

# Finite element Analysis of Semi-Grouting Sleeve Connection Member Based on ABAQUS

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**Abstract:** This paper use investigates the force transfer mechanism and failure form of semi-grouting sleeve members under axial load, analyze the weak points of structural bearing capacity and verify the reliability of the connection of steel bars through finite element analysis software. The results show that adding the axial load to semi-grouting sleeve forms a 45° oblique compression zone, which help to transfer stress between reinforcement, grouting material and sleeve. Because the maximum stress of sleeve doesn't reach its tensile resistance and the deformation of the sleeve is located at the junction of the grouting and the threaded section when the stress value of steel bars at each end of the semi-grouting sleeve reach its ultimate tensile strength, we conclude that the semi-grouting sleeve members can meet the construction quality requirements and be used to connect the steel bars at the joints of the assembled structures. It is necessary to avoid breaking down, since the deformation section will accumulate large plastic deformation during the processing of the sleeve.

## 1. Introduction

In nearly half a century of the development of sleeve members, they have been widely used in the assembly reinforced concrete structure due to the advantages of convenient construction, safe and environmental protection, reliable connection performance and so on. The characteristic of the semi-grouting sleeve connection member is that the prefabricated section of the factory is the mechanical connection of the steel bar through the bite force, while field assembly section is the connection of the steel bar grouting. After the reinforcement is inserted into the specified depth of the sleeve in the field, squeezing the high-strength grouting material into the sleeve, and then firmly unite the steel bar with the sleeve until the grouting material hardened (the factory prefabricated section will be named thread section and the field assembly section will be named grouting section below). The research and application of semi - grouting sleeve connection joint have been few investigated in China, only focusing on experimental research and being poor for the analysis of finite element theory. One hand, theoretical analysis can avoid the influence of uncontrollable factors on experimental results and increase the reliability of research. On the other hand, it can provide valuable data for the actual construction. This paper analyzes the stress change of reinforcement, grouting material and the steel sleeve to study the mechanism of force transfer and failure form among steel, grouting material and sleeve the three elements and verify the reliability of the steel bar connection.

## 2. Establishment of 3-D finite element model of half grouting sleeve connecting member

### 2.1 Model Parameter



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The numerical model designed is based on the schematic diagram Fig.1 of the semi-grouting sleeve connecting member with ribbed reinforcement. Referring to the actual semi-grouting sleeve connecting member, the design parameters of the model are determined as shown in Table 1.

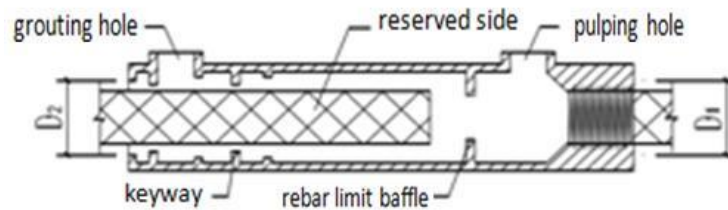


Fig. 1 semi-grouting sleeve component

Table 1 dimension parameter of semi grouting sleeve

| thread connection  | grouting connection | sleeve outer | sleeve | sleeve   | grouting reinforcement |
|--------------------|---------------------|--------------|--------|----------|------------------------|
| steel bar diameter | steel bar diameter  | diameter     | length | diameter | insertion depth        |
| /mm                | /mm                 | /mm          | /mm    | /mm      | /mm                    |
| C18                | C18                 | 40           | 193    | 35       | 150                    |

## 2.2 Selection of Cell types and Grid Division

According to the design and application characteristics of semi-grouting sleeve connection members, the sleeve structure is equivalent to the axisymmetric model of X axis symmetry. The sleeve, steel bar and grouting material all adopt 4-node non-twisted axisymmetric CAX4 solid element. CAX4 element can effectively simulate the model structure which is subjected to axial load and shape symmetry. The axisymmetric model can not only intuitively and accurately reflect the actual force of the structure, but also greatly improve the efficiency of the analytical solution. Based on the parameters in Table 1, the numerical model of grouting sleeve member is established in the finite element software ABAQUS with a mesh dividing, as shown in figure 2 and figure 3.

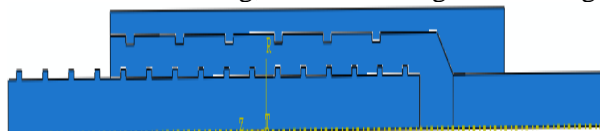


Fig.2 model diagram of the semi grouting sleeve

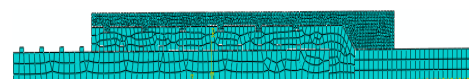


Fig.3 the meshing of model

## 2.3 Interaction Forms and Constraints

The research assumes that there will be no slip-wire phenomenon when the reinforcement in the mechanical connection section is subjected to axial tension. Therefore, the degree of freedom between Anchorage steel bar and sleeve thread is restricted by Tie connection between steel bar and sleeve, while the contact between reinforcing bar and grouting material and between grouting material and sleeve is simulated in the form of surface contact.

## 2.4 Boundary Conditions and Loading Modes

In order to simulate the actual stress of the sleeve structure and study the force situation of the whole structure with steel bars broken under ideal conditions, the end face of the steel bars are subjected to a load slightly higher than its ultimate tensile strength. Based on the axisymmetric model of sleeve model, the boundary condition of YZ plane symmetry is applied to the longitudinal section of steel bars, as shown in figure 4.

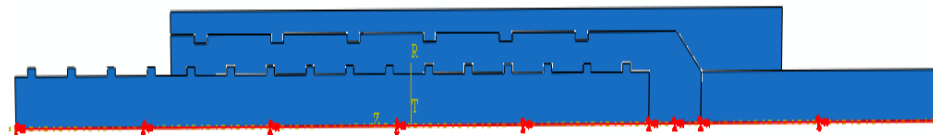


Fig.4 sketch map of model boundary condition

### 3. Stress Analysis of Semi-grouting Sleeve Members under Axial Load

#### 3.1 Force-deflection curve

As shown in figure 5 below, it can be seen that the structure is in the elastic stage at the beginning of loading, the force and displacement change linearly, and the curve increases linearly. When the load increases to 123 kN, the yield displacement is 10.2 mm and the member begins to enter the plastic deformation stage. The peak load is 169 kN.

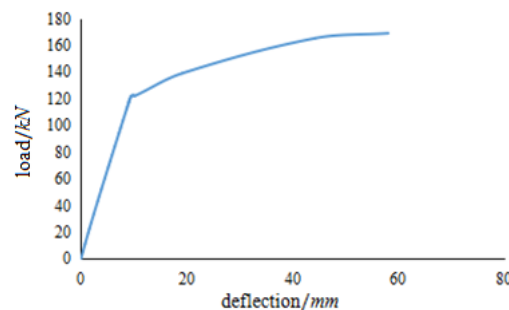


Fig.5 curve of load—displacement

#### 3.2 Stress Analysis of Semi-grouting Sleeve Members

The stress cloud diagram of steel bar, grouting material and sleeve is obtained after unidirectional loading on the sleeve structure. When tensile strength reaches 620 MPa, the member is destroyed at the outside of the sleeve. The Mises stress cloud diagram shown in Fig. 6, while Fig. 7 is the first principal stress cloud diagram, fig. 8 is the third principal stress cloud diagram, fig. 9 is the axial and circumferential stress cloud diagram of the sleeve and fig. a ~ d, respectively, are the cloud diagram of the reinforcing bar at the grouting end, the grouting material, the sleeve and the threaded steel bar.

It can be seen from the figure.6 that the stress value of reinforcement in grouting section decreases gradually from the loading end to the bottom end of the insert sleeve and the maximum stress value is 620 MPa at the loading end, while the stress value decreases gradually from the external reinforcing bar of the sleeve to the insert sleeve thread section and the maximum stress value is 625 MPa, which reaches the tensile limit of steel bar.

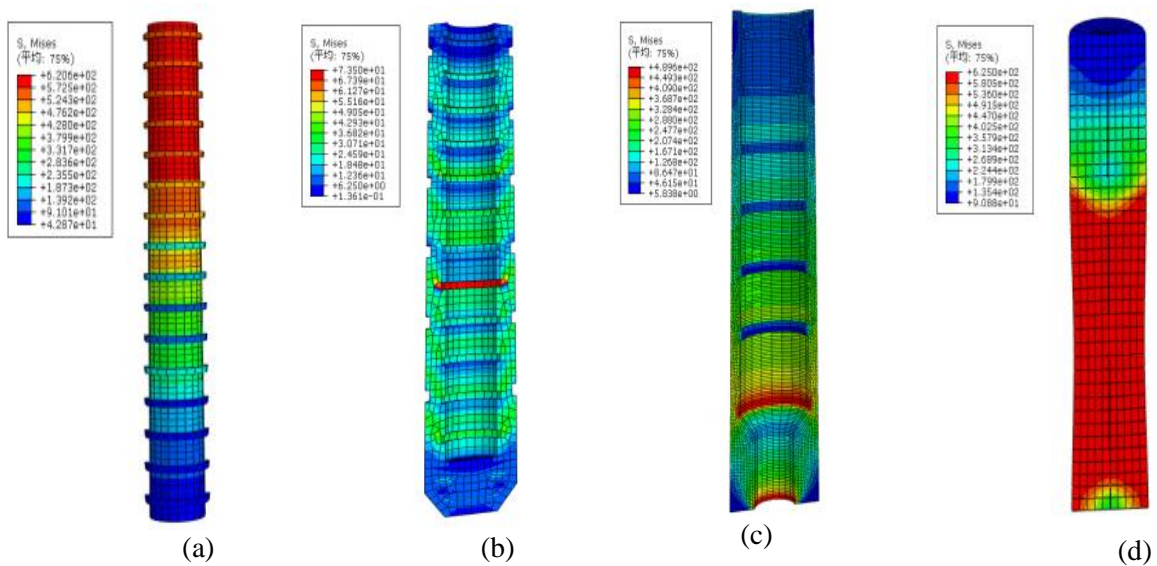


Fig.6 the Mises stress cloud chart of the semi grouting sleeve model

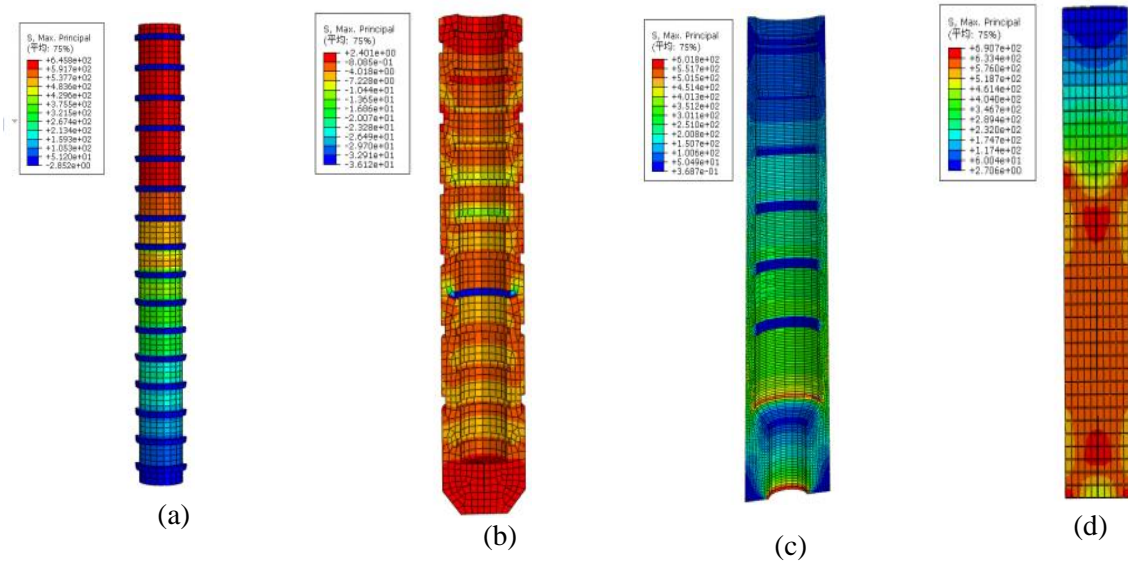


Fig.7 first principal stress cloud chart of the semi grouting sleeve model

Fig.7 shows that the stress of the sleeve rib in the grouting section is more complicated. But the stress value does not reach the yield strength of the sleeve, so the thickness of the sleeve rib can be appropriately reduced in the design and manufacture of the sleeve structure, thus the use of materials can be reduced and construction technology can be simplified.

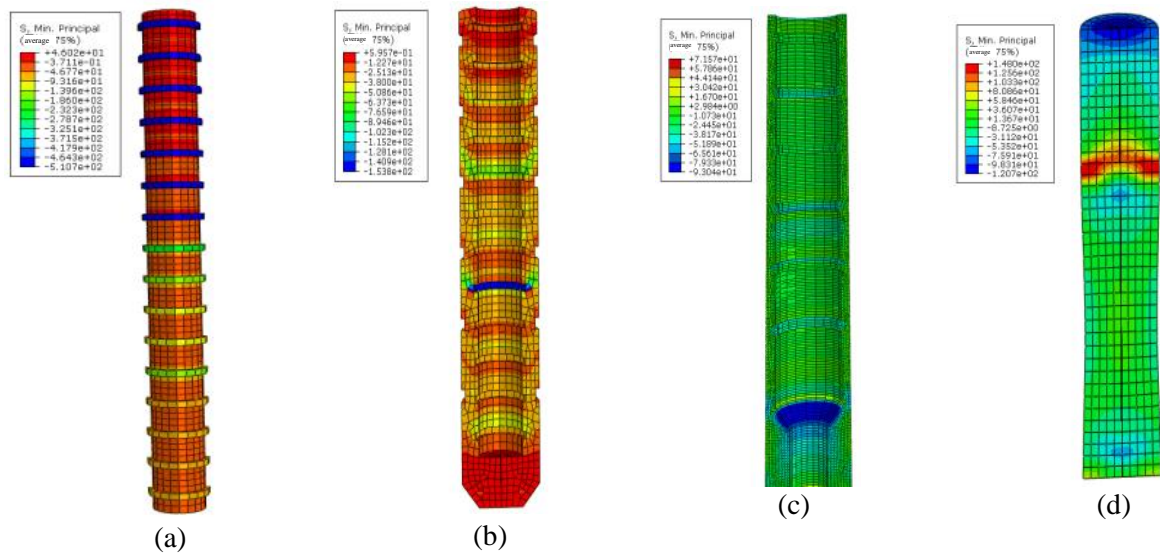


Fig.8 third principal stress cloud chart of the semi grouting sleeve model

As shown in Fig.8, the tensile stress concentration is observed at the junction of the threaded steel bar and the sleeve end, while the stress value is  $149 \text{ MPa}$ . Two obvious oblique compression bands were formed at the contact between the steel rib and the inner surface of the grouting material, so that the reinforcement stress was transferred from the grouting material to the sleeve through the compression zone.

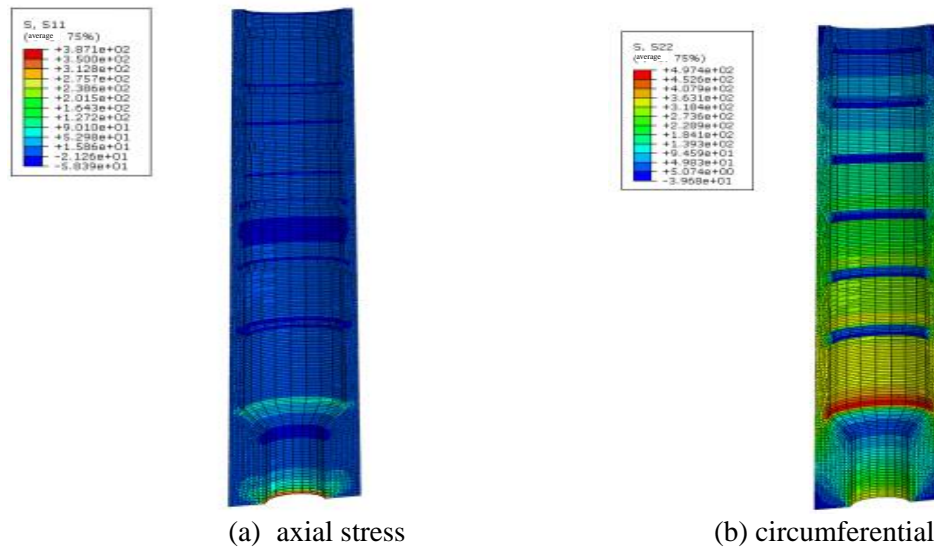


Fig.9 cloud diagram of circumferential and axial stress of semi-grouting sleeve model

It can be seen from figure 9 that the axial stress of the sleeve is mainly compressive stress, and the axial stress of the sleeve is tensile stress at deformable position with the maximum axial tensile stress  $312.8 \text{ MPa}$  during elastic stage, which is less than the yield strength. The circumferential stress is mainly tensile stress, and the maximum tensile stress at the bottom of the sleeve grouting section is  $497.4 \text{ MPa}$ , which has reached the yield strength. The wear strength shows that the sleeve structure is in a bidirectional tensile state, which is a weak point of bearing capacity. Moreover, during the processing of the sleeve, due to the reasons of the construction technology, the deformation will accumulate a large plastic deformation. Therefore, it is necessary to prevent the sleeve from breaking due to insufficient bearing capacity or insufficient plastic properties. In addition, because the circumferential stress at the end of the thread section is also large, special attention should be paid to the structural design.



#### 4. Conclusions

(1) At the initial loading stage of sleeve structure, the structure is in the elastic stage, and the force and displacement change linearly. When the yield strength is  $123\text{ kN}$ , the yield displacement is  $10.2\text{ mm}$ . When the load is  $169\text{ kN}$  reaching the tensile limit of steel bar, the member is destroyed.

(2) The stress value of bolted steel bar in threaded section is larger than that in grouting section, and the phenomenon of "necking" occurs obviously in the external steel bar of sleeve thread section, which can be seen from the change of stress value of steel bar. The tensile failure of the steel bar outside the sleeve meets the design requirements.

(3) Because of an oblique compression zone of about  $45^\circ$  forms, the stress of the steel bar is transferred to the sleeve structure through the compression belt formed by the grouting material.

(4) When the stress value of steel bar reaches the limit tensile strength of  $625\text{ MPa}$ , the maximum stress value at the junction between the grouting end of the sleeve and the thread section is  $489.6\text{ MPa}$ , which is less than the limit value of the sleeve tensile resistance of  $620\text{ MPa}$ , but it has basically reached the yield stress value. And the maximum stress produced by the threaded sleeve at the top is  $449.3\text{ MPa}$ . On the basis of these results we concluded that the bottom of the section and the top of the thread section are the weak points of the bearing capacity of the sleeve structure.

(5) The deformation place will accumulate large plastic deformation during the process of sleeve, so it is necessary to prevent the sleeve from breaking down for insufficient bearing capacity or insufficient plastic property. In addition, the structural design should be paid attention to, because of the large annular stress at the end of the threaded segment.

#### Acknowledgements

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