Seismic Retrofits Using the IEBC

Should I use 75% of IBC or ASCE 41?

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In the October 2010 Insights column (STRUCTURE®), Bruce Maison wrote an excellent article on ASCE 41-06 *Seismic Rehabilitation of Existing Buildings*, now called ASCE 41-13 *Seismic Retrofit of Existing Buildings*, and its inclusion in the *International Building Code* (IBC). A portion of Maison's article discussed a survey of Structural Engineers Association of California (SEAOC) members regarding their satisfaction with ASCE 41 and areas where the respondents felt there were opportunities for improvement. Of particular relevance to this article is that 74% of respondents wanted to see a calibration or comparison with the building code, and 64% of respondents wished there was reduced conservatism in the linear static and linear dynamic procedures and acceptability criteria. When roughly two-thirds to three-quarters of a group of structural engineers agree on the need to make changes in a standard they use as the basis of a significant part of their work, this is a clear call for action.

It is now 2016, and the author has a hunch that if the survey was conducted today, the results would be much the same. Several root questions need to be answered to address the concerns of engineers, namely:

1) Why are there two standards intended to accomplish the same result?
2) Why do retrofit designs developed using each standard often differ so much?
3) Is it appropriate to base seismic retrofit designs on the prescriptive provisions of the IBC which were written solely for the design of new buildings?
4) If there is one standard, does a "one-size fits all" approach work across all levels of seismicity?

To answer the first question, one needs to step back in time to when seismic strengthening was an emerging field. At that point, 1) the building code (let's say the UBC) was a far simpler and less prescriptive document, and 2) many practitioners and jurisdictions felt that it didn't make sense to strengthen existing buildings to the same strength level as new buildings, because existing buildings had a shorter remaining useful life. The use of 75% of the UBC seismic forces was commonly used as the required seismic demands, with the "how" part left largely up to the engineer. In those days, engineers were "engineers," much like doctors were "doctors", so this "freedom" seemed to work fairly well. Of course, some engineers designed better seismic retrofits than others, just like new buildings.

This is not to say that, at the time, the beginnings of the performance-based design revolution were not being discussed by the more elite of the profession and university researchers. However, the UBC predated ASCE 41 and its predecessor relatives (ASCE Proceedings, April 1951 Separate No. 66, ATC-14, NEHRP 178, FEMA 310/273, etc.), so it is natural that engineers, many of whom mostly design new buildings as their business, have some natural affinity for the "code." Ignoring for a moment all of the assumptions condensed and contained in a single number, the R-value, which is built upon research for new systems, these engineers were looking for a "force" to design to and move on with the work. As engineers, we think it is fair to say this.

So, to answer the first question in two or three words, "*inertia, simplicity, and familiarity*." In a perfect world, there really ought to be just one standard; why do we need two standards that get us to the same result? Seismic is different from wind in that we all agree with the USGS about seismicity, while various aspects of wind design are based on different sets of physical measurements.

The answer to the second question is a simple one, there should be *no difference*. In any world, not even a perfect world, the strengthening results shown on the construction documents for obtaining life-safety building performance should be the same regardless of the method used.

To illustrate the potential discrepancy in seismic retrofit requirements, we calculated the length of plywood shear walls necessary for a wood frame residential structure using a linear static analysis approach. We picked a location in the center of San Francisco at latitude 37.777 deg. N and -122.444 deg. W, and found that the length of the wall using the ASCE 41 provisions was *twice* that required using 75% of the IBC. Some might argue that this result is an outlier and is not representative of the situation due to unique seismicity issues and the material selected (wood), although others might counter that if the IEBC standards do not work well in the heart of earthquake country where retrofits are common, we have a problem. So we tried another location, Oklahoma City, at 35.472 deg. N and -97.517 deg. W and found a smaller, yet still significant, difference of 25%.

The third question stated another way is whether all of the "stuff" contained in the code R-value applies to the process of designing strengthening of existing buildings. The authors of ASCE 41 wrote a standard specifically for existing buildings built upon the research on existing buildings of past vintages, which do not comply with current code detailing requirements, and created an "m-factor." To be fair, the authors of ASCE 41 also knew that engineers were also looking for a "force" to design to.

The answer to the third question is "*probably not*." Determining the seismic base shear force is relatively easy, but followers of the code-approach are almost immediately faced with a daunting problem. How do they calculate the strength of the existing elements in the building, particularly when the elements do not look like replicas of modern materials that are described in the building code and related material standards?

Simply stated, the fourth question is whether large and small earthquakes impact buildings the same way or, in other words, can the effects be scaled like wind? So should the reduction "factor" also be based on the seismicity? Amongst many other factors contained in the "stuff" is the nature of the earthquake, the acceleration and velocity components and, most important of all, the duration. Except for the most brittle of materials, is the duration of shaking in areas of low seismicity long enough to damage an ordinary or intermediate concrete shear wall (of any vintage)? By that, we mean really grind it up and put it into the non-elastic range for which ASCE 41 has rightly assigned low m-factors? We think the answer is "no." There are earthquakes all of the time throughout the country in areas of low seismicity where buildings should be damaged (based on evaluation using ASCE 41 provisions), but aren't. Perhaps it is not that ASCE 41 is too conservative but that the m-factors have been developed using research data for strong earthquakes, and then applied to small ones (i.e. scaled). It seems like a little nonlinear analysis to derive the required inelastic displacement would solve this in short order. Likewise, in a near source event in a region of high seismicity, would one expect the same ordinary or intermediate concrete shear wall (detailed to past standards) to stand up to 20 seconds of really strong shaking? Again, we think not. So the answer to the fourth question is also "*probably not*."

So what is the insight here? First, retrofit designs can obviously differ greatly depending on the standard being followed. Both of the standards might yield life-safe designs, with one more conservative than the other. Alternatively, one might not be life-safe while the other is. The first possibility is unfortunate but acceptable. The second option is clearly not acceptable.

Therefore, 1) there ought to be one standard based on a performance-based approach, 2) the results need to make sense to most engineers (i.e. the strengthened building should look comparable to, but clearly weaker than, a new similar building), 3) the analysis and design techniques need to address only existing buildings, and 4) the force reduction and ductility "factors" need to be adjustable for seismicity and earthquake duration.

There are minds out there far smarter than ours that will come up with other needed improvements, but it is not asking too much to have engineers and researchers sit down and come up with one accurate standard for retrofitting existing buildings, just like there is for designing new ones.▪