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A Review on Analysis of Seismic Effect on Dam using FEM Techniques

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Abstract:

Seismic response of dam is affected by various effects such as interaction of dam with reservoir foundation, reservoir water compressibility, reservoir bed absorption and effect of sloshing waves. The safety of existing dam against seismic loads, as well as the design of new earthquake-resistant dams, has been the subject of extensive research in recent decades. This paper is review about the effect of hydrodynamic pressure on dam, dynamic analysis of dam using FEM software, behaviour of dam under dynamic loading and effect of interaction of dam-reservoir- foundation. Many research has also been done to evaluate a hydrodynamic pressure on dam, the effect of water level of reservoir that affect performance of the dam and absorption of hydrodynamic pressure waves onto the reservoir bottom materials.

Key Words: *Dam, Reservoirs, Hydrodynamic Pressure, FEM.*

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I. INTRODUCTION

A dam is hydraulic structures built across a river or stream to create a reservoir on its upstream side. Due to seismic activity the probability of failure of dam increases and which may form crack within the structures. Therefore, it is most important to check the safety of the dam against all the forces. In this paper, we consider only the hydrodynamic force on dam. Fluid-Structure interaction causes a hydrodynamic force, which can be exerted to the dam and affects it response. Numerous studies are evaluated that the hydrodynamic force that develop on the upstream face of dam during severe excitations and evaluate the behaviour of dam under the seismic load. Later on, the finite element method (FEM) was introduced because of its advantages over the established method, since FEM produces more accurate results. Initially assumption that the water in incompressible when determine the effect of the hydrodynamic forces on dams, but after it is found that compressibility of the water has an important role in the seismic analysis. Water compressibility and dam flexibility effects have been taken into account for analysing of dam. The current paper is aim in reviewing about the dynamic response of the fluid-solid structures system, modelling and analysis of dam using FEM software, reservoir water level effect and dam support conditions.

II. LITERATURE REVIEW

Pavel Zvanut (2022) analyzed the horizontal displacements of the large arch-gravity concrete dam. Two-dimensional (2D) and three-dimensional (3D) analyses of dam behavior, taking into account the active earth pressures and the hydrostatic load on the upstream side of the dam and the passive earth pressures and the hydrostatic load on the downstream side of the dam, using the FEM-based computer program DIANA. The results of the study show that of horizontal displacements of the upper part of the dam moves in the downstream direction in the case of full water reservoir, while after lowering the water level the upper part of the dam moves upstream.

Chen Wang et al (2021) concluded that the static and dynamic water pressure was applied to the upstream foundation surface as the reservoir water, which may cause downward deformation of the foundation and consequently increase the normal tensile stress at the dam heel. The dynamic interaction of the reservoir foundation had a significant influence on the dam stress. It was found that a reservoir length of 3 times the dam height is feasible for the truncation boundary of the reservoirs.

Majid Pasbani Khiavi and Ali Sari (2021) studied about the hydrodynamic pressure wave propagation in the reservoir of a concrete gravity dam caused by interaction with the foundation under vertical vibration is investigated using an analytical method. Results showed that in which the excitation frequency is less than the natural reservoir frequency, the maximum hydrodynamic pressure is not created at the bottom of the dam and occurred near the y =0.3H. Also found that the maximum responses of the system are corresponding to a case in which the excitation frequency is close to the natural frequencies of the reservoir.

Sourav Sarkhel et al (2021) performed the modal, static and dynamic analysis to determine response of concrete dam with rigid and flexible foundation by using ABAQUS. Results concluded that maximum displacement, major principal stress and shear stress is found to be higher in the flexible foundation as compared to rigid foundation of the dam. Maximum displacement observed at crest of the dam and maximum principal and shear stress are found at heel of the dam.

Albaadani Ghallab (2020) performed Simulation of Cracking in the high concrete dam of Longtan was used as an example, using the ABAQUS program based on the extended finite element method to analyse the Dam under static and dynamic conditions. Analysis of dynamic crack propagation of the Longtan gravity dam under the Koyna earthquake is carried out using the system of cohesive segments based on XFEM made in ABAQUS. The time step of integration used in the analysis is 0.01s. The result shows that cracking initiation began at (1.80s), which means that during the relatively small amplitude motion the maximum principal stress in the dam reaches the tensile strength of the concrete.

Loizos Pelecanos et al (2020) investigated the effects of dam– reservoir interaction (DRI) on the nonlinear seismic response of earth dams. The result concluded that although the dam crest accelerations seem to be insensitive to the modelling of the upstream reservoir, the hydrodynamic pressures may impose some significant additional localized stresses on the upstream dam slope.

Soumya Gorai and Damodar Maity (2019) investigate the earthquake response of concrete gravity dam under near field and far field ground motion records considering interaction with the reservoir and foundation. It is suggested that both the near field and far field ground motions should be considered for investigation of seismic safety of the concrete gravity dam-reservoir-foundation system.

Abdelmadjid Tadjadit and Boualem Tiliouine1 (2018) derived analytical expressions for the determination of hydro-seismic forces acting on a rigid dam with irregular upstream face geometry in presence of a compressible viscous fluid. It can be noted that, contrarily to hydrodynamic pressures, whatever the configuration of the upstream face, the maximum values of the hydrodynamic forces always occur at the base of the dam.

Heirany (2017) studied about dynamic analysis of roller compacted concrete (RCC) dam using ABAQUS finite element software with the change approach of foundation boundary conditions will be considered. Suggested that Including damping in nonlinear dynamic analysis of massive foundations reduces displacement of dam crest which may decrease system failure.

Ismail Aydin and Ender Demirel (2017) investigated Dam-reservoir response in terms of hydrodynamic pressure and the wave run-up on dam face is using a numerical model based on full Navier-Stokes equations with compressibility effects imbedded into the pressure equation. Results showed that Wave run-up on the dam face is a function of water depth, ground velocity, and oscillation period. Run-up height is independent of water depth when the reservoir depth.

Kalyan Kumar Mandal and Damodar Maity (2016) performed the analysis procedure, dam and foundation are modelled by displacement base finite element. However, pressure based finite element is used to simulate the reservoir. It is observed from the results that the fundamental frequency of dam decreases continuously with the consideration reservoir and foundation along with the concrete gravity dam. The magnitude and distribution of the hydrodynamic pressure within the reservoir are changed continuously with the consideration of fluid-structure and soil-structure-fluid interaction.

Manjula Vani and K.Sashikiran Babu (2016) investigated pertaining to the dam – reservoir for different shapes and depths according to classification of IS 1893 are under taken for various combination of slopes and included angles. Provided the upstream breaks at depths of 3/4, 1/2, 1/4 of dam heights and angles of 150, 300 ,450 and 600 of variable upstream faces are contemplated for each break. Results show that the pressure coefficients are varying uniformly for each inclusive angle.

Salman Movahed and B. Aminnejad (2016) analysed the Latyan concrete buttress dam subjected to different records including reservoir effects by finite element method using ABAQUS. The investigation presented in this article has led to the following conclusions, in models with full reservoir the main damage criteria is in upstream of dam and models with empty reservoir damages are almost near to center and downstream of dam.

Shong-Loong Chen et al (2015) conducted a numerical simulation to examine the influence of upstream water storage level on the response of the earth dam. The result of the analysis revealed that the EPWP near the top-third of the upstream outer shell was becoming more and more negative (suction) until the water level reached 75% of dam height indicating that this region will be in a stable state as no liquefaction is possible during excitation.

Mohammad Amin Hesari et al (2014) investigated about the Influence of joints behavior on arch dam operation during the earthquakes. The results of dynamic analysis and applied earthquake records, for both model of dam without joints and with contract and lift joints maximum stresses occur around the abutments and maximum displacements are around the crest level especially at midpoint of the crest. With inclusion of the contraction and lift joints, tensile stresses will be considerably reduced. Allowing joints slippage should further reduce tensile stresses, if such capability is available.

Magdy H. Mowafy et al (2013) study is carried out to analyze and assess the safety of concrete gravity dams and to improve its stability under earthquake type loading using ADINA program based on the Finite Element Method. The result concluded that relative uplift force decreases as the relative height of water in reservoir increases, factor of safety against overturning and sliding decreases with increasing the earthquake horizontal acceleration component and the maximum settlement increases with increasing the earthquake horizontal acceleration component and also with relative height of water in reservoir.

Shiva Khosravi and Mohammad Mehdi Heydari (2013) studied about the effects of dam-reservoir-foundation interactions on the modal behaviour of gravity dams. The computer program used to model and analyse the dam-reservoir foundation system was ANSYS. It observed that when the reservoir is empty and the foundation is rigid the main frequency of the dam is maximized. Furthermore, a minimum value for the main frequency is obtained when the dam water-foundation rock interaction is considered.

Zeydan (2013) studied about the interaction of reservoir water-dam structure and it is modelled using FEM utilizing ANSYS code. Results of maximum hydrodynamic pressure according to dynamic response of the fluid-structure system is verified with the analytical solution of Westergard. The time history of hydrodynamic pressure exerted on the upstream face of the dam, horizontal crest displacement and stresses at dam heel assign significant response for the coupled fluid-structure system.

Kaushik Das et al (2011) found out the seismic response of simple dam model by modelled and analysed with the help of ALTAIR HYPERWORKS 10 software and evaluated for a koyna earthquake ground acceleration data and the seismic response are computed for hydrodynamic pressure force for the duration of earthquake. They concluded that the maximum displacement is found at Crest of the dam and Stresses and strains starts increasing and distributing from the neck region to the other parts of dam.

Akkose et al (2008) studied about the reservoir water level effects on the nonlinear dynamic responses of an arch dam are investigated by a Lagrangian approach in which a step-by-step integration technique. Water levels in the reservoir are considered as 40, 60, 80, 100 and 120 m to investigate the water level effects on dam. The results presented, this critical water level is 100 m for the dam on rigid foundation rock, and 60 m for the dam on flexible foundation rock. After a certain water level is reached, the crest displacements of the dam and the stresses on the dam body increase significantly.

Lotfollahi yaghin and Hesari (2008) studied about the analysis of the arch concrete dam under dynamic loading without and with rock support of dam with ABAQUS. The result indicates at the midpoint of dam crest maximum displacement occur for both the condition of dam with and without support and maximum principal stress in the midpoint of the crest has increasing in respect to the midpoint of foundation for applied earthquake records.

Rajib Sarkar et al (2007) conducted to show the influence of reservoir and foundation material on the dynamic response of concrete dams. Also investigated that tensile damage of the dam structure occurred during the earthquake motion. The results indicated on the dynamic behaviour of the reservoir has no significant impact of the dam structure if reservoir depth is less than 0.7 times the full-reservoir depth.

III. CONCLUSION

- The review has explained about the effect of hydrodynamic pressure on dam, fluid- structure interaction effect, bottom absorption effects and response of the dam under seismic load
- Analysis and factors to be considered while modelling of the dam using FEM Software.
- Reduction of hydrodynamic pressure on the dam by the factors like changing slope angle on upstream face of the dam, consider different boundary condition like base of the dam is rigid or flexible, changing reservoir water level and sediment deposit absorption effect.

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