Numerical Study of Gravity Dam with Gallery Under Influence of Wave Pressure Using ANSYS.16

Nikhil D Nikam[1], S.K.Patil[2] , A.B.Pujari[3]
[1, 2, 3] K.J. College,Pune,India

Abstract- *Today, use of water resources plays an important role to promote economical, agricultural developments in each country. So, it is necessary to analyze different stresses in water retaining structure. Along with stresses due to wave pressure, Seismic load, water pressure, uplift pressure are predominant in gravity dam. Using ANSYS we can check its stresses at different locations of dam structure.*

Gravity dams form a lifeline of a country economy and their failure will create huge loss of life and properties. Two general construction methods for gravity dams are conventional placed mass concrete or RCC and in stone masonry. There are many loads are present in the design of the gravity dam due to its large size, like upstream & downstream water pressure, earthquake forces, uplift pressure, temperature effect, wind pressure. The pressure due to wave also plays important role on dam wall. This paper deals with the analyis of stresses of koyna dam of 103.00m high above ground level with varying cross section and assuming fixity at the base in accordance with IS 6512. This dam have been analyzed for different types of load using ANSYS 16.0 software.

Keywords- Wave pressure Analysis, Galleries, IS 6512,Finite Element Modelling ,ANSYS

I. INTRODUCTION

I. General

A gravity dam is a solid structure, made of concrete or masonry, constructed across the river to create a reservoir on its upstream. The section of the gravity dam is approximately triangular in shape, with its apex at its top and maximum wide at bottom. The section is so proportioned that is resisting the various force acting on it by its own weight. A gravity dam is also called as the solid gravity dam to distinguish it from hollow gravity dam in which spaces are kept to reduce the weight. Early gravity dam were built of masonry, but most of the modern gravity dam made of concrete.

A gravity dam is generally straight in plan and, therefore, it is also called straight gravity dam. A gravity dams are quite strong and durable structure. The overall cost of such dam is usually less than most other type of dam. The ratio of the base width to height of most of the gravity dam is less than 1. The upstream face is vertical or slightly inclined. The slope of the downstream face usually various between 0.7:1 to 0.8:1.

The power of waves is one of the significant force, where water related structure has to study. Waves are created by wind blowing over the surface of the water body. As the wind blows over the water suface, friction is created - producing a swell in the water. The energy of the wind causes water particles to rotate inside the swell and this moves the wave forward.

The size and energy of a wave is influenced by:

- How long the wind has been blowing
- The strength of the wind
- How far the wave has travelled (the fetch)

The waves are generally categorized in to two types constructive and destructive wave. Destructive waves are created in storm conditions. They are created from big, strong waves when the wind is powerful and has been blowing for a long time. They occur when wave energy is high and the wave has travelled over a long fetch. They have a short wave length and are high and steep. Constructive wave are created in calm weather and are less powerful than destructive waves. They have a long wavelength, and are low in height.

Figure 1.

II. CODE PROVISION IS 6512 (ClauseNo.2.1pg.no.4)

- The dam should be safe against sliding on any plane or combination of planes within the dam, at the foundation or within the foundation
- The dam should be safe against overturning at any plane within the dam, at the base, or at any plane below the base.
- The safe unit stresses in the concrete or masonry of the dam or in the foundation material should not be exceeded.

II. OBJECTIVE OF STUDY

- To study dynamic response of gravity dam due to wave pressure by developing FEM of gravity dam using Ansys.
- To analyze parameters such as Toe and Heel under the influence of hydrodynamic wave pressure.
- To find principal tensile stress location in gravity dam for future tensile crack production.
- To check effect of opening of gravity dam subjected to wave pressure at different height.

III.WAVE PRESUURE LOADING ON GRAVITY DAM IN ACCORDANCE WITH IS 6512

I. Wave pressure **-** In addition to the static water loads the upper portions of dams are subject to the impact of waves. Wave pressure against massive dams of appreciable height is usually of little consequence. The force and dimensions of waves depend mainly on the extent and configuration of the water surface, the velocity of wind and the depth of reservoir water. The height of wave is generally more important in the determination of the free board requirements of dams to prevent overtopping by wave splash. It takes into account the effect of the shape of reservoir and also wind velocity over water surface rather than on land by applying necessary correction.

For determining the height of waves the method recommended by T. Saville should be adopted.

The maximum unit pressure in kPa occurs at 0.125 h, above the still water level and is given by the equation
= 24 h, where h = height of wave in m.

The wave pressure diagrams can be approximately represented by the triangle. The total wave force P (in kN) is given by the area of the triangle, or P = 20 h^2
The force is act at a height of 0.375 h, above the still water level.

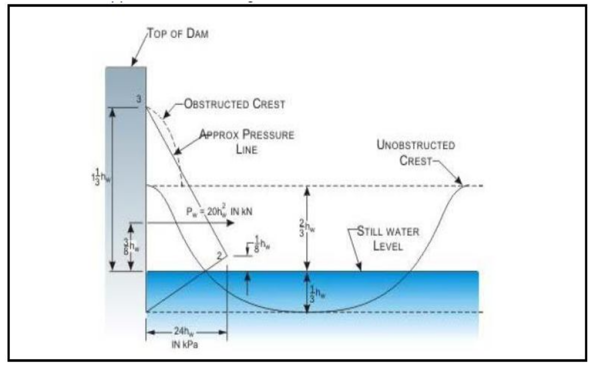


Figure 2. Wave action on dam structure

IV. NUMERICAL MODELLING IN ANSYS

For modeling of gravity dam surface elements are preferred in that particularly SOLID186, SURF 151 CONTA 174 and TARGE170 is used, description of elements are as follows

I. SOLID186 Element Description:

SOLID186 is a higher order 3-D twenty nodes solid element, exhibits quadratic displacement behaviour. The element is having three degrees of freedom per node translations in nodal x, y, & z directions.

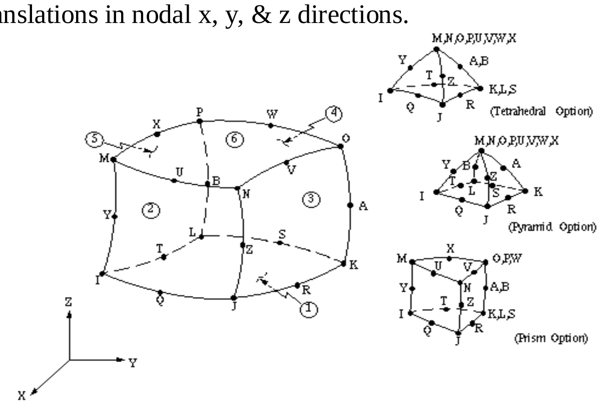


Figure 3. SOLID186 Geometrical Representation

II. SURF 151

SURF 151 may be used for different load or pressure and surface effect applications. It overlaid onto a face of any 2-D thermal solid elements (except axisymmetric harmonic elements PLANE75 and PLANE78). The element is applicable to two-dimensional thermal analyses. Different loads and surface effects may exist simultaneously. The element is defined by two to four node points and the material properties. The element x-axis is along to the I-J line of the element also has mixed formulation capability for simulating deformations of nearly incompressible elastoplastic materials, and fully incompressible hyperelastic materials.

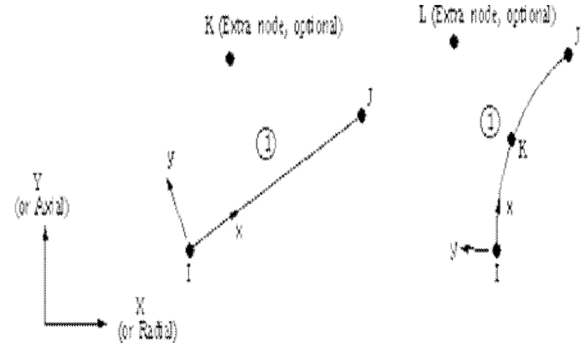


Figure 4. SURF 151

III. CONTA 174 and TARGE170

The 3-D contact surface elements (CONTA173 and CONTA174) are related with the 3-D target segment elements (TARGE170) via a shared real constant set. ANSYS looks for contact only in between surfaces with the same real constant set. For either rigid-flexible or flexible-flexible contact, one of the deformable surfaces must be represented by a contact surface.

If more than one target surface will make contact with the same boundary of solid elements , you have to define several contact elements that have to share the same geometry but relate to separate targets (targets which have different real constant numbers), or you must combine two target surfaces into one (targets that share the same real constant numbers).

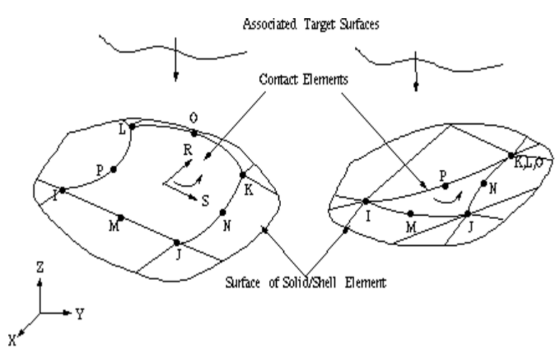


Figure 5. CONTA174 and TARGET170 element

V. PROBLEM STATEMENT

Koyna concrete dam, In Maharashtra, India, has been chosen for the finite element modeling.The Total height of the koyna dam is 103.20 m. The length of the dam is 807.2m. The dam has a varying cross section ,the width at the top is 14.8m and at bottom it is 70.0m.The HFL of the dam is 91.7m. The velocity of wind consider as per IS 6512 clause 5.8.3.2 is 120km/h.The velocity on water surface is modified as 141.6km/h.With the values of wind velocity and fetch distance (2.44km) the value of weight height is obtain with reference to IS6512:1984 Appendix A, Figure 5 as 1.27m.The material properties of the dam are grade of concrete, mass density and Poisson's ratio which is M40, 2500 kg/m and 0.3, respectively.

Table 1.

OPENING TYPE	**DAM WITHOUT OPENING (HEEL)**		**DAM WITHOUT OPENING (TOE)**	
Conditions	**Empty Reservoir**	**Full Reservoir**	**Empty Reservoir**	**Full Reservoir**
Deformation (mm)	0.0085	0.19	0.0004	0.166
Normal Elastic Strain (mm)	-7.47E-07	-3.27E-05	2.46E-09	-3.26E-06
Normal Stress (MPa)	0.745	20.8	0.035	-7.06
OPENING TYPE	**DAM WITH OPENING**		**DAM WITH OPENING**	
	(Circular)		**(Circular)**	
Condition	**Empty Reservoir**	**Full Reservoir**	**Empty Reservoir**	**Full Reservoir**
Deformation (mm)	0.014	1.076	0.00056	0.098
Normal Elastic Strain (mm)	-1.85E-06	-4.83E-05	1.40E-08	-2.09E-06
Normal Stress (MPa)	0.816	30.09	0.031	-6.27
OPENING TYPE	**DAM WITH OPENING**		**DAM WITH OPENING**	
	(Rectangular)		**(Rectangular)**	
Condition	**Empty Reservoir**	**Full Reservoir**	**Empty Reservoir**	**Full Reservoir**
Deformation (mm)	0.002	0.13	0.00019	0.047
Normal Elastic Strain(mm)	9.37E-07	-5.56E-05	1.86E-08	7.03E-07
Normal Stress (MPa)	0.75	30.02	0.03	-5.8

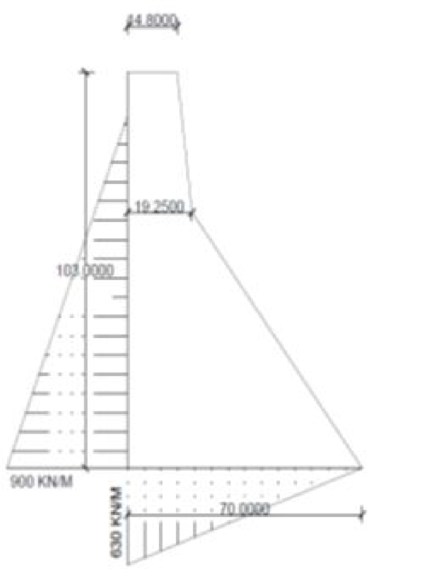


Figure 6. Koyna dam with pressure diagram

MATERIAL PROPERTIES

Table 2. Following are the material properties which are used in modeling

Dam Body	**Concrete Grade**	**M40**
	Poisson's Ratio	**0.3**
	Density	**25 kN/m3**
Water	**Mass density of water**	**9810 kgm-3**
	Fetch distance	**2.44kM**
	Wave Height	**1.27 M**

VI. RESULTS AND DISCUSSION

The model of gravity dam with geometric property of koyna dam is modeled in ansys. Empty reservoir condition and full reservoir with wave action on it condition is studied. Also the effect of wave action is applied on model at specific heights.Model with different shape of opening in dam is also modeled with same application of pressure. And the results of model like deformation, normal elastic strain, normal stress are observed. The results are listed in table.

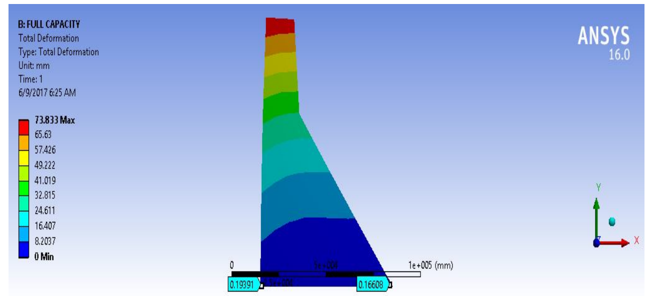


Figure 7. Deformation (Empty Condition)

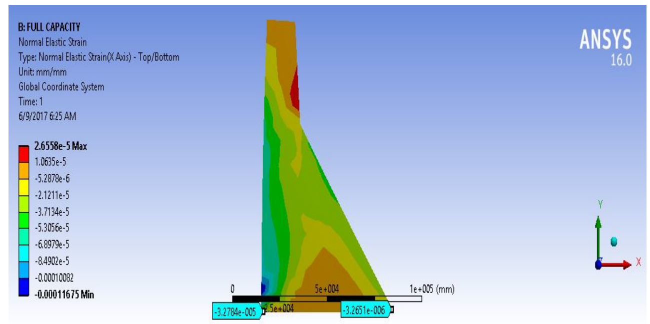


Figure 8. Normal Elastic Strain (Empty Condition)

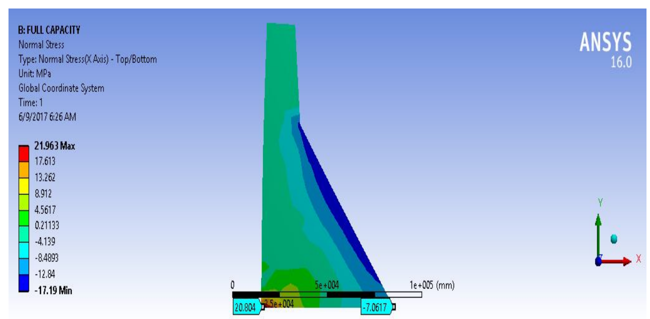


Figure 9. Normal Stress (Empty Condition)

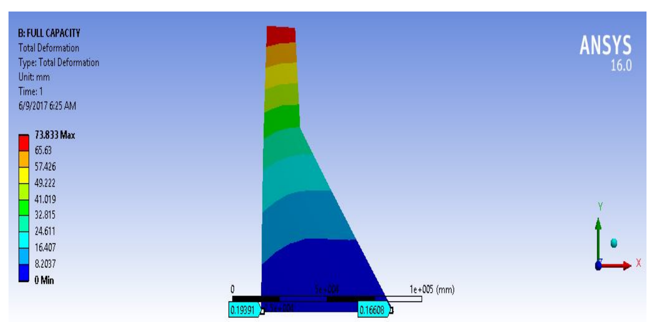


Figure 10. Deformation (Full Condition)

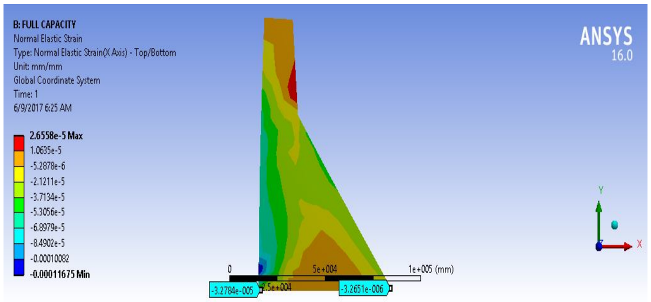


Figure 11. Normal Elastic Strain (Full Condition)

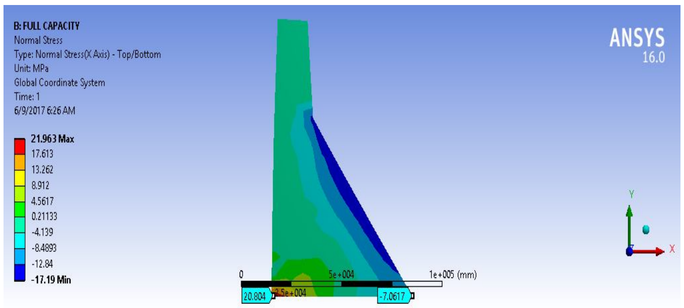


Figure 12. Normal Stress (Full Condition)

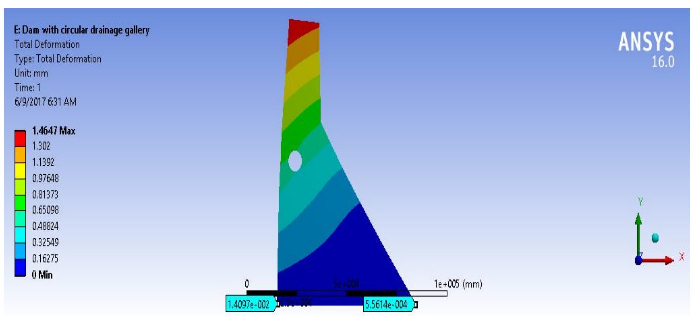


Figure 13. Deformation(Circular Opening-Empty)

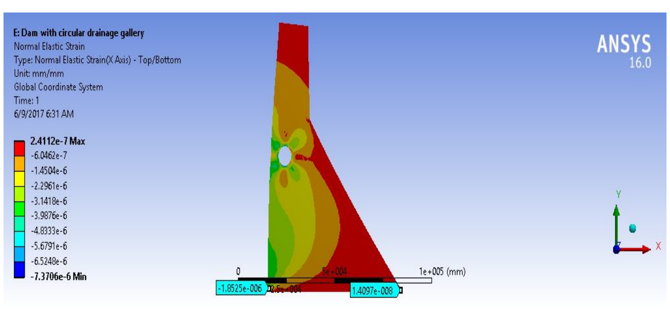


Figure 14. Normal Elastic Strain (Circular Opening-Empty)

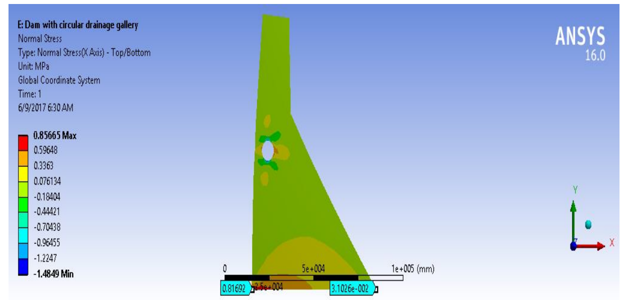


Figure 15. Normal Stress (Circular Opening-Empty)

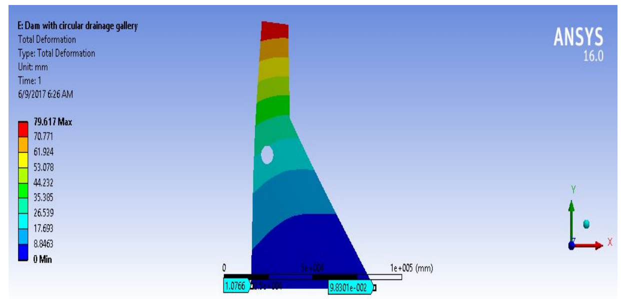


Figure 16. Deformation (Circular Opening-Full)

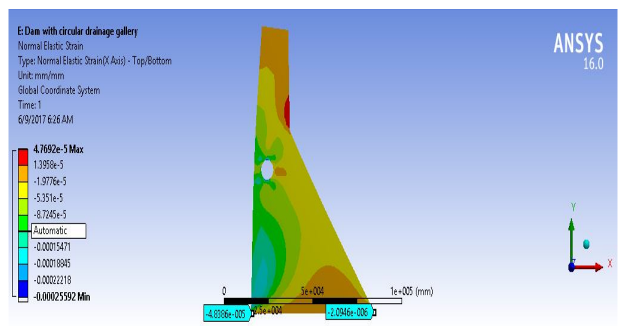


Figure 17. Normal Elastic Strain (Circular Opening-Full)

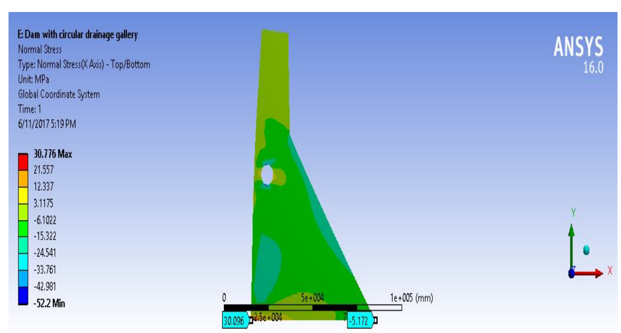


Figure 18. Normal Stress (Circular Opening-Full)

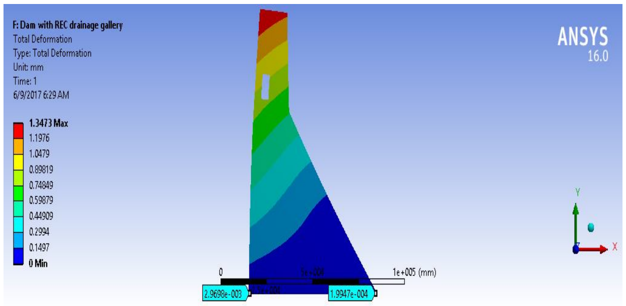


Figure 19. Deformation (Rectangular Opening-Empty)

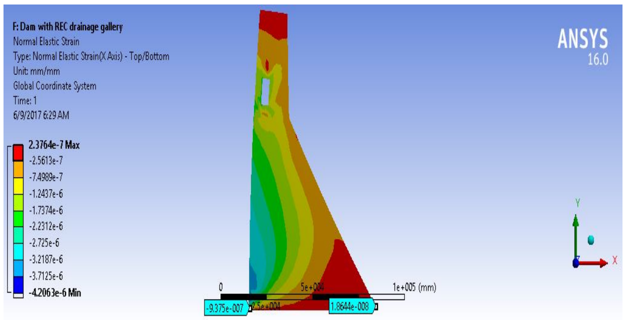


Figure 20. Normal Elastic Strain(Rectangular Opening -Empty)

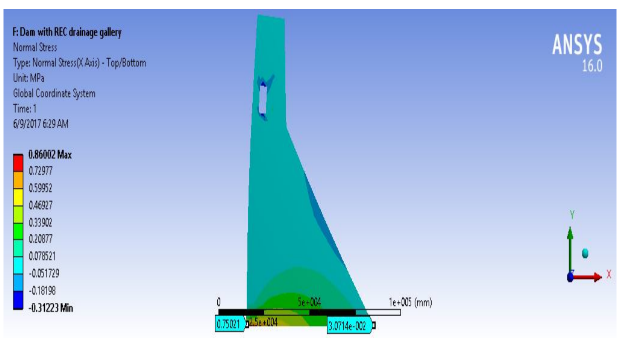


Figure 21. Normal Stress (Rectangular Opening-Empty)

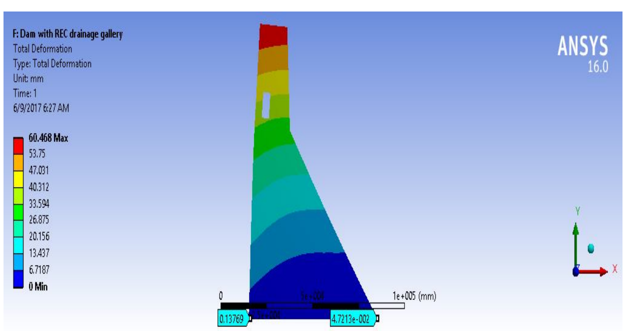


Figure 22. Deformation (Rectangular Opening-Full)

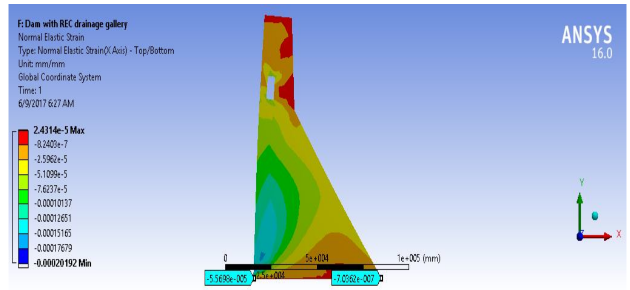
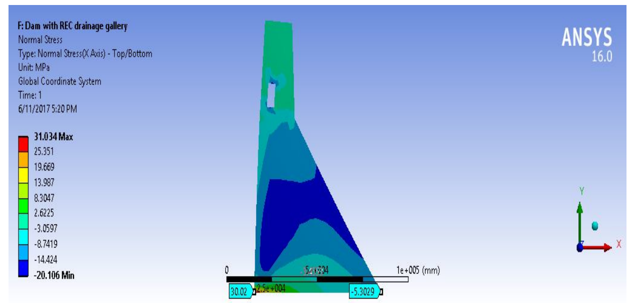
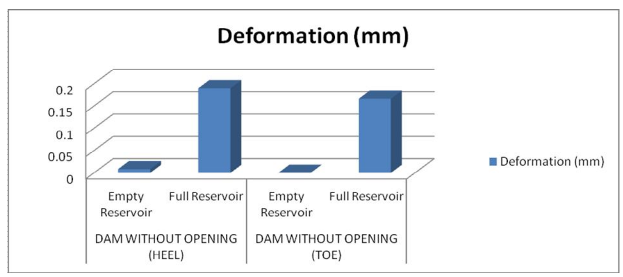


Figure 23. Normal Elastic Strain (Rectangular Opening-Full)



24. Normal Stress (Rectangular Opening-Full)



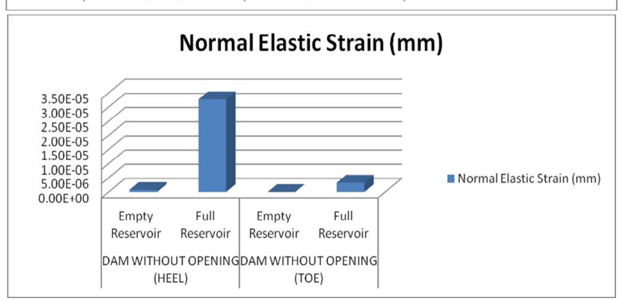


Figure 26.

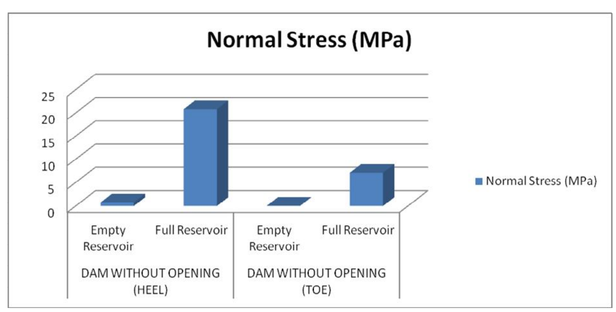


Figure 27.

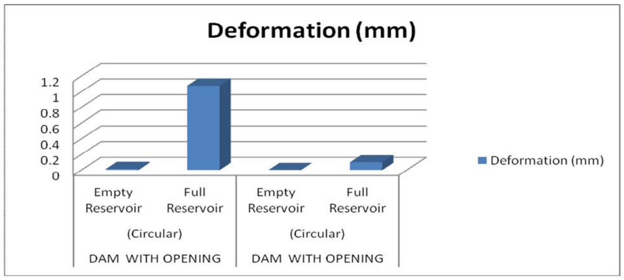


Figure 28.

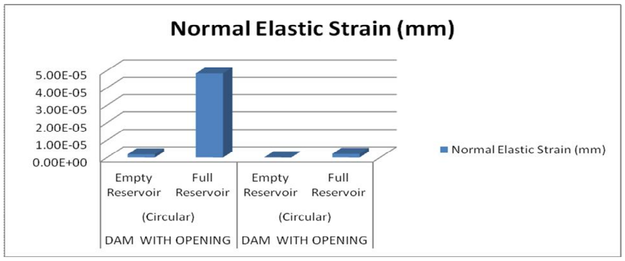


Figure 29.

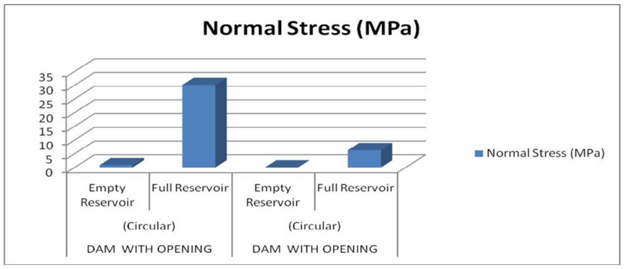


Figure 30.

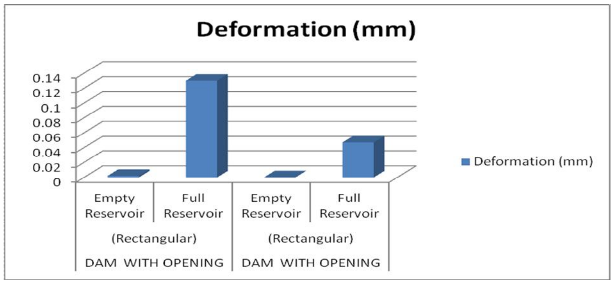


Figure 31.

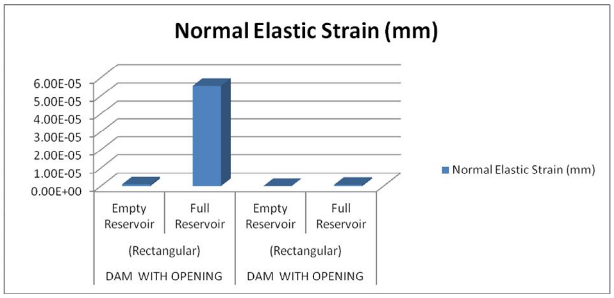


Figure 32.

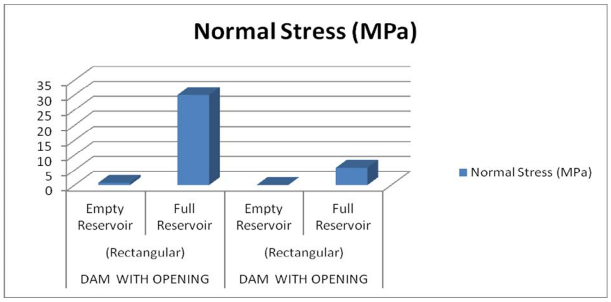


Figure 33.

VII. CONCLUSION

In the first stage of study the parametric model of gravity dam is studied in accordance with IS 6512:1984 using ANSYS16.0 and finite element model in ANSYS is proposed against self-weight and lateral load against various dimensions.

In the later stage hydrodynamic wave pressure is studied and applied to the same parametric model. As well as the model with opening gallery is also prepared in ANSYS and same type of pressure is applied on the model and results are obtained

- The values of deformation as well as formation of stresses at toe and heel for different conditions are increases with 1.0 – 2.0 % after application of wave load with compare to only self weight and water pressure.
- Due to opening, the deformation at toe increases by 25-30%.
- Due to opening, Norrmal elastic strain, Normal stress and deformation was observed maximum for circular opening provided near to steam.
- All the normal elastic strains are in permissible limit that is below 0.002.
- Normal stress at heel portion is observed maximum at circular opening for full reservoir condition, and it was 30.09 MPa while the ultimate strength is 40.0 MPa.

REFERENCES

[1] ANSYS.Version16.0Documentation.ANSYS,In.

[2] Vipin Gupta and Vishal Waghmare, “Study of Structural Behaviour of Gravity Dam with Various Features of Gallery by FEM”, ACEE Int. J. on Civil and Environmental Engineering, Vol. 3, No. 1, Feb 2014.

[3] Md. Hazrat Ali, Md. Rabiul Alam, Md. Naimul Haque,

Muhammad Jahangir Alam, "Comparison of Design and Analysis of Concrete Gravity Dam", Natural Resources, 2012, 3, 18-28 doi: 10.4236/nr. 2012.31004 Published Online March 2012.

[4] Bakenaz A. Zeidan, "Effect of foundation flexibility on dam reservoir foundation interaction", International water technology conference.

[5] Atheer ZakiMohsin, Dr. Hassan AliOmran and Dr. Abdul-Hassan,"Dyanamic response of concrete gravity dam on random soil"

[6] S. S. Bhavikatti, Finite Element Analysis, 2nd edition, New Age International Publishers, New Dehli, 2012.

[7] IS: 6512:1984, Criteria for design of solid gravity, New Delhi, India: Bureau of Indian standards.

[8] IS: 875 (Part3):1987, Code of practice for design loads (other than earthquake loads) for buildings and structures. New Delhi, India: Bureau of Indian Standards.