Elucidation of Torsional Interaction Using Eigenvalue Calculation to Propose the Seismic Design Method for Two-Story Timber Houses with 3D-Eccentricity

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Summary

It is known that the torsional response of some story influences the torsional response of another story. In this study, the interaction was formulated on the basis of eigenvalue calculation using the component mode method. In addition, approximation formulas were proposed and were checked the accuracy.

Keywords: timber house; 3D eccentricity; interaction of each story; torsional response.

1. Introduction

Torsional vibration is one of the typical collapse factors of the timber house. So, seismic design method for eccentricity should be precisive. In single-family houses, the house that has core wall is rare. Shear walls are disposed complexly in the plane. So, in many cases, each stories center of stiffness does not exist in the same vertical line. Some previous studies showed that torsional behavior of a story of two-story house with eccentricity can affect the other story. But there is not evaluation method for this behavior. In addition, the Japanese seismic design method for timber house with eccentricity ignores the interaction of the torsional behavior and the dynamic effect. This study shows the evaluation method of the interaction of the torsional behavior which is derived from eigenvalue calculation using the component mode method.

2. Examination Object

Examination objects meet the following conditions. (1) Two-story Timber house. (2) Rigid floor. (3) Single axial stiffness eccentricity (X direction). (4) 4DOF (DOF of X direction was 1 + DOF of rotational direction was 1 ×two stories). (5) Linear structure.

3. Study on Exact and Approximate Interaction

Seismic response of a story is clearly affected not only by the eccentricity ratio of the story but also by that of the other story. This interaction could be derived from eigenvalue calculation using the component mode method. Due to limitations of space, spare the details of this method. There are 2 types of interaction. One is torsional interaction of each story ($\triangle u_i/\triangle u_{os}$, Fig.3). Another is translational interaction ($x_2/x_{2\mathrm{ne}}$, Fig.4). The relationship between i story's $\triangle u_i/\triangle u_{\mathrm{os}}$ and another story's eccentricity ratio was shown in Fig.1. The relationship between $x_2/x_{2\mathrm{ne}}$ and 2nd story's eccentricity ratio was shown in Fig.2. These value which are $R_{ex1}=R_{ex2}$ and $R_{exi}=0$ aere treated as representative points. A line through two points is treated as approximate $\triangle u_i/\triangle u_{os}$. A quadratic curve through two points is treated as approximate $x_2/x_{2\mathrm{ne}}$. Approximate $\triangle$ui/$\triangle$uos and $x_2/x_{2\mathrm{ne}}$ are shown by Eq.(1)and(2). Also, when $R_{ex1}=R_{ex2}$, both values of $\triangle u_i/\triangle u_{os}$ and $x_2/x_{2\mathrm{ne}}$ is 1.0. Approximate value gave close agreement with exact value.

$$\frac{x_2}{x_{2ne}}(R_{ex1},R_{ex2})=\frac{1-C_x}{R_{ex1}}R_{ex2}^2+C\ ,\quad \frac{x_2}{x_{2ne}}(R_{ex1},0)=\frac{K_{x2}-m_2\lambda_{ne}^2}{K_{x2}-m_2\lambda^2}=C_x \tag{1}$$

$$\frac{\Delta u_1}{\Delta u_{os}}(R_{ex1},R_{ex2})=\frac{1-C_{u1}}{R_{ex1}}R_{ex2}+C_{u1}\ ,\quad \frac{\Delta u_1}{\Delta u_{os}}(R_{ex1},0)=\frac{K_{x1}(K_{x2}-m_2\lambda^2)+\lambda^2(m_1m_2\lambda^2-K_{x2}\{m_1+m_2\})}{(K_{x1}-m_1\lambda_{os}^2)(K_{x2}-m_2\lambda^2)}=C_{u1}$$

$$\frac{\Delta u_2}{\Delta u_{os}}(R_{ex1},R_{ex2})=\frac{1-C_{u2}}{R_{ex2}}R_{ex1}+C_{u2}\ ,\quad \frac{\Delta u_2}{\Delta u_{os}}(0,R_{ex2})=\frac{K_{x1}(K_{x2}-m_2\lambda^2)+\lambda^2(m_1m_2\lambda^2-K_{x2}\{m_1+m_2\})}{(K_{x2}-m_2\lambda_{os}^2)(K_{x1}-\{m_1+m_2\}\lambda^2)}=C_{u2} \tag{2a,b}$$

m_i: *i* story's mass, K_{xi}: *i* story's story stiffness, R_{exi}: *i* story's eccentricity ratio, λ: natural frequency, λ_{ne}: natural frequency without eccentricity, λ_{os}: natural frequency for the case of ignore another story, r_i: *i* story's radius of rotation

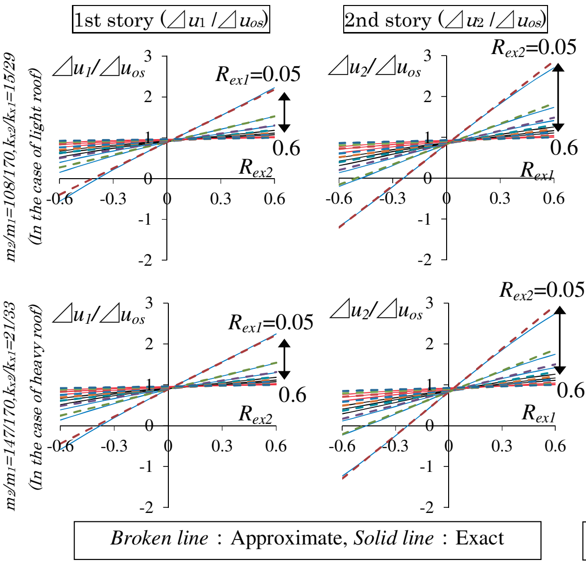


Fig. 1: Relationship between the approximate $\Delta u_i/\Delta u_{os}$ *and the exact* $\Delta u_i/\Delta u_{os}$

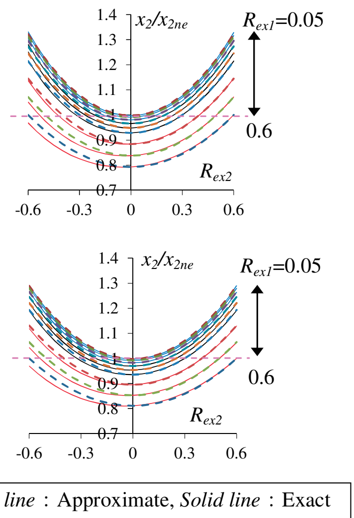
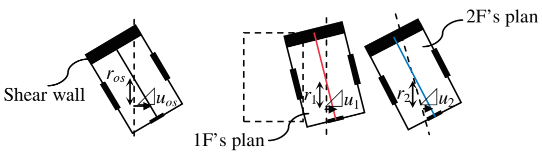
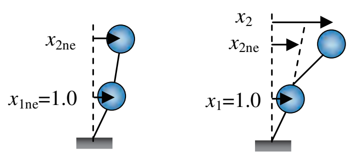


Fig. 2: Relationship between the approximate x_2/x_{2ne} *and the exact* x_2/x_{2ne}



(a) One story building *(b) Two story building*

Fig. 3: Δu_{os}, Δu_1 *and* Δu_2



(a) No eccentricity *(b) Eccentricity*

Fig. 4: x_{1ne}, x_{2ne} *and* x_1, x_2

4. Conclusions

The change of translational behaviour and torsional behaviour due to 3D-eccentricity was confirmed. Also, these changes were expressed by Eq. (1),(2) that were obtained by the component mode method. In addition, the method to obtain the approximate eigenvalue, the approximate x_2/x_{2ne} and the approximate solution of $\Delta u_i/\Delta u_{os}$ was proposed. Also, it was confirmed that their accuracy were precision.

References

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