Repair Technology for Joint Damage of Sealing Cover Plate of Concrete Faced Rockfill Dam

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Abstract. In view of damages that are common in anti-seepage coiled joints used in the water-sealing of the concrete faced rockfill dam junction surface, the construction method that uses SK hand scraping polyurea and tire base fabric to quickly repair the broken coiled joint is proposed. By polishing the surface of the commonly-used Ethylene-Propylene-Diene Monomer (EPDM) board coiled material and using a special BU primer, good adhesion can be ensured between the SK hand scraping polyurea and the EPDM board. The EPDM boards were joined by docked joints and lapped joints, the boards were coated with SK hand scraping polyurea and adhered with tire base fabric, and the tensile and peel tests are carried out. The results show that SK hand scraping polyurea and EPDM board is well bonded. The method using for the connection of EPDM board joints has the advantages of simple construction, high speed, good quality and good anti-seepage effect, and it has been successfully applied to repair of damages of concrete faced joints on Pushi River pumped storage power station in Liaoning and the Nazixia hydropower station in Qinghai.

1 Introduction

Concrete faced rockfill dam has the advantages of low investment, short construction period, good safety, convenient construction and strong adaptability, which has been widely promoted and applied at home and abroad. In the concrete faced anti-seepage system, the water-stopping of the concrete faced joints is a weak point. The joints of the concrete faced dams constructed after 2000 are provided with two water stops. The slab joints of the concrete faced joints are an important part of the whole water-stopping system. In the surface water stop design of concrete faced dam joints (peripheral joints, toe joints and faced expansion joints), plastic water-stop fillers are usually provided on the surface of the concrete faced joints, and the anti-seepage coiled materials are pressed on the surface of the plastic water-stop fillers. The material is anchored to the surface of the concrete faced. As the anti-seepage membrane of the anti-seepage cover, there are commonly used EPDM boards, rubber sheets, and composite SB rubber sheets. However, due to transportation and construction restrictions, the length of these coiled materials is generally about 20m. On the hundreds of meters long concrete faced, there are many joints on the water-stop coil cover of the concrete faced seam surface. The cover board joints are lapped joint or docked joint. These joints are often weak parts of anti-seepage system; In addition, the construction of the rim joints and the vertical joints around the concrete faced is difficult, and the quality is

also difficult to be guaranteed. At present, the main water leakage point of the concrete faced is at the joint part, and the cover board joint and the profiled joint are the key parts for forming the permeation passage. To this end, it is necessary to study a fast and reliable treatment concrete faced surface water stop cover board joint damage repair technology for the repairing of existing projects and the protection of new construction.

2 Cover board joint damage repair scheme

In order to effectively and quickly repair the damaged cover board joints without or with little impact on the normal operation of the project, it is necessary to select materials of high strength, durability, flexibility, and with strong bonding with the cover board and the concrete base for local repair. Since the durability of the EPDM coiled materials is superior to that of other materials, most of the cover boards used for the surface water stopping of the concrete faced seams are made by EPDM coiled materials. Through indoor and outdoor tests and engineering practice, the repair of the EPDM board cover joint on the seam surface adopts the scheme shown in Figure 1. The scheme is to coat the SK single component polyurea on the surface of EPDM board and concrete faced by two different special interface agents, which is bonded with the concrete base surface and the EPDM board cover. After curing, a fully enclosed flexible anti-seepage coating is formed, which can effectively and completely seal the damaged part of the joint of the

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concrete slab joint cover.

Figure 1. Schematic diagram of repair scheme for joint damage of sealing cover plate of concrete face

In the repairing scheme of the concrete faced joint surface and the EPDM cover boards, the most important step is the selection of the joint damage repairing material. The selected materials must have high strength, aging resistance and flexibility (which can adapt to the deformation of the EPDM board), and must be able to bond well with EPDM cover boards and the faced concrete. SK hand scraping polyurea is a one-component material of high strength, aging resistance, high elongation, anti-wearing, anti-seepage and anti-freezing effect, and inside the coating tire base cloth can be added,

the construction is simple and convenient. The main technical indicators are shown in Table 1. In order to ensure the bonding strength between SK hand scraping polyurea and EPDM board, a special BU primer was developed. This interface agent is flexible after curing, which can adapt to the deformation of EPDM board and SK hand scraping polyurea, and the bond strength is good. SK hand scraping polyurea has a wet interface agent E between the concrete faced concrete to ensure the bond strength between polyurea and concrete is greater than 2.5 MPa.

Table1. Main technical indicators of SK hand scraping polyurea

Technical indicators	Standard requirement	Technical indicators	Standard requirement
Tensile strength, MPa	≥ 15	Hardness, Shao A	≥ 40
Elongation at break, %	≥ 350	Adhesion (wet surface), MPa	≥ 2.5
Tear strength, kN/m	≥ 40		

3 EPDM board docked joint and lapped joint test

3.1 EPDM board docked joint test

The EPDM board was polished by a sanding machine, and the BU primer was applied to the board after its surface was cleaned. After indoor curing about 4~5h, the surface was dry, and the EPDM board was joined by docked joints. The surface was coated with SK hand

scraping polyurea, and was compounded with a tire base fabric. The SK hand scraping polyurea had a width of 50 mm (same width as the EPDM board), a length of 400 mm (200 mm on each side of the EPDM board), and a thickness of about 3 mm, and the maintenance time was 30d.

The geotextile tensile test (wide strip method) is used, the implementation standard is GB/T 15788-1995, and the test measurement results are shown in Table 2 and Figure 2.

Table 2. Tensile test results of polyurea composite-based cloth coating (the butt joint of EPDM board)

Serial number	Thickness (mm)	Wideness (mm)	Maximum load (N)	Tensile Strength (kN/m)	Elongation (%)	Stretch rate (mm/min)
1	2.96	50	620	12.4	146	200
2	2.80	50	460	9.18	86.5	20
3	2.86	50	470	9.40	67.8	20

Figure.2 Tensile test curves of polyurea composite-based cloth coating (the butt joint of EPDM board)

During the tensile test, the central polyurea dispersed the force to both sides through the base fabric, and the central polyurea composite coating changed little. The EPDM boards at both ends began to be significantly deformed first. The failure process of the bond between the polyurea composite base fabric coating and the EPDM board was that the EPDM board at both ends of the coating was thinned and thinned, resulting in the coating start disengaging with the EPDM board from both ends, and the deformation of the EPDM board gradually developed toward the middle. When the

deformation of the EPDM board was close to the lapped joint part, the polyurea composite-based cloth coating was separated from the EPDM board. The test data in Table 2 and Figure 2 show that the test loading speed has a great influence on the tensile strength of the material. The faster the loading speed, the greater the tensile strength and the greater the elongation.

3.2 EPDM board lapped joint test

The surface of the EPDM board was polished by a sanding machine, and after the surface was cleaned, the BU primer was applied. After interior curing about 4 ~ 5 h, the surface was dry. The EPDM board was joined by the lapped joint method for 50mm, the surface was coated with SK hand scraping polyurea, and was compounded with a tire base fabric. The SK hand scraping polyurea had a width of 50mm (same width as EPDM board), a length of 350mm (lapping 50mm, each side extended 150mm), a thickness of about 3mm, and the curing time was 30d.

It can be seen from the test process that under the load, the central polyurea dispersed the force to both sides through the base fabric, and the central polyurea composite base fabric coating changed little, and the EPDM boards at both ends began to appear obviously deformation. The destruction process between the coating and the EPDM board was that the EPDM board at both ends of the coating was thinned, resulting in the polyurea composite coating starting to disengage from both ends and the EPDM board. The deformation of the EPDM board gradually developed toward the middle. When the deformation of the EPDM board was close to the lapped joint part, the coating was detached from the EPDM board. From the lap test data shown in Table 3 and Figure 3 (the tensile rate is 200mm/min), when the thickness of the polyurea composite coating was large than 3mm, the EPDM joint was both a docked joint and a lapped joint. The bonding effect between the polyurea and the EPDM board was not affected, and the failure mode was from the both ends of the polyurea composite base fabric to the central portion.

Table 3. Tensile test results of polyurea composite-based cloth coating (the lapped joint of EPDM board)

Serial number	Thickness (mm)	Wideness (mm)	Maximum load (N)	Tensile Strength (kN/m)	Elongation (%)	Stretch rate (mm/min)
1	2.96	50	600	11.96	73.7	200
2	2.84	50	600	11.98	66.2	200

Table 4. Tensile test results of SK hand scraping polyurea (the lapped joint of EPDM board)

Serial number	Thickness (mm)	Wideness (mm)	Maximum load (N)	Tensile Strength (kN/m)	Elongation (%)	Stretch rate (mm/min)
1	2.0	50	420	8.34	39.5	200
2	3.8	50	490	9.76	41.69	200
3	3.5	50	380	7.66	24.5	20

The test results of the EPDM cover lapped joint and the SK hand scraping polyurea (without tire base fabric) width is 50 mm at the joint are shown in Table 4. The test

result shows that under the load, the EPDM board in the middle and both ends of the polyurea is deformed at the same time. Due to the sudden change in the thickness of

the lap joint of the two layers of EPDM board, the thickness of the polyurea is also changing. The stress of polyurea is concentrated in this part, and the damage occurs in the middle of polyurea. It can be seen from Table 4 that the greater the thickness of the central polyurea, the greater the tensile strength of the polyurea when it breaks; the stretching rate has an effect on the tensile strength of the polyurea, and when the polyurea breaks, the tensile rate increases, and the tensile strength is also greater.

Figure.3 Tensile test curves of p polyurea composite-based cloth coating (the lapped joint of EPDM board)

Figure.4 Peeling test curves of SK hand scraping polyuria and EPDM board

3.3 EPDM and polyurea peel test

In order to examine the bond strength between the EPDM board and the SK hand scraping polyurea, a peel and adhesion test was conducted. The test was divided into two groups. The first group was a peeling test of polyurea composite tire base fabric coating and EPDM board; the second group was a peeling test of polyurea coating and an EPDM. The coating width was 50 mm (the same width as the EPDM board) and the bonding length was 100 mm. The test was carried out using the peel test method of the Geosynthetics Test Procedures SL235-2012, and the tensile rate was set at 300 mm/min. The test results are shown in Table 5.

Table 5. Peeling test results of SK hand scraping polyuria and EPDM board

Sample type	Serial number	Maximum load (N)	Peel strength (kN/m)	Remarks
polyurea composite-based cloth coating	1	425	8.49	The bonding surface is torn open, the EPDM board is removed by polyurea.
	2	552	11.04	
	3	392	7.84	
polyurea coating	1	536	10.7	Polyurea is broken, the EPDM board is removed by polyurea.
	2	431	8.6	
	3	489	9.78	

The test progress show that after the coating of the polyurea composite tire based cloth on the surface of the EPDM board, as the peeling between the coating and the EPDM board, the elongation of the EPDM board is continuously increased and thinned, and the peeling strength is independent of the thickness of the polyurea composite tire base fabric coating. After the destruction, the polyurea will partially remove the EPDM board, the peel strength between the polyurea composite tire base fabric coating and the EPDM board fluctuate, indicating that the bond strength between the coating layer and the EPDM board is not uniform. The minimum peel strength is greater than 7.5 N/mm. When the polyurea is directly applied to the surface of the EPDM board, the peel strength is related to the thickness of the polyurea. When the polyurea is thin, the fracture occurs inside the polyurea.

The test results show that after using BU primer, the bonding strength of polyurea and EPDM board is higher,

which can satisfy the requirements of repairing the EPDM board; on the surface of the EPDM board joint, brushing polyurea composite tire-based fabric coating is better than direct application of polyurea coating.

4 Engineering application example

4.1 Example of damage repairing of concrete faced joints in Pushi river pumped storage power station

The upper water retaining construction of the Pushi river pumped storage power station in Liaoning is a reinforced concrete faced rockfill dam with a dam elevation of 395.50 m, a maximum dam height of 78.5 m, an annual maximum temperature of 35°C, and a minimum temperature of -38°C. The upper water retaining capacity is 13.51 million m³. The normal water storage level of

the upper reservoir of Pushi river pumped storage power station is 392.00 m, and the dead water level is 360.00m. The daily water level rises and drops drastically every day, with the maximum drop reaching 32 m. The operation and maintenance of the concrete faced rockfill dam in winters are more easily affected by the freezing than other conventional power stations. The concrete slab joints of the concrete-faced joints are embedded with rubber rods and GB flexible fillers. The surface of the filler is covered with EPDM boards, and the two sides of the EPDM boards are fixed with stainless steel boards and anchor bolts. After nearly five years operation, it was found that the stainless steel boards on both sides of the EPDM board were rusted and all the EPDM board joints were lifted and torn (see Figure 5).

The damage repair of concrete-faced joined EPDM board joints uses SK hand scraping polyurea and tire base fabric, the specific scheme of which is shown in Figure 1, and the construction steps are as follows.

(1) Cut the cocked EPDM board and change the EPDM board joint to docked joint.

(2) Polish the concrete surface and the surface of the pressure board with diamond polishing discs on both sides of the concrete faced joint, and polish the surface of the EPDM board with a steel wire polishing disc, then clean up the surface.

(3) After cleaning the concrete surface and the surface of the pressure board, the SK hand scraping polyurea can be used to coat the concrete interface agent after the concrete interface agent is dry; the surface of the EPDM board is coated with the BU primer, and when the BU interface is dry, SK hand scraping polyurea can be used for coating.

(4) After coating the SK hand scraping polyurea first time, and the polyurea surface is dried, coat the polyurea second time, and attach a layer of 50cm wide tire base fabric to the joint. After curing, the third time of polyurea was applied, and the fourth time... until the thickness of the polyurea is greater than 4 mm, and the tire base fabric trace on surface of the polyurea coating was not visible.

(5) The length of the polyurea on the surface of the EPDM board is 100 cm (longitudinal), and the overlap width between the polyurea and the concrete faced is greater than 20 cm. If required by the project, SK hand scraping polyurea can be adjusted to the same black color as the EPDM board.

Figure.5 The damage of the lapped joint of EPDM cover board

Figure.6 Operation of joints after treatment for one year

After the last layer of SK hand scraping polyurea has been applied for one day, the surface can be submerged by water. After four years operation, SK hand scraping polyurea and EPDM boards are in good condition, as shown in Figure 6.

4.2 Example of damage repairing of concrete faced joints in Nazixia Hydropower Station in Qinghai

The Nazixia Hydropower Station is located in a high-altitude and extremely cold area in Menyuan County, Qinghai Province. The reservoir dam is a concrete faced rockfill dam built on the overburden layer. The maximum dam height is 117.60 m and the dam crest length is 416.01m. In mid-April 2016, the concrete faced dam was checked after the ice cap in front of the dam was melted. It was found that, the comprehensive effect owing to the ice on the concrete surface in winter formed an ice cover and the surface of the joint of the dam was pressed and dragged down by the ice cover along with the water level of the dam decreasing, causing the joint of the joint surface of the joint to be rolled up, and the EPDM cover sheet of the water level change area is torn and broken along the fixed ends of the two sides.

In 2016, the SK hand scraping polyurea and tire base fabric solution were used to completely process the surface cover board joints of concrete faced seams above the dead water level. The construction steps are the same as the abovementioned. After one year's running test, the treated concrete faced joints are in good condition. In order to prevent damages caused by the winter icing on the surface layer cover of the concrete faced joint, in 2017, all the EPDM boards in the water level change zone were replaced by the SK hand scraping polyurea method. And after two years' operation, it was found that the treated joint and the water-stopping structure on the surface layer of the concrete faced joint of the water level change zone were not damaged.

Figure.7 Joint damage of sealing cover plate of NaZiXia concrete face

Figure.8 Repair process for joint damage of sealing cover plate of concrete face

its application. CHINA BUILDING WATERPROOFING, (12):20-22.

5 Conclusion

Polishing the surface of EPDM boards and using a special BU primer can ensure good adhesion between SK hand scraping polyurea and EPDM boards. The method of using SK hand scraping polyurea and tire base fabric to repair the damage of EPDM joints is simple to operate and efficient, and it can guarantee the quality and prevent seepage. This method can also be used for connection between new engineering slab joint surface covers and between the rim seam and the vertical seam.

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