



11 Dec 2014

## Computational Modeling in Geotechnical Eq. Eng.

D. K. Paul  
*IIT Roorkee*

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### Recommended Citation

Paul, D. K., "Computational Modeling in Geotechnical Eq. Eng." (2013). *Forum for Promotion of Soil Dynamics in India*. 4.

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# COMPUTATIONAL MODELLING IN GEOTECHNICAL EQ ENGG.



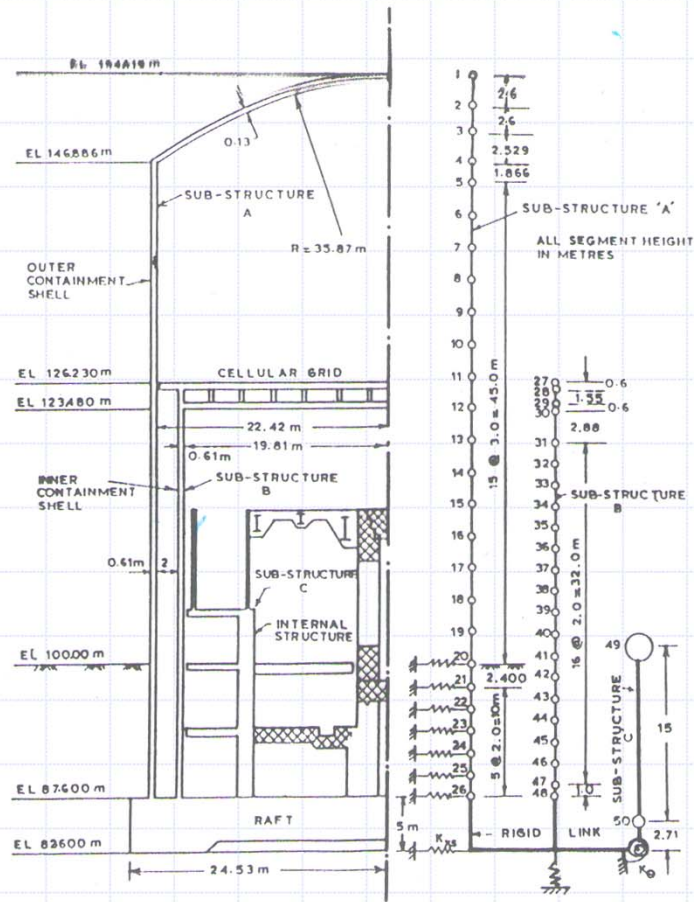
**D.K. Paul, *FNAE***

*Emeritus Fellow*

*Department of Earthquake Engineering  
Indian Institute of Technology, Roorkee*

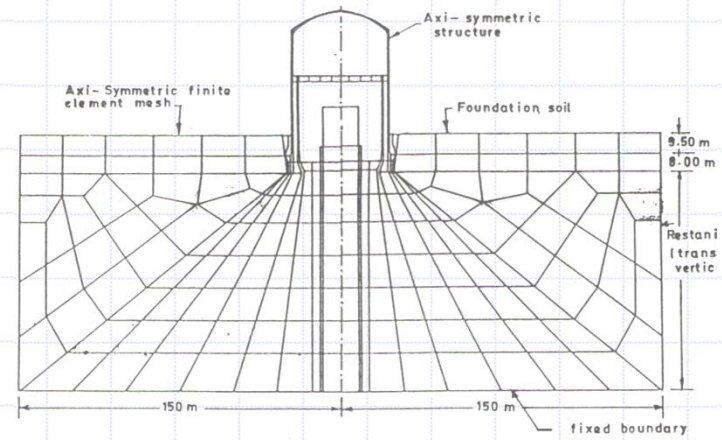
# ATOMIC POWER PLANTS ON ALLUVIAL SITE

## Dynamic soil – structure interaction



(a) Actual structure showing containments

(b) Mathematical model



Finite Element Model - Analysis

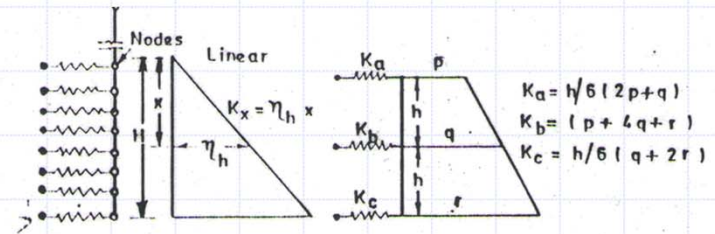


Fig.14 Lumping of soil stiffness at nodes

# SOIL- PORE FLUID INTERACTION - A UNIFIED APPROACH

$$\begin{aligned} \underline{M} \ddot{\underline{u}} + \int_{\Omega} \underline{B}^T \underline{\sigma} d\Omega &= \underline{f}_u - \underline{Q} p \\ \underline{S} \dot{p} + \underline{H} p &= -\hat{\underline{M}} \ddot{\underline{u}} + \underline{Q}^T \dot{\underline{u}} + \underline{f}_p \end{aligned}$$

Linear static / nonlinear drained/ nonlinear un-drained solution

Seepage analysis

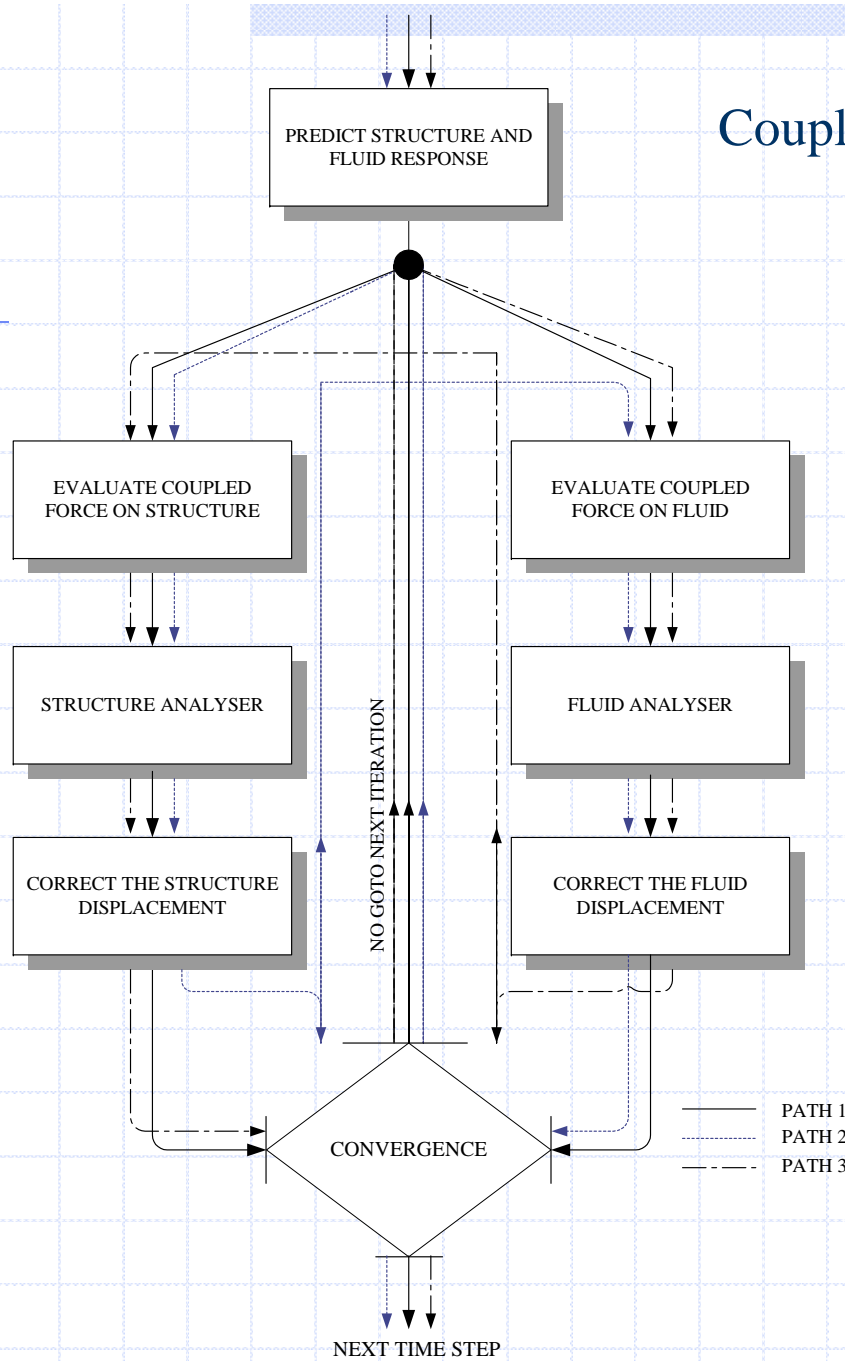
Response of saturated soil under dynamic loads

Structure-soil-pore fluid interaction

Liquefaction

Sedimentation and consolidation

# Coupled Analysis



## MODELLING ISSUES

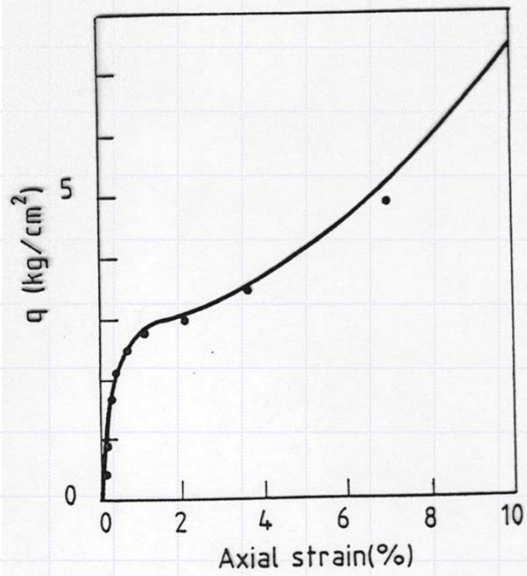
- Constitutive model of soil - nonlinear
- Dynamic soil-structure interaction

Input motion

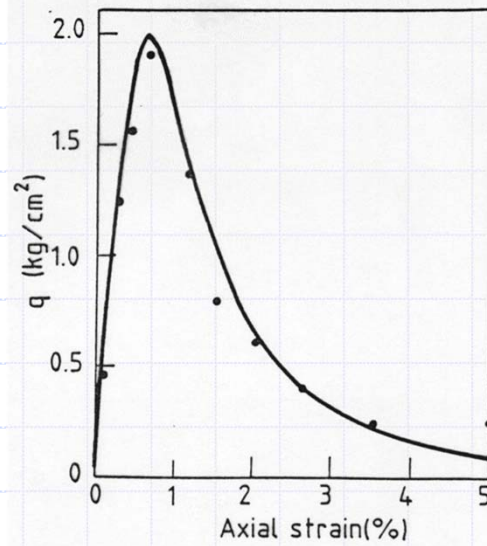
Infinite soil domain

Structure-soil interfaces

## CONSTITUTIVE MODELLING



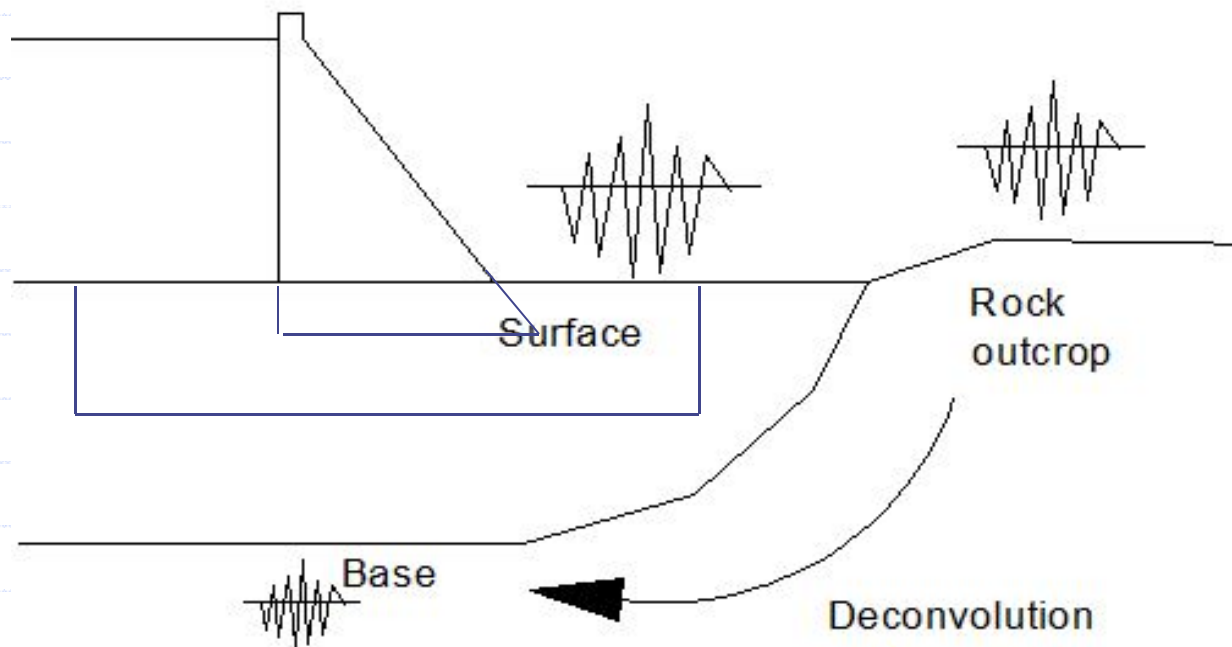
Dense sand  
 $D_r$  47%



Loose sand  
 $D_r$  27%

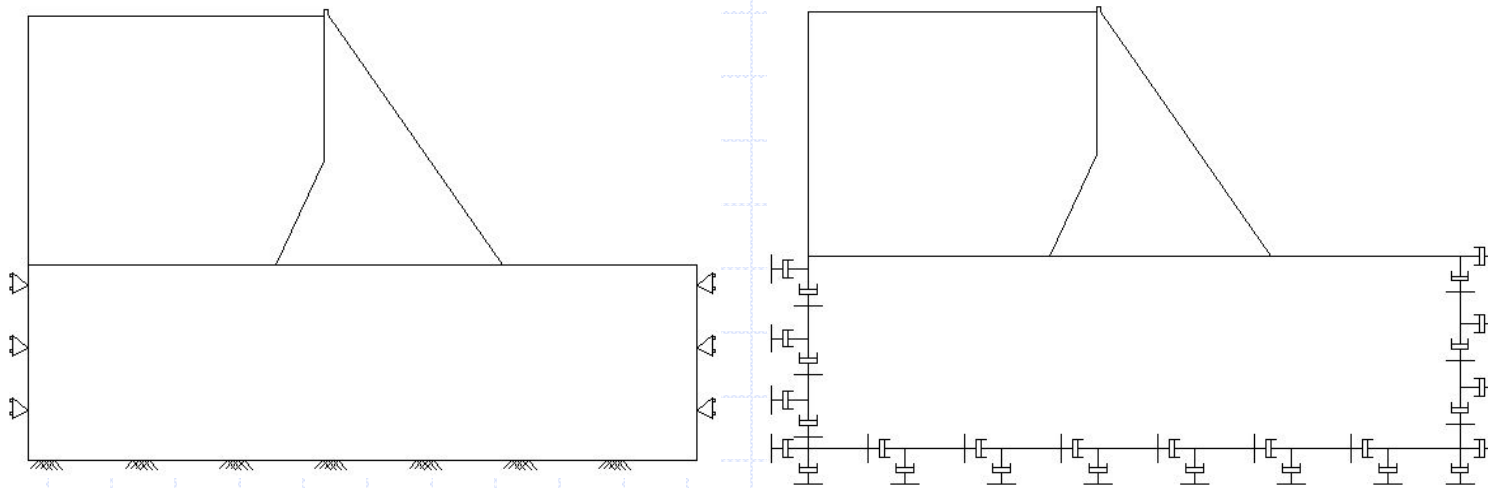


## SPECIFYING THE INPUT MOTION

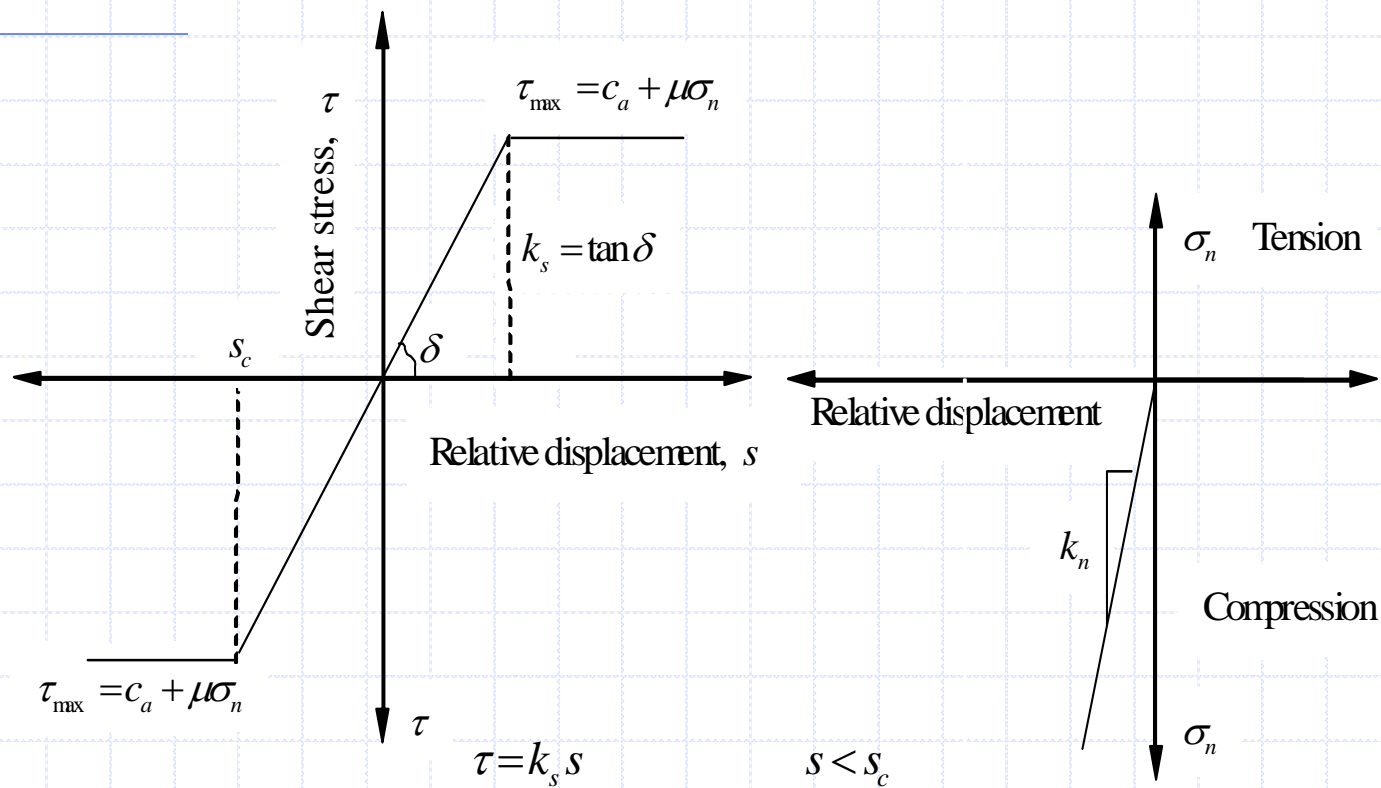




# TREATMENT OF FINITE BOUNDARIES

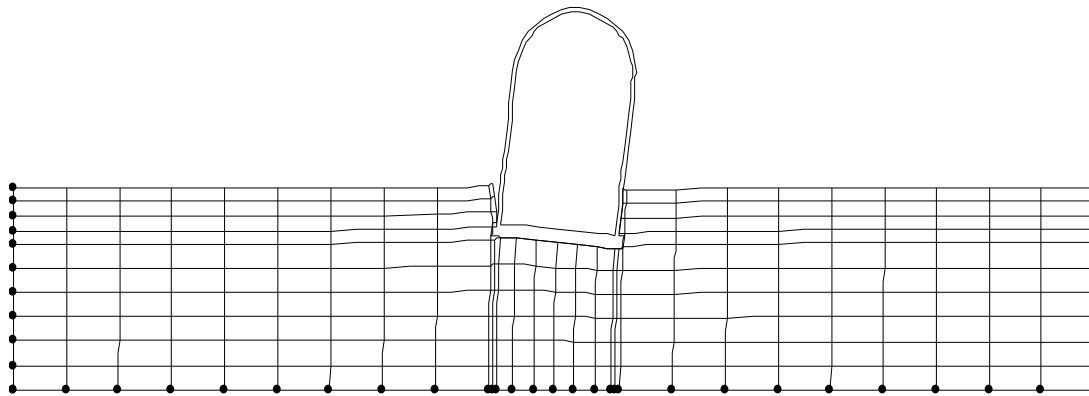


# TREATMENT OF INTERFACE (Slip and separation model)

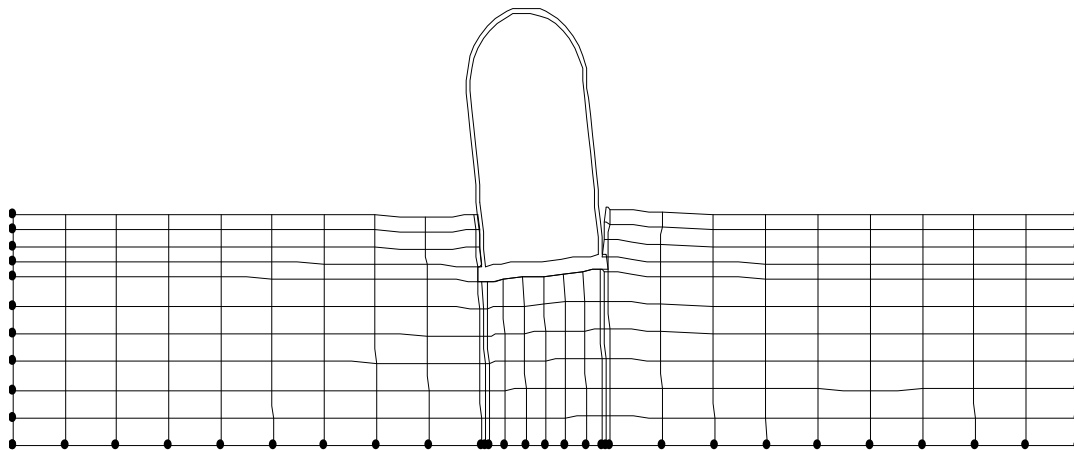


$\tau = k_s s$	$s < s_c$
$\tau_{\max} = c_a + \mu \sigma_n$	$s \geq s_c$
$k_s = \tan \delta$	$s < s_c$
$k_s = 0$	$s \geq s_c$ or $\sigma_n > 0$

## DSSI - WITH SLIP AND SEPARATION

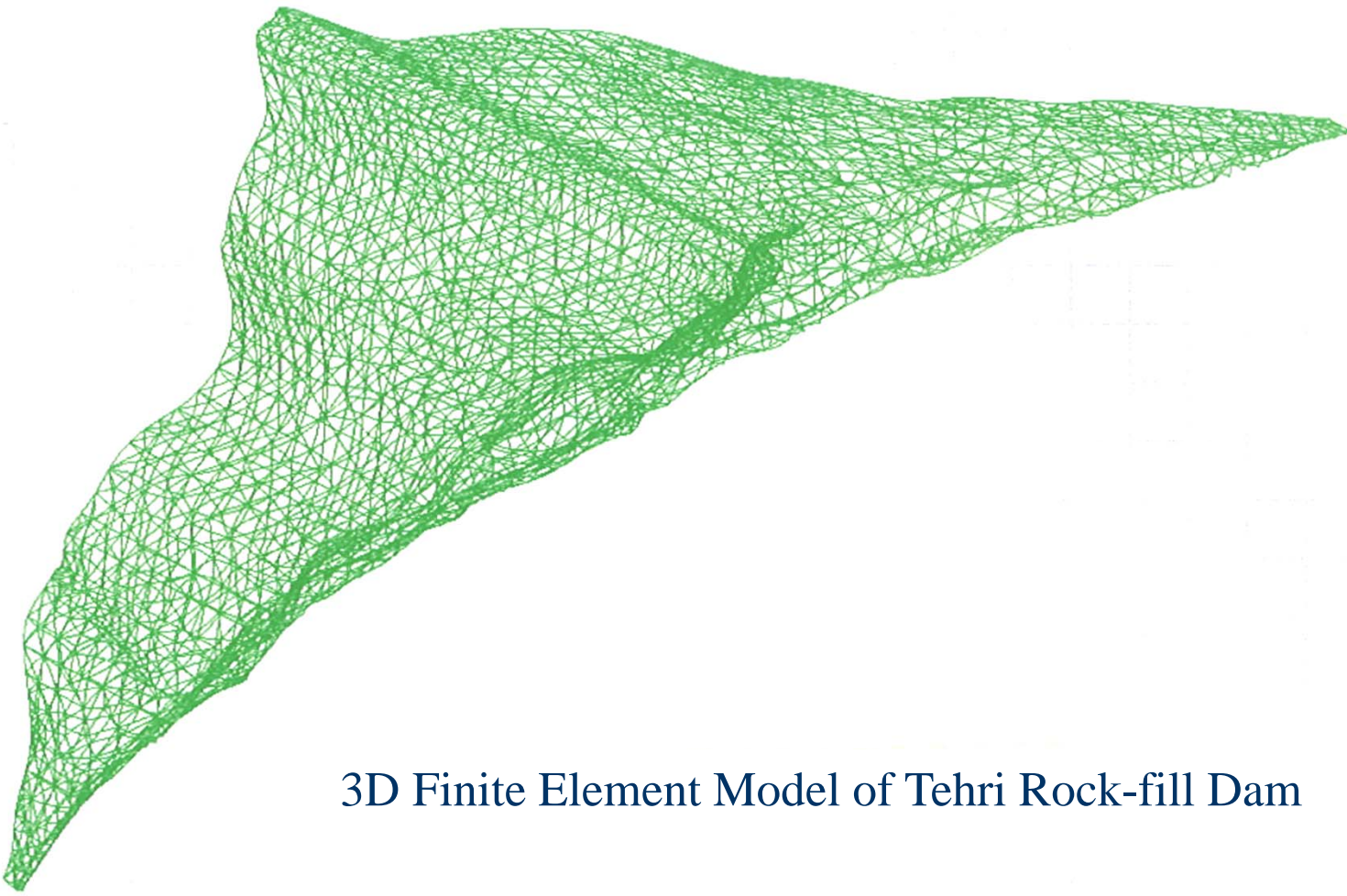


Deflected shape at the time of maximum vertical separation at heel



Deflected shape at the time of maximum horizontal separation at sides

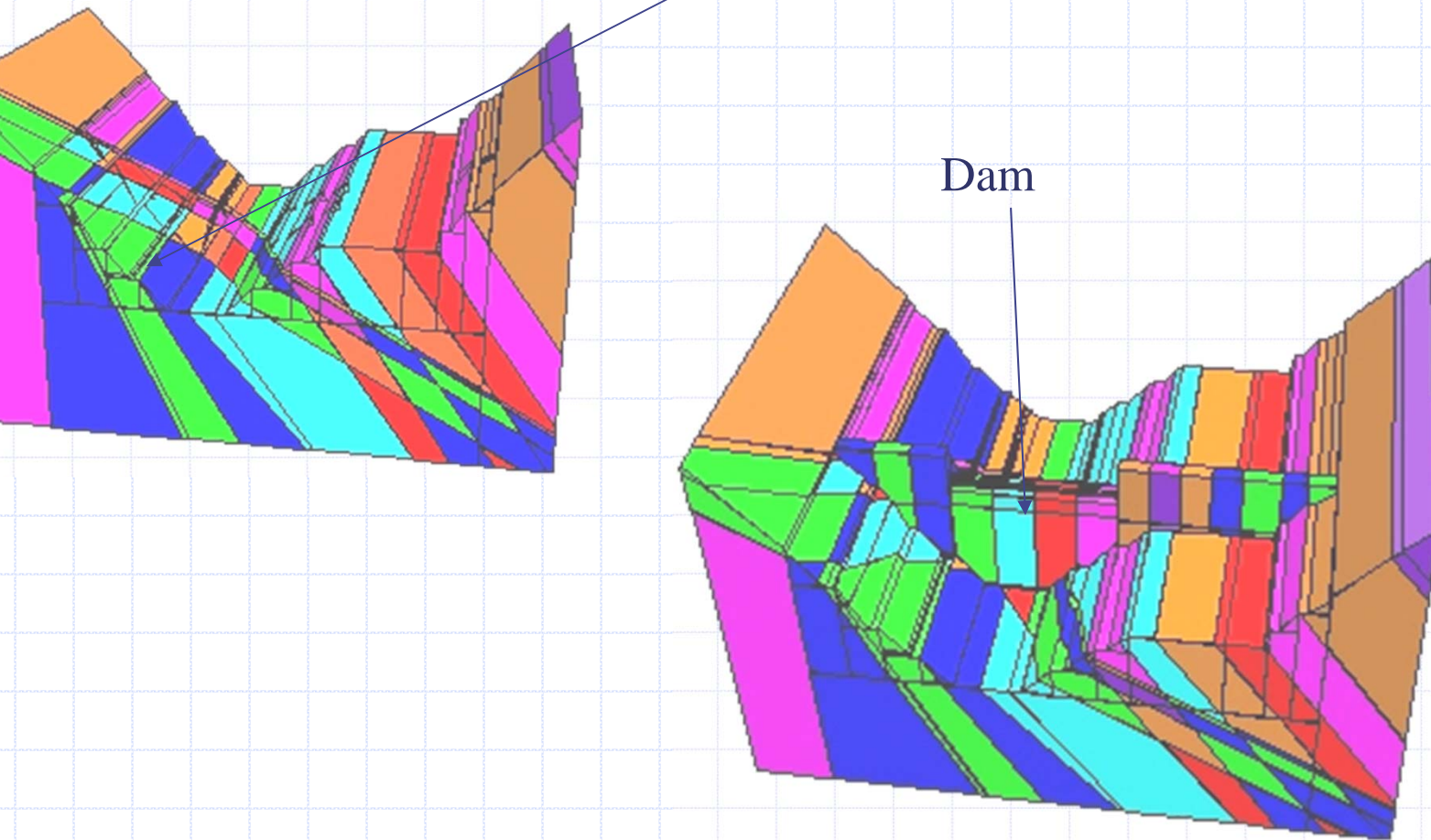
3D Seismic (FEM) Analysis  
*of*  
Tehri Rock-fill Dam



3D Finite Element Model of Tehri Rock-fill Dam

# DAM & FOUNDATION DISCONTINUITIES ( Koteswar Dam )

Lithological Discontinuities Included -3DEC



## COURSES ON GEOTECHNICAL EARTHQUAKE ENGG.

### COMPUTATIONAL MODELLING FOR GEODYNAMIC PROBLEMS

- Feb. 18 to March 1, 1997: Dr. D.K. Paul and Shyamal Mukerjee

### GEO-TECHNICAL EARTHQUAKE ENGINEERING

- 29 August to Sept. 3, 2005: Dr. B.K. Maheshwari & Dr.D.K. Paul

### GEOTECHNICAL-EARTHQUAKE ENGINEERING

- May 29-June 3, 2006: Dr. B.K. Maheshwari & Dr. D.K. Paul

# PROMOTION OF SOIL DYNAMICS IN INDIA

- TEACHING, PLACEMENTS – JOB DEMAND
- RESEARCH AND CONSULTANCY
- DYNAMIC SOIL INVESTIGATIONS
- CONFERENCES/ SYMPOSIA
- SHORT TERM COURSES/ SPECIAL LECTURES
- AWARENESS