

SEISMIC DESIGN PROCEDURE OF HIGHWAY BRIDGES - *A GEOTECHNICAL OVERVIEW*

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Geotechnical and Bridge Seismic Design Workshop
New Madrid Seismic Zone Experience

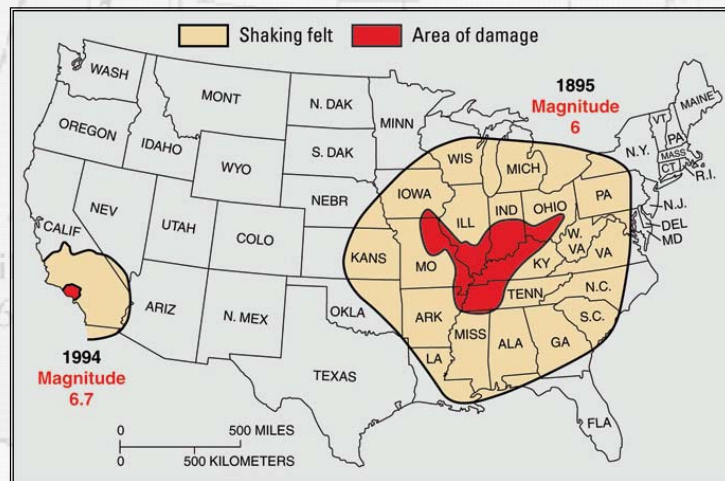
October 28-29, 2004, Cape Girardeau, Missouri



Geotech Overview - 1



1994 Northridge, CA EQ vs. 1895 Charleston, MO EQ



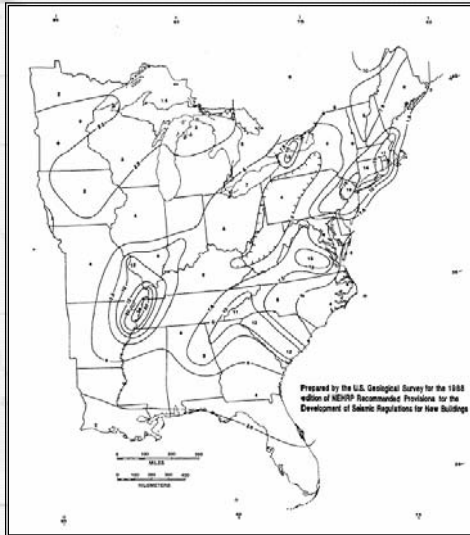
Source: <http://geopubs.wr.usgs.gov/fact-sheet/fs017-03/>



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Peak Horizontal Acceleration in Rock, % g



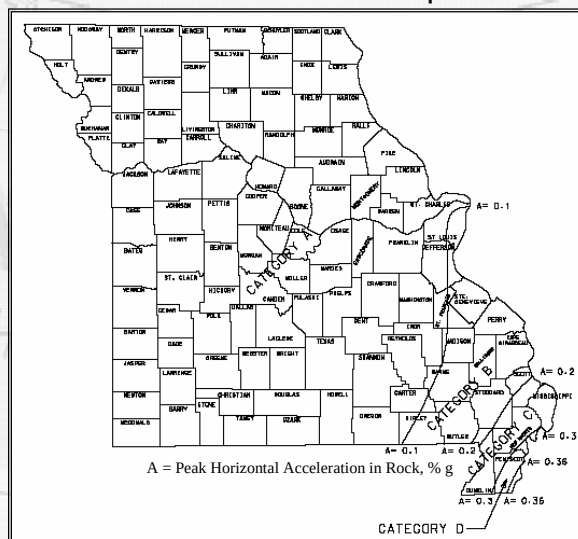
Source: AASHTO LRFD Bridge Design Specifications - Customary U.S. Units - Third Edition- 2004



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MoDOT Seismic Map



Source: <http://www.modot.mo.gov/business/manuals/documents/Section6.1.pdf>



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MoDOT Bridge Division Soil Design Parameters Request Form

Bridge Unit Request for Soil Properties

Job #: _____ N = N₆₀ = SPT Blowcounts per 12" or per 300 mm to 60% machine efficiency for granular soil in Category A or for cohesive soil in Category A, B, C, or D.
 County: _____ N = (N₁)₆₀ = SPT Blowcounts per 12" or per 300 mm, corrected to 1 TSF overburden and to 60% machine efficiency for granular soil in Category B, C, or D.
 Bridge #: _____ ϕ = phi angle, internal angle of friction, degrees.
 Route: _____ S_u = For clay, the undrained shear strength. For rock, the shear capacity, ksf or kPa.
 γ = Weight per unit volume, pcf or kN/m³ (Saturated unit weight below water table, Natural unit weight above water table).
 E = Elastic Modulus of soil, ksf or kPa, where: $E = 2\gamma(1+\nu)G$ and ν = Poisson's ratio = 0.35 (sand), 0.45 (clay), or 0.20 (rock).
 Em = Rock mass modulus for intact rock, ksf or kPa (AASHTO Div. I, Section 4.4.8.2).
 RQD = Rock Quality Designation, %.

Bent No's.	Structural Type (Seismic Category)	N #-#-#	ϕ (degrees)	S_u (ksf or kPa)	γ (pcf or kN/m ³)	E or Em (ksf or kPa)	RQD (%)	Allowable friction (ksf or kPa)	Allowable Bearing (ksf or kPa)	* F.S. Liquefaction	Water table Elev. (ft or m)	** AASHTO soil profile type
	Bridge (Category A)	X									X	
	Bridge (Category B, C, or D)	X	X	X	X	X				X	X	X
	Drilled Shafts (Category A)	X	X	X	X	X	X	X	X		X	
	Drilled Shafts (Category B, C, or D)	X	X	X	X	X	X	X	X	X	X	X
	Retaining Wall (Category A)	X	X		X						X	
	Retaining Wall (Category B, C, or D)	X	X		X						X	

* Provide safety factors for liquefaction for the recommended seismic magnitude at the bridge site. The magnitude shall be based on the probabilities of exceedance of 10% in 50 years (approximately corresponding to a return period of 500 years).
 ** Provide soil profile type (type I, II, III, or IV based on AASHTO Div. I-A, Sec. 3.5) at each boring location.
 Note: If an item above is checked, then "X" indicates the soil properties required at each boring location.

Other required soil properties:
 (or special instructions) _____
 1: _____
 2: _____
 3: _____
 4: _____

Source: <http://www.modot.mo.gov/business/manuals/documents/Section6.1.pdf>



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Failing 1500 Drill Rig



Geotech Overview - 6



Typical Boring Data

Job No.: 20000702

County: Barber

Owner: Barber Co.

Legend by: Barber

Equipment: Fairmont 1500

Rate Paid by: County, Drilling Funds

Automatic Hammer Efficiency: 72 %

Sheet 4 of 7

Design: Adams

Drawn: J.T. R.

Operator: Lambertson, Hens

Drillhole Hole No.: 5-1-43

Date of Work: 06-17, 18, 19, & 20-03

Depth No.: 57-100

MISSOURI DEPARTMENT OF TRANSPORTATION
Construction and Materials
BORING DATA (CORE & SP)

Foot	Station	Elevation	Surface Elevation	Remarks
2	512-84	107.35	512.8	510-14.3' Red and orange mottled clay, scattered gravel, very soft, moist.
TEST DATA				
Depth, ft.	SPF blow/sft	Pen. Per Foot	Wc, %	
5.0	54-10	19	2.0	25.5-30.0'
10.0	5-10-04	21	2.0	31.4
15.0	5-6-11	24	2.25	29.8-40.0'
20.0	5-10-14	26	2.25	Red sandy loam clay, scattered gravel, very soft, moist.
25.0	5-10-24	28	2.25	40.0-47.5'
30.0	6-10-10	31	1.9	47.5-52.2'
35.0	10-10-10	34	1.8	52.2-57.1'
40.0	10-14-21	41	Sanitation	57.1-61.0'
45.0	11-12-10	43	Sanitation	
50.0	11-16-11	42	General	
55.0	11-12-18	39	General	
60.0	5-6-10	19	General	
65.0	11-14-11	34	100 lbs. hammer	
70.0	6-6-11	21	Loose Sample	
75.0	6-10-10	30	1.9	
80.0	6-10-10	29	1.9	
100.0	5-10-1	2	Loose	
120.0	6-6-10	7	1.0	

SOIL CLASSIFICATION TEST DATA

Depth, ft.	L.L.	P.L.	ASTM No.
10.0	75	15	119
15.0	49	28	CL
20.0	49	23	CL
25.0	39	22	CL
30.0	39	17	CL

CORRECTION LOG-AN Inside Test Record

From	To	Rate	Rate	% RQD	Notes

WATER TABLE OBSERVATIONS

Date	Time of Day	Depth to Water	Depth to Surface

SEVEN ANALYSIS (Percent Water)

ASAPED 2.00

Depth, ft.

	40.0	45.0
1.4	100	100
1.8	100	100
4.0	100	100
6.0	100	100
8.0	100	100
10.0	100	100
12.0	100	100
14.0	100	100
16.0	100	100
18.0	100	100
20.0	100	100
22.0	100	100
24.0	100	100
26.0	100	100
28.0	100	100
30.0	100	100

Notes:

1. **SP** - Standard Penetration Test (ASTM D 1586)

2. **Wc** - Water Content (%)

3. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

4. **Wc, %** - Water Content (%)

5. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

6. **Wc, %** - Water Content (%)

7. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

8. **Wc, %** - Water Content (%)

9. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

10. **Wc, %** - Water Content (%)

11. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

12. **Wc, %** - Water Content (%)

13. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

14. **Wc, %** - Water Content (%)

15. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

16. **Wc, %** - Water Content (%)

17. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

18. **Wc, %** - Water Content (%)

19. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

20. **Wc, %** - Water Content (%)

21. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

22. **Wc, %** - Water Content (%)

23. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

24. **Wc, %** - Water Content (%)

25. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

26. **Wc, %** - Water Content (%)

27. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

28. **Wc, %** - Water Content (%)

29. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

30. **Wc, %** - Water Content (%)

31. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

32. **Wc, %** - Water Content (%)

33. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

34. **Wc, %** - Water Content (%)

35. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

36. **Wc, %** - Water Content (%)

37. **Pen. Per Foot** - Penetration per foot (ASTM D 1586)

38. **W**

Typical Earthquake Boring Log

The diagram illustrates a typical earthquake boring log, showing a vertical profile of a borehole with depth on the left (0 to 100 feet) and various data columns on the right. The log is divided into sections by depth: 0-10 ft (Topsoil), 10-20 ft (Soft clay), 20-30 ft (Stiff clay), 30-40 ft (Very stiff clay), 40-50 ft (Hard clay), 50-60 ft (Very hard clay), 60-70 ft (Extremely hard clay), 70-80 ft (Very hard clay), 80-90 ft (Extremely hard clay), 90-100 ft (Very hard clay). The log is titled "Typical Earthquake Boring Log" and includes a scale bar at the bottom.

Log Data Columns (from left to right):

- Date
- Time
- Location
- Boring No.
- Depth (ft)
- Soil Type
- SPT (blows/ft)
- R_L (lb/ft²)
- R_U (lb/ft²)
- C_u (lb/ft²)
- F_r (lb/ft²)
- F_u (lb/ft²)
- F_c (lb/ft²)
- F_t (lb/ft²)
- F_v (lb/ft²)
- F_h (lb/ft²)
- F_a (lb/ft²)
- F_s (lb/ft²)
- F_w (lb/ft²)
- F_o (lb/ft²)
- F_p (lb/ft²)
- F_m (lb/ft²)
- F_n (lb/ft²)
- F_e (lb/ft²)

Log Sections (from top to bottom):

- 0-10 ft: Topsoil
- 10-20 ft: Soft clay
- 20-30 ft: Stiff clay
- 30-40 ft: Very stiff clay
- 40-50 ft: Hard clay
- 50-60 ft: Very hard clay
- 60-70 ft: Extremely hard clay
- 70-80 ft: Very hard clay
- 80-90 ft: Extremely hard clay
- 90-100 ft: Very hard clay

Log Title: Typical Earthquake Boring Log

Scale Bar: 0 to 100 feet

Typical Earthquake Boring Log Data

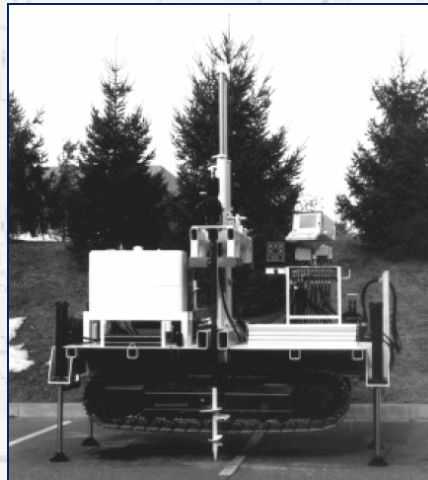
- Moisture Content
- Saturated Unit Weight
- Liquid Limit
- Plasticity Index
- ASTM Classification
- Percent < #200 Sieve
- Relative Density
- Undrained Shear Strength
- Friction Angle
- Cohesion
- Blow Count (N_{60})
- Resisting Stress Ratio
- Liquefaction F.S.
- Shear Wave Velocity
- Maximum Shear Modulus
- Shear Modulus
- Young's Modulus
- Poisson's Ratio



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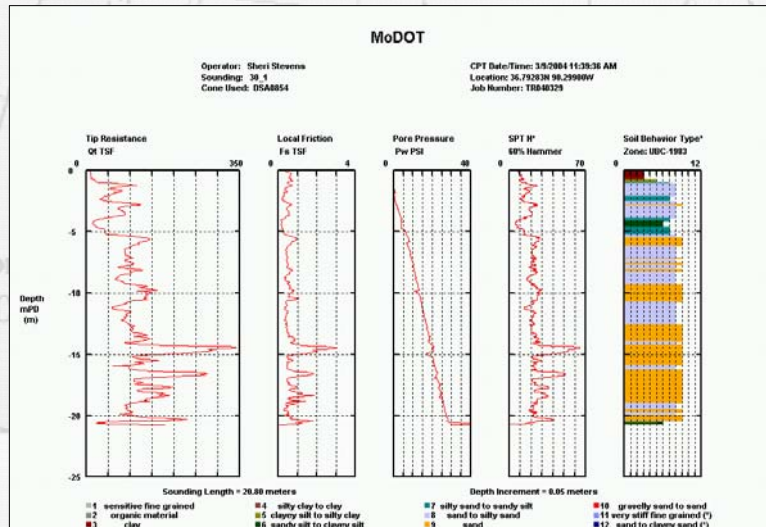
Hogentolger Track Mounted Cone Penetrometer System



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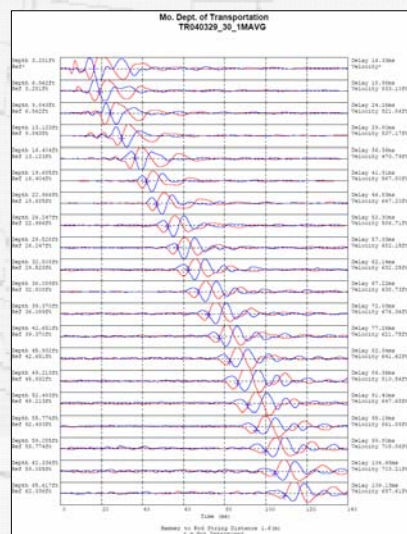
Typical Cone Penetrometer Data



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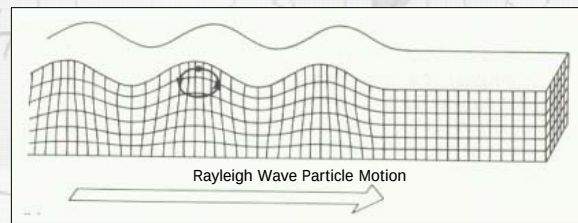
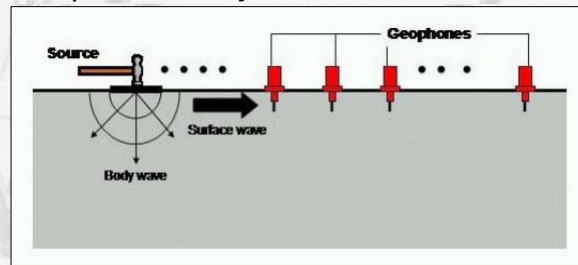
Typical Seismic Cone Penetrometer Data



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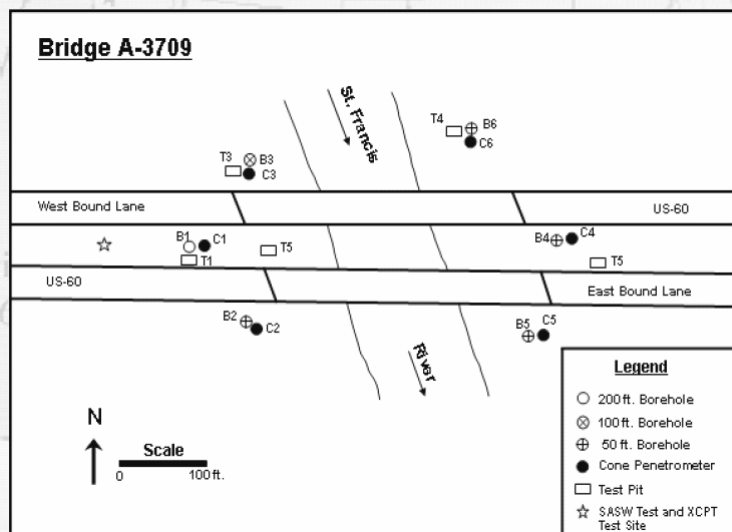
Spectral Analysis of Surface Waves



Geotech Overview -13



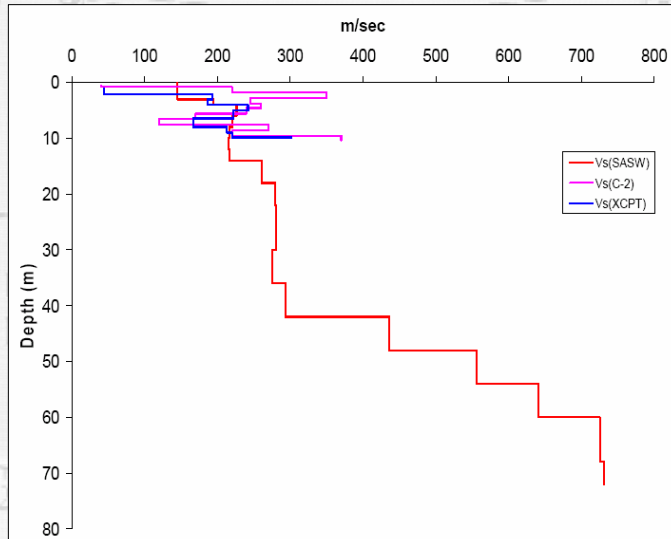
Plan View – St. Francis River Site



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Shear Wave Velocity Profile - St. Francis River Site



Source: MoDOT RDT 03-006, Anderson, et. al., 2003 (<http://168.166.124.22/RDT/reports/Ri01053/RDT03006.pdf>)



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Earthquake Effects



Loma Prieta, CA
1989



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