Chapter-1

INTRODUCTION

1.0 General

Gravity dams are structures that rely on their own weight for resistance against sliding and over turning to maintain stability. With the development of design and analytical expertise, as well as of construction techniques and equipment, dams have become ever larger with regard to both height and volume. If a dam on this scale were to fail and collapse, this could lead to probably the greatest disaster in human history. Therefore, the safety of huge structures such as concrete gravity dams is of the utmost concern to the engineers involved in the design, construction and post-built safety evaluation of dams.

Many concrete gravity dams, which are generally massive and plain concrete structures, have experienced cracking problems to various extents. Crack formation and propagation in concrete gravity dams could influence their structural stability and endanger the safety of the dams. Normally, the huge size of a concrete dam excludes direct experimental tests on the structural cracking behavior under various loading conditions. Therefore, evaluation of the possible cracking trajectory in concrete dams by means of an accurate constitutive model, in order to simulate the cracking response of the concrete effectively, becomes vital and would be a useful tool for practicing engineers to ensure the safety of dam structures.

A great deal of research on the numerical modeling of the cracking behavior of concrete has been carried out during the past few decades. In the process, many concrete crack propagation models have been developed and applied in concrete cracking analyses. Linear elastic fracture mechanics (LEFM), in which crack growth occurs when the effective stress intensity factor exceeds the material's fracture toughness, has been widely used in the analysis of concrete structures in the past. Models based on non-linear fracture mechanics (NLFM) have now become popular for analyzing concrete cracking due to the existence of a fracture process zone (FPZ) at the front of the crack tip. This requires developing a numerical model and techniques that can accurately analyze and appraise a dam structure, either for the purpose of designing a new dam or for evaluating the safety of an existing concrete dam. Although many analytical methods based on fracture mechanics have been proposed for concrete dams in the last few decades and they have not yet become a part of standard design procedures. In fact, few of the current researches from all over the world are being implemented by practicing engineers when evaluating dam safety.

Current practice for crack analysis in concrete dams is to implement either the traditional "no-tension" gravity design method, which is based on rigid body equilibrium and strength of materials to determine crack length, assuming horizontal planar crack extension, linear stress distribution and zero stress at crack tip, or a non-linear finite element method (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 time and space. Some safety guideline recommends the existence of simple uplift pressure profile in the cracks under such conditions. Few research works have been done to evaluate the safety of concrete gravity dams under transient uplift pressure in the cracks.

1.1 Motivations for Present Study

Rihand Dam, an old concrete gravity dam, situated in Sonebhadra district of Uttar Pradesh, India is inflicted with multiple cracks caused due to alkali-silica reaction (ASR). Dam is continuously sliding towards the downstream and affecting the turbines and other appurtenances of the powerhouse located near the toe of the Dam. In order to evaluate the stability and safety of concrete dams more accurately, it is necessary to develop a better model after accounting of transient uplift pressure in the cracks of the dam.

1.2 Organization of This Study

Chapter-1 gives the background, motivation, objectives and scope of present study this study.

Chapter -2 is a comprehensive literature review of the development of transient uplift pressure models, applicability of LEFM in analysis of dam stability and CMOD rate under effective creep phenomenon occurring in FPZ.

Chapter-3 presents the mathematical modeling. These modeling consist of: (i) development of integral equations with appropriate boundary conditions for calculating the transient uplift pressure in cracks (ii) plane-strain finite element formulations for dam-crown deflection and (iii) factor of safety in sliding.

Chapter-4 contains parameter estimations relevant to mathematical modeling in present study, like assumption and derivation of CMOD generating function etc. and outlines of computational procedures.

Chapter-5 contains the validation of transient uplift pressure using data of published literature. Assuming derived CMOD rate valid for present problem, uplift pressure in different cracks located at upstream face of the dam is calculated under various assumptions of crack parameters (i.e. its locations, lengths etc.). These calculated uplift pressures are applied iteratively to calculate the dam-crown deflection under reservoir level variations until result converges closely to field data. Uplift pressures and crack parameters are thus assumed to be valid for these convergent solutions and therefore these are applied to estimate the factor of safety against sliding.

Chapter-6 presents the conclusion and further scope of study. Conclusions are presented in respect of transient uplift pressure under assumed crack parameters and its verifications based on the convergent solution of dam-crown deflections. Further the scope study is discussed in respect of availability of data, new solution techniques and inclusion of additional variables in present formulations.