Seismic Codes & Standards Past, Present, Future

Philip Caldwell
Codes & Standards

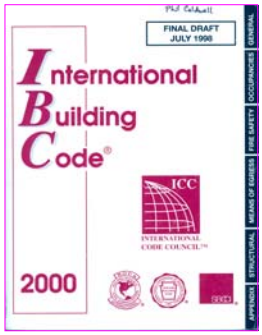
SEISMIC

Schneider Electric

2000 IBC

Seismic Shift

2000 IBC – New National Model Building Code

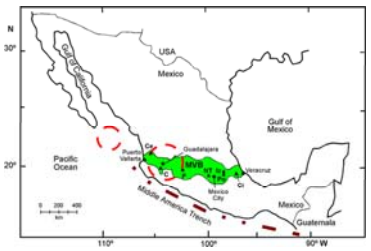


Drivers of Shift

Role of Site Effects

Modern Instrumentation – New Understanding

- Propagation
  - Wave Guides



Bulletin of the Seismological Society of America, Vol. 93, No. 3, pp. 973–985, June 2003

Modern Instrumentation – New Understanding

- Propagation
  - Wave Guides

Regional Path Effects on Seismic Wave Propagation in Central Mexico

After correlating our results with recent geological and gravimetric studies, we suggest that this **amplification** could be **due to the impedance contrast** of low-velocity volcanic rocks of the TVB overlying higher velocity limestones. If we are right, the increase of groundmotion duration would result from **mode conversion** at the southern boundary of the TVB. These path effects in the **2- to 6-sec period band** are very important for ground motion in Mexico City because the very **soft surficial deposits** in that basin **amplify greatly ground motion in this same period band**.

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Paradigm Shift Causes - Site Effects Mexico City

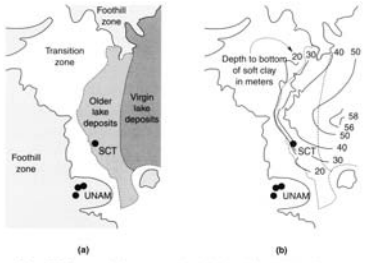
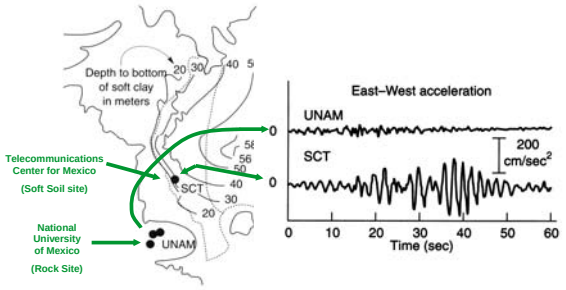


Figure 8.5 Strong-motion instruments and geotechnical conditions in Mexico City: (a) locations of strong motion instruments relative to Foothill, Transition, and Lake Zones; (b) contours of soft soil thickness. (After Stone et al., 1987.)

Kramer, S.L. (1996). Geotechnical Earthquake Engineering, Prentice Hall, Inc., Upper Saddle River, New Jersey

Paradigm Shift Causes - Site Effects Mexico City



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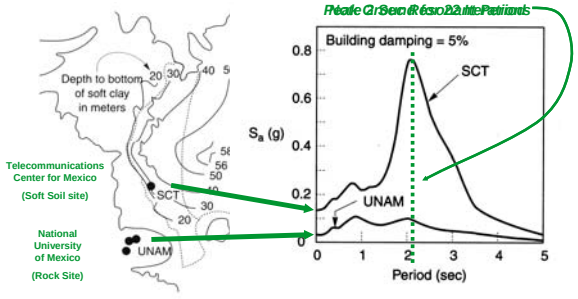
Paradigm Shift Causes - Site Effects Mexico City



Kramer, S.L. (1996). Geotechnical Earthquake Engineering, Prentice Hall, Inc., Upper Saddle River, New Jersey

Paradigm Shift Causes - Site Effects

- 1985 - Mexico City
  - Site Effects – Double Resonance

- No damage for large parts of city
- Damage to buildings 5 stories or more than 30 was slight
- Buildings in 5 to 20 story range were extensively damaged - "double resonance"

Collapsed Hospital

Photo by: Mehmet Celebi, USGS Menlo Park

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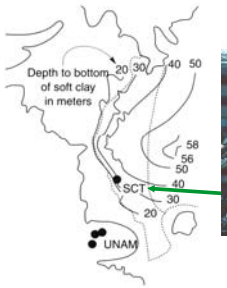
Paradigm Shift Causes - Site Effects Mexico City



Telecommunications Building

All communication circuits entering or leaving Mexico controlled from this facility

Kramer, S.L. (1996). Geotechnical Earthquake Engineering, Prentice Hall, Inc., Upper Saddle River, New Jersey

Photo by: Mehmet Celebi, USGS Menlo Park

Paradigm Shift Causes - Site Effects Loma Prieta

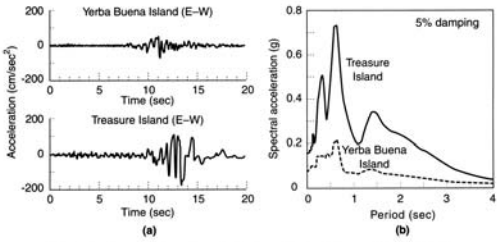


Figure 8.9 Ground surface motions at Yerba Buena Island and Treasure Island in the 1989 Loma Prieta earthquake: (a) time histories; (b) response spectra. (After Seed et al., 1990.)

Kramer, S.L. (1996). Geotechnical Earthquake Engineering, Prentice Hall, Inc., Upper Saddle River, New Jersey

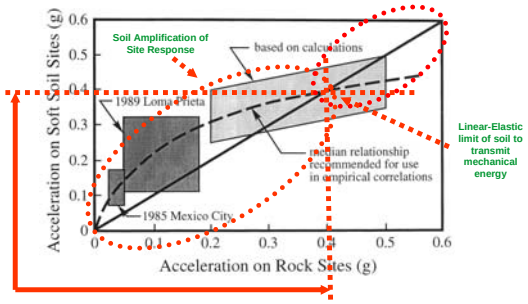
Paradigm Shift - 1994 NEHRP New Site Classes

Table 2. Summary of site categories in new seismic codes (from 1994 and 1997 *NEHRP Provisions* and *1997 UBC*), including approximate correspondence with old site categories S1 to S4

Site Class or Soil Profile Type	Description	Shear Wave Velocity $\bar{V}_s$ Top 30m (m/sec)	Standard Pen. Resistance $\bar{N}$ or $\bar{N}_{ch}$ (blows/ft)	Undrained Shear Strength $\bar{S}_u$ (kPa)
S1 A	Hard Rock	> 1500	—	—
S1 B	Rock	760 - 1500	—	—
S1 and S2 C	Very dense soil/soft rock	360 - 760	> 50	> 100
S1 and S2 D	Stiff soil	180 - 360	15 - 50	50 - 100
S3 and S4 E	Soft soil	< 180	< 15	< 50
S3 and S4 F	Special soils requiring site-specific evaluation	—	—	—

Kramer, S.L. (1996). Geotechnical Earthquake Engineering, Prentice Hall, Inc., Upper Saddle River, New Jersey

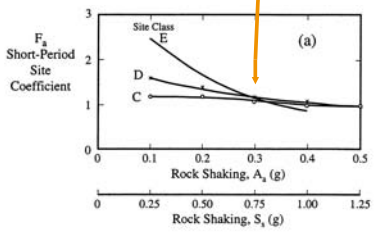
Paradigm Shift - Site Effects Lessons Learned



Kramer, S.L. (1996). Geotechnical Earthquake Engineering, Prentice Hall, Inc., Upper Saddle River, New Jersey

Paradigm Shift - Short Period Sec Site Effect

Soil nonlinearly reduces Fa coefficient at intense levels of shaking



Kramer, S.L. (1996). Geotechnical Earthquake Engineering, Prentice Hall, Inc., Upper Saddle River, New Jersey

Paradigm Shift Causes - Soil Amplification

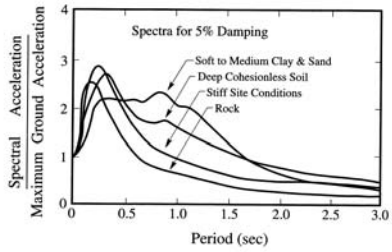


Figure 8. Average acceleration spectra for different site conditions (Seed et al. 1976a,b).

Kramer, S.L. (1996). Geotechnical Earthquake Engineering, Prentice Hall, Inc., Upper Saddle River, New Jersey

1994 NEHRP – New Site Specific Basis for Codes

- F_a , F_v Two Factor Approach
  - Fa - Short Period (0.2 sec) Coefficient Adjustment
  - Fv - Long Period (1.0 sec) Coefficient Adjustment

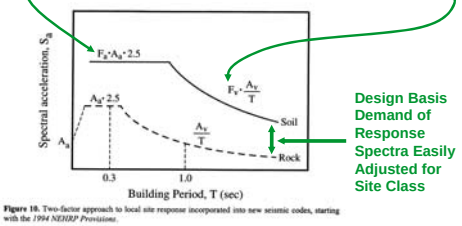


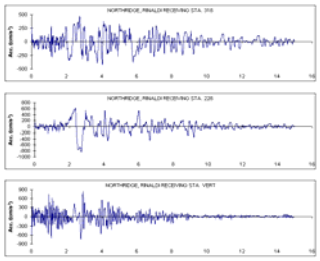
Figure 10. Two-factor approach to local site response incorporated into new seismic codes, starting with the *1994 NEHRP Provisions*.

Kramer, S.L. (1996). Geotechnical Earthquake Engineering, Prentice Hall, Inc., Upper Saddle River, New Jersey

Design Basis Demand of Response Spectra Easily Adjusted for Site Class

Seismic Hazard Different for Each Location

- Northridge – Shaking Different for Each Building Location



Strong Motion Time History's - Northridge

Trinet

Near Source – Introduced In 1997 UBC

- 1994 Northridge
  - Near Field

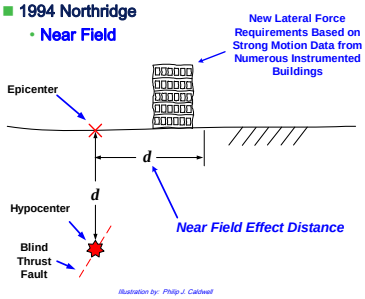


Illustration by: Philip J. Caldwell

Directivity – Cause Still Area of Active Research

- Near Field Effect

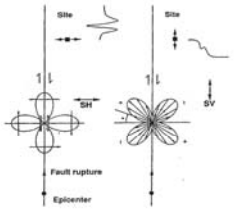
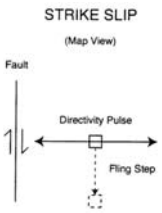


FIG. 1. Schematic diagram of directivity effects for a vertical strike-slip fault. (Somerville and Graves 1993).

Directivity – Lessons Learned

- Kobe, Japan
  - Velocity Pulse



Directivity – Lessons Learn

- Northridge
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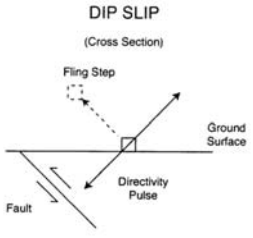


Photo by: USGS

Directivity – Lessons Learned

- Velocity Pulse

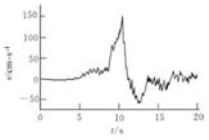


Figure 1 Ground velocity pulse recorded at Lucerne station

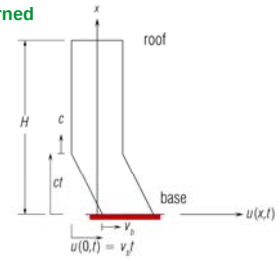
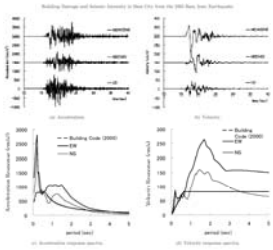


Fig. 2 Wave caused by a sudden movement at the base of a shear building, for constant velocity pulse with amplitude v_0 and for time $t < t_0$ (= pulse duration).

Directivity – Lessons Lea

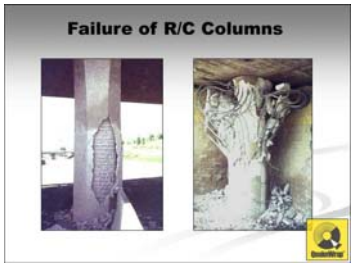
- Velocity Pulse
  - Bam, Iran



(b) Close-up of the column-beam connection.

Directivity – Lessons Learned

- Velocity Pulse
  - Lateral Force



Directivity – Lessons Learned

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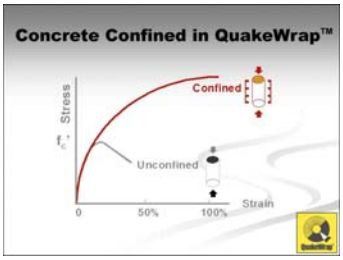


Directivity – Lessons Learned

- Velocity Pulse
  - Lateral Force

Directivity – Lessons Lear

- New SFO Bay Bridge

Photos by: Philip J Caldwell

Directivity – Lessons Learn

- New SFO Bay Bridge

Photos by: Philip J Caldwell

Lessons Learned

Instrumented Buildings

Dynamics of Building Structure – Increase Demand

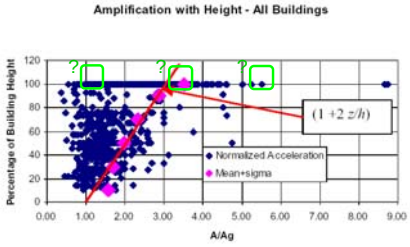
- Shaking at roof top can be three times that of grade level

1994 Northridge Earthquake - Instrumented Building
LA County Olive View - UCLA Medical Center
Sylmar, California

USGS - Northridge Report

Dynamics of Building Structure – Increase Demand

- Shaking at roof top can be three times that of grade level

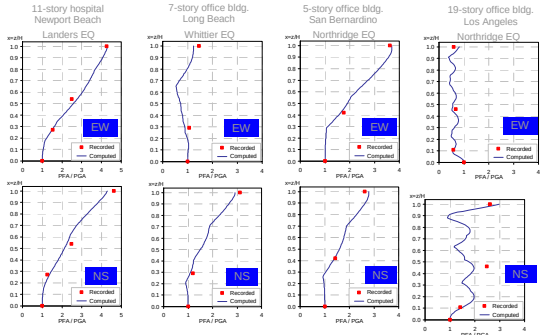


Gillengerten and Bachman, 2003

Dynamics of Building Structure – Instrumented Bldgs

Miranda, 2007

Dynamics of Building Structure – Instrumented Bldgs



Miranda, 2007

Jury Returns Verdict

Change Begins

Earthquakes That Shook the Codes

- 1985 Mexico City, Mexico
- 1989 Loma Prieta, California
- 1994 Northridge, California
- 1995 Kobe, Japan

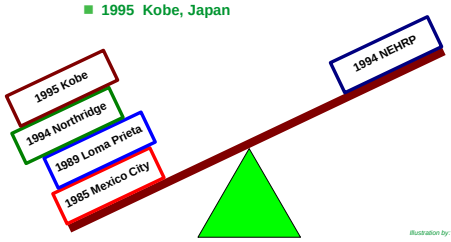


Illustration by: Philip J. Caldwell

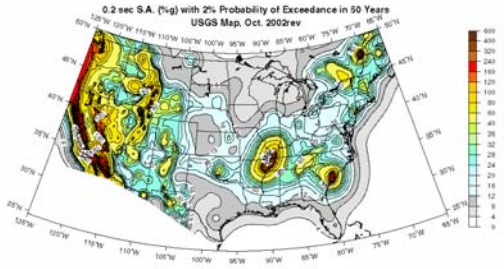
"Rocket Science"

Seismic Maps

Just U.S. – Right??

PSHA Based USGS Maps Replace "Zone Maps"

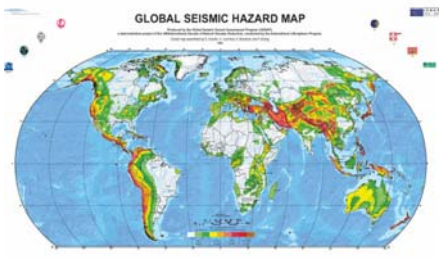
- "Science up methodology"



http://earthquake.usgs.gov

Global Influence – PSHA Universally Accepted

- UN Sponsored Global Seismicity Project



http://www.seismo.ethz.ch/GSHAP/

Global Influence – New PSHA Maps for China

2006 IBC
ASCE 7-05
Seismic Overview

Prescriptive Code Driven Seismic Performance

- Occupancy Category – Post Event Limit State Expectation

Category I ⟷ Category IV

Limit State – Collapse Prevention

Limit State – Containment

Photos by: Philip J Caldwell

Prescriptive Code Driven Seismic Performance

- Occupancy Category – Post Event Limit State Expectation

Category III ⟷ Category IV

Limit State – Life Safe

Limit State – Operational

Photos by: Philip J Caldwell

Prescriptive Code Driven Seismic Performance

- Occupancy Category – Post Event Limit State Expectation
  - Contents can change occupancy category

Category II ⟷ Category IV

Limit State – Collapse Prevention

Limit State – Operational

Photos by: Philip J Caldwell

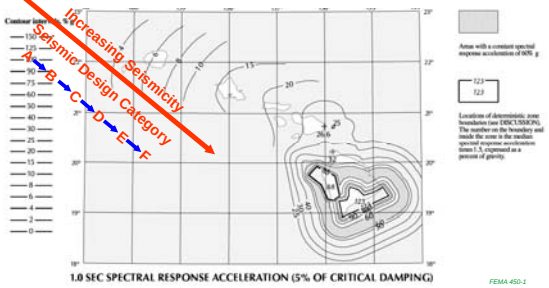
Prescriptive Code Driven Seismic Performance

- Code Plus ?

Photo by: Philip J Caldwell

Prescriptive Code Driven Seismic Performance

- Site Specific Seismicity



Prescriptive Code Driven Seismic Performance

Increasing Seismicity

TABLE 11.6-2 SEISMIC DESIGN CATEGORY BASED ON 1-S PERIOD RESPONSE ACCELERATION PARAMETER

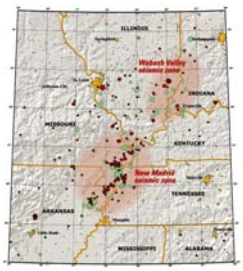
Value of S_{D1}	Occupancy Category		
	I or II	III	IV
$S_{D1} \le 0.067$	A	A	A
$0.067 \le S_{D1} < 0.133$	B	B	C
$0.133 \le S_{D1} < 0.20$	C	C	D
$0.20 \le S_{D1}$	D	D	D
$S_{D1} \ge 0.75$	E	E	E

Seismicity x Occupancy Category = Seismic Design Category

FEMA 450-1

Examples of Site Specific Compliance - NMSZ

- New Madrid Seismic Zone – Central U.S.



http://earthquake.usgs.gov

Examples of Site Specific Compliance - NMSZ

- New Madrid, MO County Jail

Photo by: Philip Caldwell

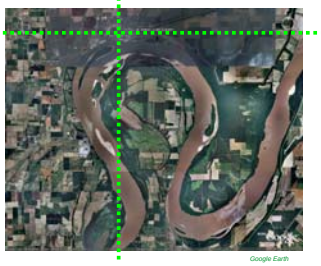
Examples of Site Specific Compliance - NMSZ

- New Madrid, MO County Jail

N 36.58904

N 36.58904

New Madrid County Jail
636 Powell Avenue
New Madrid, MO 63869



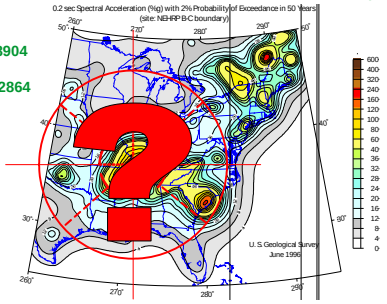
Google Earth

Examples of Site Specific Compliance - NMSZ

- New Madrid, MO County Jail – Determine S_s = ?

N 36.58904

W 89.52864



http://earthquake.usgs.gov

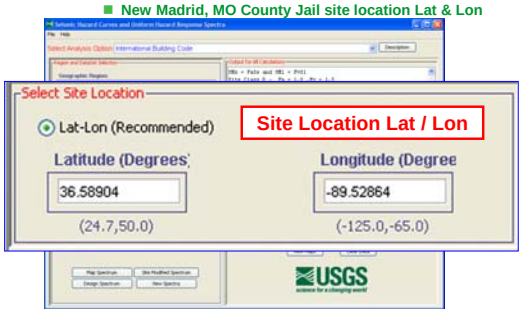
USGS Ground Motion Data Required by ASCE 7- 05

- URL for USGS site specific design data

quake.usgs.gov/research/hazmaps

Examples of Site Specific Compliance - NMSZ

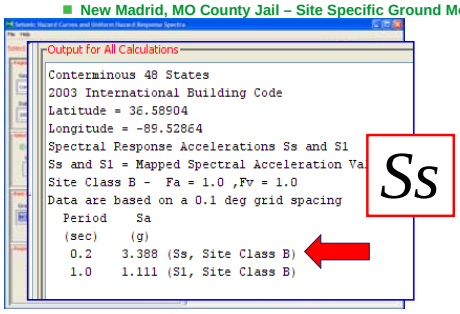
- New Madrid, MO County Jail site location Lat & Lon



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

Examples of Site Specific Compliance - NMSZ

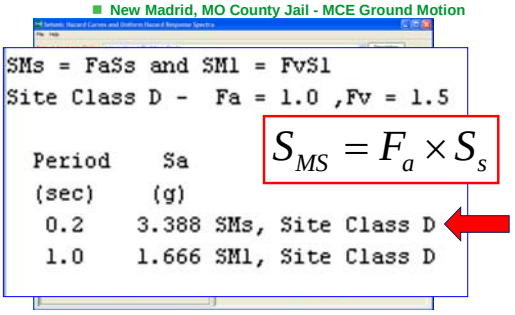
- New Madrid, MO County Jail – Site Specific Ground Motion



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

Examples of Site Specific Compliance - NMSZ

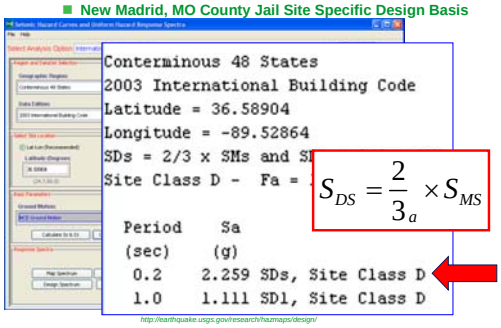
- New Madrid, MO County Jail - MCE Ground Motion



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

Examples of Site Specific Compliance - NMSZ

- New Madrid, MO County Jail Site Specific Design Basis



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

Examples of Site Specific Compliance - NMSZ

- Port Cape Girardeau, MO Example

Photo by: Philip Caldwell

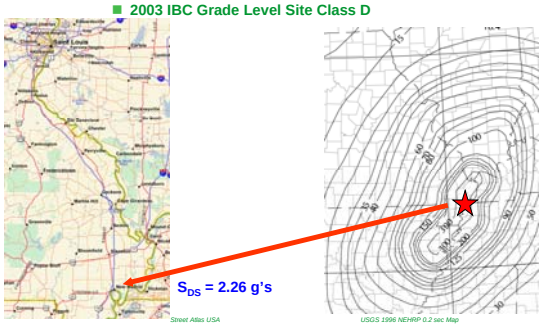
Examples of Site Specific Compliance - NMSZ

- Saint Louis Example – Old Courthouse

Photo by: Philip Caldwell

Examples of Site Specific Compliance - NMSZ

- 2003 IBC Grade Level Site Class D



Examples of Site Specific Compliance - NMSZ

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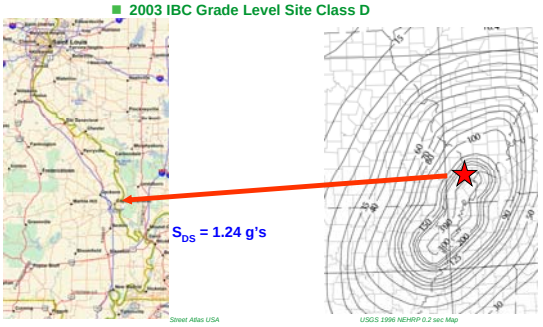

Examples of Site Specific Compliance - NMSZ

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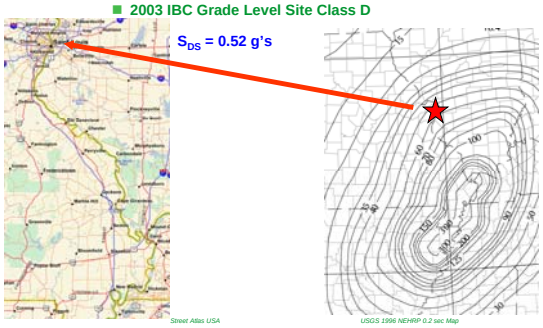
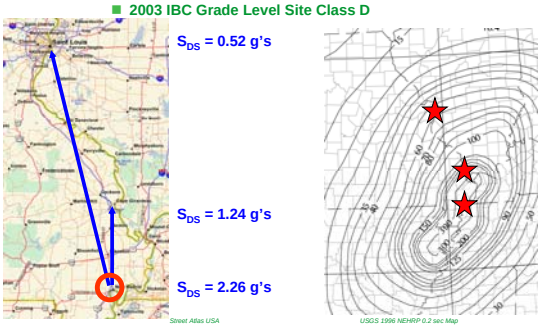


Examples of Site Specific Compliance - NMSZ

- 2003 IBC Grade Level Site Class D



Makes You Wish For "The Good Old Days"

The Building Code of Hammurabi (circa 3000 B.C.)

228: If a builder build a house for a man and complete it, that man shall pay him two shekels of silver per sar (approx. 12 sq. ft.) of house as his wage.

229: If a builder has built a house for a man and his work is not strong, and if the house he has built falls in an kills the householder, that builder shall be slain.

230: If the child of the householder be killed, the child of that builder shall be slain.