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Ultimate Strength and Ductility of PC Beams with External Tendons

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Summary

Precast segmental concrete bridges with external prestressing have become popular in the current construction trend due to their advantages such as reduced web thickness and possibility of repairs. The use of continuous beams could be a remedy for reducing the number of expansion joints, thus providing a better driving conditions. However, the inherent structural behavior of such beams is not well understood especially at the ultimate limit state. This paper describes the experimental investigation conducted to examine the flexural behavior of two spans continuous beams with external and combined prestressing, under unsymmetrical loading.

1. Introduction

One of the latest developments in the construction technology has been the use of external prestressing with precast segmental construction which lead to considerable economical and time saving. The use of continuous span structures is gaining popularity since the number of expansion joints are reduced, resulting in better driving conditions. Concern has been expressed that adequate ultimate behavior and sufficient strength could not be obtained. Moreover, lack of ductility of precast segmental bridge girders is another big issue that had to be addressed when such bridges are built as frame structures in earthquake areas. To obtain an insight of the ultimate flexural behavior of such beams, an experimental program was conducted on precast segmental two span continuous beams. In a previous investigation, the flexural behavior of such beams was studied with symmetrical loading conditions, whereas in the present study, the loading pattern was unsymmetrical to increase the moment ratio at critical sections [1]. The results of this investigation are presented in this paper, with emphasis on the influence of confinement reinforcement and combined prestressing on strength and ductility.

2. Experimental Methodology

Three specimens with equal span length of 4.05 m having a T-shaped section were cast. The layout of the specimens is shown in Fig. 1. The specimens No.1 and No.2 are with external prestressing while No.3 is prestressed with combination of internal and external prestressing. The difference between No.1 and No.2 is the provision of confinement in the compressive zone of concrete at critical locations. This was provided in view of increasing the rotational capacity at critical sections, thus improving the ductility of the structure, as shown in a previous study [2]. The confinement reinforcement is of D10 at 50 mm spaced rectangular hoops. This was provided in the top flanges in segments Nos. 5-7, and in the bottom of web in blocks Nos. 12-14. The segments are of 300 mm in length, provided with multiple shear keys. The specimens were concreted by long line match cast technique to have a good fit at the joints. These blocks were assembled and joined by epoxy resin. In specimens No.1 and No.2, two steel cables of type SWPR7A (12.4 mm dia.) were used as external tendons. In No.3, three cables of the same type with 10.8 mm diameter were used, two as external tendons and one as internal. The total design prestress of 180 kN was introduced to all the specimens, which was about 50-55% of the ultimate tensile strength of the tendons. Two point static monotonic loading was applied in each span, as shown in Fig.1. However, the left span was heavily loaded compared to the right span, thus having an unsymmetrical loading arrangement. The load ratio of right to left span was 0.3 to 1. Measurements were taken at regular intervals of loading.

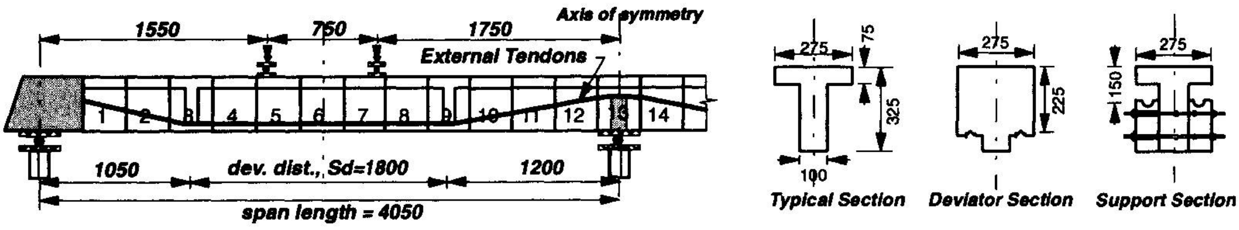

Fig. 1 Layout diagram of test specimens

Table 1. Summary of test results

No.	Description of specimens	Cracking load (kN)		Max. load (kN)	Ultimate deflection (mm)	Stress increase in ext. tendon (MPa)	failure mode
		span	support				
1	External PS, not confined	39.2	56.7	70.2	47.1	232	crushing of concrete
2	External PS, confined	44.9	56.9	71.9	80.1	323	crushing of concrete
3	Combined PS, not confined	44.1	60.9	79.6	80.1	341	crushing, yielding of int. tendon

3. Test Results and Discussion

The test results are summarized in Table 1. The load-displacement characteristics are given in Fig. 2. The maximum load of the specimen No.3 with combined prestressing is the highest, 13% higher than that of No.1. The maximum load on specimen No.1 and No.2 are nearly the same. Considering the final displacement which gives an indication of the ductility, it can be seen that both the specimens No.2 and No.3 show 70% larger than No.1. In addition, the displacement characteristics of No.2 and No.3 are similar except that No.3 has a higher load carrying capacity. From the above observations, it can be expected that a mixture of combined prestressing and confinement reinforcements provide the best solution in view of strength and ductility.

Increase in external tendon stress with midspan displacement is given in Fig.3. It could be seen that the stress increased in a nearly linear manner following almost the same path for all the specimens. In the specimens No.2 and No.3, there was a slight drop in the stress after crushing occurred. However, this increase is substantially lower than the symmetrically loaded specimens of similar layout.

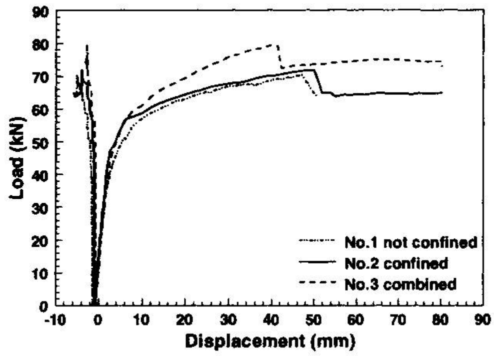

Fig. 2 Load-displacement

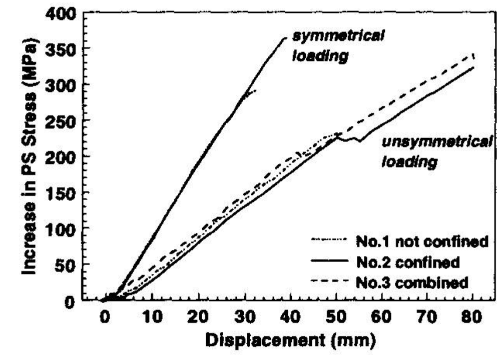

Fig. 3 Variation of tendon stress

4. Conclusions

From the experimental investigation the followings can be concluded.

- The ultimate flexural strength can be enhanced by providing combined prestressing, compared to fully externally prestresing.
- The ductility of precast segmental beams could be improved further by providing confinement reinforcement. It could be also improved by having some internal bonded tendon together with external tendons.

5. References

1. Aravinthan, T., et.al., "Moment Redistribution in Prestressed Concrete Continuous Beams With External Tendons," Proceedings of JCI, Vol. 17, No.2, June 1995, pp. 761-766.