

MULTILEVEL RELIABILITY ASSESSMENT OF MASONRY INFILL STRUT MODELS UNDER SEISMIC LOADING

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Abstract

Reinforced concrete frames infilled with masonry walls (RC-IMW) are a commonly used configuration for low-to-medium-rise buildings in Sri Lanka. To analyse their seismic performance, they are represented as equivalent infill strut models in the structural analysis. Several masonry infill strut models have been proposed in the past, yet their reliability is not well assessed. This study evaluates the reliability of five recently developed strut models using the first-order reliability method. An experimental database comprising single-bay single-storey tests and multi-storey tests was utilised. Non-linear numerical models of infilled frames were developed, and their in-plane load-displacement and time-history responses were compared with the experimental results using mean error and root mean square error. The results showed that the predicted reliability indices of the models vary between 1.03 and 4.13. Subsequently, the weighted sum method, assigning equal weight to all the considered scenarios, was employed to propose the most reliable model.

Keywords: First-order reliability method, In-plane, Masonry infills, Reinforced concrete, Seismic

1. Introduction

Reinforced concrete frames infilled with masonry (RC-IMW) buildings are common in low-to-medium-rise building construction in Sri Lanka. Although IMWs are treated as non-structural elements, they strongly interact with surrounding frames under seismic loading. Recent post-earthquake damage surveys have shown that omitting this interaction in the structural analysis led to unintended shear failures and to stiffness and torsional irregularities [1]. RC-IMWs are commonly represented in structural analysis through a macro-modelling approach, where the IMWs are idealised as masonry struts [2]. Several masonry strut models have been proposed in the past, but they are typically calibrated only against single-bay single-storey test data. Furthermore, the current literature has focused on the best predictive model, while the dispersion associated with those models has been unexamined. Their reliability, particularly for multi-storey frames, has not been verified.

In this study, the reliability of five recent infill masonry strut models, namely Liberatore et al. [3], De Risi et al. [4], Mucedero et al. [5], Huang et al. [6], and Di Trapani [7] has been evaluated. A database comprising single-bay single-storey tests and multi-storey tests was developed. Non-linear numerical models were developed in OpenSees [8] using the test database and considering five masonry strut models. The reliability indices were computed by predicting the response and employing the first-order reliability method (FORM) [9]. Response prediction and reliability index computation were carried out for yield, peak and ultimate cases for the single-bay single-storey tests and the base shear and storey drift predictions of the multi-

storey RC-IMW shake table tests. Subsequently, the model of Liberatore et al. [3] was identified as the most reliable using the weighted sum method.

2. Methodology

A database comprising 150 single-storey single-bay and three multi-storey tests was developed. Replicas of these experiments were modelled in OpenSees [8] using five recent infill masonry strut models. Numerical predictions were made and compared with experimental outcomes, determining the mean model error and standard deviation for yield, peak and ultimate force and displacement for single-storey single-bay test, as well as base shear and top storey displacement for multi-storey cases. Then the reliability indices were computed by employing the FORM [9]. The strut models were ranked (in parentheses) based on the reliability index for each case. A weight was assigned for each ranking. For 1st, 2nd, 3rd, 4th and 5th ranks 1, 0.8, 0.6, 0.4 and 0.2 were assigned, respectively. Every case was considered equally important while assigning weight. Finally, the most reliable model was identified using the sum of these weights, shown in Table 1.

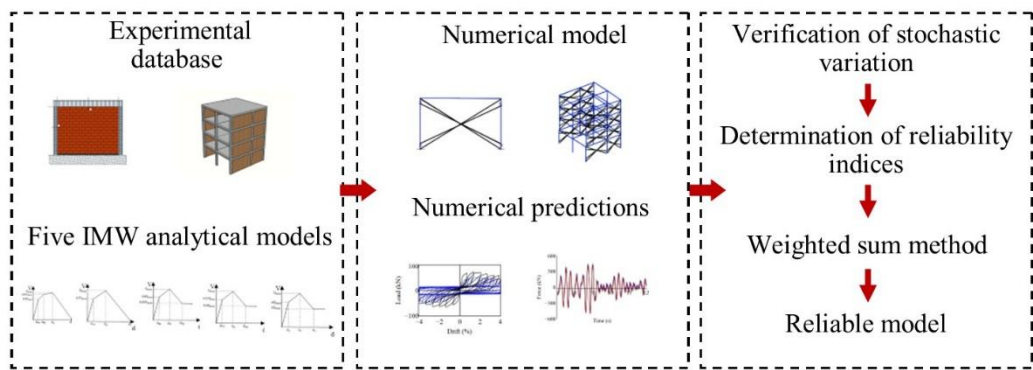


Figure 1: Methodology of the study.

3. Results and Discussion

It can be noted from Table 1 that no single model outperformed the others across all cases. Therefore, the selection of models should be guided by the specific requirements of the seismic assessment. A model offering a high reliability index for load-based cases may not be as reliable for drift-based cases, and vice versa. Overall, Liberatore et al. [3] provides more reliable predictions in most cases compared to the other models.

Table 1: Results of the study.

Parameters			Liberatore et al. [3]	De Risi et al. [4]	Mucedero et al. [5]	Huang et al. [6]	Di Trapani [7]
Single-storey single-bay frame	Yield	Drift	2.33 (5)	2.70 (2)	2.43 (4)	2.87 (1)	2.54 (3)
		Score	0.2	0.8	0.4	1	0.6
		Load	2.36 (3)	2.73 (1)	2.68 (2)	2.05 (4)	1.71 (5)
		Score	0.6	1	0.8	0.4	0.2
	Peak	Drift	3.67 (3)	3.69 (2)	3.50 (4)	2.89 (5)	3.76 (1)
		Score	0.6	0.8	0.4	0.2	1
		Load	1.65 (3)	1.83 (1)	1.82 (2)	1.53 (4)	1.29 (5)
		Score	0.6	1	0.8	0.4	0.2

Multi-storey frame	Ultimate	Drift	3.54 (1)	3.33 (2)	3.17 (4)	3.29 (3)	2.33 (5)
		Score	1	0.8	0.4	0.6	0.2
		Load	3.05 (1)	2.70 (2)	2.68 (3)	2.06 (4)	1.71 (5)
		Score	1	0.8	0.4	0.6	1
	Study 1	Storey drift	2.85 (3)	2.86 (2)	2.28 (5)	2.62 (4)	3.14 (1)
		Score	0.6	0.8	0.2	0.4	1
		Base shear	1.78 (2)	1.77 (3)	1.99 (1)	1.11 (4)	1.05 (5)
		Score	0.8	0.6	1	0.4	0.2
	Study 2	Storey drift	3.68 (1)	1.11 (4)	1.19 (3)	1.61 (2)	1.10 (5)
		Score	1	0.4	0.6	0.8	0.2
		Base shear	2.29 (3)	1.03 (5)	2.49 (1)	2.28 (4)	2.57 (2)
		Score	0.6	0.2	1	0.4	0.8
	Study 3	Storey drift	3.81 (5)	4.12 (3)	4.12 (3)	4.13 (1)	4.12 (2)
		Score	0.2	0.6	0.6	1	0.8
		Base shear	3.90 (1)	1.08 (4)	1.09 (3)	1.08 (4)	1.11 (2)
		Score	1	0.4	0.6	0.4	0.8
	Weighted sum		8.2	7.2	7.2	6.8	7.4

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