The "WTH is this?" Comparison Between
UBC 1994 & IBC 2006 for Seismic Design

WOW! Two different but not necessary mutually exclusive Codes that may or may not be on the Lateral Forces exam. Thanks, NCARB! You know how to treat us right.

So, what the hell (WTH) is the difference? Does it matter? Should I just get roaring drunk before the test and ride the lightning? I'll try to address these.

UBC 1994

First, let's bore ourselves with UBC 1994 since the older Kaplan books go into great detail. The static lateral force procedure for determining **total lateral force or shear at base** is broken down as follows:

$$V = \frac{ZIC}{R_w} W$$

V=total lateral force of shear at the base
Z=the seismic zone factor (this is based on Table 16-1 and Table 16-2 of the UBC)
I=the importance factor (this is based on Table 16-K of the UBC)
C= a numerical coefficient

$$= \frac{1.25S}{T^{2/3}}$$

R_w=a numerical coefficient (this is based on Table 16-N of the UBC)
S=site coefficient for soil characteristics (this is based on Table 16-J of the UBC)
T=the fundamental period of vibration, in seconds, of the structure in a given direction
W=the total dead load

Of course, to make things difficult, *T* (in the numerical coefficient *C*) is made up of the following:

$$T = C_t(h_n)^{3/4}$$

C_t=0.035 for steel moment resisting frames
C_t=0.030 for reinforced concrete moment-resisting frames and eccentric braced frames
C_t=0.020 for all other buildings
h_n=height of building

The base shear formula, in simple terms, refers to the structure as a whole. Unfortunately, the **components of the structure and their attachments** have an additional but similar formula:

$$F_p = ZIC_pW_P$$

F_p = lateral force on part of structure
Z & I = seismic zone and importance factor for building (this is based on Table 16-1, Table 16-2, and Table 16-K of the UBC)
C_p = horizontal force factor based on UBC table (this based on Table 16-O of the UBC)
W_p = weight of part of the structure

Finally, we have the **distribution of base shear**.

Portion of *V*, called F_t, is considered to be at the top of building:

$$F_t = 0.07TV$$

$F_t \leq 0.25V$ and may be zero When T is 0.7 seconds or less.
F_t ="whiplash effect" and applies to long period buildings

and the application of the calculation for various levels (*x*):

$$F_x = \frac{(V - F_t)w_x h_x}{\Sigma wh}$$

where
w_x=the dead load located at or assigned to level *x*
h_x=the height in feet above the base to level *x*
Σwh=the summation of the wh quantities
for each level

Now that we have the base shear formula, the component formula, and the distribution formula and the subsets that make up the variables, the big question is, *"What is going to be on the Lateral Forces exam?"* NCARB being the "fine" organization that they are, expect the worse, but since they limit what type of calculators we can use, we can figure a pretty good guess (if you get a UBC heavy test).

1) Know the base shear formula and what the variables refer to. You might be given part of the formula and a snippet from a table and asked to figure a portion.
2) Once you know the base shear formula, the variables for the others are similar and pretty easy to reason. Again, you may have a non-mathematical question that makes reference to one of the variables.
3) If you get a UBC test, expect to see some reference to the distribution formula. Since figuring distribution on stories with unequal loads (w_x)would be tedious process, it's unlikely you'll be asked something in that detail. Most likely, any problem will assume the loads are equal, so the key is to remember the upside-down triangle against the side opposite the side receiving force (F_t) with a point at the base and the hypotenuse diagonal away from the base (yeah, I know--I even confused myself writing this).
4) Some "rules-of-thumb" or assumptions you can make:
    a. The value of *Z* runs from 0.075-0.40, with Zone 4 (the shake-rattle-and-roll) zone being the max value.
    b. *I* is either 1.0 or 1.25. Emergency services get priority.
    c. In the breakdown of *C*, you have *S* (for site). This is only 1.0, 1.2, 1.5, or 2.0. If you have no clue what the site is made of, assume a 1.5.
    d. The maximum value of *C* is 2.75. Don't know the site or building period? Use this. The minimum value of the C/R_w ratio is generally 0.075.
    e. You'll need to know the difference between flexible and rigid diaphragms, but you need a UBC table to pinpoint the allowable shear based on the construction materials of the diaphragm. In simple terms, consider the following examples taken from Kaplan:

        If flexible on 3 walls, then distribution of load 1/4 for end, 1/2 for middle, and 1/4 for other end.

        Rigid is based on rigidity and forces are distributed proportionately. If you have 3 walls and the outside walls are 2 (in rigidity) and the middle is 1, then add them and distribute proportionately: outside walls would be 2/5 and middle would be 1/5.

2006 IBC (Chapter 16)

Ugh. This is a beast. The people who write Codes are probably into bondage and sado-masochism (not that that is a bad thing...err...or I know anything about that stuff). What complicates the IBC is constant reference to portions of ASCE 7 (with exceptions to make things interesting). Most of Chapter 16 is more relevant for General Structures since load bearing is the meat of this document, but seismic and wind (by necessity) are included.

One important item (from an GS and LF standpoint) related to load bearing in the IBC is *Table 1607.1 (Minimum Uniform Distributed Live Loads and Minimum Concentrated Live loads)*. If you've ever designed a building and used the IBC, you've probably seen this table and probably memorized the more common ones. Generally, the Uniform (psf) in the table is used frequently to get a rough estimate based on the square foot of the area designed, like offices at 50 psf. While memorizing this table isn't necessary, it probably is a good idea to be aware of it.

But we are dealing with seismic here, so we'll focus on that. The first thing that grabs your attention is *Section 1603.1.5-Earthquake Design Data*, which is required on the construction documents. This section mentions some key variables:

1) Seismic importance factor, I, and occupancy category.
2) Mapped spectral response accelerations, S_S and S_1.
3) Site class.
4) Spectral response coefficients, S_{DS} and S_{D1}.
5) Seismic design category.
6) Basic seismic-force-resisting system(s).
7) Design base shear.
8) Seismic response coefficient(s), C_S.
9) Response modification factor(s), R.
10) Analysis procedure used.

Just lovely--more variables and not only more, but different from the UBC. On a positive note, many of these variables are table-driven, so more than likely, you'll get a snippet of a table if you have to solve a formula. As an example, occupancy category is I, II, III, or IV and found in *Table 1604.5--Occupancy Category of Buildings and Other Structures.*

Important note: If there is anything to absolutely understand and know in the aforementioned list, learn what these mean, their implications, and their use:

1) Mapped spectral response accelerations, S_S and S_1.
2) Spectral response coefficients, S_{DS} and S_{D1}.
3) Site class.

Now for the fun: *Section 1613--Earthquake Loads*

Codes being the ultimate CYA (cover your ass), even the IBC applies some CYA with the first section. The IBC states, *"...designed and constructed to resist the effects of earthquake motions in accordance with ASCE 7, excluding Chapter 14 and Appendix 11A."* Ahh...that was informative, particularly if you don't have the 422 pages (ACSE 7-05) of gibberish gathering dust somewhere. The IBC quickly picks up steam, though.

Remember those variables I mentioned (look up!)? Here they are defined. *Section 1613.5.1* and *Section 1613.5.2* explains what these variables mean for determining "seismic ground motion values." If you don't read anything else in Chapter 16, **absolutely read** those two subsections of

Section 1613.5--Seismic Ground Motion Values. Not only are the variables defined, but the IBC gives minimum values.

Now for a key phrase to learn: **earthquake spectral response acceleration**.

Immediately following the values section, the IBC introduces us to a very different way of determining seismic considerations than the UBC. With Section 1613.5.3, you get to meet some nifty new formulas:

$$S_{MS} = F_a S_s$$
$$S_{M1} = F_v S_1$$

where:

F_a = Site coefficient defined in Table 1613.5.3(1)
F_v = Site coefficient defined in Table 1613.5.3(2)
S_S = The mapped spectral accelerations for short periods as determined in Section 1613.5.1--a contour map
S_1 = The mapped spectral accelerations for a 1-second period as determined in Section 1613.5.1--a contour map

Uh-oh! We definitely aren't in UBC-land anymore. The IBC changes things up quite a bit and here is what you must know about the IBC:

1) The contour maps are based on two different situations:
    0.2 second spectral response acceleration (5% of critical damping), Site Class B
    1.0 second spectral response acceleration (5% of critical damping), Site Class B
2) You have **short periods and 1-second periods**. When you see the subscript "*s*", think "shorty," and when you see the subscript "*1*", well...you know.

The tables mentioned for the site coefficient are pretty straightforward, and as long as a portion of a table is included, those formulas are "plug-and-play."

Unfortunately, we aren't done. WTH does S_{MS} and S_{M1} mean and why do you want those numbers? Remember the S_{DS} and S_{D1} required on the construction documents? Those coefficients are determined in *Section 1613.5.4--Design Spectral Response Acceleration Parameters* in the following manner:

$$S_{DS} = \frac{2}{3} S_{MS}$$
$$S_{D1} = \frac{2}{3} S_{M1}$$

where:

S_{MS} = **The maximum considered earthquake spectral response accelerations** for short period as determined in Section 1613.5.3
S_{M1} = The **maximum considered earthquake spectral response accelerations** for 1-second period as determined in Section 1613.5.3

About now, you're probably wanting to either get roaring drunk or Google the exact number of knots you need in a noose, but not all is lost. Notice something about these variables in the subscripts? Of course!

->Little "*m*" = MAXIMUM
->Little "*d*" = DESIGN
->Little "*s*" = SHORT
->Little "*1*" = well....you know

You could probably make a little mnemonic to remember them. When I run them together, it makes me think of the username of some loser cyber-stud on a dating site (not that I know...to much about those).

Sadly, the IBC sneaks up and tries to do naughty things to use when we aren't looking. If your site is not classified A or B, things can get ugly, but thankfully, the odds of you seeing one the formulas from *Section 1613.5.5--Site Classification for Site Design* are slim. Here's an example just for masochistic fun:

$$\bar{v}_s = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{v_{si}}}$$

This is a beaut. The formula applies to the upper 100 feet of the site profile, and from that we have the meaning of some of the variables:

n & 1 (i=1) represent the subdivision of layers of different soil and rock that range from *1 to n* at the bottom where *n* is a distinct number of layers in the upper 100 feet. The symbol *i* refers to any one of the layers between *1* and *n*. Also:

v_{si} = The shear wave velocity in feet per second (m/s)
d_i = The thickness of any layer between 0 and 100 feet (30 480 mm)

Following this formula are ones to determine the other variables in Table 1613.5.5 that determine Site Class C, D, or E. I'll leave those to the engineers.

It's very unlikely you'll see the site classification for seismic design formulas on the test. Ideally, read *Section 1613.5.5* and focus on the end of section that makes general determinations based on commonality and stereotypical usage.

Those two sections are good for a basic understanding of how the IBC goes through to classify a site. In fact, *Section 1613.5.5.1--Steps for Classifying a Site* does just that--it walks you through a series of "if-thens." *Section 1613.5.6--Determination of Seismic Design Categories* provides a cohesive list of "if-thens" based on **occupancy and short and 1-second period response acceleration**. Two tables are provided, so it's back to "plug-and-play."

The remainder of the text portions of Chapter 16 is ASCE heavy and while brief, approaches the following:

1) Alternative seismic design
2) Simplified design procedures
3) Alternatives to ASCE 7
4) Assumption of flexible design
5) Additional seismic-force resisting systems for seismically isolated structures

I would **recommend reading** this, but the constant references to ASCE 7 will leave blank spots unless you have a copy of the document.

Whew! I think that's enough for now. I can tell because this strange gray matter is running from my ears. Unfortunately, I can't provide any definitive information regarding how much content from the IBC will be on the test. My first test was UBC with 50% emphasis on wind lateral forces--my second was...I have no idea, other than NOTHING I studied for the 2nd retake was on the test. It was so vague, it took 30 minutes for me to realize that, "Yes, I guess this is a test on lateral forces.

Hopefully, I be able to create a table after I finish the wind portion that attempts to associate some commonality with the Codes for seismic and wind.

Oh, lest we forget the third question from the beginning. I do recommend getting roaring drunk or stacking up on your Valiums.

IW