

IMPACT OF VERTICAL AND HORIZONTAL GROUND MOTION ON CONCRETE GRAVITY DAM STRUCTURE

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ABSTRACT

In the building of many large concrete dams across the country. Significant dam cracking can have major environmental, economic and social consequences. Collapse of high concrete dam may cause serious harm to economic development as well as safety of the people; thereby necessitating the need for research on safety and stability of high concrete dam under high water and seismic conditions. In this project, the concrete gravity dam of Koyna was used as an example, using the ABAQUS program based on the extended finite element method to analyze the Koyna dam under static and dynamic conditions which has been commonly used for the study of crack growth. An analytical prediction of crack propagation in concrete gravity dams is presented. The two-dimensional seismic numerical study was done using acceleration-time records from Koyna earthquake in 1976 dam concrete cracking range and cracking were discussed during a seismic time. The locations that are easy to generate cracks are illustrated from the analysis and the findings showed that, during seismic activity the Koyna dam was rather unsafe. Also, the parametric study of Koyna dam has been studied by applying earthquake from downstream side. The findings of parametric study showed that, the effect of downstream side is maximum. Therefore, the results of the work can provide a valuable guide for the design and operation of the dam system.

Keywords: *Vertical ground motion, Horizontal ground motion, Dynamic Implicit Analysis, Abaqus 2017.*

INTRODUCTION

Dams are considered to be man-made structures created across a stream, a river, or an estuary for the purpose of preventing water from flowing. The main reasons for constructing dams are the supply of drinking water to human settlements, irrigation of arid and semiarid lands, or providing water required in industrial processes. They can also be used to control water flow to generate more hydroelectric power and to prevent the excessive discharge caused by rainstorms and melting snowpacks. Moreover, some of their benefits include deepening river waters for easier navigation of large barges and ships and increased water retention so that crops can thrive even during droughts. Dams do not only have hydroelectric power generation uses but also provide a lake that is helpful for tourism, as people swim in the lake or go fishing, or take part in boating activities. A multipurpose dam is one of these kinds of water control structures. In general, concrete gravity dams stretch over a valley along an approximately straight alignment and solely counteract the lateral pressure caused by the retained water with their mass. The application of concrete dams for water storage, irrigation use, and power production has been extensive and considerable in the economic growth of the country.

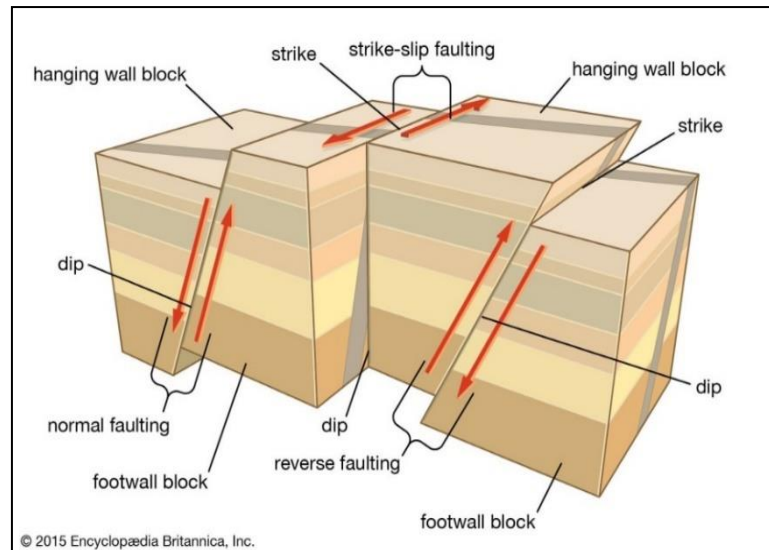


Fig.1:I Groundimotion

Vertical ground motion and horizontal ground motion

Earthquakes are classified into vertical and horizontal depending on the nature of shaking. In a vertical earthquake, the shaking is in an up-and-down motion while in a horizontal earthquake, the shaking is sideways. The significance of vertical ground motion on seismic design has been given less importance than horizontal movements. One of the main reasons is that people are convinced that the vertical component is much less significant than the horizontal ones. Vertical ground motion continues to be studied as analytical and field evidence mounts regarding its effects on structural response, resulting in a growth of interest in understanding vertical earthquake ground motions and their effects on structures.

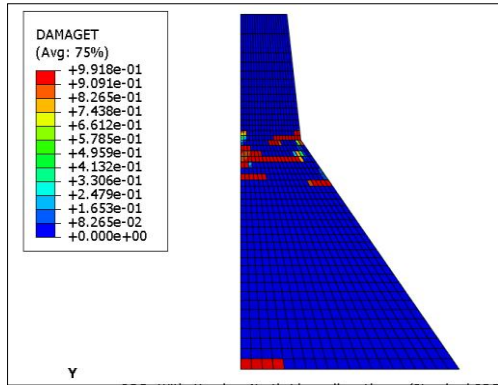
Objectives of the study

The objectives of the study are:

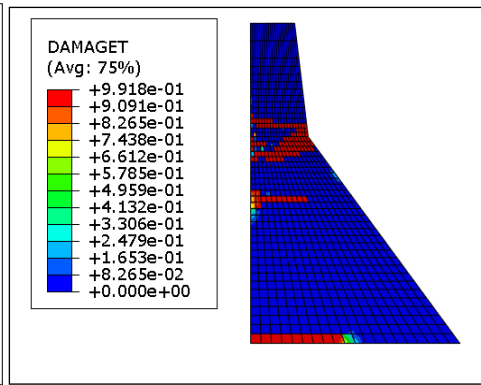
1. Studying the behaviour of a concrete gravity dam without accounting for soil-structure interaction during horizontal ground motion.
2. The study focuses on analysing the behaviour of a concrete gravity dam solely based on horizontal and vertical ground motion, without taking into account the interaction with the soil structure.
3. To study the behavior of the concrete gravity dam, taking into account the interaction between the soil structure and the horizontal ground motion.
4. To study the behavior of a concrete gravity dam in combination with horizontal and vertical ground motion to take into account soil structure interactions.

General

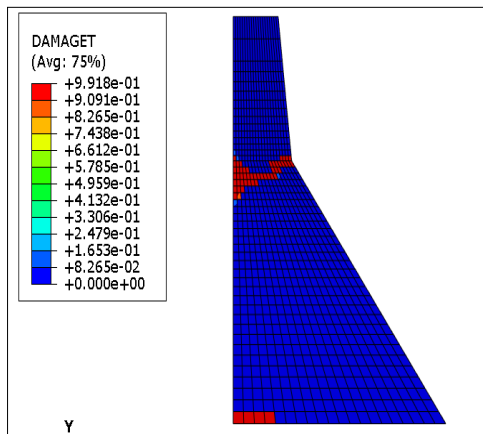
In the non linear time history analyses, two scenarios are taken into account: one involving only horizontal acceleration and the other involving both horizontal and vertical acceleration. For each scenario, variations are observed in a number of parameters such as acceleration velocity, gravitation speed, displacement angle and Vertical Displacement. The results obtained are shown in the plots below:



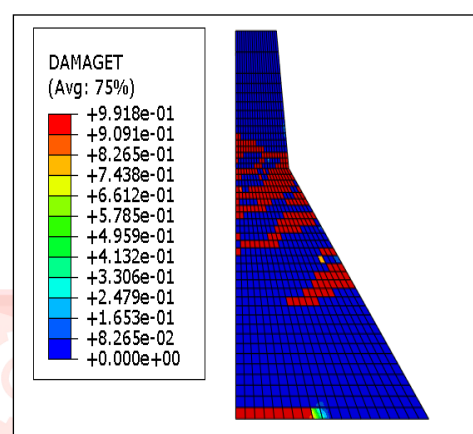
(a) RSN 126 HGM



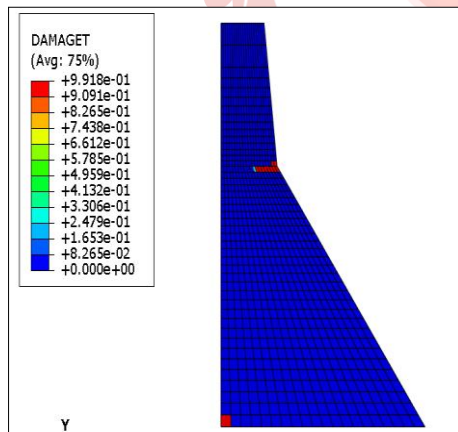
(b) RSN 126 HGM + VGM



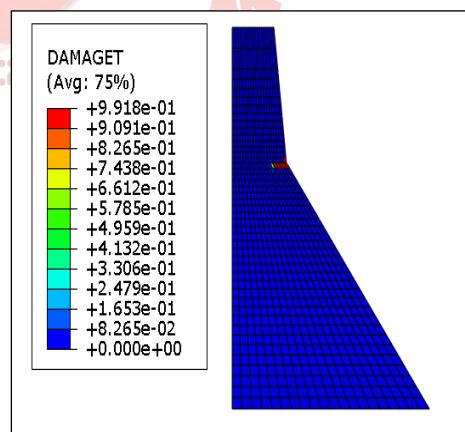
(c) RSN 160 HGM



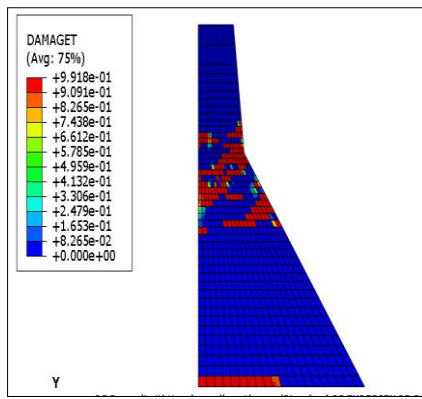
(d) RSN 160 HGM + VGM



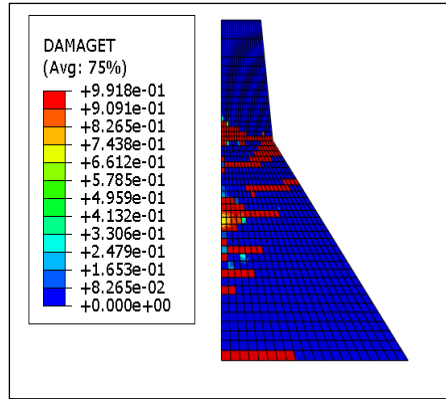
(e) RSN 165 HGM



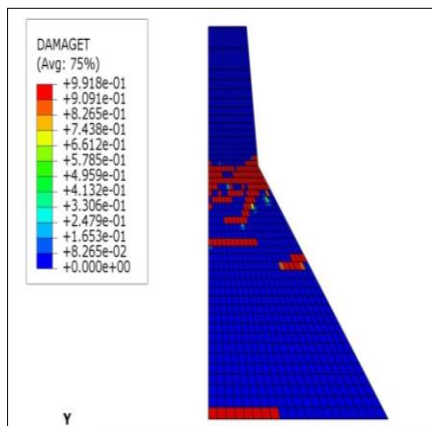
(f) RSN 165 HGM + VGM



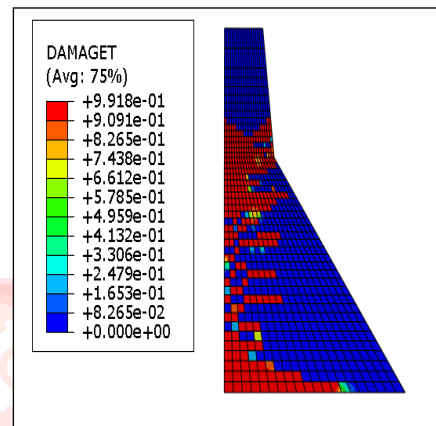
(g) RSN 753 HGM



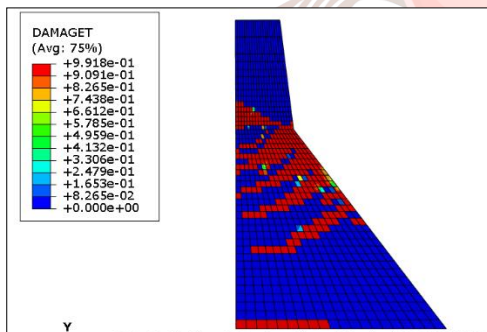
(h) RSN 753 HGM + VGM



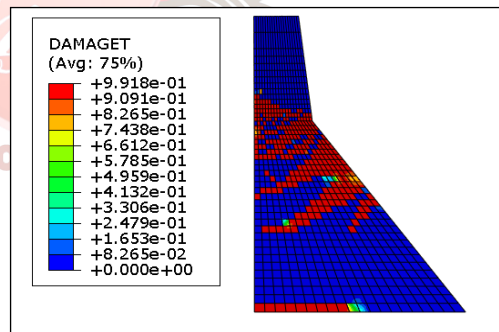
(i) RSN 825 HGM



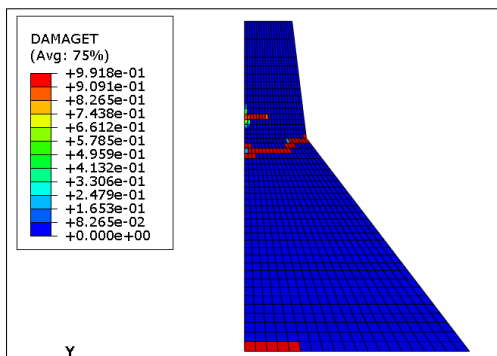
(j) RSN 825 HGM + VGM



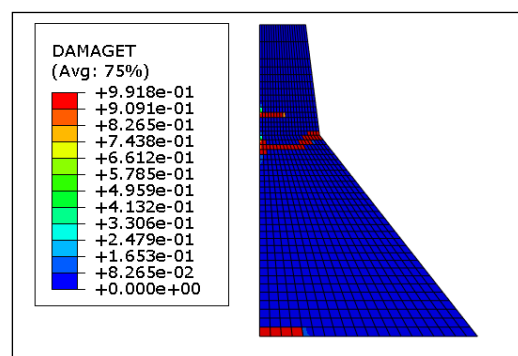
(k) RSN 1063 HGM



(l) RSN 1063 HGM + VGM



(m) RSN 4108 HGM

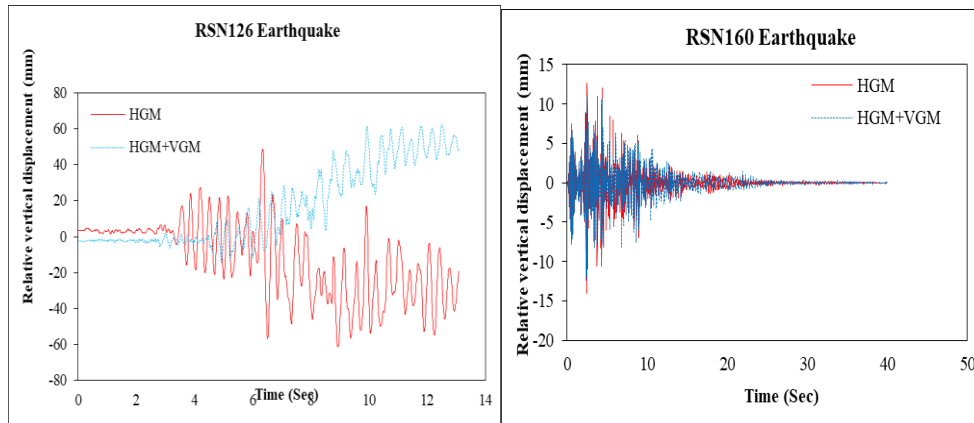


(n) RSN 4108 HGM + VGM

Fig. 2.1 Damage failures in dam strcture subjected to seven earthquakes without considering soil structure interaction

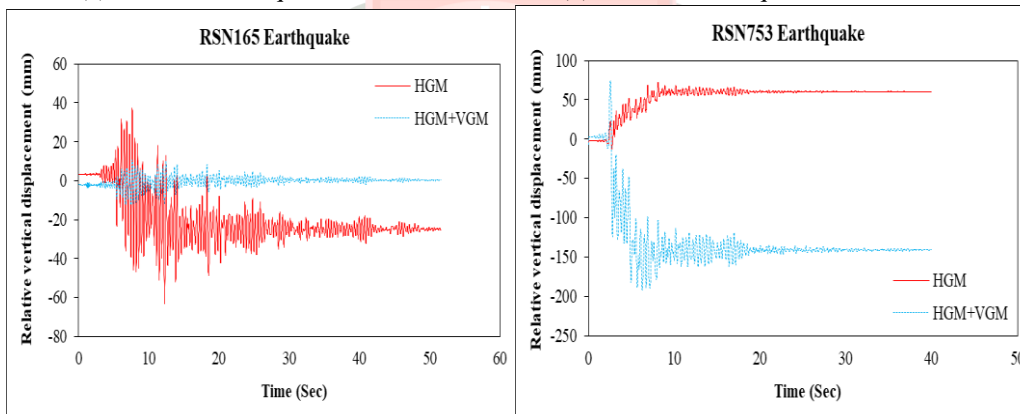
Relative vertical displacement in dam with soil structure interaction subjected to different ground motions.

The relative vertical displacement of a dam, taking into account the interaction between soil structures and ground motion, is shown in fig.4.5 below. For two cases, i.e. horizontal ground acceleration and II horizontal plus vertical ground acceleration, the relative vertical displacement is observed. The results show that, compared to the horizontal ground acceleration case, relative vertical displacement is maximum for both horizontal and vertical accelerator cases.



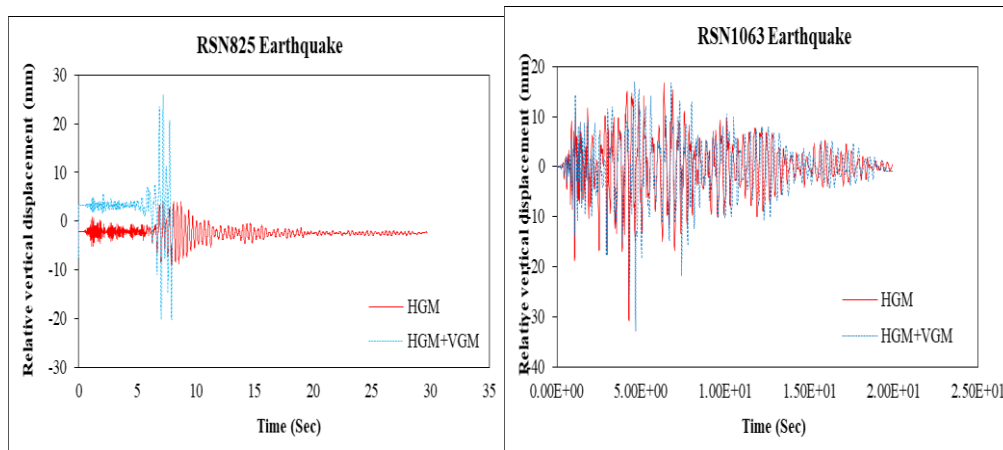
(a) RSN126 Earthquake

(b) RSN160 Earthquake



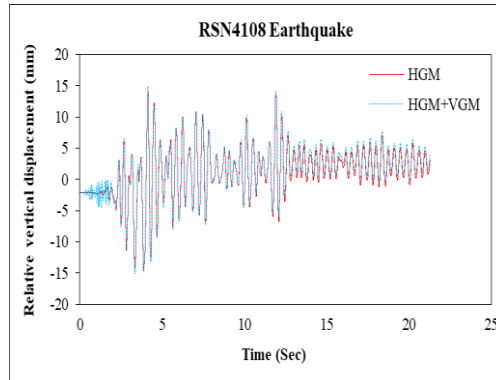
(c) RSN165 Earthquake

(d) RSN753 Earthquake



(e) RSN825 Earthquake

(f) RSN1063 Earthquake



(g) RSN4108 Earthquake

Fig. 2.2 The relative vertical displacement in dam structure subjected to seven earthquakes without considering soil structure interaction

Comparison of percentage difference of relative acceleration for HGM and HGM+VGM.

As shown in Table 4.1 below, the relative acceleration of the concrete gravity dam for HGM and HGM+VGM cases is compared and their percentage differences are calculated. Without taking into account the interaction between the soil structure and the structure, the eight different earthquakes are applied to the structure. The results show that there is percentage increase in relative horizontal and relative acceleration in (HGM+VGM) case for all earthquakes.

Table 2.1: Comparison of percentage difference of relative acceleration

RSN	Relative horizontal acceleration		Difference (%)	Relative vertical acceleration		Difference (%)
	HGM	HGM + VGM		HGM	HGM + VGM	
RSN 126	20.48	26.51	29.44 %	9.90	35.23	2.55 %
RSN 160	27.76	27.33	-1.54 %	19.95	20.54	2.95 %
RSN 165	13.76	16.01	16.35 %	4.13	7.80	88.9 %
RSN 753	29.38	25.96	-11.64 %	17.78	17.18	-3.37 %
RSN 825	35.20	51.34	35.85 %	21.63	32.37	49.65 %
RSN 1063	27.40	34.65	26.45 %	14.39	32.74	1.27 %
RSN 4108	15.06	15.30	1.59 %	6.87	15.89	1.37 %

Table 2.2: Comparison of percentage difference of relative displacement

RSN	Relative horizontal displacement		Difference (%)	Relative vertical displacement		Difference (%)
	HGM	HGM + VGM		HGM	HGM + VGM	
RSN 126	187.63	224.88	19.85 %	61.38	62.19	1.38 %
RSN 160	274.82	295.28	7.44 %	69.85	66.26	-5.14 %
RSN 165	63.25	63.75	0.075 %	12.67	12.39	-2.22 %
RSN 753	154.23	56.53	-63.34 %	72.35	191.75	1.65 %
RSN 825	183.56	253.36	38.02 %	31.21	36.52	17.01 %
RSN 1063	241.42	285.11	18.09 %	192.96	231.20	19.81 %

RSN 4108	97.24	92.59	-4.78 %	14.92	15.10	1.20 %
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CONCLUSION

The seismic behavior of concrete gravity dam structure with and without considering soil-structure interaction is studied in the present study. There are seven different earthquakes in the gravity dam. i) horizontal ground acceleration (HGM) and ii) horizontal plus vertical ground acceleration (HGM+VGM). The observations give rise to the following conclusions :

- The damage failure is more significant for RSN 1063.
- The relative horizontal acceleration is maximum in case of horizontal plus vertical ground acceleration case compared to horizontal ground acceleration case.
- The relative vertical acceleration is maximum in case of horizontal plus vertical ground acceleration case compared to horizontal ground acceleration case.
- The relative horizontal displacement is maximum in case of horizontal plus vertical ground acceleration case compared to horizontal ground acceleration case.
- The relative vertical displacement is maximum in case of horizontal plus vertical ground acceleration case compared to horizontal ground acceleration case.
- The maximum percentage increase in relative horizontal acceleration for RSN 165 is 35.85 %.
- The maximum percentage increase in relative vertical acceleration for RSN 825 is 88.9 %.
- The maximum percentage increase in relative horizontal displacement for RSN 825 is 38.02 %.
- The maximum percentage increase in relative vertical displacement for RSN 1063 is 19.81 %.

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