Too Many Codes Spoil the Design?

Conflicts and Hidden Requirements Can Hurt You!

By Kirk A. Haverland, P.E., SECB

Structural engineering is a profession that can give an individual engineer or an entire firm a wide variety of design experience. If you and your firm work in a practice that is fairly diverse in the types of clients and industries you serve, after several years you may be very competent in designing many structures from lightweight commercial or residential buildings to heavy industrial structures and several types in between. When you have this type of experience, you realize that in large part, a structure is a structure. Whether the floor system is designed for 500 psf or 50 psf, the mechanics are the same. And you learn the differences between types of structures and the relative importance of the various parameters that affect design. You know that the multi-story hospital in a high seismic zone is going to have a significantly different design and design complexity than the single level strip mall across the street from it, but you understand these differences and you can produce well-designed structures that serve their intended purpose.

If presented with an opportunity to design a structure that is a little different, hopefully you spend some time researching the idiosyncrasies of industry practices, design requirements, different codes and standards etc. You may feel after this research that you are comfortable in taking on a project. Usually, if you have done your homework, you can be successful in producing a competent design even though you may not have experience in that specific type of structure. But not always.

As structural engineers, we have codes that we use to guide us through the process. The codes have commentaries that usually clarify various code sections. Then there are different industry standards and practices that may or may not be codified or even written. This is the ground that can get us in trouble. If you do a lot of work with reinforced concrete structures you know that there are many more ACI codes and standards in addition to ACI 318. Not all of these codes and standards are updated on a regular basis, and in some there are significant conflicts between current seismic code requirements and practices versus those that were in force when the specific code or standard was written. Logic would lead us to believe that using the most recently adapted building code would govern the design. Unfortunately, this is not always true.

Let's look at a real life example where a design was deemed inadequate due to conflicts in the owner-specified codes and standards to be used for design. These conflicts created a significant financial penalty for the design firm and the contractor that hired the design firm; so this is an example of why you need to be careful.

The project was a design-build contract for a reinforced concrete chimney at a power plant. The design-build contractor had experience in both designing and constructing this type of structure. However, the contractor's in-house staff was unable to perform the design because of their current workload, so they hired a sub-consultant they had used successfully on several other projects. The sub-consultant had staff with heavy industrial experience, including tall stack structures; the firm itself had not designed any tall concrete chimneys.

The design of the structure was not overly complex; however, the project location dictated a seismic site class of F and yielded a seismic design category of E. The design parameters appeared to be fairly straightforward. The project specifications referenced the state adaptation of the 2000 IBC, ACI 307-98 *Code Requirements for Reinforced Concrete Chimneys*, and provided technical supplements for site meteorological data, seismic data and seismic design procedures.

This is not intended as a criticism of ACI, it is simply the result of many different codes and standards, all written by different committees, where it is not always possible to obtain complete agreement on changes or updates. It is my understanding that ACI does recognize that conflicts exist and is working on updating those codes and standards that may be outdated.

–Kirk A. Haverland

The owner-specified design requirements stated that the seismic design was to be per the 2000 IBC as referenced in the state adaptation of the same, and the seismic forces were to be determined from the basic parameters in the site specific seismic data. Design forces and distribution were to be determined using a dynamic analysis and procedures listed in the "specified building code". Load combinations were to be in accordance with the "specified building code". The owner-specified design requirements went on to say that non-building structures were to be analyzed using either the equivalent lateral force method or dynamic modal analysis, but then stated that seismic design of reinforced chimneys shall use the dynamic response spectrum analysis method of ACI 307-98.

At this point, it can be seen that there is a conflict. The state building code (2000 IBC) references ACI 318-99 and ASCE 7-98 which used NEHRP-97 for seismic criteria. ACI 307-98 references ASCE 7-95 which used NEHRP-94 for seismic criteria. The question then is which seismic criteria to use?

The 2000 IBC states that the site specific response spectrum maximum considered earthquake is based upon a 2% probability of exceedance within a 50 year period. In Section 1616.6, the IBC requires a modal analysis procedure per Section 1618 using site specific response spectrum. A chimney is a non-building structure, so Section 1622.2.5 refers to Table 1622.2.5(1) which lists a response modification factor R=3 for chimneys. This section also states that the vertical distribution of forces is to be in accordance with Section 1618.5 – Modal Forces, Deflections and Drifts. One could therefore reasonably conclude that by following the state adapted version of the IBC requirements using a modal analysis and a response factor R=3, that you would be correct.

Except there is the contract document reference to ACI 307-98 *Code Requirements for Reinforced Concrete Chimneys*. ACI 307, Section 4.3 *Earthquake Loads*, states that chimneys are to be designed by means of dynamic response spectrum analysis, and that the vertical component may be ignored.

It also refers to the outdated effective peak velocity acceleration maps of ASCE 7-95. Section 4.3.2, *Dynamic Response Spectrum Analysis Method*, requires a site specific response spectrum based upon a different return period (which in this case was corrected by specification), and does not indicate a value for the response modification factor (R), does not indicate a value for the seismic importance factor I_E, and fails to give specific information on methods such as determination of base shear or distribution of vertical forces. The commentary on this section provides no additional information for the missing criteria either. In following the ACI 307-98 code, where does one look for the missing parameters? One would think that it would lead back to the owner specified design requirements and the governing building code, in this case the state adapted version of the 2000 IBC.

Logically then, you can be fairly comfortable with complying with the 2000 IBC in order to satisfy the specified requirements. In this case, the site specific response spectrum was used, a modal analysis was used, and the seismic forces per IBC Section 1622.2.5 were used. The design also complied with IBC Section 1622.2.4 regarding the seismic requirements for the material, which includes ACI 318-99. So, where is the problem?

Apparently, for those "in the know" in the tall chimney design industry, a response modification factor of R=1.33 is typically used. This information is not codified in any way, and would obviously have a significant effect on the seismic forces used in the design. A construction inspector noticed a small issue in the field, which led to someone else questioning the design, which ultimately lead to the claim that the structure was not designed properly. This, even though the design and construction complied with the governing building code. The sub-contractor and engineer were forced to pay for the cost of strengthening the chimney to meet the forces from the lower unpublished R value.

The main take away from this should be that you may need to dig deeper in doing your homework for some specialized designs that are in unique industries or, regardless of your abilities and experience, you still may get into trouble. If there are conflicts in the requirements for the project, get them resolved before starting to design; don't pick the one you think is correct and merrily go on your way. The CASE *National Practice Guidelines for Specialty Structural Engineers* emphasizes the necessity to be on the same page as the Engineer of Record. While, in this particular situation, it may have been a little more difficult to do so, at least the issue would have been raised earlier in the process and then hopefully been resolved prior to construction.

The goal of The Council of American Structural Engineers (CASE) is to promote excellence in structural engineering business practices and risk management. The tool presented in this article, *National Practice Guidelines for Specialty Structural Engineers*, was developed by CASE members who volunteer their time and expertise to advance the structural engineering profession.▪

Kirk Haverland, P.E., SECB is a Principal and Regional manager for Larson Engineering, Inc. Mr. Haverland resides in Oshkosh, WI and manages Larson Engineering's Wisconsin operations. He can be reached at ***khaverland@larsonengr.com****.*