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Reference: **ASCE 41 Seismic Evaluations and Retrofit of Existing Buildings Research Needs**

Dear Jack:

The ASCE/SEI Standards Committee on Seismic Rehabilitation just recently completed the ballot process for the new edition of ASCE 41. That new standard, ASCE 41-13: Seismic Evaluation and Retrofit of Existing Buildings, is a combination of ASCE 31-03: Seismic Evaluation of Existing Buildings and ASCE 41-06: Seismic Rehabilitation of Existing Buildings. The new standard not only combines the two standards into one unified standard, but also contains many significant technical updates to its provisions. A paper from the 2012 SEAOC Convention detailing the major changes to the standard is attached.

There were a number of items that were identified early on as things that the committee wanted to do, but knew they could not because of a lack of available research. In addition many items came up during the update cycle which the committee realized research was lacking so the desired change could not be made without sufficient technical justification which the research would provide.

The following is a of identified items. Some of these items are also included in *Development of NIST Measurements Science R&D Roadmap: Earthquake Risk Reduction in Buildings.* Items included in the Roadmap are indicated as such and do not have detailed summaries, because summaries can be found in the Roadmap.

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Research Needs

1. *Calibration of the ASCE 41 Collapse Prevention Performance Level with ASCE 7 10% conditional probability of collapse in the MCE_R [also a NIST Roadmap Topic]*

   ASCE 7-10 first introduced a Risk Targeted Maximum Considered Earthquake (MCE). At the crux of those provisions is that the design provisions provide a 10% probability of collapse in that MCE. Therefore, the provisions of ASCE 7 provide a 90% confidence of Collapse Prevention. ASCE 41 contains a Collapse Prevention Performance Level and provides component criteria that indicate when this state is reached. In addition, ASCE 41-13 contains a Basic Performance Objective Equivalent to New Building Standards, which has meeting the Collapse Prevention Performance Level in the MCE_R being equivalent to that of a building designed to ASCE 7. Additionally, ASCE 41-13 provisions are going to be referenced in the commentary of the new nonlinear response history provisions in the 2015 NEHRP Provisions. However, there has not been any research done to determine what level of confidence those provisions provide and if they provide the same 90% confidence level / 10% probability of collapse.

   This research would being by assessing the confidence of the collapse prevention performance level at the MCE_R to determine if the standard provides the appropriate level of confidence. If it does not, then this research will ideally propose how the general procedure for determining modeling parameters and acceptance criteria in Section 7.6.3 of ASCE 41-13 (Section 2.8.3 in ASCE 41-06) should be revised to be consistent with providing only a 10% probability of collapse at that Collapse Prevention Performance Level.

2. *Global acceptance criteria for existing building evaluation and retrofit*

   All of the analytical procedures in ASCE 41 are component based, meaning that the evaluation of a building hinges on every component being within specified linear or nonlinear acceptance criteria. The issue here is that there are no global limits to check the building against. Therefore one can find themselves in a situation where one member is causing the entire building to be deemed a collapse hazard, while all the other elements throughout the building are well within their Collapse Preventions limits. Conversely, one can find themselves with a building that has excessive inter-story drifts, but have all the components be within their acceptance criteria. Therefore there needs to be some sort of global story drift assessment.

The SAC Joint Venture proposed a method to assess inter-story drifts based on the global structural system and the local elements. Further research to extend this to other structural systems or to come up with a different method for determining global drift limits would be very beneficial in improving the accuracy of the standard.

3. *Review and revision of the modeling and acceptance criteria*

Almost all of the nonlinear modeling parameters and acceptance criteria in ASCE 41 have not been updated since the mid-1990's when FEMA 273 was first published. Those modeling parameters were derived assuming based on all the available test data at that time. Over the past 15 years, there have been a considerable number of research projects which have extended the knowledge of how components behave. To date the only revisions to the modeling and acceptance criteria have occurred in isolated sections – reinforced concrete column, steel moment frame beam-column connections, and unreinforced masonry elements.

There is a great deal of consternation with users of the document that many component modeling and acceptance criteria are too conservative, such as the reinforced concrete shear wall provisions. An applied research effort where teams perform literature surveys to compile the available test data for all the different components listed in ASCE 41, determine if the modeling parameters and acceptance criteria needs to be changed, and propose revisions.

Also, when the nonlinear modeling parameters were developed, nonlinear static pushover was the common nonlinear modeling method used. Today nonlinear response history is becoming the common method. However, the nonlinear the tabulated parameters do not provide any guidance on how to model the hysteretic degradation that occurs in the element and therefore the current parameters are not suited for use in nonlinear response analysis. As part of the review of available literature and revisions to the modeling parameters, it is desirable to have the research effort also propose parameters for each component that provide engineers with directions on how to model the hysteretic degradation of the component.

This task would be carried out after or in conjunction with the first identified research task of assessing the confidence of the Collapse Prevention Performance Level in ASCE 41.

4. *Concrete shear wall modeling and acceptance criteria*

Regardless of whether the previously identified research topics get funded, there has been specific request by many practitioners that the reinforced concrete shear wall modeling and acceptance criteria be reviewed and updated. Observations from the 2010 Chile Earthquake showed many concrete shear wall buildings which were damaged more than ASCE 41 would have indicated to be safe, but where in fact Life Safe and did not collapse.

5. *Reinforced Masonry shear wall modeling and acceptance criteria*

   The standards committee identified the reinforced masonry provisions as something they would like to address in the coming editions of the standards. In particular, there are concerns about the accuracy and adequacy of the provisions when dealing with partially grouted walls. Research, mostly based on literature surveys coupled with some testing to fill gaps in the published testing, would be very helpful to the standards committee in revising these provisions.

6. *Research into how liquefaction affects structures and enhancements to the new liquefaction modeling provisions in ASCE 41-13*

   A new procedure to assess the effects of liquefaction on a structure was introduced in ASCE 41-13. The provisions require that the geotechnical engineer provide the structural engineer with ground motions parameters that have been altered due to liquefaction occurring, how the soil strength and stiffness are altered due to liquefaction and the predicted differential settlements and lateral spreading. Additional research is needed to provide geotechnical engineers with methods to evaluate those requirements.

7. *Revised equations to predict demands on nonstructural components and their anchorage*

   Several members of the committee expressed concern that the current nonstructural component force equation is too simply to be used in performance-based design and should be revised and revised. There were also a number of items related to nonstructural elements identified in the NIST Roadmap. If those specific items are addressed, those studies could then be taken and brought into the ASCE 41 Nonstructural Provisions.

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[Note: The following topics are contained with the NIST Roadmap.]

8. *Calibration of deficiency-based procedures of ASCE 31 and 41 (Tier 1, Tier 2, and simplified rehabilitation) with recent earthquake building performance*

   The Tier 1 Checklist and Tier 2 Deficiency-only evaluation procedures are rooted in experiences and observations from past earthquakes. The 2010 Chile and the 2010 and 2011 Christchurch earthquakes could provide a substantial number of case studies to assess the accuracy of these methods. Many modern buildings that experienced strong ground shaking were located near recorders and have drawings available. This study would take a subset of buildings from each of the three earthquakes and carry out ASCE 41-13 (since it will be the standard when these studies occur) Tier 1 and Tier 2 (and possibly Tier 3) evaluations of each building, and then correlate the results of the ASCE 41 evaluation with what actually occurred. This would provide real-world examples to assess the accuracy of the provisions.

9. *Study the variability of existing material properties and their impact on whole building performance to determine what matters and what does not matter; this study could lead to a refinement of the knowledge-factor provisions in ASCE 41 based on the specific action instead of one blanket factor, or a completely new approach to dealing with the variability and uncertainties of material properties in existing buildings*

   ASCE 41 currently requires a substantial amount of material testing. Many engineers have remarked that the amount of testing required is excessive, particularly on material that does not have much variability, like structural steel. When material variability has a great effect on the structural action, there should be enough testing to provide confidence in the material or a significant penalty for no testing. On the other hand, some actions are not affected as much by variations in the material strength and therefore do not require as much testing or as large a penalty when there is no testing. This study would provide guidance to revise the testing requirements and knowledge-factor penalty for no testing.

   This study may also find that there are better ways than the current knowledge factor in ASCE 41 to address material uncertainty and variability for existing buildings then using a penalty factor.

10. *Develop tools to identify and inventory existing buildings that are a collapse risk—the "killer buildings"*

    Engineers have a general sense of which types of buildings are the worst of the worst, such as nonductile concrete, tilt-up, unreinforced masonry, and wood soft-story multi-family or commercial buildings. However, there are not sufficient procedures to classify which buildings within those overarching types are the true "killer buildings," or what other buildings could be "killer buildings."

    There are currently on-going research efforts on nonductile concrete buildings and wood soft-story multi-familiar buildings, and there has been considerable research in the past on unreinforced masonry. The issues with concrete tilt-up are somewhat known. The focus of this study would be to integrate all that material and develop an overarching method to screen a building and determine if it is a substantial collapse risk that could be focused on high-seismic regions, but be adaptable to moderate seismic regions as well.

11. *Research program to provide better modeling and acceptance criteria for concrete elements—beams, columns, walls, and slabs—that do not conform with current special detailing provisions, and those that do not even conform to current ACI 318 non-seismic provisions*

    Nonductile concrete buildings are known to pose some of the greatest risks to the public in major earthquakes. However, current provisions within ASCE 41-06 are not sufficiently accurate to model these buildings. As nonlinear modeling is used more and more for assessing existing buildings, the need for better modeling criteria becomes more critical. Additionally, there is considerable disagreement among practitioners who deal with existing concrete buildings as to whether the linear acceptance criteria of ASCE 41-06 are too conservative or not conservative enough.

    The program would be based on NIST GCR 10-917-7 and take the recommendations from ATC-95 to create a multi-year research project that includes physical testing of elements and subassemblies of concrete elements commonly encountered in existing concrete buildings designed before modern special detailing was implemented. The goal of this project would be to provide guidance to engineers on the collapse indicators, the proper modeling parameters, and different acceptance criteria so that they can more accurately classify the behavior of nonductile concrete buildings.

12. Study on concrete-encased steel framing with and without masonry infill

Most steel buildings built before the 1970s contained steel frames encased in concrete. Those before the 1940s also commonly had masonry infill. These buildings have traditionally performed much better in earthquakes than analysis of them would predict. Therefore, the analysis provisions, modeling, and acceptance criteria need to be revised. This will require a study with physical testing.

13. Study on reinforced concrete frames with masonry infill

Many nonductile reinforced concrete frames with masonry infill were used in construction before 1950. The benefits or performance degradation that may come from the masonry infill is not widely understood. Modeling methods are somewhat crude, and some engineers have indicated they do not correlate well with testing.

There has been some work on this already through the NEES Network. This study would compile what has been done, assess the current research, and determine where the gaps are or what else is needed. The product would be an updated evaluation with modeling recommendations and a plan for additional research.

14. New tools for non-destructive investigation of building components.

It is not uncommon to encounter existing buildings that do not have construction documents. Additionally, construction quality control was not as stringent as it is today, leaving questions as to whether the material in the existing building is what was specified on the drawings. Currently the most common way to ascertain this, and the way dictated in ASCE 41, is to perform destructive testing. However, there is significant cost and disruption associated with destructive testing. Better nondestructive testing methods that could be shown to reliably ascertain existing material mechanical properties would be of great help.

We are grateful for the support that NIST has provided the ASCE 41 Standard and are both excited and grateful to have had this opportunity to present our research needs.

Very truly yours,

DEGENKOLB ENGINEERS

Robert Pekelnicky

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Associate Principal

CC: Chris Poland, ACEHR Chair

Enclosure

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