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Research on anti-seepage technology of hydraulic machines of trenching and laying down geomembrane

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ABSTRACT: hydraulic machines of trenching and laying down geomembrane, anti-seepage technology, soil dam, seepage deformation, water conservancy construction

Anti-seepage technology of hydraulic machines of trenching and laying down geomembrane, an advanced and practicably anti-seepage technology, has been developed to meet the need of water conservancy construction, especially, aim at reservoir and soil dam existed in seepage and seepage deformation.

The technology includes independently developed hydraulic machines of trenching and laying down geomembrane, an integrated set of construction technological process and design method. Hydraulic machines are composed of an augmentor, a trencher, and a hydraulic machine of laying down geomembrane. By hydraulic pressure system, the augmentor can drive and drag the trencher and machine of laying geomembrane forward or backward, and then the trencher can make a continuous trench demanded width and depth in the soil dam, at the same time, the hydraulic machine of laying down geomembrane can lay down geomembrane synchronously and backfill soil material according to demanded design, thus an anti-seepage curtain wall was formed after a period of settlement and consolidation. This especial kind of structure model enable hydraulic machines to trench a minimum radius curvature of 47m continuous trench, its practical application ability has been improved remarkably.

Hydraulic machines, completely hydraulic controlling, are fit for widely earth layers and have a high efficiency, because it can bear vibratory load, and steplessly regulate speed and reciprocally dissected frequency according to earth layers' situation. The technology can overcome weakness of poor connection and quality difficulties of construction guarantee of other anti-seepage technologies such as high pressure jet grouting. Anti-seepage curtain wall has many advantages of good seepage prevention, adaptable deformation; scour resistance to underground water, long working life and lower construction cost. At present, remarkable economic benefits has been made by laying down geomembrane of more than 100 thousand square meters at 10 water conservancy projects in Liaoning province of China.

1 BRIEF INTRODUCTION

The whole basin of Hunhe River took place the biggest flood of 100 years for the longest duration in 1995 in Liaoning Province. The fiood broke three locations of the sandy dam and sandy foundation due to seepage damage, which caused the huge loss of proporty and death of enoromous people. Therefore, the government decided to entirely harness those primary rivers in the following years. A surge of infrastrusture constrution in terms of water conservarcy and dam consolitation projects appeared in 1996 across the whole province, which resulted in all kinds of new techniques, new materials and new construction technologies widely applied to river works, however, anti-seepage treetment for sandy foundtion was of special importance.

One of the most effective anti-sapage methods for sandy bank and sandy foundation is vertical anti-seepage technology. This kind of vertical anti-seepage technology demands: First, both the thickness of anti-seepage curtain wall and the coeffecient of seepage should be smaller; the ablity to transformation should be stronger, and the quality of duraction should be perfect. Second, it has a merit of popularity. Third, the machine demands highly machinized, easily operated and has strongly adapted to the soil layers. Furthermore, the machine can trench continuosly according to the requirements. Nowadays, there are kinds of anti-seepage technologies in accord with types of mechinery. The common methods are as follows: high pressure jet grouting, water jetting, deep mixing method, trenching method hydraulic pressure clamsheell, and drilling method. Moreover, by practice few methods can satisfy the above demads, water jetting, hydraulic pressure clamshell and deep mixing methods, besides too heavy mechines, mainly remains weakness such as forming uncontinuously anti-seepage curtain wall, difficult to control constructing connection, which contributs to too bad anti-seepage results, high pressure jet grouting and drilling were those anti-seepage methods appeared earlier, so have some advantages of pefect technique, ideal construction technology, strong ablity of adaption to soil layers, and widely application, but the methods also have some disadvantages of high costs and low economic efficiency after taking an overall analysis from an angle of anti-seepage. Trenching method can not only lay down geomembrane, but also can form anti-seepage curtain wall, which has broad future with characteritics of higher economic benefits and working performance than that of other methods. However, this kind of methods are unable to suit gravel layers and have some restrictions to the trenched depth in clay layers because of mechanical operation. So it is essential to develop the new technique, new technology and new machinery on the basis of higher economic benefits, efficiency and stronger adaption. Therefore, An anti-seepage technology of hydraulic machines of trenching and laying down geomembrane was developed by Liaoning Provincial Institute of Water Resources and Hydropower.

2 TECHNIQUE PRINCIPLES

The anti-seepage technology of hydraulic machines of trenching and laying down geomembrane can be classified into mechinery development and construction technological research. Due to hydraulic operation, oil pump and hydraulic motor can drive speed reducer and curved bar to make saw pipe moving backward and forthward. Thus soil has been cut down along trenching axis, which mix with water or clay slurry, then can be drained away by reversal recycle system, so a continuous trench has been opened. Laying down geomembrane into the trench and backfilling soil, a continuous anti-seepage curtain can be formed after a short period of settlement and consolidation. Furthermore, it would have both anti-seepage and consolidation effects if concret or other soft anti-seepage materials had been poured into the trench through the holes pre-seperated by partition board.

3 TECHNIQUE CHARATERISTICS

1. The hydraulic machines of trenching and laying down geomembrane have a high machinization with low fault rate. It can be performed for all kinds of soil layers and gravel layer, but the gravel layer must be less than 30% of gravel and the gravel diameter must be below 100 mm. The trench is 200-500mm wide and 15m deep, and can be finished 150-300m^2 per 8 hours.
2. Due to applying hydraulic pressure system, the Hydraulic machines, completely hydraulic controlling, are fit for widely earth layers and have a high efficiency, because it can steplessly regulate speed and reciprocally dissected frequency according to earth layers' situation.
3. Due to applying hydraulic pressure drive, the saw pipe can bear vibratory load. The hydraulic pressure system can automatically reduce load when the load on the saw pipe excesses the rated load. So the machine can safeguard the key equipments and has a low fault rate.
4. Under the operating condition, the saw pipe can form an angle of 70-85 degree with ground surface. The angle caqn adjust 85 degree when the machine begins to turn direction. So the machine can open a continuously curved trench according to the actual demands. By pratice, the especial kind of structure model enable hydraulic machine to trench a minimum radius curvature of 47m continuous trench, its practical application ability has been improved remarkably. It is the only one of this kind unique at present in China.
5. When the saw pipe cuts the soil layers, water spraying out from the holes on the pipe with a high speed can flow away the adsorbed soil effectively. This can avoid soil adsorbing on the pipe and make operation with a high efficiency.
6. The key to making the anti-seepage curtain wall is the stability of the trench. In addition to applying traditional method with slurry or water to protect the trench wall, plastering devices are equiped on each side of the saw pipe, which can consolidate the cutting soil reciprocately. Thus can make the trench wall rather stable.
7. As far actual condition, the concret can be pour into the trench bottom below water or slurry. This can help form a effectively continuous anti-seepage wall.
8. The results of anti-seepage are pefect. The construction also can save a large amount of farmland, so the anti-seepage technology of hydraulic machines of trenching and laying down geomembrane has been widely used to river works in Liaoning Province.
9. The anti-seepage curtain wall has a low cost, long duation and low fees of maintaince and mangement.

4 ANTI-SEEPAGE DESIGN OF GOEMEMBRANCE

4.1 *Design principles*

Selecting geomembrane, as anti-seepage material must meet anti-seepage and stability demands. Therefore, the design should follow the following principles.

1. Under the designed condition, geomembrane should meet the demands of anti-aging and long service life.
2. Under the normal condition of bearing water load, geomembrane should meet the demands of anti-seepage and stress.
3. Sliding resistance stability should be satisfied between geomembrane and backfilling soil layers.
4. Exhaust valves should be designed at specific locations on geomembrane if demanding air relief. Thus can avoid ground water level rise to cause excess air pressure force to damage geomembrane.

4.2 *Selection of geomembrane*

Application geomembrane has a history of more than 40 years in China. A large amount of experiences of design and construction had been accumulated in the past two decades, especially applying geomembrane to 10 infrastructral departments. There are some materials can be used to make geomembrane, however, Polyvinyl chloride (PVC) geomembrane has been used recently related to strong tensile, against aging ability and long duration. On the basis of the experimental findings made by the former Soviet, the sevice life of PVC geomembrane burried into soil can last 120-180 years, so it can meet the engineering's requirementnts. On the other hand, PVC geomembrane is the ideal anti-seepage material for it has good quality of waterproof, good connection and strong adaption.

Generally take for vertical anti-seepage for dams, considering stability requirements, compound geomembrane should be selected as anti-seepage materials at the slope toe of the dam towards upstream. Compound geomenbrance is a kind of compund product made of unwove fubric and geomenbrance, by an unigue process. Geomenbrance mainly acts as anti-seepage material, and unwore fubric has functions such as reinforement, drainge and friction improvement. Compound geomenbrance can fall into "one layer of unwove fabric and one layer of geomenbrance" and "two layers of unwove fabric and one layer of geomenbrance". The later has more advantages over the former such as friction improvement and safty stability.

4.3 *Determine the vertical anti-seepage depth*

Anti-seepage curtain wall commonly should be inserted into water resisting layer or relatively impermeable bed, thus can reach the anti-seepage effects. Though suspended anti-seepage curtain wall can reduce water head, the results are not pefect. Refering to 2-layer's foundation, the lower layer can be considered as relatively impermeable bed if the coefficient of seepage is 100 times smaller than that of the upper one. In this case, the bottom of anti-seepage curtain wall should insert 0.50m into the lower layer, the top should be 0.50m beyond the designed eveluation.

4.4 *Determine the thickness of compound geomembrane*

According to Geosythetics Application Technique Code for Hydropower Engineering (SL/T225-98) appedix C, the calculation formula can be given.

$$T=0.204pb/\varepsilon^{1/2}$$

Where,

T-tensile strength, KN/m,
p-water head, kpa,
b-width of possible crack of the foundation, m,
ε -extensibility,%

– By assumpting crack's width, T~ ε relationship diagram can be plotted. Then determine the value of T and ε , the coefficient should be 4-5.

4.5 *Stability calculation*

According to Geosythetics Application Technique Code for Hydropower Engineering (SL/T225-98) appedix A, the stability calculation formula can be given.

$$K=r_w \operatorname{tg}\alpha / r_m \operatorname{tg}\beta$$

Where,

K-sliding resistance coefficient,
r_w -soil wet density,
r_m - soil saturated density,
α -friction angle between soil and geomembrane,
β - angle of laying down compound geomembrane

In order to improve stability, a trench of 0.3m wide and 0.4m deep should be designed for sliding resistance. See Fig. 1.

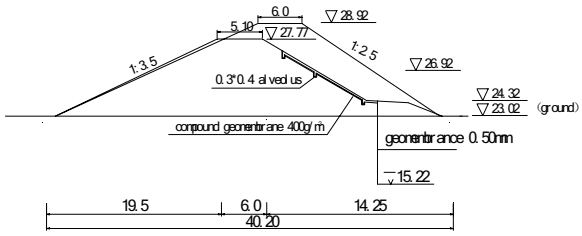

Fig. 1 standard cross sectional design drawing

5 ENGINEERING APPLICATION AND EFFECTS

5.1 *construction technology*

See Fig. 2

Make platform — Make guide trench — Install machines — Start machines — Trench(Add clay liquid) — connect geomembrane — Lay down geomembrane — Backfill — Form continuous curtain

Fig.2 Flow diagram of construction technology

5.2 *Engineering application*

The technology has been applied to more than 10 river works in Liaoning Province since developed in July 1997. The total area of anti-seepage has reached 0.2 million squre meters and remarkable economic benefits have been achived.

Matoulang Sandy Dam Anti-seepage River Works is located in Shujiatun district of Shenyang City in Liaoning Province, which is the left dam of Hunhe River's downstream. The chainage is from HZ36: 3+650~5+050. The total length is 1600m. See Fig1. The foundation is composed of sandy loess, silt sand and gravel. The average anti-seepage depth is 9.0m, the depth of inserting into the reletively impemeable bed is 0.50m. The area of anti-seepage curtain wall in the foundation is 14400m^2, in the dam body is 11429m^2, the total area is 25829m^2. Along the slope of dam towards upstream, a continuous trench was opened and a 0.50mm thickness of geomembrane was laid down into the trench vertically. Compound geomembrane was laid on the slope of the dam, covered with a layer of soil. Two kinds of materials were connected. The trench made by the machine is 9.0m deep and 0.22m wide, the average running speed is 2.35m/h. The average working rate of making trench is 280m^2/d, the highest rate is 400m^2/d.

5.3 *Application effects*

By observing the water heads in the forth and back of the dam respecdtively after treatment, the head difference is quite larger than before. The case is same to the phreatic line. The phenomena of piping and blowout were not oberved when the water level was rising. By excavating test, the geomembrane with connection were in good condition.

6 CONCLUSION

By practice, the hydraulic machines of trenching and laying down geomembrane have some characteristics with high mechinization, easy operation, quick running speed and wide adaption, which is the ideal and practicably anti-seepage technology and has a broad future.