

Earthquake Response of Concrete Gravity Dams

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Abstract

Nepal is set to construct a number of large dams to cater for its ever increasing power demand. One of the big dams in the pipeline is Arun III dam in the Sankhuwasabha district in eastern Nepal. The Arun III dam was designed in the mid 1980s and little is known about its capability to resist major earthquakes which are probable in this region. The Himalayan region is one of the most earthquake prone zones in the world but the seismic hazard level of the region is not well established. This study was undertaken with a purpose to investigate the seismic performance of the Arun III dam under site specific design ground motions.

In the first part of the research, a seismic hazard estimate was carried out for the eastern Nepal Himalayas where the Arun III dam is proposed. For the hazard study, two approaches were used:

- Probabilistic approach using Atkinson and Boore model of attenuation and
- Component Attenuation Model (CAM) methodology

The established seismic hazard was used to select design ground motions for the site. Four real earthquake accelerograms and one synthetic record were selected. While selecting the ground motions, special attention was paid to the scaling of the records to match the characteristics of the design level event.

The seismic performance of the dam was evaluated following the US Army Corps of Engineers guidelines, using both static and dynamic analysis approaches. Initially, the finite element model of the dam was developed and the seismic analysis was performed in a step by step manner starting from the preliminary level i.e. static analysis. The study the model was analysed using linear elastic dynamic analysis procedures – Response Spectrum Modal Analysis procedure and Time History Analysis procedure. The records selected from the seismic hazard study were applied as seismic loads to the finite element model of the dam structure in the dynamic analysis methodology. Then the results were analysed with the acceptance criteria established from the previous researches on gravity dams. In addition, a non-linear analysis was undertaken to evaluate the degree of cracking and damage to the dam structure under extreme earthquake excitation. Based on the analyses it was concluded that the Arun III dam is safe against collapse from the design level events but damage is probable primarily due to cracking relating to the localized high tensile stresses in the concrete.

Preface

During the course of this research a refereed conference paper to an international conference was written which has been accepted for publication. The details listed below:

D. Wagle, J.L. Wilson and K. Abdouka 2010 “Seismic performance evaluation of a concrete gravity dam in Nepal” *21st Australasian Conference on Mechanics of Structures and Materials 2010 (ACMSM21), Melbourne.*

Declaration

This is to certify that this thesis comprises:

- no material which has been accepted for the award to the candidate of any other degree, except where due reference is made in the text,
- solely of my original work and due acknowledgement has been made wherever other previously published material and references are used.
- less than 50,000 words in length, exclusive of tables, maps, charts and bibliographical references.

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Abbreviations

ADRS	Acceleration Displacement Response Spectrum
BSI	British Standards Institution
CAM	Component Attenuation Model
CSM	Capacity Spectrum Method
DCR	Demand Capacity Ratio
ELF	Equivalent Lateral Force
EM	Engineer Manual
EPGA	Equivalent Peak Ground Acceleration
ER	Engineer Regulation
FEA	Finite Element Analysis
FEM	Finite Element Method
GoN	Government of Nepal
GSHAP	Global Seismic Hazard Assessment Program
HEP	Hydro Electric Project
HFT	Himalayan Frontal Thrust
HPP	Hydro Power Project
HREP	Hydro and Rural Electrification Project
ICOLD	International Commission On Large Dams
INPS	Integrated Nepal Power System
IS	Indian Standard
ITSZ	Indus Tsangpo Suture Zone
JICA	Japan International Cooperation Agency
LDP	Linear Dynamic Procedure
LSP	Linear Static Procedure
MBT	Main Boundary Thrust
MCE	Maximum Credible Earthquake
MCT	Main Central Thrust
MDE	Maximum Design Earthquake
MFT	Main Frontal Thrust
MoPPW	Ministry of Physical Planning and Works
MW	Megawatt
M_w	Moment Magnitude
NDP	Nonlinear Dynamic Procedure
NEA	Nepal Electricity Authority
NSC	National Seismological Centre
NSET	National Society for Earthquake Technology
NSP	Nonlinear Static Procedure
OBE	Operational Basis Earthquake
PGA	Peak Ground Acceleration
PSHA	Probabilistic Seismic Hazard Estimation
RSA	Response Spectral Acceleration
RSD	Response Spectral Displacement
RSMA	Response Spectrum Modal Analysis
RSV	Response Spectral Velocity
STDS	South Tibetan Detachment System
UHRS	Uniform Hazard Response Spectrum
USACE	United States Army Corps of Engineers