TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

DEPARTMENT OF CIVIL ENGINEERING

M .Sc. Program in Structural Engineering

Thesis no:

DECOUPLED SEISMIC DEFORMATION ANALYSIS OF A ZONED ROCKFILL DAM

SHANKER DHAKAL

February – 2008

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A thesis submitted by
SHANKER DHAKAL

In partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE
IN STRUCTURAL ENGINEERING

February – 2008

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CERTIFICATE

This is to certify that the work contained in this thesis entitled “Decoupled Seismic Deformation Analysis of a Zoned Rockfill Dam”, in partial fulfillment of the requirement for the degree of Master of Science in Structural Engineering, as a record of research work, has been carried out by Mr. Shanker Dhakal (062 / MSS / r / 107) under my supervision and guidance in the Institute of Engineering, Pulchowk Campus, Lalitpur, Nepal. The work embodied in this thesis has not been submitted elsewhere for a degree.

……………………………..

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ABSTRACT

The seismic safety, in terms of crest settlement, of a zoned rockfill dam designed by the traditional empirical methods is evaluated. The proposed high dam of Bagmati Multipurpose Project (BMP), Nepal is taken as a typical case.

2D finite element method with plane strain assumption is used. The 'decoupled deformation analysis' technique is adopted in which the peak crest acceleration response obtained by dynamic analysis is utilized to predict the potential permanent settlement of the crest using the chart developed based on Newmark's analysis procedures. All calculations are performed on a PC using the available SAP2000 software package. The recorded N-S and the vertical acceleration components of the famous Imperial Valley earthquake of May 18, 1940 (El Centro, California, USA) are taken as the prescribed input ground motion. Linear direct integration time history analysis based on Wilson-θ (θ = 1.42) incremental algorithm is adopted. Damping is introduced in terms of Rayleigh's damping coefficients. Four different finite element models: rigid and flexible foundation models, each with and without reservoir; designated by RF_WOR, FF_WOR, RF_WR and FF_WR are evaluated. For the models with flexible foundation, the effective part of foundation to be taken in the model is worked out by trial procedure based on 'stress criterion'. For calculating the hydrodynamic effects in the case of the models with reservoir and also for the chart to predict the potential permanent settlement of the crest, the IS guidelines is simply followed.

A great deal of parametric studies on free vibration analysis and initial static deformation analysis are carried out. The results of the parametric studies compare well with the classical soil mechanics and the findings of the previous researches reviewed in this thesis, thereby justifying the models exercised. It is revealed that the permanent crest settlement of the BMP dam predicted with the four different models are relatively higher.

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NOTATIONS

G	Average shear modulus of elasticity at a given depth of core
[D]	Constitutive, stress-strain matrix
ξ_m	Damping constant (m subscript for m^{th} mode)
z	Depth below the crest, depth above the core
u	Displacement field in horizontal direction
v	Displacement field in vertical direction
{f}	Displacement field vector
$\{F\}_e$	Element nodal force vector
$[K]_e$	Element stiffness matrix
[C]	Global damping matrix
{d}	Global displacement vector
[M]	Global mass matrix
{F}	Global nodal force vector
[K]	Global stiffness matrix
H	Height of dam, total depth of reservoir
m	Inhomogeneity factor
ω_m	Natural vibration frequency (m subscript for m^{th} mode
ε	Normal strain
σ	Normal stress
ξ, η	Natural coordinate system of a finite element
$\{d\}_e$	Nodal displacement vector of an element
υ, ¬	Poisson’s ratio
α, β	Rayleigh’s damping coefficient
[11], ^{11}	Reference no
$\ddot{u}(t)$ }	Response acceleration vector
$\{ u(t) \}$	Response displacement vector
{r(t)}	Response vector relative to ground motion

$\{\dot{u}(t)\}$	Response velocity vector
N_i	Shape function for i^{th} node of an element
γ	Shear strain
τ_{xy}	Shear stress (subscript xy for x-y plane)
[B]	Strain-displacement matrix
$\{\varepsilon\}$	Strain field vector (tensor)
$\{\sigma\}$	Stress field vector (tensor)
G_b	Shear modulus at base of core
δt, Δt	Time increment
E	Young's modulus of elasticity
θ	Wilson's coefficient
ζ	z/H
Art.	Article
B.E.	Bachelor in Engineering
BMP	Bagmati multipurpose project
BIP	Bagmati irrigation project
FF	Flexible foundation
FSL	Full supply level
MOL	Minimum operating level
MDOF	Multi degrees of freedom
NAP	Newmark's analysis procedure
No.	Number
RF	Rigid foundation
R-O-R	Run-of-the-river
RTS	Reservoir triggered seismicity
SAP	Structural analysis program
TWL	Top water level (maximum water level)
WOR	Without reservoir
WR	With reservoir