XYPEX

Concrete waterproofing By Crystallization™

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Repairing of Heavily Cracked Reinforcing Concrete Bridge Deck Slab From Underside

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Introduction

It has been known that the deterioration to the reinforced concrete deck slabs on the Hokutoh overpass bridge was caused mainly by water penetration through cracks that resulted from cyclic loading. A permanent solution for repairing the cracked reinforced concrete deck slabs has been desired for a long time. The conventional repair method that has been adopted in the past is to physically block off water by applying a waterproofing material consisting mainly of an organic substance on the concrete deck slab. However, since this method is not effective at improving the concrete deck slab itself and the barrier material will degrade with time, this method is not considered as a long term solution.

In contrast, there is another method which waterproofs the whole concrete structure as well as the cracks by the application of a crystalline waterproofing agent, which multilies the cement gel inside the concrete substrate as well as on the cracked surface of the plate. This method using Xypex Concentrate has been employed in over a thousand applications. Most of these cases have been in a static environment without vibration or movement, but this test was on a dynamic moving structure.

In this paper, we will report the result of our investigation on the effect of Xypex Concentrate when it is applied to the continuously vibrating bridge deck. This investigation was carried out for the road bridge decks which have been heavily cracked by continuous repeated loads at the Hokutoh overpass bridge on National Route 23 in Japan.

Status of Cracked Floor Plates

The Hokutoh overpass bridge on National Route 23 was built in 1972. There has been much heavy traffic, with 40,000 large-size cars representing about 40% of the total traffic crossing this brdge everyday. Many overloaded vehicles are also utilizing this bridge. Therefore, many cracks measuring 0.1 to 0.2 mm in width have appeared in all directions on the concrete deck slabs. Depending on the location, a significant amount of efflorescence of lime is observable and indicates water leakage. Photo 1 is an example of the cracks on the underside of the concrete deck slab.

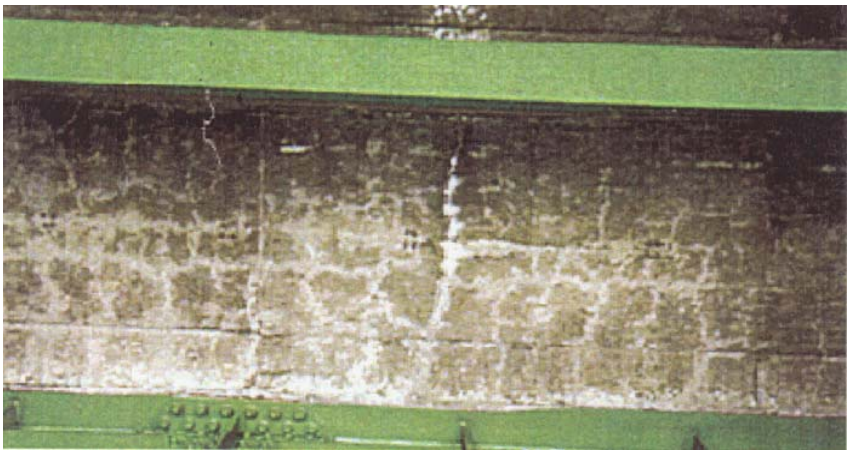

Photo 1: Evidence of cracking in concrete on underside of the deck slab.

Outline of Experiments

Two sections between the main beams of the Hokutoh overpass bridge on the down line of Route 23 were selected for testing. Xypex Concentrate was applied to one of the sections, the other section was left untreated for reference purposes. The testing was initiated on August 30th, 1994.

Application Procedures:

1. Clean up stains and remove any loose material or dust from the underside surface of the concrete deck slab using a high-pressure water blaster.
2. Spray the accelerative curing agent Xypex Gamma Cure (XG) on the surfaces.
3. Mix the powder crystalline waterproofing agent, Xypex Concentrate, with water as per the specified proportions. Apply the resultant slurry mixture using a brush (by 1.2 kg/m^2 average) on the deck surface and leave for 10 months.

Extraction of Test Samples From Plates

On July 4th, 1995, a total of 10 cores were extracted from the decks, including both the section applied with the Xypex Concentrate and the untreated section. The dimension s of the cores were 10cm in diameter and 20cm long. They were cut from the deck slabs so that each core contained cracks located at the center of the test specimen.

Test Samples and Measurement For Evaluation

The samples for testing the water blocking ability were made by cutting the extracted cylindrical core at its half line as shown in Figure 1. The lower part of the core where the cracks are more pronounced was used for testing. Pressurized water was applied on the upper surface of this test specimen and water flow was recorded. See Figure 2.

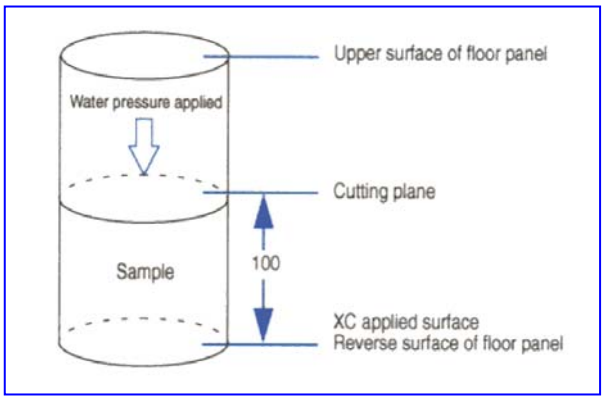

Figure 1: Test sample for water blocking ability

A compressive strength test was performed on the 20cm long test specimen.

Test samples for the Scanning Electron Microscopy (SEM) were taken at locations 5 to 6 cm and 10 to 11 cm from the surface on which Xypex Concentrate was applied. See Figure 4. The width of cracks in these sub-samples were within the range of 0.08 to 0.18 mm. Structural observations were recorded.

Water Leak Test

1) Specifications of the test:
   1. Water leak test: "Output method"
   2. Water pressure: 2kgf/cm^2
   3. Testing time: 16 hours
   4. Number of samples: 6 each

Figure 2 shows the conceptual structure of the water leak test.

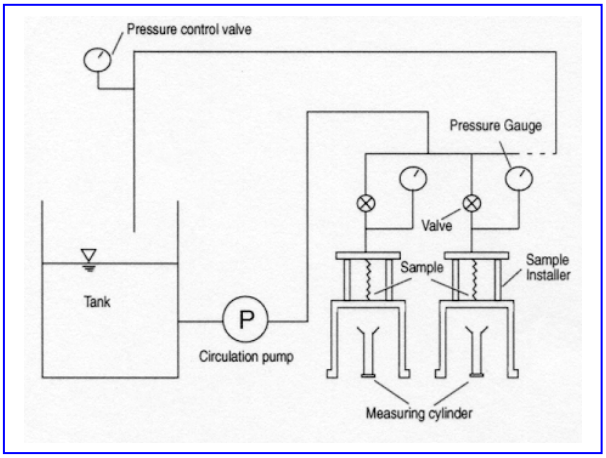

Figure 2: Conceptual structure of the water leak test

2) Results:
Test results shown in Table 1 and Figure 3 indicate that the change in outflow from the test samples at 2 hour intervals as well as the initial amount of outflow from samples.

In the group of samples to which Xypex Concentrate was applied, there are some specimens with initial leakage but the waterflow gradually decreases and finally ceases.

In contrast, the group of untreated samples had an initial outflow reaching almost 5 cc/sec (300 cc/min) and therefore it was difficult to continue the succeeding measurements. At that point, it was assumed that the amount of outflow was constant.

Table 1: Results of Water Blocking Test

Specimen Status	Sample Number	Diameter (cm)	Height (cm)	Amount of outflow (cc/min)	Water leak coefficient (10^{-5} cm/sec)	Comment
Not Applied	No. 2	10.36	10.23	4.10	27640	(Note 1)
	No. 3	10.35	10.25	5.45	31220	
	No. 5	10.37	9.96	5.27	31050	
XC Applied	No. 1	10.36	10.20	0.1500	1010.00	(Note 2)
	No. 2	10.32	10.13	0.0010	6.73	
	No. 3	10.34	10.15	0.0013	7.19	
	No. 4	10.32	10.10	0.0024	13.26	
	No. 5	10.32	10.20	0.0010	6.10	
	No. 6	10.34	10.05	0.0010	5.20	

Note 1: As for samples No. 1, 4 & 6, we were unable to obtain results due to the mishandling of specimens during installing them in the test equipment..

Note 2: Although the amount of outflow of specimen No. 1 tended to decrease, it did not reach a stable state. Measurement was stopped due to limitations of the measurement equipment.

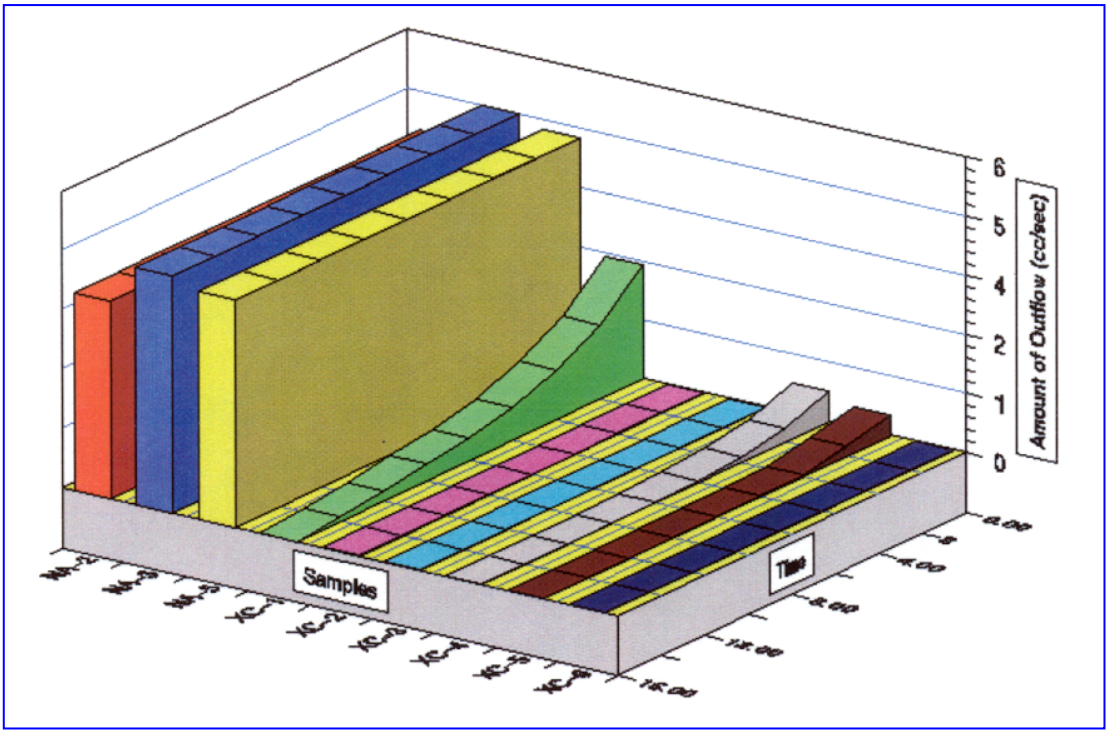

Figure 3: Change in Amount of Outflow with Time

Mechanical Strength Test

1) Specifications of the test:
   1. The compressive strength was measured in accordance with the JISA 1107 test procedure.
   2. Number of samples: 3 each

2) Results:
   Test results are shown in Table 2. Although the Xypex Concentrate samples show on average a 28% increase in compressive strength compared to the reference, we can not judge that this difference resulted only from the effect of the Xypex Concentrate application.

Table 2: Results of Mechanical Strength Test

Status of Sample	Sample No.	Diameter (cm)	Height (cm)	Maximum Load (N)	Compressive Strength Correction Factor (Mpa)	Corrected Compressive Strength (Mpa) (Note)
Not Applied	No. 7 No. 9 No.10 Avg.	10.31 10.32 10.32	19.16 10.07 14.02	152.50 170.50 159.00	18.28 x 0.99 20.39 x 0.99 19.02 x 0.94	18.1/185 20.2/206 17.9/182 18.7/191
XC Applied	No. 7 No. 8 No.10 Avg.	10.34 10.33 10.31	19.01 19.04 18.94	205.00 201.00 198.00	24.57 x 0.99 24.00 x 0.99 23.73 x 0.98	24.3/248 23.8/243 23.3/238 23.8/245

Note: Upper/Lower: (Mpa) (kgf/cm^2)

SEM Observation of Structure

1) The extraction procedure for the test specimens for SEM observation is shown in Figure 4.

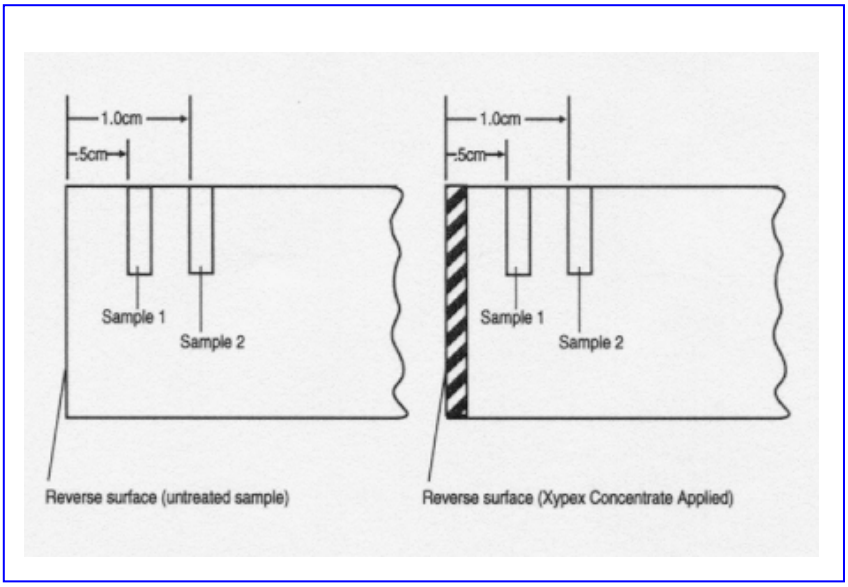

Figure 4: Location for extracting the SEM observation

2) SEM Picture Conditions:

Scanning electron beam microscopy: Model EMA-733
Condition of voltage and applied current : 20KV, 1 x 10^{-10} A
Magnification: First, the 10 micron void in the 4 x 5 mm area on the concrete specimen was focused using a 20 times magnification. Then the SEM picture was taken with magnification of 1,000 times.

3) Results:
An increase of "cement' crystals can be observed in the void of cracks in Xypex Concentrate treated sample (Photo 2). In the untreated sample (Photo 3) only the gel wall can be observed. SEM photographs on the two samples had a magnification of 1,000 times.

Conclusion:
From this experimental investigation, it was clear that the Xypex Concentrate crystalline treatment was effective in improving the durability of the concrete deck plates that are stressed by continuous and repeated load. It was confirmed that cement crystals are increased in the cracks of the concrete bridge deck and hence a waterproofing effect has resulted. Although it was observed that Xypex Concentrate may have contributed to improved compressive strength of the concrete deck slab, further verification is still required.

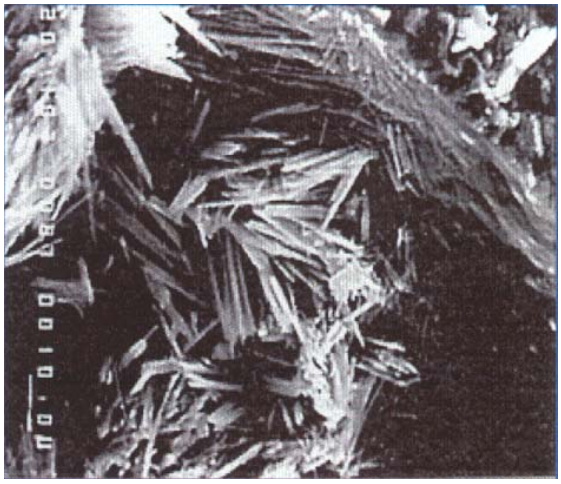

Photo 2: Xypex Concentrate Applied Sample

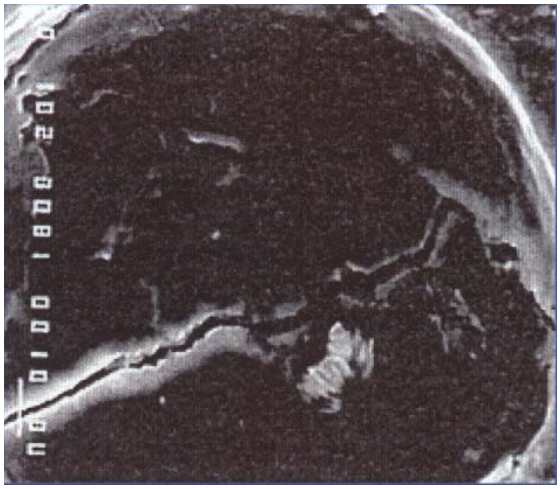

Photo 3: Untreated Sample