Load Distribution in Lateral Load Resisting Elements of Timber Structures

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1. INTRODUCTION

- ❑ Besides performing numerical simulation and mechanics analysis, **are there** any other simple and efficient methods to estimate the load distribution in buildings with semi-rigid diaphragm**?**
- ❑ **Is it** always conservative to estimate the load distribution by the envelope force approach, in which the maximum force calculated via flexible and rigid diaphragm assumptions is taken as the load applied on the lateral load resisting elements**?**
- ➢ A simplified mechanics-based model is proposed to predict the load distribution in this study.

2. MULTIPLE SPRING MODEL (MSM)

A single-storey timber building with *n* lateral load resisting elements (LLREs) under a uniform load, *p*, is shown in Fig. 1.

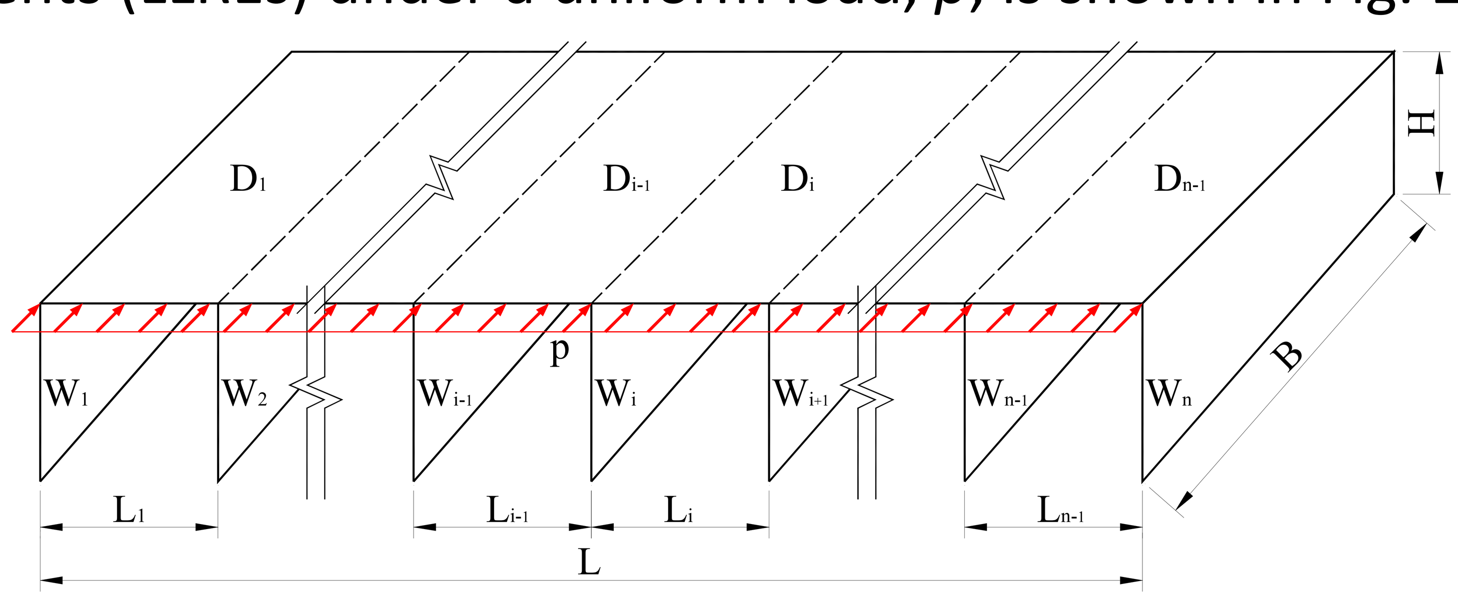


Fig. 1. *Single-storey timber building*

It can be simulated by a modified MSM (Fig. 2).

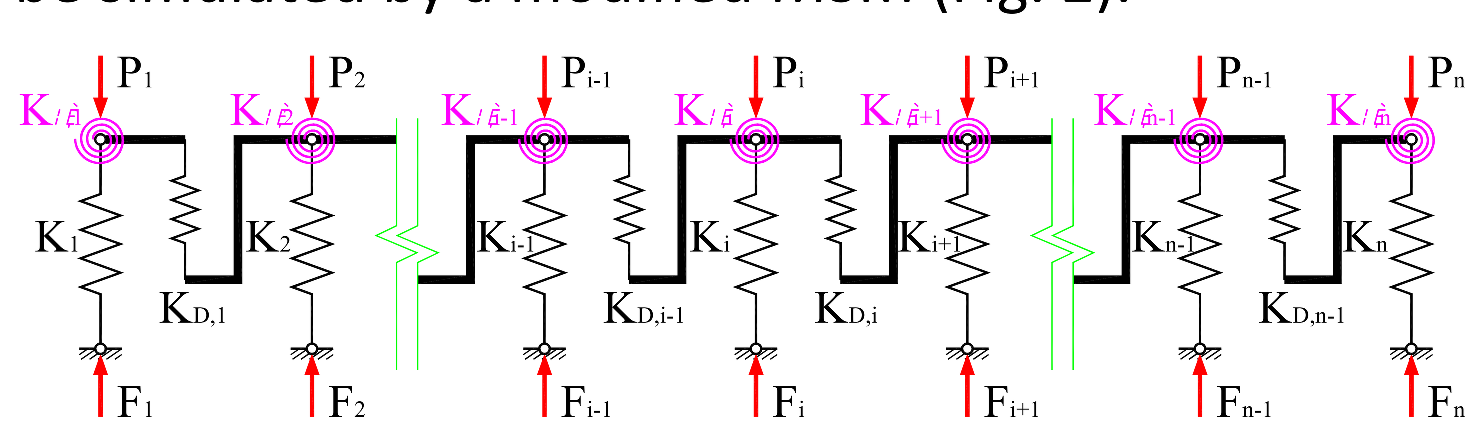


Fig. 2. *Modified multiple spring model*

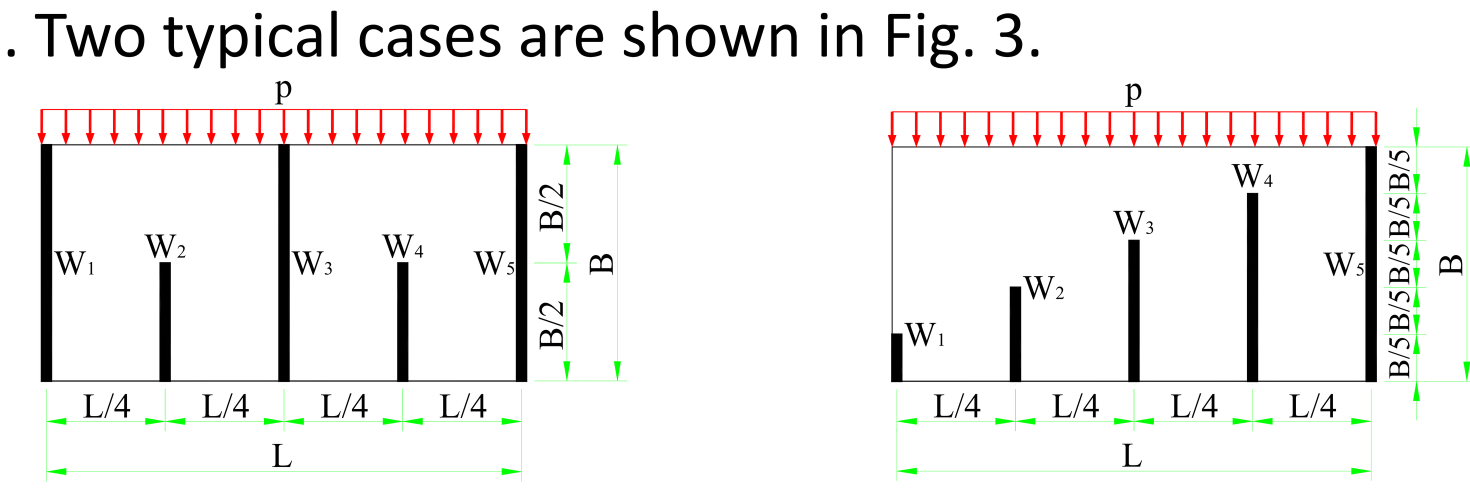
- ❑ LLRE: a translational spring with stiffness K_i
- ❑ Diaphragm segment: a translational spring with stiffness $K_{D,i}$ and two rotational springs with stiffness $K_{\theta,i}$
- ❑ Load: Uniform load → Point loads, $P_i = A_i p$

- ➢ The reactions, F_i, and translations, u_i, of the LLRE springs, and the rotations, θ_i, of diaphragm segment springs in the modified MSM can be derived by solving a system of equations with *3n* variables.

$$\begin{Bmatrix} \vdots \\ F_i \\ -P_i \\ 0 \\ F_{i+1} \\ -P_{i+1} \\ 0 \\ \vdots \end{Bmatrix}_{3n} = \begin{bmatrix} \ddots & 0 & \vdots & \vdots & 0 & 0 & 0 & 0 \\ 0 & K_i & -K_i & 0 & 0 & 0 & 0 & 0 \\ \cdots & -K_i & K_i + K_{D,(i-1)} + K_{D,i} & \left(-L_{(i-1)}K_{D,(i-1)} + L_i K_{D,i}\right)/2 & 0 & -K_{D,i} & \left(L_i K_{D,i}\right)/2 & 0 \\ \cdots & 0 & \left(-L_{(i-1)}K_{D,(i-1)} + L_i K_{D,i}\right)/2 & K_{\theta,(i-1)} + K_{\theta,i} & 0 & \left(-L_i K_{D,i}\right)/2 & K_{\theta,i}/2 & 0 \\ 0 & 0 & 0 & 0 & K_{i+1} & -K_{i+1} & 0 & 0 \\ 0 & 0 & -K_{D,i} & \left(-L_i K_{D,i}\right)/2 & -K_{i+1} & K_{i+1} + K_{D,i} + K_{D,(i+1)} & \left(-L_i K_{D,i} + L_{(i+1)}K_{D,(i+1)}\right)/2 & \cdots \\ 0 & 0 & \left(L_i K_{D,i}\right)/2 & K_{\theta,i}/2 & 0 & \left(-L_i K_{D,i} + L_{(i+1)}K_{D,(i+1)}\right)/2 & K_{\theta,i} + K_{\theta,(i+1)} & \cdots \\ 0 & 0 & 0 & 0 & 0 & \vdots & \vdots & \ddots \end{bmatrix}_{3n\times 3n} \begin{Bmatrix} \vdots \\ 0 \\ u_i \\ \theta_i \\ 0 \\ u_{i+1} \\ \theta_{i+1} \\ \vdots \end{Bmatrix}_{3n}$$

3. EFFECT OF DIAPHRAGM FLEXIBILITY

Five single-storey buildings with/without the torsional effect were analysed under the lateral load, to verify the proposed modified MSM and investigate the load distribution between LLREs. Two typical cases are shown in Fig. 3.



(a) Case II *(b) Case IV*

Fig. 3. *Single-storey timber buildings*

The force ratios, α_F, with various ratio of equivalent diaphragm stiffness to the largest stiffness of LLRE, $K_{DE}/K_{\max}$, estimated by deep beam-on-spring model (DBSM, Fig. 4) and modified MSM are illustrated in Fig. 5.

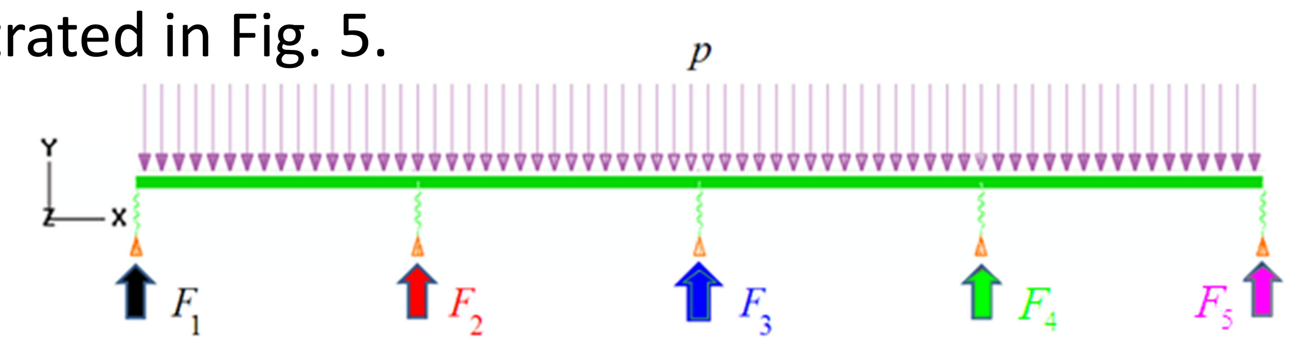
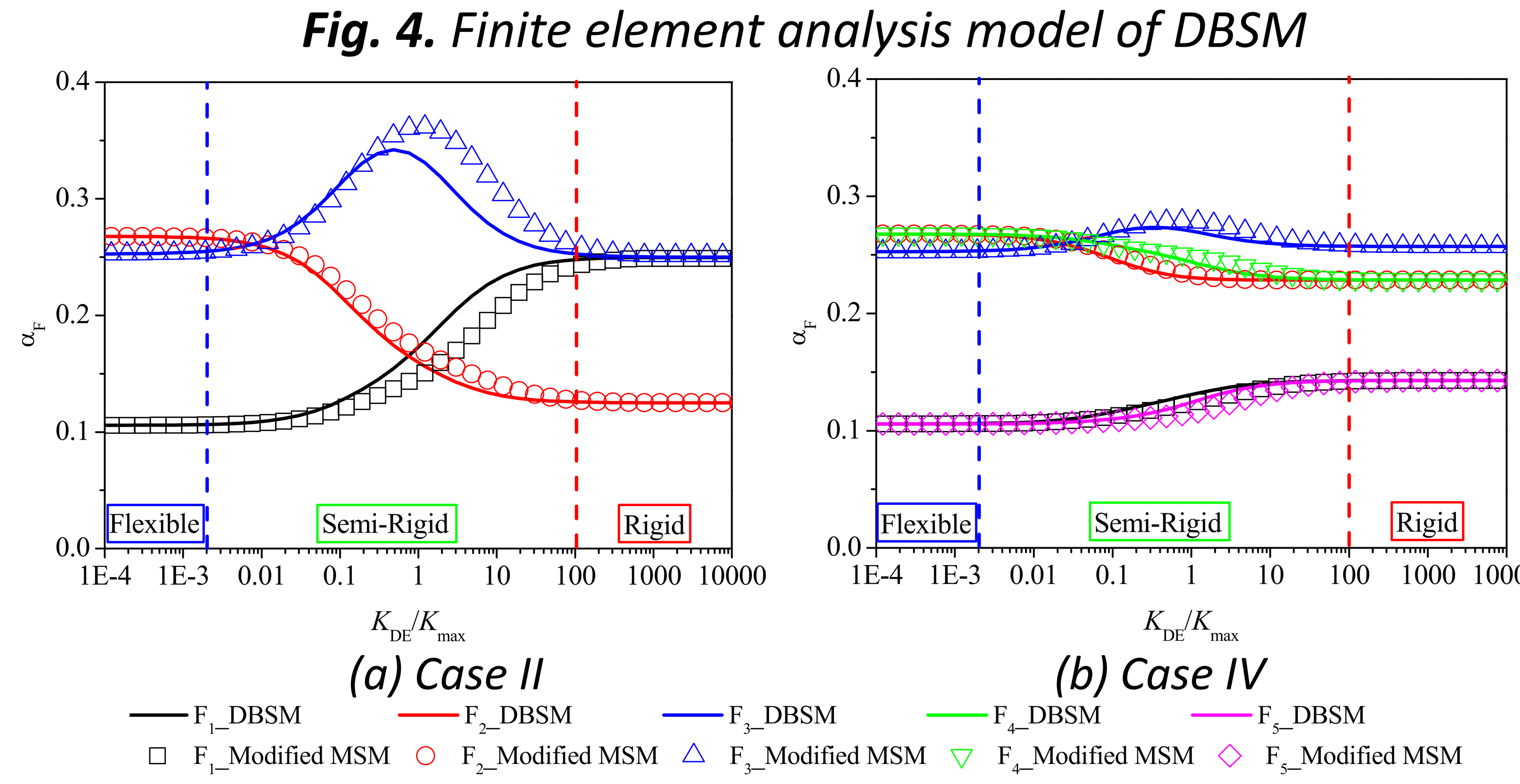


Fig. 4. *Finite element analysis model of DBSM*



(a) Case II *(b) Case IV*

Fig. 5. *Force ratio vs. stiffness ratio*

- ❑ The force ratios estimated using the modified MSM agree well with those predicated by DBSM, irrespective of whether the torsional effect is included or not.
- ❑ The range of semi-rigid diaphragm is wide and thus diaphragms in most buildings should be regarded as semi-rigid.
- ❑ The force ratios of some internal springs in the semi-rigid range are higher than the values at the two extreme regions, i.e. rigid and flexible.

4. CONCLUSIONS

- ✓ A modified multiple-spring model is proposed for calculating load distribution, and it is adequate for design use.
- ✓ The effect of diaphragm flexibility on the load distribution is investigated.
- ✓ The design method based on envelope forces may not always be conservative.