

Table of Contents

| | |
|---|----|
| ABSTRACT | I |
| ABSTRACT (in Chinese) | II |
| 1. INTRODUCTION | 1 |
| 2. AN EXPLANATION OF THE TRENDS IN TORSIONAL EFFECTS | 3 |
| 2.1 The 3DOF modal parameters | 3 |
| 2.2 The first trend of torsional effects | 5 |
| 2.3 The second trend of torsional effects | 7 |
| 2.4 The third trend of torsional effects | 7 |
| 2.5 The fourth trend of torsional effects | 12 |
| 3. CO-SHAPE OSCILLATORS FOR ASYMMETRICAL BUILDINGS | 12 |
| 3.1 The effective one-story building | 14 |
| 3.2 The physical model of the COSO | 15 |
| 3.3 The inelastic properties of the COSO | 16 |
| 3.4 The COSOs representing the higher vibration modes of the original asymmetrical building | 18 |
| 4. NUMERICAL VALIDATIONS | 23 |
| 4.1 The single-story example building | 23 |
| 4.2 The 20-story example building | 27 |
| 5. SUMMARY AND CONCLUSIONS | 38 |
| REFERENCES | 40 |

List of Tables

| | | |
|----------------|---|--|
| Table 1 | (a) The vibration periods and modal eccentricities of the 20-story example building.....9 | |
| | (b) The floor-diaphragm side having a larger displacement demand between the two sides in each direction for the first three vibration modes of the example building. ..9 | |
| Table 2 | (a) The mass and stiffness matrices of the single-story example building and those of the COSO (units: kN, m, rad, sec). 25 | |
| | (b) The properties of the two 2DOF modal systems used for constructing the COSO associated with the single-story example building..... 25 | |
| Table 3 | (a) The modal properties of the first eight vibration modes of ASY20..... 29 | |
| | (b) The properties of the 1 st and 2 nd COSOs for ASY20..... 29 | |
| Table 4 | (a) The ground motion records applied to ASY20..... 29 | |
| | (b) The peak story drifts obtained from performing NRHA to the complete finite element model of ASY20..... 29 | |
| Table 5 | The ASY20 peak responses obtained from using the FEM and COSO models and the corresponding errors. | |
| | (a) The ASY20 peak translational and rotational displacements at the CM of the 20th and 10th floors under the exertions of LA21 to LA32..... 30 | |
| | (b) The ASY20 peak base shears under the exertions of LA21 to LA32..... 30 | |
| | (c) The RMS of the errors of the ASY20 peak response estimates under the exertions of LA21 to LA32 (except LA25 and LA26)..... 30 | |

List of Figures

| | | |
|------------------|---|----|
| Figure 1 | (a) The typical one-cycle push-pull curves representing the roof translations versus the base shears and the roof rotation versus the base torque relationships in the ADRS format; (b) the typical three bilinear pushover curves for a two-way asymmetric-plan building; (c) the 3DOF modal system; (d) the floor diaphragm of a two-way asymmetric-plan building. | 5 |
| Figure 2 | The bird's-eye view of the displacement increments of the 3DOF modal system with positive eccentricities. | 8 |
| Figure 3 | (a) The typical floor diaphragm and (b) the elevation of the 20-story example building. | 9 |
| Figure 4 | The bird's-eye view and elevation of the mode shapes of the 20-story example building: (a) the first mode (b) the second mode (c) the third mode. | 10 |
| Figure 5 | Synthesis of the rotational deformation of the 20-story example building: (a) the first mode (b) the second mode (c) the third mode. | 11 |
| Figure 6 | The physical model for the COSO without damping when (a) $s_1 = 1, s_2 = -1$, and (b) $s_1 = -1, s_2 = 1$ | 17 |
| Figure 7 | The conventional SDOF oscillator. | 17 |
| Figure 8 | The COSO's (a) first and (b) second mode shapes. | 18 |
| Figure 9 | The physical model for the COSO with damping when (a) $s_1 = 1, s_2 = -1$, and (b) $s_1 = -1, s_2 = 1$ | 18 |
| Figure 10 | The concept of using COSOs to estimate the seismic responses of asymmetrical buildings. | 22 |
| Figure 11 | (a) The single-story example building, (b) its floor plan and (c) the mode shapes. ... | 25 |
| Figure 12 | The force–deformation relationships for (a) spring 1 and (b) spring 2 of the COSO associated with the single-story example building. | 26 |
| Figure 13 | (a) The translational and (b) rotational displacements at the CM and (c) the base shear of the single-story example building. | 26 |
| Figure 14 | The hysteretic loops of (a) spring 1 and (b) spring 2 of the COSO under the excitation of the 1994 El Centro earthquake. | 26 |
| Figure 15 | (a) The floor plan and (b) the elevation of the example 20-story building (ASY20).. | 31 |
| Figure 16 | (a) The 1 st to 8 th mode shapes of ASY20 normalized with respect to the Z-translational roof component, and (b) the paired Z-translational and rotational mode shapes of ASY20 normalized with respect to the roof translational and rotational components, respectively. | 32 |
| Figure 17 | The force–deformation relationships for (a) spring 1 and (b) spring 2 of the 1 st COSO, and (c) spring 1 and (d) spring 2 of the 2 nd COSO associated with ASY20. . | 33 |
| Figure 18 | The response histories of ASY20 under the applied 1989 Loma Prieta earthquake, | |

where (a) and (b) are the translational and rotational responses on the 20th floor, respectively; (c) and (d) are the translational and rotational responses on the 10th floor, respectively; and (e) is the base shear history..... 34

Figure 19 The hysteretic loops for (a) spring 1 and (b) spring 2 of the 1st COSO, and those for (c) spring 1 and (d) spring 2 of the 2nd COSO, associated with ASY20 under the applied 1989 Loma Prieta earthquake.. 35

Figure 20 (a) The peak story rotations, (b) the peak displacements at the CM, (c) the peak edge displacements on the FS, and (d) the peak edge displacements on the SS, of ASY20 under the applied 1989 Loma Prieta earthquake. 35

Figure 21 The response histories of ASY20 under the applied 1974 Tabas earthquake, where (a) and (b) are the translational and rotational responses on the 20th floor, respectively; (c) and (d) are the translational and rotational responses on the 10th floor, respectively; and (e) is the base shear history..... 36

Figure 22 The hysteretic loops for (a) spring 1 and (b) spring 2 of the 1st COSO, and those for (c) spring 1 and (d) spring 2 of the 2nd COSO, associated with ASY20 under the applied 1974 Tabas earthquake.. 36

Figure 23 (a) The peak story rotations, (b) the peak displacements at the CM, (c) the peak edge displacements on the FS, and (d) the peak edge displacements on the SS of ASY20 under the applied 1974 Tabas earthquake.. 37

Figure 24 The response histories of ASY20 under the applied Elysian Park earthquake, where (a) and (b) are the translational and rotational responses on the 20th floor, respectively; (c) and (d) are the translational and rotational responses on the 10th floor, respectively; and (e) is the base shear history..... 37

Figure 25 The hysteretic loops for (a) spring 1 and (b) spring 2 of the 1st COSO, and those for (c) spring 1 and (d) spring 2 of the 2nd COSO, associated with ASY20 under the applied Elysian Park earthquake. 38

Figure 26 (a) The peak story rotations, (b) the peak displacements at the CM, (c) the peak edge displacements on the FS, and (d) the peak edge displacements on the SS of ASY20 under the applied Elysian Park earthquake. 38