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The effect of the location and intensity of explosion on structural behavior of dams considering different depths of sediments

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ABSTRACT: In the present paper, the effect of the sediment level of the dam reservoir on the nonlinear dynamic response of a concrete gravity dam under TNT explosion has been studied in a three-dimensional numerical model. For this purpose, assuming two different levels of sediments in the dam reservoir, the effect of its level on the dynamic behavior and the amount of damage on the concrete gravity dam has been investigated. The concrete damaged plasticity model (CDP), which includes the strain hardening/softening behavior of concrete, is applied in the modeling. In the analysis, the nonlinear dynamics of the dam-reservoir-foundation system utilizing ABAQUS software and finite element method have been used. CONWEP theory was used to apply the explosion load. As a case study, the failure analysis of the Koyna concrete gravity dam located in India under the TNT explosion has been evaluated. Analyzes were performed for three different blast points and two different amounts of explosives. The results obtained from the analysis show that the farther the blast location is from the sediments, the greater the displacement in the crown of the dam. Increasing the depth of sediment in the dam reservoir will cause stress and energy consumption and ultimately reduce the damage and displacement of the dam crown.

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1- Introduction

Considering the current conditions of the world and ensuring the global and financial security of the countries, the shock caused by an explosion has been discussed. The explosion in a short period of time is associated with a lot of energy and pressure, and this unconventional pressure causes injuries and damage to the structure. Explosion is a chemical reaction in which the main explosive substance combined with high temperature and pressure is combined with oxygen in the air, and as a result of the oxidation of explosive substances, hot and high-pressure products are formed. As a result, a large amount of energy is released in a short period of time. Since the discussion of the explosion and the impacts caused to the structure in a very short period of time has been the attention of designers for a long time designers must provide a safe and optimal design with minimum cost and maximum efficiency. This requires a detailed understanding of the effects of explosions and impacts on the structure and the behavior of the structure against the effects. Because the simulation of such phenomena requires modeling and performing dynamic analysis in a short period of time, and the structure undergoes a large deformation due to rapid loading, the behavior of the material will be different from the behavior of the material in the non-explosive loading state, performing such a project will be complicated and difficult and time-consuming [1].

Due to the great complexity of analysis and the sensitivity of the issue, as well as the increase in terrorist attacks and explosion risks in recent years, good progress has been made in the field of impact and explosion engineering. To carry out a real simulation, a model with special considerations and capabilities will be needed, many of which have been specially prepared and presented for the simulation of such analysis, especially explosion and impact.

Wang and Zhang (2014) modeled the underwater explosion for concrete gravity dams by taking into account the fluid-structure-foundation interaction at different water depths and also for different distances from the stand-off point with different outputs and investigated the resulting amount of damages of the explosion [2]. Zhang et al. (2014) analyzed the structure of a concrete gravity dam with different meshes against underwater explosive loads. They concluded that the accuracy of the numerical results is strongly dependent on the mesh size [3]. Kalate (2018), evaluated the effects of explosion on air on the response of two concrete gravity and arch dams and showed that arch dams have more vulnerability and destruction than gravity dams [4]. Li et al. (2018), investigated the failure models of concrete gravity dams under the effect of underwater explosion. They investigated the effect of hydrostatic pressure and the results of their work showed that the presence of hydrostatic pressure in the heel of

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the dam is more damaging and the expansion of the explosion occurs at a lower speed in the heel. They also emphasized the importance of the placement of explosives [5].

2- Methodology

Determining the nonlinear behavior of concrete is the most important step in numerical modeling of concrete structures. In ABAQUS finite element software, the non-linear behavior of brittle materials can be defined in three ways, propagation crack model, brittle failure model, and concrete plastic damage model. Each of these models has advantages that can be used according to need [6]. Concrete damage model is the only model that can be used in both static and dynamic analysis. In this model, it is assumed that tensile cracking and compressive crushing are the two main aspects of the concrete rupture mechanism, and it is designed to model brittle material failure under cyclic loads (alternating tension and compression) in such a way that it is possible to recover the stiffness during continuous cyclic loading [7]. In the plastic damage model, it is not possible to remove elements during the analysis or to create a crack due to the lack of rupture criteria; but this model can predict the location and direction of crack formation. To avoid much damage in the elements, the meshing of the elements in the concrete plastic damage model should be done using the Adaptive Meshing technique [8]. The beginning of the failure of materials is at the same time as the beginning of the formation of microcracks in concrete materials. After the failure, the formation of these microcracks is expressed in a macroscopic form with the stress-strain softening behavior, which causes the local concentration of strain in the concrete structure. Under uniaxial compression, the initial yield stress response is linear. In the plastic region, the response is usually characterized by strain softening after a stress hardening stage, which occurs beyond the ultimate stress. Although this description is somewhat simplified, it shows the main characteristics of concrete response [9].

3- Discussion and Results

The stresses created based on the Von Mises criterion and at the points and depths are indicated in Figure 1.

In general, it can be said that by moving away from the sediments in the dam reservoir towards the crest of the dam, the stress in the dam body will increase. This is because the intensity of the blast wave decreases in the vicinity of sediments. It is necessary to explain, based on the mentioned forms, it can be said that the deeper the sediments are, the less stress occurs in the dam body. Because part of the waves is absorbed by the sediments in the reservoir the mutual interaction between concrete-sediments and water in the places close to the existing sediments causes nonlinear behavior and reduces stress and displacement.

4- Conclusions

The current research aims to study the effect of packed sediments in the reservoir, on the response of a concrete gravity dam under explosion. The sediments are assumed to be of a thickness of 10 and 20 m and the explosion is caused by 100 and 200 kg TNT explosives at three different depths. The CONWEP theory is used for blast loading. To check the level of damage to concrete gravity dams more precisely, the effects of dam-reservoir-foundation interaction have also been taken into account. The non-linear seismic analysis of the Coyna concrete gravity dam under blast effect was carried out according to the CDP model, which includes strain hardening or softening behavior. The impacts of the sediments inside the reservoir during these two modes are completely different from each other. Based on the obtained results, it can be said that the more the depth of the sediments increases, the less the displacement occurs in the crest of the dam. This is because a part of the blast wave energy is absorbed by the sediments in the dam reservoir and is reflected by the water to other parts such as the foundation. Regarding the effect of sediments on the amount of stress in the dam body and how it changes, it is not possible to comment in detail, but it can be said that by moving away from the sediments in the dam reservoir towards the crest of the dam, the stress in the dam body will increase.

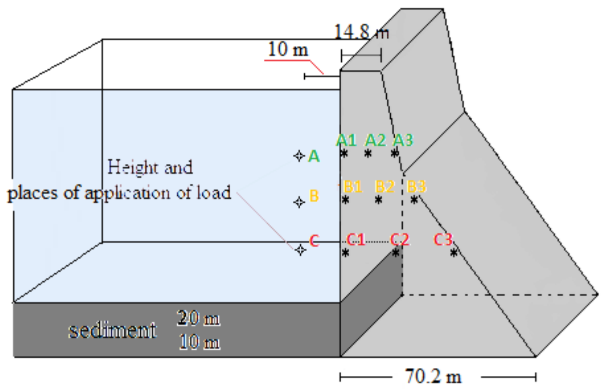

Fig. 1. Check points for maximum stress pressure

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