

Ground-floor Shop's Facade Decoration of High-rise Affects the Seismic Level

ZHOU Ping^{1, a *}

¹Institute of Xinjiang Construction of Vocational and Technical, Urumqi, 830054, China

^aLic142@126.com

*Corresponding author

Keywords: ground-floor. facade decoration. seismic level. high rise.

Abstract. Whether and in what degree the facade decoration of rent shops on ground floor in a high rise residential building affects the earthquake-resistibility of the structure? The author analyzes the mechanics quantitatively, and draw that the seismic level of the building will reduce about 0.3 level. Additionally, the way of avoiding is presented in this paper.

Introduction

If the structure of a high building shown in Figure 1, how is about its capacity of earthquake resistance? Upstairs tenants will surely feel unsafe. Suppose there appears some slight gaps during some decoration process at point A, the support there can be considered as a smooth plane support which cannot bear binding forces nor tension constraint. At the beginning few seconds of a big earthquake, if those small gaps become larger broken, point A could be looked as empty and suspended in midair, cannot withstand tension, and can neither bear side forces nor even pressure. When the vibration force act in F_1 direction, G and H will be subjected to periodic changes of great tension and pressure.

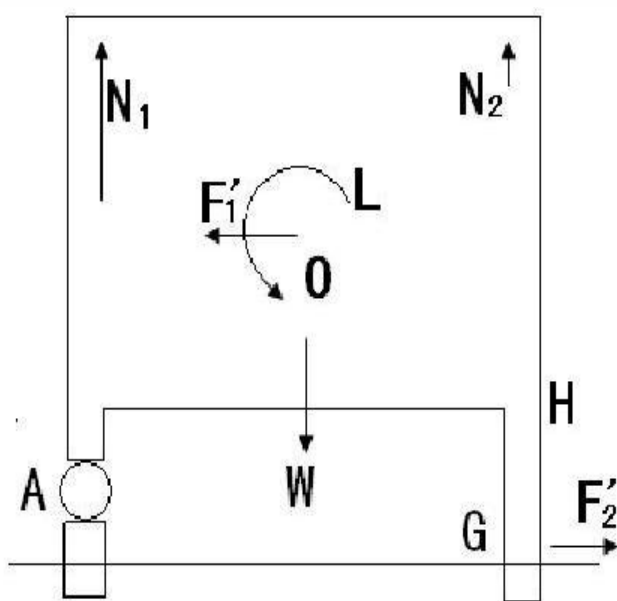


Figure 1.Simplified Force Analysis

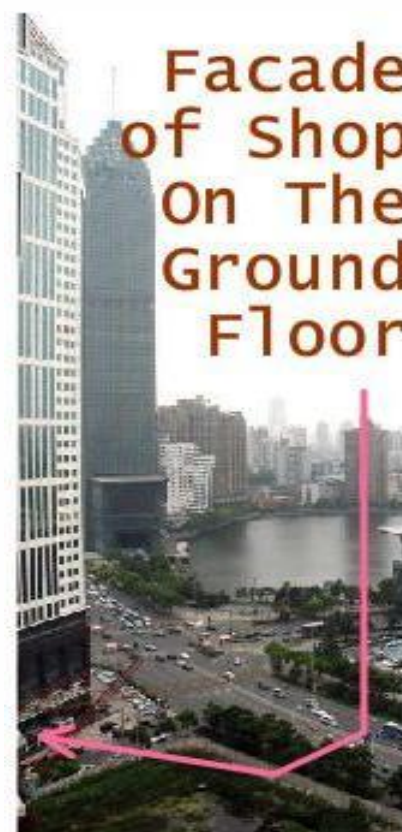


Figure 2.Facade of Shop On The Ground Floor

Will this map come true?

Nowadays in many cities in China, a lot of high-rise residential emerged because of the expensive land prices.^[1] The constructor consider their own economic interests, and the efficient use of land, the ground-floor of many high-rise residential will be made as shops for tenancy (shown as in figure 2). The businesses who rent the shop will do decorations first. And when they leave, the new tenants will usually destroy the original decoration and do the job again. They will punch some steel nails against the wall or even column in every decoration, especially the facade decoration and the outer door of guard. Particularly, will some nail hit into column and the corner of whole building, it is here that the stress is the most concentrated of whole building, and a slight loss of its strength will cause the whole building to reduce its quake-resistibility level. If many slight damage appeared mostly at the front column and also, within the height of ground floor, just as A in Figure 1, the situation of Figure 1 will come true. Then in a few seconds at the beginning of a strong earthquake, the ground floor front columns will be widespread damaged and cracking, but higher floors have less damage, as well as the side post and back wall even within ground floor. Looking the building from side, we can get a simplified mechanics model as shown in figure 1.

Now the strong earthquake continues, in the following ten seconds or longer, Point A will be suspended in midair because of the widespread damage, mechanical balance is broken, the ground floor may completely collapse, the upper floors of whole building will sit down lower. That is: the upper body of the building seems a rigid body. Because of the impact force, the second floor may collapse after, as if the whole building suddenly become another building of one or two layer shorter. The upper part of the building remains intact and the same. In Sichuan Wenchuan big earthquake, this movie showed on some multi-storied residential building.

Force Analysis And Stress Calculation

Now we come to make a stress analysis of the situation in figure1. We use the plane rigid body mechanics model to analyze. In Figure1, the column at A point has been slightly damaged earlier during some decoration process, so is easily widely damaged in the first few seconds of a strong earthquake. Since then, this point has been unable to bear great tensile and side force, assumed can also withstand pressure force temporarily. As if a roller is insert there, as in Figure 1.

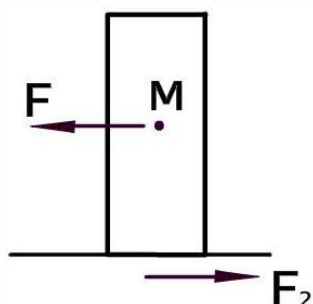


Figure 3.

And the earthquake continues.

Point O is the centroid of the building. In the earthquake, we have a vibration equation

$$\Delta x = \Delta x_{\max} \sin(\omega t + \varphi). \quad (1)$$

Here, Δx_{\max} in formula (1) is vibration amplitude, ω is circular frequency.

The acceleration is

$$(\Delta x)'' = -\omega^2 \Delta x_{\max} \sin(\omega t + \varphi).$$

Assumed M is the total mass of the upper body of the building, Then the vibrate force the building beared is F (shown as in figure3, Direction and Acting point of F is the same as F_1 in figure1) :

$$|F| = \omega^2 M \Delta x_{\max} \sin(\omega t + \phi). \tag{2}$$

From (2) we know, at the moment when F is the maximum negative value, we have,

$$|F_{\max}| = \omega^2 M \Delta x_{\max} ,$$

i.e., F'_1 is the transient maximum of vibrate force F

$$|F'_1| = |F_{\max}| , \text{ Direction to the left.}$$

At this moment the ground instantaneously moves to the right, inertial force determine F'_1 to the left.

F'_2 in figure 1 is ground's pulling force acting on building body (which shown as F_2 in figure 3). F'_1 and F'_2 form a force moment, a torque L, which get equilibrium with another torque (shown as L_2 in Figure 4) which formed by N_1, N_2 and W ($W = Mg$).

Assume the building's instantaneous pressure at A is P' (shown in Figure 5). Then we have,

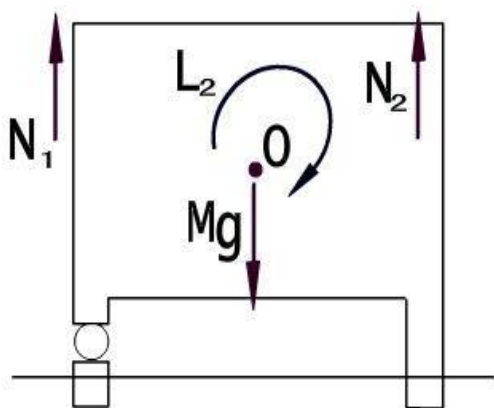


Figure 4.

$$|F'_1| = |F'_2| = |F_{\max}| = \omega^2 M \Delta x_{\max} ;$$

$W = Mg$, is a constant.

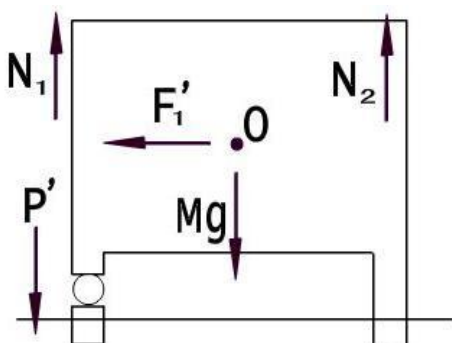


Figure 5.

$$P' = - N_1,$$

And at the moment, $N_1 + N_2 + W = 0$;

So we have,

$$N_1 = - N_2 - W .$$

It means, N_1 is a very big force at that moment.

Because the broadwise between O and A is a constant, while L is increasing with F'_1 , and is proportional to ω^2 and Δx_{\max} , therefore in a strong earthquake, the N_2 can be negative when

$|N_1| > |W|$, so it is possible that

$$|N_1| = |N_2| + |W| .$$

That is to say, the supporting force at points A, $P' = - N_1 = Mg - N_2$, may be larger than the building's weight itself, and even several times. Such a huge pressure added at point A with the circular frequency ω , where the

column had been injured earlier already. This can make the column completely broken at that point. In addition, Pressure P' makes the micro deformation of the column at A, so HG will be subject to instantaneous bending force. Because the damaged column at A don't withstand shear forces, earth's pulling force on building body will focus at G point. It makes the column bend at G point. This deformation can be considered as twice as that when A point was not damaged. In addition, lateral micro-translation of A makes the upper building's lateral micro translation as a rigid body. It will lead to bending deformation of the column at H point in opposite direction, and this micro bending deformation should be in the same order of magnitude as that at G point but in opposite direction.

That is to say, without calculating lateral movement friction, in the condition of column damaged at point A, bending damage risk of HG section column should be more than doubled in later period of time in strong earthquake compared with that in case no damage at A. Situations on different buildings (such as the construction material, etc.) is not the same, but we can draw a rough, if taking into account the lateral movement friction at point A, the bending damage risk of HG segments should increase to roughly doubled.

$$Lg2=0.301;$$

Therefore the building's seismic level should be reduced by approximately 0.3 level.

Consequence Analysis

When we put a nail into the post, the impact force would instantaneously cause some micro deformation in the column surrounding the nail, as well as some changing of stress distribution status. That will cause micro cracks increase in reinforced column, and decrease fatigue strength. Some steel nails would be put directly to reinforcing steel inside the column. That is to say, the nail hit to the post, will do more or less damage to it. And also, using percussion driller to drill holes against column is very common in decoration; similarly, it will cause some micro damage to the column.

The large differences of compressive stress on vertical components of reinforced concrete structures will bring danger to residential building^[2].

Earthquakes of low level are occurred frequently but people usually don't feel. Generally speaking, a building will have experienced many minor earthquakes before undergoing a strong earthquake. In the usually frequent slight earthquake experience, the injury in the column will be aggravated, which had been slightly damaged before, in decoration, and fatigue strength decreased. For example, a building just built only for 5-10 years may be equivalent of 50 years of age or more compared with the building of no damage in the post because the damage of its front column.

That is to say, shops decoration on ground floor in a high-rise residential building will damage the building because, that facing the street side and within the height of ground floor, columns' strength may be significantly below the design requirements. The new building, which had just been put into use, will be in fact equivalent to the old residential beyond the life spans because of those columns. In the first few seconds of a powerful earthquake, cracking will appear at damaged parts of the column, thus forming the case of point A in figure 1., and even completely broken there.

According to "The standard of dangerous building appraisal" promulgated by China's Ministry of construction, crisp cracking of concrete in column or wall, and cross-section decreasing of The main reinforcement shall be evaluated for the danger point.^[3]

Therefore, only from the large earthquake resistance point of view, it will actually reduce the high-rise residential building's lifespan very much to decorate ground-floor-shops, to put nails in columns, and even to impact drilling on the column. That is, the merchant's decoration behavior actually harms the interests of all the residents of the building greatly, and will reduce the seismic performance of the whole building with about 0.3 level. The decoration behavior not only influence the safety coefficient of all households' life, violate their right to survival, but also make the actual value of all household unit for a bigger cut, that is against all the owners of their property right.

Today's high-rise residential usually have more than 200 households, nearly a thousand people living in each. Therefore, such a decoration, only from the angle of the rigid body mechanics analysis, is a kind of dangerous behavior which can endanger public safety. And by the economic point of view, the shop's decoration for the pursuit of economic effectiveness, is under the condition of the real value greatly damaged of all the owners' houses of the building. From a legal perspective, the building constructor rent the ground floor, collect the rental, and tacitly agree the shop's front decoration and put steel nails into vertical columns, is a interests invading behavior for the purpose of his own profit which endangering the interests of all the homeowners and residents.

It is very difficult to deal with if the building has been tipped^[4]. There for, it is necessary to prevent in advance.

Solution

For this problem above, one of the practicable solutions is to add a steel sleeve on the column within the height of ground floor. Combined with steel sleeve is originally a method used in bridge pier building, if it is used in building the upright post of building, will affect the firm of adhesion of wall and column of the building.

Another solution is, the main building expand a room's width towards the street side in the ground floor. The advantage of this expanding is, that the facade decoration of round floor shops will leave away from the main columns, and also, will reduce the threats of falling objects from building to street pedestrians. The disadvantage is the increased construction area, but to reduce the occupied area is just one of the main reasons to build a high-rise residential building.

Here we have a third solutions: To bring the facade decoration or front decoration in the ground floor into the building design and construction project building, prohibiting the tenants and the residents to do it themselves, who could only do interior decoration which should undergo authorization by the designer and constructor, as well as its construction plan, just as the construction of the elevator shaft, external thermal insulation wall, and all the constructions involves building's external or interior columns by the construction unit in the later stage of the construction period. Corresponding profession regulations or local regulations should be made out.

Summary

Facade decoration of rental shops facing the street on ground floor of high rise residential, will reduce the buildings' seismic level for about 0.3 level. It infringes the rights of all the residents and house-owners of the whole building, and makes the actual value of all the houses in the building greatly reduced. Only from the angle of the rigid body mechanics analysis, that is one kind of dangerous behavior which can endanger public safety. Since construction of the building's main structure had finished, anyone, whether the constructor, households, or merchant, is not allowed to punch steel nails, or drill holes into the pillars of the building. And this could be brought into profession regulation. Namely, columns of high-rise residential building in cities should be under protection of law.

References

- [1] JIA Junwei, GONG Wei, Tilt monitoring system for super high-rise building based on MCU, Journal of Jilin Institute of Architecture & Civil Engineering(J). V01.30 No.1, Feb.(2013) 79-81.
- [2] FU Xueyi, SUN Can, WU Bing, Analysis of Creep Effect on Tall And Super Tall R.C. Buildings, Journal of Shenzhen University Science and engineering(J). V.21, No.4, (2006) 17-22.
- [3] Chongqing municipal land and Housing Authority, Standard of Dangerous Building Appraisal (JGJ125-99), Industry standard of PRC (M), Shanghai Education Press, Shanghai ,2004.

[4] XIE Xiqing, Analysis and Treatment Example of Disease of High-rise Buildings Tilt, Optimize the management of infrastructure construction(J), V.36, No.4, (2005) 115-119.