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Experimental Study on Tensile Performance of Bamboo Cable Anchor Rods with Different Weaving Processes

Shiqing Huang *, Shenggui Yang, Jingyi Guo

China Academy of Building Research, Beijing 100013, China

*** Corresponding author:** Shiqing Huang (Email: 1071868031@qq.com)

Abstract: This research mainly focuses on the research of the new type of bamboo tube body tensile anchor bar structure. For the connection node of the bamboo tube anchor bar body's bamboo material body and the end head steel strand, a structural design from outside to inside of steel sleeve - grouting is required. bamboo tube anchor bar body's bamboo material body and the end head steel strand, a structural design from outside to inside of steel sleeve - grouting material - bamboo tube - grouting material - embossed anchor is material - bamboo tube - grouting material - embossed anchor is proposed. Then, variable control experiments are conducted on the influencing factors of this structure, such as the anchor length, the length of the bamboo tube, the length of the bamboo tube, and the length of the bamboo tube. this structure, such as the anchor length of the embossed anchor, the inner wall treatment process of the bamboo tube, and the coverage range required for the steel sleeve to change direction and constrain. While studying the weak position of the connection node, the methods to improve the overall tensile Based on the deformation of the bamboo tube material under large tensile force in the experiment, the feasibility of using the bamboo tube as the anchor bar. Based on the deformation of the bamboo tube material under large tensile force in the experiment, the feasibility of using the bamboo tube as the anchor bar body to withstand tensile force in engineering applications is inferred. The experimental results show that the tensile strength of the original bamboo tube material under certain moisture content conditions basically meets the application requirements of low-impact tensile anchor bars; the tensile strength of the original bamboo tube material under certain moisture content conditions basically meets the application requirements of low-impact tensile anchor bars. The experimental results show that the tensile strength of the original bamboo tube material under certain moisture content conditions basically meets the application requirements of low- stress tensile anchor bars; the weak surface of the bamboo tube body tensile anchor bar is the bonding surface between the inner wall of the bamboo tube and the cementing body, and increasing the anchoring section length of the embossed anchor and the treatment of inorganic particles on the inner wall of the bamboo tube can enhance the bonding strength. bamboo tube can enhance the bonding strength of this weak surface and thereby improve the overall tensile performance of the node.

Keywords: Bamboo Tube Anchor Body; Connection Node; Weak Surface of Node; Length of Anchor Segment of Embossed Anchor; Treatment of Inner Wall of Bamboo Tube.

1. Introduction

Up to now, the underground space project in the domestic construction volume continues to increase, for the continuous development of underground structure construction engineering, its engineering concept is also with the recent years on the green civil engineering policy requirements continue to change and update to promote the "" 14th Five-Year "" construction industry development plan " also mentioned the development of green civil engineering related technology policy Tilt. Therefore, how to improve the development of new green civil engineering related technology in pit engineering has become the industry's forefront hotspot.

Focusing on the slope support process in foundation pit engineering, one of the major pain points at present is the engineering legacy problem of traditional rebar or stranded wire anchors. Traditional prestressed or non-prestressed anchor rods are mostly rebars or strands of various types, which are mostly left in the ground after the completion of the temporary support project, which will lead to three major problems, one of which is that the long and thin size anchors are shifted along with the soil body, leading to violation of the red line of the project site and disputes over the use of the underground space with the neighboring projects; the second one is that it will cause obstacles to the subsequent redevelopment of the underground space, especially the shield machine blades of the subway construction; the third one is that the steel blade will cause serious damages; and the third one is that it will cause serious damages to the shield machine blades of the steel blade. Secondly, the subsequent redevelopment of the underground space will be hindered, especially for the subway construction, which will cause serious damage to the shield machine blades; and thirdly, the steel material will dissociate metal ions under the influence of underground water and other factors, which will cause environmental pollution.

In recent years, domestic experts and scholars have proposed a variety of solutions to solve the above problems: a new type of retrievable anchor rod was proposed in the Development and Prospect of Retrievable Anchor Rod Technology [1] and Review of Research on Retrievable Anchor Rod Technology [2]. Zhu Yong et al. made an innovative summary [3] of the construction technology for dealing with anchor rods left behind in adjacent pits encountered in pit enclosure construction.

However, the cost of both the anchor recovery technology and the legacy anchor disposal technology remains high.

Therefore, in response to this problem, the Chinese Academy of Building Research Foundation Institute this year to focus on research and development of a without recycling, green, energy-saving low-carbon green anchor new technology - the new bamboo anchor. The principle is to use the bamboo material with high tensile strength characteristics, the use of bamboo material processed into the body of the anchor, and then design the end connection node will be the bamboo anchor body and the head and tail of the stranded wire connection.

The mechanical and destructive characteristics of moso bamboo lumber [4] gives the tensile strength of the smooth grain of each type of moso bamboo lumber produced in Zhejiang fluctuates from 150 to 220 MPa, which is a considerable strength and has certain prospects for engineering applications. Feng Yaqin et al. made an overview of the progress of research on mechanical properties and nodal connection properties of engineered bamboo, also mentioned the excellent smooth grain tensile capacity in the basic mechanical properties of engineered bamboo, and summarized the engineering bamboo connection processes such as toothed-plate connection, bolted connection, and metal-sleeve connection [5]. Zhu Liangfeng et al. did numerical simulation and finite element analysis on the engineering application case of composite soil nail wall with moso bamboo piles [6]; Que Kailin summarized an overview of the application of moso bamboo in foundation pit support [7], all of which verified the feasibility and prospect of bamboo piles applied in foundation pit engineering.

Domestic referable cases of bamboo anchors are only composite bamboo anchors [8] used in coal mine shafts in Shanxi at the beginning of this century, whose bodies are bonded by bamboo fibers and special adhesives, but the wedge-shaped body structure at the end provides a smaller anchorage force, which is only used for the support of the inner wall of the narrow passages in coal mine shafts, and it is not applicable to the stress environment of the foundation pit slopes. Therefore, in this study, the connection node is used to connect the bamboo tube anchor body with the steel strand, and under the condition that the tensile strength of the connection node and the bamboo tube material itself meets the standard, the outer end can still be used in the anchoring process of the traditional steel strand anchors without additional design.

This test innovative design of the new bamboo tube anchor body anchors from the original bamboo bamboo tube as the anchor rod body to withstand tensile force, connecting nodes by embossed anchors anchored bamboo tube interior supplemented with grout as a binder, and then set up on the outside of the steel sleeve to provide circumferential transverse constraints to prevent cracking of the bamboo tube.

2. Overview of the Experiment

2.1. Content of the Test

Bamboo tube anchor body pullout damage test is mainly divided into the first weak surface attempts to test, different embossed anchorage length tensile test, different weak node enhancement process tensile test and steel sleeve coverage test, the sampling category is shown in the table below: the length unit in the table are cm.

Table 1. Sampling Category Diagram

groups	Embossed anchor anchoring length	Length of steel sleeve coverage	Inorganic granules cemented to the inner wall of bamboo tubes	End welded steel plate	Bamboo tubes with grooves on the inside
1	10	10	clogged	clogged	clogged
2	20	20	clogged	clogged	clogged
3	30	30	clogged	clogged	clogged
4	40	40	clogged	clogged	clogged
5	50	50	clogged	clogged	clogged
6	50	10	clogged	clogged	clogged
7	50	20	clogged	clogged	clogged
8	50	30	clogged	clogged	clogged
9	50	40	clogged	clogged	clogged
10	50	50	be	clogged	clogged
11	50	50	clogged	be	clogged
12	50	50	clogged	clogged	be

Groups 1 to 5: Embossed anchor anchorage length and steel sleeve cover length gradually increase, all other variables are "No".

Groups 6 to 9: Embossed anchor anchorage length was fixed at 50 cm, the length of steel sleeve cover was gradually increased, and all other variables were "No".

Group 10: Embossed anchor anchorage length and steel sleeve cover length are both 50cm, inorganic particles cemented in the inner wall of the bamboo tube are "yes", and other variables are "no".

Group 11: Embossed anchor anchorage length and steel sleeve cover length are both 50cm, welded steel plate at end is "Yes", and other variables are "No".

Group 12: Embossed anchor anchorage length and steel sleeve cover length are both 50cm, grooving on the inner wall of the bamboo tube is "yes", and the other variables are "no".

The purpose of group 1~5 is to test the effect of different embossed anchor anchorage lengths on the overall node tensile properties; the purpose of group 5~9 is to test the effect of different coverage of the anchorage section by steel sleeves on the tensile properties of the specimens, and the purpose of group 10~12 is to test the effectiveness of different sample tensile reinforcement treatment processes.

2.2. Specimen Structure Design

The structure of bamboo anchor designed in this study from outside to inside are steel sleeve, grout, bamboo, grout and embossed anchor as shown in the figure below:

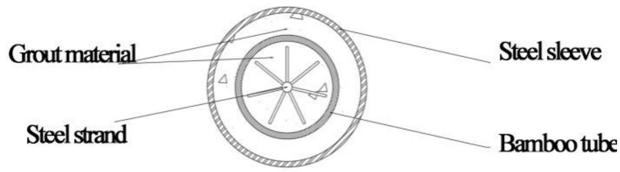


Fig 1. Schematic cross-section of the connecting node of the bamboo anchors

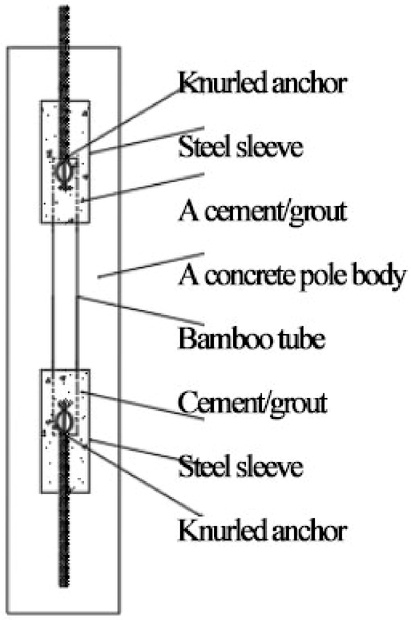


Fig 2. Section diagram of section of bamboo tube anchor rod connection node

The new bamboo anchor structure shown in the figure consists of the following main parts:

Embossed Anchors: Located at the top and bottom of the structure, they are used to secure and enhance the anchoring capacity of the anchor. Embossed anchors provide additional stability through friction with the surrounding material.

Steel Sleeve: Located on the outside of the embossed anchor, the steel sleeve is used to encase and protect the internal bamboo tube and grout. The steel sleeve provides structural support and circumferential restraint to prevent the embossed anchor pear shape from expanding under tension, causing the bamboo tube to burst from internal expansion forces, and also to increase the overall structural strength and durability.

Cement/Grout: Filled between the steel sleeve and the bamboo tube, and between the bamboo tube and the embossed anchors, it is used to hold the bamboo tube in place and provide additional support and stability. The grout also prevents moisture and other environmental factors from attacking the bamboo tube.

Concrete Pole: Located in the center part of the structure, it provides the main support and load bearing function. The concrete pole body is tightly bonded to the bamboo tube and grout to form a strong monolithic structure.

Bamboo cylinder: as a concrete pole body encased in a steel sleeve. As a natural material, the bamboo cylinder provides flexibility and tensile strength.

The overall structure is formed by the organic combination of embossed anchor, steel sleeve, grout, concrete body and bamboo tube to form a stable, strong and flexible new bamboo anchor structure. This structural design makes full use of the natural characteristics of bamboo, and at the same time improves the overall durability and load-bearing capacity through the reinforcement of steel sleeves and grout.

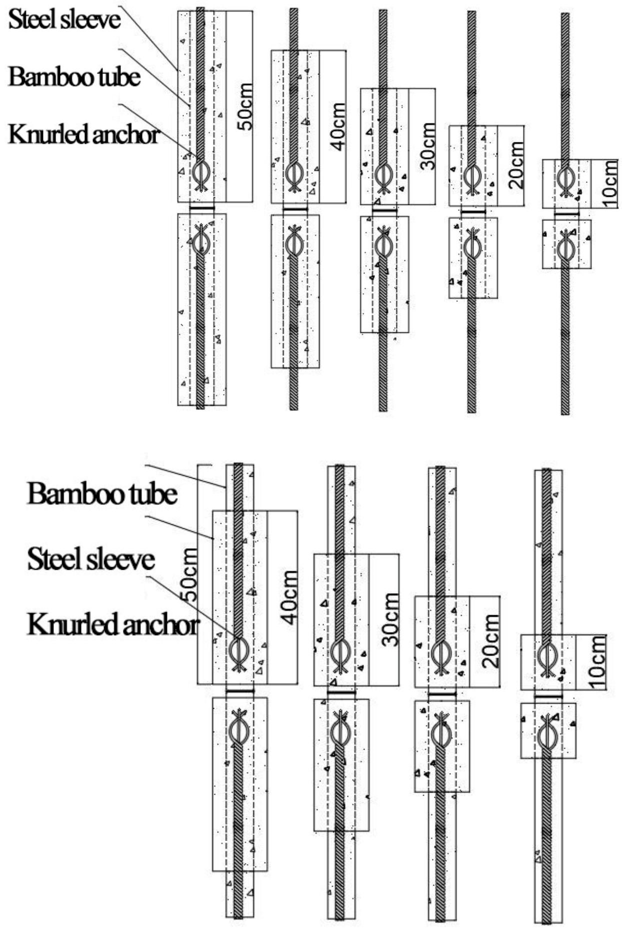
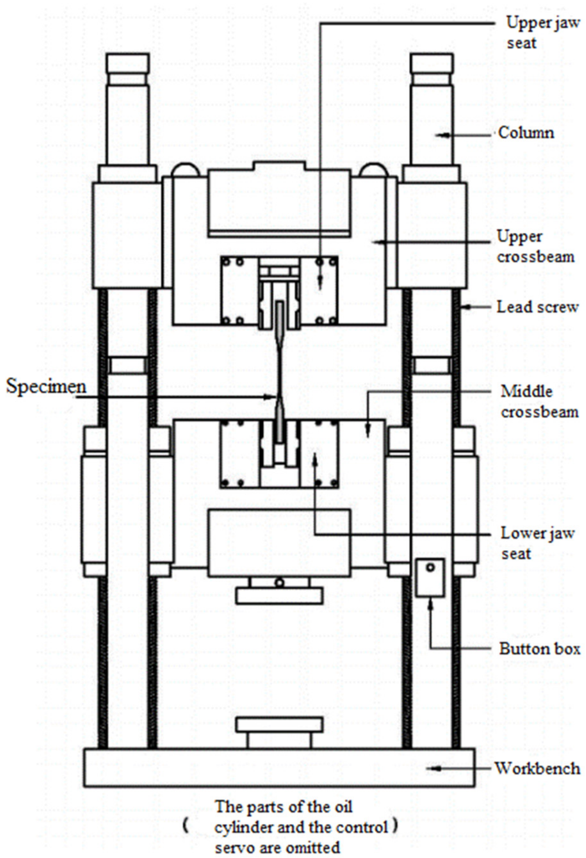


Fig 3. Schematic structure of test components for groups 1~9

2.3. Test Equipment and Loading



(a)

(b)

Fig 4. Structural schematic diagram and range entity diagram of 50-ton universal testing machine

The main equipment used in this test is universal testing machine, using supporting operating system to control the loading process, the main test equipment for the 50t model universal testing machine, loading space of 1.8m, leaving 10cm deformation elongation reserved space, the total length of the specimen shall not exceed 1.7m, so the control of the middle of the bamboo tube exposed section of 10cm, to remove the two ends of the clamping section of 30cm, then the steel sleeve and embossed anchors. The limit length of the anchoring segment can reach up to 50cm, the structure of the universal testing machine is shown in Fig 4.

Since the fixture type of the testing machine is only applicable to 32.0mm nominal diameter fine-rolled rebar, it is necessary to use a rebar-strand adapter to convert the strand at both ends of the specimen to be clamped.

As shown in the figure below:

Fig 5. Solid drawing of 32 rebar supporting fixture

After the preliminary test the adapter can withstand the tensile force of more than 25t, to meet the test requirements.

For setting the loading parameters in the operating system of the universal testing machine, reference is made to the content of the tensile test method for wood material samples in Chapter 7 of GB/T 20671.7-2006 Classification System and Test Methods for Non-Metallic Gasket Materials [9], as well as Chapter 1 of GB-T228-1-2021 Tensile Tests for Metallic Materials [10]: under room temperature conditions with steel as the Typical tensile test program for metallic materials, the loading parameters of the testing machine are set to grow 500N/mm² per minute, and the test is ended when the sample undergoes fracture damage or bond-slip damage.

attention is needed in this test:

1. After testing, this test, the universal testing machine records the specimen deformation elongation 95% by the cemented body and the bamboo tube wall of the slip volume, a small portion of the deformation by the material itself, and thus all the experimental groups of specimen elongation is larger, basically up to 50mm or so, so the end of the test the key consideration is the tensile stress whether it still grows in the test machine reserved deformation length of 10cm space, tensile stress no longer grows to end the test. Within the space of 10cm of deformation length reserved for the testing machine, the tensile stress can end the test if it is no longer growing.

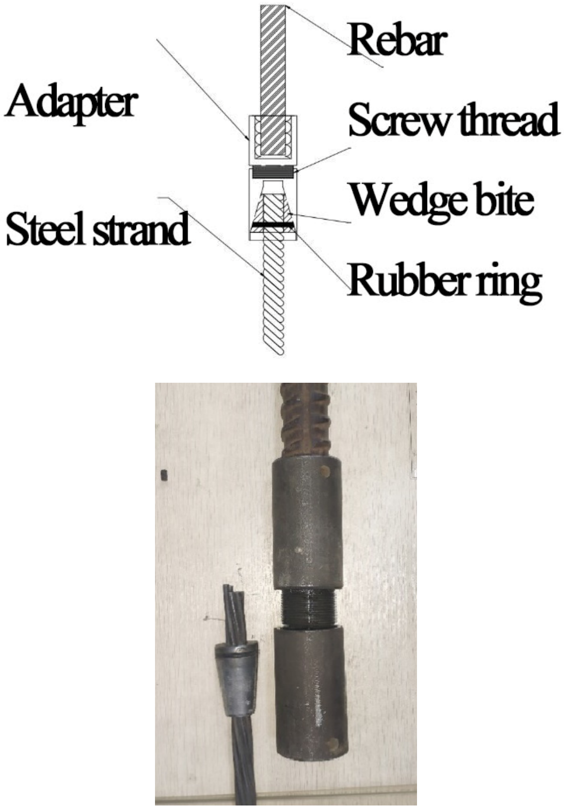


Fig 6. Structural schematic and solid diagram of threaded steel strand adapter

2. The end of all samples made by this test are bamboo tube wall and the cement body bonding damage, but at the end of the test and record the destruction of the finished sample, but also need to cut open the specimen internal observation, check the inner wall embossed anchor pear-shaped body and the destruction of the grout cement body, if there is a whole grout collapse damage should be discarded to re-test the sample data.

3. Test Results and Analysis

3.1. Testing of Weak Surfaces of Bamboo Anchor Joint Nodes

According to the group 3 size data for a set of prior weak surface test test test, through the specimen damage to deduce the weakest surface of the connection node, mainly observe the bamboo tube material along the line of fracture, transverse cracking, grout cement pressure damage and bonding slip damage. As shown in the figure below:

In the experiment, it was found that the ultimate tensile force stopped rising but the displacement kept increasing, and it was observed that the grout cement in the bamboo tube at the end was pulled outward while maintaining good integrity, and the inner wall of the bamboo tube and the outer surface of the cement in the tube suffered from bonding damage and a lot of slippage, which was preliminarily deduced that the weak surface was at the above mentioned position.

Fig 7. Example of weak structural surface location

Fig 8. Damage of grout cement in bamboo tube

Figure in the middle section of the collodion material flush section and broken pieces for the end of the pulling test cross-section of the external material to take the core caused by the non-test process by the strand embossing anchorage force. Observation of the upper section of the cemented body, the integrity of the more complete, pressurized shear cracks are concentrated in the pear-shaped body above the part of the collapse of the damage is concentrated in the pear-shaped body section of the strand by the pear-shaped expansion of the body to close the bite to hold the part of the strand.

3.2. Tension-deformation Curves of Bamboo Anchor Body Specimens

Table 2. Data table of ultimate displacement and ultimate tensile force

groups	Limit displacement (mm)	Ultimate tensile force (kN)
1	50.50	22.55
2	47.88	42.79
3	60.00	55.93
4	61.58	95.55
5	57.89	153.63
6	67.77	28.02
7	50.32	46.26
8	66.91	56.30
9	67.21	97.90
10	45.04	189.43
11	61.10	37.76
12	50.38	155.00

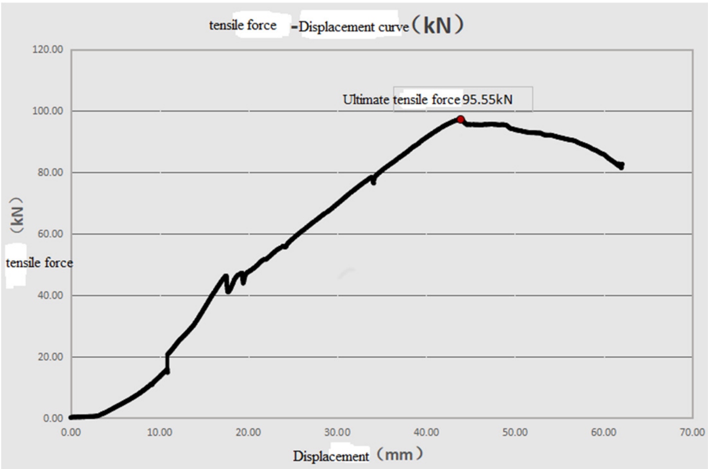


Fig 9. Group 4 Sample Tension Displacement Curve

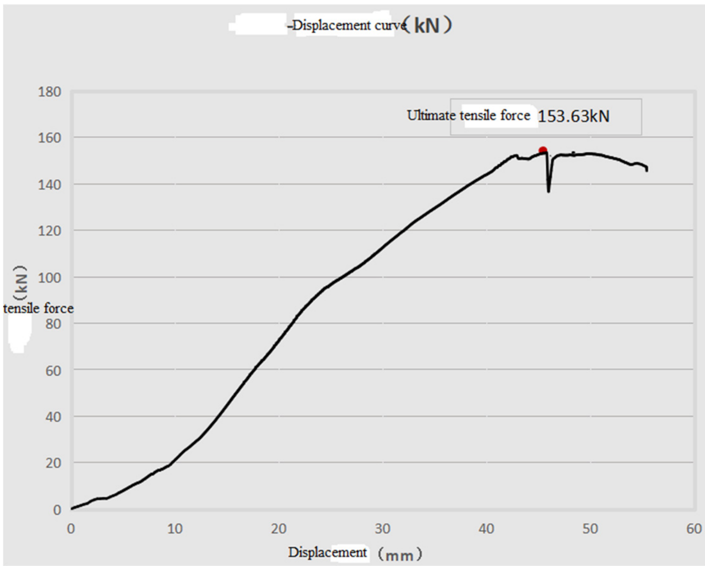


Fig 10. Tensile force-displacement curve for group 5 samples

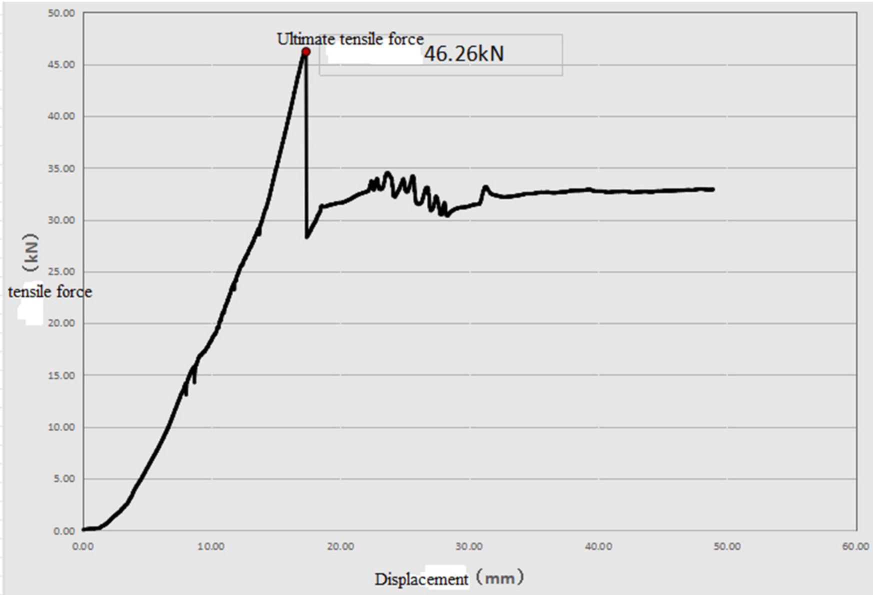


Fig 11. Tensile force-displacement curves for group 7 samples

As the weak surface of the connection structure is the contact surface between the inner wall and the outer surface of the adhesive body inside the cylinder, the factors affecting the adhesion between the adhesive body and the inner wall of the bamboo cylinder are the area of the contact surface, the roughness of the inner wall of the bamboo cylinder, the length of the outer steel sleeve, and whether or not to add other enhancement processes. According to the various factors to control different groups, with reference to the categories in Table 1, 12 groups of categories for the drawing test, the results are shown in the table 2.

Due to space constraints, this paper does not list all the groups of samples of the tension-displacement curve, the following selection of three typical groups of curves as an example of illustration: the unit of the tension in the figure is kN, and the unit of the displacement is mm.

3.3. Analysis of Test Results

3.3.1. Impact of Embossed Anchor Anchorage Section Lengths

Comparative analysis from group 1~5, under the condition that the steel sleeve providing circumferential restraint completely covers the anchoring segment of the embossed anchor inside the bamboo tube, the ultimate tensile strength of the specimen increases with the increase of the length of the anchoring segment, and the relationship curve is shown below:

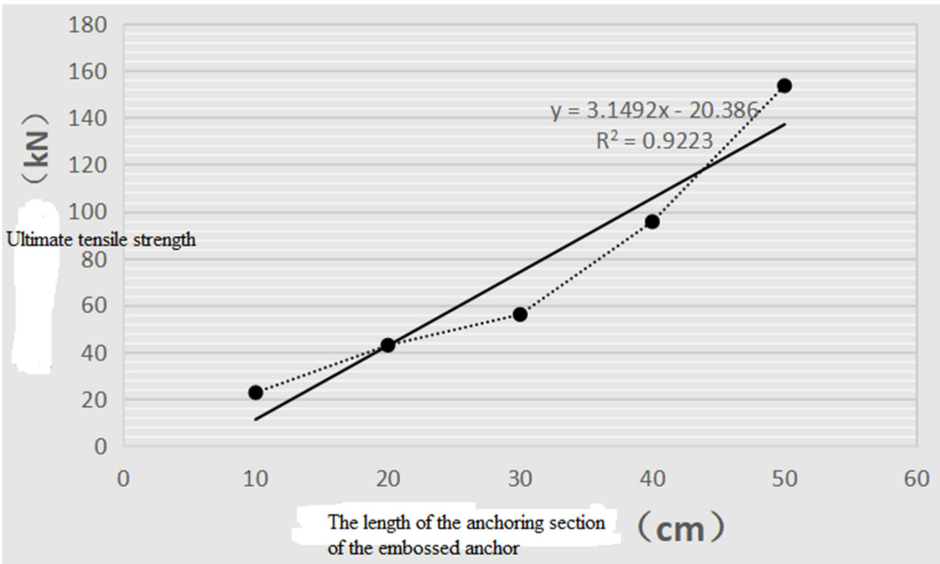


Fig 12. Relationship between the ultimate tensile strength of the specimen and the anchoring length of the embossed anchor

Calculating the correlation index $R^2 = 0.9223$, a linear regression was performed on the data in the graph, resulting in the regression equation:

$$y = 3.1492x - 20.386 \quad (1)$$

y - ultimate tensile strength of the specimen (kN);

x - length of the embossed anchor anchoring section (cm);

This test group is limited by the size range of the test equipment, the total length of the specimen cannot continue to grow, embossed anchor anchoring section length can only be set to a maximum of 50cm, but the final damage phenomenon of group 5 is still the inner wall of the bamboo tube and the grout bonding surface slipping damage, the bamboo tube material itself in addition to a small number of longitudinal cracks without significant loss, therefore, in order to explore the full use of the size of the original bamboo used in the test of bamboo tubes need to be the theoretical tensile force embossed anchor anchorage length, shall be calculated according to the above equation:

Referring to Hao Jiping et al. in "Experimental study on the mechanical properties of bamboo in the direction of the smooth grain" [11], the test results of the smooth grain tensile properties of the domestic engineering bamboo material, and the same method of sampling and testing of Hunan moso bamboo bamboo used in the test, the average value of the smooth grain ultimate tensile strength of the original bamboo material was finally tested to be 135 MPa. the average dimensions of the bamboo canisters used in the test were 8.5 cm of the inner diameter and 9.2 cm of the outer diameter, and the theoretical ultimate tensile strength of bamboo canister was calculated to be 525.48 kN. The average size of the bamboo tube used in the test was 8.5cm in inner diameter and 9.2cm in outer diameter, and the theoretical ultimate tensile strength of the bamboo tube was calculated to be 525.48kN. According to the relationship of Equation (1), the length of the corresponding embossed anchor anchorage section theoretically needs to be 173.33cm, in order to fully exert the tensile capacity of the bamboo tube body.

3.3.2. Influence of Length of Outer Steel Sleeve Cover

By Figure 7 shows the results, it can be seen mainly in the grout cement body and embossed anchor to expand the pear-shaped body of the combined section of the expansion of the pressure damage, the main role of the outer steel sleeve to provide circumferential constraints, to prevent the bamboo tube burst, so the change in the coverage of the steel sleeve in this test need to be completely wrapped in the conditions of the pear-shaped body, to the end of the direction of the extension of the set of different lengths of the coverage.

The form of damage is shown below:

Fig 13. Example of tensile damage of short steel sleeve specimen

The bamboo tube section not covered by the steel sleeve burst in the circumferential direction, and the internal cementation body of the bamboo tube swelled the bamboo tube and pulled it out, resulting in an overall bonded slip.

Comparison of the ultimate tensile strength results from group 6~9 with group 1~4 respectively reveals that: the groups covered by steel sleeves with lengths of 10cm, 20cm, 30cm and 40cm are similar to the groups covered by steel sleeves but with lengths of bamboo tubes of 10cm, 20cm, 30cm and 40cm respectively, with the extreme values slightly greater than the extreme values of group 1~4. It can be seen that the bamboo tube connecting the nodes is prone to circumferential expansion cracking, and only the steel sleeve wrapped to provide circumferential constraints on the length of the section can play a role.

3.3.3. Influence of Other Treatment Processes on the Bonding Properties of Members

Referring to the modification process [12] carried out by Zhong Kunlu on the new bamboo reinforced concrete bamboo members, group 10 bonded a flat layer of inorganic particles to the inner wall of the bamboo cylinder; group 11 welded a layer of steel matting to the outer ends of the steel casing of the members; and group 12 carved grooves into the inner wall surface of the bamboo cylinder.

Comparison of the above three groups and group 5 experimental results, found that: welded steel pads will make the steel sleeve outward slippage, so that cannot wrap embossed anchors to expand the pear-shaped body segments, resulting in the failure of circumferential constraints, the structural bonding effect of the weakening effect. The inner wall surface of the bamboo tube for grooving or bonding inorganic particles of the process can enhance the structural bonding performance, which to additional inorganic particles of the process to enhance the effect is more significant, and its treatment process is shown in the figure below:

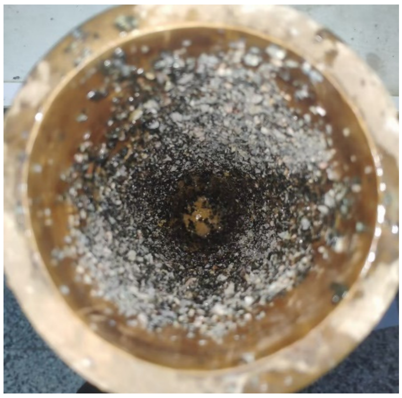


Fig 14. Inorganic particles bonded to the inner wall of bamboo tube

4. Nclusionsco

By analyzing the results of the above tests, the following conclusions were drawn:

(1) The average inner diameter of 8.5cm, the average outer diameter of 9.2cm of Hunan produced moso bamboo tubes used in this test, the actual limit of smooth grain tensile strength of at least 189kN or more, the ideal value of 525kN or so, theoretically fully utilizing the tensile properties of the bamboo tube material embossed anchor anchoring section length needs to be reached more than 1.73m, its mechanical properties to meet the requirements of the project's practical application.

(2) Bamboo tube anchor body anchor connection node weak surface in the bamboo tube wall and grout cement bonding effect surface, can be increased through the growth of embossed anchor anchoring segment length to increase the contact area, or bamboo tube wall bonding additional inorganic particles to enhance the bonding force of the surface.

(3) External steel sleeve to provide the ring constraint for the bamboo tube anchor body anchor connecting structure of the key factors of synergistic force, have ring constraint of embossed anchor anchorage section length is the effective length.

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