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Quantification of Combined Irregularity for Unreinforced Masonry Façades

Abstract

Unreinforced masonry (URM) is one of the oldest and most popular construction material used in underdeveloped and developing countries. It represents a large percentage of the total building stock around the world even in the highest seismic zones. URM is characterized by its high seismic weight and low ductile capacity which makes it extremely vulnerable to lateral motion. The in-plane seismic capacity of URM is often estimated using simplified nonlinear models such as the Equivalent Frame Method (EFM). The simplified nonlinear models are proven to produce reliable results for façades with regular opening layouts. However, the reliability of EFM becomes questionable in the case of façades with irregular opening layouts. This study presents a general methodology to quantify irregularity and to develop a threshold for the use of simplified nonlinear models.

Figure 1. URM façade with a regular opening layout [1]

Figure 2. URM façade with an irregular opening layout [1]

Equivalent Frame Method (EFM)

EFM discretizes a façade into an idealized frame with deformable elements (where the nonlinear response is concentrated) connected to the rigid nodes (parts not usually subjected to damage). Piers are the main vertical resistant elements carrying both vertical and lateral loads. Spandrels are the secondary horizontal elements which couples the response of piers in the case of lateral loads. This discretization is relatively easy when the openings are regularly placed along the length and height of a façade. However, the irregularity in opening layout affects the geometry, load-distribution and boundary conditions of the piers as shown in figure 3.

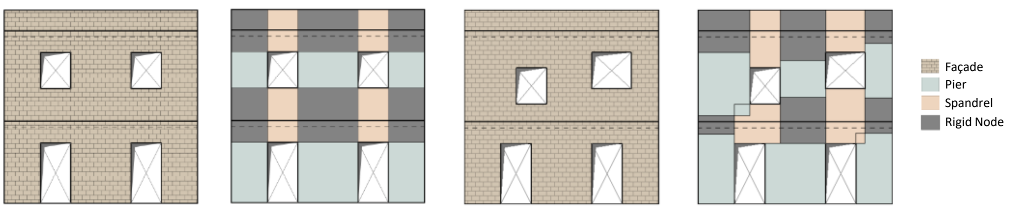

Figure 3. Effects of irregularity on the geometrical discretization of the equivalent frame method [2]

Methodology

The proposed methodology is a three-step process. The first step is to discard the façade configurations which causes uncertainties in the geometry and response of EFM. For this purpose, minimum compatibility requirements such as the percentage of opening area, number of slender piers per floor, minimum edge distance etc., are reviewed. In the second step, façades complying to the initial requirements are included in the calculation of normalized combined irregularity index (IC) with respect to each floor level. In the third step, the combined irregularity index is used to define Global Irregularity Limits (GIL) which consequently sets the threshold for estimating the reliability of simplified nonlinear methods. The reliability of response parameters is checked in comparison to complex nonlinear models.

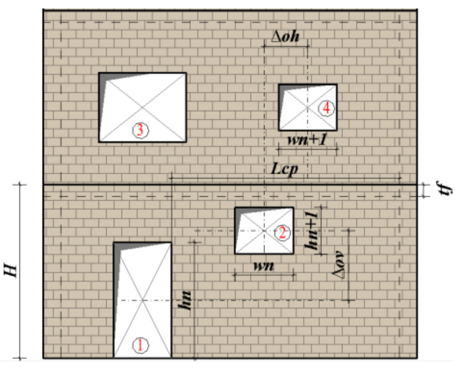

Figure 4. Geometrical parameters required for irregularity quantification

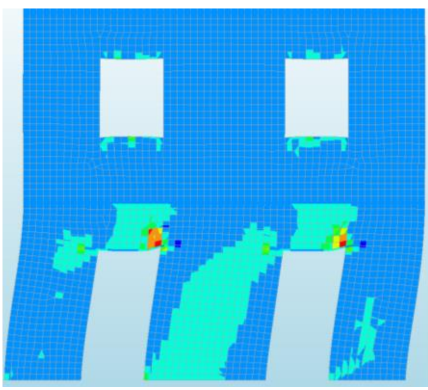

Figure 5. Calibrated finite element model used as a baseline for response error estimation

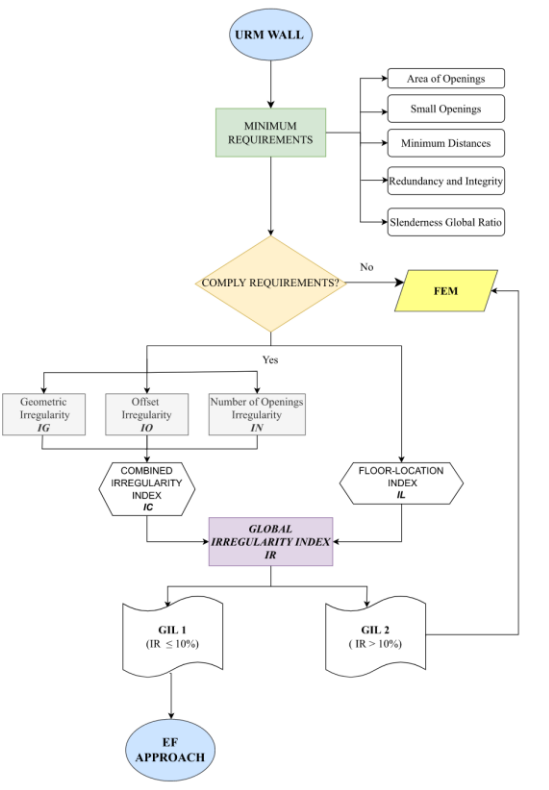

Figure 6. Overview of the proposed methodology

Preliminary Results

The preliminary results indicate that the proposed calculation concurs well with the expected behavior. EFM shows negligible response errors in the case of low irregularities. However, with the increase in irregularity, EFM produces errors in response parameters reaching up to 40% in comparison to more complex finite element models.

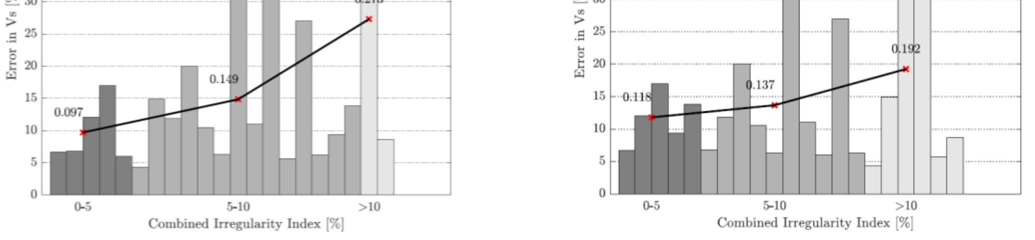

Figure 6. Combined irregularity index vs in-plane base shear capacity for different sets of normalizing parameters. Multiple sets of normalizing parameters are tested to determine the best descriptive set for the considered data

References

[1] Lagomarsino, Sergio, et al. (2013). TREMURI program: an equivalent frame model for the nonlinear seismic analysis of masonry buildings. *Engineering structures*, 56, 1787-1799.

[2] Petrovčič, Simon, and Vojko Kilar. (2013). Seismic failure mode interaction for the equivalent frame modeling of unreinforced masonry structures. *Engineering structures* 54, 9-22.

[3] F. Parisi, and N. Augenti. (2013) Seismic capacity of irregular unreinforced masonry walls with openings. *Earthquake Engineering & Structural Dynamics*, pp. 101-121