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FLEXURAL BEHAVIOR OF A PRECAST MEMBER REINFORCED WITH EXTERNAL TENDONS

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ABSTRACT: This paper describe an experimental investigations made in a box cross-section precast concrete member analyzed under a pure bending. The strength behavior and the joint opening behavior of the precast member, initially internally prestressed, represtressed with external tendons after cracking.

The experimental results revealed that there is no remarkable difference in load-strain relation, strength, deflection and failure mechanism between a new prestressed structure and an old structure represtressed after cracking. The comparison between the experimental results and results of numerical analyses have shown that, for the deflection behavior, a simple integration method can be used, However, for the stress behavior, a better method, as FEM, should be used to get a significant result.

INTRODUCTION: Prestressed concrete has been widely used in construction for quite a long time, specially in bridges. In almost all structures, the prestressing system has been internal prestressing. However, recently the use of external prestressing has increased remarkably in all over the world, most extensively in building new structures [1]. This research study further investigated the use of external prestressing for old existing structures. So the aim of this studies is to analyze the behavior of a precast prestressed concrete beam reinforced by external tendons including the behavior of the joint and the failure mode of members for the practical design.

PROGRAM OF EXPERIMENT: The experiments was done on a segmental five concrete blocks beam, with a box shape cross-section. The blocks was reinforced with a minimal reinforcement steel and prestressed with internal or external tendons or both. All cases of experiments are shown in Table 1. In the joint, four shear keys and an epoxy resin was used. Fig. 1 shows the layout of the test beam and the loading method. The materials used for the specimens was a normal strength concrete with a minimal reinforcement; Compressive strength 320 kg/cm^2, Tensile strength 32 kg/cm^2 and Young's modulus 3.1x10^5 kg/cm^2; and an SPWRA seven wire strand, diameter 12.4 mm, Tensile strength 185.5 kg/cm^2, Yield stress 165.7 kg/cm^2 and Young's modulus 1.92x10^5 kg/cm^2 [2].

Table 1 Cases of the experiments

Case	Span (cm)	Nber	Tendon layout	Joint	
1	580	1	internal	Epoxy	up to failure
2	580	1	external	Epoxy	up to failure
3	580	1	internal + external	Epoxy	up to failure
4	580	1	internal + external	Epoxy	after the first cracks external prestressing was applied

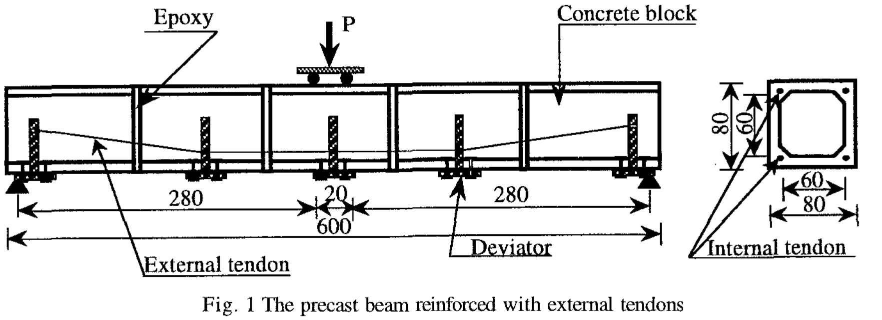


Fig. 1 The precast beam reinforced with external tendons

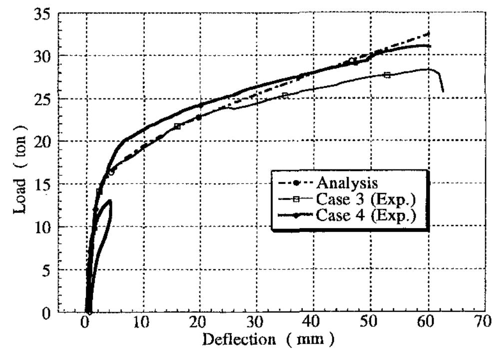
BASIC OF THE ANALYTICAL METHOD: For the analysis of the load-deflection, load-strain behaviors and the crack and failure loads, a simple integration method was used [3]. The nonlinear analysis models were adopted from the following assumptions; (1) Plane sections still remain plane after bending, (2) Nonlinear of the materials (concrete, reinforcements and prestressing steel) are considered through the use of constitutive relations of materials, (3) Only pure flexural deformation are considered. The ultimate limit stage is defined when either the concrete strain at extreme compression fiber (ε_{cu}) reaches 0.0035, or the tensile stress of the prestressing tendons exceed the nominal tensile strength, the reinforcement steel was negligible.

RESULTS AND DISCUSSION: The test results and the calculeted results are summerized in Table 2. The behavior of the tests beams can be described by the deflection and strain at mid-span versus the applied load up to failure.

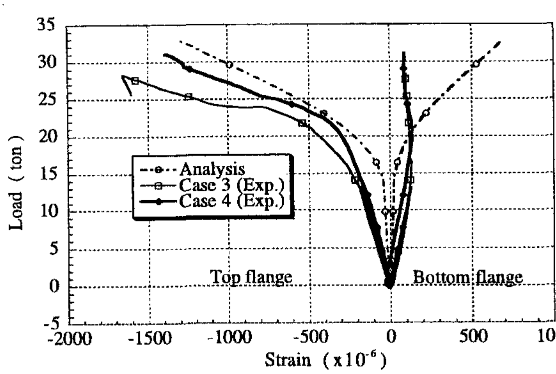
Figure 2(a) shows the load-deflection curves for case 3 in which the beam is initially fully prestressed with internal and external tendons, case 4 in which the beam is first prestressed with internal tendons and after cracking represtressed with external tendons, as well as, the calculeted result. For case 4, there is an abvious difference in the deflection behavior between the first loadin g stage and the second loading stage. It is considered that it is directly due to the effect of the prestressing force applied to the structure through only the internal tendons and both of the internal and external tendons. However, the behavior of the second loading stage of case 4 after represtressing with the external tendons almost same than case 3. No significant difference is observed. Also it can be observed that the analytical curve fits with the experimental one. Figure 2(b) shows a comparison of the strain behavior on the upper flange and bottom flange of the test beams of case 3 and case 4. Strains are proportional to the loads up to the crack load. After crack, there are complex changes. In both cases, strain grows rapidly in the compression side, on the other hand strain of the tensile side goes down by extend value. This indicate that upper side of the section resist to compression stress up to final stage, however the bottom side become half free at the last stage. The analytical curve fit to the experimental curves for the compression side, however for the tension side, it is difficult to controlled with a simple method. The opening of joints close to the center of the span for case 3 and case 4 are shown in figure 2(c). The behavior of the shear keys was quite satisfactory with no evidence of slip occurring between blocks up to failure. A sudden final crack opening failure was expected by slip of joint, but in these studies the epoxy resin and shear keys of joint were sufficient to resist up to the final stage of the experiments.

Table 2 Crack and Failure loads

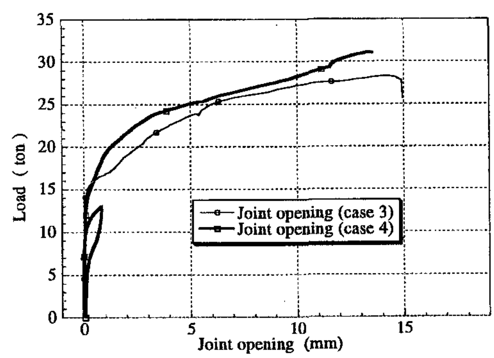
Case	Crack load (ton)		Failure load (ton)		Failure mode
	Anal.	Exp.	Anal.	Exp.	
1	13.5	12	20.9	19	crushing of concrete (center block, upper flange)
2	11	-	12.8	8	crushing of concrete (Anchorage zone)
3	16.4	16	32.5	28.2	crushing of concrete (Anchorage zone)
4	13.5 16	13 20	- 32.5	- 31	crushing of concrete (Anchorage zone)



(a) Load-Deflection behavior



(b) Load-Strain behavior



(c) Joint opening behavior

Fig.2 Behavior of the precast beam

CONCLUSIONS: The experimental investigation in the flexural behavior of a precast concrete member reinforced with external tendons were carried out using a precast beams made by five concrete box culvert blocks. The difference between the use of internal tendons and external tendons was also observed. The following conclusions could be drawn from the above study

1- The flexural behavior of a precast concrete beam reinforced with external tendons after cracking doe's not differ from the behavior of a precast concrete beam initially prestressed with external tendons.

2- There is no remarkable difference in failure mechanism between a new prestressed structure and an old structure represtressed after cracking.

3- A precast prestressed concrete member representing cracks or joint opening can be restored using external tendons.

4- A precast concrete structure can be reinforced for a greater carrying load by represtressing it with external tendons.

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(3) M. Fujii, K. Kobayashi: "Precast Concrete Structure", Kakumin Kogakusha, 30 May 1979.