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Mechanical Property Study on the Planting Bar Strengthening Structure based on Midas/civil Solid Element

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Abstract. When using Midas/civil solid element modeling to analyses a simple strengthening model by enlarging section method, it is found that the temperature stress of the model without implant reinforcing bars is very large under the overall temperature load, which is inconsistent with the actual engineering situation. When the model is implanted the reinforcing bars, the temperature stress generated by the overall temperature load becomes normal. It can be concluded that the defects of temperature stress anomalies caused by different linear expansion coefficients of different materials can be effectively corrected by implanting reinforcing bars in solid element models. When the defect of solid element model is corrected, its application prospects will become extremely broad, and it may eventually replace the calculation methods of internal force, stress and displacement provided by current engineering specifications.

1. Introduction

In recent years, with the continuous increase of service time and vehicle load, many old bridges in China have been damaged and need to be strengthened urgently[1]. Among them, the main damage phenomena affecting structural safety are surface cracking, crushing of stressed members and corrosion of stressed steel bars. For damages affecting the safety of structures, enlarging section strengthening method is often used to strengthen damaged parts in China. This is a very common strengthening method for stressed members, whose main steps are as follows: first of all, clean up the crushed material on the surface of the stressed member; then drill holes in the stressed member and implant steel bar vertically; finally, pour a new layer of concrete outside the member[2]. This strengthening technology is widely used in engineering field and has good effect. But in domestic academia, many researchers believe that there are some shortcomings in the calculation method of this technology in design code, such as inaccurate mechanical assumptions, low calculation accuracy and vague calculation results[3]. With the rapid development of computer technology, the existing finite element simulation software can easily simulate and analyze the solid element structure model. Therefore, compared with the calculation method provided by the design code, it is more suitable for engineering application to use the finite element simulation software to establish the solid element simulation model of enlarging section strengthening method to analyze old bridges or other similar structural components[4].

However, although it is more reasonable and precise to use finite element solid element model to analyze the damaged structure strengthened by enlarging section strengthening method, there are still



some shortcomings, mainly the abnormal temperature stress on the interface between old and new materials in the commonly used solid element structure model[5]. In the last published paper, the author of this article has studied this phenomenon and concluded that the main reason for the abnormal temperature stress are that the linear expansion coefficients of two different materials at the contact interface between new and old materials are quite different[6].

In order to solve the shortcomings of the commonly used solid element structure model of enlarging section strengthening method, the author of this paper, by analyzing the mechanical characteristics of several models and communicating with many engineers and technicians, draws a conclusion that the main reason for the abnormal temperature stress is that there are no reinforcing bars embedded in the solid element model. In this paper, a common solid element model is used as the research object to simulate two times, one with implant reinforcing bars and the other without. By comparing the two simulate results of the model, the differences between them are analyzed to verify the conclusion, and to provide a research basis for optimizing the existing solid element modeling method of enlarging section strengthening method.

2. Modeling overview

This paper mainly verifies the rationality of the internal force distribution of the element solid element model with implant reinforcing bars under load, then, the geometric dimensions of the model will be simple and regular. In order to make the material conform to the actual engineering and continue the research of the author's last published paper, the material chosen will be the same as that paper (except for reinforcing bars, because there are no reinforcing bars implanted in that paper). In order to keep the model under complex stress conditions as far as possible, the boundary conditions of structural models tend to be simple and statically indeterminate. In order to ensure the coherence of the research, the finite element analysis software still uses Midas/civil.

The specific process and parameters of modeling will be described in detail in later chapters.

3. Process of modeling and analysis

3.1 Build the Midas/civil software model

The model studied in this paper is a cuboid with a geometric dimension of 6.0m in length, 4.0m in width and 5.0m in height. The model uses regular hexagonal solid element with 0.2m edge length. planting is designed by inserting reinforcing bars perpendicular to the interface between new and old materials, with the spacing of reinforcing bars 0.4m and arrange reinforcing bars in parallel. The Midas/civil software model is shown in Figure 1.

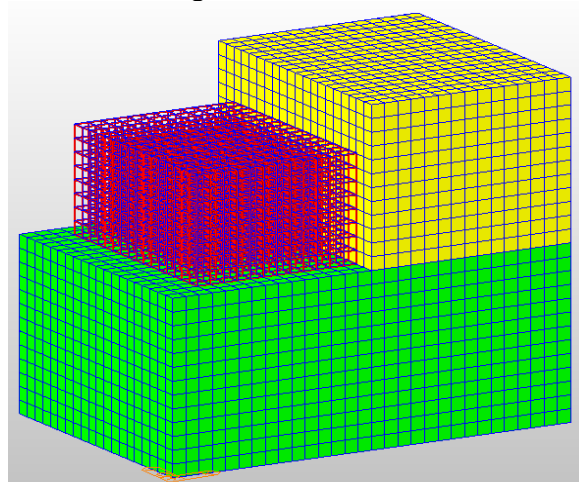


Figure 1. The Midas/civil software model(implant reinforcing bars)

3.2 Materials and boundary conditions

There are three kinds of materials[7] used in this model, they are:

Old materials(The green part in Figure 1) $E=7300\text{MPa}$, Coefficient of thermal expansion $\alpha_1=8.00 \times 10^{-6}$, $f_{cd}=0.99\text{MPa}$, $f_{tmd}=0.102\text{MPa}$;

Strengthening material(The yellow part in Figure 1) $E=30000\text{MPa}$, Coefficient of thermal expansion $\alpha_2=1.00 \times 10^{-5}$, $f_{cd}=11.73\text{MPa}$, $f_{tmd}=1.04\text{MPa}$, $f_{vd}=2.09\text{MPa}$;

Reinforcing bar(The purple line in Figure 1) $d=22\text{mm}$, $E=200000\text{MPa}$, Coefficient of thermal expansion $\alpha_3=1.20 \times 10^{-5}$ $f_{sd}=330\text{MPa}$.

The boundary conditions of this model are statically determinate structure with four bottom edges as fulcrums.

3.3 Model load

The loads used in this model include dead weight, vertical pressure, horizontal pressure, overall temperature and temperature gradient[8].

Dead weight: Gravity multiplied by mass;

Vertical pressure : Vehicle load pressure;

Overall temperature: Model Overall temperature increased by $30\text{ }^\circ\text{C}$;

Temperature gradient: According to Bridge Specifications.

4. Analysis of model calculation results

4.1 Calculation results of the model

Comparing the calculation results between implant reinforcing bars model and model without bars, there are obvious differences between them.

The calculation results of the two models under different loads are shown in Table 1.

Table 1. calculation results(maximum stress) of the two models.

Item		Dead weight (MPa)	Vertical pressure (MPa)	Overall temperature (MPa)	Temperature gradient (MPa)
The whole model	implant reinforcing bars	0.570	0.047	1.354	1.778
	without bars	0.548	0.046	2.372	1.657
The contact interface	implant reinforcing bars	0.100	0.014	1.354	0.436
	without bars	0.105	0.015	2.372	0.867

The stress nephograms of two models are shown in Figure 2 and Figure 3.

4.2 Analysis of calculation results

According to the data in Table 1, it can be found that the maximum internal stress of solid element model under dead weight load, vertical pressure load and temperature gradient load has little relationship with the condition of implant reinforcing bars, but under overall temperature load, the maximum internal stress of the model is greatly affected by implant reinforcing bars, and the maximum stress of the model without implant reinforcing bars are 75% more than that of the model

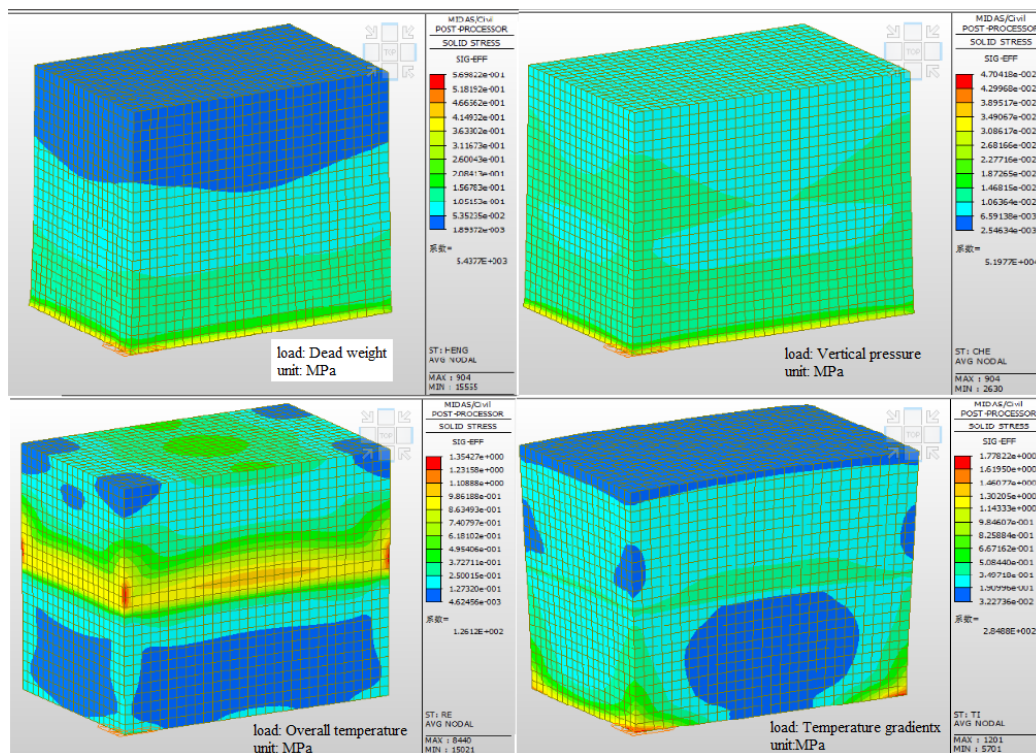


Figure 2. The Stress nephograms of implant reinforcing bars model

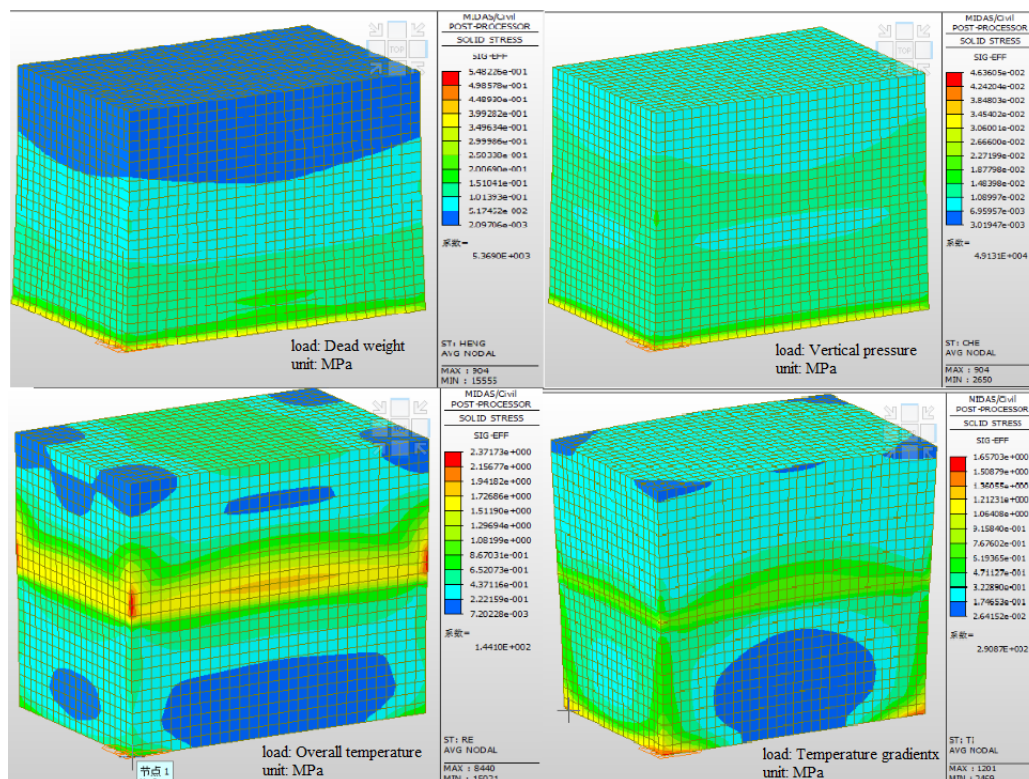


Figure 3. The Stress nephograms of no bars model

with implant reinforcing bars. This coincides with one of the conclusions of the author's last paper: "The stress of the solid element model without implant reinforcing bars under the overall temperature load is very huge and abnormal"[6].

According to Figure 2. and Figure 3. the maximum internal stress of the two solid element models under dead weight load, vehicle load and temperature gradient load appears at the constrained position of the bottom boundary, which is consistent with the basic principles of mechanics. Furthermore, under the overall temperature load, the maximum stress in both models appears at the contact interface, which accords with the viewpoint put forward at the beginning of this paper that "there is an abnormal phenomenon of temperature stress in the interface between old and new materials in the commonly used solid element structure model"[6].

4.3 Relationship between implant reinforcing bars and temperature stress

Although the data in Table 1. have shown that the temperature stress of solid element model under the action overall temperature load is greatly affected by the implanting reinforcing bars, the results of computer simulation can not be completely equivalent to the real situation, because some unknown factors may interfere with the model and distort the results.

In order to further verify the validity of the model results, the reinforcing bar of the model is reduced by 25%, 50%, 75% and the results are obtained by calculation. Then the maximum temperature stress generated by the overall temperature load is extracted from the results, and the relationship between the maximum temperature stress and the rate of implant reinforcing bars is drawn as shown in Figure 4.

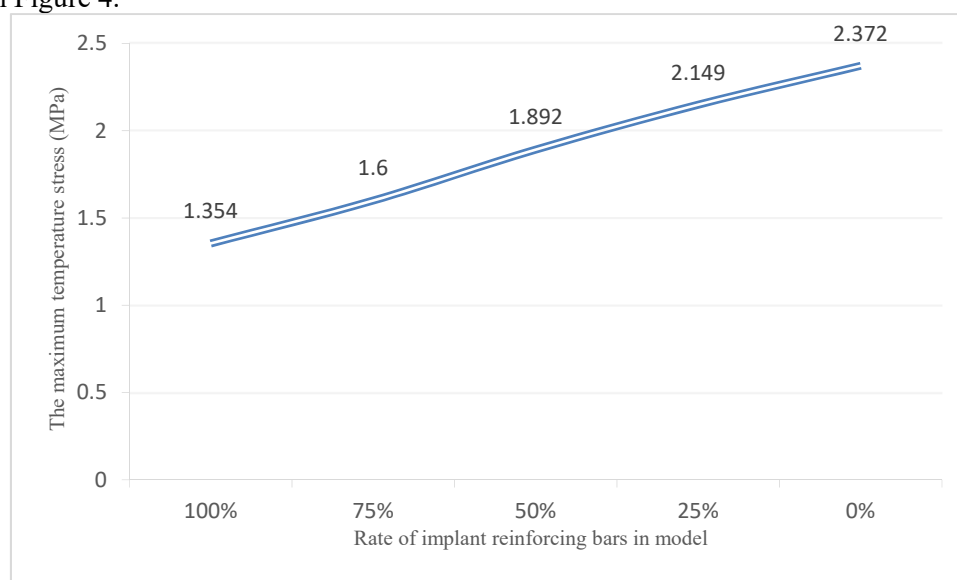


Figure 4. The relationship between the maximum temperature stress and the rate of implant reinforcing bars

According to Figure 4., the temperature stress produced by the overall temperature in the model of Midas/Civil solid element is inversely proportional to the number of implant reinforcing bars, which shows that implant reinforcing bars indeed have an effect on restraining the abnormal temperature stress.

5. Conclusion

According to the research in this paper, the finite element computer model of solid element based on Midas/civil is greatly influenced by the overall temperature and the temperature stress is also very large under the condition of without implant reinforcing bars. Therefore, when strengthening old arch bridges or other similar large-scale damaged structures with enlarging section method, it is suggested that reinforcing bars should be implanted in the model so as to make the temperature stress in the calculation results more suitable for the real situation.

In addition, for the structures strengthened by enlarging section method, the section size, material properties and reinforcing bars conditions have changed greatly before and after strengthening.

Therefore, it is not suitable to use classical two-dimensional mechanical algorithm to solve their internal forces, stresses and deformations. The classical mechanical algorithm provided by the current engineering specifications has become unsuitable for the development of the times[9]. In contrast, the finite element computer modeling method based on three-dimensional solid element is superior to the classical mechanical algorithm in terms of condition coincidence, calculation accuracy, analysis process management and result precision.

It is well known that the computer finite element model based on solid element is the closest to the real structure. However, its calculation accuracy increases with the increase of the number of dividing units, while the speed of computer operation model decreases with the increase of the number of units[10]. Therefore, the main difficulty of using solid element modeling to analyze large-scale structures is that the computer performance can not meet the engineering needs (if supercomputers are used, the cost is too high). In the future, with the development of 5G network, the computing mode based on cloud computing will greatly improve the computing speed of single computer in network, which will provide sufficient hardware support for running large solid element model.

Although this paper only verifies that the calculation results of a simple solid element model with implant reinforcing bars conform to the mechanical principle and meet the engineering needs. But it also indicates a possibility that in the near future, the distributed finite element method based on cloud computing will be used to process more detailed solid computer models of implant reinforcing bars (reinforcing bars and prestressed reinforcement) and will become the specifications formula for engineering industry to analyze stressed structures, and the existing two-dimensional classical mechanical algorithm will be withdrawn from engineering specifications, just as a supplement for computing simple force component.

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