ABSTRACT

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Title: Effects of Hydrostatic Pressure on the Stability of Open-top Liquid Storage Tanks Subjected to Wind Loading.
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The relationship between the liquid height, buckling behavior and uplift deformation of empty and partially filled steel open-top aboveground storage tanks subjected to wind load were numerically investigated using finite element analysis. Aboveground storage tanks are prone to be influenced by wind pressure, especially for the empty state or at the partial filled configurations due to their thin-walled circular cylindrical steel shell walls which may buckle at stress levels much less than the yield stress of steel material. Buckling behavior is a common and undesirable failure mode experienced by the tank shell subjected to wind load. Furthermore, because tanks are relatively light weight structures at empty or partially filled configurations, uplift deformation should be considered when they are subjected to high wind loads.

In order to explore the interplay between the stored-liquid level, wind loading and uplift deformation of the tanks, two set of models were used: (1) cylindrical shell with open top and with the completely fixed base, and (2) cylindrical shell cylinder with open top and flat bottom continuously supported by compression-only springs simulating a flexible soil foundation. Linear bifurcation analysis (LBA) and geometrically nonlinear analysis including imperfections (GNIA) were performed as linear and nonlinear methods using a general purpose FEA software ABAQUS. Different geometries of the modeled tank were conducted. Tank height and diameter of the models were the main factors in the study. Height of modeled tanks ranging from 40 ft (12.2 m) to 56 ft (17.1 m) and the tank diameters ranging from 200 ft (61 m) to 320 ft (97.5 m) were modeled. The modeled tanks and stiffening rings of various sizes were designed based on API Standard 650, an American standard. In accordance with API 650 rules, only the top stiffener was considered in the study and no intermediate stiffeners were modeled since the design wind load is 90 mph (145 km/h).

Failure behaviors, buckling and uplift displacement, will be studied with models which various tank heights with the same diameter of the cylindrical tank and the identical height of the models but designed with different tank diameter. Based on the results of this study, as hydrostatic load increased, the buckling load increased as well when the hydrostatic height exceeded a half of the modeled tank height. Furthermore, the modeled tanks with higher imperfection magnitude was less likely to buckle at higher hydrostatic liquid levels. In uplift deformation study, uplift behavior did not occur when the storage tanks subjected to the design wind load. However, in some cases that the modeled tank did not experience buckling behavior had relatively large displacement since the model can sustain the higher wind velocity, it might be overturned by such high wind gusts. In terms of different boundary conditions, the difference rise of buckling load as the hydrostatic levels increased. Furthermore, the value of buckling load of the modeled tanks was higher at completely fixed at the base of shell than the boundary condition that was pinned at one-fifth radius of the flat bottom. Note that the radial displacement that buckling or unloading occurred was larger at the pinned boundary condition fully fixed bottom.