

Anti-Seismic Mechanism of Palace Type Building in China

Rui Gao^{1, a}, Lingqiang Yang^{1, b}, Yan Wang^{1, c}

¹ School of Civil engineer and architecture, University of Jinan, Jinan, Shandong province, China

^acea_Gaor @ujn.edu.cn, cea_yanglq @ujn.edu.cn ^b, eo_wangy @ujn.edu.cn ^c

Keywords: palace building; timber frame system; Structure methods; China

Abstract. Chinese traditional wooden structure, applied to the foundation column directly above is the main form of connection between the column node, without any connection between the vertical support column, and base and foundation provides only horizontal friction. Gold box bucket bottom slot hall-type building is a kind of the highest rank traditional architecture in China. Under the horizontal inertia force, post partial pendulum and the weight of roof make it reset, as a result, it formed a phenomenon—it is on high level but does not fall (high tumbler). When stigma swing, then cap block move. When the friction was eliminated between flower arm and cap block, relative displacement occurs and we call it “soft neck role”. “The phenomenon of high tumbler” and “soft neck”. These two factors determine the excellent seismic performance of the lifted building.

Introduction

Chinese traditional palace has a unique wooden structure, courtyard style layout, axial symmetry features, which reflects the traditional culture by nature, and reflects the concept of culture and value pursuit—the unity of man and nature. Traditional palace construction which pays attention to foundering orderly, magnificence conveys a strong sense of hierarchy and strict etiquette spirit.

Chinese traditional wooden structure, applied to the foundation column directly above is the main form of connection between the column node, without any connection between the vertical support column, and base and foundation provides only horizontal friction. This paper through the monotonic loading test of column node were two pieces of wood frame swing floating shelf type and pin tenon, analysis of the influence of column slip on the wooden frame structure performance; using structural mechanics to establish the three-dimensional entity of a single room wooden frame structure model, the slippage of this parameter by comparing the column node whether or not, to identify changes of frame column lateral displacement, absolute acceleration, the structure of the hysteresis curve of the seismic performance. The analysis results show that the relative slip of column base can significantly improve the structure and seismic performance of timber frame.

Phenomenon of High Tumbler

There is only friction on contact surface of the architecture between columns and column bases, cap block and baluster capital. it can be reduced to a level placed floating shelf in mechanics. But it is particularly noteworthy that the weak contains a great potential. It is this potential power of Chinese traditional hall building to resist the attacks of the strong earthquake, so it was saved to the thousands of years, analysis are as follows.

According to the “build French” regulation, it is usually with second material in a large hall-type building, the column diameter is 42, the height of Column is 375, The stigma reduced to 24 (to adapt to block head), as Fig. 1a. This system under the action of N in vertical static load, the column bottom is pressured uniformly (or eccentric), in a static balance stable state. The column carrying horizontal F, when an earthquake occurs, due to the particle in the capital, there is friction effect under column, The pillars will fall on one side, the tilting process is the contact point A and B outside stigma and cap block do circular motion, with O₂ as the center respectively, AO₂ and BO₂ as radius (like pole vault a little), the length of AO₂ is 378 and BO₂ is 375.3 (Fig. 1 b). Compared with the height of column, AO₂ is longer 3, it is 5cm as second-class material, However BO₂ just taller 5mm than the height of

column, which can be neglected. In this way, the movement process of the stigma is that point A arcs upward, AO2 as radius rising to the point A', Point B arcs down, BO2 as radius down to the point B', therefore it forms a very small angle α between the column foot and column base surface (Fig 1b). Look at cap block, because of its flat pendulum floating shelf in the capital (excluding stigma tenon), there is not binding to spin placed of posts, but there are axial bracket arm in top open, it will constraint cap block, make it unfree to tilt, when the stigma tilt, cap block remains level, but it is not the original horizontal position (i.e. AB), due to point A do arcuate movement upward point B do arcuate movement downward, it will open a tiny wedge crack between stigma and the end of sumac ($B'A'B'$), at this point, the upper load N passed the stigma only through point A' (or small surface), greatly friction occur on contact surface, so it is not easy to emerge horizontal movement between cap block and stigma, it can only make up arc movement along with point A of the stigma. so that the wedge crack is maintained, but it is just for a moment, the connections of component and load paths changed, the condition of static equilibrium is destroyed, forming a new pattern of force transmission, once the wedge crack take plac, namely the load on roof concentrate to bracket set on columns layer, passed to the following pillars through point A' of the cap block, pillars transfer the load to foundation only through point O2, but the connection of A' and O2 is not linear, while there is a horizontal distance A'O2, the horizontal distance of two points is equal to horizontal distance 33 from point A to O2. the result is to emerge a anti-torque, namely the load N on roof forces the column to swing oppositely around the center point O, to restore the state of static equilibrium and keep frame stability and normal work. This kind of phenomenon is very like folk toy "tumbler". The different is that the toy tumbler center of gravity focus on the bottom, the building center of gravity focus on the top, so we call it "high tumbler" phenomenon.

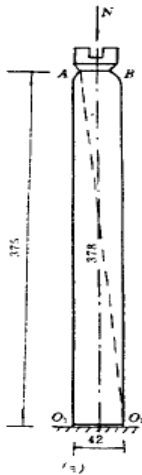


Fig. 1 Phenomenon of high tumbler

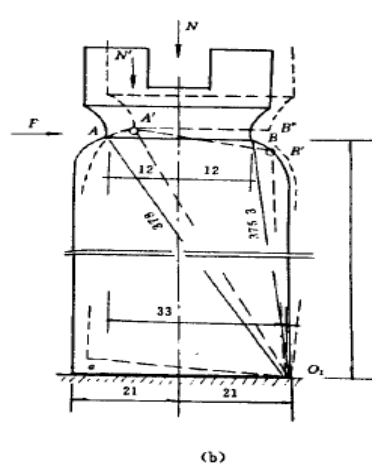
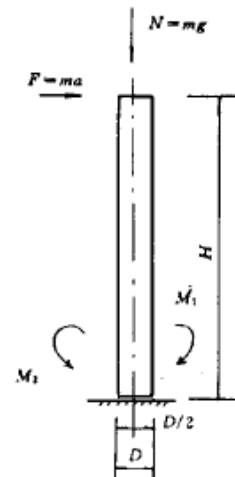


Fig. 2 Pillar force in the most unfavorable conditions



But in fact, there are eaves column and side feet in song dynasty (Fig 2), namely column foot outward tilt 1% (about four copies), if we want to make framework safely, it should satisfy that:

$$M_2 \leq N \cdot [(D/2) - 4], \text{ namely } y, \quad \frac{F \cdot H}{N} \leq \frac{D}{2} - 4 \quad (1)$$

It suggests that the octave earthquake happened can make pillar overthrow with side foot. However as mentioned above, at this moment when the posts will overturn, the role of the upper load point has been moved to point A, the anti-bending moment arm increased eight. The frame system can still ensure safety relying on "high tumbler phenomenon" in octave earthquake even with side feet.

The re-mix changes of the force which produced by buildings in the earthquake, rather like the Chinese Taiji exercise, it avoid positive, without digging force resistance but from the side, using the flexibility to overcome the stiffness, fiddling thousand jin with four liang and wining it artfully. The action of the force is straight when the building is in static equilibrium, the vertical tectonic of frame

deformed immediately, form a new structure state, counteract it with gravity from the side, while the horizontal force pressure in the top of column issued by earthquake, which is much better than the approach of focusing on reinforcement.

“Soft neck” Function of Bracket Set on Columns

When the horizontal earthquake hit the chapter, the cap block and axial bracket arm gripped by cap block move following chapter just as figure 3, slow arch and beam fettered by bulk bucket also deform at the same time, it diverges extrusion and shear to prevent the deformation of block cap and mud way arch and resists earthquake. On the other hand, because the first flower arm in the structure do the special treatment, when the cap block move, it will do, the relationship among the first flower arm, cap block and dirt track arch is flat pendulum floating shelf (figure 3 b). Special treatment on the structure is opened method and size of the flower arm and mud road arch. At the opening bite place of the flower arm and mud road arch, it is 10 at the top opening, below is 5 in mud road arch, it is 5 at lower opening, above is 16 in flower arm, the opening width is 20. It rides dirt track arch and septum ear, there are 2 cracks on each side of the septum ear at the same time. In order to ensure the stability of the roof system, block cap is only affected by the friction exerted by flower arm and pressure exerted by yinzi shoulder, there are 2 relative displacement at least, namely flower arm could move less even motionless, when the block cap moves. Since posts could tilt swing, block cap could move and lower arm could move less even motionless under earthquake force. With the below members moving exchange for upper members less moving even not moving construction method, it is much like toys “soft neck and big head doll” the bracket set on columns play the role of “soft neck”.

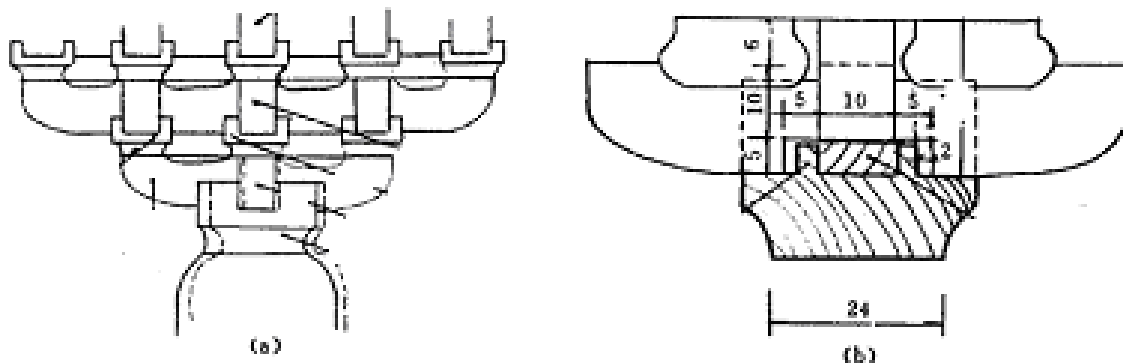


Fig. 3 Role of soft neck in ;bracket set on columns

Conclusions

Pillars and cap block swing synchronously under the level seismic force, it absorbs seismic energy by using self-weight of roof and the "Soft neck" effect formed by the relative displacement between arc and beam, besides, it presents the "high tumbler phenomenon", to ensure the system safe and reliable. It can be said that the excellent seismic performance of timber-halls frame system is achieved by its unique structural design, there is close relationship between both, there has very important significance to maintenance and protection of ancient building.

From the seismic point of view, the hall-type building is based on the pattern of movement-control-movement to keep dynamic balance, unlike the modern structure to enhance stiffness confrontation to keep balance, it shows the unique idea of "flexibility to overcome stiffness" Chinese traditional architectural structure and tectonics.

The roof layer is a rigid, to ensure normal use of roofing maintenance layer; column amount layer is flexible and provides sufficient deformation capacity; bracket set on columns layer is the nexus transitive layer, in three components of the hall-frame system, three components unified with each other as a whole, reflecting the concept of considering structural system integrally.

Acknowledgements

This work was financially supported by the Shandong Natural Science Foundation (ZR2014EL038).

References

- [1] Chinese Academy of Sciences Institute. History of Chinese ancient architecture technology. Science Press. 1990.
- [2] Ma Bingjian. Wood construction technique in ancient China. Science Press. 1991.
- [3] Nima Khorsandnia. Hamid R. Valipour. Nonlinear finite element analysis of timber beams and joints using the layered approach and hypoelastic constitutive law. *Engineering Structures* 46 (2013) 606–614.
- [4] Jochen Kohler. John Dalsgaard Srensen. Probabilistic modeling of timber structures. *Structural Safety* 29 (2007) 255–267