codes & standards

Where the Past Meets the Future

ASCE 31-03

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Evaluating Existing Buildings

The evolution of seismic provisions in building codes for new buildings has a very clear, detailed history. The initial provisions were based on the perception that buildings resisted earthquakes by strength alone. Following the 1971 San Fernando Earthquake came a new understanding that buildings needed both strength and ductility to provide good behavior. As such, provisions evolved to include detailing requirements for new buildings. As we enter the 21st century, performance-based seismic provisions are starting to emerge with focus on even better building behavior and performance to reduce and limit large economic losses , as observed in Northridge and Kobe.

While the main focus has been on improving seismic provisions for new buildings, seismic provisions for use in the evaluation of existing buildings have had a more muddled path. Applicability of seismic provisions for new buildings to evaluate existing buildings is limited; existing buildings are already constructed, the materials are defined, and the details of construction are in place. Therefore, a different approach was needed for existing buildings, and various guidelines have been published over the years.

Figure 1. Earthquake reconnaissance observations from India showing structural systems that did and did not perform well.

Finally, with the publication of *ASCE 31-03: Seismic Evaluation of Existing Buildings,* the first nationally applicable seismic evaluation standard is now available. The document has its roots both in the lessons learned from past earthquakes and in the latest performance-based seismic analysis techniques, giving the design professional the broadest perspective when evaluating existing buildings.

Revisiting the Past

Since the 1930s, structural engineers have learned the most about the behavior of structures by visiting sites damaged by earthquakes, and observing what works and what does not work in gravity-load-carrying and lateral-force-resisting systems (see *Figure 1*). In fact, the first seismic code provisions were the direct result of observations from earthquakes. This practice continues today, with members of the Earthquake Engineering Research Institute (EERI) visiting and collecting data on earthquakes throughout the world.

ASCE 31-03 directly incorporates this practice of chasing earthquakes into its evaluation methodology through the Tier 1 Screening Phase. The evaluation begins with the Tier 1 Screening Phase, which is intended to screen out good buildings and/or identify potential deficiencies. This phase of ASCE 31-03 consists of checklists defining building features that have proven themselves to have behaved poorly during previous seismic events.

These checklists have evolved over the past twenty years, and were developed by cataloguing of potential weak links in buildings from observations in previous earthquakes. They have been used and improved upon in previous seismic evaluation documents, including ATC-14: *Evaluating the Seismic Resistance of Existing Buildings* (1987), *FEMA 178: NEHRP Handbook for the Seismic Evaluation of Existing Buildings* (1992), and *FEMA 310: Handbook for the Seismic Evaluation of Buildings – A Prestandard* (1998) (See *Figure 2*).

Based on the levels of performance and seismicity, the design professional chooses the appropriate structural, geologic and nonstructural checklists, and proceeds to fill them out using information from existing documentation, testing results and site visits. In some statements, a quick calculation of forces and stresses is required. These calculations, called Quick Checks, are to provide an average estimate of the demands on the structure, and to determine if a more detailed calculation is required.

Once the Tier 1 Evaluation is complete, the building will either meet the chosen performance level or have some potential deficiencies. For buildings with potential deficiencies, the design professional may choose to continue on to a Tier 2 Evaluation, or stop the evaluation and report his/her findings.

Back to the Future

Over the last two decades, the worldwide economic losses due to moderate to large earthquakes have been significant. The structural engineering community and public policy makers have deemed these losses too large to ignore. As a result, numerous performance-based

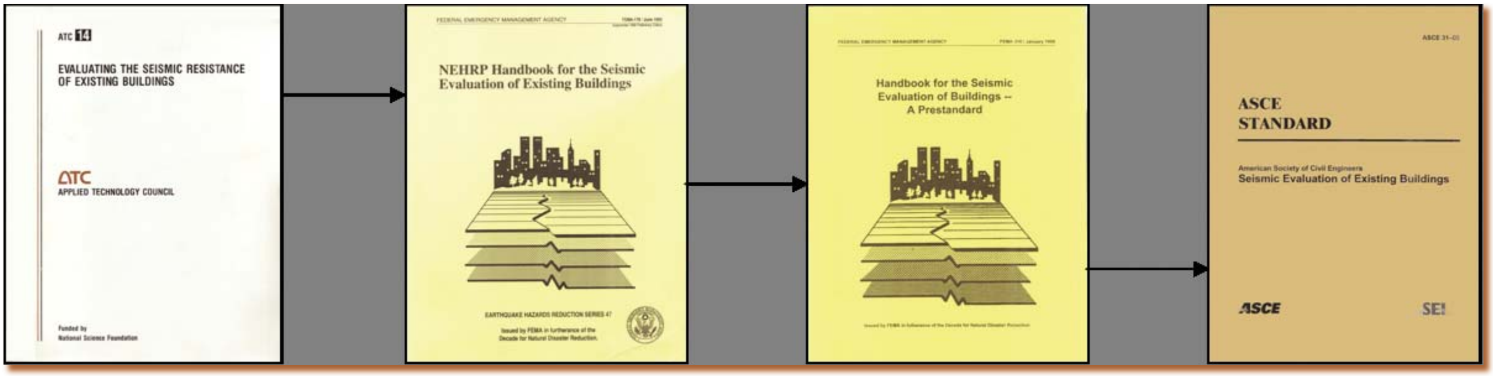

Figure 2. Evolution of seismic evaluation documents (from left): ATC-14 (1987), FEMA 178 (1992), FEMA 310 (1998), and ASCE 31-03 (2003).

seismic guidelines have been published with the intent to control and, when appropriate, minimize property and business interruption losses. ASCE 31-03 has adopted these state-of-the-practice methodologies into the second and third parts of its document, the Tier 2 Evaluation Phase and Tier 3 Detailed Evaluation Phase.

The purpose of a Tier 2 Evaluation is to identify any weak links (fatal flaws) in the building through linear analysis. For most buildings, only the deficiencies that are identified in the Tier 1 Phase are analyzed. However, rather than use the traditional equivalent lateral force methodology in current codes, ASCE 31-03 uses the performance-based methodology of pseudo lateral forces originally developed for *FEMA 273: NEHRP Guidelines for the Seismic Rehabilitation of Buildings*.

The building is evaluated at the expected displacement of the structure during the demand earthquake. Since the analysis is linear, this means that the forces associated with the expected displacement are unrealistically high. The forces for each component are determined, and then the components are evaluated based on the ductility of the element. This ductility, or m-factor, reduces to the pseudo force level to a point where the component can be evaluated on a realistic force level. For a graphical comparison of the equivalent and pseudo lateral force methods, refer to *Figure 3*.

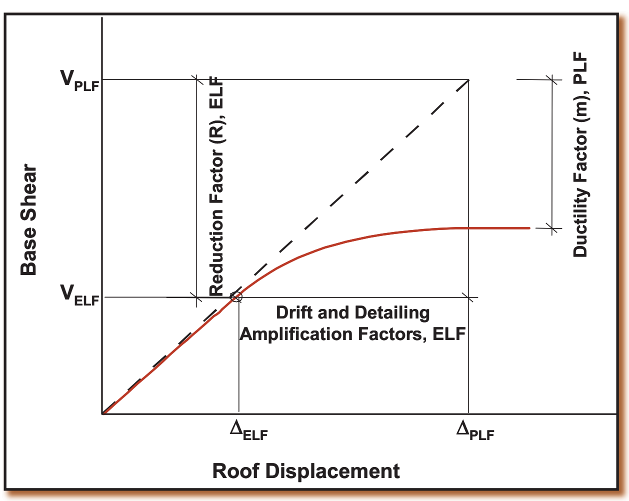

Figure 3. Graphical comparison of the equivalent and pseudo lateral force methods.

In order to evaluate the components, the design professional must first classify each element as either deformation- or force-controlled. Deformation-controlled elements are those that provide deformation to the entire building through inelastic behavior. An example of a deformation-controlled action is a flexural hinge in a beam. Deformation-controlled elements are evaluated using m-factors, which vary for various elements and materials. Force-controlled elements are those that exhibit little or no inelastic behavior before loss of strength. An example of a force-controlled action is a shear-critical concrete column. Force-controlled elements are evaluated for the maximum force that can be delivered by surrounding elements.

In order for a building to meet the chosen performance level in a Tier 2 Evaluation, all force-controlled elements must be prevented from experiencing substantial yielding by the yielding of deformation-controlled elements, and deformation-controlled elements must not exceed their ductility capacity.

If the structure being evaluated still has deficiencies following a Tier 2 Evaluation, a Tier 3 Detailed Evaluation may be performed. The Tier 3 provisions in ASCE 31-03 adopt the latest procedures from design provisions for new buildings or seismic rehabilitation of existing buildings. Because a linear analysis was already performed in Tier 2, Tier 3 requires the implicit or explicit modeling of the nonlinear response of the building, with the purpose of determining the failure mechanism for the structure. As a result, a Tier 3 evaluationuses uses the latest nonlinear analysis techniques developed in the last five years, such as those in *FEMA 356: Prestandard and Commentary for the Seismic Rehabilitation of Buildings*.

Summary

With the publication of ASCE 31-03, the first nationally applicable seismic evaluation standard is available to the structural engineering community. It draws on lessons learned from past earthquakes while utilizing analytical procedures founded in the latest engineering principles. This allows the methodology to focus only on the elements that have been shown to be weak links in earthquakes, and consider them as they interact within a structural system. The result is either the verification of the adequacy of an existing building or the identification of the extent of seismic strengthening required.

ASCE 31-03 can be used by jurisdictions and design professionals not only to evaluate the adequacy of a building, but to set structural criteria and public policy to address local socioeconomic issues.▪

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