Technology of geomembrane on earth-rock dam for seepage prevention

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ABSTRACT: Xixiayuan reservoir with capacity of 1.62×10^8 m^3 situated main-stream of Yellow river, Henan province, is a compensative regulation reservoir of Xiaolangdi hydro-junction. Xixiayuan earth-rock dam is 20.2 m high and 2609 m long, with geomembrane on its upstream face to prevent seepage. The putting manner of geomembrane near bottom anchor location and left and right side anchor location is treated to improve stress condition according to the result of numerical simulation by FLAC^{3D}. The anchor devices are simulated to check impermeability by permeability experiment at laboratory. In dam construction, weld experiment is performed, in which the weld temperature is changed according to different environment temperature and the feasible weld temperatures are achieved corresponding different environment temperature from 2°C to 33°C. Other weld experiments of geomembrane are done under especial circumstance in construction site such as dew, windy dust and complex membrane face with PET fibre. The experiment result shows that weld quality can not be maintained. The earth-rock dam was completed and the geomembrane on the dam was checked by uncovering protection layer after performing 1 year. The check result shows the weld seals normal.

1 INTRODUCTION

Xixiayuan reservoir with capacity of 1.62×10^8 m^3 is situated main-stream of Yellow river. Xixiayuan earth-rock dam is 20.2 m high, 2609 m long and 8 m wide at crest, with composite geomembrane on its 1:2.75 upstream face and with concrete cutoff in its foundation to prevent seepage. This is the first application of geomembrane in important project on large main rive like Yangtze River and Yellow River. Composite geomembrane consists of PET(polyester) textile /PE(polyethylene) membrane /PET textile and its two specs of $400gm^{-2}$/0.8mm/$400gm^{-2}$ & $400gm^{-2}$/0.6mm/$400gm^{-2}$ are applied respectively on deferent sect of earth-rock dam. On the dam, membrane is joined with concrete cutoff at its bottom, with concrete guide levee at its left and right sides and with concrete wave wall at its crest, so that a whole seepage prevention system forms.

2 ANALYSIS AND MEASURE AT KEY PLACE SCOPE OF STUDY

2.1 Analysis method

Displacement of membrane near the anchor place is simulated by FLAC^{3D} which is based on three-dimensional Lagrange explicit finite difference method. The membrane is disposed as grid element which has been designed in FLAC^{3D} and is presented elastic model. Between membrane and sand-gravel, contact elements are disposed. The constitutive law of sand-gravel is presented nonlinear elastics and the tangent shear modulus E_t is showed as follows while shear poisson ratio μ_t is not showed here.

$$E_t = \left[1-\frac{R_f(1-\sin\varphi)(\sigma_1-\sigma_3)}{2c\cos\varphi+2\sigma_3\sin\varphi}\right]^2 \cdot KPa\left(\frac{\sigma_3}{p_a}\right)^n \qquad (1)$$

In the formula of E_t and μ_t, well known parameters c, φ, R_f, K, n, G, F, D are determined by experiment and here showed in Table 1.

Table 1. Calculating parameters

Materials	γ_d kN/m^3	C kN/m^2	φ°	K	n
Dam gravel	21	0	32	600	0.62
Foundation gravel	21	0	32	650	0.64
Contact of gravel ~concrete			22	3.5×10^4	1.0
Contact of gravel ~geomembrane			20	2.0×10^4	1.0

Continued Table 1 Calculating parameters

Materials	R_f	G	F	D	K_{ur}
Dam gravel	0.71	0.30	0.15	6.54	1000
Foundation gravel	0.73	0.29	0.15	6.50	1100
Contact of gravel ~concrete	0.9				
Contact of gravel ~geomembrane	0.8				

The calculation parameters of membrane, concrete and rock bed see table 2.

Table 2 Elastics parameters

materials	γ_d kN/m^3	φ°	E MPa	μ
Membrane (touch gravel)		20.0	180	0.35
concrete	24		22000	0.167
rock bed	21		800	0.167

2.2 *Comparative displacement and countermeasure at key place*

Flexible membrane can suit displacement of dam at most region, but it likely failure near the anchor due to clamp effect. Calculating result shows that maximum comparative displacement of the membrane near the anchor place is 13 cm and relative anchor place and vertical displacement of the dam are showed Figure 1 and Figure 2.

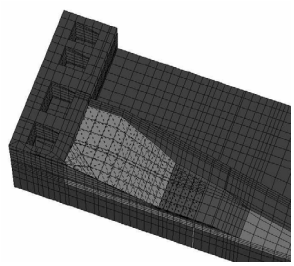

Figure 1. Dam joining concrete levee and element disposing.

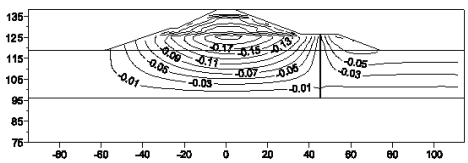

Figure 2. Vertical displacement of the dam (m).

The comparative displacement of membrane near anchor area can be absorbed by engineering countermeasure that the membrane from anchor stretches 20 cm opposite the displacement direction of the dam then it is put on the upstream face of the dam. As the dam displaces when reservoir running, the membrane will be returned original location according to design without in it.

3 WELD TECHNOLOGY OF MEMBRANE

3.1 *Weld temperature in site under different air temperature*

The weld temperature of membrane not only relates to membrane category such as the melt temperature region of LDPE is 108°C～126°C while it of HDPE is 126°C～136°C, but also relates to weld machine such as with the same temperature in a heat iron weld machine and in a heat wind weld machine the membrane will receives different heating quantity. However, the welding quality relates air temperature and the affection of air temperature can be compensated by coordinating welding temperature. In order to gain good weld quality, welding experiment simulating site condition is performed.

In the air temperature range of fitting weld of 2°C～33°C, there is a welding experimental point per 5°C. Three different welding temperatures are taken place at each welding experimental point while a mean tensile strength is achieved by performing six samples each welding temperature. A feasible welding temperature is gained by comparing three different mean tensile strength at same welding experimental point. The relationship between air temperature and feasible welding temperature which is gained by comparing tensile strength with different welding temperature at each experimental point is presented in Figure 3 (membrane of 0.8mm thick) and Figure 4 (membrane of 0.6mm thick).

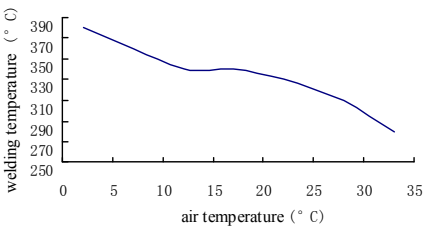

Figure 3. Feasible welding temperature ~ air temperature (membrane of 0.8mm thick)

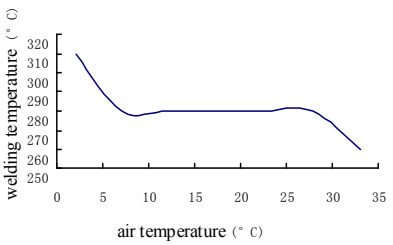

Figure 4. Feasible welding temperature ~ air temperature (membrane of 0.6mm thick)

3.2 *Welding technology under especial conditions*

The quality of welding is tested by press air into path between two welding seals lasting 5min and the maximum pressure value of the meter is 0.4MPa. At air temperature of 22°C, the fill-air pressure is above 0.4MPa with 320°C of welding temperature and 1.8m/min of welding velocity under normal condition. The welding experiments at the same air temperature with welding temperature of 330°C under three especial conditions are described as follows.

(a) Welding place with wetting

The heat quantity received by weld place is non-uniform due to wetting on the welding place such as dew or drizzle and it will weaken the strength of fill-air test. The strength value of air-fill is 0.14MPa seeing Table 3 and Figure 5.

(b) Welding place with dust

Sometimes, when welding performing, dust from soil path through truck near operation site falls on the wielding place by gale. Because PE is not pure when dust is melted into material, the strength of fill-air test will reduce. The strength value of air-fill is 0.24MPa seeing Table 3 and Figure 6.

(c) Welding place with PET fibre

There is some PET fibre adhibited on PE welding place due to careless omission of composite technology. Because the melting temperature of PET is high than that of PE, the PET fibre will not melt at the melting temperature of PE, so that the wielding area of PE will less than original design area and the strength of fill-air test will reduce. The strength value of air-fill is 0.14MPa seeing Table 3 and Figure 7.

Table 3 Test results of welding under especial conditions

Conditions	Weld temperature °C	Fill-air strength MPa
Normal	320	above 0.4
With wetting	330	0.14
With dust	330	0.24
With PET fibre	330	0.14

According to above statement, the some additional measures must be taken in the welding process under especial conditions.

Figure 5. Sample with wetting

Figure 6. Sample with dust

Figure 7. Sample with PET fibre.

Welding operation should give up when drizzle weather. After wed or drizzle, welding place must be wiped until the place is dry then welding operates.

Welding operation should be avoided under weather of wind blown dust. When occasional gale blows dust at site, the welding place must be cleaned before welding operation.

If there are some PET fibre adhibited on PE welding place, PET fibre must be rubbed off by sand paper before welding operation.

4 MEMBRANE ANCHORING AND TEST

4.1 *Technology on membrane anchoring*

Membrane is put on the upstream face of the dam. Besides its top is buried in slot behind the wave wall at dam crest, its bottom and two lateral sides are anchored on concrete structures. Because the length of anchoring on concrete cutoff under foundation is above 2600m, the impermeable reliability of the anchoring location is very important. The of anchoring technology at site is that a rubber is put on the crest of concrete wall which is rubdown, then membrane is installed on the rubber and another rubber is put on the membrane, and then type Π steel is pressed on them and the pressure supplied by fastened bolts acts on them through double limbs of Πsteel. The voids between concrete and rub as well as between rub and membrane will be eliminated by fastening mechanism so that the anchoring system achieves tight from water.

4.2 *Impermeable experiment of anchoring system*

Materials, installing elements and installing program of anchoring system in laboratory are same with construction site besides concrete is substituted by steel. Water pressure is acted on the anchoring system by high pressure pump, metal pipe and head tank, seeing Figure 8. In experimental program, water pressure is increased gradually with 0.1MPa gap and it is sustained in 5h. At the same time, seepage quantity is recorded. The ultimate water pressure supplied in experiment is 0.5MPa. The test results of three anchoring systems are showed as Table 4.

Figure 8. Seepage experiment device of anchoring system.

Table 4 . Seepage results under water pressure 0.5 MPa

Test item	Sample 1	Sample 2	Sample 3
Sustained time hour	5	5	5
Total seepage ml	107	0	11
Unit seepage ml/s·m	0.0119	0	0.0012

Mean unit seepage of three samples is 0.0043 ml/s·m. Theoretically, the total seepage through anchoring system of 2600m long in dam is 11.2 ml/s, while actually, the installation quality at site is much lower than that in laboratory. Even if several magnitudes are increased, the total quantity of seepage through anchoring system in dam is still small.

5 PARTIAL TREATMENT OF MEMBRANE

Membrane put on the dam face presents a fan sector at location of bended dam axis, however shape of composite geomembrane product is of rectangle. Therefore, key of membrane put smoothly is that membrane put together must be according with sector dimension of dam face at bended axis. The width difference Δ between up joined edge and bottom joined edge each breadth of membrane can be given as

$$\Delta = \frac{a-b}{n}$$

Where, a = Length of up arc of sector,
b = Length of bottom arc of sector,
n = Number of membrane in sector.

Because normal composite technology only produces the composite geomembrane with equivalent width of joined edge, in order to obtain composite geomembrane with width difference Δ between original joined edge and ended joined edge, the composite technology must be innovated and it is achieved by engineer and producer. The detail of technology innovation is not introduced here.

6 CONCLUSION

Xixiayuan earth-rock dam with composite geomembrane on the face for seepage prevention completed on May 2007. After running one year with water storage, in order to inspect the reliability of the membrane, water level of reservoir descends. The protecting layer covering the membrane with recovering record of operated flaw is discovered and result of inspect shows that welding seals of the membrane is perfect without any seepage point.

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