



## Seismic Design of Liquid Storage Tanks

Praveen K. Malhotra



# Seismic Design For Liquid Storage Tanks

**Manmohan Dass Goel,Ratnesh  
Kumar,Sangeeta S. Gadve**



## **Seismic Design For Liquid Storage Tanks:**

*Seismic Design of Liquid Storage Tanks* Medhat A. Haroun, George William Housner, 1981      **Seismic Design and Retrofit of Cylindrical Liquid Storage Tanks** Hussain Bhatia, 1997      **Seismic Design Rules for Flat Bottom Cylindrical Liquid Storage Tanks** N. J. I. Adams, 1991      Seismic Design and Analysis of Tanks Gian Michele Calvi, Roberto Nascimbene, 2023-02-28

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

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*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      **Seismic Design and Analysis of Tanks** Gian Michele Calvi, Roberto Nascimbene, 2023-03-21

*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 Seismic Design of Industrial Facilities Sven Klinkel, Christoph Butenweg, Gao Lin, Britta Holtschoppen, 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 Seismic Resistant Design of Liquid Storage Tanks in Japan Fujikazu Sakai, Hiroshi Ogawa, 1982 Shell Structures, Theory and Applications Wojciech

Pietraszkiewicz, Czeslaw Szymczak, 2005-09-22 Shells are basic structural elements of modern technology Examples of shell structures include automobile bodies domes water and oil tanks pipelines ship hulls aircraft fuselages turbine blades loudspeaker cones but also balloons parachutes biological membranes a human skin a bottle of wine or a beer can This volume contains full texts of over 100 papers presented by specialists from over 20 countries at the 8th Conference Shell Structures Theory and Applications 12-14 October 2005 in Jurata Poland The aim of the meeting was to bring together scientists designers engineers and other specialists in shell structures in order to discuss important results and new ideas in this field The goal is to pursue more accurate theoretical models to develop more powerful and versatile methods of analysis and to disseminate expertise in design and maintenance of shell structures Among the authors there are many distinguished specialists of shell structures including the authors of general lectures I V Andrianov Ukraine V A Eremeyev Russia A Ibrahimbegovic France P Klosowski Poland B H Kruplin Germany E Ramm Germany J M Rotter UK and D Steigmann USA The subject area of the papers covers various theoretical models and numerical analyses of strength dynamics stability optimization etc of different types of shell structures their design and maintenance as well as modelling of some surface related mechanical phenomena

**Above Ground Storage Tank Oil Spills** Merv Fingas, 2022-09-17 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

**Recent Developments in Structural Engineering, Volume 1** Manmohan Dass Goel, Ratnesh Kumar, Sangeeta S. Gadve, 2024-05-02 The book presents the select proceedings of 13th Structural Engineering Convention It covers the latest research in multidisciplinary areas within structural engineering Various topics covered include structural dynamics structural mechanics finite element methods structural vibration control advanced cementitious and composite materials bridge engineering soil structure interaction blast impact fire material and many more The book will be a useful reference material for structural engineering researchers and practicing engineers

**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      **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      Sustainable Development of Smart Cities Infrastructure (SDSCI-2023) (Volume-1) H.K. Sharma, Arun Goel, Pankaj Munjal, 2023-05-25 Sustainable development of smart cities infrastructures is of paramount importance and need to be planned designed constructed operated and de commissioned in a manner that ensures economic social environmental and institutional sustainability over the entire infrastructure life cycle Smart cities infrastructure however be cost effective disaster resilient environmentally friendly conserving natural resources and sustainable ensuring faster delivery of quality and durable structures which include roads building bridges energy and water infrastructures Government of India is going to encourage Public Private Partnership PPP as an alternate option to build most of the infrastructures which can be useful both for green field as well as brown field smart cities projects The present book is a collection of contributed research and review papers presented at the National Conference on Sustainable Development of Smart Cities Infrastructure SDSCI 2023 held at National Institute of Technology Kurukshetra in May 2023 The subject matter is grouped into nine sessions which include research articles pertaining to sustainable development of smart cities urban and rural planning transportation built environment and management sustainable and smart technologies materials construction and maintenance advance modelling characterization of structures energy and environment performance of smart cities infrastructure under extreme loading conditions green buildings structural health monitoring and ICT in smart cities data mining and machine learning for sustainable infrastructure GIS and remote sensing future trends and prospects of smart cities innovative technologies building energy and efficiency and sobriety and sustainable resilience to natural and man made disasters and smart materials etc The book would be a valuable reference for researchers students structural designers site engineers and all related engineers involved in the field of sustainable development of smart cities infrastructure      **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      **Lees' Process Safety Essentials** Sam Mannan, 2013-11-12 Lees Process Safety Essentials is a single volume digest presenting the critical practical content from Lees Loss Prevention for day to day use and reference It is portable

authoritative affordable and accessible ideal for those on the move students and individuals without access to the full three volumes of Lees This book provides a convenient summary of the main content of Lees primarily drawn from the hazard identification assessment and control content of volumes one and two Users can access Essentials for day to day reference on topics including plant location and layout human factors and human error fire explosion and toxic release engineering for sustainable development and much more This handy volume is a valuable reference both for students or early career professionals who may not need the full scope of Lees and for more experienced professionals needing quick convenient access to information Boils down the essence of Lees the process safety encyclopedia trusted worldwide for over 30 years Provides safety professionals with the core information they need to understand the most common safety and loss prevention challenges Covers the latest standards and presents information including recent incidents such as Texas City and Buncfield

**Lees' Loss Prevention in the Process Industries** Frank Lees, 2012-11-05 Safety in the process industries is critical for those who work with chemicals and hazardous substances or processes The field of loss prevention is and continues to be of supreme importance to countless companies municipalities and governments around the world and Lees is a detailed reference to defending against hazards Recognized as the standard work for chemical and process engineering safety professionals it provides the most complete collection of information on the theory practice design elements equipment regulations and laws covering the field of process safety An entire library of alternative books and cross referencing systems would be needed to replace or improve upon it but everything of importance to safety professionals engineers and managers can be found in this all encompassing three volume reference instead The process safety encyclopedia trusted worldwide for over 30 years Now available in print and online to aid searchability and portability Over 3 600 print pages cover the full scope of process safety and loss prevention compiling theory practice standards legislation case studies and lessons learned in one resource as opposed to multiple sources *Earthquake Resistant Construction of Gas and Liquid Fuel Pipeline*

*Systems Serving, Or Regulated by the Federal Government* Felix Y. Yokel, Robert G. Mathey, 1992 **Seismic Design and Practice into the Next Century** Edmund Booth, 2022-05-04 The papers from 18 countries in Europe and elsewhere contain discussions of quite radical innovations in material technology design philosophy experimental techniques and analytical approaches that will affect seismic design practice into the next century Papers are organised into 9 sections Ground motion and seismic hazard studies Seismic design of foundations Seismic design of steel concrete and masonry buildings Seismic design of offshore nuclear and petrochemical installations Seismic design of bridges dock and power station structures Repair and strengthening of bridges and buildings Active and passive methods of seismic control Dynamic testing methods Seismic codes of practice The proceedings will provide essential material for all those from both industrial and research organisations needing to keep in touch with the state of the art in earthquake engineering and related earth sciences

*Failure Analysis - Structural Health Monitoring of Structure and Infrastructure Components* Gobinath



Ravindran,Vutukuru Mahesh,Moustafa Moufid Kassem,2023-10-18 Failure Analysis Structural Health Monitoring of Structure and Infrastructure Components is a collection of chapters written by academicians researchers and practicing engineers from all over the world The chapters focus on some developments as well as problems in structural health monitoring SHM in civil engineering structures and infrastructures The book covers a variety of multidisciplinary topics including SHM risk analysis seismic analysis and various modeling and simulation methodologies This book is an excellent resource for undergraduate and postgraduate students academics and researchers across a wide variety of engineering disciplines as well as for practicing engineers and other professionals in the engineering industry      **Earthquake**

**Geotechnical Engineering for Protection and Development of Environment and Constructions** Francesco Silvestri,Nicola Moraci,2019-10-22 Earthquake Geotechnical Engineering for Protection and Development of Environment and Constructions contains invited keynote and theme lectures and regular papers presented at the 7th International Conference on Earthquake Geotechnical Engineering Rome Italy 17 20 June 2019 The contributions deal with recent developments and advancements as well as case histories field monitoring experimental characterization physical and analytical modelling and applications related to the variety of environmental phenomena induced by earthquakes in soils and their effects on engineered systems interacting with them The book is divided in the sections below Invited papers Keynote papers Theme lectures Special Session on Large Scale Testing Special Session on Liquefact Projects Special Session on Lessons learned from recent earthquakes Special Session on the Central Italy earthquake Regular papers Earthquake Geotechnical Engineering for Protection and Development of Environment and Constructions provides a significant up to date collection of recent experiences and developments and aims at engineers geologists and seismologists consultants public and private contractors local national and international authorities and to all those involved in research and practice related to Earthquake Geotechnical Engineering

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