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Out-of-plane seismic performance and fragility analysis of anchored brick veneer

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Abstract

The out-of-plane seismic fragility of single-story brick veneer walls built over a wood frame backup was evaluated analytically. Two-dimensional (2-D) finite element (FE) brick veneer wall strip models were developed, based in part on earlier experimental findings, and nonlinear time history analyses were then carried out by subjecting these FE models to synthetic earthquake ground motions representing the seismic characteristics of the central and eastern US. Onset of damage at key tie connection locations was used to evaluate the damage limit states of brick veneer walls; the two damage states considered in this fragility study were onset/accumulation of wall tie damage (described as repairable damage), and brick veneer wall instability/collapse. Throughout the analytical fragility study, brick veneer wall panel component properties were taken as deterministic, therefore mainly focusing the work on wall damage uncertainty due to seismic demand; sensitivity of wall damage probabilities to variability in ultimate capacities of the tie connections was reviewed afterwards. Three types of tie connection properties and two distinct tie layouts were represented in the FE wall models; the influence of typical wood frame house backup properties on out-of-plane seismic performance of brick veneer walls was also assessed. Seismic fragility functions were computed to represent current design standards and also common construction practices for residential brick veneer.

Highlights

► Damage limit states were defined for anchored brick veneer walls. ► Seismic fragility of single-story brick veneer walls was evaluated analytically. ► Current design standards and common construction practices were investigated. ► Brick veneer generally meets performance objectives in low seismicity regions. ► Standard methods of construction are not recommended in higher seismicity regions.

Keywords

Brick masonry veneer; Metal tie connections; Fragility analysis; Nonlinear dynamic analysis

Figures and tables from this article:

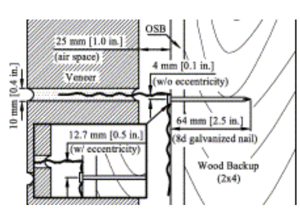

Fig. 1. Section view of corrugated sheet metal tie installation with 90-degree bend located at the nail and at an eccentricity above the nail.

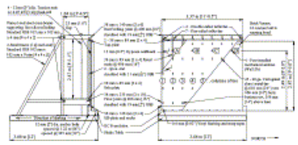

Fig. 2. Elevation views of the wall test structure.

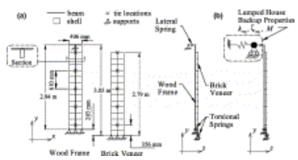

Fig. 3. (a) Front and side views of simplified 2-D wall strip model representing a single-story solid brick veneer wall panel. (b) Side view of wall strip with lumped properties representing a house backup structure.

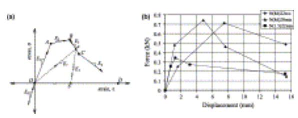

Fig. 4. (a) Tie connection hysteresis model. (b) Average idealized tensile force – displacement behaviors of three types of tie connections from and .

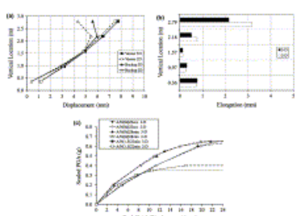

Fig. 5. (a) Peak outward displacements and (b) tie elongations along the centerlines of 3-D and 2-D wall panel models with N (8d)28min type ties subjected to the M10-0.38 g input. (c) M10 earthquake input PGA vs. total displacements at top center of brick veneer for three different types of wall panels.

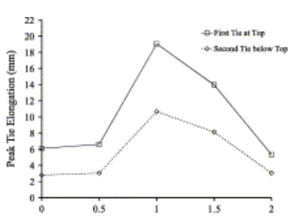

Fig. 6. Peak tie elongations at the topmost and second from top ties for a wall strip model with N(8d)22ecc type tie connections subjected to all twenty synthetic earthquake records scaled to a PGA of 0.5 g.

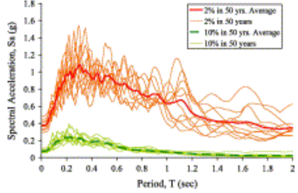

Fig. 7. Uniform hazard synthetic ground motion response spectra (4% damping) for Memphis, Tennessee, soil conditions [46].

Figure options

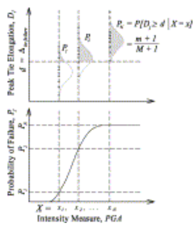

Fig. 8. Example of seismic fragility analysis methodology.

Figure options

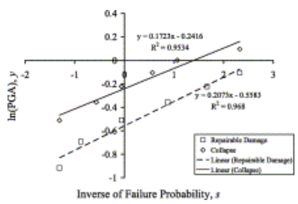

Fig. 9. Probability paper and lognormal parameter calculations for wall A/N(8d)22ecc and T_{backup}/T_{wall} equal to 0.0, based on results summarized in Table 6 and Table 7.

Figure options

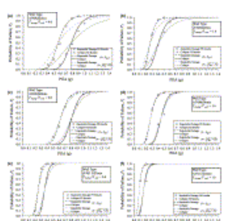

Fig. 10. Seismic fragility curves for brick veneer walls with (a – b) N(8d)22ecc, (c – d) N(8d)28min and (e – f) N(1.5)22min types of tie connections with a vertical spacing of 610 mm.

Figure options

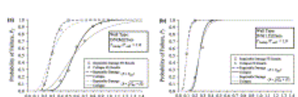

Fig. 11. Seismic fragility curves for brick veneer walls with (a) N(8d)22ecc and (b) N(1.5)22min types of tie connections with a vertical spacing of 406 mm.

Figure options

Table 1. Prescriptive installation requirements for corrugated sheet metal ties.

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Table 2. FE model material properties.

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Table 3. Solid FE wall model parameters with damage states and M10 earthquake input PGAs.

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Table 4. Performance levels and damage for architectural cladding components per ASCE 41-06.

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Table 5. Summary of wall panel parameters for fragility analysis.

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Table 6. Computed tie displacements from nonlinear time history analyses and calculations of Repairable Damage limit state (*i* – *ii*) probabilities, for wall strip A/N(8d)22ecc with T_{backup}/T_{wall} equal to 0.0.

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Table 7. Computed tie displacements from nonlinear time history analyses and calculations of Collapse limit state (*iii*) probabilities, for wall strip A/N(8d)22ecc with T_{backup}/T_{wall} equal to 0.0.

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Table 8. Summary of lognormal distribution parameters.

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Table 9. Probability of exceeding key damage limit states for residential brick veneer construction located in Urbana, Illinois, and Memphis, Tennessee.

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Table 10. Damage limit state PGAs at 5% P_f 95% for selected brick veneer walls with worst-case scenario backup support properties.

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1

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