The influence of filled walls on seismic performance of reinforced concrete frame structure

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Abstract

Currently the infilled walls structure design of reinforced concrete frame filled walls into is acting on a frame beam are wiring load is calculated, and the natural period of the structure by 0.6-0.7 reduction coefficient of reduction. While ignoring the interaction of infilled walls and frame structure, the article describes the effect of infilled walls on seismic performance from the horizontal bearing capacity, stiffness, natural vibration period and constraint effect. Infilled walls frame structure can improve the bearing capacity of the level; increase structural stiffness; reduce natural vibration period of structure. Design should avoid infilled walls and frame structure form of short columns and short beam.

Keywords

Infilled walls; Frame structure; Seismic performance.

1. Introduction

Frame structure is a structural system, widely used in construction. It`s advantage is flexible layout, interior space is large, and so on. Widely used in multilayer shop building, hospital buildings, hotels and other buildings. Frame structure uses porous masonry or lightweight concrete blocks as infilled walls to perform a functional partition. As an important part of construction, traditional design ignoring the interaction of filling wall and frame structure, and regard infilled walls as line load, only consider the reduction of structural natural vibration period is insufficient.

2. The influence of infilled walls on bearing capacity of structure

Under the action of horizontal load, infilled walls and frame between the contacts is not very close at the beginning of loading, structure in the elastic state, it can be thought of as almost all of the horizontal load borne by the frame. With the increase of load, the infilled walls and frame close contact, the load infilled walls bear is bigger and bigger. Before the overall structure overturning, infilled walls and frame to resist horizontal load together. The ability of frame structure with infilled walls to bear capacity greater than the pure frame structure. And the earthquake energy frame structure with infilled walls absorb is 3.2 times than the pure frame structure [1]. Zhu Ronghua [2] and Liu Yumei [3] on their own did dynamic seismic response simulation test and pseudo-static test to frame structure with infilled walls, the result show that the ability of frame structure with infilled walls to bear capacity is about 1.5 times of the pure frame structure.

Literature [4] proposes calculation formula of the lateral force of the frame:

$$V_u = V_{r,w} + V_{u,f} \tag{1}$$

According to formula: $V_{r,w}$, $V_{u,f}$ correspond to the lateral force of the infilled walls and the frame, Can be determined respectively by the following formula;

$$V_{r,w} = \mu\left[\sigma_0 + 0.6\frac{1}{\alpha A_w}(\frac{H_w}{L_w})V_w\right])A_w \tag{2}$$

Shear-bend break:

$$V_{u,f} = \frac{0.1}{0.1+\lambda} f_c b_c h_0 + 0.8 f_v \frac{A_{sv}}{s} h_0 + 0.7N + \frac{2M_{y,c}}{H} \tag{3}$$

bend-bend break:

$$V_{u,f} = \frac{4M_{y,c}}{H} \tag{4}$$

According to formula: μ is masonry friction coefficient, Generally in 0.6 -0.7; σ_0 is the average compressive stress on the infilled walls; αis location coefficient of interaction between frame and infilled walls ; A_w, I_w, H_w the cross section area , moment of inertia and the height of the infilled walls; V_w is the horizontal force infilled walls bear ; λShear span ratio; $M_{y,c}$ frame column reinforced yield bending moment.

3. The influence of infilled walls on the structural stiffness

The in-plane stiffness of the infilled walls is very big. As a result of the existence of infilled walls, the level of the frame structure of lateral stiffness increased [5]. Many academics did the test of seismic performance on frame of infilled walls, but the results are large difference. Some frame structure stiffness increased six times[6], but others increased nine times[7].We can see there are many factors to affect the improvement of frame structure stiffness, without exception all the framework of the lateral stiffness increased, there is an obvious stiffness effect.

Due to the use function requirement of buildings, sometimes infilled walls is uneven horizontal layout and different vertical layout of each layer. The infilled walls of uneven horizontal layout will have detrimental impact on framework of torsion [5]. The infilled walls can increase the torsional stiffness of the structure in even and symmetrical layout to prevent unequal stress of structure, which caused by torsional effect. But if the arrangement of infilled walls is uneven symmetrical, it will make the stiffness center of structure deviated from quality center, and strengthen the torsional effect of the structure. The different kind of vertical arrangement of infilled walls makes it not continuous in the vertical stiffness. The floor, whose fill rates are relatively small became the weak floor due to the more weak stiffness than adjacent floors. Under the seismic action, the weak layer easily be destroyed even collapse. It should be considered at design time that to avoid the existence of the weak layer, the quantity of infilled walls should not be less than 60% of adjacent layers.

However, the lateral stiffness of frame structure with infilled walls is not equal to the sum of stiffness of infilled walls and frame lateral. Because ultimate tensile strength of mortar of infilled walls generally at about 0.25 MPa, when lateral force of the earthquake action is greater than the ultimate strength of mortar, bonding between brickwork is damaged, infilled walls cracks, in-plane stiffness of infilled walls decrease. When the infilled walls is completely destroyed, its effect on structure disappears. When stiffness of infilled walls degradation occurs, the lateral displacement of the structure is more obvious. Thus it can be seen that under earthquake action, when frame structure is into the late elastic stage, infilled walls is already at ultimate strength of damage. If still use the stiffness in the initial stage, it`s harmful to structure. So, at structural seismic design time, stiffness after degradation should be taken to improve the accuracy and safety of the design analysis. Literature [4] put forward formulas for calculating the lateral stiffness between the layers:

$$K = \beta / \left[\frac{H^3}{3E_w I_e} + \frac{\kappa H_w}{G_w A_e} \right] \tag{5}$$

According to formula:$\beta$is the factor cause walls deformation modulus decreased, $\beta \le 1$,$\beta=1$, H, H_w is the height of frame and infilled walls, κ is infilled walls shear coefficient ,E_w, G_w the elastic modulus and shear modulus of walls, A_e, I_e is the effective area of horizontal section and effective moment of inertia . It can be determined by the following formula:

$$A_e = A_w + 2\alpha_c A_f \frac{G_f}{G_w} \tag{6}$$

$$I_e = I_w + 2\alpha_c \frac{E_f}{E_w}(I_f + 0.25 A_f L^2) \tag{7}$$

According to formula: I_w is the horizontal section and moment of inertia of the infilled walls; α_c is the framework to lateral contribution stiffness coefficient, When frame contact well with infilled walls, it is equal to 1, when there is gap, it is equal to 0; A_f, I_f is the frame column section area and moment of inertia; G_f is the frame column shear modulus; L is the frame span.

4. The influence of infilled walls to structural natural vibration period

Since the natural vibration period is one of the important parameters of structural dynamic characteristics. When design the frame structure with infilled walls, you should think about the infilled walls` influence on frame structure system by using period reduction factor 0.6-0.7 to reduce natural vibration period [9]. According to increasing the number of infilled walls to increase the stiffness of whole structure, while the natural vibration period is inversely proportional to the stiffness [10]. Therefore, with the increase of infilled walls filling rate, frame structure of the natural vibration period decreases [11].

Infilled walls` influence of the different arrangement of plane frame structure is different on natural vibration period. When the amount of infilled walls decorate in the transverse and longitudinal directions is uniform, the natural vibration period of the structure decreases with the increasing of the filling rate. But when the fill rate is fixed, change of infilled walls arrangement has no effect on natural vibration period of the structure almost. When the amount of infilled walls decorate in the transverse and longitudinal directions is not uniform and the fill rate is fixed, change of infilled walls arrangement has great effect on natural vibration period of the structure, even makes natural vibration period increase. Due to different arrangement of infilled walls in a vertical frame structure ,the influence degree of the natural vibration period is different.Hu Bijiao [12] and Liang Fengyi's [13]researches show that when the filling rate is the same, the weak layer central position at the bottom , the middle , the top of the structure ,the natural vibration period decreases in turn. The infilled walls at the top have a greater influence on the natural vibration period of structure, while at the bottom is weaker.

From literature [4], we know that walls materials have important effects on the stiffness of frame structure, different material block of infilled walls have the different degree of influence on natural vibration period of structure. For light aggregate concrete block, when the filling rate and fill method is the same, structural natural vibration period of bulk density larger blocks is relatively larger. According to Du Qi [14] and others` analysis of the bulk density in grade 900 and 1200 of light aggregate concretes, it been found that effect of level 900 bulk density of lightweight aggregate concrete block on the natural vibration period is bigger. Its' period reduction factor is less than 1200 level density of light aggregate concrete block, but the gap is slight, the biggest gap is 7.72%.

5. Infilled walls constraint effect

The infilled walls makes the main structure components limited by a certain degree of deformation and reduces the calculated height of beam or column. Most of the time the constraint effect of infilled walls causes safety hidden trouble to structure.

When set up a general window between adjacent columns, infilled walls is just like elastic restraint in the ends of the frame column. Thus the calculation height of column reduced and formed a short column structure [15].After the formation of short column, its stiffness improved, the shear of column bear greatly increased, and the deformation ability dropped, brittle shear failure under the seismic action is easy to happen .When set up a door opening in the infilled walls, infilled walls is just like elastic restraint in one end of the frame beam to reduce the calculation span of beam and form the short beam structure [16] . In 1997, Zhu Zhida [17] tested the seismic behavior of the reinforced concrete short beams, the result showed that the short beam brittleness is big, ductility is poor and easily be destroyed into shear failure.

In addition, as the results of 9.21 earthquake, many brittle shear failures appeared in the underlying column of infilled walls frame structure. Because of the combination of infilled walls and beams, artifacts similar to the walls beam formed. The stiffness of the beam greatly increased, and is greater than the stiffness of beam column. So that the original design of the strong column weak beam system became a strong beam weak column system. In Literature [18] there is a test against the shock on the frame beam and the upper walls of the walls beam. It showed that the combination of the walls beam bending stiffness is bigger than frame column, and can even see it as a new beam bending stiffness is infinite. In this case, many designers believe that the strong column weak beam system is actually a strong beam weak column system.

6. Conclusion

Infilled walls can improve the level of the frame structure bearing capacity and absorb the energy of the earthquake, it`s necessary to strengthen the construction measures of the infilled walls to prevent from falling off under the action of earthquake. When arrange the infilled walls, it should be uniform and symmetrical between the layers, the vertical change should not be mutation in frame structure. Avoid formation of weak layer .As for the determination of period time deduction factor, it`s better on the basis of 0.65 to add and subtract according to the actual situation. Finally it`s necessary to avoid infilled walls and frame structure form short column and short beam.

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