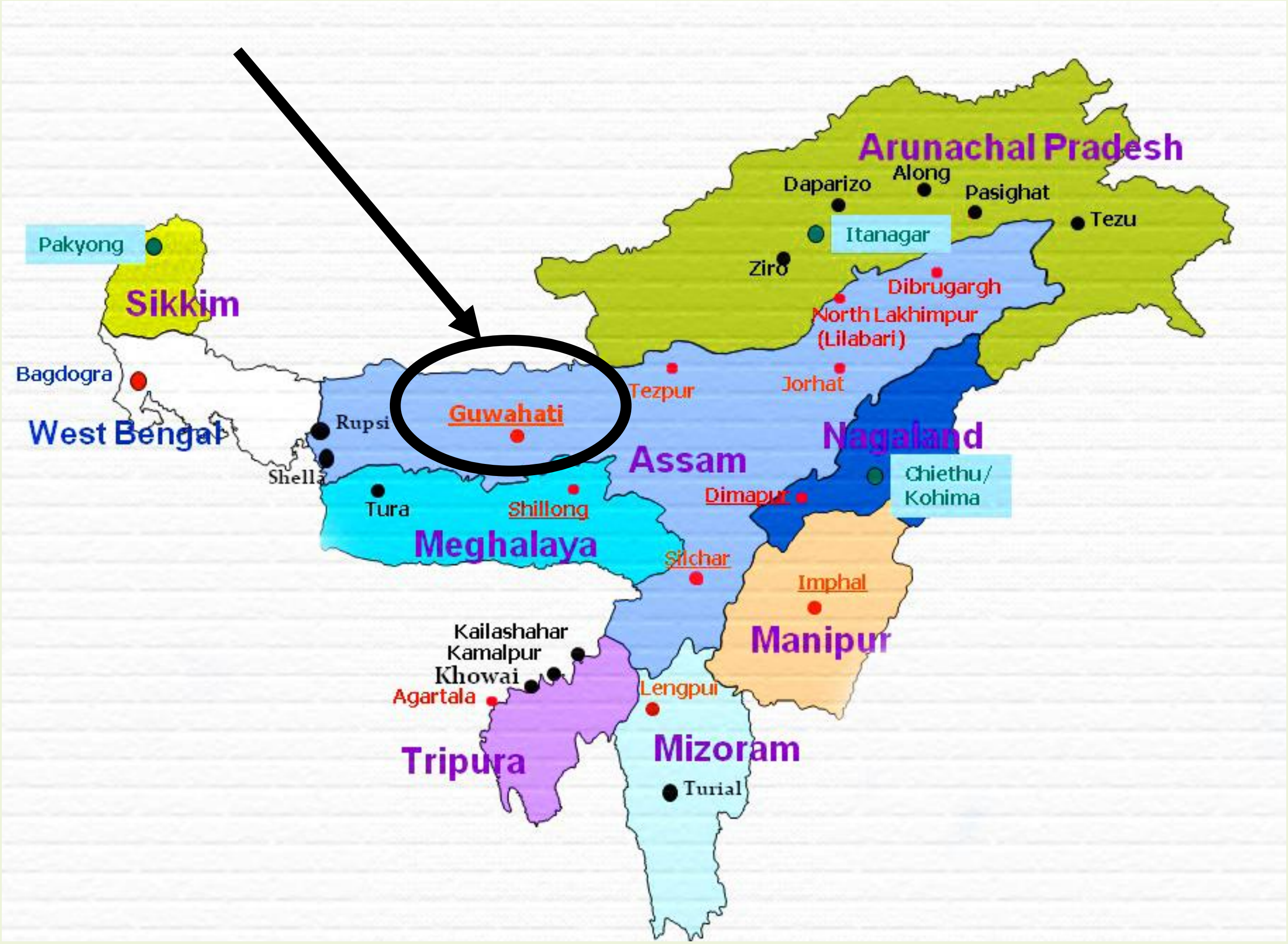
Università degli Studi del Molise

Invited Talk
Universita degli Studi del Molise
Campobasso, Italy

Geotechnical Practices and Applications for Infrastructure Development

Dr. Arindam Dey
Associate Professor
Geotechnical Engineering Division, Department of Civil Engineering
Center for Disaster Management and Research (CDMR)
Indian Institute of Technology Guwahati

Geographical Location of IIT Guwahati



Some Glimpses of the IIT Guwahati Campus

AD_Research Group

- Students in the group (until date) - 159
  - ❖ Doctoral Research Students (23): Completed – 8, Ongoing – 15
  - ❖ M.Tech./MS(R) Students (34): Completed – 30, Ongoing – 4
  - ❖ B.Tech. Students (26)
  - ❖ Intern Students (47)
  - ❖ Credit Seminar Students (29)
- Research Publications (until date) - 269
  - ❖ Books: 2; Book Sections: 32; ASCE GSP: 3
  - ❖ International Journals: 51; National Journals: 15
  - ❖ ASCE Specialty Conference: 1; International Conference: 46; National Conference: 85
  - ❖ International Symposium: 7; National Symposium: 3
  - ❖ International Workshop: 3; National Workshop: 7
  - ❖ National Seminar: 8; Technical Reports: 6

Infrastructure and Development

- **Infrastructures** are the fundamental facilities and systems serving a country, city, or other area, including the services and facilities necessary for its economy to function.
  - **Infrastructures** are the physical components of interrelated systems providing commodities and services essential to enable, sustain, or enhance societal living conditions







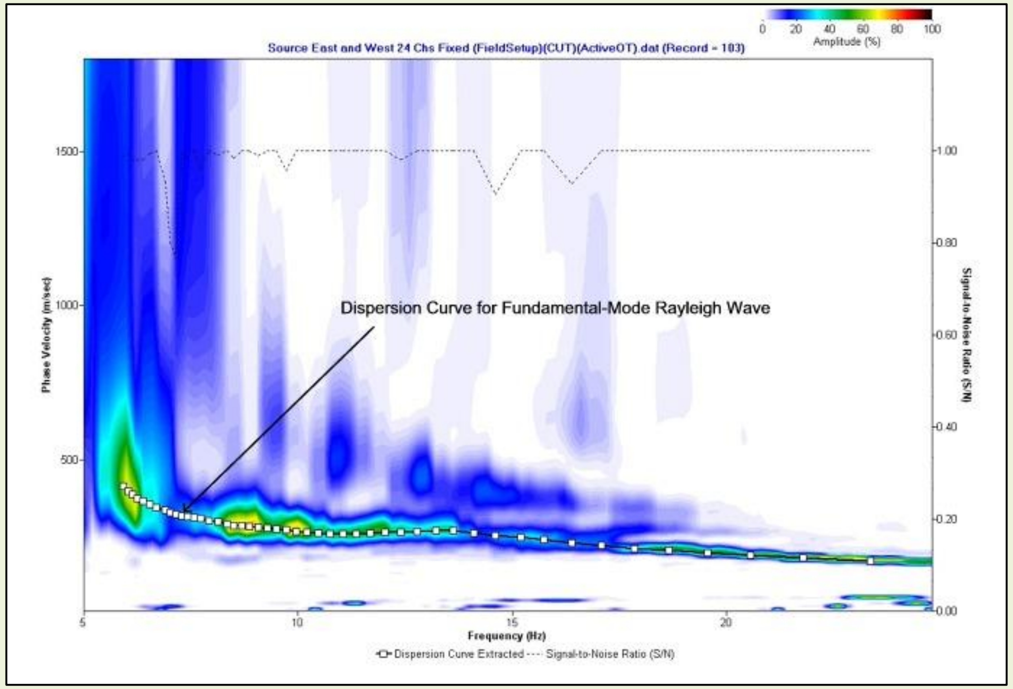
Geotechnical Engineering for Infrastructure Development

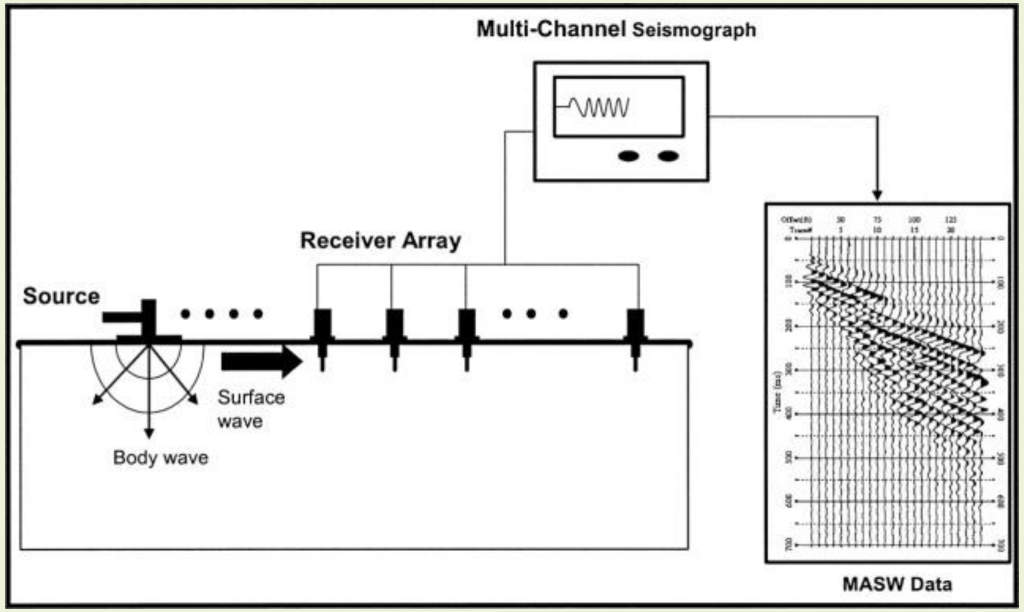
- Vistas of geotechnical engineering interrelated with infrastructure development
  - Geotechnical and Geophysical Investigations
  - Shallow, Deep and Hybrid foundations on horizontal grounds and slopes
  - Ground Improvement for constructions in difficult subsoil conditions
  - Soil Dynamics, Earthquake Geotechnics, Ground Response and Liquefaction Analysis
  - Soil-Structure Interaction
  - Rainfall Induced Landslides, Landslide Hazard and Slope Stabilization
  - Geosynthetic Engineering and Reinforced Soil Structures
  - Rigid and Flexible Earth Retention Systems
  - Pavement and Railway Geotechnics
  - Dam and Embankment Engineering

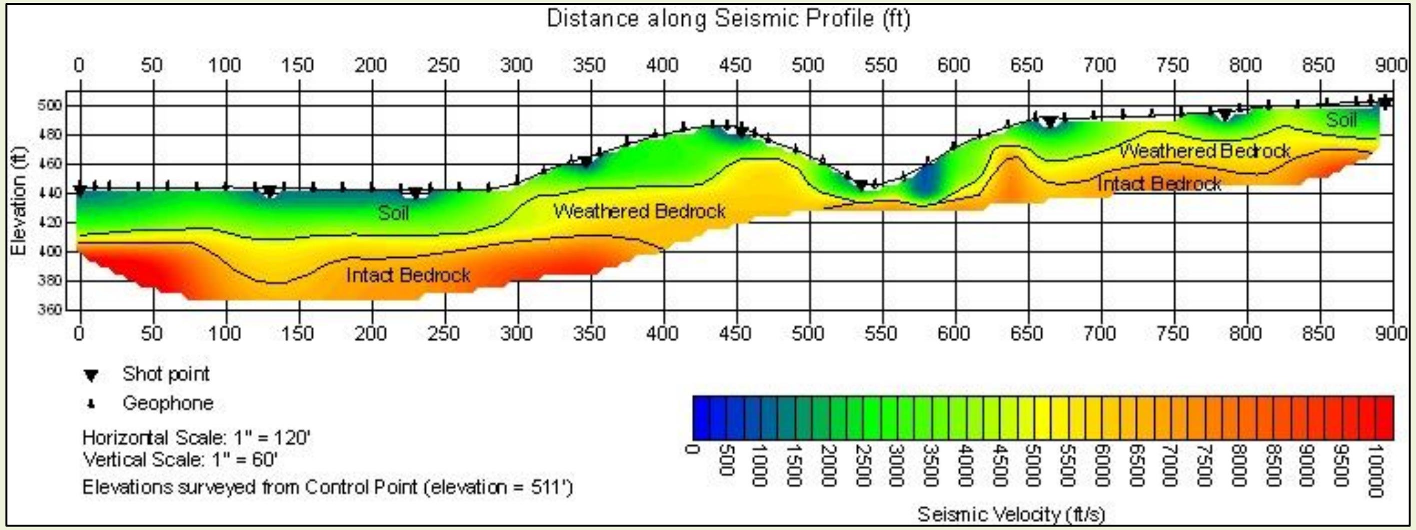
KNOW THE SUBSURFACE

Multichannel Analysis of Surface Waves (MASW) Surveys

- Shear wave velocity profiling of soil substrata
- Operates on the dispersive capacity of soils

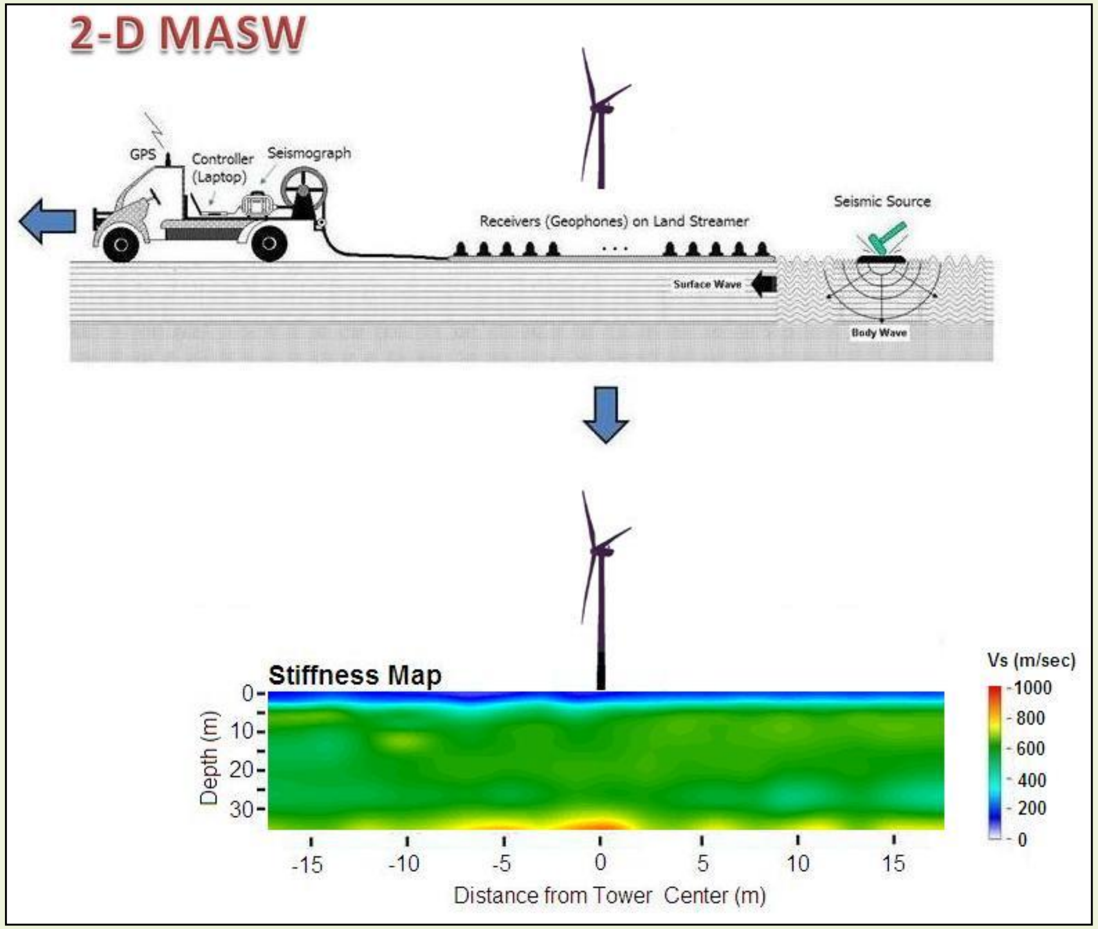


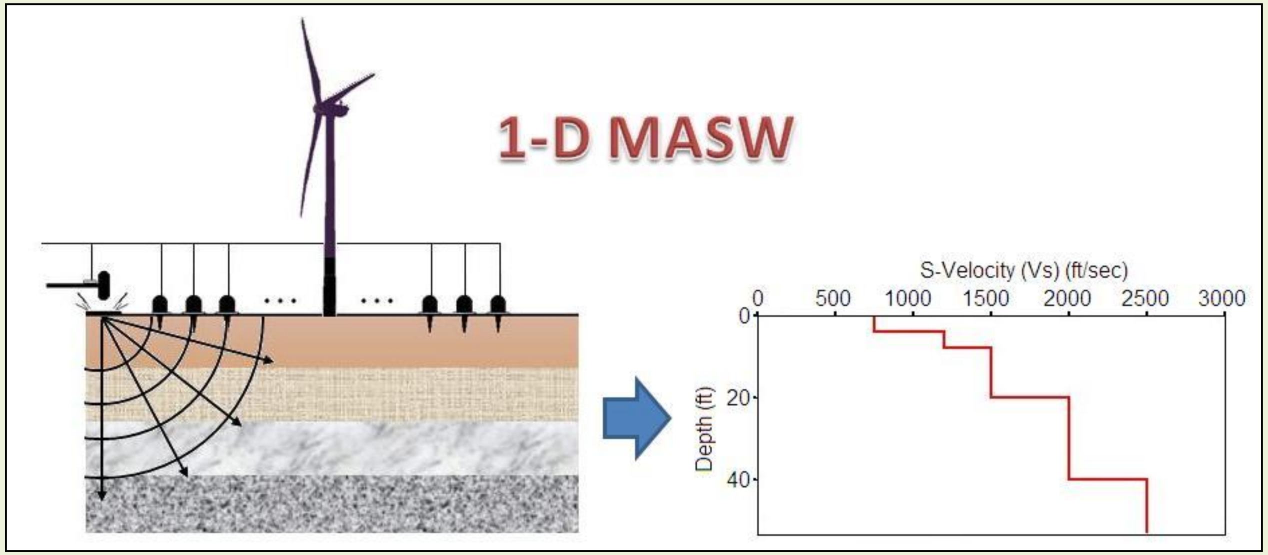


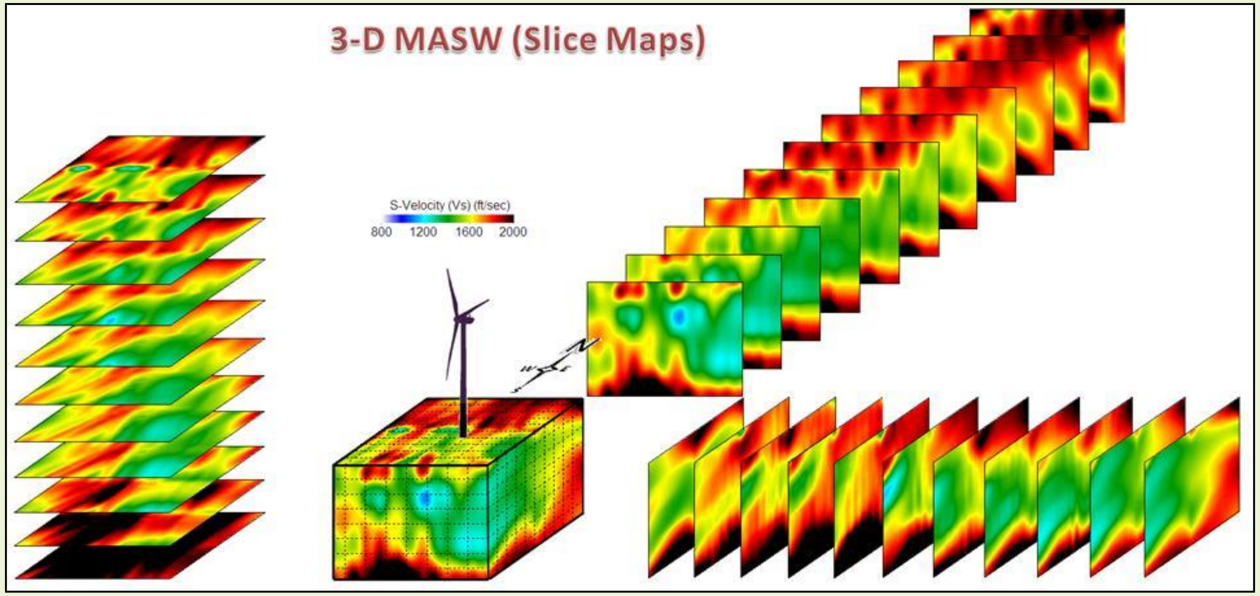


Subsurface Profiling through Inversion Analysis

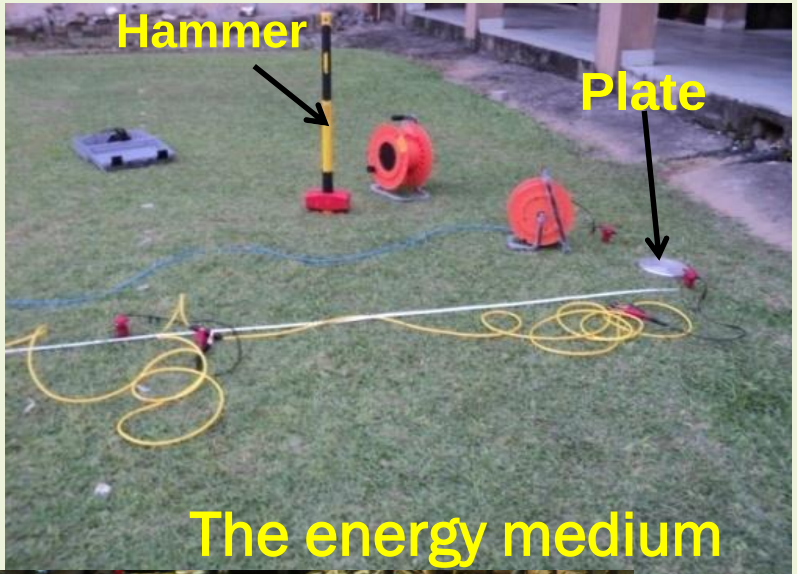
- Evaluating ground stiffness
- 1D, 2D or 3D formats

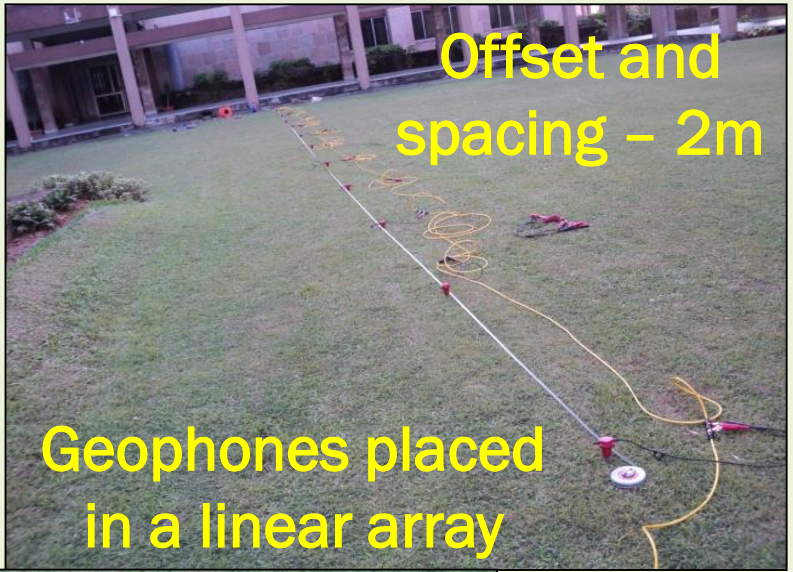






MASW Survey Components

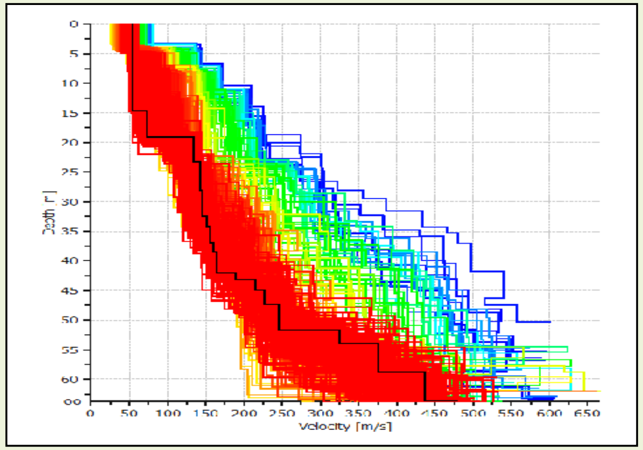


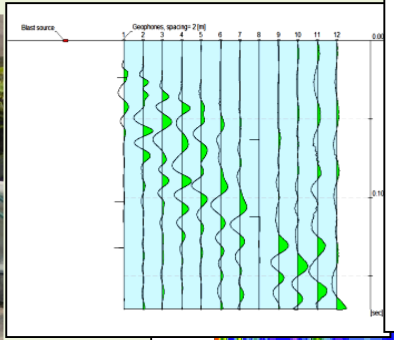


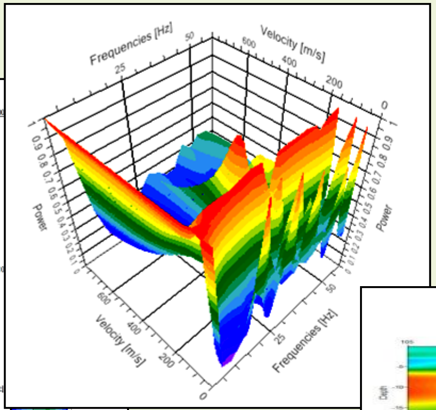
Subsurface Profiling using Active MASW Survey

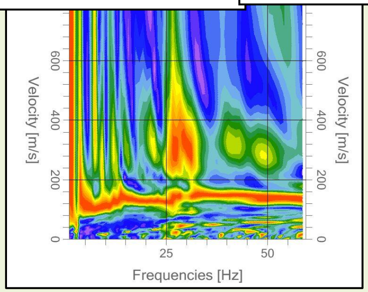
Jumrik

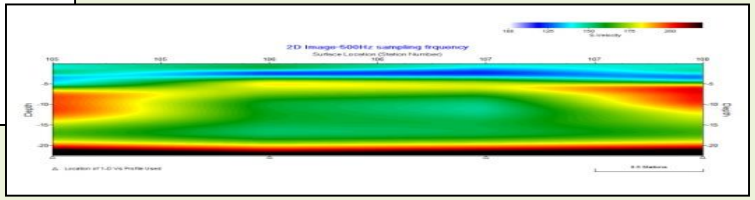
- MASW (Multichannel Analysis of Spectral Waves)
  - Seismic exploration technique using NDT
  - Soil stratigraphy and shear wave velocity profile (1D, 2D or 3D)
- Active MASW Survey
  - Impact source using sledgehammer or automated drop weight
  - Depth of investigation: 20-30m with good resolution

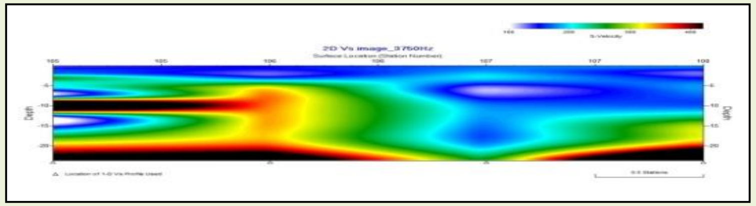




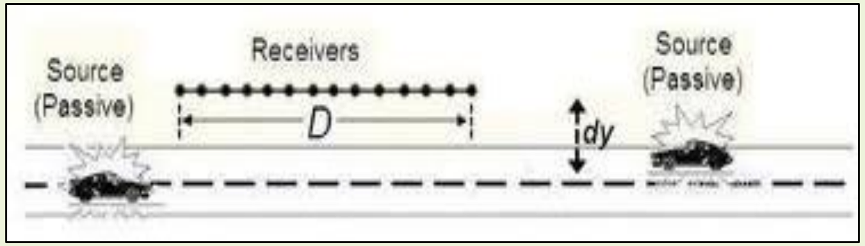






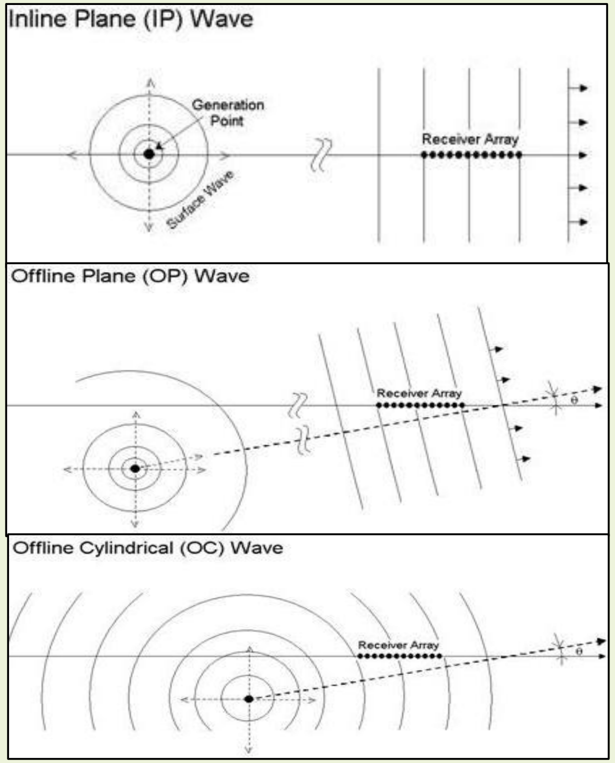


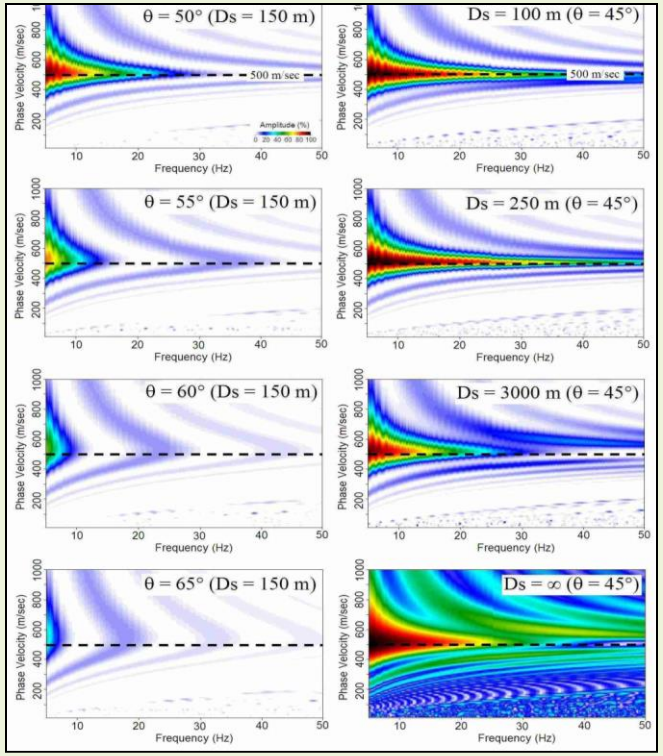
Subsurface Profiling using Passive Roadside MASW Survey

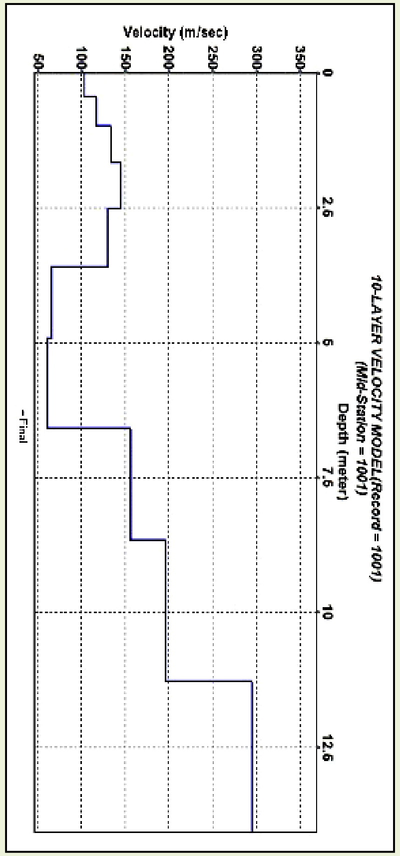


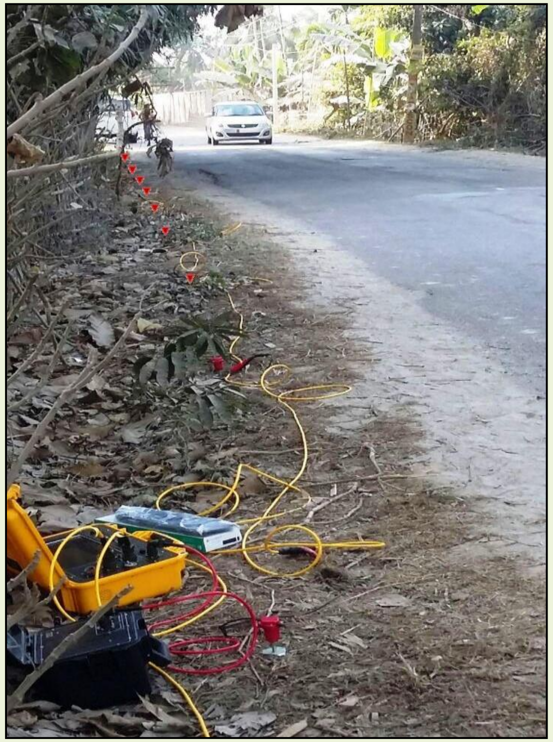
- Passive Roadside MASW Survey
  - ❖ Adopted in populated urban areas
  - ❖ Utilization of vehicle loading as energy source
  - ❖ Depth of investigation: 20-50m (Good resolution)

Dipjyoti





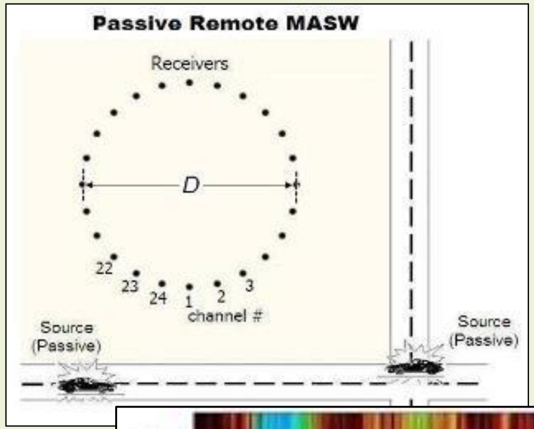


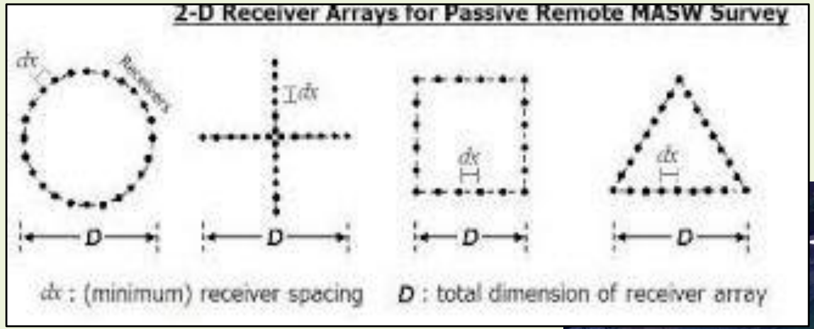


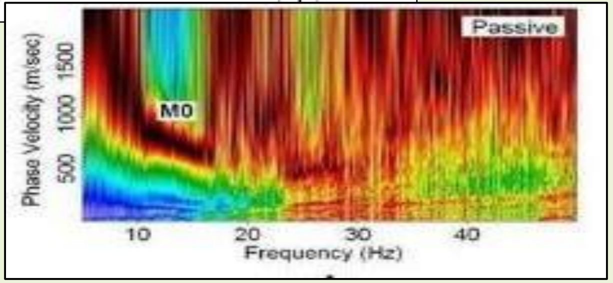
Subsurface Profiling using Passive Remote MASW Survey

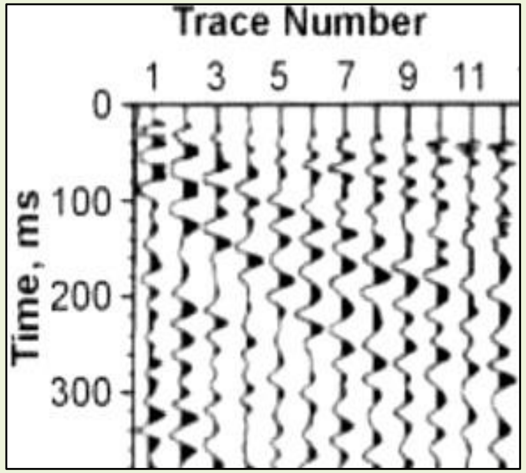
- Passive Remote MASW Survey
  - ❖ 2D Array of geophone receivers
  - ❖ Utilization of long wavelength ambient noise source
  - ❖ Depth of investigation: 30-120m (Good resolution)

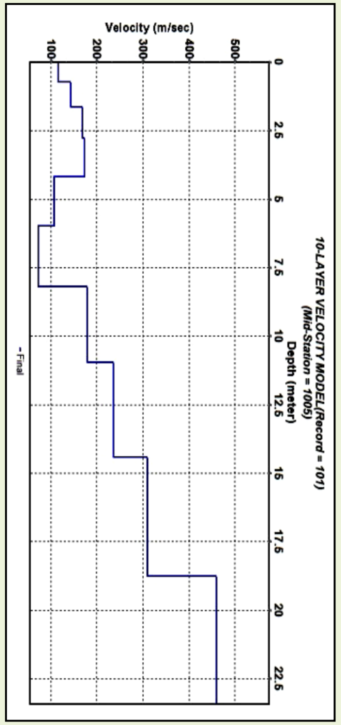
Shibayan





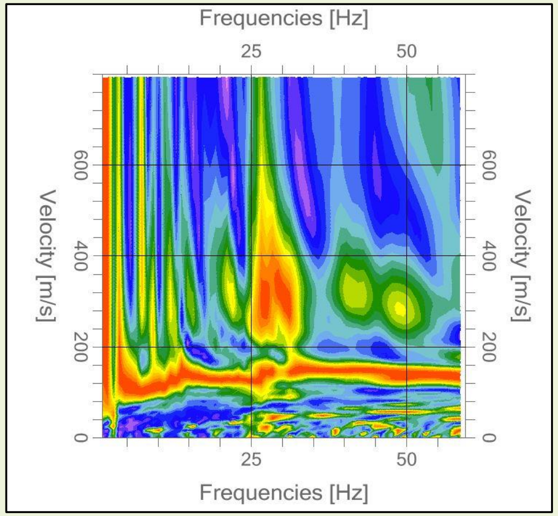


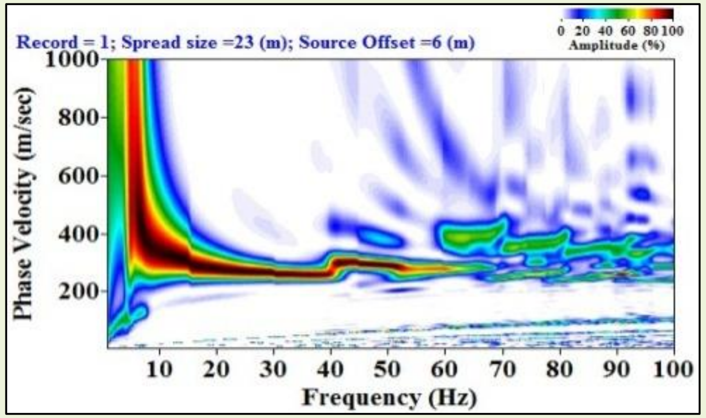


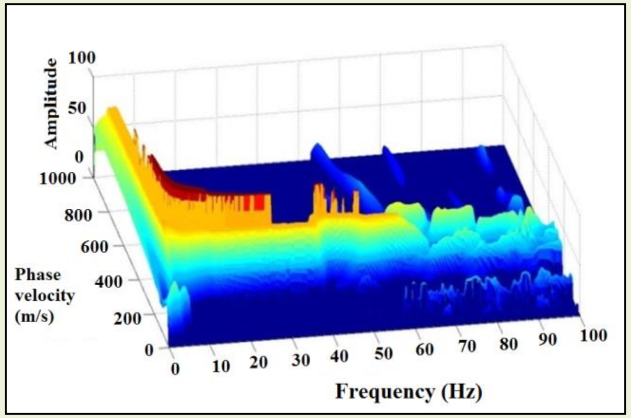


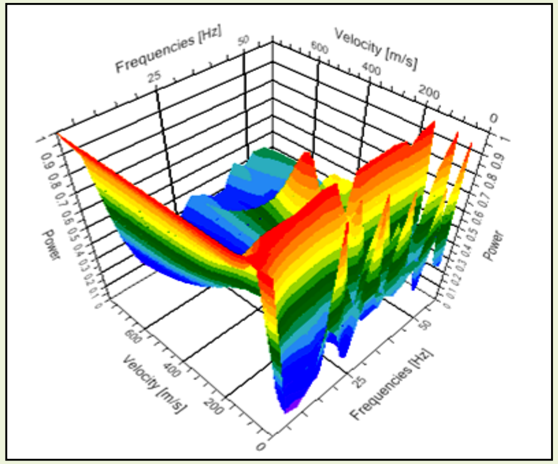
Automated Extraction from 3-D Dispersion Image

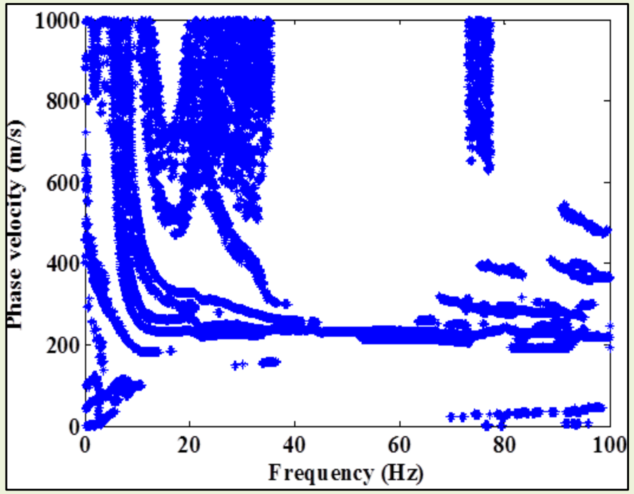
- Image processing techniques and Matlab coding

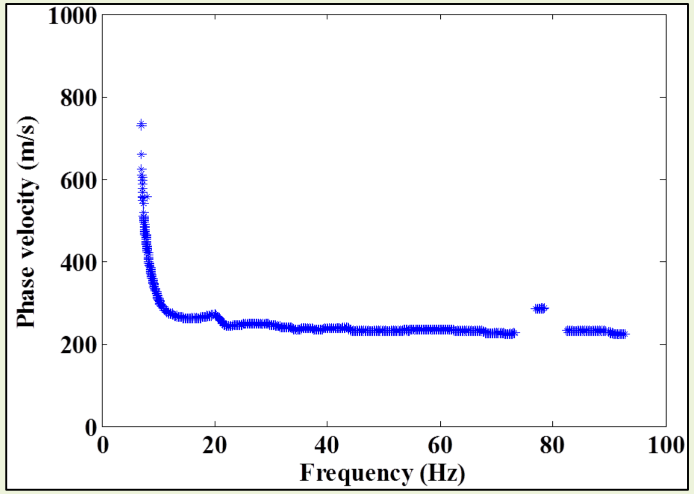






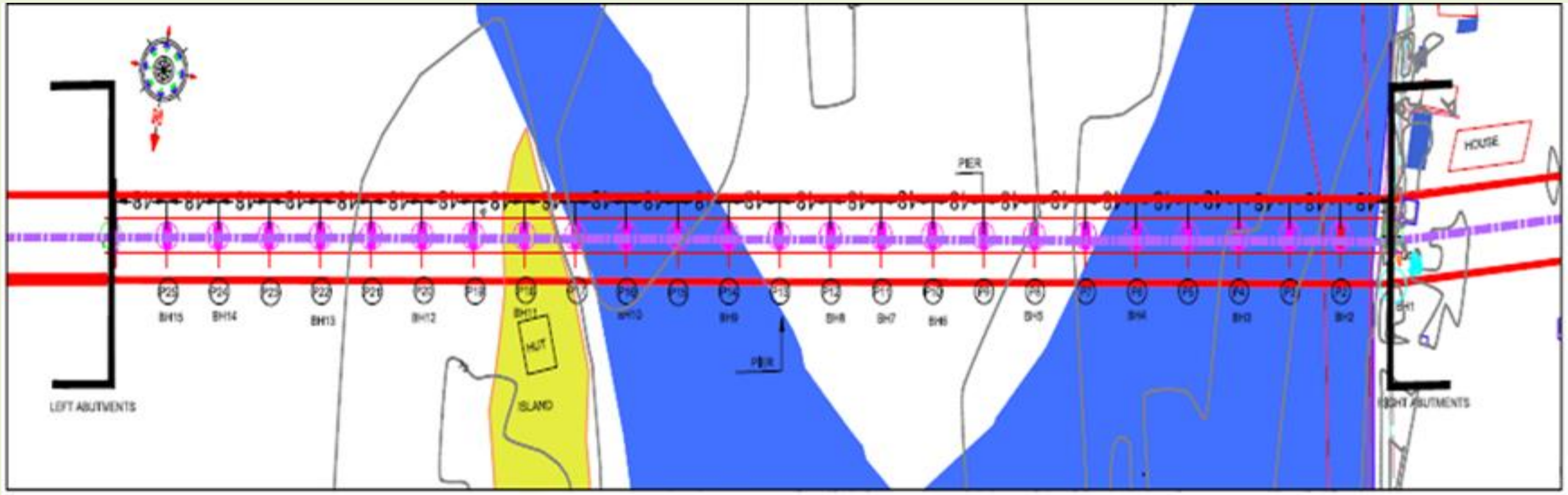






MASW Survey of 1.2 km long Jia-Bharali River Bed

- A new 4-lane (1.2 km) carriageway bridge over Jiya-Bharali River bed
  - National Highway and Infrastructure Development Corporation Limited (NHIDCL)
  - Located in Tezpur District, Assam state
  - Connects NH-52A and NH-37
    - **Project completed with Simplex Infrastructures Ltd**



Jumrik

Madhulatha

Rana

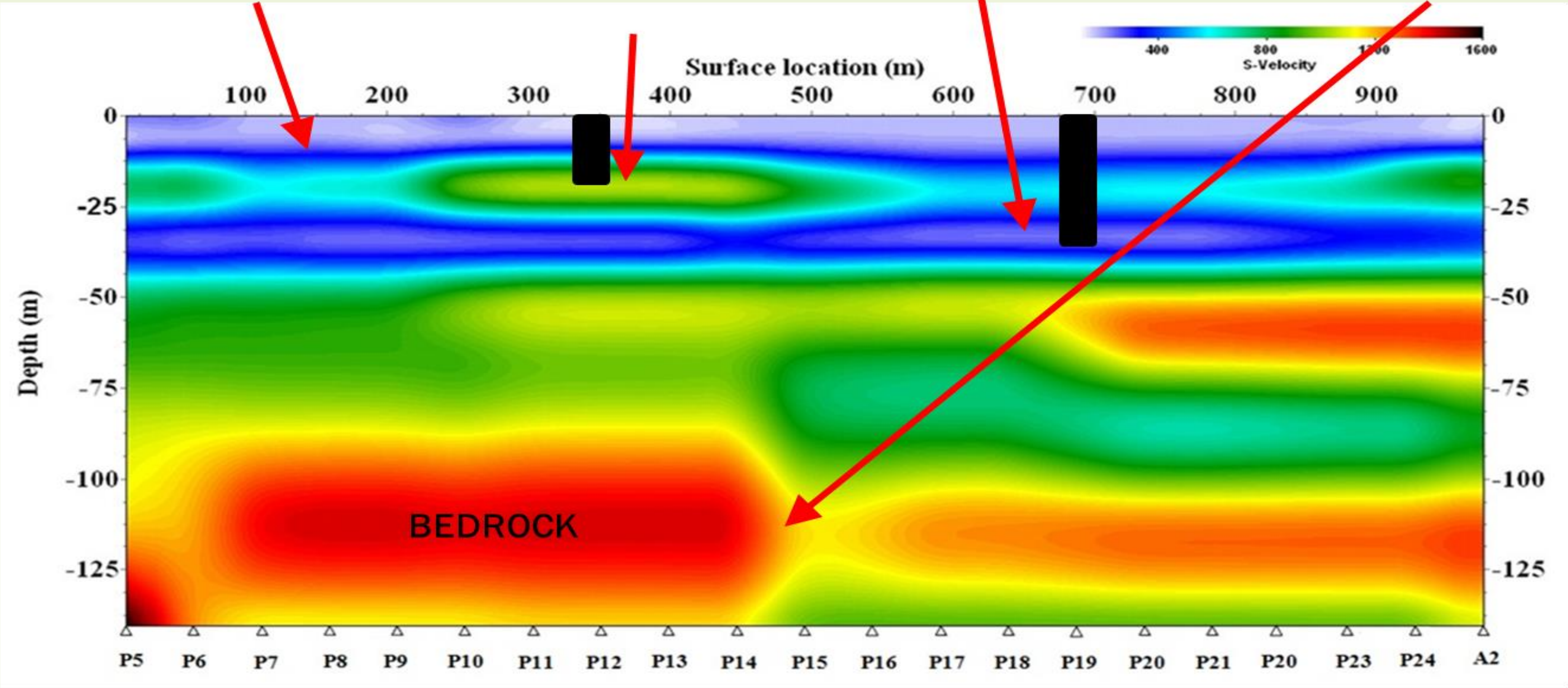
Chiranjib

Erodible Top Sediment

Perched Hard Layer

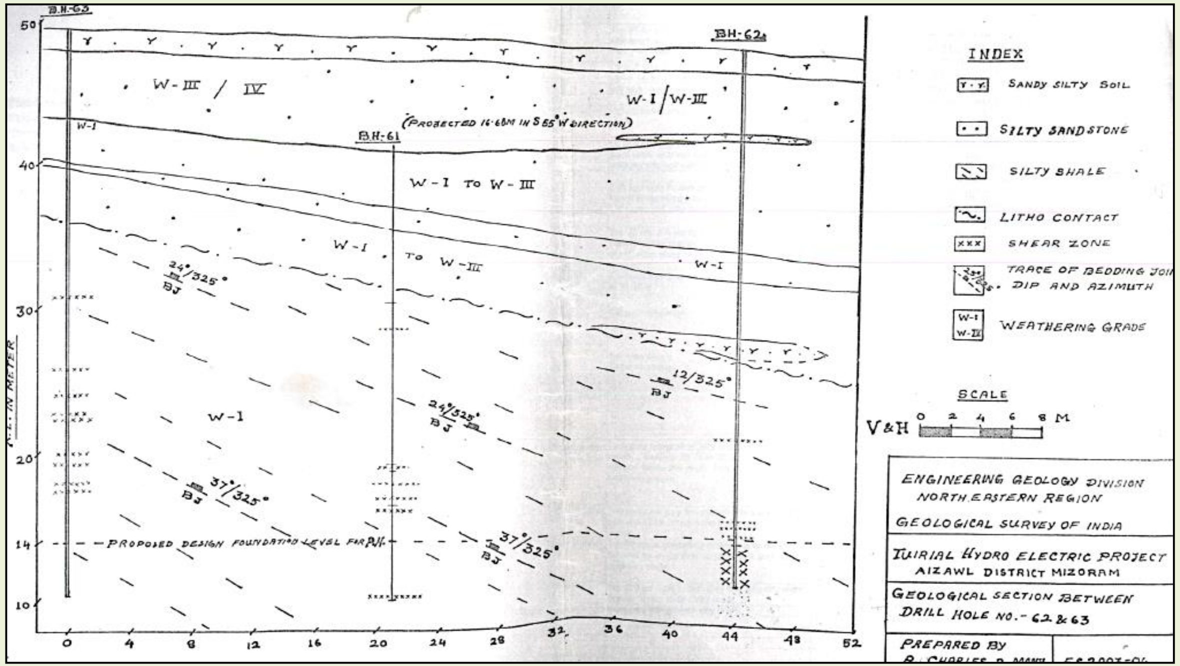
Soft Soil Stratum

Very hard strata / Bedrock



2-D shear wave velocity profile obtained from a roll-along active MASW conducted along the alignment of the proposed bridge over Jia-Bharali (P5-A2)

Tuirial Hydroelectric Power Plant Project, Mizoram



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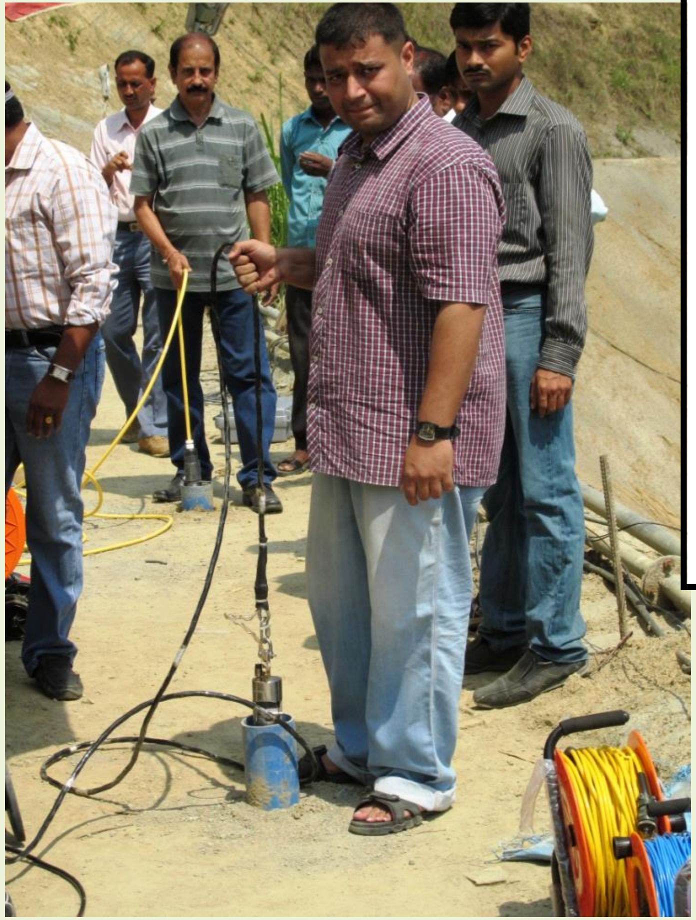
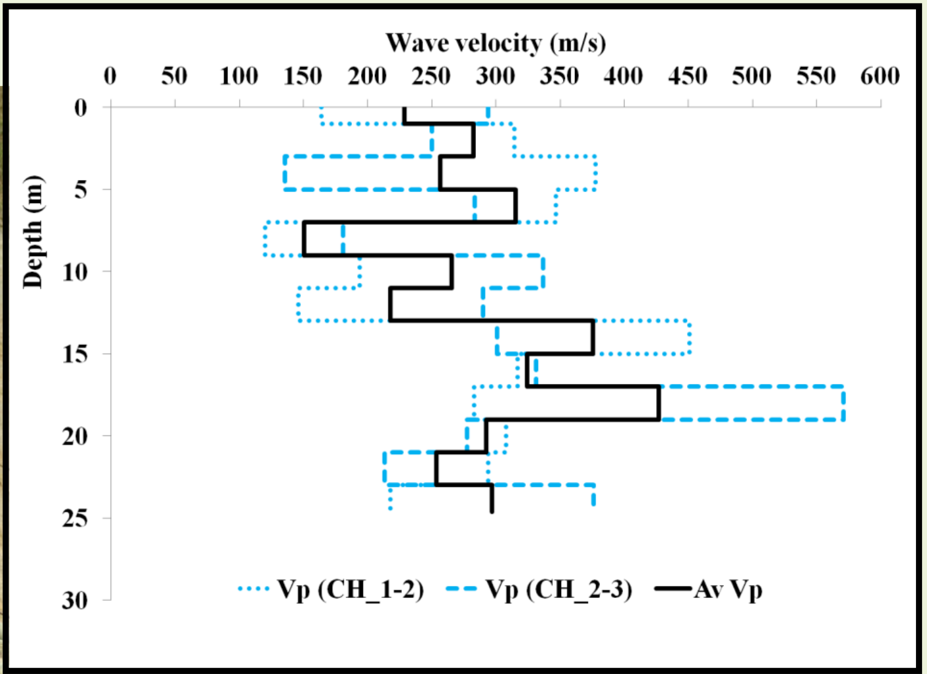
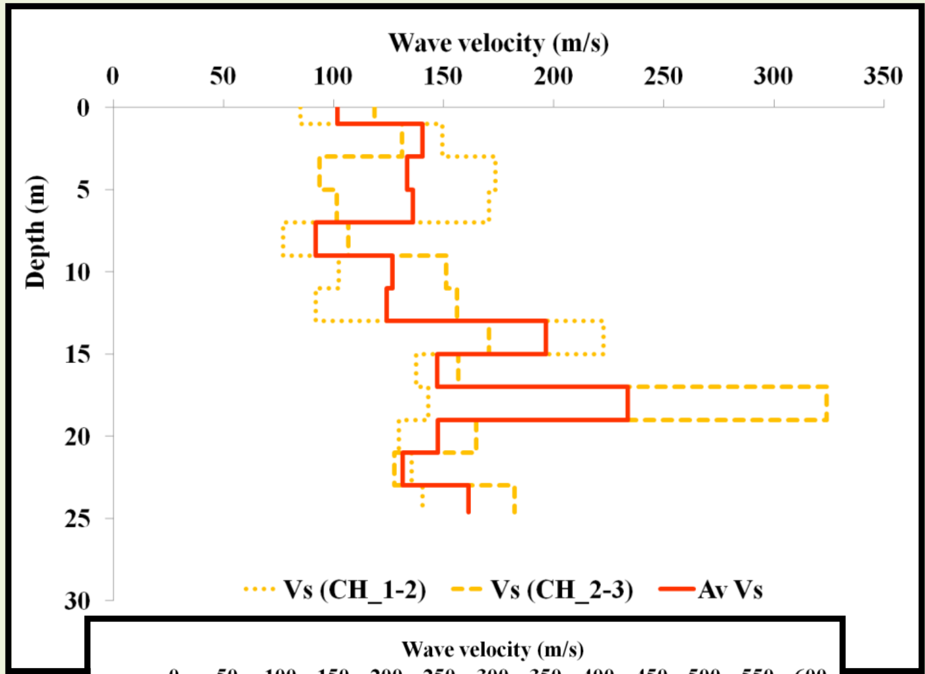
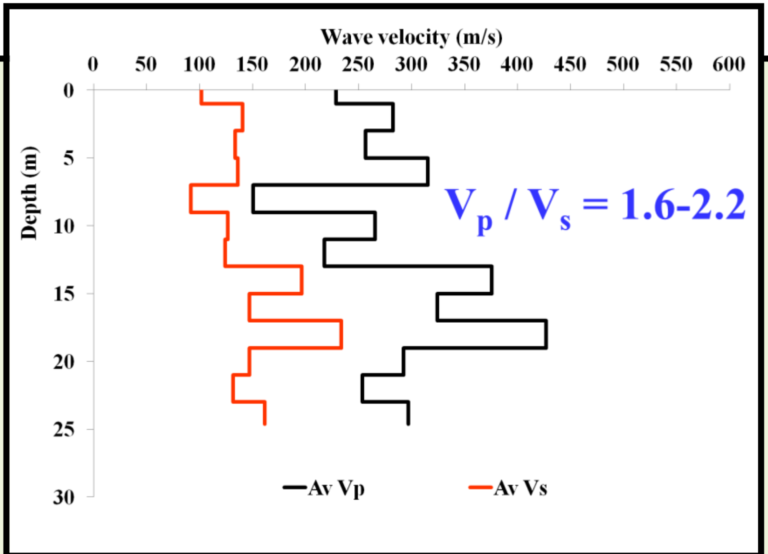




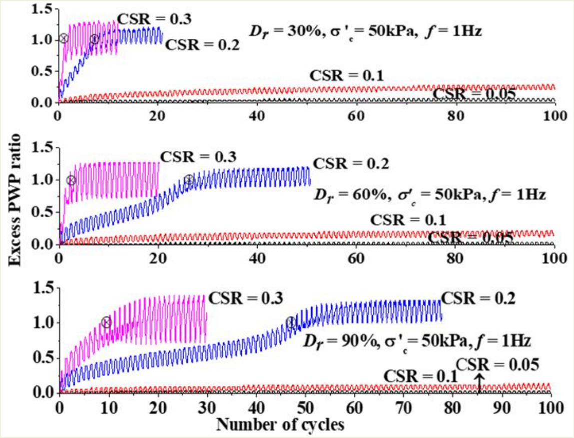


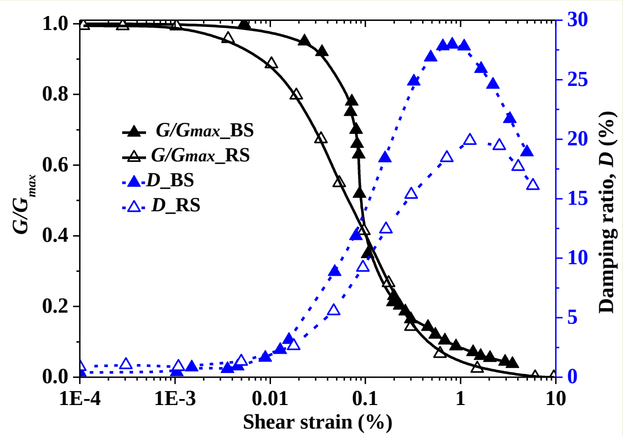


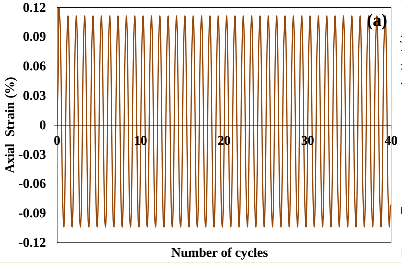
Dynamic Response of Typical Soils of NE India

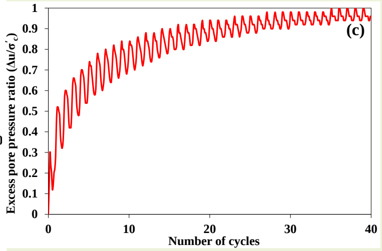
Shiv

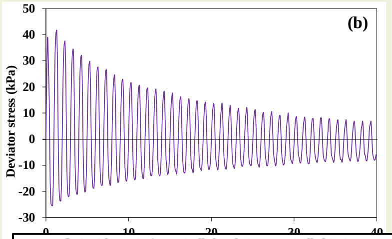
- Cyclic Triaxial tests
  - ❖ Strain and Stress controlled tests
    - **Shear modulus degradation**
    - **Evolution of damping ratio**
    - **Liquefaction potential evaluatio**

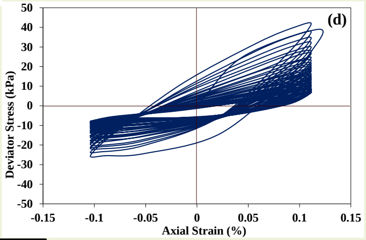


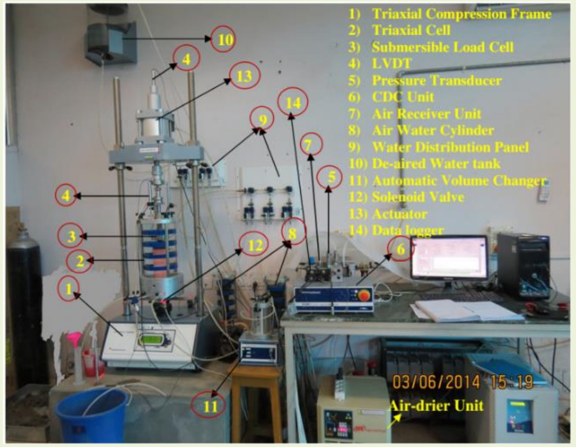












Liquefaction Criteria for Saturated BS

➢ BS (D_r = 30%-90%) liquefy under the following optimum conditions

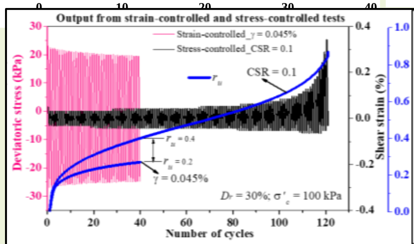
❖ PGA ≥ 0.36g

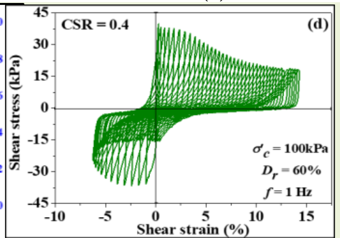
❖ CSR ≥ 0.3

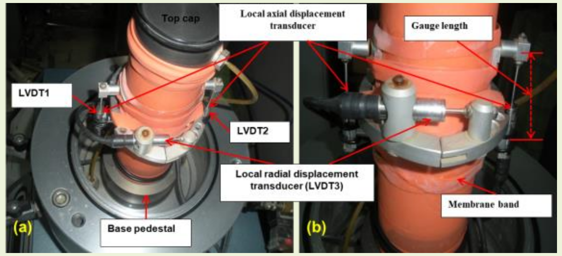
❖ γ_{max} > 0.5%

❖ Limiting value of γ = 0.5% is to be adopted for liquefaction evaluation study for BS soil at loose condition

❖ Limiting value of γ = 1.0% is to be adopted for liquefaction study for BS soil at dense condition

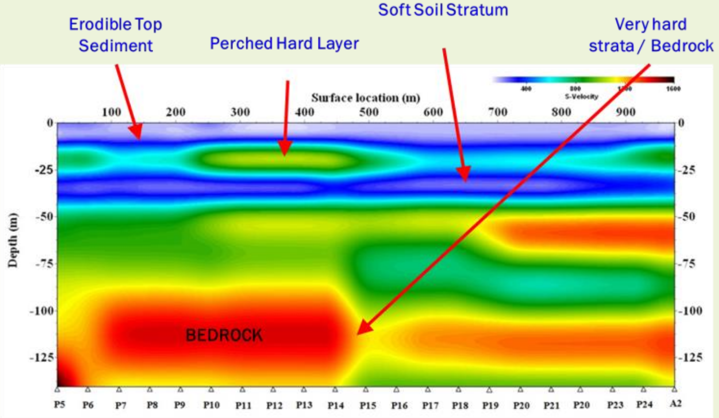


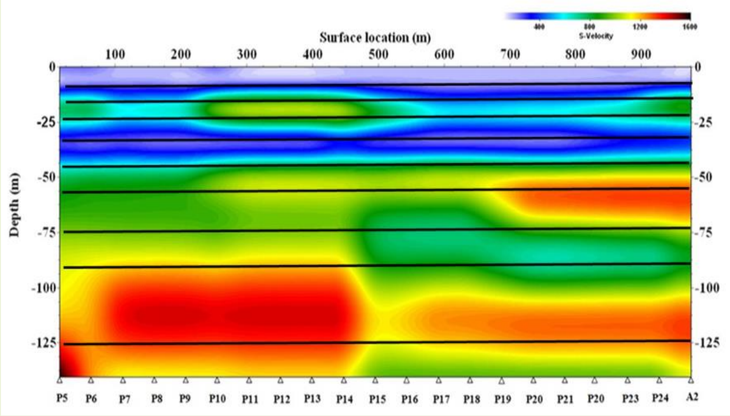


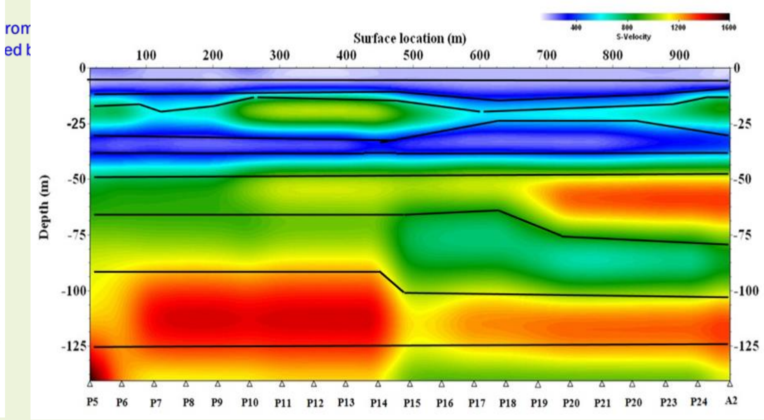


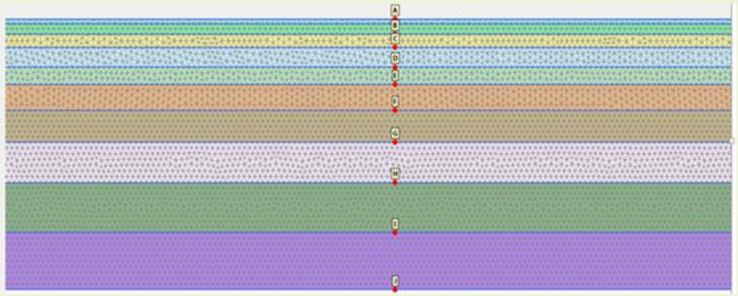
Representation of Subsurface 1-D and 2-D GRA Models

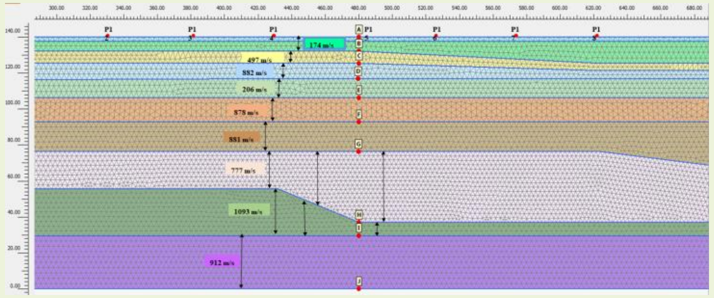
Madhulatha

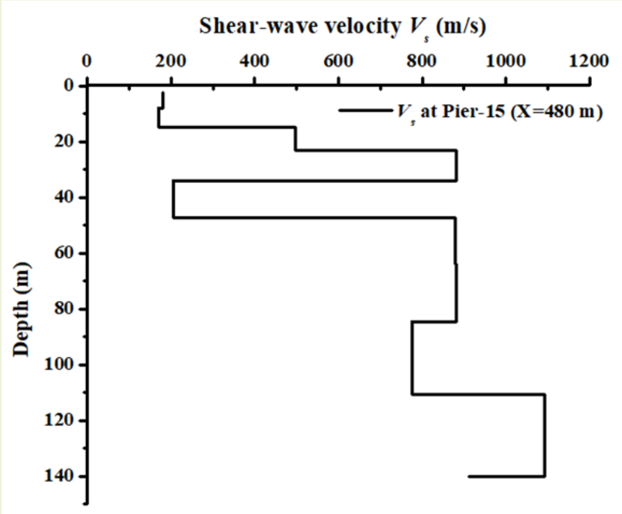


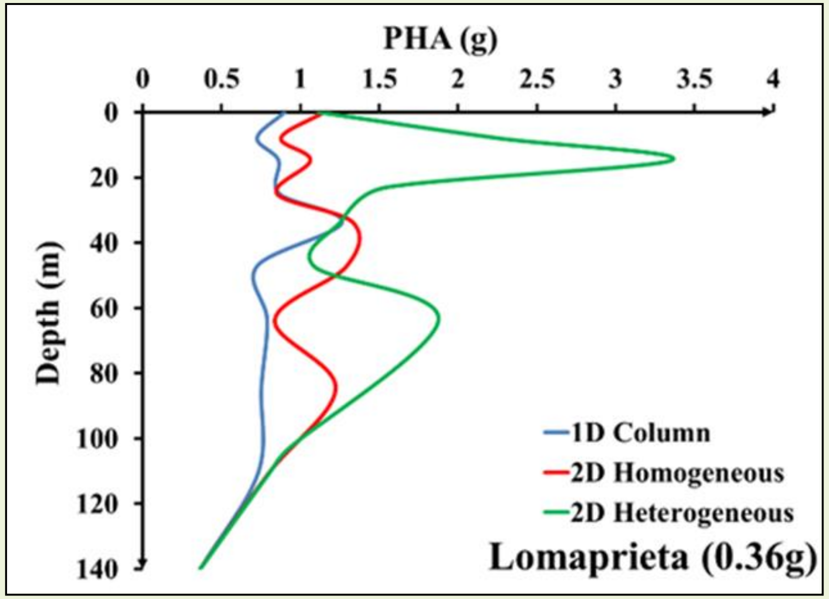




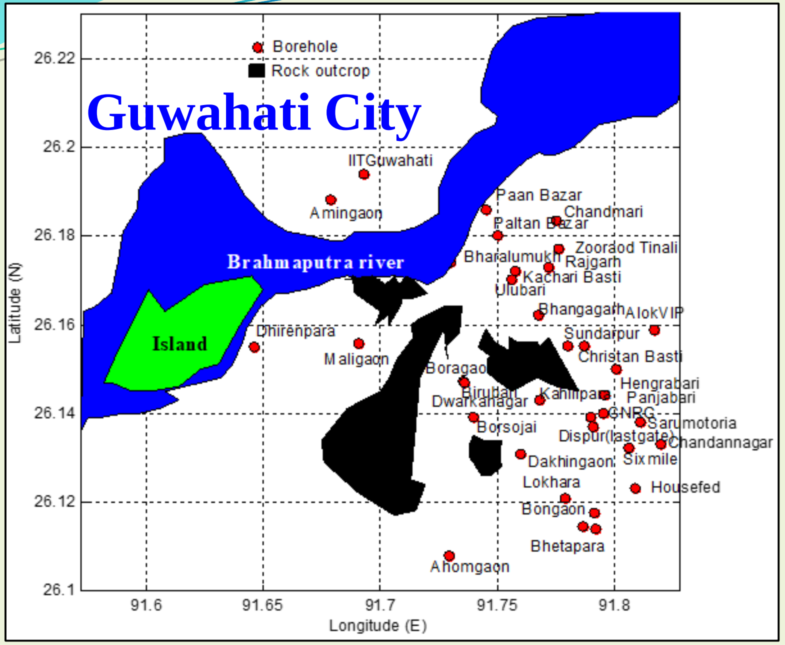


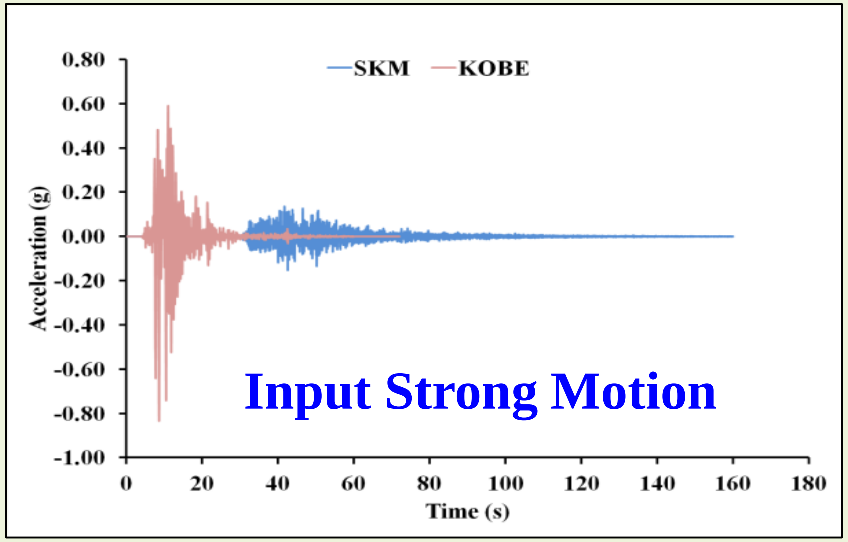


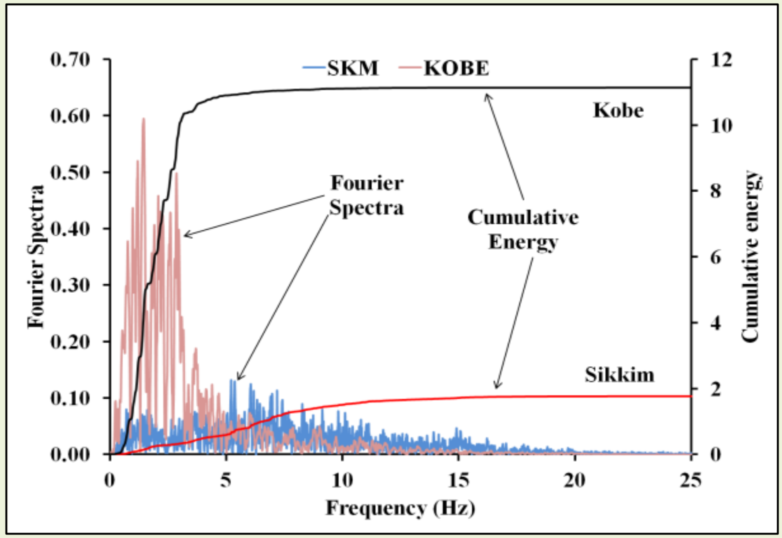


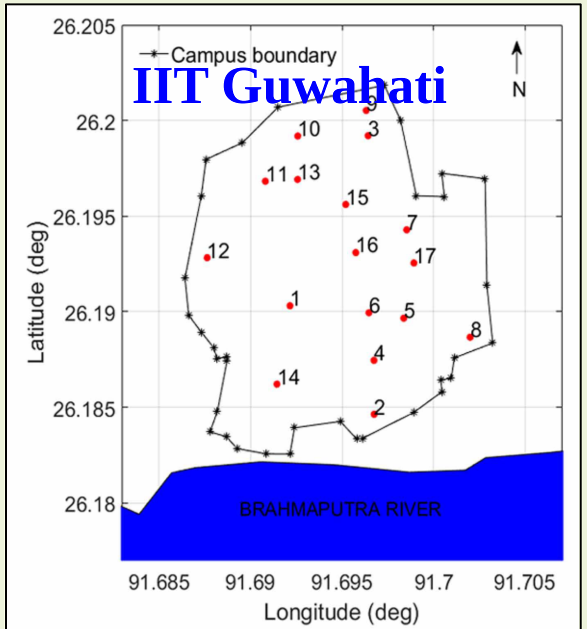


GRA of Guwahati City and IIT Guwahati





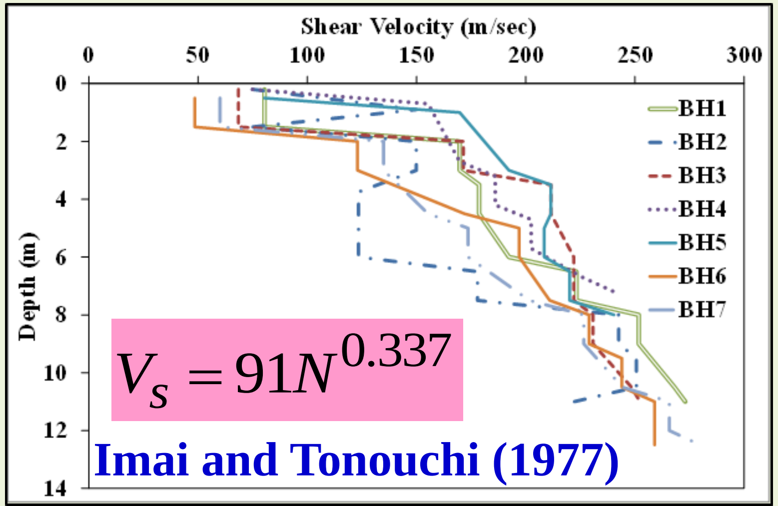




Typical Borehole Profile

Layer No.	Thickness (m)	Soil Type	Depth (m)	Field Density (kN/m³)	Average Field Density (kN/m³)	SPT N-Value	Shear Wave Velocity, v_s (m/s)	Average v_s (m/s)
1	0.75	Clay	0.75		18.9			78.23
2	0.75		1.5			6	136.5	
3	0.5		2	18.9				147.5
4	1		3		19.05	4	138.3	151.2
5	1.5		4.5			7	164	
6	0.5		5	19.2				138
7	1		6		18.4	2	112	112
8	1.5		7.5			2	112	
9	0.5		8	17.6				138
10	1		9			7	164	185.3
11	1.5		10.5		18.55	15	206.7	
12	0.5		11	19.5				192
13	1		12			9	177	174
14	1.5		13.5		19.25	8	170.75	
15	0.5		14	19				209
16	1	Sand	15			27	247.1	248.5
17	1.5		16.5		19.35	28	250	
18	0.5		17					245.7
19	0.5		17.5	19.7				
20	0.5		18			25	241.5	244.3
21	1.5		19.5		19.65	27	247.1	
22	0.5		20	19.6				262.8
23	1		21			40	278.5	282.6
24	1.5		22.5		20.05	44	286.7	
25	0.5		23	20.5				296.7
26	1		24		21.05	55	306.8	315.5
27	1.5		25.5			66	324.3	
28	0.5		26	21.6				324.3

V_s Profile

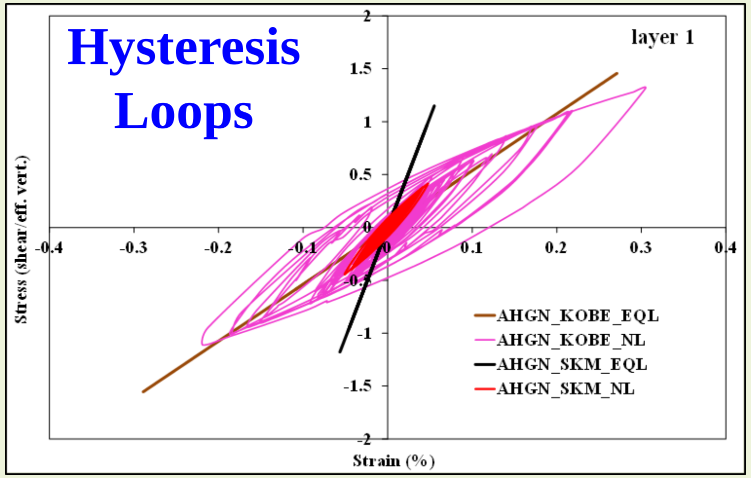


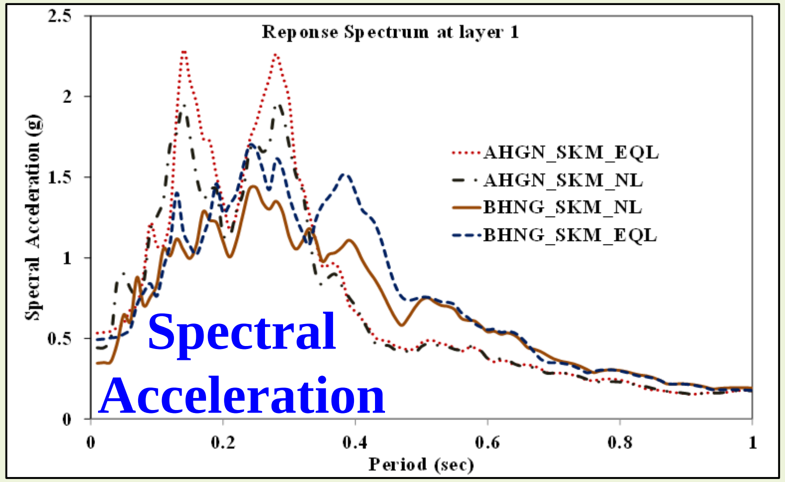
Fourier and Energy Spectra

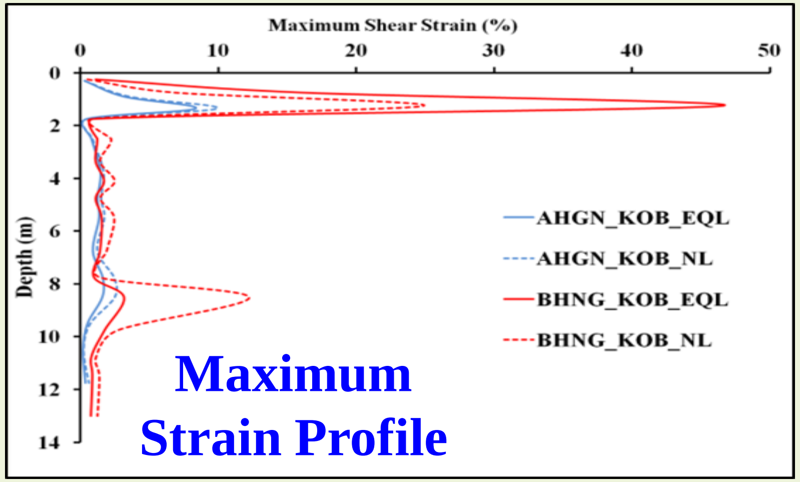
Devdeep

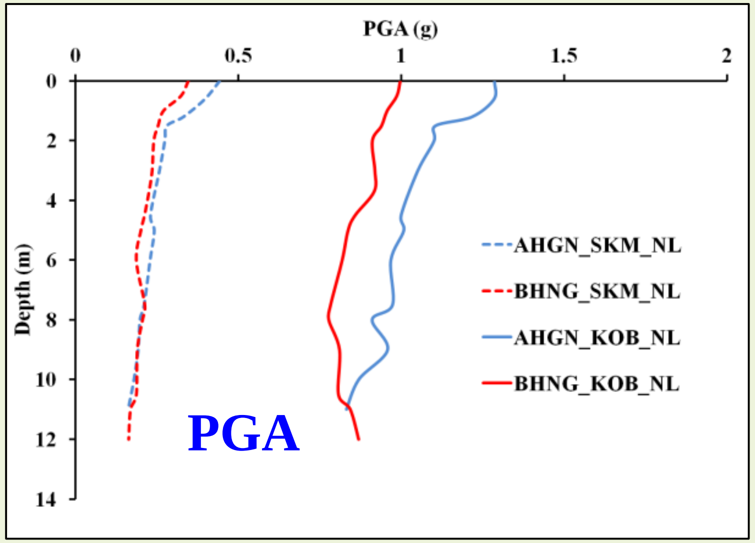
Shiv

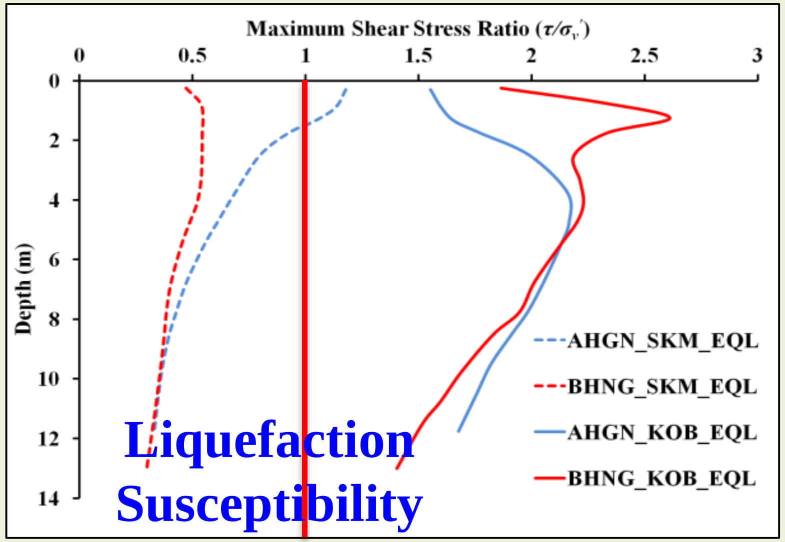
Typical GRA Results and Representations

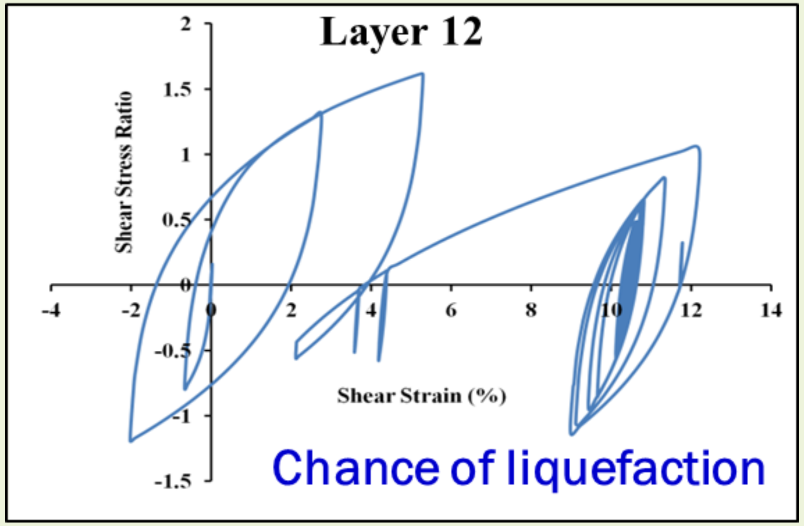








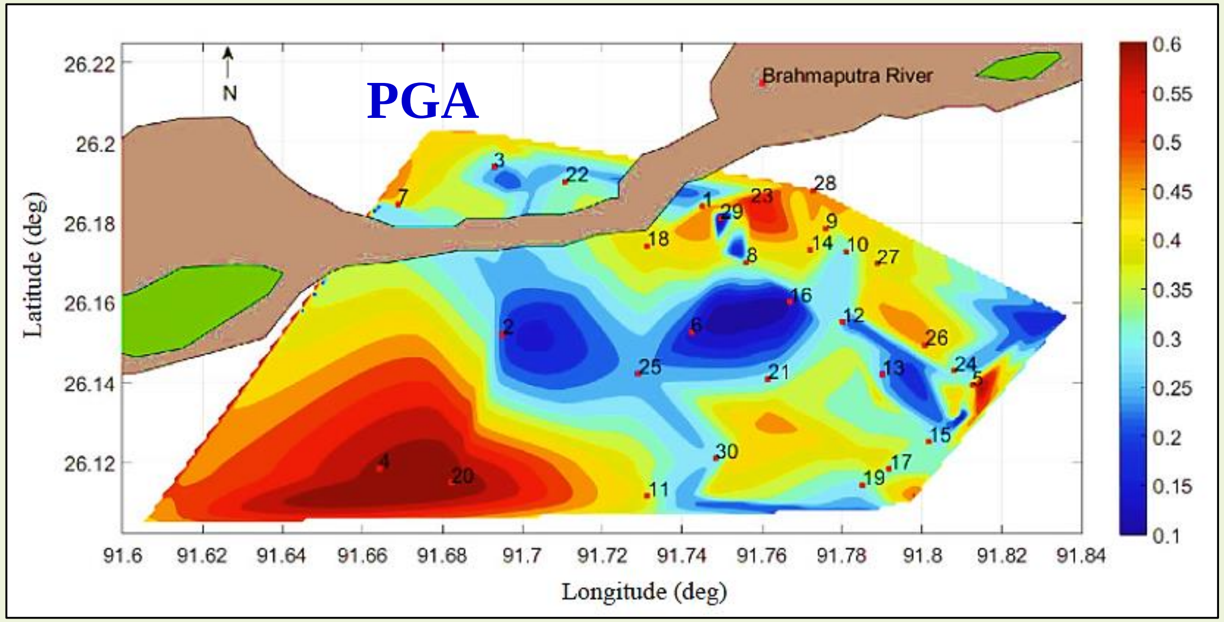


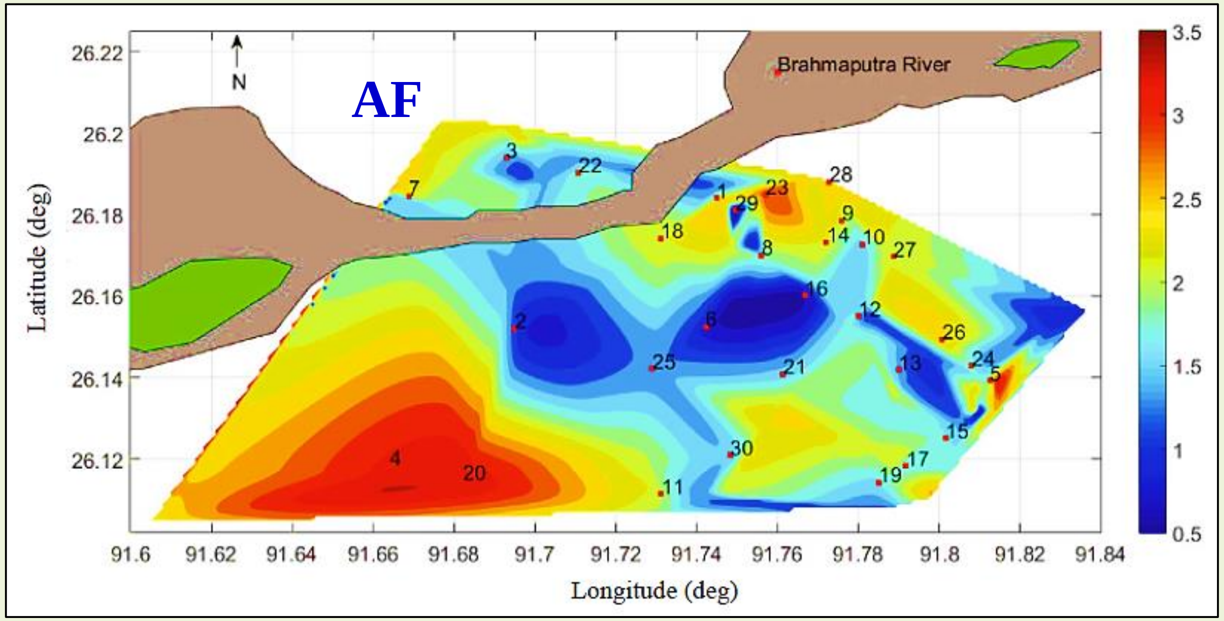


Typical PGA and AF Contour Map of Guwahati City

Shiv

- Manifestation of Local Site Effects due to varying geology
  - Local Amplification and Attenuation of bedrock motion





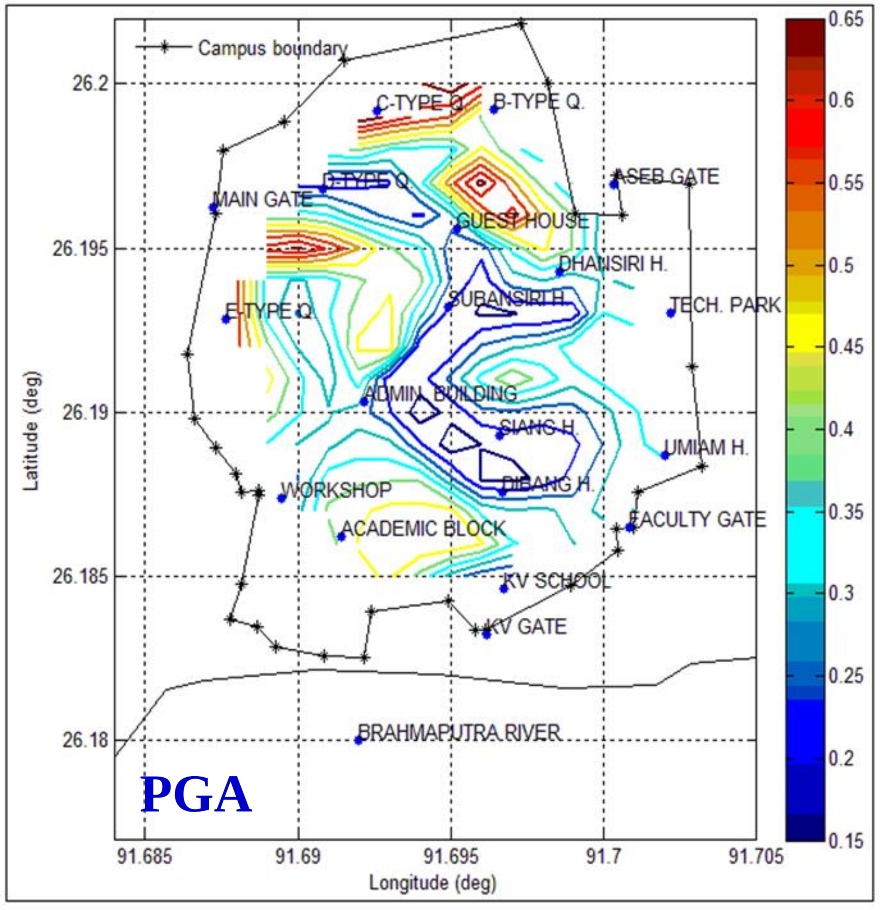
Nepal Eq: PBRA = 0.18g

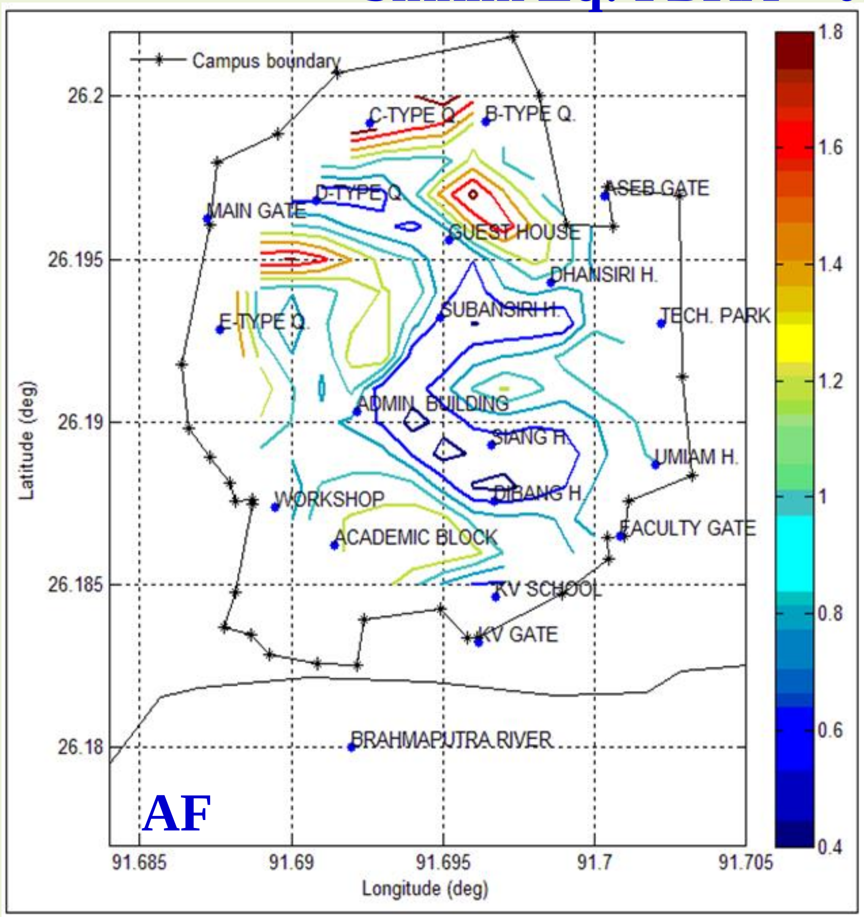
Typical PGA and AF Contour Maps of IIT Guwahati

Devdeep

- Manifestation of Local Site Effects due to varying geology
  - ❖ Local Amplification and Attenuation of bedrock motion

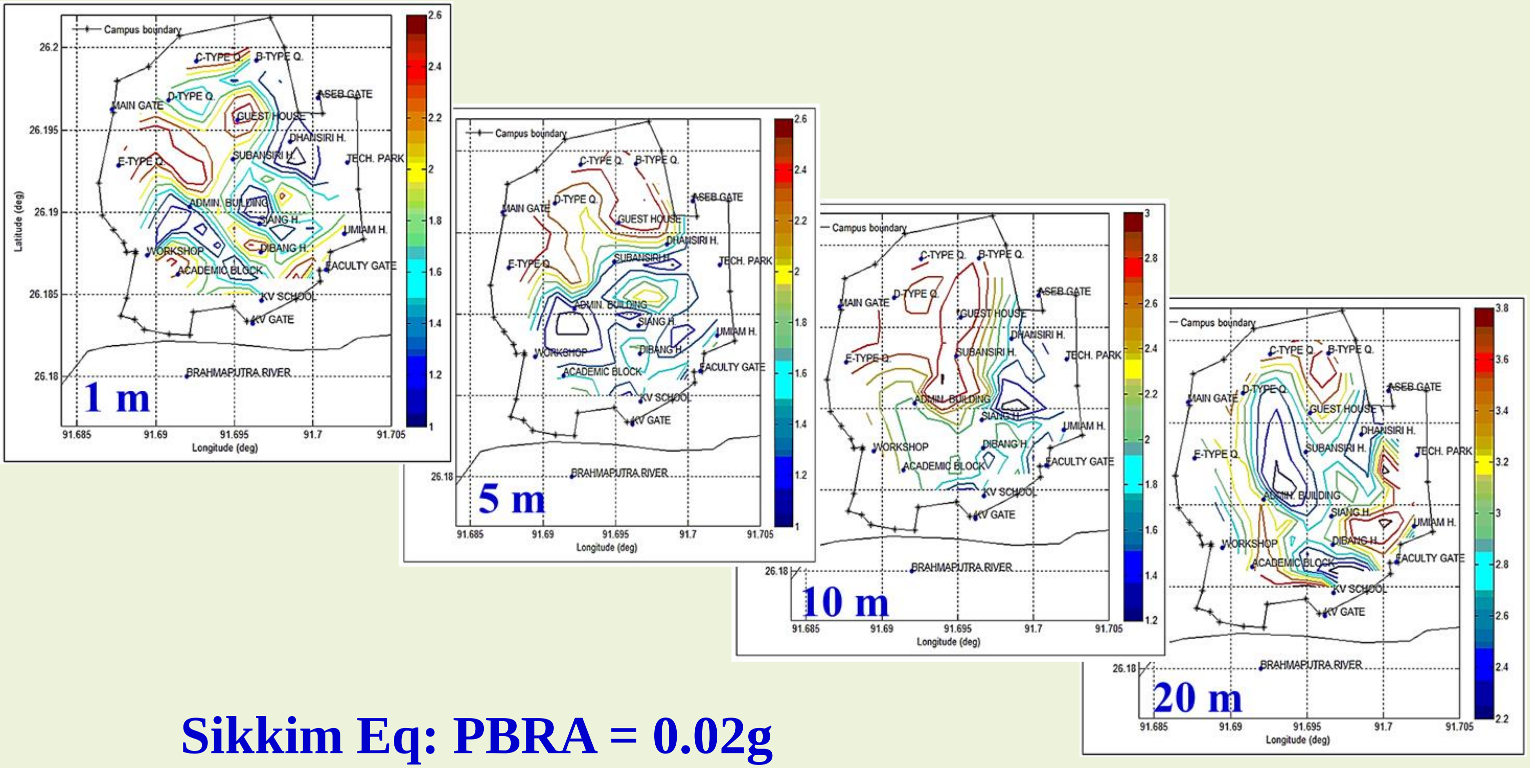
Sikkim Eq: PBRA = 0.36g



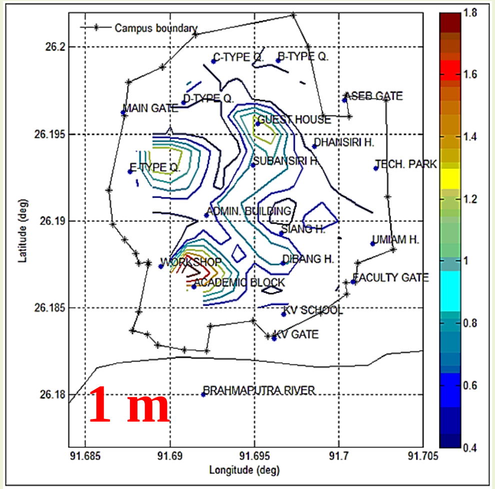


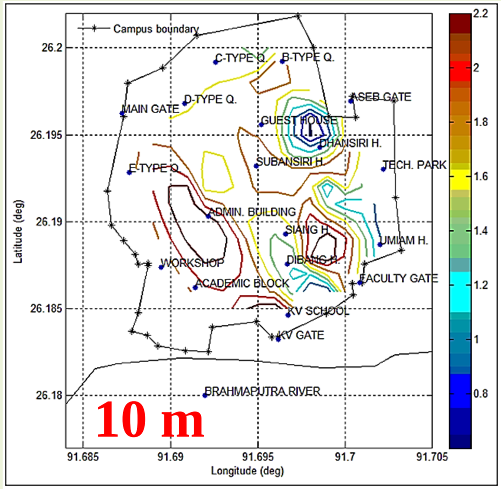
Liquefaction FoS Maps of IIT Guwahati

- Influence of peak bedrock acceleration
  - ❖ No liquefaction for lower bedrock motions
    - **FoS > 1 at all places in the campus**
  - ❖ *Substantial liquefaction at higher bedrock motions*
    - FoS < 1 at many places in the campus at both shallow and deeper strata



Sikkim Eq: PBRA = 0.02g



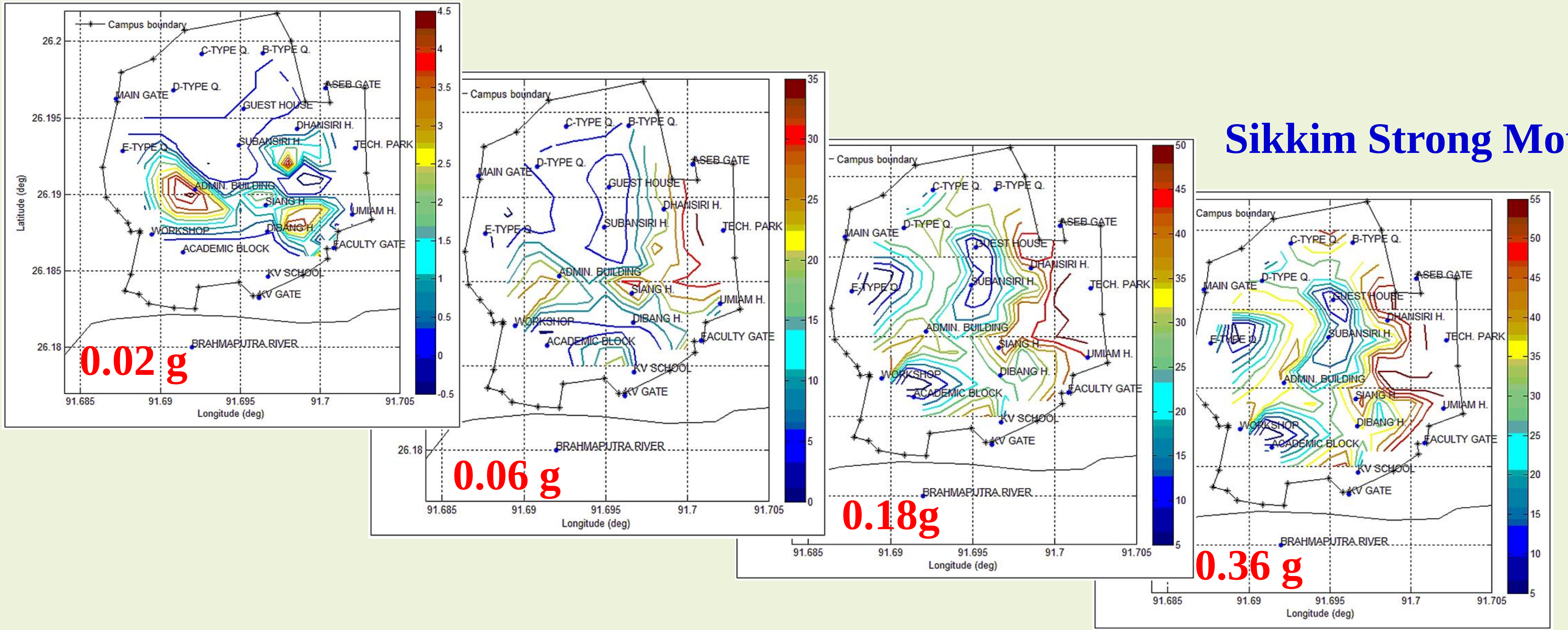


Sikkim Eq: PBRA = 0.36g

Liquefaction Potential Index (LPI) of IIT Guwahati

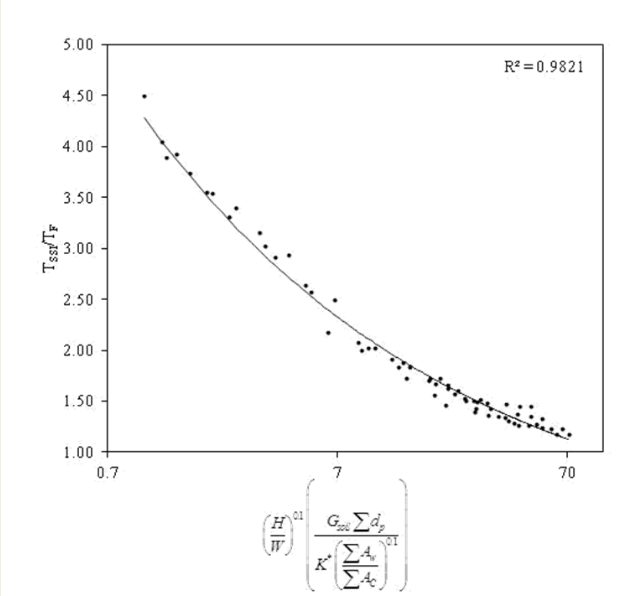
- Indicates susceptibility to liquefaction
  - ❖ LPI < 5 → No liquefaction
  - ❖ 5 < LPI < 15 → Moderate liquefaction
  - ❖ LPI > 15 → Severe liquefaction

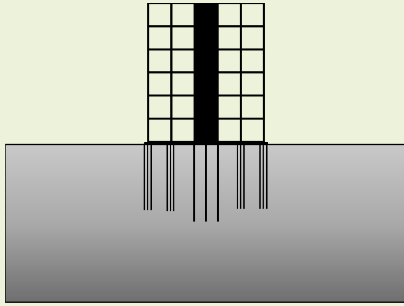
Sikkim Strong Motion

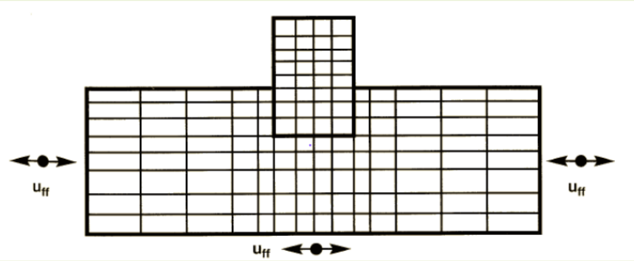


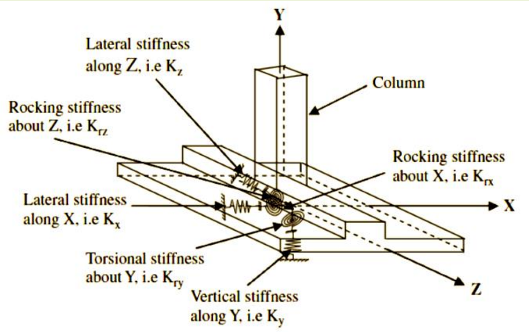
Seismic Soil-Structure Interaction

- Soil-Structure Interaction
  - ❖ Seismic analysis of integral abutment RC bridges
  - ❖ Seismic behavior of RC wall-framed buildings
  - ❖ Kinematic and Inertial interaction of building foundations

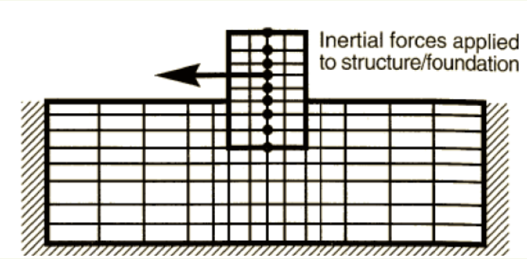


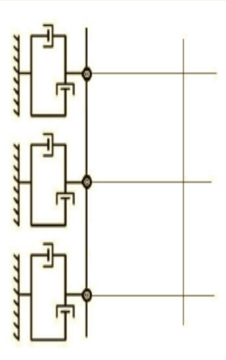


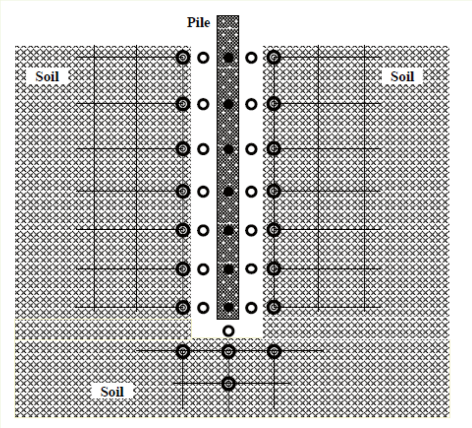


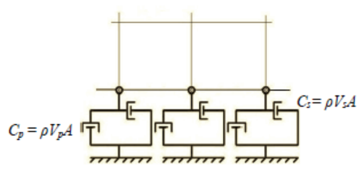


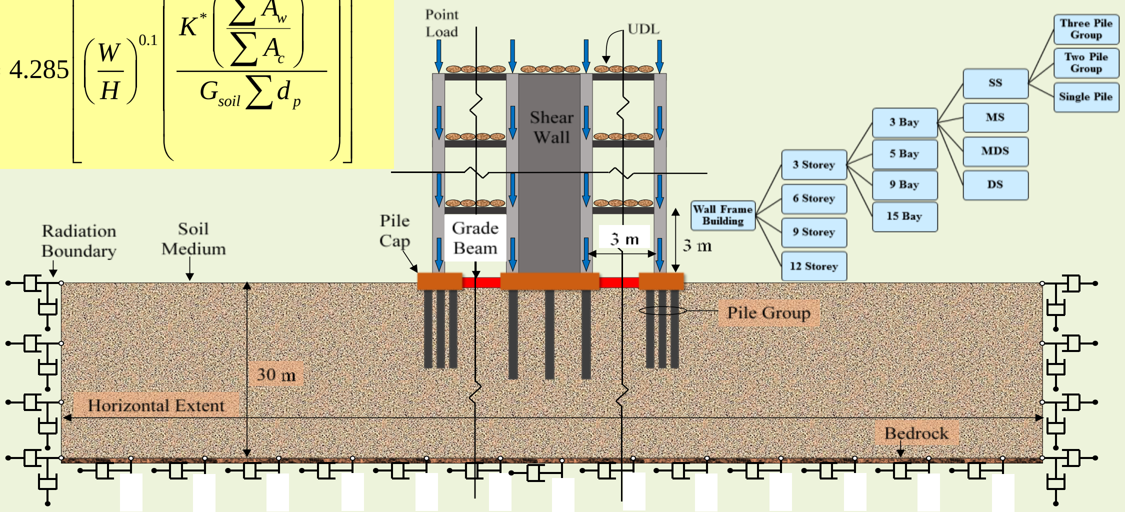
$$\frac{T_{SSI}}{T_F} = 4.285\left[\left(\frac{W}{H}\right)^{0.1}\left(\frac{K^*\left(\frac{\sum A_w}{\sum A_c}\right)^{0.1}}{G_{soil}\sum d_p}\right)\right]^{0.314}$$







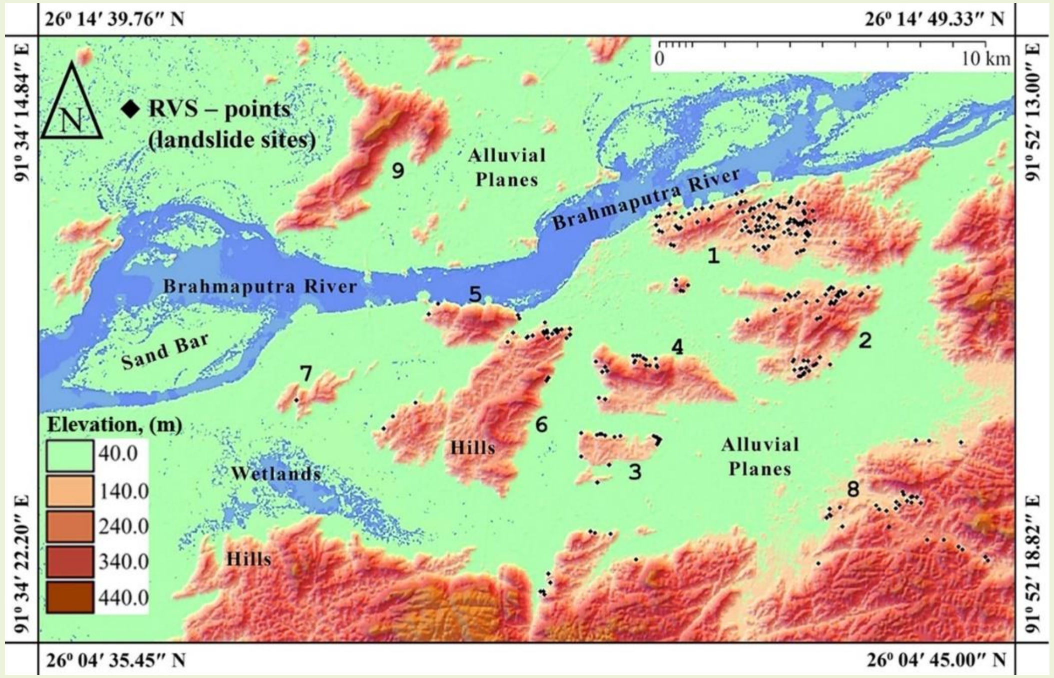




Rainfall Induced Landslide Hazard of Guwahati City

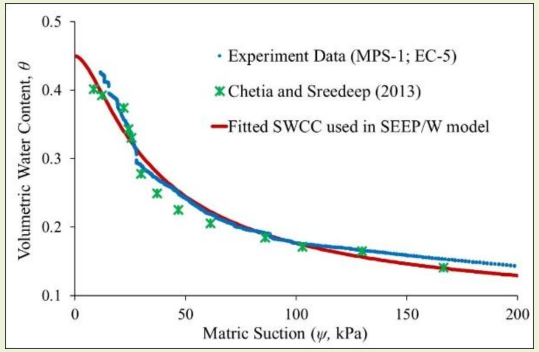
Chiranjib

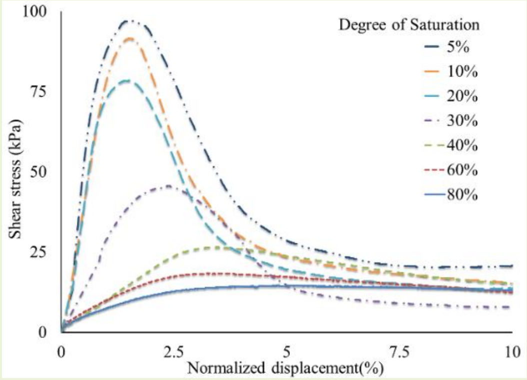
- Study area and characterization of hillslope soils

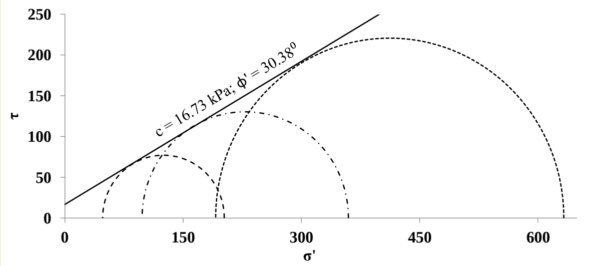


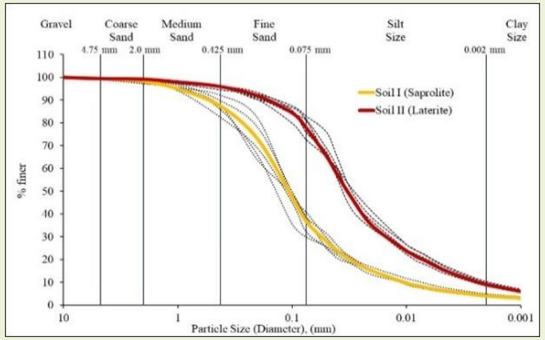
8 major hill series:

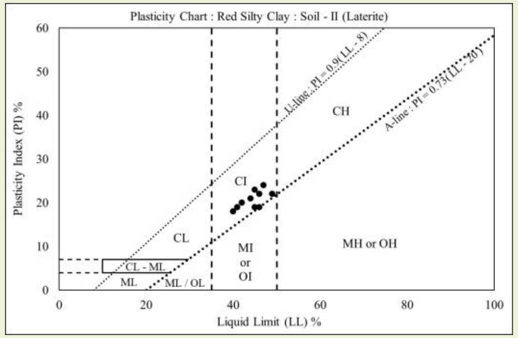
(1) Nabagraha and Sunsali hill series
(2) Japorigog hill
(3) Sonaighuli and Jutikuchi hill series
(4) Narakashur hill
(5) Nilachal hill
(6) Fatasil hill
(7) Jalukbari hill
(8) Khanapara hill
(9) Agyathuri hills







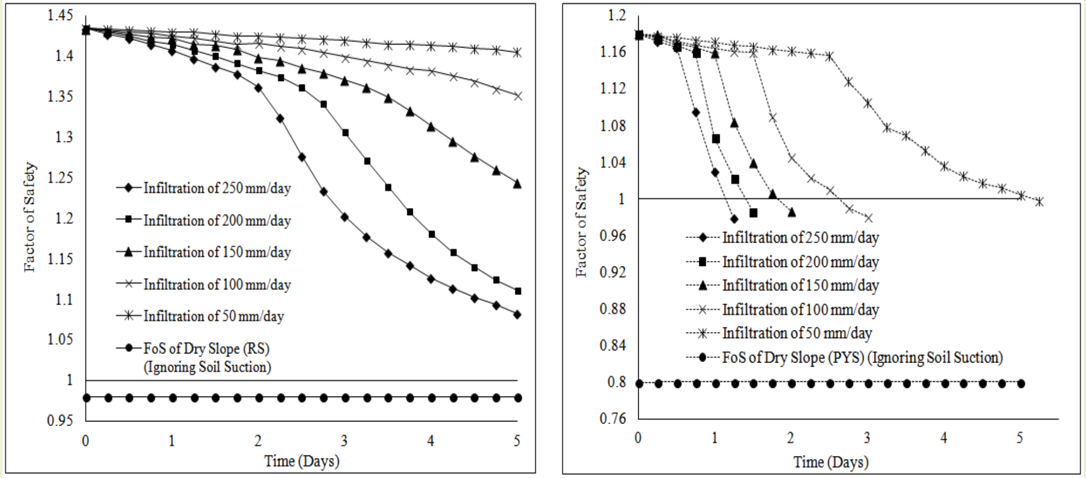




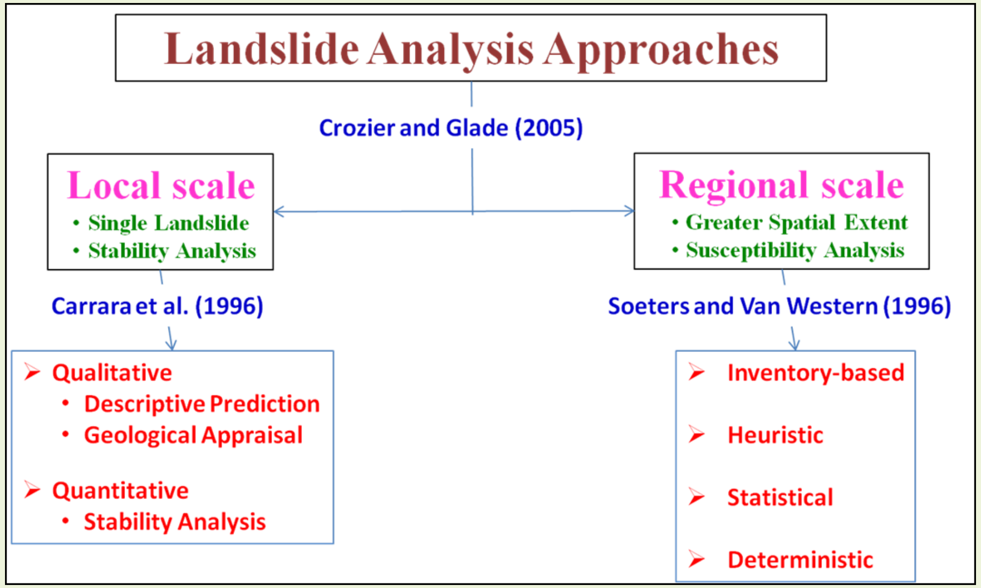
Rainfall Induced Landslide Hazard of Guwahati City

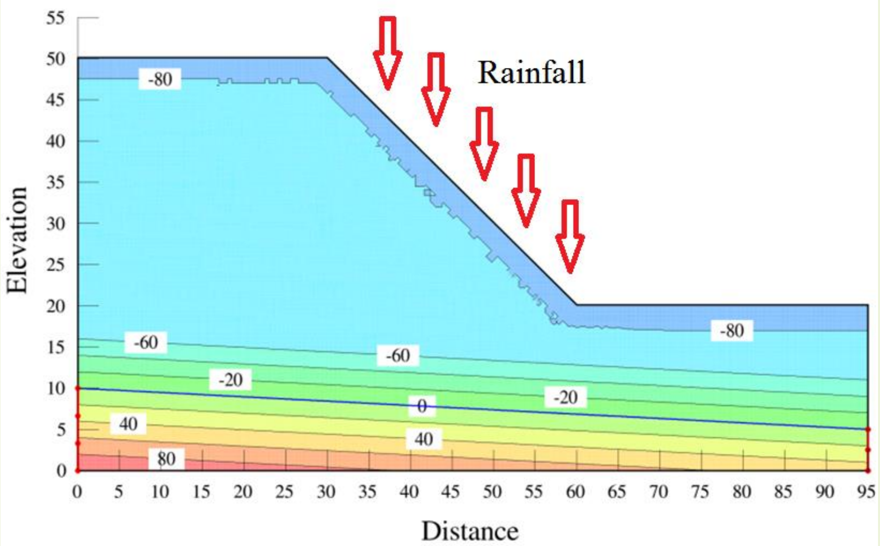
- Local-scale deterministic slope stability analysis

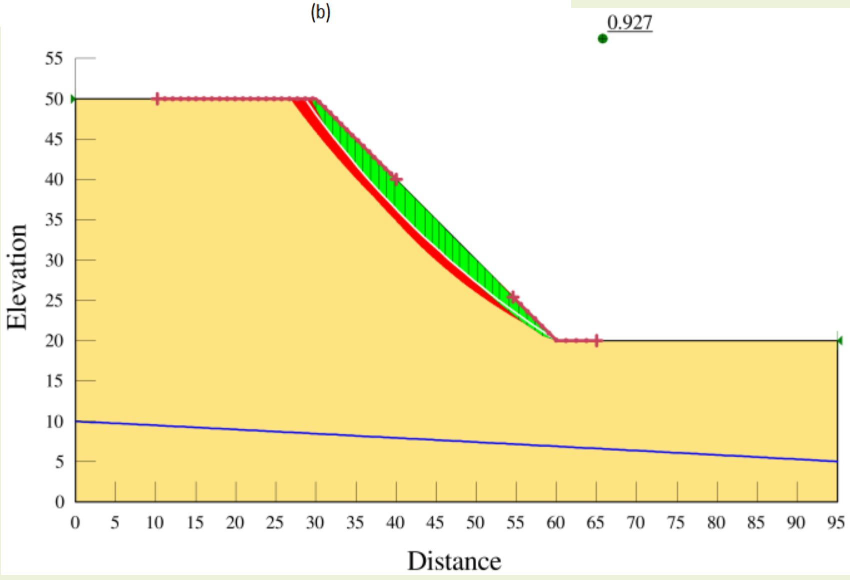
- Applied Infiltration
  - Five different rates of infiltration
    - 50 mm/day
    - 100 mm/day
    - 150 mm/day
    - 200 mm/day
    - 250 mm/day

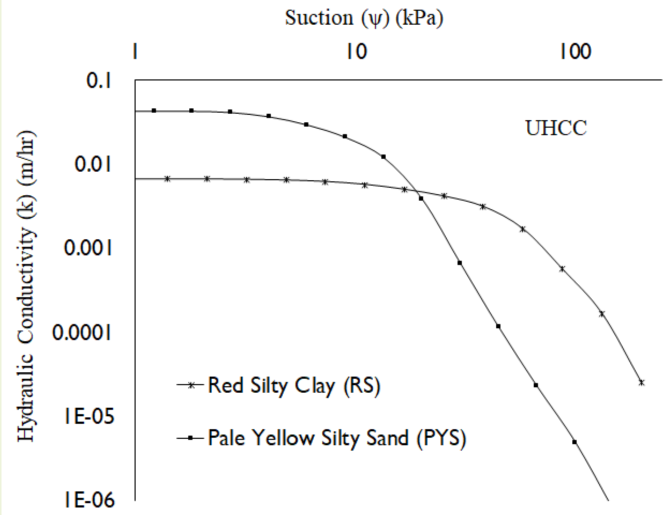


(a) (b)



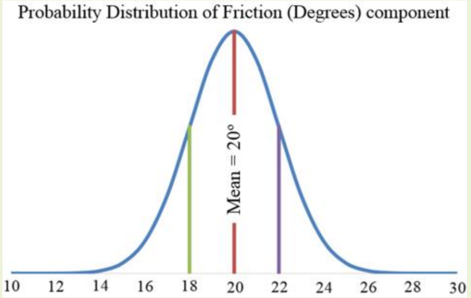


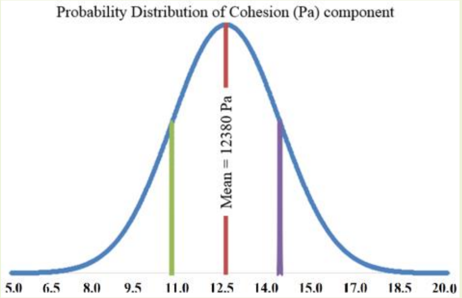


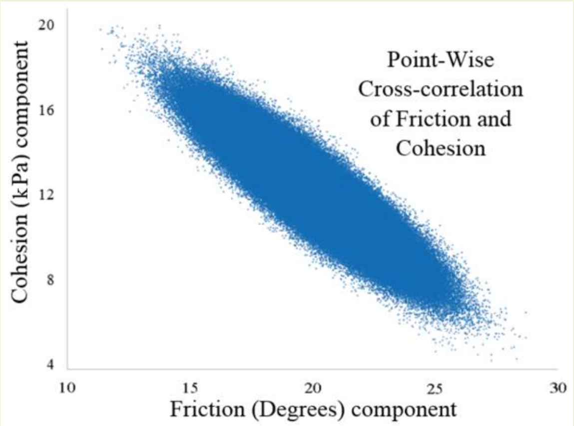


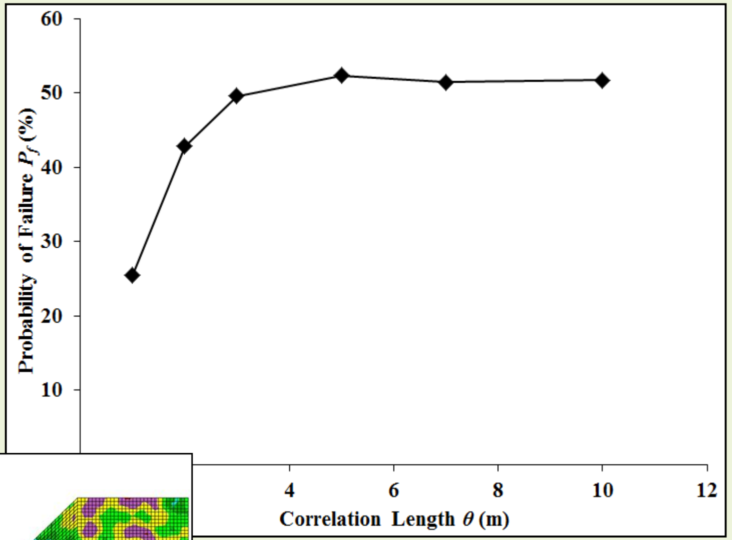
Rainfall Induced Landslide Hazard of Guwahati City

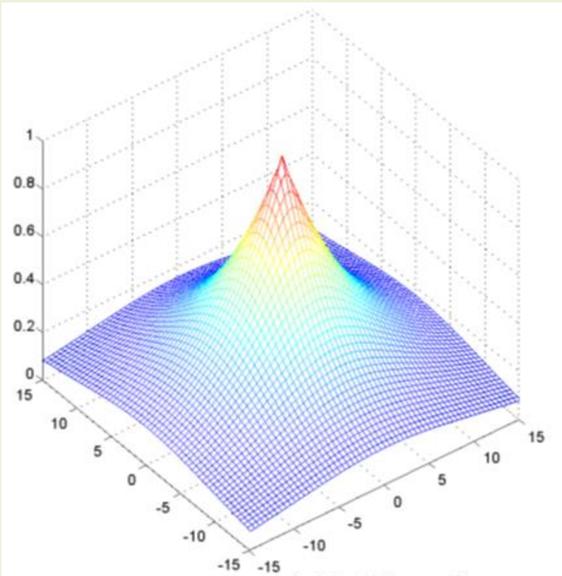
- Local-scale probabilistic slope stability analysis
  - ❖ Application of Random Field for soil parameters for catering uncertainty in soil parameters



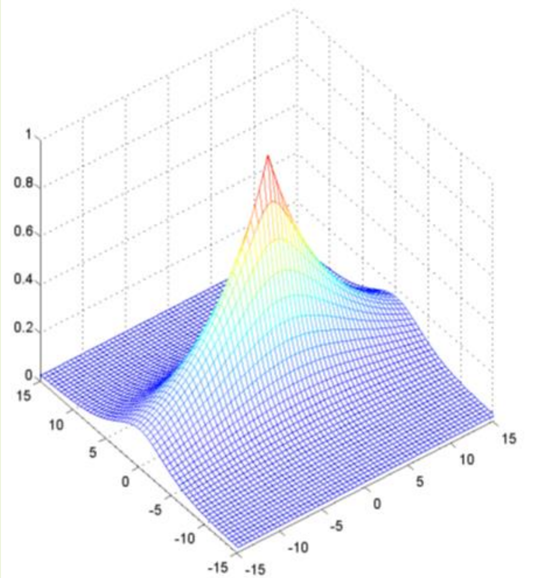




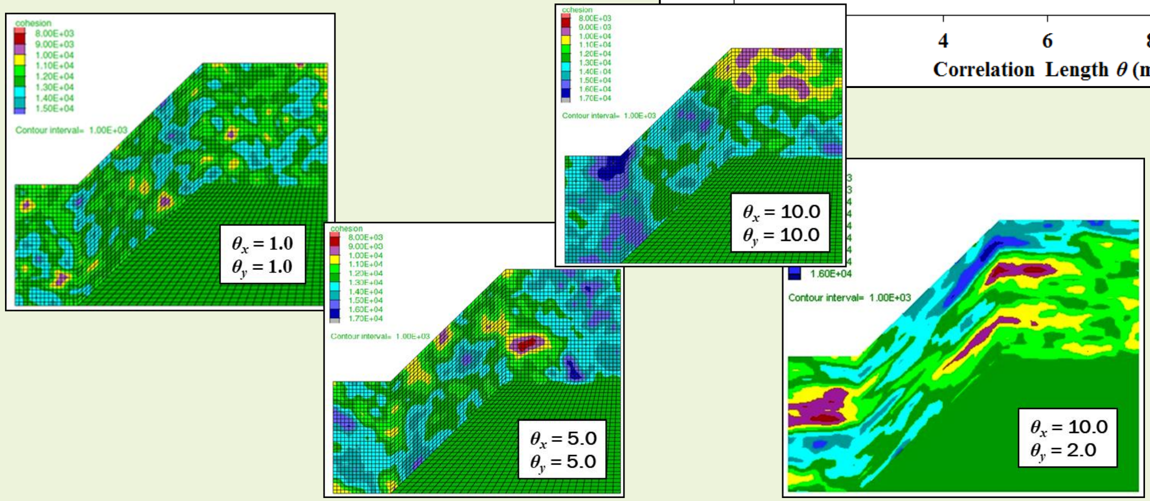




$\Theta_x = \Theta_y = 15.0$m over a field of dimension 15 m

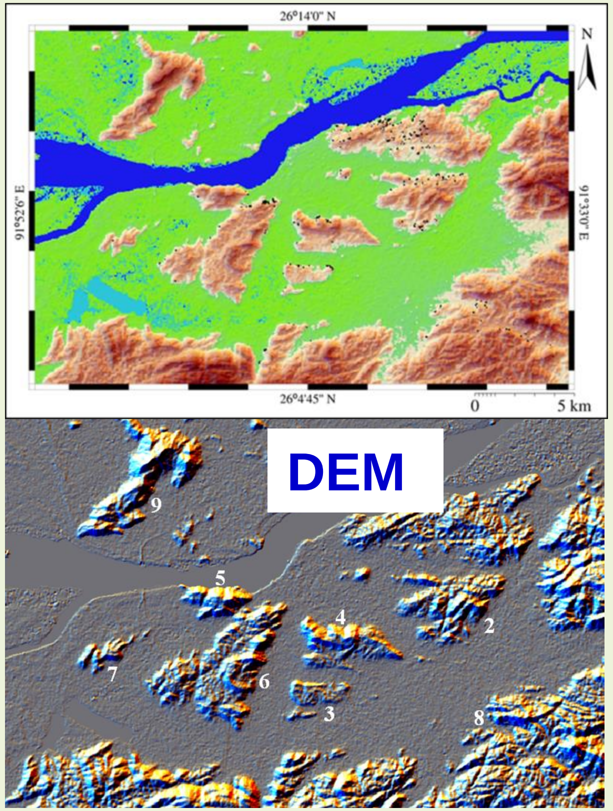


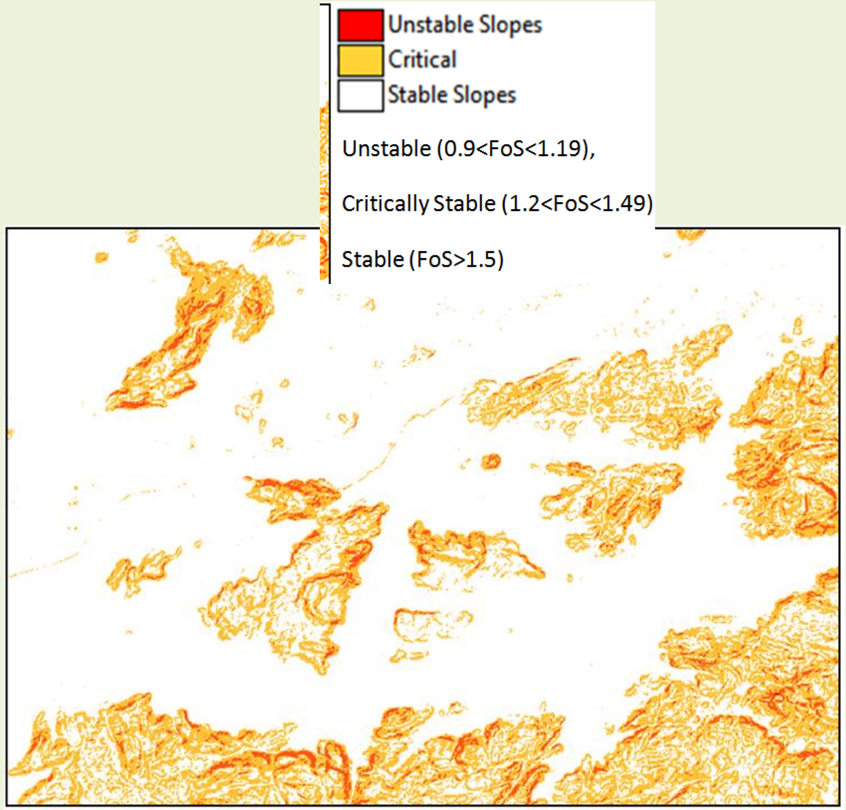
$\Theta_x = 15$m; $\Theta_y = 5.0$m over a field of dimension 15 m



Landslide Susceptibility and LHZ of Guwahati City

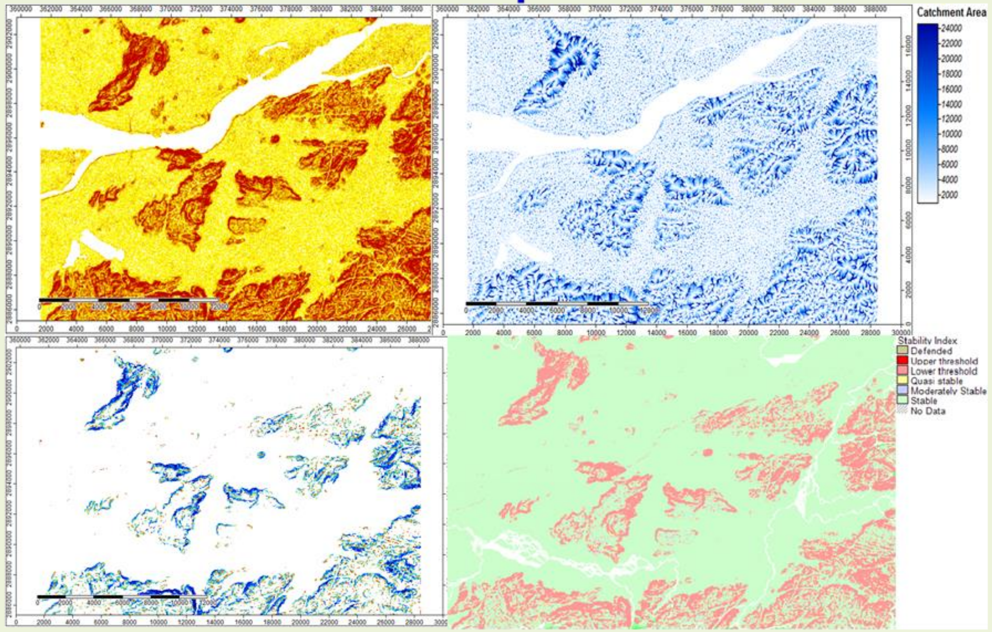
- Regional Scale Stability Analysis
  - Landslide Hazard Zonation and Landslide Susceptibility Studies
    - **SHALSTAB, TRIGGRS, SINMAP, Physically Based Models**
    - **GIS platform for Digital Elevation Models (DEM)**





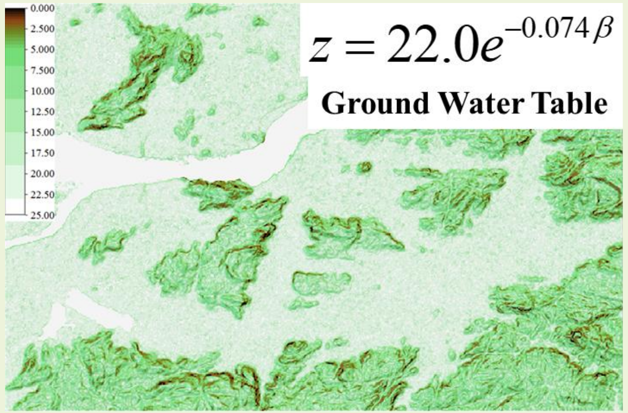
Slope Map

Map of Catchment Area



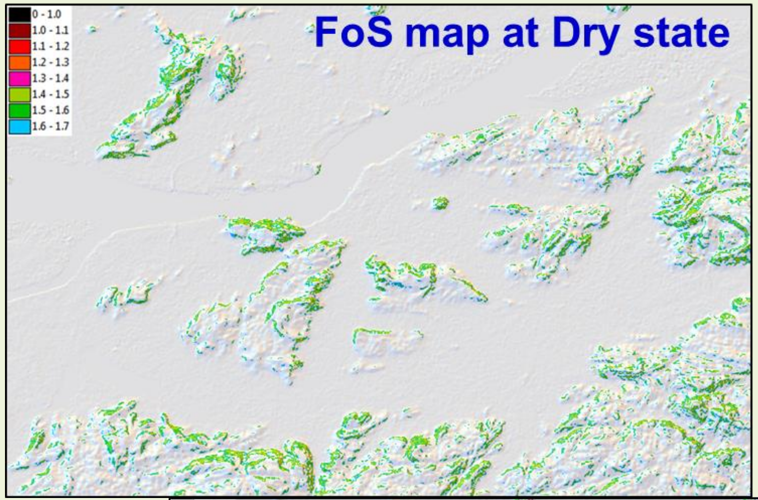
Steady-State Recharge Map

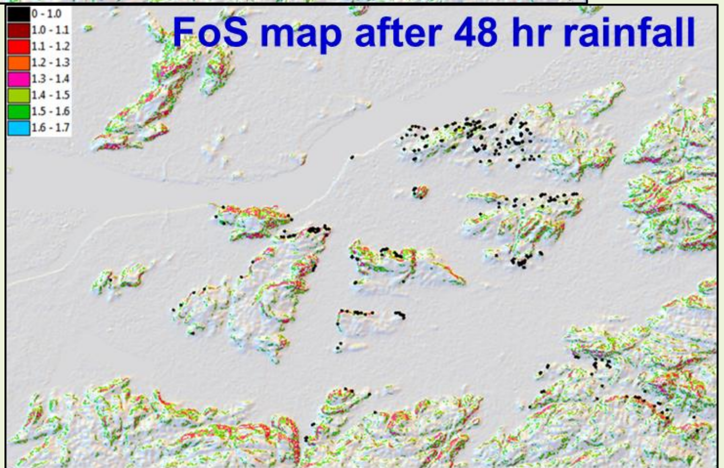
Map of Stability Index



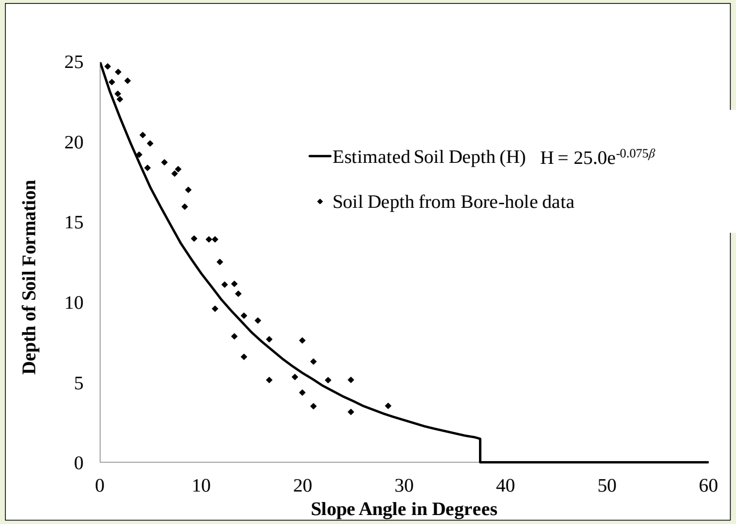
Rainfall Induced Landslide in Guwahati Region

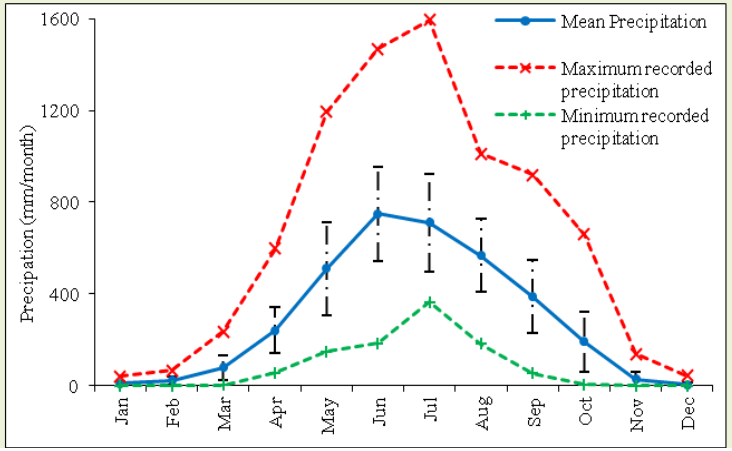
- Regional Scale Landslide Hazard Analysis
  - ❖ Incorporation of variability in rainfall and soil depth



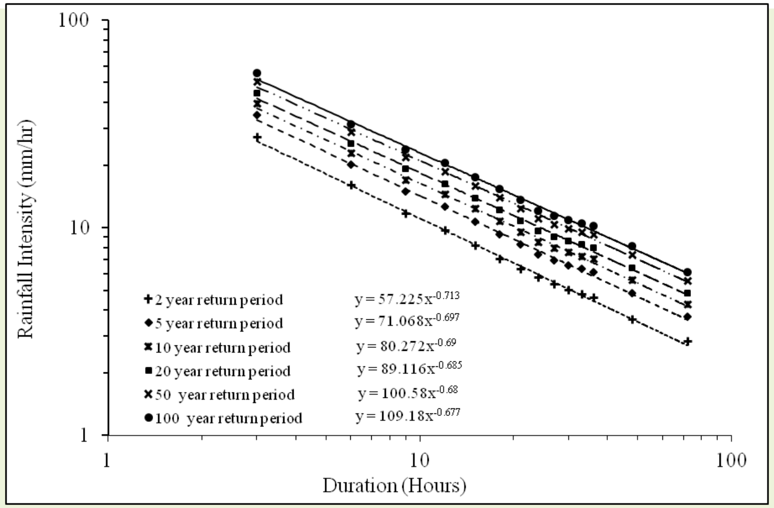


Variation of weathered soil thickness and slope angle



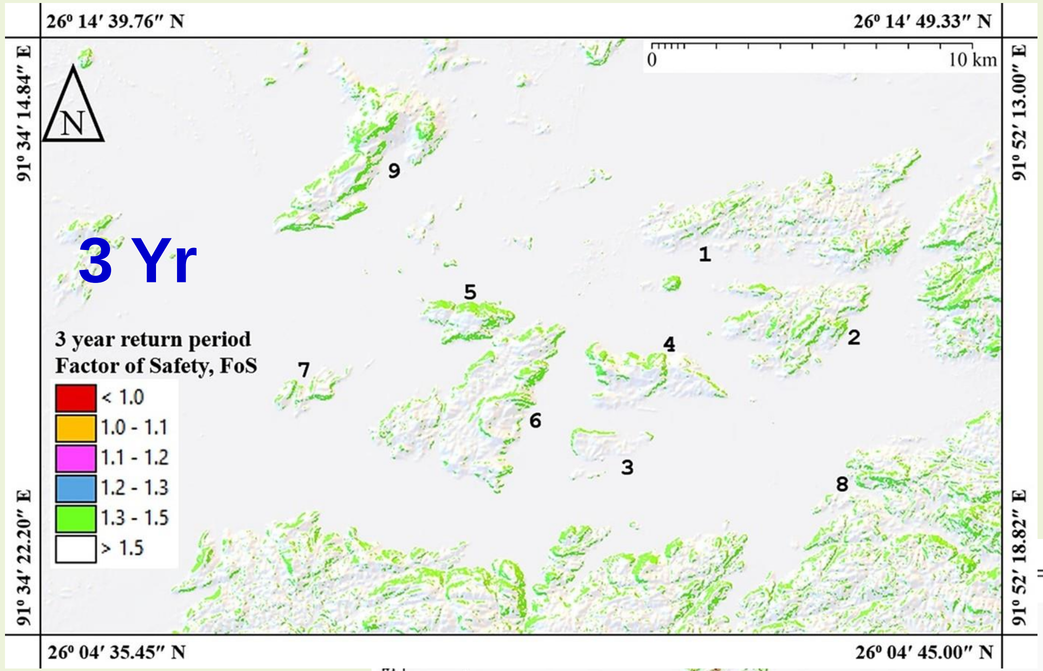


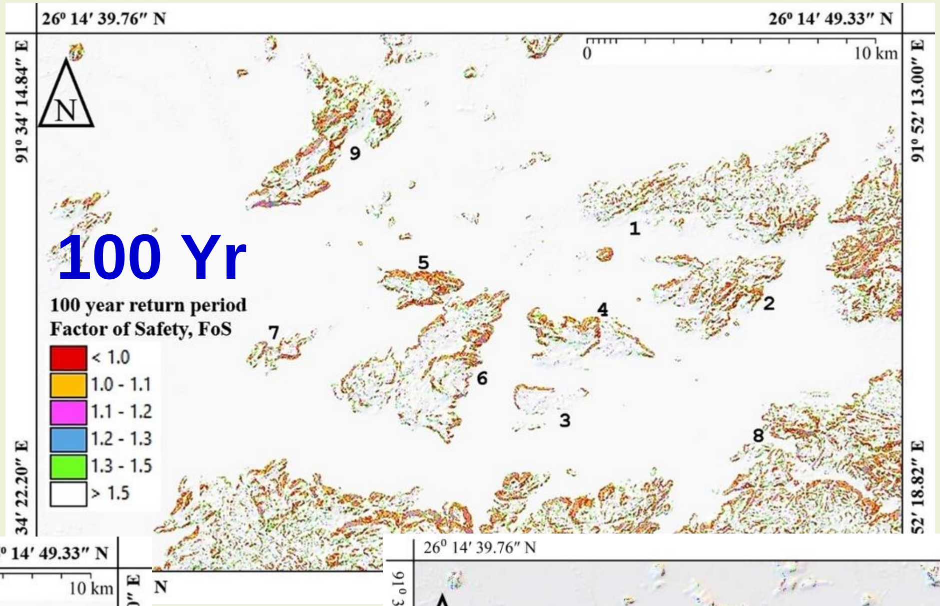
Monthly mean rainfall based on 100 years data (1901-2002) at Kamrup metropolitan

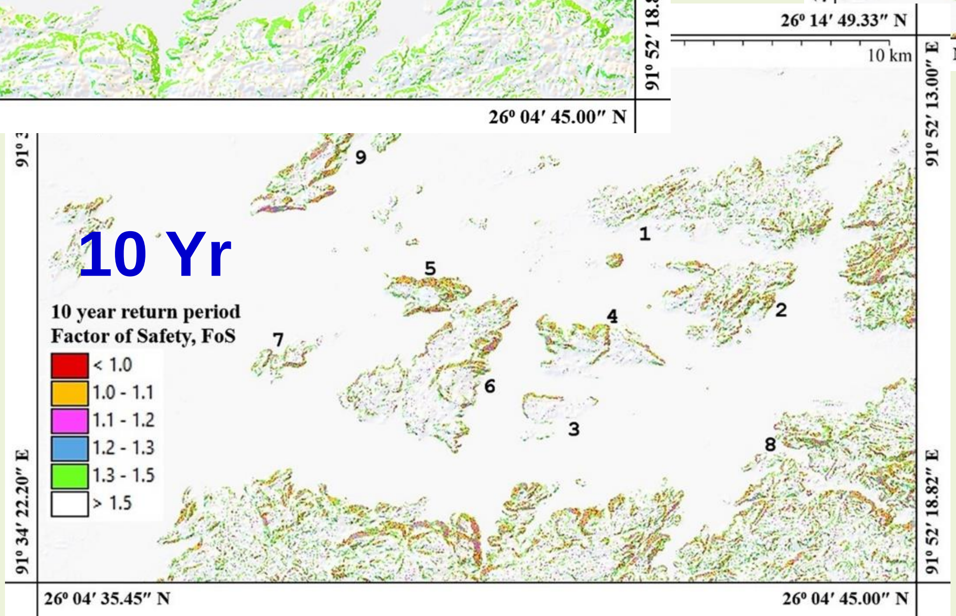


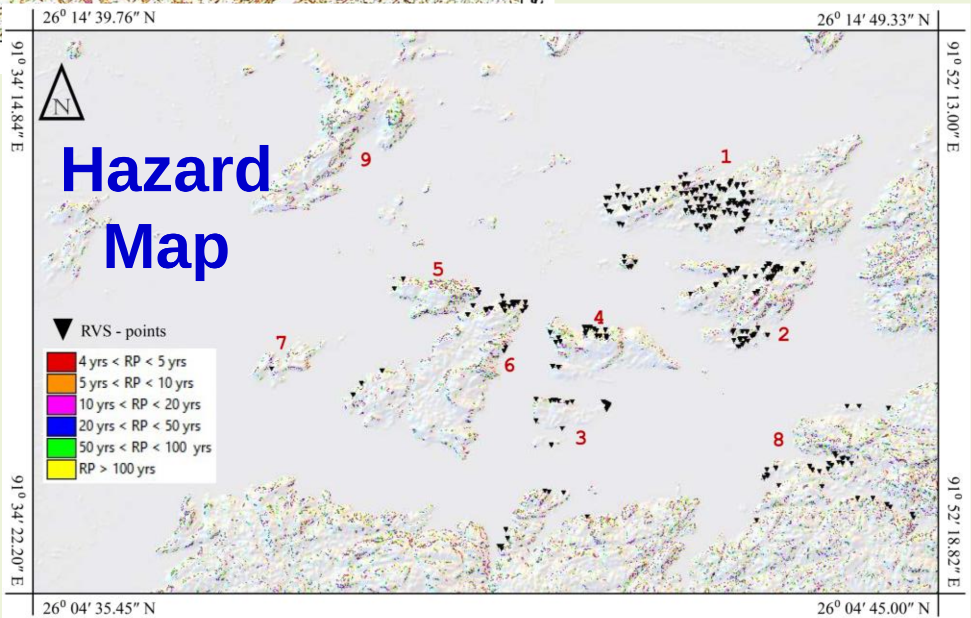
IDF curves for Guwahati region

Landslide Hazard Map of Guwahati City





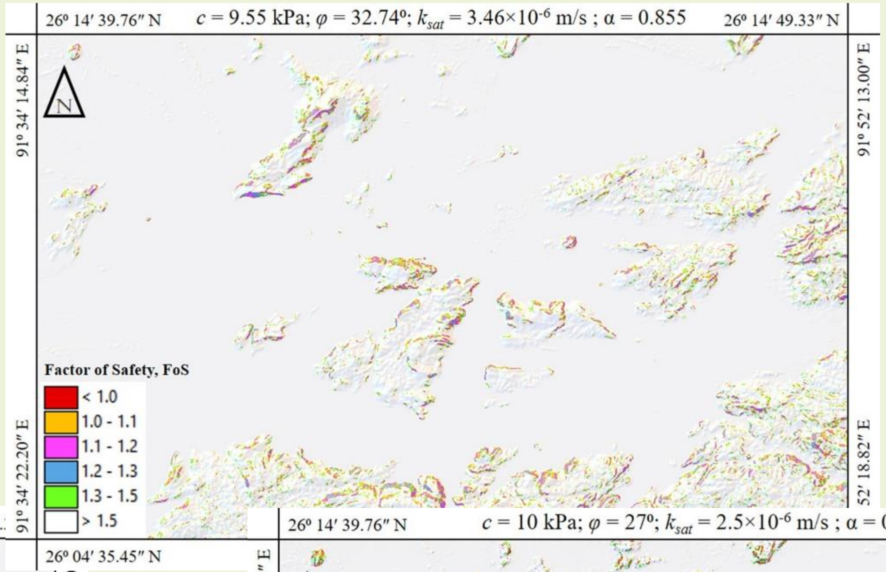


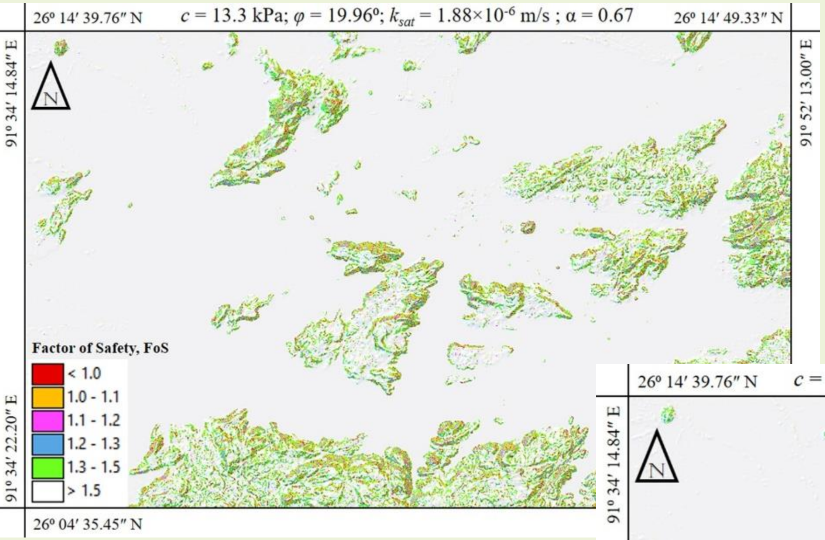


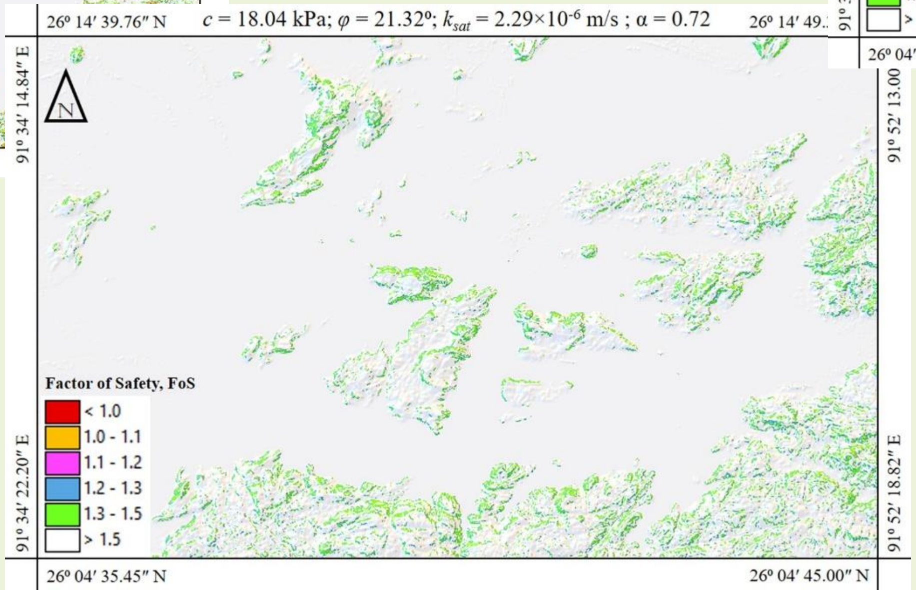
Effect of Return Periods

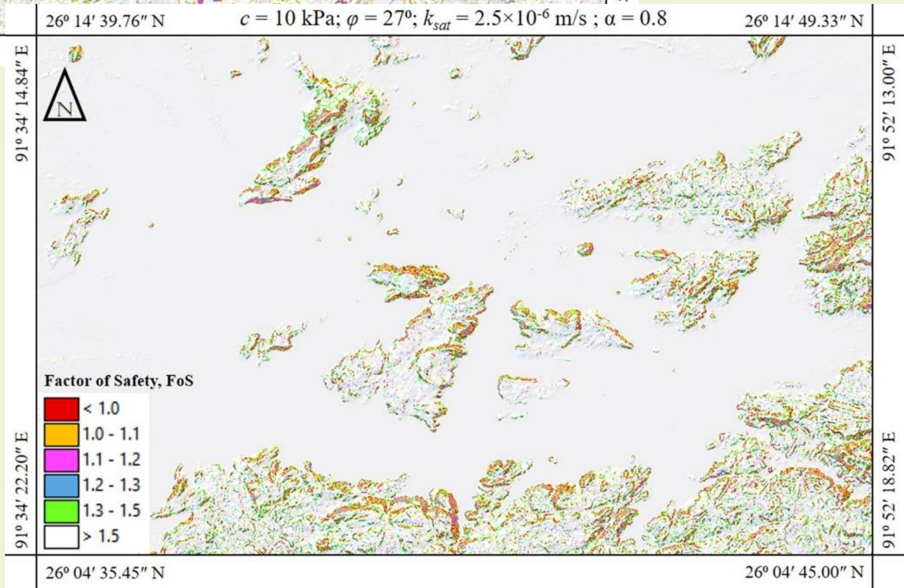
Probabilistic Landslide Hazard Analysis of Guwahati City

- Influence of uncertainty of soil parameters
  - ❖ For different mean value of soil strength parameters

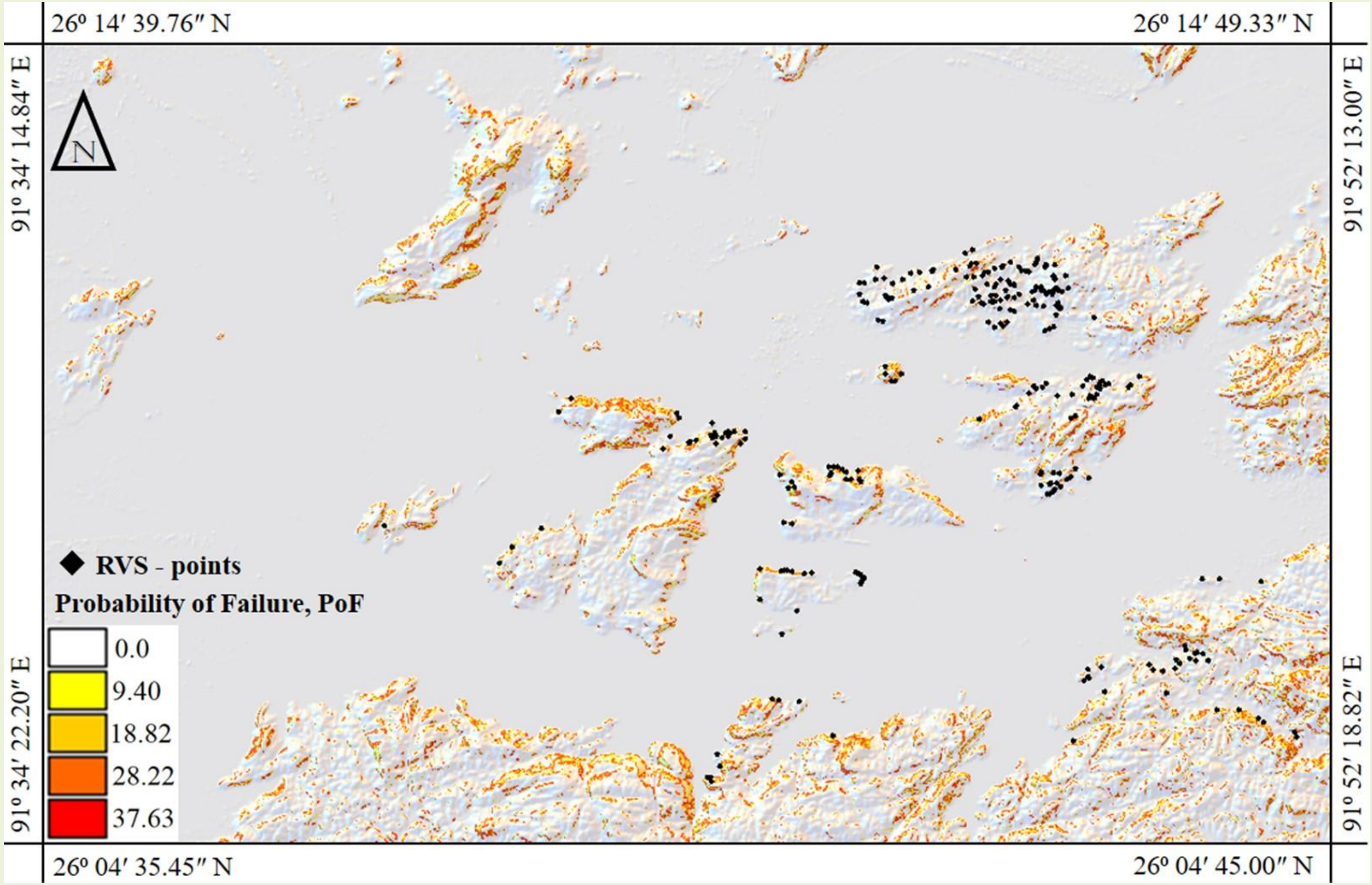








Probability of Failure (PoF) Map of Guwahati City



Forensic Analysis of Landslide and Mitigation

Priyanka

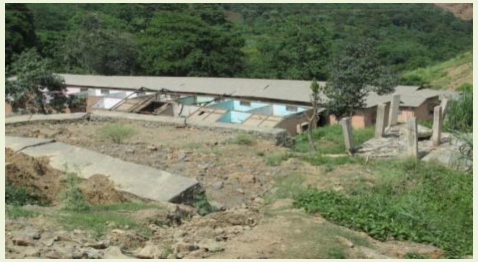
Ruplekha

- Calcom Cement Plant, Umrangso, Assam





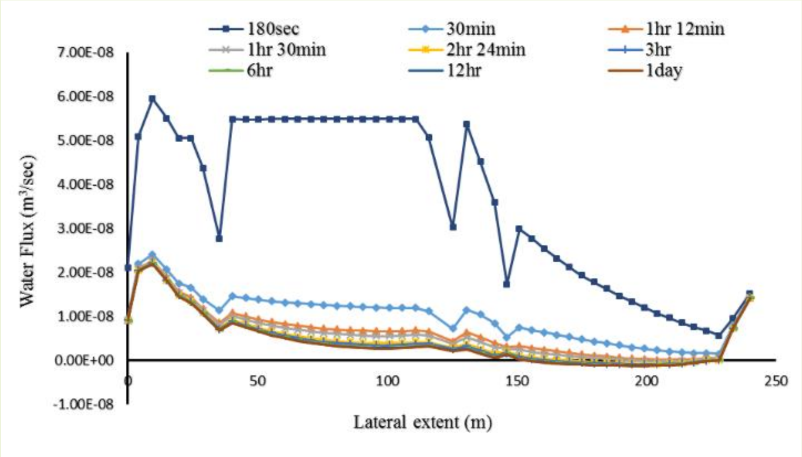


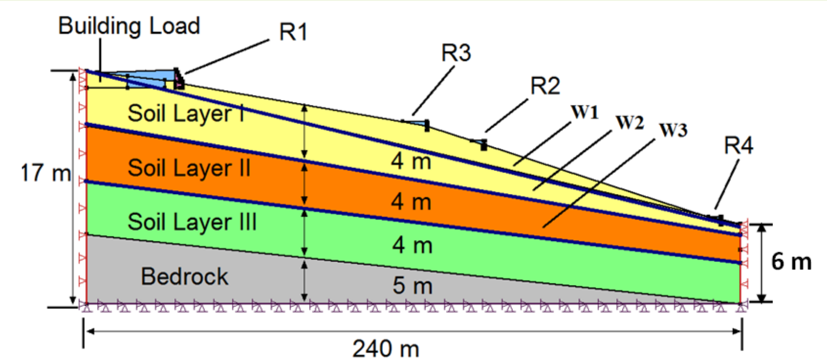




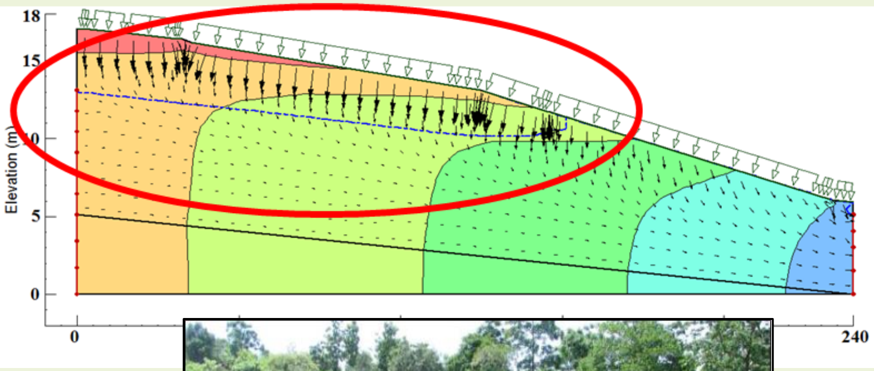

Forensic Analysis of Landslide and Mitigation

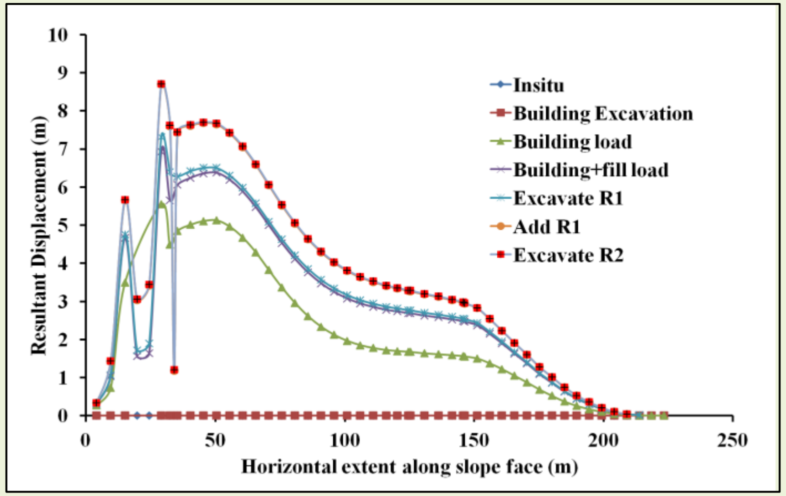
- Approximate model based on available nearby borehole data
  - ❖ Sequential construction simulated in FE model
  - ❖ Water Table depth at failure location was unknown





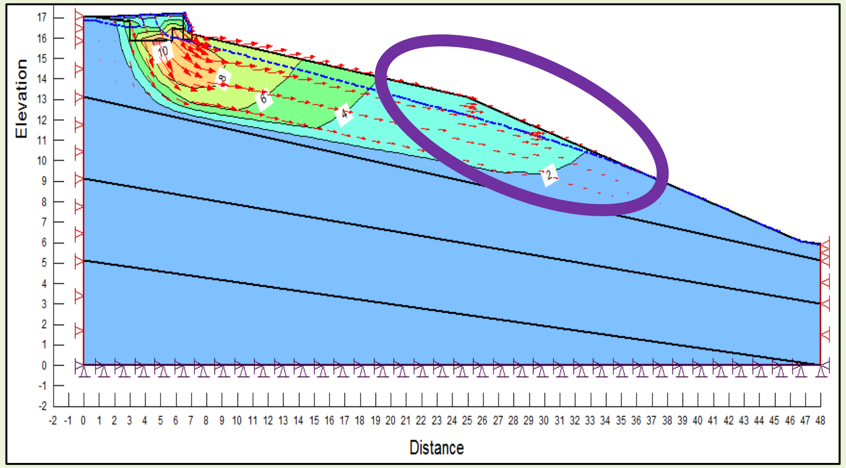
Sl. No.	Stage of construction	Dry	Water level at a ht. of 17m (W_1)	Water level at a ht. of 13m (W_2)	Water level at a ht. of 9m (W_3)
		FoS Values	FoS Values	FoS Values	FoS Values
1	In-situ	2.112	1.411	1.588	1.511
2	Building foundation excavation	2.1	1.373	1.577	1.513
3	Imposition of building load	0.976	0.821	0.793	0.769
4	Filling back of foundation	0.967	0.850	0.802	0.774
5	Excavation for R1	1.015	0.875	0.825	0.805
6	Construction and backfilling of R1	0.985	0.838	0.798	0.785
7	Excavation for R2	1.373	0.817	1.065	1.025
8	Construction and backfilling of R2	1.344	0.752	0.967	1.007
9	Excavation for R3	1.288	1.029	1.035	0.975
10	Construction and backfilling of R3	1.294	1.024	0.984	0.959

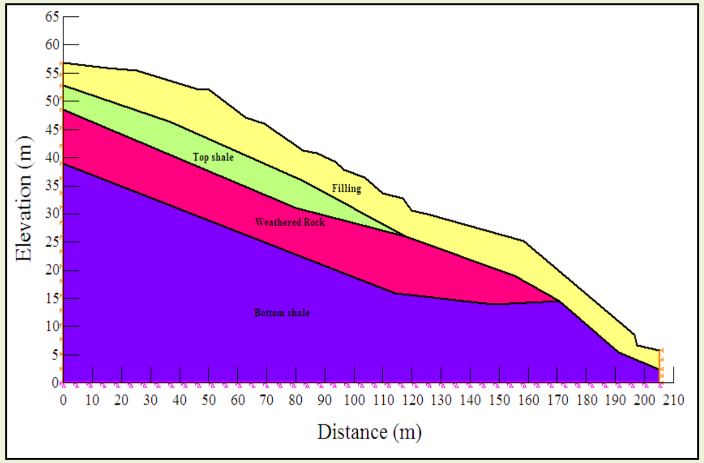


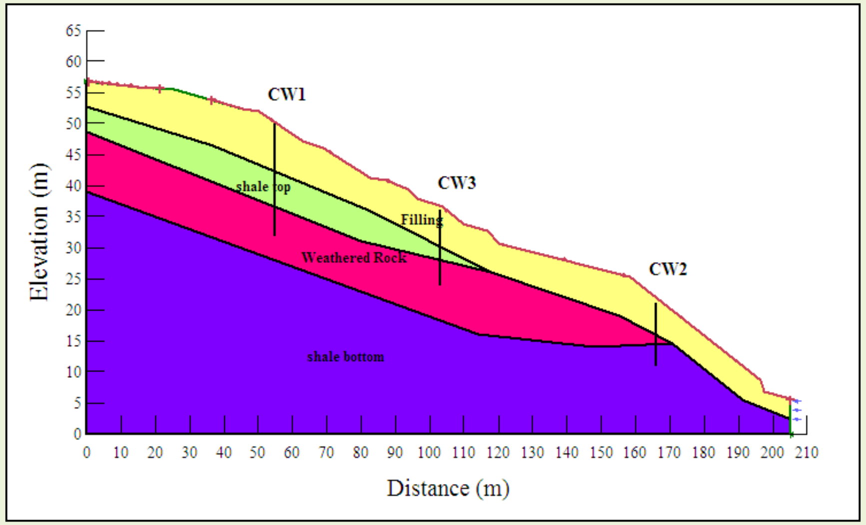


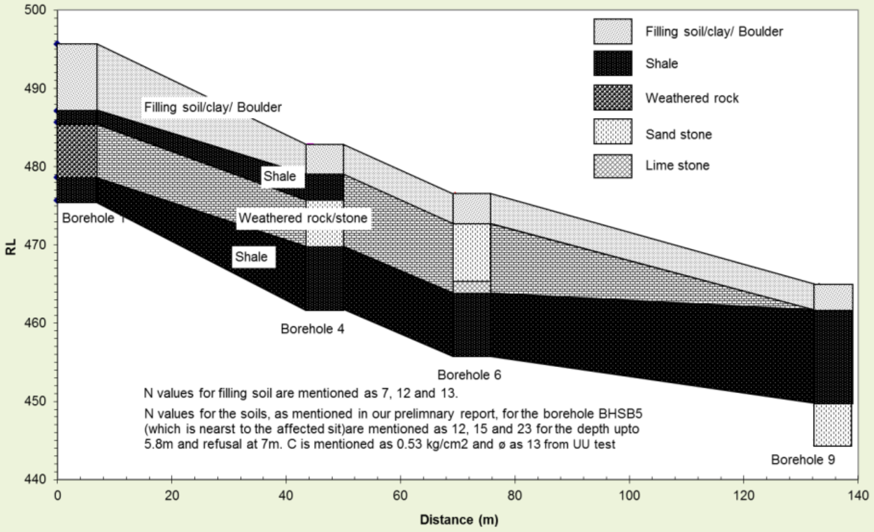
Forensic Analysis of Landslide and Mitigation

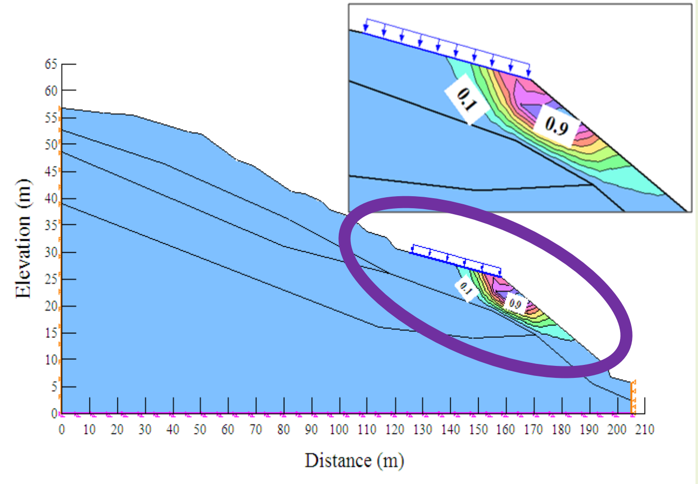
- Mismatch with field displacement in approximate model

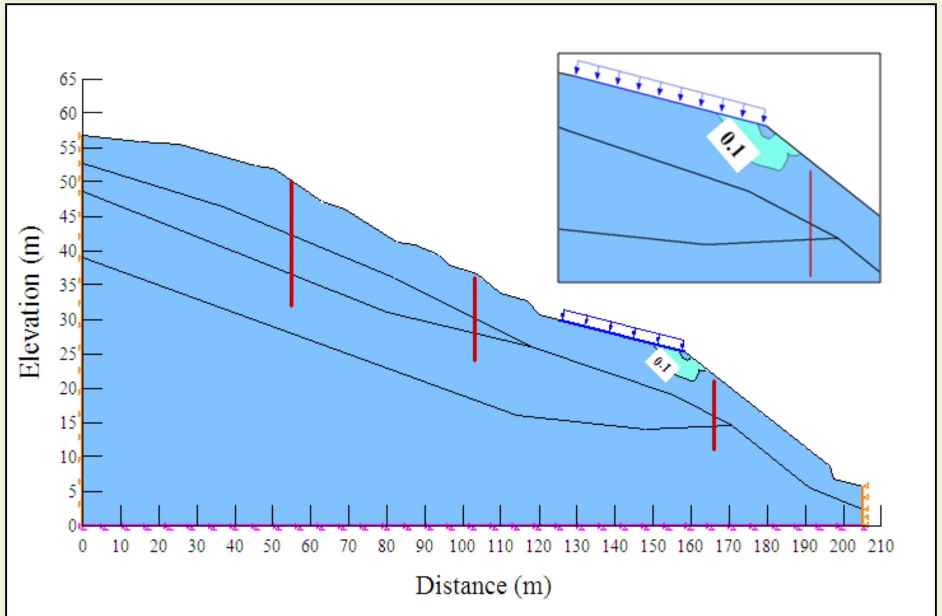










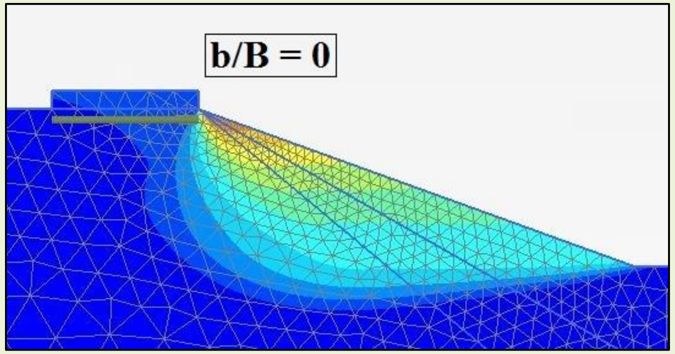


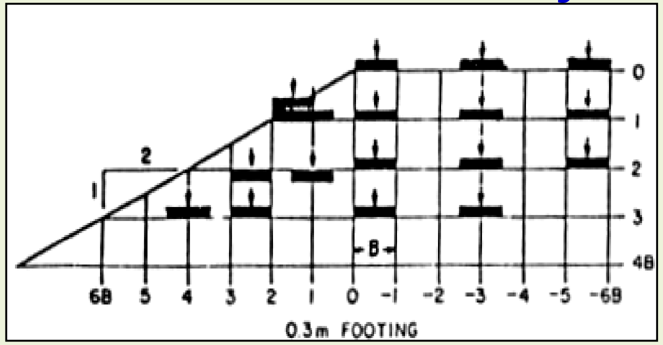
Response of Foundations on Slopes

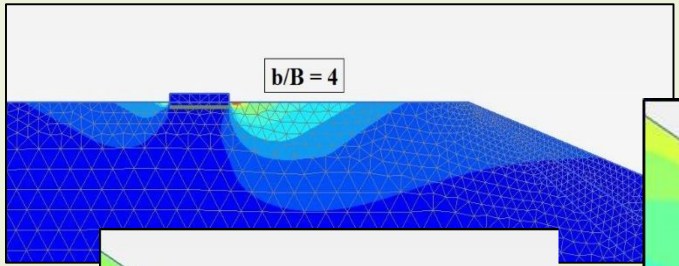
- Static and seismic behavior of foundations on slopes
  - ❖ FE Analysis to identify the evolution of failure mechanism

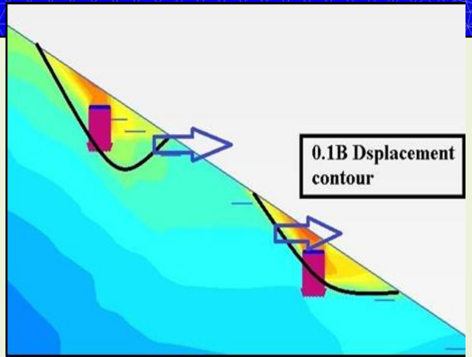
Rana

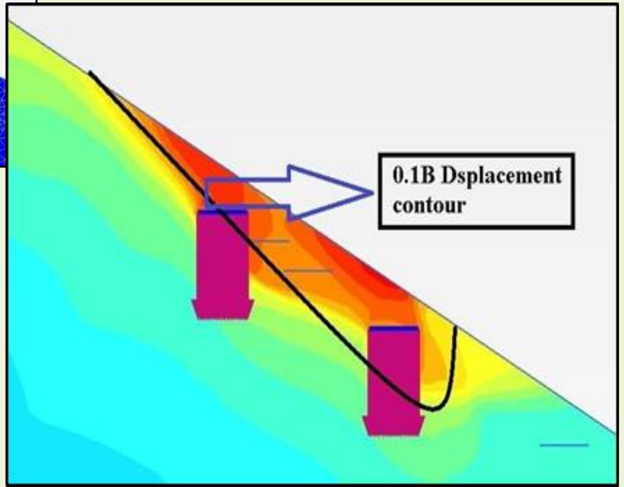
Abhijit

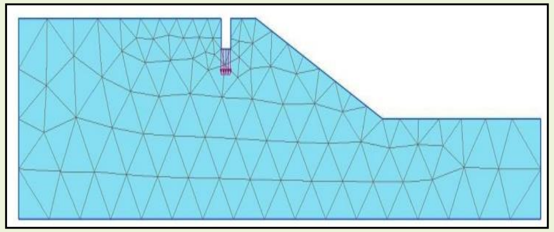


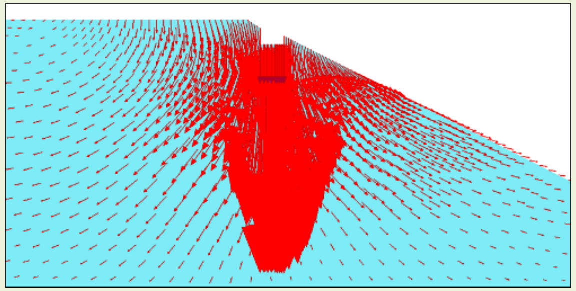


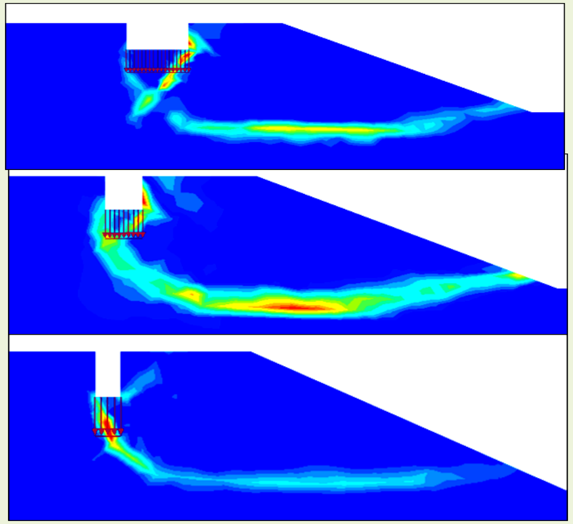




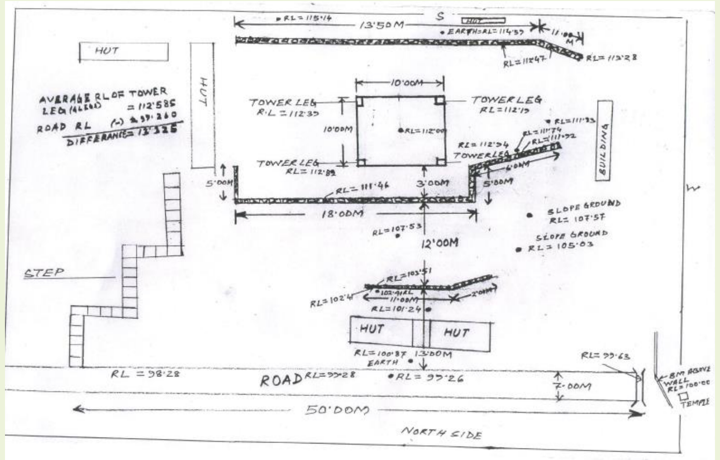


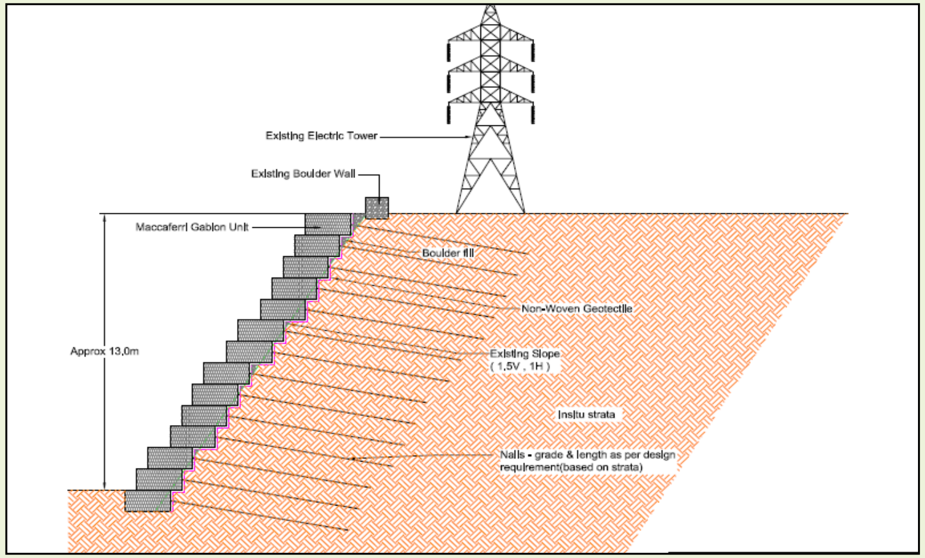


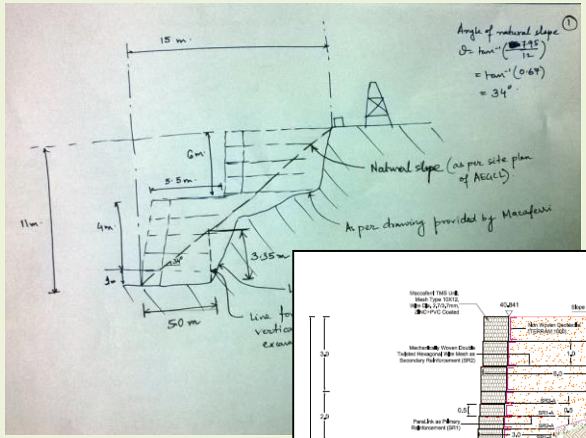


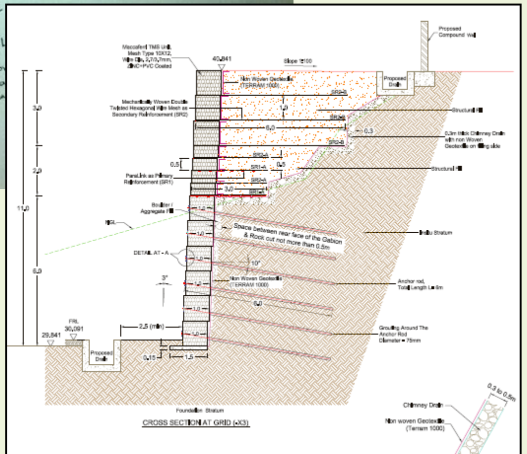


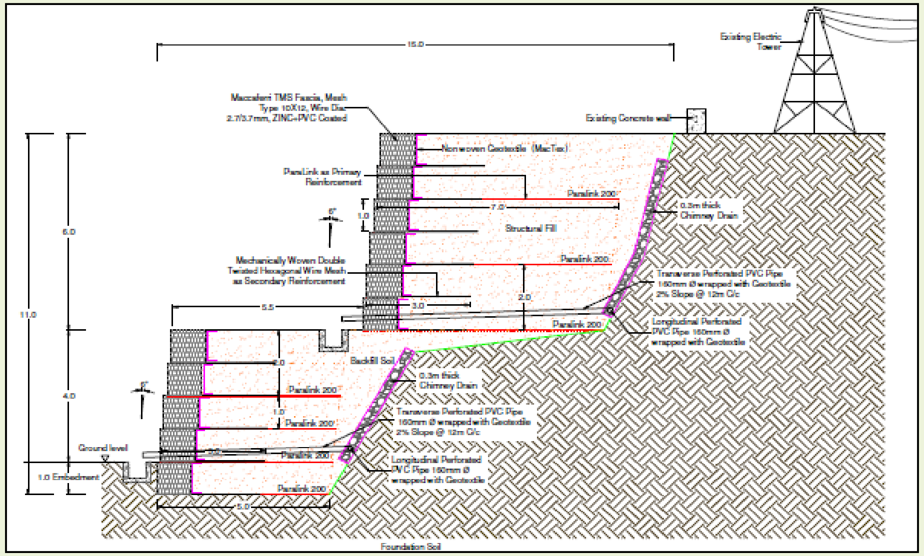
AEGCL Transmission Tower on Disturbed Slope, Sarusajai



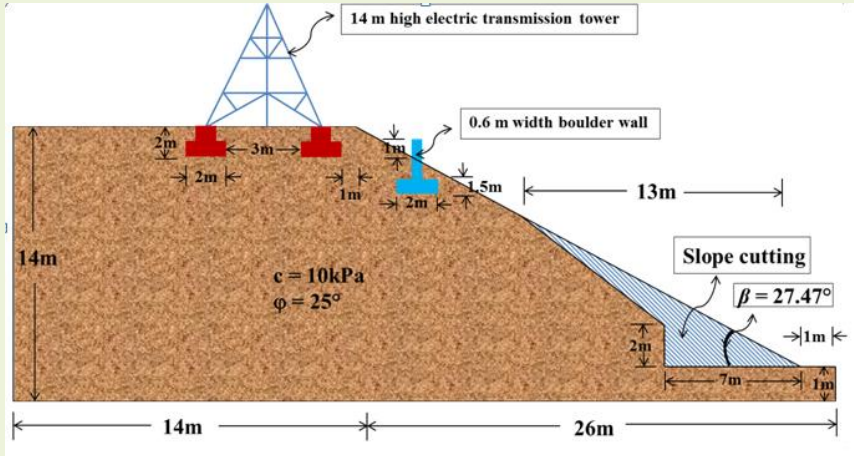


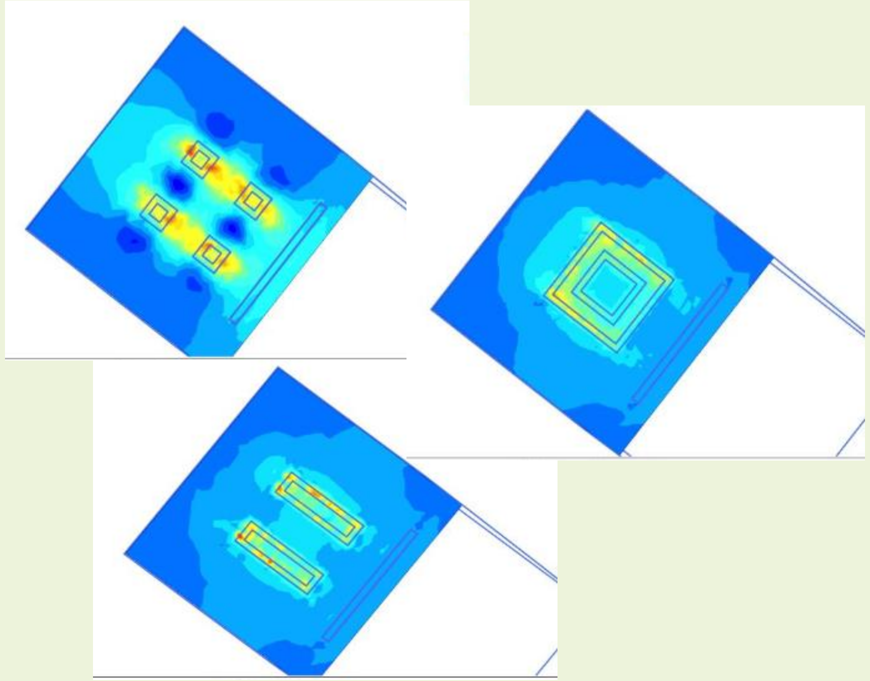


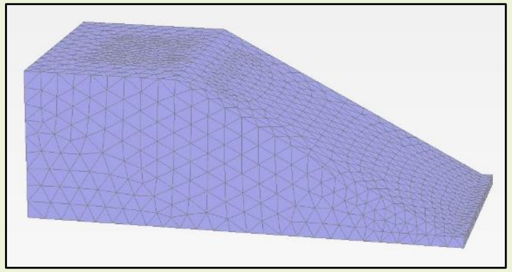


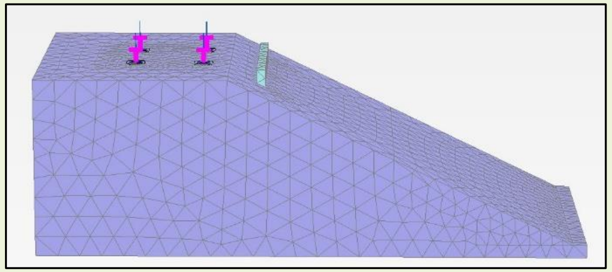


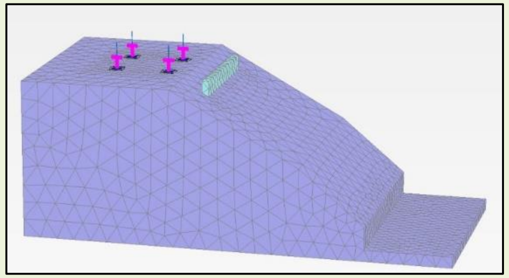
AEGCL Transmission Tower on Disturbed Slope, Sarusajai

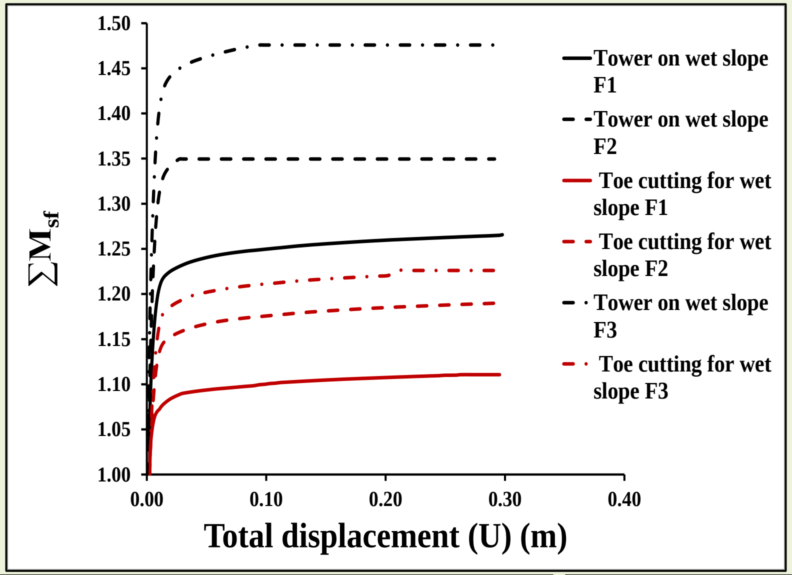


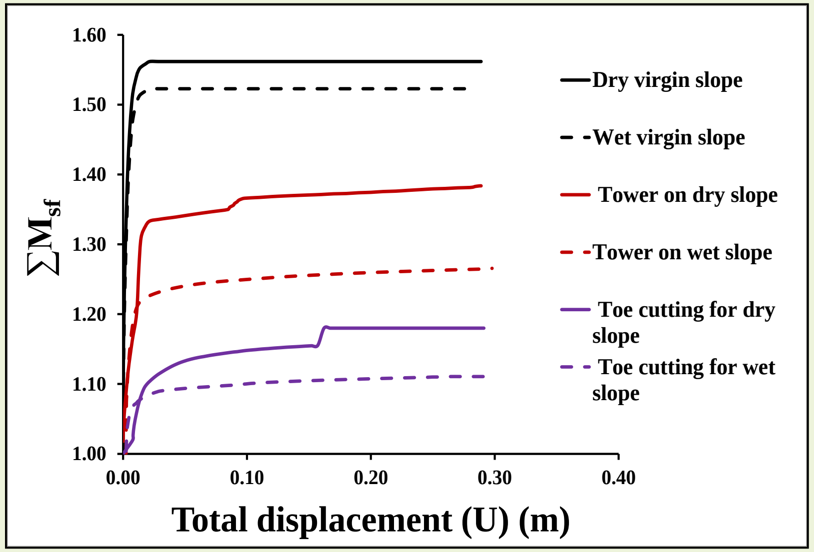


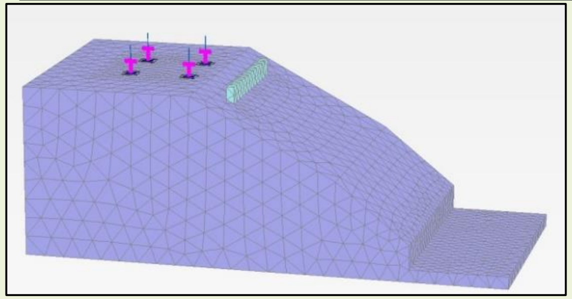


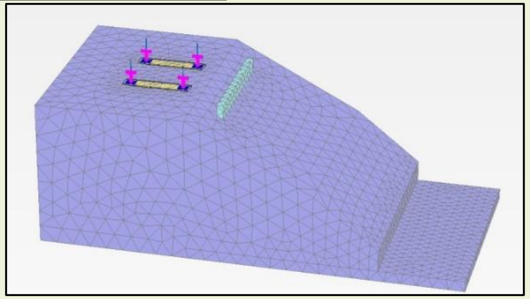


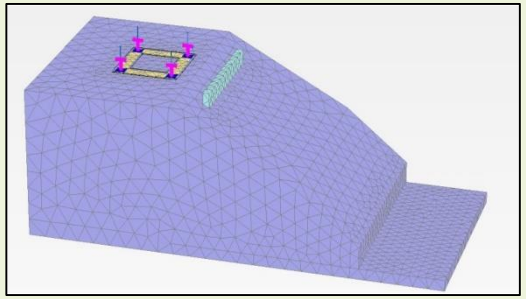








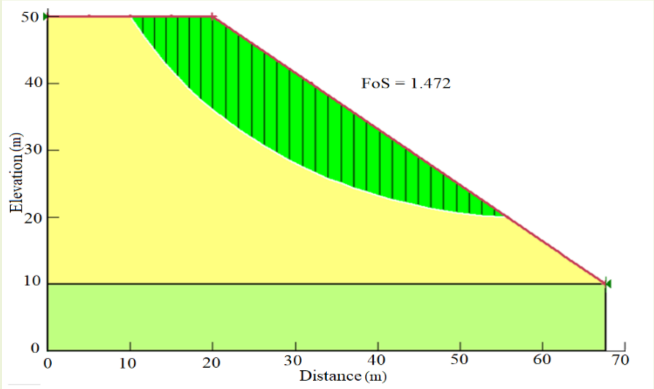


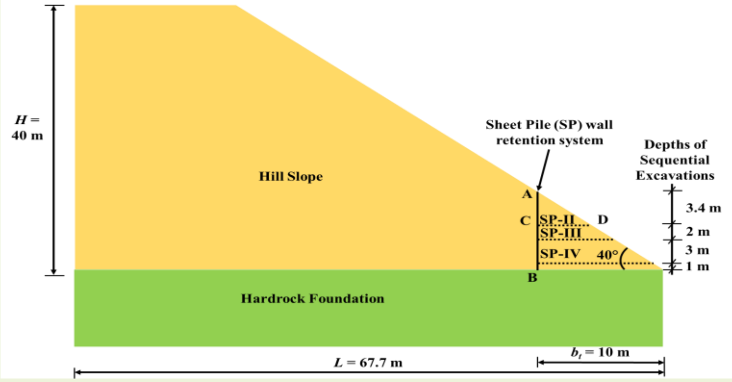


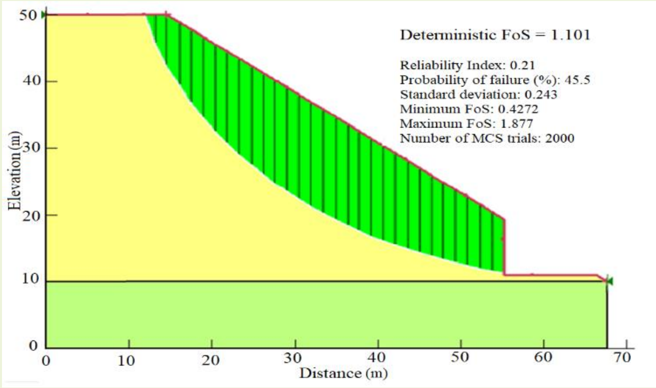
Probabilistic Stability Assessment of Toe-Excavated Hillslopes

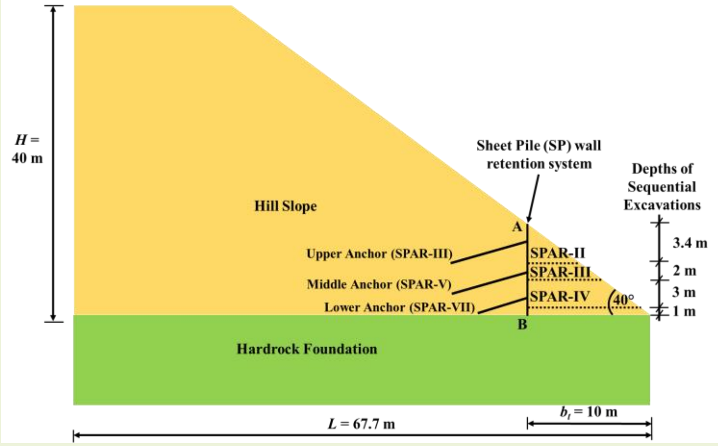
Rubi

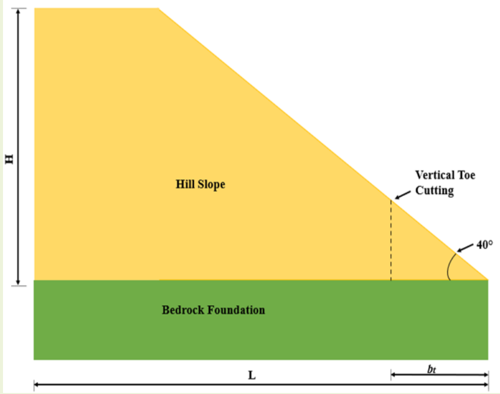
- Consideration of uncertainties and variabilities
  - ❖ Slope stability assessment and mitigation
  - ❖ Ranndom FE and Probabilistic assessment

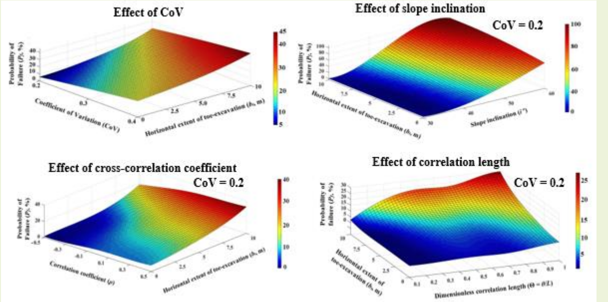


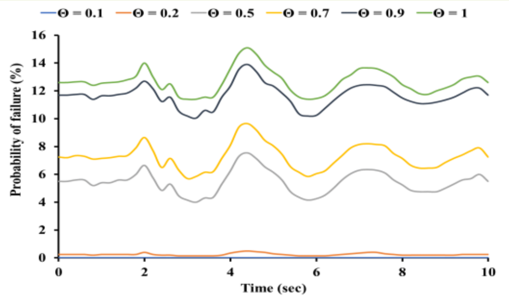


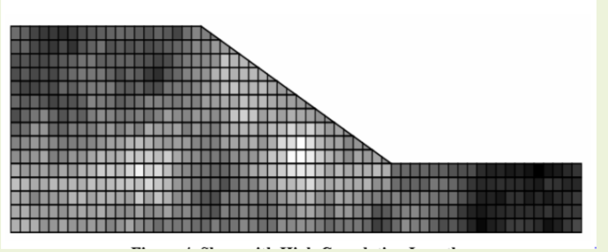






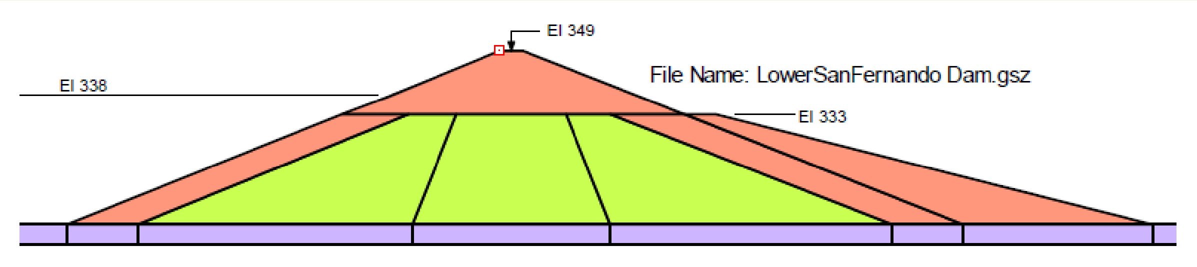


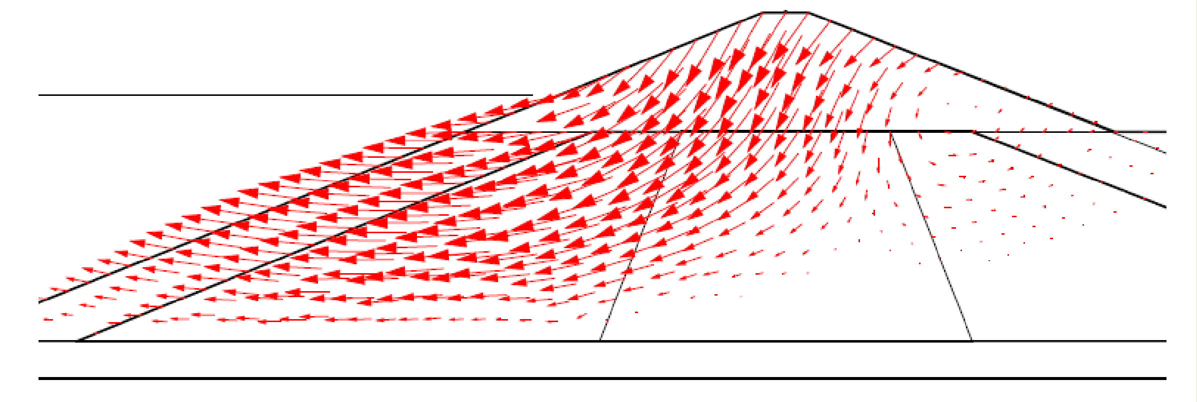


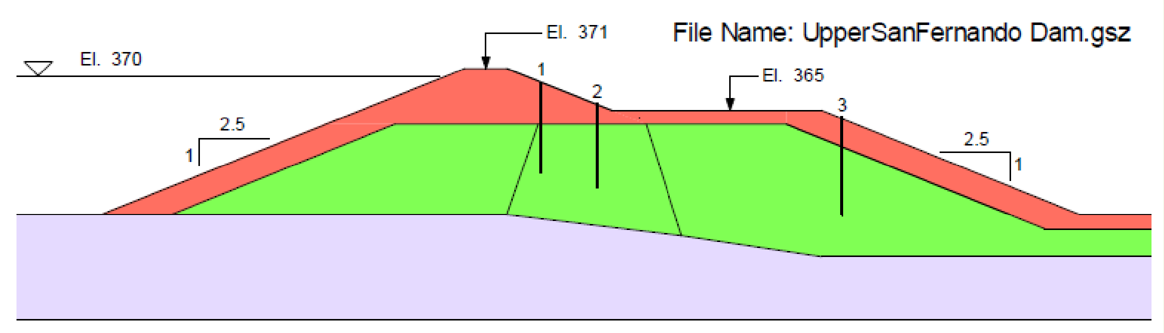


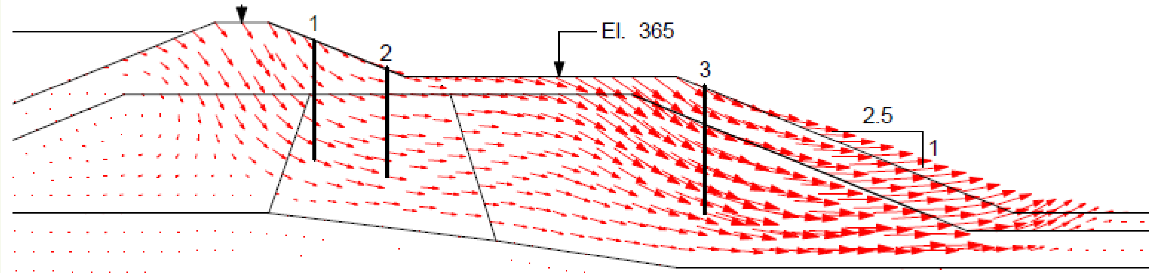
Geotechnical Engineering of Earthen Dams and Embankments

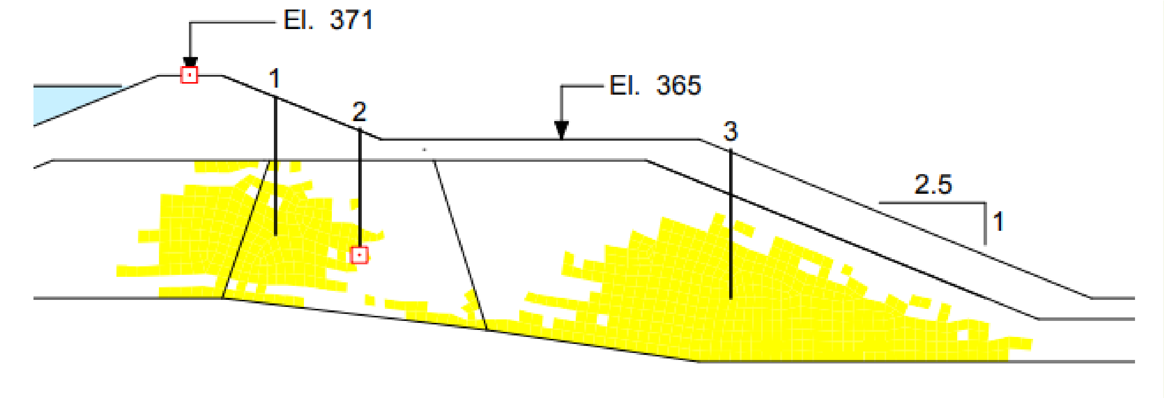
- Curious case of San Fernando Dam Failure due to 1971 San Fernando Earthquake





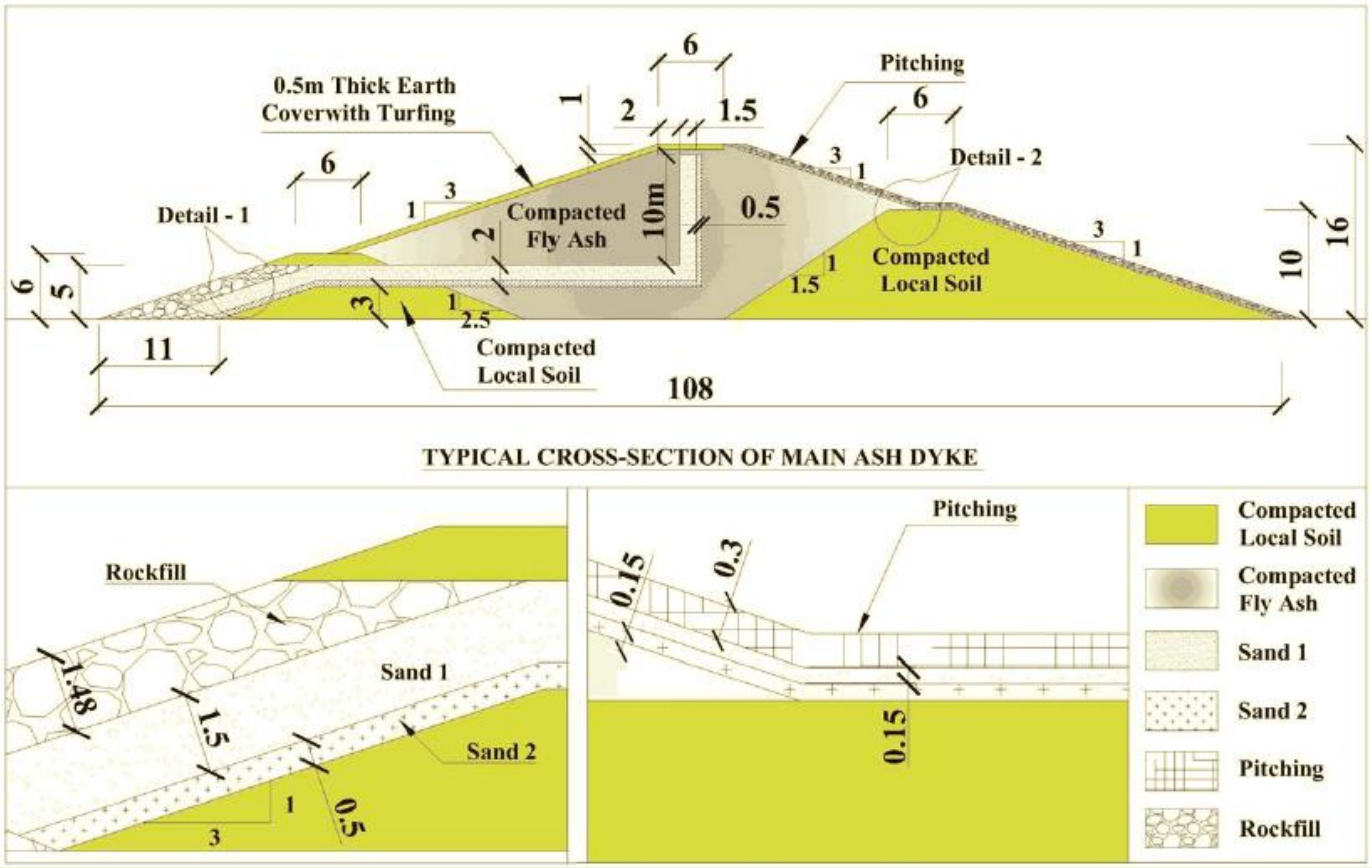




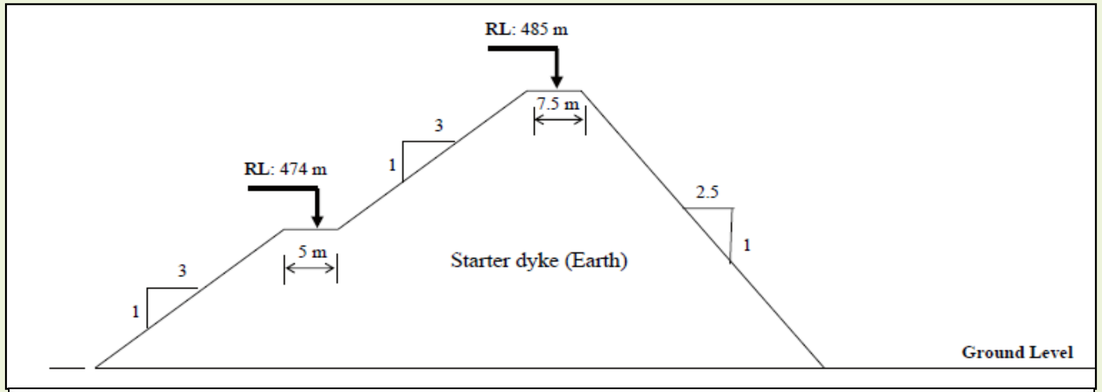


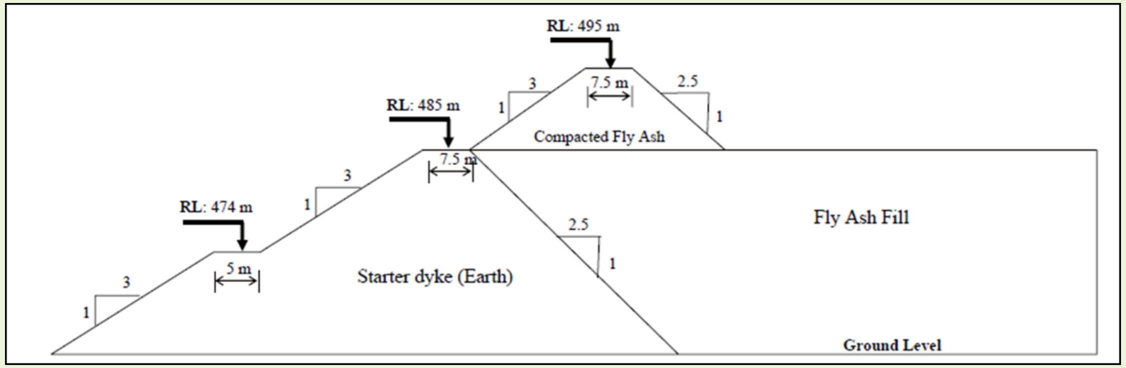
Proper drainage is absolute necessity

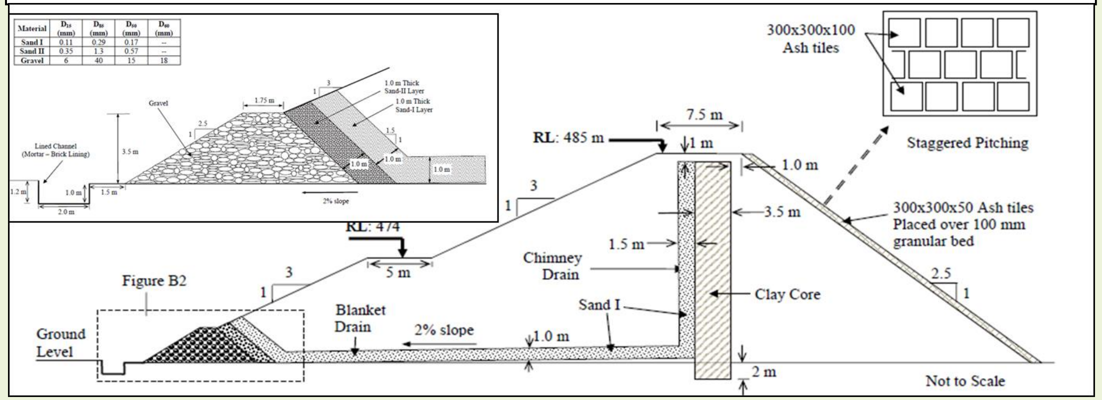
Stability of Ash Dyke, NTPC, Bongaigaon, Assam

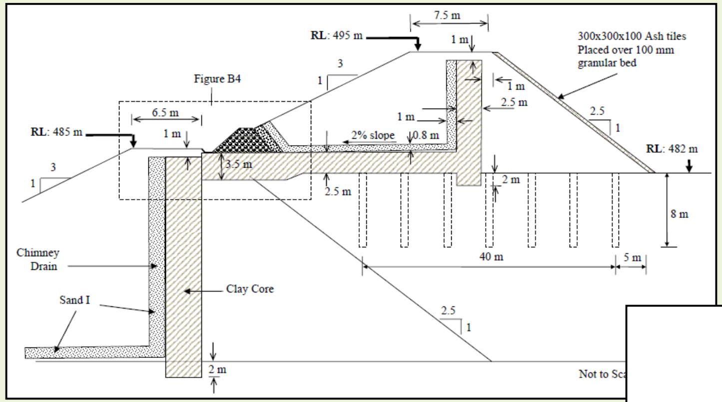


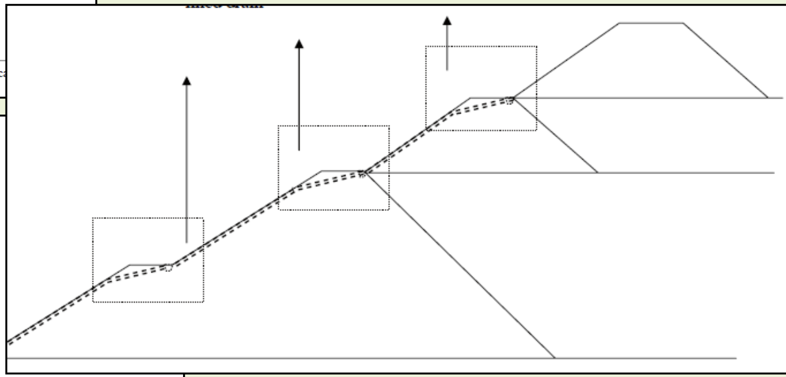
Ash Dyke, NTPC, Birsinghpur, MP

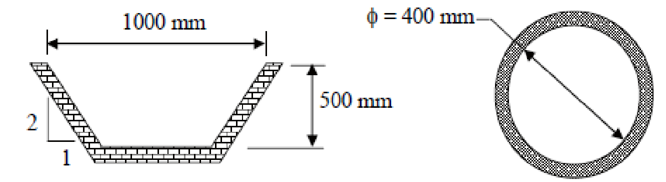








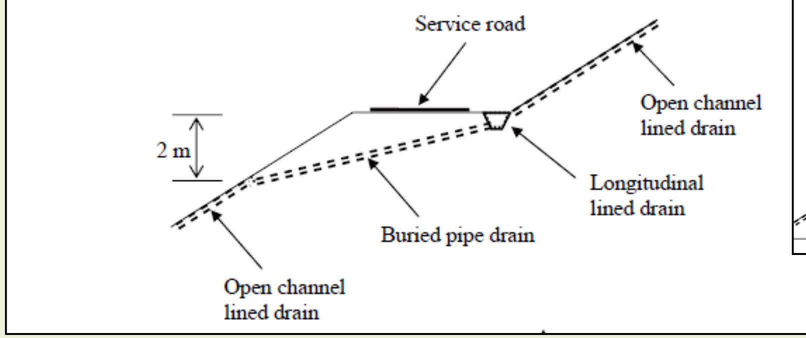




Section of open channel lined drain

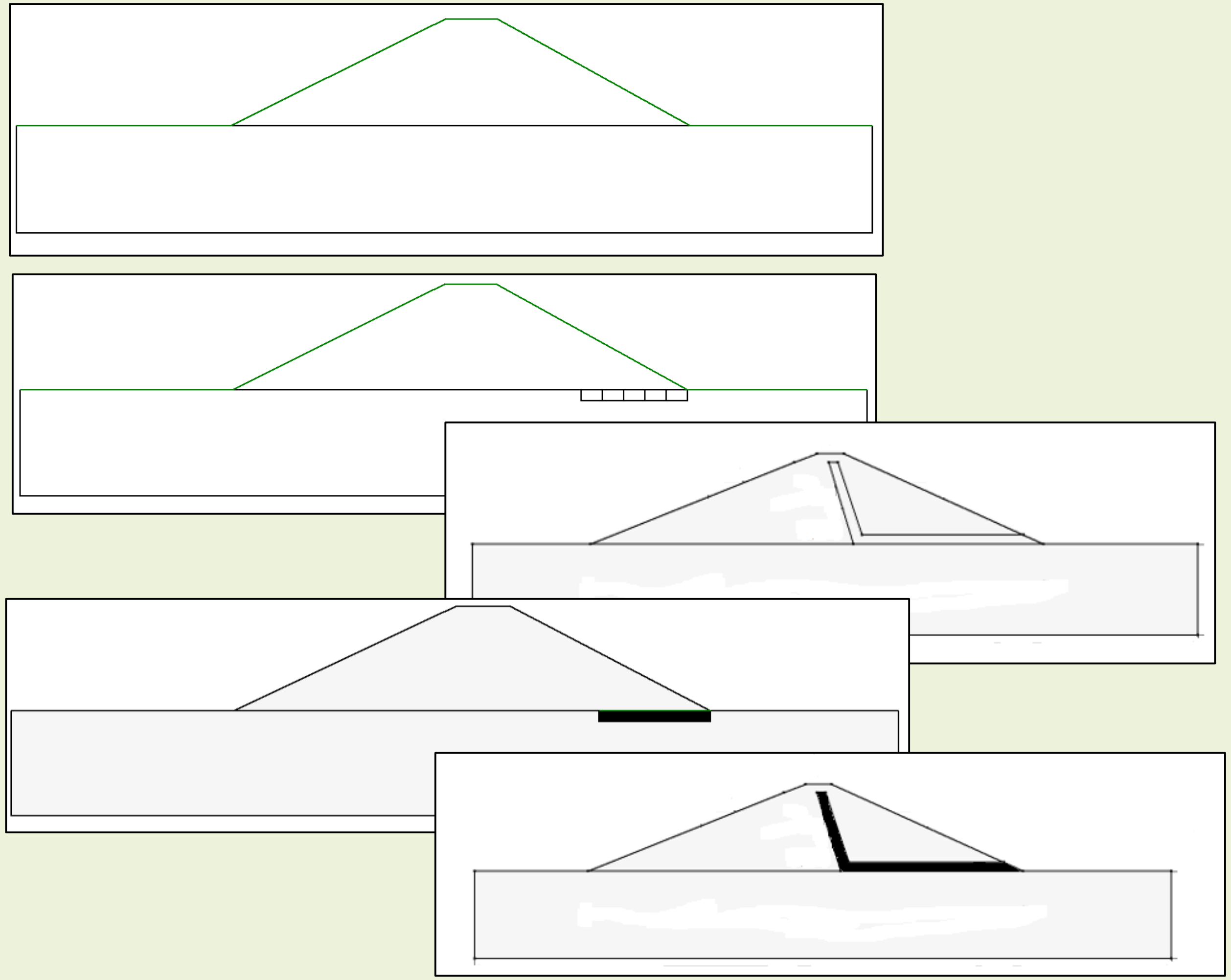
Section of buried pipe drain

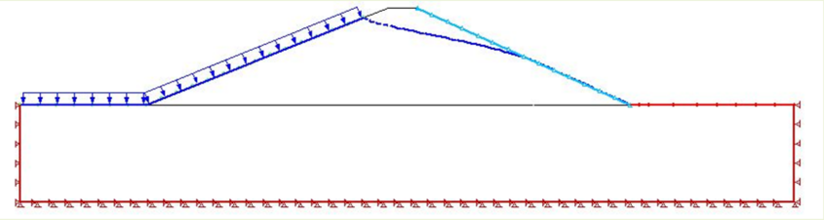
Service road



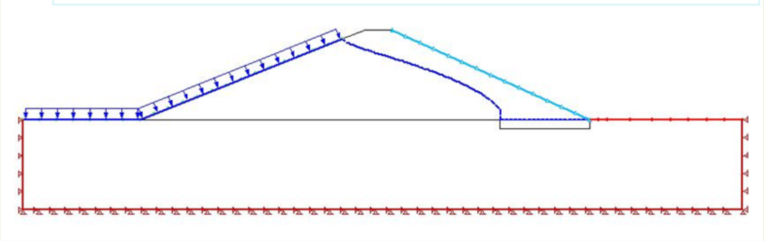
Clogging of Drainage Blanket of an Earthen Dam/Dyke

- Clogging of drainage blanket jeopardizes the geo-hydraulic stability of earthen dam

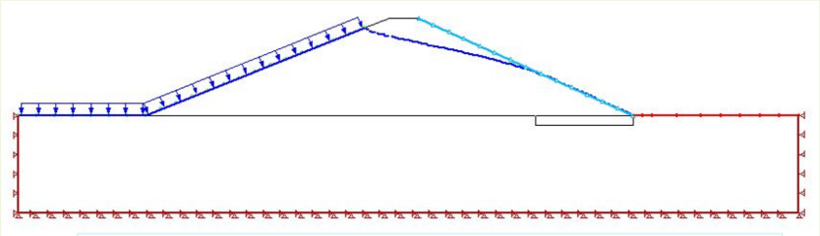




Without drainage blanket condition (NDC)



Fully functional drainage blanket condition (FDC)

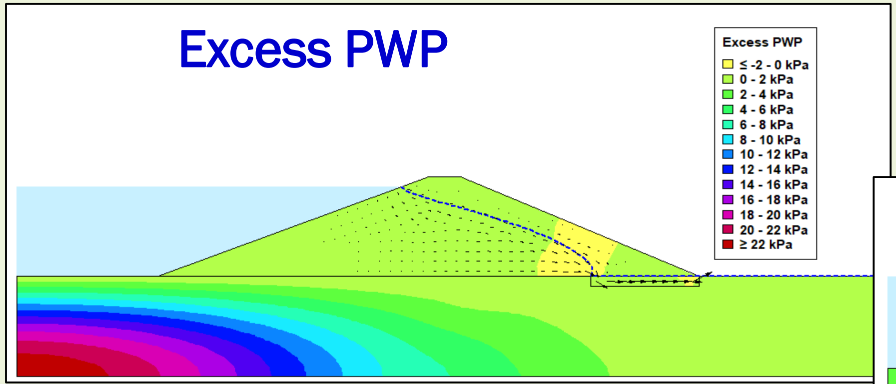


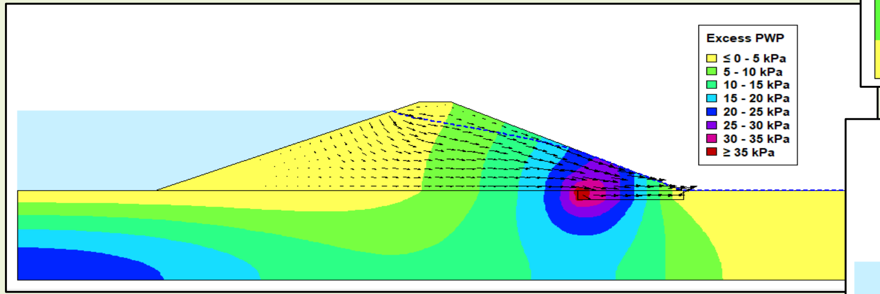
Clogged drainage blanket condition (CDC)

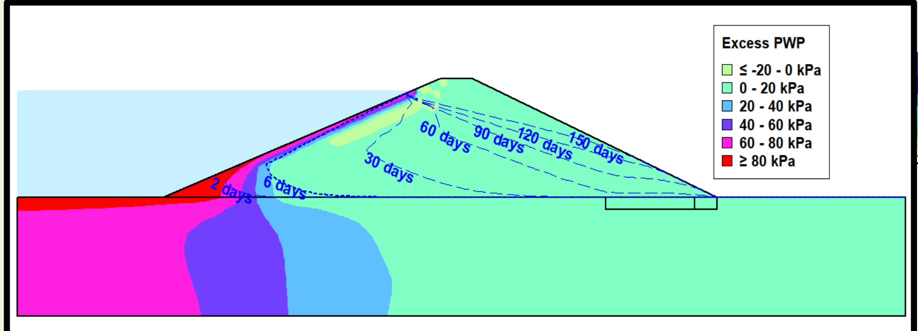
Priyanka

Clogging of Drainage Blanket of an Earthen Dam/Dyke

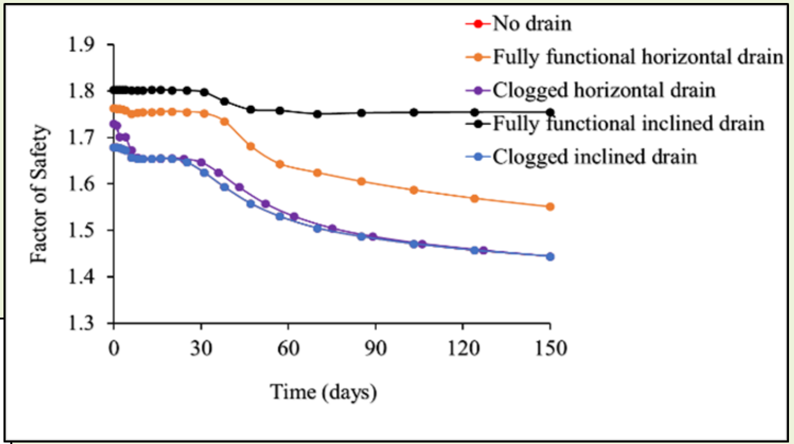
- Clogging of drainage blanket jeopardizes the geo-hydraulic stability of earthen dam

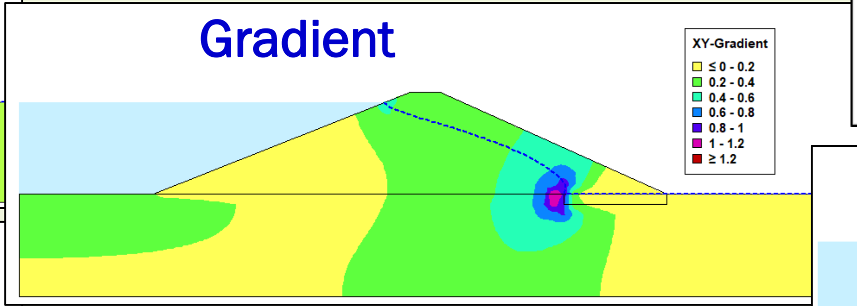


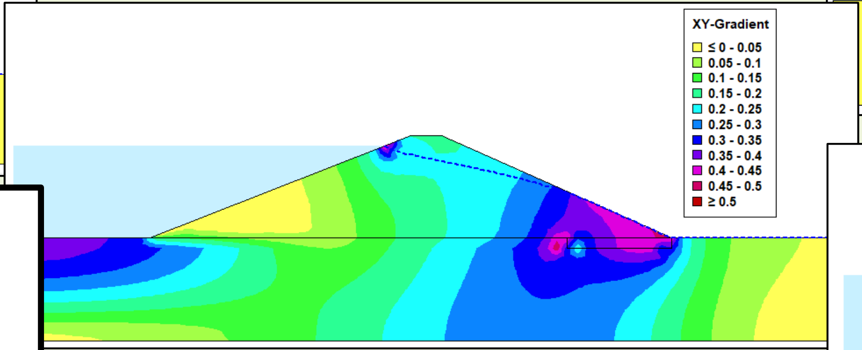


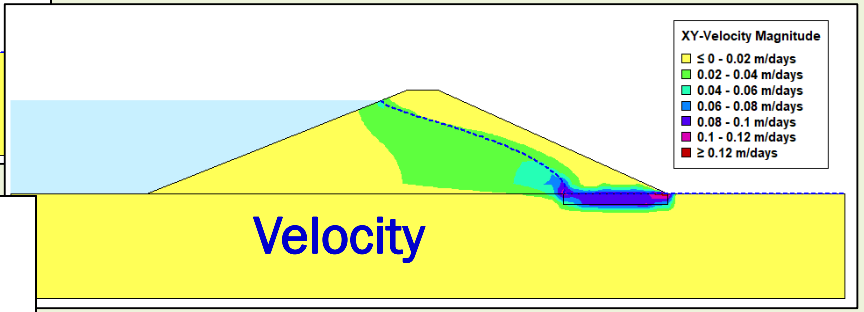


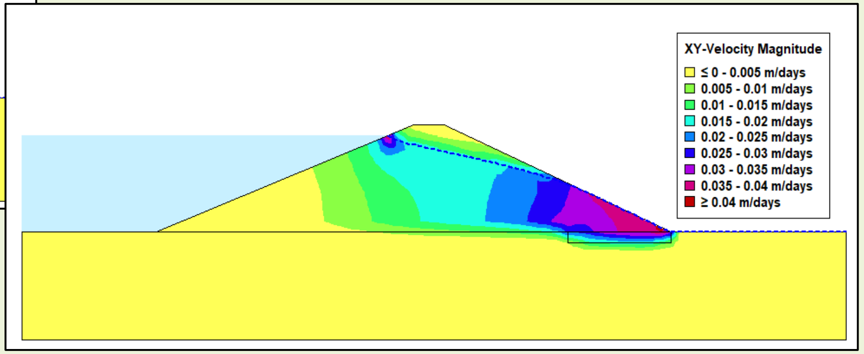
Long-term reduction of FoS of d/s face due to reservoir rise-up







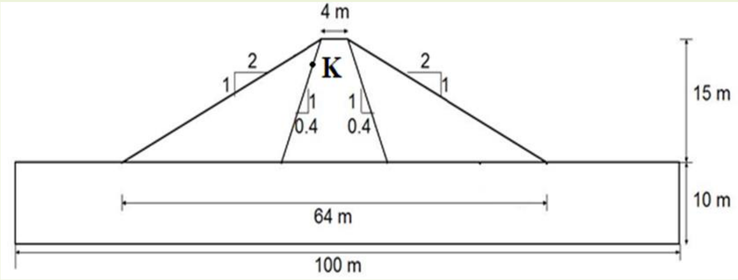


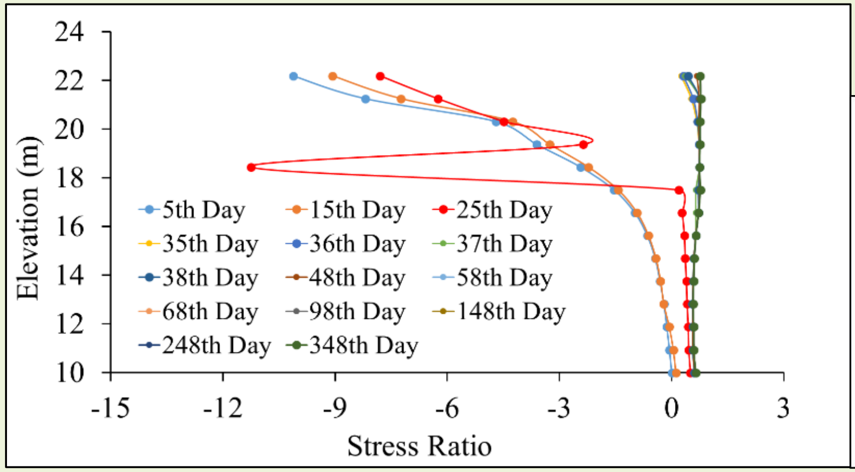


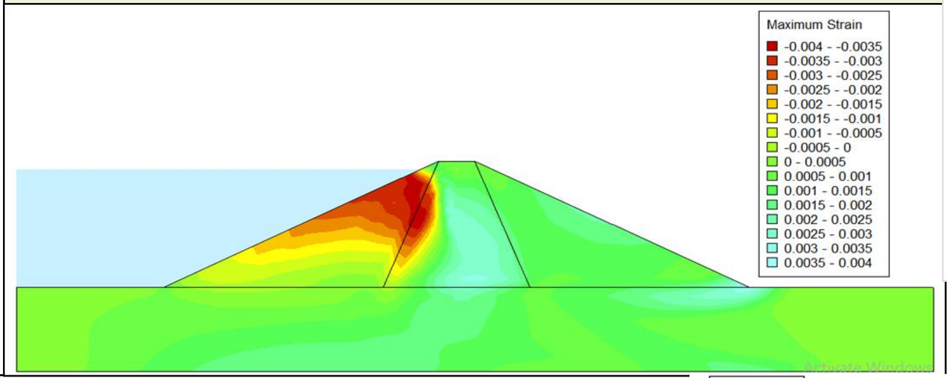
Long-term rise of phreatic surface

Core-Cracking of Zoned Earthen Dam

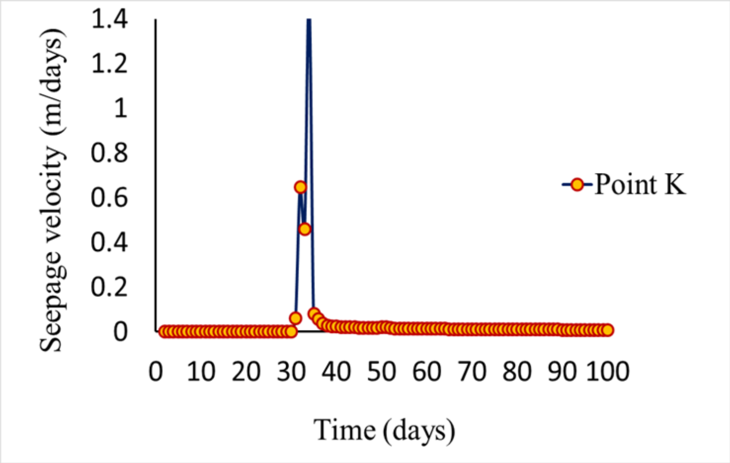
- Location of initiation of cracking
- Path of propagation of cracking

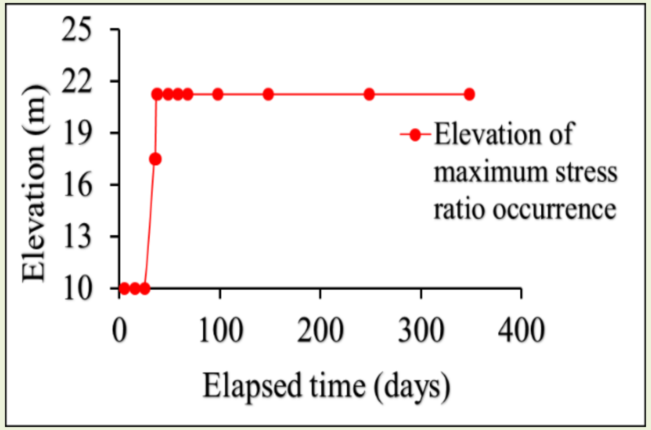


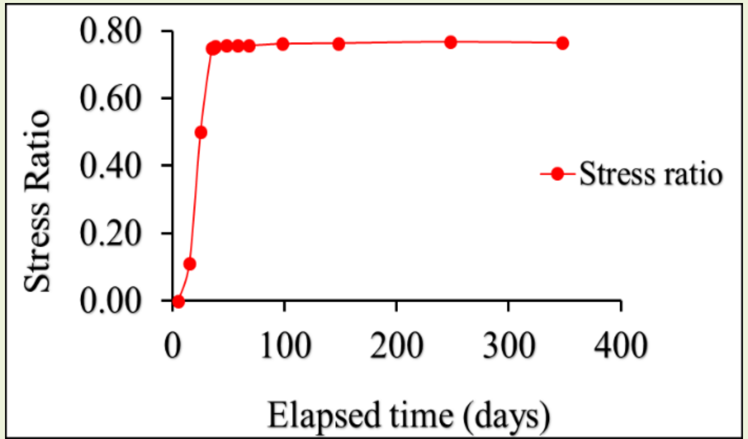


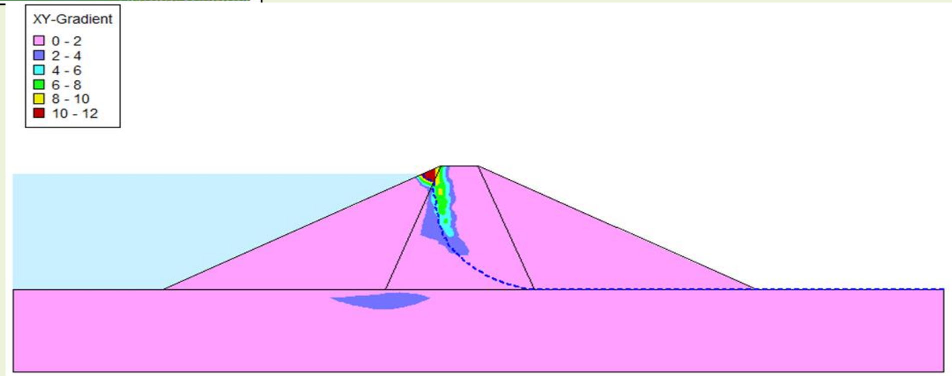


Strain contours on 38th day





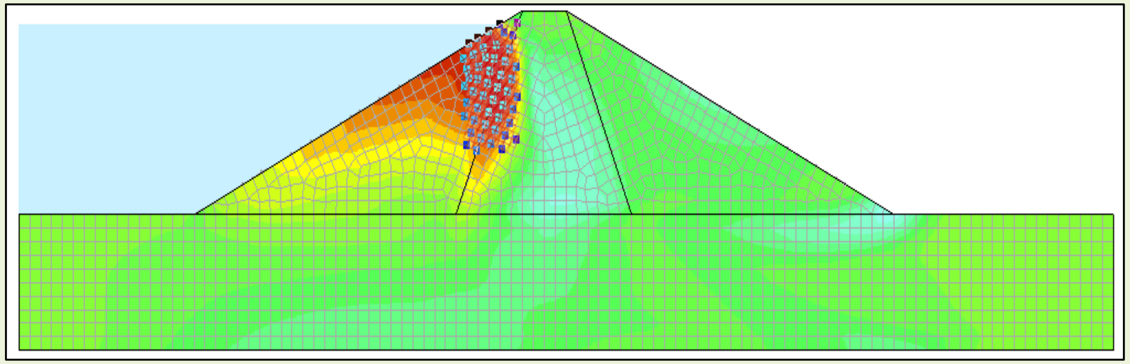


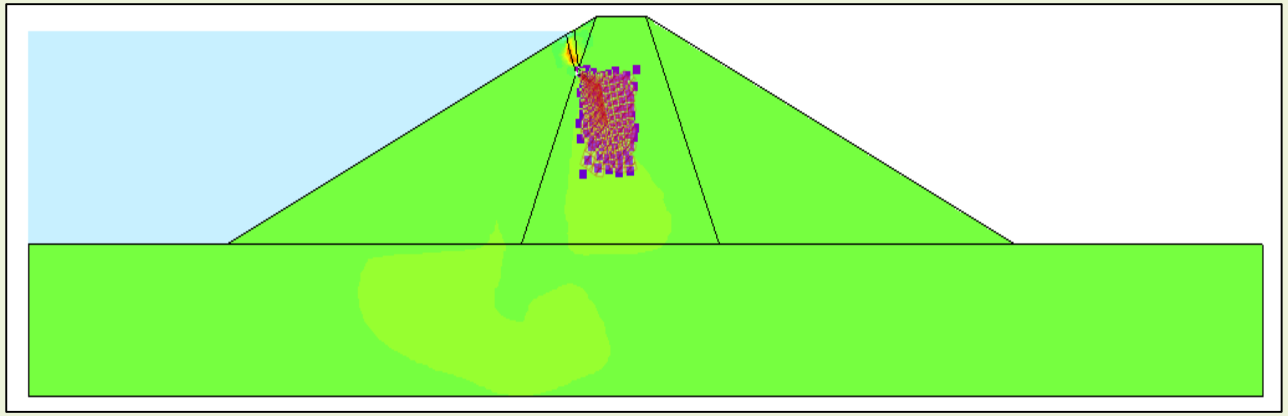


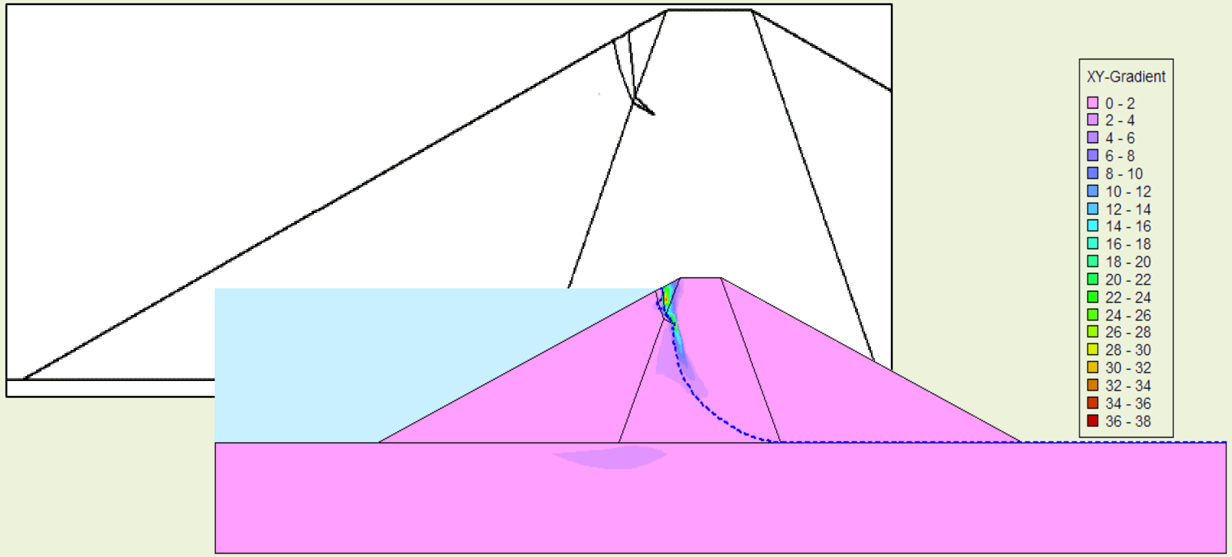
Hydraulic gradient contour on 38th day

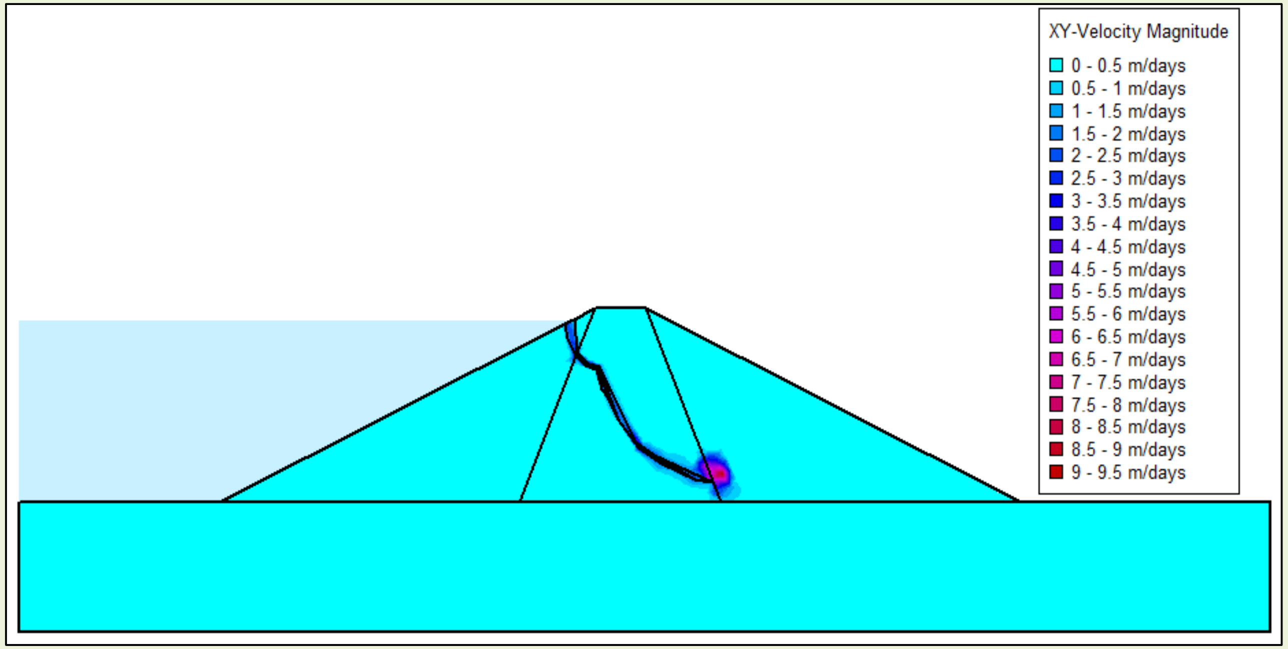
Core-Cracking of Zoned Earthen Dams

- Location of initiation of cracking
- Path of propagation of cracking







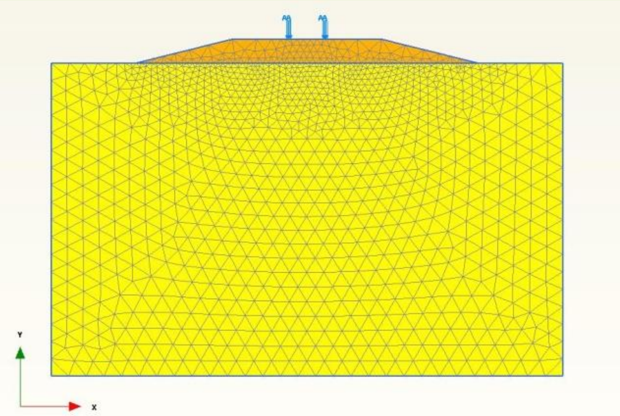


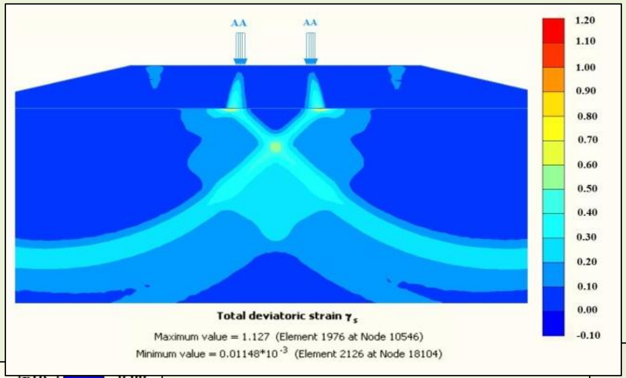
Unreinforced Unpaved Roads

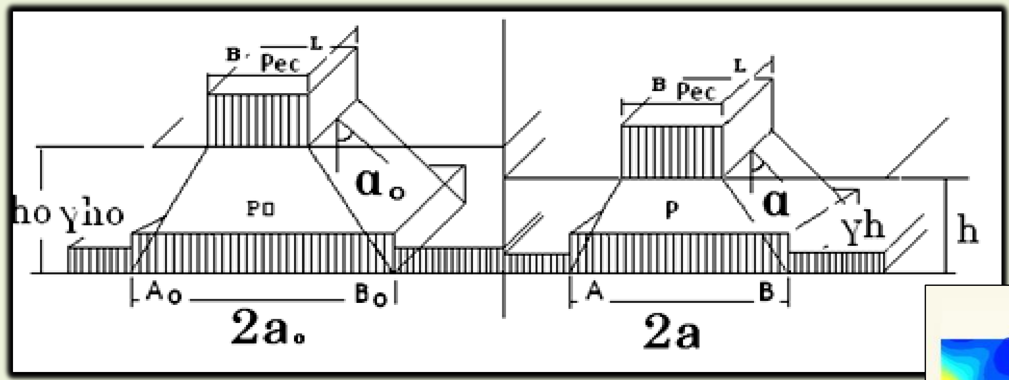
- Unreinforced unpaved roads
  - ❖ Unpaved roads resting on c-φ subgrade
  - ❖ Improvisation over Giroud and Noiray's technique
  - ❖ Finite element analysis using PLAXIS
  - ❖ Finite element based design of unpaved road
  - ❖ Percentage improvement using geosynthetics

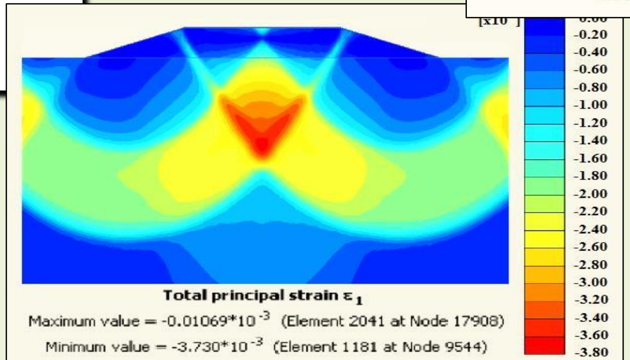
Lokesh

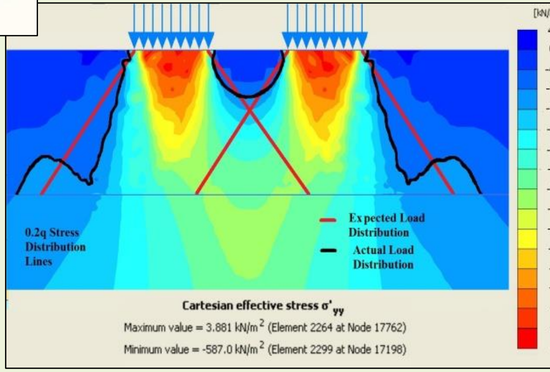
Shivraj







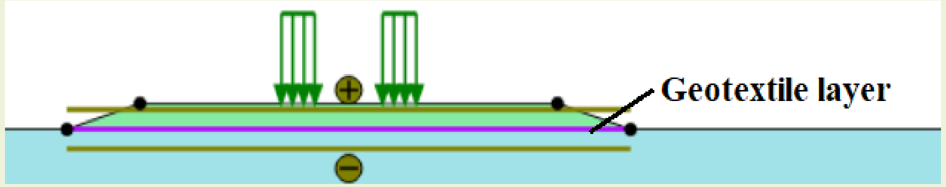


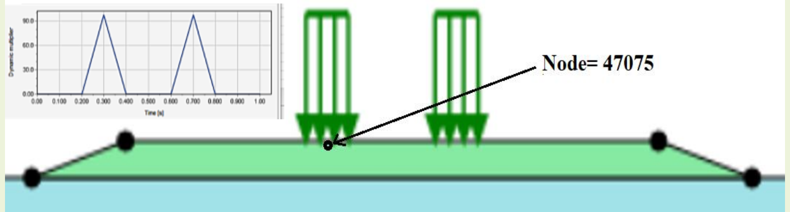


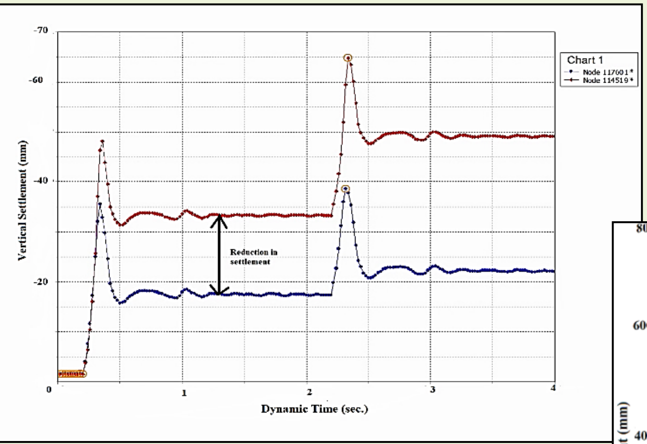
Geosynthetic Reinforced Unpaved Roads

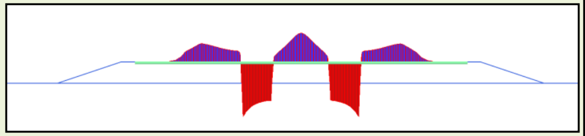
Nayan

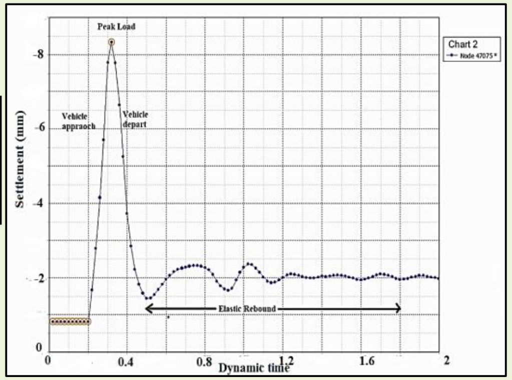
- Design of geosynthetic reinforced unpaved roads
  - ❖ Development of Finite Element based design algorithm
  - ❖ Influence of repetitive loading

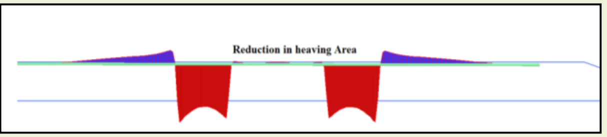


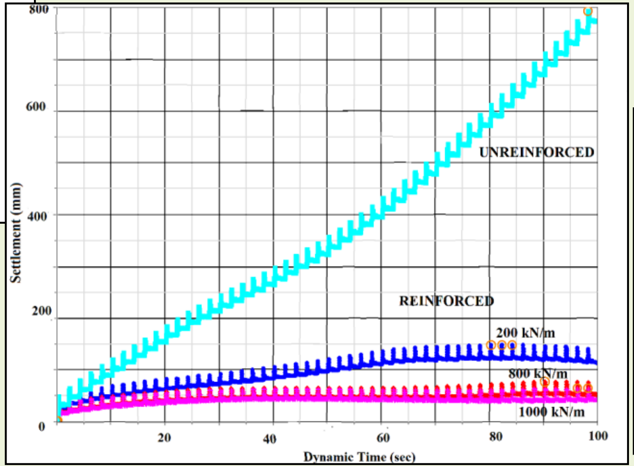


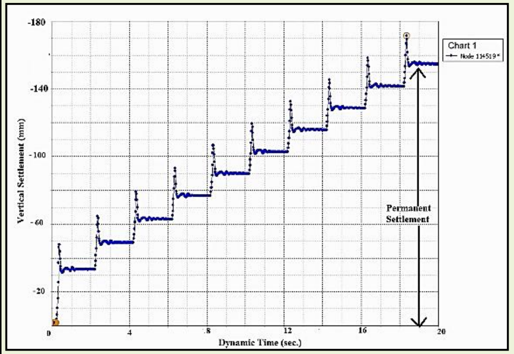


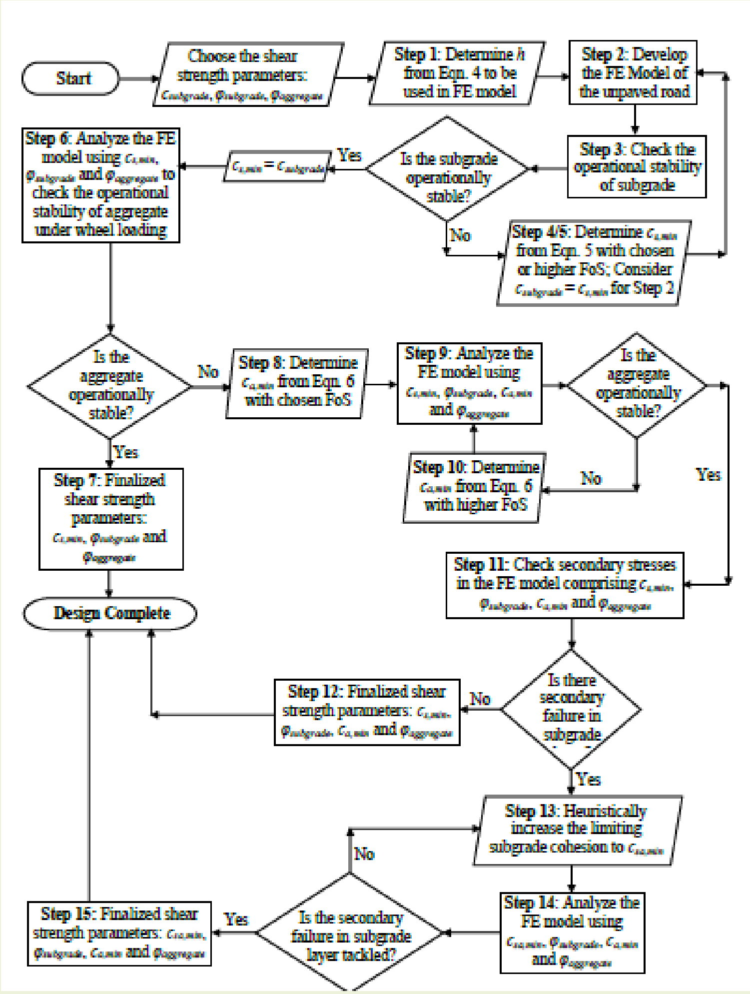










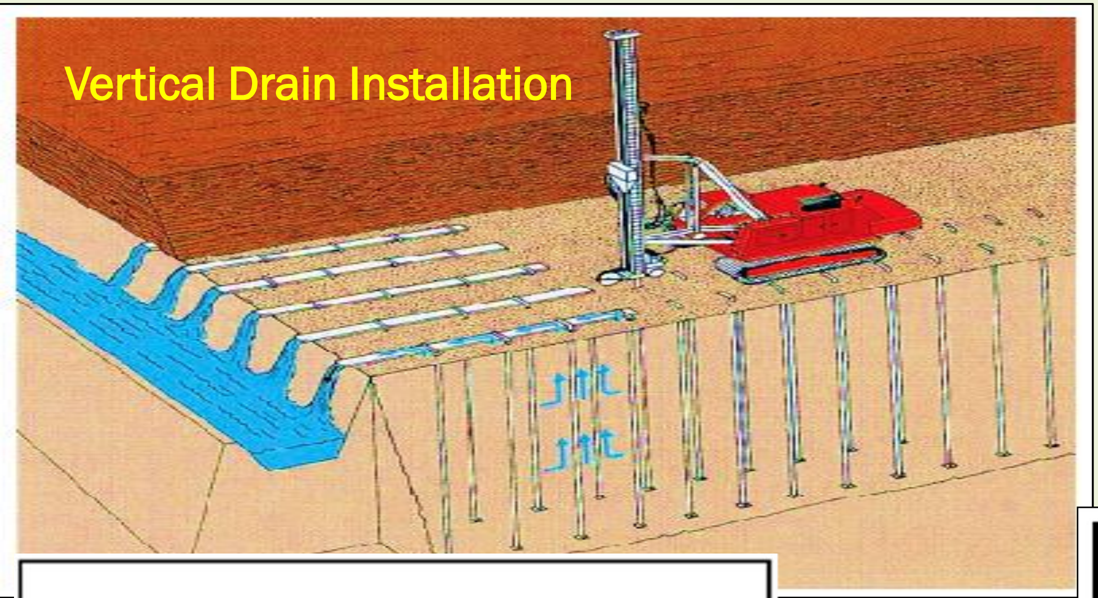


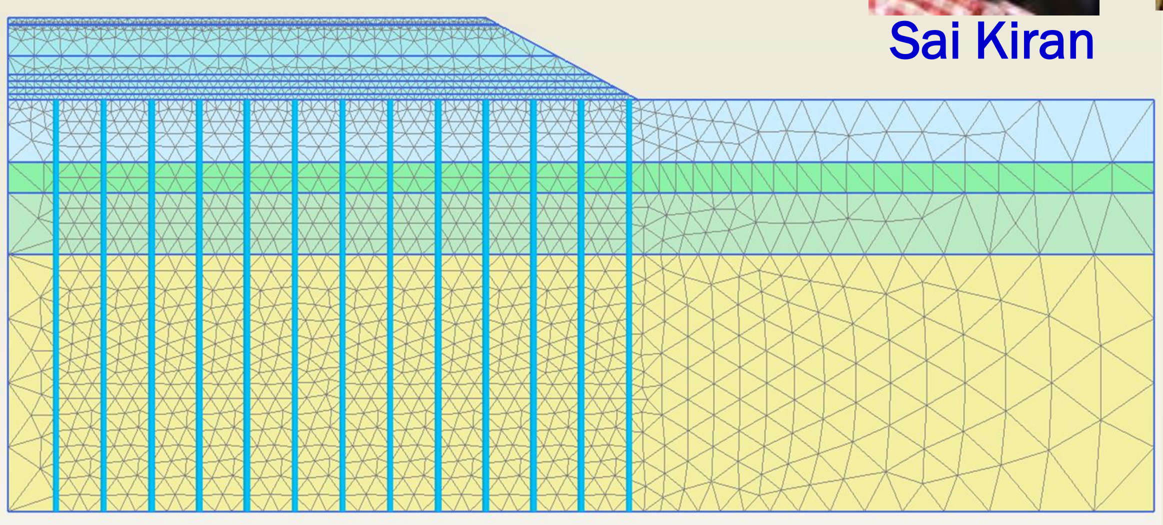
Soft Ground Improvement using Preloading with PVDs

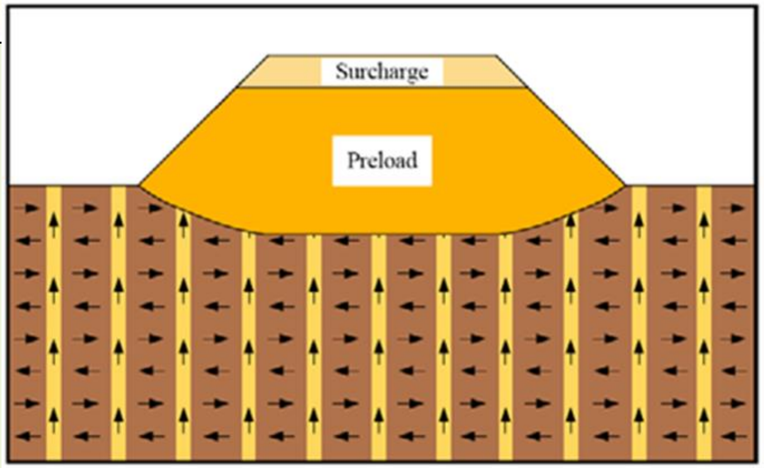
Sai Kiran

Rajesh

- Accelerated consolidation through radial drainage and excess PWP dissipation







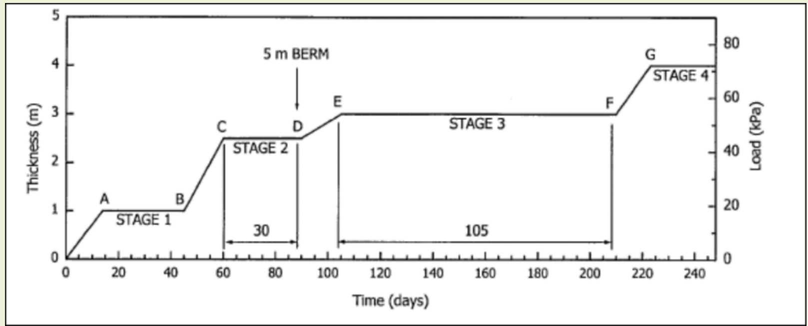
Filter Sleeve

Filter jacket to prevent entry of soil particles

Plastic Core

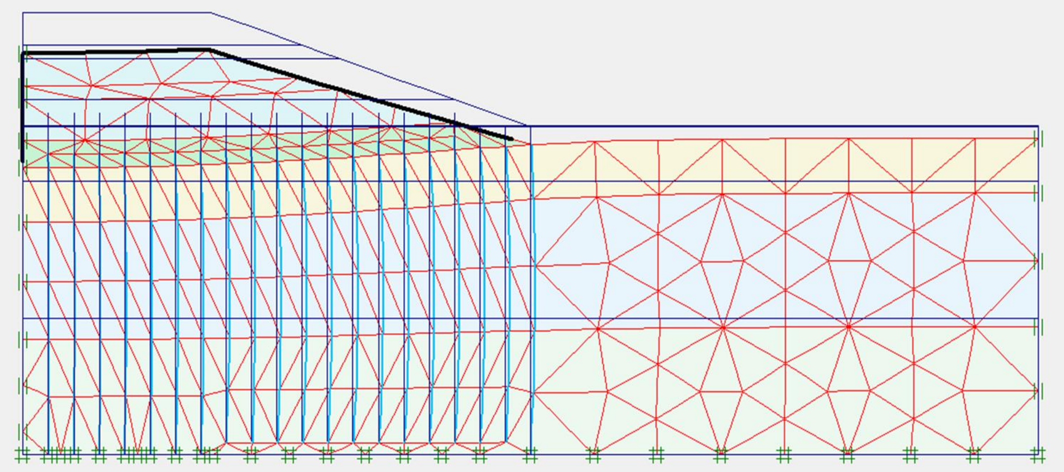
Central core for to allow water to flow

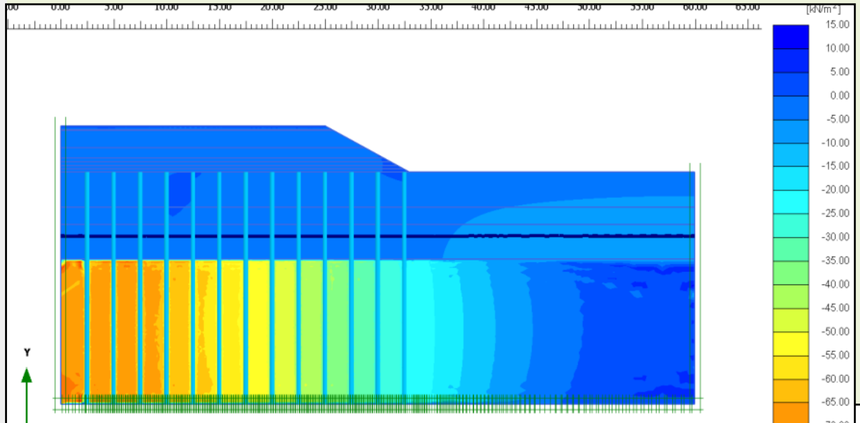
Typical PVD (Global Synthetics 2010)



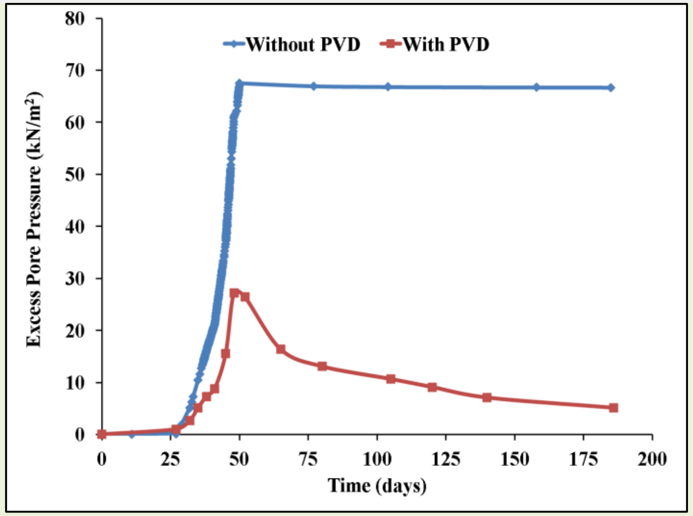
Soft Ground Improvement using Preloading with PVDs

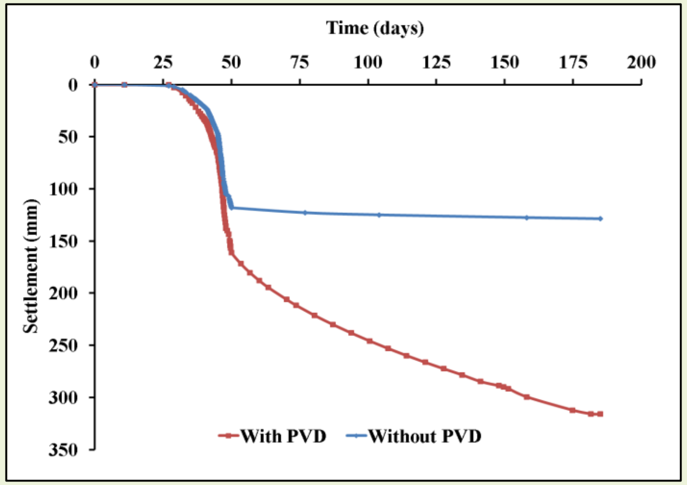
- Typical observations of ground improvement through PVD and Preloading

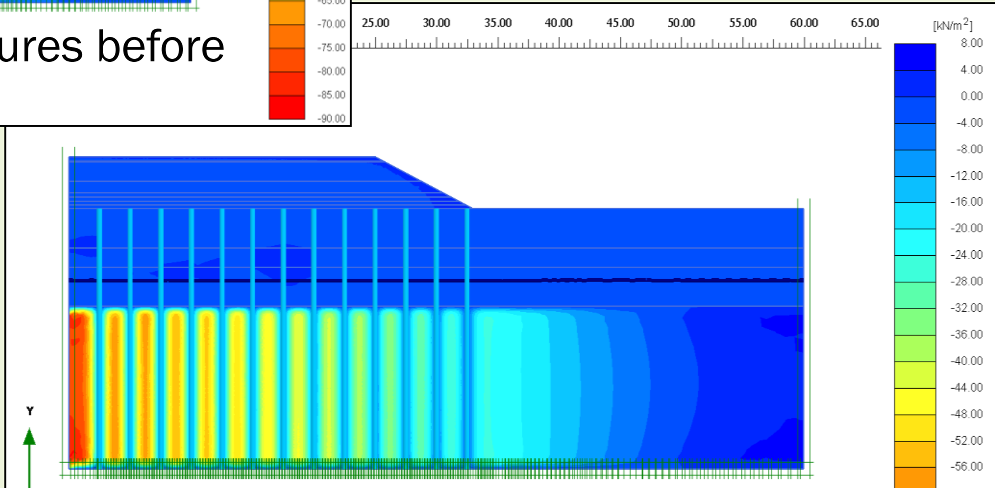




Excess Pore Pressures before consolidation







Excess Pore Pressures after consolidation

Heritage Railway Station, Udaipur, Agartala

- Application of preloading and PVD for developing of railway yard in a ditch marshland







Heritage Railway Station, Udaipur, Agartala

- Application of preloading and PVD for developing of railway yard in a ditch marshland

Other Ongoing Researches

- Research is a continuous effort to know the unknown
  - Seismic Response of Bridge Piers – Emte
  - Response of Single Pile Embedded in Inclined Stratigraphy – Debasmita
  - Soil Liquefaction and its Mitigation using Prefabricated Vertical Drains – Samrat
  - Reservoir Induced Seismicity – Anulekha
  - Hillslope stabilization using Geocells – Sureka
  - Risk Assessment of Earthen Dams and Embankments – Naveen
  - Engineering Behaviour of Varved Clays and Glaciolacustrine slopes – Deepali
  - Regional Scale Rainfall Induced Landslide Hazard Zonation – Manohara, Pooja
  - Seismic Microzonation – Aditya
  - Seismic Response Analysis of GRS and MSE Walls – Mihretab
  - Theoretical and Analytical Modeling of Complex Geotechnical Problems – Naina
  - Geosynthetics for Roadway Subgrades under Freezing-Thawing cycles - Chukhu

Thank You for Patient Hearing

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