Design Improvement of Sandy Soil Levees in Hydro-engineering Projects, China

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Abstract. Soil levees are widely constructed in thousands of rivers in China. While due to the limitation of on-site materials, some projects have to use sandy soil as the filling material. The South-North Water Transport Project, flood control projects of the Yangtze River and Yellow River, water diversion irrigation projects in the northwest of China, and some coastal seawall projects all contain sandy soil levees. Considering the slope stability, many sandy soil levees are designed with slope ratio 1:4 or 1:5, which need a lot of land cover and soil filler. So the section design and construction technology of sandy soil levees are improved. To increase the stability and narrow the section, methods such as the geotextile reinforcement, sand geotube construction, "sandwich" filling and soil modifying methods are common ways. Among them, the geotextile reinforcement and sand geotube construction are quite effective and widely applied. And engineering applications are listed. So, the sandy soil levee can be widely promoted.

Keywords: Sandy soil levee · Section design · Geotextile reinforcement Geotube construction

1 Introduction

Many cities and more than 40 million hectares of land are located along the rivers in China. In 1998, a catastrophic flood disaster happened in the Yangtze River, and caused great economic losses. So, levee construction is very necessary. The fill material is the key point for the levee. Soil levee is the main form. Sandy soil is not appropriate to be used as the levee fill material. However, due to the limitation of on-site materials, some projects have to use sandy soil as the fill material. Thus the sandy soil levees are applied. The South-North Water Transport Project, flood control projects of the Yangtze River and Yellow River, water diversion irrigation projects in the northwest of China, and some coastal seawall projects all contain sandy soil levees. For example, there are 600 km sandy soil levees in the Songhua River. This paper summarizes the application and development of sandy soil levee construction technology in China's hydro-engineering projects.

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2 The Code for Levee Design

The Code for design of levee project [1] stipulates that the anti-sliding stability safety factor of soil levee slopes should not be less than the value specified in Table 1 in accordance with the Sweden's Arc Method or simplified Bishop Method.

Table 1. Anti-sliding stability safety factor of levee slopes

Scale			1	2	3	4	5
Safety factor	Swedish Arc Method	Normal condition	1.30	1.25	1.20	1.15	1.10
		Non-normal condition I	1.20	1.15	1.10	1.05	1.05
		Non-normal condition II	1.10	1.05	1.05	1.00	1.00
	Simplified Bishop Method	Normal condition	1.50	1.35	1.30	1.25	1.20
		Non-normal condition I	1.30	1.25	1.20	1.15	1.10
		Non-normal condition II	1.20	1.15	1.15	1.10	1.05

Note: Non-normal condition I means construction period, Non-normal condition II means the average water level and an earthquake occurs.

Researches show that the anti-sliding stability safety factor of sandy soil levees can basically meets the requirement when the levee slopes being designed as ratio 1:4 or 1:5, but the margin of safety factor is little. Furthermore, if the sandy soil levees are designed with slope ratio 1:4 or 1:5, that need a lot of land cover and soil filler. Meanwhile, the cost for land acquisition and construction is large. Therefore, to narrow the levee section and reduce the land acquisition, the design and construction technology of sandy soil levee needs to be improved.

3 Design Improving for Sandy Soil Levees

The common design improving methods for sandy soil levees are summarized as the followings.

(1) Geotextile reinforcement method. The geotextiles are layered with intervals along the height of the soil levee, as the same as the reinforcing steel bars in the concrete. And gravel or clay is wrapped at the end of each layer. The detailed design of the geotextile reinforcement method can be found in the Technical code for application of geosynthetics [2].
(2) Sand geotube levee construction method. The sand is rushed by the use of high-pressure water, then the sand and water mixture are pumped into the bags. Due to the elastic restoring force of the bag material and the gravity effect of the sand

itself, and with the permeability of the bag, water can quickly filtered through the bag, so the sand will consolidate in the bag and have some shear strength. Then bags are stacked into the levee core, and a protective layer is built outside to form the levee.

(3) "Sandwich" filling method. The sand layer and the other material layer are stratified, which the layers are interlaced like a sandwich. Each layer has different quality control standard.

(4) Soil modifying method. The physical properties and engineering characteristics of the filling sand can be improved by two ways. The physical way is to mix the sand with other soils which are better for levee construction. The chemical way is to mix the sand with cement.

For the methods, geotextile reinforcement method can enhance the slope stability, and also prevent the slope from the erosion of wind, rain and river wave through the wrapped gravel (or clay). The sand geotube levee can be constructed rapidly, so it's widely used in coastal reclamation projects. "Sandwich" filling method is mainly used in the highway subgrade. Soil modifying method is a reliable method. However, the complex construction process, the difficulty of uniform mixing, and the high construction cost make it not easy to be applied.

So the geotextile reinforcement and sand geotube method are the most effective ways for design improving of the sandy soil levees construction.

4 Engineering Applications

Geotextile Reinforcement Method in Sandy Soil Levees. Some sandy soil levees are constructed in the South-North Water Transport Project. For example, there is a planned 7.32 km length levee near Shijiazhuang city. The original designed clay levee need to expropriate clay land and have a long distance transport. While the local material is mainly sand. In addition, 280000 m^3 sand had been excavated in the channel and have no place to stack. So the sand levee design is decided. The levee slope ratios are designed to be 1:3 inside the river and 1:2.5 outside.

While the slope stability safety factor is calculated to be 1.34 in accordance with the Simplified Bishop Method [3], failing to meets the code requirement 1.5. So the geotextile reinforcement is applied. The total tension required for reinforcement T_s [2] is calculated as

$$T_s = (F_{sr} - F_{su}) \frac{M_D}{D} \tag{1}$$

where: F_{sr} is the required safety factor, F_{su} is the calculated safety factor, M_D is the bending moment, D-Force arm of T_s. Also, some levees in the Songhua River are constructed by sand. To narrow the levee section and reduce the land cover. Geotextile reinforcement method is applied. So the slope ratio is decreased from 1:4 to 1:3. High-strength woven cloth is used for the reinforcement material. The thickness of each soil layer of is 40 cm. The length of the bottom layer is 8 m. The top layer is gradually

reduced to 4 m. The length of the wrapped geotextile is 2 m. The safety factor is calculated to be 1.42, which is greater than the required 1.25.

Li and Jie [4] analyzed the reinforcement effect relating to the strength, quantity, distance, and length of the geotextile. And the slope form is also discussed. In addition, the reduction coefficient of the geotextile strength under long operating period is taken into account.

Sand Geotube Levees. There are a lot of fine sand resources in the estuary of the Yangtze River, while the clay material is quite scarce. So the sand geotube levees are widely applied. Due to the non-cohesion and poor anti-erosion ability of sand, it is easy to lose body soil under the hydrodynamic force in front of the levee. While the reliability of geotube levee is to prevent the sand loss of the levee body essentially. With the sand filled into bags, the levee slope ratio can also be design as 1:3 inside the river and 1:2.5 outside. Cai et al. [5] developed a method for the optimal design of the structural section of sand geotube levee. The project cost can be reduced by more than 20%. Peng et al. [6] summarized the field testing results of many practical engineering geotextiles, concluded that the durability of sand bags can be more than 30 years, and proposed some anti-aging measures.

5 Conclusions and Suggestions

The background and situation of the sandy soil levee are summarized. Then the design improving methods and their applications are studied. The following conclusions are got. (1) Sandy soil levee are widely applied in China's hydro-engineering projects. The levees with slope ratio 1:4 or 1:5 need a lot of land cover and soil filler. So improving the design and construction technology is necessary; (2) The common design improving methods for sandy soil levee are geotextile reinforcement, sand geotube construction, "Sandwich" filling, soil modifying and so on. While geotextile reinforcement and geotube construction are the most effective ways; (3) The engineering applications of the sandy soil levees with section design improved are studied. The improved design can enhance the slope stability and narrow the section. Also some major factors are comprehensively considered; (4) Based on the engineering experiences, Sandy soil levees can be widely promoted.

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