Scientific Journal of Technology Volume 2 Issue 05, 2020
ISSN: 2688-8645

Development Status of Fiber Reinforcement Technology in Construction Engineering

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Abstract

With the continuous development of China's construction industry, structural reinforcement technology has also received widespread attention in the industry. This article mainly introduces the development status of fiber reinforced technology at home and abroad in terms of the presence or absence of prestress, the effect of cracks, anchoring methods and numerical simulation, and analyzes the current difficulties of the reinforced technology.

1. Development Status at Home and Abroad

1.1. Research in Domestic Related Fields

Zhang Jianwen [1], Zhang Tanxian [2] [3], Jiang Xinpei [4], Su Youwen [5] [6], studied the related work of the reinforcement material with or without prestress, as follows:

Based on the existing test results, Zhang Jianwen and Cao Shuangyin [1] summarized three failure modes of reinforced concrete beams strengthened by prestressed CFRP, and derived a simple calculation of the flexural capacity of the beam under the type I failure form of prestressed FRP formula; Zhang Tanxian and Lü Xilin [2] [3] conducted comparative tests on whether the CFRP fabric is prestressed and whether the prestressed beam has initial stress, etc. After analysis, the bearing capacity and work of the prestressed CFRP fabric on the reinforced beam are obtained The effect of the performance is better. In addition, in the pre-test preparation stage, the full life cycle of the beam subjected to the first and second stress bending was analyzed in detail, and the derivation of the relevant formulas at each stage was completed, which was in accordance with the test; Jiang Xinpei, Liu Lina, and Deng Zichen [4] applied prestressed carbon fiber to strengthen the test of the six RC presplitting beams. At the degree of presplitting, the size of the prestress was analyzed. By comparing YLB2 and YLB4, the prestressing degree of the reinforced beam There is no obvious difference in yield load, ultimate load and failure form, but it has a greater influence on its stiffness; Su Youwen, Zhan Ni et al. [5] conducted an experimental study on the flexural performance of damaged RC beams strengthened with prestressed CFRP cloth. First, it was concluded that the CFRP cloth reinforced beams were pre-stressed regardless of whether the beams were pre-stressed. It can effectively improve the bearing capacity of the beam. Secondly, the cracking bending moment of reinforced concrete beams strengthened by traditional CFRP cloth and prestressed CFRP cloth increased by 15.32% and 45.40%, respectively, and the ultimate bending moment increased by 13.83% and 28.84%, respectively; in addition [5][6] The beam is reinforced with carbon fiber cloth and prestressed carbon fiber cloth after the cracking load is more obvious than the beam without damage. The beam's flexural normal section bearing capacity and flexural stiffness are more improved. The improvement effect of stress carbon fiber cloth reinforcement is more obvious.

Tan Yuan [7], Meng Luxiang [8], Li Shihong [9], He Chusheng [10] studied the crack behavior of prestressed FRP reinforced concrete beams under stress.

Tan Yuan, Xue Weichen, and Wang Xiaohui [7] studied the calculation formula of the crack resistance of the bonded prestressed FRP reinforced concrete beam and the calculation formula of the maximum crack width. Based on the "Concrete Structure Design Code" and the recommended formula of the ACI318-05 code, by calculating the cracking bending moments of 30 bonded prestressed FRP reinforced concrete beams in six experiments at home and abroad, the former calculation of crack resistance is obtained. The accuracy is higher, and the maximum average error and standard deviation are 13% and 0.13, respectively; based on the modified formula of "Specifications for Design of Concrete Structures" and the ACI440.1R-06 code, the linear load test of 24 bonded prestressed FRP reinforced concrete beams The calculated value is compared with the test value, and the accuracy of the former is better than the latter. The maximum average error and standard deviation of each group of test pieces of the calculated value and the test value of the maximum crack width formula are 15% and 0.12, respectively; Meng Luxiang and Tao Xuekang [8] conducted a flexural performance test study on partially prestressed concrete beams with bonded prestressed ribs of aramid fiber and epoxy-coated common steel bars. In reference to the "Code for Design of Concrete Structures" GB5010-2002 .After analyzing the equivalent stress of aramid fiber reinforcement, the formula for calculating the average crack width of aramid fiber reinforced concrete beams with bonded prestressed reinforcement and epoxy-coated non-prestressed reinforcement is finally given; Li Shihong and Zhang Huaidong [9] conducted an experimental study on reinforced concrete beams reinforced with prestressed carbon fiber cloth. Compared with carbon fiber reinforcement, when the reinforced concrete beams reinforced with prestressed carbon fiber were damaged, the former had a crack width of 2.1 mm and 2.0 mm, and The deflection of the latter is 1.0mm and 0.9mm; at the same time, the deflection of the latter is lower than that of the former, 62.3mm and 58.2mm of the former, and 42.2mm and 40.3mm of the latter; He Chusheng, Wang Wenwei, Yang Wei, Ye Jianshu [10] conducted an experimental study on 4 reinforced concrete beams reinforced with CFRP cloth and 1 comparative beam. The variables considered in the test were carbon fiber stress-to-strength ratio, fatigue load amplitude and CFRP cloth adhesive layer. The test results show that the unreinforced comparative beams have fewer and wider cracks when subjected to fatigue loads; the beams reinforced by non-prestressed CFRP cloth have many and dense cracks, and the crack height is low and the width is small. , The total number of cracks is greater, the height is lower, and the width is smaller. Due to the carbon fiber cloth participating in the work, the development of cracks during fatigue loading of the test beam is limited, thereby effectively improving the fatigue life of the reinforced beam and improving the working performance of the beam.

Tian Anguo [11], Liu Le [12], Wang Wenwei [13], Huang Jinlin [14] studied the anchorage and anchoring methods of reinforced concrete beams reinforced by prestressed materials.

Tian Anguo [11] pointed out that the core technology of fiber cloth reinforcement technology is a reliable anchoring method and a practical tensioning method, and unconventional, designed a "first anchoring, then tensioning" anchoring device and prestress .The process reduces the loss of prestressing by the traditional tensioning method. Its concept is clear, the design is reasonable, and the force is clear; Liu Le [12] set the number of fiber cloth layers and the U-shaped anchor form as parameters, and tested the reinforced concrete beams reinforced by six BFRP cloths, and concluded that the U-shaped hoop anchor was used to prevent the fiber cloth-concrete interface from peeling and increase the beam limit. Good effect on bearing capacity and improving ductility; Wang Wenwei, Dai Jianguo, and Zhang Lei [13] explored the prestress loss location of reinforced concrete beams reinforced with post-tensioned prestressed carbon fiber cloth. The results show that the slippage between the prestressed carbon fiber cloth and the anchor and deformation of the anchor during the unwinding process Instantaneous loss is the main part, accounting for 12.6% -18.2% of the initial prestress, while the time-dependent loss is only 2.3% -3.9%; Huang Jinlin, Huang Peiyan, Zheng Xiaohong [14] made a systematic analysis and summary of the prestress loss during the whole process of using prestressed technology to strengthen reinforced concrete beams, and conducted experiments on 25 prestressed carbon fiber boards to strengthen reinforced concrete beams The percentage of prestress loss in each process was measured in detail, and the calculation formula of the prestress loss value caused by the prestress slippage between carbon fiber board and anchor, elastic compression of concrete and stress relaxation of carbon fiber board was given;

Chu Shaohui [15], Wang Xiaoyan [16], Wan Jun [17], Jiang Xinpei [18] conducted a simulation analysis of reinforced concrete beams reinforced with prestressed FRP materials in the finite element.

Chu Shaohui, Zhao Shiyong, and Zhao Cunbao [15] conducted a ¼ beam ANSYS finite element simulation to study the effects of three factors such as the number of fiber cloth layers, concrete strength, and longitudinal tensile reinforcement ratio on the reinforcement effect, and obtained the following conclusions: beam bearing The force is proportional to the number of fiber cloth layers, but the beam stiffness is only significantly improved when the fiber cloth is bonded to three layers; the reinforcement effect is proportional to the concrete strength and inversely proportional to the reinforcement ratio; Wang Xiaoyan, Yan Bowen, Jiang Xinpei [16] conducted a finite element analysis of frame beams strengthened with prestressed carbon fiber cloth using ANSYS. The simulation results are in good agreement with the test data, reflecting the reference value of the finite element analysis simulation to the stress process of the prestressed FRP reinforced concrete beam, which can be used in practical engineering applications; Wan Jun [17] pointed out that the fatigue damage of reinforced beams is a complex nonlinear cumulative process, and the three physical quantities of fatigue bending compressive deformation modulus, steel bar area and fiber residual strength are used as the damage measures of concrete, steel bar and carbon fiber cloth. , The nonlinear damage process analysis of concrete beams is realized by piecewise linear analysis method, which can consider the stress redistribution during fatigue damage caused by the different damage mechanisms of the constituent materials; Jiang Xinpei, Wang Xiaoyan, and Liu Lina [18] corresponded to the load-deflection tri-fold model of reinforced concrete beams strengthened with CFRP cloth, and proposed a method for calculating the cross-section stiffness and beam deflection of the beam under the pre-stress condition.

1.2. Research in Related Fields Abroad

Hamid Saadatmanesh [19] [20], Håkan Nordin [21], Reykjavik University [22], Xinyan Guo [23], etc. studied the cracks of RC beams strengthened by prestressed FRP.

Hamid Saadatmanes [19] [20] strengthened the pre-stressed CFRP beams with cracks and found that some cracks were closed, which greatly improved the working performance of the beam during normal use; In order to verify the applicability of prestressed CFRP in reinforcement of reinforced concrete beams, Nordin and Täljsten [21] conducted 15 full-length RC beam tests with different bonding lengths. Two types of CFRP were studied. It was found that the use of prestressed CFRP rods can improve the cracking, yield and ultimate load of the strengthened beam; Reykjavik University [22] reinforced the beam with unprestressed BFRP bars and prestressed BFRP bars. It was found that concrete beams reinforced with BFRP prestressed bars significantly inhibited the development of cracks, and the limit obtained by prestressed BFRP bars was obtained Little change in bearing capacity and without prestress; Xinyan Guo [23] carried out experimental research and numerical simulation on cyclic loading of reinforced concrete beams reinforced with 27 prestressed carbon fiber laminates. Through the above reinforcement measures, it is conducive to inhibiting the development of cracks. Among them, the main crack propagation rate is When the level is 15% and 22%, it is reduced by 38.6% and 43.0% respectively. At the same time, the higher the prestress level, the better the effect of suppressing crack development.

ISSN: 2688-8645

Ilker Fatih Kara [24], Bahareh Nader Tehrani [25], Hui Peng [26] [27] studied and analyzed the reinforcement effect of reinforced concrete beams strengthened by prestressed FRP materials, among which the variables Including beam bearing capacity, deflection, ductility, etc.

Ilker Fatih Kara, Ashraf F. Ashour, Mehmet Alpaslan Ko¨rog˘lu [24] simulated the flexural performance of reinforced concrete beams reinforced with prestressed FRP rods / strips installed near the surface, and concluded that higher prestress levels can be effectively improved The conclusion of beam cracking and yield load, but compared with the absence of prestress, the ductility of the beam is reduced; Bahareh Nader Tehrani, Davood Mostofinejad, Seyed Mohammad Hosseini [25] carried out the resistance of 7 reinforced concrete beams with a cross-sectional size of 200 × 300mm, a span of 2600mm, and four-point loading prestressed CFRP plate groove external bonding (EBROG) Bending test, the test results show that compared with the application of EBR reinforcement technology, EBROG technology strengthened member, its bending performance is better, the load capacity, ductility of the beam and the CFRP plate peeling strain increased by 18%, 53% and 36%. In the samples with prestressed levels of 20% and 30% respectively, the cracking load of the prestressed beam increased significantly on average by 115% and 155%;Hui Peng, Jianren Zhang, Shouping Shang, Yang Liu, CS Cai F. ASCE [26] conducted a fatigue test on RC beams reinforced with prestressed CFRP plates. The application of prestress can significantly enhance the fatigue performance of the beam. In the test, the beam PRF1 reinforced with the prestressed CFRP plate did not have significant fatigue degradation after 3 million loading cycles, and the yield load of the beam PFR1 after fatigue testing was monotonous The beam PFRS under load is extremely close; Hui Peng, Jianren Zhang, CS Cai, Yang Liu [27] conducted a static loading test on seven rectangular reinforced concrete beams, one of which was a test reference beam and six of them were FRP slab reinforced beams installed near the surface. The test results showed that By installing FRP slats near the surface, the load-bearing capacity of the flexural members is significantly improved. Compared with unreinforced beams, the use of near-surface prestressed FRP slats can increase the ultimate bearing capacity of the beam by 122%, compared with non-reinforced Pre-stressed FRP slats are installed near the surface, which increases the ultimate bearing capacity of the beam by 44.2%.

2. Difficulties in Structural Reinforcement Technology

Foreign research on FRP reinforcement and maintenance of concrete structures started earlier. Relevant data on the failure mode of prestressed FRP reinforced concrete beams have been agreed, including crushing failure of concrete and tensile failure of FRP bars, but its Anchorage methods and tensile prestressed materials are still major difficulties. First of all, the bonding problem of the joint surface of the concrete and the reinforcement material needs to be solved urgently. According to a large number of tests, the failure of the reinforcement beam is mostly the peeling of the joint surface, which greatly reduces the reinforcement effect. Secondly, when pre-stressing the reinforcement material, uneven stress will occur, which may make the material stress concentrated and fail to achieve the desired reinforcement effect. Finally, the economic cost, how to mass-produce reinforcement materials to reduce costs, is a challenge to processing equipment. The above three points can be considered as the most difficult points in the field of structural reinforcement.

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