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Experimental Study on Flexural Behavior of Concrete Beams Strengthened with Concrete Composites based on Energy Method

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ABSTRACT. With the development of materials science, new practical reinforcement and transformation technologies have emerged. The steel plate-concrete composite reinforcement technology forms a new practical reinforcement technology that can significantly improve the bearing capacity and structural rigidity of the bridge by rationally applying the steel plate and concrete materials and the reasonable structural arrangement of the interface joints. However, research on this aspect at home and abroad is not deep enough. It can be seen that the research on the steel-concrete composite reinforced concrete bridge has important theoretical significance and engineering practical value.

Keywords: *Material Science; Concrete Composity, Energy Method*

1. Introduction

The life cycle of a bridge is divided into the following three phases: construction period, use period and aging period. With the passage of time, the bridge gradually undergoes damage and defects under the action of natural environment and traffic load, resulting in a decrease in structural bearing capacity and durability. The main reasons for the reliability of the bridge structure are as follows:

(1) Changes in design loads. With the continuous improvement of highway bridge design specifications, the design load has been developed from the steam grades 6, 8 and 13 to the steam - 15, 20 and super 20 grades. The current design load is highway - grade II, highway - grade I. However, many of our highway bridges are designed according to design codes promulgated in the late 1960s and early 1980s, with low load ratings.

(2) The traffic volume is increasing. Most of the bridges built in China from the 1960s to the 1970s are still in operation. Due to the low design load of the bridges and the lack of maintenance, many bridges have been unable to adapt to the increasing traffic demand.

(3) Ageing and disease of the structure. Due to the defects in the design and construction of the bridge and the unfavorable environment (such as freezing and thawing, carbonization, alkali aggregate reaction, chloride ion intrusion, etc.), the concrete and steel bars of the upper and lower structures of the bridge are seriously corroded and the bearing capacity is reduced.

(4) The impact of external unfavorable loads such as overload and overrun limits the safety of the bridge structure. According to the "National National Highway Census Main Data Bulletin" published by the National Bureau of Statistics in February 2002, due to various factors in the design, construction and use process, 9957 of the 278,809 bridges built in China were characterized as Dangerous bridges, more than one third of the bridges have structural defects or different levels of functional hazards. According to the 2006 National Highway Maintenance Statistics of the Ministry of Communications, by the end of 2006, there were 6,628 dangerous bridges in the fifth category with dangerous technical conditions in the country, and the bridge carrying capacity was insufficient and directly affected the safety of bridge operations." Guangdong Province 2000 Census Results It shows that more than 4,000 of the more than 18,000 bridges have insufficient bearing capacity.

Insufficient bearing capacity, aging and damage of existing bridges are a worldwide problem. Some developed countries, such as the United States, Japan, Western Europe and Northern Europe, are also facing serious problems. For example, the United States conducted a survey of national highway bridges from 1978 to 1981 in four years. At that time, there were 566,000 road bridges in the United States, of which more than 40% had different degrees of damage, and the structural strength of 98,000 bridges was reduced. Stop or only restrict access. Japan's bridges built according to the old design standards before 1956 have about 5,500 bridges with insufficient carrying capacity. More than 10,000 bridges in French roads need to be reinforced. Therefore, the maintenance and reinforcement of existing bridge structures has become an urgent issue in the engineering field. Exploring efficient, simple, economical and practical structural reinforcement methods without interrupting the function of the bridge structure has become an important task for bridge reinforcement design and researchers.

2. Introduction to the Energy Method

There is currently no exact definition of the energy method, and different fields have different content. In a broad sense, the energy method is a method of analyzing, testing, judging, calculating, and solving problems based on energy laws, theorem, and other related laws and theorems based on energy conservation and functional relations. It is physics. The most important method [3] has been applied in physics and engineering, and has made great progress. It has also achieved certain results in biological research. At present, in the field of sports biomechanics, a research method combining energy and energy transfer in human body motion and biology is collectively referred to as energy method. The core problem of its research is the transformation of energy and energy in motion, from which the efficiency of motion and the rationality of technology are analyzed.

The biggest feature of the energy method is simplicity. The basis of the energy method is the conservation of energy in physics and its corresponding theorems and rules. The energy method does not consider the complex force changes in motion, with energy as the key to analysis, and because energy is scalar, in comparison, In the study of many practical problems, the listed equations are simple in form, have a small number of equations, and are simple to operate, often receiving twice the result with half the effort. The physics method is the most basic and most common method of motion biomechanics research. However, most of the current methods are Newton's classical mechanics. The kinematics and parameters of human motion are analyzed, such as the distance, velocity, time, acceleration of motion. Angle, angular velocity, angular acceleration, force and load, etc. First, the measurement and calculation of these parameters are quite complicated and have large errors, especially for the application of living organisms. Second, the method of Newton's classical mechanics has been fully applied to all corners of sports biomechanics. Some functions; Third, the analysis of kinematics and parameters is only part of the physics method, not all. In the existing research, Newton's classical mechanics method has done its best, and the energy method has less application in sports biomechanics. That is to say, sports biomechanics does not make full use of physics research methods. Llord was originally used to analyze human motion by energy method, while Word? Smith was a model of energy law. In 1985, he published his calculation of the world's best men's athlete track competition using the energy balance equation in Biomechanics J magazine. The record has only 1% error, and the maximum error is only 1.5%. However, China has not yet seen research in this area.

The energy method is a research method that jumps out of the system to see the problem. The birth and germination of sports biomechanics benefit from the development of physiology and anatomy. Therefore, the research methods in the early stage of sports biomechanics are mostly biological experiments and observations. Many famous research results are obtained from in vitro experiments, such as Measurement of human inertial parameters (corpse method), famous Hill equation, measurement of muscle contraction force, etc. However, with the development of sports biomechanics, people are increasingly aware of the complexity of organisms, especially the biological rejection of human body, the non-reproducibility of human motion parameters and the random dispersion characteristics of parameters, which requires measurement methods and research. The method is formulated to avoid harm to the human body and contact, as far as possible from the overall point of view, the classical mechanics method is obviously unable to do so. The energy law overcomes the shortcomings of studying the problem from the perspective of human mechanical motion law, and can better reflect the human body's motion characteristics.

3. RESEARCH STATUS OF BRIDGE REINFORCEMENT TECHNOLOGY

In recent years, domestic and foreign scholars have carried out a lot of research and practice on bridge reinforcement technology and methods, and achieved remarkable results. At present, the commonly used reinforcement methods include: increasing section and reinforcement method, external tension prestressing reinforcement method, pasting sheet reinforcement method, changing structural stress system reinforcement method, adding longitudinal beam reinforcement method, adding horizontal connection reinforcement method and Bridge deck paving reinforcement.

In the traditional method of increasing the cross-sectional area reinforcement, the main beam, shotcrete, and outer concrete are increased to increase the section size of the main beam, thereby increasing the moment of inertia or geometric bending modulus of the main beam section to achieve reinforcement of the main beam and improve The purpose of carrying capacity. According to different load sizes and clearance conditions, it can be divided into two types of reinforcement schemes: increasing the cross-sectional area and adding reinforcing steel. The method has a long construction time on site and has a certain reduction in the clearance of the bridge after reinforcement. The external prestressing reinforcement method is to change the internal force of the original structure by laying steel rods or struts on the outside of the beam and anchoring with the reinforced beam body, and then applying prestressing force to force the added struts or struts to force. Distribute and reduce its stress level, reduce the mid-span deflection and crack width, and achieve the purpose of improving the bearing capacity of the bridge. The external prestressing reinforcement method has little effect on the normal operation of the bridge, but it has a certain influence on the appearance of the original structure after reinforcement.

The adhesive sheet reinforcement technology is widely used in experimental research and engineering applications at home and abroad. The common bonding materials are mainly steel sheets and fiber composite materials. The United States, Japan, the United Kingdom, Canada and other countries have established specialized research institutions and prepared relevant regulations, guidelines and manuals. In China, in 1990, the “External Adhesive Steel Plate Reinforcement Method“ has been included in the appendix of China Engineering Construction Standardization Association “Technical Specification for Concrete Structure Reinforcement“ (CECS25:90); the development of bonded steel technology in the mid-1990s reached In its heyday, some new or improved methods of bonding steel were derived, such as “steel-bonded steel“, “wet-coated steel pouring“, “spot welding wet-clad steel“ and so on. Fiber composite material (FRP) reinforced bridge structure technology is a new, efficient and convenient structural reinforcement technology emerging in the international market in the late 1980s. The main features of FRP materials are high tensile strength, good corrosion resistance and good performance. Anti-fatigue strength and low density. However, most of the research on FRP material reinforced bridge technology is still based on basicity, verification and experiment. In many aspects, further research is needed. When using FRP, a new structural reinforcement method to reinforce concrete flexural members, how to make full use of FRP The high strength characteristics and contribution to the cracking load, stiffness and maximum crack width during normal use of the component are not two difficult problems. In general, the method of pasting the sheet has the characteristics of hardly changing the shape and use of the component after the reinforcement, the cost is low, the construction is simple and rapid, and the impact on production and life is small, but the reinforcement method improves the bearing capacity of the bridge. The section stiffness also has its limitations, and it has high requirements on the flatness and cleanliness of the adhesive surface and poor durability.

The method of strengthening the structural stress system is to change the structural stress system by adding additional members or components, and reduce the internal force and deformation of the load-bearing members, thereby improving the bearing capacity of the bridge. The additional longitudinal beam method is to add a longitudinal beam with high rigidity and high bearing capacity under the condition that the abutment foundation can provide sufficient bearing capacity, and the new beam is connected with the original beam to achieve common force. After the addition of the longitudinal beam, the load is redistributed in the bridge structure, which reduces the load on the original beam. As the number of main beams increases, the bearing capacity and rigidity of the bridge are improved. Increasing the horizontal joint reinforcement method and the bridge deck pavement reinforcement method can increase the integrity of the bridge and make the structural force more uniform.

The above-mentioned common reinforcement methods have their own advantages and defects. The urgent situation of reinforcement and reconstruction of old dangerous bridges makes bridge reinforcement and transformation technology one of the most important topics of contemporary civil engineering, and constantly explores effective and economical reinforcement methods and new types. The reinforcement material has become a hot spot in the field of civil engineering research. The steel plate-concrete composite reinforcement technology studied in this paper is a bridge reinforcement method that obtains superior performance, novel and practical performance by making reasonable use of two materials of steel plate and concrete, giving full play to the tensile strength of the steel plate and the compressive performance of the concrete. The innovation of bridge reinforcement technology provides a new idea for concrete bridge reinforcement.

4. EXPERIMENTAL MODEL DESIGN AND ANALYSIS OF EXPERIMENTAL RESULTS

Before the test, based on the full study of relevant literature at home and abroad, the preliminary dimensions of the test beam reinforcement were determined by considering the actual test conditions and the market supply of raw materials. In the test, two steel plate-concrete composite reinforced concrete rectangular beams and two steel plate-concrete composite reinforced concrete T-shaped beams were designed, which were numbered SPCCSB-1~SPCCSB-4, and the unreinforced beams were designed identically. The test beam SPCCSB-4 is pressed to the ultimate load before reinforcement, and is reinforced after unloading. The number before reinforcement is RCB-I, which is mainly used to compare the mechanical properties of the four test beams before and after reinforcement; the test beam SPCCSB-3 reinforcement Before applying a certain load, it is reinforced after unloading. The number of concrete beams before reinforcement is RCB-2, which is mainly used to study the influence of damage degree on the stress mechanism and ultimate bending capacity of the test beam. The rectangular test beam has a total length of 3700mm, a calculated span of 3450mm, a beam width of 200mm, a original beam height of 320mm, and a height of 406mm after reinforcement.

Test beam SPCCSB. 1, SPCCSB. 3 and SPCCSB. The planting reinforcement is encrypted near the 4 fulcrums, and the span is large. The test beam SPCCSB. 2 The span of the full-span planting bar is 200ram, mainly to compare the influence of the variation of the spacing of the planting bars on the mechanical properties and failure modes of the test beam; the test beam SPCCSB. 1 and SPCCSB. 2 using double-point loading, test beam SPCCSB. 3 and SPCCSB-4 adopt single-point loading method, mainly to study the effect of shear-to-span ratio on the bending resistance of test beams; test beam SPCCSB. 1 and SPCCSB. 2 for non-destructive reinforcement, test beam SPCCSB. 3 and test beam SPCCSB. 4 A certain load is applied before reinforcement, so that the concrete beam has a certain damage and then unloaded, and then the steel plate-concrete composite reinforcement is used to compare the influence of different damage degree on the stress of the test beam. The total length of the T-shaped test beam is 5000mm, the calculation span is 4750mm, the original beam height is 400mm, the wing width is 400mm, the web thickness is 100mm, and the beam height is unchanged after reinforcement. In order not to increase the beam height, the concrete is not poured between the bottom of the T-section beam and the reinforcing steel plate, but the mortar with the side studs and the underfill is kept working together with the original structure.

The original beam is a reinforced concrete double-strength beam, in which the rectangular beam is 2110, the longitudinal reinforcement is 3016, the horizontal distribution is 208, the stirrup is 06 steel, the concrete height is 80mm, and the reinforcement steel plate is Q235. B, the thickness is 6 mm, the width is 200 rm, and the length is 3180 mm. The planting bar adopts 112 HRB335 hot-rolled ribbed steel bar, the planting depth is 120mm, the drilling hole diameter is 115, the stud type is 010×55, the stud spacing is 100mm, and the test results of the test beam reinforcement steel plate and steel bar are shown in the table. 2.3. The T-shaped beam is 1206 for longitudinal reinforcement and 4116 for longitudinal reinforcement. The stirrups and horizontal distribution steel are 12I 6 round steel bars. The width of the concrete on both sides of the beam is 70mm and the height is 130mm, concrete surface is 70mm high. The reinforcing steel plate adopts Q235.B, the total length is 4480mm, the thickness is 4mm, and the reinforcing steel plates on both sides are 130mm high. In order to prevent the overhead welding and meet the welding size requirements, the bottom reinforcing steel plate has a large width, about 260mm. The planting bar adopts 114 HRB335 hot-rolled ribbed steel bar. In order to prevent the planting bar from penetrating the web, it causes greater damage to the original beam. According to the structural requirements, the planting bar extends into the web 70mm, the hook length is 60mm, and the drill is drilled. The hole diameter is 18 mm, which meets the requirements of the specification.

Inspection beam SPCCSB. 1 and test beam SPCCSB. 2 Double-point loading method is adopted. When the test load is less than 0.2Pu (P. is the failure load), the concrete has not been cracked. At this time, the strain of the steel plate and the main rib is much smaller than the yield strain. When the load is greater than 0.2 Pu and less than 0.8 Pu, a number of vertical cracks appear in the reinforced concrete at the mid-span, and the crack height extends upward to the bottom of the original beam, and the crack width grows slowly; the new and old concrete when the load is about 0.7Pu Longitudinal relative slip occurred, but the value was small. Longitudinal cracks were observed in the test, and the crack width was about 0.02 mm. When the load was about 0.8 Pu, the longitudinal cracks of the new and old concrete joints were from the end of the tendons. The reinforced concrete end extends at a height of 1/2, the concrete is cracked, and then the end of the planting hole wall is cracked, and the crack extends from the planting hole to the loading point. Continue to load the load to be transferred by the next row of planting ribs, and so on, and the oblique cracks in the shear span are increasing. When the ultimate load is close to Pu, the cracks in the joint surface between the original beam concrete and the reinforced concrete penetrate, the stripping area is continuously enlarged, the load is drastically reduced, and the test beam is broken.

The failure modes of the steel-concrete composite reinforcement test beam are brittle peeling failure and plastic bending failure. Brittle stripping failure refers to the failure of the test beam when the test beam reinforcement steel plate and the longitudinal tension of the original beam are not up to the yield strain, and the test of the test beam is caused by the peeling of the interface between the new and old concrete interface or the steel plate and the newly added concrete; After the longitudinal tensile strength of the tensile reinforcement, the upper edge concrete is crushed quickly and the test beam is broken. Among them, the test beam SPCCSB. 1 and SPCCSB. 2 The new and old concrete interface has undergone significant peeling, which is a brittle peeling failure; the test beam SPCCSB. 3 After the main rib yields, the new and old concrete interface peels off, so plastic bending failure can be considered; test beam SPCCSB. 4 There was no obvious peeling phenomenon at the interface between the new and old concrete during the whole process of loading. At the end of the test, the crack was dominated by vertical cracks and bending failure occurred. There was no phenomenon that the planting bar was pulled out during the test, so the peeling failure was mainly caused by insufficient shearing of the interface between the old and new concrete.

The comparison of ultimate bending capacity of steel-concrete composite reinforced rectangular test beams before and after reinforcement is shown in Table 1. It can be seen from the table that the increase of bearing capacity after reinforcement is mainly reflected in two aspects, namely the yield bend of longitudinally tensioned steel bars. The moment and the limit bending moment increase.

Table 1 Comparison of ultimate flexural capacity of rectangular test beams before and after reinforcement

No.	Main tendon yielding moment%(KN.m)	Improve(%)	Ultimate bending moment (KN.m)	Improve (%)
RCB.1	59.82	/	60.49	/
SPCCSB.1	149.66(Not yielding)	150	149.66	147
SPCCSB.2	136.48(Not yielding)	128	136.48	126
SPCCSB. 3	192.34	222	198.55	228
SPCCSB. 4	199.32	233	204.41	238

Test beam SPCCSB. 1 and test beam SPCCSB. 2 The peeling failure occurred, and the main ribs did not reach the yield strength, but the ultimate bending capacity was increased by 147% and 126% respectively compared with that before the reinforcement; the test beam SPCCSB. 3 and test beam SPCCSB. 4 The flexural bearing capacity of the longitudinal tensile steel is 3.22 and 3.33 times before the reinforcement, respectively. It can be seen that the contribution of the strengthened steel plate to the bearing capacity is huge. Comparative test beam SPCCSB. 1 and test beam SPCCSB. The ultimate bending capacity of 2 found that the larger the spacing of the planting bars, the smaller the load when the test beam is peeled off; the test beam SPCCSB. 3 and the comparison of the ultimate bending capacity of the test beam SPCCSB-4 found that the degree of damage has little effect on the bearing capacity.

The bending stiffness of the reinforced concrete beam is significantly greater than that of the reinforced concrete beam before reinforcement. This is mainly due to the increase of the section of the original beam due to the addition of concrete. In addition, the presence of the reinforced steel plate improves the bending resistance of the test beam. Stiffness also helps a lot. The slope of the bending moment-deflection curve of the test beam is the bending stiffness, and the greater the slope, the greater the bending rigidity. When the load is less than the rectangular bending moment before and after the reinforcement of the rectangular test beam, the test beam is in the elastic stage, the curve of the straightness curve rises, and the reinforced concrete has not been cracked. Significantly increased; when the load is greater than 0.2Mu less than 0.8Mu. When the test beam is in the elastoplastic stage, the mid-span bending moment-deflection curve increases nonlinearly. At this stage, there are multiple vertical cracks in the four test beam spans, and multiple oblique cracks appear above the end reinforcing concrete, but the crack width is not Large, up to approximately 0.15mm: continue to load the test beam SPCCSB. 1 and SPCCSB. 2 The bending moment-deflection curve showed a falling section, which was caused by the peeling of the new and old concrete interface. As the shear span ratio increases, the influence of shear stress becomes smaller, and the test beam SPCCSB. 3 and SPCCSB-4 new and old concrete interface did not significantly peel off before the test beam reached the limit state, the ductility of the test beam was better.

5. Conclusion

In this paper, the combined reinforcement technology is applied to the reinforcement of the real bridge main beam, and the bearing performance of the main beam strengthened by this reinforcement technology is analyzed. Under the load, the calculated values of the main beam strain of the composite reinforcement are reasonable, and the strain proof coefficient of the composite reinforced base beam is less than 1 and relatively uniform. The data results show that the reinforcement method can ensure the overall stress performance of the new and old structures is better. The combined reinforcement method has an excellent effect on the stiffness of the main beam and the overall work performance.

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