Investigation of Shear Response of Nuclear Power Plant Wall Elements using High Strength Materials

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Summary

This paper presents the results of twelve reinforced concrete shell elements subjected to shear and biaxial stresses. Elements were constructed by one-third scale of real NPP wall elements and were monotonically loaded until failure. The results were compared with predictions from the Modified Compression Field Theory (MCFT). The concrete compressive strength, steel yield strength and reinforcement ratio of APR1400 that is current model of NPP in Korea were used for reference elements. And the high strength concrete, high yield strength steel and decreasing reinforcement ratio were used for other elements. The ultimate load was accurately predicted with a mean test to predicted ratio of 0.95 and a coefficient of variation of 6.6 %. The shear strains at peak stress were also accurately predicted with a mean test to predicted ratio of 1.01 and a coefficient of variation of 13.4 %. These results show the applicability of MCFT to shear design of NPP wall.

Keywords: axial stress; compression; high yield strength steel; MCFT; shear.

1. Introduction

In recent years, design codes have incorporated compression field approaches for the design of reinforced concrete structures subjected to shear. The Modified Compression Field Theory [1] has become the basis of the shear designs such as AASHTO LRFD, CEB-FIP, CSA Standards and Eurocode 2 [2]. It is expected that ASME, ACI 318 and ACI 349 design codes that commonly used in the design of Nuclear Power Plant (NPP) will implement MCFT based provisions in the near future [3, 4, 5]. Code provisions in NPP structures, requiring high levels of conservatism, may result in uneconomical designs. For example, Code provisions limit the yield stress of steel up to 420MPa, and it makes nuclear containment facilities contain excessive amount of steel.

NPP structures receive a variety of loading conditions such as high-pressures and seismic events. A nuclear accident brings high pressures inside the power plant, resulting in large biaxial tensions in the facility walls. In Seismic events, large shears combined with axial stresses occur near the base of nuclear containment structures. Hence, pure membrane shear, membrane shear combined with biaxial tension and membrane shear combined with biaxial compression tests were carried out.

In the MCFT predictions for heavily reinforced concrete members, the ρf_y ratios in both directions are important factors in determining the ultimate shear strength. When the same ρf_y ratio is maintained, using higher yield strength for the steel means that specimens have lower reinforcement ratio, and it causes larger steel strains. More compression softening and lower tensile stresses in the cracked concrete are occurred in these large steel strains, and it reduces member strength. Similarly, the MCFT predicts that crack widths will be larger when using higher steel strengths for members with similar ρf_y ratios. We call this phenomenon the strain effect in shear.

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