A numerical investigation of seismic performance for an RC frame with latticed concrete infill walls

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Abstract: Expansive polystyrene granule cement (EPSC) latticed concrete wall can be used as an infill wall. After the expanded polystyrene granule cement form has been demolished, the part that remains is a latticed concrete infill wall comprising lattice beams and columns whose cross section is circular with a diameter of 0.12 m. The horizontal and vertical rebar are arranged within the beams and columns. The dynamic responses of a full-scale single-story reinforced concrete (RC) frame with latticed concrete infill walls subjected to earthquake-induced ground motion are simulated using the nonlinear finite element ABAQUS software. This study aims to investigate the effects of different types of earthquakes on the structure and the acceleration responses of the structure. The results obtained indicate that the structure has excellent seismic behavior, although the structural responses vary between earthquakes. This research may help in promoting the design and application of RC frames with latticed concrete infill walls.

1. Introduction
The expansive polystyrene granule cement (EPSC) latticed concrete wall is a composite wall made of expanded polystyrene granule cement forms and concrete lattice beams and columns. A latticed concrete infill wall serves as the skeleton of the EPSC latticed concrete wall. EPSC latticed concrete walls can be used in either load-bearing or non-load-bearing walls, and they are suitable for both interior and exterior wall applications. Using these walls provides good economic and environmental benefits.

Latticed concrete walls have been the subject of a number of studies. For example, cyclic lateral loading tests to investigate the seismic behavior of the latticed concrete wall have been conducted by various researchers. Most of these researches have focused on the shear span ratio of the wall. Sun et al.² conducted a series of cyclic lateral loading tests on 8 latticed concrete walls with a shear span ratio of 0.77, 0.84, and 1.0. Cai et al.³ also studied the seismic behaviors of 6 latticed concrete walls with different shear span ratios. Both these studies found that the latticed wall has good deformability. Zhou et al.⁴, ⁵ studied the influence of aspect ratio on seismic performance and found that both common concrete and recycled concrete lattice walls have high load-bearing capacity. Dusicka et al.⁶ studied the in-plane lateral performance of full-scale grid walls with two different aspect ratios and two different vertical loading conditions. They found that the vertical loading has an effect on the strength and effective stiffness of the wall. Additionally, a few researchers have performed shaking table tests. Tang et al.⁷ conducted a series of shaking table tests to investigate the seismic behavior of
a full-scale RC frame with an EPSC latticed concrete infill wall. They found that the designed RC frame with the EPSC latticed concrete infill wall has satisfactory seismic performance.

Experimental investigations provide invaluable opportunities for researchers to study the seismic behaviors of the latticed concrete walls. Since the cost of these tests is high, some researchers have conducted their investigations through numerical simulations. Cao et al. [8] studied the seismic behavior of a twelve layer frame-latticed concrete wall in a high-rise residential building using ANSYS. They found that the door and window openings of the wall were the weakest parts of the structure. Asadi et al. [9] conducted a numerical study to determine the ductility and response modification factors for a latticed concrete wall in ABAQUS. They found that the latticed concrete wall has an acceptable ductility for use in high seismic-risk zones.

A new type of latticed concrete infill wall was used in this study. The diameter of the concrete lattice beams and columns is 120 mm. The application of this new type of latticed concrete infill wall faces great challenges due to the lack of historical earthquake performance, experimental data, and numerical studies. In this research, a numerical investigation of the seismic behavior of an RC frame with latticed concrete infill walls was conducted, and the numerical simulation data are analyzed in this paper.

2. Structure and Finite Element Model
This study considers a 3.0 m high, one-story building composed of an RC frame and latticed concrete infill walls. The dimensions are shown in figure 1[7]. The cross section sizes of the rectangular columns and beams are 0.3 × 0.3 m and 0.25 × 0.3 m, respectively[7]. The thickness of the slab is 0.06 m[7]. The sizes of the door and window openings are 0.9 × 2.1 m (width × height) and 1.5 × 1.8 m (width × height), respectively[7]. The strength grade of the concrete used in the RC frame and slab is C30.

The dimensions of the EPSC are 0.9 × 0.6 × 0.21 m(L × b × h). The cross section of the concrete lattice beams and columns is circular with a diameter of 0.12 m (t = 0.045 m), which is smaller than that used by Tang et al. (diameter = 0.16 m)[7]. The spacing of the concrete lattice beams or columns is 0.3 m, as shown in figure 2. The EPSC was removed before conducting the numerical simulations so that only the concrete lattice beams and columns remained. The strength grade of the concrete used in the latticed concrete infill walls is C20.

The plastic damage constitutive model was adopted for concrete in ABAQUS software. The concrete was modeled using solid element C3D8R. The finite element model is shown in figure 3. An additional mass of 1500 kg was applied in the numerical model[7].
3. Numerical Simulation Results and Analysis

The seismic response of a structure will vary greatly with the input seismic waves. To conduct the seismic analysis of a structure, the three elements of the ground motion parameters must be fully considered when selecting typical strong seismic waves from historical records. These elements are amplitude, frequency spectrum, and duration. Two typical strong earthquake records were selected for this study: the El Centro NS record (1940) and the Taft EW record (1952). The acceleration time histories from 0.00-30.00 s of the two input ground motions are shown in figure 4. The peak ground acceleration values of the records were adjusted to 0.3 g. The adjusted seismic waves were then input along the y-direction (shown in figure 5) of the structure. The acceleration measurement location arrangement is shown in figure 5.

![Figure 3. Finite element model of RC Frame with Latticed Concrete Infill Wall.](image)

![Figure 4. Acceleration time histories of the two input ground motions.](image)

![Figure 5. Acceleration measuring point arrangement:(a) Wall A; (b) Wall B; (c) Wall C (D); (d) Slab.](image)

Part of the acceleration response results of the numerical simulations are shown in figure 6 and 7; the figures show the acceleration time histories at the various measurement locations for the El Centro NS record (adjusted) and the Taft EW record (adjusted), respectively. The peak acceleration magnification factors \( a_{1 \text{ max}} \) and \( a_{0 \text{ max}} \), where \( a_{0 \text{ max}} \) is the peak acceleration of the input acceleration record at the bottom of the wall and \( a_{1 \text{ max}} \) is the peak acceleration at the acceleration measurement location, along the height of the structure are shown in figure 8. In figure 8, the average of the AA1
and AA2 peak acceleration magnification factors is taken as the peak acceleration magnification factor at a height of 1.5 m for wall A; the same is true with AB1 and AB2 for Wall B, while AC1 and AD1 are used for walls C and D, respectively.

![Image](image.png)

Figure 6. Acceleration time histories for El Centro NS record (Adjusted).

At the bottom of the wall, the peak acceleration for the El Centro NS record (Adjusted) is a little less than 0.3g. The seismic responses are stronger for the walls with openings (walls A and B) than for those without openings (walls C and D).

![Image](image.png)

Figure 7. Acceleration time histories for Taft EW record (Adjusted).

Given the Taft EW record (adjusted) as the input motion, the peak acceleration at the bottom of the wall is a little less than 0.3g. The seismic responses are stronger for the walls with openings (walls A and B) than for those without (C and D), which is similar to the El Centro NS record (Adjusted) results.

![Image](image.png)

Figure 8. Peak acceleration magnification factors of the structure: (a) Wall A; (b) Wall B; (c) Wall C (D).

Peak acceleration magnification factors of the structure are shown in figure 8. The peak acceleration magnification factor for walls with openings (walls A and B) is larger at the acceleration measurement locations around the openings (AA1, AA2, AA3, AB1, and AB2), compared with that at the slab (AL1) for both of the adjusted records. The peak acceleration magnification factors are different for different input motions for the same wall. For the walls without openings (C and D), the peak acceleration magnification factors increased along the height of the wall for both the El Centro NS record (adjusted) and the Taft EW record (adjusted). It is worth mentioning that the magnification factor for walls without openings is close to 1.05.
4. Conclusions
A numerical investigation into the seismic performance of an RC frame with latticed concrete infill walls was performed, and the results show that the whole structure has an excellent seismic behavior. Seismic performance can vary among walls. For example, walls without openings have better seismic resistance in comparison with walls with openings. The peak acceleration magnification factors will also vary with the input motion. For walls with openings, strengthening those openings might be considered when it is necessary to improve the seismic resistance of the structure.

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