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Collapse of dispersive soil and its prevention using geotextiles

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ABSTRACT: A large number of hydraulic works had been constructed and were being constructed in the western part of Song-Nen Plain of Heilongjiang Province, China. Most of them were damaged and eroded. This paper has examined primary reasons for an erosive damage due to the behavior of dispersive clayey soil. These are: soil dispersion; a dynamic water flow of erosive damage; a by-pass of water flow; etc. This paper introduces the model test method and the test process to protect erosion using geotextiles. Based on the test results in 1985, we found that the geotextiles used to prevent the soil from erosive damage were very effective and durable.

1 INTRODUCE

Song-Nen Plain is $1*10^5$ km² in area and locates in the western part of Heilongjiang Province, China. High natrium content soil is distributed in the area. The so-called "alkali gullies".

In the Plain some earth structures were built from high natrium content soil, when they are being constructed or have been built, we found more than hundreds erosive pockets due to collapse and damage by rainwater, as shown in Photo 1 and 2.

From a large number of tests, it has been proved: some earth structures have been damaged because of soil dispersion. Based on the damage mechanism of dispersion and the preventive function of geotextiles, a model pinhole test had been undertaken in the laboratory. We are successful to explore the possibility of using geotextiles to prevent damage and bring to civil engineering practice, some good effects were obtained.

Photo. 1

Photo.2

2 IDENTIFICATION OF THE DISPERSIVE SOIL

From the field investigation, we had secured samples to determine the engineering properties. Sampling location was shown in Fig. 1.

The dispersive soil is identified by the following method:

1. Clastic test (wetting and drying);
2. Two-hydrometer test;
3. Chemical analysis of pore water ;
4. Pinhole test.

The results of the tests were given in Table 1. The results of four types of tests are consistent, so the soil is dispersive. We conclude some earth structures are damaged because of dispersive behavior of soil.

Table 1 The summary results of various test methods

NO.	drying clastic test	wetting clastic test	two-hydrometer test	pinhole test	proe water analysis
S-1	◎	◎	△	◎	◎
S-2	◎	◎	△	◎	◎
S-3	○	○	○	○	○
S-4	◎	◎	◎	◎	◎
S-5	◎	◎	◎	◎	◎
S-6	◎	◎	△	◎	◎
S-7	◎	◎	◎	◎	◎
S-8	◎	◎	◎	◎	◎
S-9	◎	◎	◎	△	◎
S-10	◎	◎	◎	◎	◎
S-11	◎	◎	◎	◎	◎
S-12	○	○	△	○	◎
S-13	◎	◎	○	◎	◎
S-14	◎	◎	◎	◎	◎
S-15	◎			◎	
S-16	◎			◎	
S-17	◎			◎	
S-18				◎	
N-1	○	○	△	○	○
N-2	○	○	△	○	○
N-3	◎	◎	◎	△	○
N-4	◎	△	◎	◎	○
N-5			○	○	○
F-1	◎	◎	◎	◎	◎
F-2	◎	△	◎	○	◎
F-3			△	○	△

◎ dispersive ○ non-dispersive △ middle-dispersive

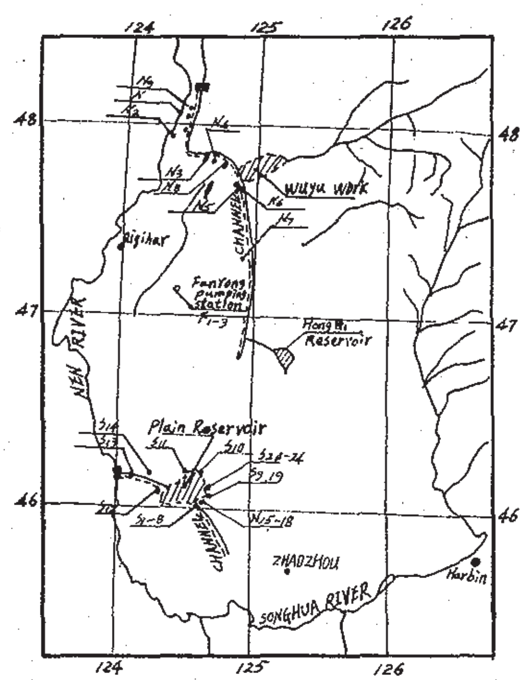
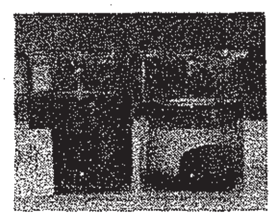


Fig. 1 Sampling location



* right is non-dispersive sample
** left is dispersive sample

Photo. 3 Wetting clastic test

3 THE EROSIVE CONDITION OF DISPERSIVE SOIL STRUCTURE

The dispersive clayey soil contains very high natrium ions around the soil particles because of the large thickness of the soil hydro-membranes existing in the double electronic layer. The attractive force between the soil particles, therefore, is very small. As the soil wetted, or immerssed in water, particles on soil surface began to separate one by one. No critical velocity exists in erosive damage, in the still water, the clayey soil particles were in suspention, as shown in Photo 3.

But the test data of dispersive clayey soil in the western part of Heilongjiang Province indicate that the coefficient permeability of soil is very low, for example, sample S-2: $k_{10}=3.3*10^{-9}$cm/s. When seepage gradient is not high, and the coefficient is very small, the seepage cannot occured in soil. As to S-2, the soil sample is 4 cm long, the seepage gradient is 70, after 15 days there were only a few pollution area in the sample end. So we can infer, if the thickness of clay is 20 m, and a gradient is 70, it will take twenty years to saturate the clay. Therefore, it seems that some damage conditions of dispersive earth structure are: the soil is dispersive; the water is pure and there exists a by-pass to allow the water flow.

4 TEST RESULT OF PREVENTION FROM EROSION ON GEOTEXTILES

Under purified water flow, the dispersive clayey soil is a kind of non-cohesive soil, therefore, we undertake conventional treatment by a sandfilter, it is very successful to control erosive damage if the sandfilter is made carefully. According to the filter function of the geotextile it can be used instead of sandfilter.

4.1 The selection and property of the geotextiles

Based on engineering property of dispersive soil; the erosive damage condition and products available in China, we selected geotextiles, manufactured by Jiamusi No-woven Textile Mill of Heilongjiang Province. They are needle-knitted DS450-Ⅱ and polyester combined with polypropylene 1:1. The thickness is 0.35 cm; the weight is 450 g/m²; the elongation is 57.0 %; the tensile strength is 37.8 $kg/_5cm$; the coefficient of permeability $K_{10}=4.83*10^{-3}$ cm/s; the effective diameter $O_{90}=0.114$ mm.

4.2 The selection of protected soil

The problem only concern with dispersive soil, so we believe that non-cohesive soil had a property of non-cohesive soil in pure water, then a typical damage soil (higher clay content) had been selected, used for testing.

The properties of dispersive soil sample S-4 collected from the field were given as followed:
Dispersion degree: D=49 %;
Natrium percent: 95.7 %.
Pinhole test: white fog appeared after several seconds, grain scattered and suspended; other details are shown in Fig. 2. From Fig.2 we found: the sample S-4 is

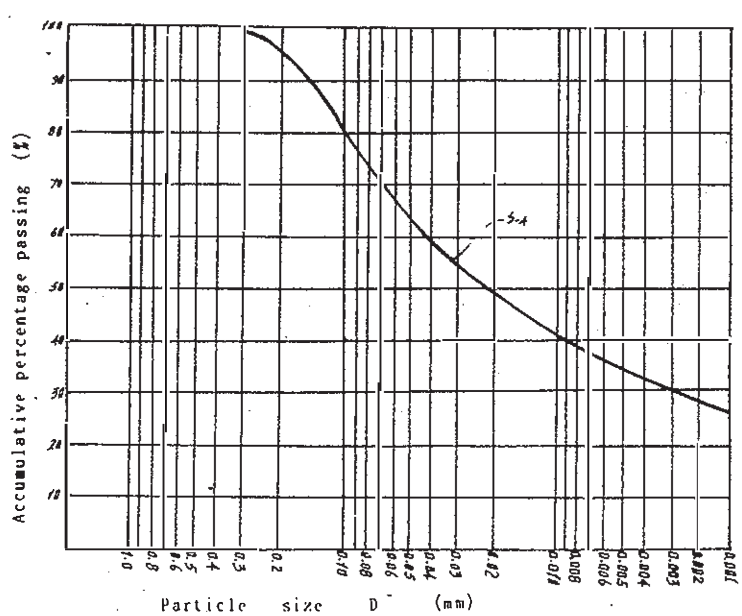
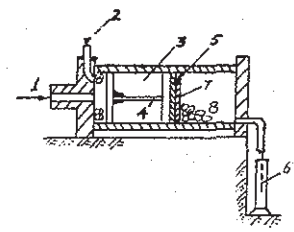


Fig. 2 Sample S-4 grain composition

excellent composited soil. Let us consider from the conventional method of sandfilter design, compare it with a poor composited soil, it is easier to treat. The key to the question is that the dipersive soil has both physical and chemical effects of damage, it seems that there is not a critical volocity in pure water, in general the critical volocity of non-dispersive soil is less than 10 cm/s. If the volocity is more than 100 cm/s, the dispesive soil becomes poor erosion-resistance.

4.3 Test result from laboratory

Because of the damage condition, we found, the key to the problem that was the earth structure cracked from upstream to downstream in the dikebody. In order to obtain this erosive condition, we undertake with pinhole test, designed by J.L.Sherard (U.S.A.), the property of sample S-4 is given as following: $r_d = 1.6$ g/cm³; W=15.3 %;the sample is 4 cm long; a hole sized 1 mm or 2 mm at the center of the sample. As shown in Fig.3, the sample is in the pinhole unit. Geotextile DS450-Ⅱ is used as filter. And also for safety, distilled water is used in testing. The water flows horizontally. The load applied are water heads of 5, 15, 45, 135 cm respectively. From the relations between the varity of water flow and the collapse of dispersive soil, we can evaluate the filter effects. See Table 2.



1--constant water head
2--upstream piezometer
3--dispersive clay sample
4--pinhole
5--wire mesh
6--graduated cylinder
7--geotextile
8--gravel

Fig. 3 Geotextile filter test equipment

4.4 Analysis of test results

Six sets of test were carried out, NO.01-04 gave good effects, infiltration water turning clear quickly, no soil particle in water, the pihole is not enlarged obviously, and very small area is polluted only around the pinhole; NO 05-06 has large pollution area, and pinhole enlarged, after water flowed through the hole, some of them escaped and flowed along the edges of the container.

According to these data mentioned above, which gives the common feature, the water flow turned clear gradually and the erosive damage was stopped.

Table 2 Goetextile as filters in pinhole test

NO	γ_d (mg/m³)	WATER CONTENT (%)	LAYER OF GEO-TEXTILE	LAYER OF WIRE MESH	HOLE SIZE mm BEFORE TEST	HOLE SIZE mm AFTER TEST	WATER HEAD (cm)	FLOWING WATER COLOR	NOTE
01	1.60	15.3	1	no	1.0	1.5	135	milkwhite clean	diameter of the pinhole pollution
02	1.60	15.3	1	no	1.0	1.5	135	as above	as above pollution
03	1.60	15.3	1	no	1.0	1.5	5.0	as above	as above pollution
04	1.60	15.3	1	no	2.0	2.0	5.0	as above	as above pollution
05	1.60	15.3	1	2	2.0	5.0	45	little muddy	pollution at the below part pollution
06	1.60	15.3	1	2	1.0	4.0	5.0	as above	as above pollution

1 up right is distilling water only;
2 up left is high dispersive sample after 10 min

Photo4 Wetting clast test

5 CONCLUSION

5.1 The geotextile is the effective mean to control the dispersive soil from erosive damage.

5.2 When designing geotextile instead of sandfilter, the geotextile and soil must be quite fit well in the engineering practice, as samples NO.05-06, otherwise, the earth structures will be escaped partially due to flow along the edges of the by-pass.

5.3 The damage mechanism of geotextile used to prevent the dispersive soil from erosion was difference from ordinary clayey soil or non-clayer soil. It is not a catalyst function based on geotextile, which makes a bridge structure in net and accompanies with filter region. But the geotextile filter effect in dispersive soil works is, the soil is dispersed in water, a part of latex dispersive flocculation materils occured and a part of fine soil particles flow through the by-pass or geotextile. Second, the particles on the soil surface bagan to separate one by one, large particles and non-dispersive particles made a discharge curtain (pollution area) by clogging or blocking in the geotextile filter body, with forming the process of this curtain, (forming the process of discharge system). The permeability of geotextile began to reduce due to clogging and blcking. The particles which moved further distance arranged one by one and made the filter region enlarged, in the end a steady hydraulic system was formed and a discharge steady condition was satisfied (the water was clear, pinhole not enlarged, the current was steady).

5.4 For the ordinary soil (clayer soil and loose soil), the clogging problem of geotextile usually is the important basis of design. For the dispersive soil, because of the damage condition, which exists in water by-pass, particles began to erode, so that a part of flow was controlled, the object will be obtained. Because the fine particles were clogged and more fine particles were blocked, the geotextile became the materials of forming discharge curtain. there was no problem when the geotextile was used for discharge design in dispersive soil.

5.5 For the geotextile the seepage standard of discharge design on dispersive soil must have a higher pemeability (due to a pipe water flow), also it has a homogenous and a discharge pore (formed a steady discharge curtain).

6 THE EARTH STRUCTURES DESIGN AND PERFORMANCE

The Southern Division Work in Heilongjiang was located in the distributed region, a filling reservior was made of 33 dikes, NO. 16 dike was built from dispersive soil, the total length of NO.16 dike is 430m long, the height of dike is 3m, the upstream slop ratio is 1:3, the downstream is 1:2.5, r_d=1.5 g/cm^3.

The properties of soil are:

S.P.	WL (%)	WP (%)	IP	0,002 (%)	Activity degree	
2.67	21.2	18.4	2.8	18	0.156	ML

The pinhole test result is:

No	water head (mm)	Q (1/min)	water content	r_d g/cm^3	dia- (mm)	color	classify
1	5	350	13	1.64	5	muddy	dis-persive

The results of dispersion degree are:

without dispagent 0.005(%)	dispersive agent 0.005(%)	dispersive degree (%)	classify
13		61.9	dispersiv

The geotextile tested is SD450-Ⅱ, other indices are as above.

Beside the design indices mention above, we must think about the protected range of prevention from water-flow erosion: to prevent dam crest from raining, because the dam was located in subdry land, always appeared rainstorm, for more dry dispersive soil before raining, it is very strong,but it can be eroded by pure water easily; to prevent dam slop from erosion, for the dispersive soil which will be stood a non-stready wave action, also the erosive damage is very serious; to prevent the downstream dam body from the seepage water, the water flow by-pass which made the soil grain moved it will be important part of protection. Particular attention must be paid to the erosive damage for dispersive soil which must have a by-pass of seepage, so the location of design is dependent upon the water level of reservior.

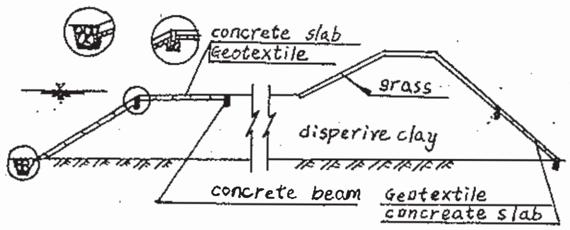


Fig.4 16# Dam at Southern Diversion Works

Fig. 4 demonstreated the structural design, The NO. 16 dike was constructed in 1978 and completed in 1987. It performs very well.

There are various methods to treat the erosion of dispersive soil, but using geotextile instead of sandfilter, is both durable and cheap.

There is no design criteria yet about using geotextile filter, people often prefer to adopt the design from the field and the data from the laboratory which, we believe, is reliable and feasible.

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