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CONSIDERATION ON THE MONITORING OF PRE-STRESSED CONCRETE BRIDGE

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Abstract

A pre-stressed concrete (PC) is a structure where a crack is rarely generated. However, there are some PC bridges which the crack has generated by chloride attack. In some instances, a PC tendon was broken on some PC bridges where a crack is generated and large displacement may have occurred on PC central hinge bridge.

The authors presumed stress states and the pre-stress of such superannuated PC bridges using the stress releasing method. A stress state and pre-stress were presumed to be from released stress that had acted on the concrete and rebar. Moreover, on the PC bridge where large displacement has occurred it is presumed the creep coefficient is from the stress distribution of concrete and rebar obtained from the stress releasing method. Consequently, the cause of the big displacement of this bridge was specified.

This paper is about the monitoring method of superannuated PC bridges while introducing the presumed method of the stress state and pre-stress of PC bridges by the stress releasing method.

INTRODUCTION

A concrete structure has high durability and it is believed that maintenance is unnecessary. However, in some concrete structures, there is degradation damage from chloride attacks, carbonation, an a alkali aggregate reactions, etc. Cracks and steel rod corrosion etc. has appeared notably in recent years.

Especially the pre-stress concrete structure, (PC structure), such as a highway bridge, a railroad bridge, and a building, has introduced pre-stress into the structure with PC steel materials. PC bridge which are located near the seashore show the examples where PC steel materials are fractured by damage from salt water to figure 1.1.

Degradation, such as carbonation, chloride attacks and an alkali aggregate reaction, reduces the durability of a concrete structure. A degradation factor permeates into concrete and it is begins to corrode rebar and PC tendons in concrete. If the degradation advances further, it can cause PC tendons to break and , pre-stressing will decrease and a load-proof performance will also decrease.

Therefore, the suitable measure of a PC structure is made by presuming and predicting the reduction of pre-stress. And the safety of PC structure is intentionally maintainable.

However, the technology which measures the exact amount of pre-stress introduced into PC structure is not established. Therefore, authors presumed press Torres by two methods. This paper reports the presumed method of pre stress. And the view of the new measurement method is described.

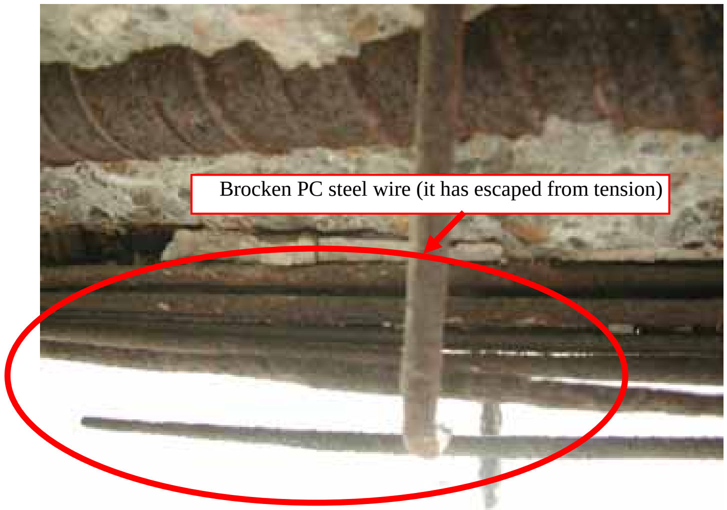

Figure 1.1 PC structure which PC steel materials fractured by chloride attack[1)]

PRESUMPTION OF PRE-STRESS DUE TO REBAR RELEASING METHOD AND SLOT-STRESS[2)]

The pre-stress force of the existing bridge is estimated from dead load stress measured due to the release of rebar and concrete stress.

PC tendons and rebar are arranged in a pre-stressed concrete bridge. The strain of rebar arranged in PC bridge are caused by dead load, shrinkage, creep. Therefore, these strains can be measured by the release of rebar stress.

Moreover, utilizing concrete stress release methods such as slot-stress, the stress of concrete due to dead load can be investigated.

The rebar stress released method and slot-stress were measured at the position shown in Fig.2.1. The sensor was installed in the rebar located at the lower flange, which ever continuously monitored in long term. (This sensor life is about 20 years)

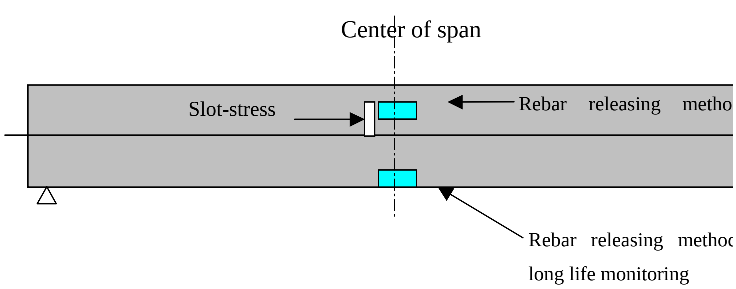

Fig.2.1 Rebar releasing method and Slot-Stress

Rebar releasing method

The dead load stress is measured using the rebar releasing method as follows:

1) The concrete covering of the rebar is removed, then strain gauge is installed on the rebar, measuring its stress, before cutting the rebar.
2) The rebar was cut using a grinder, etc and the stress of the rebar is measured after the cutting.
3) The strain of the rebar is calculated from the difference between data taken before and after cutting.

Since the thermal expansion due to welding connection will effect additional strain occurrence, a special coupling which connected the cut rebar shown in the photograph was developed.

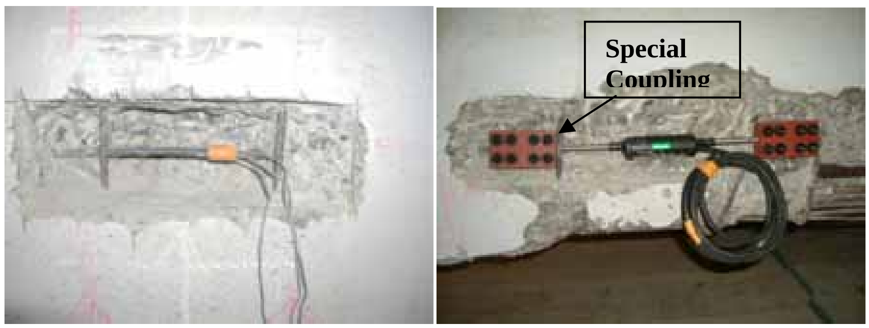

Fig.2.2 Rebar releasing method

Slot-stress

The mechanical-deformation-based technique for measuring stress in concrete has been derived from the mining industry where it is used to measure stresses in rock masses. The method is also widely used in metals or plastics. Its principle is simple, the strain field is relieved by coring or slotting the material, the change of the strain in the relieved area is measured and the stress is calculated taking into account the elastic properties of the material and the geometry of the cut.

However, in concrete, the modulus of elasticity varies with concrete mix, age, curing and environmental conditions. In order to eliminate the need to know the elastic properties of the concrete, a flat jack can be inserted into the slot and pressurized. As a result the initial strain field will be restored. The combination of the measured data on strain and pressure will give the value of the stress as shown in Figure 8.

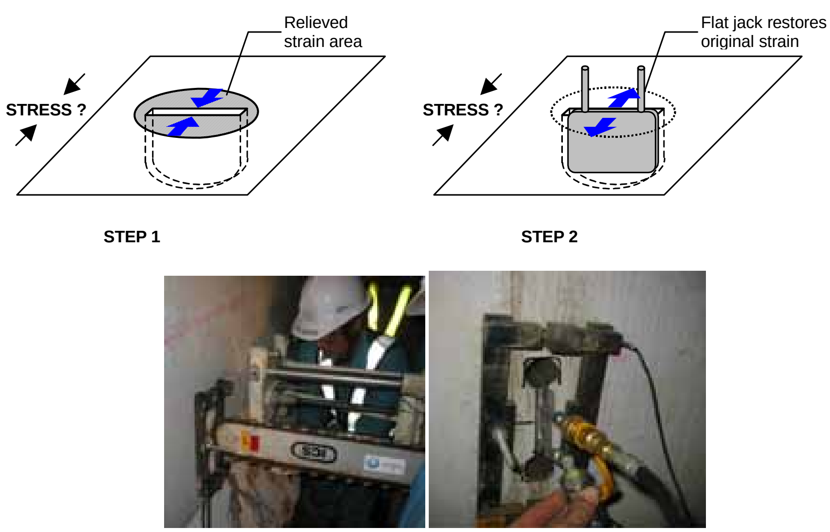

Fig.2.3 Slot-Stress

Presumption of pre-stress force due to rebar releasing method and slot-stress

The effect on strain of shrinkage and creep, etc. is included in strain of rebar. Then, the distribution of concrete strain was obtained from the slope of the measured rebar strain distribution and slot-stress. Table 2.1 and Figure 2.4 shows the strain distribution of rebar and concrete. A concrete modulus of elasticity coefficient was assumed to be 25000N/mm^2 which had been obtained from the analysis explained in the previous paragraph.

Pre-stress force presumed from a concrete stress on the upper edge and the lower edge of section was shown in Table 2.2. As a result, the pre-stress level on lower edge of span1, span2 became about 16.7N/mm^2. This amount is 6.5N/mm^2 below the requirement from pre-stress design. This presumed pre-stress level became equal into which two PC tendons were cut from the analysis of the foregoing paragraph.

The pre stress of a PC bridge has been presumed by combining the rebar releasing method and slot-stress method, which are the stress releasing methods. However, the rebar releasing method removes a wide range concrete. For this reason, the PC structure is damaged and it is the cause of error of the rebar releasing stress measurement. The slot stress method has the fault to which the place to measure is limited in order to trench [a width of about 20cm and a depth of about 15-20cm].

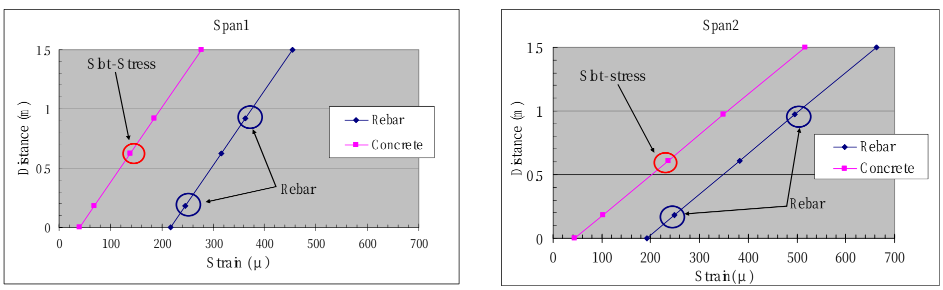

Fig.2.4 Strain distribution

Table 2.1 Strain distribution of rebar and concrete

	Span1			Span2		
	Distance(m)	Rebar (μ)	Concrete(μ)	Distance(m)	Rebar (μ)	Concrete(μ)
Upper edge	0	455	278	0	662	516
Rebar strain	0.58	363	186	0.53	496	349
Slot-stress	0.88	315	138	0.89	383	236
Rebar strain	1.32	246	69	1.32	248	101
Lower	1.5	217	40	1.5	191	45

Table 2.2 Section Stress

Unit N/mm^2

	Span1			Span2			Design Pre-stress
	(1) D+P	(2) Dead load	(3)=(1)-(2) Pre-stress	(1) D+P	(2) Dead load	(3)=(1)-(2) Pre-stress	
Upper edge	6.95	9.48	-2.53	12.89	9.48	3.41	-3.81
Lower edge	1	-15.56	16.56	1.12	-15.56	16.68	23.02

PRESUMPTION OF THE PRE-STRESS BY THE RELEASING STRESS MEASURING METHOD OF THE CORE CIRCUMFERENCE [3)]

The outline of the releasing stress measuring method of the core circumference

Uniform stress, such as dead load and pre stress, is acting on the concrete of a PC bridge. On the other hand, if stress acts on the component which the hole opened, it is known that 3 times as many concentration stress as this will occur around an opening. If a core is carried out to the component on which uniform stress is acting from that, stress will redistribute around a core and the stress state of the core circumference will change. (Figure 3.1 reference) The open stress of the measured core circumference part is analyzed, and the stress state of a component can be presumed. (Figure 3.2 reference)

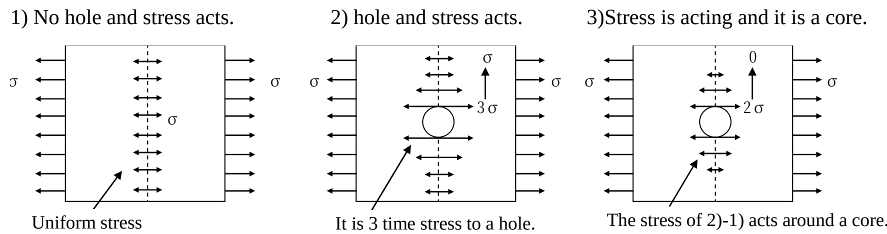

Fig. 3.1 Change of horizontal stress

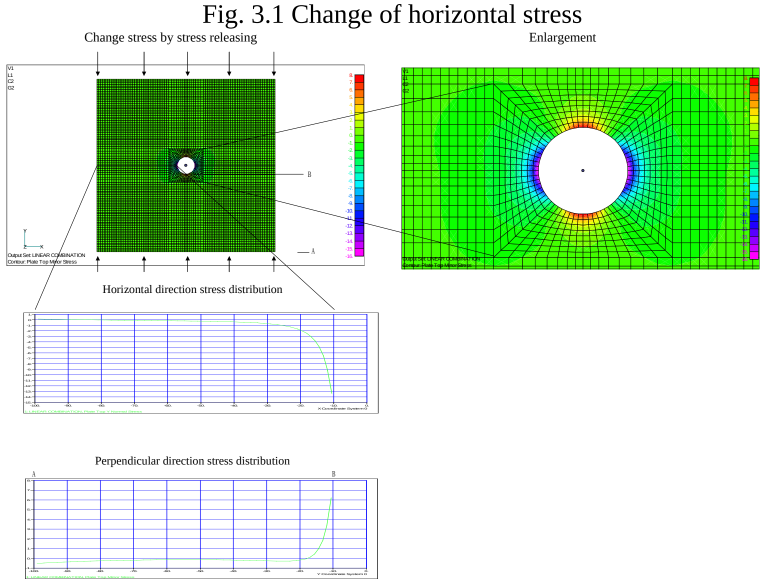

Fig. 3.2 Releasing stress distribution of the core circumference

Presumption of pre-stress due to releasing stress measurement of the core circumference

Releasing stress measurement of the core circumference

Open stress measurement of the core circumference was measured with 3 axis strain gauges (5mm), as shown in a photograph 3.1.

The following procedures performed core circumference distortion measurement.

1) A steel rod is investigated and a core position is decided.
2) Strain gauges are installed in the concrete surface.
3) The strain before a core is measured.
4) A core is carried out by the cutter.
5) The strain after a core is measured.
6) The difference of the strain a core before and after is relesing stress of the core circumference.

Presumption of pre-stress

The releasing stress which the core circumference measured was analyzed and the dead load stress state was presumed. A dead load stress distribution is shown in Fig. 3.4. The stress distribution obtained from measurement is a slope contrary to the stress distribution at the time of a design. As for this, the dead load stress state of the present PC bridge differs from the state where the design assumed.

The stress for beam dead load etc. was deducted from the dead load stress state of Fig. 3.3, and the amount of pre-stress was presumed. It turns out that the pre-stress from measurement decreases from the pre-stress of a design.

As mentioned above, presumption of the pre-stress of a PC bridge is possible by the releasing stress measuring method of the core circumference. However, the releasing stress of the core circumference is a stress change in the very minute range, as shown in Fig. 3.2. For this reason, open stress measurement of the core circumference in a strain gauge, has large errors.

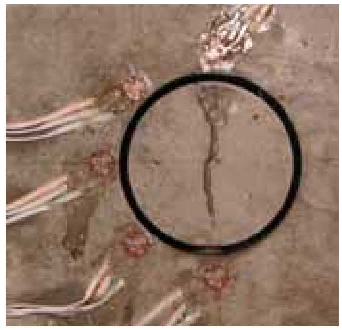

Photo. 3.1 A strain gauge and core

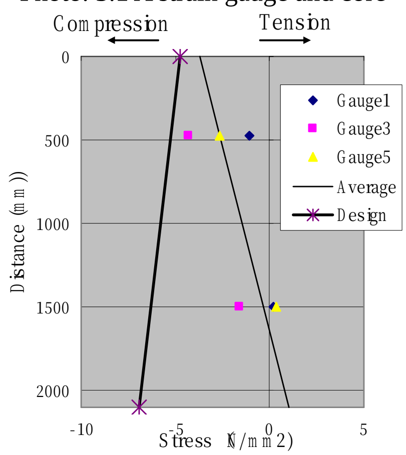

Fig. 3.3 Dead load stress distribution

CONCLUSIONS

The stress state of a PC structure has been found by the stress releasing methods, such as the rebar releasing stress method, the slot stress method, and a releasing stress measuring method of the core circumference. However, in any method, the error is large and there is a problem in the application on a real structure. Especially measurement of stress change in the range with the core circumference minute by the releasing stress measuring method of the core circumference is difficult by the existing measurement techniques, such as a strain gauge.

The open stress method of the core circumference was changed into the existing measuring method, and the change stress of a core circumference part was measured by Full-field Optical Stress and Strain Measurement Methods.、 The picture photographed with the digital camera and scanner after a 50mm core is shown in a photograph 4.1. The picture of a digital camera and a scanner was analyzed by Digital Image Correlation Method. As shown in Fig. 4.1, the releasing stress distribution of a core circumference part can be grasped by Digital Image Correlation Method of a digital camera and a scanner.

This has suggested a possibility that the stress state of an established real structure can be found, by combining the stress releasing method and full-field optical stress and strain measurement methods. In order to measure the stress state of the dead load of real structures, such as a PC structure, the measuring instrument is installed and measured in advance at the time of construction. However, a stress state may be measured in the combination of the stress releasing methods and Full-field optical stress and strain measurement methods, such as dead load of an existing real structure, without installing a measuring instrument beforehand.

Digital camera Scanner

Photograph 4.1 Full-field optical stress and strain measurement methods pictures [3)]

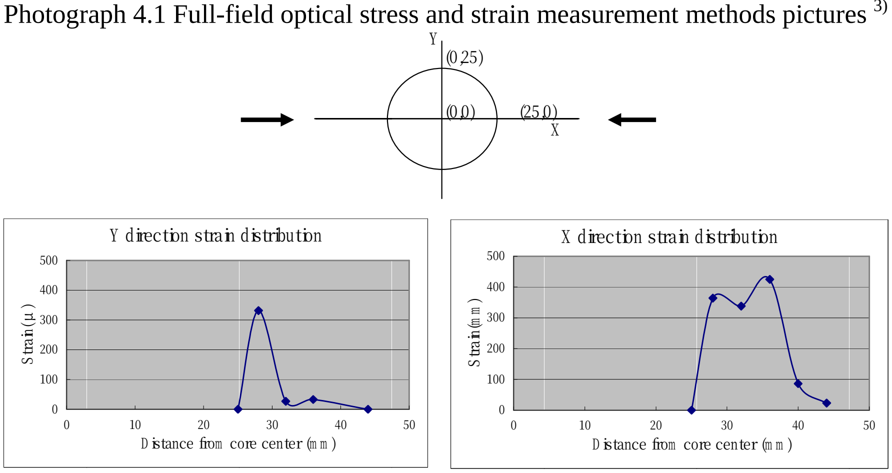

Fig. 4.1 X-axis direction strain distribution of core circumference by digital Image correlation method[3)]

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