

PAPER • OPEN ACCESS

Experimental Study on Flexural Behavior of RC Beams Strengthened by External Prestressing

To cite this article: Yinglei Cheng and Xinsheng Xu 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **267** 032071

View the [article online](#) for updates and enhancements.

Experimental Study on Flexural Behavior of RC Beams Strengthened by External Prestressing

Yinglei Cheng¹, Xinsheng Xu^{1*}

¹ School of Civil Engineering and Architecture, University of Jinan, 336Nanxinzhuan West Road, Jinan 250022, Shandong, China

*Corresponding author's e-mail: xinsheng_xu@163.com

Abstract. The efficient external prestressing reinforcement technology has the characteristics of simple construction, clear force transmission and convenient changing of cables, and has become a hot spot in the research of concrete structure reinforcement. In this paper, the external prestressed steel members are taken as the research object, and the two test beams are subjected to two-point loading test. The load-deflection curve is drawn. The ultimate bearing capacity, crack morphology and deflection of bending reinforced RC beams adopted external prestressing technology were compared and evaluated based on the experimental and theory analyzation. The experimental results show that the efficient external prestressing reinforcement technology can significantly improve the performance of concrete members and can be applied to structural reinforcement.

1. Introduction

A typical building will experience significant deterioration and damage after 30 to 50 years of use. In recent years, more and more buildings in China have approached or even exceeded the design base period [1], and most of them can no longer meet the needs of modern society for production, life and operation. Statistics show that the reconstruction will save about 40% of the investment compared with the new construction, shorten the construction period by about 50%, and recover the investment speed by 3~4 times faster than the new construction [2]. Therefore, the identification, renovation and reinforcement of existing buildings have become one of the key points of construction in China, which has also promoted the continuous development of reinforcement technology [3]. In the past 50 years since the end of the Second World War, the world construction industry has experienced three different development periods [4]. China's infrastructure has been controlled by macro-control policies, and the proportion of investment in new construction and reinforcement is timed. However, due to the wave-like changes in the ground, from the overall trend, China's construction industry is gradually entering the second phase. According to conservative estimates, more than 40% of the projects have quality problems that require identification, repair and reinforcement [5]. It can be seen that the detection and identification of buildings and the implementation of proper management, maintenance, reinforcement and transformation to extend their service life are not only extensive, but also a long way to go, which has become an urgent problem to be solved in China.

2. Specimen design

The test members are all designed as simple-section beams with rectangular section. The concrete strength grade is C15, the thickness of the protective layer is 25mm, the section size is



$b \times h = 150\text{mm} \times 300\text{mm}$, the span is $l = 2400\text{mm}$, and the calculation span is $l_0 = 2300\text{mm}$. The bottom of the beam is $3\Phi 14$, the upper frame is $2\Phi 8$, and the stirrup is $\Phi 6@150/200$.

Table 1. Test beam design parameters

Specimen number	Concrete strength(MPa)	Longitudinal reinforcement	Reinforcement rate (%)	Reinforcement situation
L310	C15	$3\Phi 14$	1.15	Not reinforced
L313	C15	$3\Phi 14$	1.15	One external tendon on each side

In order to measure the strain of the steel bar on the control section of the reinforced concrete structure, before the concrete is poured, the KH502 quick glue paste resistance strain with small creep, good electrical insulation performance and sufficient tensile and shear strength is used in advance. Tablets and waterproof and moisture-proof treatment. After the strain gauge leads and wires are soldered, the wires are straightened out and taken out from the appropriate part of the concrete member.

3. Experimental method

The monotonic loading static test is applied to the bending test beam, and the test beam is smoothly and continuously applied in a short period of time, and the load is added to the component failure from "zero". The two-point loading is realized by the distribution beam, and the vertical reaction device is mainly composed of a vertical load frame, a jack connecting piece and a test pedestal. One end of the test is a fixed hinge support and the other end is a rolling hinge support. The two points of the simple support member should be on the same level, and the height difference should not exceed 1/50 of the test piece span. In order to ensure the close contact between the test piece and the support surface, mortar is used for levelling between the buttress and the steel plate and the steel plate and the member. The specific test device is shown in Figure 1. Take a calculation span of 2300mm and a pure bend length of 700mm.

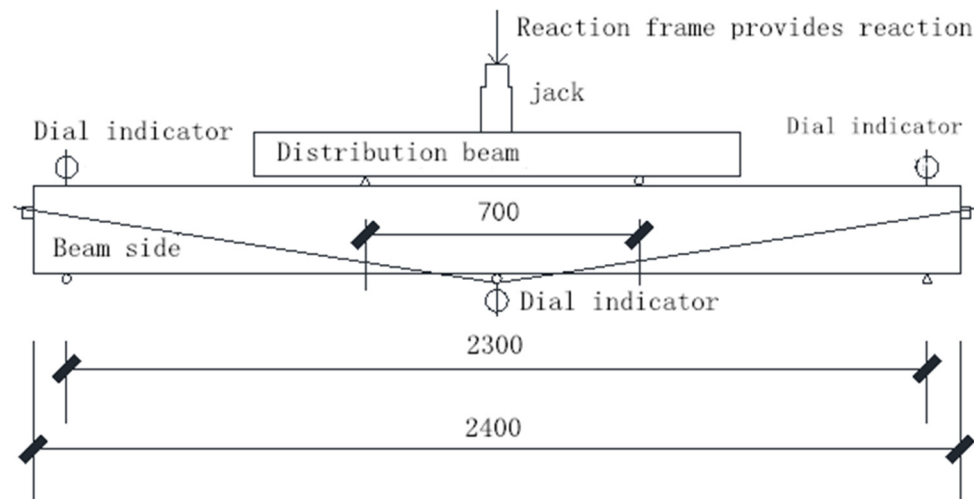


Figure 1. Test diagram

The test was carried out according to the current national standard "Test Methods for Concrete Structures" (GB 50152-92). During the test, all components are loaded with a screw jack, and the pressure sensor controls the loading amount and the grading load to ensure that the relative error of the loading amount does not exceed plus or minus 5%. The test beam was preloaded prior to the formal test. Prior to the standard load, the loading value of each beam of the comparison beam was controlled at 10% of the standard load. When the load is added to near the calculated breaking load, the loading value of each stage is controlled at 5% of the standard load. The loading level of the reinforced beam is appropriately adjusted according to the test results of the comparative beam. Under the action of 1.0

time's standard load, the load was held for 30 min, and the rest of each load was held for 10 min. At the end of the load, while reading the dial gauge to measure the deflection of the member, the static strain gauge is used to automatically record the strain of the concrete and the reinforcement under the load level. After each load is loaded, the length and width of all cracks have been measured.

The specific steps of the external prestressing reinforcement are as follows: drilling; clearing; end anchoring; ribbing; tensioning.

4. Experimental phenomena and analysis

4.1 Experimental data

Table 2. Experimental data.

	L310	L313
Cracking load (KN)	13.4	19.1
Steel yielding (KN)	56.87	72
Ultimate bearing capacity (KN)	75	105
Maximum deflection in mid-span (mm)	57	45
Maximum crack width (mm)	1.05	3.2
Maximum strain of tensile steel bars ($\mu\epsilon$)	682	1068
Limit load increase percentage (%)	/	40

4.2 Analysis of experimental results

4.2.1 Bearing capacity. After the efficient prestressing steel wire is strengthened by the efficient prestressing steel wire, the cracking load and ultimate load of the beam L313 have been significantly improved, which is 42.5% and 40% higher than that of the comparative beam. After the efficient external prestressing and bending reinforcement of the test beam, the crack resistance is obviously improved. At the same time, the ultimate bearing capacity is also greatly improved. It can be seen that the efficient external prestressing reinforcement method can solve the problem that other reinforcement methods cannot solve. The "stress lag" phenomenon is an effective method for bending and strengthening.

4.2.2 Crack. It can be seen from the results of this test that the efficient external prestressing reinforcement of L313 not only improves the cracking load and ultimate load, but also effectively inhibits the development of cracks. The concrete manifestation is: the initial generation of the reinforced beams, the generation and development of cracks. The beam is effectively restrained. Under the same load, the number, width and height of cracks in the reinforced beam are significantly smaller. The development process of the crack is similar to that of the comparative beam, and the height and width of the crack increase with the increase of the load. When the longitudinal reinforcement of the beam is close to yielding, the crack of the comparative beam L310 is rapidly extended and widened; after the longitudinal beam of the reinforced beam L313 yields, the external prestressing tendon begins to bear the main tensile force, and the concrete crack continues, but the length of the crack and The width increases slowly and the number of cracks increases. When L313 is about to be destroyed, the main crack develops near the mid-span and concentrated loading points. The maximum width of the crack is 3.2mm, and there are many small secondary cracks at the bottom of the reinforced beam.

In general, the reinforcement of the prestressed tendons in vitro can effectively suppress the occurrence and development of cracks. Under the same load, the maximum crack width and height of the strengthened beams are significantly reduced. When the components are finally destroyed, the number of cracks in the strengthened beams is higher than that of the comparative beams. More, the

cracks are distributed fine and dense, and the crack resistance of the reinforced beams is significantly improved.

4.2.3 Deformation analysis. A comparison of the mid-span deflections of all test beams under various loads is shown in Figure 2. From the data analysis, it can be seen that in the initial stage of loading, the deflection of the beam span of each test piece is not much different; after the concrete in the tension zone is cracked, the deflection of the unreinforced test piece grows rapidly, and the deflection of the strengthened beam grows relatively slowly. Under the same load, the deflection of the reinforced beam is smaller than that of the unreinforced beam, and this difference increases with the increase of the load. It can be seen that the efficient external prestressing reinforcement method can improve the bending rigidity of the component to a certain extent. During the entire failure process, although the ultimate load (75kN) that can be withstood when the beam L310 is finally destroyed is only slightly larger than the yield load (56.87kN) when the steel has just reached yield, the increase in deflection is quite large. This means that the member has a large deformation capacity in the case where the section bearing capacity does not change significantly, that is, the ductility of the member is good. The ductility of the prestressed steel wire bending reinforcement beam L313 is slightly worse.

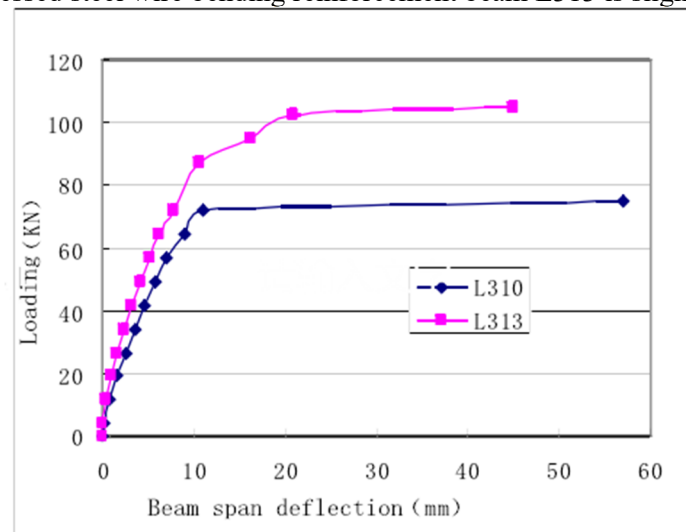


Figure 2. Comparison of load-deflection curves.

5. Conclusions

The main conclusions of this paper are as follows:

- (1) The efficient external prestressing reinforcement method can effectively improve the flexural capacity of concrete members, and the bearing capacity of the strengthened members is improved by about 40% compared with the unreinforced members.
- (2) The efficient external prestressing reinforcement method can effectively improve the crack resistance of concrete members, and the cracking load of the reinforcement members is increased by 42.5% compared with the unreinforced members.
- (3) The efficient external prestressing reinforcement method can effectively suppress the occurrence and development of cracks. Under the same load, the maximum crack width and height of the strengthened beams are significantly reduced, and the crack resistance is obviously improved.
- (4) The efficient external prestressing reinforcement method can improve the bending stiffness of the member to a certain extent. Under the same load, the mid-span deflection of the reinforced beam is smaller than that of the unreinforced beam, and the difference increases with the increase of the load; the maximum deflection of the reinforced beam is reduced by 21.05% compared to the unreinforced beam.

Acknowledgments

The authors acknowledge the financial support provided by the Key Research and Development Program of Shandong Province of China (2017GSF22103) and the School of Civil Engineering and Architecture at the University of Jinan.

References:

- [1] Zhang, Q.L., (2018) Existing building structure seismic capacity identification and reinforcement design method. *Building materials and decoration.*, 06:93-94.
- [2] Lu, C.D., (2018) Research and application of concrete structure detection and reinforcement technology. *Chinese & Overseas Architecture.*, 6:191-193.
- [3] Chen, N.J., (2017) Research on Reliability Evaluation and Reinforcement Scheme Comparison of Reinforced Concrete Structure Buildings. *NANCHANG UNIVERSITY.*, 3: 35-41.
- [4] Cheng, S.G., (2018) Retrospect and Prospect of China's Earthquake Identification and Strengthening for 50 Years. *Building Science.*, 34:26-32.
- [5] Hong, S.H., Chen, Y.X., (2010) Investigation and develop trend of rehabilitation techniques of concrete structure. *Concrete.*, 36: 128-129.