Design of cylindrical wall considering the increment of strain of reinforcing bar considering the shape under seismic loading

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1. Introduction

Nuclear power plant (NPP), housing radioactive materials, pose significant economic and environmental risks in the event of material leakage. To mitigate such accidents, stringent design measures, including maximal reinforcing bar ratios, are implemented in nuclear power plant structures. Given that earthquake loading represents the most critical external force in accident scenarios, ensuring high seismic performance is imperative. Consequently, wall thickness are often designed to be 1.2 meters to enhance structural integrity.

Numerous experimental studies have investigated the shear strength of reinforced concrete walls. However, these studies predominantly focus on planar walls with and without boundary elements, with few considering post-tensioning effects. Additionally, research on the shear strength of cylindrical walls remains relatively scarce. Notable exceptions include structural tests conducted by Uchida et al. (1979) and Ogaki et al. (1981), who reported on the shear strength ductility and seismic capacity of reinforced concrete cylindrical vessels.

This study aims to contribute to the understanding of cylindrical wall shear strength by subjecting cylindrical and planar reinforced, post-tensioned concrete wall specimens to cyclic lateral loading. The design of all test specimens adheres to the reinforcing bar and tendon ratios employed in actual containment buildings of nuclear power plants in Korea

2. Effect of cylindrical shape

The target building of this study is the containment building of nuclear power plant. Thus, the aspect ratio of cylindrical wall is about 1.0 and the thickness and radius of wall is 1,200 mm and 50,000 mm, respectively. Because of the ratio of thickness and radius is closed to zero, the cylindrical wall can be assumed as thin wall.

The hollow cylindrical wall cannot transfer the lateral force (i.e. seismic load, or wind load) through the centre of the cross section unlike planar, I-shaped, or circular walls. Thus, the stress due to the lateral load is transferred along the cross section. In this case, the direction of the load must be continuously changed along the cross section. Therefore, the confining force for lateral force is required (**Figure 1**).

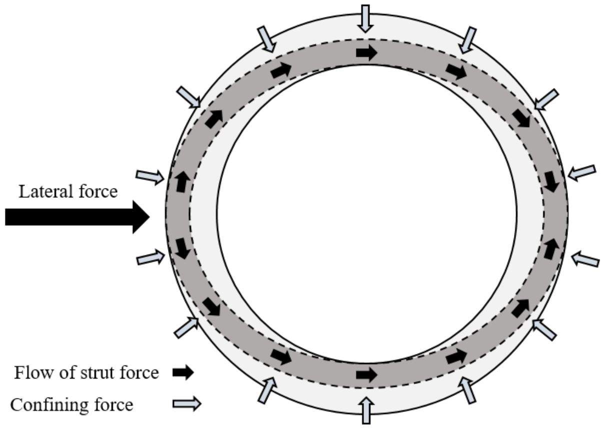

Figure. 1. Concept of confining force

The confining force occurs indirectly through the tensile stress of the vertical and horizontal reinforcing bars. The confining force by vertical reinforcing bar was calculated to be very smaller than that by horizontal reinforcing bar. On the other hand, in the case of horizontal reinforcing bars, a higher additional strain appeared in the cylindrical section for the same strength.

As previous mentioned, the confining force of thin wall can be simply expressed below equation.

$$f_{Confine} = \frac{F}{Rw} = \frac{\sigma_c t w}{Rw} = \sigma_c \frac{t}{R}$$

However, for calculating the exact confining force, cracking angle of wall which is related to the aspect ratio or detail of reinforced concrete wall is required. The detail of confining force is not treated in this paper.

3. Strain increment of cylindrical wall under lateral loading

In order to investigate the effect of radius on shear strength, finite element analysis (FEA) was utilized, and horizontal strain measurements were extracted from the FEA program. Figure 2 illustrates the concept of horizontal strain in a cylindrical wall. As a consequence of the deviation force induced by the radius effect, the radius of the wall expands. Consequently, the horizontal strain in the wall escalates with the increase in radius. Thus, the horizontal strain exhibited by a cylindrical wall under lateral loading is the cumulative result of strain arising from shear deformation and the influence of radius expansion. This understanding is crucial for comprehensively assessing the behavior of cylindrical walls under lateral forces.

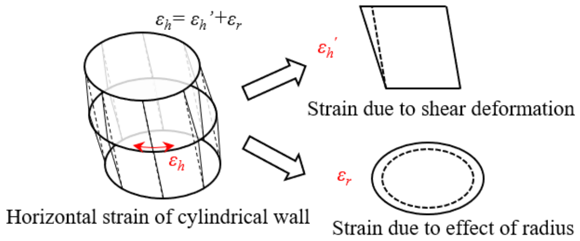

Figure. 2. Concept of strain contribution of cylindrical wall

4. Conclusion

In this study, finite element analysis was conducted to investigate the impact of radius variation on the shear strength of reinforced concrete walls. The shape of the cross-section plays a pivotal role in determining the shear strength of the wall. Specifically, in the case of cylindrical walls, the presence of confining forces becomes crucial in resisting lateral pressures. These confining forces primarily stem from the tensile stress exerted by horizontal reinforcing bars. Additionally, the radial compressive stress induced by these bars contributes to the overall confining force.

Hence, it becomes imperative to consider the incremental strain of horizontal reinforcing bars resulting from deviation forces. Moreover, owing to the unique stress distribution characteristics within cylindrical sections subjected to radial stress, the failure modes observed on the interior and exterior surfaces differ.

The findings from analyses suggest a noticeable increment in the strain of horizontal reinforcing bars. However, it's essential to acknowledge that the load path can also be influenced by factors such as the aspect ratio and crack angle. Therefore, further investigation is warranted to ascertain the point at which the radius effect becomes negligible or to quantify the ratio of the radius effect in shear deformation accurately. This would shed more light on the nuanced interplay between radius variation and shear strength in reinforced concrete walls. In addition, the effect of confining force decreased when the thickness was increased or radius of cylindrical wall was decreased.

ACKNOWLEDGMENTS

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