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The observation and analysis of stress-strain behaviors in reinforced region of sandy dam

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ABSTRACT: In connection with one dam, which were constructed with local abundant fine silty sand and woven geotextiles, this paper presents the method for building wrap-typed reinforced dam, the long-term monitoring results and analysis of stress-strain behaviors of dam body as well as its settlement. Monitoring results show that the woven geotextile with higher elongation may be better inconformity with dam deformation, which will not reach its max. value at the time of completion and will increase continuously because of creep property of geotextile in reinforced region the strains in different layers of geotextile are not the same; and even in same layer, they are not homogeneous. In comparison with the results of laboratory tests, the filed observation always gives lower values, showing that in reinforced soil the creep of geotextile occurred under confined condition is different from that given by laboratory, which is under unconfined condition. So it may be said, design using laboratory parameter is on safe side. Besides, the paper also gives the results of observation of settlement, vertical and horizontal stresses in dam body. All of observations and analyses point out that constructing the fine silty sand dam by means of geotextile-reinforcement technology is feasible and cost-effective. The conclusions drawn from the paper are useful and practical for the subsequent similar dam design and construction.

1 INTRODUCTION

The Shifusi Reservoir, Located on main course of Liaohe River, Liaoning Province, China, with a dam crest length of 46 km, is the largest river-typed plain reservoir in province up-to-date. The construction started in 2001. The fill materials were of great amount. but the local material available mostly did not meet the requirements So it was decided to construct the dam using local fine silty sand which will be wrapped layer by layer by woven geotextiles.

The fundamental date for the structure are:

(1) Soil: fine silty sand with dry unit weight γ_d = 1.648 g/cm^3, coefficient of permeability h = 10–5 cm/s;
(2) Geotextile: PP woven geotextile with tensile strength Tu = 40.87 kN/m (MD) and the corresponding strain δ = 30%;
(3) Dam geometry: fine silty sand dam with upstream clay sloping core on the existing dam, upstream slope 1:3, downstream, slope (reinforced) 1:1.5, horizontal drains buried in dam body and 3-D plant mattress on downstream slope.

2 IN-SITU MONIORING OF STRESSES IN DAM BODY

2.1 *Layout of transducers in dam cross-sections*

In-situ monitoring points were placed in two different sections: section I (stake No. R4-1+065) and section II (R5-0+300). In both sections the arrangements and measuring devices installed were the same. At bottom of reinforced zone for both sections two TY-2 type stress transducers were installed for vertical stresses; in middle flat dilatometer installed for horizontal stresses; Also, at bottom middle and upper layers of geotextiles, 18 displacement transducers were installed with vertical spacing of 1.5 m as shown in Fig. 1 and Fig. 2.

2.2 *Measured stress-strain behaviors in geotextiles*

From dam completion in 2001.10.08 to 2004.05.28, in the period of 2 years and 8 months, 18 sets monitoring were taken for both sections. It can be seen that the readings are continuous, regular and repeatable. Here, the max. strains in different layer

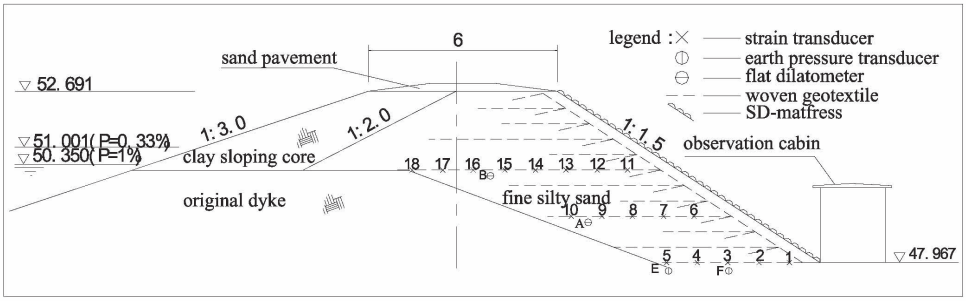

Figure 1. Layout of measuring points in cross section I (R4 1+065).

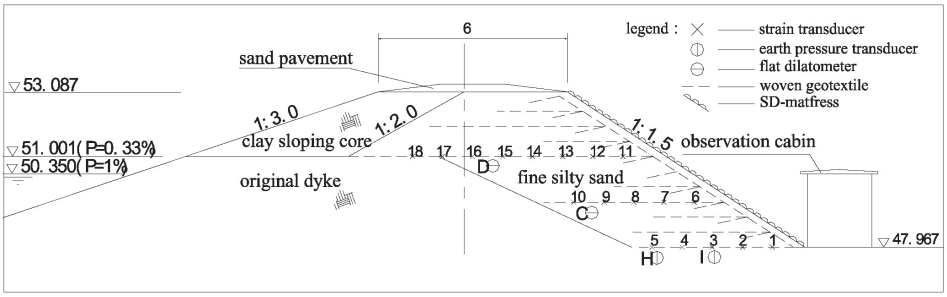

Figure 2. Layout of measuring points in cross section II (R5-0+300).

geotextiles (section I : I-4, I-8, I-14; section II:II-14) are taken for analysis, see Table 1. It can be seen:

(1) The strains in geotextiles increase with the rising of dam. After completion, all geotextiles in different layers develop tensile stresses, but of different values. The strains developed follow the order: strain in bottom layer>middle layer<upper layer, see Fig. 3 for cross section I. In same layer, the central strain is apparently larger than those on both sides and their distribution trace a curve as shown in Fig. 4.

(2) After completion, the strains still increase with time due to creep, but the rates gradually decrease,

Table 1. Max. strains in geotextiles (%).

No. of cross-scetions	Cross section I				Cross section II
Location of geotextiles layer	Bottom layer	Middle layer	Upper layer		Upper
Measuring point	I-4	I-8	I-13	I-14	II-14
Average strain	2.03	1.73	1.90	1.20	1.01
Max. strain	3.60	2.60	3.20	1.80	1.40

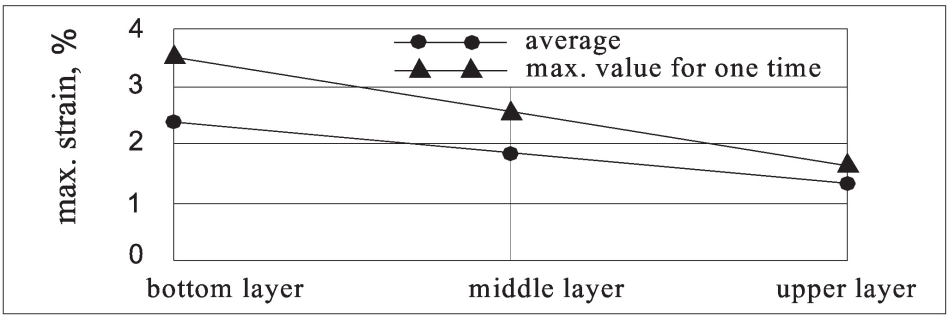

Figure 3. Max. strains in three layers of geotextile for sections I.

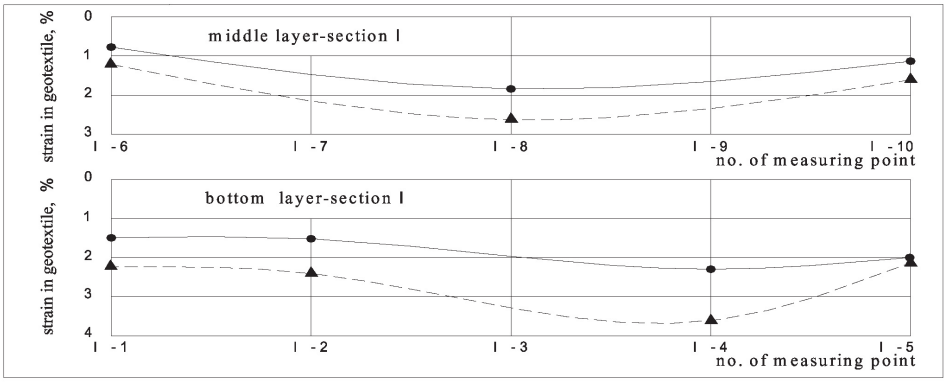

Figure 4. Strains in layers of geotextiles for sections I.

showing the geotextile approach stable under constant loading.

(3) As seen from Table 1, the strains in geotextiles for this project are very small (max. 3.6%) in comparison with designed value (8.26%), it shows that the geotextile strengths are far from full mobilization. In addition, the degrees of mobilization for three layers are different, so geotextiles with different strength may be used for different layers for saving.

(4) The dam has been already working nearly 4 years, no abnormal phenomenon has been observed, in combination with observation, it may be said the dam is stable under present unfilling condition.

2.3 *Measured vertical stresses in reinforced zone*

The dry and moist unit weights of dam are 16.48 kN/m^3 and 17.30 kN/m^3 respectively. The comparison of the average measured and calculated vertical stresses at bottom of dam are listed in Table 2, from which it may be seen:

(1) Through 18 set observations within 32 months, the measured and calculated vertical stresses are nearly equal at both pt. E of section I and pt. H of section II. But at pt. F of section I and pt. I of section II, the measured stresses are about 15% higher than the calculated. For the latter case, the deviation may be to the residual stresses left in measuring devices exerted by heavy machinery during compaction. Besides, the stresses both in reinforced and unreinforced zones are basically equal.

(2) It is found that the time has no effect on vertical stresses, for 32 months observations.

2.4 *Measured horizontal stresses in reinforced zone*

The horizontal stresses in reinforced zone were measured using flat dilatometer. During reservoir filling, the effective horizontal stress at certain point is:

$$\sigma'_{he} = \sigma_{he} - \mu_w$$

Where:

- σ'_{he} – measured stress;
- μ_w – static water pressure at the point.

The coefficient of earth pressure at rest:

$$K_o = \alpha \frac{\sigma_{he} - u_w}{\sigma_{vo} - u_w}$$

Where:

- σ_{vo}, σ_{he} the vertical and horizontal stresses at the point respectively;
- α – correction coefficient, for normally consolidated clay, $\alpha = 0.8$.

In reinforced zone the measured and calculated horizontal stresses are shown in Table 3, from which it can be seen:

(1) The measured horizontal stresses at "deeper points" (A and C) are always larger than those at "shallower points (B and D), which is in conformity with the general rule.

Table 2. The comparison of average vertical stresses (kPa).

Section	I		Section	II	
Measuring point	Measured	Calculated	Measuring point	Measured	Calculated
E	63.1	61.0	H	66.5	63.2
F	42.2	36.8	I	49.3	40.7

Table 3. Horizontal stresses and calculated K_0 (average) (kPa).

Section	I			Section	II		
Measuring point	Measured horizontal	Measured vertical	K_0	Measuring point	Measured horizontal	Measured vertical	K_0
A	52.2	57.6	0.72	C	55.5	57.6	0.77
B	36.3	44.	0.65	D	30.8	35.9	0.68

(2) Before filling, there is no static water pressure, the measured average horizontal stresses both at deeper points A and C and at shallower points B and D are slightly smaller than that by overburden by soil weight pressure. It may be caused by the fact that the soil is still not completely consolidated. With the gradual consolidation, the measured stresses approach to the calculated.
(3) For both sections I and II, the Ko values calculated from measured horizontal stresses are variable, and Ko at deeper points A and C are larger than those at shallower points B and D.
(4) The Ko values calculated from measured horizontal stresses for reinforced zone vary in a range of 0.65~0.77, they are larger than the corresponding range 0.42~0.57 for the unreinforced zone which is after the book ⟨⟨Soil Mechanics⟩⟩, In this project, the former is about 30% larger than the latter.

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