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Opinion paper

A critique of the ICOLD method for selecting earthquake ground motions to design large dams

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Abstract

The practice for selection of earthquake ground motion for design of large dams as recommended by the International Committee on Large Dams (ICOLD) bulletin 72 is examined. It is shown that the recommended practice is flawed and does not bear a scrutiny on the basis of statistical theory. The ground motion attenuation relationships are derived on the basis of different sets of assumptions and different sets of data, and with different standard errors. Estimates from these different attenuation relationships cannot be averaged (weighted, or otherwise) as recommended in the bulletin due to the presence of standard errors for each of these relationships.

Keywords: Seismic hazard assessment; Ground motion attenuation; Earthquake resistant design; Regression analysis

1. Introduction

The Appendix 2 of the International Committee on Large Dams (ICOLD) Bulletin 72 (ICOLD, 1989), hereafter referred to as the Bulletin, contains a recommendation which states that seismic ground motion can be specified by peak or effective peak values of expected acceleration, velocity, and/or displacement. Therein the attenuation relation is defined as an empirically derived relationship to obtain peak parameter of ground motion at a site in terms of energy release (magnitude) at source and distance from source to site. These relationships are very sensitive to distance and magnitude. The reasons behind the scatter are also stated in the Bulletin. The peak ground acceleration (PGA) is the most commonly used seismic parameter for a site despite its various shortcomings. The guideline does not recommend the use of any specific attenuation relationship among the various relationships that have been developed in the recent years to estimate PGA. But it recommends that "... consideration should be given to using *weighted* (emphasis added) average of values provided by several of the most accepted and reliable equations for this variable". The guideline also provides references for equations

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that are deemed to be the most frequently used ones in the United States to estimate PGA. These are (1) Ambraseys, (1973 and 1978 in ICOLD, 1989); (2) Trifunac and Brady (1975); (3) Campbell (1981); (4) Boore and Joyner (1982); (5) Bolt and Abrahamson (1982); (6) Seed and Idriss (1982); and (7) Idriss (1985). This simply implies that weighted average of the derived values of peak horizontal ground acceleration (PGA) from various attenuation relationships (equations) shall be used in arriving at a design parameter for a project. This is a dangerous proposition and cannot be defended by any means. We explore the implications of this proposition and show that the ground motion estimates obtained in this manner lack a physical significance. Prior to that, however, a summary of the basic data provided by the Bulletin (ICOLD, 1989) as *several of the most accepted reliable* equations need to be presented. A brief discussion on general method of estimation of attenuation law follows and finally we conclude with comments on the said recommendation of the guideline.

2. Summary of the equations

Out of all the references for the equations of PGA stated in the Bulletin (ICOLD, 1989), only three (Campbell, 1981; Bolt and Abrahamson, 1982; Idriss, 1985) of them deal with the equation of PGA and it is surprising to note that rest of them do not deal with the attenuation relationships at all! First part of the summary will be with regard to the references cited in the Bulletin that do not directly deal with the subject.

3. Out of context references

At serial number 2 in the list of references in the Bulletin figures an entry for "Ambraseys, N.N. (1973): Fifth World Conference on Earthquake Engineering". However, there are no articles by Ambraseys on the subject of attenuation relationship in the entire proceedings of "The Fifth World Conference on Earthquake Engineering". There are only three discussions by Ambraseys in this proceedings. The first one (Ambraseys, 1973a) is on response spectra scaling given the information of earthquake source mechanism. The second one (Ambraseys, 1973b) is on cracking of Canyon Dam. The last one (Ambraseys, 1973c) is on the soil–structure interaction effects observed during Caracas Earthquake. The list of reference in the Bulletin does not contain any publication by Ambraseys in the year 1978. An excellent review on the subject of ground motion estimation (Douglas, 2003) is currently available, wherein it is indicated that Ambraseys (1975) proposed an attenuation relation for PGA with Local Magnitude (M_L) and hypocentral distance as independent variables based on European strong motion data. Douglas (2003) states that this article provides little information on the data selection. The Richter magnitude data is between 3.5 and 5.0 and the hypocentral distance data between 5 km and 35 km are used in proposing attenuation relation for Europe.

The article of Trifunac and Brady (1975) deals with the correlation between Modified Mercalli Intensity (MMI) and peak ground motion. This paper proposes three relationships (i) between MMI and PGA, (ii) between MMI and peak ground velocity (PGV), and (iii) between MMI and peak ground displacement (PGD).

The Boore and Joyner (1982) article is a review that deals with the necessary condition to improve the empirical projection (prediction) of strong ground motion. However, it discusses one of their paper (Joyner and Boore, 1981) that is on the subject of discussion.

The monograph of Seed and Idriss (1982) shows some illustrative plot of peak horizontal acceleration with closest distance from zone of energy release for some given earthquake surface wave magnitude M_S. This monograph does not prescribe any empirical attenuation relation for estimating PGA in terms of earthquake magnitude and distance.

4. References on the subject

Campbell (1981) proposed an attenuation relation, using data of western north America and some near-source earthquakes from other parts of the world, that does not have anelastic attenuation term. It contains a geometric spreading term, exponentially