ESG
Entertainment Structures Group
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Engineering for the Entertainment Industry

Disclaimer: This article is not intended to be a thorough treatment of the topic of structural evaluation. Local, state and national building codes should be consulted. The author cannot be responsible for any evaluation based solely upon this article.

Please note: This is a supplement to the spring issue of the ESG Report. In this expanded web supplement we're including a generic analysis report example and using different values to illustrate the same point.

For clarification, we should note that this article represents a very distilled, generalized discussion of certain code requirements that may or may not apply from location to location. It is in no way intended to be a substitution for a thorough engineering analysis. Even though we're discussing general IBC seismic design criteria, the actual requirements vary from jurisdiction to jurisdiction. You should always check with your local building code official to ensure compliance with the codes applicable to your project location. For simplicity, our design examples are highly condensed. The full breadth and scope of this topic covers subject matter contained in multiple volumes of reference documents and codes. The mathematical formulas just in the code requirements alone utilize over 100 variables, symbols and notations, covered in many pages.

CALIFORNIA'S ADOPTION OF IBC CODE

We're using California as our example for several reasons: first, it is commonly recognized as a high-seismic area. Second, it is the last state to adopt the IBC as its primary code basis, and so it is the area most impacted by these changes. Third, many of our readers who use roof truss systems in California also use E1.21 as a reference standards document. This article will help those users better understand the ramifications of the change.

UBC-based and IBC-based codes both provide similar objectives for seismic design, with one major difference. UBC codes contained all of the seismic requirements and reference tables within the code itself, whereas IBC-based codes refer to ASCE 7 *Minimum Design Loads for Buildings and Other Structures*. The UBC methodologies vary slightly from what ASCE 7 specifies, but the net result is still essentially the same. In fact, the IBC results can be better in some cases, which we'll demonstrate by generic comparison later in this article.

As noted in previous articles, all systems must be analyzed for lateral load components. This lateral load could be wind-related or seismic. A general goal of seismic design is to determine the lateral loads that must be applied to the lateral force resisting system. In ASCE 7 this is referred to as Cs – the *Seismic Coefficient* – and is the overall percentage of gravity load that must be applied as lateral load. The previous California Building Code required analysis for three different variables – C_a, C_t, and C_v – each derived from the same type of data as the Cs variable used in ASCE 7.

AN OVERVIEW OF TWO CODES – PAST & PRESENT

We'll use an example with design criteria applied using the 2001 California Building Code, and then will compare that with another result obtained using the 2007 California Building Code requirements. We'll outline the primary values needed, and their significance to the analysis.

Seismic design is dependent on site geology and soil conditions. Because seismic events involve movement of the earth, the way soil reacts to this movement is critical. According to the 2001 California Building Code (1997 UBC), the seismic design value is based on several variables: soil profile, seismic site category, zone 4 near-source factors, and profile-specific seismic coefficients.

The soil profile uses the load-bearing capacity of the soil to establish its shear capacity – its ability to resist lateral sliding forces — expressed as S_A, S_B, S_C, S_D, S_E, or S_F according to the site-specific soil conditions. This information can be easily obtained from a geotechnical engineering report, which is the most accurate way to determine correct values. If you don't have this information for the actual site, the code requires a worst-case assumption, which could critically affect the overall results.

Next, we find the seismic zone (Z), which refers us to the actual site location and to seismic zone maps. These maps are based on site geology, proximity to known faults, and statistical probability of seismic occurrences. These categories are generally classified as zone 1 (least probability) through zone 4 (highest probability). According to the 2001 California Building Code, California is primarily comprised of zones 3 and 4. The zone classification also considers the magnitude of seismic activity experienced in these areas. Because of this, when in zone 4 another variable (the *Seismic Zone 4 Near-Source Factor*) takes into consideration the distance from an actual fault statistically known to produce high magnitude activity.

Finally, we establish specific Seismic Response Coefficients (C_A and C_V), which give us the seismic force acceleration and velocity values, based on the site's soil profile type. Remember, we referred to these variables earlier, as required for C_S, used in ASCE 7.

AN EXAMPLE

Without looking at a total load per se, and certainly without addressing a complete seismic analysis, we can summarize the results of what our lateral loads would be for a temporary project located on a site in California, as follows:

- Without a geotechnical report, we must assume soil profile S_D
- Worst-case near source factors yields $C_S = 0.31$ (31% of the total gravity load applied as lateral)
- Best-case near source factors yields $C_S = 0.259$ (26% of the total gravity load applied as lateral)

These results are different than what the analysis for a permanently installed structure might yield, because different design assumptions are permissible for a temporary structure. Also note that for the web example, we selected a site where geotechnical report data would justify the assumption of a Seismic Design Category C. It's different than the site we used in the official publication, but the point is still the same.

COMPARING THE TWO CODES

When applying IBC requirements, the soil profile types are now addressed as site class definitions – they are nearly identical in nature – while seismic zones are now addressed as seismic design categories (SDC), these categories range from A through E. The IBC equivalent to UBC's soil profile D is a site class definition D – again, without a geotechnical report this is a required assumption. Using IBC, the C_S value for the same project is 0.231 (23% of the total gravity load applied as lateral). The resulting seismic mass is slightly less, and so is more favorable in this case.

You should notice that both cases required design assumptions in the absence of a geotechnical report. If your system must be analyzed for seismic design criteria, you should consider the importance of obtaining this information because it might permit the use of a lower site class definition, which could make a significant difference in the lateral force resisting system design. It might even mean the difference between an acceptable analysis and a failed analysis.

Another consideration is that the IBC Seismic Design Category dictates the extent of structural detailing requirements, which can be significant for high seismic areas because the lateral force resisting system must be fully detailed in these cases. There are very few locations in California where Seismic Design Category "D" does not apply, and that is yet another reason why system owners are being surprised. Again, our web example uses a general location in Northern California, where Seismic Design Category "C" can be used because geotechnical report information supports its use.

Furthermore, with the IBC, Seismic Design Categories "D" and higher also require design in accordance with AISC 341 *Seismic Provisions for Structural Steel Building*. This provides direction for steel structures, but what about aluminum that is commonly used for temporary structures? The Aluminum Design Manual is largely silent on these particulars, so we make assumptions similar to those for steel, but use the material properties for aluminum. Aluminum structures are also subject to the additional analysis requirements of the Aluminum Design Manual. The IBC does not address temporary structures, so the engineer is faced with some potential challenges in the overall design criteria selection.

THE TRANSITION

Irrespective of code requirements, we have a few issues at play here. One immediate concern is with California's recent transition to IBC basis, but the real issue is the amount of time it's taken to accomplish this transition. Many other parts of the country have been using IBC codes for several years, and in those areas most analysis are not questioned because they already use the IBC code requirements as a basis for design. In California, however, the adoption of IBC represents the type of change that naturally triggers scrutiny of analysis performed under the older codes. Our readers owning systems that move around from state to state (including California) are very likely to encounter rejection of permit submittals for a system that was analyzed under a previous code. In addition, there will be challenges related to obtaining geotechnical reports for a temporary system, where time factors become even more critical.

Another related issue that directly affects the entertainment industry is the E1.21 standard, and how it addresses lateral loads. It provides considerable guidance and alternatives to wind-related lateral loads because we experience wind loads in every part of the country. In fact, wind loads usually govern the design criteria for roof truss systems. However, E1.21 does not provide much guidance for seismic loads because we don't experience severe seismic conditions in many areas of the country. That's not to say E1.21 is deficient in any way; it simply provides the most usable information for the most common conditions. Practically speaking, wind is easy to monitor, and it's easy to address (both in design and in the operations management plan). Its loads can be resolved to a silent planet using bracing, ballast, or by limiting the amount of effective surface area. Seismic activity is considerably more unpredictable, and can also be more difficult to resist.

ANALYSIS EXAMPLE:

Our example covers four analysis scenarios: two IBC-based, and two UBC-based, each with and without a geotechnical report to support certain design assumptions. Having a geotechnical report for the site is at the crux of these examples. While we always start with the spectral design maps to establish base design requirements for the site, we can be more accurate with a site-specific geotechnical report. With it, we justify the use of Category C. Without it, we must assume a Seismic Design Category D. Note that this data is referenced in the two IBC examples, under the section heading *Maximum considered spectral response (ASCE 7-11.4.3).* At the end of each analysis report you see the resulting Cs value. Overall, the IBC results are better than the UBC results, but you should also see that having the geotechnical report yields better results for both codes.

CONCLUSION

So, let's recap the salient points. In comparing the two different code methodologies, the new IBC accomplishes a few helpful things for temporary structures: the loads are not much different – perhaps even less using IBC. There is more ambiguity in the IBC, and therefore more code interpretation is permitted. This is in our favor when applying ASCE 37-02. The requirement for geotechnical report information is not new, but when faced with a comparison between old and new code requirements, it can be extremely helpful in the lateral force resisting system design.

With wind, the lateral forces are all pressure related and in a sense are irrespective of gravity. Thus, you can manage the design assumptions and limit the public's exposure to potentially dangerous situations by using the mechanisms provided by an E1.21 Operations Management Plan to forecast, monitor, and reduce the area of pressure effect, which actually does decrease the lateral loads.

With seismic however, lateral loads are expressed as a percentage of gravity loads, and cannot be mitigated in the same manner.

Current trends indicate that localities are implementing permit processes where they did not previously exist and that AHJ's are requiring sealed drawings for temporary structures more than ever before. When was the last time you had to submit your system(s) for permitting purposes? When was the last time a code official rejected your drawings because they did not reflect current code requirements? There are certain realities for which no easy solution exists, and in these cases we hope to provide you with information that helps you better understand the why, if not the how.

Do you have general questions about what you've read here? Send them to us at rjn@ssastructural.com