Outline of “Expansion Distributions and Mechanical Behaviors of Chemically Prestressed Concrete Beams Using Expansive Concrete”

膨張コンクリートを用いたCPC梁の膨張分布と力学的性状


*

**

***

****

* Chunhe LI, Ph.D.: University of Miyazaki
李 春鶴，博士（工学）：宮崎大学
** Kentaro SUHARA, Ph.D.: Denka Co.,Ltd.
栖原 健太郎，博士（工学）：デンカ（株）
*** Yukikazu TSUJI, Dr.Eng.: Gunma University, Maebashi Institute of Technology
辻 幸和，工学博士：群馬大学・前橋工科大学
**** Hirohisa OTAKE: Denka Co.,Ltd.
小竹 弘寿：デンカ（株）
Contact: lichunhe@cc.miyazaki-u.ac.jp

Keywords: chemically prestressed concrete beam, expansive strain distribution, mechanical beam behaviors, chemical prestressing
DOI: 10.11474/JPCI.NR.2022.209

1. Introduction

For chemically prestressed concrete (CPC) beams using expansive concrete in reinforced concrete (RC) beams, the expansive strain from the chemical prestressing applied to the concrete and the chemical prestrain applied to the rebar varies greatly according to factors related to not only the concrete mix but also the rebar arrangement.

This paper reports experimental and analytical results for the expansive strain distributions and mechanical behaviors of CPC beams with T-shaped cross-sections and those with rectangular cross sections, each with different rebar arrangements and three different mix proportions. Mix proportions 0 and 1,1* are without and with expansive additive, respectively.

The paper received the Outstanding Paper Award from the Japan Prestressed Concrete Institute (JPCI) in 2021.

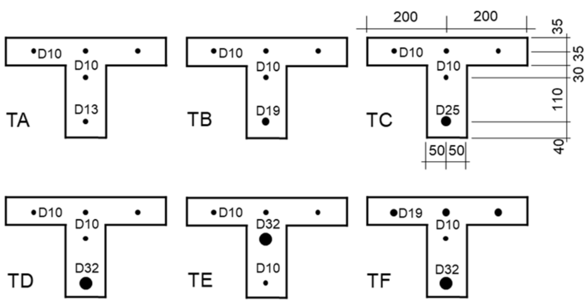

Fig. 1 T-section beams with different rebar layouts

2. Outline of the Experiment

The beam specimens had either a T-shaped cross section (specimens TA–TF) or a rectangular cross section (specimens RA–RE), with names to distinguish rebar layouts of the specimens as shown in **Fig. 1**[1]. All rebar arrangements were vertically asymmetric, even in the specimens with rectangular cross sections. The specimen length was fixed at 1,200mm, and no stirrups were used. The loading tests were performed on concrete at 28 days of age. Two types of expansive concrete were used, with different unit contents of expansive additive, resulting in expansive strain of approximately 500×10^{-6} (mix proportion 1) and 900×10^{-6} (mix proportion 1*) at 7 days of age, as measured using a uniaxial restraint device such as that specified in Annex B of JIS A 6202.

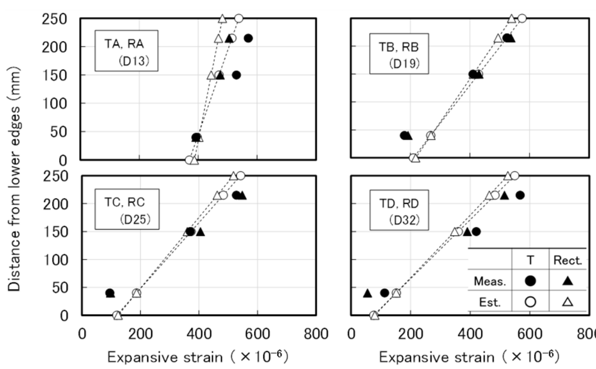

Fig. 2 Distributions of expansive strain for T-shaped and rectangular cross sections with varying lower rebar diameter (mix proportion 1)

3. Methods for Estimating Expansive Strain and Flexural and Shearing Behaviors

The analysis to estimate the distributions of expansive strain and chemical prestress was performed based on the assumption that a constant amount of work is done by expansive concrete on the rebar acting as the restraint [2]. Flexural analysis was then performed using a layered model[1]. The diagonal crack initiation strength and shear compression fracture strength were calculated using the formulas specified in the Japan Society of Civil Engineers (JSCE) Standard Specifications for Concrete Structures, with a material coefficient of $\gamma_b = 1.0$.

4. Experimental Results and Analytical Values

(1) Distribution of Expansive Strain

Fig. 2 shows examples of the distribution of axial expansive strain for different nominal diameters of the lower-section rebar. For both T-section and rectangular cross-section specimens, the greater the content of reinforcement in the lower section, the greater the degree of restraint on concrete expansion and the smaller the expansive strain at that location.

For the amount of work done (U) in this expansive strain estimation, the analysis used the A-type method of uniaxially constrained expansive strain (JIS A 6202), and the estimated values shown by the dotted lines for both the T-sections and rectangular cross sections are nearly equal to the measured values.

(2) Tensile Strain of Reinforcement

Fig. 3 shows the relation between the amount of strain increase in the rebar and the external force moment. Comparing RB0 of the RC beams with RB1 of the CPC beams, the figure shows the calculated and experimental values for the lower rebar, and those values are in good agreement. The increase in strain in the lower rebar is reduced even after flexural cracks develop, with the extent of reduction corresponding to the chemical prestrain applied to the lower rebar. The flexural crack width can thus also be reduced in proportion to the increase in strain in the lower rebar.

(3) Loads of Flexural and Shearing Cracks

Initial flexural cracking occurs in the beam section with constant bending moment. **Fig. 4** compares the experimental and calculated values for the flexural cracking initiation load. For both T-section and rectangular cross-section beams, introducing chemical prestress in the CPC beams with mix proportion 1 increased the flexural cracking initiation load for both rebar configurations compared with the RC beams with mix proportion 0.

Flexural cracks developed in the shear span, followed by diagonal cracking in the direction of the load point. **Fig. 5** shows the experimental and calculated values for the shear cracking initiation load. As in the case of the flexural cracking initiation load, applying chemical prestress in the beam's axial direction increased the experimental values for the shear cracking initiation load in the CPC beams compared with RC beams. This suggests that the effect of applying chemical prestressing can be calculated by the formula in the JSCE Standard Specifications for Concrete Structures.

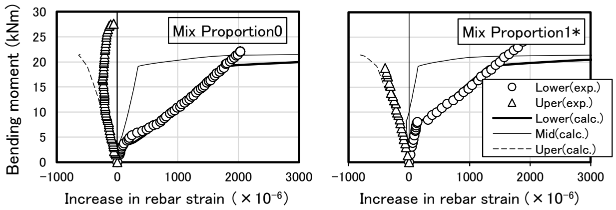

Fig. 3 Relations between increased lower rebar strain and external force moment (RB section)

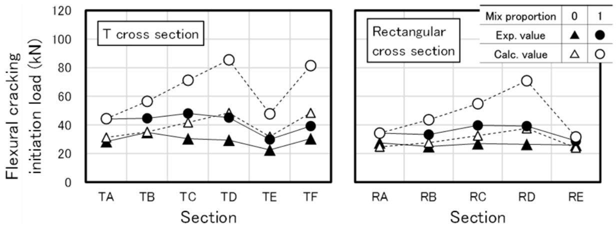

Fig. 4 Comparison of flexural cracking initiation loads in RC and CPC beams (mix proportions 0 and 1)

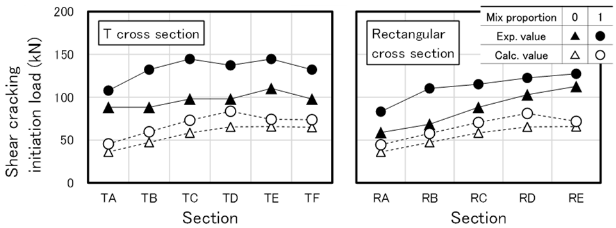

Fig. 5 Shear cracking initiation loads in RC and CPC beams (mix proportion 0 or 1)

5. Conclusion

This paper reported for the first time the results of uniformly conducted experiments involving mainly varying the amounts of rebar allocated at the lower level. The experimental values agreed well with the values estimated based on the assumption of constant work done and those calculated from a layered model.

References

[1] Li, C., Tsuji, Y., Suhara, K.: *Mechanical Behaviors of CPC Beams with Different Arrangement of Reinforcement*, Proceedings of the 28th Symposium, JPCI, Nagoya, pp.741-746, Nov. 2019 (in Japanese).

[2] Tsuji, Y.: *Estimation Method of Chemical Prestress and Distribution of Expansive Strains*, Concrete Journal, Vol.19, No.6, JCI, Tokyo, pp.99-105, June. 1981 (in Japanese).