

# 2020 NEHRP Recommended Seismic Provisions: Design Examples, Training Materials, and Design Flow Charts

FEMA P-2192-V3/November 2021

Volume III: Design Flow Charts



**FEMA**



# **2020 NEHRP (National Earthquake Hazards Reduction Program) Recommended Seismic Provisions: Design Flow Charts**

Prepared for

Federal Emergency Management Agency

U.S. Department of Homeland Security

By

Building Seismic Safety Council

National Institute of Building Sciences

Washington, D.C.

NOTICE: Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of the Federal Emergency Management Agency. Additionally, neither FEMA nor any of its employees make any warranty, expressed or implied, nor assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, product, or process included in this publication.

The National Institute of Building Sciences (NIBS) brings together members of the building industry, labor and consumer interests, government representatives, and regulatory agencies to identify and resolve problems and potential problems around the built environment. NIBS is a nonprofit, non-governmental organization established by Congress in 1974.

The Building Seismic Safety Council (BSSC) was established in 1979 under the auspices of NIBS as a national platform for dealing with the complex regulatory, technical, social, and economic issues involved in developing and promulgating building earthquake hazard mitigation regulatory provisions that are national in scope. By bringing together in the BSSC all of the needed expertise and all relevant public and private interests, it was believed that issues related to the seismic safety of the built environment could be resolved and jurisdictional problems overcome through authoritative guidance and assistance backed by a broad consensus. BSSC's mission is to enhance public safety by providing a national forum that fosters coordination of and improvements in seismic planning, design, construction, and regulation in the building community.

This report was prepared under Contract HSFE60-15-D-0022 between the Federal Emergency Management Agency and the National Institute of Building Sciences.

This FEMA resource document can be obtained from the FEMA online library:  
<https://www.fema.gov/emergency-managers/risk-management/building-science/earthquakes>.

# 2020 NEHRP Recommended Seismic Provisions: Design Examples, Training Materials, and Design Flow Charts

## Volume III: Design Flow Charts

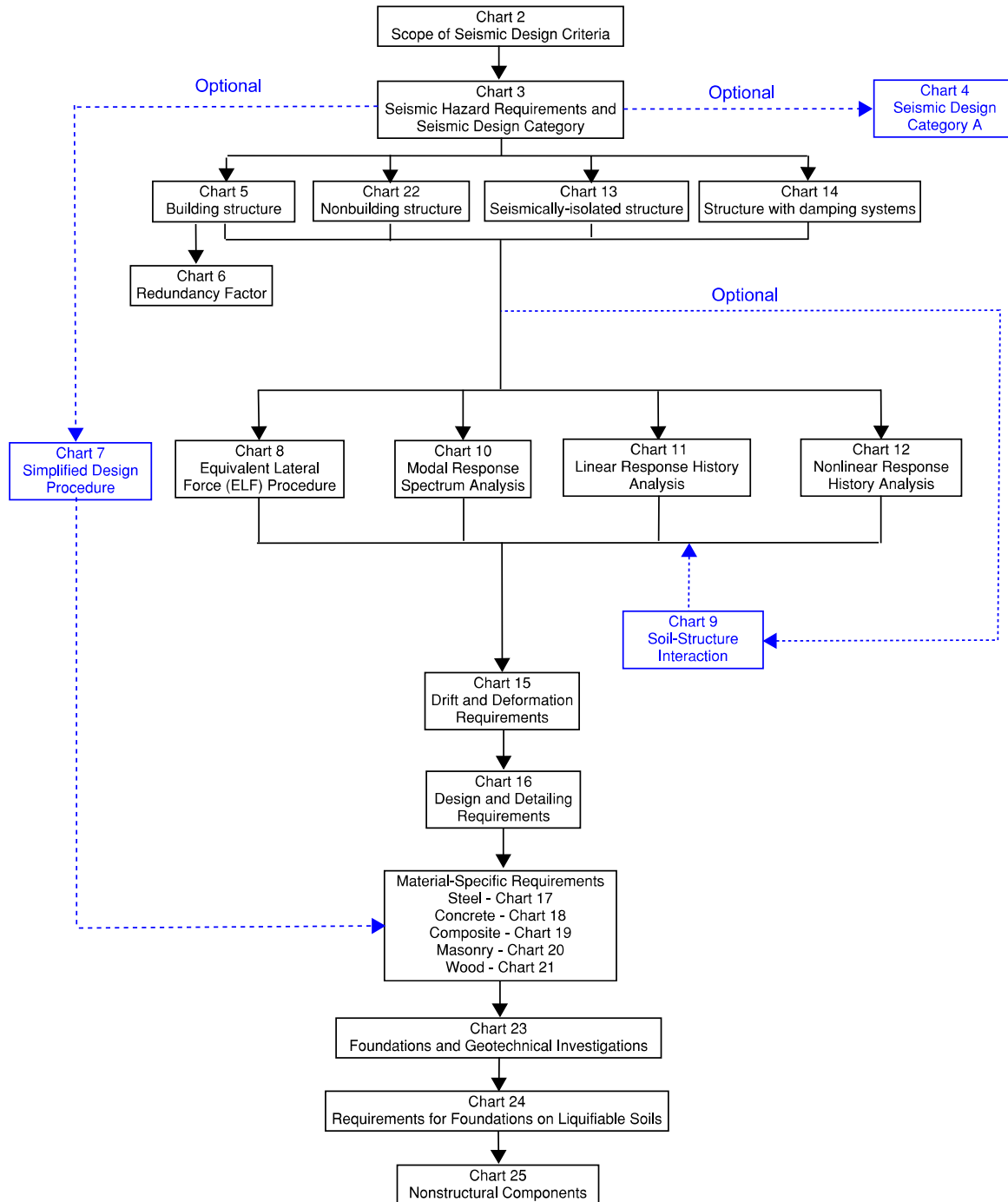
FEMA P-2092-V3 Volume III *Design Flow Charts*, as one of the *NEHRP Provisions'* supporting products, contains a series of flow charts to help practicing engineers better understand the provisions in the *2020 NEHRP Recommended Seismic Provisions for New Buildings and Other Structures* (FEMA P-2082) and *ASCE/SEI 7-22 Minimum Design Loads and Associated Criteria for Buildings and Other Structures*.

Design flow charts were prepared as part of the 2015 *NEHRP Provisions* supporting materials. Those flow charts were used as a starting point for updates by Bret Lizundia and Jorge Moreno of Rutherford + Chekene. The updated flow charts incorporate revisions between the 2015 *Provisions* and the *2020 NEHRP Provisions* (and between ASCE/SEI 7-16 and ASCE/SEI 7-22). A general overview of the overall design process is provided in Chart 1, with the rest of the charts focusing on specific topics. The goal of the charts is to highlight the key steps and provisions and the recommended order of implementation. The charts also identify the interrelationships and dependencies of the steps and provisions on one another. To keep the charts reasonably concise, not every step has been addressed, and the reader is cautioned to review the *2020 NEHRP Provisions* and ASCE/SEI 7-22 carefully as they apply to the specific project of interest.

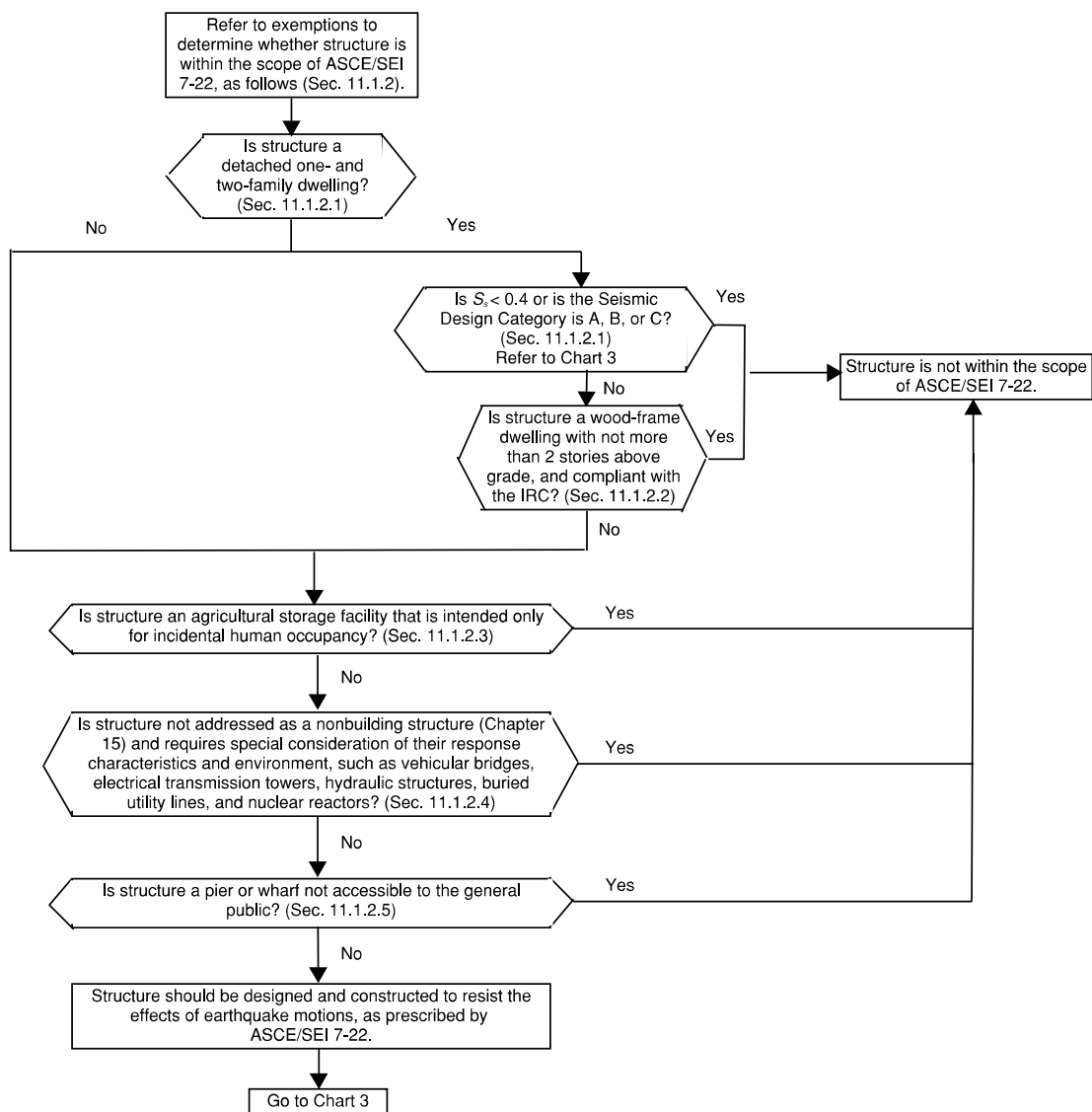
# Table of Contents

Chart 1 – Overall Summary of Flow .....	5
Chart 2 – Scope of Seismic Design Criteria .....	6
Chart 3 – Seismic Hazard Requirements and Seismic Design Criteria .....	7
Chart 4 – Seismic Design Criteria A .....	9
Chart 5 – Seismic Design Requirements for Building Structures .....	10
Chart 6 – Redundancy Factor .....	11
Chart 7 – Simplified Design Procedure .....	12
Chart 8 – Equivalent Lateral Force (ELF) Analysis .....	13
Chart 9 – Soil-Structure Interaction (SSI) .....	15
Chart 10 – Modal Response Spectrum Analysis .....	17
Chart 11 – Linear Response History Analysis .....	19
Chart 12 – Nonlinear Response History Analysis .....	20
Chart 13 – Seismically-Isolated Structures .....	22
Chart 14 – Structures with Damping Systems .....	23
Chart 15 – Drift and Deformation Requirements for Building Structures .....	24
Chart 16 – Design and Detailing Requirements for Building Structures .....	25
Chart 17 – Steel Structures .....	26
Chart 18 – Concrete Structures .....	27
Chart 19 – Composite Steel and Concrete Structures .....	27
Chart 20 – Masonry Structures .....	28
Chart 21 – Wood Structures .....	28
Chart 22 – Seismic Design Requirements for Nonbuilding Structures .....	29
Chart 23 – Foundations and Geotechnical Investigation .....	31
Chart 24 – Requirements for Foundations on Liquefiable Soils .....	32
Chart 25 – Nonstructural Components .....	33

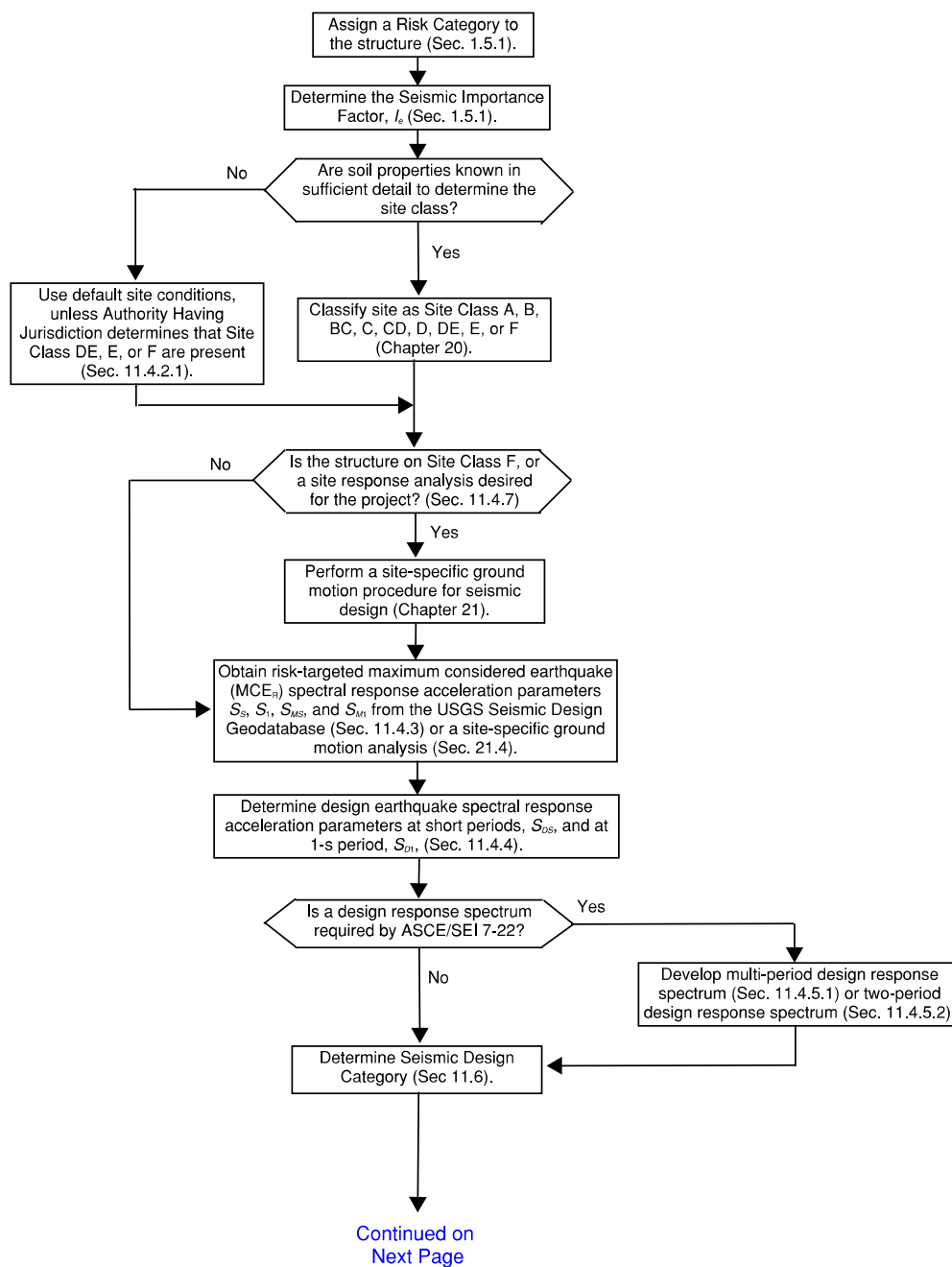
**Chart 1  
Overall Summary of Flow**



**Chart 2**  
**Scope of Seismic Design Criteria**



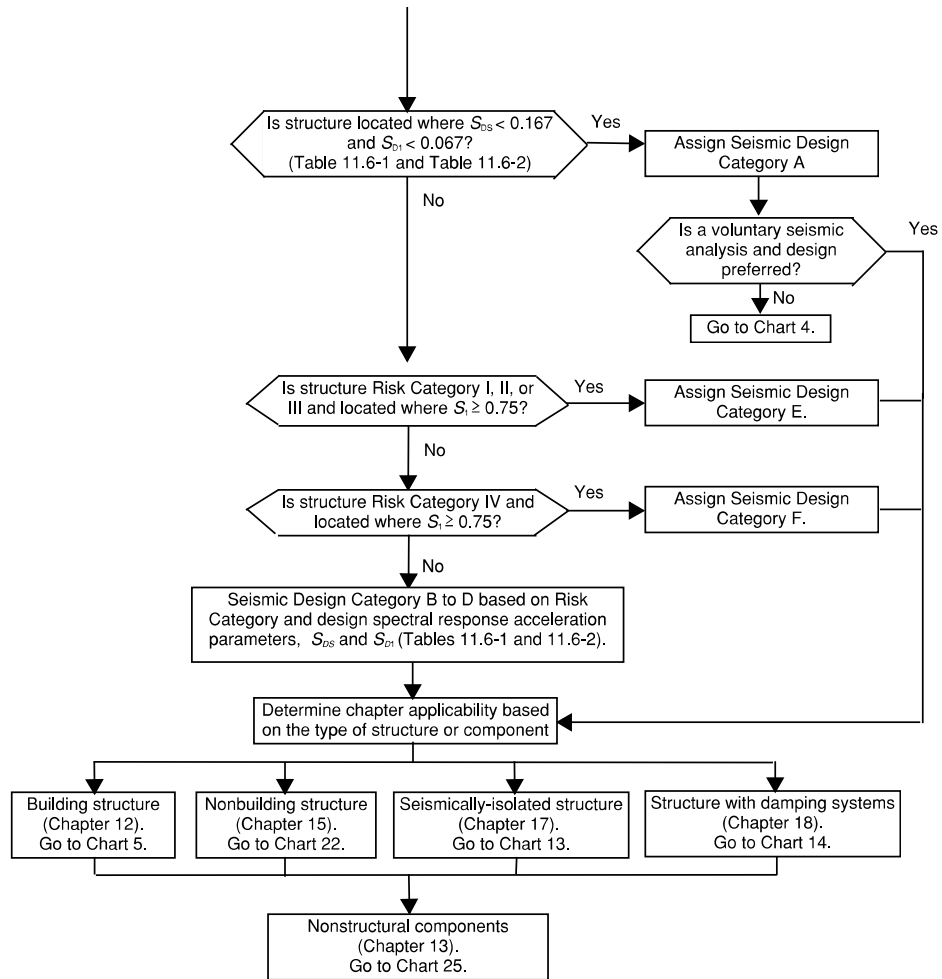
**Chart 3**  
**Seismic Hazard Requirements and Seismic Design Category**



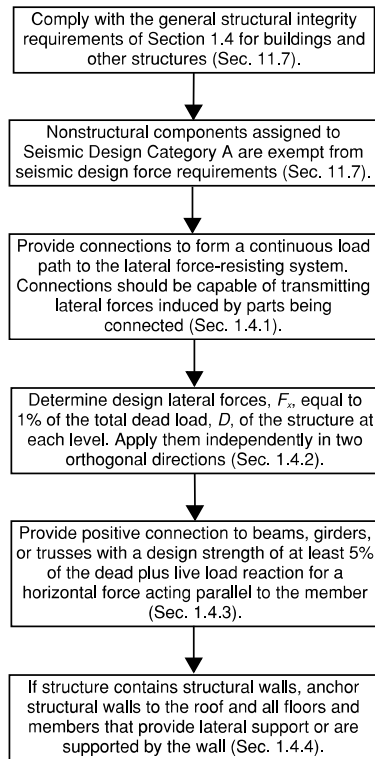


**Chart 3**  
**Seismic Hazard Requirements and Seismic Design Category**  
**(Continued)**

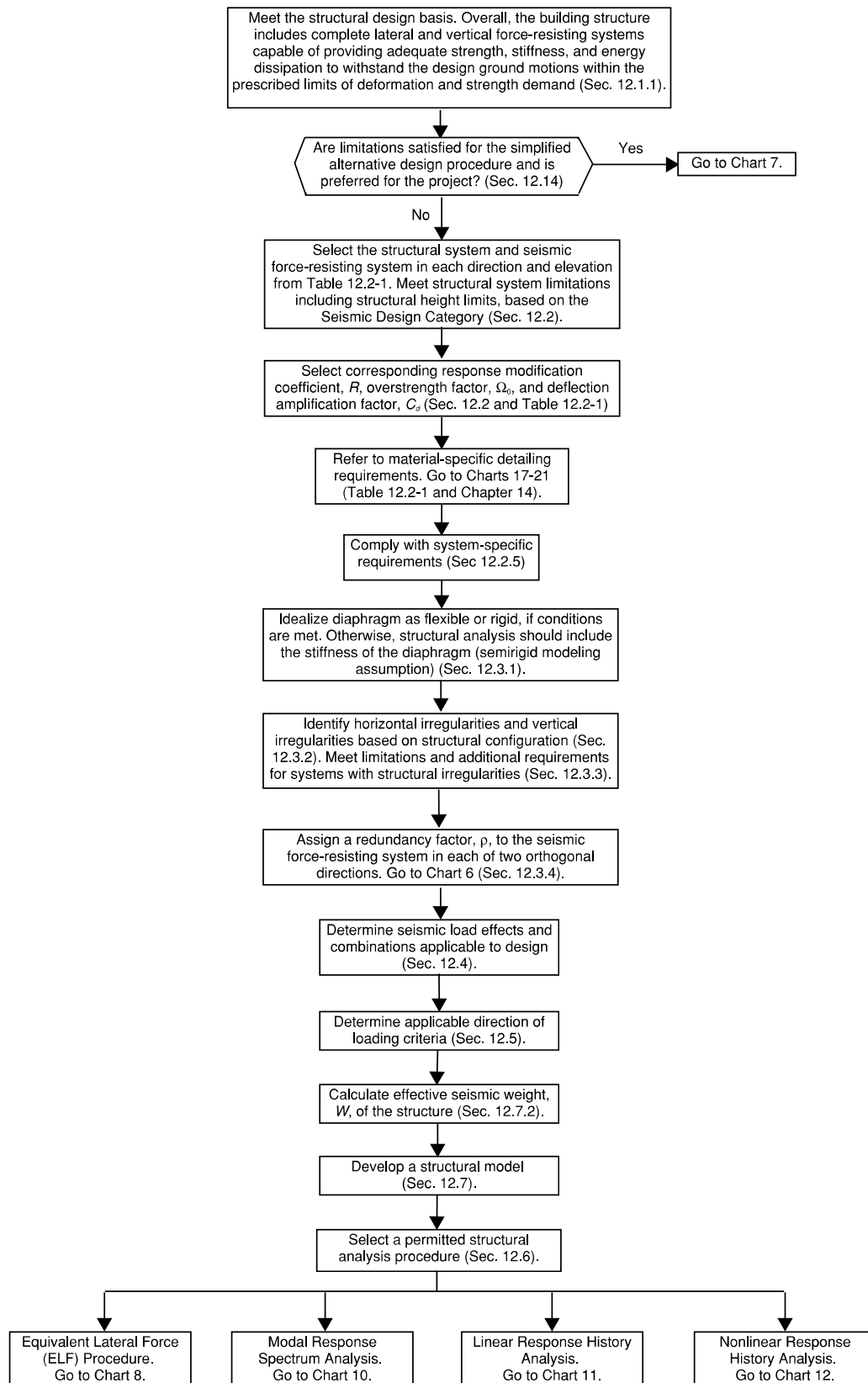
Continued from  
Previous Page



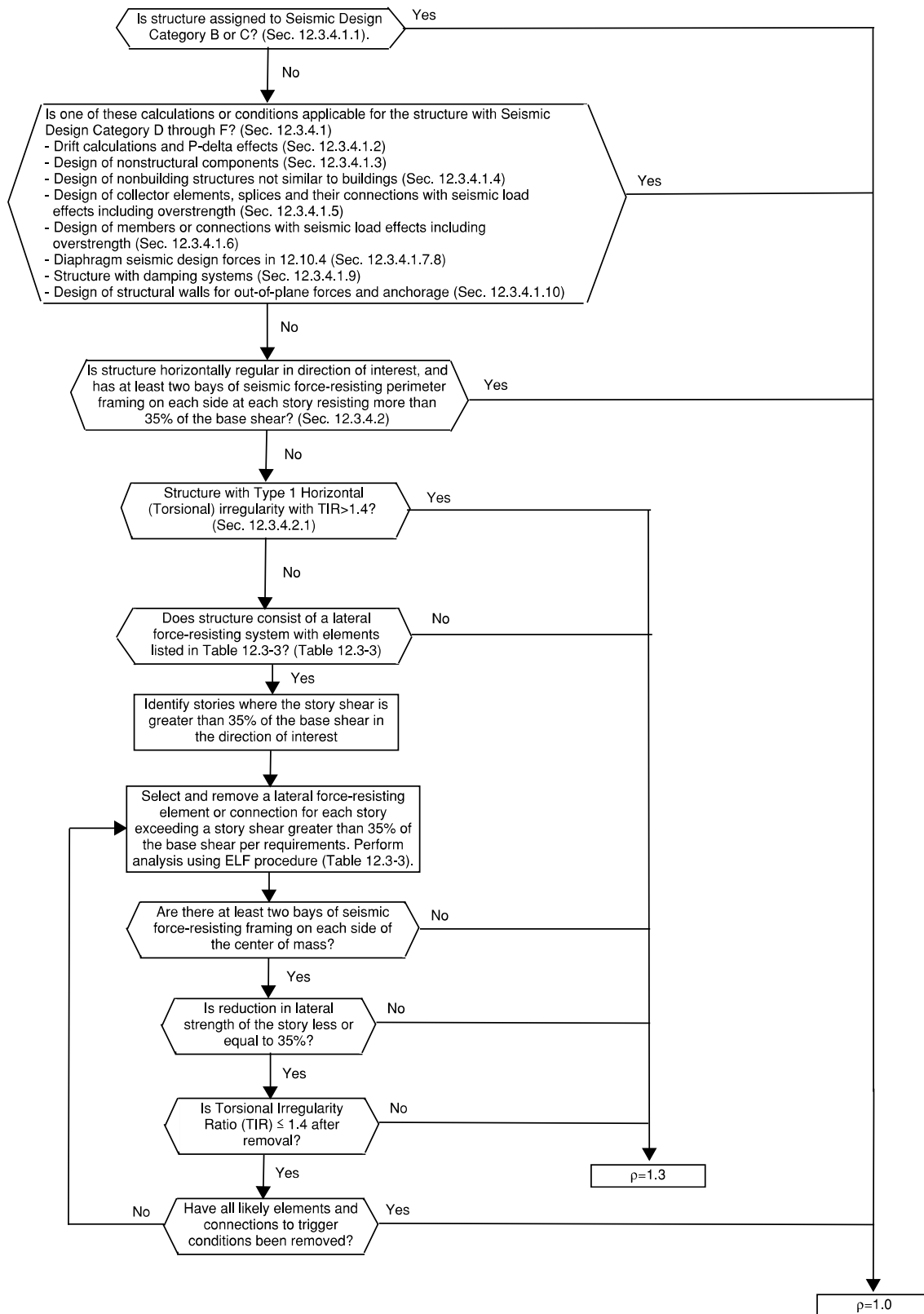
**Chart 4**  
**Seismic Design Category A**



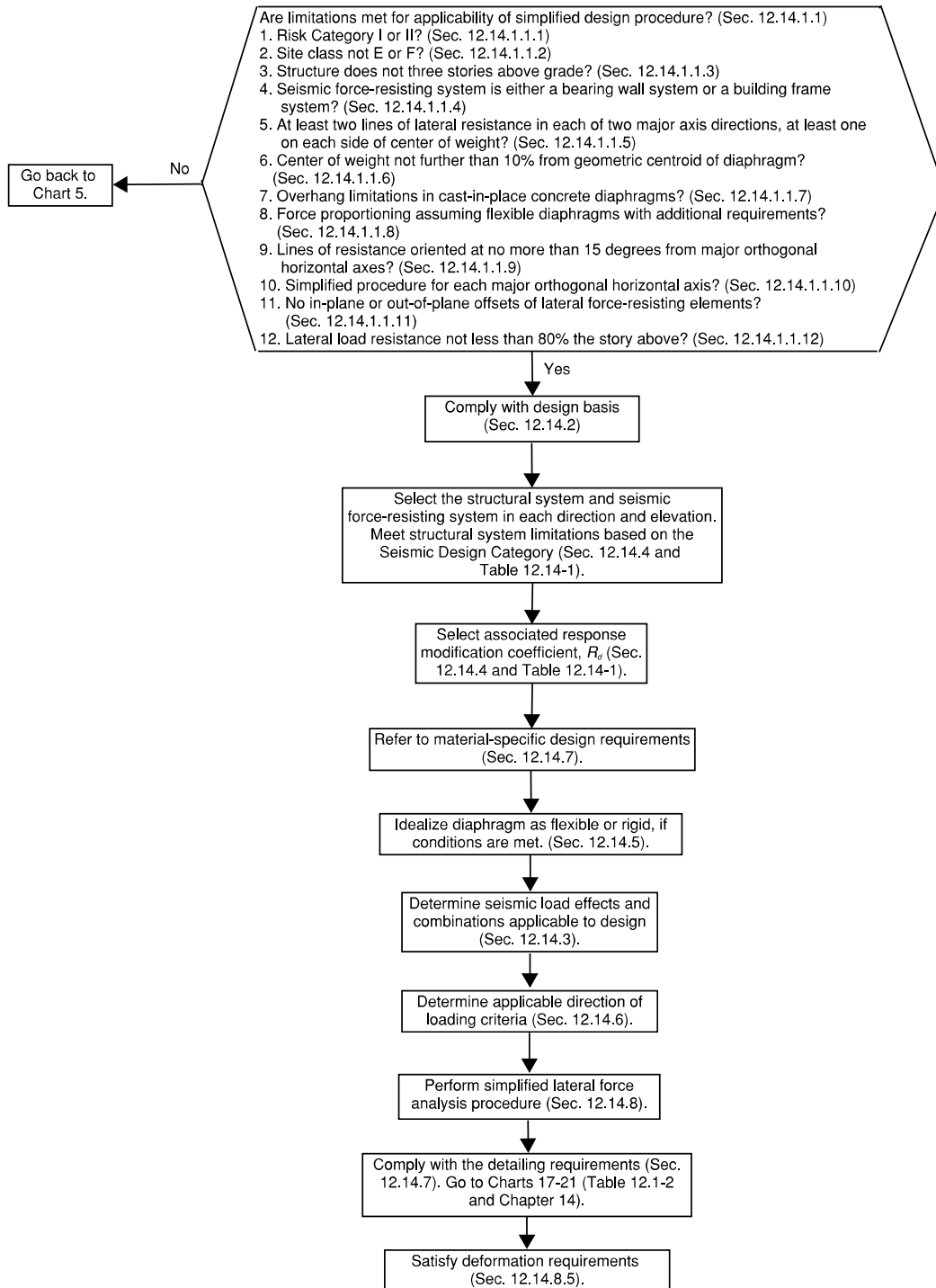
**Chart 5**  
**Seismic Design Requirements for Building Structures**



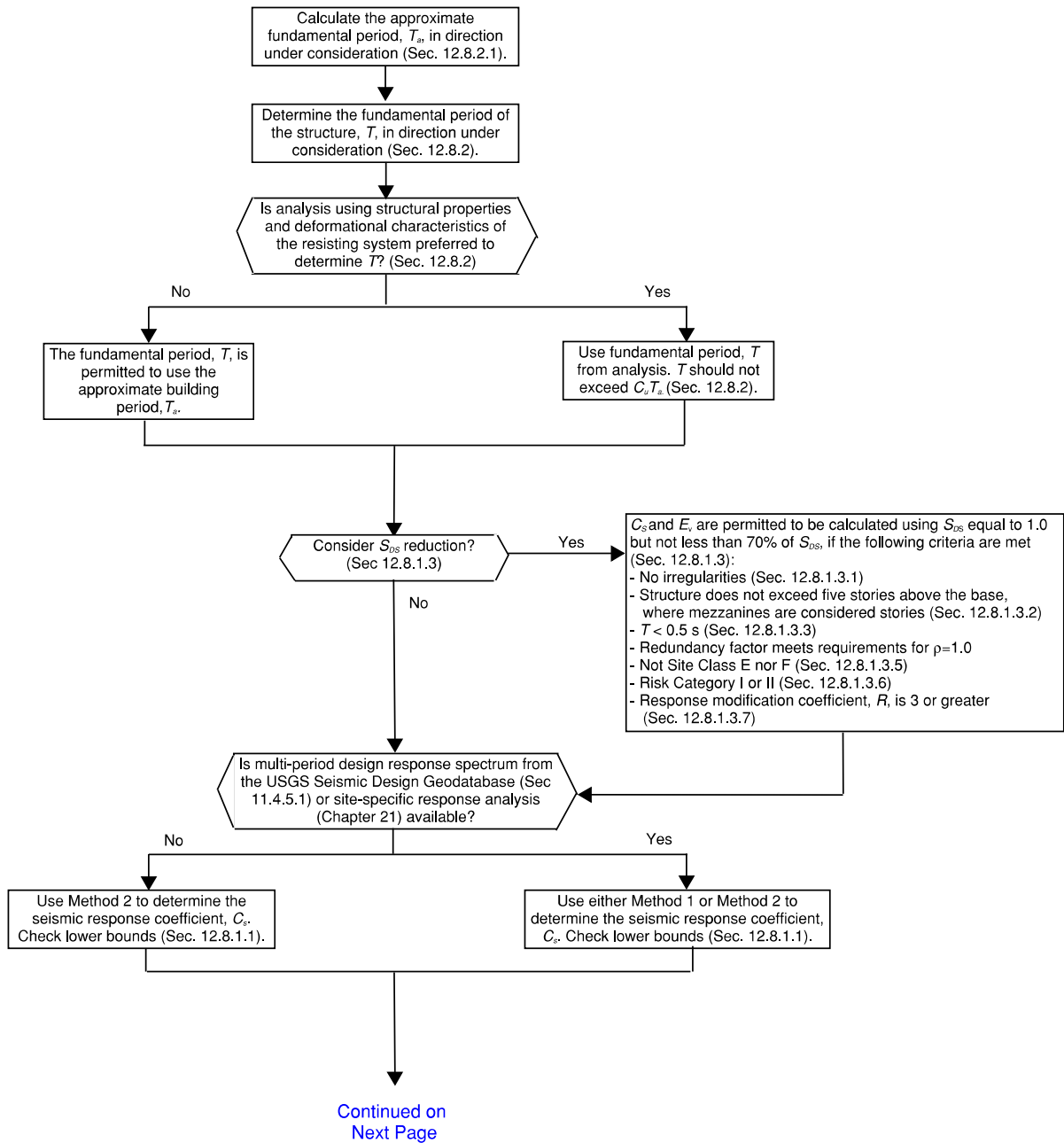
**Chart 6**  
**Redundancy Factor**



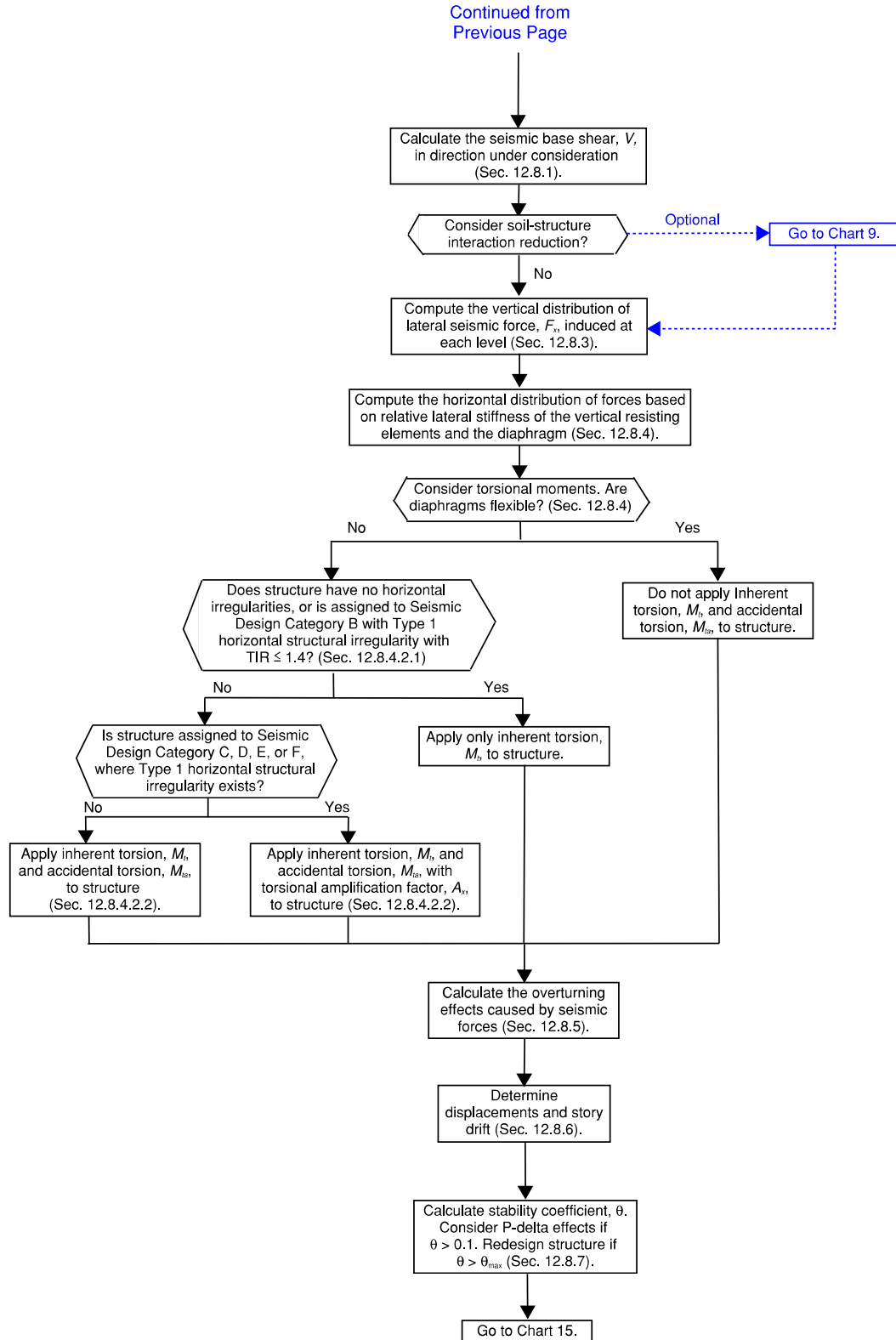
### Chart 7 Simplified Design Procedure



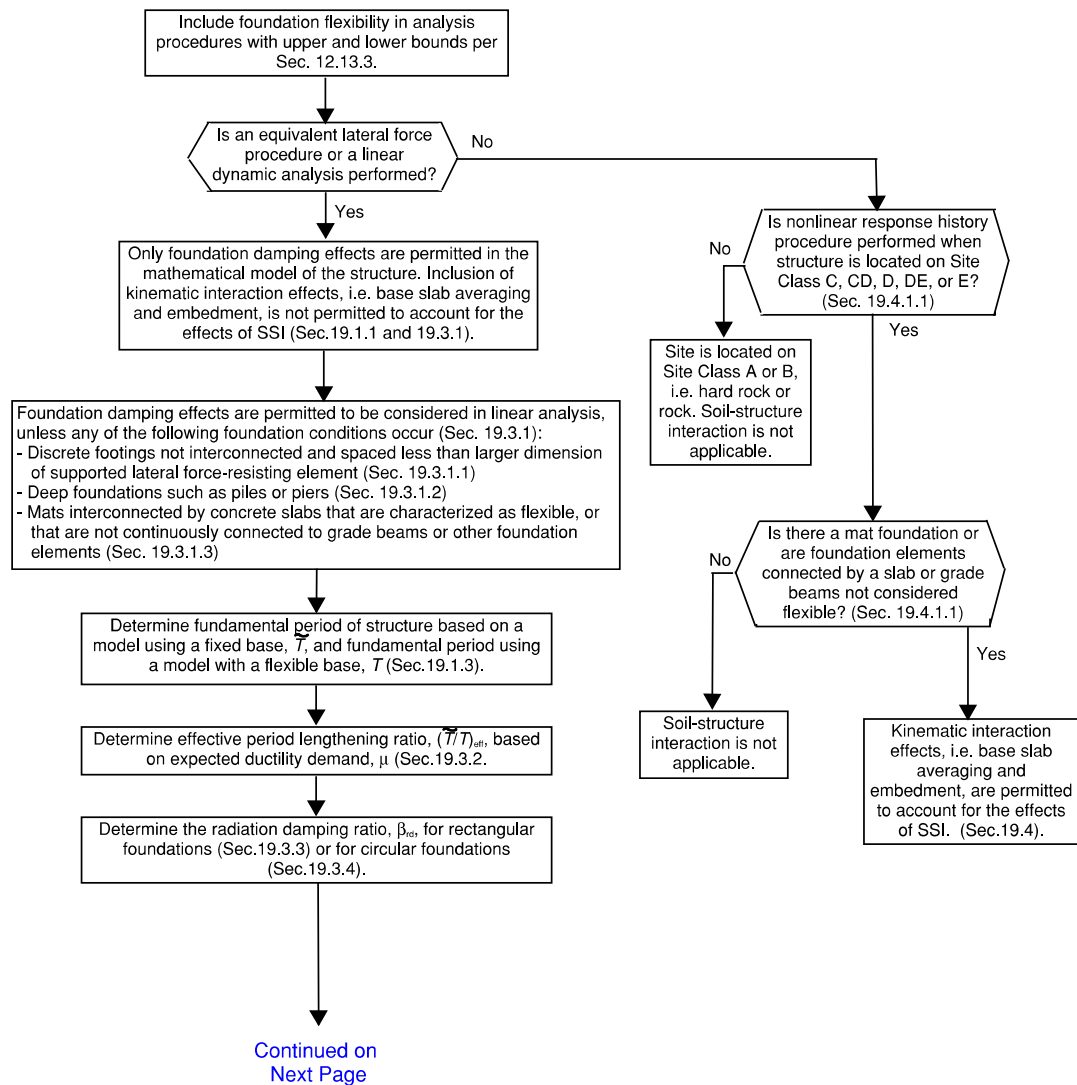
**Chart 8**  
**Equivalent Lateral Force (ELF) Analysis**



**Chart 8**  
**Equivalent Lateral Force (ELF) Analysis**  
**(Continued)**

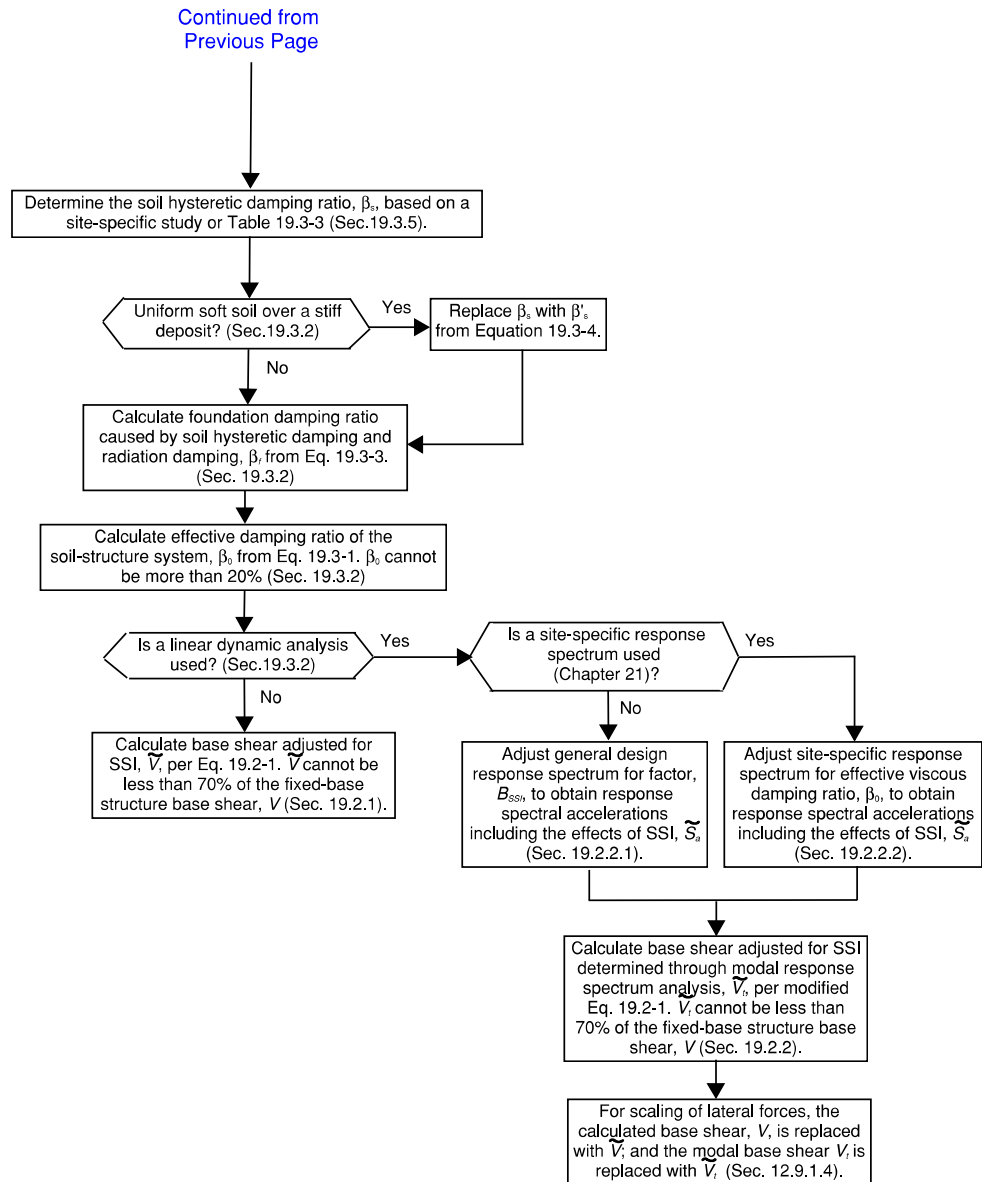


**Chart 9**  
**Soil-Structure Interaction (SSI)**

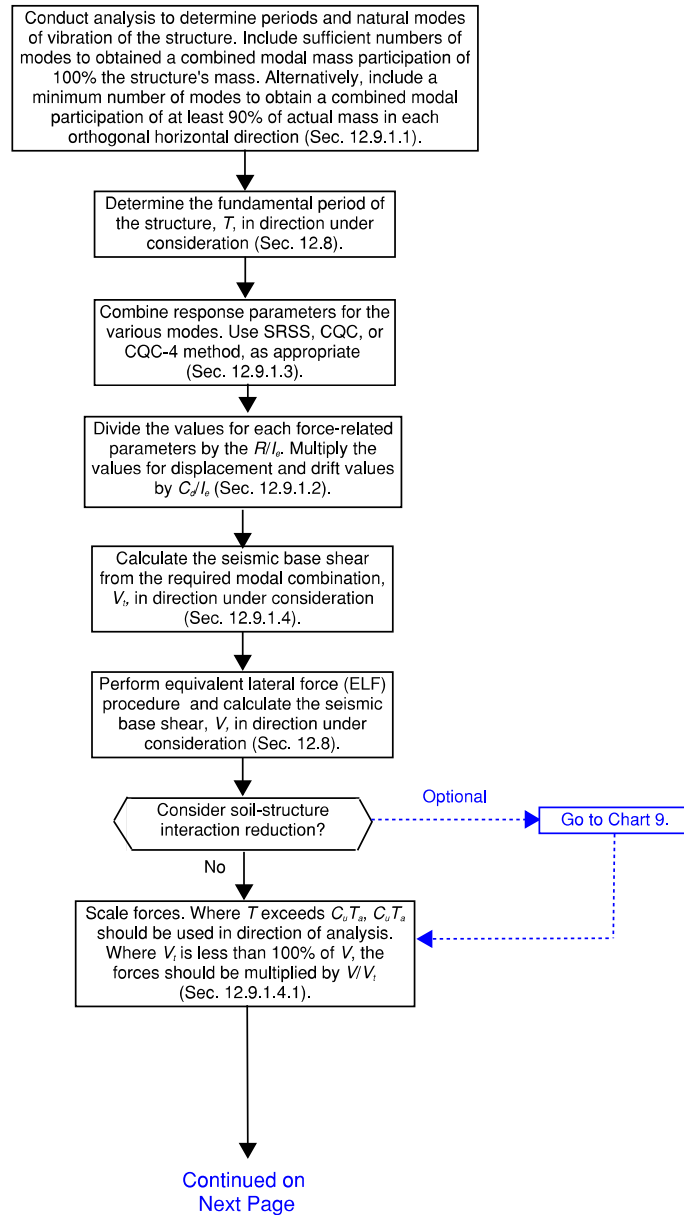




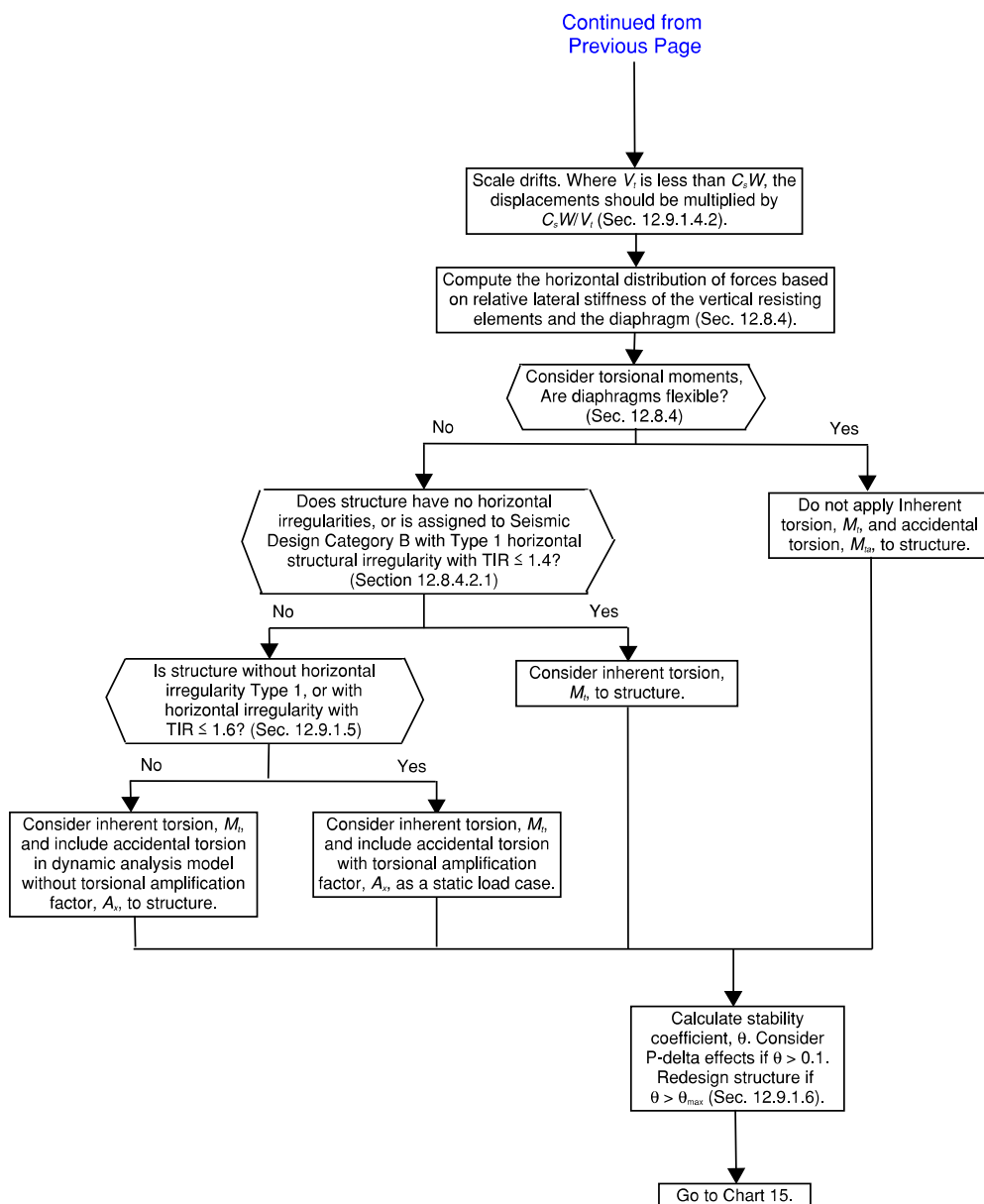
**Chart 9**  
**Soil-Structure Interaction (SSI)**  
**(Continued)**



**Chart 10**  
**Modal Response Spectrum Analysis**



**Chart 10**  
**Modal Response Spectrum Analysis**  
**(Continued)**



**Chart 11**  
**Linear Response History Analysis**

Meet general modeling requirements (Sec. 12.9.2):

- Three-dimensional (3D model) model (Sec. 12.9.2.2)
- Adequate distribution of stiffness and mass throughout the structure's lateral load-resisting system and diaphragms (Sec. 12.9.2.2.1)
- Include P-delta effects (Sec. 12.9.2.2.1)
- Include accidental torsion, where required (Sec. 12.9.2.2.2)
- Adequate foundation flexibility modeling, where required (Sec. 12.9.2.3)
- Same number of modes to include as provisions for modal response spectrum analysis (Sec. 12.9.2.2.4)
- Damping not exceeding 5% critical for any mode with vibration period  $\geq T_{lower}$  (Sec. 12.9.2.2.5)

Determine  $T_{lower}$  and  $T_{upper}$ . The mathematical models to compute these periods should not include accidental torsion but should include P-delta effects (Sec. 11.3).

$T_{lower}$  is the period of vibration at which 90% of the actual mass has been recovered in each of the two orthogonal directions.

$T_{upper}$  is the larger of the two orthogonal fundamental periods of vibration.

Select a suite of at least three pairs of ground acceleration histories derived from artificial or recorded ground motion events (Sec. 12.9.2.3).

Match spectrally each component of ground motion over the period range  $0.8T_{lower}$  to  $1.2T_{upper}$ . Over the same period range, the average of 5% damped  $S_d$  ordinates should not fall above or below the target spectrum by more than 10% (Sec. 12.9.2.3.1).

Apply ground motion acceleration histories to two orthogonal directions independently, designated as X and Y (Sec. 12.9.2.4).

For each ground motion analyzed, determine the maximum elastic base shear in the X and Y directions,  $V_{EX}$  and  $V_{EY}$ , respectively (Sec. 12.9.2.5.1).

For each ground motion analyzed, determine the maximum inelastic base shear in the X and Y directions,  $V_{IX}$  and  $V_{IY}$ , respectively, by multiplying  $V_{EX}$  by  $I/R_x$  and  $V_{EY}$  by  $I/R_y$  (Sec. 12.9.2.5.1).

Consider soil-structure interaction reduction?

Optional

Go to Chart 9.

No

Calculate base shear scale factors in each direction of response,  $\eta_x$  and  $\eta_y$  (Sec. 12.9.2.5.2).

Combine the force response to account for the elastic and inelastic contribution (Sec. 12.9.2.5.3).

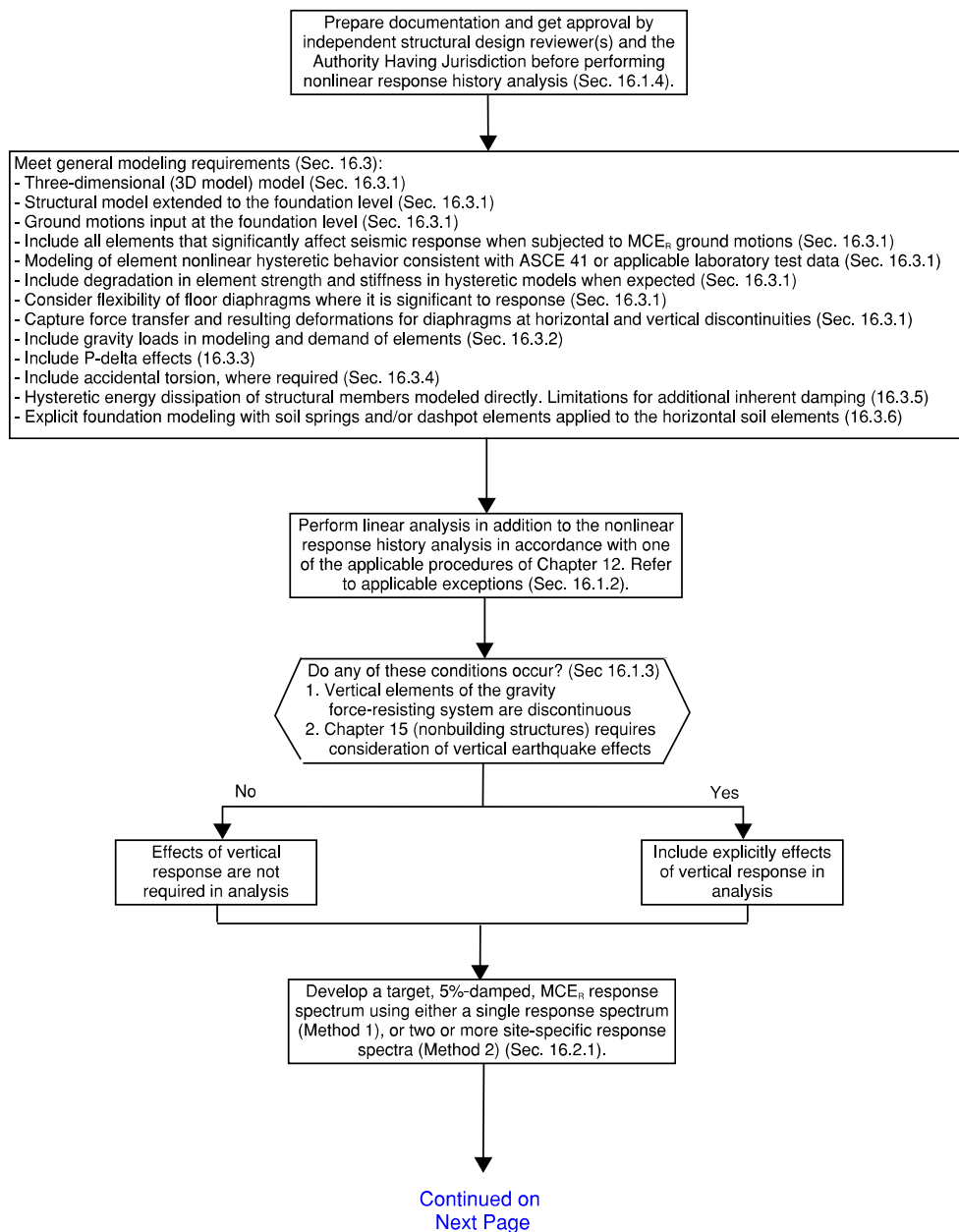
Combine the displacement response to account for the elastic and inelastic contribution (Sec. 12.9.2.5.4).

Envelope the combined force response quantities in both orthogonal directions for all ground motions (Sec. 12.9.2.6).

Determine the story drift for each ground motion analyzed in each direction using the combined displacement responses (Sec. 12.9.2.7).

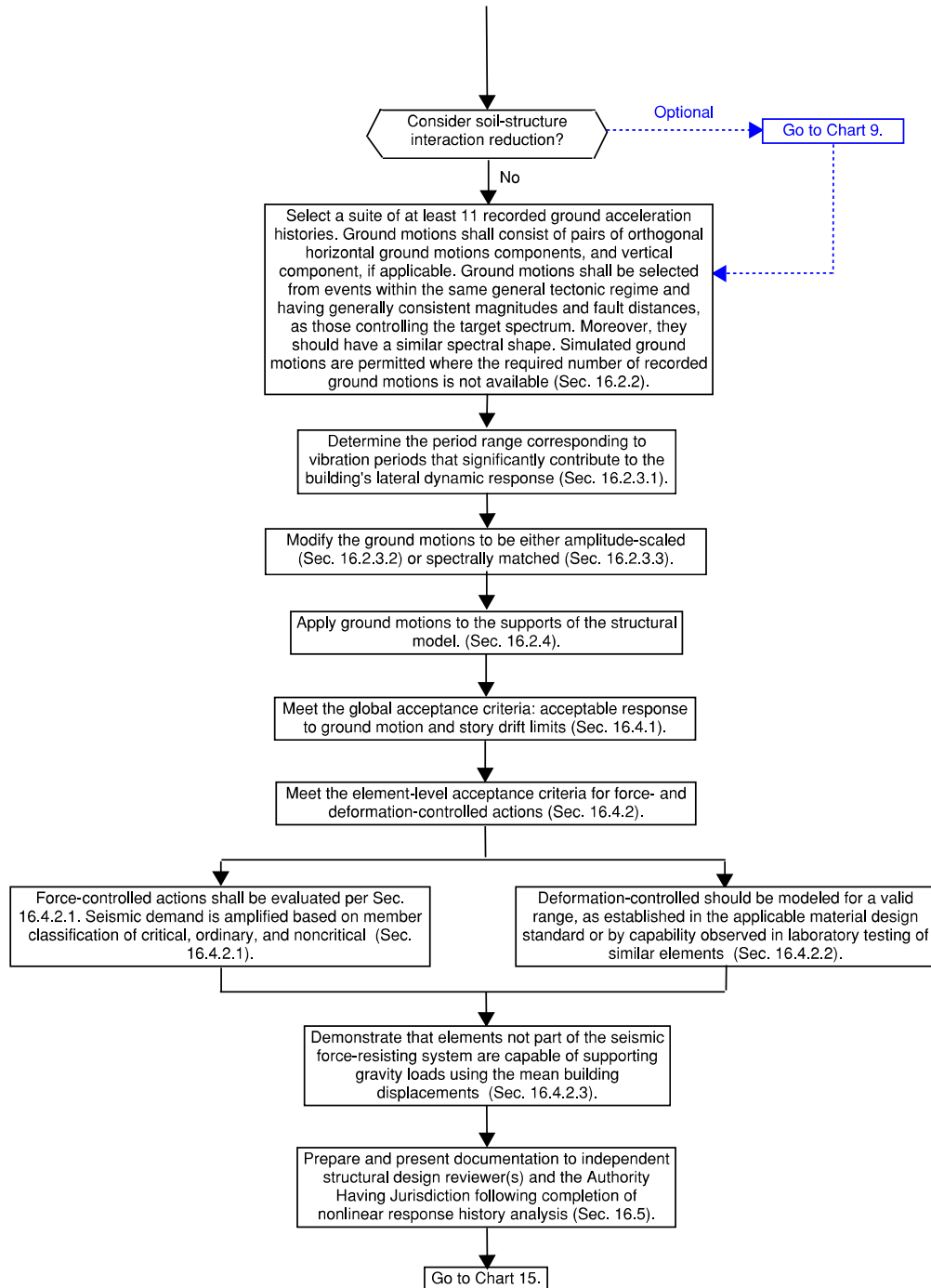
Go to Chart 15.

**Chart 12**  
**Nonlinear Response History Analysis**

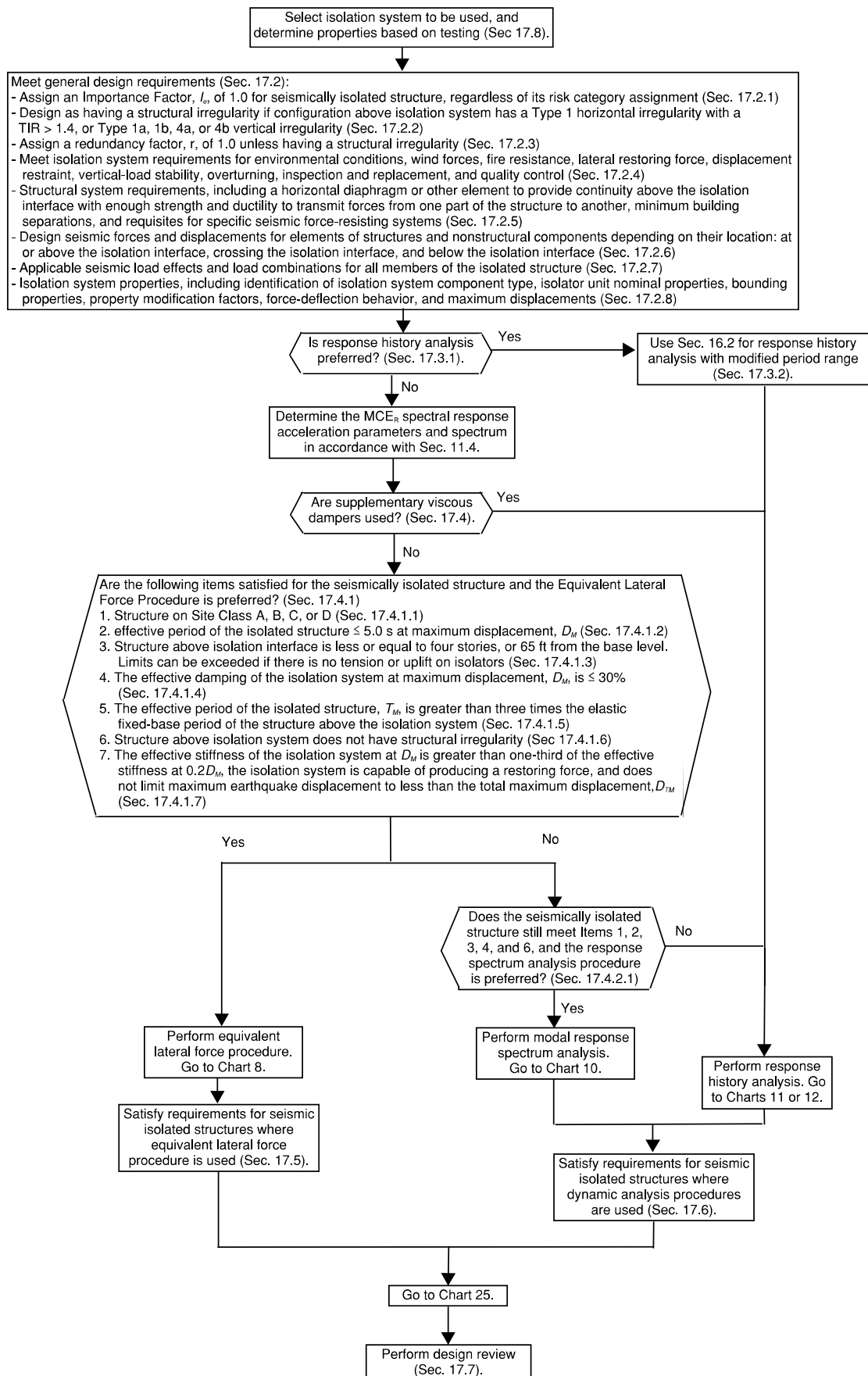


**Chart 12**  
**Nonlinear Response History Analysis**  
**(Continued)**

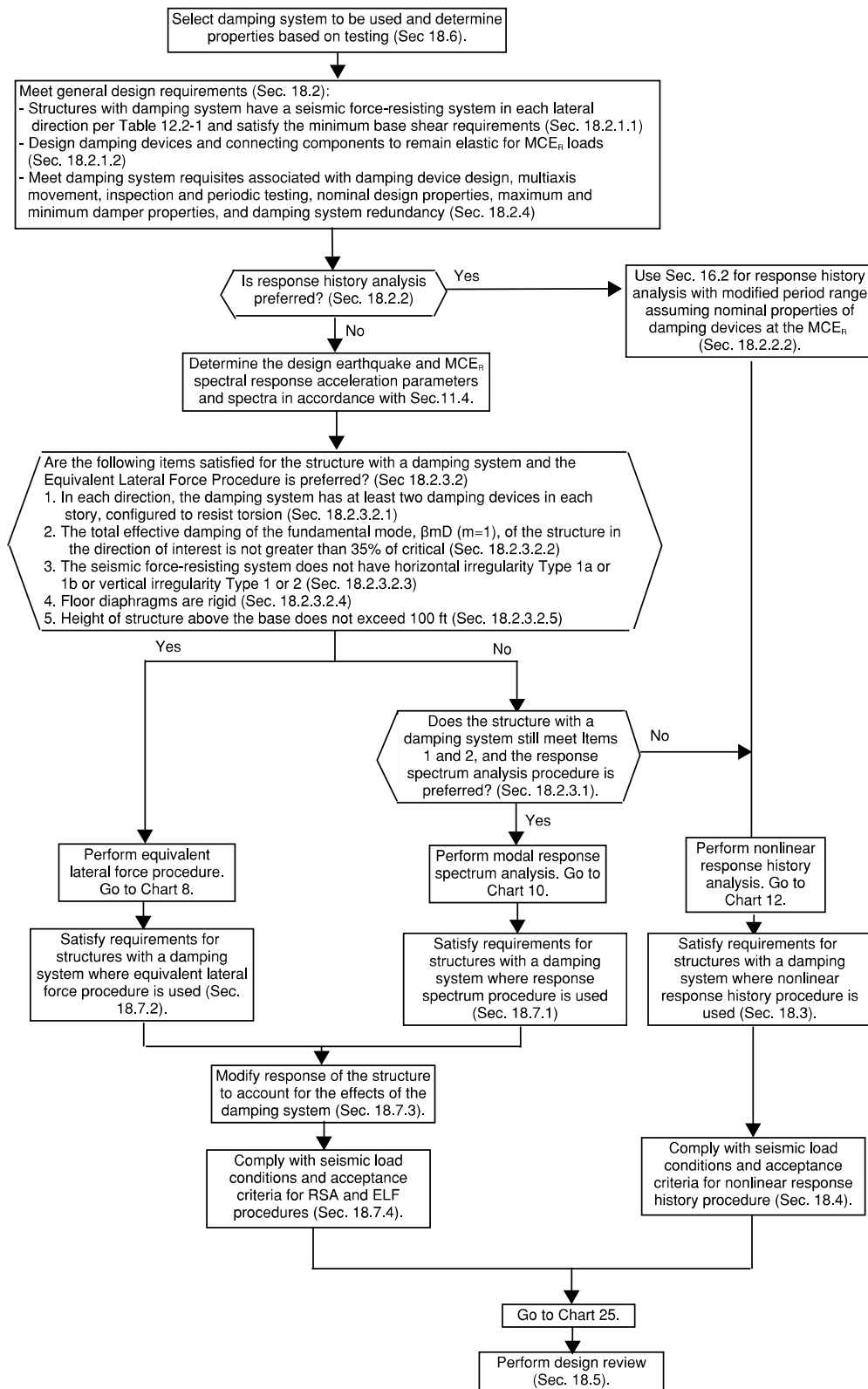
Continued from  
Previous Page



**Chart 13**  
**Seismically-Isolated Structures**

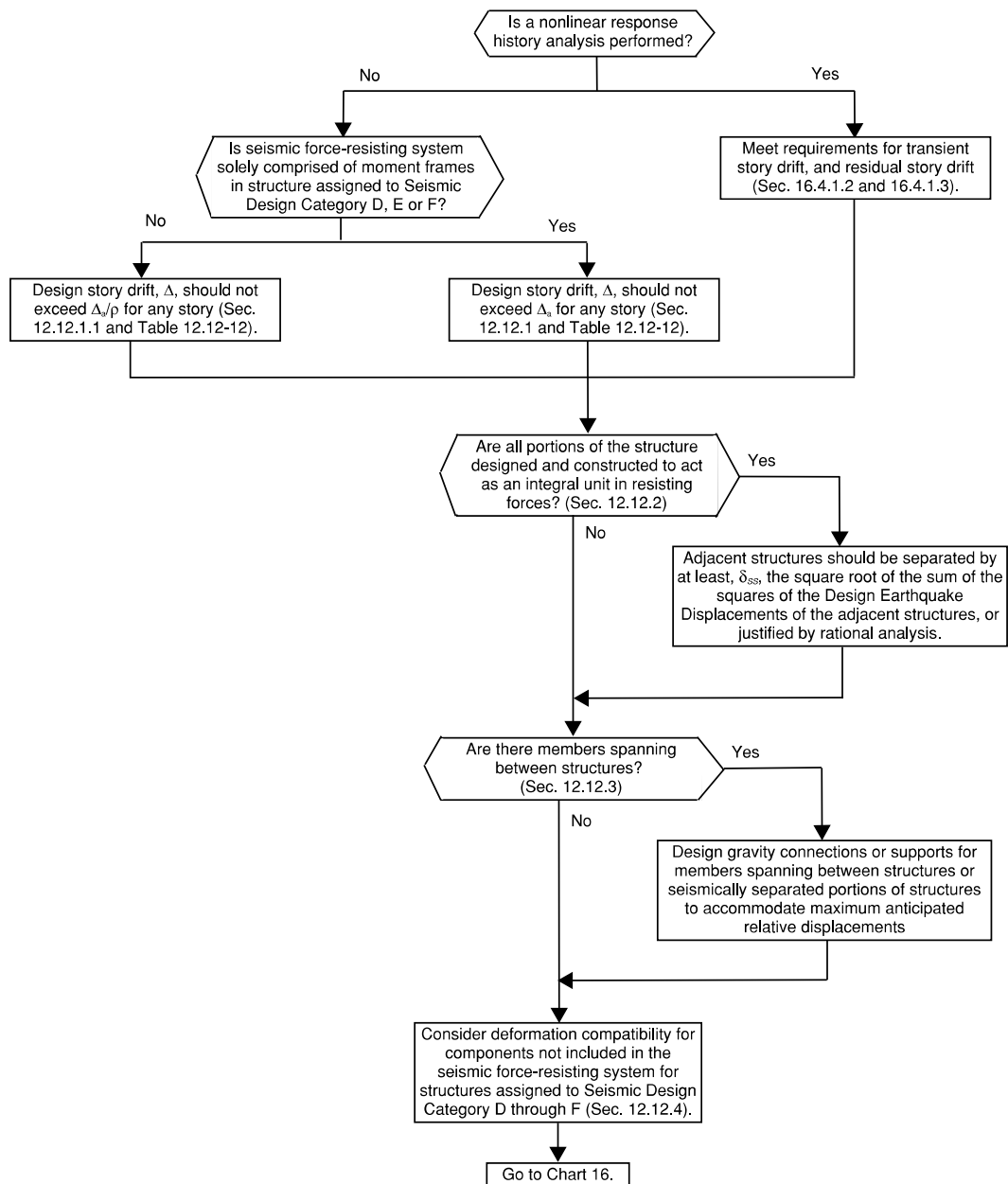


**Chart 14**  
**Structures with Damping Systems**

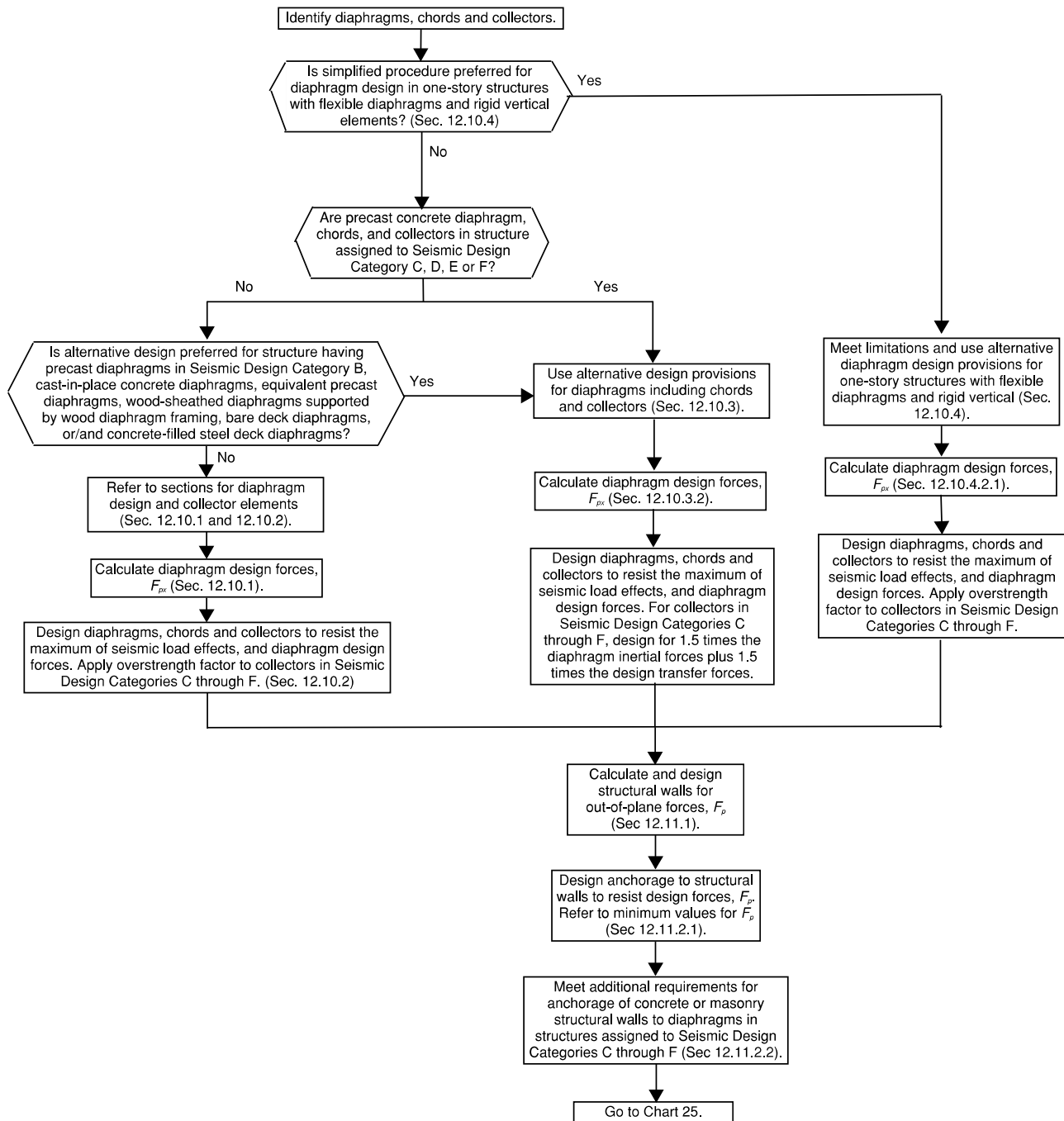




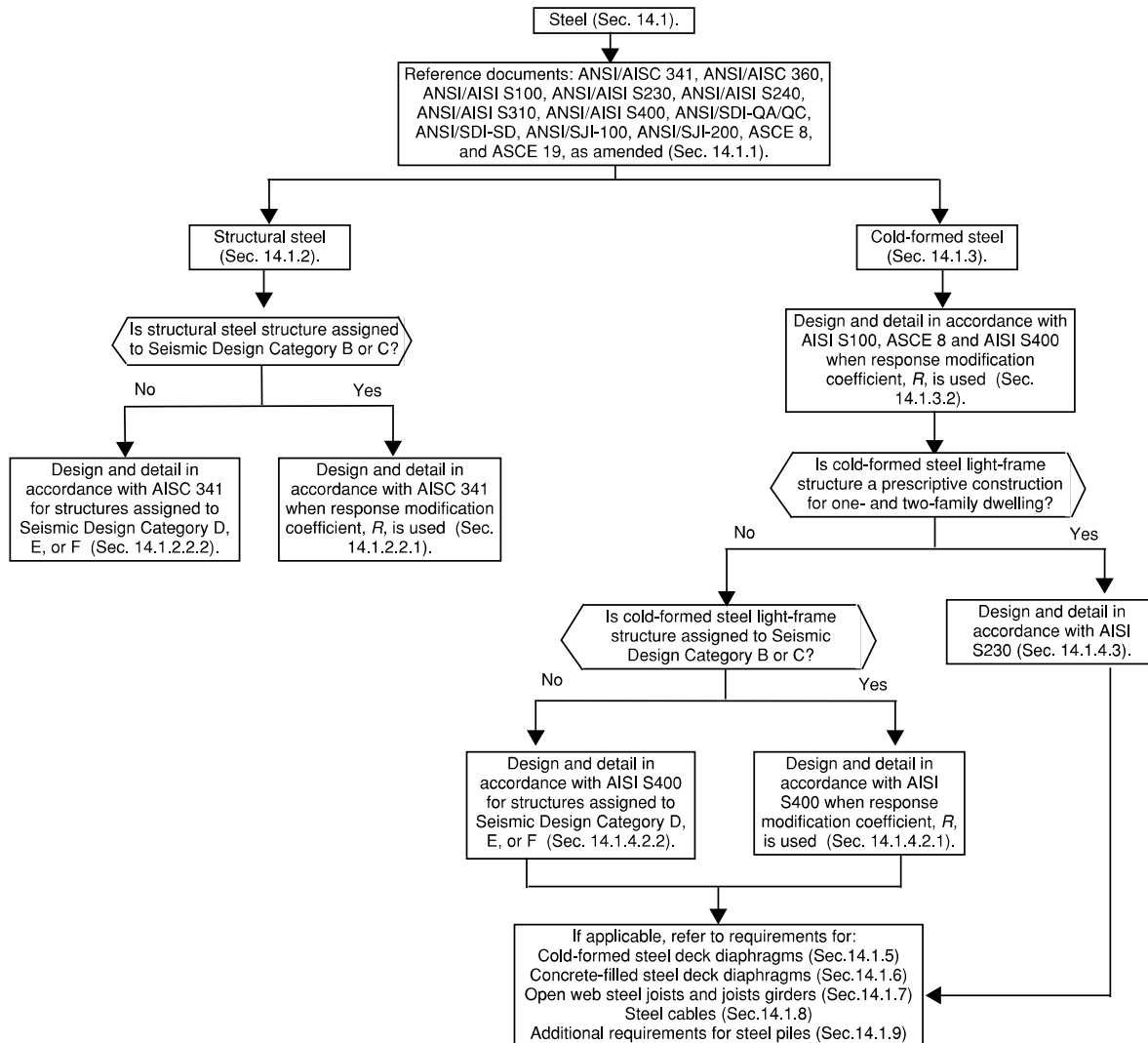
**Chart 15**  
**Drift and Deformation Requirements for Building Structures**



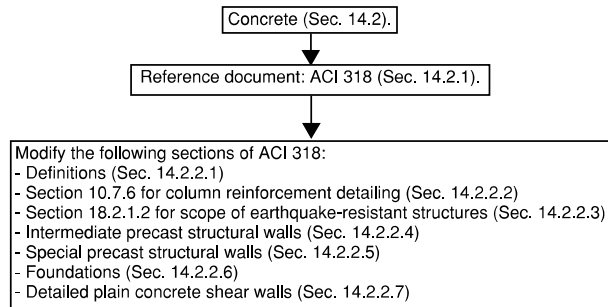
**Chart 16**  
**Design and Detailing Requirements for Building Structures**



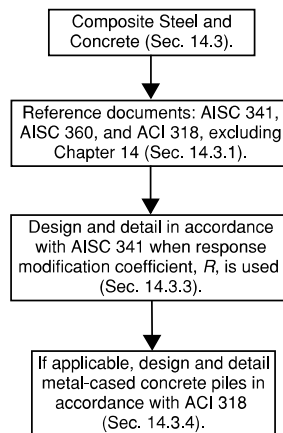
**Chart 17**  
**Steel Structures**



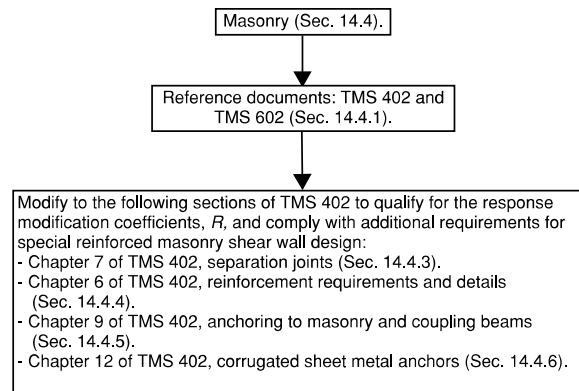
**Chart 18**  
**Concrete Structures**



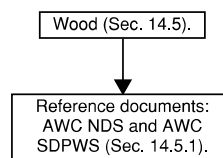
**Chart 19**  
**Composite Steel and Concrete Structures**



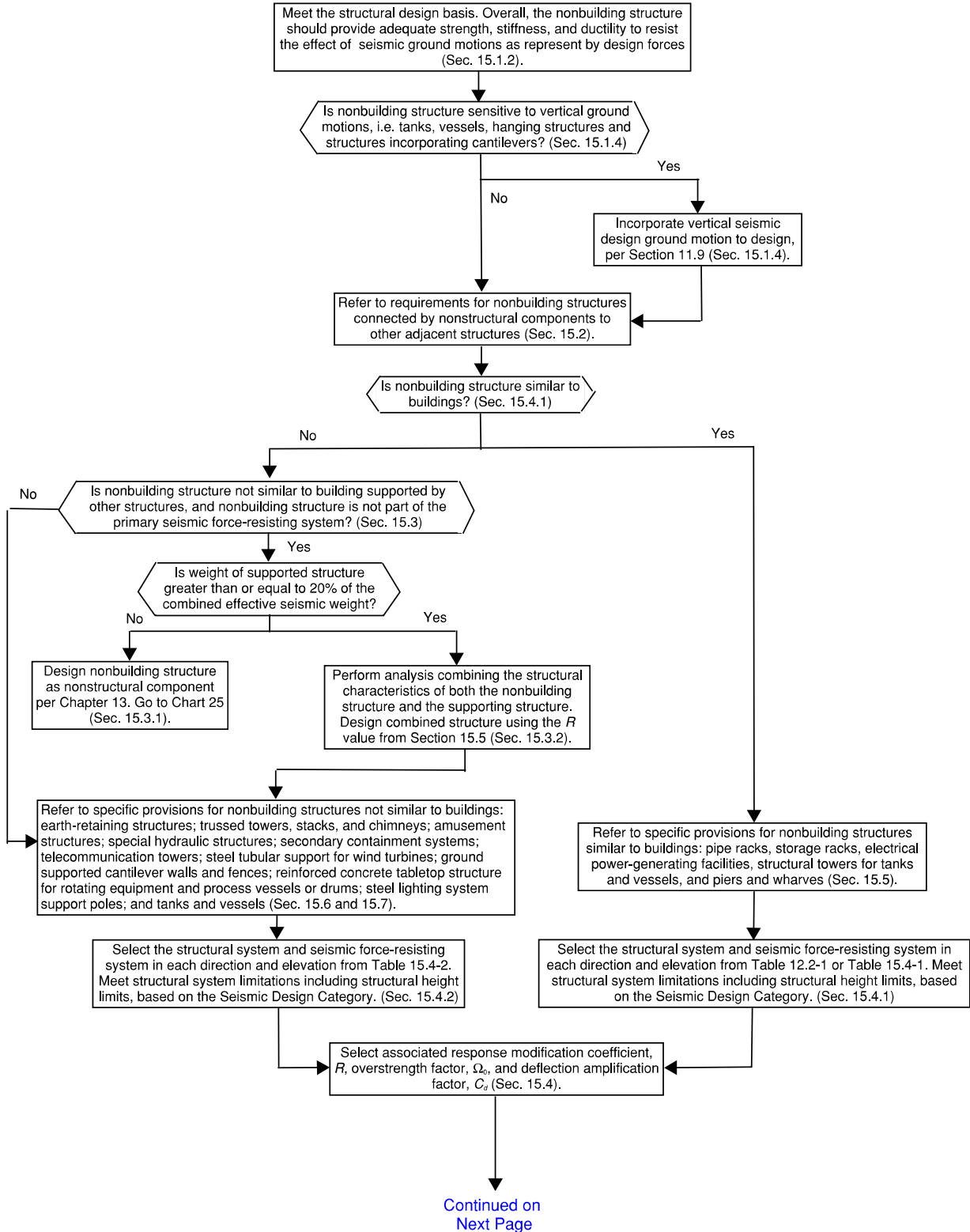
**Chart 20**  
**Masonry Structures**



**Chart 21**  
**Wood Structures**

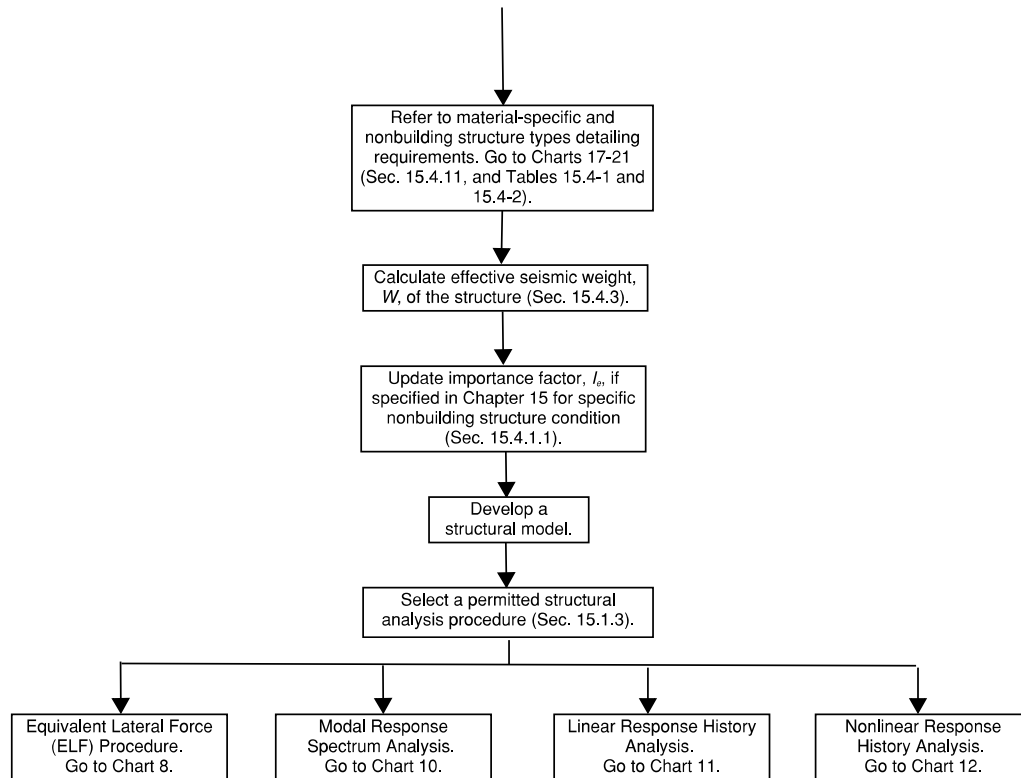


**Chart 22**  
**Seismic Design Requirements for Nonbuilding Structures**

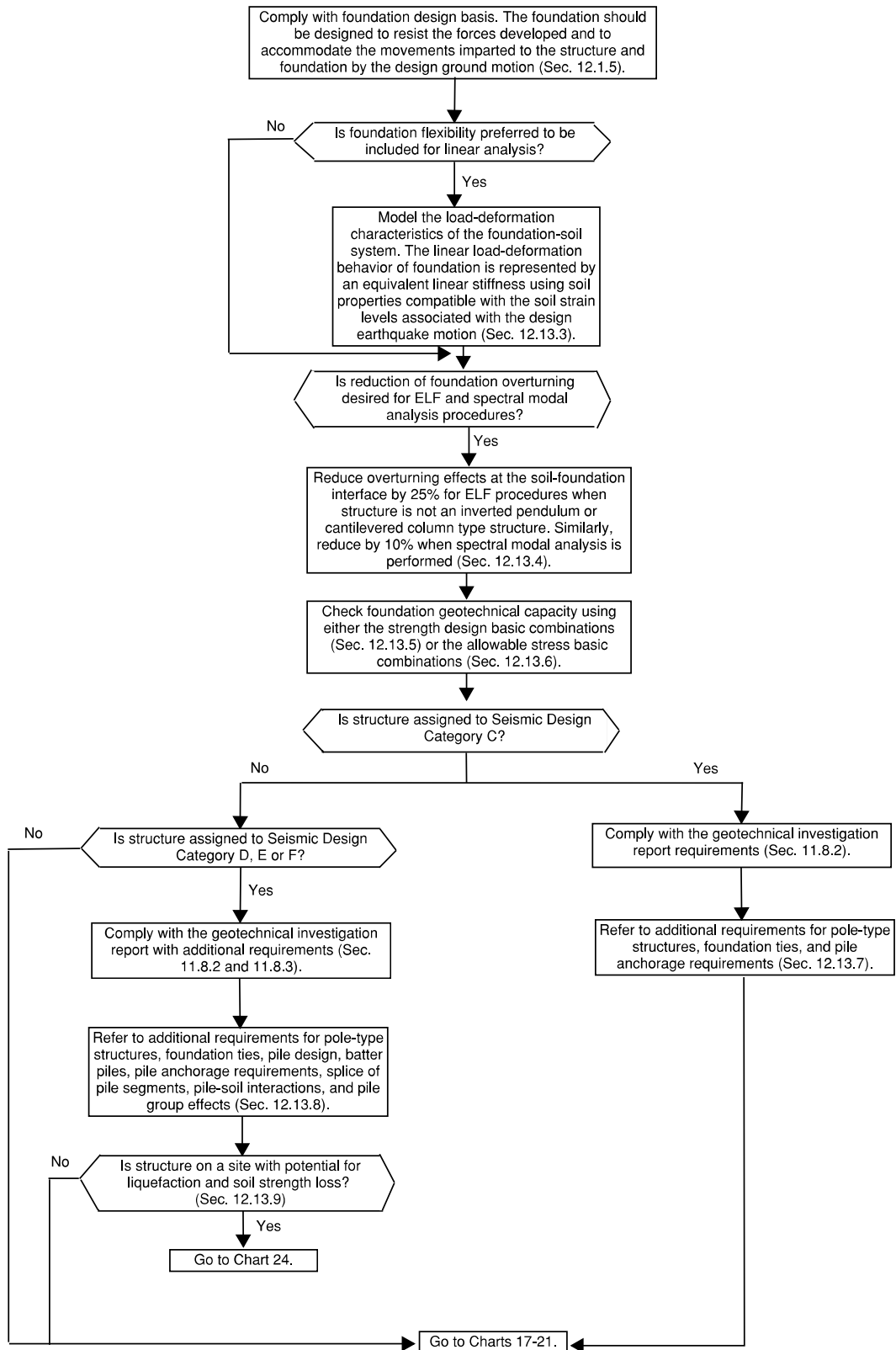


**Chart 22**  
**Seismic Design Requirements for Nonbuilding Structures**  
**(Continued)**

Continued from  
Previous Page

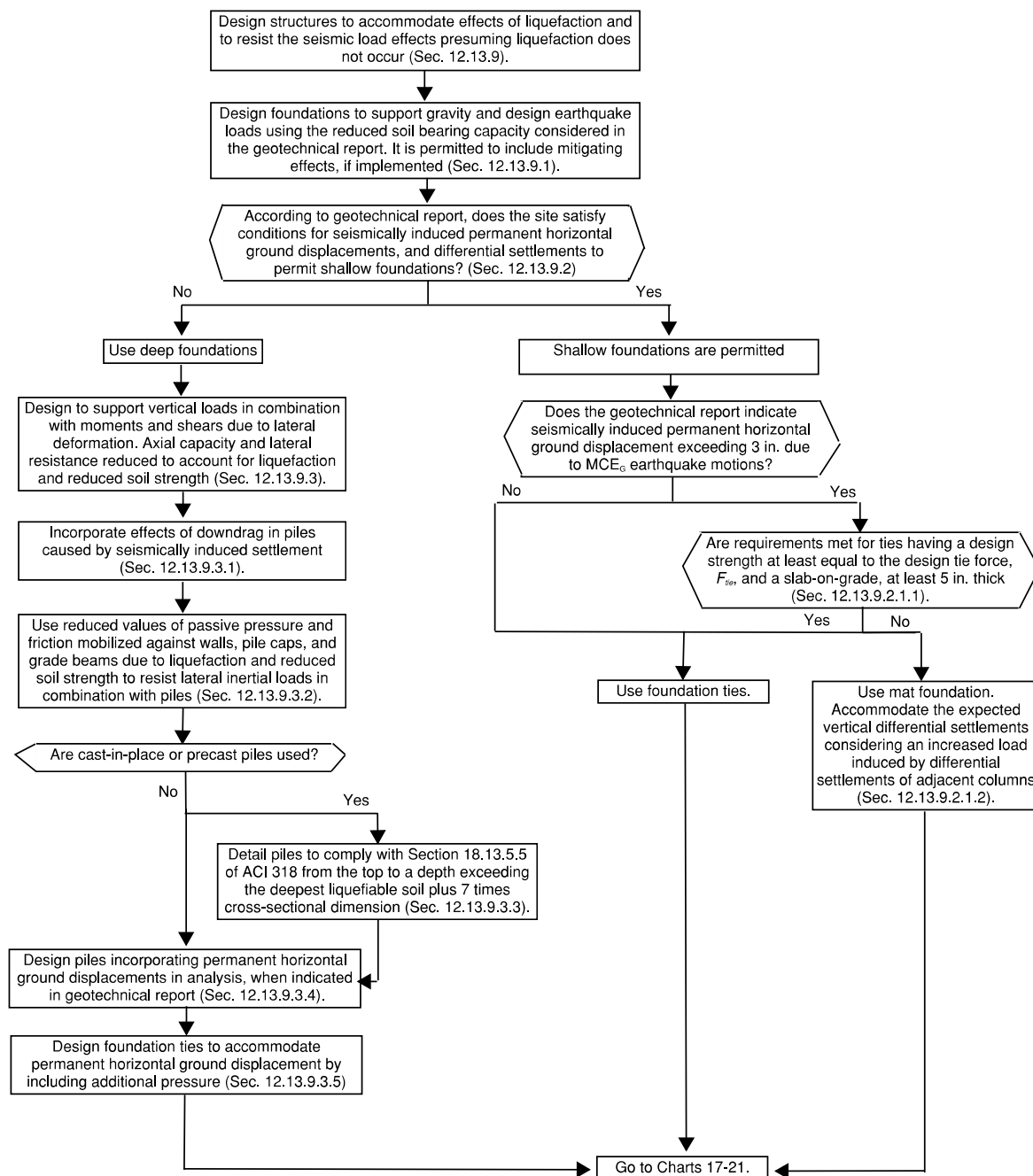


**Chart 23**  
**Foundations and Geotechnical Investigation**

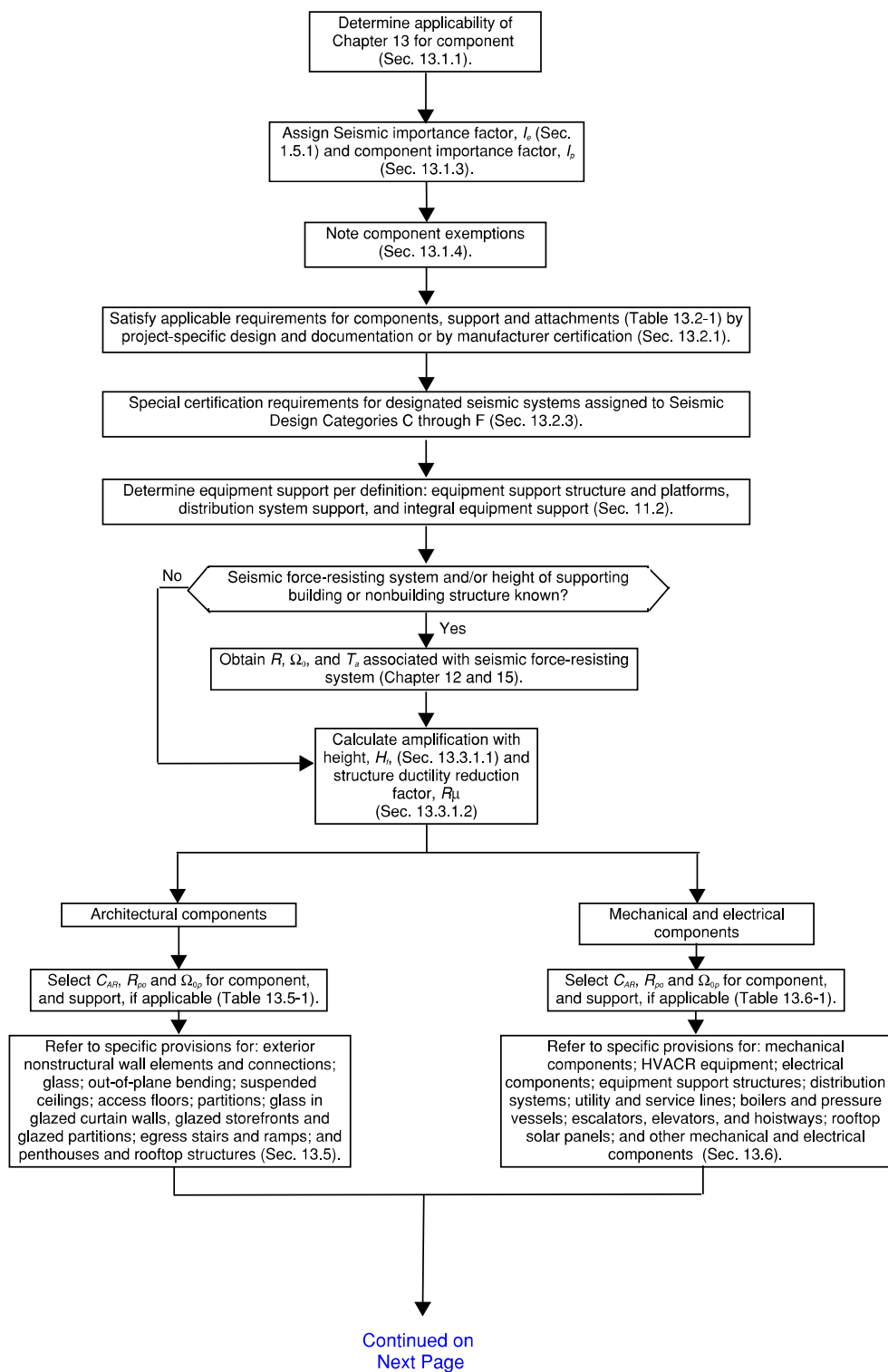




**Chart 24**  
**Requirements for Foundations on Liquefiable Sites**



**Chart 25**  
**Nonstructural Components**



**Chart 25**  
**Nonstructural Components**

