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Dynamic Analysis of Concrete Gravity Dams due to Nonuniform Translation and Rotational Components of Earthquake Considering Reservoir Interaction

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ABSTRACT

The main purpose of this paper is presentation of proper finite element formulation for dynamic analysis of concrete gravity dams under nonuniform translational and rotational components of earthquake considering dam- reservoir interaction. Time delay of travelling waves is considered to generate the nonuniform ground motion and the rocking component of earthquake has been obtained using the corresponding translational components based on classical elasticity and elastic wave propagation theories in term of wave frequency functions. The translation and rocking components of ground motion are applied to support points of dam-reservoir bottom and analyses are done using finite element method based on Lagrangian-Lagrangian approach. Results show that the rocking component and time delay of travelling translation waves can considerably affect linear dynamic response of concrete gravity dams in some cases.

KEYWORDS:

Nonuniform Translation of Ground Motion, Rocking Component, Dam - Reservoir Interaction, Lagrangian Method.

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1- BRIEF INTRUDUCTION

Often in the seismic analysis of structures, the nonuniform ground excitation due to spatially varying ground acceleration is neglected. Also the kinematics of any point in a medium is ideally expressed in terms of three translational and three rotational components but only translational components are usually considered in calculations. The theory of nonuniform ground excitation is the first established by Chopra [1] on dynamic analysis of dams. Then other researchers study its effects using several methods on dynamic response of dams [2, 3]. Newmark [4] was perhaps the first to establish a relationship between the torsional and translational components of a ground motion based on constant velocity of wave propagation assumption. Lee and Liang [5] have used wave propagation and classical elasticity theories based on constant wave velocity to develop the algorithms for generating rotational motion from the corresponding available translational motions and Hong-Nan Li et al [6] proposed an improved approach based on frequency dependent wave velocity to generate the rotational components. The studies about the effect of rotational and translational components on structure response are very few. In this research the effects of nonuniform rotational and translational components of ground motion on dynamic response of concrete gravity dam are investigated.

2- METHODOLOGY

The main purpose of this research is evaluation of dynamic response of concrete gravity dams considering nonuniform three correlated translational and rotational components of ground motion and dam-reservoir interaction using finite element method. For this purpose the rotational component of ground motion is obtained using translational components and relation of classical elasticity between rotation and wave propagation theories considering frequency dependent wave velocity. Then the nonuniform ground accelerations considering time delay of wave propagation are generated. Finally these rotational and translational nonuniform components are applied in finite element model and the dynamic response of system are calculated using Newmark method and Lagrangian-Lagrangian approach based on displacement unknown in both solid and fluid domains. In addition with change of earthquake acceleration and water elevation, the normalized response of dam is evaluated.

In this paper, the Pine Flat concrete gravity dam is used to study where its geometrical characteristics are shown in Fig. 1[7].

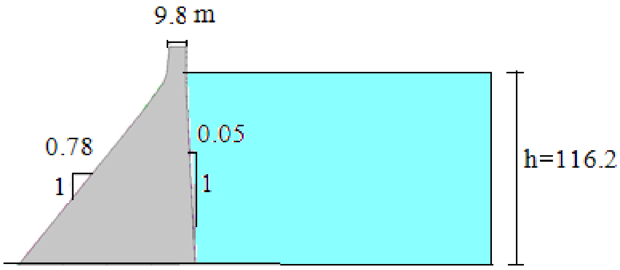

Figure 1. The Geometrical characteristic of Pine Flat dam- reservoir system

The three earthquakes where are used in calculations are Northridge 1994, Taft and San Fernando1971.

The material properties of dam are the elasticity modulus; E_d = 2.275*10^{10} N/m^2, density; ρ_d= 2500 kg/m^3, poison ratio; υ= 0.2. The bulk modulus and density of water are also considered K_w= 2.07*10^{10} N/m^2 and ρ= 1000 kg/m^3.

3- NUMERICAL RESULTS

The horizontal and vertical displacement of dam crest for dam- reservoir systems subjected to uniform two translational components, 2C, nonuniform two translational components, N2C, and nonuniform three components, two translational added by their correlated rotational components, N3C, are obtained and the ratio of response due to N2C and 2C which is named as normalized response N1H, N2H and N1V, N2V are presented in Tables 1 and 2.

4- CONCLUTION

Obtained results show that the effects of nonuniform translational and rotational components of ground motion on the dynamic response of concrete gravity dams can be low or high depend on their frequency amplitude and power spectrum. In addition with increasing of water elevation, the rotational effect will increase and the normalized response also will change.

5- MAIN REFERENCE

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Table 1. Maximum horizontal displacements and normalized response

Reservoir	Earthquake	Maximum horizontal displacement (m)			N1H	N2H
		2C	N2C	N3C		
Empty	TAFT	0.0311	0.0215	0.0321	0.691	1.032
	.SAN	0.0663	0.0598	0.0637	0.902	0.961
	.NORT	0.0594	0.0476	0.241	0.801	4.057
1/3full	TAFT	0.0308	0.0191	0.0238	0.620	0.773
	.SAN	0.0855	0.0756	0.0771	0.884	0.902
	.NORT	0.0682	0.0530	0.2360	0.777	3.460
2/3full	TAFT	0.0500	0.1150	0.1230	2.300	2.460
	.SAN	0.0766	0.0757	0.0842	0.988	1.099
	.NORT	0.0683	0.0667	0.3570	0.976	5.350
full	TAFT	0.0334	0.2760	0.2750	8.260	8.230
	.SAN	0.1140	0.2850	0.2850	2.500	2.500
	.NORT	0.0725	0.4230	0.4680	5.830	6.45

Table 2. Maximum vertical displacements and normalized response

Reservoir	Earthquake	Maximum vertical displacement (m)			N1V	N2V
		2C	N2C	N3C		
Empty	TAFT	0.0096	0.0063	0.0097	0.656	1.010
	.SAN	0.0225	0.0217	0.0233	0.964	1.035
	.NORT	0.0143	0.0164	0.0771	1.147	5.392
1/3full	TAFT	0.0084	0.0049	0.0069	0.583	0.821
	.SAN	0.0246	0.0247	0.0256	1.004	1.036
	.NORT	0.0180	0.0151	0.0716	0.839	3.977
2/3full	TAFT	0.0160	0.0396	0.0425	2.475	2.656
	.SAN	0.0261	0.0296	0.0325	1.134	1.245
	.NORT	0.0202	0.0255	0.1130	1.262	5.594
full	TAFT	0.0120	0.0851	0.0859	7.091	7.158
	.SAN	0.0382	0.1660	0.1670	4.345	4.372
	.NORT	0.0257	0.1580	0.1870	6.147	7.276

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