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Rocking Response of Tanks Containing Two Liquids Digital Analysis of Liquid Propellant Sloshing in Mobile Tanks with Rotational Symmetry Hydrodynamic Effects in Tanks Containing Layered Liquids Liquid Sloshing in Tanks with Internal Structures The Coupled Dynamic Response of a Tank Partially Filled with a Liquid and Undergoing Free and Forced Planar Oscillations Seismic Design and Analysis of Tanks Miscellaneous Notes on the Rubens Family of Holland Free Vibration Analysis of a Tank Containing Two Liquids Liquid Sloshing in Tanks with Internal Structures Catalogue of Important Modern Drawings, Paintings and Sculpture Liquid Storage Tanks Under Seismic Excitations Fluid Mixing and Gas Dispersion in Agitated Tanks Parametric Study of Seismic Interaction of Liquid Storage Tanks with Foundation Soil Mechanical Models for Tanks Containing Two Liquids Effects of Fixity Conditions on the Seismic Response of Liquid Storage Tanks The Canadian Patent Office Record and Register of Copyrights and Trade Marks Hydrodynamic Pressure in a Tank Containing Two Liquids Head to Base Transfer Function Characteristics of a Cylindrical Tank Partly Filled with Liquid Volatile Organic Liquid Storage Tanks Emissions, Background Information for Proposed Standards Experimental Sloshing Characteristics and a Mechanical Analogy of Liquid Sloshing in a Scale-model Centaur Liquid Oxygen Tank Response of Liquid Storage Tanks with Soil-structure Interaction and Uplift Effect Sloshing Analysis of Viscous Liquid Storage Tanks Sealed-foam, Constrictive-wrapped, External Insulation System for Liquid-hydrogen Tanks of Boost Vehicles Heat Transfer to Uninsulated Missile Tanks Containing Liquid Hydrogen Experimental and Analytical Investigation of Interfacial Heat and Mass Transfer in a Pressurized Tank Containing Liquid Hydrogen Preliminary Investigation of Catastrophic Fracture of Liquid- Filled Tanks Impacted by High-velocity Particles Liquid-hydrogen-flowmeter Calibration Facility; Preliminary Calibrations on Some Head-type and Turbine-type Flowmeters The Handling and Storage of Liquid Propellants Scientific Canadian Mechanics' Magazine and Patent Office Record The Canadian Patent Office Record ???? ???? ?????? Specifications and Drawings of Patents Issued from the U.S. Patent Office Plastic Buckling of Unanchored Liquid Storage Tanks Under Dynamic Loads Liquid Sloshing Dynamics Theory of the Fluid Oscillations in a Circular Cylindrical Ring Tank Partially Filled with Liquid An Experimental Investigation of the Damping of Liquid Oscillations in Cylindrical Tanks with Various Baffles Reference Gauging System for a Small-Scale Liquid Hydrogen Tank Modelling of Sloshing in Free Surface Tanks for ShipMo3D Ship Motion Predictions The Equilibrium Free Surface of a Contained Liquid Under Low Gravity and Centrifugal Forces Earthquake Analysis of a Cylindrical Liquid Storage Tank with a Dome by Finite Element Method

Seismic Design and Analysis of Tanks A detailed view on the effects of seismic activity on tank structures As the use of above-ground and underground storage tanks (ASTs and USTs) continues to grow—with approximately 545,000 in the USA alone—the greatest threat to ASTs and USTs is earthquakes, causing the contamination of groundwater, a vital source of drinking water throughout the world. These tanks suffer a great deal of strain during an earthquake, as a complicated pattern of stress affects them, such that poorly designed tanks have leaked, buckled, or even collapsed during seismic events. Furthermore, in oil and gas industrial plants, the risk of damage is even more critical due to the effects of explosion, collapse, and air or soil contamination by chemical fluid spillages. Seismic Design and Analysis of Tanks provides the first in-depth discussion of the principles and applications of shell structure design and earthquake engineering analyses focused on tank structures, and it explains how these methodologies can help prevent the destruction of ASTs and USTs during earthquakes. Providing a thorough examination of the design, analysis, and performance of steel, reinforced concrete, and precast tanks, this book takes a look at tanks that are above-ground, underground, or elevated, anchored and unanchored, and rigid or flexible, and evaluates the efficacy of each method during times of seismic shaking—and it does so without getting bogged down in impenetrable mathematics and theory. Seismic Design and Analysis of Tanks readers will also find: A global approach to the best analytical and practical solutions available in each region: discussion of the latest US codes and standards from the American Society of Civil Engineers (ACSE 7), the American Concrete Institute (ACI 350,3, 371.R), the American Water Works Association (AWWA D100, D110, D115), and the American Petroleum Institute (API 650) an overview of the European codes and standards, including Eurocode 8-4 and CEN-EN 14015 Hundreds of step-by-step equations, accompanied by illustrations Photographs illustrating real-world damage to tanks caused by seismic events Perfect for practising structural engineers, geotechnical engineers, civil engineers, and engineers of all kinds who are responsible for the design, analysis, and performance of tanks and their foundations—as well as students studying engineering—Seismic Design and Analysis of Tanks is a landmark text, the first work of its kind to deal with the seismic engineering performance of all types of storage tanks. A study on the dynamic response of a tank containing two different liquids under seismic excitation is presented. Both analytical and numerical (FEM) methods are employed in the analysis. The results obtained by the two methods are in good agreement. The response functions examined include the hydrodynamic pressure, base shear and base moments. A simple approach that can be used to estimate the fundamental natural frequency of the tank-liquid system containing two liquids is proposed. This simple approach is an extension of the method used for estimating the frequency of a tank-liquid system containing only one liquid. This study shows that the dynamic response of a tank filled with two liquids is quite different from that of an identical tank filled with only one liquid. A study of the dynamic characteristics of rigidly supported upright circular cylindrical tanks containing two different liquids is presented. The governing differential equations for the tank-two liquid system are obtained by application of the Rayleigh-Ritz procedure in combination with Lagrange's equation. The response functions examined include the fundamental natural frequency, the associated mode of vibration and hydrodynamic pressure exerted against the tank wall. Unlike the cases of tanks containing one liquid in which the dynamic response is controlled by four parameters, the dynamic response of a tank that contains two liquids is controlled by six parameters. The numerical results are presented in tabular and graphic forms, and are compared with those of the identical tank filled with one liquid. Also, a simple approximate equation for evaluating the fundamental natural frequency for preliminary design is proposed. The problem of liquid sloshing in moving or stationary containers remains of great concern to aerospace, civil, and nuclear engineers; physicists; designers of road tankers and ship tankers; and mathematicians. Beginning with the fundamentals of liquid sloshing theory, this book takes the reader systematically from basic theory to advanced analytical and experimental results in a self-contained and coherent format. The book is divided into four sections. Part I deals with the theory of linear liquid sloshing dynamics; Part II addresses the nonlinear theory of liquid sloshing dynamics, Faraday waves, and sloshing impacts; Part III presents the problem of linear and nonlinear interaction of liquid sloshing dynamics with elastic containers and supported structures; and Part IV considers the fluid dynamics in spinning containers and microgravity sloshing. This book will be invaluable to researchers and graduate students in mechanical and aeronautical engineering, designers of liquid containers, and applied mathematicians. The effect of viscosity on the sloshing response of tanks containing viscous liquids is studied using the in-house finite element computer code, FLUSTR-ANL. Two different tank sizes each filled at two levels, are modeled, and their dynamic responses under harmonic and seismic ground motions are simulated. The results are presented in terms of the wave height, and pressures at selected nodes and elements in the finite element mesh. The viscosity manifests itself as a damping effect, reducing the amplitudes. Under harmonic excitation, the dynamic response reaches the steady-state faster as the viscosity value becomes larger. The fundamental sloshing frequency for each study case stays virtually unaffected by an increase in viscosity. For the small tank case, a 5% difference is observed in the fundamental frequency of the smallest (1 cP) and the highest (1000 cP) viscosity cases considered in this study. The fundamental frequencies of the large tank are even less sensitive. As a supplement to a recently reported study, the hydrodynamic wall pressures and the associated tank forces induced by horizontal ground shaking in a rigid, vertical, circular cylindrical tank containing liquid layers of different thickness and mass densities are examined, and comprehensive numerical solutions are presented for two-layered and some three-layered systems which elucidate the underlying response mechanisms and the effects of the various parameters involved. Both the impulsive and convective actions are studied. Additionally, solutions are presented for multi-layered systems approximating liquid wit an exponential, continuous variation in density, and the interrelationship of the solutions for the continuous system and its discretized, layered approximation is discussed. Liquid storage tanks are essential structures and, for this reason, it is important that they remain in operation after a strong earthquake. However, despite the development of design specifications mainly based on numerical studies, strong earthquakes still caused severe damage to storage tanks. The parameter that affects most significantly the seismic behaviour is the fixity of storage tanks. Despite the significance the support condition has not received much attention. The main objective of this doctoral research is to investigate, through physical experiments, the effects of tank support conditions. A good understanding of this support influence will enable more efficient seismic deigns of storage tanks in the future. The first part of the study presents a comparison of two worldwide most commonly used specifications for seismic design of storage tanks. The comparison focused on how both specifications consider the influence of soil-structure interaction and uplift in the design. Values of base shear and overturning moment were compared under different fixity conditions. The comparison reveals that there is no agreement in the current practice with respect to a proper incorporation of the effects of the fixity conditions in the analysis. An aluminium scaled tank model is utilised to investigate the effect of uplift on the seismic response. A comparison of the seismic behaviour of the tank with and without anchorage is described. Recorded ground motions scaled to the New Zealand design spectrum and three tank aspect ratios (liquid-height/radius) were considered. The experiments showed that the tank shell acceleration increased when uplift was allowed. This implies that the inertial forces developed by the tank were higher when the tank was free to uplift. In the next stage a PVC model tank containing water is utilised. The same fixity conditions as the previous experiments and three tank aspect ratios (liquid-height/radius) were also considered. The study confirmed the results obtained in the previous stage regarding to the increase of tank accelerations when the tank was no provided with anchorage. As anticipated the tank displacements increased when uplift was allowed. However, axial compressive stresses, which are a control parameter in the design, decreased by between 35% and 64% with tank uplift. A numerical model confirmed these results. The experimental findings prove that uplift has a beneficial effect on the seismic behaviour of storage tanks by reducing the axial stresses developed in the tank shell. However, it was also proved that accelerations and displacements increased when the tank was allowed to uplift. Large accelerations and displacements may damage the piping connected to the tank due to large relative movement between tank and surroundings. To control excessive relative movements the utilisation of slip-friction connectors is proposed. The movable connectors represent an intermediate condition between an unanchored and a fully anchored tank. A series of shake table experiments on a scale model PVC tank containing water is investigated. A comparison of the seismic behaviour of a fully fixed system (tank with anchorage), a system free to uplift (tank without anchorage) and a partially fixed system (tank with slip-friction connectors) is described. The experiments showed the beneficial effects of slip-friction connectors on storage tanks. In comparison with those of an unanchored tank the uplift displacement reduced. Compared to a fully fixed tank the axial stresses also reduced. A numerical model is proposed which corroborates these results. Finally, the effect of soil-structure interaction is investigated. In all the previous experiments a rigid base was considered. In this stage, a physical model on sand in a box is considered. The sand simulated the soil by providing a flexible base. The experiments were performed using actual records scaled to the New Zealand spectrum for a Wellington site. The results showed that while the top displacement and the tank shell acceleration increased when the model was placed on a flexible base (sandbox), axial compressive stresses decreased in comparison with the case when the model was placed directly on the stiff shake table. The results showed that the effect of soil-structure interaction on the seismic response of storage tanks is similar to that of uplift. In general, a more flexible base, either due to uplift or supporting soil, will reduce the stresses developed in storage tanks. However, it will simultaneously increase the maximum accelerations and displacements. The safety and reliable performance of nuclear power plants is of great concern to both the nuclear community and the general public. A nuclear power plant has to be designed to withstand any earthquakes that may occur at its location. Since a nuclear power plant has many liquid storage tanks, the dynamic response of these tanks under seismic excitations must properly analyzed in order to design these tanks to survive the earthquakes to which they may be subjected. The dynamic response of liquid-storage tanks subjected to ground excitations has been the subject of numerous studies in the past thirty years. However, most of the studies were focused on the responses of the tanks such that the contained liquid can be considered to be incompressible and inviscid. Thus, the effect of liquid viscosity on the dynamic response of the liquid-tank system is often ignored. This is justified for water-storage tanks because water has a very small viscosity. However, there are cases where the liquid viscosity is not small in comparison with that of water. For such cases the designs of these tanks based on the inviscid assumption become questionable, and the effect of viscosity on the dynamic response needs to be assessed. To the best of our knowledge, due to the complexity of the problem, the effect of viscosity has not been studied satisfactorily to date. Since the governing equations are very complicated if viscosity is included in the analysis, the closed form solutions in most cases are unattainable. Therefore, it is necessary to use a computer code to solve the equations-numerically. The computer code used in this study is the finite element code, FLUSTR-ANL(FLUid-STRucture interaction code developed at Argonne National Laboratory) (Chang et al. 1988). In this study, the tanks are assumed to be rigid and rigidly supported on their bases, and the responses are considered to be linear. This book covers the essentials of fluid mechanics and explains how to apply fundamental principles to achieve optimum time and capacity efficiency with a minimum of waste. Individual chapters are devoted to the mixing tank, power consumption in turbulent flow, power consumption in viscous creeping flow, mixing in turbulent agitated tanks, and laminar mixing and gas dispersion in agitated tanks. The book provides guidelines for performing design calculations, determining design limits and validating design methodology. The book also covers safety considerations and scale-up processes, and includes technical references to assist the validation of design equations. This study presents an analysis of the transfer function of head motion to base motion for a thin-walled cylindrical tank partially filled with a liquid. This transfer function is part of the overall structural description for the analysis of POGO type instabilities in rocket vehicles. The analysis utilized the double Laplace transform to achieve a closed form approximate solution. An experimental verification of the analysis was performed using a cylindrical plastic tank containing water. The results clearly demonstrated the importance of considering fluid resonance effects on head to base reponse. Indeed, for at least two fluid heights the fluid mode effects dominated the mechanical modes for this transfer function. Ship roll motions in waves can be significantly influenced by the presence of tanks containing liquids, which experience sloshing. Sloshing effects must be considered when transporting liquid cargo; however, sloshing can also be used to advantage. Many vessels have specially designed flume tanks to provide passive roll stabilization. This report describes the implementation of a model of fluid sloshing in tanks for the ShipMo3D ship motion library. The sloshing model is based on potential flow, giving a solution that is computationally efficient and robust. The potential flow model includes a simplified treatment of flow damping arising from viscous effects. The tank sloshing model has been implemented for computations in both the frequency and time domains. Example computations for a generic frigate demonstrate the reduction of roll motions using a flume tank. The well-known Housner's mechanical model for laterally excited rigid tanks that contain one liquid is generalized to permit consideration of tanks that contain two liquids under the horizontal and rocking base motions. Two mechanical models are developed herein; one is for rigid tanks and the other for flexible tanks. The model for rigid tanks has a rigidly attached mass and infinite number of elastically supported masses. The rigid attached mass which possesses a mass moment of inertia represents the impulsive component, whereas the elastically supported masses which do not possess mass moment of inertia represent the convective component of the response. These masses and their heights are chosen such that, under the same base motions, the base shear and base moments of the model match those of the original liquid-tank system. The spring stiffness constants for the elastically supported masses in the model are determined from the sloshing frequencies of the liquid-tank system. The model for flexible tanks, however, only represents the impulsive action of the hydrodynamic response. It has an elastically supported mass that does not possess mass moment of inertia and a member that has no mass but possesses a mass moment of inertia. This latter model is proposed for the study of the effect of the soil-structure interaction. Liquid storage tanks are important components of industrial facilities and, when located in earthquake prone regions, should be designed to withstand the earthquakes to which they may be subjected. There are cases in which the density of the tank content is not uniform. For such cases, the dynamic responses of tanks containing liquids with different densities must be studied. A study on the dynamic response of upright circular cylindrical liquid-storage tanks containing two different liquids under a rock base motion with an arbitrary temporal variation is presented. Only rigid tanks were studied. The response quantities examined include the hydrodynamic pressure, sloshing wave height and the associated frequencies, base shear and moments. Each of these response quantities is expressed as the sum of the so-called impulsive component and convective component. Unlike the case of tanks containing one liquid, in which the response is controlled by one parameter, height-to-radius ratio, the response of tanks containing two different liquids are controlled by three parameters: height-to-radius ratio, and mass density ratio and height ratio of the two liquids. The interrelationship of the responses of the tank-liquid system to rocking and lateral base excitations is established by examining numerical results extensively. It is found that some of the response quantities for a tank-liquid system under a rocking base motion can be determined from the corresponding response quantities for an identical tank under a horizontal base motion.

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