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Application of geotextiles in deepwater channel regulation project of the Yangtze Estuary

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ABSTRACT: in these paper , the application of new soft mattress for bed protection and sand-bagged dike of large synthetic Geotestiles has been in details introduced. And the new soft mattress is characterized by in sit manufacture, simple technics, high mechanization, making use of sands nearby and laying as a whole, etc. Which guarantees the schedule, stability and safety of the construction of leading jetties and groins

1 OVERVIEW OF THE DEEPWATER CHANNEL REGULATION PROJECT OF THE YANGTZE ESTUARY

As a huge rivermouth with great sedi- ments, the Yangtze Estuary consists of three-order bifurcations and four outlets. A backstop-belt has been formed at the Yangtze Estuary because 4.7 hundred million tons of sediments from the up- stream move and silt annually at the river mouth where the salt-water and freshwater mixed together. In order to improve the navigation capacity so that containers IV can go through round-the-clock, containers□□□ and ship with the throughput capacity of 10,0000 tons can tide up the channel of the Yangtze Estuary, a channel with a depth of 12.5m is to be constructed in the south and north channel.

Instead of rubble bed protection, soft mattresses have become the only material used for bed protection during deepwater channel regulation project of the Yangtze Estuary. A conclusion that no soft mattresses, no regulation projects of the Yangtze estuary was made by experts. What is more, large containers were very useful in the project.

2 SOFT MATTRESSES FOR BED PROTECTION

There were three kinds of new soft mattresses such as rubstone soft mattress, sand-rib soft mattress, and complex soft mattress (rubstone and sand-rib) that were widely used in the first phase. The length of soft mattress relied on the width of dikes and the additional length. The maximum length reached 140m. According to the width of the flat roof of lay-ship, its maximum width reached 40m.

Sand-rib mattress: By filling finesands and silt into long bags that was made of Geotextiles and linking the bags with sheaths, polypropylene belts and mattresses together, the sand-rib soft mattress was made. Its materials were made of machine-made polypropylene piece goods with long fabric (it was characterized by high strength) and non-woven terylene piece goods with short fabric that had been stitched up. Major advantages of sand-rib soft mattress for bed protection included making use of sand nearby, in-field-manufacture, simple technic, high schedule and low cost.

Rubstone soft mattress: Its materials were the same as that of the sand-rib mattress. By placing rubstone (which were built in special field) net into mattress and linking them together by polypropylene belts at the flat roof of lay-ships, the rubstone soft mattress was made. The size of single rubstone-net was usually 4.5×9.5m or 4×5m. The major advantages of rubstone soft mattress included building and placing as a whole, easy for transport-ation and high mechanization, etc. Although the cost was higher than sand-rib soft mattress, the rubstone soft mattress was more sustainable to the distortion of river bed and current.

Complex soft mattress: It consisted of sand-rib soft mattress and rubstone soft mattress. Sand-rib soft mattresses were placed under the dikes, as well as outside of the dikes, and the rubstone soft mattresses were placed inside (in the channel) of the dikes. In the first phase, this method was widely used.

Aimed at the characteristic of bad conditions, shortage of the effective work- day and high construction strength of projects of the Yangtze Estuary, the above mentioned soft mattresses that were suitable to the high mechanization works guaranteed the schedule. Besides, the structural integrity made them resistant to the distortion of river bed.

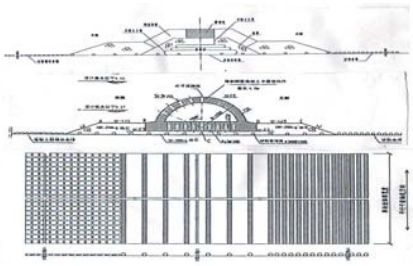

Figure 1: structure of soft mattresses

2.1 Materials of soft mattresses

Soft mattersses have been applied as bed protection in many projects. Their materials consist of woven synthetic and machine-made synthetic.

One of the primary functions of soft mattress is sand reserving. It is also illuminated in the technical specifications for Geotextile applications, and the none- woven terylene piece goods should be used. Now the technics of making these materials are well-rounded. Geotextiles with a lay of rocks pressed on it are widely used in the coastal projects.

The strong points of none-woven terylene piece goods include filtrability, permeability and good separateness. However, as their intensity is low, they are liable to be distorted. Characteristized by sand reserving, high resistance to filtration, high inten-

sity and stability, new synthetic Geotextiles can overcome these troubles. The synthetic Geotextiles applied in the projects of Yangtze Estuary are made of machine-made polypropylene piece goods (230g/m^2) and non-woven terylene piece goods (150g/m^2).

In synthetic Geotextiles, interval between threads decreases from 0.1mm to 0.07mm or less and vertical permeability index increases from about 10^{-3}~10^{-4}cm/s to 10^{-2}cm/s. Thickness increases from 0.5mm to 2mm or more. Intensity remains at the same level. Because of improvement of these indexes, permeability, sand reserving, resistance against aging and structural integrity are improved.

2.2 Polypropylene belt

Polypropylene belt, which is placed in the direction that is vertical to the axis of dikes, is in favor of keeping stability and abating sink of dike base. Since '70s, polypropylene belts were widely used to even the force on soft mattress, improve their intensity and reduce the extension of geotextiles. They were netted up and down soft mattresses or sewed directly into soft mattresses (Their width was 5cm or 7cm).

Soft mattress that has been laid into water was fairly long because of water depth and tide. The weight of the rubbles and sand-ribs was mainly taken by polypropylene belt. It is necessary to use Polypropylene belt in rubbles and sand-ribs to guarantee their stability.

2.3 How to stitch Geotextiles

Because the length of Geotextiles became much longer, the traditional stitching method was not feasible. So, a round-return transportation machine with a length of 84m and height of 2m has been made. The machine kept in pace with sew-machine. Being sewed, the stitched Geotextiles was hung up to hooks of the machine tightly. Because Geotextiles was carried by transportation machine, work intensity was reduced. Before the application of transportation machine, work efficiency kept 88m^2/d per people. Now it reached 700m^2/d per people, 7 times more than before.

2.4 How to manufacture rubstones

Rubstones were built in steal model, which was made up of two layers. With a thickness of 80cm, a hole (Φ16mm) was drilled in the middle part. Polypropylene-ropes(Φ16mm) that were aging-resistance ran through it. Polypropylene ropes were crisscross placed in models. Then the whole structure was concreted, the size of single rubstone was 400×400×160(mm). The concrete proportion was C20.

The rubstones was transported to the bunks by bus. Then they were shipped to lay-ships by ships with a capacity of 1000 tons.

2.5 How to fill sand-rib

Sand-ribs filled in situ came from silt nearby. Before construction, experimental filling should be done with small bags. Only when such data as mortar intensity, force on sand bags during mortar-filling and filling time were available, the construction could began. According to recent research, the power of slop pumps and water pumps was 15 to 22kw, sand transportation tube was soft rubble tube with a diameter of 10cm, discharge of high pressure water-pumps was 60 to 160m^3 per hour, discharge of standing slope pumps was 160 to 250 m^3 per hour. The diameter of single sand-rib wasΦ300 mm, the length of which was 35m. And one or two sand-rib was placed on every meter.

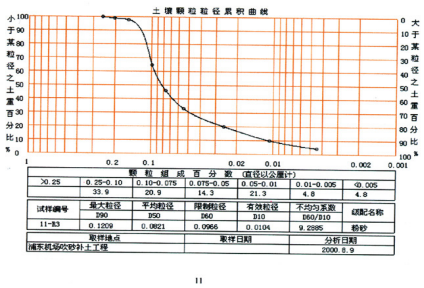

Figure 2 accumulative curve of sediment diameter

2 Quality-control of soft mattresses manufacturing

The Geotextiles should stitched according to design strictly. And sample tests should be done. Among a 10000m^2 of stitched-Geotextiles, one sample test should be done by qualified test-department according to design criteria or specifications. During sand-filling, field sample tests were needed to gain such parameters as sand reserves, diameter series of sand and filling density. It is necessary that rubstones should be made upon the specifications.

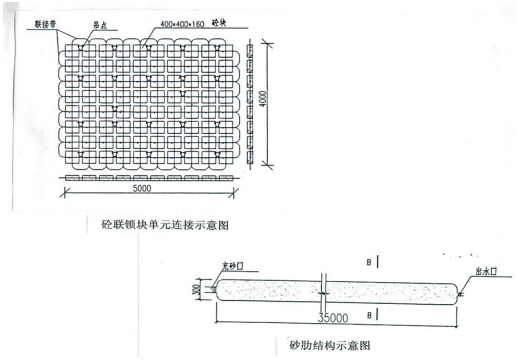

Figure 3 layout of the units of rubstone and sand-rib soft mattresses

2.7 How to lay soft mattresses

According to capacity, lay-ships used in Yangtze Estuary can be divided into two classes: those of 600 tons and those of 3000 tons. A lay ship is equipped with a work roof that is 18 to 40m wide, a slide-board (it can overturn to 45°) along side, and a crane with a capacity of 10 tons. Also, a rolling-off-machine and transport-ation equipments for Geotextiles, DGPS system with positioning software and screens are included.

2.8 Design bed protection of soft mattress

2.8.1Criteria of permeability and sand reserving ability of Geotextiles

In the case of one way seepage and permanent-loads, design criteria are:

$$Q_{95}<d_{85}\ ;\quad Q_{90}>d_{15}\ ;$$

Q_{95}, Q_{90}—— equivalent interval size(mm) They mean that on the interval size curve of Geotextiles, 95% or 90% of sands are smaller than this value.

d_{85} , d_{15} —— they are sands, which occupy 85% or 15% of the gross weight, smaller than the diameter on sifting curve of all sands.

According to diameter data of bed sands, the characteristic diameter of the bed sands is: 0.13 to 0.15mm of d_{85}, 0.05 to 0.08mm of d_{15}. Thus stitched Geotextiles with an interval size of 0.07mm was suit-able for construction design.

2.8.2 Intensity of Geotextiles and poly-propylene belt

T_a——permitted tensile intensity (KN/m)

$$T_\alpha = \frac{T_u}{K_m}$$

T_u—— ultimate intensity (KN/m)

K_m—— safety parameter

The major forces on Geotextiles and polypropylene belt included load during construction, current and wave.

The design intensity of Geotextiles was 1/3 of the ultimate intensity while that of polypropylene belt was 1/2 of ultimate intensity.

Because materials of soft mattress and Geotextiles and polypropylene belt were tied together, part of load was placed on Geotextiles while most of gross load was burdened on polypropylene belt. It is safe to take the belts with a width of 5cm and 7cm and place mattress at the area where water depth was 6 to 10m (During high tide).

2.8.3 Resistance against floating

$$t_m = \frac{v^2}{\theta^2 \gamma'_R g}$$

t_m—— thickness of mattress;

$$\gamma'_R = \frac{\gamma_m - \gamma_w}{\gamma_w}$$

V_{cr}——design velocity (m/s);

θ—— parameter;

y'_R—— no-unit weight of mattress under water;

The safety parameter of sand-rib soft mattresses is: $S_N<5$. That of rubstone soft mattress is: $S_N<5.7$.

2.8.4 width of the beyond-lay soft mattress

According to experiments, width of the beyond-lay soft mattress was determined by maximum eroded depth before dikes and gradient. Width of soft mattresses at north leading jetty adopted in the first phase was 20m or 30m. According to observation, the actual gradient caused by erosion was better than estimation. It was no more than 1:4 to 1:5. It's because that soft mattress was plastic enough to resisted erosion along edges of mattress.

3 SLOPE DIKE THAT TAKE SAND-FILLED BAGS AS ITS CORE

Geotextiles is born with such quality as good separation, high resistance against filtration, high intensity, permeability and good protective function, etc. Instead of stones, more and more sand bags made of Geotextiles are used as the core of slope dikes. Moreover, Geotextiles and synthetic membrane are taking the place of detritus filtration layer or lay against filtration that was made up of clay.

Sand-filled bags used in the construction of slope dikes have been improved from one layer to several layers with non-woven terylene clothes as its against-filtration-layer. Since special lay ships were made, sand-filled bags can be placed not only at the area with low hydrophily and lower wave but also at deep water area.

3.1 Container structures and materials

Aimed at the high wave and gale of Yangtze Estuary, stitched synthetical Geotextiles with high intensity and resistance against filtration was used around bags while normal machine-woven or woven Geotextiles was used at top or bottom part of bags (these parts would be covered after sand filling). This kind of bag reduced the leakage of sands in construction when no surface protection layer was built. At the less important part where wave and current was weak, cheap machine-woven or woven Geotextiles was applied. This method was widely used in the first phase projects of the Yangtze Estuary.

3.2 Structure stability during construction and machine selection

Sand-bag-dike core is usually long and flat with large scale. The stability of this system is higher than rubstones dike core. But as the sand-filling ration is approximately 80%, sands were easy to leak out from the bags on the top of dike. Model tests indicated that the critical wave high of stability was 2.2m. But in some area, the design wave-high is higher. Aimed at this condition, the above two layers of bags were divided into several pieces in the direction of dike axis. Based on model tests, this method highly improved the stability.

4 CONCLUSION

More than 14 minions m^2 of Geotextiles were used in the first phase projects of the Yangtze Estuary. In particular, machine made non-wonve terylene piece goods and woven terylene piece goods were applied. The sand-rib soft mattress filled with silt in field and rubstone soft mattress that was characterized by erosion resistance and plasticity was selected as the structure of soft mattress. It started the new vision of application of Geotextiles in the soft mattress.

4.1 Characteristic of the soft mattress

(1) With such characteristics as high intensity,small diameter, good permeabili-ty, little effect on current and adaptability to different torpography, new soft mattress consists of synthetic Geotextiles could resist gale, sea and gush in Yangtze Estuary. In order to guarantee the safety of leading jetty, it is wise to applied new soft mattress.

(2) It was easy to place. In the first phase project, soft mattresses laid by one ship was more than $4000m^2$ a day, 9 times higher than traditional method. Thereby, the schedule was guaranteed.

(3) Its cost is low. The unit price of sand-rib soft mattresses was 50% of the traditional rubble bed protection. That of rubstone soft mattresses was 80% of rubble bed protection. It was even lower than that of brushwood-soft mattresses. It saves a lot of money for the first phase projects.

4.2 Improvement of mortar-bags

On July 1, 2000, the first phase projects of the Yangtze Estuary finished. In the first phase, based on the successful application of the soft mattresses with new Geotextiles, large-scaled sand-filled-core slope dike and mortar bags, the bed protection construction completed very well. Not only the recess of Jiang-Ya shoal was stopped, the good condition of the Diversion was kept, but also the whole building was protected as the soft mattress bed protection was constructed ahead of the construction of dike body.

With the printsman of technical specification for Geotextiles application of the national transportation department and the improvement of the manufacturing of Geotextiles, the application of Geotextiles in the channel projects is promising.