ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 2, February 2018

Nonlinear dynamic Analysis for an Underground Powerhouse Structure Considering Soil Interaction

[1] Sagar Patil, [2] Rahul Patil, [3] Saurabh Nirkhe
[1] Post-Graduate student, Department of Civil Engineering, Deogiri Institute of Engineering, Aurangabad, Maharashtra State, 431028, India.
[2] .Assistant Professor, Department of Civil Engineering, Deogiri Institute of Engineering, Aurangabad, Maharashtra State

Abstract: **-- The project deals with the analysis and design of an underground Power House constructed on three different soil types. Though each and every powerhouse has mostly similar components and machines the analysis and design of civil structures in a plant are always done with different ideas and optimized techniques. Hence this paper is based on some new and different considerations in analysis and design aspects and optimization. The objective of this project also lies in knowing the difference between analysis and design of conventional structures and important structures or special structures. There are huge different machines in power house which are subjected to axial thrust as well as vibrations. The structure results are found by means of 'ANSYS'. Optimum analysis results in optimum design. As earthquake ground shaking affects all structures below ground in case of an underground powerhouse and since some of them must sustain or withstand the strongest earthquake ground motion, they have to be designed and checked for different types of design earthquakes. In the seismic design of underground structures, it must be taken into consideration that the earthquake hazard is a multi-hazard, which includes ground shaking, fault movements, mass movements blocking entrances, intakes and outlets, etc. Special problems are encountered in the pressure tunnels due to hydrodynamic pressures and leakage of lining of damaged pressure tunnels. The seismic design and performance criteria of underground structures of hydropower plants are discussed in a qualitative way on the basis of the seismic safety criteria applicable to large dams.**

I. INTRODUCTION

The powerhouse of a hydroelectric development project is the place where the potential and kinetic energy of the water flowing through the water conducting system is transformed into mechanical energy of rotating turbines and which is then further converted to electrical energy by generators. In order to achieve these functions, certain important equipment's are necessary that control the flow entering the turbines from the penstocks and direct the flow against the turbine blades for maximum efficient utilization of water power. A powerhouse also accommodates equipment that is necessary for regular operation and maintenance of the turbine and power generating units. For example, overhead cranes are required for lifting or lowering of turbines and generator during installation period or later for repair and maintenance. For the crane to run, guide rails on columns are essentially required. The maintenance of a unit is done by lifting it by the crane and transporting it to one end of the power house where abundant space is kept for placing the faulty unit. A workshop nearby provides necessary tools and space for the technicians working on the repair of the units. A control room is also essential in a powerhouse from where engineers can regulate the valves controlling water flow into the turbines or monitor the performance of each unit to the main power grid. Power houses that receive water from a reservoir through a penstock may be termed as power generating units detached from head works. There is another class of powerhouse that utilizes the water head directly from the water body. These are usually the run-of the river type power houses, which are located as a part of a barrage in a river or those which utilize the head difference of a canal fall. The detached power houses may be surface or underground types depending upon its position with respect to the ground surface. In-stream or run-of-river power houses are mostly surface type.

EARTHQUAKE DYNAMIC ANALYSIS

Due to the complication of the dynamic analysis of soil media under earthquake excitation, the majority of the previous studies were carried out using linear or equivalent linear analysis. To carry out such analysis using non-linear analysis, advanced analysis should be carried out to follow the nonlinear stress-strain behavior considering the actual

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 2, February 2018

path of hysteresis loop for random loading and unloading shear stress cycles. Due to the complex nature of the equations associated with non-linear constitutive models, convergence may not be achieved unless powerful solver is utilized. The objectives of this study are to simulate the full interaction between bedrock motion, subsurface soil and tunnel lining, under seismic excitation using the non-linear numerical model.

SIESMISC ANALYSIS

For the determination of seismic responses there is necessary to carry out seismic analysis of structure. The analysis can be performed on the basis of external action, the behavior of structure or structural materials, and the type of structural model selected. Based on the type of external action and behavior of structure, the analysis can be further classified as: (1) Linear Static Analysis, (2) Nonlinear Static Analysis, (3) Linear Dynamic Analysis; and (4) Nonlinear Dynamic Analysis. Linear static analysis or equivalent static method can be used for regular structure with limited height. Linear dynamic analysis can be performed by response spectrum method. The significant difference between linear static and linear dynamic analysis is the level of the forces and their distribution along the height of structure. Nonlinear static analysis is an improvement over linear static or dynamic analysis in the sense that it allows inelastic behavior of structure. A nonlinear dynamic analysis is the only method to describe the actual behavior of a structure during an earthquake. The method is based on the direct numerical integration of the differential equations of motion by considering the elasto-plastic deformation of the structural element.

Nonlinear Dynamic Analysis

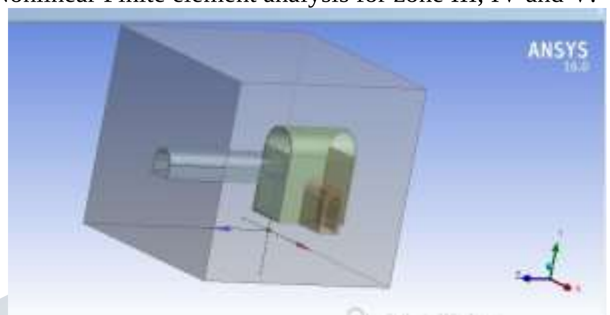
It is known as Time history analysis. It is an important technique for structural seismic analysis especially when the evaluated structural response is nonlinear. To perform such an analysis, a representative earthquake time history is required for a structure being evaluated. Time history analysis is a step by step analysis of the dynamic response of a structure to a specified loading that may vary with time. Time history analysis is used to determine the seismic response of a structure under dynamic loading of representative earthquake.

II. STRUCTURE DETAILS

An underground powerhouse having three main parts namely, Access tunnel, Powerhouse cavern unit and a Transformer cavern is analyzed. The dimensions of the tunnel are as follows:

	Width	Side wall height (m)	Arch height (m)	Length (m)
Powerhouse Cavern	20	24	5	47
Transformer Cavern	10	10	3	14
Access tunnel	6	4	3	43

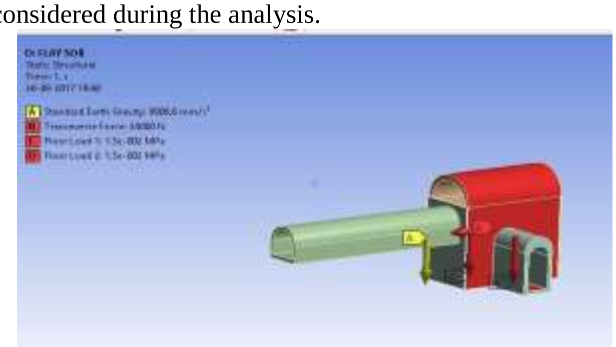
Nonlinear Finite element analysis for zone III, IV and V.



SSI model in ANSYS 16

III. PROBLEM STATEMENT

An underground powerhouse project is carried out in a fractured soil mass. It consists of a series of underground structures. Three main parts of the powerhouse are analyzed in this study: the power house cavern, transformer cavern and access tunnel. The domain of rock mass with dimensions 130 m _ 114 m _ 110 m is considered. Three joint sets are identified based on the analysis of the collected data from field survey, and the detailed information is shown in Table 3. Three types of surrounding soils are considered in this paper, clayey, silty and sandy soil conditions. The effect of earthquake waves on each of the soil types and the ultimate effect on the powerhouse structure are analyzed with the help of ANSYS. Earthquake zones like zone III, zone IV and Zone V have been considered during the analysis.



Loading on MODEL

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 3, Issue 2, February 2018

IV. OBJECTIVE

The following objectives are to be attained after the analysis of the structure.

a) Nonlinear finite element analysis for zone III, IV and V.

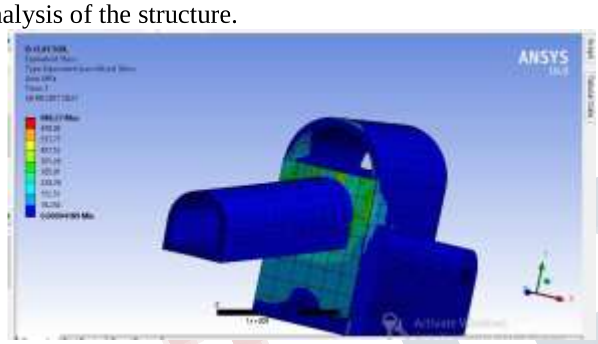
b) To compare Normal stress, Shear stress, Bending stress and Maximum principal stress.

c) Identification of cracks.

d) To perform free vibration analysis of above models to calculate Natural frequency and Time period.

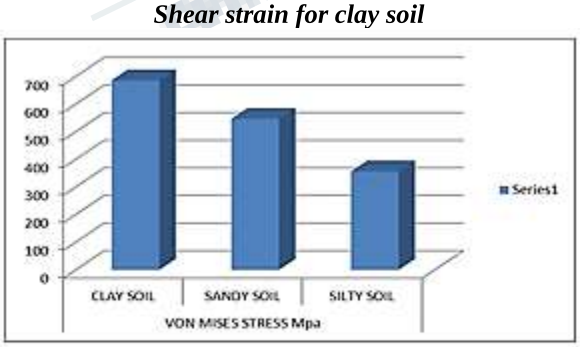
V. RESULT AND DISCUSSION

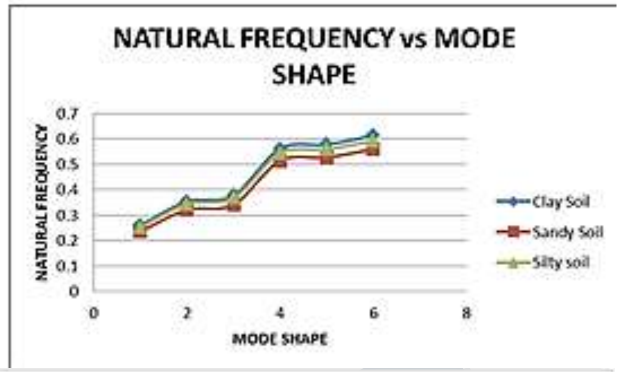
The following objectives are to be attained after the analysis of the structure.

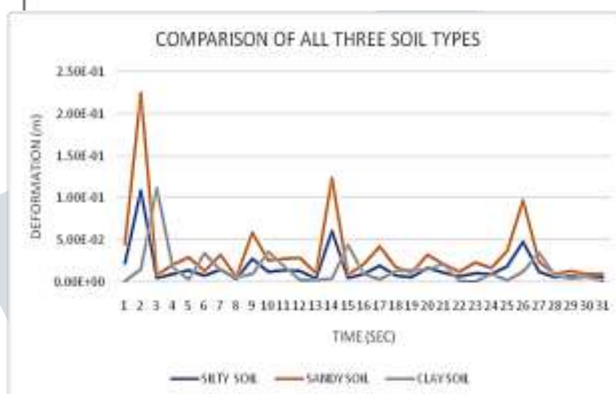


Von-mises Stress for clay soil

Shear strain for clay soil







VI. CONCLUSION

• In this paper soil structure interaction of underground tunnel is studied using FEA tool ANSYS. After applying load it is observed that the normal stress, von-misses stress, shear strain is less as compared to salty soil and sandy soil.

• However there is no abrupt change is observed in natural frequency and time period of structure.

• The structure reaches to its elastic strain limit 0.002 as well as plastic strain limit 0.0035 for all three cases

REFERENCES

[1] Dong Xuecheng, Tian Ye, Wu Aiqing. Rock mechanics in hydraulicengineering. Beijing: China Water Power Press, 2004 (in Chinese).

[2] Wang Yinhui. Excavation construction of underground powerhouse inBaishan hydropower station. Underground Engineering Techniques,1982, (1): 271–284, 292 (in Chinese).

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 2, February 2018

[3] Wu Aiqing, Xu Ping, XuChunmin, et al. Researches on stability forsurrounding rock masses of underground power house in the ThreeGorges project. Chinese Journal of Rock Mechanics and Engineering,2001, 20 (5): 690– 695 (in Chinese).

[4] Liu Quanpeng, Dong Dezhong. Excavation and its support in roof ofthe underground powerhouse. Underground Engineering Techniques,1996, (3): 61–68 (in Chinese).

[5] Fu Jing, Ding Xiuli, Zhang Lian. Numerical analysis on improvementof stability of underground grotto group surrounding rock mass withfilling in Karst region. Journal of Yangtze River Scientific ResearchInstitute, 2006, 23(4):47–50 (in Chinese).

[6] Li Yuji, Song Jing, Liu Gaofeng, et al. The problem and its treatmentabout wall rock stability of Goupitan hydropower station'sunderground powerhouse in Wujiang River. Resources EnvironmentandEnineering, 2009, 23 (5): 754–757 (in Chinese).

[7] Ding Xiuli, Dong Zhihong, Lu Bo, et al. Deformation characteristicsand feedback analysis of surrounding rock of large undergroundpowerhouses excavated in steeply dipped sedimentary rock strata.Chinese Journal of Rock Mechanics and Engineering, 2008, 27 (10):2 019–2 026 (in Chinese).

[8] Wu Aiqing, Ding Xiuli, Chen Shenghong, et al. Research ondeformation and failure and characteristics of an undergroundpowerhouse with complicated geological conditions by DDA method.Chinese Journal of Rock Mechanics and Engineering, 2006, 25 (1):1–8 (in Chinese).

[9] Zhang Lian, Ding Xiuli, Fu Jing. Three-dimensional numericalanalysis of stability of surrounding rocks of Shuibuya undergroundpowerhouse. Rock and Soil Mechanics, 2003, 24 (Supp.1): 120–123(in Chinese).

[10] Ding Xiuli, Sheng Qian, Wu Aiqing, et al. Numerical modeling ofexcavation and support of the underground powerhouse of theShuibuya hydropower project. Chinese Journal of Rock Mechanicsand Engineering, 2002, 21 (Supp.1): 2 162–2 167 (in Chinese).

[11] Yu Yong, Yin Jianmin, Yang Huoping. Rock mass classification forunderground powerhouse of Shuibuya Project. Chinese Journal ofRock Mechanics and Engineering, 2004, 23 (10): 1 706–1 709 (inChinese).

[12] Hu Ying, XieJunbing, Hu Haoran, et al. Research on the keyshotcrete technologies for the underground tunnel chambers ofShuibuya project. Water Power, 2003, 29 (9): 27–30 (in Chinese).

[13] Fu Yong. Study on the excavation and support method for theunderground powerhouse complex of Shuibuya hydropower projectand its practice. Yunnan Water Power, 2004, 20 (4): 68–71 (inChinese).

[14] Ding Xiuli, Fu Jing, Liu Jian, et al. Study on creep behavior ofalternatively distributed soft and hard rock layers and slope stability

[15] analysis. Chinese Journal of Rock Mechanics and Engineering, 2005,24 (19): 3 410–3 418 (in Chinese).

[16] Wu Aiqing, Yang Qigui, Zhou Huoming, el at. Rock mechanical studyof underground powerhouse in Shuibuya project. Journal of YangtzeRiver Scientific Institute, 2006, 23 (4): 1–7 (in Chinese).