Preface

Many concrete gravity dams have experienced cracking formations and propagation which could influence their structural stability and endanger the safety of the dams. Although many analytical methods, based on fracture mechanics, have been proposed for concrete dams in the last few decades, they have not yet become part of standard design procedures. Current practice for crack analysis in concrete dams is to implement either the traditional "no-tension" gravity design method or a non-linear FEM analysis including plasticity models and contact simulation. In all these FEM analyses, uplift pressure in the cracks is either neglected or assumed constant during both static and dynamic loading conditions. However, during earthquakes or varying reservoir levels, uplift pressure in the existing cracks of the concrete gravity dams varies with both time and space. Some safety guideline recommends the existence of simple uplift pressure profile in the cracks under such conditions. Very few research works have been done to evaluate the safety of concrete gravity dams under transient uplift pressure in the cracks.

In present study, one dimensional mathematical modeling of transient uplift pressure in the single wedge-shaped crack has been done on the basis of various assumptions and understanding of hydrodynamic phenomenon occurring during crack-wall motion. One dimensional continuity and Louis (1969) momentum equations for different flow regimes (laminar/ turbulent) and hydraulic roughness has been coupled separately for opening and closing phase of crack-wall motion. The resulting partial differential equations contain unknown pressure as function of space and time together with some important unknown parameters like saturation length, stagnation point and stagnation pressure. These unknown parameters are first solved using known or assumed boundary conditions and equation resulting from application of Reynolds transport equation of mass conservation to control volume chosen between crack mouth and stagnation point during closing phase. After calculating these flow parameters, partial differential equations are derived in integral form separately for opening and closing mode to calculate pressure field at any given time. Numerical solution of transient uplift pressure in single crack is validated using data from the literature. Uplift pressures, computed at different time during opening and closing phases of crack wall motion, are in good agreement with measured data in the literature.

To study the dam-crown deflection under the effect of uplift pressure in cracks of concrete gravity dams, plane strain linear elastic equations have been developed, assuming that LEFM is applicable for cracks in concrete gravity dams. A six degree of freedom triangular plane strain finite element has been used in FE model for dam-crown deflection with transient uplift pressure in cracks as one of the boundary conditions.

Further, in the present study, sliding factor of safety as recommended by USACE (1995) has been used, assuming that cohesion is zero. Sliding factor of safety is calculated separately for two uplift pressure conditions in cracks: (i) Uplift pressure distribution as recommended by USACE and (ii) Uplift pressures as calculated in present study.

Rihand dam is inflicted with multiple cracks caused due to various factors. Crack parameters like CMOD rate, number of cracks, their geometry and locations are unfortunately not available. CMOD rate caused due to creep in FPZ of cracks are affected by (i) fatigue caused due to reservoir level variations (ii) interactions of multiple cracks etc. Therefore, after several trials for choosing the CMOD-rate generating functions, one that provides the satisfactory result, are chosen. Same criteria have been used to find the number, geometry, and locations of cracks at upstream face of the dam.

Transient uplift pressures in cracks of the dam are calculated and discussed at slope-changing point and dam-foundation interface. It is assumed that the crack wall motion occurs due to creep in FPZ and monthly reservoir level variation. Six years of data record for monthly reservoir level variations has been used. During first quarter of each year of data record, saturation length at the heel is more than saturation length at the slope- changing point and uplift pressure during this period decreases. But in second quarter of each year, uplift pressure begins to increase. In third and fourth quarter of each year both the cracks are subjected to increased uplift pressure with peak uplift pressure going beyond the applied crack mouth pressure and reaches maximum value in eleventh month of each year.

Results for dam-crown deflections of dam correspond to minimum root-mean- square- error (RMSE) values for each year of recorded data. Computed dam- crown deflection during first six month (when reservoir level increases) shows larger difference with field data, but during crack closing phase (reservoir level decreases), computed values almost follows the field data.

Factor of safety against sliding (FSS) in dam at slope changing point by present model is very high in comparison to FSS value calculated using USACE uplift criteria in the cracks. This result gives a very important insight that safety of the dam at slope-changing point is more conservative by present method than used by USACE. At dam foundation interface USACE criteria of FSS value changes very slowly in each year, but uplift values in cracks in present study makes the trend of FSS value to decrease faster and at the end of each cycle (eleventh month) and tend to go even below the FSS value calculated by USACE.