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An analytical study of the out-of-plane details for walls and partitions presented in appendix 6 of standard No. 2800 (4th edition)

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ABSTRACT

Investigations of the failure modes of walls and partitions observed in past earthquakes indicate that the provisions introduced following the Sarpol-e Zahab earthquake require further evaluation. In this research, by concentrating on understanding the out-of-plane bending, the six principal provisions of Appendix 6 of standard No. 2800 have been reviewed. For the numerical study of the out-of-plane behavior of walls, finite element modeling has been used in Abaqus software in two groups. The numerical modeling investigates the out-of-plane behavior of a 7-meter-long and 3-meter-high wall under four different detailing conditions (Group 1) and a Leca block wall under realistic loading conditions with two different construction details (Group 2).This study indicates that it is necessary to revise the limitation on the number of building stories in the condition of connecting the wall to the structure, the limitation on the free length and height of the wall, and the size of the gap in the condition of separating the wall from the structure in the Appendix 6 of the standard No. 2800. Furthermore, the bed-joint reinforcement will not be effective for the system due to the out-of-plane bending direction of the walls. The results of the analyses show that walls with minimal details and continuous wall posts will behave similarly against the out-of-plane forces. Consequently, revising these detailing requirements could significantly reduce steel consumption and construction costs while maintaining satisfactory structural performance.

KEYWORDS

Wall post, Appendix 6 of standard No. 2800, Connecting the wall to the structure, Arching action, Out-of-plane bending

1. Introduction

The out-of-plane failure of non-structural masonry walls occurs when seismic forces act perpendicular to the wall plane. The Out-of-plane capacity of masonry infills depends on several parameters, including slenderness and aspect ratios, boundary conditions, masonry compressive strength, openings, vertical loads, prior in-plane damage, and frame stiffness [1–3]. Following the Sarpol-e Zahab earthquake earthquake, the mandatory use of a considerable quantity of steel for wall posts was introduced to prevent out-of-plane collapse. Nevertheless, this conservative measure incurs significant costs while not necessarily ensuring optimal performance. [4]. On the other hand, the positive effects of well-connected infill walls—such as increased lateral stiffness, strength, and energy dissipation capacity—are undeniable [5]. While extensive research has been conducted on the out-of-plane strength of walls [6-12], the optimization of wall posts presented in Appendix 6 of Standard No. 2800 for separated walls has not been adequately addressed. This research aims to address this gap by conducting a deep analytical and numerical study of the out-of-plane behavior of walls.

2. Methodology

The research methodology is twofold. First, a comprehensive analytical review of the current code provisions of Appendix 6 of Standard No. 2800 is conducted, focusing on the concepts of out-of-plane bending, arching action, and the

philosophy of utilizing wall posts. Second, a detailed finite element modeling (FEM) approach is employed using Abaqus software to simulate the out-of-plane behavior of walls under uniform lateral loading. The numerical modeling is divided into two groups. The first group investigates a 7-meter-long and 3-meter-high wall under four different detailing conditions, while the second group examines a Leca block wall under realistic loading conditions with two different construction details, comparing the performance of minimal detailing against continuous (full-length) wall posts. The results of the analysis of the Group 1 models are presented in Table 1.

3. Discussion and Results

In Group One, the full-length wall post reduces the deformation of Model 2 to 1/10 that of Model 1, bringing it within the permissible limit of 1/200, whereas it shows no significant advantage over minimum detailing. The intermediate wall post halves horizontal stress (with no significant difference between Models 2 and 3), while Model 4 (arching action) experiences about 1/7 the stress of Model 1. Vertical stress is not notably different across the four models and exceeds horizontal stress in Models 2–4, indicating that bending occurs in the horizontal direction—making bed-joint reinforcement ineffective. In Group Two, full-length vertical and horizontal elements reduce flexural tensile stresses and out-of-plane deformations by up to a factor of two; however, even with minimum detailing (using less than 20% of the steel at one-fifth the cost), values remain within permissible limits.

4. Conclusions

This study critically reviews six main clauses of Appendix 6 of Standard 2800 regarding out-of-plane restraint of walls. The results show that the story limits in the condition of connecting the wall to the structure, free wall length and height limits, and separation-joint width require revision, and that the mandated bed-joint reinforcement is not particularly effective against out-of-plane forces. Except in special cases such as the concrete short-column phenomenon, walls with minimum detailing and full-length wall post perform similarly; thus, a fundamental revision of Appendix 6 would improve seismic performance while yielding significant savings in steel and construction costs.

5. References

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Table 1: Analysis results for the Group 1 models [5].

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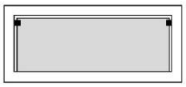
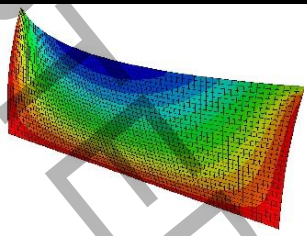
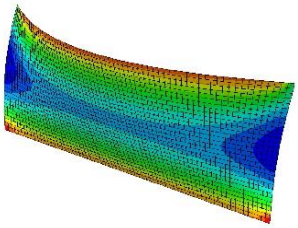
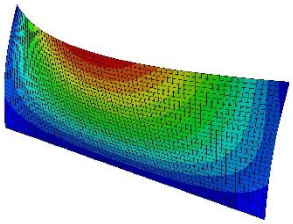
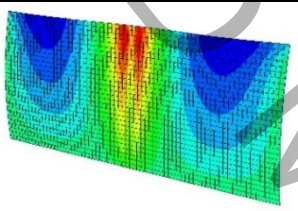
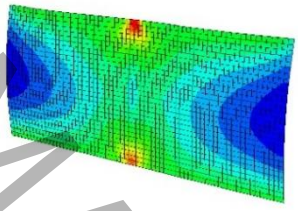
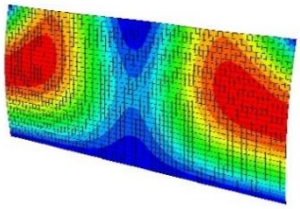
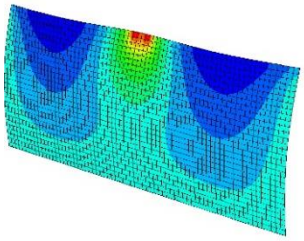
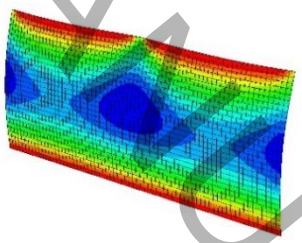
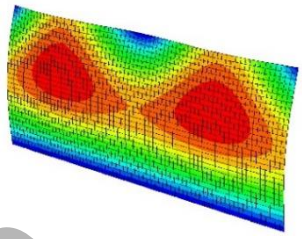
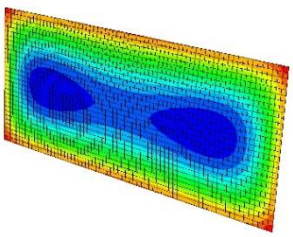
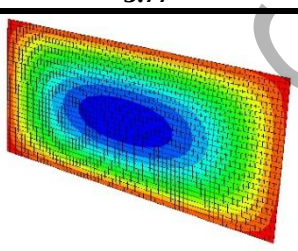
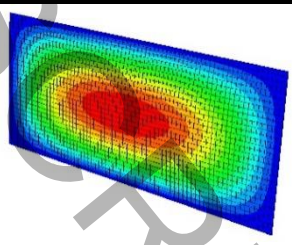
			
Model 1	6.71	4.22	3.77
			
Model 2	**2.55**	**2.95**	**0.3**
			
Model 3	**3.12**	**3.77**	**0.45**
			
Model 4	**1.01**	**2.95**	**0.26**

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