



# Seismic Evaluation and Design of Petrochemical and Other Industrial Facilities

Third  
Edition

Task Committee on Seismic Evaluation  
and Design of Petrochemical Facilities

This is a preview. [Click here to purchase the full publication.](#)

**ASCE**

# **Seismic Evaluation and Design of Petrochemical and Other Industrial Facilities**

*Third Edition*

Prepared by  
Task Committee on Seismic Evaluation and Design of  
Petrochemical Facilities of the  
Energy Division of the  
American Society of Civil Engineers



**Published by the American Society of Civil Engineers**

This is a preview. [Click here to purchase the full publication.](#)

## Library of Congress Cataloging-in-Publication Data

Names: American Society of Civil Engineers. Task Committee on Seismic Evaluation and Design of Petrochemical Facilities, author.

Title: Seismic evaluation and design of petrochemical and other industrial facilities / prepared by Task Committee on Seismic Evaluation and Design of Petrochemical Facilities of the Energy Division of the American Society of Civil Engineers.

Other titles: Guidelines for seismic evaluation and design of petrochemical facilities

Description: Third edition. | Reston : American Society of Civil Engineers, [2020] | Revision of Guidelines for seismic evaluation and design of petrochemical facilities. | Includes bibliographical references and index. | Summary: "This report offers practical recommendations regarding the design and safety of new and existing petrochemical facilities during and following an earthquake" – Provided by publisher.

Identifiers: LCCN 2019041768 | ISBN 9780784415481 (print) | ISBN 9780784482667 (PDF)

Subjects: LCSH: Petroleum refineries—Design and construction. | Earthquake resistant design—Standards—United States.

Classification: LCC TH4571 .G85 2020 | DDC 665.5/3—dc23

LC record available at <https://lccn.loc.gov/2019041768>

Published by American Society of Civil Engineers

1801 Alexander Bell Drive

Reston, Virginia 20191-4382

[www.asce.org/bookstore](http://www.asce.org/bookstore) | [ascelibrary.org](http://ascelibrary.org)

Any statements expressed in these materials are those of the individual authors and do not necessarily represent the views of ASCE, which takes no responsibility for any statement made herein. No reference made in this publication to any specific method, product, process, or service constitutes or implies an endorsement, recommendation, or warranty thereof by ASCE. The materials are for general information only and do not represent a standard of ASCE, nor are they intended as a reference in purchase specifications, contracts, regulations, statutes, or any other legal document. ASCE makes no representation or warranty of any kind, whether express or implied, concerning the accuracy, completeness, suitability, or utility of any information, apparatus, product, or process discussed in this publication, and assumes no liability therefor. The information contained in these materials should not be used without first securing competent advice with respect to its suitability for any general or specific application. Anyone utilizing such information assumes all liability arising from such use, including but not limited to infringement of any patent or patents.

ASCE and American Society of Civil Engineers—Registered in US Patent and Trademark Office.

*Photocopies and permissions.* Permission to photocopy or reproduce material from ASCE publications can be requested by sending an email to [permissions@asce.org](mailto:permissions@asce.org) or by locating a title in the ASCE Library (<http://ascelibrary.org>) and using the "Permissions" link.

*Errata:* Errata, if any, can be found at <https://doi.org/10.1061/9780784415481>.

Copyright © 2020 by the American Society of Civil Engineers.

All Rights Reserved.

ISBN 978-0-7844-1548-1 (print)

ISBN 978-0-7844-8266-7 (PDF)

Manufactured in the United States of America.

26 25 24 23 22 21 20 1 2 3 4 5

# ASCE Petrochemical Energy Committee

This publication is one of five state-of-the-practice engineering reports produced to date by the ASCE Petrochemical Energy Committee. These engineering reports are intended to summarize current engineering knowledge and design practice and present guidelines for the design of petrochemical facilities. They represent a consensus opinion of the task committee members who are active in their development. These five ASCE engineering reports are

1. *Design of Anchor Bolts in Petrochemical Facilities*,
2. *Design of Blast Resistant Buildings in Petrochemical Facilities*,
3. *Design of Secondary Containment in Petrochemical Facilities*,
4. *Seismic Evaluation and Design of Petrochemical and Other Industrial Facilities*  
(Note: First and second editions were titled *Guidelines for Seismic Evaluation and Design of Petrochemical Facilities*, and the name was modified for the third edition at the request of ASCE Publications), and
5. *Wind Loads for Petrochemical and Other Industrial Facilities*.

A. K. Gupta organized the ASCE Petrochemical Energy Committee in 1991, which was initially chaired by Curley Turner. Under their leadership the five task committees were formed, initially publishing the five reports in 1997. The Committee was subsequently chaired by Joseph A. Bohinsky and Frank J. Hsiu. In 2005, Magdy H. Hanna reorganized the ASCE Petrochemical Energy Committee, and the following four task committees were formed to update their respective reports:

- Task Committee on Anchorage Design,
- Task Committee on Blast-Resistant Design,
- Task Committee on Seismic Evaluation and Design for Petrochemical Facilities, and
- Task Committee for Wind-Induced Forces.

Building codes and standards have changed significantly since the publication of these five reports, specifically in the calculation of wind and seismic loads and analysis procedures for anchorage design. In addition, new research in these areas and in blast-resistant design has provided opportunities to improve the recommended guidelines. ASCE has determined the need to update two of the original

reports and publish new editions based on the latest research and for consistency with current building codes and standards.

In 2014, the Energy Division Executive Committee Chair J. G. (Greg) Soules requested the following two task committees to update their respective reports:

- Task Committee on Seismic Evaluation and Design of Petrochemical Facilities, and
- Task Committee for Wind-Induced Forces.

#### Current ASCE Petrochemical Energy Committee

James R. (Bob) Bailey	Exponent—Chairman
J. G. (Greg) Soules	CB&I Storage Tank Solutions LLC

# The ASCE Task Committee on Seismic Evaluation and Design of Petrochemical Facilities

This revised document was prepared to provide guidance in the seismic design of new petrochemical and other industrial facilities and the seismic evaluation of existing facilities. Though the committee membership and the intent of this document are directed to petrochemical facilities, these guidelines are applicable to similar situations in other industries. The intended audience for this document includes structural design engineers, operating company personnel responsible for establishing seismic design and construction standards, and local building authorities.

The task committee was established because of the petrochemical industry's significant interest in addressing the wide variation of petrochemical-industry-related design and construction practices and standards that are applied throughout the country. Another primary purpose was to address the need for consistent evaluation methodologies and standards for existing facilities. Most governing building codes and design standards address only new design, and clearly retrofitting existing facilities to meet current standards would be prohibitively expensive. Furthermore, standards for new design do not address all of the conditions that may be found in existing facilities.

These guidelines are intended to provide practical recommendations in several areas that affect the safety of a petrochemical facility during and following an earthquake.

In the area of new design, these guidelines emphasize interpretations of the intent of building codes as applied to petrochemical facilities and practical guidance on design details and considerations that are not included in building codes.

For existing facilities, these guidelines provide evaluation methodologies that rely heavily on experience from past earthquakes, coupled with focused analyses. The guidelines emphasize methods to address seismic vulnerabilities that building codes do not cover, but that experienced engineers can identify.

This book also provides background information and recommendations in several areas related to seismic safety where the structural engineer may interact with other disciplines and with plant operations. These areas include seismic hazards, contingency planning, and post-earthquake damage assessment.

The original version of this document, published in 1997, was developed by a committee of industry representatives chaired by Mr. Gayle S. Johnson. A reconstituted committee led by Mr. J. G. (Greg) Soules created the second edition, published in 2011.

For this third edition, several key individuals dedicated significant amounts of time to formulating, writing, and reviewing in detail specific sections of this document. Those members are identified as follows.

### **The ASCE Task Committee on Seismic Evaluation and Design of Petrochemical Facilities**

J. G. (Greg) Soules, P.E., S.E., SECB  
CB&I Storage Tank Solutions LLC  
Chair

Gayle S. Johnson, P.E.  
Ahmed Nisar, P.E.

Simpson Gumpertz & Heger Inc.  
InfraTerra, Inc.

The committee would like to thank the following individuals for their reviews and other contributions.

#### **Reviewers and Other Contributors**

Robert E. Bachman, S.E.

Michael W. Greenfield, Ph.D., P.E.

Christopher Hitchcock, CEG

Justin D. Reynolds, P.E.

Paul B. Summers, S.E.

Guzhao Li, Ph.D., S.E.

Robert Bachman Consulting

Greenfield Geotechnical LLC

InfraTerra, Inc.

Simpson Gumpertz & Heger Inc.

Simpson Gumpertz & Heger Inc.

Simpson Gumpertz & Heger Inc.

# Contents

<b>Chapter 1 Introduction .....</b>	<b>1</b>
1.1 Objective.....	1
1.2 Related Industry Codes, Standards, and Specifications.....	3
1.3 Organization of the Book .....	4
References.....	5
<b>Chapter 2 Design and Evaluation Philosophy .....</b>	<b>7</b>
2.1 Introduction .....	7
2.2 Considerations for New Design.....	7
2.3 Considerations for the Evaluation of Existing Facilities.....	8
2.4 Cautions Regarding Design and Evaluation.....	9
2.5 Performance Objectives and Risk Categories.....	10
2.6 Design Approach for New Facilities .....	13
2.7 Evaluation of Existing Structure/Replacement in Kind .....	14
2.8 Considerations for Regulatory Requirements .....	15
2.9 Considerations for Temporary Facilities .....	17
2.10 Structural Observation and Inspection.....	18
2.11 Quality Assurance.....	18
2.12 Peer Review.....	18
References.....	19
<b>Chapter 3 Seismic Hazards .....</b>	<b>21</b>
3.1 Introduction .....	21
3.2 Earthquake Basics .....	22
3.3 Ground Shaking.....	23
3.4 Design Ground Motions .....	26
3.5 Ground Failure.....	36
3.6 Tsunami and Seiche .....	40
References.....	43
Appendix 3.A Ground Shaking .....	46
Appendix 3.B Earthquake-Related Coastal Inundation .....	55
<b>Chapter 4 Seismic Analysis .....</b>	<b>63</b>
4.1 Introduction .....	63
4.2 Structural Systems in a Petrochemical Facility .....	64
4.3 Selection of Analysis Procedures .....	67
4.4 Equivalent Lateral Force Procedure.....	68



4.5 Dynamic Analysis Methods .....	83
4.6 Considerations for Existing Facilities.....	87
References.....	90
Appendix 4.A Typical Period (T) Computations for Nonbuilding Structures.....	91
Appendix 4.B Guidelines for Determining Base Shear for Combination Structures.....	102
Appendix 4.C Determination of Base Shear for Selected Structures .....	108
Appendix 4.D Stability Check Using Energy Balance Approach.....	120
Appendix 4.E Methodology for Determination of Sliding Displacements.....	132
Appendix 4.F Guidance for California Accidental Release Prevention (CalARP) Program Seismic Assessment.....	135
Appendix 4.G Examples of Configurations of Petrochemical Structures Where Dynamic Analysis Is Recommended.....	184
<b>Chapter 5 Primary Structural Design.....</b>	<b>195</b>
5.1 Introduction .....	195
5.2 Design Criteria .....	195
5.3 Design Considerations .....	204
5.4 Structural Details .....	222
5.5 Physical Interaction of Structures and Components .....	233
5.6 Geotechnical Considerations .....	235
References.....	237
<b>Chapter 6 Walkdown Evaluations of Existing Facilities.....</b>	<b>241</b>
6.1 Introduction .....	241
6.2 Basis for Performing Walkdowns .....	241
6.3 General Methodology.....	242
6.4 System Considerations .....	245
6.5 Evaluation of Components.....	246
6.6 Limitations .....	271
References.....	271
<b>Chapter 7 Design and Evaluation of Tanks at Grade.....</b>	<b>273</b>
7.1 Introduction .....	273
7.2 Past Earthquake Performance of Flat-Bottomed Tanks.....	274
7.3 Walkthrough Inspection.....	277
7.4 Analytical Evaluation .....	284
7.5 Mitigation of Seismic Effects.....	292
7.6 Considerations for Future Investigation .....	293
7.7 Design of New Tanks.....	293
References.....	294

<b>Chapter 8 Earthquake Contingency Planning.....</b>	<b>297</b>
8.1 Introduction .....	297
8.2 Purpose .....	297
8.3 Scope of Response Plan .....	297
8.4 Pre-Earthquake Preparation .....	298
8.5 Incident Recognition .....	299
8.6 Command and Control/Mobilization System.....	299
8.7 Roles and Responsibilities of Team Personnel.....	300
8.8 Inspection Methodology.....	300
8.9 Assembling of Inspection Data/Reporting Results.....	301
Reference.....	301
<b>Chapter 9 Post-Earthquake Damage Assessment .....</b>	<b>303</b>
9.1 Introduction .....	303
9.2 Pre-Investigation Activities .....	305
9.3 Performing Field Inspections .....	306
9.4 Evaluation of Load-Carrying Systems .....	307
9.5 Identification of Damaged Structures.....	308
9.6 Documentation.....	308
9.7 Inspection Team .....	309
9.8 Recommended Equipment .....	310
References.....	310
<b>Chapter 10 Retrofit Design .....</b>	<b>311</b>
10.1 Introduction.....	311
10.2 Upgrade Situations .....	311
10.3 Criteria for Voluntary Seismic Upgrading .....	312
10.4 Seismic Retrofit Considerations for Plant Structures and Buildings.....	312
References.....	315
<b>Chapter 11 New and Existing Marine Oil Terminals .....</b>	<b>317</b>
11.1 Introduction.....	317
11.2 MOT Descriptions .....	318
11.3 Historical Performance .....	318
11.4 State of Practice.....	318
11.5 Overall Approach.....	319
11.6 Existing Marine Oil Terminals.....	321
References.....	322
<b>Chapter 12 International Codes.....</b>	<b>323</b>
12.1 Introduction.....	323
12.2 Code Conformance.....	323
12.3 Multiple Code Conformance.....	324
12.4 Cautions When Performing Code Comparisons .....	325