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Appendix VII A Note on Earthquake Design of Caltech Buildings

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History

For a period of about 30 years Caltech required new buildings to be designed for 50% additional lateral forces (over code values) and review of the seismic structural design by the structural engineering faculty. However, the design requirements for each of Caltech's last three major buildings, Cahill Center, Annenberg Center, and Schlinger Laboratory, did not include an increase in lateral forces over those prescribed in the California Building Code. Caltech's special seismic design requirements however, did continue to include review by structural engineering faculty. The applicable editions of the building code and the referenced seismic provisions are in parenthesis as follows; Cahill Center (2001 California Building Code (CBC), 1997 Uniform Building Code (UBC)), Annenberg Center (2007 CBC, 2006 International Building Code (IBC)), and Schlinger Laboratory (2007 CBC, 2006 IBC).

Summarizing Caltech's history of increased lateral forces, Prof. Paul Jennings writes; *in 1965, after the Alaskan Earthquake of 1964, George Housner wrote a note entitled Earthquake Design Considerations for Caltech Buildings. In this note he recommended that Caltech buildings should be designed for lateral forces 50% larger than those specified by the Uniform Building Code. Presumably he sent this to the administration then. Also, I recall George telling me about this time that he and Don Hudson had looked at the plans of all of Caltech's older buildings to judge their earthquake hazard … In 1979, George wrote a memo to Bob Fort, the Director of Physical plant, reminding him that that Caltech has used more stringent earthquake requirements than appear in the building code and that he and I had reviewed the design of a building before it was let out to bid … …* [Paul Jennings, EQ Resistance of Caltech Buildings, email to Ken Hargreaves and others, May 21, 2010].

The earliest record of a building design incorporating this 50% increase is in Facilities' building data base for Baxter Hall. Using the provisions of the 1967 UBC, Baxter Hall's preliminary structural design was completed in mid-1967, final design was completed in early 1969, and the building was occupied in 1971. For the 1969 final design the "*C*" factor was increased from 0.10 to 0.15.

This simple addition of 50% more lateral loads morphed into an *Importance Factor* of 1.5 for subsequent buildings. Braun Laboratories (1976 UBC), Watson Laboratories (1976 UBC), Beckman Institute (1985 and 1988 UBC), Avery House (1991 UBC), Moore Laboratory (1991 UBC) and Sherman Fairchild Library (1991 UBC) all increased the code required *Importance Factor* to 1.5 from 1.0. The first use of unmodified code lateral forces was the Wilson South Parking Structure, using the 1997 edition of the Uniform Building Code.

Important code changes initiated in the 1997 UBC support the decision to abandon the simple addition of 50% more lateral force. Site-specific soil amplification characteristics defined by average near surface shear wave velocity were introduced as a *Soil Profile Type* in the 1997 UBC[1]. The 1997 edition also included the distance to the nearest fault, its capability to produce a large magnitude earthquake and the historical rate of seismic activity on the fault which, combined with the soil profile, prescribed an effective seismic force about 43% larger than the seismic coefficients required by building codes for earlier buildings on campus[2]

[1] Twenty years earlier, the 1976 UBC had increased lateral building forces with a site-structure resonance coefficient dependent upon the ratio of building period of vibration to a characteristic site period. The site period was determined by geotechnical data which proved be overly subjective for effective code enforcement and consequently, the 1988 UBC substituted a site coefficient representing soil amplification of seismic lateral forces. The near surface soil profile was determined by geotechnical data for type and stiffness of the subsurface soils. By the mid-1990s geophysical research using arrays of strong motion records lead to a definition of near surface *Soil Profile Type* using site-specific average shear wave velocity in the upper 100 ft.

[2] C_a = seismic coefficient, a function of Seismic Zone Factor Z=0.4, Soil Profile Type S_D, Closest Distance To Seismic Source *1.6 km,* Seismic Source *Type B.* UBC Equation 30-5, C_a = 0.44 x 1.3 = 0.572, therefore, increase of C_a over K is [1-(0.572/0.40)] =+43%.

Furthermore, additional code developments after the 1971 M_w 6.7 Sylmar, 1989 M_w 6.9 Loma Prieta and 1994 M_w 6.7 Northridge earthquakes resulted in new building structures better able to resist future earthquakes. Notable improvements culminating in the 1997 Edition of the Uniform Building Code include better estimates of strong ground motions, accounting for the behavior of rock and soil foundations, the requirements of ductile structural members and their connections and reinforcement of stiff building structures.

Recommendations for Future Buildings

Applicable Building Code

2009 California Building Code, Title 24 Part 2, or later edition.

Quality assurance

The cornerstone supporting an active and serious concern about the earthquake performance of Caltech's buildings has been and will continue to be active participation by structural engineering faculty. This participation has the affect of a Quality Assurance (QA) program. It is a systematic monitoring during design of the earthquake performance of a building, through discussion and analysis, to ensure that standards of good performance are being met.

The Process

- Select appropriate faculty member or members for the building project.

- Faculty member(s) meet with project design engineer during design development phase to discuss Caltech's special seismic performance requirements and express any special concerns. The Faculty may require some analyses that help insure that the structure has the needed capacity. The Caltech project manager or his delegate may attend this meeting.

- A second meeting is held to review the final design, the results of any special analyses that the Faculty has requested, such as a dynamic analysis or a push-over study, and any special problems or features of the building. This is typically the last opportunity Faculty has to influence the structural design. The Caltech project manager or his delegate will attend this meeting.

- The Caltech project manager or his delegate will review the structural plans for special seismic features before the plans are released for construction.

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