Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2020, 7(7):204-209**

Review Article

ISSN: 2394-2630
CODEN(USA): JSERBR

A Review of Near-Fault Directivity Effect on Seismic Response of Concrete Gravity Dam

Mohsen Yaghooti[1], Mohammad Ali Sotoudeh[2], Ali Dehghan Bonadaki[2]

[1]MSc student in structural engineering, Faculty of Engineering, Islamic Azad University, Damavand Branch, Yaghooti1075@gmail.com
[2]Assistant Professor, Faculty of Civil Engineering, Islamic Azad University, Damavand Branch

Abstract The breadth and importance of the role of dams in various sectors has made these structures one of the most important infrastructures in the world. The performance of these massive structures against dynamic loads, such as earthquake loads, is one of the issues that researchers and designers of these structures have always faced. Also, since the characteristics of earthquakes vary in both amplitude and frequency content for structures at near and far distances to the source of the earthquake, it is necessary to study and compare such effects on structures. Therefore, the importance of studying the earthquake phenomenon in the dam industry as one of the most complex and costly construction activities has always been considered by various communities. In this study, important factors that cause instability and sensitization due to earthquakes on cracking in concrete gravity dam have been investigated. To this end, the effect of the orientation phenomenon as an important parameter on the seismic response of concrete gravity dam under close field records has been investigated. A review of studies in this area shows that the orientation phenomenon has been neglected in many studies.

Keywords Forward directivity, Coupled dam reservoir system, Incremental dynamic analysis, Rupture Directivity, Gravity dams

Introduction

Hydrodynamic pressures caused by stored water sometimes lead to cracking and failure in concrete dams, especially in earthquake-prone areas. This is important because it carries irreparable risks and causes severe loss of life, property and water loss. Therefore, the analysis and modeling of the dynamic behavior of concrete dams, which are an important part of the infrastructure of any country, has particular importance.

In the past, seismic analysis of gravity concrete dams was often ideally considered using two-dimensional blocks in analysis and design, and earthquake effects were usually simplified by defining an earthquake coefficient. But over the years, more emphasis has been placed on nonlinear analysis of concrete dams. Another thing to consider in the analysis is the distance between the site and the fault and its registered movements. Movements recorded near active faults have different characteristics than conventional movements recorded at a distance from the fault due to the effects of progressive orientation and variable displacement.

The frequency content of earthquakes in the near and far fields shows that the vibrations reached to different parts of the structure depend on the distance from the fault and the location of the structure depending on the direction of the waves from the fault. The history of seismic behavior studies of different types of dams also shows that they have different frequency content due to earthquakes in the far and near field of the fault, they show different behaviors. So that the accelerations obtained from the area close to the fault will have a less effective time but with high frequency components will be far from the accelerations recorded from the earthquakes in the far area.

Among the most important distinguishing features of this movement are the existence of long period pulses in the time history of acceleration, velocity and momentum, the ratio of the maximum velocity to the maximum acceleration in the time history, the high frequency content of the mapping and the short duration of the component perpendicular to the fault. This feature is observed due to the phenomenon of orientation in the areas before fault because in the propagation of rupture to the site (at a speed close to the shear waves) due to the nature of the larger amplitude and less time, the most seismic energy (due to rupture) reaches the site as a strong pulse.

Another important point about the characteristic of earthquakes in the near-energy field is that the component perpendicular to the fault line is longer than the parallel component along the fault line. Each of these features has different effects on different structures. Also, in such earthquakes, the accumulation of energy in a short period of time and in one pulse can cause a shock-like movement.

Using the principles of structural engineering as well as non-linear dynamic analysis, the effect of the forward orientation phenomenon on the seismic response of concrete gravity dams under near field records will be examined.

The phenomenon of progressive orientation occurs when the rupture extends to the site and the fault slides toward the site. In this case, due to the proximity of the fault rupture speed to the earthquake shear waves, when the rupture front is released from the earthquake center to the site, the waves released due to successive landslides in different areas of the fault near the fault front [1]. As a result, in the phenomenon of progressive orientation, the direction of the wave reaches the site frequently and in the form of a strong shock, which can be detected as a strong pulse of movement in the direction perpendicular to the slip and at the beginning of the earthquake record. Therefore, progressive orientation conditions can be identified by low durability and large-range pulses and medium to long periods.

Orientation occurs in both side-slip and deep-slip faults. In the lateral slip failure mechanism, the radial shear displacement model on the reverse fault causes the motion pulse to be perpendicular to the slip direction.

Another characteristic of earthquakes near faults is the permanent displacement of the earth due to its static deformation in the areas close to the fault [2]. This static displacement, also called the displacement jump step, occurs within a few seconds of a fault slip. Since this residual displacement occurs in the direction of the fault slip, it is not involved in the earth's pulse motion, which is perpendicular to the direction of the slip.

Concrete Dams (Arches - Gravity)

Today, concrete gravity dams are among the most numerous types of dams built. The advantages of concrete gravity dams include reducing the execution time (the volume is much less than the body of the earth dam), the possibility of running and placing overflow on the dam body, reducing the dimensions of the diversion tunnel (length and diameter of the tunnel), shorter length of water pipes and metal shelters, reduction of reservoir tower dimensions and reduction of risk and vulnerability of these structures against earthquake, overall competitive cost of the project, Less damage to the environment due to the much smaller volume of materials required (which leads to a reduction in the volume of borrowed resources, a reduction in truck and other loading and unloading machinery, and a proportionate reduction in carbon dioxide emissions) [3].

Concrete dams are generally in the form of arched dams (single arches and double arches) and gravity dams. Single-arched concrete dams have arches in the direction of the horizon (plan) and double-arched dams have arches both in the direction of the horizon and in the vertical direction (sections) [4]. The stability of these dams depends on their shape. The volume of concrete used in arched concrete dams is about 50% less than the gravity dam. Double arched dams are built in narrow valleys with rocky supports (because most of the force enters the supports). Another form of concrete dam is gravity type. Since the water pressure must be very resistant to the weight of the dam structure, this type of dam usually has a very large volume [5]. Obviously, in the construction of structures with this volume, the most economical issue is the issue of supply of materials; Therefore, these dams usually use the materials available at their construction site. Obviously, the most available of these materials are stone and soil. Gravity dams for these reasons are now made in two types of concrete dams and earthen dams [6]

Literature Review

In the last two decades, several studies have been conducted on the different effects and characteristics of near-field ground motion characteristics. The impact of earthquakes in the near field on the seismic behavior of structures has been the subject of much research. Recent earthquakes such as Kobe (1995), Northridge (1994), Prieta (1989) have shown more unique features of earthquakes in nearby areas [7]. Major analyzes of concrete gravity dams based on numerical methods including the application of fracture mechanics in dynamic analysis in different dam conditions, slip investigation and its probabilities in earthquake occurrence, estimation and seismic analysis of dams with different concrete models including continuous failure model The effect of cavitation phenomenon has been the effects of the interaction of the dam and the reservoir and the modeling of the construction seams in the dam body. In addition to the above analysis, several seismic table tests have been performed on small-scale laboratory samples.

Sarkar et al. (2007) Analyzed the Koyna dam model with reservoir and foundation based on the nonlinear behavior of concrete in traction and calculation of dam and reservoir and foundation interaction under Koyna earthquake and examined the effect of reservoir elevation and resilience module on the dam response as a parameter. He concluded that reducing the modulus of elasticity of the foundation increases the displacement response and also if the height of the tank is less than 70% of the full state, the impact of the tank on the dam response is negligible [8].

Mao and Taylor (1997) evaluated the effect of different parameters on the nonlinear analysis of gravity dams and the study of the nonlinear behavior of gravity dams with free height. The results show that for medium-height dams, cracking at the base of the dam occurs on the slope discontinuity [9].

Zhang and Ohamachi (2000) studied cracking dams. In this study, the crack crack model was used and the tank was modeled with the idea of the added mass of Westgard [10].

Olivier and Cevara (1995) presented a general methodology for analyzing large concrete dams under seismic excitation, the mechanical behavior of concrete was modeled using an isotropic damage model that is applicable to both tensile and compressive damage [11].

Rahimzadeh (2002) examined the seismic response of arched concrete dams due to the earthquake near and far. The most important characteristics of near faults earthquakes were identified as Existence of long cheek pulse movements, Differences in chronological components, Between the components perpendicular to the direction of the fault relative to the parallel component of the fault and Apply impact force to the structures along the leading path of the fault near it [12].

Sotoudeh (2017) examined the subject of quantitative and qualitative evaluation of concrete gravity dams. A case study of the research was the Pine Flat dam. In the numerical modeling, the effects of the dam and the reservoir were considered and the foundation of the dam was considered rigid. In the qualitative evaluation section, the issues related to measuring the rate of structural failure in concrete gravity dams such as formation, position, size and possible direction of cracking have been discussed and examined. Also, by examining the crack profiles in the body of the dam, 30 fault patterns have been identified in the Pine Flat gravity dam under earthquakes in the near field with pre-existing effects. Then, by focusing on the relationship between the vibrational behavior of the structure and its failure, as well as the patterns of dam failure, the seismic performance of the dam is determined qualitatively and the conditions of structural failure are defined [13].

Nik Khakian et al. (2018) analyzed the three-dimensional behavior of a Pine Flat gravity dam without considering seams along with nonlinear behavior of dam body materials using finite element method. The results showed the highest relative displacement of the crown in the longitudinal direction related to the records containing the horizontal component and the lowest relative displacement in the middle point of the dam crown in the longitudinal direction related to the application of the transverse component alone. Comparison of three-dimensional models also shows that the transverse component of the earthquake, which is ignored in two-dimensional analysis, has increased the damage applied to the right and left lateral supports, as well as the neck area of the dam in general three-dimensional models [14].

In a study, Altunisik et al. (2009) evaluated the performance of the Saraya concrete dam on the SAKERIA River using Euler's methods, under the influence of near field and far field records. The ANSYS model was used to model Finite element. The results of the dynamic characteristics obtained (including maximum displacements, minimum and maximum stresses and strains) had a good approximation with the analysis of ground motions from similar sites [15].

Bayrakter et al. (2010) examined the effect of near and far faults on seismic responses of different types of dams such as gravity concrete dams [16].

In 2013, Zhang and Wang studied the effect of near-far field faults on seismic damage on gravity concrete dams[17].

Mehmat Akkose and Ermen Simsek (2010) examined the nonlinear seismic response of concrete gravity dams to near-field fault movements, including dam, water, sediment, and foundation interactions. In this study, the modified NONSAP program was used for elastoplastic analysis. Also, the results of linear and nonlinear analyzes for far fields and near fields were compared [18].

Kummari et al. (2018) examined the implications of using the demand capacity ratio (DCR) model in evaluating the performance of gravity concrete dams. The results showed that DCR values could be sensitive to severely fragmented Arias even within a narrow range of terrain parameters [19].

Berat Feyza Soysal et al. (2017) evaluated land movement scale methods for concrete gravity dams. For this purpose, three gravity concrete dams were selected. The nonlinearity of the materials, the interaction of the reservoir dam, and the vertical component of the earth's motion were examined in that study. The displacement parameters, maximum crown acceleration and crack size were selected as the required engineering parameters and the predictive effectiveness of the average demand and the related scattering level were compared and then the number required for effective analysis was determined [20].

Gaohui Wang and Sherong Zhang (2013) examined the effects of ground motion in near field and far field on nonlinear dynamic response and seismic damage on weighted concrete dams. For this purpose, 10 earthquake records were selected that show the movement of the earth with an apparent pulse rate to show the characteristics of the Earth's movements in the near field. Analysis of the results showed that these movements in the near field have a great impact on the dynamic response of the system (dam - reservoir - foundation) and have the potential to produce more severe dam damage to the dam area than the far field [17].

In recent years, good research has been done on the seismic response of concrete gravity dams under near-field and far-field records [21-26].

Conclusion and Recommendation

The characteristics of the earthquake in the near faults are strongly influenced by the effect of the spring and the conditions of the construction site. Due to the fact that dams are usually built in mountainous areas, the presence of faults at long distances, especially near dams, is inevitable. Therefore, dynamic analysis of such dams under near-field earthquakes can be effective in identifying and selecting the type of dam in their optimal performance. Earthquakes in the near field have a higher acceleration and a more limited frequency content at higher frequencies than earthquakes in the far field. The mapping of these earthquakes, especially when exposed to the effect of progressive orientation, has a high-speed pulse with strong amplitudes, which is often seen at the beginning of the earthquake's time history. Progressive orientation occurs when the vector of the rupture front vector is directed towards the desired site.

The large pulses of acceleration, velocity, and displacement, with different geometric shapes and structures, can be seen in the time history of near-field earthquakes. The long-term pulses of displacement, velocity and acceleration observed in the chronological history of large earthquakes, induce a lot of energy in the form of ground impact movements to structures. Research in this field emphasizes that the intensity and weakness of these pulses have a direct relationship with the direction of wave propagation relative to the seismic station, seismic fault mechanism and soil conditions in the structure. Also, in the history of different times of large earthquakes, it has been observed that the pulses mentioned in the stations located in the area close to the fault show different characteristics.

Another effect of movements recorded in the near field compared to the far field from the fault is the strong vertical movements of the earth. In most near-field earthquakes, the Peak Ground Acceleration (PGA) is 1g, the Peak Ground Velocity (PGV) is 1.5 m/s, and the Peak Ground Displacement (PGD) is 1 m.

The overall result of this research has been to prove the effects of the region's topography and soil type on the frequency content of the earthquake's time history, especially for frequencies greater than 1 Hz.

Recommendations

An overview of the studies conducted so far on the effect of seismic response under near field and far field records, the following are suggested in future studies:

In many studies, the effects of the orientation phenomenon, especially the forward direction orientation, on seismic response under near field records have not been considered. In other words, the results of structural analysis seem to be compared under two components of near field records, one with progressive effects and one without progressive effects, So, it is suggested that the records be collected in the Near field has progressive effects, Far field without progressive effects and far fields groups. At each level of intensity, a nonlinear dynamic analysis on the dam structure should be performed in terms of dynamic effects and using finite element software.

References

[1]. Zanjani, N.A., W. Wang, and S. Kalyanasundaram, The effect of fiber orientation on the formability and failure behavior of a woven self-reinforced composite. Journal of Manufacturing Science and Engineering, 2015. 137(5).

[2]. Yadav, K.K. and V.K. Gupta, Near-fault fling-step ground motions: characteristics and simulation. Soil Dynamics and Earthquake Engineering, 2017. 101: p. 90-104.

[3]. Shahiri Parsa, A., et al., Evaluation of Drought Changes of Isfahan City based on the Best Fitted Probability Distribution Function. pdf.

[4]. Sadeghian, M.S., et al., A Statistical Review of the Most Cited ISI Papers in the Field of Reservoir Operation. International Journal of Review in Life Sciences, 2015.

[5]. Fazlolahzade Sadati, S.K., et al., Water Yield Estimation in Polrudwatershed Based on Empirical Methods and Modelling in Geographic Information System (GIS). Journal of river engineering, 2014. 2(7).

[6]. ShahiriParsa, A., et al., Evaluating the Suspended Sediment of Mahabad Dam Using Statistical Methods.

[7]. Chang, S.E. and N. Nojima, Measuring post-disaster transportation system performance: the 1995 Kobe earthquake in comparative perspective. Transportation research part A: policy and practice, 2001. 35(6): p. 475-494.

[8]. Sarkar, R., D. Paul, and L. Stempniewski, Influence of reservoir and foundation on the nonlinear dynamic response of concrete gravity dams. ISET Journal of Earthquake technology, 2007. 44(2): p. 377-389.

[9]. Mao, M. and C. Taylor, Non-linear seismic cracking analysis of medium-height concrete gravity dams. Computers & structures, 1997. 64(5-6): p. 1197-1204.

[10]. Zhang, H. and T. Ohmachi, Seismic cracking and strengthening of concrete gravity dams. Journal of Japan Society of Dam Engineers, 2000. 10(3): p. 232-240.

[11]. Cervera, M., J. Oliver, and R. Faria, Seismic evaluation of concrete dams via continuum damage models. Earthquake engineering & structural dynamics, 1995. 24(9): p. 1225-1245.

[12]. Rahimzadeh, F. and O. Omidi, Investigating the Effects of Nonlinear Concrete Behavior on Seismic Response of Arc Concrete Dam, in First Conference on Structural Safety and Improvement. 2002: Tehran, Amirkabir University (Tehran Polytechnic).

[13]. Sotoudeh, M.A., Quantitative and qualitative evaluation of concrete gravity dams. 2017.

[14]. Nik Khakian, B. and M. Alam Bagheri, Non-linear seismic analysis of three-dimensional concrete dam with different length-to-height ratios. Practical Journal and Research of Civil Engineer Modares, 2018. 18.

[15]. Bayraktar, A., et al., Comparison of near-and far-fault ground motion effect on the nonlinear response of dam–reservoir–foundation systems. Nonlinear Dynamics, 2009. 58(4): p. 655.

[16]. Bayraktar, A., et al., The effect of reservoir length on seismic performance of gravity dams to near-and far-fault ground motions. Natural Hazards, 2010. 52(2): p. 257-275.
[17]. Zhang, S. and G. Wang, Effects of near-fault and far-fault ground motions on nonlinear dynamic response and seismic damage of concrete gravity dams. Soil Dynamics and Earthquake Engineering, 2013. 53: p. 217-229.
[18]. Akköse, M. and E. Şimşek, Non-linear seismic response of concrete gravity dams to near-fault ground motions including dam-water-sediment-foundation interaction. Applied Mathematical Modelling, 2010. 34(11): p. 3685-3700.
[19]. Kummari, J.M. and S. Venkatesan. Implications of using demand-capacity ratio model on the seismic performance evaluation of concrete gravity dams. in Australian Structural Engineering Conference: ASEC 2018. 2018. Engineers Australia.
[20]. Soysal, B.F., B.Ö. Ay, and Y. Arici, Evaluation of the Ground Motion Scaling Procedures for Concrete Gravity Dams. Procedia engineering, 2017. 199: p. 844-849.
[21]. Huang, J., Earthquake damage analysis of concrete gravity dams: modeling and behavior under near-fault seismic excitations. Journal of Earthquake Engineering, 2015. 19(7): p. 1037-1085.
[22]. Yazdani, Y. and M. Alembagheri, Seismic vulnerability of gravity dams in near-fault areas. Soil Dynamics and Earthquake Engineering, 2017. 102: p. 15-24.
[23]. Gorai, S. and D. Maity, Seismic response of concrete gravity dams under near field and far field ground motions. Engineering Structures, 2019. 196: p. 109292.
[24]. Bhandari, R.S. and H.R. Parajuli, Nonlinear time history analysis of large concrete dam considering near-field earthquake effect.
[25]. Başbolat, E.E., A. Bayraktar, and H.B. Başağa. Seismic reliability analysis of high concrete arch dams under near-fault effect. in 4th International Conference on Earthquake Engineering and Seismology, Turkey. 2018.
[26]. Hariri-Ardebili, M., et al., Random finite element method for the seismic analysis of gravity dams. Engineering Structures, 2018. 171: p. 405-420.