DOI: http://dx.doi.org/10.12989/sem.2008.30.1.131
Structural Engineering and Mechanics, Vol. 30, No. 1 (2008) 131-133

Technical Note

Behaviour of a weir under earthquake loading

M. M. G. V. Shyamalee†, C. K. Pathirana‡, H. Abeyruwan‡† and K. R. B. Herath‡‡

Department of Civil Engineering, University of Peradeniya, Peradeniya, Sri Lanka

(Received January 8, 2008, Accepted April 14, 2008)

1. Introduction

Earthquakes cause varying degree of damage to structure depending on the intensity felt at the location of it. The weir considered in this study is supported in a trench in solid rock at the bed of the river. A two dimensional (plane strain) stress analysis was carried out on the weir cross section, using SAP 2000 (1998) finite element code. Four-node quadrilateral isoparametric elements were used in the analysis, and it would provide general stresses developed in a cross section of the weir in the vicinity of the center line (axis) of the river.

2. Methodology

The analysis was based on a two-dimensional finite element model. Bottom of the weir is connected to a solid rock, justifying bottom boundary condition of the weir as fixed. A grout curtain extends into the bed rock, hence the uplift force on the weir at the foundation was not considered (Shyamalee *et al.* 2007). The weir is made of Grade 25 concrete; Young's modulus and the Poisson's ratio of the concrete were taken as 24 kN/mm^2 and 0.2 respectively. For the ultimate limit state the following combinations of earthquake action ranging from 0.1 g (1 g = 9.81 m/s^2) to 0.5 g of ground acceleration in the flow direction and lateral to the flow direction were considered.

1) Hydrostatic pressure distribution at upstream for the case of water level at 0.5 m above the crest of weir.
2) Self weight of weir.
3) Water collected on stilling basin.
4) Hydrostatic pressure distribution at downstream for full and no water level.
5) Hydro-seismic forces

The fields of σ_{xx} and σ_{yy}, and displacement in the weir and maximum stresses and displacements near critical locations (Shyamalee *et al.* 2007) for the above load combinations were extracted from the results of the analysis.

† Lecturer, E-mail: shyamalee@civil.pdn.ac.lk
‡ Lecturer, E-mail: chin@civil.pdn.ac.lk
‡† Senior Lecturer, E-mail: helarisi@civil.pdn.ac.lk
‡‡ Senior Lecturer, Corresponding author, E-mail: krbh@civil.pdn.ac.lk

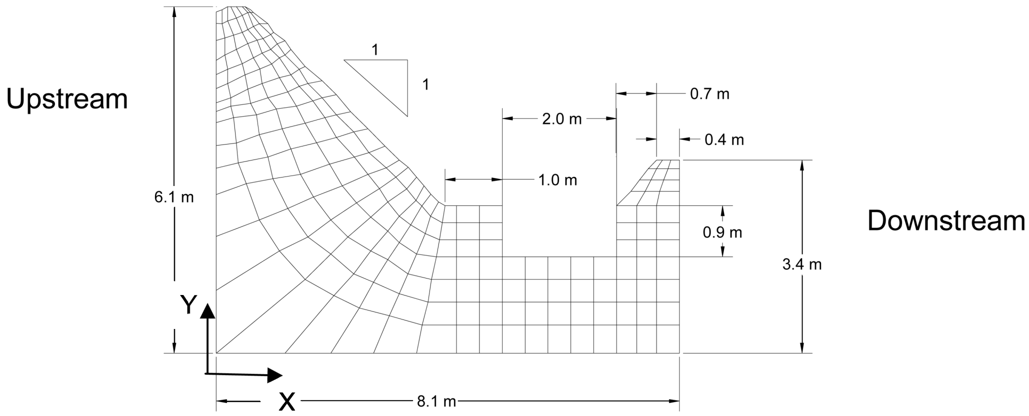

Fig. 1 Finite element mesh used for the analysis

The finite element mesh used for the analysis is shown in Fig. 1. Bottom nodes along the *X*-axis are fixed. *Z* direction is parallel to the longitudinal axis of the weir.

3. Results

3.1 *Load Case 1*: Ultimate limit state corresponding to upstream water level is 0.5 m above the crest of the weir; downstream water is up to the crest level, stilling basin is full of water, and self weight of the dam.

3.2 *Load Case 2*: Ultimate limit state corresponding to upstream water level up to the crest of weir, downstream is empty (no water), stilling basin is empty, and the self weight of the dam.

Fig. 2 and Fig. 3 show that σ_{yy} near upstream toe increases while σ_{xx} decreases with the increase of earthquake ground acceleration. It is also observed that both σ_{xx} and σ_{yy} near downstream toe decreased with the increase of earthquake ground acceleration.

Maximum horizontal displacement (u) and maximum vertical displacement (v) observed at the crest of the weir are reported in Table 1.

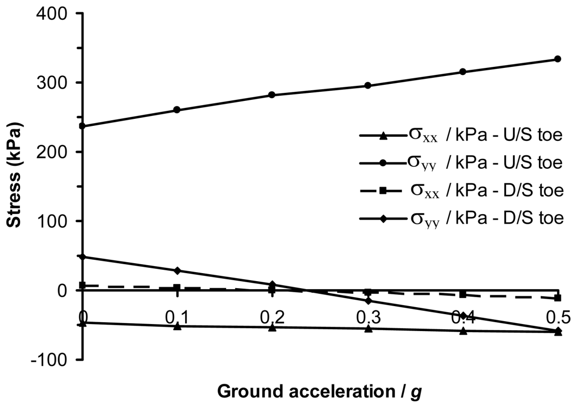

Fig. 2 Stress variation with ground acceleration in *X* direction for the *Load Case 1*

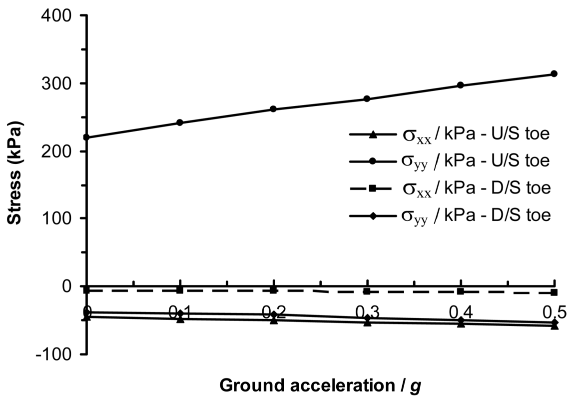

Fig. 3 Stress variation with ground acceleration in *X* direction for the Load Case 2

Table 1 The effect of ground acceleration along *X* direction, maximum displacement values at the crest of the weir

Ground acceleration along *X* direction / g	Load Case 1		Load Case 2	
	u / mm	*v* / mm	*u* / mm	*v* / mm
0	0.067	0.024	0.061	0.022
0.1	0.073	0.027	0.068	0.025
0.2	0.081	0.030	0.075	0.027
0.3	0.085	0.031	0.079	0.029
0.4	0.091	0.033	0.085	0.031
0.5	0.097	0.035	0.090	0.033

Though there is no corresponding significant increase in both *X* and *Y* direction displacement values for *Load Case 2*, the horizontal displacement is marginally higher than those obtained for *Load Case 1.* When the ground acceleration is along the *Z* direction, *u* and *v* displacement values at the crest of the weir are less than the values obtained for ground acceleration in *X* direction.

4. Conclusions

For general water loading on the weir, tensile stresses develop in the upstream area of the weir with the maximum occurring at the upstream toe. The tensile stress near upstream toe increases with the increase of ground acceleration along *X* direction. The stress is still lower than the allowable tensile strength of concrete even for a high horizontal ground acceleration of 0.5 g. Finally, it can be concluded that there is not any significant variation of stresses due to a moderate earthquake loading on a comparable weir.

References

SAP2000 Non-linear, Version 7.41, Analysis Reference User's Manuals, Computers and Structures Incorporation (CSI), Berkeley, California, USA, 1998.

Shyamalee, M.M.G.V., Pathirana, C.K. and Herath, K.R.B. (2007), "Analysis of a weir for an earthquake loading", *Proc. of the Int. Conf. on Mitigation of the Risk of Natural Hazards, IIIRRR, University of Peradeniya,* Sri Lanka, March.

Shyamalee, M.M.G.V., Pathirana, C.K., Abeyruwan, H. and Herath, K.R.B. (2007), "Initiation of thermal cracks in a weir", *Proc. of the Peradeniya University Research Sessions, PURSE,* University of Peradeniya, Sri Lanka, November.

Shyamalee, M.M.G.V., Pathirana, C.K., Abeyruwan, H. and Herath, K.R.B. (2007), "Earthquake effect on a weir", *Proc. of the 63rd Annual Sessions of Sri Lanka Association for the Advancement of Science,* Open University, Sri Lanka, December.