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Seismic Behaviour and Stability Analysis of Gravity Dam

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Abstract : Dams are constructed to store water in large capacity for future use. Due to large storage the loads acting over the upstream side of the dam are heavy and, during earthquakes, in addition to these load a huge loads act on it because of ground motions. It may results in the failing of structure and thereby resulting in loss of life, social, economic and environmental crisis. The seismic vibration created at the time of earthquake must be minimized by proper application of engineering principles and so it is necessary to determine the behaviour of concrete gravity dam in the same basis. The dynamic analysis with Response spectrum method and time history method are the efficient ways to analyze the dam. In this paper, time history method is used to study the seismic behaviour and the stability of gravity dam. It is done by using STAAD-PRO. According to the Indian standard code of practice, dynamic analysis shall be done for dam with different heights as 70m, 80m and 120m have been analyzed and the results obtained are compared, to determine the structural performance of concrete gravity dam. The effect of some parameters which influences the seismic performance, height of dam and loading patterns are to be investigated.
Keywords : Gravity dam, Dynamic Analysis, STAAD-PRO.

1.0 Introduction

A dam is a solid barrier, made of concrete or masonry, constructed across a river to hold the water and raise its level act as a reservoir. Dams are important to develop the civilization for long time. Dams are mostly helpful in rainy season by collecting the waters from the hills and rivers in which the dams are located. The stored water can be used in various ways such as hydropower generation, irrigation, aquaculture etc. It also helpful in preventing the flood and its damage during heavy rain[1,2,3]. Dams are classified into different types based on their structure as, Gravity dams, Arch dams, Arch-gravity dams, Barrages and Embankment dams. Especially gravity dam are popular in these days because of it can be provide in any where even in steep valleys and when it is build on strong foundation it can be built up to a maximum practical height. The main reason is, it does not fail suddenly, and their failure can be predicted well in advance. The capacity of storage of dam is depend upon the stability of the structure whereas the stability depends upon the soil condition. Anti-sliding stability of gravity dam is a key factor that affects the safety of the dam. The structure should be designed to withstand the water pressure, uplift pressure, silt pressure, wave pressure and wind pressure.

During earthquake due to ground motion an additional seismic force will act on the structure of the dam. This additional force lead to collapse of structure and affects the dynamic nature of structure it may cause the cleavage/cracks in the gravity dam. The straight crack appear in the dam will be unstable when the peak acceleration reaches five times the magnitude of Koyna earthquake, while the dam with curved crack will be unstable when the peak acceleration reaches eight times the magnitude of koyna earthquake. Some cracks are penetrated to foundation level and the whole dam may break into blocks and sudden flood will occur[4,5,6]. To prevent this, the stability of the dam should be improved and checked by analyzing the basic parameters. The analyzing of the dam structure can be done with the help of STAAD- PRO. It is primary design software which is provided for the learning of principles of structural stability. It can also be used for research and development on stability of gravity dam.

Dynamic analysis can be performed to determine the design seismic force and its distribution to difference levels along the height of the structure[7,8]. It may be performed either by Time history method or by Response spectrum method. The main objective of the present study is defined as to develop a time history method for seismic analysis of concrete gravity dam. It includes method to calculate principal stress, shear stress, displacement, bending moment, reactions and deflection. Time history method is basically a method of seismic analysis for the simulation of an earthquake motion[9,10,11]. It is done by using time acceleration data as input function and then the performance of the gravity dam is evaluated with various mode shapes and time acceleration. The designing of structure to improve stability against ground motion we have to check the following criteria which are over turning, sliding and development of tension[12,13].

2.0SPECIFICATION OF DAMS

1. Specification of 80m dam

Height of dam = 80m
Base width of dam = 45m
Top crest = 6m
Free board = 5m
Weight of dam = 48562.500KN
Water pressure = 344.886KN/m^2
Uplift pressure = 367.875KN/m^2
Wave pressure = 23.544KN/m^2

Earthquake force

a) Body force = 440.625KN/m^2

b) Water force = 6.150KN/m^2

2. Specification of 90m dam

Height of dam = 90m
Base width of dam = 70m
Top crest = 10m
Free board = 8m
Weight of dam = 635000KN
Water pressure = 366.458KN/m^2
Uplift pressure = 402.21KN/m^2
Wave pressure = 23.544KN/m^2

Earthquake force

a) Body force = 1868.750KN/m^2

b) Water force = 6.724KN/m^2

3. Specification of 120m dam

Height of dam = 120m
Base width of dam = 90m
Top crest = 12m
Free board = 10m
Weight of dam = 159750KN
Water pressure = 494.588KN/m^2

Uplift pressure = 539.550KN/m^2
Wave pressure = 23.544KN/m^2

Earthquake force

a) Body force = 4586.538KN/m^2

b) Water force = 9.019KN/m^2

3. LOAD AND LOAD COIMBATIONS

Self weight of dam (DL)
Water pressure (WP)
Silt pressure (SP)
Uplift pressure (UP)
Earthquake pressure (EQL)
Time History loads (TH)
DL+WP+SP+UP+EQL+TH

4.0 Methodology

Time history method of analysis was generally based on an appropriate ground motion and the accepted principles of dynamics[13]. It is the dynamic analysis of structure with every increment in time when the structure is subjected to specific ground motion. Time history analysis is the study of the dynamic response of the structure at every addition of time when its base exposed to a particular ground motion. Static techniques are applicable when higher mode effects are not important. This is for the most part valid for short, regular structure[14]. Thus, for all structures, with torsional symmetries, or no orthogonal frame works, a dynamic method is needed.

In order to study the seismic behavior of structure subjected to low, intermediate and high frequency content ground motions, dynamic analysis is required. The STAAD PRO software is used to perform linear time history analysis[15]. The three different heights of dams are modeled as three dimensions. The time acceleration values for different cities are tabulated. These values are assigned to the corresponding dams and linear time history analysis is performed

Table1. Time acceleration details

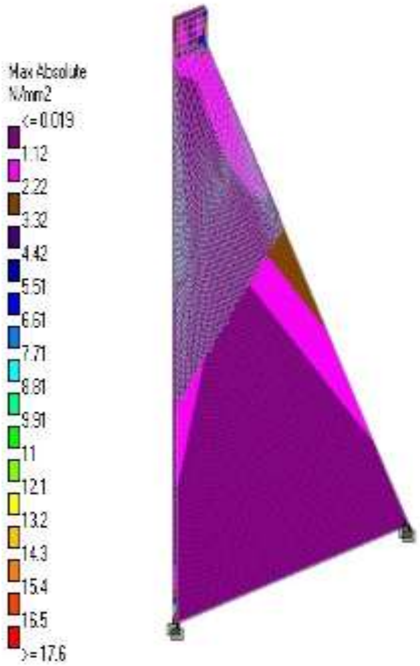
Time interval (sec)	Acceleration (m/s^2)
0.0000	0.006306
0.0200	0.003640
0.0400	0.000990
0.0600	0.004280
0.0800	0.007580
0.1000	0.010870
0.1200	0.006820
0.1400	0.002770
0.1600	0.001280
0.1800	0.003680
0.2000	0.008640
0.2200	0.013600
0.2400	0.007270
0.2600	0.000940
0.2800	0.004200
0.3000	0.002210
0.3200	0.000210
0.3400	0.004440

5.0 Results and Discussion

Absolute stress of the three dams was compared by taking its maximum value.

Table2. Max absolute pressure

Height of dam	Max. absolute stress (N/mm^2)
80 meter	17.6
90 meter	14.5
120 meter	14.2



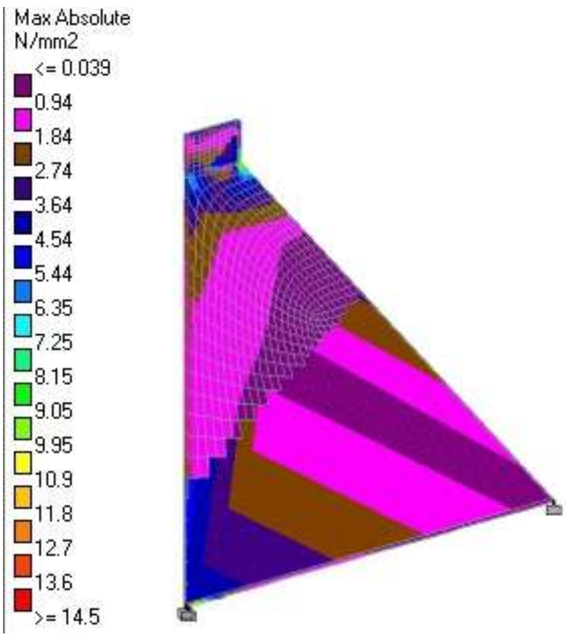


Fig 1: 80m damFig 2: 90m dam

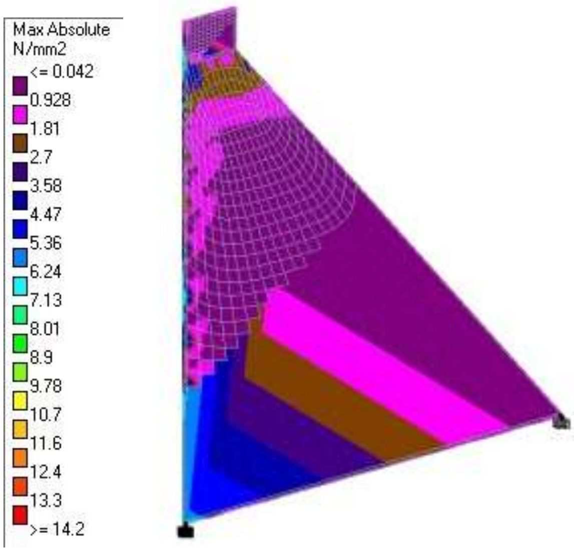


Fig 3: 120m dam

Max and mini principal stress of the three dams was compared by taking its maximum value

Table3. Maximum and Minimum principal stress

Height of dam	**Max. principle stress**	**Min. principle stress**
80m	14.8	1.21
90m	6.97	0.892
120m	10.8	0.492

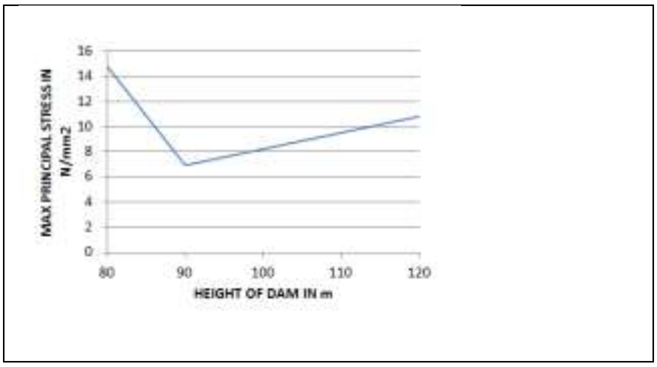


Fig4. Maximum principal stress

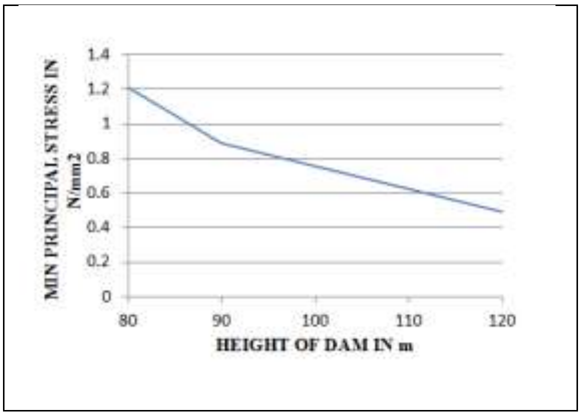
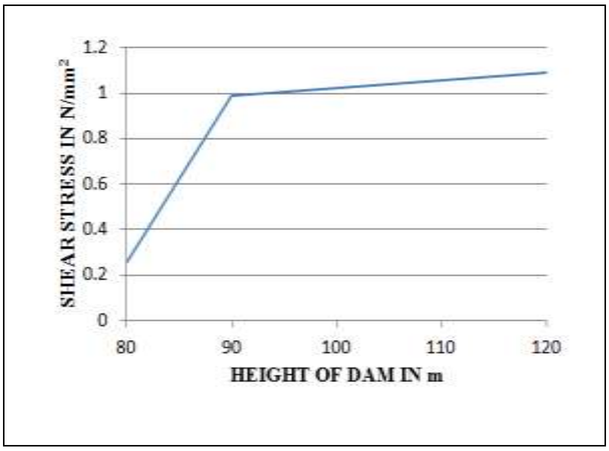


Fig5. Minimum principal stress

Shear stress of the three dams was compared by taking its maximum value



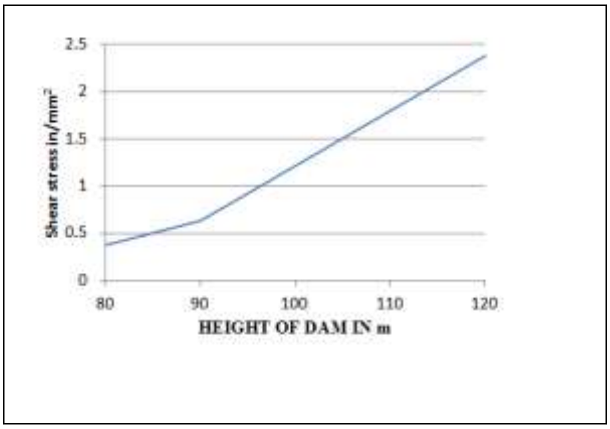


Fig6. Shear stress at x direction

Fig7. Shear stress at y direction

Table4 shear stress

Height of dam	**Shear stress (X- direction)**	**Shear stress (Y- direction**
80m	0.259	0.372
90m	0.987	0.634
120m	1.09	2.38

5.2 Dynamic Characteristics

A dynamic characteristic of the three dams was compared by taking its frequency, period, mass participation values.

Table5 Dynamic characteristics of 80m dam

Mode	**Frequency in Hz**	**Periods in sec**	**Mass participation X in %**	**Mass Participation Y in %**	**Mass participation Z in %**
1	0.095	10.507	0.000	0.000	65.954
2	0.320	3.124	0.000	0.001	19.451
3	0.751	1.331	0.000	0.000	2.444
4	0.968	1.033	0.003	0.002	6.821
5	1.464	0.683	0.001	0.003	2.170
6	1.607	0.622	0.003	0..004	0.566

Table6 dynamic characteristics of 90m dam

Mode	**Frequency in Hz**	**Period in sec**	**Mass participation X in %**	**Mass participation Y in %**	**Mass participation X in %**
1	0.091	11.402	0.000	0.002	51.843
2	0.259	3.856	0.005	0.002	19.438
3	0.523	1.911	0.001	0.000	0.136
4	0.647	1.545	0.026	0.017	5.290
5	1.009	0.992	0.198	0.044	0.250
6	1.172	0.853	0.003	0.028	0.011

Table7 Dynamic characteristics of 120m dam

Mode	Frequency in Hz	Period in sec	Mass participation X in %	Mass participation Y in %	Mass participation X in %
1	0.045	22.391	0.000	0.001	50.136
2	0.151	6.625	0.000	0.000	21.855
3	0.298	3.352	0.001	0.001	0.458
4	0.396	2.528	0.000	0.000	4.557
5	0.645	1.551	0.000	0.000	0.075
6	0.661	1.513	0.001	0.001	0.002

6.0 Conclusions

From the results it is conclude that the maximum absolute stress values (14.5N/mm2)for 120mdam is reasonable as compare to other dams. But there is no large huge difference between 90mdam's values (14.2N/mm^2).

We consider maximum and minimum principal stresses (6.97N/mm^2, 0.893N/mm^2)90m dam is efficient as compare to other two dams.

The shear stress value (0.259N/mm2, 0.372N/mm2) for 80m dam is better as compare 90m and 120m dams.

Finally we compare the dynamic characteristics for different heights of dam the 90m dam frequency, time period, mass participation are reasonable than other dam.

The main advantage is that stress variation through the dam body can be studied carefully and the slopes can be designed according to the stress pattern. Therefore, while comparing these three different heights of dam, the 90m dam is more efficient than others.

7.0 References

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