Chapter 6
Earthquake Load Cases

6-1. Load Combinations

The cyclic and oscillatory nature of vibratory response can cause critical tensile stresses to occur in either the upstream or the downstream face of the dam. Therefore, the earthquake load cases must consider combinations of the design earthquake loading with other loads which lead to critical tension in both the upstream and downstream faces. Usually two or more OBE load cases and two or more MCE load cases must be evaluated. The discussion of earthquake load cases that follows refers to seismic criteria regarding ground shaking and foundation fault displacement as discussed in paragraphs 2-2 and 2-3, respectively, and not stability criteria described in paragraph 2-1. Load case requirements for stability are covered in EM 1110-2-2200.

6-2. Dynamic Loads To Be Considered

The design earthquake imposes several types of dynamic loads on the dam. The greatest dynamic load is the inertia load caused by the response of the concrete mass to ground motion accelerations. Next is the hydrodynamic load created by a high reservoir and tailwater condition. Hydrodynamic forces are imposed on the dam due to motions of the dam reacting with the surrounding water, and motions of the reservoir bottom. Finally, backfill or silt deposits against the faces of the dam will interact with the structural mass of the dam in a manner similar to the hydrodynamic load.

6-3. Static Loads To Be Considered

The effects on the dam structure due to static loads, as discussed below, are determined by conventional static analysis methods. The results of the dynamic and static analyses are combined by superposition to determine the total stresses for the earthquake load case.

a. Reservoir and tailwater loads. Load cases shall be included to cover both the highest and the lowest reservoir pool elevations that can be judged on a statistical basis to have a reasonable chance of occurrence at the time of the design earthquake.

(1) Flood frequency data from project flood flow and flood routing studies provide a basis for establishing reasonable high pool elevations. Each dam must be evaluated based on its own set of unique conditions.

(2) The conservation pool elevation for the project shall be used for earthquake load cases involving low pool conditions. If there is no established conservation pool, use the lowest average pool elevation that can best be judged to exist for a 30-day period in a normal yearly flow cycle.

(3) Where tailwater is applicable for an earthquake load case, the elevation shall be selected which increases the response while being consistent with the reservoir conditions.

b. Backfill load. Earth or rock fill placed against either face of the dam has both a static and dynamic load effect during an earthquake. These loads shall be included in all earthquake load cases. Static loading shall be based on at-rest pressures. Dynamic loading may be approximated by the Mononobe and Okabe method utilizing the inertia force acting on the Coulomb sliding wedge in the appropriate direction as discussed in EM 1110-2-2502. For finite element analyses the dynamic effect may be approximated by added mass based on the Coulomb sliding wedge.

c. Siltation load. During the life of the dam, silt may build up against the upstream face to a depth which may cause a moderate increase in the tensile stresses in load cases where tension in the upstream face is critical. For these load cases, siltation loading shall be considered based on the full depth expected during the life of the dam. In load cases where tension in the downstream face is critical, the siltation load will decrease the tensile stresses. For these load cases a zero depth of silt shall be assumed. When silt is included, both static and dynamic loading effects should be incorporated using the same methods as discussed for backfill loads.

d. Gravity loads. Gravity loads shall include the weight of the RCC, weight of backfill or silt on battered faces of the dam, and weight of equipment if significant.

6-4. Static Loads Not To Be Considered

There are several types of loads where the magnitude of the load and the load pattern that would exist at the time of the design earthquake event cannot be defined on a logical basis or to any degree of accuracy. However, based on the general nature and range of magnitude normally associated with loads of this type, and in comparing these loads with the dynamic and static loads already discussed, these loads normally do not contribute significantly to the results of the analyses for earthquake load cases. However, the designer should at least make a cursory evaluation of these loads to be sure that no unusual site conditions exist that would warrant including one or more of them in the earthquake load cases. For this reason, a brief discussion of these loads is included.

a. Pore pressure. When evaluating dam stability using the seismic coefficient method described in paragraph 2-1, uplift is considered to act over the entire interface area. Under the MCE, any cracking in the concrete would only extend just beyond the microcracking level. These fine cracks are open and subject to buildup of internal water pressure for a short period of time due to the oscillatory nature of the dynamic response. Therefore, uplift or internal water pressure within concrete cracks would be quite small and may be ignored in the dynamic analysis phase of design.

b. Temperature stresses. Except under extreme climatic conditions, temperature stresses need not be included as part of the earthquake load cases.

c. Wind load. Wind load on an RCC dam is so small it can be considered insignificant.

d. Ice load. Ice loading need not be included as part of an earthquake load case except for unusual climatic conditions which would cause a great depth of ice to exist over an extended period of time.