Revision of ASCE 4

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REVISION OF ASCE 4

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The original version of ASCE Standard 4, "Seismic Analysis of Safety-Related Nuclear Structures" was published in September, 1986. It is ASCE policy to update its standards on a five year interval and the Working Group on Seismic Analysis of Safety Related Nuclear Structures was reconvened to formulate the revisions. The goal in updating the standard is to make sure that it is still relevant and that it incorporates the state of the practice in seismic engineering or, in some cases, where it has been demonstrated that state-of-the-art improvements need to be made to standard practice, new improvements are included.

With regards to relevance, the Working Group has decided that while the name of the standard retains the word “nuclear”, the standard has applicability beyond just nuclear structures and should be considered for all safety-related structures. Another philosophical change relates to the specification of a specific performance level of a structure designed or evaluated by the methods in the standard. In the 1986 version, the resulting goal of the techniques specified was to produce seismic design responses that have about a 90% chance of not being exceeded for a given design earthquake, assuming that the input response spectrum is specified at the mean plus one standard deviation level. This reflected the standard practice of the Nuclear Regulatory Commission licensing provisions. However, in the new standard, it was decided that the goal should be generalized such that the output parameters maintain about the same probability of non-exceedance as the input. This is accomplished by specifying methods for analysis with essentially no conservative bias except for small levels of conservatism added only to account for uncertainty in modeling.

Additional consideration is given to the use of the analytical techniques in the standard for the evaluation of existing facilities. For example, guidance is given for evaluation of facilities for seismic events beyond the design basis. Such analyses may be used to assess the seismic risk or margin for new facilities or for operating facilities subjected to changing perceptions of seismic hazard. The guidance for such evaluation is included in a non-mandatory appendix.

The contents of the new standard cover the same areas as the original version, with some additions. The contents are as follows:

- Input - response spectra and time histories
- Modeling of structures
- Analysis of structures
- Soil-structure interaction
- Input for subsystem analysis
- Special structures - buried pipes and conduits, earth-retaining walls, above-ground vertical tanks, raceways, and base-isolated structures.
- Appendix A
  - Seismic probabilistic risk assessment
  - Margin assessment

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SEISMIC GROUND MOTIONS

The provisions for determining input ground motions include many of those included in
the original standard and are augmented to reflect recent developments. Input motions
are specified as free-surface motions at the top of competent foundation materials.
However, for thin relatively soft layers overlying stiffer competent materials, the motions
are specified as outcrop motions at the elevation of the top of competent material.
Consideration of parameters in addition to peak ground acceleration, such as peak ground
velocity, peak ground displacement, and effective duration, are included in the definition
of seismic input. Probabilistic hazard assessments are specifically recognized as an
acceptable method of determining ground motions.

Additional guidance is given for the determination of both site-specific response spectra
and site-independent response spectra. Site specific spectra are required for soft soil
sites, sites susceptible to high frequency motions, and near-field sites. Also, special
provisions are given for vertical spectra for near-field sources. Additional guidance is
also given for determination of time histories. In order to assure adequate power at all
frequencies in the range of interest, the power spectral density of the time history must be
verified. Additional requirements related to input motion are specified for seismic-
isolated structures.

MODELING OF STRUCTURES

In the original standard, consideration of the possibility of accidental torsion was
specified. However, no guidance was given on how to consider such torsion. Therefore,
in the revision, the consideration of accidental eccentricity has been specified to be a
minimum eccentricity of 5% of the building dimension perpendicular to the direction of
motion in the analysis. Such eccentricity is to be applied in addition to any known
eccentricity. It is believed that this provision brings the standard into conformance with
the UBC and NRC practice. However, it is further specified that the torsional moments
from this accidental eccentricity be only used to determine structural forces and only to
increase such forces. These torsional moments shouldn’t be used to modify the dynamic
properties of the structure or to alter the in-structure spectra.

In the Structural Materials Properties section, consideration was given to the findings of
the working group on the stiffness of low-rise concrete shear walls. After a few
iterations, it was decided that no change to the basic material properties of concrete was
needed. However, values of Poisson’s ratio have been added. The application of
different damping for different stress levels has been clarified and additional notes
provided in the table on damping. In addition, clarifications on modeling of damping
have been provided.

The section on Dynamic Coupling Criteria has been extensively rewritten to correct
errors and update certain provisions. Dynamic coupling criteria are used to determine
when the analysis of a primary structure model must consider the presence of a secondary
system. Mass and stiffness of the secondary system play a role in making this
determination. Guidance is given for single-point attachment substructures and the figure
showing decoupling criteria has been clarified. Since the guidance for multipoint
attachment involves extensive use of new developments, the bulk of the specific guidance
is included in the Commentary. It is hoped that users of the standard will try out the
Commentary provisions and provide feedback as to their usefulness and ease of
application.

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ANALYSIS OF STRUCTURES

The guidance given in the original standard for time-history and response spectrum analysis methods has remained essentially the same except for the means to determine the number of nodes to include in modal superposition. For both modal superposition time history analysis and response spectra analysis, the number of modes to include is such that the inclusion of all remaining modes does not result in more than 10% increase in total responses of interest. In lieu of this method, the analysis should include all the modes having frequencies less than the ZPA frequency and then add back in the residual rigid response due to the missing mass.

The formulation for time-history analysis of multiply-supported systems has been reformulated to better represent current practice. The response spectrum technique remains the same. To account for relative support displacements, pseudo-static response is superposed on the inertial portion of the response. A caution has been added to ensure that pseudo response is not corrupted by baseline drift of the support displacements and baseline correction applied if warranted.

For combination of modal and component responses, the generalized double sum method applicable to the response spectrum method has been refined slightly. In the current version of ASCE 4-86, a discrete demarcation was established between damped periodic responses, where the contributions are combined by SRSS, and in-phase (essentially rigid) response, where the contributions are combined algebraically. In the revised version, the transition between these two regimes is modeled by a continuous, linear transition. However, the former method is still allowed. In addition, the original CQC method is explicitly allowed and the formulation specified.

SOIL-STRUCTURE INTERACTION

In the SSI section, the guidance for fixed-base analysis, spatial variation, 3-D effects, and non-linear behavior of soil remain essentially unchanged. In the area of uncertainties, two levels of the coefficient of variation for soil shear modulus, \( C_v \), are given. The minimum value is still specified to be 0.5 where the shear modulus is base on site-specific studies. If generic values are used or higher uncertainty exists, \( C_v \) is increased to 1.0.

New guidance has been given in the commentary for the calculation of soil springs for embedded structures so that simplifies analyses may be conducted for this case. Another area where new guidance is provided is for wave incoherence. A table has been added listing frequency-dependent reduction values to account for wave incoherence over large foundations of various plan dimensions. In the area of material properties, a specification has been added indicating that confining pressure be considered in determining shear modulus and damping in addition to strain level. Reference to the confining pressure effects for soil material properties has been provided in the commentary.

INPUT FOR SUBSYSTEM SEISMIC ANALYSIS

Additions have been made in both in-structure response spectra and in-structure time-history input. For response spectra, peak shifting, as specified in ASME Code Case N-397 has been added as an acceptable method for treatment of uncertainty as well as the commonly used peak broadening and lowering. In addition, guidance has been given for interpolating between given spectra to determine spectra at intermediate damping values. In a parallel way, equivalent peak broadening and lowering for in-structure time histories has been specified.
SPECIAL STRUCTURES

For the existing sections on special structures, the changes include correcting the formulation of the M-O Theory for earth-retaining structures and adding modern references for above-ground vertical tanks. In addition, two new section have been added. The first addresses raceways, which includes cable trays and conduit systems. Since there is an ASCE working group on raceways, detailed analytical or experience-based techniques are not provided. Instead, damping values unique to these systems are specified for those engineers who choose to evaluate raceways by analysis. The commentary contains documentation on how the damping values were determined. Second, a section on seismic-isolated structures was added which contains analysis techniques unique to isolated structures. Again, since there is an ASCE working group to address seismic isolation, detailed provisions are left to this working group's report.

EVALUATIONS BEYOND DESIGN BASIS

A non-mandatory appendix has been added in recognition of current efforts to evaluate existing nuclear facilities for evaluation beyond their original design basis. Two techniques are described, seismic probabilistic risk assessment (SPRA) and seismic margin assessment (SMA). The appendix includes a history of both methods as well as an a description of the purpose and overview of each. In addition, it contains a comparison of the methods to each other and to the methods described in the Standard 4 itself. References are provides to assist the reader in obtaining detailed procedures.

CONCLUSION

The working group expects to complete its efforts on the new revision of the Standard by February, 1995, turn the document over to the Nuclear Standards Committee by March, and print the document in the Fall.

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