Engineering Geology & Seismology Review for Public Schools & Hospitals in California

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www.conservation.ca.gov/cgs
3 Types of Ground Failure

- Fault Rupture
- Liquefaction & Seismic Compression
- Landslides
1906 Damage to Schools

Four-Story High School in San Jose
CCR Title 24 Reviews for Hospitals & Public Schools are performed by the California Geological Survey by Certified Engineering Geologists with support from Senior Seismologists. C.G.S. works under contract to OSHPD and DSA.
California Codes & Regulations

- Alquist-Priolo Earthquake Fault Zoning Act
  Public Resources Code §2621 et seq. --- for active faults

- California Seismic Hazard Mapping Act
  Public Resources Code §2690 et seq. --- for liquefaction & landslides

- California Building Standards Administrative Code
  CCR Title 24, Part 1 --- specific rules for California agencies
  California Building Code, especially Chapters 16, 18, 33
  CCR Title 24, Part 2 --- derived from IBC and upgraded for California

- California Education Code
  CCR Title 5, Campuses for Public Schools & Community Colleges

- Specific Licensure for Engineering Geologists, Geotechnical Engineers, Structural Engineers, Architects
  Business & Professions Code; applies to 3 separate Registration Boards
Calif. Code of Regulations, Title 24

California Building Standards Administrative Code
CCR Title 24, Part 1 --- specific rules for California agencies

California Building Code, especially Chapters 16, 18, 33
CCR Title 24, Part 2 --- derived from IBC and upgraded for California
EERI Monograph Series
Two examples of ten EERI monographs.
Engineering Geology
References
AEG volumes – Northern & Southern California
ASCE Standard 7-05

Minimum Design Loads for Buildings
& Other Structures

www.asce.org

2006 IBC and 2007 CBC will be cross-linked to sections of ASCE Standard 7-05
New Sources of Geologic Information

- Latitude & Longitude = easily looked-up
- Alquist-Priolo Fault Zone Maps = pdf
- Liquefaction and Landslide Zone Maps = pdf
- Earthquake Ground Motion attenuation formulas derived from robust new CSMIP dataset
- CGS Statewide Fault Model – on-line 2002
- GeoRef & GeoScience World = find geology refs
- Training Sessions by EERI & SSA = like this one!
Important Publications from CGS & SCEC

- Special Publication 118: RECOMMENDED CRITERIA FOR DELINEATING SEISMIC HAZARD ZONES IN CALIFORNIA
- Special Publication 117: GUIDELINES FOR EVALUATING AND MITIGATING SEISMIC HAZARDS IN CALIFORNIA (1997)
- Special Publication 117: RECOMMENDED PROCEDURES FOR IMPLEMENTATION OF DMG SPECIAL PUBLICATION 117: GUIDELINES FOR ANALYZING AND MITIGATING LANDSLIDE HAZARDS IN CALIFORNIA
Note 48 Checklist

- Used by consulting geotechnical firms to ascertain completeness of their engineering geology reports.

- **Uniformly** used by the Engineering Geologists within the California Geological Survey.

- All consulting geotechnical firms are judged to the same statewide level of scrutiny at 4 DSA regional offices & two OSHPD offices.

- Concise 2-page checklist format provides comprehensive overview for the entire process --- insights for owners/architects for scoping of contract.

- Citations to specific Code sections of CCR Title 24, CBC.
Outline of Note 48

- **Location of the Campus** – latitude & longitude
- **Engineering Geology**—geologic maps, boreholes, cross-sections, active fault trenching, geotech tests, expansive soils, flooding & erosion
- **Earthquake Ground-Motion**, UBE & DBE
- **Liquefaction & Seismic Settlement**
- **Landslides**
- **Exceptional & Unusual Geologic Hazards**
- **Consultant Review of Grading Plans**
- **Report Documentation & Signatures of CEG and RGE**
Regional Geology & Regional Fault Maps
Detailed Geologic Map of Site, 1 inch ≈100 feet
Subsurface Geology & Adequate Boreholes
Geologic Cross-Sections, 1 inch ≈20 feet
Active Faulting Evaluation; fault trenching
Geologic Hazards Zones – Official SHMA Maps
Geotechnical Testing – full suite of lab tests
Expansive Soils
Type II or Type V portland cement
Flooding & Severe Erosion
Geologic Site Investigation — Regional to Site-Specific Mapping

Earthquake Epicenter Map - 1:500,000
Regional Geologic & Fault Maps - 1:250,000
Geologic Quadrangle Maps, 1:24,000
Alquist-Priolo Fault Zone Quads, 1:24,000
Liquefaction & Landslide Zone Maps, 1:24,000
Geologic Map of Site, 1 inch ~100 feet
Grading Plans, 1 inch ~40 feet
Geologic Cross-Sections 1 inch ~20 feet
Borehole Logs & Fault Trench Logs
1 inch ~ 5 feet
Public Schools and Hospitals must be Set-Back $\geq$ 50 feet from Active Faults.

- CBSAC §4–317e

Fault Trenching Must be Performed by a Certified Engineering Geologist
References for Active Faults & Fault Trenching Methods
Alquist-Priolo Earthquake Fault Zoning Act
last amended and renamed in 1994

California Geological Survey, Special Publication 42, Hart & Bryant, 1999 edition, 38 pages. SP-42 is posted as .pdf on CGS website. 547 quads are zoned for active faulting.
547 Fault Zone Maps Issued

5000+ Miles of Active Faults Officially Zoned
Seismology
Note 48 Checklist

- Historic Seismicity - simple EQ map, Map Sheet 49
- Characterize & Classify the Geologic Subgrade
- California Seismic Zone 3 or 4
- Near-Source Coefficients – if applicable, cap @ Ca=0.66g
- Probabilistic Seismic Hazard Analysis, UBE & DBE
- Normalized Spectral Acceleration
- Deaggregated Seismic Source Parameters – modal magnitude & fault distance
- Seismic Retrofit—Senate Bill 1953 & Division VI-R
- Scaled Time-Histories of EQ Ground-Motion
Classify the Geologic Subgrade

Table 16A-J of Code

Necessary Step to Choose the Appropriate Attenuation Formula

**Type B =** Rock

\[ Vs = 760-1500 \text{ m/sec} \]

**Type C =** Soft Rock or Very Dense Soil

\[ Vs = 360-760 \text{ m/sec} \]
\[ \text{SPT } N > 50 \text{ blow-counts} \]

**Type D =** Stiff Soil (≈ typical alluvium)

\[ Vs = 180-360 \text{ m/sec} \]
\[ \text{SPT } N = 15-50 \text{ blow-counts} \]
Probabilistic Seismic Hazard Mapping

Historic Earthquakes (1800 - 1994) with Magnitudes 5 and Greater

Slip Rates of Major Active Faults

Preliminary Surface Geologic Materials

Peak Acceleration (%g) with 10% Probability of Exceedance in 50 Years
Draft USGS Map, Aug. 2002b

CGS Map Sheet 48
Liquefaction Note 48 Checklist

- Geologic Setting for Liquefaction
- Liquefaction Methodology: *Cite & Use:*
  - Youd, Idriss, & 19 others (2001)
  - Seed & 10 others (2003)
  - Martin & Lew (1999) SCEC publication
- Liquefaction Calculations, MSF, SF>1.3
- Seismic Settlement - Entire Soil Column – wet & dry
- Lateral Spreading -- if near cut-slope or riverbank
- Remedial Options for Liquefaction - list several
- Acceptance Criteria for Liquefaction Remediation
Evaluate and mitigate liquefaction hazards at construction sites by:

- Avoidance (if possible) during site selection
- Liquefaction Analysis with Calculated Settlements (total and differential, d/L)
- Foundation Design or Remediate the Subgrade

California Seismic Hazards Mapping Act of 1990
Liquefaction Zoning Process

Zone Edge

Liquefaction

OFFICIAL ZONE

Holocene Alluvial Fan – soft sand

"top of the Pleistocene"

Pleistocene Alluvial Fan – indurated

50-foot water table
Landslides
Note 48 Checklist

- Landslide Mapping --- detailed
- Geologic Subsurface Mapping using Large-Diameter Boreholes
- Geologic Cross-Sections
- Geotechnical Strength Parameters
- Landslide Stability Analyses
- Landslide Repair Options
Landslide Books & Manuals

Two examples of Landslide monographs

SR-247 Nat. Res. Council

SCEC & ASCE book
SLOPE STABILITY ANALYSIS

INFINITE SLOPE MODEL

Static Conditions:
- $FS = \frac{R}{D} = \frac{W \cos \alpha \tan \phi}{W \sin \alpha} = \frac{\tan \phi}{\tan \alpha}$

Dynamic Conditions:
- $a_y = (FS - 1)g \sin a$ (Newmark’s Equation)
Grading Plan Review
Note 48 Checklist

- Consulting Geotech Review of Penultimate Grading Plans & Foundation Plans
- Called-Inspections for CEG & RGE
- Subdrain Plans & Surface-Water
- Cut-Fill Prisms & Seismic Compression of Fills
- Deep Foundations -- piles & caissons
- Retaining Walls, Fill Buttresses, Geosynthetics
Report Documentation
Note 48 Checklist

Geology, Seismology, & Geotechnical References --- concise & pertinent to site

Engineering Geology Report
 signed by Certified Engineering Geologist

Geotechnical Engineering Report
 signed by Registered Geotechnical Engineer
Begin with the End in Mind

Begin with the End in Mind

Subsurface Strategy

Work backwards through these Parameters:

Ultimate Question: What will be the Seismic Settlement? Differential Settlement? Total Settlement?

Multiple Settlement Calculations — formula of: Tokimatsu & Seed, 1987

Multiple Geologic Cross-Sections — through foundations

Adequate geotechnical lab testing — consolidation tests & void ratios

Adequate subsurface data — frequent sampling in sands

Adequate depth of boreholes — 50 feet deep

Adequate number of boreholes — within building footprint

Visualize geologic subgrade & anticipate complex stratigraphy

= ✋ planning of the drilling program.
Four Modes of Settlement

- **Unsaturated Seismic Settlement**
  above historic-highest water surface

- **Saturated Seismic Settlement**
  due to liquefaction below water table

- **Consolidation Settlement**
  under static load of building

- **Hydrocollapse**
  soils with high void-ratio,
  plus anthropic water (lawn watering, etc.)
Basement Excavations

SB-1953 Seismic Upgrades & Replacement Hospitals

An increasing number of urban Hospitals are using Basements

- Sufficiently deep boreholes, >50 ft
- Emphasis on lateral stability, seismic settlement, hydrogeology (dewatering), and pile depths
- Underpinning of existing buildings and city streets (gas, water, sewer)
1994 Northridge Earthquake
Parking Structure Collapse
Parking Structures

3 & 4-Story Reinforced Concrete with Heavy Column Loads

An increasing number of urban Community Colleges & Hospitals are planning Parking Structures

- Sufficiently deep boreholes, $\geq 50$ ft
- Emphasis on seismic settlement, particularly differential, $\partial \div L$
- Determine optimum depth to stratigraphic horizon for Pile Tips
Useful Hints to Expedite Your Project

- Retain an Engineering Geologist to select a campus with **minimal geologic hazards**. Use long-range planning for adroit site acquisition. **Schools**: Do not accept inferior properties from tract developers (with: active faults, landslides, liquefaction).

- Select a **qualified CEG & RGE** for the design team.

- Begin geologic field-work in a **timely manner** (avoid winter drilling & earthwork during rains).

- Provide preliminary ground-motion to the Structural Engineer in a timely manner. Avoid **costly re-design** --- one year later.

- Plan the **layout & depth of boreholes** commensurate with the subsurface geologic conditions, and column loads and basements.
Practical Hints for Engineering Geology Report Writing

- Use digital field photographs to showcase the site geologic conditions and adjacent property.
- Keep abreast of new publications in seismology, engineering geology, & geotech engineering (SSA, EERI, AEG, ASCE, AGU)
- Write Succinctly & Focus on Subsurface Conditions.
- Rely on Deep Boreholes & Frequent Samples.
- Prepare Detailed Geologic Cross-Sections.
- Always Calculate the Differential Settlement when in alluvial terrain (no estimates)
- Offer Multiple Strategies for site remediation and seek cost-effective geotechnical solutions.
- Let the Structural Engineer “solve” the Foundation Design.
- Use an Executive Summary with Concise Findings
- Step-Out Ahead of Code Minimums; Seek to write a Standard-of-Practice report.
Geotechnical Consultants have better access to new Seismic Hazard Zone Maps, new Metadata & Digital Mapping for Earthquake Ground-Motion & Geologic Hazards.

Action Begins with Knowing: Where the Problems Are

CCR Title 24, Calif. Bldg. Code = custom code for California hazards

Statewide Uniformity of Reviews using Note 48 Checklist by the California Geological Survey

Result: Improved Earthquake–Resilient Construction Where it is Needed Most in California