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Research on the dynamic behaviors of semi-rigid CFST frame-shear wall

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ABSTRACT: Concrete filled steel tubular (CFST) structure is a new type of structure. Assuming that concrete filled steel stub frame-shear wall is continuous elastic structure with infinite degree of freedom, free vibration equation is built. Furthermore, the effects of semi-rigid connection on natural periods and frequencies are studied. The formula to calculate the coefficient of natural periods is deduced. ANSYS is employed to determine the modal analysis. The results obtained from finite element analysis are consistent well with those obtained from formula. The results show that semi-rigid connections tend to increase the natural period. However, the effect on higher modes is negligible. The seismic design suggestions of the semi-rigid concrete filled steel stub frame-shear wall are proposed. The proposed methods may supply references for the engineers.

1 Introduction

In recent years, CFST shear wall structure with its wide adaptability and good seismic performance is widely used in high-rise buildings. In general, concrete filled steel tube columns and beams (steel or reinforced concrete beam) is connected neither fully rigid nor ideal hinge, under the action of load will show a certain degree of semi rigid [1]. Semi rigid connection change of concrete filled steel tubular frame lateral stiffness, structural stiffness characteristic value corresponding to changes. As everyone knows, eigen value of structural stiffness changes will affect the frame shear wall structure of the vibration cycle and frequency dynamic characteristics, and the natural vibration period of the structure subjected to dynamic loading structure and frequency is an important parameter in the design, but also the response spectrum analysis and time history analysis of foundation. So emphasis should put on the design of this system. Therefore, study of semi rigid connection effect on the dynamic characteristics of the earthquake area, the structure design according to the actual semi rigid connection to consider, can more accurately be internal force analysis of structure, promote the economic and reasonable structural design. Based on frame shear wall structure in cooperative work assumption, the frame shear wall structure as an infinite number of degrees of freedom elastic continuum structure, with the establishment of the differential equations of free vibration equation, and thus obtained the semi rigid connection of frame shear structure natural period of vibration. The seismic design suggestions of the semi-rigid concrete filled steel stub frame-shear wall are proposed.

2 Calculations of semi rigid connection structure stiffness characteristic value

When the connection is semi rigid, the connection can be equaled to rotational spring [2]. If we do not consider the beam axial deformation and shear deformation, semi rigid beam element stiffness matrix can be expressed:

$$[K]=\frac{2EI}{L\ (1+4\alpha+3\alpha^2)}\begin{bmatrix}2+3\alpha & 1\\ 1 & 2+3\alpha\end{bmatrix} \tag{1}$$

In which α is the ratio of beam end rigidity and connection stiffness.When the connection is semi rigid, the beam stiffness reduction factor for $(1+1.5\alpha)/(1+4\alpha+3\alpha^2)$, transfer coefficient of reduction coefficient for $1/(2+3\alpha)$. Due to the column is continuous, so the column rotational stiffness and the transmission coefficient do not change. The semi rigid connections of CFST frame shear structure stiffness characteristic value:

$$D=\frac{V}{\Delta}=\beta\frac{12i_C}{h^2} \qquad (2)$$

In which $S=\frac{1+1.5\alpha}{1+4\alpha+3\alpha^2}$; $\beta=\frac{S\bar{i}}{2+S\bar{i}}$ .So the eigen value of structural stiffness is expressed for:

$$\lambda=H\sqrt{\frac{Dh}{EI}}=H\sqrt{\frac{C_F}{EI}} \qquad (3)$$

3 Influence on the self vibration period and frequency

Assumed frame shear wall structure work together, the deformation curve as shown in Figure 1 [3]. Uniform distribution, mass per unit length is m. Structure as the infinite freedom degree continuous structure, frame-shear wall structure free vibration differential equations of motion for the [4]:

$$EI\frac{\partial^4 y}{\partial z^4}-C_F\frac{\partial^2 y}{\partial z^2}=-m\frac{\partial^2 y}{\partial t^2} \qquad (4)$$

If $y=\varphi(z)T(t)$, $\frac{\partial^4 y}{\partial z^4}=\varphi^{(4)}(z)T(t)$, $\frac{\partial^2 y}{\partial z^2}=\varphi''(z)T(t)$,

$\frac{\partial^2 y}{\partial t^2}=\varphi(z)\ddot{T}(t)$, (1)is equal (5)

$$\varphi^{(4)}(z)T(t)-\frac{\lambda^2}{H^2}\varphi''(z)T(t)=\frac{\lambda^2}{C_F H^2}\left[-m\varphi(z)\ddot{T}(t)\right] \qquad (5)$$

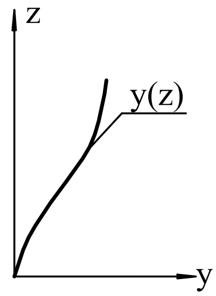


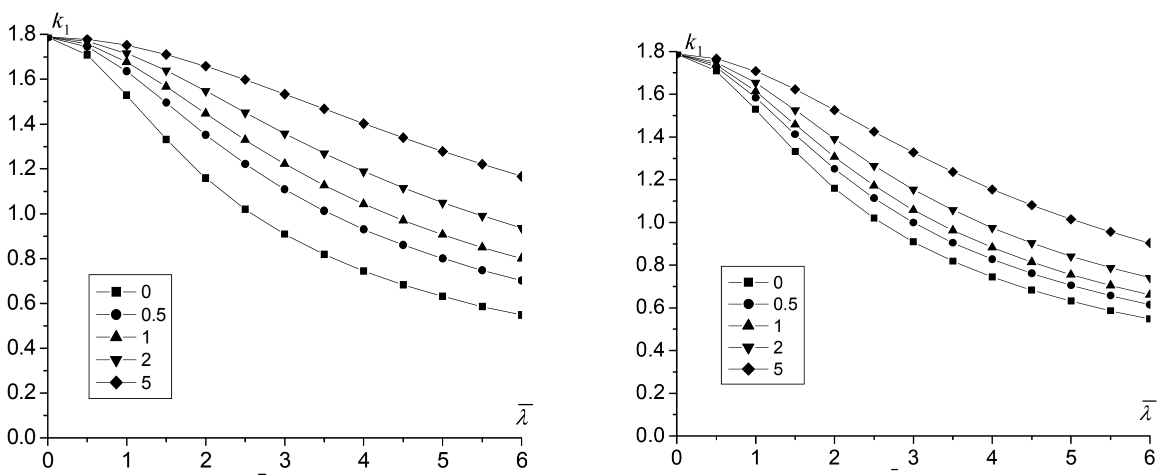
Fig 1 Deformation curve of the structure

If $\frac{\ddot{T}(t)}{T(t)}=-\omega^2$, (5)can be divided into (6) and (7).

$$\ddot{T}(t)+\omega^2T(t)=0 \qquad (6); \qquad \varphi^{(4)}(z)-2a^2\varphi''(z)-b^4\varphi(z)=0 \qquad (7)$$

Type of cycle influence coefficient can be expressed $k_i=\frac{2\pi}{\lambda_{1i}\sqrt{\lambda^2_{1i}-\lambda^2}}$.

Assumed rigid connection of frame shear wall structure stiffness characteristic value of nominal rigidity characteristic value $\bar{\lambda}$, hinged to frame shear wall system as an example, studies of beam column linear stiffness ratio of beam, the rigidity of beam end connection stiffness ratio, nominal rigidity characteristic value and other parameters of semi-rigid connection of frame shear wall structure period of vibration effect. Length of be confined to, the article is given only and two different connection stiffness (= 0, 0.5, 1, 2, 5) of the first natural period of structure influence coefficient diagram, as in Figure 2 (a), (b) shown below. As can be seen from the graph:



$\bar{i}=0.5$ (a) $\bar{i}=5$ (b)

Fig 2 First natural period of structure influence coefficient

(1) semi rigid connection makes the natural vibration period of the structure increases, and along with the increase of cycle, also increased, but the increasing trend of gradual. When = 0.5, = 2; = 0.5 and 5 respectively 1.3519, 1.6585. This is because the semi-rigid connection makes the stiffness of the structure is reduced, the corresponding period increases.

(2) rigid connection, i.e. = 0, the natural vibration period of the structure with beam and column linear stiffness ratio of unrelated; considering semi rigid connection, the connection stiffness under the same circumstances, along with the increasing, the natural vibration period of the structure is reduced; when = 2, = 2; = 0.5 and 5, respectively. 1.5472, 1.3912. This is because as increases, the rigidity of the structure increases, decreases cycle.

(3) semi rigid connection to the structure of the second period and the third period the influence trends were similar, but the rate of decrease, such as = 0.5, = 2, if = 0 three cycles before the influence coefficient is respectively 1.1591, 0.2536, 0.0979; when = 5 three cycles before the influence coefficient is respectively 1.6585, 0.2811, 0.1011, change extent is respectively 43.09%, 10.84%, 3.27%. Semi rigid connections on low order modes of vibration period of significant influence of high modes, the little effect on natural vibration period can be ignored..

4 Numerical results and discussion

In order to verify the formula, the universal finite element software ANSYS is employed to analysis the structure. Because the formula derivation assumed calculation diagram is a plane system, so the finite element analysis of unit selection should also pay great attention to the choice of plane unit, otherwise the previous order zero frequency. Semi rigid connection of steel pipe concrete frame shear wall structure is mainly composed of shear wall, frame beam column and nodes. Shear wall with PLANE42 unit simulation, the unit has two translational degrees of freedom of plane entity unit, through key options can be simulated with the thickness of shear wall. Column and beam is simulated by BEAM3, BEAM3 is plane Euler beam element, each node has X and Y displacement direction and the Z axis angle displacement of 3 degrees of freedom; shear wall with frame between the rigid rod chain with LINK1 unit simulation, the unit as a two-dimensional space and axial tension and pressure, without considering the bending moment, each node has X and Y direction of displacement of two degrees of freedom, its rigidity by increasing the elastic modulus of the material to achieve; modeling beam column connection establishment with the position of the different nodes, coupling beam to column connections at different node, and then through calculation example diagram in Figure 3

The same position two on different nodes to generate spring damper element COMBINE14 to realize the simulation of semi rigid connection of [5].

As shown in Figure 3 20 layers of steel concrete frame shear wall structure, height is 3M, wall thickness 200mm, frame beam section is 300mm ×600mm, concrete filled steel tube column with diameter of 600mm, =1, other dimensions such as shown in the figure (figure not specify the size of mm). Elastic modulus is 3e10N/m^2, density is 2500kg/m^3. Calculation of the first three cycles, the formula for calculating results and finite element calculation results are shown in Table 1, formula considering the effect of axial deformation.

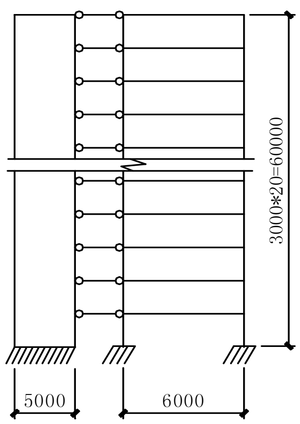


Fig3 Calculation example

Table1 Natural period Unit（second）

T / α	first period		second period		third period	
	formula calculated	finte element calculation	formula calculated	finte element calculation	formula calculated	finte element calculation
0.5	1.373	1.452	0.268	0.278	0.100	0.107
1	1.446	1.568	0.273	0.285	0.100	0.108
2	1.533	1.660	0.276	0.289	0.101	0.108
3	1.583	1.701	0.279	0.291	0.101	0.109
4	1.617	1.723	0.280	0.292	0.101	0.109
5	1.650	1.738	0.281	0.292	0.101	0.109

As you can see from table 1, the formula calculation and finite element analysis results are in good agreement with; natural vibration period is in 7% the following. On the higher mode of vibration period, the results of the two methods tends to be equal, the first few modes from the vibration cycle, calculated results are slightly smaller than the results of finite element analysis.

With the results of finite element analysis, the results of calculation using the response spectrum method for calculating equivalent seismic action, will make the equivalent seismic action are relatively large, the structure is advantageous for the [6].

5 Conclusions

The most important conclusions drawn from the present study are as follows:

(1)In order to frame shear structure of collaborative work assumption, the frame shear wall structure as an infinite number of degrees of freedom elastic continuum structure, with the establishment of the differential equations of free vibration equation, which is derived semi rigid connection of frame shear structure formula of vibration period.

(2) The use of the finite element analysis software ANSYS verification of the formula, the results are in good agreement with. Formula for the calculation of the cycle is slightly smaller than the finite element calculation of the cycle, in the earthquake zone by response spectrum method for calculating equivalent seismic action, will make the equivalent earthquake offset is large and the structure is safe, the structure design is advantageous.

(3) Study of semi rigid connection of structural self vibration period effect. Analysis results show that, semi-rigid connection makes the structural self vibration period increases; semi rigid connections on the low order vibration mode effect on natural vibration period of the more significant, the higher modes of vibration period of little effect can be ignored.

(4) Along with the beam rigidity of connection stiffness ratio increases, the effect of semi-rigid connections on the cycle of slow, when more than 2 effects is very small, so when more than 2 can be thought of beam to column connections is hinged.

(5) In the frame shear wall structure in the preliminary design, general stiffness characteristic value in 1.1～ 2.2 between. In seismic area of frame shear wall structure design of senior high school entrance examination into the semi rigid connection, according to the connection stiffness revised the appropriate nominal rigidity characteristic value.

(6) The formula can be used in seismic areas of semi rigid connection of frame shear wall structure design, the periodic coefficient chart, simple application, convenient for engineering designers. The formula can also be applied to the consideration of semi rigid connection of steel concrete mixed structure system.

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