Appendix B
Design Example Problem

B-1. General Layout of Dam

a. This design example is for a new RCC dam with a straight axis located in a relatively wide canyon site. The highest nonoverflow section of the dam has a cross section which is constant over a considerable length of the dam and is considered critical for design. The dam is to be constructed with no vertical monolith joints.

b. Because of the wide canyon and straight axis, the dam can be adequately represented two-dimensionally. A transverse cross-sectional element will be used to model the dam.

B-2. Site Location

a. The dam is located in northern California, in seismic Zone 3. The proposed dam will be well over 100 ft in height; therefore, the design earthquakes must be described by site-specific design response spectra.

b. The nearest potential seismic source is a fault located approximately 35 km from the site. Fault displacement in the proposed dam foundation is not considered a reasonable possibility for this site.

B-3. Design Work Completed

For this example the design procedure will be assumed to have progressed as follows:

a. The stability analysis and stress analysis phase of design is complete for the non-earthquake load conditions and a proposed dam cross section has been developed which satisfies the overturning, sliding, and stress criteria in accordance with EM 1110-2-2200.

b. The proposed dam cross section for the critical monoliths is as shown in Figure B-1. H_s = 600 ft, and other key dimensions are shown in the figure.

c. A stability analysis was conducted using the seismic coefficients and the seismic zone maps provided in ER 1110-2-1806. The proposed dam cross section satisfies the stability requirements of EM 1110-2-2200 for these load conditions.

B-4. Factors Influencing Seismic Design

Due to the seismic zone and height of the dam, a dynamic stress analysis is required. Factors that influence the design are:

a. The low pool and normal pool elevations (el) used for the OBE and MCE design load conditions have been selected as follows:

Low pool (conservation pool el)
= el 2220.0 H=270 ft

Normal pool
= el 2445.0 H=495 ft

b. Tailwater, siltation, or static earth (backfill against the dam face) are not applicable to the OBE or MCE design load condition for this section of the dam.

c. The deformation modulus of the foundation rock expressed as Young's modulus of elasticity is

E_f = 3,500,000 psi = 504,000 ksf

d. The density of the foundation rock is 160 lb/ft^3.

e. Poisson's ratio u = 0.20 is assumed for the rock foundation.

f. The material characteristics and layering distribution of the reservoir bottom sediment deposits have not been estimated. Therefore, the wave reflection coefficient for the reservoir bottom will be based only on the water and the foundation rock. The wave reflection coefficient is calculated as follows:

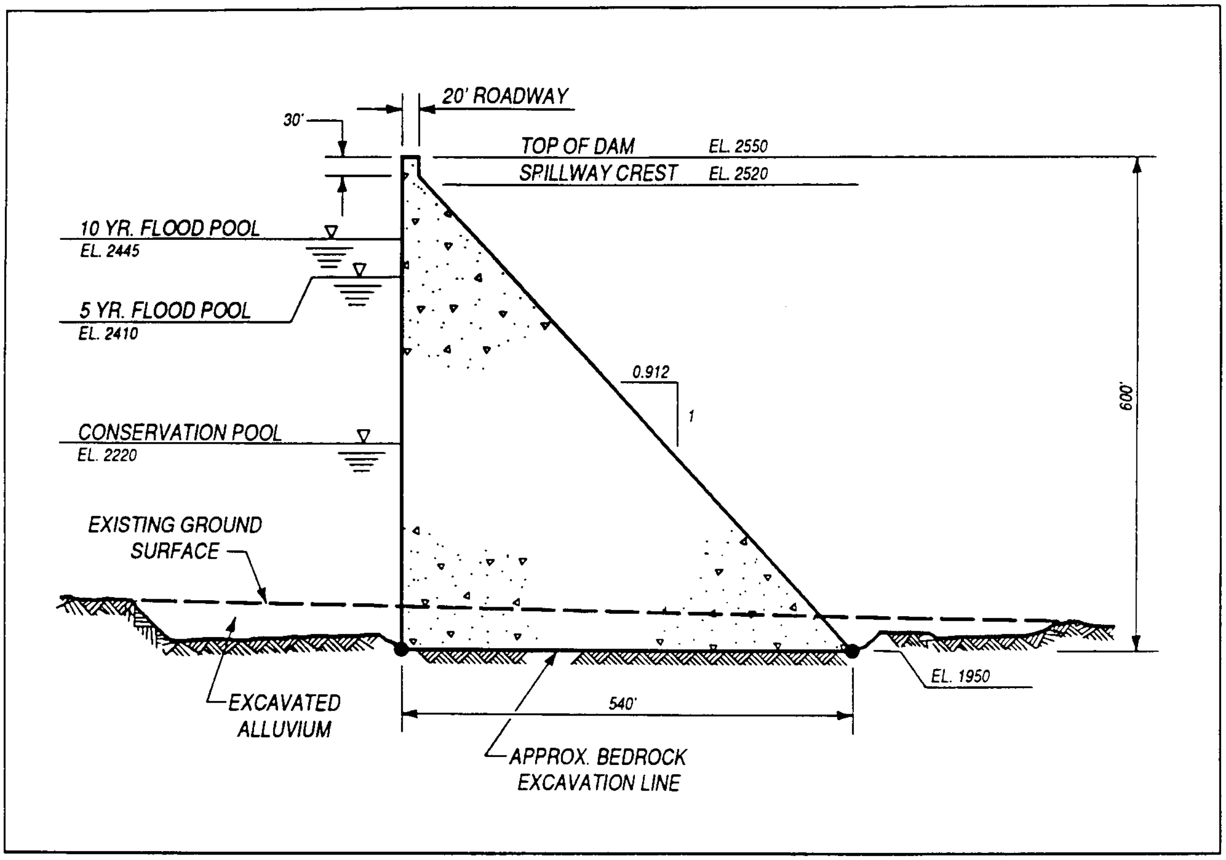

Figure B-1. Design example problem: Proposed dam cross section for the critical non-overflow monolith

$$\alpha = \frac{1 - k}{1 + k}$$

where $k = \rho C / \rho_r C_r$

$$\rho_r = \frac{160}{32.174} = 4.973 \ (lb\text{–sec}^2)/ft^4$$

$$C_r = 12 \times \sqrt{\frac{3{,}500{,}000}{4.973}} = 10{,}067 \ ft/\text{sec}$$

thus $k = \dfrac{1.938(4{,}720)}{4.973(10{,}067)} = 0.1827$

$$\alpha = \frac{1 - 0.1827}{1 + 0.1827} = 0.69$$

B-5. Basic RCC Mix Design

A typical basic RCC mix design will be used for the example problem. Characteristics of the basic RCC mix are as follows:

a. MSA > 1.5 in.

b. Consistency < 30 sec vibration.

c. Lift joints will have mortar bedding.

d. f'_c = 3,000 psi.

e. Unit weight = 155 pcf.

f. The seismic modulus of elasticity of the RCC is calculated as follows:

E = static modulus = $57{,}000\sqrt{3{,}000}$
= 3,122 ksi

E_r = ratio of seismic strain rate to quasi-static rate is assumed to be 1,000

E_s = seismic modulus = E' = $E(E_r)^{0.020}$
= $3{,}122(1{,}000)^{0.020}$

E_s = 3,590 ksi = 517,000 ksf

g. Poisson's ratio for high seismic strain rate is calculated as follows:

u' = 0.7u = 0.7 × 0.20 = 0.14

h. Direct tensile strength has been determined from cores taken from test-fill placements and is

f'_t = 290 psi (for the parent concrete)

f'_t = 205 psi (for the lift joints)

B-6. Superior RCC Mixes

The design for this example problem will not be considered to have progressed to the stage where zones of superior RCC concrete will be included in the computer models for analyses. However, the analyses will indicate if superior zones are needed, and, if so, where the zone boundaries might be located.

B-7. Horizontal Design Response Spectra

Since the site is in Seismic Zone 3, site dependent design response spectra are required to establish the design earthquakes. The standard design response spectrum for the horizontal component of ground motion shown in Figure 5-1 and Table 5-1 will be considered to be the site dependent design response spectrum. The design response spectrum will be anchored using the peak ground accelerations (PGA's) provided in Table 5-2, which for seismic Zone 3 are:

OBE: 0.210 g

MCE: 0.550 g

B-8. Vertical Design Response Spectra

For this example, the vertical design response spectrum will be considered equal to the horizontal design response spectrum described above; however, it will be anchored on the basis of the ratio of the vertical component PGA to the horizontal component PGA as shown in Figure 5-3.

B-9. Dynamic Analysis Procedure

a. This example problem represents an RCC dam subject to critical seismic design conditions as defined in Chapter 8. Under these critical seismic conditions, the simplest method of dynamic analysis to utilize a dam-foundation-reservoir model composed of a composite finite element-equivalent mass system shall be used for either preliminary or final design. Appendix D will show the analysis of the example problem by this method. To reduce the amount of data and to make the procedure easier to follow, only the MCE load cases will be analyzed. Analysis for the OBE load cases would follow the identical procedure.

b. Although an RCC dam subject to critical seismic conditions would not normally be analyzed by Chopra's simplified method, Appendix C shows an analysis of the example problem by this method for demonstration purposes and to allow a comparison of the results by the two different methods.