Repair Method of Aged Reservoir and Irrigation Canal with Asphalt Panel

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ABSTRACT: Infrastructure such as reservoirs, asphalt facing dams and irrigation canals constructed some 30 years ago during the high-economic growth period in Japan, is facing the time of repair showing the decreased function due to aging. Under severe socio-economic situation and with environmental consideration, the shift to recycling society is becoming a pressing issue and the establishment of the method is needed to make a longer life by an appropriate repair and reinforcement according to the cause and level of the damage.

We have developed a method to prolong the life of an existing structure without replacing by demolishing it; that is to put the asphalt panel on the damaged impervious wall of reservoirs and irrigation canals.

The thickness of the material is 6〜10mm and it is viscoelastic made from special asphalt mastic. It is excellent in the resistance against abrasion and weathering and the response to cracks, which is required as a lining material

By a joint research with Shimane University and partly funded by the Government for four years starting from April, 2005, we established a performance evaluation technique of the material under the construction environment. We evaluated the performance demanded as a lining material by its composition and made model tests and numerical analysis. We also confirmed the adaptability at construction sites.

Finally, presented are the repairing works of an irrigation canal and a reservoir, both of which are made of cement concrete.

KEYWORDS: asphalt panel, lining material, irrigation canal, reservoir, crack protection.

1 INTRODUCTION

In Japan, many of the major irrigation canals with a total length of 45,000 km and 210,000 reservoirs were constructed in the country's high-growth period (1960~1980), and more than 30 years have passed since then. Not a few of these facilities have increasingly degraded in functional capability due to decrepitude and are nearing the time to be repaired. As to the leakage from reservoirs, there are cases in which urgent action has to be taken to ensure safety. For maintenance and repair of the irrigation stock which entails a vast amount of money, it is called for to establish a method to make existing structures long-lasting without demolishing by appropriate repair and reinforcement conforming to the cause and degree of degradation, taking into account the pressing problem of the current harsh economic climate and transition to the recycling-oriented society.

We have had a repair method using an asphalt panel (name of material: Gulf seal) as the facing technology for agricultural reservoirs and dams since 1964. This method has been field-proven at 1,100 sites with a total area of 1,100,000 ㎡. Even in the current situation of diminished demand for new construction, the asphalt panel is still in demand as a repair material for reservoirs owing to the appreciation of its durability.

We developed a method of applying an asphalt-based adhesive to the surface of a decrepit concrete-covered reservoir, concrete canal, among others, and applying asphalt panels over the entire surface. We termed this method "hybrid liner method".

Through the government-private sector joint research made for 4 years from April 2005, we established a method of evaluating material performance under the working environment consistent with the actual condition and evaluated the performance requirements for facing materials by element test, model test and numerical analysis. We have confirmed the compatibility of this method by field demonstration test and have been continuing a follow-up survey.

This paper presents details about the repair by this method of a decrepit concrete reservoir and a concrete canal.

2 STRUCTURE BY THIS METHOD

The structure by this method is as shown in Fig. 1 and consists of three layers; primer layer, adhesive buffer layer and surface covering layer. The amount of the primer layer and adhesive buffer layer is 0.3 L/㎡ and 1.2 kg/㎡, respectively. The thickness of the surface covering layer is 6-10 mm. The section of the asphalt panel is shown in Fig. 2.At the joint, a buffer mat is additionally placed as a non-adhesive layer in some cases.

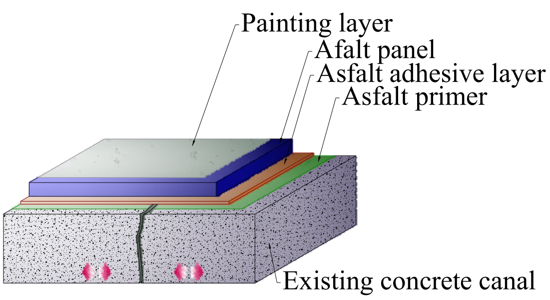

Figure 1: Structure by This Method

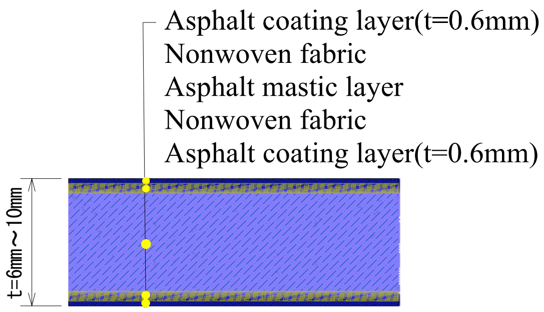

Figure 2: Section of Asphalt Panel

3 MATERIAL CHARACTERISTICS

3.1 Structure of asphalt panel

The mix proportion of asphalt mastic as the base material is shown in Table 1. The manufacturing method is to sandwich the hot asphalt mastic between nonwoven fabrics and coat the fabric surfaces with the same special blown asphalt as that of the base material to unite these materials.

Table 1: Mix Proportion of Asphalt Mastic

Material	Special blown asphalt	Stone dust	Fabric	Total
Mix ratio (%)	5 5	3 9	6	1 0 0

3.2 Physical properties

Being composed of asphalt mastic and nonwoven fabrics, the asphalt panel is viscoelastic and a thick material of 6mm, thicker than geo-membrane made with synthetic rubber or plastic of 1.5mm～2mm in thickness. Therefore, the asphalt panel has the feature that is hard to be damaged. The physical properties of the asphalt panel are shown in Table 2.

Table 2: Physical Properties of Asphalt Panel

Test Item	Standard	Test method for reference
Thickness (mm)	6 mm～10 mm	Measurement by caliper
Density (g /cm^3, 20℃)	1.3±0.15 or more	ASTMD2041-64T
Soluble content of ethane trichloride (%)	5.5±0.5	ASTM-D994
Tensile strength (MPa、60℃)	0.35 or more	ASTM-D638
Coefficient of permeability (cm/sec)	1 x 10^{-9} or less	JIS-A1218

4 PERFORMANCE EVALUATION

The target performance required of repair materials was established according to the results obtained by grasping the cause and degree of degradation of the irrigation canal as well as the expansion and contraction behavior of the canal. The target performance is shown in Table 3.

Table 3: Target Performance

Item	Established target performance
Flowability (roughness coefficient)	0.013 or less
Abrasion resistance	Lower than value of JIS mortar
Response to Cracking	1.0 mm or more
Response to Zero-span	Displacement amplitude:.2±0.1 mm, number of repetitions: 18250 or more
Response to joint expansion and contraction	Durability over 40 years (50 or more repetitions with yearly variation)
Weather resistance	No decrease in tensile strength of sample after 37 years.
Bond strength	0.7 N/mm^2 or more

4.1 Flowability (surface roughness coefficient)

The target value of roughness coefficient, n, is 0.013 （roughness coefficient for cast-in-place concrete）. The roughness coefficient of the asphalt panel in a laboratory test canal was 0.012 (Photo 1).

Photo 1: Experimental Measurement of Roughness Coefficient

4.2 Abrasion resistance

One of the degradation phenomena peculiar to concrete irrigation canals is the abrasive action by running water and soil and sand included. Such selective abrasion results in the degradation in roughness coefficient and loss of coarse aggregate, which decreases the irrigation function and structural strength. In the present case, we measured the abrasion resistance of the asphalt panel by the selective abrasion test developed through the government-private sector joint research. The established test conditions are shown in Table 4. According to the test results, the abrasion loss of the asphalt panel was 1,019 mm^3, 39% of the value of 2,634 mm^3 in the case of the JIS mortar. Therefore, the asphalt panel fully satisfies the target value. The test machine and sample are shown in Photo 2.

Table 4: Performance of Selective Abrasion Test Machine

Item	Performance
High-pressure spray pressure	2.0 MPa
Quantity of high-pressure spray water	80.88 L/min
Revolving speed of specimen	Variable up to118 rpm
Distance of spray nozzle	130 mm
Size of specimen	195 mm×145 mm×38 mm
Evaluation method	Abrasion loss in mm^3, lower than value of JIS mortar

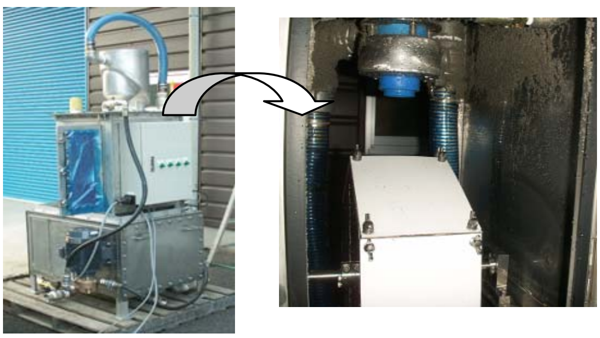

Photo 2: Selective Abrasion Test Machine

Photo 3: State of Specimen Abraded

4.3 Response to cracking

We investigated the daily variations in crack width observed in the concrete canal in Matsue City, Shimane Prefecture. Daily variations measured in March, October and December were 0.175mm ~0.629mm

As a result, the performance requirement for repair materials was determined as 1.0mm at 0℃ from the variation characteristics of the crack width and we carried out the tensile strength test. The variation under the maximum load (4.61Mpa) was 5.1 mm so that this material was confirmed to have a response to cracking greater by 5 times or more

4.4 Response to zero-span

In this paper, the opening and closing phenomenon which is severer condition than static expansion of the crack and joint is referred to as the "zero-span". A soft material capable of responding to this phenomenon is called for. As to the zero-span phenomenon, we evaluated the repetition effect of the daily variation in an actual canal in addition to 3) Response to cracking. As a result o f the repeated tensile test made under the test conditions of Table 5, no fracture was observed in any of the samples and the ratio of decrease in tensile load was 70%. This is due to the viscoelasticity of the asphalt panel and it is effective against the response to zero-span.

Table 5: Conditions for Response to Zero-span Test

Item	Test conditions
Section of specimen	Surface of mortar plate covered with asphalt panels
Test condition	Repeated tension, initial (0.2 mm±0.1mm)
Test temperature	Normal temperature
Evaluation method	No. of repetitions: 18,250 （365 days x 50 years） or more

Photo 4: Zero-span Test under Way

Photo 5: State of Specimen

4.5 Response to expansion and contraction of joint

The relative displacement of the joint was determined as 3.3 mm from the linear expansion coefficients (100×10^{-6}) of the asphalt panel and the linear expansion coefficients (10×10^{-6}) of the concrete, assuming a 10 m long concrete canal. Specimens were fabricated, assuming the non-adhesive section of the joint to be 5 cm long. As a result of the repeated tensile test made under the test conditions of Table 6, no fracture was observed in any of the samples and the ratio of decrease in tensile load was 72%. This is due to the viscoelasticity of the asphalt panel and it is effective against the response to zero-span.

Table 6: Conditions for Response to joint Movement Test

Item	Test conditions
Non-adhesive section	5 cm
Test condition	3.3 mm
Test temperature	Normal temperature(20~23℃)
Evaluation method	No. of repetitions: 50 （50 years） or more

4.6 Weather resistance

There are two types of weather resistance test methods, i.e., sunshine type and xenon type. Either of them is unsuitable for the asphalt panel having asphalt as the main component because its temperature becomes too high. Therefore, we took samples from the area having actually passed 37 years after construction and carried out the tensile strength test under the test conditions of Table 7. Consequently, the test results could be confirmed to be virtually equivalent to those of the test in 1966 as shown in Fig. 3.

Table 7: Conditions for Tensile Strength Test

Item	Test conditions
Year of sample fabrication	1966 (40 years ago)
Shape of specimen	Dumbbell-like
Test speed	10 mm/min
Test temperature	22℃, 55℃
Evaluation method	Tensile strength, deformation under max. load

Photo 6: Sampling State

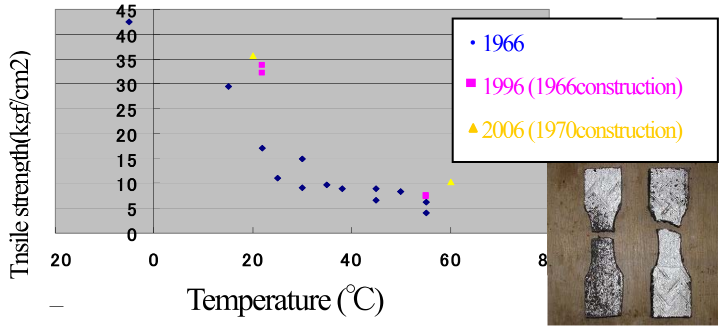

Figure 3: Results of Tensile Strength Test

4.7 Bond strength test

The present method applies asphalt panels to existing concrete structures, among others, using special blown asphalt as adhesive. The bond strength is specified in the Guidelines for Design and Execution of Surface Protection Work (draft) prescribed in the country. With reference to this, the target value of bond strength was determined as 0.7 N/mm^2 or more (Flexible type).

The bond strength test was carried out under the test conditions of Table 8. As a result, the bond strength was 0.94 N/mm^2 at 23℃ and 1.49 N/mm^2 at 0℃ as shown in Fig. 4.

Table 8: Conditions of Bond Strength Test

Item	Test conditions
Test method	"Building Research Institute" type bond strength test machine
Shape of specimen	40 mm x 40 mm＝1,600 mm^2
Test speed	1,500- 2,000 N/min
Test temperature	23℃、0℃
Evaluation method	Bond strength:0.7N/mm^2 or more

Photo 7: Bond Strength Test under Way

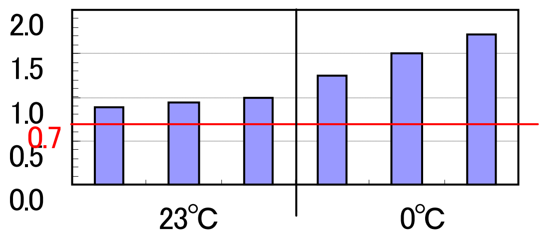

Figure 4: Results of Bond Strength Test

Thus, this method as a repair method for concrete canals was confirmed to satisfy the established target value.

5 DECREASING EFFECT OF VISCOELASTICITY OF ASPHALT PANEL ON ZERO-SPAN PHENOMENON

In this study, we confirmed that the mechanism of zero-span and how the viscoelasticity of the asphalt panel acts for the response to zero-span phenomenon. The joint section in this model is as shown in Fig. 5. We input the general representative figure as physical numerical value for each material, and input the sine curve of temperature data obtained at Asahikawa City, Hokkaido. The analysis result for yearly variation is as shown in Fig. 6 & Fig. 7.

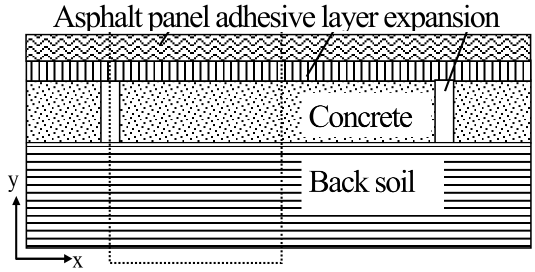

Figure 5: Structure Model

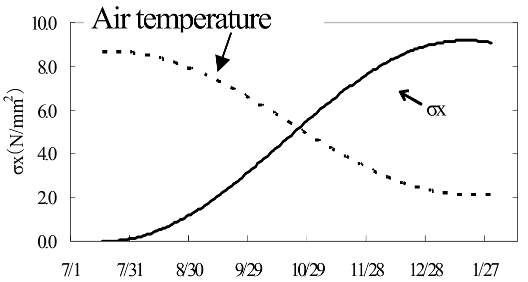

Figure 6: Analysis Result for Yearly Variation (material assumed as elasticity)

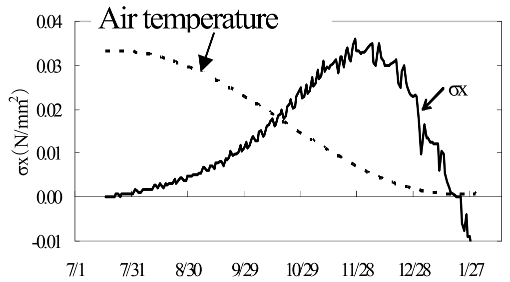

Figure 7: Analysis Result for Yearly Variation (material assumed as viscoelasticity)

In Fig. 6, the tensile stress σx max at the nearest of expansion was 9.2N/mm^2. As the tensile stress σx max of the asphalt panel at -10℃ is 5.6N/mm^2, it is expected that asphalt panel is damaged in the case where it is elastic. In Fig. 7, as the tensile stress σx max of the asphalt panel at -10℃ is 0.036N/mm^2 in the case where it is viscoelastic, σx max decreased down by up to 0.4%.The analysis result for daily variation is as shown in Fig. 8 & Fig. 9. In these Figures, the highest peak of σx is 1.7N/mm^2 in the case that it is as elastic and 0.46N/mm^2 in the case that it is as viscoelastic. The ratio is 4 to 1.

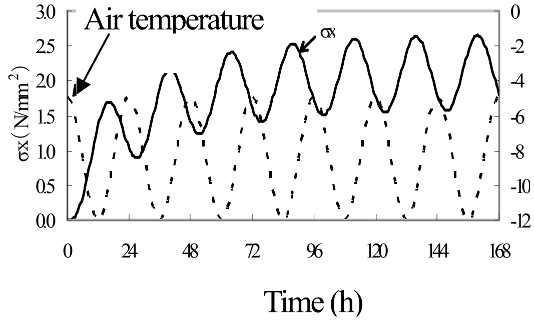

Figure 8: Analysis Result for Yearly Variation (material assumed as elasticity)

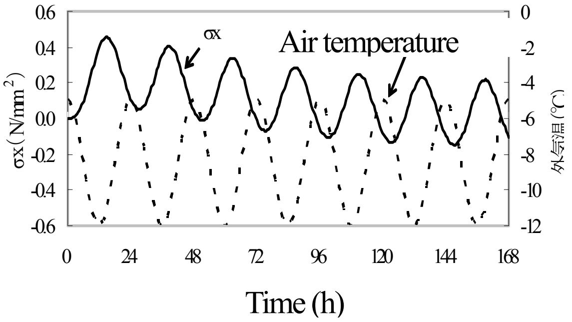

Figure 9: Analysis Result for Yearly Variation (material assumed as viscoelasticity)

As a result, the viscoelasticity of the asphalt panel has a decreasing effect in tensile stress to lessen the zero-span phenomenon.

6 REPAIR METHOD

The standard procedure of carrying out this repair method for cast-in place concrete canal is shown below.

Figure 10: Work Flow

7 CASE OF RESERVOIR REPAIR WORK (Futaishi district, Hiyoshi City, Kagoshima Prefecture)

The present method has been field-proven for use in lining concrete canals as well as in repairing reservoirs made of impervious soil material (clay). In the reservoirs of the most common sealing-zone type, concrete blocks are placed for protection of surface soil in many cases. With this type, in the event of leakage, the cause is difficult to identify and it takes time and money to make repair from the embankment side. Therefore, the present method for changeover to the surface facing type by application of asphalt panels over the surface of concrete for surface protection is advantageous as a repair method. A case of work by this method is described as follows.

7.1 Condition of the existing reservoir

This reservoir was constructed about 30 years ago. It was shielded by the "sealing-zone" method using clay and by covering the entire surface with 8 cm thick cast-in-place concrete. The concrete surface showed a number of small and large cracks and part of the embankment was leaky.

7.2 Features of this method

This method has the following features.

① No need for removing concrete.
② Firm adhesion to the concrete surface with many curves.
③ Easy inspection and repair.
④ Ability to cover cracks and construction joints.
⑤ Economical life cost.
⑥ Long durability of asphalt panel (30 years or more).

7.3 Investigation of measures against spring water and cracking

This method shields the reservoir from within it. Therefore, the safety on the embankment side could be ensured, but stripping and blistering under the backside water pressure by spring water from the mountain side were concerned about. Hence, it was decided to install vertical and horizontal drains and discharge water into the reservoir through weep holes.

7.4 Repair procedure

The procedure of carrying out this repair method is shown below.

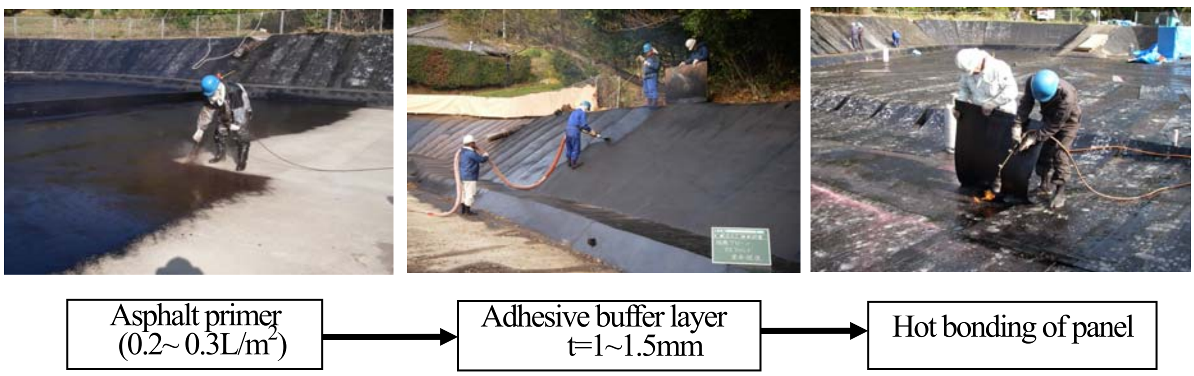

Figure 12: Work Flow

Photo 8: Before Work

Photo 9: After Completion

8 CONCLUSIONS

In developing this method, we first investigated variations in width of joint and crack in an existing concrete canal and elucidated the target performance to meet the demand for a service life of 40 years or more. The obtained results satisfied the target values as described below:

① The roughness coefficient was 0.012 with respect to the target value of 0.013.

② The abrasion resistance in terms of abrasion loss was 39% of that of the JIS mortar.

③ The response to cracking was 5.1 mm, about 5 times as great as the target value of 1 mm. The response to zero-span phenomenon and to joints proved to induce no cracks as a result of the repeated tensile strength test equivalent to a period of 50 years.

④ The weather resistance proved to cause no decrease in tensile strength of samples taken from the area having passed 37 years after construction.

⑤ The bond strength was 0.94 N/mm^2 with respect to 0.7 N/mm^2 specified in the Guidelines for Design and Execution of Surface Protection Work (draft).

⑥ Moreover, according to the results of experimental application in a concrete canal being in service in Shimane Prefecture, the values of variation in joint width, variation in crack width, stress in material, etc. were below the target values established by laboratory testing. The canal could carry out its function as prescribed without causing cracks and damages.

In the analytical study, we have clarified the viscoelasticity of asphalt panel decreases in tensile stress and it is effective against the response to zero-span

9 CLOSING REMARKS

Though developed with a view to repairing concrete canals, the present method was also adopted for repair of concrete-covered reservoirs, asphalt facings in dams and asphalt mat type reservoirs. In some of these structures, blistering occurred under backside water pressure, so we took action to remove this defect by using weep holes and attained good results. We consider that what remains to be done in the future is to establish a method of treating backside water and measures against loading by severe weather conditions.

I would like to thank Professor I. Natsuka and other relevant members of Shimane University for their considerable assistance with the development of this method and also thank Mr. T. Funakura, assistant manager, and other relevant members of the Agriculture, Forestry and Fisheries Section, Hioki City, Kagoshima Prefecture, for their guidance in execution of this work.

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