Fault Rupture

Caltrans structures -- bridges, tunnels, buried reinforced concrete boxes (RCB), or buildings -- near active faults may be subjected to surface fault rupture. Surface fault rupture can cause large deformations in structures, depending on the type of fault, total displacement, and angle of the fault offset relative to the structure. Memo to Designers (MTD) 20-10 requires a *Surface Fault Rupture Displacement Hazard Analysis* (SFRDHA) where any portion of the structure is located:

- Within an Alquist–Priolo Earthquake Fault Zone (APEFZ), as defined by the California Geological Survey.

- Within 1,000 feet of an unzoned fault (not located in an Alquist–Priolo Earthquake Fault Zone) that is Holocene (up to 11,000 years) or younger in age.

Unzoned faults are faults that have moved in the last 11,000 years but which are not sufficiently active and well-defined to be zoned by CGS with currently available data.

Screening for Fault Rupture Potential

To screen for fault rupture potential, determine whether the structure is in an APEFZ or near a fault that has moved in the Holocene. Faults with movement older than Holocene (e.g., Quaternary faults) should not be evaluated for fault rupture hazard.

Consult the CA Geological Survey, Alquist-Priolo Earthquake Fault Zone Maps.

> If any portion of the structure is in an APEFZ, a *Surface Fault Rupture Displacement Hazard Analysis* is required for the structure.

If a SFRDHA is required, search the Caltrans Geotechnical Archive (GeoDOG)

> Surface Fault Rupture Displacement Hazard Analyses were conducted for over 250 structures in the State Highway System. Most Caltrans bridges in AP Zones have been evaluated for fault rupture hazard using the current fault rupture displacement calculation methodology (Petersen et al., 2011, Moss and Ross, 2011, or Youngs et al., 2003). The information in archived fault rupture evaluations should be evaluated on a case-by-case basis, and may need to be re-calculated (e.g., because new evidence, improved mapping, or rupture calculation methodologies become available). In many cases, the calculated potential offset in the archived SFRDHA will be adequate information for design and no further evaluation will be needed. Contact Fault.Rupture@dot.ca.gov to determine if the existing SFRDHA is adequate or if it should be updated.

To request assistance in developing a SFRDHA for a proposed structure, email Fault.Rupture@dot.ca.gov and provide the following information:

- Project Information
- Bridge, tunnel, buried RCB, or building location (Lat/Long, County-Route-Postmile)
- Proposed structure layout plan
- Summary of screening

The fault rupture specialist will acknowledge the receipt of the request and will either verify that recommendations in the existing report are still valid or will require a new SFRDHA.

Surface Fault Rupture Displacement Hazard Analysis

Performed by a geologist experienced in fault evaluations, this work will consist of an in-depth literature review, site reconnaissance, and mapping fault geomorphic expression to accurately locate the fault with respect to the structure. In cases where there is a confirmed fault rupture hazard, the SFRDHA will provide magnitude and orientation of anticipated surface displacement relative to the structure.

<New rupture models are being developed (FDHI, 2022) and this module will be revised to include the updated SFRDHA calculation methodology once adopted by the Department. Related questions or comments can be submitted to Fault.Rupture@dot.ca.gov>

Reporting

If screening determines that a SFRDHA is not required, state the following in the SPGR, PFR, of FR:

"The structure is not located within an Alquist-Priolo Earthquake Fault Zone or 1,000 feet from any unzoned fault that is Holocene or younger in age. Therefore, per MTD 20-10, the structure is not considered susceptible to surface fault rupture hazards."

If a SFRDHA has been performed state the following in the SPGR, PFR, or FR:

"*A Surface Fault Rupture Hazard Displacement Analysis was performed, and the offset and orientation results documented in a Fault Rupture Report dated (DATE)."*

When a SFRDHA is performed, prepare a report addressed to the Chief, Office of Earthquake Engineering and Research, and copy the Geoprofessional. The report must include:

- Executive Summary, including Bridge or structure name, Bridge number, location, azimuth of bridge or structure, azimuth of fault, and angle between bridge or structure and fault (sub-parallel, sub-perpendicular, or approximately 45º), fault name, fault type, magnitude and slip direction of potential offset, horizontal and vertical vector components of offset (for dip-slip faults).

- Bridge Review: List the existing and proposed bridge structure type and foundation type and summarize previous creep or earthquake damage from bridge inspection reports or literature, if relevant.

- Literature Review: Identify the sources and types of literature, reports, images, maps, communication with researchers, plans used for the SFRDHA.

- Fault evaluation: Fault name, fault type, history of recent and historical movement, surface expression near the project site. For many cases, the Fault Evaluation Report (FER) that accompanies the AP Map is an authoritative source for fault evaluations. Use air photos and LiDAR to evaluate fault expression near the structure.

- Field Investigations: Map the fault expression using air photos and LiDAR, and perform a site visit to find an accurate site-to-source distance. Summarize any subsurface exploration used for the investigation. Append any logs, maps, photos, or reports as necessary to support the findings.

- Fault Rupture Analysis: Report the probabilistic fault displacement with probability of exceedance of 5% in 50 years. Report and cite sources for each of the hazard calculation inputs: slip rate, moment magnitude, distance to nearest corner of bridge or structure, creep rate, fault dip. Report outputs – magnitude, style, and azimuth of offset, horizontal and vertical vectors of offset (for dip-slip faults). Include tables and graphs presenting the findings of the analysis. If the calculated potential rupture at the structure is zero, document that.

References

1. Abrahamson, N., 2008, Appendix C, Probabilistic Fault Rupture Hazard Analysis, San Francisco PUC, General Seismic Requirements for the Design on New Facilities and Upgrade of Existing Facilities

2. California Geological Survey, 2018, Earthquake Fault Zones: A Guide For Government Agencies, Property Owners / Developers, and Geoscience Practitioners for Assessing Fault Rupture Hazards in California, CGS Special Publication 42, https://www.conservation.ca.gov/cgs/Documents/Publications/Special-Publications/SP_042.pdf

3. California Geological Survey, 2002, Guidelines for Evaluating the Hazard of Surface Fault Rupture, CGS Note 49, https://www.conservation.ca.gov/cgs/Documents/Publications/CGS-Notes/CGS-Note-49.pdf

4. Caltrans, Memo to Designers 20-8, Analysis of Ordinary Bridges that Cross Faults (INACTIVE)

5. Caltrans, Memo to Designers 20-10, Fault Rupture

6. Caltrans, 2021, STP- 20.22, Analysis of New Bridges in Fault Rupture Zones, https://dot.ca.gov/-/media/dot-media/programs/engineering/documents/structure-technical-policy/section-20/202112-stp2022analysisofnewbridgesinfaultrupturezones-a11y.pdf

7. Dawson, T., and Weldon, R., 2012, UCERF3 Appendix B: Geologic Slip Rate Data and Geologic Deformation Model: https://pubs.usgs.gov/of/2013/1165/

8. Fault Displacement Hazard Initiative: https://www.risksciences.ucla.edu/nhr3/fdhi/home

9. Field, E.H., Biasi, G.P., Bird, P., Dawson, T.E., Felzer, K.R., Jackson, D.D., Johnson, K.M., Jordan, T.H., Madden, C., Michael, A.J., Milner, K.R., Page, M.T., Parsons, T., Powers, P.M., Shaw, B.E., Thatcher, W.R., Weldon, R.J., II, and Zeng, Y., 2013, Uniform California earthquake rupture forecast, version 3 (UCERF3)—The time-independent model: U.S. Geological Survey Open-File Report 2013–1165, 97 p., California Geological Survey Special Report 228, and Southern California Earthquake Center Publication 1792, http://pubs.usgs.gov/of/2013/1165/

10. Moss, R. and, Ross, Z., 2011, Probabilistic Fault Displacement Hazard Analysis for Reverse Faults, BSSA Vol. 101, pp 1542 – 1553

11. Petersen, M., and others, 2011, Fault displacement hazard for strike-slip faults: Bulletin of the Seismological Society of America, Vol. 101, No. 2, pp. 805–825

12. US Geological Survey, 2008, National Seismic Hazard Maps – Fault Parameters

13. Wells, D., and Coppersmith, K., 1994, New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement: Bulletin of the Seismological Society of America, Vol. 84, No. 4, pp. 974-1002

14. Youngs et al., 2003, A Methodology for Probabilistic Fault Displacement Hazard Analysis, EQ SPECTRA