# Research on Hysteretic Performance of Steel Reinforced Concrete T-shaped Column

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**Abstract.**Through applying MSC.Marc nonlinear finite element software, this research is to explore the ductility performance of steel reinforced concrete T-shaped columns under reciprocating loading. The result shows that the MSC.Marc calculation results are quite consistent with the experimental data, and can objectively reflect the mechanical properties of steel reinforced concrete special-shaped columns. These mean that the MSC.Marc software can be used for performing simulation analysis on the steel reinforced concrete special-shaped column hysteretic performance. Through changing the axial compression ratio, shear span ratio and load angle to research the ductility performance of steel reinforced concrete T-shaped columns under reciprocating loading, the main conclusions are as follows: The bearing capacity of steel reinforced concrete t-shaped cross section column decreases with the increase of shear span ratio; displacement ductility decreases with the increase of axial compression ratio; mechanical properties of the web load are superior to the ones of the flange load.

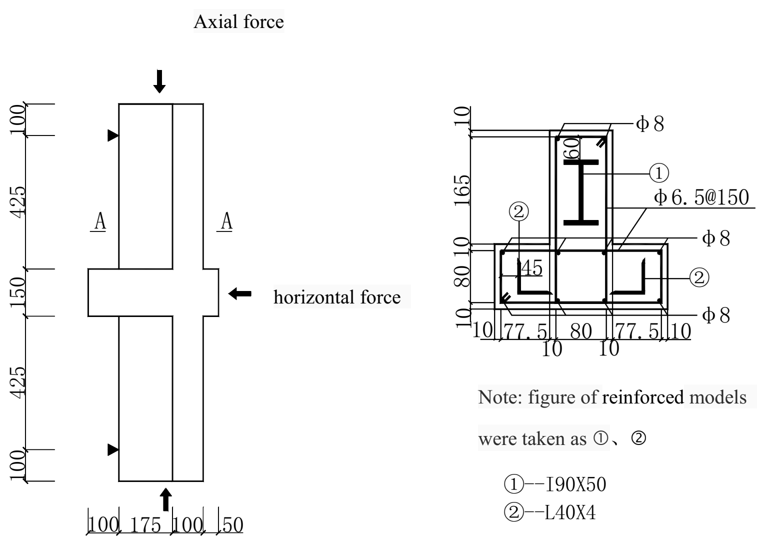
**Keywords:**Steel Reinforced Concrete T-shaped Column, Hysteretic Performance, Axial Compression Ratio, Shear Span Ratio, Load Angle

## 1 Introduction

Performing experiment is a traditional research approach to study the component and structure stress performance, failure mechanism and calculation method. It possesses many characteristics, such as objective, scientific and intuitive. However, a large number of tests will cost a great deal of money, manpower, and time as well. Meanwhile, the number of specimens, and the changes of parameter are always limited. Hence, through utilizing the numerical simulation method, it can help researchers to make up the defects of experiment.This article first applies MSC. Marc software to the tested steel t-shaped column in order to carry out the numerical simulation analysis, thus proving the validity of the model and parameter selection. Then, through changing the axial compression ratio, shear span ratio and loaded angle, the numerical simulation research of steel bone t-shaped column will be implemented that provides the basis for further research of ductility performance of steel reinforced concrete special-shaped columns under repeated loading.

## 2 Summary of Test

This article first to the xi 'an university of science and steel reinforced concrete short column T section T15-11-07 [1] for numerical simulation analysis. Detailed design parameters of T15-11-07 column as shown in figure 1 shows, test adopted beam type load. Adopted for the C40 concrete strength test, the measured concrete cube compressive strength is 49.9 Mpa, the elastic modulus of Ec 3.45 × 104Mpa. The measured section L40 yield strength of 320 mpa, steel I90 yield strength of 335; longitudinal reinforcement HPB235 measured yield strength of 310 mpa, stirrup HPB235 measured yield strength of 300 Mpa. T15-11-07 column shear span ratio λ = 1.53, the test of axial pressure coefficient $n_{st}$ =0.42, steel ratio $\rho_{ss} = 3.37\%$.




(a) λ =1.53 (b) A-A

**Fig.1** Dimensions and reinforcement details of steel T-shape specimen（λ =1.53）

## 3 The Finite Element Analysis

### 3.1 Unit type

As shown in figure 2, the finite element model is consistent with the actual size test components. More specifically, concrete material is selected 7 unit simulation, steel is selected shell139 unit simulation, and both the longitudinal reinforcement and stirrup are adopted rebar146 unit simulation, without considering bond-slip between concrete and steel bone or rebar. In order to ensure that the same displacement are imposed onloading surfaces, researchers can use Link in Marc to make all nodes of the loading surface in the y direction be constraint coupling.

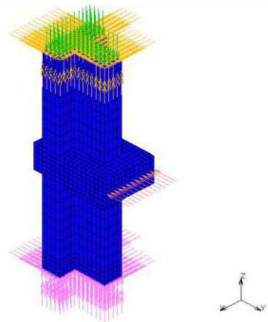


**Fig.2** The FEM model of T15-11-07

# 4 Build Material Model

## 4.1 The concrete material model

From the point of mechanical performance, special-shaped columns and short limb shear wall, micro concrete plane by Bazant et al constitutive model can well reflect the shear wall in the concrete under complex stress state and loading history on the mechanical properties of [2] [3] [4] [5]. In this article use the development of micro concrete surface such as Tsinghua university zhi-weimiao constitutive model program [6], it can analyze all kinds of complex stress of concrete, the calculation results and test results is good, and showed a strong ability of nonlinear analysis. The simulation results of the concrete cube block [7], as shown in figure 3.

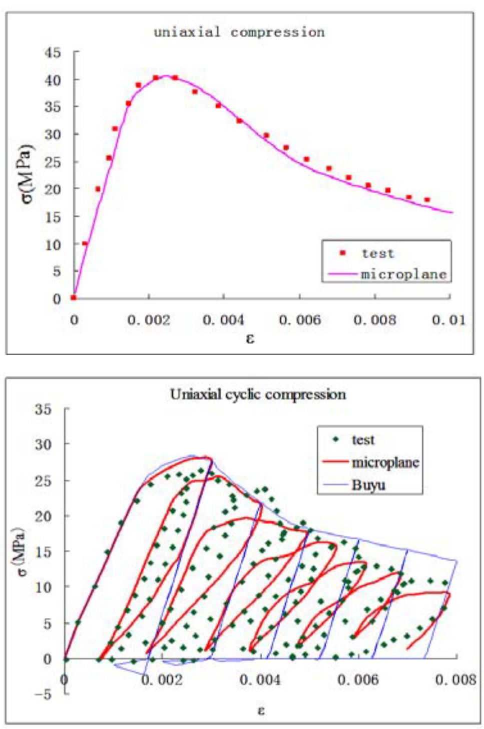



**Fig.3** Compared the result of calculating with the test

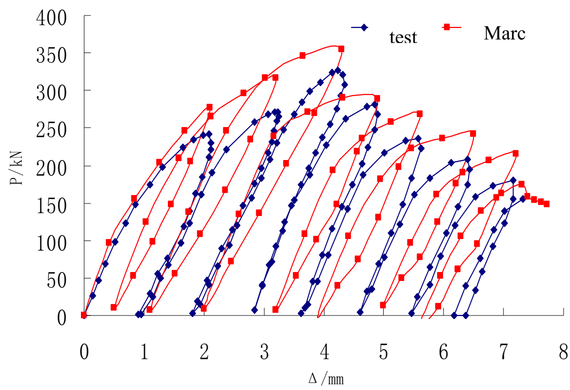



**Fig.4** Load (*P*)−displacement ( *Δ* ) hysteresis loops of specimenT15-11-07

### 4.2 The steel bar and steel model

Both rebar and steel model are the ideal elastic-plastic models, and their yield strength is from the test data.

### 4.3 The finite element calculation results and analysis

Can be seen from the figure 4, before the first loaded to cracking, the calculated results agree well with the test results, due to calculation model didn't consider the bond-slip between material and other factors, cracks appear after can obvious differences of the two, the bearing capacity of the test value is lower than the calculated value of Marc, and the plastic deformation is obviously larger than the calculated value of Marc. Overall, the calculation results and test results, compared to match better, can reflect under repeated load of steel reinforced concrete short column T section mechanical properties.

## 5 Steel reinforced Concrete t-shaped Column Hysteretic Performance Study

### 5.1 Steel reinforced concrete special-shaped columns specimen design

Size is 200 * 500 (unit is mm, same below) of steel reinforced concrete t-shaped cross section column analysis model, the cantilever beam loading mode, as shown in figure 5. Specimen material parameters are shown in table 1 and table 2 and table 3. Concrete cube compressive strength is 14.3 Mpa, bone ratio, ratio of longitudinal reinforcement and depth, rate of reinforcement volume.

**TABLE 1** MECHANICAL PROPERTIES OF STEEL

| Steel specification | yield strength ($f_{sy}$ /Mpa) | ultimate strength ($f_{su}$ /Mpa) | modulus of elasticity E （Mpa） |
|---|---|---|---|
| 工 80×120×10 | 210 | 300 | $2.0\times10^5$ |
| T80×40×10 | 210 | 300 | $2.0\times10^5$ |

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**TABLE 2** MECHANICAL PROPERTIES OF REINFORCED BAR

| diameter(mm) | yield strength ($f_y$/ Mpa) | ultimate strength ($f_u$/Mpa) | modulus of elasticity E（Mpa） |
|---|---|---|---|
| 6 | 300 | 375 | $2.0\times10^5$ |
| 8 | 300 | 457 | $2.0\times10^5$ |

**TABLE 3** SPECIMEN CALCULATION PARAMETERS

| Specimen number | axial compression ration | Shear span ratio $\lambda$ | Load angle $\alpha$ |
|---|---|---|---|
| SRC_TT1 | 0.3 | 1.5 | Along the web |
| SRC_TT2 | 0.5 | 1.5 | Along the web |
| SRC_TT3 | 0.3 | 1.2 | Along the web |
| SRC_TT4 | 0.3 | 1.5 | Along the flange |

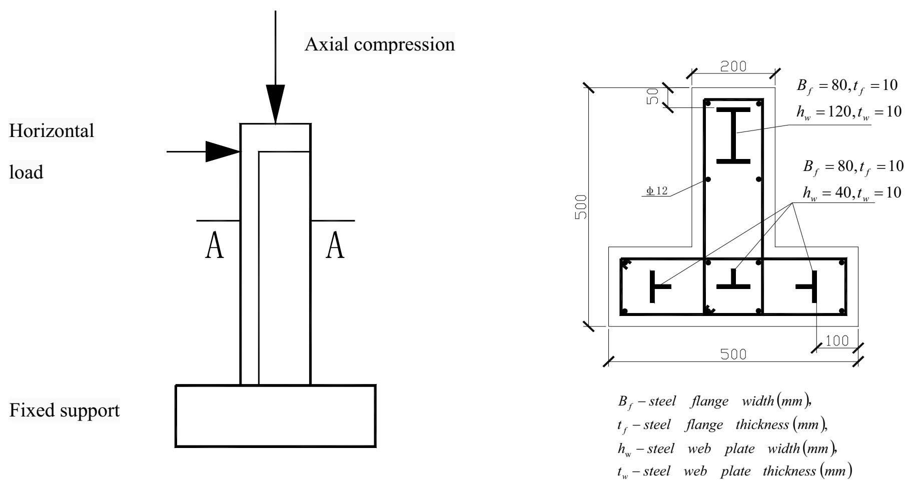



**Fig.5** Applying load mode and member section

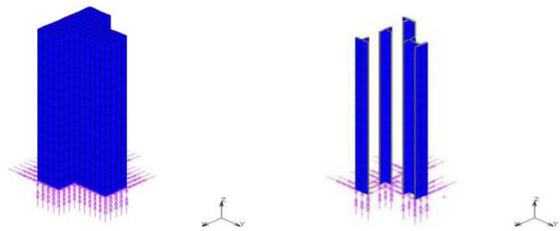


**Fig.6** The FEM model of steel reinforced concrete T-shaped column and steel

### 5.2 Finite element model

Unit type and material model with 3, bone, steel bar and steel specimen parameters shown in table 1 and table 2 and table 3 respectively, the finite element model as shown in figure 6.

### 5.3 The calculation results and analysis

As shown in figure 7, in front of the specimen cracking, surrounded by hysteresis curve area is small,basic linear relationship between force anddisplacement, in the process of reciprocatingload effect, rigidity degeneration is not obvious,the residual deformation is tiny, componentin a flexible working state. After cracking in the components, and the hysteresis loop back started the curve with the increase of the load step by step, hysteretic curve is leaning to the displacement of the shaft, the hysteresis loop back surrounded area increases gradually, with the increase of load, the stiffness degradation of the specimens, entered the stage of work suggests that specimen. Can understand from the following three factors affecting the steel reinforced concrete t-shaped cross section column hysteretic performance changes:

### 5.4 The influence of axial compression ratio

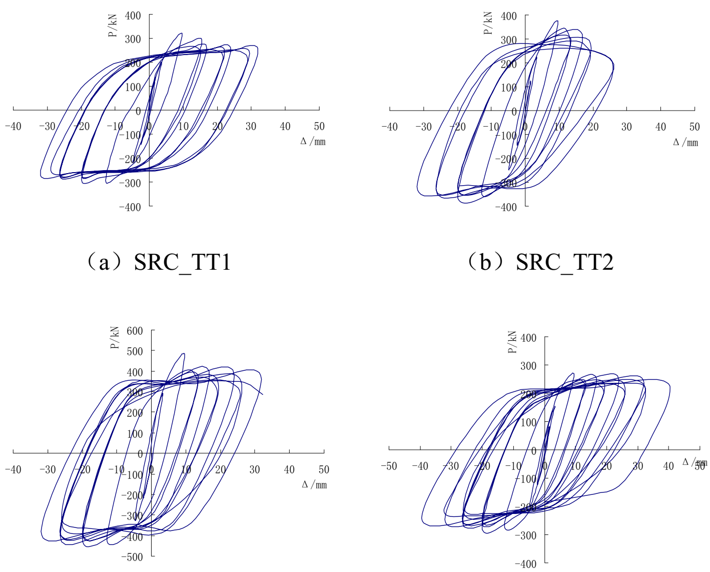
Under the effect of low axial compression ratio, steel reinforced concrete T-shaped column hysteretic performance is very good, full hysteresis loop, the spindle. Comparison in figure 7 (a) and (b) and figure 8 SRC_TT1 and SRC_TT2 skeleton curve, the axial compression ratio of steel reinforced concrete t-shaped cross section column hysteretic properties of the important factors. Other factors in the same situation, along with the increase of axial compression ratio, the hysteresis curve falling faster, hysteresis loopsignificantly narrowed, hysteresis loop number is also reduced.

### 5.5 The influence of shear span ratio.

Comparison in figure 7(a) and (c) and figure 8 SRC_TT1 and SRC_TT3 skeleton curve, reducethe shear span ratio can obviously increasethe steel reinforced concrete T-shaped column shear bearing capacity of column.

### 5.6 The influence of the load Angle

Respectively along the steel reinforcedconcrete T-shaped cross section column of twoengineering axis loading, from (a) and(d)of figure 7 and figure 8 SRC_TT1 、SRC_TT4 skeleton curves, along the direction of web load component of the bearing capacity is greater than the load along the direction of the flange, this is because the load along the direction of the web, the sections are far away from the section centroid, can give full play to the tensile properties of the steel, and along the flange loads, because the artifacts to shift,reduce its bearing capacity.




（a）SRC_TT1 （b）SRC_TT2

（c）SRC_TT3 （d）SRC_TT4

**Fig**.7 Load (*P*)-displacement (*Δ*) hysteresis loops

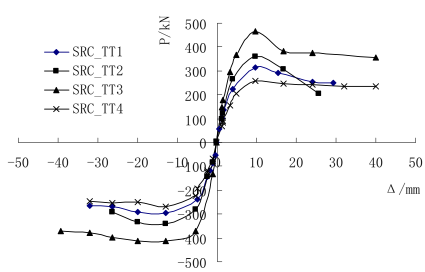



**Fig.8** Skeleton curves of specimen

## 5.7 The displacement ductility coefficient calculation

The displacement ductility coefficient of structure or component means the ratio of the ultimate displacement to the yield displacement.

$$\mu_{\Delta} = \Delta_u / \Delta_y \quad (1)$$

In this formula:

$\Delta_u$——the limit displacement, ultimate displacement limit load drop 15% when taking the corresponding displacement

$\Delta_y$ ——the yield displacement, it can be defined by the energy method.

By four pillar of steel reinforced concrete T-shaped column of skeleton curve calculation, get the displacement ductility coefficient of them, as shown in table 4, known after joining steel special-shaped columns has good ductility and displacement ductility coefficient were greater than 3, even can reach 6. Can see from table 4, and decreases with the increase of axial compression ratio, axial compression ratio increased from 0.3 to 0.5 30% lower displacement ductility, axial compression ratio are the main factors that control the ductility; Along the flange loads ductility little change, but the bearing capacity is reduced.

TABLE.4 DUCTILITY OF SPECIMEN

| Specimen number | axial compression ration | Shear span ratio $\lambda$ | Load angle $\alpha$ | Displacement ductility $\mu_\Delta$ | Variation rate of ductility coefficient $\mu_\Delta$ |
|---|---|---|---|---|---|
| SRC_TT1 | 0.3 | 1.5 | Along the web | 5.35 | ------ |
| SRC_TT2 | 0.5 | 1.5 | Along the web | 3.67 | -31.4% |
| SRC_TT3 | 0.3 | 1.2 | Along the web | 6.31 | 19.7% |
| SRC_TT4 | 0.3 | 1.5 | Alongthe flange | 5.73 | 7.1% |

## 6 Conclusion

After successful simulation test, this article through to select correct model and reasonable parameters, the steel reinforced concrete T-shaped section columns in an axial compression ratio, shear span ratio and load Angle numerical simulation test. By using Marc software, through the reasonable selection of material parameters to simulate steel reinforced concrete T-shaped section columns under different load cases of hysteretic performance test, can get reasonable results; Steel reinforced concreteT-shaped cross-section load-carrying capacity decreases with the increase of shear span ratio; Displacement ductility decreases with the increase of axial compression ratio; Along the web plate loading mechanics performance is better than that of the flange load; Steel reinforced concrete t-shaped section columns has good ductility performance, displacement ductility coefficient were greater than 3.

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