EXERCISE 1

Verification of a gravity dam according to the Swiss directives

a) Introduction

As part of the renewal of the concession for the XYZ dam, the construction of which was completed on June 14, 1988, verification of the seismic safety of the dam was required according to current Swiss directives[1].

For this exercise, it is requested to carry out the static and dynamic safety verifications of the dam according to the current directive. In addition, a safety verification for the full reservoir is required:

- Static analysis: Safety against sliding and overturning
- Dynamic analysis: Safety against failure, sliding and overturning

Bonus:

- *Justify whether the structure is eligible for the simplified verification of earthquake safety for small gravity dams, according to part 7.1 of the directive*[1]*.*
- *Carry out the analyses (static and dynamic) with an empty reservoir. Comment by comparing with the results obtained for the full reservoir.*

b) Dam type and geometry

The dam XYZ is a concrete gravity dam with two main cross-sections (see *Figure 1*). The two sections have significantly different geometries and must be checked separately. The characteristics of the dam are as follows:

Crest:	1154 MSL
Water level in the reservoir:	1152 MSL
Water height in the reservoir:	
Chute:	19 m (foundation 1133 MSL)
Principal section:	15 m (foundation 1137 MSL)
Significant height considered for classification:	19 m
Block width:	10 m
Chute width:	6 m
Total reservoir capacity:	38'000 m^3
Crest length:	70 m
Freeboard:	2.60 m

[1] Directive sur la sécurité des ouvrages d'accumulation - Partie C3 : Sécurité en cas de séisme

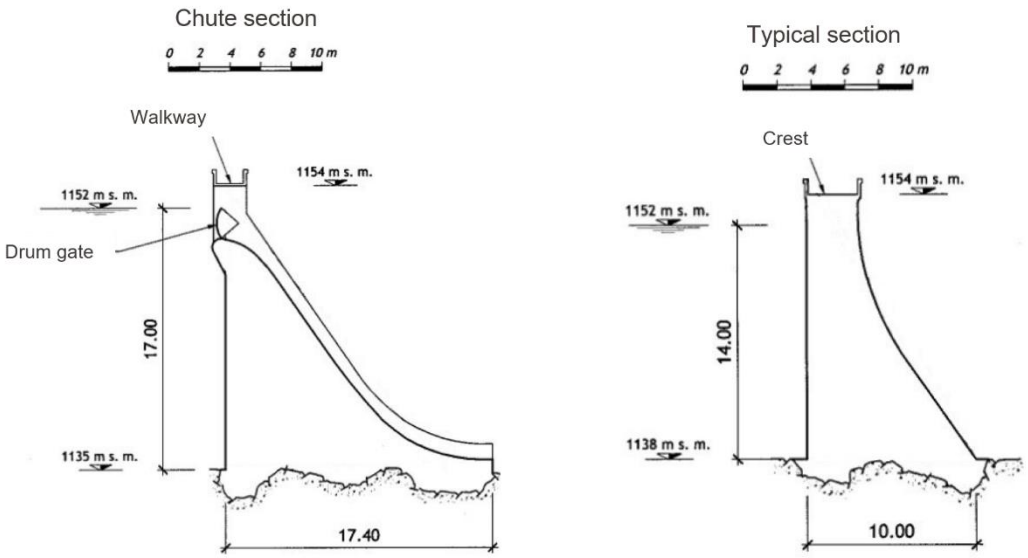

Figure 1: Gravity dam. Main cross-sections

c) Situation

The site is located at a latitude of 46.446° N and longitude of 9.189° E with respect to the WGS84 coordinate system.

d) Geology of the foundation

The foundation is made off a compact gneiss with a shear wave speed equal to 2’500 m/s.

e) Classification

According to Swiss directives (see also *Figure 2* below), the dam is of category III (h=19 m, v=38'000 m^3).

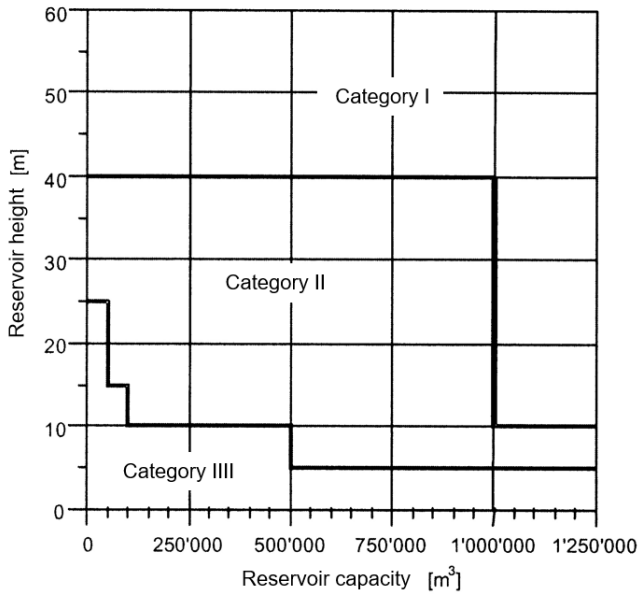

Figure 2: Dam category

f) Verification earthquake

The verification earthquake return period is 1,000 years for category III structures.

The seismic hazard map (see *Figure 3*) provided by the European Facilities for Earthquake Hazard and Risk (EFEHR)[2] gives the corresponding reference horizontal acceleration for the dam site.

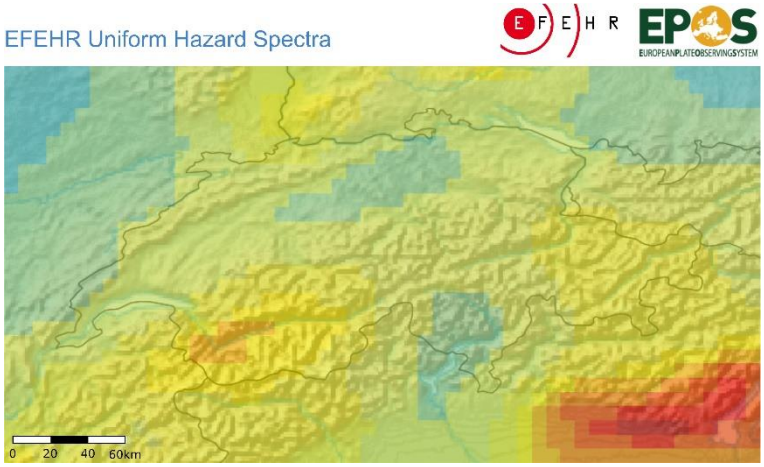

Figure 3: Seismic hazard map

g) Structural characteristics of the dam and characteristic material values

The following hypotheses have been accepted on the basis of the project documents as well as the literature for concrete structures.

- The dam material is assumed isotropic
- The strength parameters of the foundation rock were chosen based on values indicated in the literature for similar lithologies
- The uplift distribution is assumed triangular with an uplift coefficient of k=0.4 for the static analysis and k=1 for the dynamic analysis (Attention, uplift must not be considered during the verification of the safety against internal failure unless water is expected inside)
- The main characteristics and assumptions considered for the analysis are summarized in Table 1 (the values are already reduced for the foundation of Category III structures).

[2] EFEHR: hazard spectra

Problem characteristics		
Dam		
Static elasticity modulus	E_s	= 20'000 MPa (1)
Dynamic elasticity modulus	E_d	= 1.25 Es = 25'000 MPa
Poisson's coefficient	ν	=0.25 (1)
Density	ρ	= 2'450 kg/m^3 (2)
Damping	4 %	
Static compressive strength	f_{cs}	= 15 MPa (1)
Dynamic compressive strength	f_{cd}	=1.5 f_{cs} = 22.5 MPa
Dynamic tensile strength	f_{td}	=0.1 f_{cd} = 2.25 MPa
Dynamic tensile strength of concrete lifts	$\sigma_{t, max}$	=1 MPa
Ground		
Compressive rock strength	σ_c	= 5 MPa
Tensile strength concrete / rock	σ_t	= 0.3 MPa
Shear strength concrete / rock	c	= 0.3 MPa

(1) Based on the following reference:

Donaggio, E ; « Manuale del calcestruzzo armato », Zanichelli 1990.

(2) Admitted based on hypothesis of the dam project:

« Relazione tecnica del progetto esecutivo », 1956

Table 1: Calculation hypotheses