2011

AASHTO Guide Specifications for

LRFD Seismic Bridge Design

2nd Edition

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FOREWORD

Following the 1971 San Fernando earthquake, significant effort was expended to develop comprehensive design guidelines for the seismic design of bridges. That effort led to updates of both the AASHTO and Caltrans design provisions and ultimately resulted in the development of ATC-6, *Seismic Design Guidelines for Highway Bridges*, which was published in 1981. That document was subsequently adopted by AASHTO as a Guide Specification in 1983; the guidelines were formally adopted into the *Standard Specifications for Highway Bridges* in 1991, then revised and reformatted as Division I-A. Later, Division I-A became the basis for the seismic provisions included in the *AASHTO LRFD Bridge Design Specifications*.

After damaging earthquakes in 1980s and 1990s, and as more recent research efforts were completed, it became clear that improvements to the seismic design practice for bridges should be undertaken. Several efforts culminated in the publication of ATC-32, *Improved Seismic Design Criteria for California Bridges: Provisional Recommendations* in 1996; the development of Caltrans' *Seismic Design Criteria*; publication of MCEER/ATC-49 (NCHRP 12-49), *Recommended LRFD Guidelines for the Seismic Design of Highway Bridges* in 2003; and the development of the South Carolina *Seismic Design* Specifications in 2001. Thus in 2005, with the T-3 Seismic Design Technical Committee's support, work began to identify and consolidate the best practices from these four documents into a new seismic design specification for AASHTO. The resulting document was founded on displacement-based design principles, recommended a 1000-yr return period earthquake ground motion, and comprised a new set of guidelines for seismic design of bridges. During 2007, a technical review team refined the document into the Guide Specifications that were adopted at the 2007 annual AASHTO Highways Subcommittee on Bridges and Structures meeting. The following year, further refinement was completed by the team and was adopted. The 2007 document, combined with the modifications approved in 2008, form the basis of these Guide Specifications.

The scope of these Guide Specifications covers seismic design for typical bridge types and applies to noncritical and non-essential bridges. The title of the document reflects the fact that the Guide Specifications are approved as an alternate to the seismic provisions in the *AASHTO LRFD Bridge Design Specifications.* These Guide Specifications differ from the current procedures in the LRFD Specifications in the use of displacement-based design procedures, instead of the traditional, force-based "R-Factor" method. This new approach is split into a simplified implicit displacement check procedure and a more rigorous pushover assessment of displacement capacity. The selection of which procedure to use is based on seismic design categories, similar to the seismic zone approach used in the *AASHTO LRFD Bridge Design Specifications*. Also included is detailed guidance and commentary on earthquake-resisting elements and systems, global design strategies, demand modeling, capacity calculation, and liquefaction effects. Similar to the LRFD force-based method, capacity design procedures underpin the Guide Specifications' methodology, and these procedures include prescriptive detailing for plastic hinging regions and design requirements for capacity protection of those elements that should not experience damage.

These Guide Specifications incorporate recent experience, best practices, and research results and represent a significant improvement over the traditional force-based approach. It is expected that these Guide Specifications will be revised as refinements or improvements become available.

AASHTO Highways Subcommittee on Bridges and Structures

PREFACE

This second edition of the *Guide Specifications for LRFD Seismic Bridge Design* includes technical content approved by the Highways Subcommittee on Bridges and Structures through 2011. In addition to revising the first edition content, he authors have added Appendix B, "Design Flowcharts."

An abbreviated table of contents follows this preface. Detailed tables of contents precede each Section and Appendix.

AASHTO Publications Staff

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SECTION 1:

INTRODUCTION

1.1—BACKGROUND

The state of practice of the seismic design of bridges is continually evolving, and the *AASHTO Guide Specifications for LRFD Seismic Bridge Design* was developed to incorporate improvements in the practice that have emerged since publication of ATC 6, *Seismic Design Guidelines for Highway Bridges*, the basis of the current AASHTO seismic design provisions. While small improvements have been incorporated into the AASHTO seismic design procedures in the intervening years since ATC 6 was published in 1981, these Guide Specifications and related changes to the current *AASHTO LRFD Bridge Design Specifications* represent the first major overhaul of the AASHTO procedures. The development of these Guide Specifications was performed in accordance with the recommendations of the NCHRP 20-07/Task 193 Task 6 Report. The Task 6 effort combined and supplemented existing completed efforts (i.e., AASHTO Standard Specifications Division I-A, NCHRP 12-49 guidelines, SCDOT specifications, Caltrans *Seismic Design Criteria*, NYCDOT *Seismic Intensity Maps* (1998), and ATC-32) into a single document that could be used at a national level to design bridges for seismic effects. Based on the Task 6 effort and that of a number of reviewers, including representatives from State Departments of Transportation, the Federal Highway Administration, consulting engineers, and academic researchers, these Guide Specifications were developed.

Key features of these Guide Specifications follow:

- Adopt the seven percent in 75 yr design event for development of a design spectrum.
- Adopt the NEHRP Site Classification system and include site factors in determining response spectrum ordinates.
- Ensure sufficient conservatism (1.5 safety factor) for minimum support length requirement. This conservatism is needed to accommodate the full capacity of the plastic hinging mechanism of the bridge system.
- Establish four Seismic Design Categories (SDCs) with the following requirements:

  SDC A

  - No displacement capacity check needed
  - No capacity design required
  - SDC A minimum requirements
  - No liquefaction assessment required

C1.1

This commentary is included to provide additional information to clarify and explain the technical basis for the specifications provided in the *Guide Specifications for LRFD Seismic Bridge Design*. These specifications are for the design of new bridges.

The term "shall" denotes a requirement for compliance with these Specifications.

The term "should" indicates a strong preference for a given criterion.

The term "may" indicates a criterion that is usable, but other local and suitably documented, verified, and approved criterion may also be used in a manner consistent with the LRFD approach to bridge design.

The term "recommended" is used to give guidance based on past experiences. Seismic design is a developing field of engineering that has not been uniformly applied to all bridge types; thus, the experiences gained to date on only a particular type are included as recommendations.

SDC B

- o Implicit displacement capacity check required (i.e., use a closed form solution formula)
- o Capacity checks suggested
- o SDC B level of detailing
- o Liquefaction assessment recommended for certain conditions

SDC C

- o Implicit displacement capacity check required
- o Capacity design required
- o SDC C level of detailing
- o Liquefaction assessment required

SDC D

- o Pushover analysis required
- o Capacity design required
- o SDC D level of detailing
- o Liquefaction assessment required

- Allow for three types of a bridge structural system:
  - o *Type 1*—Design a ductile substructure with an essentially elastic superstructure.
  - o *Type 2*—Design an essentially elastic substructure with a ductile superstructure.
  - o *Type 3*—Design an elastic superstructure and substructure with a fusing mechanism at the interface between the superstructure and the substructure.

1.2—TECHNICAL ASSISTANCE AGREEMENT BETWEEN AASHTO AND USGS

Under the agreement, the U.S. Geological Survey (USGS) prepared two types of products for use by the American Association of State Highway and Transportation Officials (AASHTO). The first product was a set of paper maps of selected seismic design parameters for a seven percent probability of exceedance in 75 yr. The second product was a ground motion software tool to simplify determination of the seismic design parameters.

These guidelines use spectral response acceleration with a seven percent probability of exceedance in 75 yr as the basis of the seismic design requirements. As part of the National Earthquake Hazards Reduction Program, the USGS's National Seismic Hazards Mapping Project prepares seismic hazard maps of different ground motion parameters with different probabilities of exceedance. The maps used in these Guide Specifications were prepared by the USGS under a separate Technical Assistance Agreement with AASHTO, for use by AASHTO and, in particular, the Highways Subcommittee on Bridges and Structures.

1.2.1—Maps

The set of paper maps covered the 50 states of the United States and Puerto Rico. Some regional maps were also included to improve resolution of contours. Maps of the conterminous 48 states were based on USGS data used to prepare maps for a 2002 update. Alaska was based on USGS data used to prepare a map for a 2006 update. Hawaii was based on USGS data used to prepare 1998 maps. Puerto Rico was based on USGS data used to prepare 2003 maps.

The maps included in the package were prepared in consultation with the Subcommittee on Bridges and Structures. The package included a series of maps that provide:

- The peak horizontal ground acceleration coefficient, PGA,
- A short-period (0.2-sec) value of spectral acceleration coefficient, S_s, and
- A longer-period (1.0-sec) value of spectral acceleration coefficient, S_1.

The maps are for spectral accelerations for a reference Site Class B.

1.2.2—Ground Motion Tool

The ground motion software tool was packaged on a CD-ROM for installation on a PC using a Windows-based operating system. The software includes features allowing the user to calculate the mapped spectral response accelerations as described below:

- PGA, S_s, and S_1: Determination of the parameters PGA, S_s, and S_1 by latitude–longitude or zip code from the USGS data.
- Design values of PGA, S_s, and S_1: Modification of PGA, S_s, and S_1 by the site factors to obtain design values. These are calculated using the mapped parameters and the site coefficients for a specified site class.

In addition to calculation of the basic parameters, the CD allows the user to obtain the following additional information for a specified site:

- Calculation of a response spectrum: The user can calculate response spectra for spectral response accelerations and spectral displacements using design values of PGA, S_s, and S_1. In addition to the numerical data, the tools include graphic displays of the data. Both graphics and data can be saved to files.
- Maps: The CD also includes the seven percent in 75-y maps in PDF format. A map viewer is included that allows the user to click on a map name from a list and display the map.

1.3—FLOWCHARTS

It is envisioned that the flowcharts herein will provide the engineer with a simple reference to direct the design process needed for each of the four SDCs.

Flowcharts outlining the steps in the seismic design procedures implicit in these Guide Specifications are given in Figures 1.3-1 to 1.3-5.

The Guide Specifications were developed to allow three global seismic design strategies based on the characteristics of the bridge system, which include:

- *Type 1*—Design a ductile substructure with an essentially elastic superstructure.
- *Type 2*—Design an essentially elastic substructure with a ductile superstructure.
- *Type 3*—Design an elastic superstructure and substructure with a fusing mechanism at the interface between the superstructure and the substructure.

The flowchart in Figure 1.3-1 guides the designer on the applicability of the Guide Specifications and the seismic design procedure for bridges in SDC A and single-span bridges. Figures 1.3-2 through 1.3-4 show seismic design procedure flowcharts for bridges in SDC B through D respectively. Figure 1.3-5 shows foundation design and detailing flowcharts.

Alternate flowcharts are provided in Appendix B.

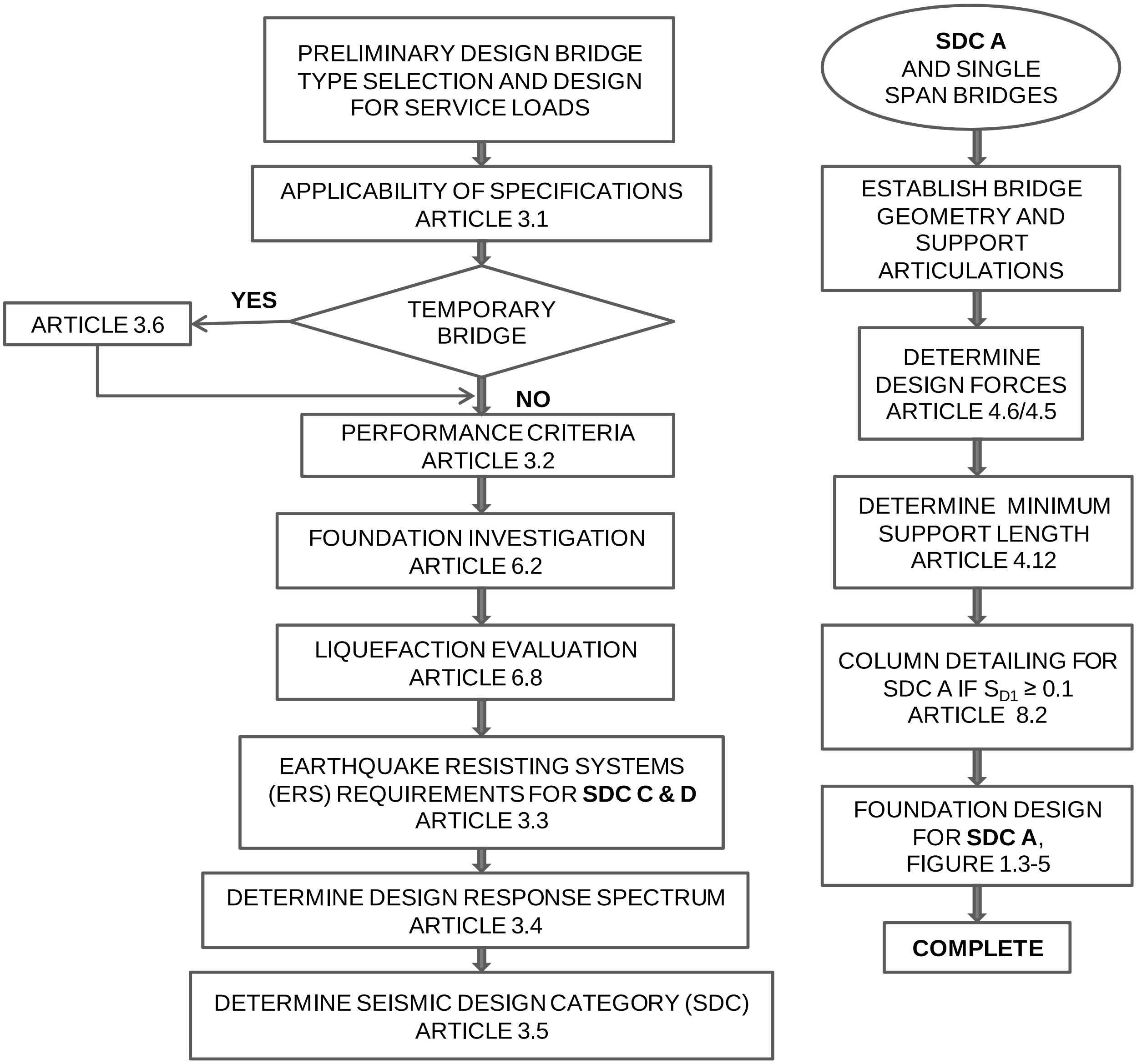


Figure 1.3-1—Applicability of the Guide Specifications and the Seismic Design Procedure for Bridges in SDC A and Single-Span Bridges

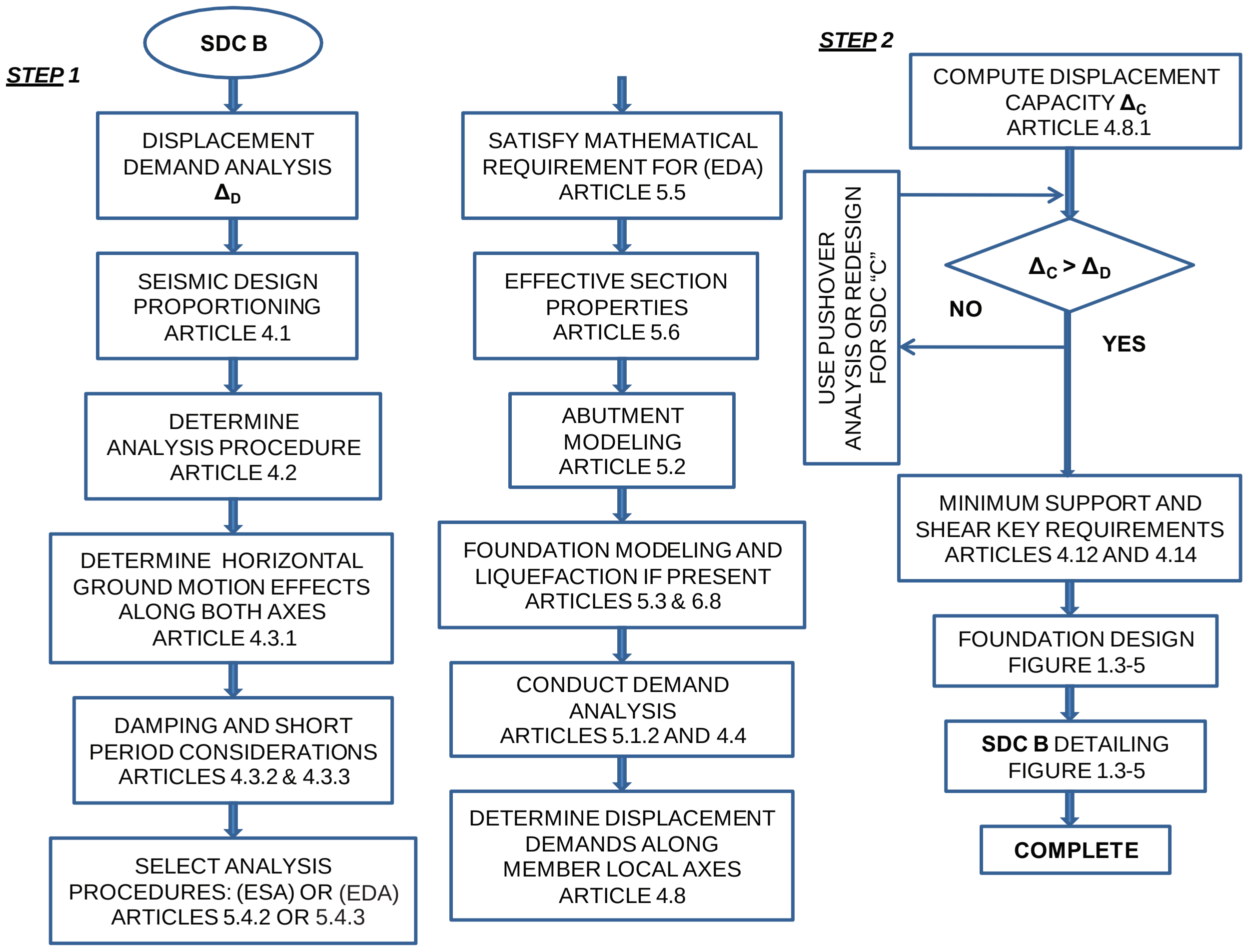


Figure 1.3-2—Seismic Design Procedure Flowchart for Bridges in SDC B

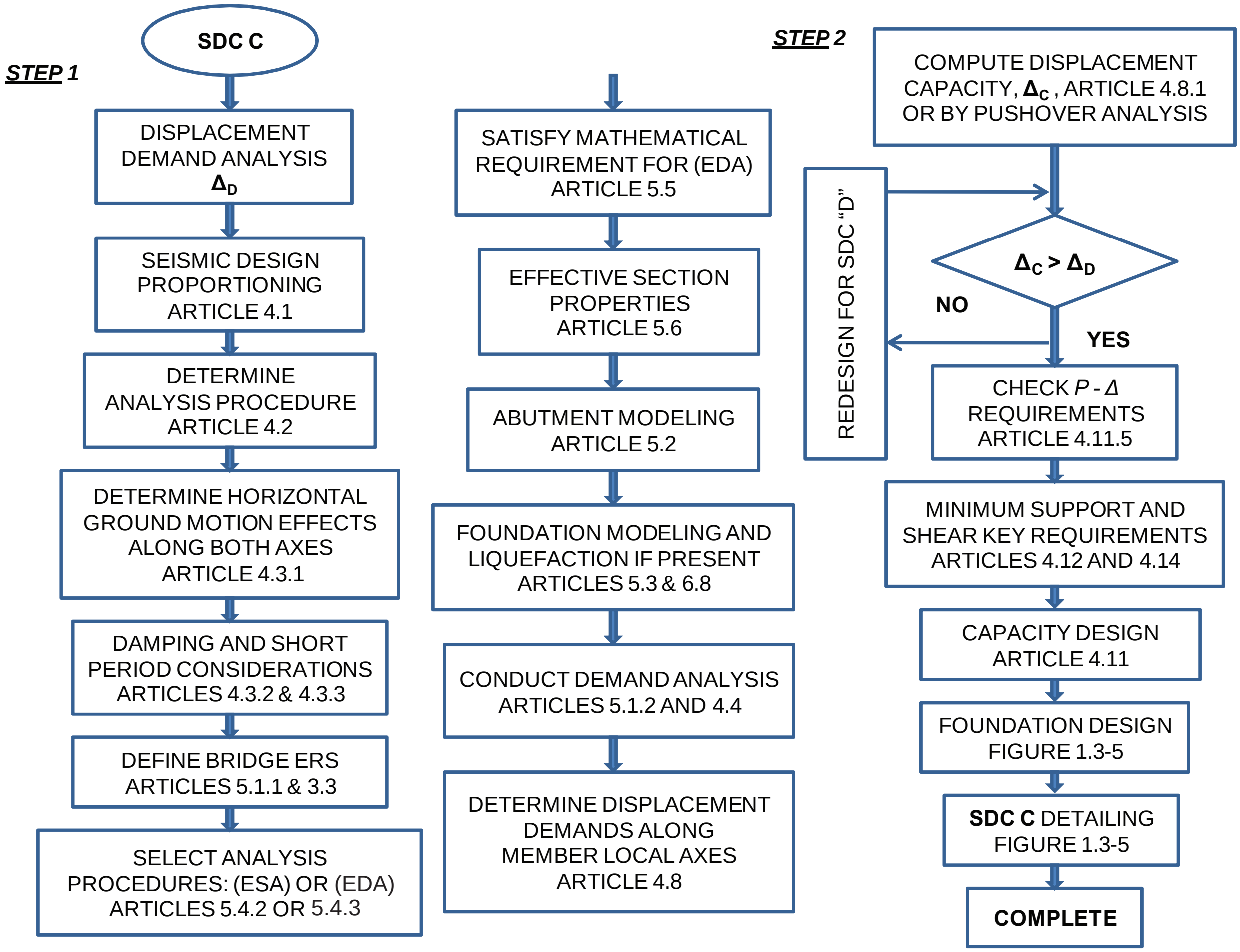


Figure 1.3-3—Seismic Design Procedure Flowchart for Bridges in SDC C

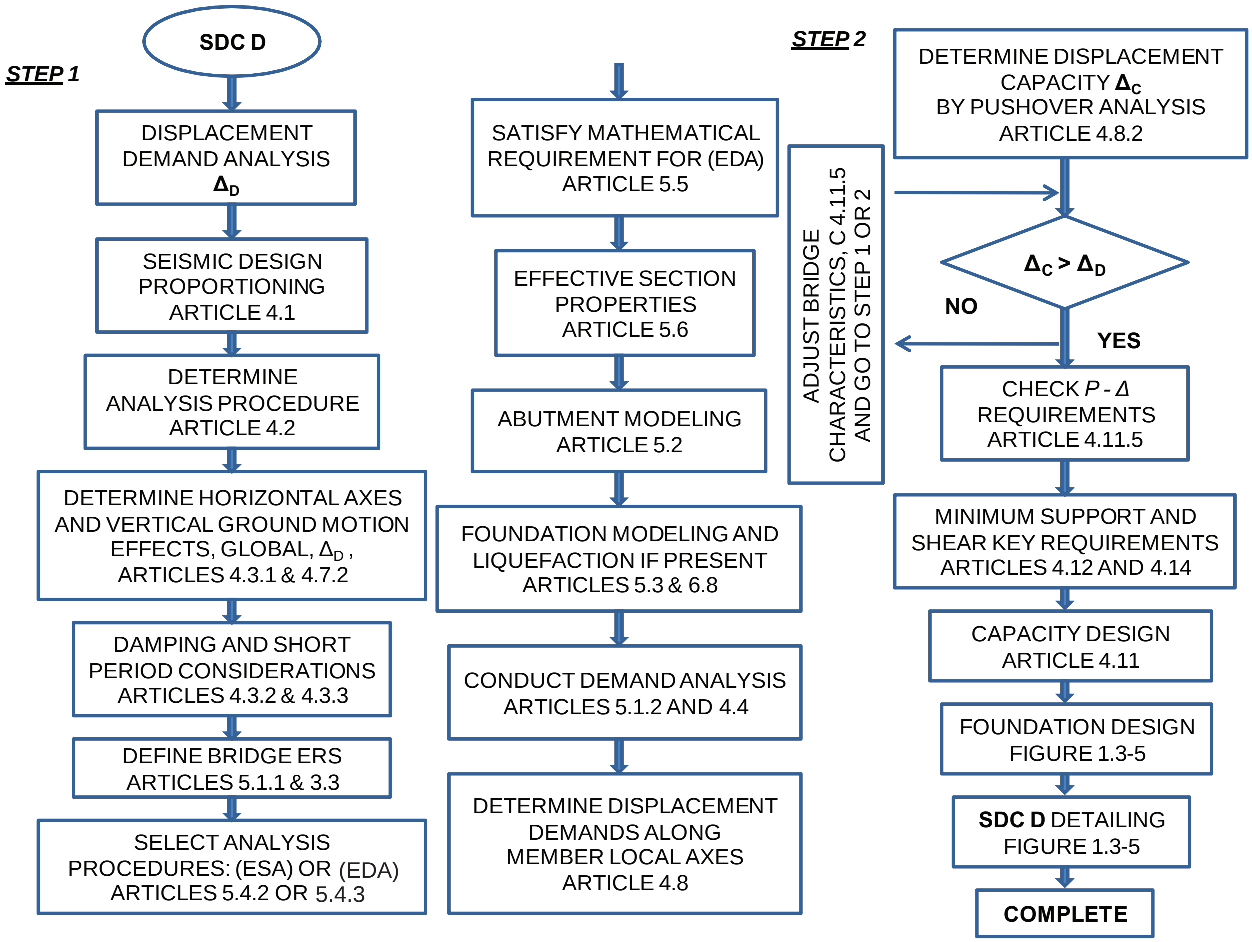
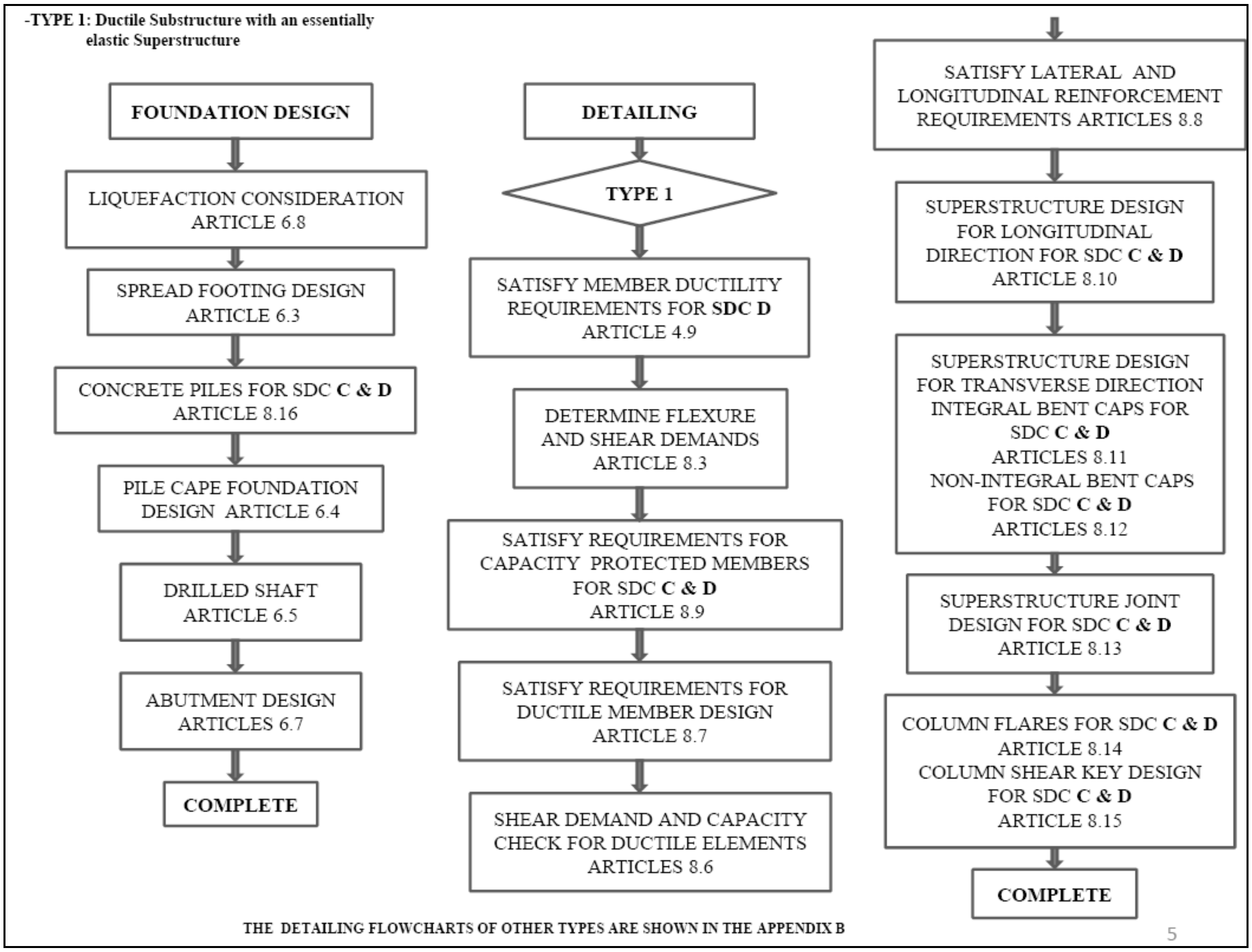


Figure 1.3-4—Seismic Design Procedure Flowchart for Bridges in SDC D



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