ABSTRACT

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Title: Studies on Aboveground Storage Tanks Subjected to Wind loading: Static, Dynamic, and Computational Fluid Dynamics Analyses
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Due to the slender geometries of aboveground storage tanks, maintaining the stability under wind gusts of these tanks has always been a challenge. Therefore, this thesis aims to provide a through insight on the behavior of tanks under wind gusts using finite element analysis and computational fluid dynamic (CFD) analysis. The present thesis is composed of three independent studies, and different types of analysis were conducted. In Chapter 2, the main purpose is to model the wind loading dynamically and to investigate whether a resonance can be triggered. Researches on tank subjected to static wind load have thrived for decades, while only few studies consider the wind loading dynamically. Five tanks with different height (H) to diameter (D) ratios, ranging from 0.2 to 4, were investigated in this chapter. To ensure the quality of the obtained solution, a study on the time step increment of an explicit dynamic analysis, and a on the mesh convergence were conducted before the analyses were performed. The natural vibration frequencies and the effective masses of the selected tanks were first solved. Then, the tanks were loaded with wind gusts with the magnitude of the pressure fluctuating at the frequency associating with the most effective mass and other frequencies. Moreover, tanks with eigen-affine imperfections were also considered. It was concluded that resonance was not observed in any of these analyses. However, since the static buckling capacity and the dynamic buckling capacity has a relatively large difference for tall tanks ($H/D \geq 2.0$), a proper safety factor shall be included during the design if a static analysis is adopted. Chapter 3 focus on the effect of an internal pressure generated by wind gusts on open-top tanks. Based on boundary layer wind tunnel tests (BLWT), a significant pressure would be generated on the internal side of the tank shell when a gust of wind blow through an open-top tank. This factor so far has not been accounted for by either ASCE-7 or API 650, despite the fact that this internal pressure may almost double the design pressure. Therefore, to investigate the effect of the wind profile along with the internal pressure, multiple wind profiles specified in different design

documents were considered. The buckling capacities of six tanks with aspect ratios (H/D) ranging from 0.1 to 4 were analyzed adopting geometrically nonlinear analysis with imperfection using an arc-length algorithm (Riks analysis). Material nonlinearity was also included in some analyses. It was observed that the buckling capacity of a tank obtained using ASCE-7/API 650 wind profile is higher than buckling capacities obtained through any other profiles. It was then concluded that the wind profile dictated by the current North American design document may not be conservative enough and may need a revision. Chapter 4 intends to investigate how CFD can be applied to obtain the wind pressure distribution on tanks. Though CFD has been widely employed in different research areas, to the author's best knowledge, only one research has been dedicated to investigate the interaction between wind gusts and tanks using CFD. Thus, a literature review on the guideline of selecting input parameter for CFD and a parametric study as how to choose proper input parameters was presented in Chapter 4. A tank with an aspect ratio of 0.5 and a flat roof was employed for the parametric study. To ensure the validity of the input parameters, the obtained results were compared with published BLWT test results. After confirming that the selected input parameters produces acceptable results, tanks with aspect ratio ranging from 0.4 to 2 were adopted and wind pressure distribution on such tanks were reported. It was concluded that the established criteria for deciding the input parameters were able to guarantee converged results, and the obtained pressure coefficients seem to yield conservative design.