BUCKLING RESPONSE OF CORRODING GROUND BASED STEEL STORAGE TANKS UNDER SEISMIC LOADING

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ABSTRACT

Steel liquid storage tanks are highly susceptible to corrosion from within. Shell corrosion significantly alters the seismic response of ground-based cylindrical steel storage tanks. Investigations on the effects of imperfections in thin cylindrical shells show that large local buckling can occur at the locations of the corrosion-induced imperfections. In this paper, a numerical study is conducted to investigate the effects of internal shell corrosion on the dynamic buckling of three cone roof ground-based, steel cylindrical tanks with height to diameter ratios (H/D) of 0.40, 0.63 and 0.95, subjected to horizontal seismic base excitations. Internal corrosion is considered as a time dependent uniform thinning of the wall at the upper and the lower parts of the tank. Detailed numerical models of the tank-liquid systems at different stages of corrosion degradation are subjected to two representing accelerograms and for each model the critical peak ground acceleration (PGA) for dynamic buckling of the shell and its associated mode of failure are evaluated. It is found that in all three tanks, the critical PGA is markedly reduced with thinning of the shell, irrespective of the type of ground input. The buckling mode of failure of the tanks also changed from an elastic diamond-shaped failure at the top of the shell to an elasto-plastic elephant foot type failure near the base, after 10 years for the shorter tanks (H/D = 0.4 and 0.63) and after 15 years for the tallest tank.

INTRODUCTION

The long-term effect of corrosion is a significant thinning of the wall section, particularly at lower levels; resulting in imperfections in the shell. The seismic response of a thin-walled cylindrical shell structure is highly dependent on the nature and magnitude of imperfections in the geometry of that structure. Earlier investigations on the effects of imperfections in thin cylindrical shells showed that; large local buckling can occur at the locations of the imperfections(Donnell & Wan, 1950 and Miller, 1978). The service life of steel storage tanks is generally planned to be in the range of 20 to 40 years. However, failures of some storage tanks caused by corrosion are reported to have happened after only 1.5 to 2.5 years in service (Medvedeva and Tiam, 1998). Corroded steel tanks are particularly susceptible to seismic loading as the imperfections caused by corrosion highly amplify the seismic response. Corrosion in steel storage tanks occurs mainly due to the presence of residual water at lower levels and water condensate, atmospheric oxygen and acid gases at upper levels of the tank. The rate of corrosion in upper levels (Zone (I) in Fig. 1) is reported to be around 0.4mm/yr, whereas, in the lower levels(zone (III))it averages around 0.5mm/yr (Medvedeva and Tiam, 1998).

Little is reported on the effects of corrosion on the dynamic and seismic response of steel storage tanks. The effects of corrosion on the uplift capacity of bottom annular plate of storage tanks subjected to seismic loading (Yamaguchi, 2006) as well as, the stability loss due to corrosion of thin-shell cylindrical tanks (Gutma, 2000 and Bergman, 2006)have been investigated. In a recent work, Dehghan-Manshadi and Maheri