Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.V)

7-6-20

# ANALYSIS OF SEISMIC RESPONSE FOR HIGH-RISE BUILDING STRUCTURE UNDER VERTICAL GROUND MOTION

Wang Zhizhong[1] Huo Da[2] Li Xiaoguang[3]

1 Jiamusi Architectural Designing Institute,Jiamusi,HeilongJiang,China
2 Zhengzhon Institute of Technology.Zhengzhou,Henan,China
3 Jiamusi Architectural Designing Institute.Jiamusi,HeilongJiang,China

## SUMMARY

In this paper, seismic response for high-rise building structure under vertical ground motion is researched by axial vibration differential equation of continuous elastic body and mode-resolution method,The effect of structure,stiffness,structure mass and undergound soil stiffness to the response is considered

## INTRODUCTION

When earthquake occur, the ground motions are complex motions. presently in aseismic design of high-rise building structure, the seismic response for high-rise building structure under horizontal ground motion is only considered, and orher seismic response is not considered. This is simple method. When a violent earthquake occur, the seismic response for high-rese building structure under vertical ground motion is not ignored. sometimes the maximum vertical component of ground motion acceleration is equal to this maximum horizontal component, and more then.Thus we must pay attention to the seismic response for high-rese building structure under vertical ground motion. Until recently in some papers the seismic response for high-rise building structure under vertical ground motion is reaserched by lumped-mass method. That can be calculated directly using eguation (1)

$$Pvi = 0.75\alpha v \frac{WiHi}{\sum_{i=1}^{n} WiHi} W \qquad (1)$$

Where Pvi is a vertical seismic action of the ith floor and $\alpha v$ is a vertical seismic effect coefficient, Wi is a structural weight of the ith floor, Wi is all seructure weight, Hi is a floor height of the ith floor.

In China,the high-rise building structures are R.C.structures, and standerd storeys number are a large percent of all storeys. Thus mass distribution and stiffness distribution of high-rise building structure are equally distribution. In this paper, the high-rise building structure is simplified as vertical cantilever beam. We consider its axial vibraton differential equation and compute its vibration mode and frequency. The seismic response under vertical ground motion is analysised by mode-resolution method.

## THE SEISMIC RESPONSE FOR HIGH-RISE BUILDING STRUCTURE UNDER VERTICAL GROUND MOTION

We use a vertical cantilever beam to illustrate the high-rise building structure, and assume that there is a lumped-mass (water tank room, spinning resyaurant) at the top of the beam, and it lies on elastic soil stratum. Where H is structural all depth, E is a modulus of elasticity of material, F(x) is cross-sectional area, Fo is bottom area of fundation. and C is soil stiffness.

From axial vibration differential equation of continuous elastic body We have

$$\frac{d}{dx}\left(Kx\frac{dX}{dx}\right)+\omega^2 m(x)X(x)=0 \tag{2}$$

if there is equal section, We have

$$\frac{d^2X}{dx^2}+\frac{\omega^2}{a^2}X=0 \tag{3}$$

Where

$$a=\sqrt{\frac{E}{\rho}} \tag{4}$$

For a boundary condition that we assume, we have following vertical vibration mode-curve, i.e.,

$$Xj(x)=\sin\frac{ZjX}{H}+\frac{Zj}{K}\cos\frac{ZjX}{H} \tag{5}$$

Where Zj is jth root of frequency equation

$$tgZ=\frac{K-rZ}{Z(1+Kr)} \tag{6}$$

where

$$r=\frac{m}{\rho FH} \tag{7}$$

$$K=\frac{CH}{EF}$$

The jth mode frequency of structural vertical vibration is

$$\omega j=\frac{a}{H}Zj \tag{8}$$

vertical seismic action of jth vibration mode of high-rise building structure is

$$Pvj(x)=nj\ Cv\,\alpha vj\ mg(x)\ Xj(x) \tag{9}$$

Where Cv is a structural effect coefficient under vertical ground motion, $\alpha vj$ is a effect coefficient of vertical earthquake, mg(x) is a density of vertical weight contibution, Xj(x) is jth vibration mode function and nj is mode effect coefficient of jth vibration mode, i.e.,

$$n_j=\frac{\int m(x)\ X_j(x)\ dx}{\int m(x)\ X_j^2(x)\ dx} \quad (10)$$

For a high-rise building structure, we have

$$n_j=\frac{(1-\cos Z_j+\frac{Z_j}{K}\sin Z_j)+\lambda Z_j(\sin Z_j+\frac{Z_j}{K}\cos Z_j\ )}{\frac{1}{2}\beta+\lambda Z_j\ (\sin Z_j+\frac{Z_j}{K}\cos Z_j\ )} \quad (11)$$

Where

$$\lambda=\frac{m}{\rho F} \quad (12)$$

$$\beta=\frac{Z_j^2}{K^2}\ (Z_j+\sin Z_j\cos Z_j)+2\frac{Z_j}{K}\sin^2 Z_j+(Z_j-\sin Z_j\cos Z_j \quad (13)$$

Form Ref. we can obtain that vertical seismic stress of jth vibration mode is

$$\sigma_j=\frac{2E}{H}\cdot\frac{\Delta_j Z_j}{\rho\sin Z_j}\sin\frac{Z_j(H-x)}{H} \quad (14)$$

THus we obtain vertical seismic maximum stress of high-rise building structure under vertical ground motions as following equatio. i.e.

$$\sigma(x)=\frac{2E}{H}\sqrt{\sum \phi_j^2(x)} \quad (15)$$

$$\phi_j(x)=\frac{\Delta_j\ Z_j}{\beta\sin\ Z_j}\sin\frac{Z_j(H-x)}{H} \quad (16)$$

Where is displacement response spectrum of jth vibration mode of structure.
We have

$$\Delta v(T)=17\ C\alpha\ T^2 \quad (17)$$

where C is a structural effect coefficient under horizontal ground motion and $\alpha$ is a effect coefficient of horizontal earthquake.

## ANALYSIS OF SEISMIC RESPOMSE FOR HIGH-RISE BUILDING STRUCTURE UNDER VERTICAL GROUND MOTIONS

A shear wall structure of high-rise building is 12 storeys above ground and 1 storey underground. The height betwen storeys is 2.9m and all structural depth is 34.8m. Exterior wall is made of expanded perlite aggregate concrete, and 28cm in thichness. Internal wall is made of reinforced concrete in situ,and 16cm in thichness. Aseismic design magnitude of the shear wall structure is 9 degree. Site soil is II classification.The elastic modulus of compression for site soil is 60KN/cm and the all weight of the building is 44000KN.

Computing in this paper method, we can obtain weight internal force, horizontal seismic force,vertical seismic force and combination of the forces of shear wall in 3rd axis. Internal force values of shear wall limbs of the shear wall are shown table (1).

Table 1 KN

| wall limb | sto- rey | weignt force Ng | horizontal seismic force $\overrightarrow{Nh}$ | horizontal seismic force $\overleftarrow{Nh}$ | vertical seismic force Nv | $\overrightarrow{Ng+Nh}$ | $\frac{(4)}{(5)}$ *100 | $\overleftarrow{Ng+Nh}$ | $\frac{(4)}{(7)}$ *100 | Ng+Nh+Nv Nmax | Ng+Nh+Nv Nmin |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| 1 | 12 | -119.2 | 190.37 | -190.37 | 44.86 | 71.07 | 3.31 | -309.47 | 14.8 | -354.33 | 115.93 |
| | 11 | -229.8 | 365.29 | -365.29 | 88.43 | 135.49 | 65.2 | -595.09 | 14.9 | -683.52 | 223.92 |
| | 10 | -340.4 | 523.3 | -523.30 | 130.86 | 182.90 | 71.5 | -863.70 | 15.2 | -995.56 | 314.76 |
| | 9 | -451.0 | 666.05 | -666.05 | 168.76 | 215.05 | 78.4 | -1117.05 | 15.1 | -1285.81 | 383.81 |
| | 8 | -561.6 | 792.85 | -792.85 | 203.81 | 231.25 | 100.8 | -1354.45 | 15.0 | -1558.26 | 435.06 |
| | 7 | -672.2 | 903.82 | -903.82 | 233.47 | 231.62 | 100.8 | -1576.02 | 14.8 | -1809.49 | 465.09 |
| | 6 | 782.8 | 998.94 | -998.94 | 258.27 | 216.14 | 119.5 | -1781.74 | 14.4 | -2040.01 | 474.41 |
| | 5 | -893.4 | 1078.24 | -1078.24 | 276.60 | 184.84 | 149.6 | -1971.64 | 14.0 | -2248.24 | 461.44 |
| | 4 | -100.4 | 1141.70 | -1141.70 | 289.01 | 137.70 | 210.0 | -2145.70 | 13.4 | -2434.71 | 426.71 |
| | 3 | -1114.0 | 1189.33 | -1189.33 | 293.86 | 75.33 | 390.0 | -2303.33 | 12.7 | -2597.19 | 369.19 |
| | 2 | -1225.2 | 1221.00 | -1221.00 | 292.24 | -4.20 | 695.8 | -2446.20 | 11.9 | -2738.44 | 288.04 |
| | 1 | -1335.6 | 1236.82 | -1236.82 | 284.15 | -98.78 | 287.6 | -2572.42 | 11.0 | -2856.57 | 185.37 |
| 2 | 12 | -15.26 | 10.22 | -10.22 | 7.45 | -5.04 | 147.8 | -25.48 | 29.2 | -32.93 | 2.41 |
| | 11 | -30.52 | 19.60 | -19.60 | 14.69 | -10.92 | 134.5 | -50.12 | 29.3 | -64.81 | 3.77 |
| | 10 | -45.78 | 28.12 | -28.12 | 21.68 | -17.66 | 122.7 | -73.90 | 29.3 | -95.58 | 4.02 |
| | 9 | -61.03 | 35.79 | -35.79 | 28.04 | -25.24 | 111.1 | -96.82 | 28.9 | -124.86 | 2.80 |
| | 8 | -76.29 | 42.60 | -42.60 | 33.87 | -33.69 | 100.5 | -118.89 | 28.4 | -152.76 | 0.18 |
| | 7 | -91.55 | 48.56 | -48.56 | 38.80 | -42.99 | 90.2 | -140.11 | 27.6 | -178.91 | -4.19 |
| | 6 | -106.80 | 53.67 | -53.67 | 42.92 | -53.13 | 80.7 | -160.47 | 26.7 | -203.39 | -10.21 |
| | 5 | -122.07 | 57.93 | -57.93 | 45.96 | -64.14 | 71.6 | -180.00 | 25.5 | -225.96 | -18.18 |
| | 4 | -137.33 | 61.34 | -61.34 | 48.02 | -75.99 | 63.2 | -198.67 | 24.1 | -246.69 | -27.97 |
| | 3 | 152.58 | 63.90 | -63.90 | 48.83 | -88.68 | 55.1 | -216.48 | 22.5 | -265.31 | -39.85 |
| | 2 | -167.84 | 65.60 | -65.60 | 48.56 | -102.2 | 47.5 | -233.44 | 20.8 | -282.00 | -53.68 |
| | 1 | -183.10 | 66.45 | -64.45 | 47.22 | -116.7 | 40.5 | -249.55 | 18.9 | -296.77 | -69.43 |

## CONCLUTIONS

We can obtain following conclutions.

The seismic response for high-rise building structure under vertical ground motion must be considered in aseismic design. The more structural depth is high the more ratio of vertical seismic internal force to weight in ternal forace is large

When vertical seismic action is considered, the axial forces of shear walls and frame columus are larger than that when it is not considered. And size of structural element section is larger.

When aseismic design magniture is 9 degrss, vertical seismic internal force is 20--50 percent for weight internal force. for different structural element there is different effect.

For shear wall structure of high-rise building, some structural elements are eccentric compression when vertical seismic action is not cnsidered and turn into eccentric tension elements when vertical seismic action is comsidered In this paper, we consider only the effect of structural stiffness structural mass and underground soil stiffness to the response. The value of elastic modulus of compression and interaction of underground soil foundation and structure must be reserched further.

## REFERENCE

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