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Reliability Estimation of RCC Dam Structure due to Earthquake

Sayed Abul Hossain, Satyajit Pal, Jafar Sadak Ali

Abstract*: *Dams are assessed and created according to conventional factor of safety methodology. A few disadvantages with this approach occur; as an example failure that is varying for structures where in actuality the factor of safety is the same. This component that is traditional facto of safety methodology imposes conservative assumptions when it comes to both design and analysis. Reliability analysis of structures suggests the estimation associated with limit state probabilities of the framework under adverse or loading that is ecological its intended period of use. Many aspect that is important of seismic reliability analysis is recognition of uncertainties, options for modelling and analysis, analytical formulation regarding the restriction state surface and integrated of probability thickness function. The limit state possibility of the structure is integrated using the seismic danger of the site in the seismic reliability analysis associated with the dam structure. In this study, Koyna dam framework is modelled and seismic reliability associated with the framework that is dam empty reservoir are analyzed. The transient analysis is done by considering Lucerne earthquake records. The randomness of ground movement, uncertainties in its event, definition of the intensity parameters are considered in seismic reliability analysis. The material uncertainties of the dam are included in the research. Due to complexity of analysis included, different level of simplifications are produced in the reliability analysis. The reservoir depth is varied to examine its influence on the seismic reliability analysis. The crest displacement and the base shear force are the responses obtained to study the seismic reliability analysis. The performance requirements are developed on the basis of the reliability analysis of the dam structure.

***Index Terms*: Koyna Dam, Reservoir Depth, Seismic Reliability, Uncertainties.**

I. INTRODUCTION

Dams are crucial infra-structures their failure could leads to large financial and social consequences because of this, quantitative risk analysis has gained extensive attention in modern times. Dam safety management is becoming a vital element of all dam engineering projects all over the world. Dams provide services such as water supply, irrigation, flooding hydropower and control energy. Seismic excitation loads are the most crucial tasks that must definitely to be considered in concrete dam design. Old strategy for concrete dam design views forces as a result of seismic excitation as comparable fixed force that are with the addition of area of the reservoir .However, the formulation that is pseudo-static perhaps not satisfactory to reproduce the dynamic behaviour for the combined system of dam-foundation-reservoir. A solid gravity dam comes into a required vibration state, that initiates vibrating motions associated with the upstream face with as for the static at nonetheless place when you look at the earthquake. These general displacements of dam-reservoir s disrupt the state of tension-prior to your earthquake motion-in the size that is certainly fluid and later cause force waves. This framework that is certainly complementing which develops quickly within the fluid of reservoir, requires pressure trend propagation and reflection procedures at solid boundary of this reservoir and also at its free area. As a notice of seismic response associated with the combined fluid-structure framework, entirely the wave representation during the face that is upstream of intrigue. The immediate results of revolution representation is the fact that the hydraulics stress, due to the deformation that is certainly flexible of dam. The hydrodynamic stress should be provided within the analysis by considering liquid compressibility when you look at the reservoir. In the design of a framework dam-reservoir hydraulic pressure on dam faces is essential, especially caused by earthquake surface motions. The pressure that is certainly hydraulic in the dam geometry, the compressibility of liquid in the reservoir in addition to absorption of stress waves at the end associated with reservoir. To get the stress that is hydraulic two kinds of practices are analytical and numerical people.

Literature review prove that there is a lot of work in days gone by in the dynamic reaction associated with concrete gravity dam with dynamic excitation. O.C. Zienkiewicz and P. Bettes contemplated the dam reservior in a combined manner thinking about the adaptability of the dam. Fenves and Chopra introduced a strategy that is basic analysis of concrete gravity dams under seismic actions. A.M. Jablonski and J.L. Humar explained the effective use of the constant boundary element method in the three-dimensional boundary element reservoir design for seismic evaluation of arch and gravity dams. Tsai and Ketter acquired solution regarding the dam-reservoir issue using a mix of FEM, BEM with particular integrals, model analysis, and sub structuring. Many researchers have actually experimented with expand the response range method of evaluation when it comes to complete instance of multi-support excitation . Recently, Der Kiureghian create a means for fixed vibration that is random of MDOF methods that might be easily applied for building using response spectrum when it comes to earthquake. Soliman and Datta also used comparable evaluation process to find the response of piping system under non-stationary multi-component random ground movement that .

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* Correspondence Author (s)

Sayed Abul Hossain*, Civil Engineering, CIET, Budbud, Bardhaman, India
Satyajit Pal, Civil Engg, MCET , Murshidabad, India.
Jafar Sadak Ali, Civil Engineering, Aliah University, Kolkata, India

Seismic analysis of gravity dam-reservoir structures using the eulerian approach and lagrangian carried out by Y. Calayir, A.A. Dumanoglu and A. Bayraktar . F. Guan and I.D. Moore created practices that are

new modelling reservoir-dam and foundation-dam conversation. A hybrid numerical procedure is recommended when it comes to powerful frequency domain reaction of earth dams resting for a foundation that is multi-layered. Araujo and Awruch used a probabilistic finite element method for the analysis of the concrete gravity dam . Ghaemina and Ghobarah studied the nonlinear reaction that is certainly seismic of gravity dam considering the conversation associated with dam and reservoir. Dynamic soil-structure interaction analysis via coupled finite-element and boundary-element method was studied by Masoud R. Kazemi compare between level of protection given by traditional that is allowable and Ultimate Limit States or Reliability Based assessment of the gravity based structures susceptible to different load situation. Q.S.Li at el. studied the FEM method for seismic evaluation of tall structure under random seismic activity. S.Kucukarshan, S.B.Coskun and B.Taskin studied the transient analysis of dam reservoir relationship like the reservoir bottom effects. Abhijit Chaudhuri and Subrata Chakraborty developed basic framework of the time different unconditional reliability of linear elastic multi degree of freedom frameworks with uncertain parameter afflicted by the general earthquake floor motion, a non-stationary process in both amplitude and regularity content. Manohar C.S and Abbas A.M calculated the seismic

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II. MATH

Newark's β Numerical integration method

$$\dot{u}_{i+1}=\dot{u}_i+[(1-\gamma)\Delta t]\ddot{u}_i+(\gamma\Delta t)\ddot{u}_{i+1} \qquad (1)$$

$$u_{i+1}=\dot{u}+(\Delta t)\dot{u}_i+[(0.5-\beta)(\Delta t)^2]\ddot{u}_i+[\beta(\Delta t)^2]\ddot{u}_{i+1} \qquad (2)$$

The parameter β and γ define the deviation of acceleration over a time step and define the stability and accuracy characteristics of the method.

Typical section for γ is $\frac{1}{2}$ and $\frac{1}{6}\le\beta\le\frac{1}{4}$ is adequate from all factors of view, including that of accuracy. These two equations, combined with the equilibrium equation at the end of the time step, provides the basis computing $u_{i+1}, \dot{u}_{i+1}$ and $\ddot{u}_{i+1}$ at time $i+1$ from the known u_i, $\dot{u}_i$ and $\ddot{u}_i$ at time i. Iteration is required to implement these computations because the unknown $\ddot{u}_{i+1}$ appears inside the proper aspect of the equation.

Finite element model (FEM) generation:

$$[\bar{K}]=[T]^T[K][T] \qquad (3)$$

$$[\bar{M}]=[T]^T[M][T] \qquad (4)$$

where $[M]$ is elemental mass matrix,

L=length of element, $\bar{M}$ = mass per unit length. The local coordinate of stiffness matrix and mass matrix is transfer to the global coordinate stiffness matrix and mass matrix by using the transformation matrix $[T]$ Now the global stiffness matrix $[\bar{K}]$ and the global mass matrix $[\bar{M}]$ are calculated as below

As the gravity dam is considered plate element, total number of plate elements=42, total number of nodes =63, hence total degrees of freedom 3X63=189, bottom most element is considered rigidly fixed with the base hence reduce degrees of freedom =180. After assembling the global stiffness matrix and mass matrix eigen solution gives.

$$\left\|[\bar{K}]-w^2|\bar{M}|\right\|=0 \qquad (5)$$

to get the natural frequencies and mode shape of the 2D equivalent dam model.

Reliability evaluation

The total reliability concept is one of the most important theorems in the overall reliability of the structure under parameter uncertainties. Knowing that conditional

$$R_{uc}(x_0,t)=\int_{1.....N}...\int R_c(x_0,t\,|\,\{\Delta d\})\,f\left(\{\Delta d\}\right)d\Delta d_1,.......,d\Delta d_N$$

The output power spectral density takes the form

$$S(\omega)=\frac{1+4\xi_g^2\left(\omega/\omega_g\right)^2}{\left[1-\left(\omega/\omega_g\right)^2\right]^2+4\xi_g^2\left(\omega/\omega_g\right)^2}S_0 \qquad (6)$$

Kanai- Tajimi function has nonzero value in the origin of the axis, which is not realistic. In order to avoid this problem Clough-Penzine model use two different filters, always derived from singular degree of freedom system transfer function. One of this filter removed the low frequency content of the Gaussion white noise so that the final function can be written as:

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$$S_f(\omega)=\frac{\omega_g^4+4\omega^2\omega_g^2\xi_g^2}{\left(\omega^2-\omega_g^2\right)^2+4\omega^2\omega_g^2\xi_g^2}\frac{\omega^4}{\left(\omega^2-\omega_f^2\right)^2+4\omega^2\omega_g^2\xi_f^2}S_0 \qquad (7)$$

Filter parameter proposed by Neuenhofer and Kiureghian

Table 1: Soil properties of dam

Soil type	ω_g (rad/s)	ξ_g	ω_f (rad/s)	ξ_f	S_0 m^2/s
Soft	5.0	0.2	0.5	0.6	1.0
Firm	15.0	0.6	1.5	0.6	1.0

III. Result and Discussion

To illustrate the proposed method to reliability estimation based on frequency domain analysis and total reliability of the concrete gravity dam, a numerical code is developed in MATLAB 9.2 platform based on the theoretical formulation. The numerical model of a 103 meter high concrete gravity dam with base 70 m, top diameter 14.8 m, chest is 19.25m. No upstream side slope is considered. The downstream slope from top to chest is $1/6.54$ and from chest to base is $1/1.38$. Here the dam is considered as plate elements discretized in 40 numbers of four-noded beam elements.

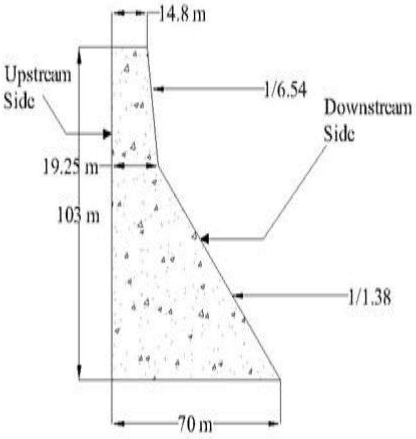

Figure 1. Dam diagram of height 103m

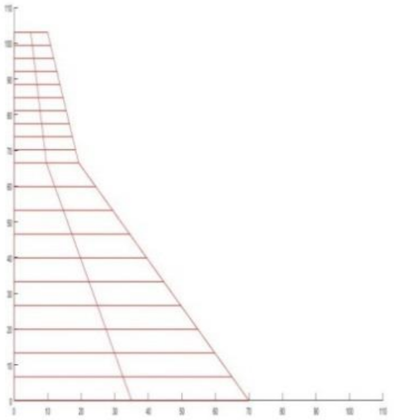

Figure 2: Numerical model of dam in MATLAB

Table 2: Material properties of dam

Height (m)	Material	Base (m)	Top (m)	Chest (m)	Mass Density (kg/ m^3)	Young Modulus (GPa)
103	Concrete	70	14.8	19.25	2500	31

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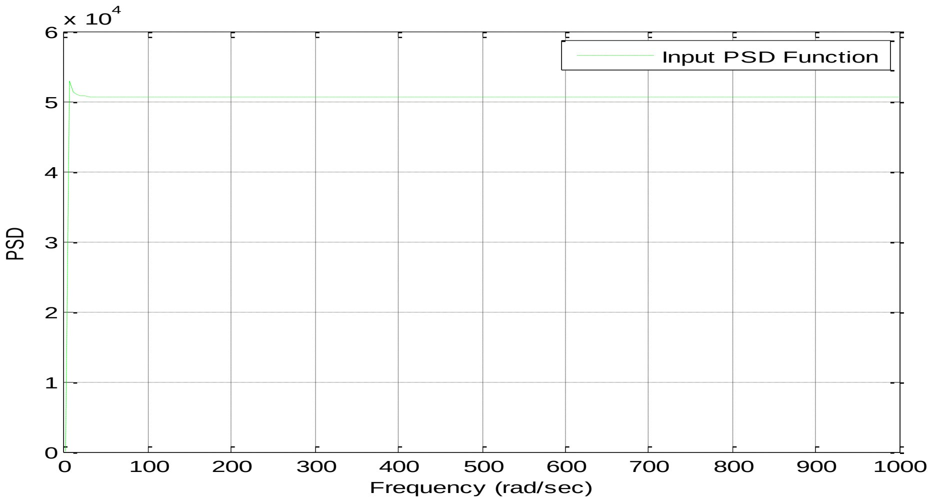

Figure 3. Plot of Input Power Spectdral Density Function (PSDF) of Acceleration

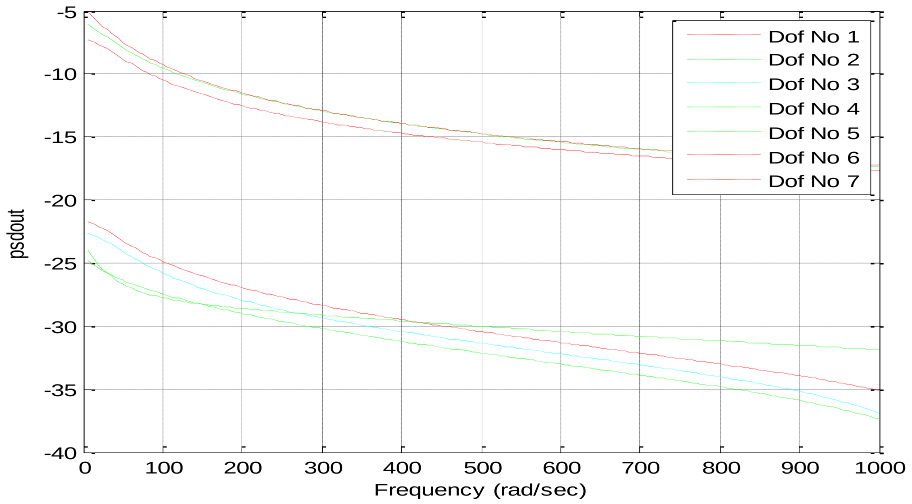

Figure 4. Plot of Output Power Spectral Density Function (PSDF) of Acceleration

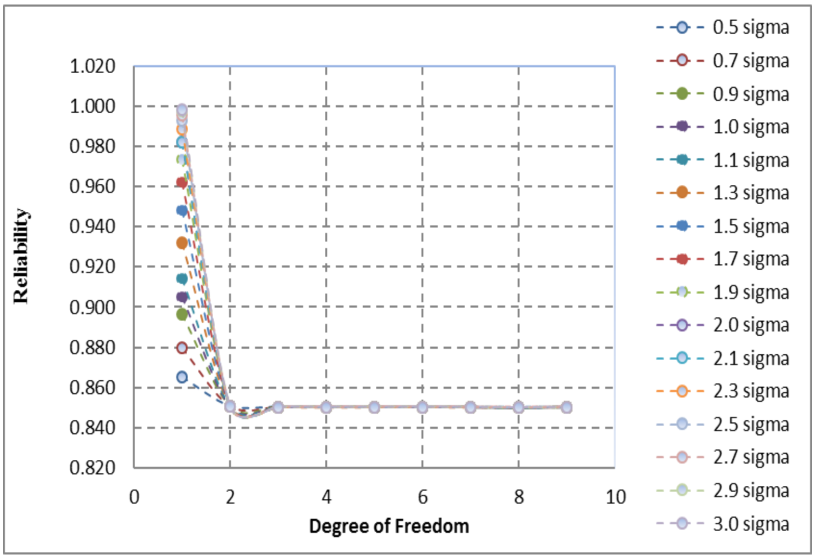

Figure 5. Plot of Reliability at first degree of freedom

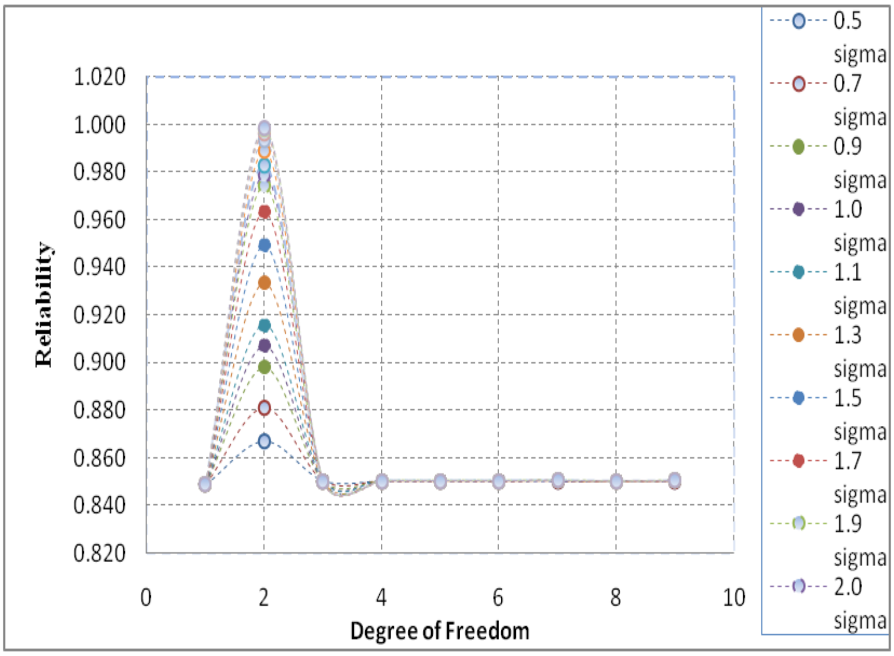

Figure 6. Plot of Reliability at second degree of freedom

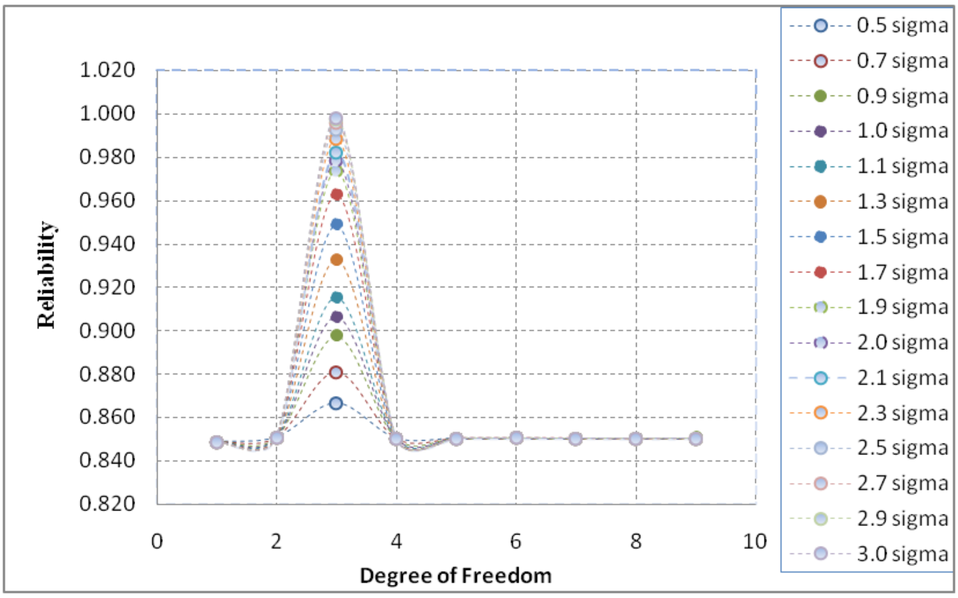

Figure 7. Plot of Reliability at third degree of freedom

IV. CONCLUSION

Based on the various results obtained from the present numerical study, the following conclusions may be done. The reliability analysis of concrete gravity dam structure seems to be significantly important considering the random nature of loading and uncertainties associated with the design and construction of dam structure. The total reliability as derived significantly varies with respect to cross sectional area, moment of inertia if considered as random variable. Reliability at different degrees of freedom of the structure largely depends on the crossing level for any stochastic random process. The reliability of the structure at different DOF does not change if no of damaged element is less and The Reliability value gradually reduced in all DOF if most of the member in the structure is damaged.

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