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Nonlinear numerical simulation of RC frame-shear wall system

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ABSTRACT

Reinforced concrete (RC) shear walls are widely used to enhance the global stiffness of building structures. In this paper, the macro model presented by Linde and Bachmann (1994) is selected as a baseline model to establish an improved shear wall numerical model that can be incorporated in the force analogy method (FAM). The multi-layer RC frame-shear wall structure is selected to express the procedures of nonlinear seismic analyses with the FAM.

1. INTRODUCTION

Reinforced concrete (RC) shear walls are widely used to enhance the global stiffness of building structures. Two broad categories (microscopic and macroscopic models) have been developed to simulate the inelastic behavior of RC shear walls. The microscopic models can provide a refined interpretation by sacrificing computational time and memory. The macroscopic models require much less computational time than the microscopic models and have an outstanding accuracy in the analysis. This paper focuses on the macroscopic model for application in the force analogy method (FAM).

The concept of the FAM was first proposed by Lin (1968) and Wong and Yang (1999) firstly applied the FAM to civil structures for nonlinear dynamic analysis. More researches about the FAM have been performed for nonlinear dynamic analyses by Li et al. (2011, 2012, 2013) and Wong et al. (2002, 2003,2006,2007, 2103) up to now.

This paper aims at developing a procedure for modeling RC shear walls behavior in the FAM, and demonstrating that the complex force-deformation behavior can be

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efficiently incorporated in the FAM. The macro model presented by Linde and Bachmann (1994) is selected as a baseline model to establish an improved shear wall numerical model that can be incorporated in the force analogy method (FAM) in this paper. The application of the proposed procedure is verified by performing a nonlinear seismic analysis for a RC frame-shear wall structure.

2. PHYSICAL THEORY AND FAM MODELS OFSHEAR WALL MEMBER

The macro model shown in Fig. 1 for simulating the hysteretic response of shear wall members presented by Linde and Bachmann (1994) is selected here as a baseline model to develop an improved version for incorporating it in the fore analogy method (FAM).

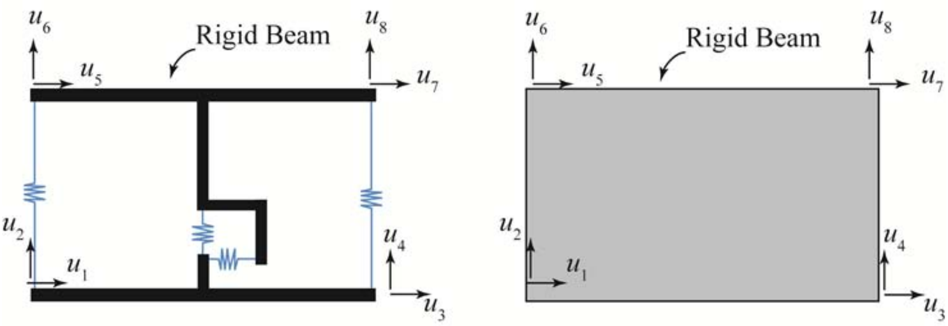


Fig. 1 The macro model proposed by Linde and Bachmann (1944).

2.1 Local Plastic Mechanisms in the FAM

In order to simulate the response of shear wall members in the FAM, an improved model including three local plastic mechanisms is developed here based on the above macro model. Four degree of freedoms, including two horizontal and two rotational degrees of freedoms, x_1, x_2, x_3, and x_4, are retained as shown in Fig. 2. As shown in Fig.2, there are three local plastic mechanisms, including two vertical sliding hinges (VSHs) and one horizontal sliding hinge (HSH). The element stiffness matrices can be written as:

$$\mathbf{K^e} = \begin{bmatrix} K^s & -K^s(h-h_c) & -K^s & -K^s h_c \\ -K^s(h-h_c) & K^s(h-h_c)^2 + K_e\dfrac{l^2}{2} & K^s(h-h_c) & K^s(h-h_c)h_c - K_e\dfrac{l^2}{2} \\ -K^s & K^s(h-h_c) & K^s & K^s h_c \\ -K^s h & K^s(h-h_c)h_c - K_e\dfrac{l^2}{2} & K^s h_c & K^s h_c^2 + K_e\dfrac{l^2}{2} \end{bmatrix} \quad (1)$$

where h is the height of the shear member, h_c is the height of the horizontal sliding hinge (HSH). K_e is the initial stiffness of the two outer vertical springs and K^s is the initial stiffness of the middle horizontal spring.

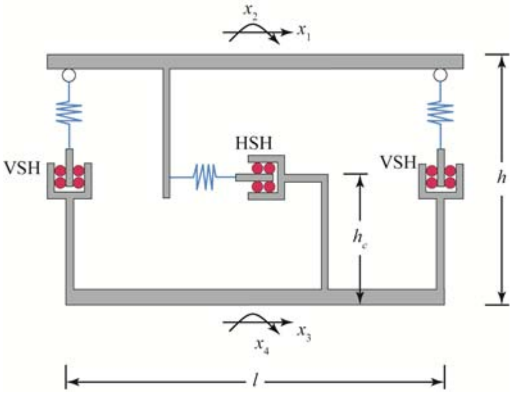
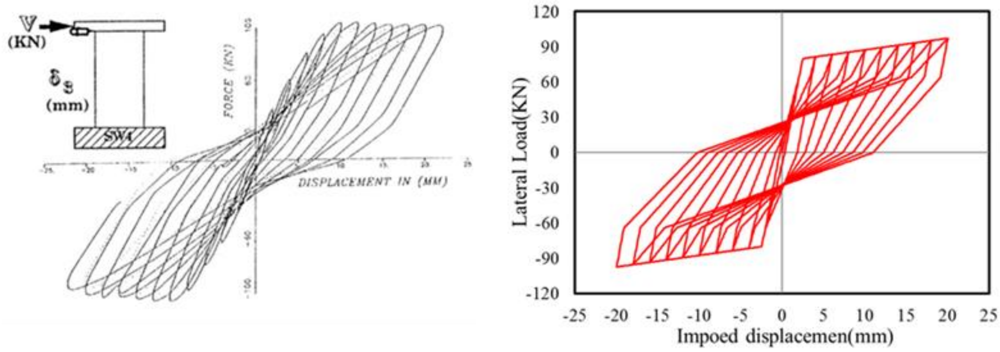


Fig. 2 Numerical model of shear wall members in the FAM.

3. MODEL VERIFICATION

The shear wall member labeled SW4 from Pilakoutas & Elnashai (1995) is selected to verify the implementation of the physical theory shear wall model in the FAM.



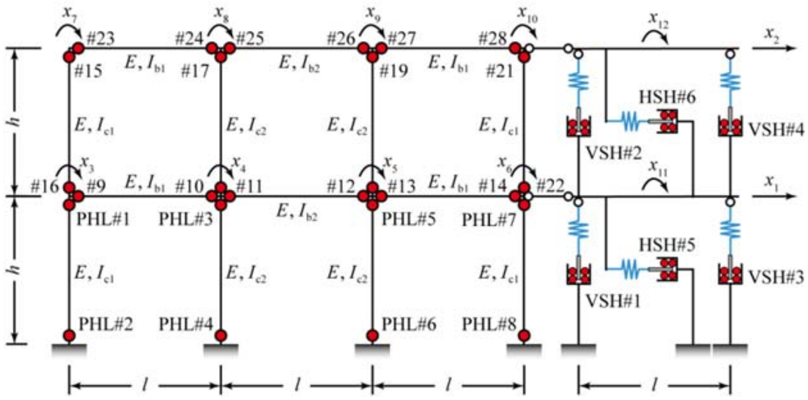
(a) test result; (b) simulation result;

Fig. 3 Comparison between the test and simulation result

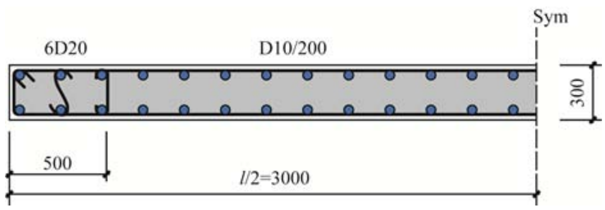
Fig. 3 compares the test result with the simulations result using the modeling approach previously described. It can be seen from Fig.3 that the overall characteristics of the hysteretic response represent the true behaviors and a good agreement is given. The shear wall model in the FAM reasonably captures overall the cyclic response and it is judges to be adequate available.

4. NUMERICAL EXAMPLE

Consider the 2-story RC frame-shear wall structure with shear wall length l=6m and height h=4m as shown in Fig. 4(a). The sectional parameters are shown in Fig. 4(b) and the RC frame parameters are provided in Table.1. The structure is subjected to El Centro earthquake with peak acceleration scaled to 9.5m/s^2. The displacement responses of selected floors are shown in Fig.5. Fig.6 shows the hysteretic loops of selected springs.



(a) The two- story RC Frame-Shear Wall Structure numerical model



(b) Sectional parameters of shear wall

Fig. 4 RC frame-shear wall model: (a) the two- story RC Frame-Shear Wall Structure (b) sectional parameters

Table. 1 The parameters of the RC frame-shear wall structure.

Parameters	Values
Column c1 yield moment, M_{pc1}	1.25 MN-m
Column c2 yield moment, M_{pc2}	0.95 MN-m
Beam b1 yield moment, M_{pb1}	0.75MN-m
Beam b2 yield moment, M_{pb2}	0.45 MN-m
Cross sectional moment of inertia, I_{c1}	0.0012 m4
Cross sectional moment of inertia, I_{c2}	0.0052m4
Cross sectional moment of inertia, I_{b1}	0.0054 m4
Cross sectional moment of inertia, I_{b2}	0.0026 m4
Young's modulus, E	20Gpa

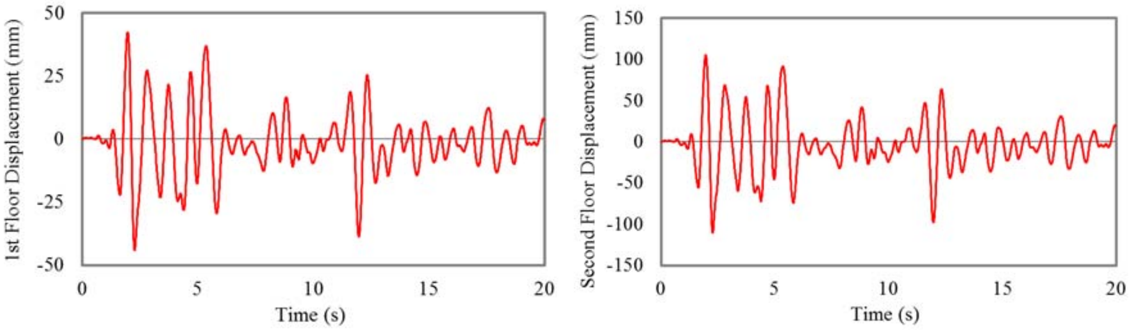


Fig. 5 Global displacement responses of the two-story RC frame-shear wall structure:(a) Displacement response of 1st floor (b) Displacement response of second floor.

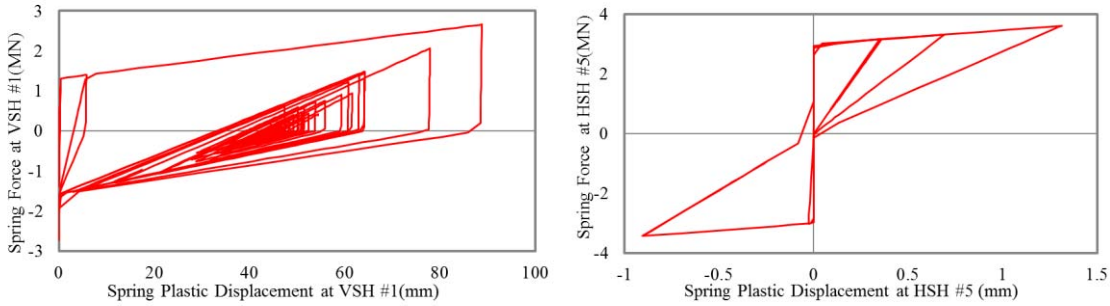


Fig. 6 Hysteretic loops of VSH#1, HSH#5 of the two-story RC frame-shear wall structure: (a) Hysteretic loops of VSH#1 (b) Hysteretic loops of HSH#5

5. CONCLUSION

The present work focuses on the implementation of an existing macroscopic model for RC shear walls for use in the FAM. The validity of the plastic mechanisms in the FAM is verified against a RC shear wall under cyclic loadings, the numerical simulation result has good agreement with the experimental data. The RC shear wall model was implemented in a RC frame-shear wall structure of which the inelastic response occurs in both the frame and walls to demonstrate the value and potential of the proposed model for modeling the complex inelastic dynamic frame-wall structural behavior with the FAM. Thus, the study presented to incorporate a realistic macroscopic model into the FAM providing an efficient new approach for conducting nonlinear dynamic analysis of RC frame-shear wall structures.

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