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Research on Design of High Rise Building Based on Seismic Design Theory

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This paper gives a brief introduction to the design and background of performance-based seismic design, the basic theoretical framework and requirements of performance-based design, the application and development of performance-based design in the world. Based on the theory of performance-based seismic design, the design, analysis and research of the engineering example are carried out to demonstrate the safety of the structure. Based on the analysis and design of a super high-rise project, this paper analyzes the type and extent of the structural overrun in the engineering example, and determines the seismic performance of the structure. Using PKPM SATWE to model and calculate the PMSAP and GSSAP, three common structural design software of earthquake in small earthquakes, the elastic calculation results were analyzed; the structure of elastic time history analysis and modal decomposition method were analyzed; in the earthquake, remove the structure of minor components non seismic. Analysis on the bearing capacity of structural component performance according to its seismic performance objectives; for the construction of local floor holes such as floor irregular plane, in the seismic elastic slab stress analysis, to ensure the earthquake floor can reliably transfer the horizontal force; using finite element software PUSH&EPDA and ABAQUS are static and dynamic pushover analysis of buildings under rare earthquake; considering the additional P－Δ effect may bring over height analysis.

1. Introduction

According to the statistics, most of the building structures are controlled by the earthquake, and the earthquake disaster is one of the most natural disasters. To occur through the recent earthquake and harm that, with the development of economy and the development of new materials and new technology to further strengthen the earthquake fortification measures, reduce the failure and collapse of building structures caused by the earthquake, significantly reduced so the number of casualties caused by. However, with the development of intelligence and network, the damage caused by the earthquake is still very serious, and even cause the global economic shock. Therefore, in the seismic design, but also to consider the loss of function during the repair or other functions due to the loss of function and the removal of the costs. The structure of the earthquake proof structure of the high-rise building is shown in Figure 1. The earthquake damage to the building is shown in Figure 2 (Soebiyan et al., 2017).

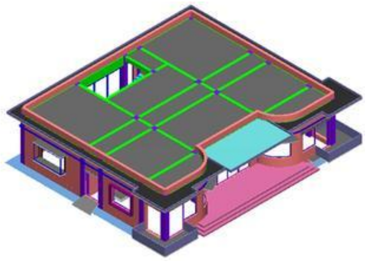

Figure 1: Schematic diagram of building shockproof structure

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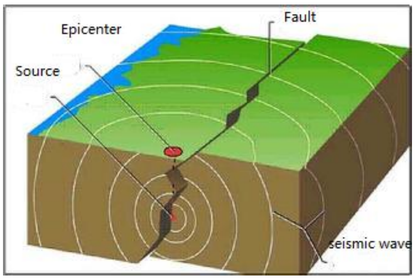

Figure 2: Schematic diagram of earthquake damage to buildings

The performance-based seismic design is not a revolution in the traditional design concept, but is based on the traditional design concept. The traditional three level seismic design idea is at the primary level, low level, the goal is not clear on the level, the initial performance based seismic design of the factors (An et al., 2014).

2. Performance based seismic design theory and design method

The performance level of the building is the performance level of the structure, and the combination of the nonstructural performance level (Huang et al., 2014). For the seismic design of super high-rise buildings, the safety performance level of the structure is not concerned with the non-structure. Basic objectives: the general requirements of the building should have a, B, C, D combination of items. The more important or higher risk performance after earthquake damage is the combination of E, F and G.

The seismic fortification intensity of this project is seven degrees, class III site, the design of the seismic grouping for the first group, the design of the basic seismic acceleration value of 0.1g, the characteristic period of 0.45s, seismic fortification classified as B. According to the seismic safety evaluation of the engineering report, the relevant conclusions are as follows: soil types in this project for soft soil soft soil equivalent shear wave velocity is 127.15 ~ 151.56m/s, construction site for the class III, ground micro tremors cycle averaged 0.45 seconds according to the "code for seismic design of buildings" (GB500112010) the provisions of article 4.1.1, the site can be divided into seismic favorable site for building. According to the total height of buildings, the seismic fortification intensity, building use, the tower system frame core wall structure. The main anti lateral force component for shear wall, mainly set up in the elevator core tube and stair position to provide lateral and torsional stiffness; in order to improve the lateral vertical lateral force resisting member stiffness and reduce section, using high strength concrete and concrete filled steel tubular column. In order to strengthen the stiffness and the overall stability, a single span frame is added on the side of the tower. According to the characteristics of the structural system, the cast-in-place reinforced concrete beam slab system is adopted in this project. 1 basement floor with plate structure, plate thickness h = 800 ~ 1200mm; the basement slab with two-way slab layout, plate thickness h = 180mm; the first floor (the basement roof) by means of beam plate structure, plate thickness h = 200mm; the plate thickness is 120mm, the standard floor thickness is 100mm, the local 110mm. The roof plate thickness h = 120mm. The 2 floor near the core is weak, try to reduce the size and the concave holes to avoid weakening the floor too large, this part of the floor is increased by H = 150mm and double two-way reinforcement layer, standard structure layout in Figure 3 is shown in figure 2 to strengthen the weak parts of the plate reinforcement, to resist the deformation of the local discontinuous floor on both sides of the uneven stress caused by cracking. According to the geological exploration data, the technical and economic comparison and optimization, the basis of selection of drilling punching pile foundation, pile bearing stratum for weathered rock, weathered rock saturated uniaxial compressive strength standard value of 10.70Mpa, the pile diameter is Phi 2200 mm to 2600, the basement uplift pile against underground water buoyancy (Shen and Zhou, 2014).

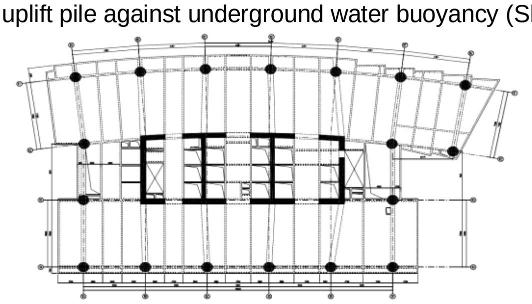

Figure 3: Layer structure layout standard drawing tower

The comparison between the standard reaction spectrum and the safety evaluation report is shown in Figure 4. West Tower for high-rise building super B height, seismic intensity of 7 degrees, according to the "Regulations" and "technology for concrete structures of tall building code for seismic design of buildings" requirements for elastic time history analysis under earthquake calculation. In order to eliminate the non-seismic secondary structural members, the bearing capacity of the structure is analyzed according to the seismic performance objectives. In the earthquake is calculated by elastic method, shear reinforcement bars were not over all vertical components, a shear elastic beam; shear wall or part of the floor beams between super reinforcement, reinforcement frame column, beam needs to be higher than under the frequent Earthquake demand. The smaller part of the columns and beams appear over reinforced, restrained edge member reinforcement ratio larger occurs shear wall, but the shear section checking meet requirements.

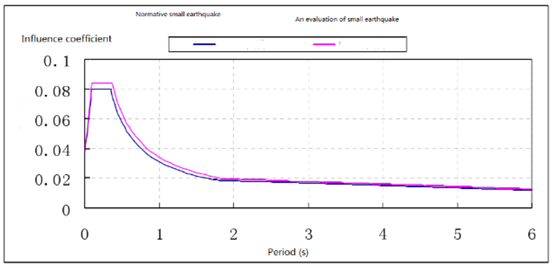

Figure 4: Comparison of the normalized response spectra and response spectra of safety assessment reports

3. Related parameters calculation

3.1 Floor stress analysis

In order to meet the requirements of seismic performance objectives, to ensure the earthquake floor can reliably transfer the horizontal force, for the construction of 2 floors, 5 floors in the opening floor of the irregular plane, GSSAP is used in seismic elastic slab under the action of stress analysis, Figure 5, 6 floor building two layer elastic analysis the earthquake the maximum principal stress in the downstairs board (unit: KN-m3). According to the seismic fortification target of "great earthquake and no collapse", the PUSH&EPDA program is used to analyze the static pushover analysis of buildings under rare earthquake. The calculation is carried out in two steps: firstly, the representative value of gravity load is applied, and the horizontal load is kept constant when the horizontal load is applied. According to the "special review of technical points on seismic design of high-rise building" (built quality [2010] No. 109) requirements for the height of more than 200m in the building of dynamic elastic-plastic analysis, this project uses on the west of the rare earthquake using the finite element software ABAQUS under dynamic elastic-plastic time history analysis. 1 the project is highly 261.4m super B class high rise building. The structure of the standard floor is approximately rectangular, a dual lateral force resisting system composed of external steel tube concrete column and core tube; 2 core tube composed along Y to assign five I-shaped wall along weak axis X to web wall 11 meters long, the flange wall is about 5 meters long, the beam connection between the walls; 3 axis (Y direction) and weak axis (X direction) the length of about 1.42, about 0.72 to two cycles, the stiffness difference; 4 4 floor structure with big openings, accounting for about 1/3 of floor area, cross layer column 12 meters high. The nonlinear seismic response analysis model can be divided into three levels: material model; component model. The component model is obtained by the constitutive characteristics of the material and cross section geometric parameters of member.

3.2 Nonlinear seismic response analysis model

Dynamic characteristics: according to the construction simulation of the loading sequence under the vertical dead load and live load, and after considering the influence of the construction leveling for the treatment of the corresponding bar, the structure of the six modes as shown in figure 7. The maximum value of MISES stress of steel is 441N/mm2, which is located in a beam of 22 layer bracing. MISES stress is mainly concentrated in the 6 layer, the 22 layer and the support layer of the Liang Gangjin, the other positions of the steel MISES stress are less than 390 N/mm2. The maximum value of MISES stress of steel tube concrete column is 343N/mm2, which is located in a column with 22 layers and diagonal bracing. More than 90% stiffness degradation of concrete beams most, supporting beam concrete bracing 6 layer, 22 layer and 37 layer stiffness degradation by up to 99%, at the bottom of concrete-filled steel tube concrete columns stiffness is about 30%-40%, in the upper part by the stiffness degradation of less than 20%. Most of the beam column concrete has no compression stiffness degradation, in the 6 layer, the 22 layer and the support layer of the beam supporting the span of the middle (that is, the support of the diagonal position), the compressive stiffness of concrete degradation are up to 90%. The stiffness degradation, MISES stress and plastic strain performance evaluation: 1 steel MISES the maximum stress value is 429N/mm2, MISES stress is mainly located in the reinforcing layer (7 layer, 23 layer, 38 layer) supporting beam steel bracing, other position of the steel MISES stress was less than 390 N/mm2. 2 at the last moment, the plastic strain of steel is 0.0104, and the maximum position appears in the layer of the beam with the support of the support of the layer, the plastic strain of the beam of the 6 layer and the support of the beam with the support of the 22 layer is larger, and the maximum value is respectively 0.00685 and 0.00851, respectively (Hou and Guo, 2014). The results show that the plastic strain of the steel is more than 37. The plastic strain of the beam column is smaller in other positions. Stiffness degradation of more than 90% 3 most concrete coupling beams, concrete joist bracing 6 layer, 22 layer and 37 layer stiffness degradation by up to 99%, at the bottom of concrete-filled steel tube concrete columns stiffness is about 30%-40%, in the upper part by the stiffness degradation of less than 20%. 4 most of the beam column concrete has no compression stiffness degradation, in the 6 layer, the 22 layer and the support of the beam of the support of the middle of the span (that is, the support of the diagonal position), the compressive stiffness of concrete degradation are up to 90%. Floor damage: in addition to the four corners of the tower floor damage is not large, most of the other positions of the floor of the tensile damage are more serious, but no reinforcement yield. The plastic damage performance evaluation of the floor: 1 the main compressive damage of the floor is concentrated in the floor near the lower end of the 6, the 22 and the 37 layers. 2 in addition to the four corners of the tower floor tensile damage is small, most of the other floor location of tensile damage is more serious, most concrete floor crack, but no reinforcement yield, should be appropriate to strengthen floor reinforcement (Xu et al., 2014).

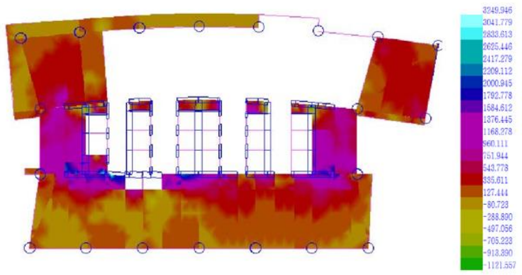

Figure 5: X normal stress nephogram of 0 degree seismic plate

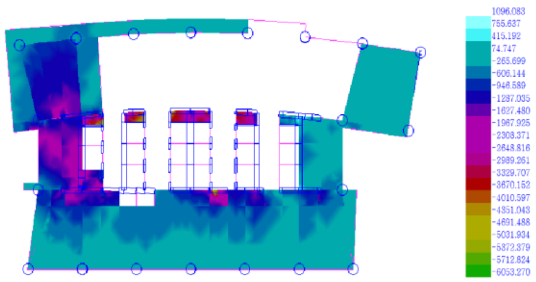

Figure 6: Y normal stress nephogram of 90 degree seismic plate

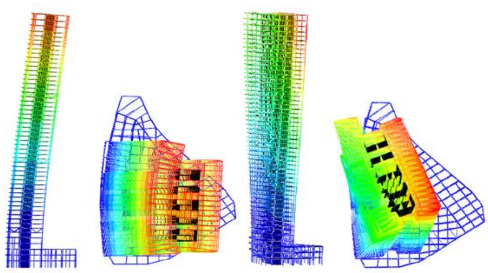

Figure 7: System structure vibration diagram

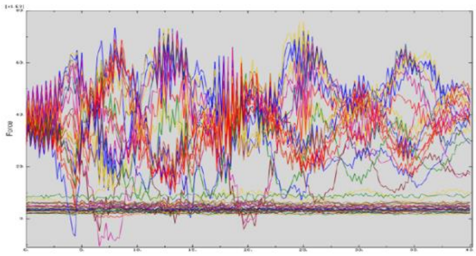

Figure 8: Column vertical force time history

3.3 Maximum stress calculation of system

Evaluation of seismic performance of shear wall: 1 the compressive deformation of the shear wall is more serious in the middle and upper part of the wall, and the tensile damage of the short wall is more serious. 2 in the process of 5.0s-20.0s, the shear wall damage is slow. In the process of 20.0s-30.0s, the tensile damage of the shear wall is accelerated, and the 1-7 layer of the structure has a large area of tensile damage, the 30.0s-40.0s process, the further development of the shear wall damage. Generally speaking, the tensile damage of the shear wall is mainly concentrated in the lower part, and the middle and upper shear wall has no tensile damage. 3 shear wall steel bars are not tensile yield. From Figure 8 we can see, in three to the earthquake frame column 1, column 2 and 3 appear tensile, the maximum tensile for -10549kN, -4784kN and -5385kN, there were no other force of column base. The basal column tension evaluation: 1 most column in compression, column 1, column 2 and 3 appear tensile, the maximum tension is -10549kN, -4784kN and -5385kN; 2 according to the above tension value, estimate the vertical reinforcement ratio on the steel column: rate of 1.46% with column 1, the tensile steel pipe, coagulation the soil column, steel area to meet the requirements. According to the location of the wall, the core wall - points are divided into 23 groups, each group for second of them, the wall force, 4, 5, 8, 9, 12, 13, 14, 17, 18, 21, 22 and 23 groups were wall tension, the maximum tensile force is -13299KN, uplift the design can be with the basement weight superposition based review. 2 according to the above tensile value, the vertical distribution rate of external wall are estimated: the tensile reinforcement ratio of wall 23 is at least 1.15%. The maximum value of MISES stress of steel is 429N/mm2, which is located in a beam of 22 layer bracing. MISES stress is mainly concentrated in the 6 layer, the 22 layer and the support layer of the Liang Gangjin, the other positions of the steel MISES stress are less than 390 N/mm2. Steel MISES steel concrete column the maximum stress value is 345N/mm2, a pillar position in the 22 layer and the diagonal intersection, intersecting diagonal outriggers and column MISES stress are larger, are more than 300 N/mm2, the rest are below 250 N/mm2 (Pei and Han, 2015).

4. Analysis results of engineering examples and main measures of transfinite treatment

According to the calculation results, combined with the "technical specification for concrete structures of tall building" (JGJ3 - 2010) and structural seismic conceptual design theory and a high rule, are summarized as follows: 1 the effective mass coefficient is greater than 90%, the number of modes is enough; 2 in the first period and the first torsional translational cycle is less than 0.85, meet the standard requirements; 3 under wind load and earthquake action, inter story displacement angle is "Guangdong rules" Transfinite review requirements; 4 X, Y direction shear weight ratio meet the standard requirements; 5 irregular torsion of the main structure weak parts usually appear in the overall structure design of the edge region, to reduce the vertical edge structure of the axial compression ratio, shear compression ratio and improve the stirrup ratio, reinforcement ratio and other measures to improve the ductility of the structure, to avoid brittle failure, in addition to the concave convex angle, weak floor The floor slab with thickened double layered reinforced through reinforcement structure (Ma and Han, 2015); 6 to meet the requirements of the lateral stiffness irregularity of requirements; 7 floors between the lateral shear bearing capacity is larger than that of the upper layer shear capacity of 80%, no weak layer, meet the standard floor capacity uniformity requirements; 8 the structure stiffness weight ratio EJd/GH - more than 1.4, through the overall stability checking; 9 wall, column axial compression ratio meets the standard requirements. The total of three natural waves and three artificial wave analysis, according to the calculation of the six wave, it can be seen that the results meet each of the seismic base shear is not less than the results of response spectrum 65% conditions 1, average shear at the bottom is not less than the modal response spectrum method results 80% 2; comparison shows that the response spectrum analysis results of control structure in elastic stage, elastic time history analysis of the floor reaction force and displacement average less than most standard response spectrum results. But the time history analysis of shear calculation of local floor than the mode decomposition slightly larger, the earthquake will be the mode decomposition enlarge about 1.1 times, the analysis results of envelope; 3 floor displacement curve in bending type, displacement curve is smooth and no mutation, reflect the lateral stiffness of the structure is more uniform. 1 under the rare earthquake in the performance point, the direction of the maximum elastic-plastic displacement angle between layers were in accordance with the "Regulations" provisions of article 4.6.5 technology of concrete structures in high-rise buildings, shear wall structure layer is less than the elastic-plastic displacement angle limit of 1/120; 2 in the loading structure at the beginning of a beam damage after that, there are very few beam plastic hinge, the wall in the performance point when the damage is mainly at the bottom of the tension side of the small wall had a small area of the damage, but there is no continuous development of the situation; 3 directions of nappe, bending damage at the bottom of the shear wall around the outer layer standard stress, not shear failure. Two directions of nappe, bottom shear wall bearing several pieces of destruction, but were not shear failure; 4 design by increasing the stirrup ratio, reinforcement ratio and other measures, and steel set in the wall, enhance the flexural strength and ductility of shear wall structure of the edge region, tensile; the 5 towers in the process of calculation, frame column and core tube reinforcement according to structure pushover analysis, individual wall column Bending Yield, yield of bending wall column according to earthquake force review (Nie and Ding, 2014).

5. Conclusions

Using three spatial structure analysis program for structural analysis of elastic wave field artificial selection of two group III site on seismic waves and three sets of "seismic safety evaluation report" provided by the structure of the elastic time history analysis, and the results of response spectrum analysis results in envelope design. In order to understand the seismic performance of the key components, the corresponding measures should be taken. According to the situation, using the SATWE EPDA&PUSH module and ABAQUS under rare earthquake static and dynamic elasto-plastic analysis; the analysis considered the effect of additional P－Δ over height may bring, to determine the structure can meet the second stage of seismic fortification requirements, and the corresponding measures are formulated to strengthen the weak component. Through calculation and analysis can be drawn West Tower is a high-rise building with super B height, structure and layout of the overall structure of the design process is optimized, as appropriate, to strengthen the structural measures in the corresponding treatment of the important components, so it has good seismic performance.

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