

EARTHQUAKE ANALYSIS OF ROLLER COMPACTED CONCRETE DAMS

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Introduction

The construction of roller compacted concrete (RCC) dams has become widespread during the last decade. At present there are more than 170 dams of the kind, made entirely or partially by the RCC method all over the world (these under project and these less than 15 m height inclusive). This fact determines the interest in the RCC dams properties. The most important advantages are the reduction of building prices [1] and planned terms [2], the absence or decreased number of joints [1], the possibility for performing special procedures for improving the temperature conditions [3], etc.

Some works in which these problems are treated are known, but only in two of them [4,5] the results of the dynamic investigations have been reported. In the other works such investigations are only mentioned.

The concrete elasticity modulus must be known for the dynamic investigation of RCC dams. The most comprehensive data are represented in [6]. The recommended limits for the RCC elasticity modulus values are from 15 to 25 GPa [1]. The problems of their determination are discussed [3,7] and 50 GPa is pointed out to be a theoretical upper limit in [7].

The GRDAM programme for a numerical analysis of concrete gravity dams

A computer programme GRDAM for a numerical analysis of gravity dams is made. The Finite Elements Method (FEM) has been used as a contemporary and very popular

instrumentation for analyzing the dynamic response of dams. The use of volumetric finite elements (tetrahedrons) increases essentially the FEM's advantages and enables a more accurate description of the objects' geometry as well as the physical and mechanical characteristics.

The approximations of displacements for the tetrahedron elements and the shape forms are linear so the integration is performed in a closed form, i.e. an approximation computing error is not introduced and processing time is being saved.

The earthquake effect is taken into account by the Spectrum Method. A technique for receiving scale multiplier of displacements for calculated seismic forces has been used [8].

The programme realization and some results of the implemented numerical investigations are reported earlier in [9, 10].

Numerical analysis of RCC dams

The GRDAM programme has been used for analysing the Willow Creek RCC Dam (USA) – the world's first dam made entirely of RCC, and the Miyagase RCC dam (Japan) – one of the highest RCC dams in the world. Some basic data on the geometry and concrete [2, 3, 11] and on the finite elements meshwork are represented in Table 1.

The results are obtained by the seismic coefficient $k_S = 0,27$ for an earthquake of the 9th degree according to the MSK - scale. The water influence is not discussed in this work.

The three typical modes for each dam are shown in Fig. 1 and Fig. 2. The normalized transversal and vertical displacements in the longitudinal profile along the y and z axes are indicated in the plane of the drawing and the longitudinal displacements – along the x axis – with 45° incidence.

Table 1

Dams' parameters	Willow Creek			Miyagase
Height, m	50,77			155
Length, m	411,5 [†]			400
Elasticity modulus, MPa	13169	19168	22409	24000
Poisson's ratio	0,17	0,18	0,21	0,20
Volume weight, kN/m ³	24,66	24,83	24,83	24,80
Number of nodal points	276			275
Number of tetrahedrons	1020			1032
Number of degrees of freedom	636			630

[†] Full crest length of the dam – 543 m

The cross profiles are related to the sections where the maximum displacements are located while these along the x and z axes are shown in the plane of the drawing and the transversal ones along the y axis – with 45° incidence.

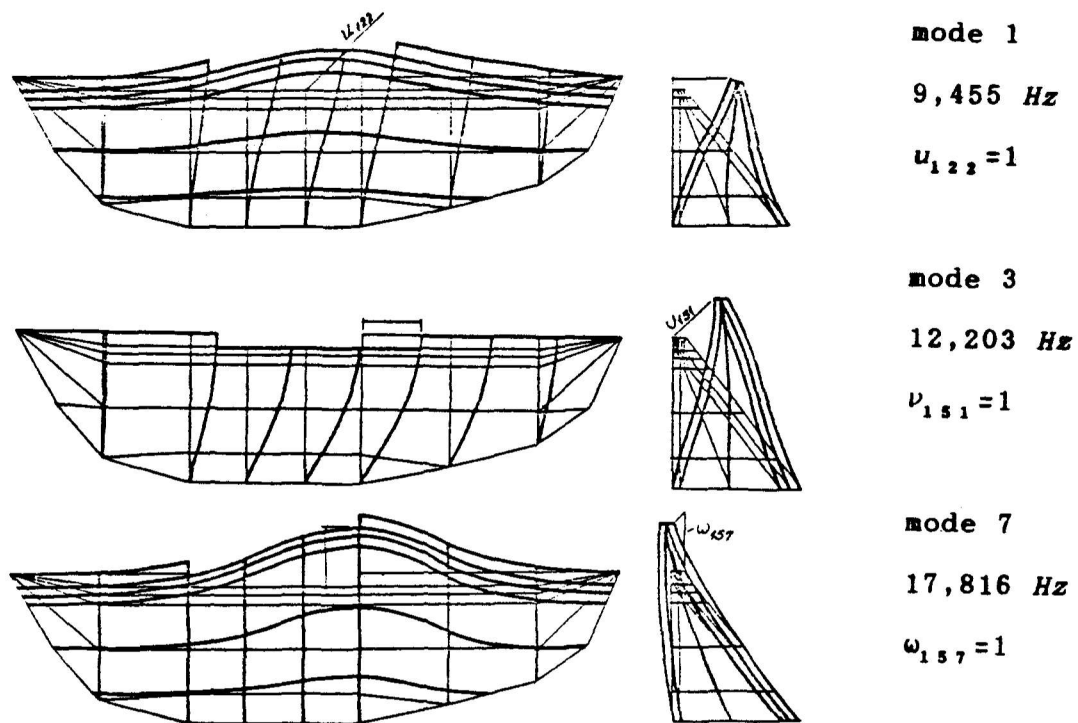


Fig. 1

Investigation of the influence of the elasticity modulus

The elasticity modulus increases proportionally to time. Its influence towards the dynamic characteristics of the analysed RCC dams is determined at constant values of the Poisson's ratio and of volume weight of concrete. For both dams the elasticity modulus is chosen within the limits of 10 to 50 GPa and for the Willow Creek dam the relations E_2/E_1 and E_3/E_1 are constant.

The maximum dynamic vertical stresses σ_{ZZ} summed for 10 modes for the investigated ranges of the elasticity modulus and their frequency areas are represented in Table 2. It is shown that the maximum stresses decrease in the course of time contrary to the concrete elasticity modulus.

Conclusions

By means of the GRDAM programme a spectrum of frequencies and modes with

maximum displacements in the three directions has been obtained for the analysed dams. This is one of its principal priority over the conventional plain models for the numerical analysis. The modes keep their types for different elasticity modulus and the maximum displacements appear in the same nodal points.

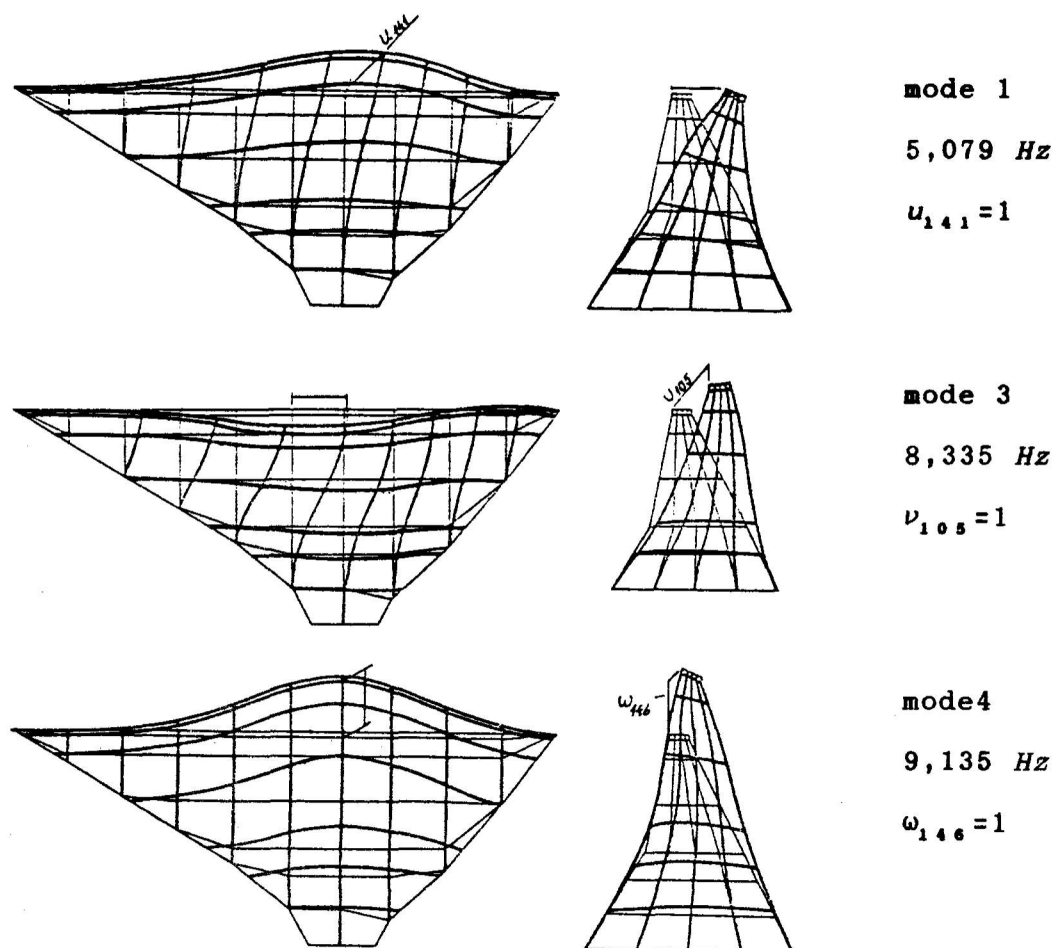


Fig. 2

Table 2

Willow Creek dam				Willow Creek dam				Miyagase dam			
$E^\dagger$	f_1	f_{10}	σ_{zz}	$E^\dagger$	f_1	f_{10}	σ_{zz}	$E^\dagger$	f_1	f_{10}	σ_{zz}
GPa	Hz	Hz	MPa	GPa	Hz	Hz	MPa	GPa	Hz	Hz	MPa
8,14	6,3	14,4	1,183	10	7,6	17,1	0,896	10	3,3	9,9	1,672
18,25	9,5	21,6	1,178	20	10,8	24,2	0,891	20	4,6	14,1	1,670
26,33	11,4	25,9	1,171	30	13,2	29,6	0,885	30	5,7	17,2	1,667
41,58	14,3	32,6	1,166	40	15,2	34,2	0,882	40	6,6	19,9	1,665
48,51	15,4	35,2	1,164	50	17,0	38,2	0,880	50	7,3	22,2	1,663

† Arithmetic average elasticity modulus for a dam with three zones

‡ Elasticity modulus for dams with one zone

The data on the concrete physical and mechanical characteristics should be determined reliably and accurately for the different zones and ages for the precise determination of the strain and stress conditions of RCC dams, of the conventionally constructed gravity dams and especially of the older ones.

The building on RCC dams is a perspective activity that could satisfy the necessity of water and electric power with comparatively small investments without any essential damages on the environment and with great chances for refunding because of the short construction terms.

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