Shake, Rattle & Roll with
ASCE 7-The Seismic Chapters

As seen through the breakdown of **IBC 2006 Section 1613-Earthquake Loads**, we found that favorite friend of the IBC 2006, "*designed in accordance with ASCE 7*" show up over and over. The information they referenced couldn't be that bad, right? Unfortunately, once you find the truth, you'll pray a fault opens below you and ends your suffering. It is bad. Very bad.

The secrets behind seismic loads and "*designed in accordance with ASCE 7*" are not relegated to one simple chapter. No, sir. Here's what you'll find:

1) Chapter 11-Seismic Design Criteria
2) Chapter 12-Seismic Design Requirements for Building Structures
3) Chapter 13-Seismic Design Requirements for Nonstructural Components
4) Chapter 14-Material Specific Seismic Design and Detailing Requirements (thankfully, this is excluded from IBC 2006--see **IBC 2006 Section 1613.1-Scope**)
5) Chapter 15-Seismic Design Requirements for Non-building Structures
6) Chapter 16-Seismic Response History Procedures
7) Chapter 17-Seismic Design Requirements for Seismically Isolated Structures
8) Chapter 18-Seismic Design Requirements for Structures with Damping Systems
9) Chapter 19-Soil Structure Interaction for Seismic Design
10) Chapter 20-Site Classification Procedure for Seismic Design
11) Chapter 21-Site-specific Ground Motion Procedures for Seismic Design
12) Chapter 22-Seismic Ground Motion and Long-Period Transition Maps
13) Appendix 11A-Quality Assurance Provisions (this is also excluded from IBC 2006)
14) Appendix 11B-Exisiting Building Provisions

Had enough yet? I'll pause while you go vomit....back already? Doesn't this look just dandy? Before you panic, all this isn't required reading for the Lateral Forces Exam. In fact, I'd hazard a guess that only a structural engineer specifically trained in seismic design would ever look at all this material (they get to use books and graphing calculators, after all).

So where do we begin? How do we make sense? All hope isn't lost.

Chapter 11-Seismic Design Criteria

This is where things start, and you'll quickly recognize some of the variables and coefficients in the 2 1/2 pages (two-columns per page) of notation. There are many and the ASCE emphasizes that the notation presented only applies to seismic design. Since the scope of the information is vast, I'm going to diverge from normal presentation and just very briefly list various tables, a few formulas and their corresponding variables and coefficients.

Section 11.4.2-Site Class

This is determined from a Table in Chapter 20 by way of a series of calculations, but the most relevant information is the Site Class and definition:

Site Class	Definition	Site Class	Definition
A	Hard Rock	B	Rock
C	Very dense soil & soft rock	D	Still soil
E	Soft clay soil	F	Soils requiring site response analysis

Section 11.4.3-Site Coefficients and Adjusted Maximum Considered Earthquake (MCE) Spectral Response Acceleration Parameters

Here is an acronym that you see often in reading on seismic design: **MCE**. This means "*maximum considered earthquake*" and is used in conjunction with "*maximum considered earthquake (MCE) spectral response acceleration.*" Quite a mouthful. *Section 11.4.3* brings out the spectral response coefficients in formulas and some tables, which I'm going to reproduce just for context, but are certainly not required to memorize. Also, this section ties in exclusively with the following *Section 11.4.4*. If there is anything information to keep in mind for the Lateral Forces exam as it relates to these sections, **remember the following**:

1) " S" = spectral response acceleration
2) "Subscript S" = short periods (0.2 seconds)
3) "Subscript 1" = 1-second periods
4) "Subscript M" = maximum
5) "Subscript D" = design

The ASCE throws a few curveballs later, and you have to refer to the notation chart to understand their use of the subscript in the context the section its being used. Rest assured though, if you are at a cocktail party and you see a geeked-out engineer scribble "$S_{DS} = 0.25$" on a napkin, you can wow your friends by saying, "*He's working on the* *design earthquake spectral response acceleration parameters at short periods. It's a seismic design category B or C based on the occupancy.*" Head immediately toward the alcohol afterwards.

The following are the formulas, tables, and definitions found in *Section 11.4.3* and *Section 11.4.4*. Ignore at your leisure.

$$S_{MS} = F_a S_s$$

$$S_{M1} = F_v S_1$$

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

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

S_S= the mapped MCE spectral response acceleration at short periods (based on the maps)
S_1= the mapped MCE spectral response acceleration at 1-second period (based on the maps)
S_{MS}= MCE spectral response acceleration at short periods, adjusted for Site Class effects
S_{M1}= MCE spectral response acceleration at 1-second period, adjusted for Site Class effects
S_{DS}= the design earthquake spectral response acceleration parameters at short periods
S_{D1}= the design earthquake spectral response acceleration parameters at 1-second period
F_a= short period site coefficient based on Table 11.4.1
F_v= 1-second period site coefficient based on Table 11.4.2

An important note about the maps: when you see the contours or selected points, they are a % of *g, acceleration due to gravity*. You don't want to just grab a number and use it as your S_s or S_1.

The coefficient *F* can be tricky. *F* normally means "force" of some type at some point, but you have to make sure to check your subscript.

Table 11.4.1 Site Coefficient, F_a

Site Class	Mapped MCE Spectral Response Acceleration Parameter at Short Period				
	$S_s \leq 0.25$	$S_s = 0.5$	$S_s = 0.75$	$S_s = 1.0$	$S_s \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	Call your engineer				

Table 11.4.1 Site Coefficient, F_v

Site Class	Mapped MCE Spectral Response Acceleration Parameter at 1-second Period				
	$S_1 \leq 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 \geq 0.5$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	Call your engineer				

(I've highlighted the baseline values)

Section 11.4.5-Design Response Spectrum

This section is mostly for instances when standard and site-specific procedures can't be used, and several formulas are involved as well as graphing. In this section, only two variables are relevant for our use:

S_a= spectral response acceleration (g)
T= fundamental period of the structure in seconds

Interesting note: If you are bored, masochistic or have already counted the socks in your sock drawer, the USGS has a pretty nifty piece of software that figures all the values in *Section 11.4* and draws the design response spectrum graph by merely typing in a zip code. You can even choose what Code standard you are using. It's actually kind of fun to play with (can you use the word "fun" when talking about seismic design?). A lot of the design babble starts to make sense once you mess with this software. You can download it here:

http://earthquake.usgs.gov/research/hazmaps/design/

Section 11.5.1-Importance Factor

Anytime you see reference to *importance factor* in Codes, you see the variable, *I*. Also, importance is almost always a value based on occupancy type (the common IBC table). Importance is very simple to remember since there are only three values:

Occupancy I or II = 1.0
Occupancy III = 1.25
Occupancy IV = 1.5

Section 11.6-Seismic Design Category

This section, while short, contains several conditionals and the "if-then" language gets convoluted quickly, but fortunately, the section is chart-driven. Here is the most important thing to remember about this section: **the seismic design category chosen will be used in many charts for defining the constraints of the structure and its components**.

I'm going to reproduce the charts and include my own as Step 1, which illustrates an oddball conditional.

Step 1 (based on 1-second period)

Value of S_1	Occupancy Category	
	I, II, or III	IV
$S_1 \geq 0.75$	E	F

otherwise, use one of the following tables (these are the primary categories):

Table 11.6.1-1--Seismic Design Category Based on Short Period Response Acceleration Parameter

Value of S_{DS}	Occupancy Category		
	I or II	III	IV
$S_{DS} < 0.167$	A	A	A
$0.167 \leq S_{DS} < 0.33$	B	B	C
$0.33 \leq S_{DS} < 0.50$	C	C	D
$0.50 \leq S_{DS}$	D	D	D

Table 11.6.1-1--Seismic Design Category Based on1-secondPeriod Response Acceleration Parameter

Value of S_{D1}	Occupancy Category		
	I or II	III	IV
$S_{D1} < 0.067$	A	A	A
$0.067 \leq S_{D1} < 0.133$	B	B	C
$0.133 \leq S_{D1} < 0.20$	C	C	D
$0.20 \leq S_{D1}$	D	D	D

Chapter 12-Seismic Design Criteria

No, we aren't going here in detail, or the other chapters for that matter. This chapter is where everything comes together, but it is vast and complex. As an analogy, imagine the Kaplan material for the Lateral Forces test being a sheet of ice covering a cesspool. Chapter 12 is the waist-deep sludge you sink into when the ice breaks, and the following chapters have you in over your head (literally and figuratively). There a few things to make note of in Chapter 12, though, mainly to see the comparison to the old UBC--several items are easily recognizable

First, Chapter 12 is immediately table-driven by way of *Table 12.2-1--Design Coefficients and Factors for Seismic Force-Resisting Systems*. Remember how we went through the maze in Chapter 11 to get the Seismic Design Category? Well, here is where you use it. In very simplified steps, you basically do the following:

1) Pick your Seismic force-resisting system
2) Check your limitations and permissibility based on the Seismic Design Category
3) Record the response modification coefficient, system over-strength factor and deflection amplification factor
4) Head over to *Section 12.8-Equivalent Lateral Force Procedure*

Let me step back and mention something from the table. A common question is "*What is this mysterious "R" value?*" The answer is found in Chapter 12 and Table 12.1.1:

> R= the Response Modification Coefficient which is a numerical value based on the type of seismic force-resisting system used.

That's really all you need to know about *R* since the exact value must be derived from a table and varies considerably.

Section 12.8.1-Seismic Base Shear

Good old base shear. Here it is. For the sake of comparison, here are the old formulas from the 1994 UBC (I'm not going to rehash the meaning of the coefficients):

1994 UBC formula for determining base shear

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

with C = a numerical coefficient

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

and T is approximated by the following formula:

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

The ASCE 7-05 version, which is also the IBC 2006 version, comes in two flavors: **<u>equivalent and simplified</u>**:

ASCE 7-05/IBC 2006 <u>Equivalent</u> formula for determining base shear

$$V = C_s W$$

where:

C_S= is the seismic response coefficient
W= is the effective seismic weight

with C_s determined by the formula:

$$C_s = \frac{S_{DS}}{\left(\frac{R}{I}\right)}$$

where:

S_{DS}= the design earthquake spectral response acceleration parameters at short periods
R= the response modification factor
I= the occupancy importance factor

A couple additional formulas for C_s follow, but they mainly provide and upper and lower limits, and the ASCE notes that C_s shall not be less than $C_s = 0.01$. The most important item to recognize is the interjection of T in those formulas I've not shown, and it means:

T= the fundamental period of the structure(s) determined in *Section 12.8-2*

Just like determining T in the 1994 UBC, determining T in ASCE 7 requires access to a table, with the exception that the ASCE requires an additional formula that references another table to provide a range for the upper limit and approximate fundamental period.

If certain criteria are met (mainly height), the simplified version can be used, which is very similar to the 1994 UBC:

ASCE 7-05/IBC 2006 <u>Simplified</u> formula for determining base shear

$$V = \frac{FS_{DS}}{R}W$$

where:

$$S_{DS} = \frac{2}{3}F_a S_s$$

F= 1.0 for one-story buildings, 1.1 for 2 story buildings, and 1.2 for three-story buildings
R= the response modification factor
W= effective seismic weight of structure that shall include the total dead and other loads (a short list follows)
F_a= the design earthquake spectral response acceleration parameters at short periods
S_S= the mapped MCE spectral response acceleration at short periods (based on the maps)

And, that is it folks for the underpinnings of **ASCE 7-The Seismic Chapters**. I think I hear the school-bell ringing, so class must be over. Obviously, what we have discussed is no more than that frosty film on your windshield in the morning when compared to the "biblical" scope of all the ASCE 7 seismic chapters. That is fine with me: ***Vēnī, vīdī, vīcī*** (I came; I saw; I conquered...or at least made a fine mess of things).

How much of this will you see on the Lateral Forces Exam? Probably nothing or maybe a few coefficients, but at least you have the "secret" knowledge behind those mysterious words in the IBC 2006: "designed in accordance with ASCE 7).

Please warn me in advance if my text causes you to find yourself sitting in a dark closet, rocking back and forth, mumbling "Die, IW.Die IW.....I think I can catch the next flight to Belize.

IW-the blue-haired freak