

Seismic Design For Liquid Storage Tanks

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Earthquake-Resistant Structures Abbas Moustafa 2012-02-29 This book deals with earthquake-resistant structures, such as, buildings, bridges and liquid storage tanks. It contains twenty chapters covering several interesting research topics written by researchers and experts in the field of earthquake engineering. The book covers seismic-resistance design of masonry and reinforced concrete structures to be constructed as well as safety assessment, strengthening and rehabilitation of existing structures against earthquake loads. It also includes three chapters on electromagnetic sensing techniques for health assessment of structures, post earthquake assessment of steel buildings in fire environment and response of underground pipes to blast loads. The book provides the state-of-the-art on recent progress in earthquake-resistant structures. It should be useful to graduate students, researchers and practicing structural engineers.

Earthquake Analysis and Design of Industrial Structures and Infra-structures Indrajit Chowdhury 2018-10-06 Despite significant development in earthquake analysis and design in the last 50 years or more, different structures related to industry, infra structure and human habitats get destroyed with monotonic regularity under strong motion earthquake. Even the recent earthquake in Mexico in September 2017 killed a number of people and destroyed national assets amounting to hundreds of millions of dollars. Careful evaluation of the technology reveals that, despite significant development in earthquake

engineering, most of the books that are available on the market for reference are primarily focused towards buildings and framed type structures. It is accepted that during an earthquake it is buildings that get destroyed most and has been the biggest killers of human life. Yet, there are a number of structures like retaining walls, water tanks, Bunkers, silos, tall chimneys, bridge piers etc that are equally susceptible to earthquake, and if damaged can cause serious trouble and great economic distress. Unfortunately, many of these systems are analyzed by techniques that are too simplified, unrealistic/obsolete or nothing is done about them, ignoring completely the seismic effects, as no guidelines exist for their analysis/design (like seismic analysis of counterfort retaining walls or dynamic pressures on bunker walls etc.). This highly informative book addresses many of these items for which there exists a significant gap in technology and yet remain an important life line of considerable commercial significance. The book is an outcome of authors' academic research and practice across the four continents (USA, Europe, Africa and Asia) in the last thirty two years, where many of these technologies have been put in practice, that got tested against real time earthquakes. All methods presented herein have been published previously in peer reviewed research journals and international conferences of repute before being put to practice. Professionals working in international EPC and consulting engineering firms, graduates taking advanced courses in earthquake engineering, doctoral scholars pursuing research in earthquake engineering in the area of dynamic soil structure interaction (DSSI) and advanced under graduates wanting to self-learn and update themselves on earthquake analysis and design are greatly benefited from this book.

Effects of Fixity Conditions on the Seismic Response of Liquid Storage Tanks Miguel Ormeño-Godoy
2015 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 designs 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 not 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.

Steel Water Storage Tanks: Design, Construction, Maintenance, and Repair Steve Meier 2010-04-05 The first comprehensive steel tanks book published in more than a decade Developed by members of the American Water Works Association (AWWA) General Steel Tank Committee, *Steel Water Storage Tanks: Design, Construction, Maintenance, and Repair* is the most authoritative source of industry information available. This in-depth reference describes the use of steel tanks for potable water storage and includes details on tank sizes, capabilities, styles, construction, appurtenances, site selection, design, operation, maintenance, rehabilitation, inspection, and security. Complete coverage of: Tank history, typical configurations, locating, sizing, and selecting Selecting and specifying appurtenances Controlling corrosion Contractual considerations Foundations Construction of welded-steel water-storage tanks Construction of bolted-steel water-storage tanks Operation Inspecting new-tank construction Maintenance, inspection, and repair Potable water security Tank rehabilitation

Seismic Analysis of Safety-related Nuclear Structures, and Commentary on Standard for Seismic Analysis of Safety Related Nuclear Structures American Society of Civil Engineers 1987-01-01

Recent Advances in Earthquake Engineering Sreevalsa Kolathayar

Structural Dynamics G.I. Schueller 2012-12-06 This book contains some new developments in the area of Structural Dynamics. In general it reflects the recent efforts of several Austrian research groups during the years 1985 - 1990. The contents of this book cover both theoretical developments as well as practical applications and hence can be utilized by researchers as well as the practicing engineers. Quite naturally,

realistic modeling of a number of load types such as wind and earthquake loading, etc. , requires taking into account statistical uncertainties. Hence these loads have to be characterized by stochastic processes. As a consequence, stochastic aspects must play a major role in modern structural dynamics. Since an extended modeling of the load processes should not be counterbalanced by simplifying the structural models, considerable efforts have been put into the development of procedures which allow the utilization of e. g. FE models and codes which are utilized presently in context with simplified, i. e. "deterministic" load models. Thus the processing of the additional information on loads as well as including statistical properties of the material allows to provide additional answers, i. e. quantification of the risk of structural failure. This volume concentrates on four major areas, i. e. on load modeling, structural response analysis, computational reliability procedures, and finally on practical application. Quite naturally only special fields and particular, i. e. selected types of problems can be covered. Specific reference is made, however, to cases where generalizations are possible.

Seismic Design Rules for Flat Bottom Cylindrical Liquid Storage Tanks N. J. I. Adams 1991

Experimental Evaluation of Seismic Design Methods for Broad Cylindrical Tanks Douglas Potter Clough
1977

Seismic Design of Liquid-containing Concrete Structures (ACI 350.3-01) and Commentary (ACI 350.3R-01) ACI Committee 350 2001 Types of liquid-containing structures - General criteria for analysis and design - Earthquake load distribution - Stresses - Earthquake-induced earth pressures - Dynamic model.

Behaviour of Steel Structures in Seismic Areas Federico Mazzolani 2009-12-03 Behaviour of Steel Structures in Seismic Areas comprises the latest progress in both theoretical and experimental research on the behaviour of steel structures in seismic areas. The book presents the most recent trends in the field of steel structures in seismic areas, with particular reference to the utilisation of multi-level performance bas

Dynamic Analysis of a Frame-supported Elevated Water Tank Purna Prasad Dahal 2013 Elevated water tanks are widely used to store water for drinking as well as for fire extinguishing purposes. After a severe earthquake, the need of water for drinking as well as fire control will increase dramatically. To ensure that water tanks remain functional after an earthquake, proper analysis method should be followed in order to calculate the response of a structure for earthquake. In this study, the lateral forces developed during earthquake are investigated from commercially available SAP2000 software and the results are compared with the 2006 edition of the ACI standard "Seismic Design of Liquid-Containing Concrete Structures and Commentary" (ACI 350.3-06). The elevated concrete tank is modeled for full, half-full and empty conditions. Linear modal time history analysis is performed using scaled ground motions. Three-directional ground motion records from five different earthquakes have been scaled to the design level and applied to the structure. Sloshing behavior of water inside the tank and the effect of vertical ground motion on the columns have been investigated. It is found that, vertical ground motions can increase the axial forces in columns by up to 20 %, and the ACI 350.3-06 design method is not always conservative. As seismic response depends on both the dynamic properties of the structure and the spectral characteristics of ground motions, more research is needed to understand and model the seismic response of elevated water tanks.

Structural Safety of Industrial Steel Tanks, Pressure Vessels and Piping Systems Under Seismic Loading (INDUSE). 2013 Liquid storage tanks, pressure vessels and industrial piping are steel structural systems, present in all industrial facilities (chemical and petrochemical industries, and power plants). Safeguarding their structural integrity against earthquakes constitutes a key issue towards increased safety and unhindered operation of the industrial facility. Their structural behaviour, and in particular seismic design, is quite different than steel buildings and has several particularities, requiring a combined civil and mechanical engineering expertise. The particularities stem from their shape and geometry, the presence of high internal pressure, and the dynamic behaviour of the enclosed liquid, which may affect significantly their load and deformation capacity. The design of those structures has been dominated by the use of American standards (API 650, ASME VIII and B31.3).[^]Nevertheless, for the case of seismic design, those standards (especially ASME standards for pressure vessels and piping) contain very limited provisions, referring mainly to structural design codes and specifications. European specifications (EN 14015, 13445,

13480) also contain limited provisions for the earthquake-resistant design of industrial equipment. An effort has been made in Eurocode 8 (EN 1998-4), which concerns almost exclusively vertical-cylindrical liquid storage tanks. Nevertheless, those rules do not cover all possible limit states and, furthermore, they need significant improvement to reach a level of applicability for design practice. The program consists of an interdisciplinary research effort INDUSE that combines civil and mechanical engineering expertise, for the purpose of developing guidelines, which can be used for the seismic design of liquid storage tanks, pressure vessels and piping, within the Eurocode design framework.[^]Towards this purpose, extensive experimental, analytical, and numerical work has been conducted within the INDUSE project with the synergy of academic units, research centres and industrial partners. The guidelines are novel and unique, incorporating modern aspects of earthquake-resistant design, and are aimed at:

- expanding EN 1998-4 provisions towards an integrated seismic design of liquid storage tanks and attached equipment, incorporating some special features and all possible failure modes (WP5) and
- extending the applicability of Eurocode 8 (EN 1998) concepts for the cases of industrial pressure vessels (WP6), and piping systems (WP7).

The following intermediate goals have been achieved within the INDUSE project:

- A basic comparison has been performed between current seismic design provisions in European and American standards together with an assessment of seismic damages in industrial facilities (WP1).[^]
- Taking into account the particularities of each structural system, seismic actions have been determined (WP2).
- Extensive experimental testing has been conducted on key piping components (e.g. nozzles, pipe connections/branches and elbows) under strong cyclic loading; furthermore a piping system has been tested under pseudo-dynamic loading (WP3).
- Finite element analyses on these components have been performed, simulating the experiments and covering a wide range of geometric, material and loading parameters (WP4).

The results of the above investigations are summarised below, demonstrating the achievements of INDUSE project objectives, work package per work package.

Liquid Sloshing Dynamics Raouf A. Ibrahim 2005-05-19 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.

Experimental and Numerical Investigation of Liquid Storage Tanks Under Seismic Excitation Iman Bahreini

Toussi 2016 Liquid storage tanks are a crucial type of structures. They are used to store various types of liquids and liquefied gases in different situations. In seismic regions, functionality of these structures after severe earthquakes is an important factor in their design. In earthquake-prone regions, the sloshing phenomena has an important role in the design procedure. Current design codes and guidelines (e.g. ACI 350.3 and ASCE 7) are based on analytical studies that in some cases can be inaccurate in prediction of forces and pressures. Since a long time ago scientists have studied the sloshing phenomena in liquid storage tanks with different methods including analytical, numerical and experimental studies. In the current study, rectangular ground-supported tanks are studied and the effect of seismic loading on them is investigated both experimentally and numerically. For the experimental tests, the tanks were placed on a shaking table and using high-speed HD cameras, tests were filmed and later analyzed frame by frame to capture the critical moments. To investigate the bi-lateral effect of base excitation on the tanks, they were oriented on the table with four different angles. In the numerical study, a computational fluid dynamics tool - OpenFOAM - was used to simulate the tank motion and finally the results were compared with the experiment in order to develop a reliable model.

Seismic Design of Liquid-containing Concrete Structures and Commentary (ACI 350.3-06) ACI Committee

350 2006-01-01

Eurocode 8, Design of Structures for Earthquake Resistance 2006 Earthquake-resistant design, Structures, Structural design, Seismology, Silos, Tanks (containers), Pipelines, Safety measures, Reliability, Performance, Classification systems, Damping, Verification, Dynamic pressure, Seismic loading,

Construction systems parts, Shell structures, Anchorages, Foundations, Pipes, Underground, Hydrodynamics, Earthquakes, Seismic coefficient, Mathematical calculations, Pressure

Seismic Design of Industrial Facilities Sven Klinkel 2013-09-04 Seismic Design of Industrial Facilities demands a deep knowledge on the seismic behaviour of the individual structural and non-structural components of the facility, possible interactions and last but not least the individual hazard potential of primary and secondary damages. From 26.-27. September 2013 the International Conference on Seismic Design of Industrial Facilities firstly addresses this broad field of work and research in one specialized conference. It brings together academics, researchers and professional engineers in order to discuss the challenges of seismic design for new and existing industrial facilities and to compile innovative current research. This volume contains 50 contributions to the SeDIF-Conference covering the following topics with respect to the specific conditions of plant design: · International building codes and guidelines on the seismic design of industrial facilities · Seismic design of non-structural components · Seismic design of silos and liquid-filled tanks · Soil-structure-interaction effects · Seismic safety evaluation, uncertainties and reliability analysis · Innovative seismic protection systems · Retrofitting The SeDIF-Conference is hosted by the Chair of Structural Statics and Dynamics of RWTH Aachen University, Germany, in cooperation with the Institute for Earthquake Engineering of the Dalian University of Technology, China.

Earthquake-Resistant Structures Abbas Moustafa 2012-02-29 This book deals with earthquake-resistant structures, such as, buildings, bridges and liquid storage tanks. It contains twenty chapters covering several interesting research topics written by researchers and experts in the field of earthquake engineering. The book covers seismic-resistance design of masonry and reinforced concrete structures to be constructed as well as safety assessment, strengthening and rehabilitation of existing structures against earthquake loads. It also includes three chapters on electromagnetic sensing techniques for health assessment of structures, post earthquake assessment of steel buildings in fire environment and response of underground pipes to blast loads. The book provides the state-of-the-art on recent progress in earthquake-resistant structures. It should be useful to graduate students, researchers and practicing structural engineers.

European Seismic Design Practice - Research and Application A.S. Elnashai 2022-03-24 It is evident that European earthquake engineering research and design practice is assuming a role of increasing importance on the international scene. This is primarily due to two considerations; firstly the emergence of a core of European earthquake engineers who are co-operating on a long-term basis for the development of seismic design criteria specific to the European environment and secondly the identification of new problems in existing design practice in the USA and in Japan. It is in this context that European earthquake engineering activities and publications are eagerly observed and awaited by the international community. Includes a compact set of papers from leading research institutions, laboratories and companies in Europe, with a healthy number of contributions from elsewhere. It represents the European state-of-the-art and practice in earthquake testing, analysis & design of civil engineering works as well as strong-motion & hazard studies.

Advances in Mechanism Design II Jaroslav Beran 2016-08-17 This book presents the most recent advances in the research of machines and mechanisms. It collects 54 reviewed papers presented at the XII International Conference on the Theory of Machines and mechanisms (TMM 2016) held in Liberec, Czech Republic, September 6-8, 2016. This volume offers an international selection of the most important new results and developments, grouped in six different parts, representing a well-balanced overview, and spanning the general theory of machines and mechanisms, through analysis and synthesis of planar and spatial mechanisms, linkages and cams, robots and manipulators, dynamics of machines and mechanisms, rotor dynamics, computational mechanics, vibration and noise in machines, optimization of mechanisms and machines, mechanisms of textile machines, mechatronics to the control and monitoring systems of machines. This conference is traditionally organised every four year under the auspices of the international organisation IFToMM and the Czech Society for Mechanics.

Recent Advances in Seismic Response Analysis of Cylindrical Liquid Storage Tanks Akira Maekawa 2012

Above Ground Storage Tank Oil Spills Mervin Fingas 2022-09-30 Supply of oil and gas continues to increase as well as natural events such as hurricanes, while engineers and safety managers are not well trained on storage tank engineering and leak detection, one of the most vulnerable and least studied

components of oil and gas storage equipment. Above Ground Storage Tank Oil and Chemical Spills gives engineers and researchers a training guide on tank design, tank failure modes and risk analysis. Bridging between research and application, this reference sends an integrated engineering approach backed by both corporate and academic contributors focused specifically on storage tanks, their spills, case histories, and technical aspects of leakage from storage tanks. Additional topics include regulations, differences between spills from storage tanks and other sources, and supported by extensive data and additional references. Above Ground Storage Tank Oil and Chemical Spills delivers a much-needed knowledge source for today's engineers and managers to keep supply and personnel safe. Learn from both academic and corporate contributors, bridging between research and practical application Understand lessons learned with case studies and extensive data Know the differences between spills from storage tanks and other sources

Seismic Analysis of Structures and Equipment Praveen K. Malhotra 2020-11-24 This book describes methods used to estimate forces and deformations in structures during future earthquakes. It synthesizes the topics related to ground motions with those related to structural response and, therefore, closes the gap between geosciences and engineering. Requiring no prior knowledge, the book elucidates confusing concepts related to ground motions and structural response and enables the reader to select a suitable analysis method and implement a cost-effective seismic design. Presents lucid, accessible descriptions of key concepts in ground motions and structural response and easy to follow descriptions of methods used in seismic analysis; Explains the roles of strength, deformability, and damping in seismic design; Reinforces concepts with real-world examples; Stands as a ready reference for performance-based/risk-based seismic design, providing guidance for achieving a cost-effective seismic design.

Seismic Design and Performance T.G. Sitharam 2021-03-26 This volume presents select papers presented at the 7th International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics. The papers discuss advances in the fields of soil dynamics and geotechnical earthquake engineering. Some of the themes include seismic design of deep & shallow foundations, soil structure interaction under dynamic loading, marine structures, etc. A strong emphasis is placed on connecting academic research and field practice, with many examples, case studies, best

practices, and discussions on performance based design. This volume will be of interest to researchers and practicing engineers alike.

Modern Earthquake Engineering Junbo Jia 2016-10-01 This book addresses applications of earthquake engineering for both offshore and land-based structures. It is self-contained as a reference work and covers a wide range of topics, including topics related to engineering seismology, geotechnical earthquake engineering, structural engineering, as well as special contents dedicated to design philosophy, determination of ground motions, shock waves, tsunamis, earthquake damage, seismic response of offshore and arctic structures, spatial varied ground motions, simplified and advanced seismic analysis methods, sudden subsidence of offshore platforms, tank liquid impacts during earthquakes, seismic resistance of non-structural elements, and various types of mitigation measures, etc. The target readership includes professionals in offshore and civil engineering, officials and regulators, as well as researchers and students in this field.

Earthquake Engineering and Structural Dynamics in Memory of Ragnar Sigbjörnsson Rajesh Rupakhety 2017-12-07 This book presents methods and results that cover and extend beyond the state-of-the-art in structural dynamics and earthquake engineering. Most of the chapters are based on the keynote lectures at the International Conference in Earthquake Engineering and Structural Dynamics (ICESD), held in Reykjavik, Iceland, on June 12-14, 2017. The conference is being organised in memory of late Professor Ragnar Sigbjörnsson, who was an influential teacher and one of the leading researchers in the fields of structural mechanics, random fields, engineering seismology and earthquake engineering. Professor Sigbjörnsson had a close research collaboration with the Norwegian Institute of Science and Technology (NTNU), where his research was mainly focused in dynamics of marine and offshore structures. His research in Iceland was mainly focused on engineering seismology and earthquake engineering. The keynote-lecture based chapters are contributed by leading experts in these fields of research and showcase not only the historical perspective but also the most recent developments as well as a glimpse into the future. These chapters showcase a synergy of the fields of structural dynamics, engineering seismology, and earthquake engineering. In addition, some chapters in the book are based on works carried out under the leadership and initiative of Professor Sigbjörnsson and showcase his contribution to

the understanding of seismic hazard and risk in Iceland. As such, the book is useful for both researchers and practicing engineers who are interested in recent research advances in structural dynamics and earthquake engineering, and in particular to those interested in seismic hazard and risk in Iceland.

Seismic Analysis of Liquefied Natural Gas Tanks 2006 The primary objective of this project is to study the utility of the simplified analogs for the analysis and design of liquid storage tanks constructed using conventional and protective systems. A vertical, cylindrical LNG tank that could be constructed in a region of moderate to high seismicity is evaluated using response-history analysis. Data reported and statistically sorted include (a) base shear, (b) global overturning moment, and (c) wave height in the tank (used for freeboard calculations). The Finite Element (FE) method is utilized to model the tank, as well as the contained liquid. ANSYS, a finite element code that combines structural and fluid simulation capabilities, is used to model the structure in the three-dimensional space and perform modal and nonlinear seismic analysis. The tank is considered to have a fixed base, for the conventional design, and to respond within the linear elastic limit. Seismic isolation is implemented by introducing horizontal inelastic beam elements between the base and the ground. The responses of the conventional and isolated tanks are also reported and compared, for the two earthquake levels, and the effect of seismic isolation is investigated. (Abstract shortened by UMI.).

Seismic Design and Analysis of Tanks G. M. Calvi 2022-03-09 A detailed view on the effects of seismic activity on tank structures As the use of underground storage tanks (USTs) continues to grow—with approximately 545 thousand in the US alone—the greatest threat to from USTs is the contamination of groundwater, a vital source of drinking water throughout the world and one that close to half of Americans rely upon. 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. *Seismic Design and Analysis of Tanks* provides the first in-depth discussion of the principles and applications of shell structure design and earthquake engineering focused on tank structures, and how these methodologies can help prevent the destruction of USTs during earthquakes. Providing a thorough examination into the design, analysis, and performance of steel, reinforced concrete, and precast tanks, this book takes a look at tanks that are aboveground, underground, or elevated and

evaluates the efficacy of each method during times of turbulence—and it does so without getting bogged down with impenetrable math and theory. Readers will also find: Global approach for 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), American Concrete Institute (ACI 350,3, 371.R), American Water Works Association (AWWA D100, D110, D115), and the American Petroleum Institute (API 650) An overview of European codes and standards including Eurocode 8-4 and CEN-EN 14015 Hundreds of step-by-step equations accompanied by illustrations Photographs that feature real-world damage to tanks caused by seismic events Perfect for practicing structural engineers, geotechnical engineers, civil engineers, and engineers of all kinds who are responsible for the design, analysis, and performance of tanks and foundations—as well as students studying engineering—Seismic Design and Analysis of Tanks is the first work of its kind to deal with seismic engineering performance of storage tanks.

Earthquake Design Practice for Buildings David Key 1988 Illustrated and with a large number of photographs, diagrams and graphs, this title is a sound guide not only to the practising engineer who is unfamiliar with the concepts of seismic design but also to those familiar with the concepts but who want a concise design guide to what is sound engineering practice.

Design and Construction of LNG Storage Tanks Josef Rötzer 2019-08-22 Worldwide, the use of natural gas as a primary energy source will remain vital for decades to come. This applies to industrialized, emerging countries and developing countries. Owing to the low level of impurities, natural gas is considered to be a climate-friendly fossil fuel because of the low CO₂ emissions, but is at the same time an affordable source of energy. In order to enable transport over long distances and oceans (and hence create an economic and political alternative to pipelines) , the gas is liquefied, which is accompanied by a considerable reduction in volume, and then transported by ship. Thus, at international ports, many LNG tanks are required for temporary storage and further use. The trend towards smaller liquefaction and regasification plants with associated storage tanks for marine fuel applications has attracted new players in this market who often do not yet have the necessary experience and technical expertise. It is not sufficient to refer to all existing technical standards when defining consistent state-of-the-art specifications and requirements. The switch to European standardisation has made it necessary to revise and adapt

existing national codes to match European standards. Technical committees at national and international level have begun their work of updating and completing the EN 14620 series. In the USA, too, the corresponding regulations are also being updated. The revision of American Concrete Institute standard ACI 376 Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases, first published in 2011, will be completed in the spring of 2019, and the final version, published in autumn 2019. This book provides an overview of the state of the art in the design and construction of liquefied natural gas (LNG) tanks. Since the topic is very extensive and complex, an introduction to all aspects is provided, e.g. requirements and design for operating conditions, thermal design, hydrostatic and pneumatic tests, soil surveys and permissible settlement, modelling of and calculations for the concrete structure, and the actions due to fire, explosion and impact. Dynamic analysis and the theory of sloshing liquid are also presented.

Seismic Isolation of Elevated Liquid Storage Tanks Pravin B. Waghmare 2012-07 Features:: Section on:
1. Overview of seismic investigation of liquid storage tanks. 2. Earthquake resistant design of liquid storage tanks. 3. Seismic base isolation systems. 4. Seismic isolation of liquid storage tanks. 5. Mathematical modeling of tanks. 6. Spring mass model for seismic analysis. 7. Structural model of elevated liquid storage tanks. 8. Design of isolators. 9. Behavior of elevated tanks on shaft isolated with elastomeric bearings.

A Translation of the Stability of Elastic Equilibrium Warner Tjardus Koiter 1970 A general theory of elastic stability is presented. In contrast to previous works in the field, the present analysis is augmented by an investigation of the behavior of the buckled structure in the immediate neighborhood of the bifurcation point. This investigation explains why some structures, e.g., a flat plate supported along its edges and subjected to thrust in its plane, are capable of carrying loads considerably above the buckling load, while other structures, e.g., an axially loaded cylindrical shell, collapse at loads far below the theoretical critical load.

Further Study of the Earthquake Response of a Broad Cylindrical Liquid-storage Tank Model George C. Manos 1982

Liquid Storage Tanks Under Seismic Excitations 1993 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.

Earthquake-Resistant Structures Abbas Moustafa 2012-02-29 This book deals with earthquake-resistant structures, such as, buildings, bridges and liquid storage tanks. It contains twenty chapters covering several interesting research topics written by researchers and experts in the field of earthquake engineering. The book covers seismic-resistance design of masonry and reinforced concrete structures to be constructed as well as safety assessment, strengthening and rehabilitation of existing structures against earthquake loads. It also includes three chapters on electromagnetic sensing techniques for health assessment of structures, post earthquake assessment of steel buildings in fire environment and response of underground pipes to blast loads. The book provides the state-of-the-art on recent progress in

earthquake-resistant structures. It should be useful to graduate students, researchers and practicing structural engineers.

Seismic Design of Liquid Storage Tanks Medhat A. Haroun 1981

Seismic Resistant Design of Liquid Storage Tanks in Japan Fujikazu Sakai 1982

Seismic Design and Retrofit of Cylindrical Liquid Storage Tanks Hussain Bhatia 1997

Guidelines for the Seismic Design of Oil and Gas Pipeline Systems American Society of Civil Engineers.
Committee on Gas and Liquid Fuel Lifelines 1984