ASCE 41-13: Seismic Evaluation and Retrofit ~~Rehabilitation~~ of Existing Buildings

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Abstract

For the past 3 years the ASCE/SEI Standards Committee on Seismic Rehabilitation has been working to combine ASCE 31-03 into ASCE 41-06 while also updating both standards. The result of that humongous effort is the soon-to-be released ASCE 41-13: Seismic Evaluation and Retrofit of Existing Buildings. The new combined standard has eliminated any inconsistencies that previously existed between the two standards. Now the user decides if they want to go forward with lower performance objectives traditionally used for existing buildings, as was the case within ASCE 31 or an equivalent hazard to a new building, similar to the Basic Safety Objective in ASCE 41. In addition, the Tier 1 checklists have been significantly modified and reorganized. The use deficiency-only procedures (Tier 2) have been greatly expanded to regular buildings of greater heights. Plus, there have been a number of significant technical changes including updated analysis provisions with more emphasis on nonlinear response history analysis, provisions for bucking restrained braced frames, expanded liquefaction provisions, a new foundation rocking analysis procedure, substantially updated URM provisions, and a full updated Chapter on Seismic isolation and Energy dissipation.

Introduction

ATC 14 (1987) and FEMA 273 (1997) were both landmark documents. Each represented major turning points in how the profession addressed evaluating the seismic hazards posed by existing buildings and mitigating those hazards through retrofit. ATC 14 created the concept of screening buildings for potential deficiencies which had been observed in similar buildings in major earthquakes to increase a building's risk to life safety. FEMA 273 was the first time that "displacement-based" methodologies were set forth and guidelines for nonlinear analysis of all types of building structures were provided. Prior to those documents, seismic evaluation and retrofit was left solely to the judgment of the practitioner as he or she attempted to use standards intended for new building design to evaluate and retrofit existing buildings.

Following the publication of both ATC 14 and FEMA 273, the Federal Emergency Management Agency (FEMA) began to support efforts to transition those documents from guidelines into national standards. Those efforts produced updated documents in pre-standard form (FEMA 178, 1992; FEMA 310, 1998; and FEMA 356, 2000). In addition to altering the text of those documents to be enforceable standards language, many technical updates were also incorporated. Also, the displacement based analysis procedures from FEMA 273 were simplified and incorporated into FEMA 310 to bring some consistency to the two documents.

The standardization efforts culminated with the publication of ASCE 31-03 *Seismic Evaluation of Existing Buildings* in 2003 and then in 2006 with ASCE 41-06 *Seismic Rehabilitation of Existing Buildings.* These documents were produced following ASCE's standards development process, which required significant balloting of both pre-standard documents through a diverse committee of practitioners, academics, and industry representatives followed by a public comment period. All comments made throughout the process were responded to by the ASCE/SEI Standards Committee on Seismic Rehabilitation. In one instance significant public comments to ASCE 41-06 led to the publication of a supplement to that document (ASCE, 2008).

From ATC 14 through ASCE 31-03 and from FEMA 273 through ASCE 41-06, these documents have found widespread use throughout the profession, especially in California and within the Federal Building Standards RP4, RP6 and RP 8. Regulatory agencies, such as OSHPD and DSA, public building owners, such as the US General Service Administration, and the Department of Veterans Affairs, have directly referenced or permitted the use of these documents to evaluate and retrofit existing buildings.

As the documents were used more and more, inconsistencies were discovered between ASCE 31 and ASCE 41. Many of the inconsistencies were intentional. The most significant being the ingrained philosophy that existing buildings should be given a break when being evaluated and therefore not be held to the same standards as a new building. While another philosophy held that if someone choses to carry out a seismic retrofit, they should do so to a performance level commensurate with a new building unless some other performance objective is intentionally and explicitly chosen. Other inconsistencies were created because of the simplification of the ASCE 41 analysis procedures and member acceptance criteria in ASCE 31. Lastly, inconsistencies were created because the base documents, ATC 14 and FEMA 273, were transitioned into standards documents on different schedules, out of phase with each other, with some differences in the committee membership making those revisions.

Another issue of consternation within the profession was the inconsistencies between ASCE 41 and ASCE 7 (2010). Many of these inconsistencies had been known since the publication of FEMA 273 and relate to the fundamentally different applications of the two standards. The different applications led to differences in procedures between the two documents. Because ASCE 7 was written for use in the design of new structures, it can employ “force-based” procedures which utilize a global building ductility factor, the R-factor, based on the details of construction. ASCE 41 uses “displacement-based” procedures which assess the ductility of each element action (shear, flexure, etc.) individually because the ductility of the individual elements in the structural system may not be consistent with each other. Irrespective of discrepancies within procedures, the intended performance objective for a typical Risk Category II building is the same in ASCE 7 as the Basic Safety Objective in ASCE 41. Also, because ASCE 7 does not contain specific guidance on the use of nonlinear analysis procedures, ASCE 41 has often been used as the basis for new building designs which utilized nonlinear analyses.

When the standards committee met in December 2009 to kick-off the update cycle for ASCE 31 and 41, the aforementioned inconsistencies were at the forefront of everyone’s mind. Another topic that garnered a lot of discussion was a proposition to combine ASCE 31 and 41 into one standard. At that meeting, the committee broke up into 3 subcommittees. One was tasked with looking at what technical updates to ASCE 41 should be made, another was tasked with looking at what updates and simplifications could be made to the ASCE 31 Tier 1 screening, and the last was tasked with determining if the documents should be combined or stay as separate, but well-coordinated standards. Once the ASCE 41 subcommittee determined the technical updates needed, it created technical issue teams to address all of those updates.

Combined Standard

The committee chose to combine the standards into one document and coordinate the evaluation and retrofit procedures. The combined standards retains the three-tired approach found in ASCE 31-03, while relying on the technical provisions in ASCE 41-06 as the basis for all the analytical procedures.

The Tier 1 Screening is essentially the same as it was in ASCE 31-03, with some reorganization and technical changes to the checklists. Those changes are discussed in more detail later in the paper. The Screening is still intended as the first pass that one would make through the building to get familiar with it. It is intended only to be used as an evaluation method and not for retrofit design.

The Tier 2 “Deficiency-Based” procedure is now intended to be used for either evaluation or retrofit. As before, the user can go further in evaluating all the potential deficiencies identified in the Tier 1 screening or simply chose to fix those potential deficiencies with a retrofit design. Unlike ASCE 41-06, there is no difference in building size when a deficiency-based retrofit can be used versus when a deficiency-only evaluation can be performed. Previously the retrofit requirements were significantly more restrictive.

In order to eliminate inconsistencies within the document, the specific Tier 2 analysis procedures and ASCE 31-03m-factors were eliminated. The user is pointed to the subsequent sections of the standard that are used for Tier 3 for analysis procedures and m-factors. The benefit to this is that there is no difference between Tier 2 and Tier 3 in terms of force demands or member acceptance criteria. The only issue with this is that users of ASCE 31-03 who are not familiar with ASCE 41 procedures may find it difficult at first due to all the additional material they have to read and greater number of possible m-factors. The committee made every possible effort to alleviate this by providing a detailed flow chart and specific pointers throughout the chapter that contains the Tier 2 procedures to the appropriate sections in the rest of the standard. The benefit, of course, is a better analysis because it is more specific.

In merging the two documents, the committee felt that the "Full-Building" Tier 2 in ASCE 31-03 was really no different than a systematic evaluation. Since the Tier 3 procedure was thought to be a systematic (as opposed to deficiency-based) evaluation or retrofit, it was felt that there was no need for this separate procedure. Therefore the "Full-Building" Tier 2 procedure was eliminated, so Tier 2 now only refers only to "Deficiency-Based" procedures and where one would previously have performed a "Full-Building" Tier 2, they now perform a Tier 3 evaluation.

The Tier 3 procedure is intended to be a systematic analysis of the building, which can be used either for evaluation or retrofit. The Tier 3 procedure encompasses all four analysis (Linear Static, Linear Dynamic, Nonlinear Static, and Nonlinear Dynamic) procedures from ASCE 41-06. The user can chose to apply any procedure, subject to specific limitations for each procedure. However, the permission to use a new building design standard for Tier 3, which was permitted in ASCE 31-03, has been eliminated because the new building standard cannot be properly applied to an existing building unless a completely new structural system is provided.

The outline of the new standard is as follows:

Chapter 1	General Requirements
Chapter 2	Seismic Performance Objectives and Ground Motions
Chapter 3	Evaluation and Retrofit Requirements
Chapter 4	Tier 1 Screening .
Chapter 5	Tier 2 Deficiency-Based Evaluation and Retrofit
Chapter 6	Tier 3 Systematic Evaluation and Retrofit
Chapter 7	Analysis Procedures and Acceptance Criteria
Chapter 8	Foundations and Geologic Site Hazards
Chapter 9	Steel
Chapter 10	Concrete
Chapter 11	Masonry
Chapter 12	Wood and Cold-Formed Steel
Chapter 13	Architectural, Mechanical, and Electrical Components
Chapter 14	Seismic Isolation and Energy Dissipation
Chapter 15	System-Specific Performance Procedures
Chapter 16	Tier 1 Checklists
Appendix A	Guidelines for Deficiency-Based Procedures
Appendix B	Use of ASCE 41-13 within Mitigation Programs

The new standard is based on the philosophy that procedurally there is no difference between evaluation and retrofit design. Retrofit design is simply evaluating a building in an altered state and adjusting the alterations until the building's evaluation meets the desire performance objective. Therefore there is no difference between a Tier 2 or Tier 3 evaluation or retrofit. The analysis procedures and acceptance criteria are the same. If the user wishes to carry out an evaluation or retrofit with the intention of accepting higher risk of collapse or lesser performance, as was the case with ASCE 31-03, then the user must now explicitly choose a lesser seismic hazard or a lesser performance level.

New Earthquake Hazard Parameters

As discussed earlier, it has been a commonly accepted within the profession to evaluate existing buildings to a lower force level than new buildings. The most common way this was carried out was to use 75% of new building design forces. That concept was contained with ATC-14 and carried through to ASCE 31-03. In the Tier 2 procedures in ASCE 31-03 the 75% factor was actually buried within the m-factors. Those m-factor were approximately 1.33 (1/0.75) times their ASCE 41-06 counterparts, with some additional simplifications. Then in the Tier 3 procedure of ASCE 31-03, the user was explicitly directed to use a standard such as ASCE 41-06 or ASCE 7-05 and multiply the demand forces by 0.75.

The committee agreed that the philosophy of permitting existing buildings to be evaluated, and even upgraded, to a lower hazard should be retained. There are a number of reasons for this, which are discussed in detail in the ASCE 41-13 Chapter 2 commentary. They are:

- Permitting buildings recently built to not be immediately rendered deficient when there are minor changes to the new design standards.
- The increased risk due to the lower hazard is acceptable because of the presumption that an existing building has a shorter remaining life than a new building.
- The cost of retrofitting to achieve commensurate performance can be disproportional to the increased benefit as opposed to doing something to make the building better by mitigating the most egregious deficiencies.

With the decisions to retain the philosophy of allowing existing buildings to be evaluated and possibly upgraded to a lower hazard than new buildings, the question then became what that hazard should be. While the 0.75-factor has been engrained within the profession for many years, it is somewhat arbitrary. The committee chose to follow the path put forth in the 2010 California Building Code in the section on accepted seismic performance for state-owned building which utilized different return period seismic hazard parameters instead of the 0.75-factor.

In Section 3417 of the CBC two reduced earthquake hazards are stipulated to correspond to the BSE-1 and BSE-2 hazards in ASCE 41-06.

In ASCE 41-06 the BSE-2 hazard is the same as the ASCE 7-05 Maximum Considered Earthquake (MCE), which is an earthquake with a 2% probability of exceedance in 50 years (a 2,475-year return period), 150% of the mean deterministic earthquake, or some pre-determined "water-level" parameters (see Part 2 of the 2009 NEHPR for discussion on the "water-level" parameters). The BSE-1 is the lesser of an earthquake with a 10% probability of exceedance in 50 years (a 475-year return period) or 2/3 of the BSE-2 parameters.

The stipulated reduced hazard for existing state owned buildings in the 2010 CBC is an earthquake with a 5% probability of exceedance in 50 years (a 975-year return period) for the BSE 2 and for the BSE-1 is an earthquake with a 20% probability of exceedance in 50 years (a 225-year return period).

The committee chose to retain the BSE-X designation for the seismic hazards. Therefore, the 5%/50 hazard was named the BSE-2E and the 20%/50 hazard was named the BSE-1E. The suffix "E" was introduced to designate that these are reduced hazards associated with existing buildings.

Since ASCE 41-06 had a performance objective that was commensurate with what was commonly accepted for new buildings, the committee felt it important to retain the option to have performance objectives equivalent to new buildings standards. Therefore the committee chose to include a second pair of seismic hazard parameters which would be the Risk Adjusted MCE (MCE_R) and the Design Basis Earthquake (DBE) from ASCE 7-10. These hazards were named the BSE-2N and BSE-1N respectively, with the "N" suffix indicating new building standards equivalent hazards.

Table 1 shows the short period, S_{XS}, parameter for the four different hazards and Table 2 shows the long period, S_{X1}, parameter for the four different hazards. These unpublished results were produced by Nico Luco at USGS for the Committee.

Table 1 – Short Period Hazard Parameters

Region	City	BSE-2N MCER	BSE-2E 5%-50yr	BSE-2 E/N	BSE-1N 2/3 x MCER	BSE-1E 20%-50yr	BSE-1 E/N
Southern California	Los Angeles	2.40	1.76	*0.73*	1.60	0.84	*0.53*
	Northridge	1.69	1.46	*0.87*	1.13	0.81	*0.72*
	Long Beach	1.64	1.18	*0.72*	1.10	0.57	*0.52*
	Irvine	1.55	1.04	*0.67*	1.03	0.53	*0.52*
	Riverside	1.50	1.29	*0.86*	1.00	0.79	*0.79*
	San Bernardino	2.37	2.39	*1.01*	1.58	1.28	*0.81*
	San Luis Obispo	1.12	0.78	*0.70*	0.74	0.39	*0.52*
	San Diego	1.25	0.85	*0.68*	0.84	0.31	*0.37*
	Santa Barbara	2.83	2.16	*0.76*	1.89	0.87	*0.46*
	Ventura	2.38	1.73	*0.73*	1.59	0.82	*0.52*
Northern California	Oakland	1.86	2.14	*1.15*	1.24	1.19	*0.96*
	Concord	2.08	2.06	*0.99*	1.38	1.08	*0.78*
	Monterey	1.53	1.11	*0.72*	1.02	0.54	*0.53*
	Sacramento	0.67	0.45	*0.67*	0.45	0.27	*0.60*
	San Francisco	1.50	1.51	*1.00*	1.00	0.85	*0.85*
	San Mateo	1.85	1.71	*0.93*	1.23	0.85	*0.69*
	San Jose	1.50	1.58	*1.05*	1.00	0.97	*0.97*
	Santa Cruz	1.52	1.23	*0.81*	1.01	0.67	*0.67*
	Santa Rosa	2.51	2.39	*0.95*	1.67	1.02	*0.61*

Table 2 – Long Period Hazard Parameters

Region	City	BSE-2N MCER	BSE-2E 5%-50yr	BSE-2 E/N	BSE-1N 2/3 x MCER	BSE-1E 20%-50yr	BSE-1 E/N
Southern California	Los Angeles	0.84	0.61	*0.72*	0.56	0.30	*0.69*
	Northridge	0.60	0.51	*0.85*	0.40	0.29	*0.73*
	Long Beach	0.62	0.43	*0.69*	0.41	0.21	*0.70*
	Irvine	0.57	0.38	*0.66*	0.38	0.20	*0.73*
	Riverside	0.60	0.51	*0.85*	0.40	0.30	*0.75*
	San Bernardino	1.08	1.02	*0.94*	0.72	0.51	*0.70*
	San Luis Obispo	0.43	0.30	*0.71*	0.28	0.15	*0.70*
	San Diego	0.48	0.31	*0.65*	0.32	0.13	*0.67*
	Santa Barbara	0.99	0.74	*0.75*	0.66	0.31	*0.61*
	Ventura	0.90	0.64	*0.71*	0.60	0.30	*0.67*
Northern California	Oakland	0.75	0.79	*1.06*	0.50	0.43	*0.86*
	Concord	0.73	0.71	*0.97*	0.49	0.37	*0.75*
	Monterey	0.56	0.40	*0.72*	0.37	0.19	*0.68*
	Sacramento	0.29	0.20	*0.68*	0.20	0.12	*0.77*
	San Francisco	0.64	0.62	*0.97*	0.43	0.32	*0.75*
	San Mateo	0.86	0.72	*0.84*	0.57	0.32	*0.64*
	San Jose	0.60	0.55	*0.92*	0.40	0.33	*0.82*
	Santa Cruz	0.60	0.46	*0.77*	0.40	0.24	*0.69*
	Santa Rosa	1.04	0.97	*0.94*	0.69	0.40	*0.60*

As can be seen from the tables there are some locations where the ratio of new to existing demand is close to .75; showing little change. There are isolated cases where it is higher or lower. . This is a consequence primarily of the deterministic caps imposed on the ASCE 7-10 MCE_R. The committee felt that obviously the "E" hazard should never be greater than the "N" hazard, and thus the "E" hazards would be capped at the "N" hazard values. The committee did not believe that a different deterministic cap for the "E" hazards was appropriate. For regions where there is little to no difference between the BSE-2N and BSE-2E, it was believed that signified the seismic hazard to be great enough that the existing buildings should not be given the traditional break.

ASCE 41-13 Performance Objectives

The concept of marrying seismic hazard levels with structural and nonstructural performance levels to create a performance objective was retained in ASCE 41-13. Both ASCE 31-03 and ASCE 41-06 had various performance objectives set forth explicitly. ASCE 41-13 has two sets of explicitly defined performance objectives, the Basic Performance Objective for Existing Buildings (BPOE) and the Basic Performance Objective Equivalent to New Building Standards (BPON). In addition to those two sets of explicit performance objectives, ASCE 41-13 retains the Enhanced Performance Objective and Limited Performance Objective categories.

The Basic Performance Objective for Existing Buildings (BPOE) uses the BSE-1E and BSE-2E hazard levels. Unlike ASCE 41-06, the BPOE is not a single performance objective, but rather a table of different performance objectives based on the Risk Category that would be assigned to a building. The decision to map the performance objectives to Risk Categories was made because the widespread use of ASCE 31-03 and ASCE 41-06 had led to numerous building codes, various federal state and local jurisdictions, and engineers to do their own mapping of the Risk Categories to performance objectives, without consistency. The committee felt that it was important for there to be some standardization of this practice and therefore it was brought into the BPOE. Table 3 summarizes the BPOE.

This set of performance objectives are intended to be the one that approximates the performance objectives within ASCE 31-03 which accepted a higher level of risk. The BPOE is used for all three tiers of evaluations. With Tier 1 and Tier 2 only requiring evaluation at the BSE-1E level and Tier 3 requiring evaluation at both the BSE-1E and BSE-2E levels.

Table 3 – Basic Performance Objective for Existing Buildings (BPOE)

	Tier 1	Tier 2	Tier 3	
Risk Category	BSE-1E	BSE-1E	BSE-1E	BSE-2E
I & II	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Collapse Prevention Structural Performance Nonstructural Performance Not Considered (5-D)
III	See Note 1 for Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Limited Safety Structural Performance Nonstructural Performance Not Considered (4-D)
IV	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Life Safety Structural Performance Nonstructural Performance Not Considered (3-D)

The reason that Tier 1 and Tier 2 only need to have one seismic hazard check while Tier 3 requires a check of two hazard levels relates to the fundamental basis of the deficiency-based procedures. The deficiency-based procedures are based on decades of observations of actual damage to buildings in major earthquakes worldwide. The original documentation is contained in ATC 14. Because of a lack of specific strong motion records, all events were considered equal even though many were likely BSE 2 level events. It is fair to conclude that since the procedures were calibrated to a BSE 1 level event and many of the buildings actually experienced a BSE 2 level events successfully, only a one level check would be needed.

It is important to recognize that the inventory of damaged buildings used to infer the deficiency-based procedure was mostly of moderate size and height. The committee felt that a similar limitation was needed to designate when the deficiency-only procedures could be used. A number of criteria regarding the building's size, structural system, and configuration was developed which must be met in order for one to be able to use the deficiency-based provisions.

However, for a Tier 3 systematic procedure which is intended to be used universally regardless of the building configuration, size or structural system, the dual-earthquake check is necessary to ensure sufficient robustness and margin of safety beyond the design-level earthquake. This covers those buildings which are outside of the historic data.

The concept of permitting the user to perform a seismic retrofit or target an evaluation to a level greater or less than the Basic Performance Objective has been retained. The Enhanced Performance Objective remains as any level greater than the BPOE. Some example application of an Enhanced Performance Objective are retrofitting for a Risk Category higher than the building would normally be assigned, an evaluation using a higher seismic hazard than stipulated, or a retrofit to a higher structural or nonstructural performance level using the same earthquake hazards as the BPOE table calls for.

ASCE 41-13 retains the Limited Performance Objective and keeps the two specific subsets – Reduced Performance Objective and Partial Retrofit Objective. The Reduced Performance Objective is the opposite of the Enhanced Performance Objective. The evaluation or retrofit targets a performance level, uses a seismic hazard, or is for a Risk Category less than the BPOE. The Partial Retrofit Objective means that some, but not all of the seismic deficiencies are mitigated.

A new performance objective included in ASCE 41-13 is the Basic Performance Objective Equivalent to New Building Standards (BPON). This set of performance objectives is intended to provide a link between ASCE 7 and ASCE 41 when a seismic evaluation or upgrade is required to be equivalent to a new building. The performance objectives are based on the Risk Category that would be assigned to the building based on the applicable building code or ASCE 7. Table 4 presents the BPON.

Because the BPON is designed to be equivalent to a new building, only a full-building systematic evaluation or upgrade can be used. The seismic hazards used for this performance level are the BSE-1N and BSE-2N. While there have not been definitive studies done on the specific equivalence between the two standards, the committee felt that by targeting Collapse Prevention in the MCE_R, one is achieve the similar performance to what is spelled out in the commentary in the *2009 NEHRP Provisions.* Specifically, Table C11.5-1 in the 2009 *NEHRP Provisions* was used as the basis for the BPON.

Table 4 – Basic Performance Objective Equivalent to New Building Standards (BPON)

	Seismic Hazard Level	
Risk Category	**BSE-1N**	**BSE-2N**
I & II	Life Safety Structural Performance; Position Retention Nonstructural Performance (3-B)	Collapse Prevention Structural Performance; Nonstructural Performance Not Considered (5-D)
III	Damage Control Structural Performance; Position Retention Nonstructural Performance (2-B)	Limited Safety Structural Performance; Nonstructural Performance Not Considered (4-D)
IV	Immediate Occupancy Structural Performance; Operational Nonstructural Performance (1-A)	Life Safety Structural Performance; Nonstructural Performance Not Considered (3-D)

Structural Performance Levels

The three main structural performance levels, Immediate Occupancy (IO), Life Safety (LS), and Collapse Prevention (CP) have not been changed from ASCE 41-06. There are, however, two new, specifically defined, performance levels – Damage Control and Limited Safety. Those new levels were necessary to describe the target structural performance levels for Risk Category III structures in both the BPOE and BPON. Damage Control is the level halfway between IO and LS and Limited Safety is the level halfway between LS and CP.

The performance ranges between IO and LS and LS and CP, which were defined in ASCE 41-06 as Damage Control and Limited Safety, have been renamed Enhanced Safety Performance Range and Reduced Safety Performance Range in order to avoid the confusion with the newly created performance levels.

Nonstructural Performance Levels

There were significant changes to the nonstructural performance levels. There were two main reasons for the changes. The first was the recognition that many of the items identified in ASCE 31-03 and ASCE 41-06 as life safety hazard have never been documented in past earthquakes to actually be life safety hazards. The second one was the realization that the performance levels in ASCE 31-03 and ASCE 41-06 did not match those in ASCE 7.

In ASCE 41-13, there are now only three specific nonstructural performance levels – Operational, Position Retention, and Life Safety. These revised performance levels simplify the nonstructural provisions in ASCE 41-13 and make them consistent with ASCE 7.

The Operational performance level is the same as was defined in ASCE 41-06. The nonstructural components are in a state following the earthquake such that they can resume their pre-earthquake function. This performance level is consistent with what the intended performance of nonstructural components should be when I_p = 1.5 in ASCE 7 based on the *2009 NEHRP Provisions'* commentary.

The Position Retention performance level is where the nonstructural elements are damaged and may not function, but they are secured in place following the earthquake. This performance level is intended to match the intended performance of nonstructural components when I_p = 1.0 in ASCE 7 based on the *2009 NEHRP Commentary*. This means that elements that do not require bracing per ASCE 7 because of the building being in a lower seismic hazard area will now not require bracing per ASCE 41-13.

The Life Safety performance level is where nonstructural components are damaged and dislodged from their position, but the consequences of the damage do not pose a risk to life safety. Major falling hazards are still anchored. The ASCE 41-13 Life Safety level is significantly less than what was termed Life Safety in ASCE 31-03 and 41-06. To determine what was a true life safety hazard the committee relied upon FEMA-E74 (2011) and their collective experiences observing damage following major earthquakes.

Deficiency-Based Procedures

There were many updates to the deficiency-based procedures. The most significant update was the limitations on when these types of procedures could be used. In ASCE 31-03, there was a table which indicated under which height Tier 1 and deficiency-only Tier 2 Evaluation would be permitted. There was a similar table in ASCE 41-06 Chapter 10 which indicated when the simplified rehabilitation, which just corrected ASCE 31-03 identified deficiencies, could be used. That concept was retained, but most of the height limits were increased. Also, as stated earlier, the same table now applies to both evaluation and upgrade. Table 5 contains some examples of the changes for systems in regions of high seismicity.

Table 5 – Height Limits for Deficiency-Base Procedures in High Seismicity for Life Safety Performance

	ASCE 31-03	ASCE 41-06	ASCE 41-13
Steel Moment Frames	3	3	8
Steel Braced Frames	6	3	8
Concrete Moment Frames	6	Not Permitted	8
Concrete Shear Walls	6	3	8
Light Frame	2	2	4
Tilt-up	2	2	2
URM	No Limit	2	4

The increase in height limits came primarily from the additional experiences that have come from observing coming buildings in major earthquakes over the past 20 years. Prior to this update, theses tables had never really been reviewed or revised since they were originally conceived in the mid 1990's.

Another major change was when mixed systems can be evaluated and retrofit using deficiency-based procedures. A mixed system, in ASCE 41-13 context, is a system which has different lateral force resisting elements in one direction. Examples could be a tilt-up shear wall building with an interior steel braced frame or a seven-story steel moment frame over a three story concrete shear wall building. There are now explicit provisions in ASCE 41 when you can consider those types of buildings in a deficiency-based evaluation or retrofit. When the mixed system is a horizontal combination of systems, the performance level is Life Safety or lower, the diaphragm is flexible, and the building is below the more restrictive height limit of the different systems one can use the deficiency-based procedures. For vertical combinations, the performance level is Life Safety or lower, and the building is below the more restrictive height limit of the different systems one can use the deficiency-based procedures

Tier 1 Screening

There were major organizational changes to the Tier 1 Checklists. A significant editorial effort was undertaken to simply and streamline the Tier 1 Screening. The first major change was the creation of a Basic Configuration Checklist, which contains all the statements for Very Low seismicity, about building configuration regularity and the geologic and foundation components, which were common to all building types and unnecessarily repeated in each ASCE 31-03 checklist. Following that, there are checklists specific to each common building type.

All the structural checklists were reorganized so that there is one checklist for Life Safety and one separate, stand-alone checklist for Immediate Occupancy for each common building type. Also, there are no longer separate checklists for buildings with stiff or flexible diaphragms. Lastly, the checklist statements are ordered such that the items for Low Seismicity come first, followed by Moderate and finally with High. Therefore someone evaluating a building in a region of Moderate seismicity need not read through a number of statements that don't apply.

The nonstructural checklist was condensed down to one single checklist. Each checklist statement has a marker which indicates which level of seismicity and performance level (LS or IO) the statement is required to be checked for.

In addition to the editorial changes, there were a number of technical updates to the checklists. Most of the technical updates related to paring back the Life Safety checklist requirements. The committee undertook a detailed review of all the checklist statements, questioning whether each statement was really an observed life safety issue or not. This lead to a number of statements being moved from LS to IO-only or being revised to address the life safety concern in a more specific way. Additionally, the change in the definition of Nonstructural Life Safety and coordination of levels of seismicity with ASCE 7 led to a significant paring back of the nonstructural Life Safety checklist.

Recognizing that existing buildings can vary from what their drawings indicate due to construction deviations, alterations or just deterioration, the committee added more detailed direction on minimum on-site investigation and condition assessment. All the checklist statements related to condition assessment have been moved to this section. The purpose of this section is to place the responsibility on the evaluating engineer for verifying the condition of the structure and confirming the completeness and adequacy of the available drawings.

The last major change to the Tier 1 Screening was an updating of the Benchmark Building table and an expansion of the requirements for benchmarking a building. The table which indicates what the earliest code a building could be designed to which permits it to be deemed to comply with a specific performance objective was updated. Specifically, the benchmark year for concrete buildings was moved up from the 1976 UBC to the 1994 UBC due in part to observations from the 2011 Christchurch Earthquakes. There were also a series of requirements set forth that one must meet in order to benchmark a building. They relate to verifying the accuracy and completeness of the existing drawings with respect the benchmark code, minimum field verification of the existing drawings, condition assessment, and a confirmation of no geologic hazards at the site.

Tier 2 Evaluation/Retrofit

Conceptually there were no major changes to the Tier 2 procedure. The crux of the procedure is still to simply evaluate the identified potential deficiencies from the Tier 1 screening or to retrofit them. The major change, however, is in the procedures used to do that.

As discussed earlier, in an effort to bring consistency to the evaluation and retrofit procedures and for consistency between Tier 2 and Tier 3, the simplified analytical methods of ASCE 31-03 were abandoned for the more detailed procedures within ASCE 41. Recognizing that this was a significant change, the chapter which presents the Tier 2 procedures was completely re-written to provide as much guidance as possible to the specific sections of the analysis, foundation, or material chapters where the user needs to go to find the information to carry out the specific evaluation or retrofit procedure for each specific deficiency.

The material found in Chapter 4 of ASCE 31-03 which provided commentary on the Tier 1 and Tier 2 deficiencies has been retained, but moved to Appendix A.

Technical Updates

While the combination and reformatting of ASCE 31-03 and ASCE 41-06 took up a considerable amount of the committee's time, there were still a number of significant technical changes that were made to the provisions. Chapters 8 through 14 contain the bulk of the analysis procedures, material and foundation modeling parameters and acceptance criteria. The format of those chapters is essentially unchanged from ASCE 41-06. All the technical updates have been incorporated into those chapters.

The following is a brief, high-level summary of the technical changes to those chapters.

Analysis

The most significant change to the analysis chapter was the expansion of the nonlinear response history analysis provisions. There have been significant advances in this analysis method and it has found more widespread use within the profession since the provisions were originally written in FEMA 273. The new provisions seek to clarify the number of ground motion records needed, how to select and apply damping, and how to apply the output to evaluation. There was clarification made to permit the modeling of force-controlled elements in the nonlinear model and permitting them to fail and allow force redistribution provided gravity load support is not compromised.

There were also some modifications made to allow for greater use of the linear procedures. In ASCE 41-06 there were certain irregularities which prohibited the use of the linear procedures. Those irregularity triggers have been relaxed.

There was also a significant change made to the knowledge-factor, which reduces the element capacities based on a lack of testing and other information about the building. Now if the user has a good set of construction drawings and is evaluating or upgrading to Life Safety or lower performance, then the knowledge-factor can be taken as 0.9 instead of 0.75.

Geotechnical/Foundation

There were three major updates to the Geotechnical and Foundation chapter. The first was revisions to the liquefaction section and a new structural analysis procedure to assess the consequences of liquefaction. The second was a significant update of the foundation rocking procedures and yielding at the soil-foundation interface. The last was an update to the soil-structure interaction provisions.

The most significant update to the liquefaction procedures is a new three-step structural analysis procedure to assess the consequences of liquefaction. Observations from the 2010 and 2011 Christchurch Earthquakes were that numerous structures were damaged by liquefaction, but did not collapse. The new liquefaction analysis procedures allow the engineer to first evaluate the structure assuming no liquefaction occurs and then a second time with ground motions and foundation parameters that have been altered due to liquefaction. Following that analysis, the anticipated lateral spread and differential settlements are imposed on the structure and it is assessed to determine if it can remain stable under those.

There has been a significant change to how foundation rocking and yielding at the soil-foundation interface are addressed. ASCE 41-06 decoupled the two actions and had separate checks for each. In reality this never occurs. If the soil is stiff, rocking will dominate the response. If the soil is soft, then yielding of the soil will govern. However, neither will occur independent of the other. The new rocking procedures provide m-factor tables and nonlinear acceptance criteria for these actions as a function of the gravity load on the foundation and the stiffness of the underlying soil.

The soil-foundation-structure interaction (SFSI) material, which was first introduced in ASCE 41-06 and based on material from FEMA 440 (2005), was reviewed and revised. NIST funded a significant effort related to SFSI which will be published soon as ATC-84 (2012). Based on work done in that project, the kinematic effects provisions (base-slab averaging and embedment) were revised and some limitations placed on them.

Steel

The only major changes to the steel section were the introduction of provisions for buckling restrained braced frames and the modification of some of the acceptance criteria for braced frames.

Concrete

There were only minor chances to the concrete chapter related to minimum reinforcement in shear walls, biaxial column effects, rebar testing requirements and concrete core sampling requirements.

Wood & Cold-Formed Steel

The Wood and Cold-Formed Steel (CFS) Light Frame provisions had some formatting changes. Provisions for wood and CFS were separated. Additionally, the applicable reference standards where one can find capacities for wood and CFS elements were updated.

Masonry

There were some significant changes to the masonry chapter, many of which were prompted by observations from the 2010 and 2011 Christchurch Earthquakes. Bed joint sliding was reintroduced as a deformation-controlled action. The provisions and acceptance criteria for wall and pier rocking were updated. There were also updates related to diagonal tension, out-of-plane actions, and anchorage to masonry walls.

Seismic Isolation & Energy Dissipation

Both the Seismic Isolation and Energy Dissipation provisions were revised. The provisions for Seismic Isolation were revised to permit the use of upper and lower-bound isolator properties in design and then specifying tolerances as opposed to requiring testing of the isolators before design could be completed. Along with this change were changes to the quality control requirements for isolator manufacturers. There were also modifications to the design and quality control requirements for energy dissipation devices. Lastly, the peer review requirements were reduced from a panel to one independent peer reviewer.

System-Specific Procedures

One of the last changes to ASCE 41-13 was the creation of a new chapter for system-specific procedures. The impetus for this chapter was what to do about the special procedure for unreinforced masonry buildings found in ASCE 31-03. That procedure has been in use for many years and the committee wished to retain it. Because the procedure is specific to a system which has a combination of elements of different materials, it could not be easily brought into any one of the material chapters. Therefore, it was placed in a new chapter.

The intention is that as more of these system specific procedures are developed they would eventually be placed into this chapter. The requirement being that the procedure must be able to be utilized in conjunction with a seismic hazard level specified in the standard and the performance target of the procedure must be declared in terms of one of the levels in the standard.

Consistency with ASCE 7

In addition to creating the BPON, referencing the MCE_R, and aligning the nonstructural performance levels, the committee made several changes to better align ASCE 41-13 with ASCE 7. The most significant of those changes related to the seismic hazard science, the site specific response spectra, and response history scaling. Regardless of the return period chosen for the seismic hazard, ASCE 41-13 requires the same attenuation relations and other ground motion science be used as is required in ASCE 7. The seismic hazard parameters should all be “Maximum Direction.” When a site specific response spectrum is used, the scaling with respect to the USGS response spectrum will be the same as in ASCE 7.

Another very significant change to align ASCE 41-13 with ASCE 7-10 was the correlation of ASCE 41-13 Levels of Seismicity with the ASCE 7-10 Seismic Design Categories (SDC). This eliminates confusion and helps greatly in the coordination of the nonstructural performance levels. Below is the new ASCE 41 Levels of Seismicity with the corresponding ASCE 7 SDC.

Very Low	SDC A
Low	SDC B
Moderate	SDC C
High	SDC D, E, & F

There are some other modifications throughout ASCE 41 to align with ASCE 7. The out-of-plane wall anchorage force equations have been updated to correlate with the changes that were made to ASCE 7-10. There were some changes made to align the nonlinear response history provisions of the two standards.

Summary

When published, ASCE 41-13 will represent a new state of the practice in seismic evaluation and retrofit of existing buildings. The new standard combines seismic evaluation and retrofit into one document and brings consistency to the process. The new standard has incorporated many technical advances which have occurred in the past six years along with lessons learned from many recent earthquakes.

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