論 文

# [2134] ポリマー含浸コンクリート型わくと複合鋼管パイプを用いたPC工法

## PRESTRESSING METHOD BY RELEASING COMPRESSION WITH POLYMER IMPREGNATED CONCRETE FORM AND COMPOSITE PIPE

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### 1. INTRODUCTION

The utilization of the post-compressed reinforcement in the prestressed concrete was invented by Dr.H.Reiffenstuhl and was applied to the construction of the ALM bridge in Austria. In Poland Dr.S.Drewnowski tested many beams with post-compressed reinforcement and presented the new type of anchorage system.

In Japan,this construction method is called Bi-Prestressing System and some bridges were built by this method recently. (1)

On the other hand, the polymer impregnated concrete permanent forms were used for increasing the durability of the beams in the severe environment.With this PIC form,not only the durability, but also the cracking moment of the beam increases 20-30 % compared with the ordinary beam. (2) It is necessary to ensure the high fracture moment and ductility for the safty of the beam. Pre-compressed composite reinforcements were placed on the upper side of the beam for this purpose. The idea to use the composite pipe for pre-compressed reinfocement was patented by Gihachi Nakajima and was use for changing the compression to tention after the hardening of concrete. (3)

This paper deals with the whole effect of prestressing method by releasing compresion (PMRC) together with PIC permanent forms and compressed composite pipes.

### 2. THE PRELIMINARY TEST FOR DEMONSTRATE THE EFFECT OF THE PMRC

A simple test was carried out to prove the effect of releasing compression with two jointed beams,the one of which was pre-compressed.The procedure of the test was demonstrated as follows: Prestress the upper of the beam by te tendon, then combine the another lower beam with epoxy resin. Release the compression force of the upper beam. One fourth of compression and tension prestress were given at the edges and the center of the beam. Mode of action is shown in Fig 1.

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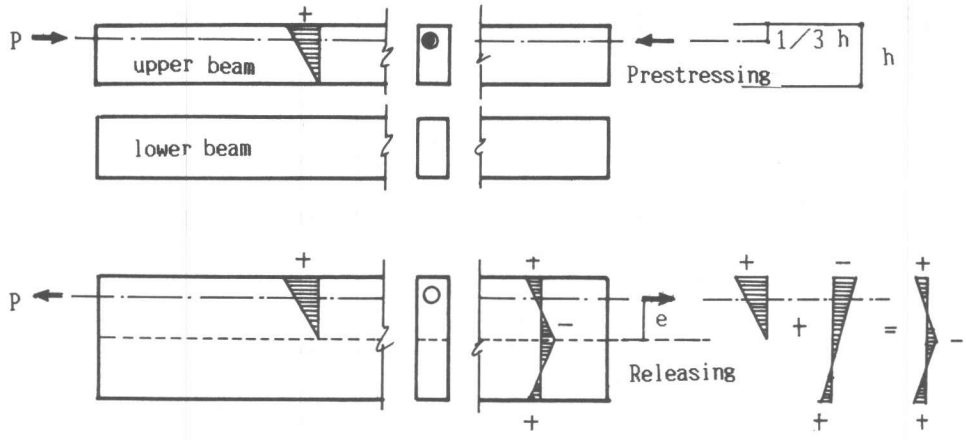


Fig 1 Mode of action

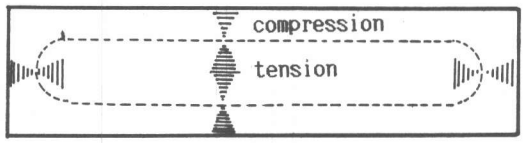


Fig 2 Stress distribution by FEM

Fig 2 shows the stress distribution calculated by Finite Element Metod.The tendonless prestressed concrete beam can be made by this method. The experiment showed that the cracking moment of the combined beam was 1.5 times of that of the same sectioned ordinary beam. Therefore,the effect of the PMRC was verified.

## 3. THE SECOND TEST FOR PC BEAMS WITH PIC PERMANENT FORMS

To obtain the high integrity of PC beams,the PIC permanent forms were used. The physical properties of PIC are shown in Table 1 and the fablication of PIC permanent forms is illustrated in Fig 3

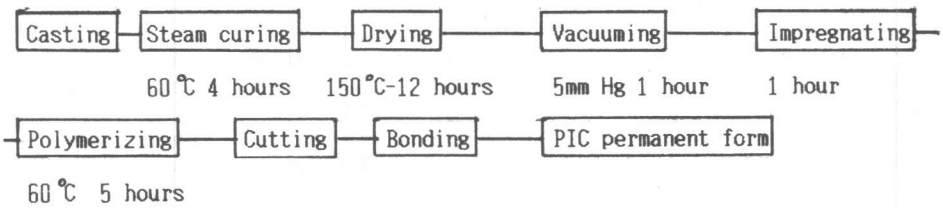


Fig 3 Fablication of PIC permanent form

Table 1 Summary of Properties of PIC

| Description of Properties | Specification of Test | Test Results |
|---|---|---|
| 1. Mechanical Properties | Compressive strength, ϕ10x20cm | 1500kg/cm$^2$ |
| | Modulus of rupture, 10x10x40cm | 240kg/cm$^2$ |
| | Tensile strength, ϕ15x15cm | 120kg/cm$^2$ |
| | Modulus of elasticity, ϕ10x20cm | 4.5x10$^5$kg/cm$^2$ |
| | Poison's ratio, ϕ10x20cm | 0.18 |
| | Density | 2.4 |
| | Coefficient of thermal expansion | 1.1x10$^{-5}$/°C |
| | Creep coefficient | 0.08 |
| | Fatigue limit (10$^7$cycle) | 63% |
| 2. Resistance to freezing and thawing | (1) in Air -40°C +60°C 30 cycle | No change |
| | (2) in Water -30°C +60°C 230 cycle | 4% decrease |
| 3. Resistance to chemical attack | (1) 2% $H_2SO_4$ 1000 hours | 40% decrease |
| | (2) 2% NaOH 1000 hours | No change |
| 4. Resistance to Ultra-Violet radiation | Weather meter 3000 hours | No change |

The details and the loading method of beams with PIC forms are shown in Fig 4. The bond properties between PIC forms and placed concrete were obtained by the direct shear and flexural test. The bond strength was about 30 kgf/cm$^2$ and there were no problems concerning the behavior of the beam under static and dynamic loads. From the test results, the initial cracking load of the PC beam with PIC permanent forms was 20-30 percent higher than that of the ordinary type.

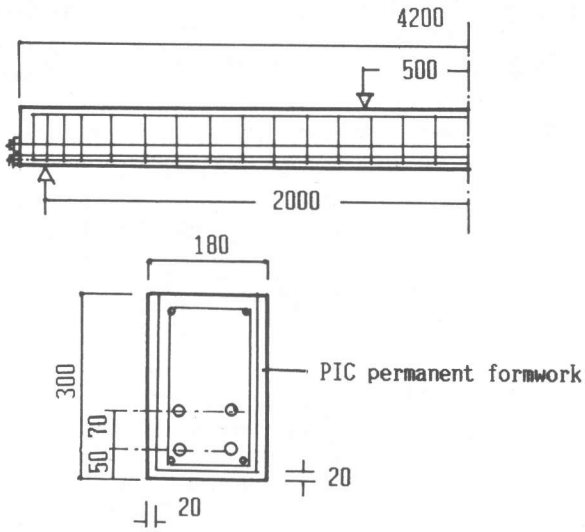


Fig 4 PC beam with PIC permanent form

## 4. THE MAIN TEST FOR PMRC

The detail of PC beams for PMRC is shown in Fig 5. The pre-compressed reinforcement made of composite steel pipe and concrete was prepared before casting in the beam. The section is shown in Fig 6. The quick hardening cement was used,and at the age of 10 days,the composite pipe was pre-compressed by PC bars.The stresses of the steel pipe and concrete were 1200kgf/cm² and 200kgf/cm². The load-strain curve of the composite pipe under the compression test is shown in Fig 7, and it can be seen that the pre-compressed reinforcement acts such as the PC bars at releasing compression. The PIC permanent forms were manufactured and the concrete was placed with PC bars and another reinforcement.

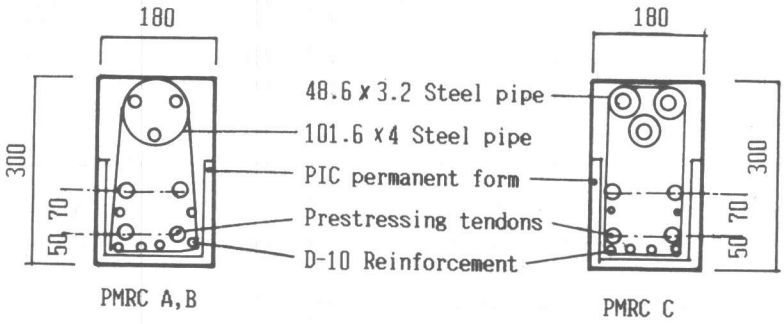


Fig 5 Detail of PC beams for PMRC

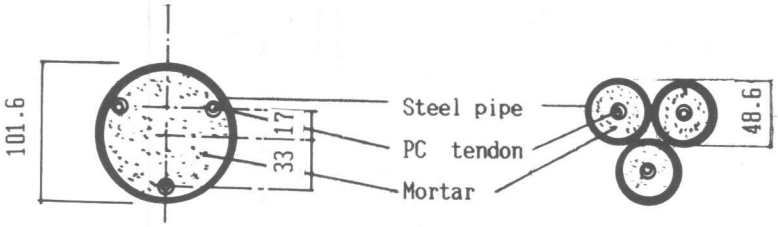


Fig 6 Section of the pre-compressed reinforcenent

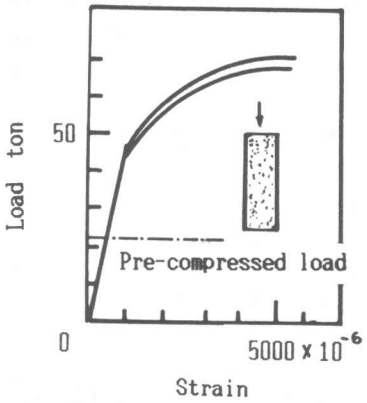


Fig 7 Load-Strain Curve

The PMRC beams were loaded as follows: At first,the load was increased up to 80 percent of the calculated cracking moment of the beam. Then,the stress of the pre-compressed composite pipe was released. At that moment,the load increased in spite of the decrease in deflection of the beam. Second,the load was increased to the cracking moment. When the crack occured,the load was decreased to zero and increased to the maximum flexural moment. Then, the load was decreased to zero. At last, the load was increased to verify the ductility of the beam with composite pre-compressed reinforcement.
Fig 8 shows the load-deflection curve of PMRC beams with ordinary PC beam and PIC permanent formwork. The summary of the test results are shown in Table 2.

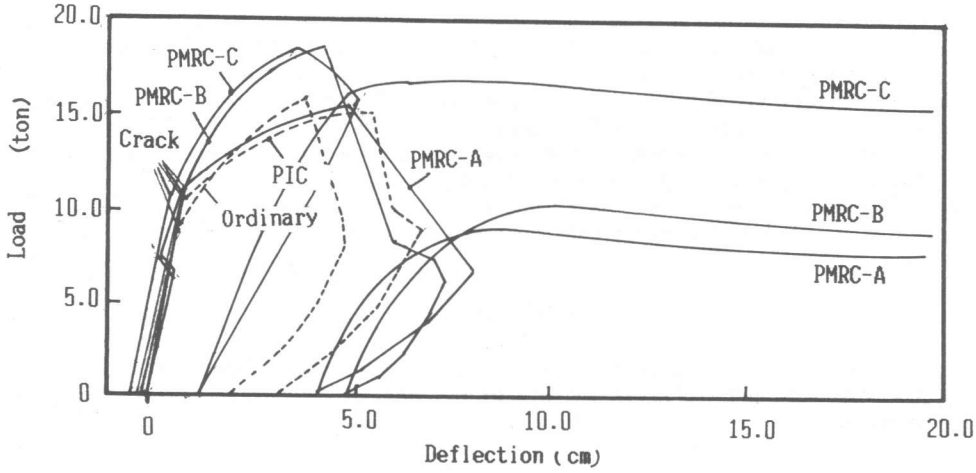


Fig 8 Load-Deflection Curve

Table 2 Summary of the tests

| No. | Type of Specimen | Concrete Strength kgf/cm² | Initial Cracking Load Ⓐ ton | Ultimate Flexural Load Ⓑ ton | Ⓑ/Ⓐ |
|---|---|---|---|---|---|
| 1 | Ordinary | 557 | 8.0 (100) | 16.0 | 2.00 |
| 2 | PIC | 567 | 10.0 (125) | 15.1 | 1.51 |
| 3 | PMRC-A | 595 | 10.8 (135) | 15.2 | 1.41 |
| 4 | PMRC-B | 595 | 11.0 (138) | 18.3 | 1.66 |
| 5 | PMRC-C | 595 | 11.0 (138) | 17.8 | 1.62 |

Fig 8 shows the effect of the PIC permanent forms and the pre-compressed composite pipes : The initial cracking load of the PMRC beams were 1.25-1.38 times of the ordinary PC beam. The deflection of the PMRC A,B and C were decreased by releasing compression. The amount of which were shown in the rise of the beams after the load decreased to zero. The ductility factor of the PMRC beams were 5.0-7.0. The ratio of the ultimate flexural load to the initial cracking load was decreased by using PIC permanent forms, but recovered by reinforcements and the high integrity of the beams were ensured by composite steel pipes which were used for pre-compressed reinforcements.

## 5. CONCLUSION

The PMRC with PIC permanent forms and composite pipes has following advantages :

a. The cracking moment higher than that of the same sectioned PC beam can be obtained and the ratio of the span by depth of the beam will be 30-35.
b. The ductility of the beam are increased by composite pipes which is used for the pre-compressed reinforcement.
c. The amount of the creep of the beam will be decreased by PIC permanent forms and by releasing prestress forces.
d. The durability of the beam is ensured by the low permeability of PIC form.
e. The PC tendons for prestressing composite pipes can be used repeatedly.

## ACKNOWLEDGEMENT

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