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DYNAMIC AND FATIGUE EVALUATION OF AN ARCH DAM SUBJECTED TO EARTHQUAKE.

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ABSTRACT: For a wide variety of problems in structures, linear and nonlinear solid mechanics, dynamics, and submarines structural stability problems FEM can be used, based on the development in computer technology. As to arch dam stress analysis, the conventional trial-load method has got lots of successful experience, but also has some disadvantages. For instance, it is hard to deal with complicated foundation, topography feature etc. At these aspects, the Finite Element Methods (FEM) has large advantage. Finite element method is an essential and powerful tool for solving structural problems not only in the marine field but also in the design of most industrial products and even in non-structural fields. This paper mainly focuses on the location of major stress concentration points and deflections of the dam under dynamic loads and also to evaluate the fatigue life of the structure by using ANSYS.

KEYWORDS: Double curved arch dams, Dynamic analysis, fatigue analysis, Maximum Credible Earthquake (MCE) ,

1. Introduction

Due to water scarcity, necessary to design structures which were able to regulate the water level. building dams became an appropriate method and for this reason a continuous development of dam structures began. the growing demand for electric energy gained from hydropower also promoted this progress. dams were built of soil and rock for thousands of years, until concrete became one of the most common building material. now a days, structural and topographic as well as economic reasons specify the geometry and building material a dam structure is built with. in the special topographical case of a narrow valley with stable valley sides, engineers started to design dams with a special shape and therefore special structural behavior. simultaneously they reduce the volume of the building significantly by using this new design, which is known as arch dam. Idukki dam consists of three major dams. It has been constructed across the Periyar river in a narrow gorge between two granite hills. It is 169.164m in height and 19.81m thick at the base.

Double curved arch dams feature horizontal as well as vertical arches. Therefore, the geometry of double curved arch dams is the most suitable concerning load transfer and volume reduction and can be fitted to nearly every asymmetric valley shape. The vertical sections are commonly realized with circles, whereas the horizontal arches are often realized with conic sections, basket-handle arches or logarithmic helixes. Despite the fact that double curvature dams have the most convenient structural behavior, the effort, regarding design and construction is enormous. without using modern calculation methods, such as the Finite Element Method, it would be hardly possible to investigate strains, displacements and stresses for such a complex geometry.

Stress results are used to evaluate the dam performance in the response to each loading combination. The evaluation starts with comparison of the computed stresses with strength of the concrete reduced by a factor of safety, but will also involve determination of location, magnitude, extent, and direction of high stresses should some crack-inducing stresses be expected. If all factors of safety are met the dam is considered to perform satisfactorily, even though some minor contraction joint opening may occur.

2. Load Combinations

Arch dams should be evaluated for all appropriate load combinations. Depending on their probabilities of occurrence, three basic loading combinations, Usual, Unusual, and Extreme should be considered. The usual loading combination considers the effects of all loads that may exist during the normal operation of the dam. The unusual loading combination refers to the loads acting on the dam during the flood stage. The extreme loading combination includes any of the usual loading combinations plus the effects of the Maximum Credible Earthquake (MCE). Rare loading conditions which have a remote probability of occurrence at any given time, have a negligible probability of simultaneous occurrence and should not be combined.

Dam Load Classification (Source: KSEB)

B	**Max Operation Level: 732.43m**	UNUSUAL LOAD	In combination with: Concrete Weight, Full Silt Level, Minimum Concrete Temperature, OBE of 0.06g,
C	Normal Operation Level: 716.28m	EXTREME LOAD	In combination with: Concrete Weight, Full Silt Level, Minimum Concrete Temperature, DBE of 0.12g,

Concrete Elastic Constants (Source: KSEB)

Load Conditions	Sustained Modulus of Elasticity	Poisson Ratio
Usual Load Conditions, D, E, F	21,000 Mpa	0.17
Unusual Load Conditions, B	28,000 Mpa	0.22
Extreme Load Conditions, A, C	31,000 Mpa	0.27

Coefficient of Thermal Expansion for concrete (Source: KSEB)

Load Conditions	Sustained Structural Conditions
Usual Load Conditions, D, E, F	1.2 x 10-5/°C
Unusual Load Conditions, B	1.2 x 10-5/°C
Extreme Load Conditions, A, C	1.2 x 10-5/°C

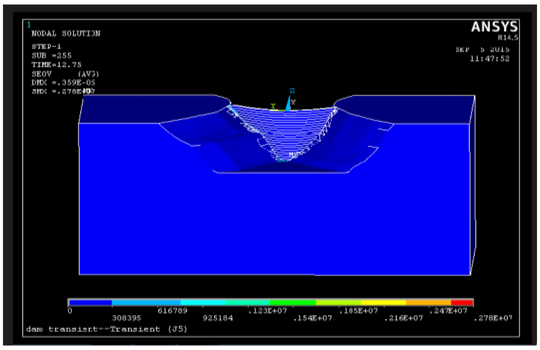
2.1. Evaluation of stress results

Evaluation of the computed stresses should begin with validation of numerical results by careful examination of the deflected shapes and stress distributions due to individual loads. Such data should be inspected for unusual deflected shapes, exceptional high or low displacement and stress magnitudes, and unexpected stress distributions that differ significantly from the results of other arch dams and cannot be explained by intuition. Force equilibrium should also be verified by comparing the sum of reaction forces to the sum of applied loads. Problems usually arise from the input data and modeling errors and should be corrected. Compressive stresses usually meet the criteria but tensile stresses caused by temperature loads, or other unfavourable situations may be significant. When significant tensile stresses are indicated, sections of the arches and cantilevers subjected to excessive tension are assumed to be cracked. This cracking will result in the re-distribution of stresses and loads. For example, localized loss of cantilever action caused by cracking at the base of the dam can be compensated by increased arch action. If cracking appears to be significant, non-linear analysis or linear analysis of the "as cracked" model may be required.

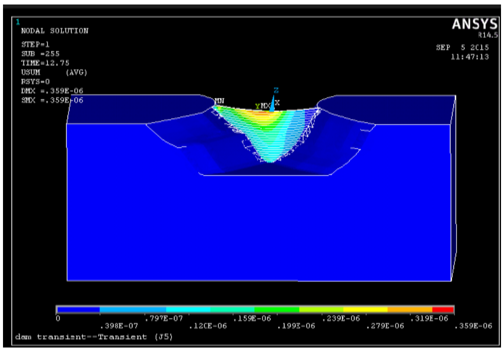
Factors of Safety for Existing Arch Dams(Source: Engineering Guidelines by FERC)

Loading Combination	Compressive Stresses
Usual	2.0
Unusual	1.5
Extreme	1.1

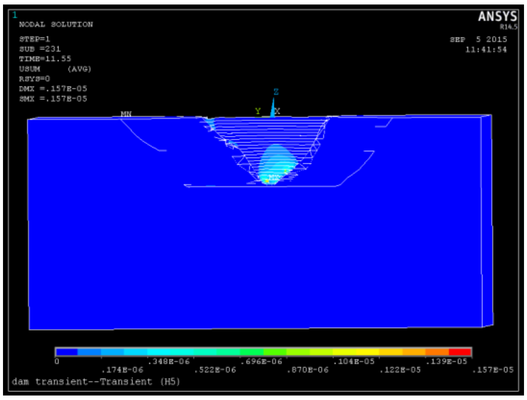
3. Results



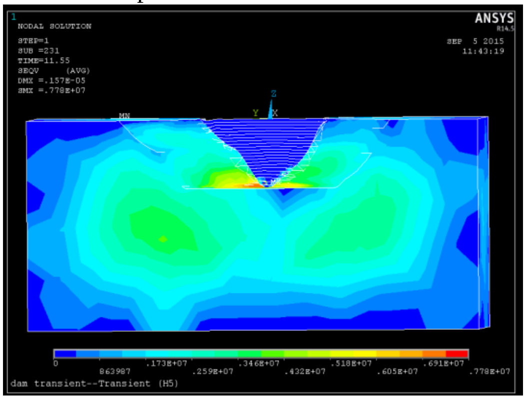
Von mises stress in Load combination B



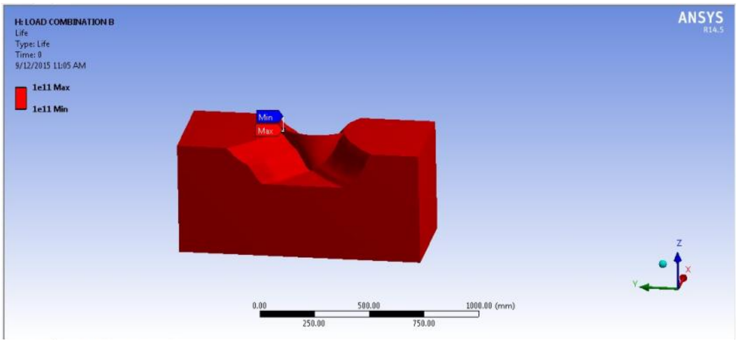
Displacement in Load combination B



Von mises stress in Load combination C



Displacement Load combination C



Fatigue analysis of an arch dam

4. Conclusion

The maximum displacement obtained in the dynamic condition is 0.77 cm. The limiting value of displacement as per KSEB norms is 5 cm. It can be observed that all the displacement values are within the prescribed limit.
The maximum stress obtained in the dynamic condition is 15.76MPa.Limiting stress as per "Engineering guidelines" by FERC is the concrete compressive strength reduced by the prescribed factor of safety. Hence, for usual load combination, limiting stress was found to be 13.25 MPa, for unusual load combination 17.67 MPa and for extreme load combination, the limiting stress was 24.09 MPa. It can be observed that the maximum compressive stress values for the proposed model have not exceeded the limiting values as per FERC.

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