# Science and Technology
# for Disaster Risk Reduction

**Dr. Sreevalsa Kolathayar**
Department of Civil Engineering
National Institute of Technology Karnatak

**Secretary, India Chapter, International Association for Coastal Reservoir Research (IACRR)**

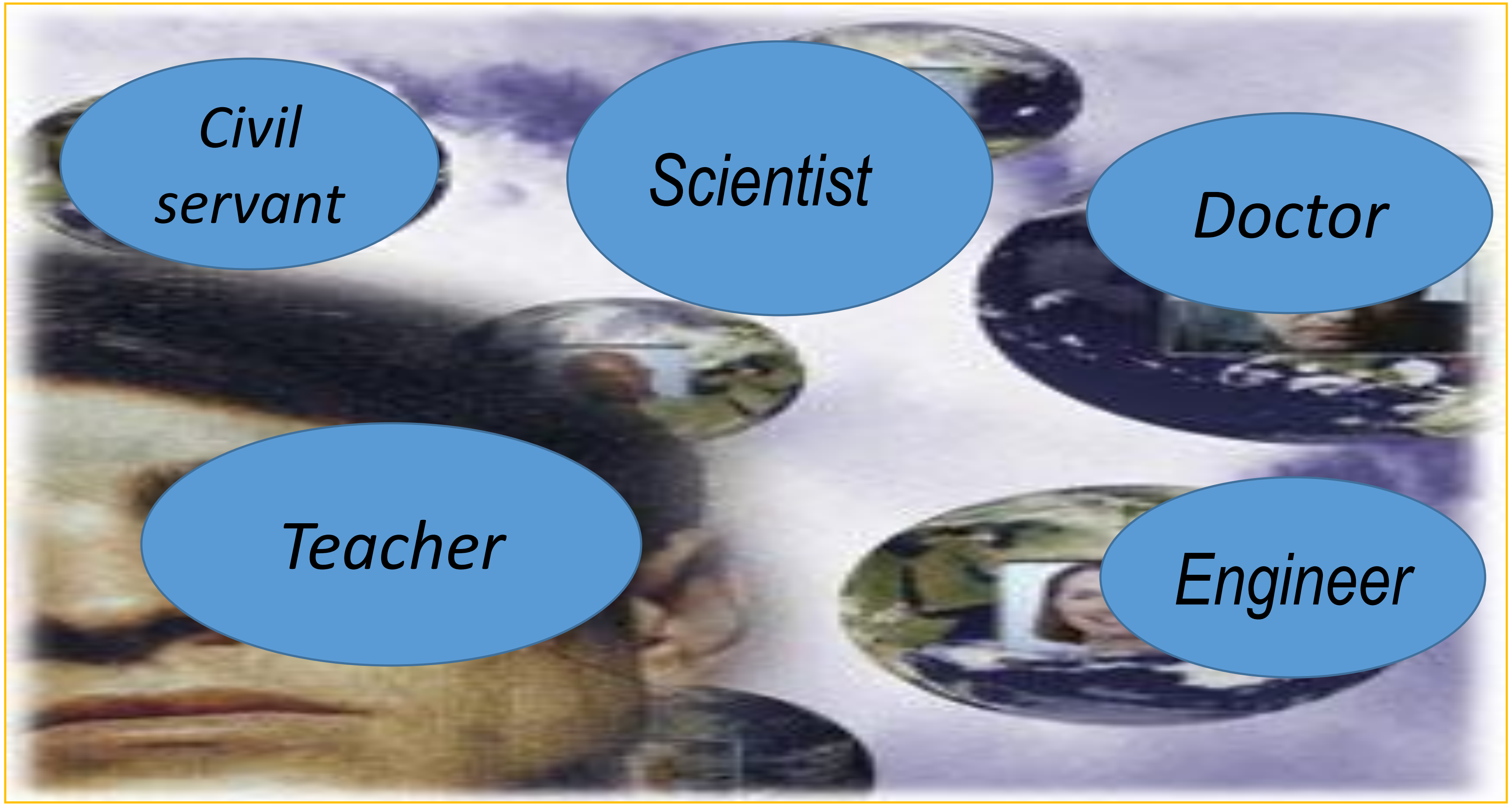
**Executive Committee Member, Indian Society of Earthquake Technology**

**TC Member, Earthquake Engg Committee, American Society of Civil Engineers (ASCE)**

# Why Career Guidance ?

- ***Today's Generation Students Never plan for their future.***
- ***Follow the crowd.***
- ***Choose by influence of others.***
- ***Accept the parent's verdict by force.***
- ***Get tempted by current trends.***
- ***Influenced by media.***
- ***Live in Fantasy World.***
- ***Lack Motivation.***

# What do you want to be



# What do we want

- *Security*
- *Money*
- *Happiness and Joy*
- *Satisfaction*
- *Respect in society*



# *What leads to lack of career success*

- ***Career not matching with one's interest***
- ***Career not matching with one's potential***
- ***Career not matching with one's personality***

# *Do you know what you want…?*

# Difference between Career and Job

- Job is something you do simply to earn money.
- Job has minimal impact on your future work life,
- Job offers few networking opportunities,

- Career provides experience and learning to fuel your future.
- Career requires one's interest and skills.
- Career is a series of connected employment opportunities.

# PUC -- SCIENCE

## Available Combinations

- PCMB (Physics, Chemistry , Mathematics, Biology)
- PCMC (Physics, Chemistry , Mathematics, Computer Science)
- PCME (Physics, Chemistry , Mathematics, Electronics)
- PCMG (Physics, Chemistry , Mathematics, Geology)
- PCBH (Physics, Chemistry , Biology, Home Science)
- PCBS (Physics, Chemistry , Biology.)

# *PHYSICS*

*Physics is the scientific study of matter and energy and how they interact with each other.*

# *Chemistry*

*Chemistry is the science of the composition, structure, proportions and reactions of matter, especially of atomic and molecular systems to the composition structure.*

# *Mathematics*

*Mathematics is the study of patterns of structure, change and space more in formally.*

# Biology

*Biology is the science of the life and of living organisms including their structure, function, growth, origin, evolution and distribution.*

# *Computer Science*

*Compute science is the field of computer hardware and software. It includes system analysis, design application and system software design.*

# *Electronics*

*Electronics is the study and use of electrical devices that operate by controlling the flow of electrons or the electrically charged particles in devise.*

# Geology

*Geology is the scientific study of the origin history and structure of a specific region of the earths crust.*

# *Home science*

*Home Science has been defined as a field of study built upon many disciplines for the purpose of achieving and maintaining the welfare and wellbeing of home and family life in an ever changing society.*

# Available combinations after PUC in Science

## CAREER IN MEDICINE

***MBBS :*** *BACHELOR OF MEDICINE & BACHELOR OF SURGERY.*

***BAMS :*** *BACHELORE OF AYURVEDA MEDICINE & SCIENCE.*

***BNYS :*** *BACHELOR OF NATUROPATHY.*

***BHMS :*** *BACHELOR OF HOMEOPATHY & MEDICINE & SCIENCE.*

***BDS :*** *BACHELOR OF DENTAL SCIENCE.*

# CAREER IN ENGINEERING

- ***Software engineer***
- ***Mechanical engineer***
- ***Electrical & Electronics***
- ***Civil engineer***
- ***Automobile engineer***
- ***Bio Technology***

# *Course after PUC*

- *BCA : Bachelor of Computer Application (3 years).*
- *BSc : Bachelor of Science(3 years).*
- *B.VSc : Bachelor of Veterinary Science (3 years).*
- *BSc in Forestry (3 years).*
- *BEM : Bachelor of Environmental Science (3 years).*
- *BSc in Physiotherapy.*
- *BSLH : Bachelor of Speech Language and Hearing (3 years).*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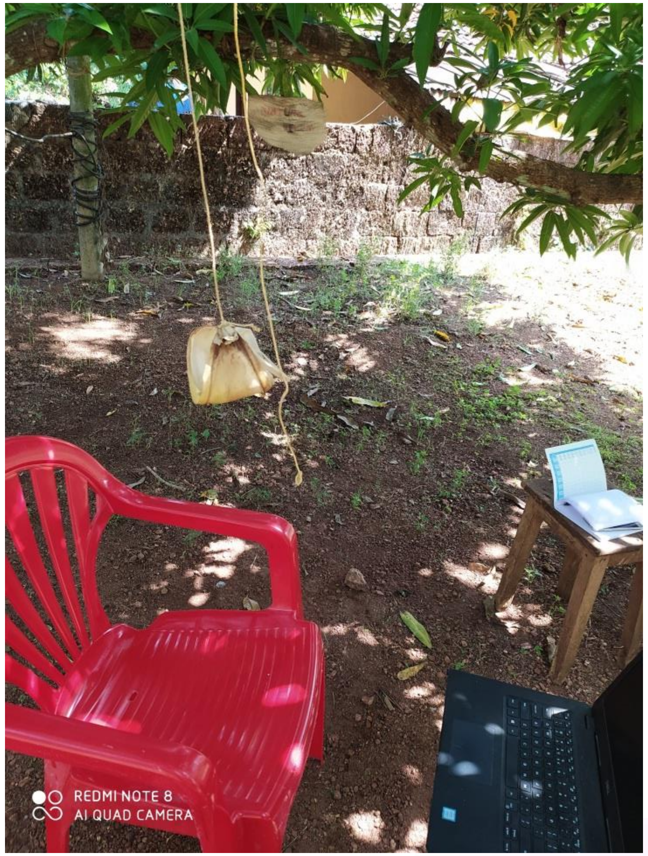
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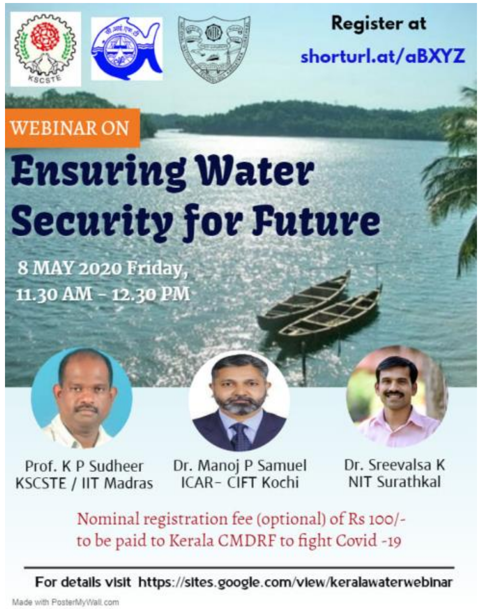



# Prof gets webinar 'wards' to chip in for Covid fund

Sruthy Susan Ullas
@timesgroup.com

**BRAIN WAVE:** Sreevalsa K said participants in his webinar in Coimbatore contributed about Rs 5,000 towards Covid relief

**Bengaluru:** A National Institute of Technology-Karnataka(NIT-K) professor has hit on a unique way of contributing to the country's Covid fight. If one wants to join the webinars he hosts, many of which arepopular, one needs to donate a small amount to the PM's or chief minister's relief funds.

Sreevalsa K, 35, an alumnus of IIT Kanpur and Indian Institute of Science, is an assistant professor in the department of civil engineering, NIT-K. A geo-technical engineer, Sreevalsa's interests lie inearthquake hazards and water conservation.


"The first webinar was conducted by a college in Coimbatore for its students and faculty members. As the poster of the programme became popular,many people asked whether they could join it. However, it was a closed programme. That's when I decided to host webinars on similar subjects that have aroused so much interest. To ensure participants have genuine interest and would sit throughout the class, I decided to keep a small registration fee.But, instead of taking the money, I thought it would be a good idea to redirect it to Covid funds," said Sreevalsa.

The amount could be as small as Rs 50. The participants can upload the receipt online while registering.

"The first webinar, which had 80 participants, would have raised around Rs 5,000. I intend to host a webinar every week," he said.

Webinars are conducted in collaboration with the government or societies like Indian Society of Earthquake Technology, Kerala State Council for Science and Technology or with academic institute like NIT-K. Theparticipants include students, faculty and members from industry across thecountry. There was also a registration from Nepal.

Sreevalsa is now in his hometown, a village in Kasaragod. He conducts regular online classes for NIT-K students and the webinars. His water conservation class is about a 500-year-old water reservoir in his native place,Klayikode village.

"There's no network in the house. I've to either go to thefield or the pond to conduct classes," he said.

Now, an executive committee member of the Indian Society of Earthquake Technology, he's also a member of technical committee on earthquakes and soil dynamics, American Society of Civil Engineers.


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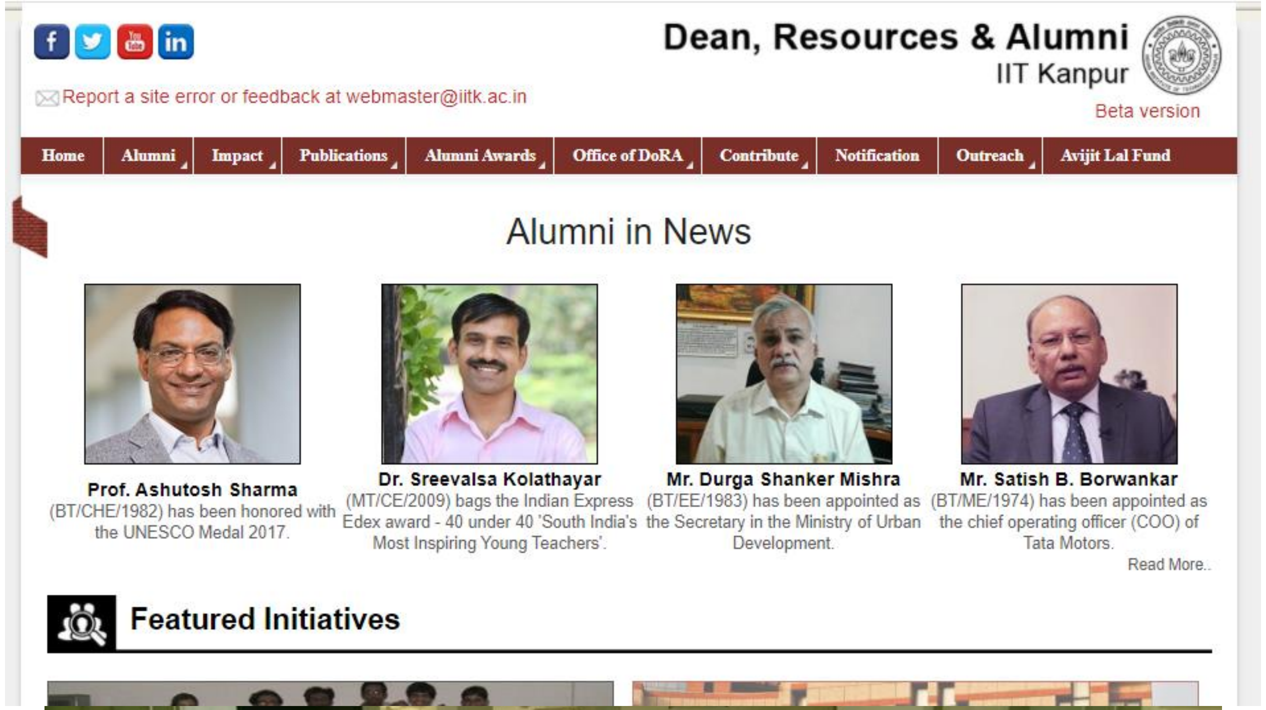
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Alumni in News
Prof. Ashutosh Sharma
(BT/CHE/1982) has been honored with the UNESCO Medal 2017.
Dr. Sreevalsa Kolathayar
(MT/CE/2009) bags the Indian Express Edex award - 40 under 40 'South India's Most Inspiring Young Teachers'.
Mr. Durga Shanker Mishra
(BT/EE/1983) has been appointed as the Secretary in the Ministry of Urban Development.
Mr. Satish B. Borwankar
(BT/ME/1974) has been appointed as the chief operating officer (COO) of Tata Motors.
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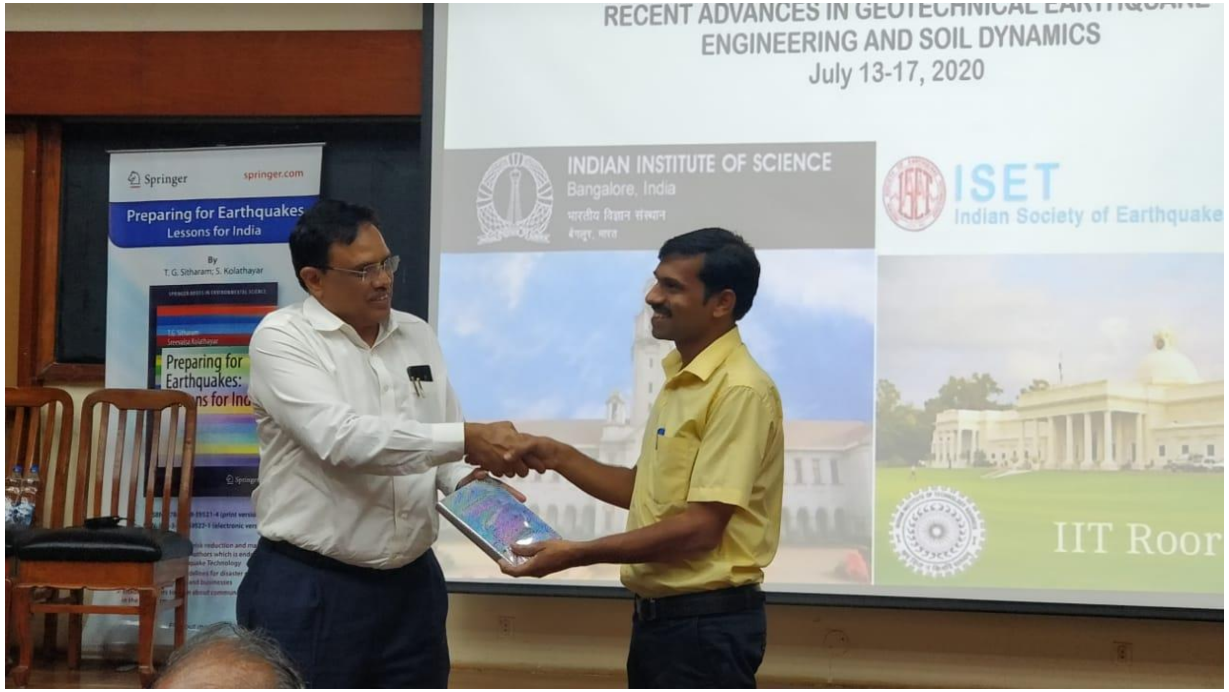
Featured Initiatives





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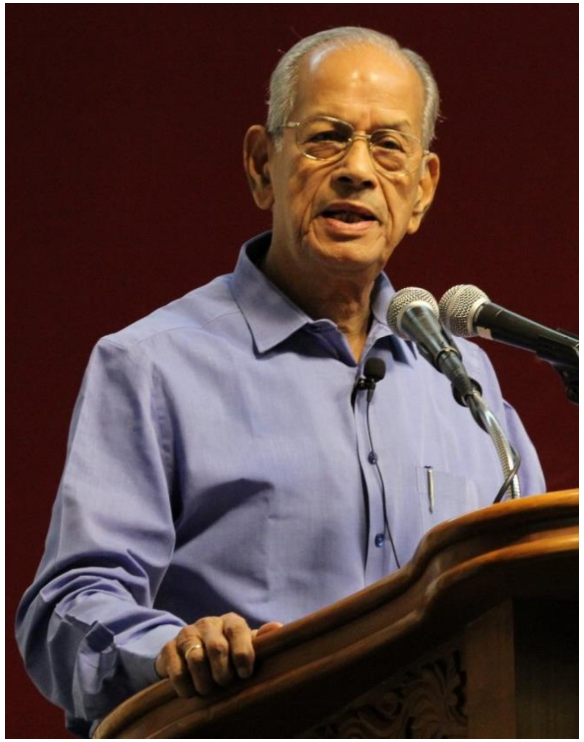

AMRITA VISHWA


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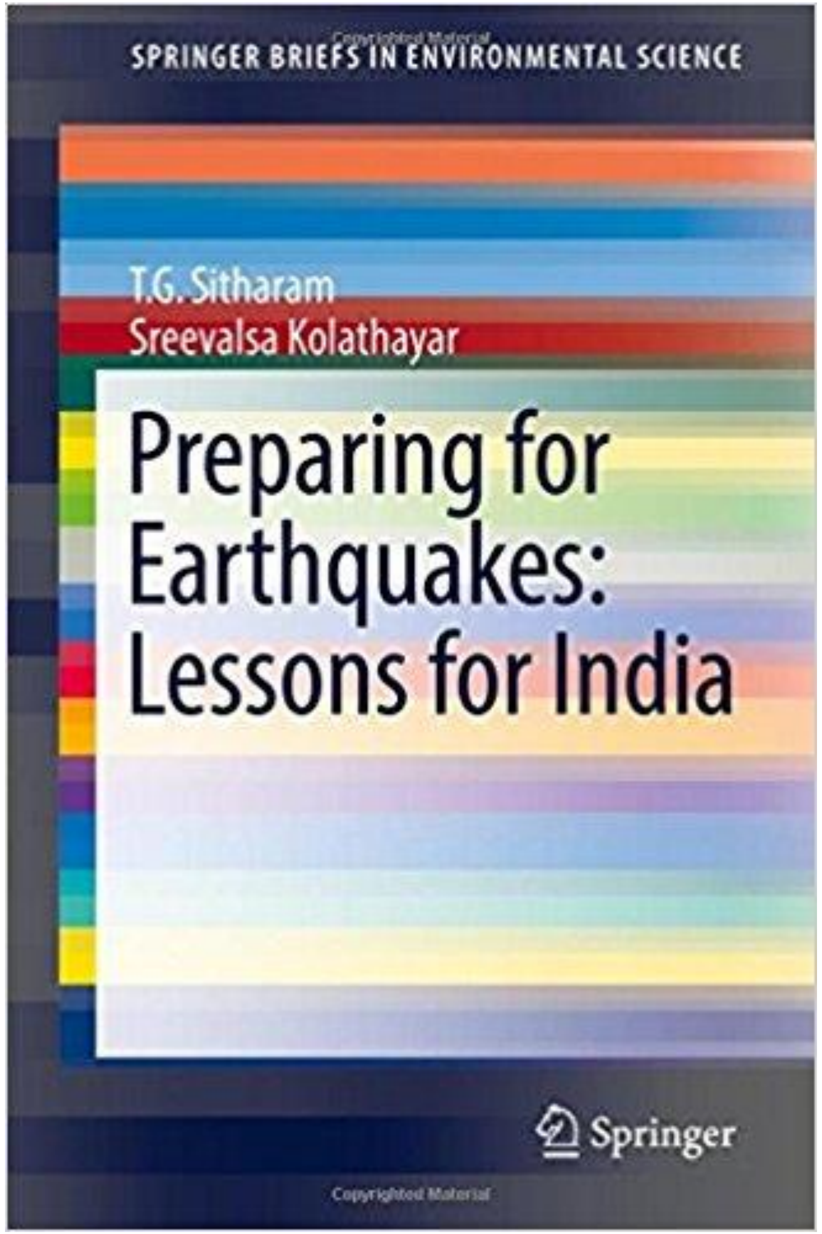
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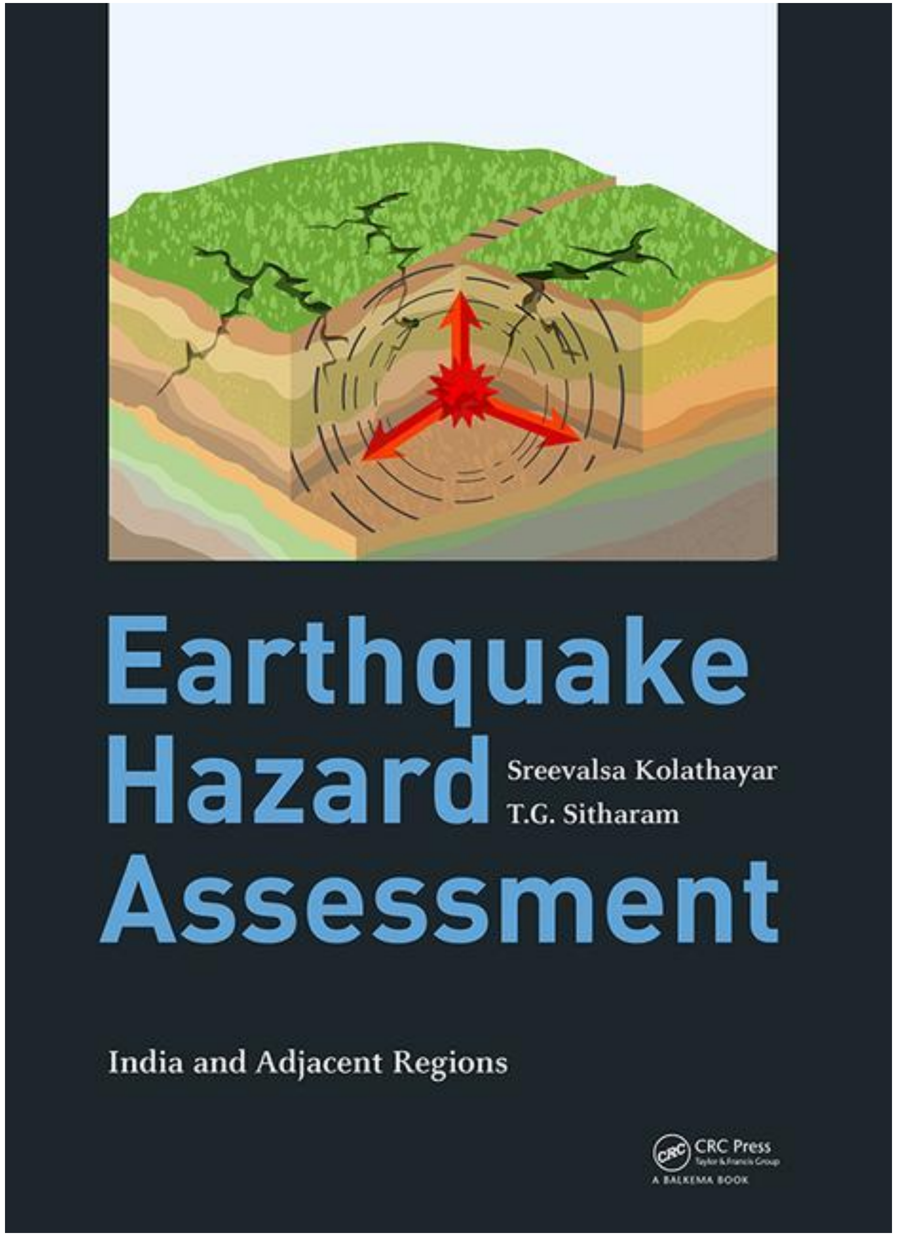
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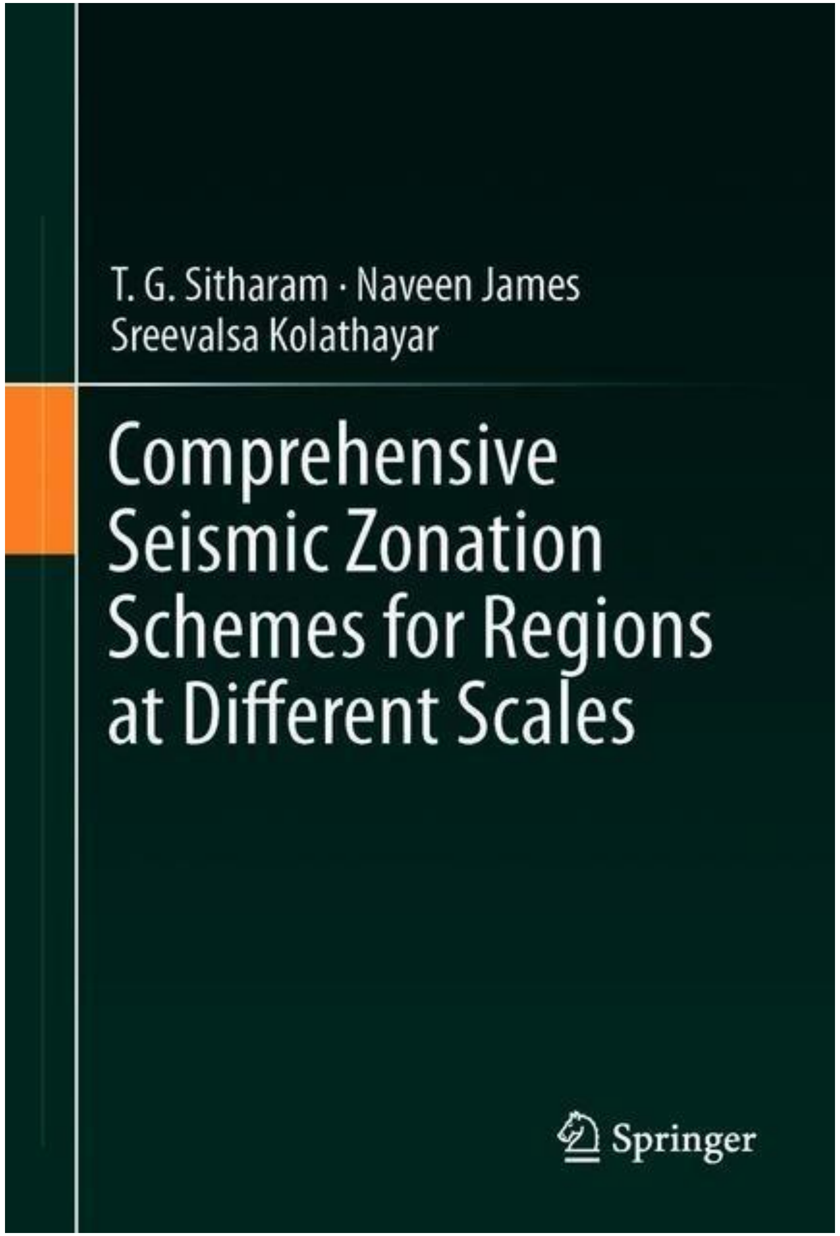
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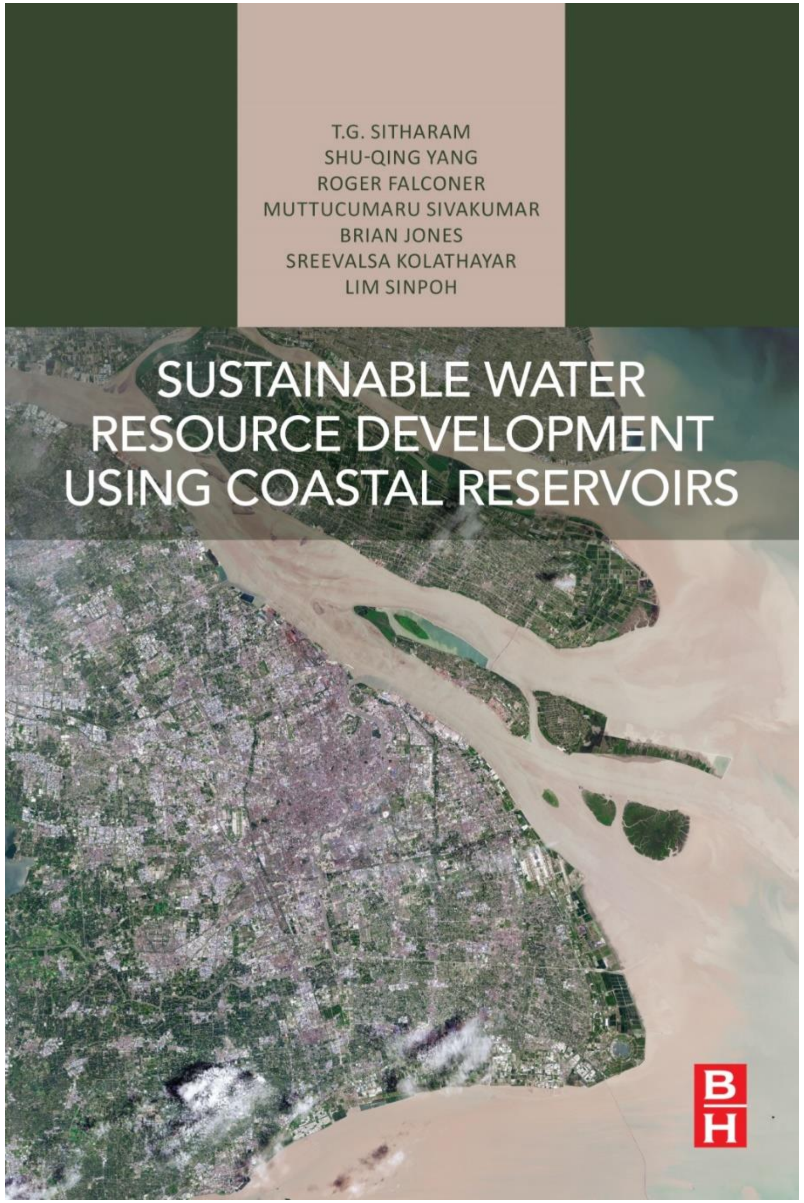
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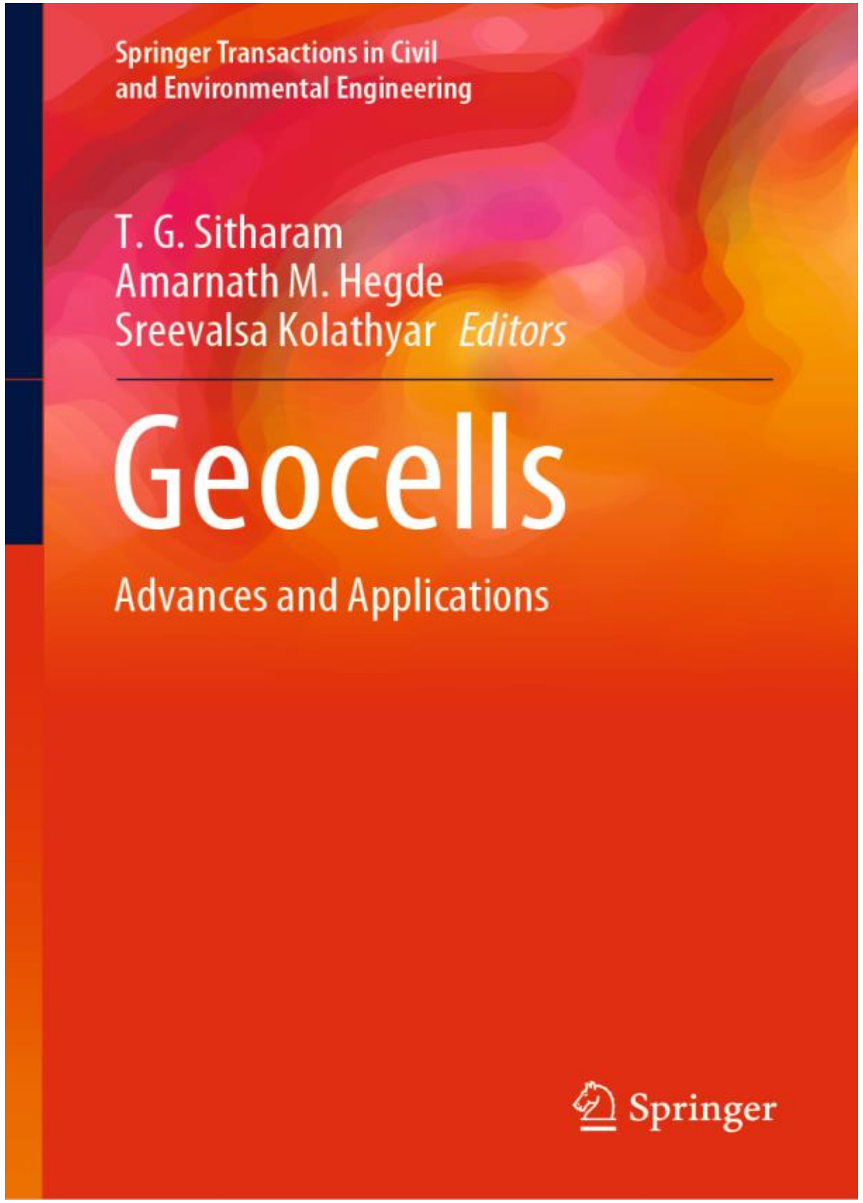
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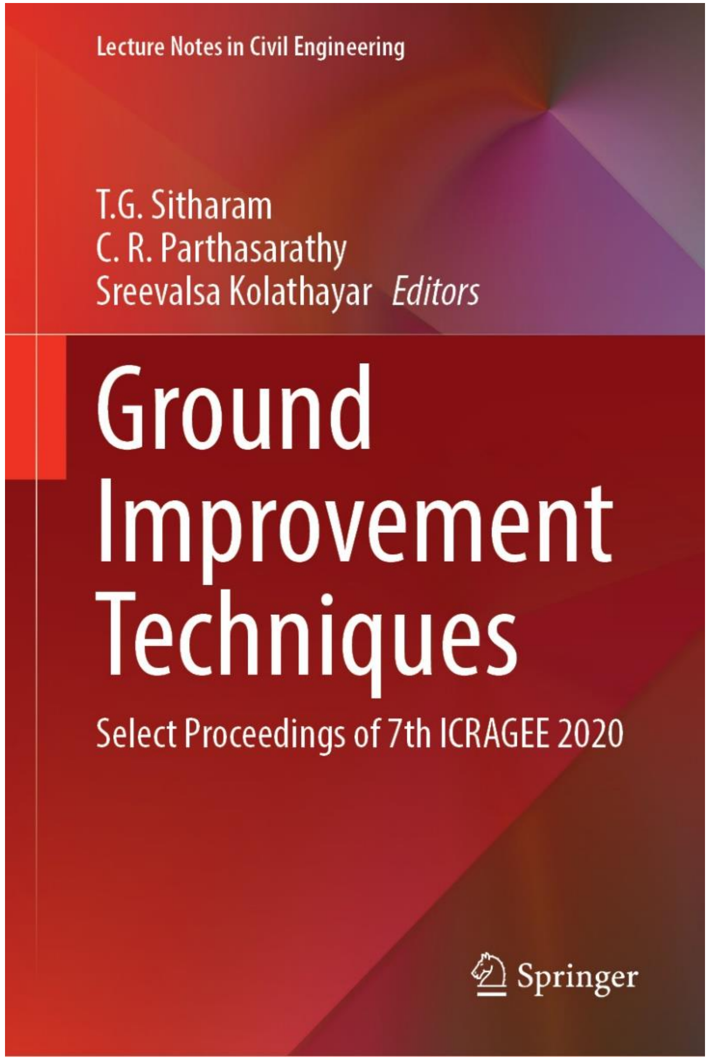
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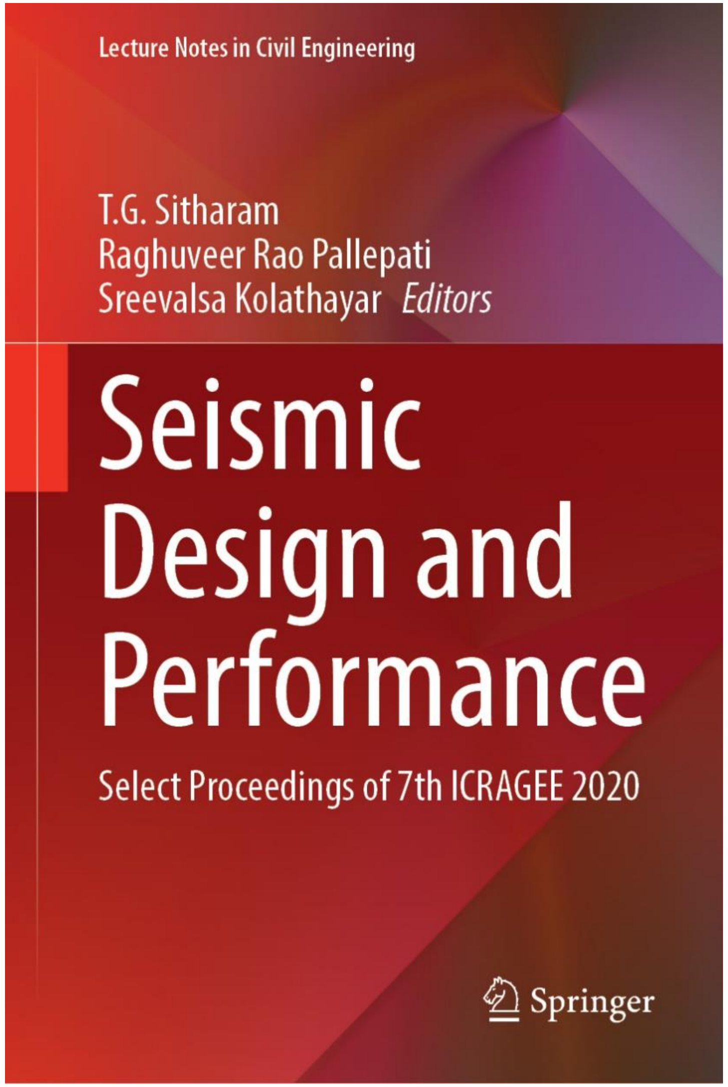
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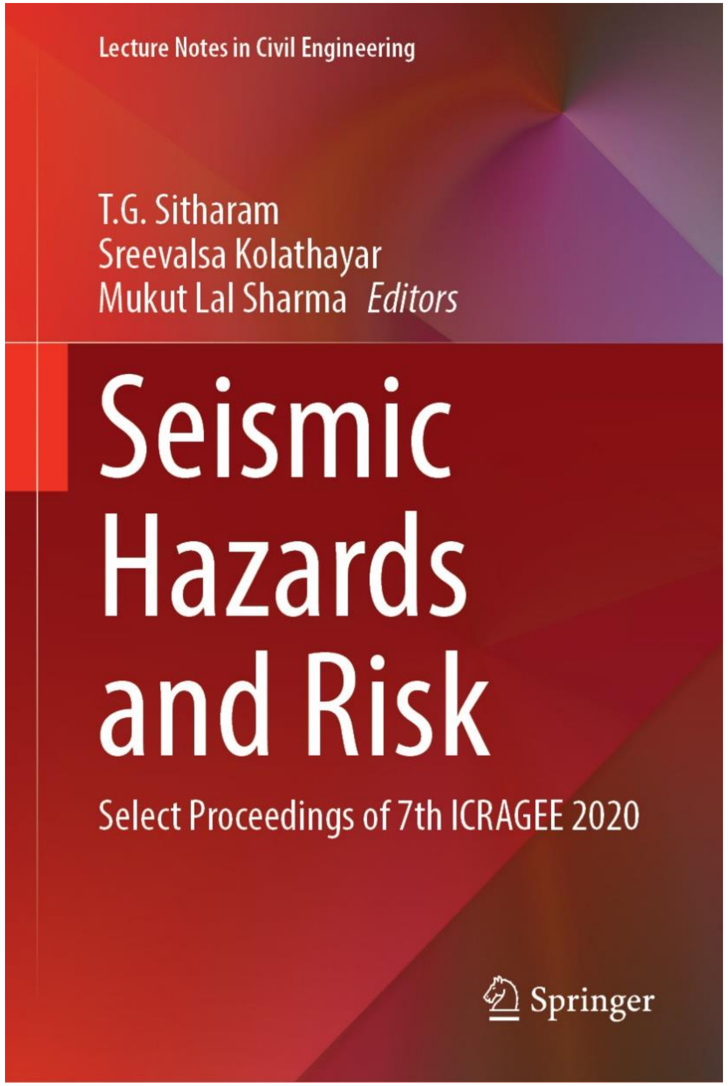
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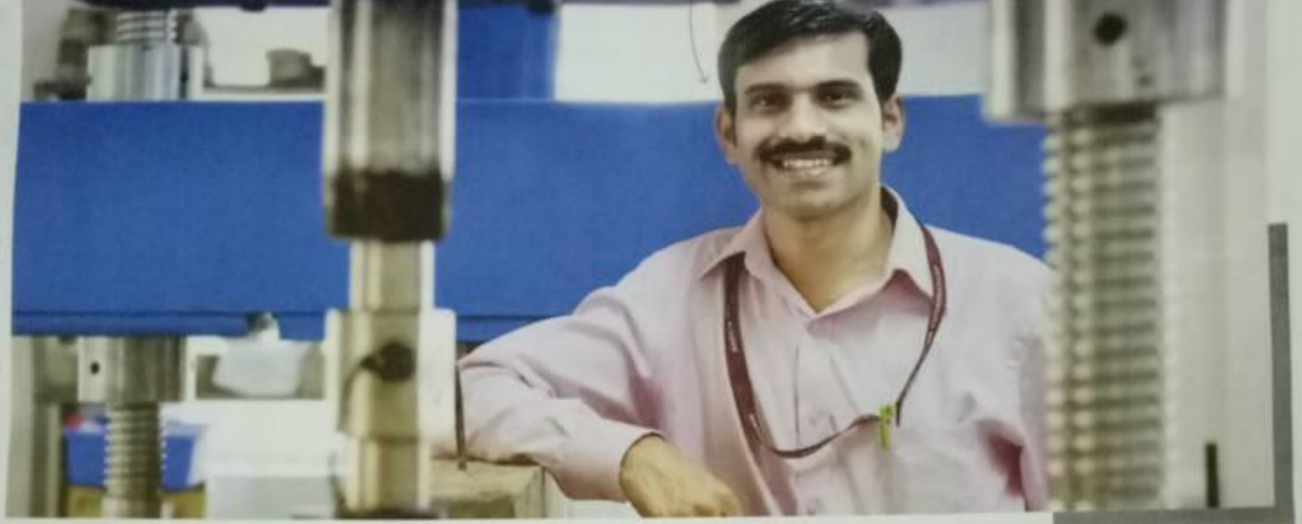


Sreevalsa Kolathayar's love for Earth and earthlings are beyond words. He is actively involved in Earthquake Preparedness to give them a better place to live in

# FEELING QUAKES BEFORE THEY HIT

Dr Sreevalsa Kolathayar might be the only person who wrote to the NDMA about the risks before the 2008 earthquakes. ***Jasmine Jerald*** finds out more about his measures to get people prepared for earthquakes

**SREEVALSA KOLATHAYAR**

Asst Prof and Research Coordinator

**AGE** 31

**WORK LOG**

Apart from teaching and mentoring his students at Amrita Vishwa Vidyapeetham, Coimbatore, Sreevalsa Kolathayar has been a part of various social impact projects as he finds this insurmountable drive to help rural students like him and find opportunities

Earthquakes generally don't kill people. It's the poor infrastructure that takes lives. When a high magnitude earthquake hits California, there are hardly any casualties, as it all comes down to the sturdiness of the buildings," explains Dr Sreevalsa Kolathayar, Assistant Professor and Research Coordinator, Department of Civil Engineering at Amrita Vishwa Vidyapeetham, Coimbatore, who had even written to the National Disaster Management Authority (NDMA) way before the 2015 Nepal earthquake about the high threat of earthquakes in the Himalayas. Sreevalsa, who was always a bright student, has been teaching from the age of fourteen. "I was studying in a government school when I was given the opportunity to move to a Navodaya Vidyalaya School in the same area. From then on, I was teaching children in my village," says the 31-year-old, who has co-authored *Preparing for Earthquakes: Lessons for India* alongside his mentor T G Sitharaman, which was earlier released in twelve Indian languages but is now expected to be published by a US publishing house.

After his Civil Engineering degree from Government Engineering College, Thrissur, this professor started his own company, Ignited Minds along with a few friends. But soon enough, he knew that teaching was his calling. He did his master's at IIT Kanpur, where he was also actively participating in the social activities of the college like volunteering and teaching in the villages nearby. While pursuing his PhD at Indian Institute of Science (IISC) Bangalore, he met his professor Sitharam, who has been his biggest source of inspiration and that's the start of his fascination towards earthquake preparedness. During his doctorate on earthquake hazard preparedness, he was the Chairman of the IISC Students Council and even spent two months at the Universitat Politecnica de Catalunya (UPC) commonly called BarcelonaTech, as an international research staff.

> We've been trying to get the government's attention towards high-risk areas which are geographically more prone to earthquakes
>
> Dr Sreevalsa Kolathayar

"After I returned, I joined Indian School of Mines, Dhanbad but at that time the Civil Engineering department was being set-up, so I helped out. But I knew that administrative work isn't for me. That's when I helped Ramakrishna Mission set-up a school in Chapi, a small village in Ranchi," explains Sreevalsa. He says that the state that's rich in natural resources also has many children who have the capacity to be some of the brightest minds in the country. "Alcohol is the main reason why these children don't get the education they deserve. Many teenagers get the wrong guidance and even the parents don't do much," explains the professor. He says that they used to conduct character building workshops for the students that teach them to be financially independent and recover from drug and alcohol addiction. "We trained two students to handle the classes on their own before I left and a student of mine, who I am still in touch with, got into organic farming and is now doing very well," says Sreevalsa proudly. He finds that education is key to fighting against Naxal activity in those areas.

save earth

After joining Amrita Vishwa Vidyapeetham in 2015, he's been pivotal in mentoring research projects of his students. He even helped them in developing a mobile app called BhookampRaksha that works to give any commoner an assessment of his/her preparedness for an earthquake and what safety measures needs to be taken.

**STOMPING GROUND**

Amrita Vishwa Vidyapeetham, Coimbatore

**IF NOT A TEACHER, THEN WHAT?**

Sreevalsa says he cannot imagine not being a teacher as its something that he naturally does but if not teaching he would have chosen to start an NGO on his own that works to help students in rural areas

**THE HONOUR ROLL**

- Marie Curie Fellowship by European Union, 2013
- Founder member and Faculty Advisor to 'Think India', a forum for bright students from premium institutes like IISc, IITs, IIMs, AIIMS, NLUs
- Served as Member, Special Committee to prepare national guidelines on Earthquake Preparedness and is the co-author of *Preparing to face Earthquakes: Lessons for India*

2015

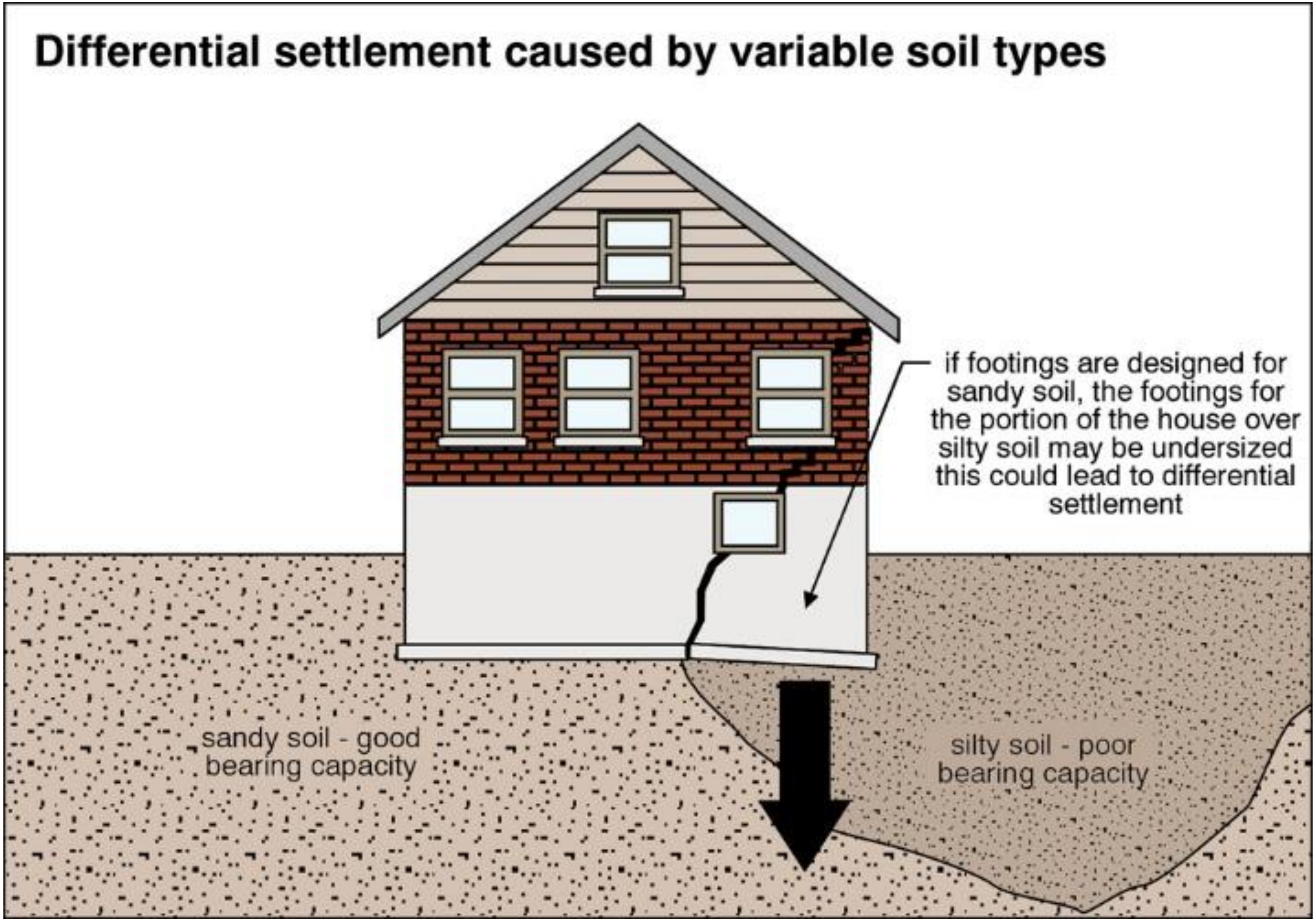
Sreevalsa joined Amrita Vishwa Vidyapeetham as a faculty in 2015

# Natural Hazards

- Geological disasters
  - Avalanches and landslides
  - Earthquakes
  - Sinkholes
  - Volcanic eruptions
- Hydrological disasters
  - Floods
  - Tsunami
- Meteorological disasters
  - Cyclonic storms
  - Droughts
  - Thunderstorms
  - Hailstorms
  - Heat waves
  - Tornadoes
- Wildfires
- Space disasters

# Man made Hazards

- Societal hazards
  - Criminality
  - Civil disorder
  - Terrorism
  - War
  - Industrial hazards
  - Engineering hazards
  - Waste disposal
  - Power outage
  - Fire
- Hazardous materials
  - Toxic metals
  - Radioactive materials
  - CBRNs
- Transportation
  - Aviation
  - Rail
  - Road
  - Space
  - Sea travel
- Environmental hazards


Differential settlement caused by variable soil types
if footings are designed for sandy soil, the footings for the portion of the house over silty soil may be undersized this could lead to differential settlement
sandy soil - good bearing capacity
silty soil - poor bearing capacity

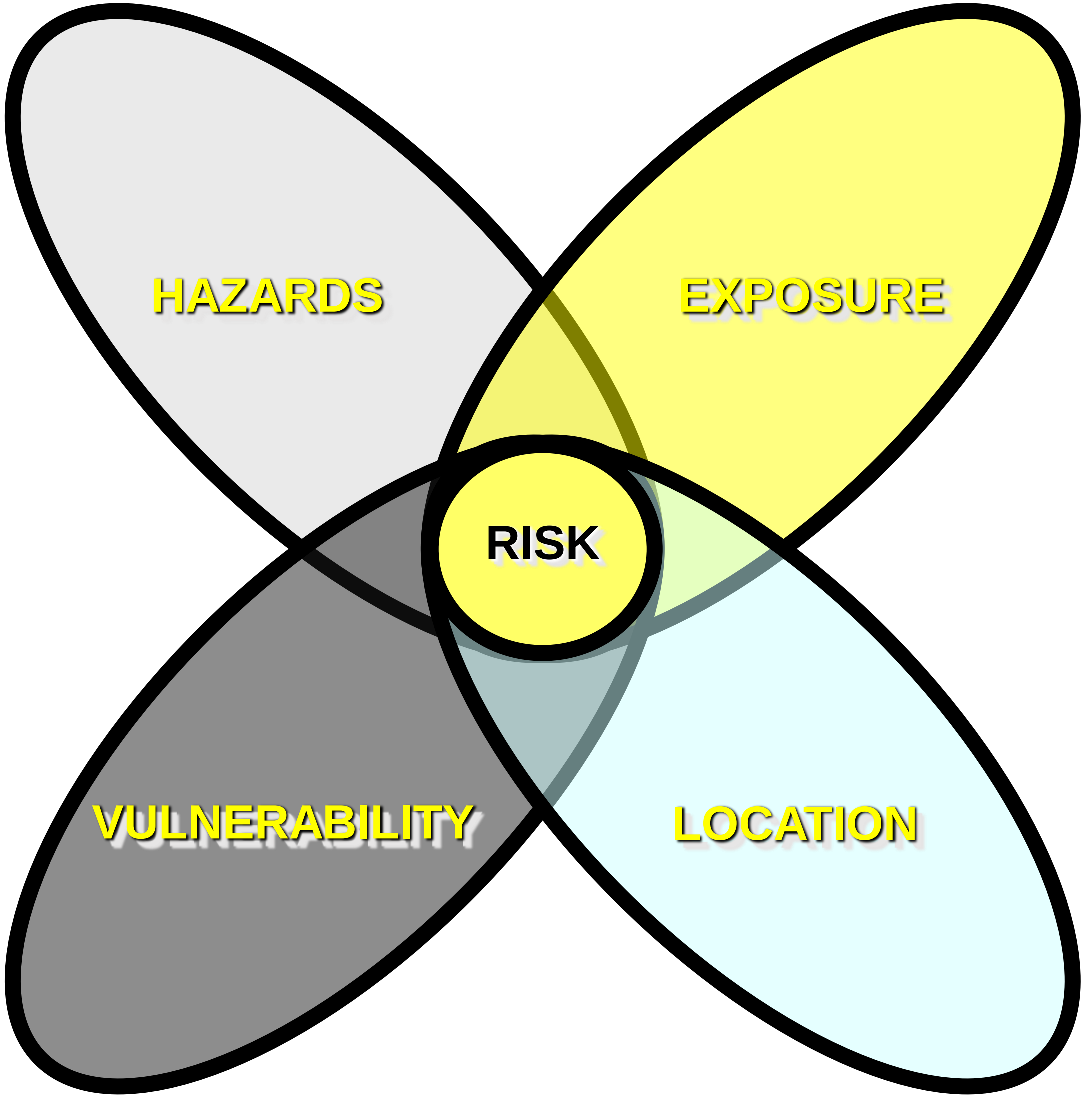
# Hazard or Disaster?

"There is no such thing as "natural disasters." Natural hazards—floods, earthquakes, landslides and storms—become disasters as a result of human and societal vulnerability and exposure, which can be addressed by decisive policies, actions and active participation of local stakeholders. Disaster risk reduction is a no-regret investment that protects lives, property, livelihoods, schools, businesses and employment."

From the Chengdu Declaration of Action, August 2011

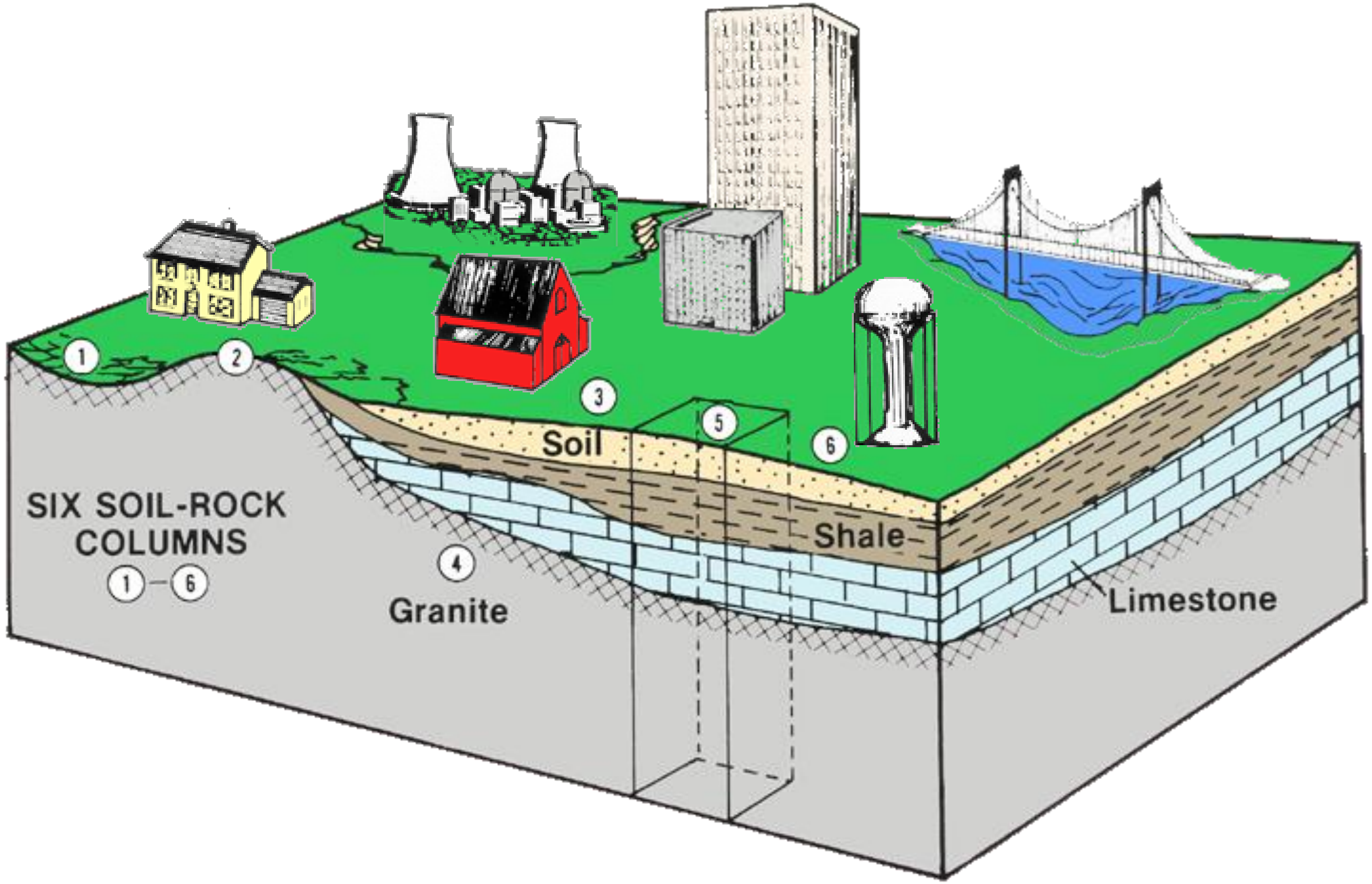
The strategy of the Chengdu Declaration of Action includes enhancing cooperation between cities, e.g. sister-city model, strengthening local capacity and national-local cooperation; incorporating disaster resilient initiatives into urban development planning; raising more awareness in cities about disaster risk reduction, international debates and improving disaster preparedness and emergency management of cities.

# ELEMENTS OF RISK




Risks represent the presence of vulnerable elements in areas exposed to hazards -UN

# A COMMUNITY HAS BUILDINGS AND INFRASTRUCTURE NEEDING PROTECTION



# Earthquake

Paras Shah / AP

# Geogrid Reinforced Earth Retaining Wall Before Earthquake (Kobe)

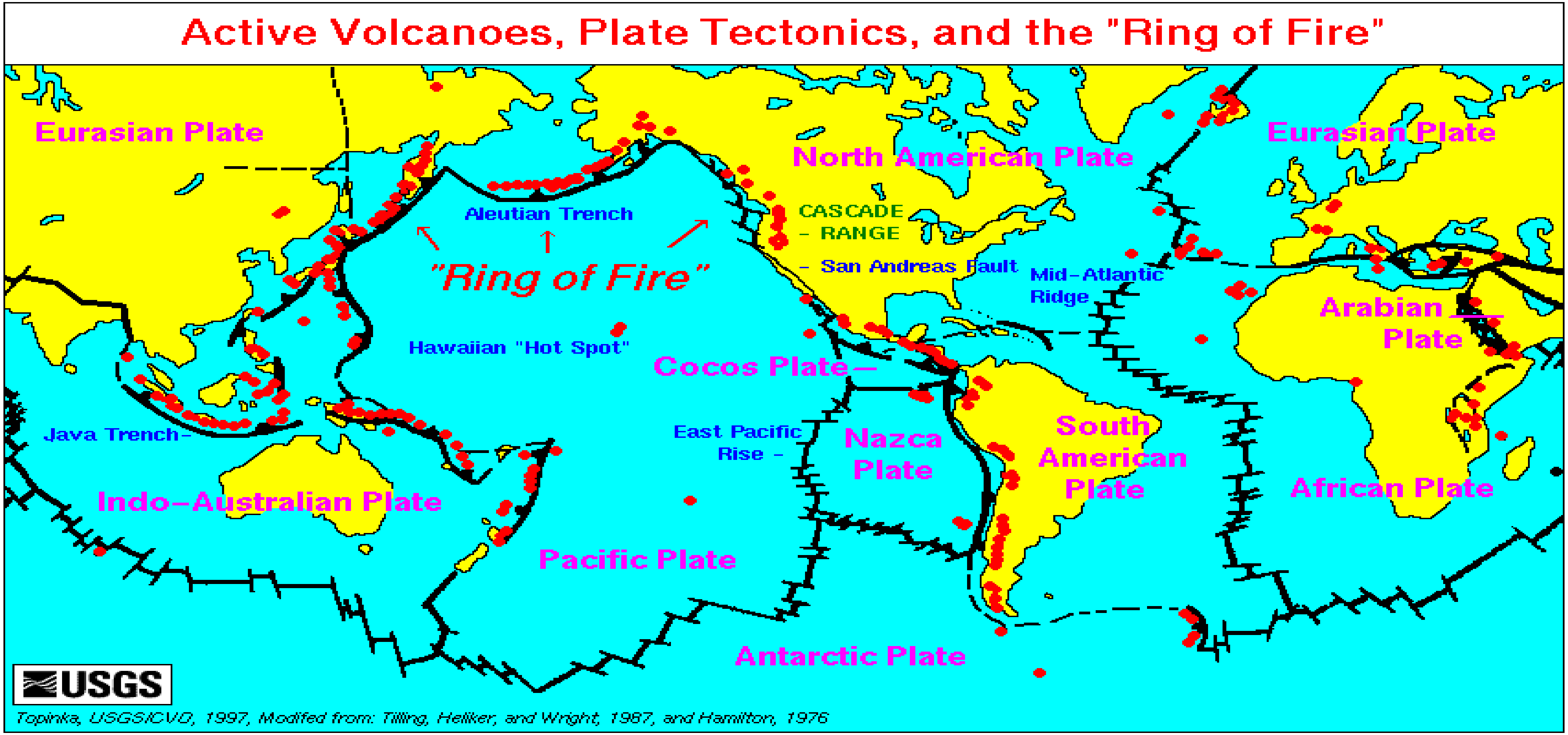
Geogrid-reinforced soil RW along JR Kobe Line (1992)

Retaining Wall

Geogrid-reinforced soil RW along JR Kobe Line (1995)


Stable Retaining Wall after the Earthquake

Our planet is restless. We can never control its activities inside and cannot control its vibrations…



# Introduction to Seismology

# Introduction

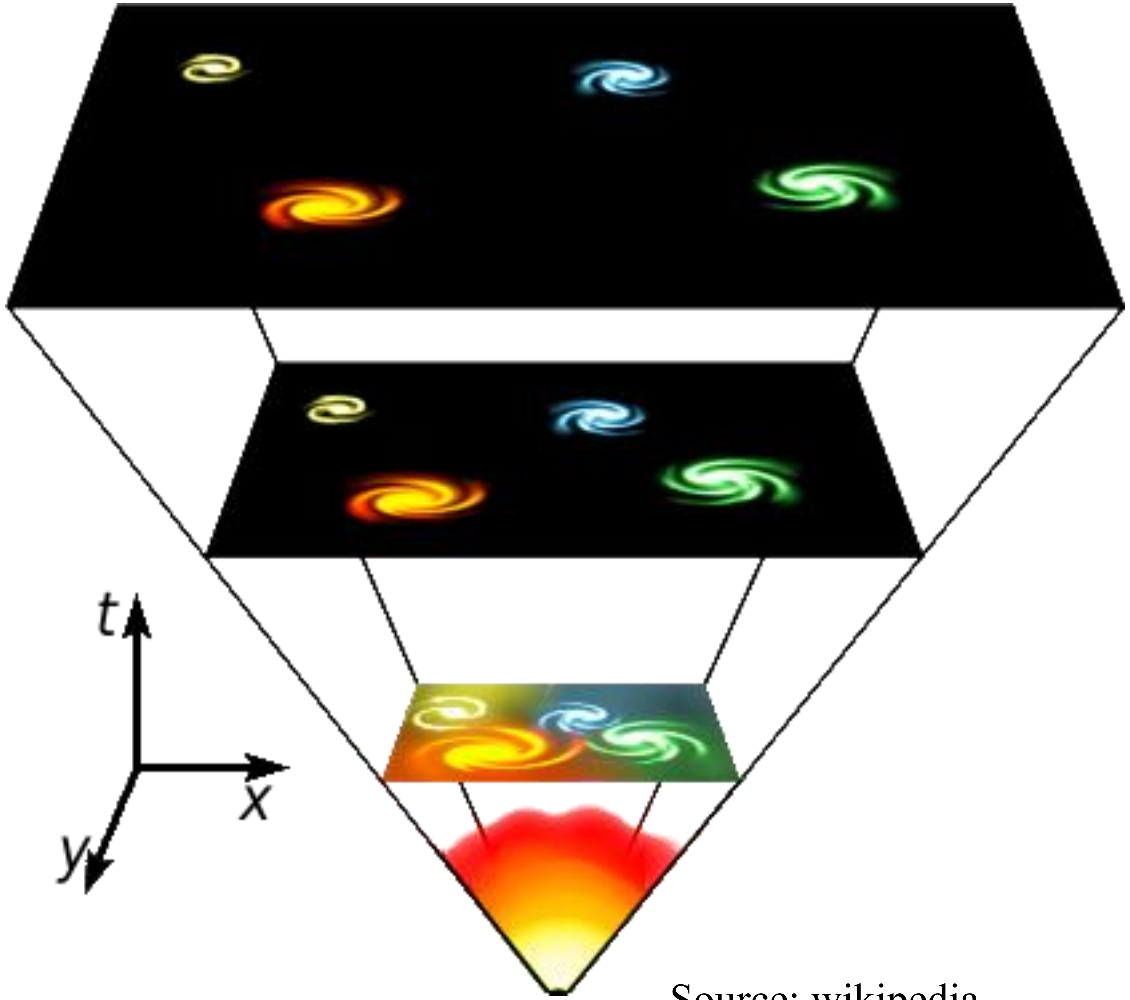
Seismology is the branch of Geophysics concerned with the study and analysis of Earthquakes and the science of energy propagation through the Earth's crust.

Engineering Seismology is concerned with the solution of engineering problems connected with the Earthquakes. Seismology is extremely important because:

- Study of earthquakes gives us important clues about the earth’s interior
- Understanding earthquakes allows us to minimize the damage and loss of life

# Origin of our Universe

**Big Bang model** - the universe began with an explosive expansion of matter, which later became what we know as stars, planets, moons, etc.  This event is thought to have occurred 10 - 15 billion yrs ago.




Source: wikipedia

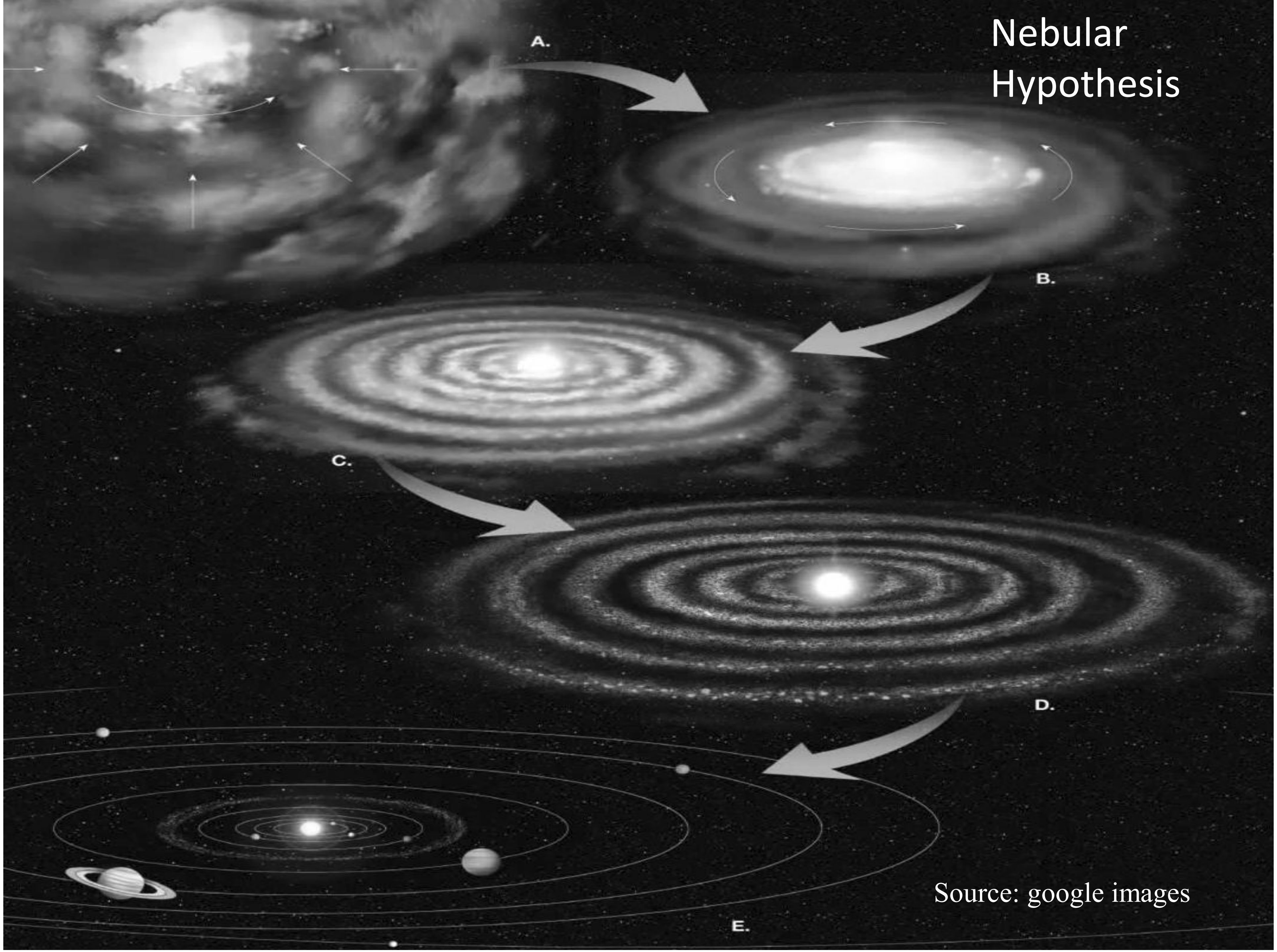
# Origin of Our Solar System

**Nebular Hypothesis:** Earth and the other bodies of our solar system (Sun, moons, etc.) formed from a "vast cloud of dust and gases" called a nebula.

The nebular cloud consisted of **H** and **He**, and a small percentage of the heavier elements we find in the solar system.

Within the rotating disk, the rocky material and gases began to nucleate and accrete into protoplanets

# Nebular Hypothesis




Source: google images

# Formation of Earth's Layers

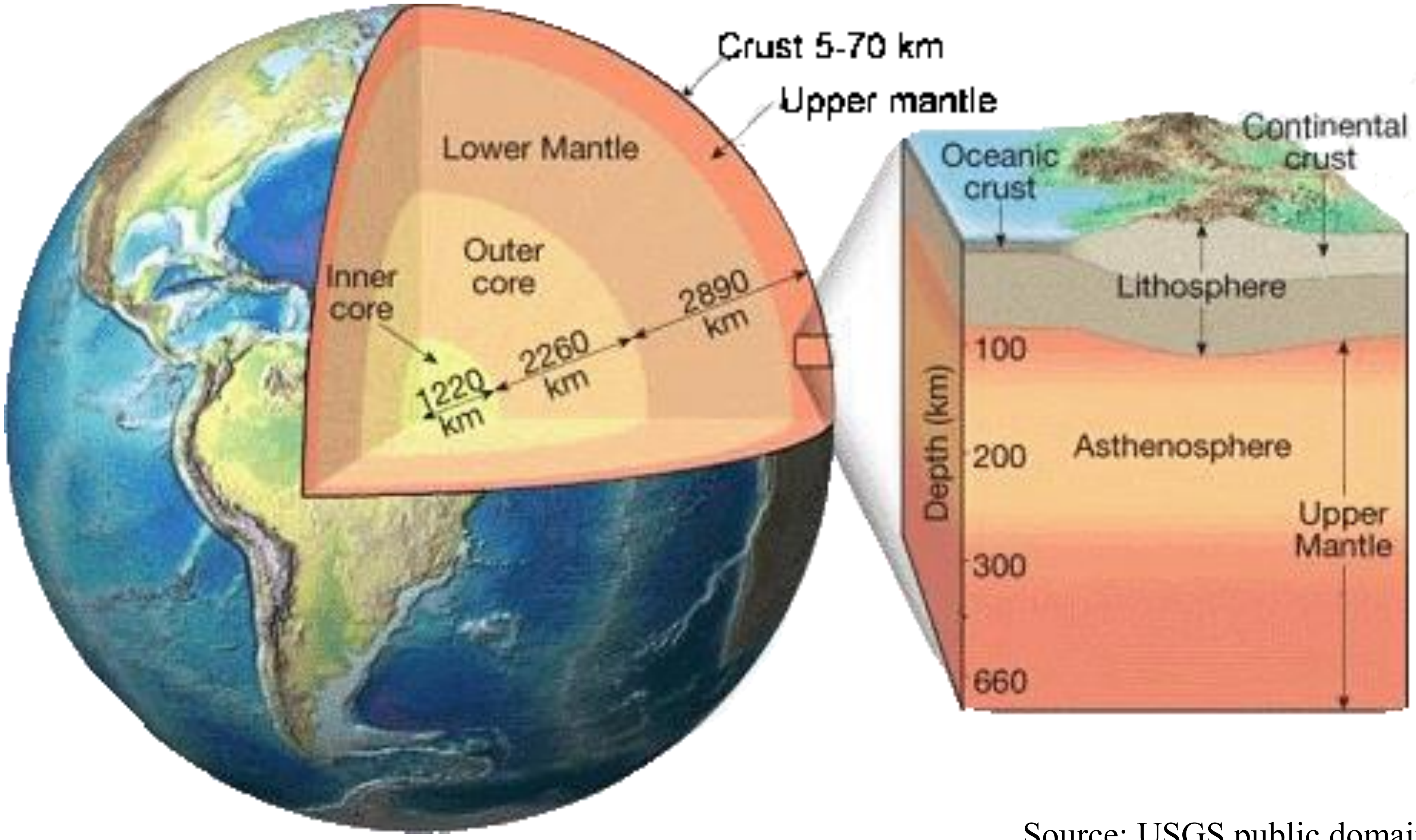
- When Earth was formed, it was extremely hot from the bombardment of space debris, radioactive decay and high internal pressures. These processes caused Earth's interior to melt.
- Molten Earth separated based on melting points and density into regions of chemical and physical differences as it cooled.
- Molten Iron & Nickel melted early and being more dense, sunk to the center of the Earth. Solid Iron & Nickel formed the **Inner Core**. Molten Iron & Nickel formed the **Outer Core**. Less dense solid material formed the **Mantle**. The least dense rock at the surface cooled up completely as the **Crust**.

# Layers of the Earth

- **Crust**
  - Continental crust (5-70 km✶)
  - Oceanic crust (~6 km)
- **Mantle**
  - Upper mantle (650 km)
  - Lower mantle (2890 km)
- **Core**
  - Outer core: liquid (2260 km)
  - Inner core: solid (1220 km)

✶ Values in brackets represent the approximate thickness of each layer

# Layers of the Earth




Source: USGS public domain

# Layers of the Earth

The earth is divided into four main layers: **Inner core, outer core, mantle** and **crust**.

The core is composed mostly of iron (Fe) and is so hot that the outer core is **molten**, with about 10% sulphur (S). The inner core is under such extreme **pressure** that it remains solid.

Most of the Earth's mass is in the mantle, which is composed of iron (Fe), magnesium (Mg), aluminum (Al), silicon (Si), and oxygen (O) **silicate** compounds. At over 1000°C, the mantle is solid but can deform slowly in a **plastic** manner.

The crust is much thinner than any of the other layers, and is composed of the least dense calcium (Ca) and sodium (Na) aluminum-silicate minerals. Being relatively cold, the crust is rocky and **brittle**, so it can fracture in **earthquakes**.

# What is an earthquake?

# What is an earthquake?

- An earthquake is the vibration of Earth produced by the rapid release of accumulated energy in elastically strained rocks
  - Energy released radiates in all directions from its source, the focus
  - Energy propagates in the form of seismic waves
  - Sensitive instruments around the world record the event

# What causes an earthquake?

# What causes an earthquake?

## Movement of Tectonic Plates

Earth is divided into sections called Tectonic plates that float on the fluid-like interior of the Earth. Earthquakes are usually caused by the sudden movement of earth plates

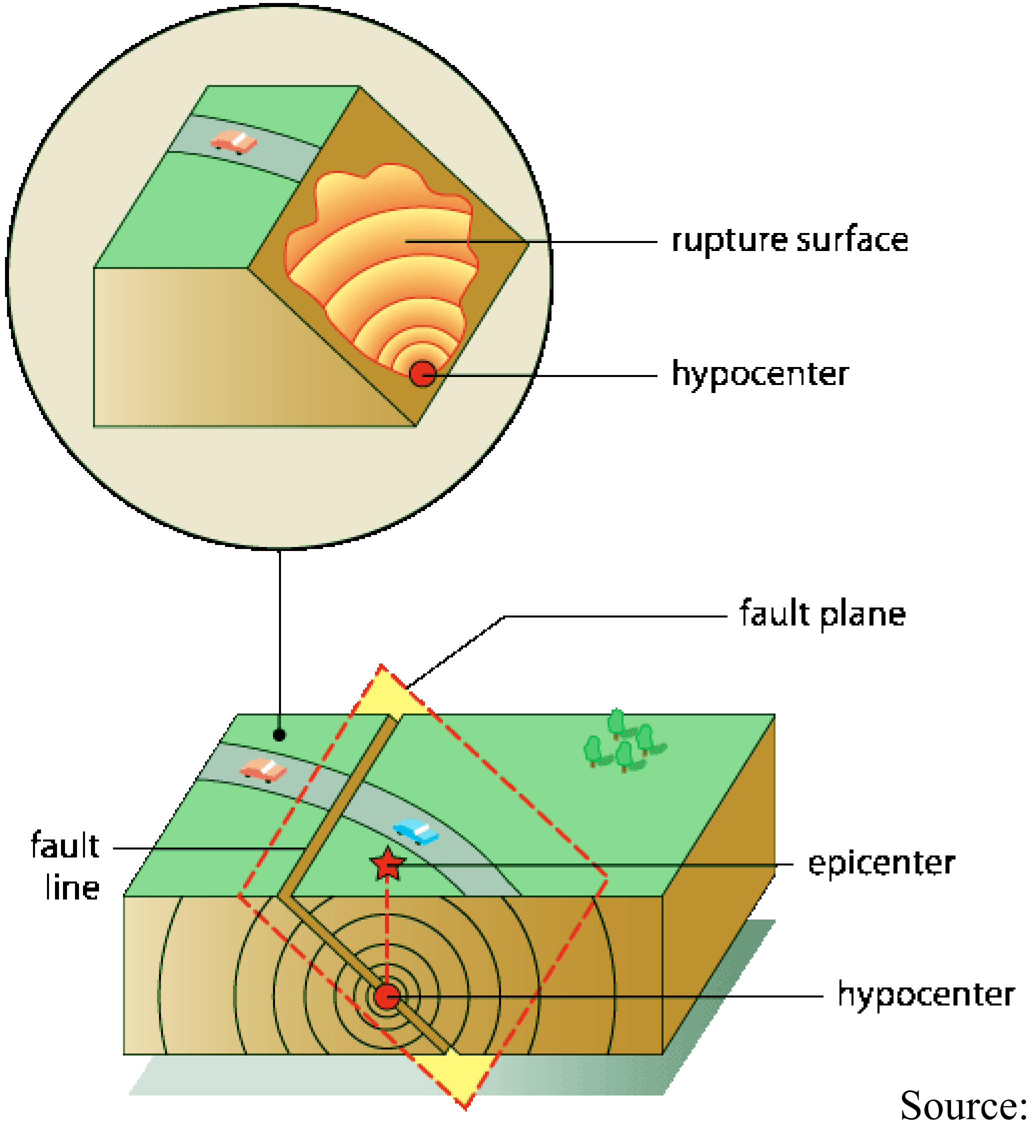
## Rupture of rocks along a fault

Faults are localized areas of weakness in the surface of the Earth,sometimes the plate boundary itself

# Movement of Tectonic Plates

Source: http://www.topnews.in

# Rupture of rocks along a fault




Source: USGS public domain

# Earthquake Terminology

**Fault**: Weakness in the rock

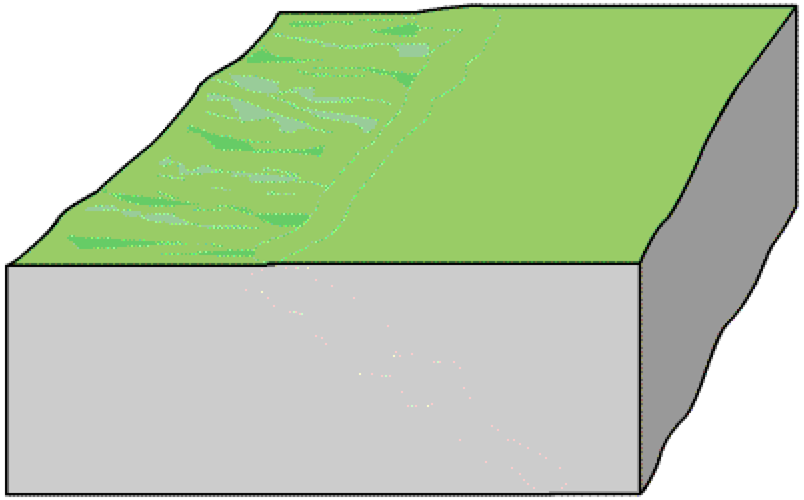
**Fault Plane**: Plane of weakness in rock

**Rupture surface**: The portion of the fault which slips when the earthquake occurs

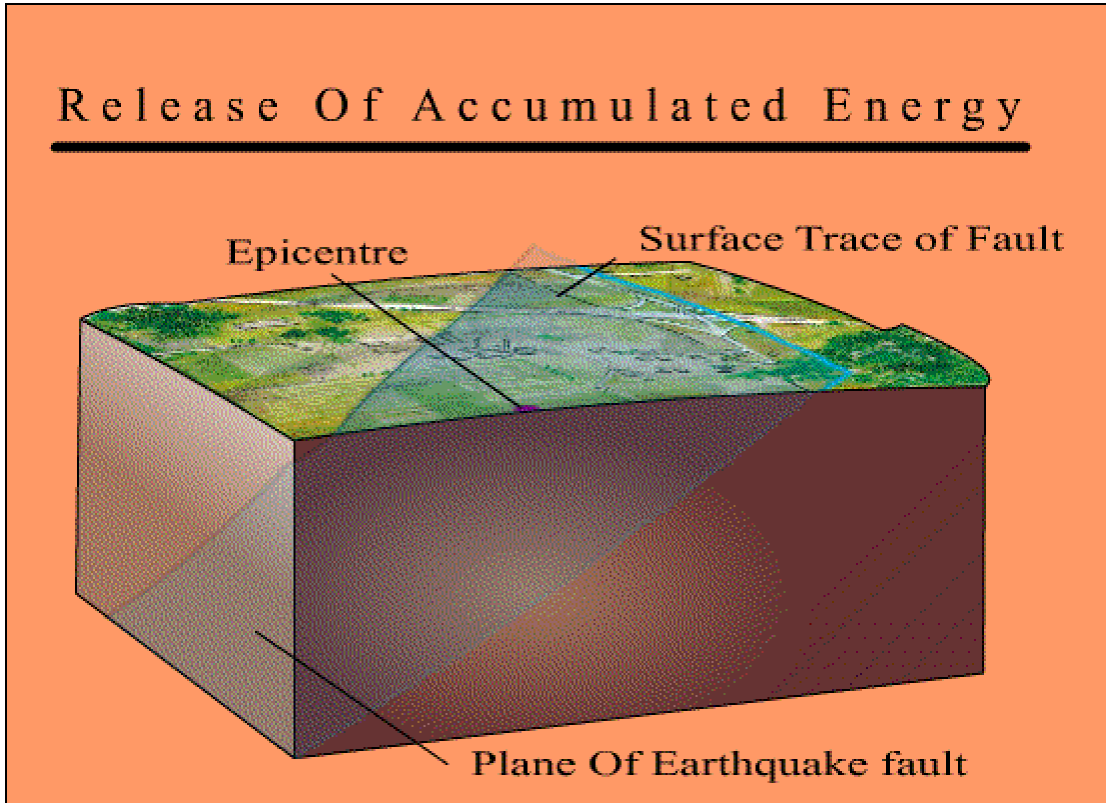
**Hypocenter/Focus**: The place located deep within the Earth where rocks suddenly break, causing an earthquake, and from where seismic waves propagate

**Epicenter**: The point of the earth's surface directly above the focus of an earthquake

# Sequence of earthquake events



# Release of accumulated energy



# Theory of continental drift

# Continental drift

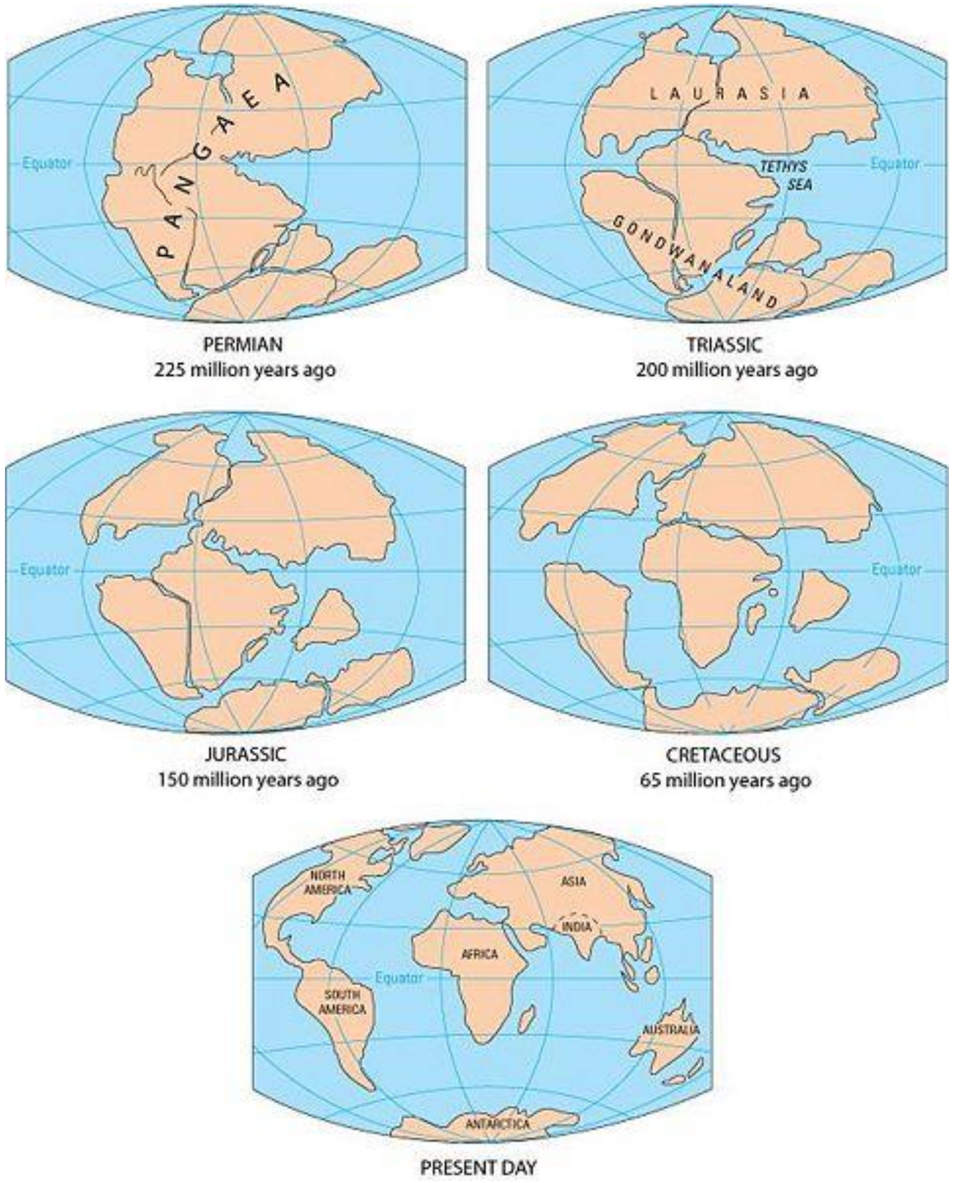
- Theory that continents and plates move on the surface of the Earth was proposed by Alfred Wegener in 1915.


Source: wikipedia

# Theory of Continental drift

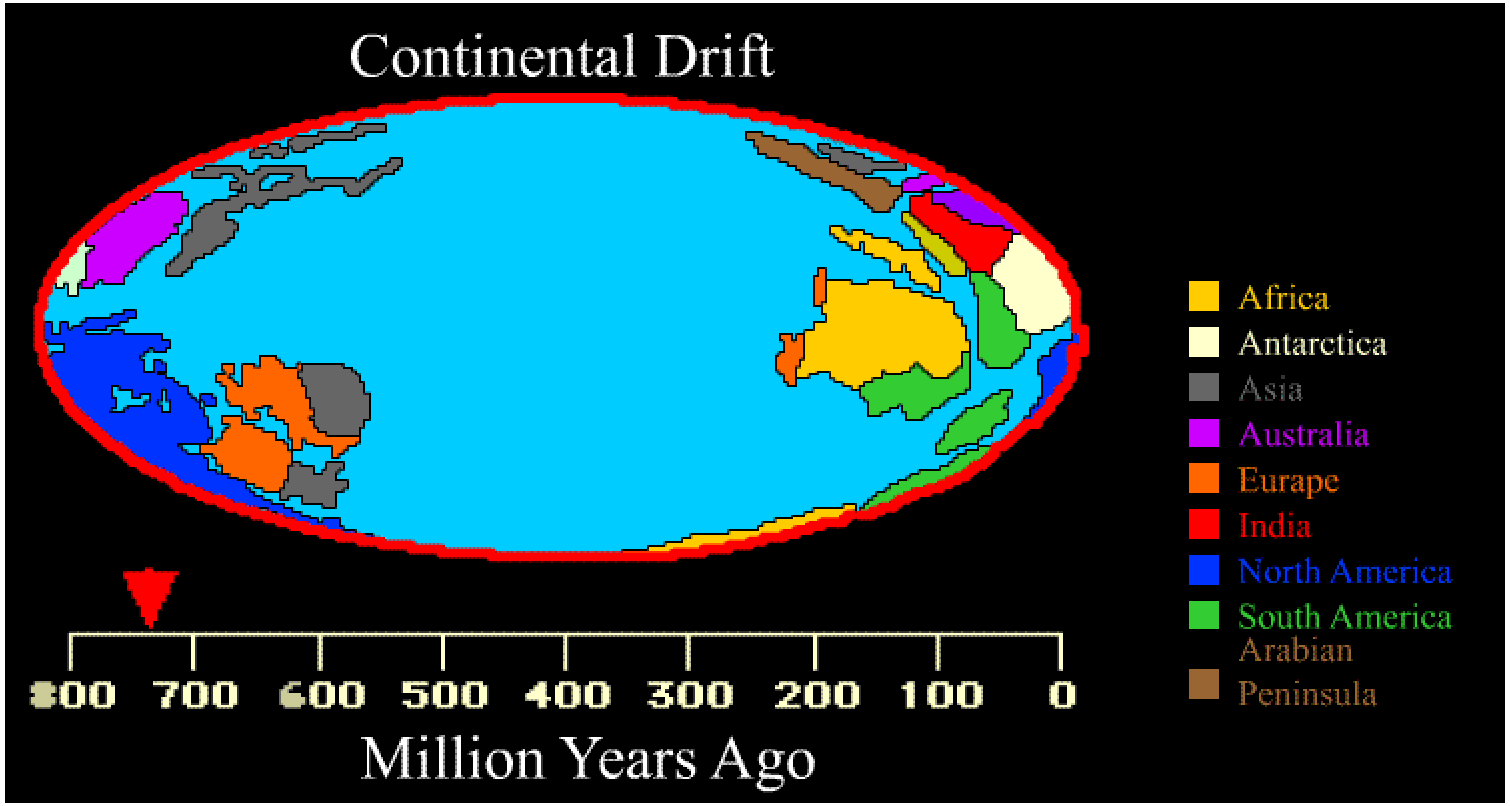
- Continental similarities and fitting of the shapes of the continents was the basis for the theory of continental drift proposed by Wegener.
- Wegener noticed that the eastern outline of SouthAmerica and western outline of Africa fit like pieces of a jigsaw puzzle. He noticed similar fits among the other continents.
- Wegener theorized that a single supercontinent called **Pangaea** existed sometime during the late Paleozoic Era, 350 million to 225 million years ago. He maintained that the landmass broke up and that its pieces dispersed and drifted, eventually reaching their present positions.
- After several decades, Wegener’s theory led to the revolutionary theory of plate tectonics, which could explain the observed evidence for large scale motions of the Earth's lithosphere

# Maps by Wegener (1915), showing continental drift

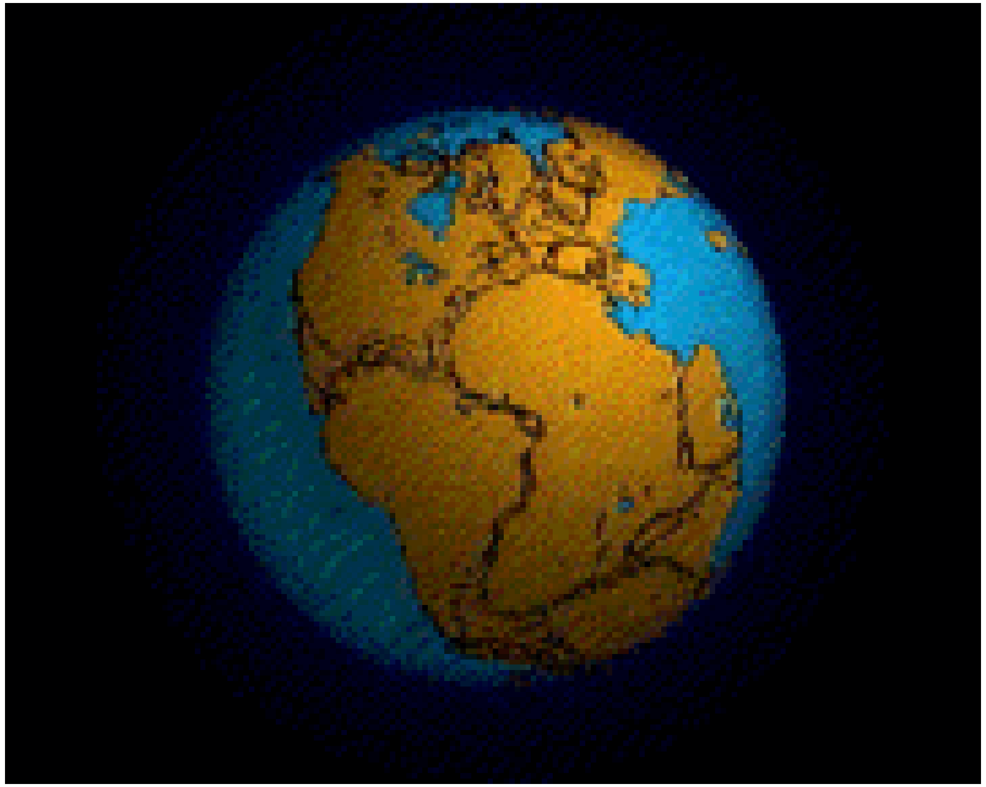



Source: http://geology12-8.wikispaces.com

# Theory of continental drift



# Theory of continental drift



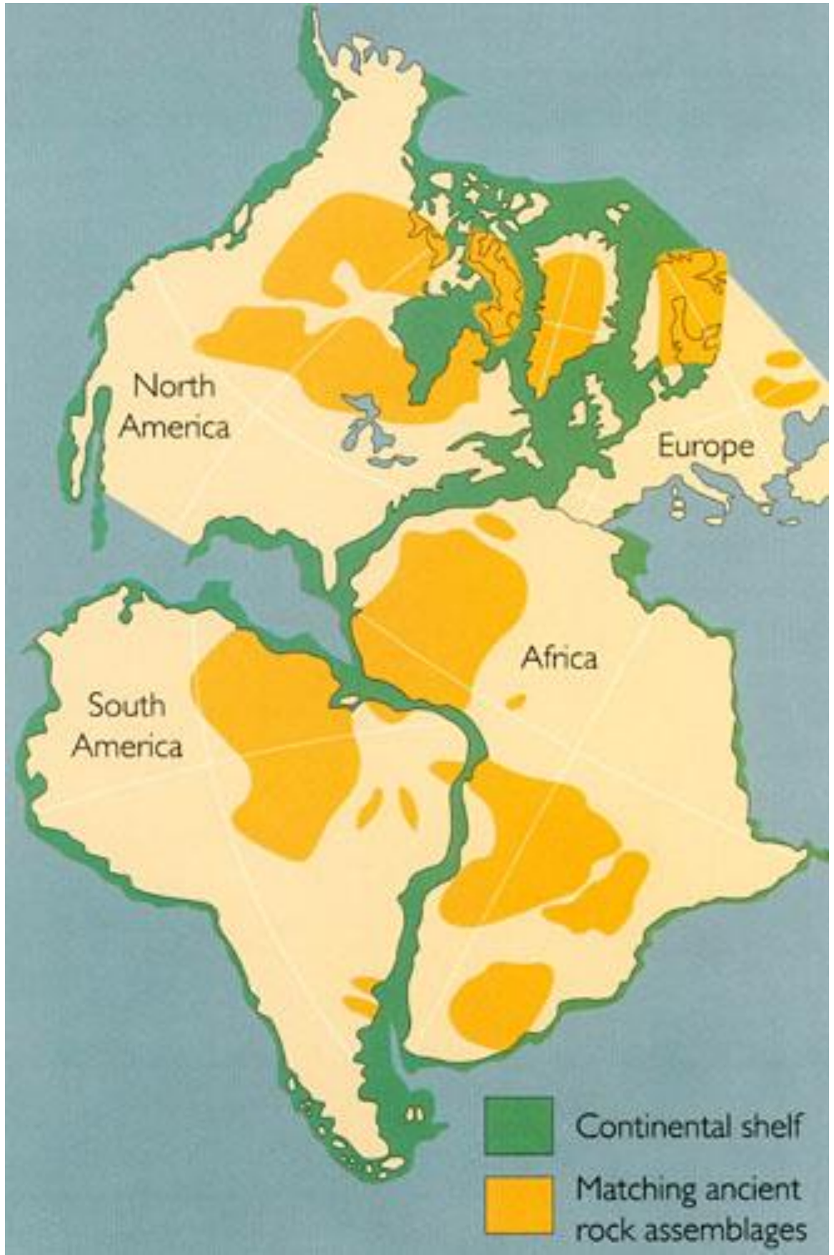
Source: wikipedia

# Evidence for continental drift

- Matching coastlines
- Matching mountains
- Matching rock types and rock ages
- Matching glacier deposits
- Matching fossils

# Evidence for continental drift

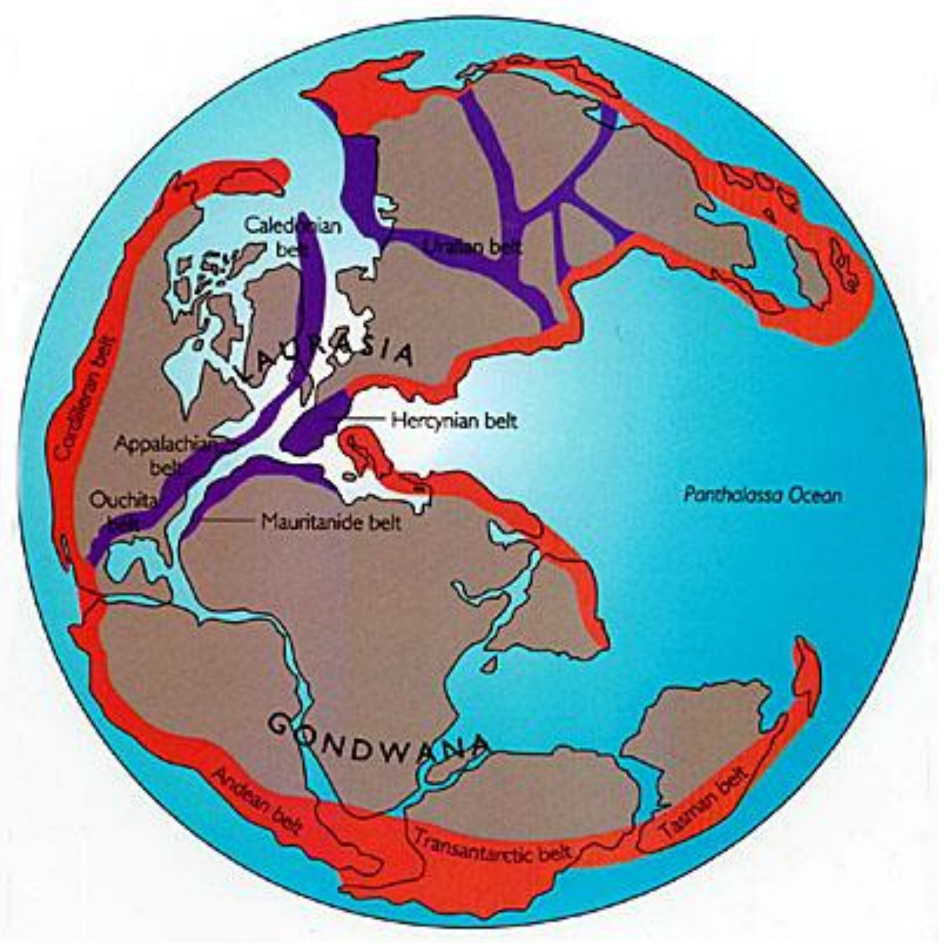
## Matching coastlines




Source: http://geology12-8.wikispaces.com

# Evidence for continental drift

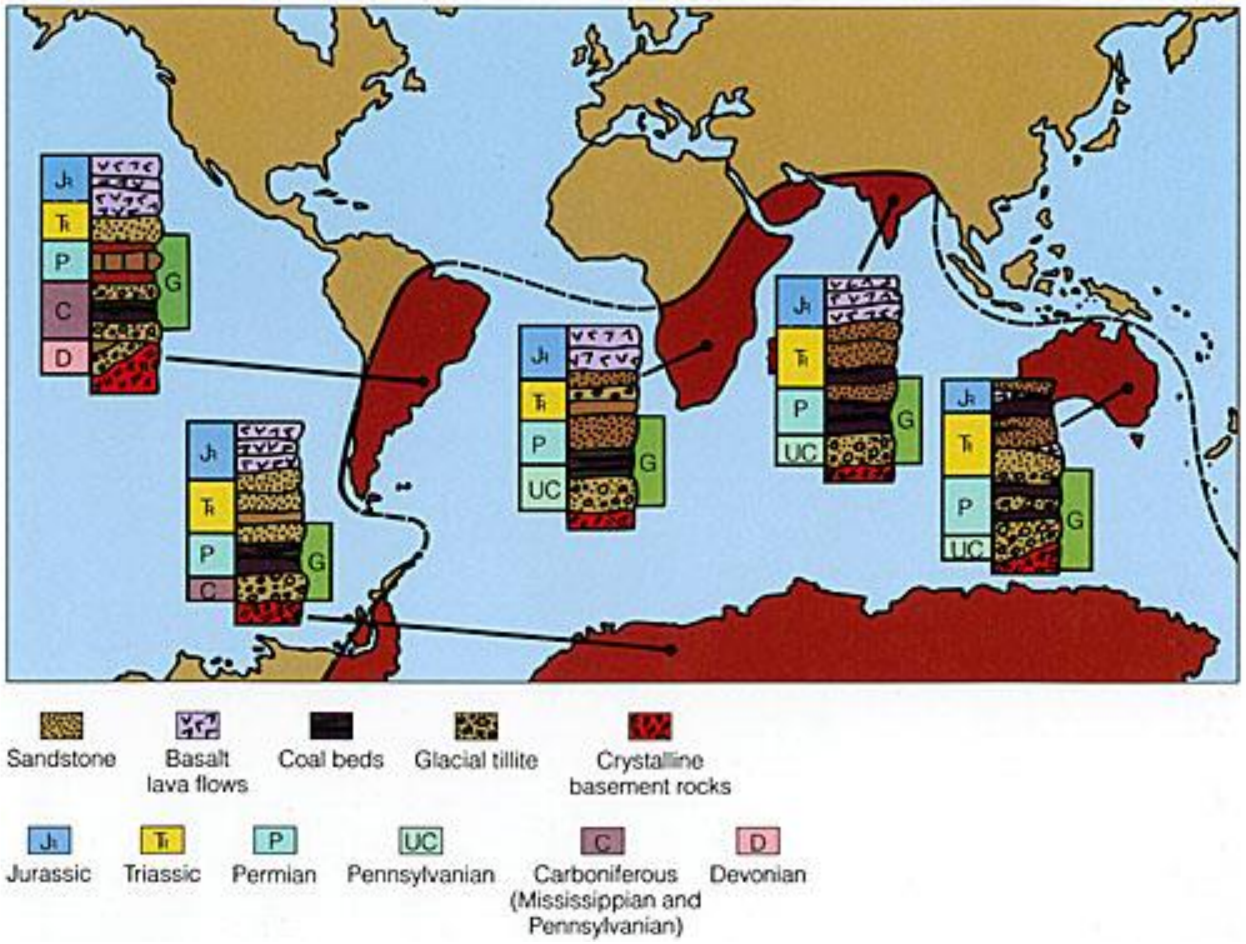
Matching mountain ranges




Source: http://geology12-8.wikispaces.com

# Evidence for continental drift

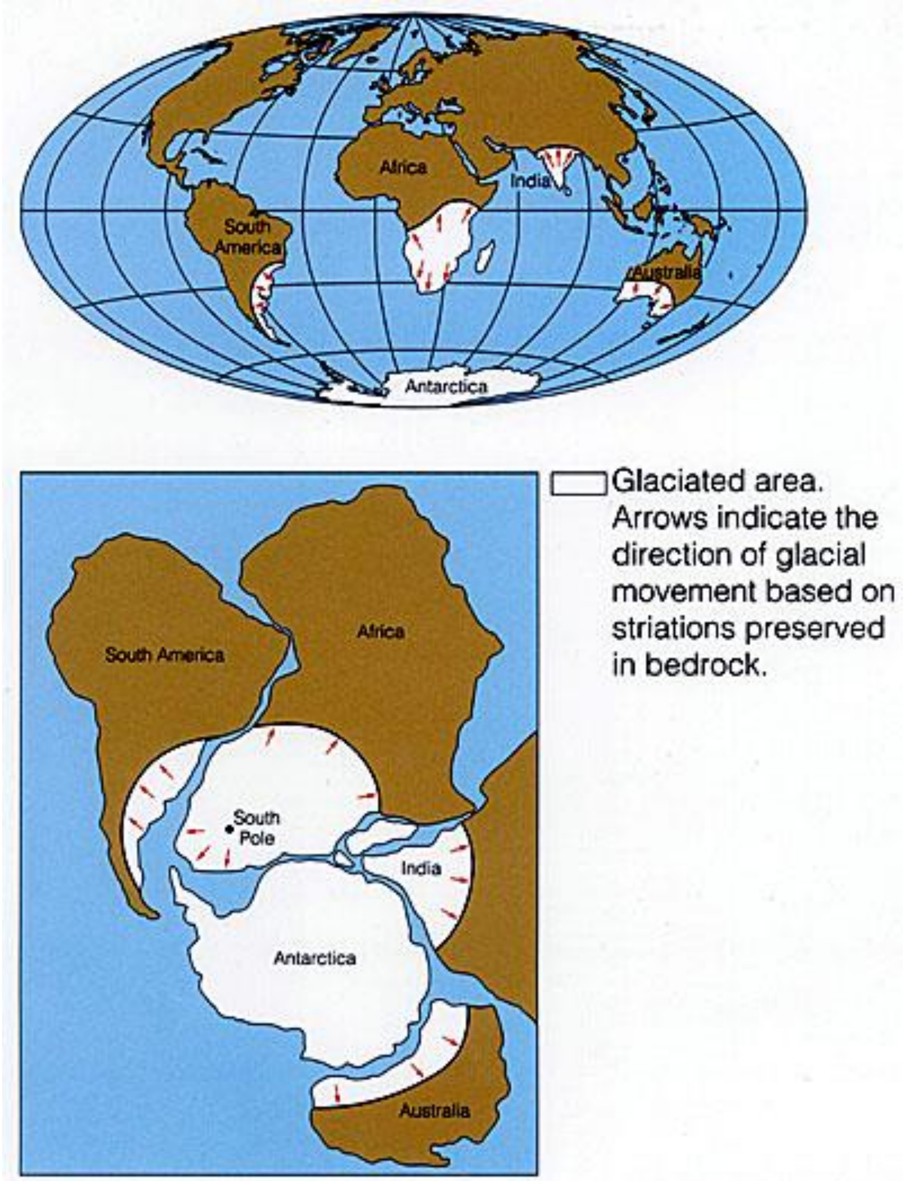
Matching rock types and ages of rocks




Source: http://geology12-8.wikispaces.com

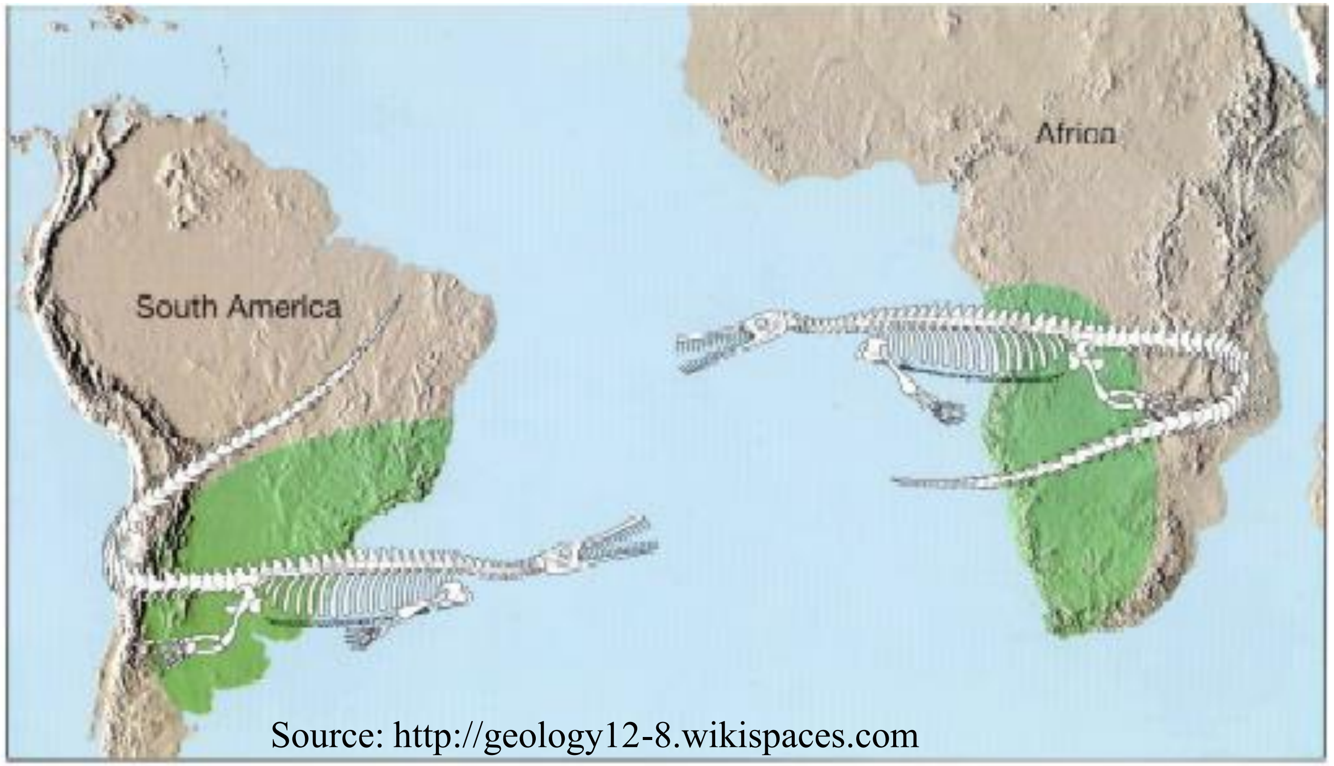
# Evidence for continental drift

Matching glacier deposits 300 million years ago




Source: http://geology12-8.wikispaces.com

# Evidence for continental drift




Fossils of of Mesosaurus (aquatic reptile) found on both sides of Atlantic

# Earthquakes and Plate Tectonics

Earthquakes are not randomly distributed over the Earth's surface. They are observed to be concentrated in specific zones. Volcanoes and mountain ranges also found in these zones. **Theory of plate tectonics** which combines many of the ideas about continental drift explains the reasons for these seismological activities.

Plate tectonics tells us that the Earth's rigid outer shell (lithosphere) is broken into a mosaic of oceanic and continental plates which can slide over the plastic aesthenosphere, which is the uppermost layer of the mantle. The plates are in constant motion. Where they interact, along their margins, important geological processes take place, such as the formation of mountain belts, earthquakes, and volcanoes.

**Lecture-2**

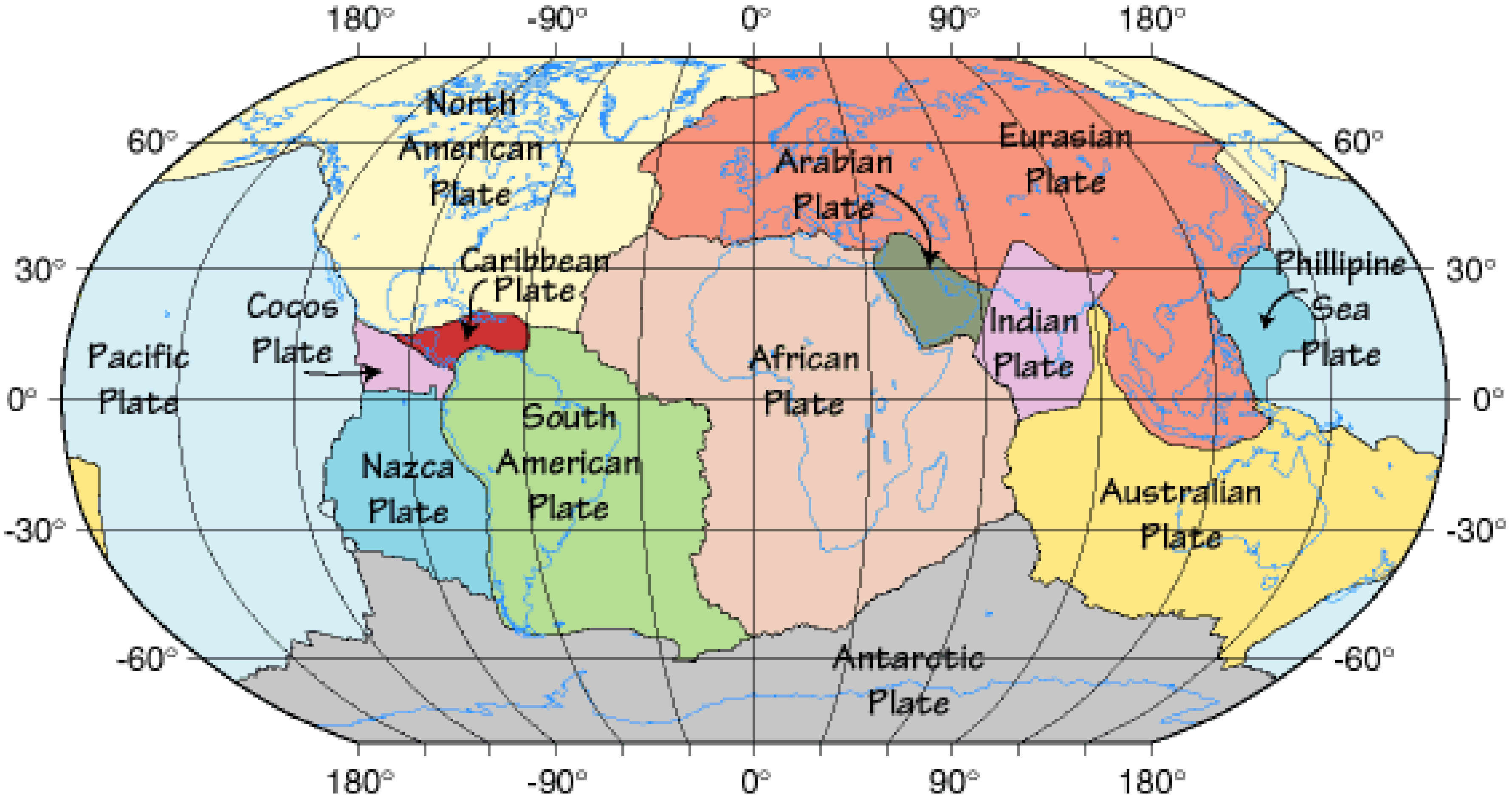
# PLATE TECTONICS

Part -I

# Theory of Plate tectonics

- The theory of Plate tectonics was proposed in 1960s based on the theory of continental drift.
- This is the Unifying theory that explains the formation and deformation of the Earth's surface.
- According to this theory, continents are carried along on huge slabs (plates) on the Earth's outermost layer (Lithosphere).
- Earth's outermost layer is divided into 12 major Tectonic Plates (~80 km deep). These plates move relative to each other a few centimeters per year.

# Tectonic plates of Earth




Source: http://eqseis.geosc.psu.edu

# Evidence for plate tectonic movements

Wegener's theory of continental drift was not accepted initially because Wegener could not propose a mechanism which could explain the motion of continents.

Today plate tectonics and continental drift are accepted as facts because of following evidences.

—Matching coastlines of the continents

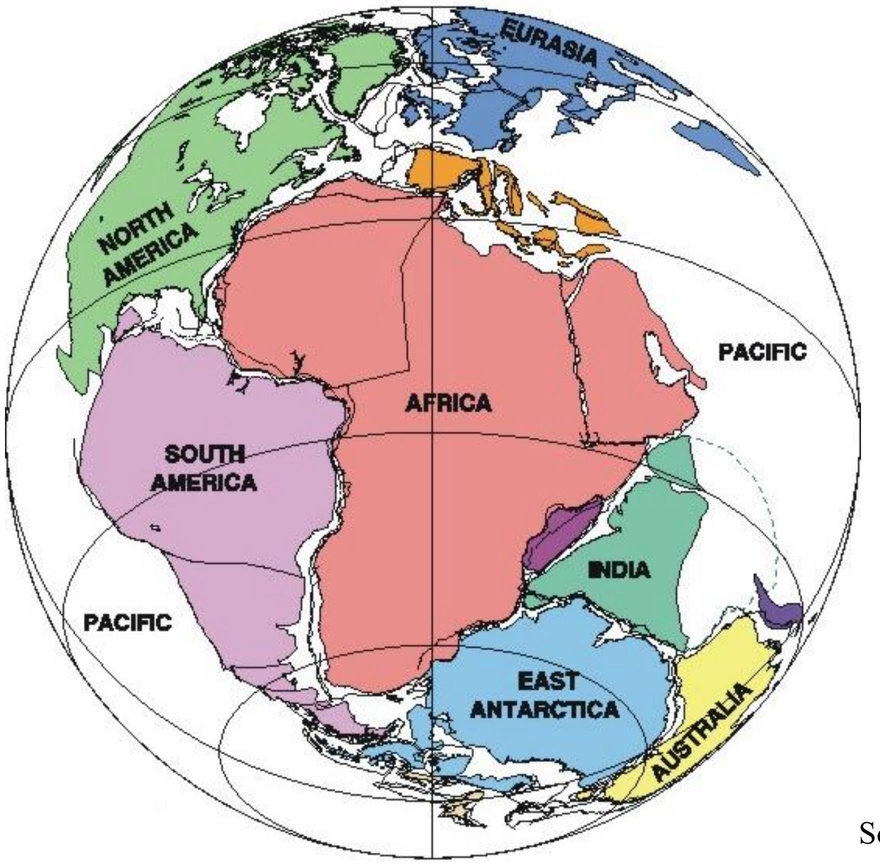
—Matching mountain ranges and rock types and age of opposite shorelines

—Matching glacier deposits and fossils of opposite shores

—Ocean floor spreading

—Geodetic measurements through satellites

# Evidence for plate tectonic movements




Source: wikipedia

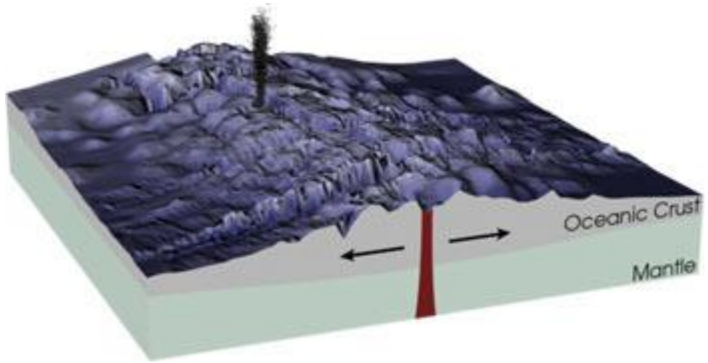
Matching shapes, rock types, rock ages, mountains, glacier deposits and fossils along the shorelines of continents

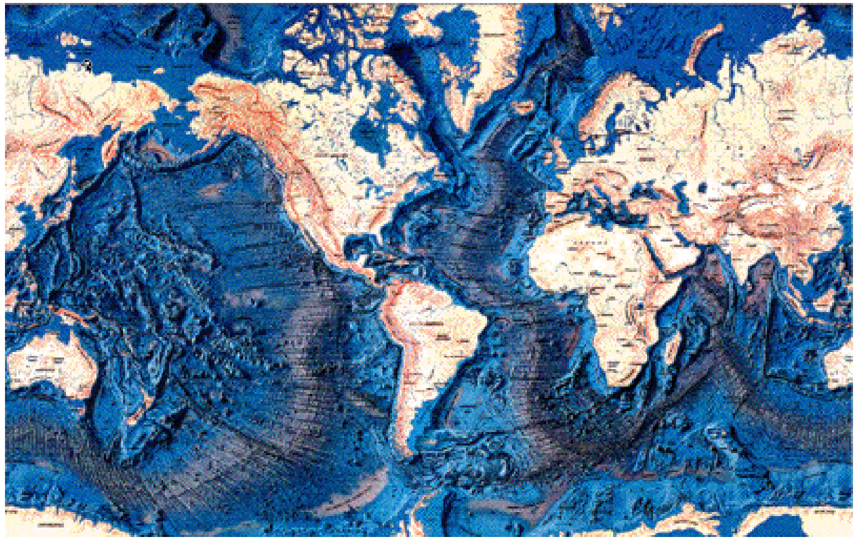
# Ocean floor spreading

Discovered in oceans by ships dragging magnetometers (1940s and 1950s)

Extensive mapping of magnetic stripes is carried out since then.

A series of under-water mountains called mid-ocean ridges is found throughout the world. These mountains are formed as new sea floor is created from magma that rises up from the mantle below.

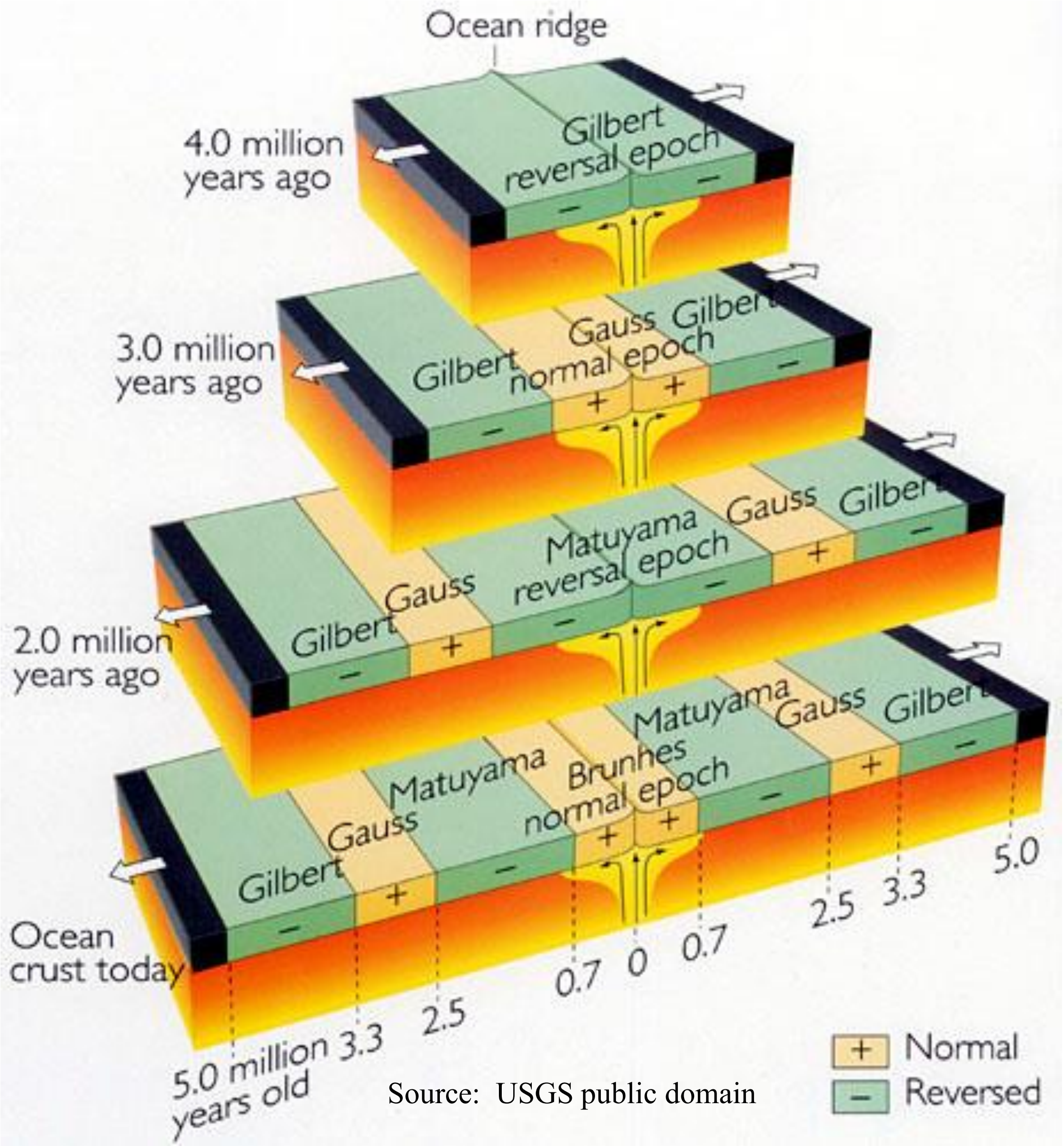


Source: **wikipedia**

# Earth’s magnetic field

Magnetic field of Earth reverses on semi-regular basis. Minerals act like compass needles and point towards magnetic north. “Hot” rocks record the direction of the magnetic field as they cool.



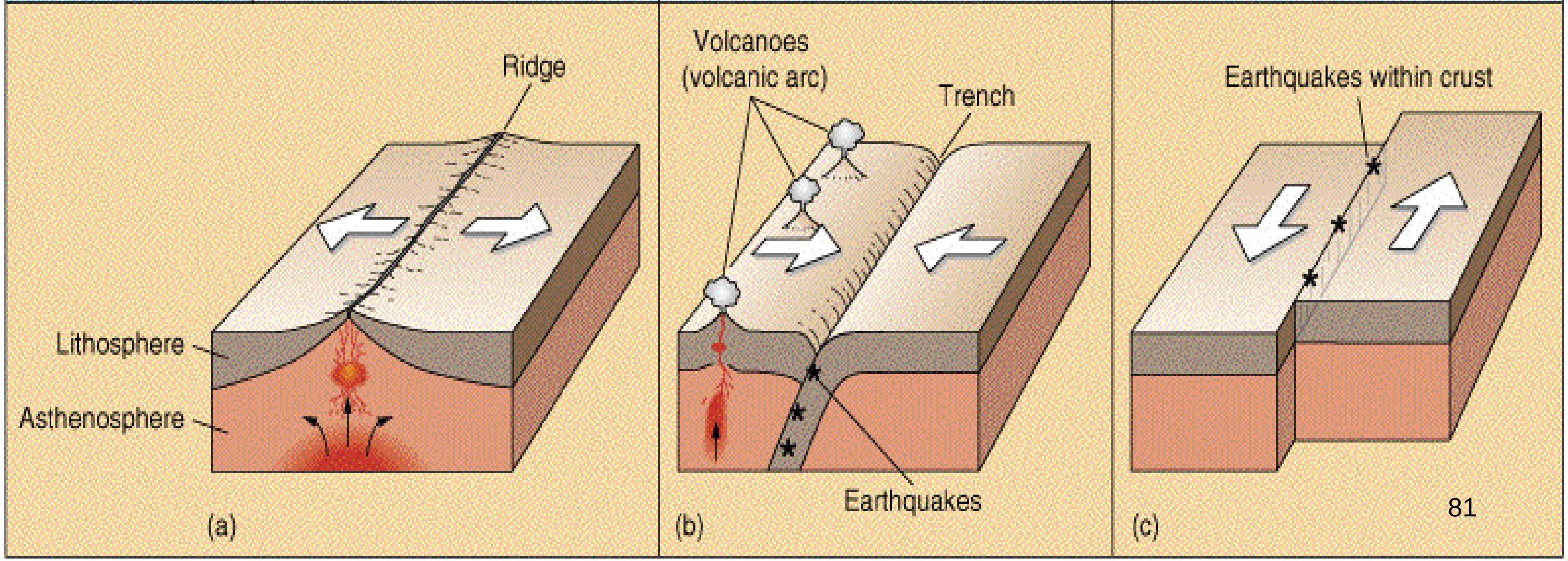

Source: USGS public domain

# Types of plate boundaries

- Divergent plate boundaries: where plates move apart
- Convergent Plate boundaries: where plates come together
- Transform plate boundaries: where plates slide past each other

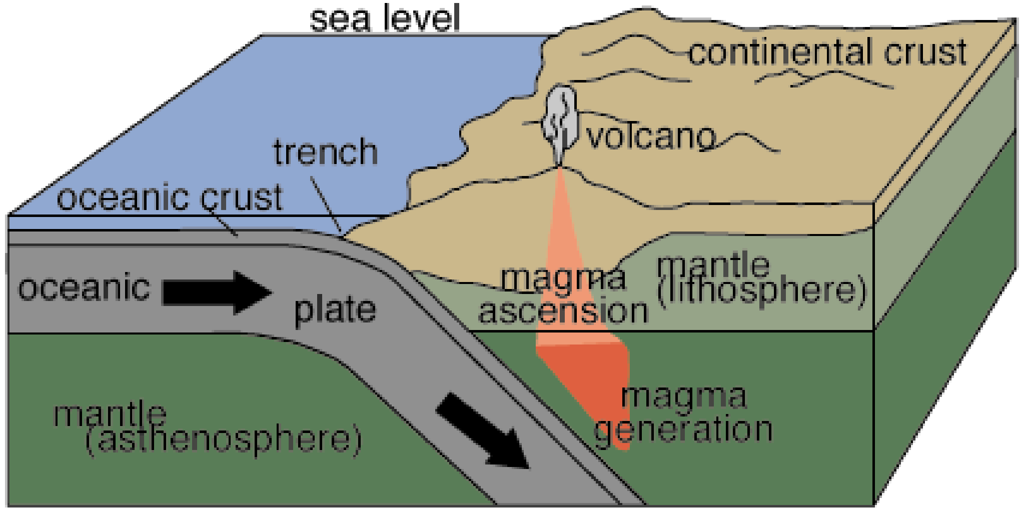
# Types of plate boundaries

| Type of Margin | Divergent | Convergent | Transform |
|---|---|---|---|
| **Motion** | Spreading | Subduction | Lateral sliding |
| **Effect** | Constructive<br>(oceanic lithosphere created) | Destructive<br>(oceanic lithosphere destroyed) | Conservative<br>(lithosphere neither created or destroyed) |
| **Topography** | Ridge/Rift | Trench | No major effect |
| **Volcanic activity?** | Yes | Yes | No |



# Ocean- Continent convergent margin

- Ocean-continent plates collide
- Ocean plate subducts below continent
- Forms a subduction zone
- Earthquakes and volcanoes

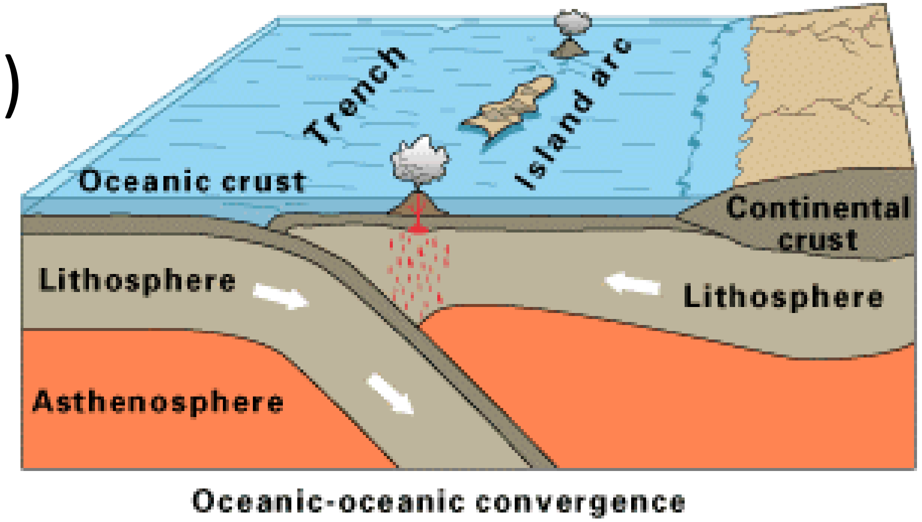



Magma is generated at subduction zones where dense oceanic plates are pushed under lighter continental plates.

Source: USGS public domain

# Ocean-ocean convergent margin

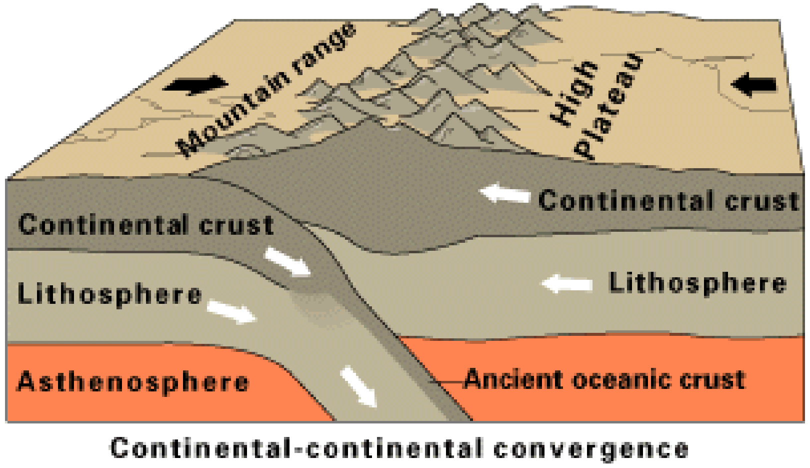
- 2 oceanic plates collide
- One plate dives (subducts) beneath other
- Forms subduction zone
- Earthquakes and volcanoes




Source: USGS public domain

# Continent-continent convergent margin

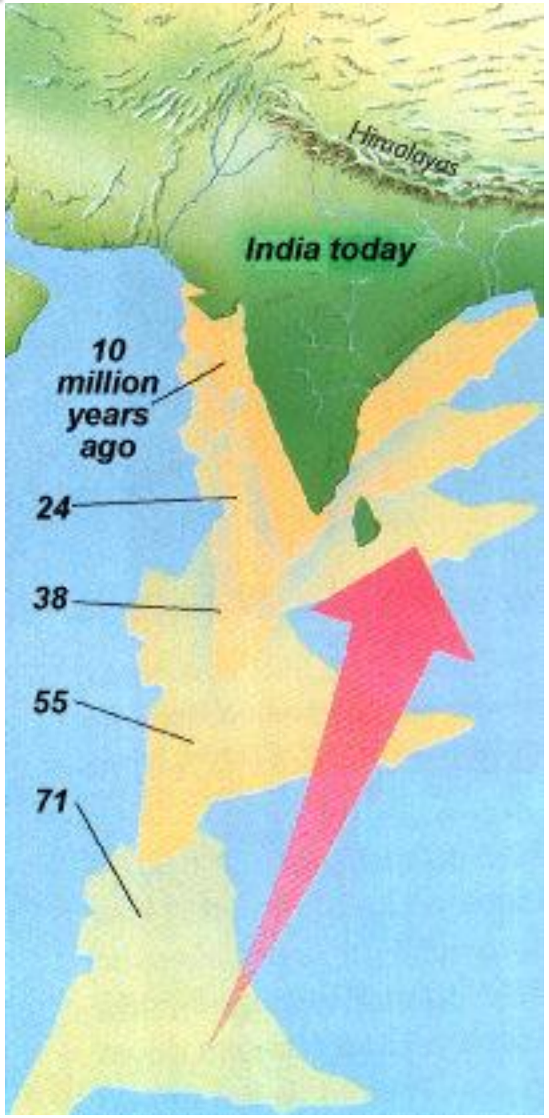
- Two continental plates collide
- Neither plate wants to subduct
- Collision zone forms high mountains
- Earthquakes, no volcanoes




Source: USGS public domain

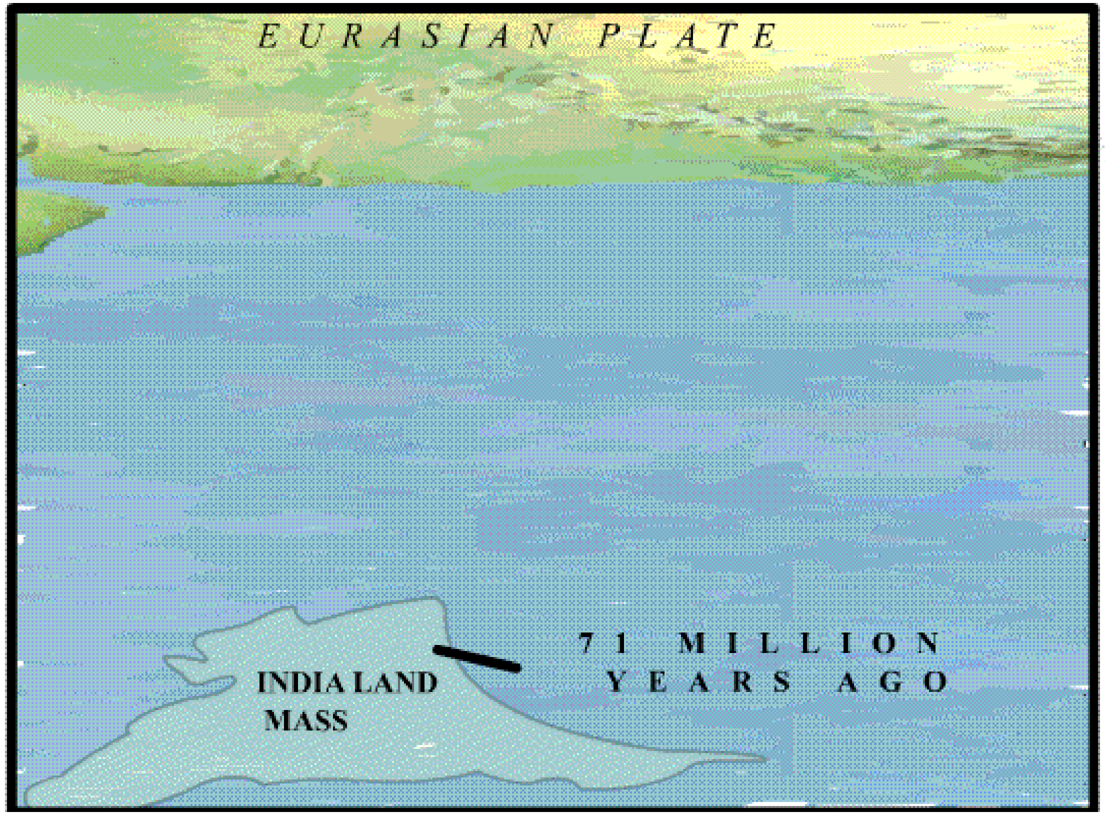
# Himalayas: Continent-continent convergent margin

Millions of years ago India and an ancient ocean called the Tethys were sat on a tectonic plate. This plate was moving northwards towards Asia at a rate of 10 centimeters per year. The Tethys oceanic crust was being subducted under the Asian Continent. The ocean got progressively smaller until about 55 milion years ago when India 'hit' Asia. Because both these continental landmasses have about the same rock density, one plate could not be subducted under the other. The pressure of the impinging plates was relieved by the formation of Himalayas



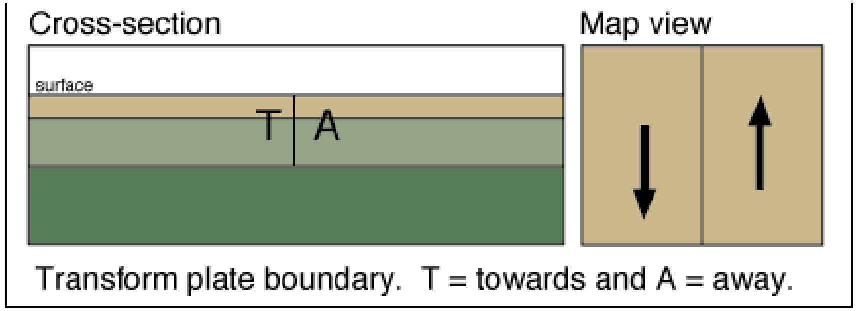

Source: USGS public domain

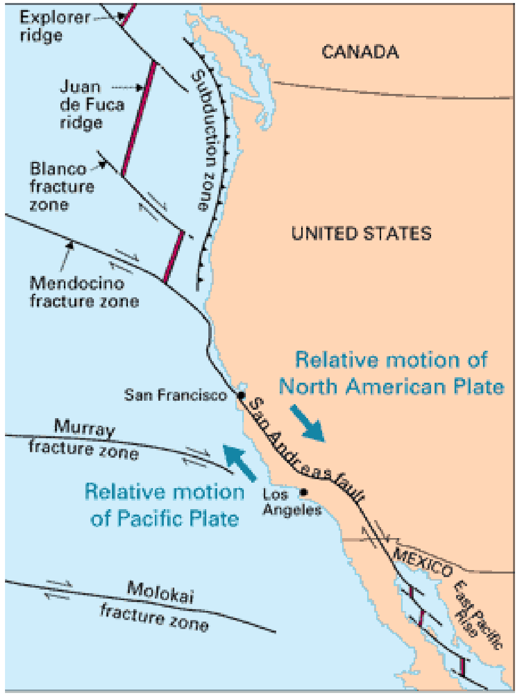
# Himalayas: Continent-continent convergent margin



# Transform plate boundary

- Two plates slide past each other
- Lithosphere is neither consumed nor destroyed.
- Earthquakes, no volcanoes
- Responsible for most of the earthquakes




Source: USGS public domain

# What drives plate movement?

For many years, it was believed that mantle convection is the main driving force for plate movement.

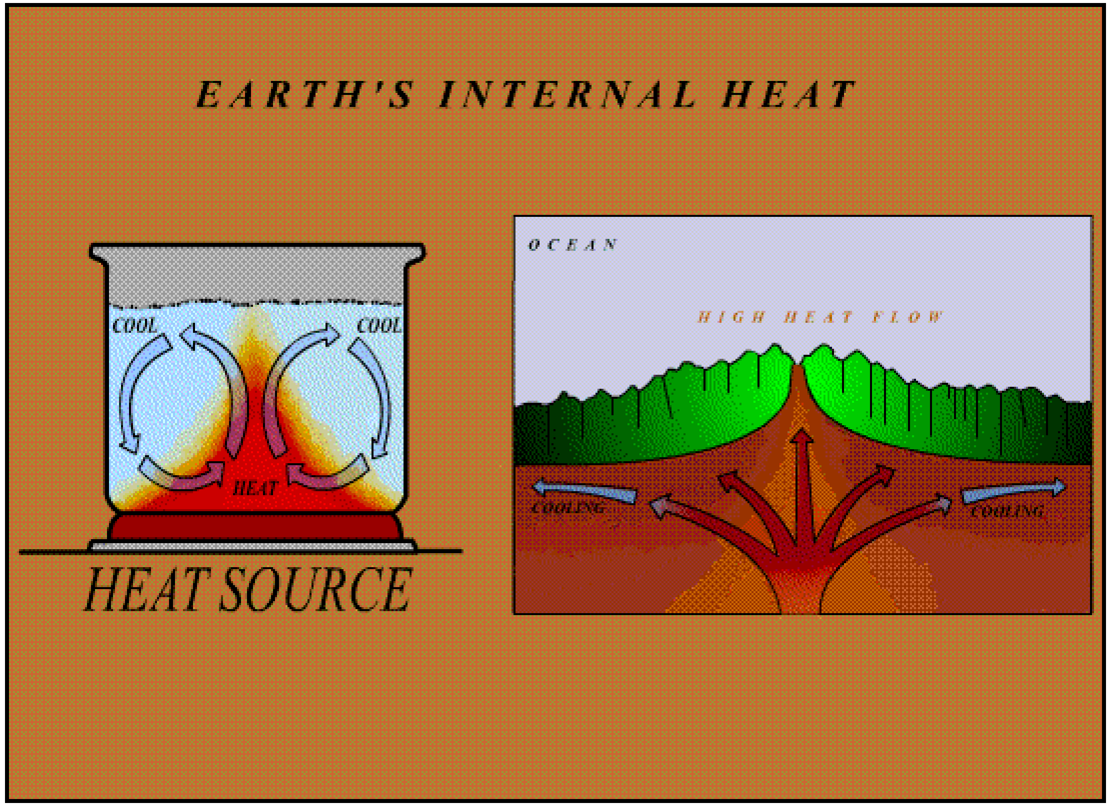
hot, less dense material rises along mid-ocean ridges, cools, and subsides at subduction zones, and the plates "ride" these convection cells

Recent modeling suggests that the force of convection is not enough to push enormous lithospheric plates (e g. North American plate). Geologists suggest that gravity is the main driving force

cold, dense oceanic crust sinks at subduction zones, pulling the rest of the plate with it. Magmatic intrusions at spreading ridges are passive - the magma merely fills a hole created by pulling two plates apart.

# Earth’s internal heat

- The Earth convects like a pot of water on a stove trying to dissipate heat.



# Seismicity of India

# Tectonic Provinces of India

The Indian landmass, covering an area of about 3.2 million sq km, has three broad morphotectonic provinces, namely

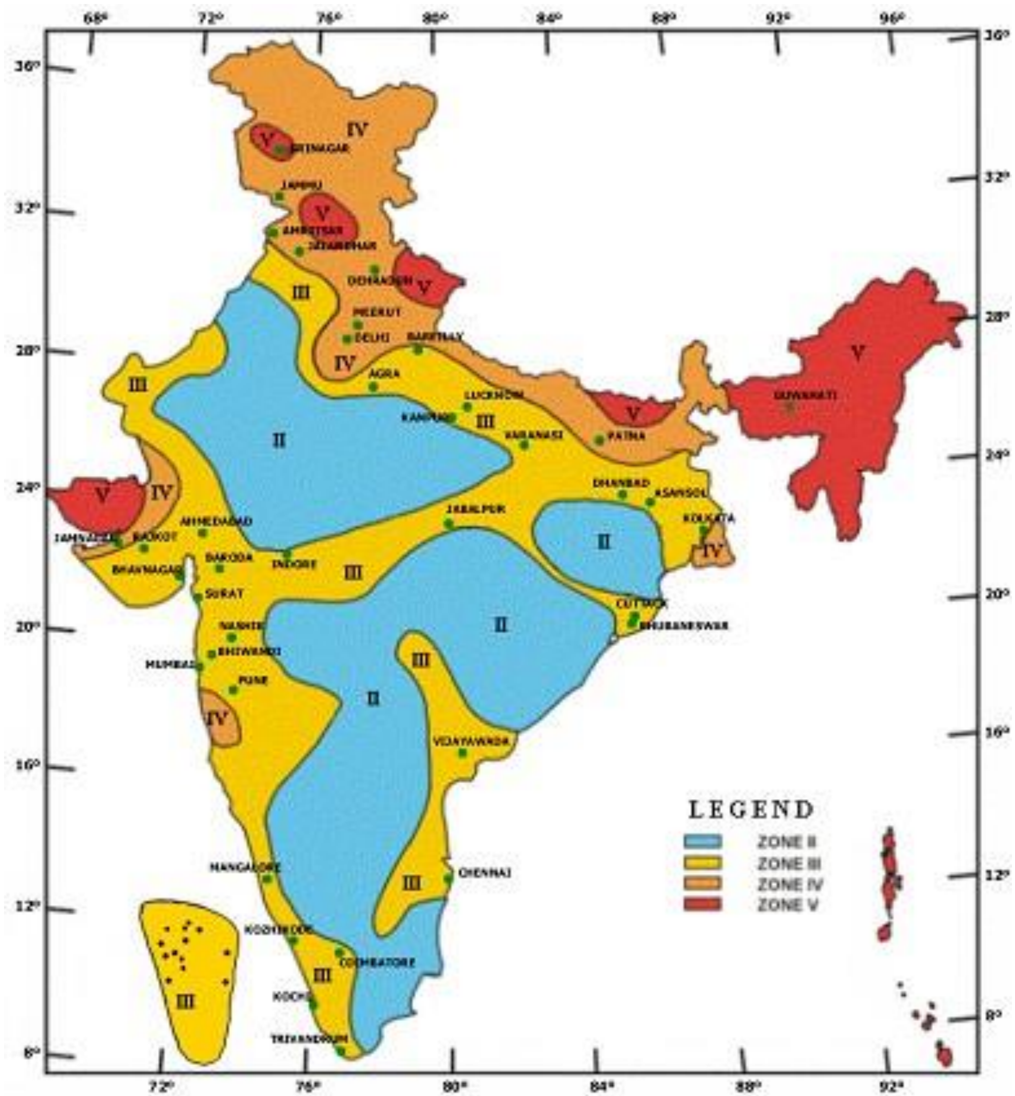
i) Himalaya and Tertiary mobile belt
ii) Indo-Gangetic foredeep
iii) Peninsular shield

All of these areas are characterized by distinctive stratigraphic, tectonic and deep crustal features.

The Himalaya marks the largest active continent-continent collision zone that has witnessed four great earthquakes in a short time span of 53 years between 1897 and 1950.

The Peninsular India is a mosaic of Archaean nucleus with peripheral Proterozoic mobile belts, Cretaceous volcanism and rift-drift Mesozoic passive coastal basins.

# Seismicity of India



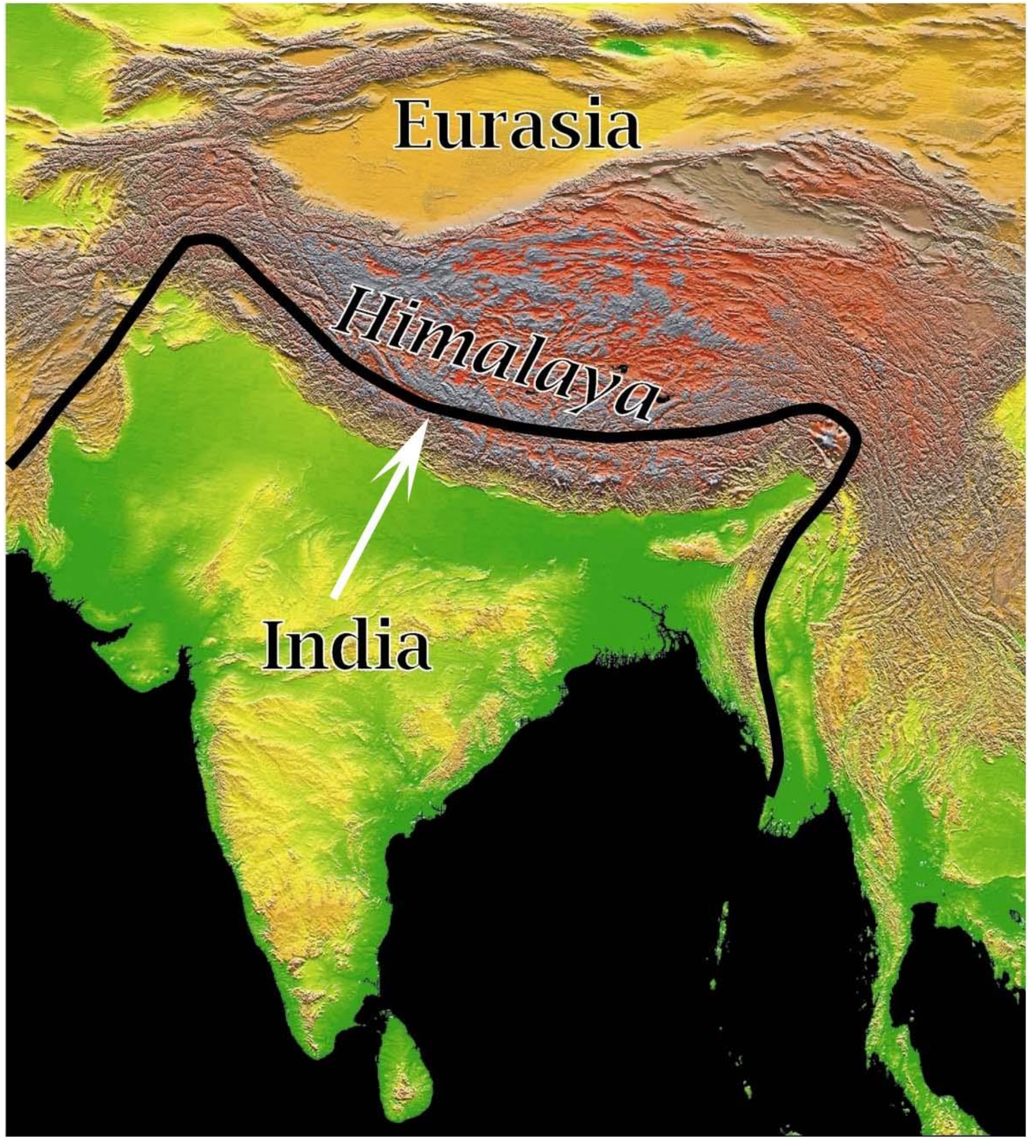

Zone V: Highest risk zone
Zone IV: High damage risk zone
Zone III: Moderate damage risk zone
Zone II : Low damage risk zone

IS 1893 (Part 1) 2002

# Seismicity of India

| Major & moderate earthquakes in India | | | | |
|---|---|---|---|---|
| DATE | EPICENTER | | LOCATION | MAGNITUDE |
| | Lat(Deg N) | Long(Deg E) | | |
| 1819 June 16 | 23.6 | 68.6 | KUTCH,GUJARAT | 8.0 |
| 1869 JAN 10 | 25 | 93 | NEAR CACHAR, ASSAM | 7.5 |
| 1885 MAY 30 | 34.1 | 74.6 | SOPOR, J&K | 7.0 |
| 1897 JUN 12 | 26 | 91 | SHILLONG PLATEAU | 8.7 |
| 1905 APR 04 | 32.3 | 76.3 | KANGRA, H.P | 8.0 |
| 1918 JUL 08 | 24.5 | 91.0 | SRIMANGAL, ASSAM | 7.6 |
| 1930 JUL 02 | 25.8 | 90.2 | DHUBRI, ASSAM | 7.1 |
| 1934 JAN 15 | 26.6 | 86.8 | BIHAR-NEPAL BORDER | 8.3 |
| 1941 JUN 26 | 12.4 | 92.5 | ANDAMAN ISLANDS | 8.1 |
| 1943 OCT 23 | 26.8 | 94.0 | ASSAM | 7.4 |
| 1950 AUG 15 | 28.5 | 96.7 | ARUNACHAL PRADESH-CHINA BORDER | 8.5 |
| 1956 JUL 21 | 23.3 | 70.0 | ANJAR, GUJARAT | 7.0 |
| 1967 DEC 10 | 17.37 | 73.75 | KOYNA, MAHARASHTRA | 6.5 |
| 1975 JAN 19 | 32.38 | 78.49 | KINNAUR, HP | 6.2 |
| 1988 AUG 06 | 25.13 | 95.15 | MANIPUR-MYANMAR BORDER | 6.6 |
| 1988 AUG 21 | 26.72 | 86.63 | BIHAR-NEPAL BORDER | 6.4 |
| 1991 OCT 20 | 30.75 | 78.86 | UTTARKASHI, UP HILLS | 6.6 |
| 1993 SEP 30 | 18.07 | 76.62 | LATUR-OSMANABAD, MAHARASHTRA | 6.3 |
| 1997 MAY 22 | 23.08 | 80.06 | JABALPUR, MP | 6.0 |
| 1999 MAR 29 | 30.41 | 79.42 | CHAMOLI DIST, UP | 6.8 |
| 2001 JAN 26 | 23.0 | 70.0 | BHUJ, GUJARAT | 7.6 |
| 2005 Oct 08 | 34.43°N | 73.54°E | KASHMIR | 7.6 |
| 2011 Sept 18 | 27.723°N | 88.064°E | SIKKIM | 6.9 |

# Movement of Indian Plate




Source: wikipedia

# India Colliding with Asia

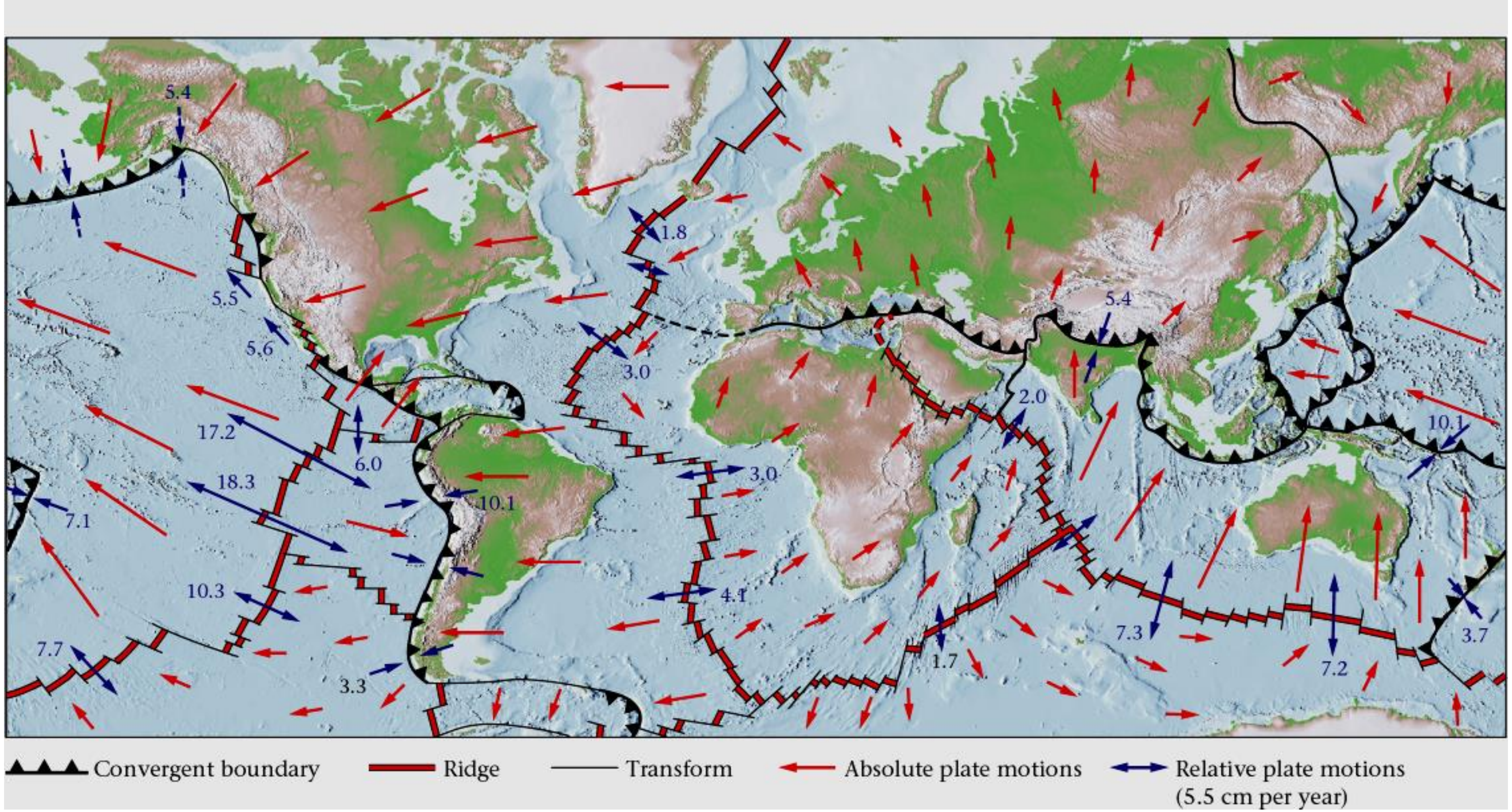
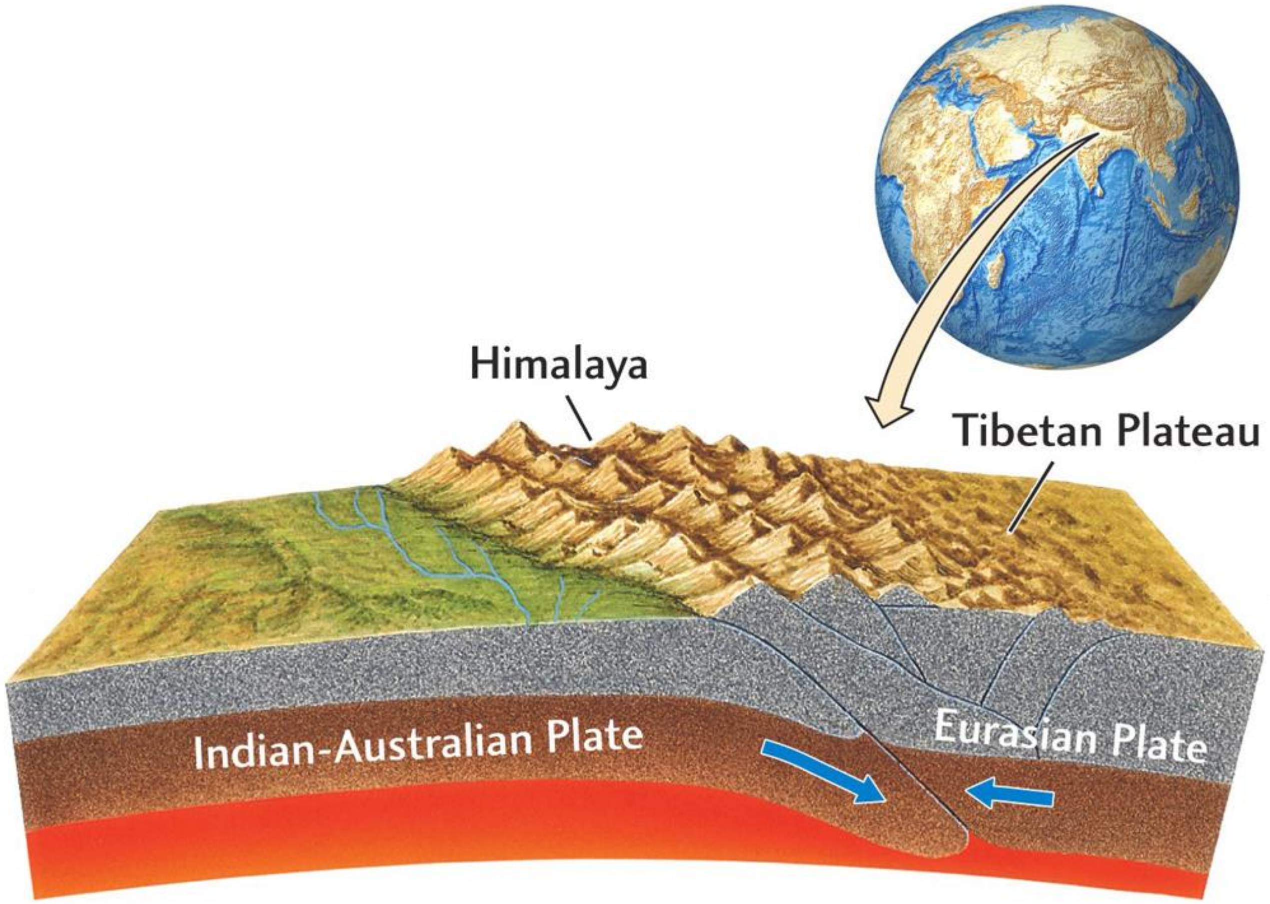



Fig: Plate tectonic Movements around the globe

Source: wikipedia

# Indian plate subducting

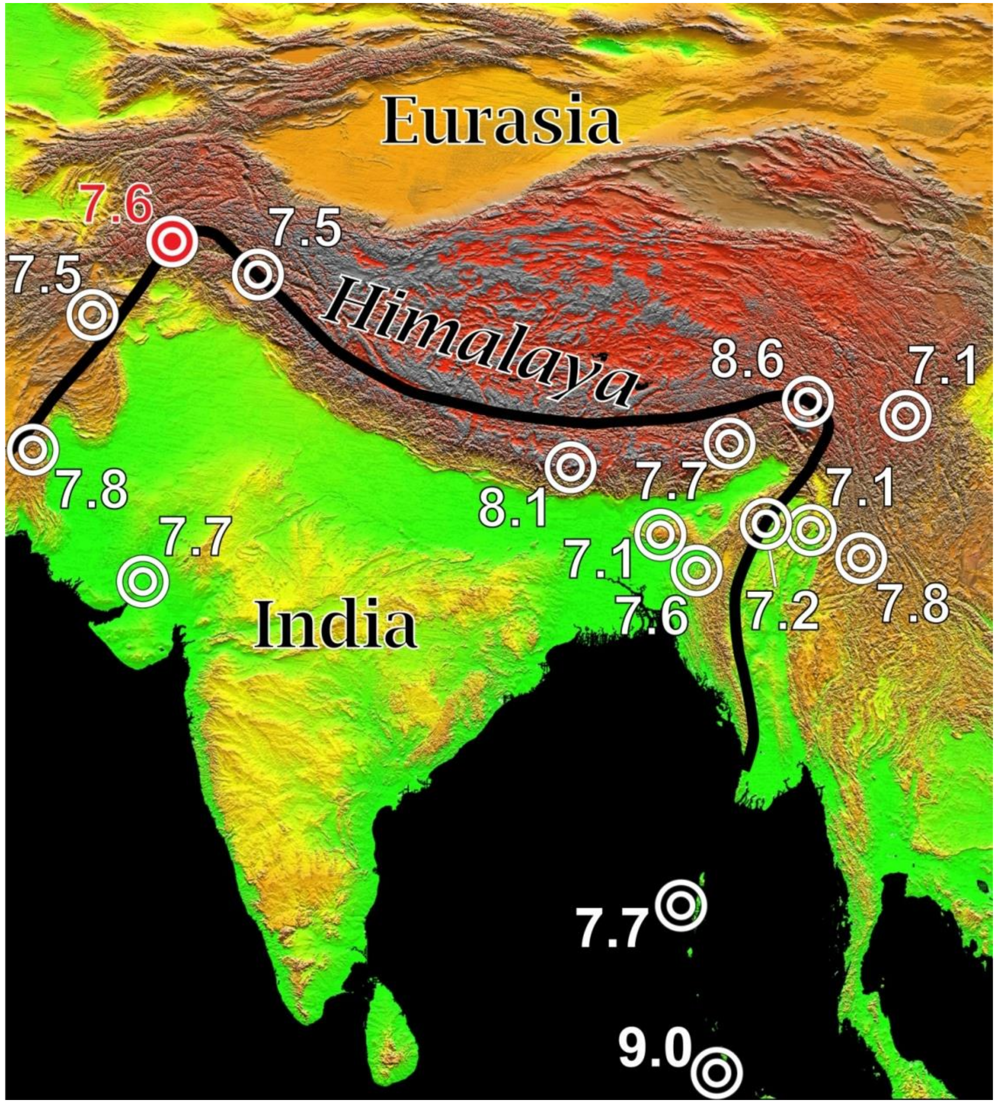



Source: wikipedia

# Movement of Indian Plate

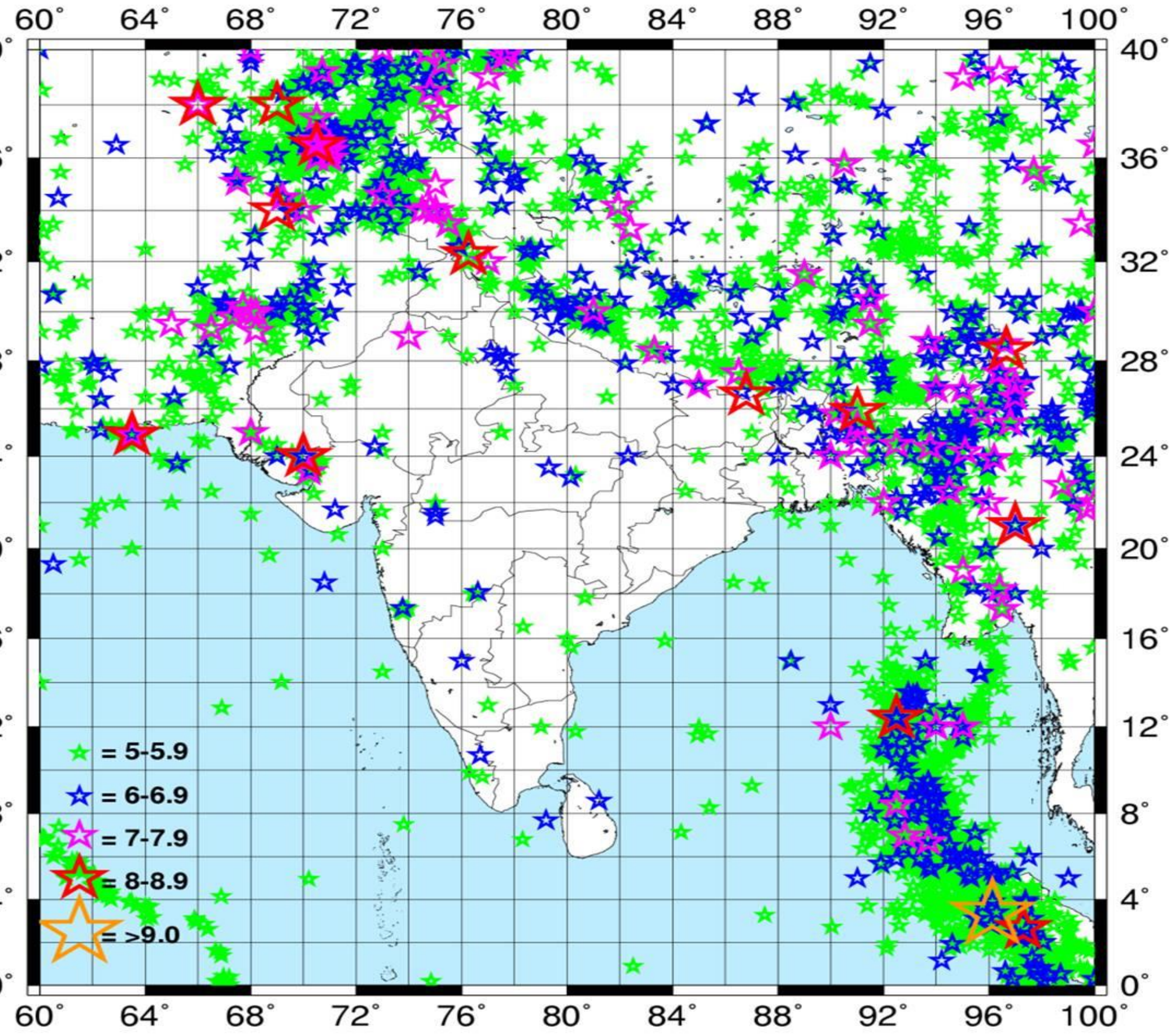
- Indian Plate is subducting beneath Eurasian Plate

- This is a convergent boundary, involving mountain building activity and seismicity.




Source: wikipedia

# Seismicity of India




**(1505 to March,2010) (M>5.0)**

Distribution of earthquakes in India. Source: India Meteorological Department (IMD)

1897 Shillong

Source: Encyclopedia (Global Earthquakes)

1905 Kangra

1934 Bihar-Nepal

Source: Bihar State Disaster Management Authority

2005 Kashmir

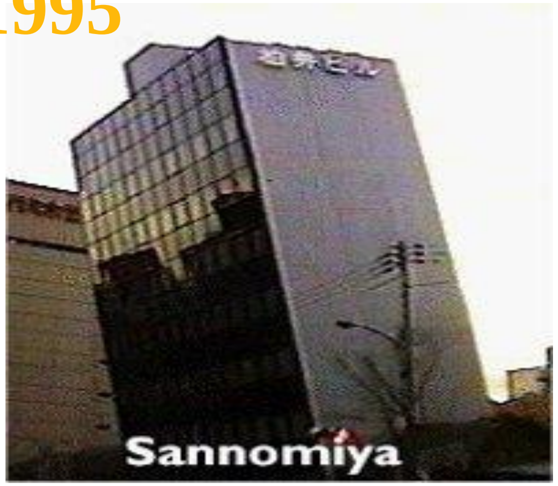
# Damages due to local site effects and liquefaction in earthquakes


Earthquake Damage in Mexico City, Mexico, September 19, 1985 - resonance

Million Dollar Bridge after 1964 Alaska earthquake


Showa Bridge after 1964 Niigata earthquake

1995




Building in Kobe after 1995 earthquake


Bridge in Taiwan after 1999 Chi-Chi earthquake


Kandla port building after 2001 Bhuj earthquake

The effect of the subsoils on the earthshaking and building damage is emphasized.

# Earthquake Doesn't Kill People... Buildings do.

Many deaths and injuries in earthquakes result from collapse of structures.

Solution lies in "buildings"
And not in "earthquakes" as such

*How one can actually minimize the risks, and at the end, what really matters would not be the emergency response after so many lives were taken, but how to secure the lives and the properties from the hazards...i.e. "Engineering preparedness ..."*

**Evaluation of Hazard is the KEY**

# Long Term Human Response to Earthquakes

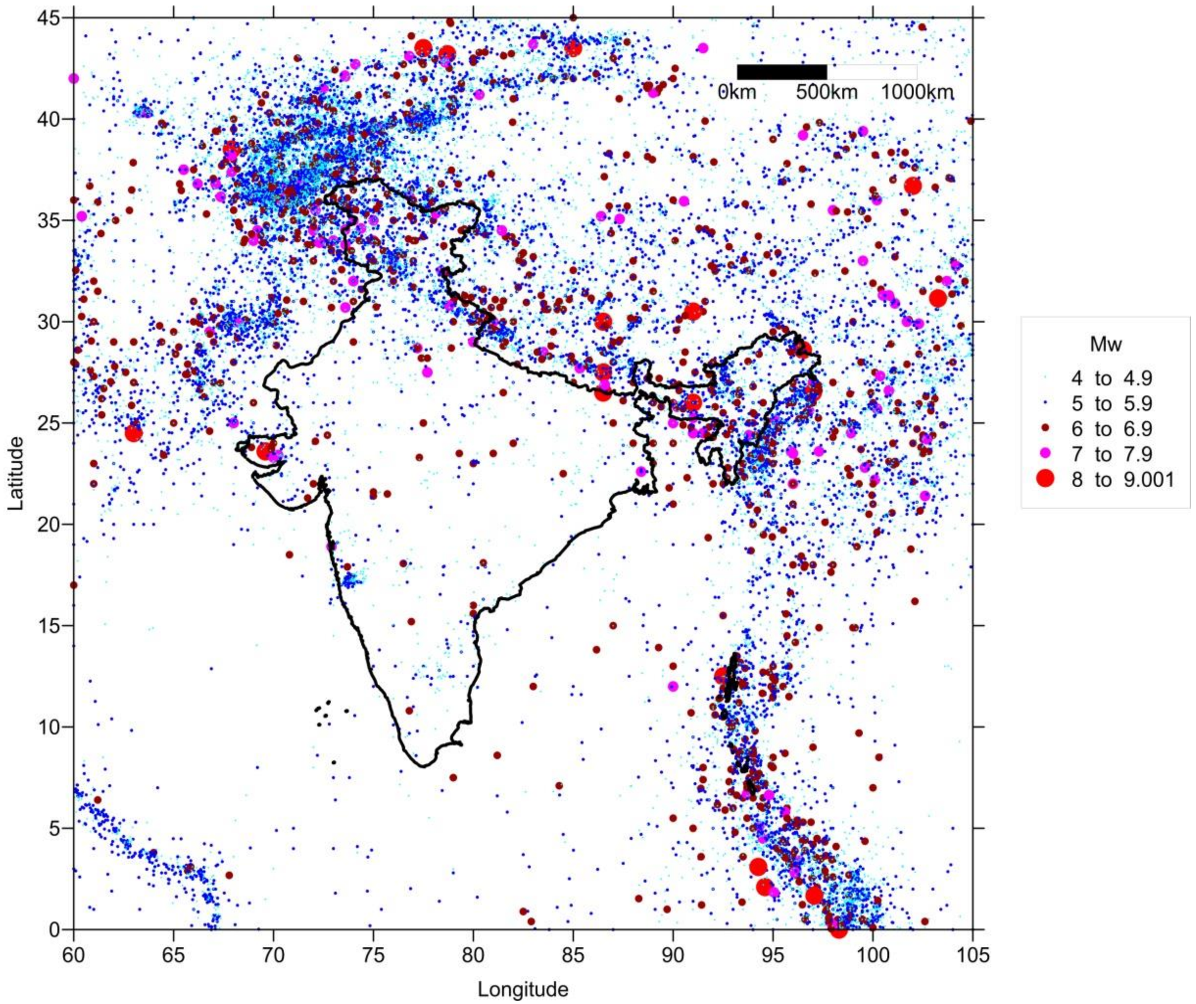
**(Key, 1988)**

| Stage | Time | Event | Reaction | |
|---|---|---|---|---|
| | | | Positive | Negative |
| 1 | 0-1min | Major EQ | | Panic |
| 2 | 1min to 1week | Aftershocks | Rescue and Survival | Fear |
| 3 | 1week to 1month | Diminishing Aftershocks | Short Term repairs | Allocation of blame to builders, designers, officials, etc |
| 4 | 1month to 1year | | Long term repairs, Action for higher standards | |
| 5 | 1year to 10years | | | Diminishing interest |
| 6 | 10yrs to next EQ | | | Reluctance to meet costs of seismic provisions, etc., Increasing non-compliance with regulations |
| 7 | The next EQ | Major EQ | Repeat stages 1-7 | |

**Community Preparedness**

# Earthquakes in India

- Collision of Indo-Australian plate to Eurasian plate is a region of greatest continental tectonic deformation in the world
- 15% of great earthquakes ( M 8.0) in the 20th Century
- Assam EQ =8.5 – 7th largest
- Major earthquakes are at plate boundaries, intraplate, and along known faults

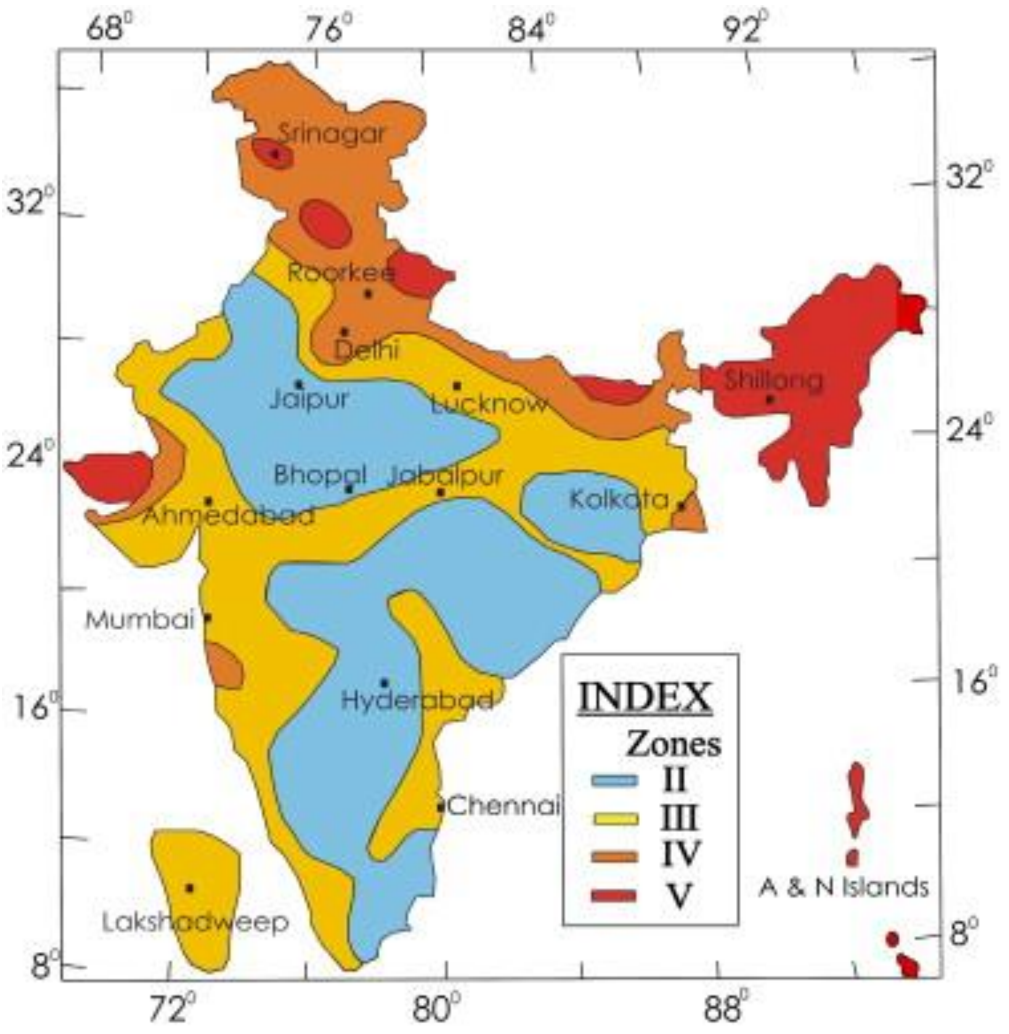



Kolathayar S and Sitharam T G (2012)

# List of Major Earthquakes in India in Last 100 years

| Date | Event | Time | Magnitude | Max. Intensity | Deaths |
|---|---|---|---|---|---|
| 12 June 1897 | Assam | 16:25 | 8.7 | XII | 1500 |
| 8 Feb. 1900 | Coimbatore | 03:11 | 6.0 | X | Nil |
| 4 Apr. 1905 | Kangra, Himachal Pradesh | 06:20 | 8.6 | X | 19,000 |
| 15 Jan. 1934 | Bihar-Nepal | 14:13 | 8.4 | X | 11,000 |
| 31 May 1935 | Quetta | 03:03 | 7.6 | X | 30,000 |
| 15 Aug. 1950 | Assam | 19:31 | 8.5 | X | 1,530 |
| 21 Jul. 1956 | Anjar | 21:02 | 7.0 | IX | 115 |
| 10 Dec. 1967 | Koyna | 04:30 | 6.5 | VIII | 200 |
| 23 Mar. 1970 | Bharuch | 20:56 | 5.4 | VII | 30 |
| 21 Aug. 1988 | Bihar-Nepal | 04:39 | 6.6 | IX | 1,004 |
| 20 Oct. 1991 | Uttarkashi, Uttranchal | 02:53 | 6.6 | IX | 768 |
| 30 Sep. 1993 | Killari (Latur) | 03:53 | 6.4 | IX | 7,928 |
| 22 May 1997 | Jabalpur, Madhya Pradesh | 04:22 | 6.0 | VIII | 38 |
| 29 Mar. 1999 | Chamoli, Uttranchal | 12:35 | 6.8 | VIII | 63 |
| 26 Jan. 2001 | Bhuj, Gujarat | 08:46 | 7.7 | X | 13,805 |
| 08 Oct 2005 | India-Pakistan | 09.20 | 7.4 | X | 20,600 |

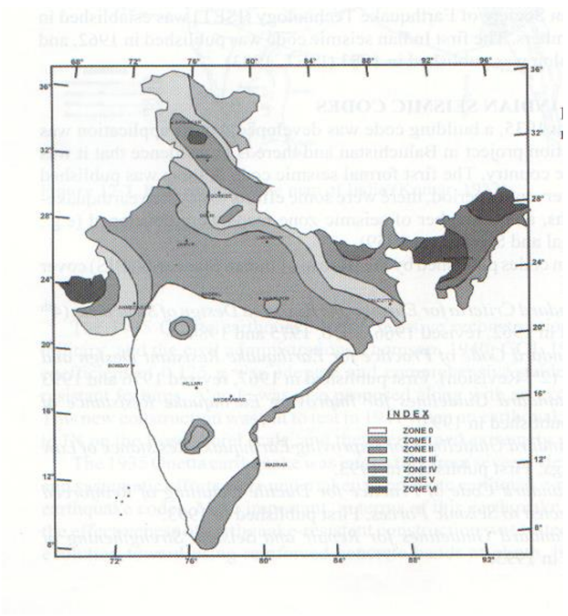
EQ's happened both at plate boundaries and intra plate (in the shield region)




Map showing the four seismic zones of India (after BIS: 1893 (Part 1), 2016).

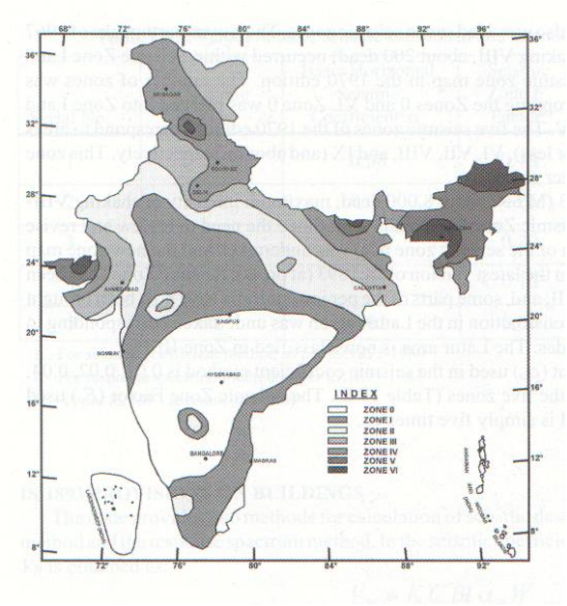
# Development of Seismic Zonation Map (BIS-1893)

1962



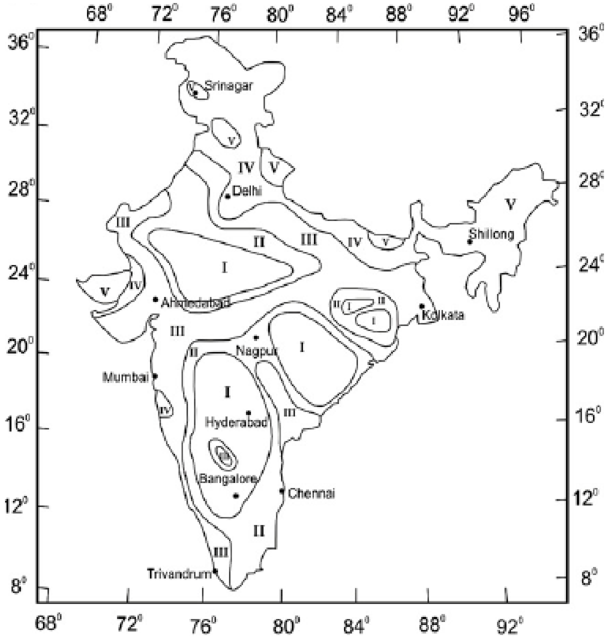

Based on EQ epicenters

1966



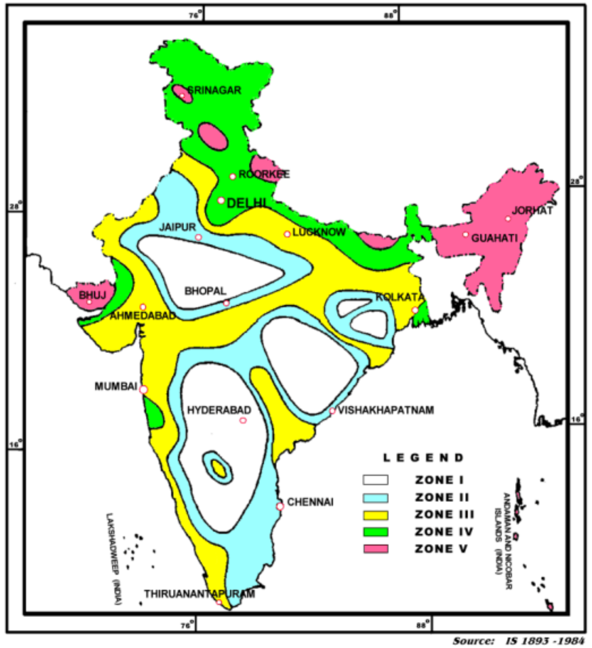

Geology and tectonic features

1970



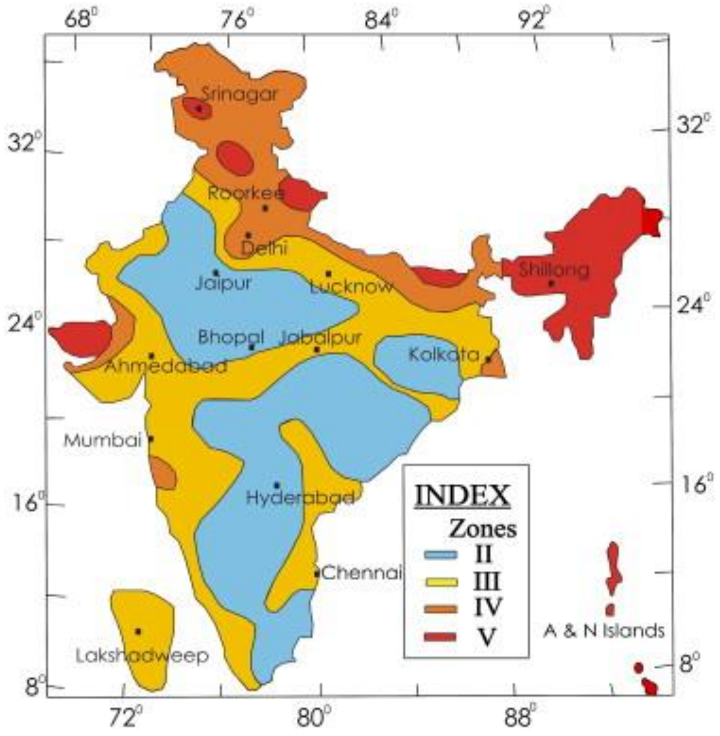

After 1967 Koyna Earthquake.

1984




Past EQs and Regional tectonics.

- The occurrence of the 1993 Latur earthquake followed by the destructive earthquakes of 1997 Jabalpur and 2001 Bhuj raised questions on the validity of the seismic zonation map.
- This further led to the revision of the seismic zonation map and in 2002, only four zones were identified: II, III, IV and V




Seismic zonation map of India (BIS, 2002)

- BIS-1893 delineates different seismic zones entirely based on geology & past seismic activity and is getting revised from time to time, after major earthquakes.
- "Indian standard in its current form does not provide a quantified seismic hazard for each region, but lumps large part of the country into unstructured regions of equal hazard." - Raghu Kanth and Iyengar, 2006)

# Earthquake Data

The historic earthquake data were compiled from the work of various researchers

- Dunbar et al 1992
- Oldham 1883
- Basu 1964
- Kelkar 1968;
- Tandon and Srivastava 1974;
- Rastogi 1974;
- Chandra 1977, 1978;
- Kaila and Sarkar 1978;
- Rao and Rao 1984;
- Srivastava and Ramachandran 1985
- Biswas and Dasgupta 1986
- Guha and Basu 1993
- Bilham, R. 2004 etc.

# Instrumental Data

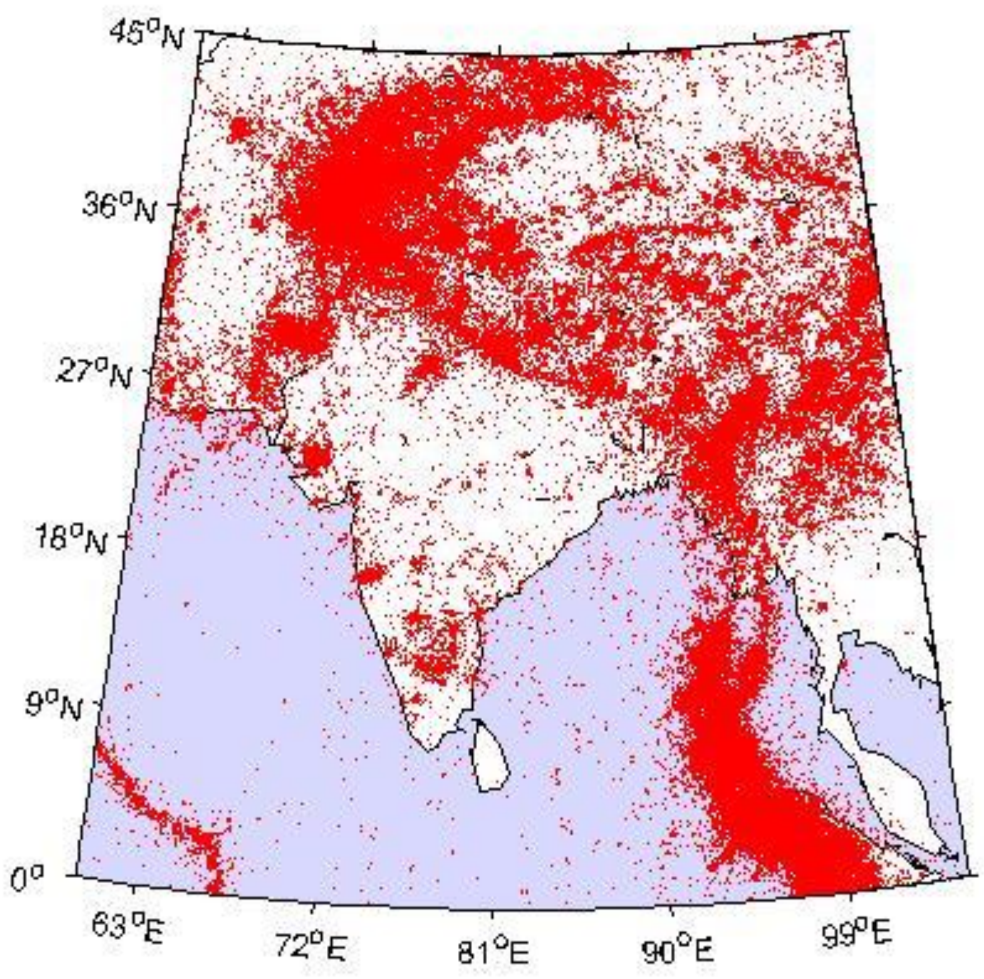
NATIONAL AGENCIES

- Guaribidanur Array (GBA)
- Indian Meteorological Department (IMD)
- Indira Gandhi Centre for Atomic Research (IGCAR) Kalpakkam
- National Geophysical Research Institute (NGRI) Hyderabad.

INTERNATIONAL AGENCIES

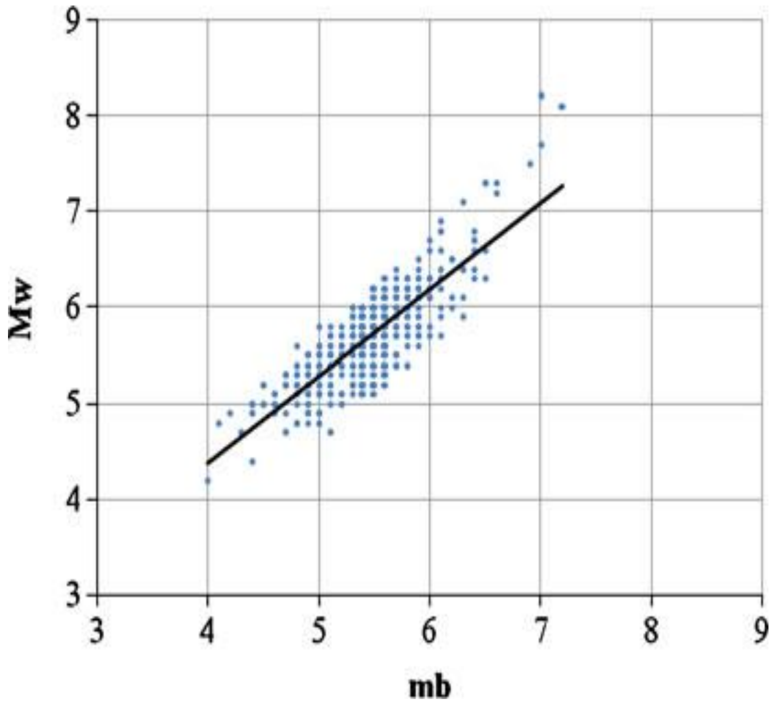
- International Seismological Center (ISC) data file (for the time period between 1964 and 2010),
- Harvard seismology
- USGS/NEIC catalog (for the time period between 1973 and 2010).

**Spatial distribution of the epicenters of earthquake events for the period from 250BC to 2010AD - Data compiled from 21 sources**

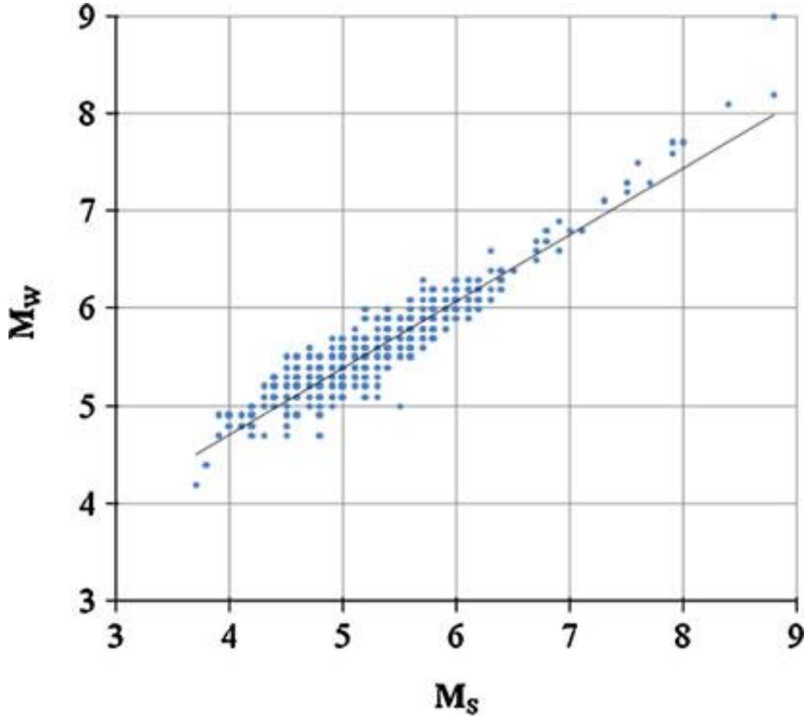



Kolathayar et al. (2012). Spatial variation of seismicity parameters across India and adjoining areas. Natural Hazards (Springer) 60 (3), 1365-1379. IF: 1.9, Citations: 16

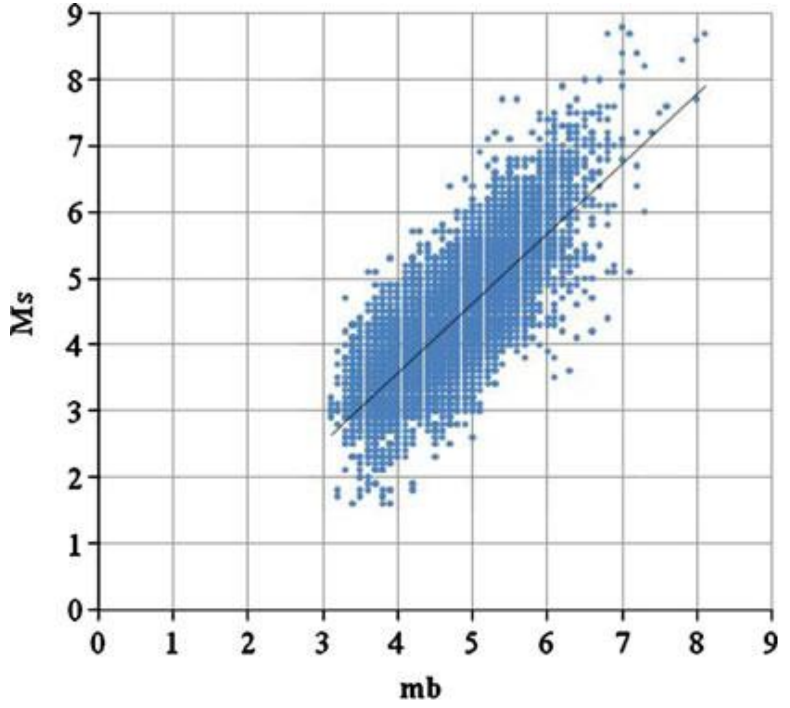
# Region Specific Magnitude Conversion Relations




$M_W = 1.08(\pm0.0152)m_b - 0.325(\pm0.081)$
$R^2 = 0.732$, n = 1,850



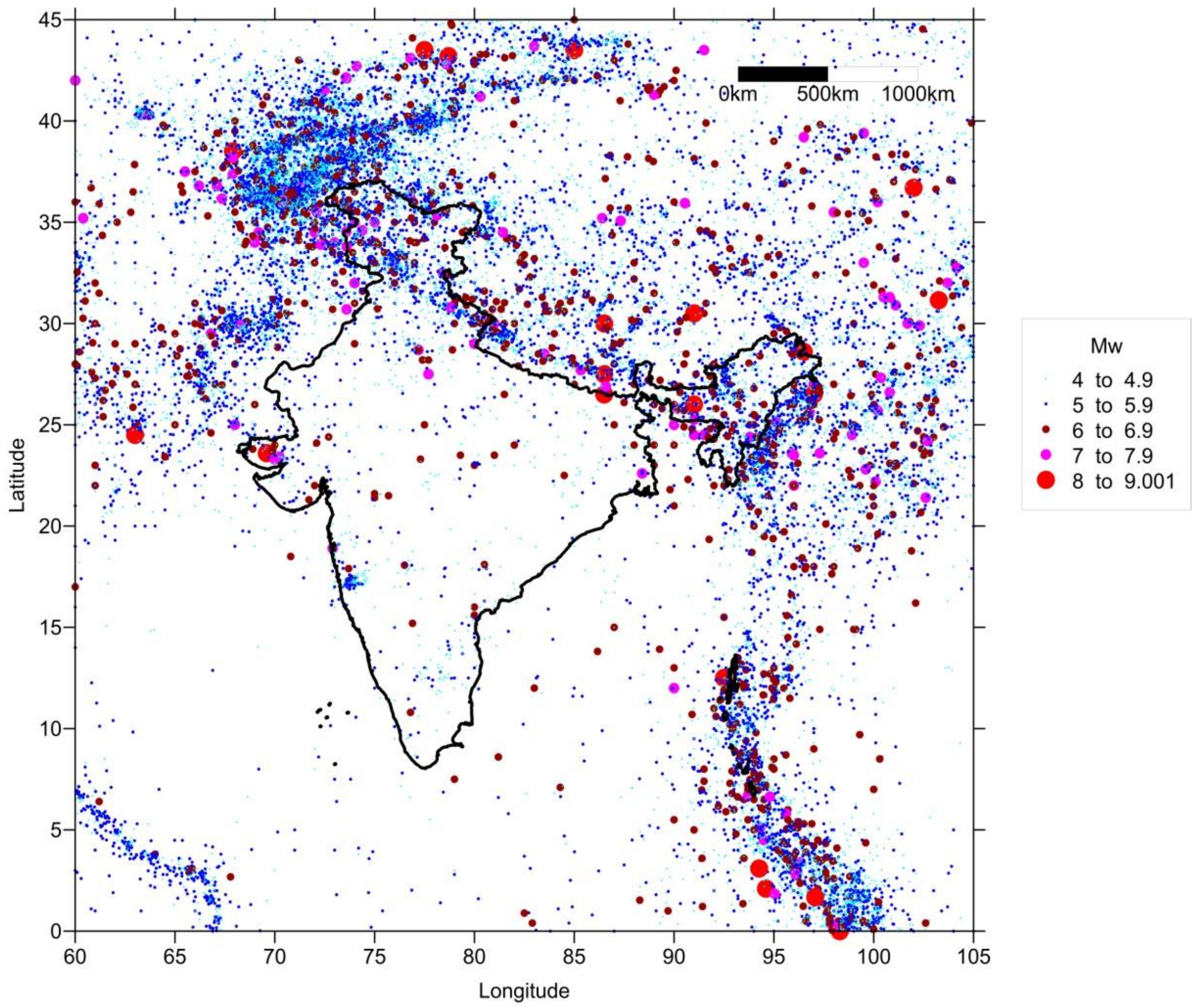

$M_W = 0.681(\pm0.010)M_S + 1.993(\pm0.053)$
$R^2 = 0.893$, n = 1,254



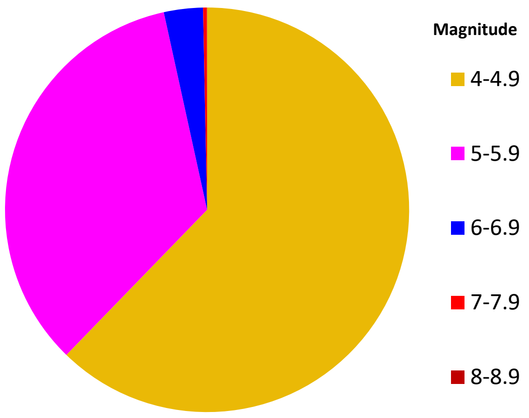

$M_S = 1.057(\pm0.006)m_b – 0.649\ (\pm0.028)$
$R^2 = 0.659$, n = 16,734

Kolathayar S and Sitharam T G (2012) Characterization of Regional Seismic Source Zones in and around India.
**Seismological Research Letters** (Seismological Society of America) 83(1) 77-85. (IF: **3.78**) **Citations: 19**

# Distribution of Earthquake events in and around India

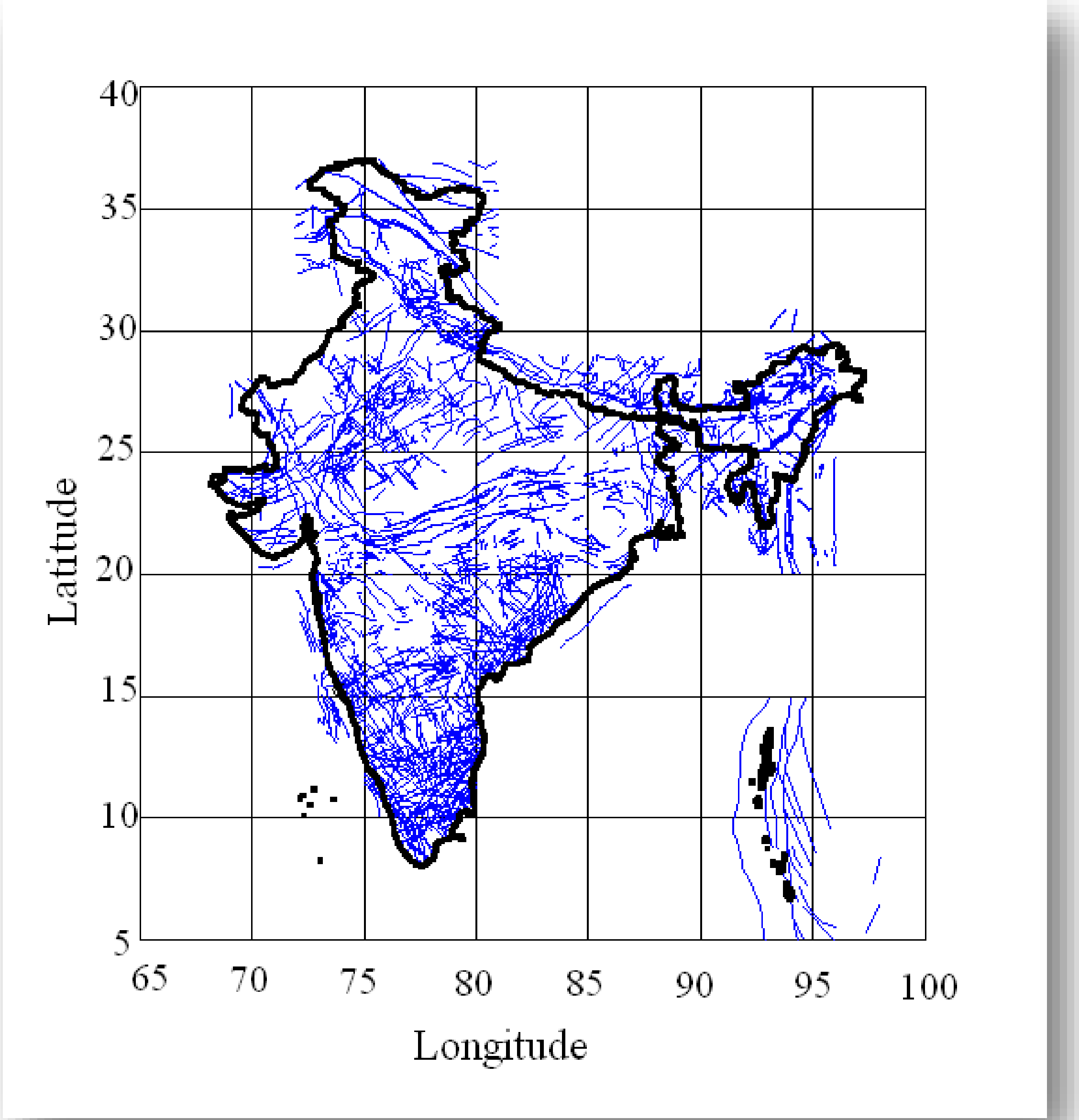


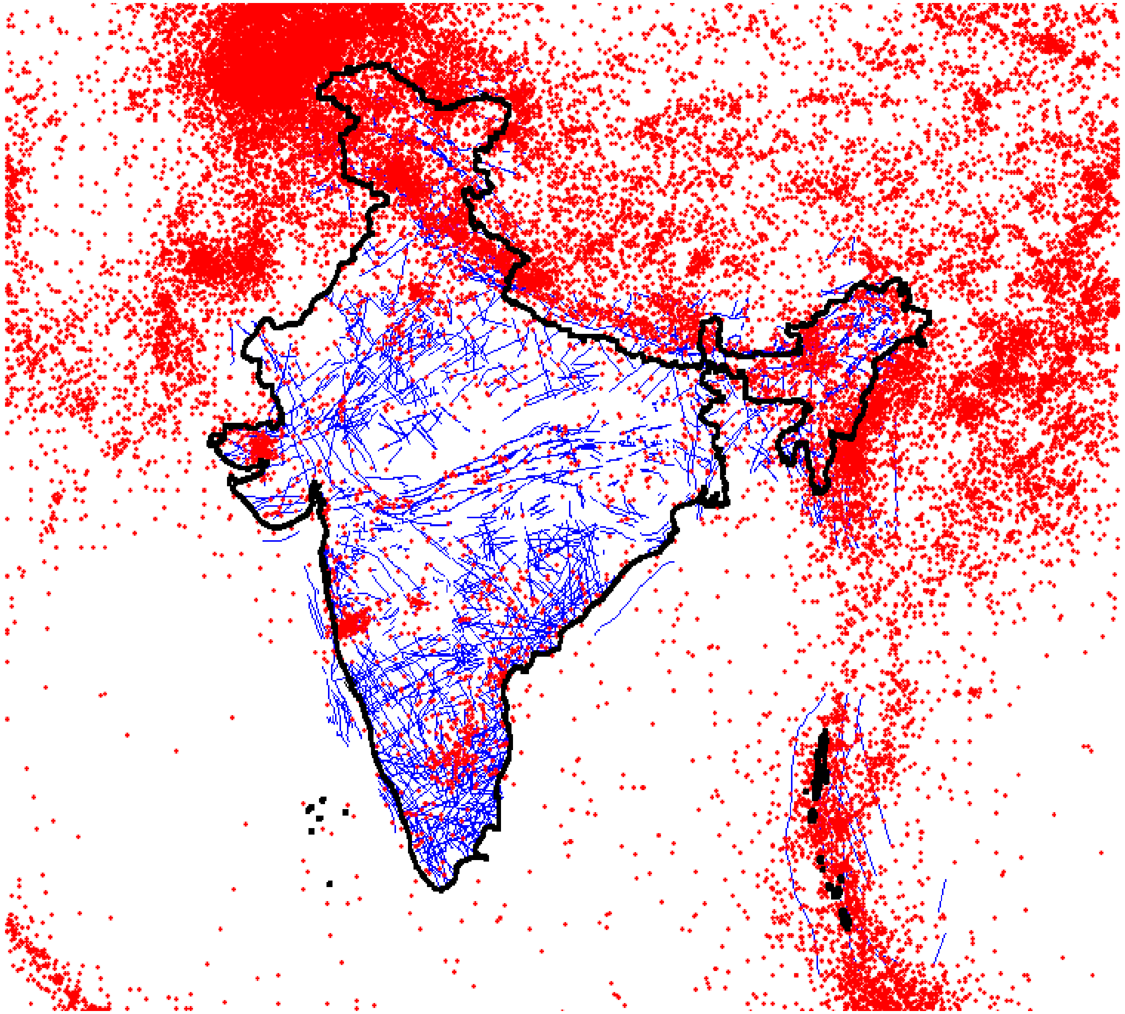

Map generated with 27146 independent Earthquake events (Mw≥4)




| Magnitude ($M_W$) | No. of events |
|---|---|
| 4 – 4.9 | 16079 |
| 5 - 5.9 | 9879 |
| 6 – 6.9 | 1036 |
| 7 – 7.9 | 129 |
| 8 - 9 | 22 |

Kolathayar S and Sitharam T G (2012) Characterization of Regional Seismic Source Zones in and around India. **Seismological Research Letters** (Seismological Society of America) 83(1) 77-85. (IF: 3.78)

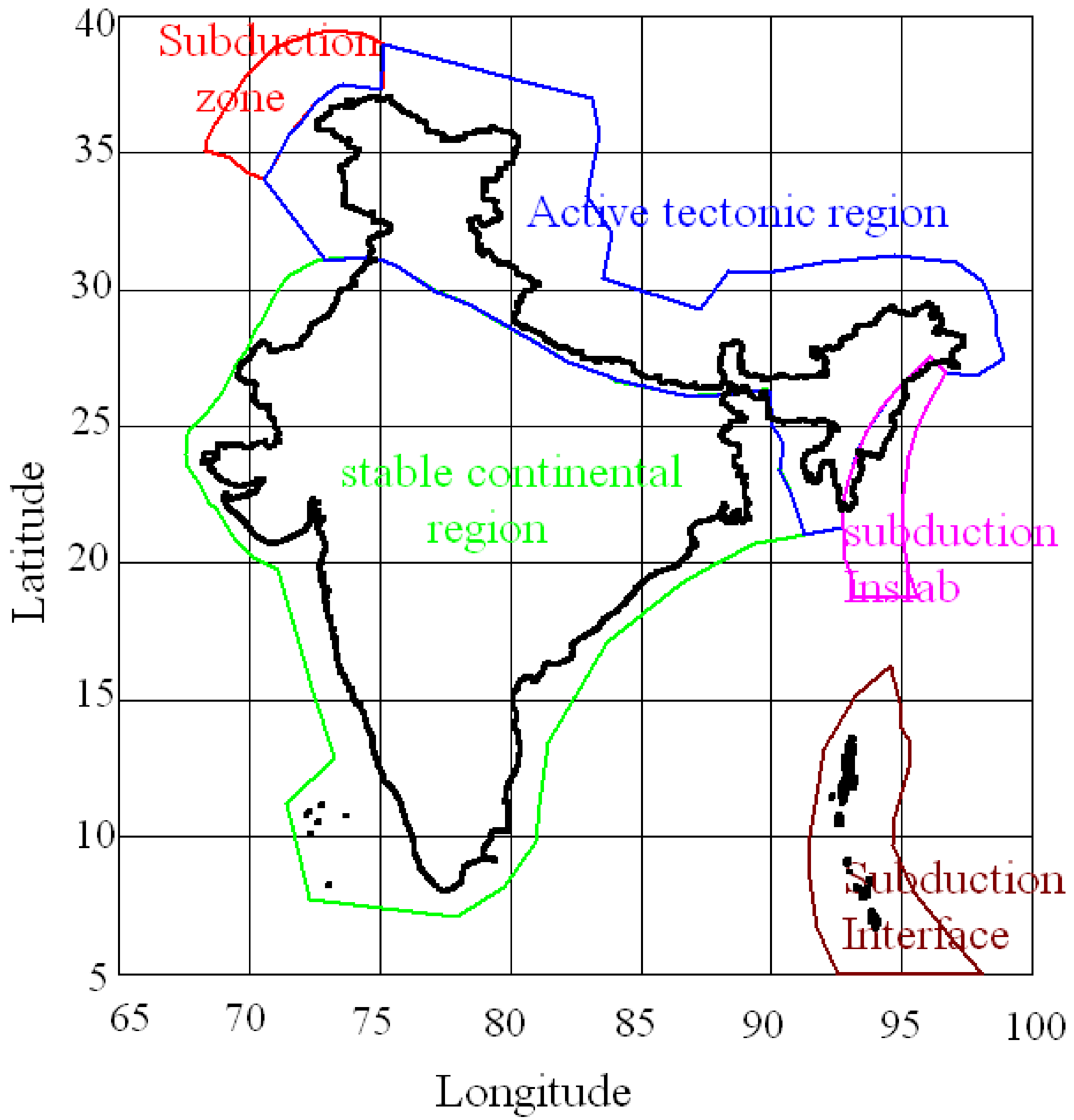


Linear seismic sources identified in India (after SEISAT, 2000) completely digitized

Kolathayar et al. (2012) Deterministic Seismic Hazard Macrozonation of India. **Journal of Earth System Sciences (Springer)** 121(5). 1351–1364. **Citations: 18**

# Tectonic provinces in and around India

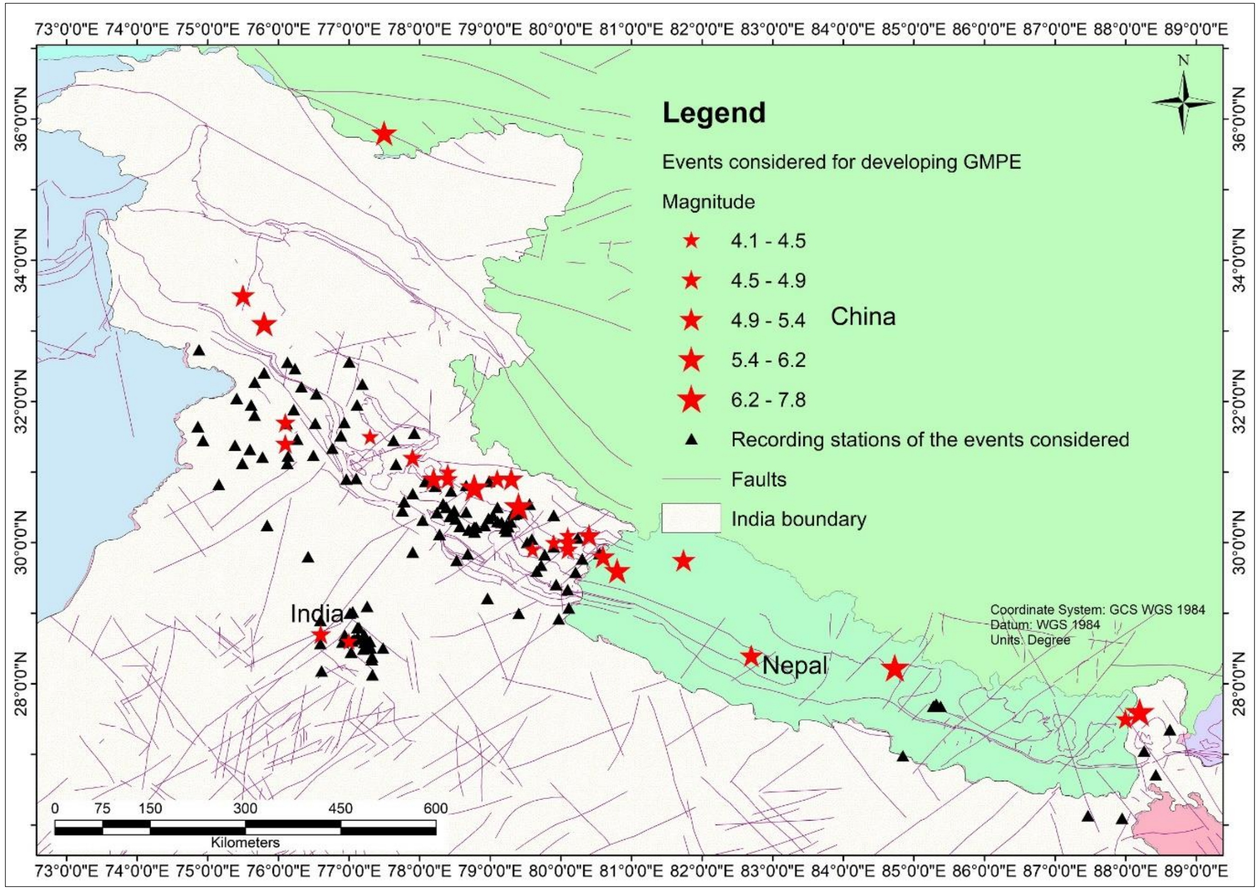



After Nath et al., 2010 and Kolathayar et al., 2012

# Ground motion Attenuation

## National Strong Motion Instrumentation Network of India

IIT Roorkee, between 1985 and 1991 deployed 135 analog strong motion accelerographs in the Himalayas forming three strong motion arrays: UP array, Kangra array and Shillong array. Later a total of 280 digital seismographs covering the Northern and Central Himalayas, NE Himalayas and the Delhi region.

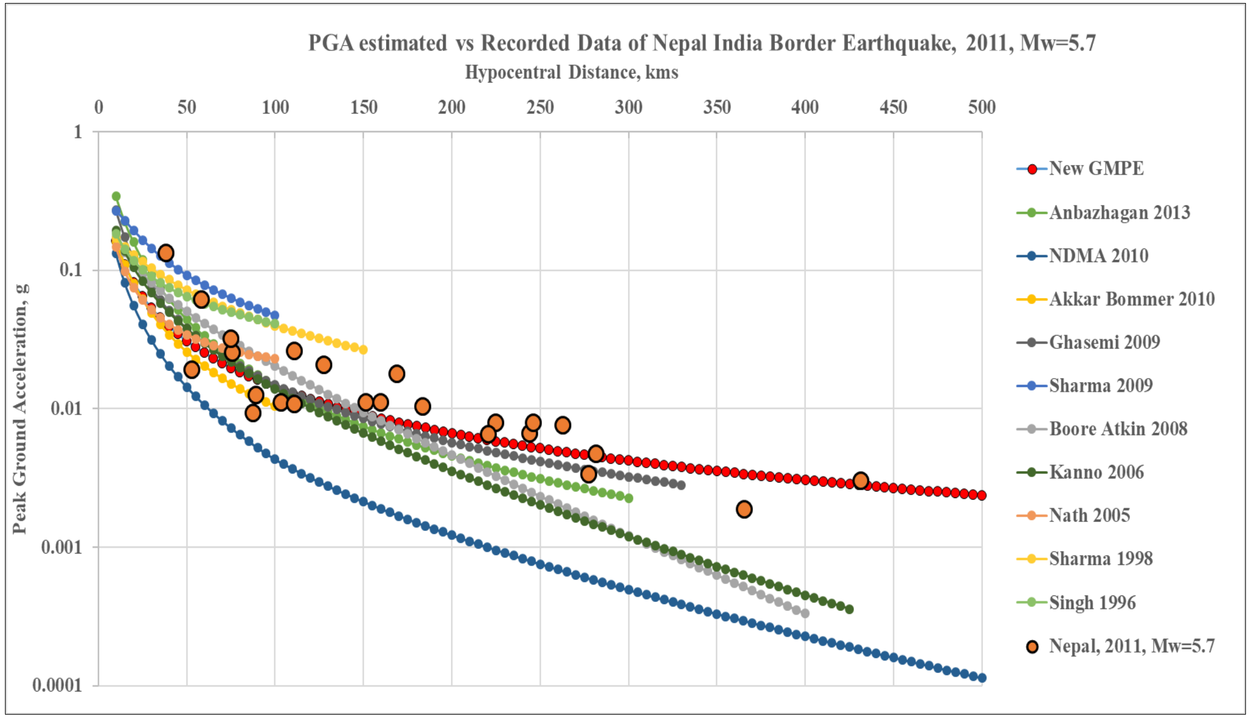



- Seismotectonic map of the Himalayas showing seismic sources, recording stations and events considered

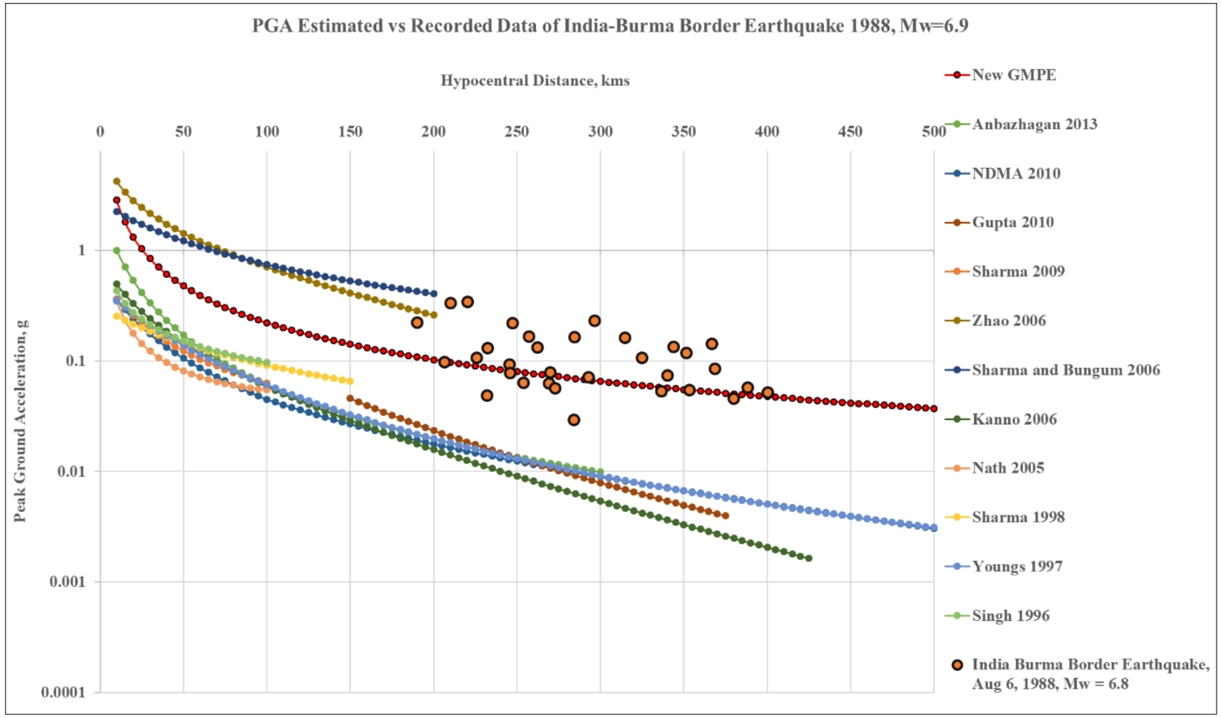
Data Sources: PESMOS, CESMD, COSMOS

# Development of GMPE for Himalayas and NE

- GMPE for North and Central Himalayas: $\log Y = -2.097 + 0.443M - 1.13 \log (X + e^{0.110M}) \pm 0.549$
- GMPE for North East Himalayas: $\log Y = -2.415 + 0.577M - 1.11 \log (X + e^{-1.057M}) \pm 0.480$



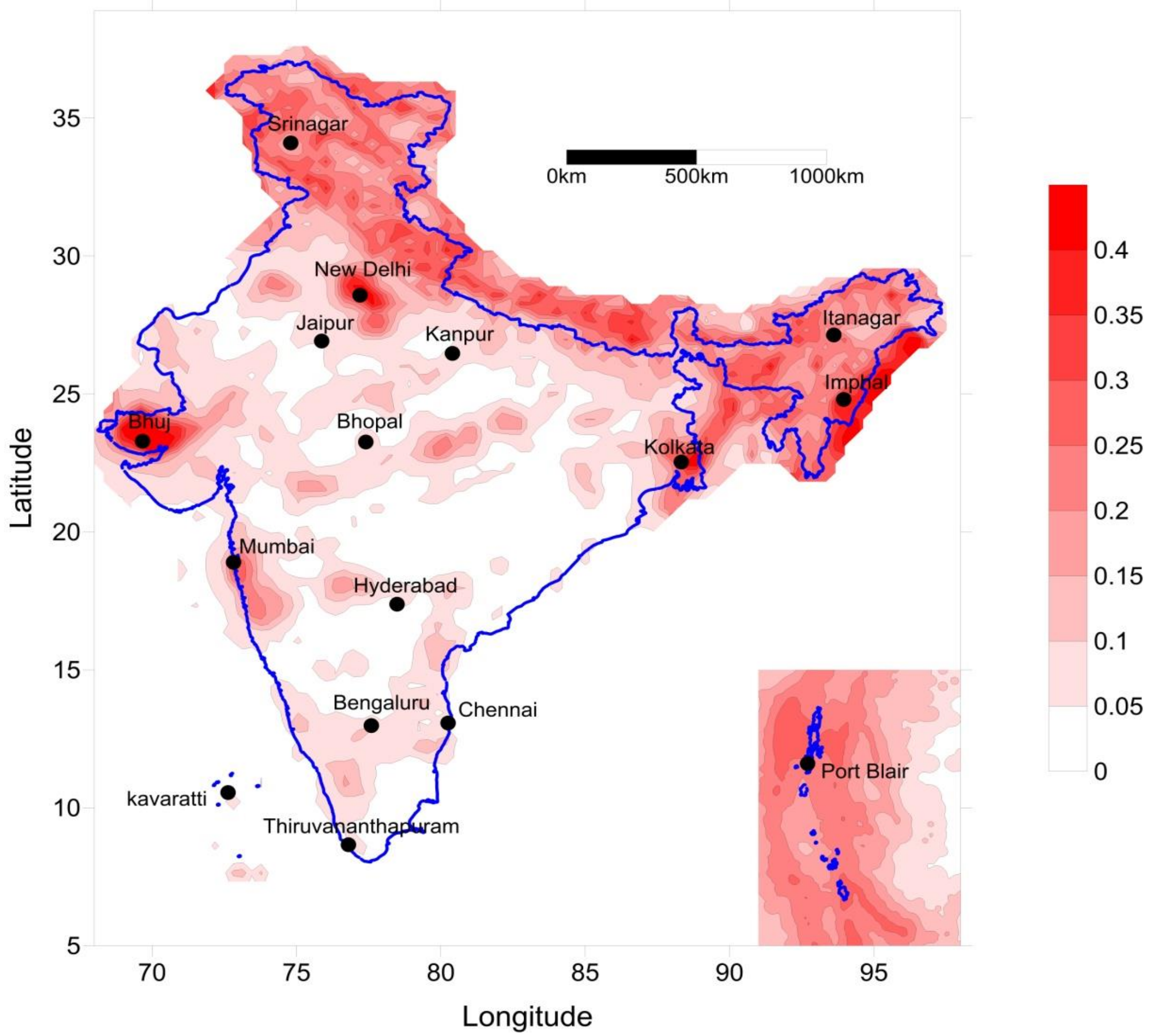

Original recorded data of Nepal-India border earthquake of Apr 4, 2011, vs PGA predicted using new GMPE and previous GMPEs



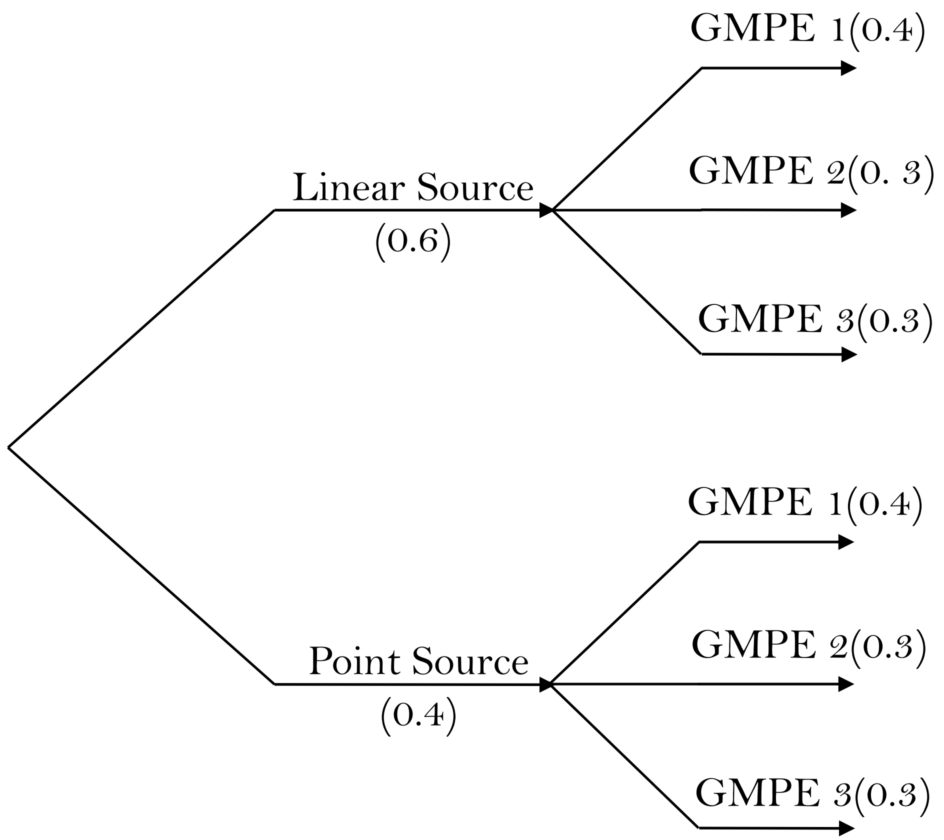

Original recorded data of Sonipat earthquake of Sep 7, 2011, vs PGA predicted using new GMPE and previous GMPEs.

Ramkrishnan R, Kolathayar S and Sitharam TG (2019, 2020)

# Deterministic Seismic Hazard Assessment

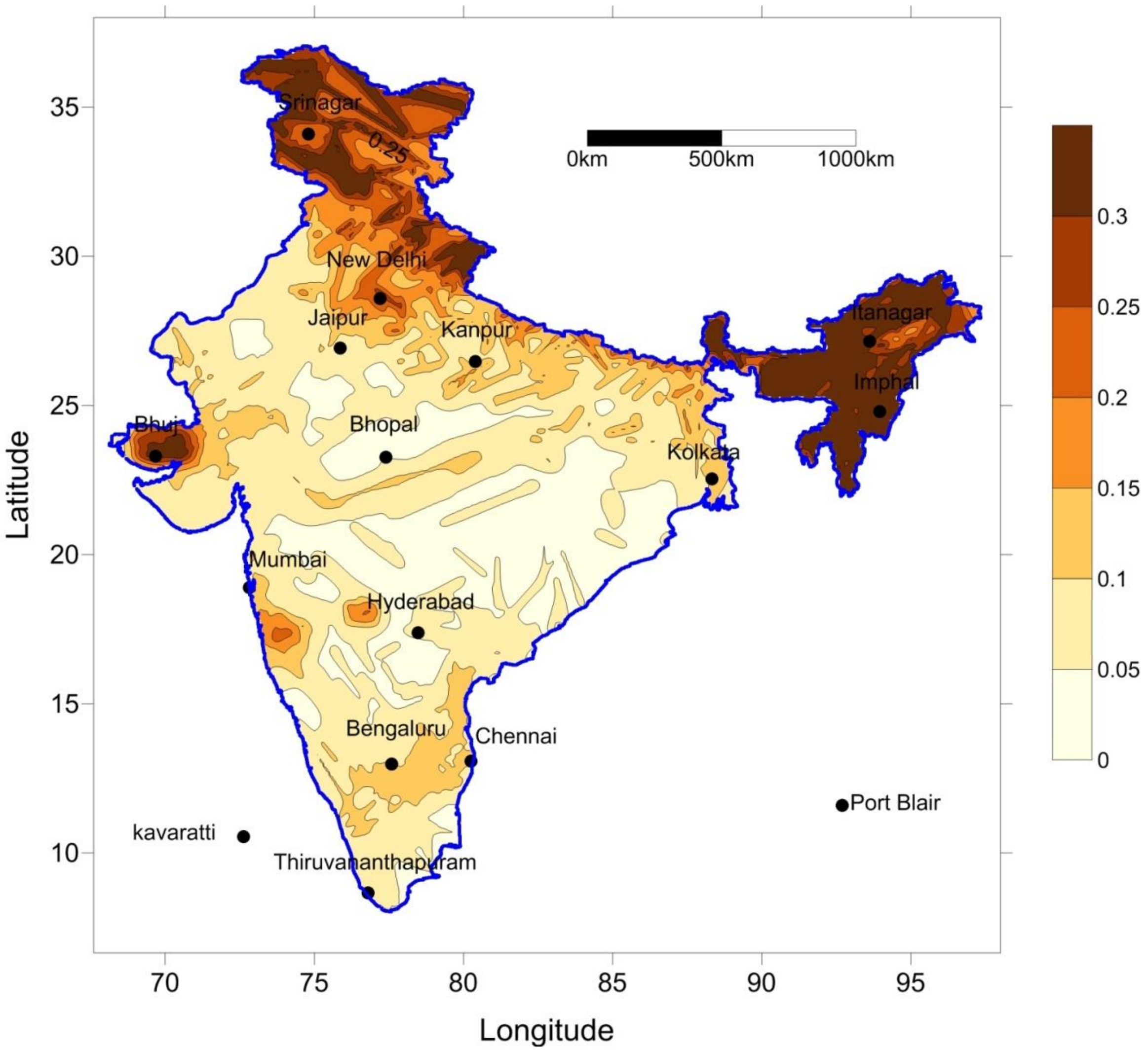



Spatial variation of PGA (g) value from DSHA

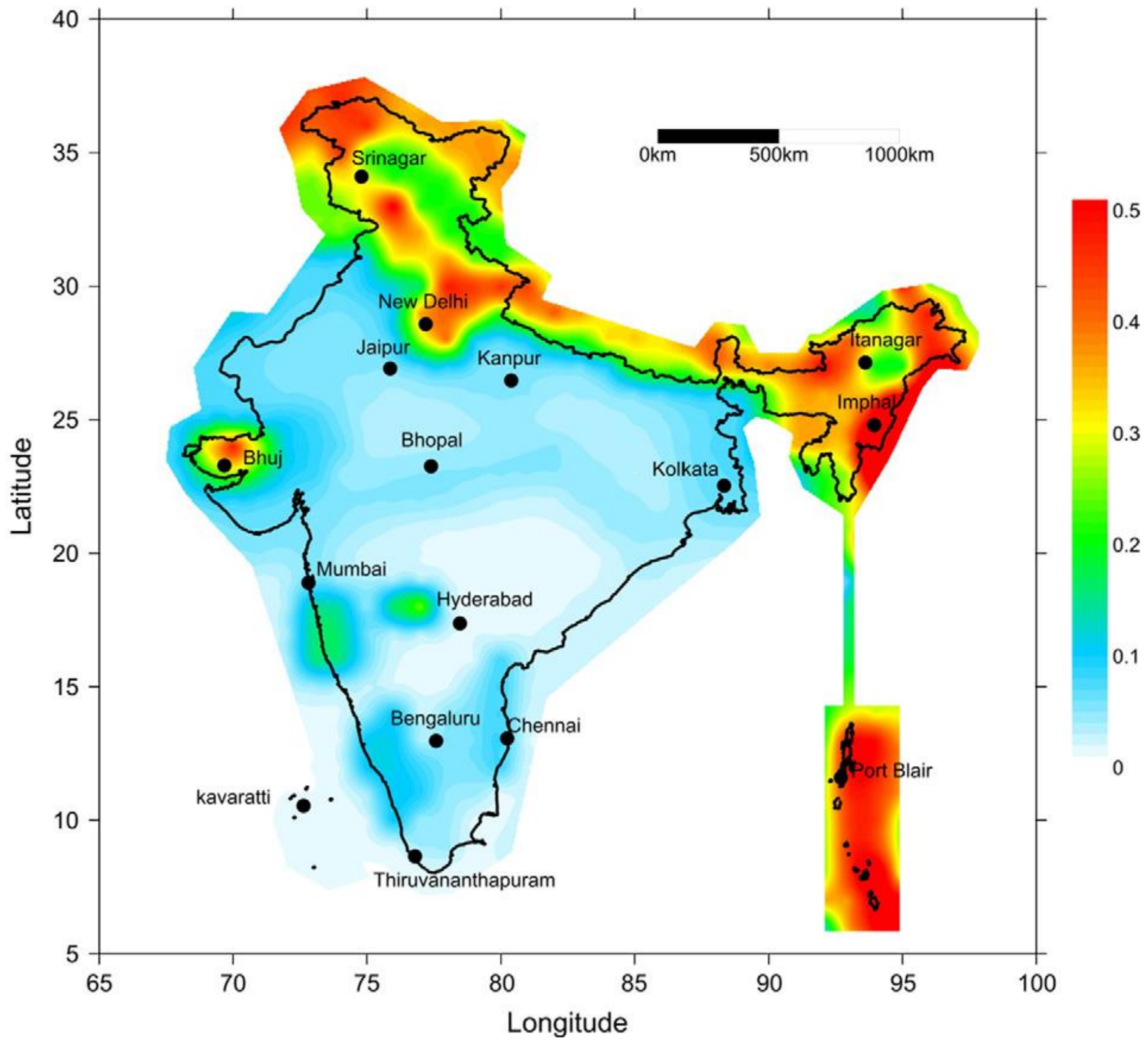



Logic Tree Framework

Kolathayar et al. (2012) Deterministic Seismic Hazard Macrozonation of India. **Journal of Earth System Sciences (Springer)** 121(5). 1351–1364.




PGA values (g) for 475 years return period (Logic Tree)

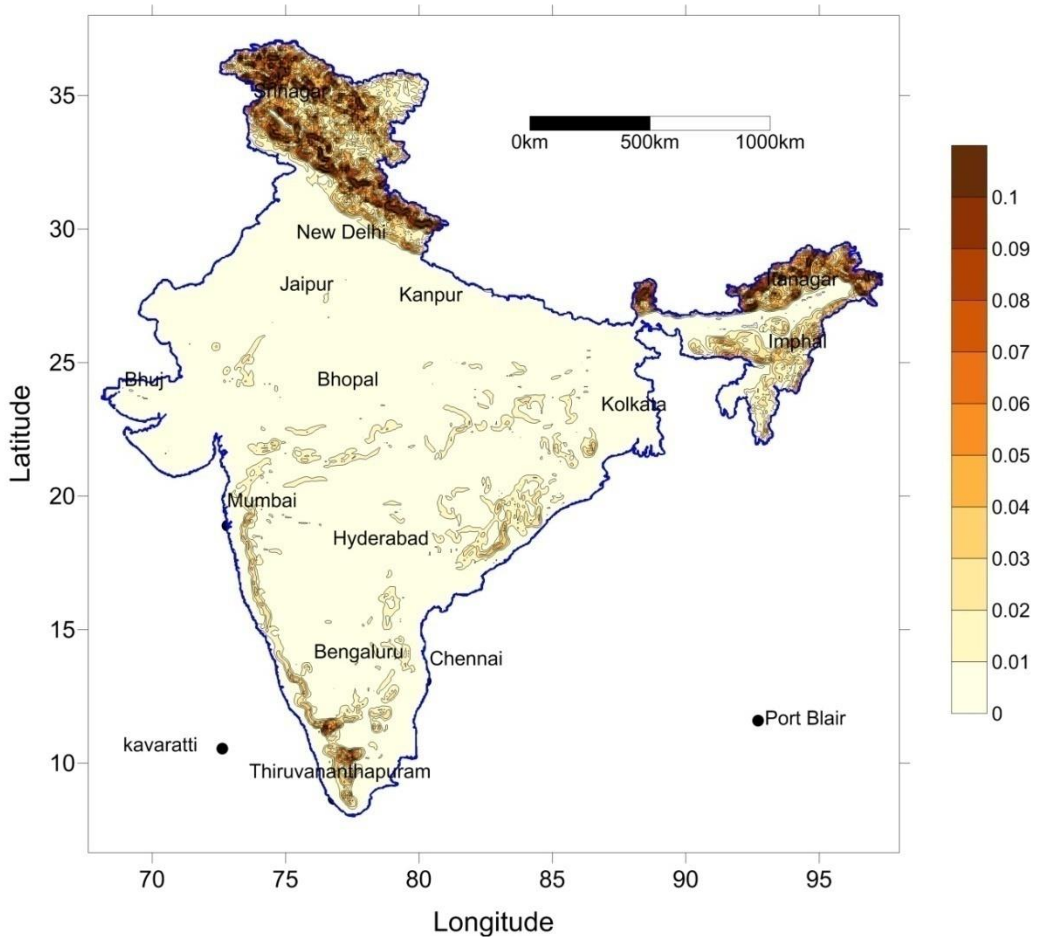



PGA values (g) for 475 years return period (Areal source)

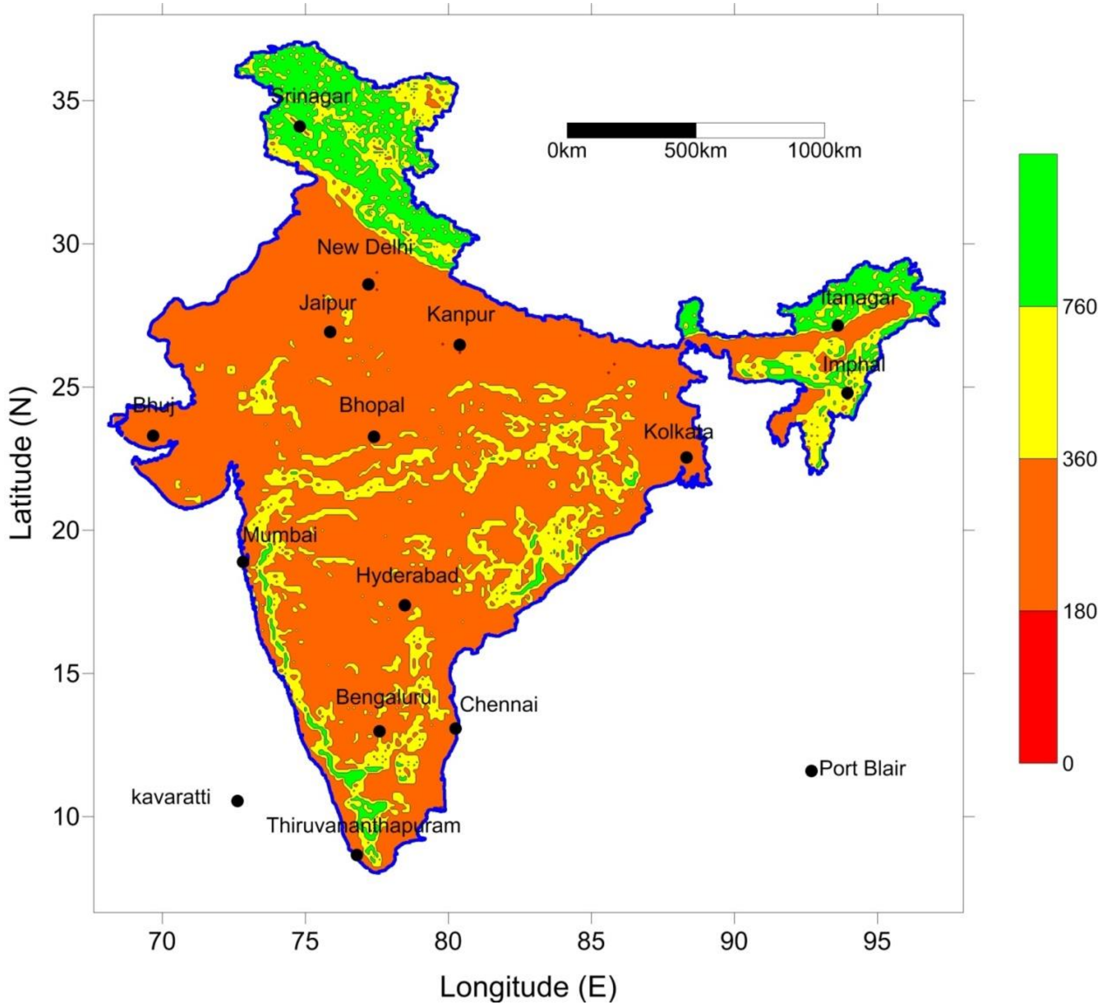
Kolathayar S & Sitharam TG. Earthquake Hazard Assessment. **ISBN 978-1-138-30923-4**, ***CRC Press Balkema, Taylor & Francis Group***, London, 2018.

Sitharam T G and Kolathayar S (2013) Seismic Hazard Analysis of India using Areal Sources. **Journal of Asian Earth Sciences Elsevier (2013)** 62: 647-653. **(IF: 3.515)**

# Topographic gradient as a proxy for site characteristics



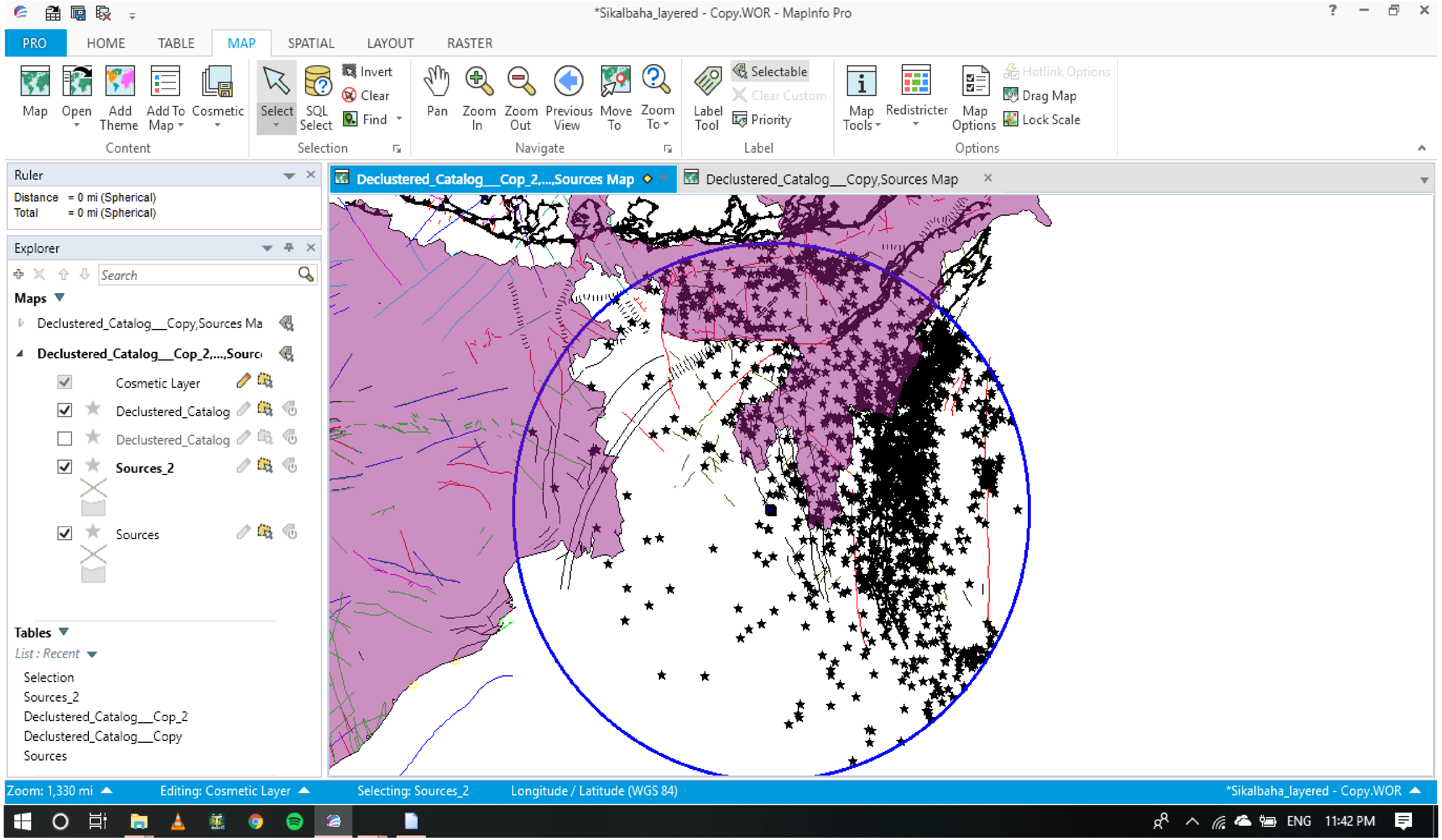

Contour map showing the spatial variation of slope value (m/m)



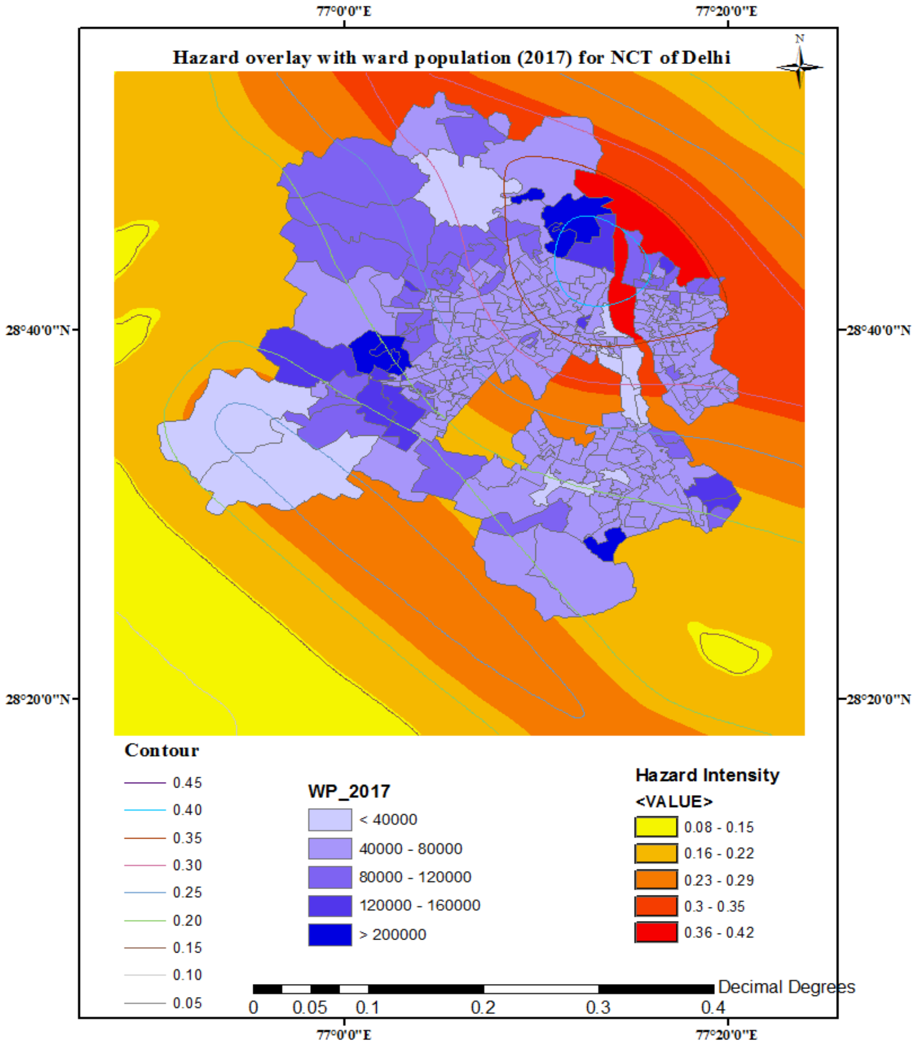

VS30 (m/s) contour map derived from the slope values

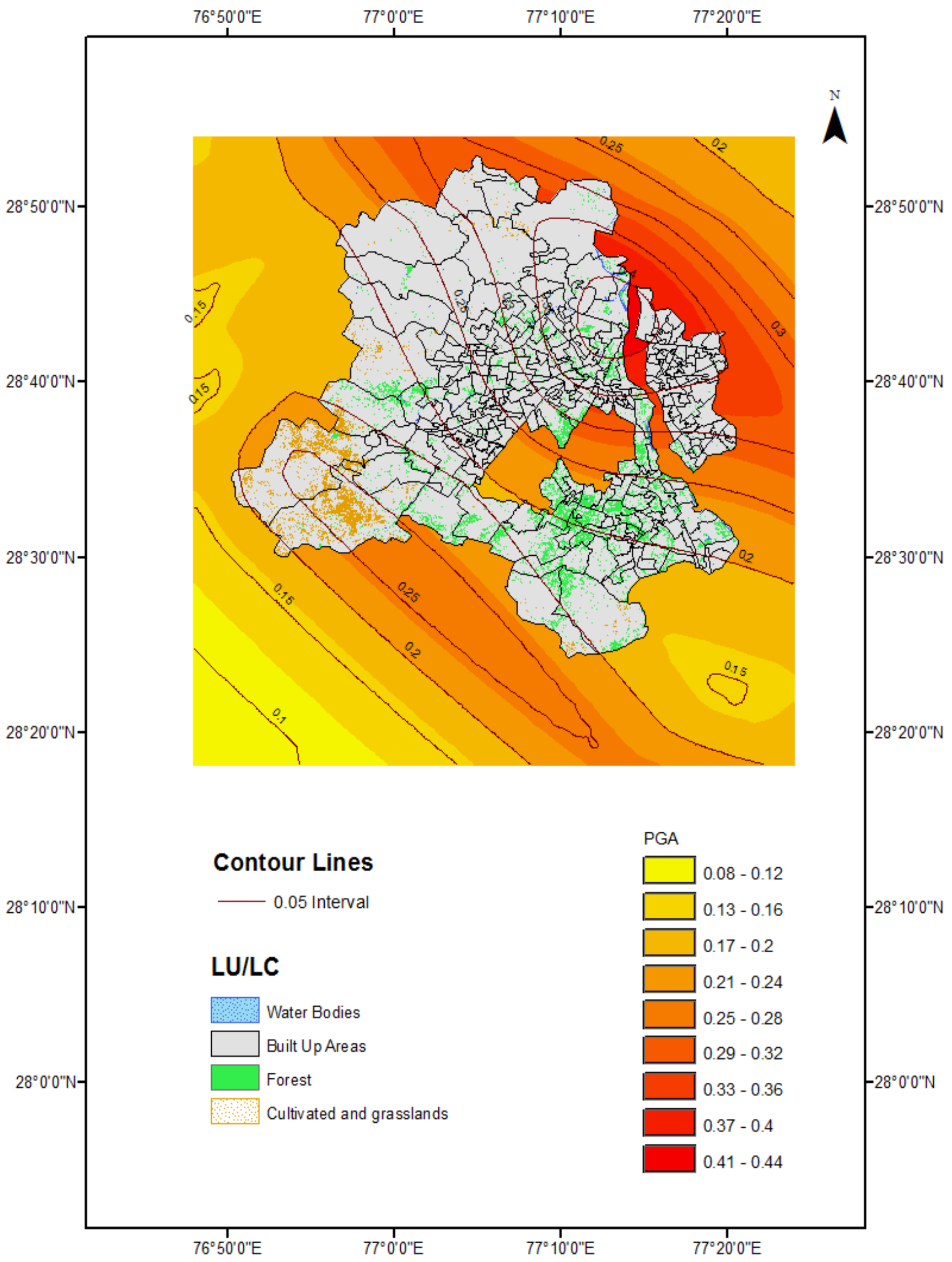
T.G. Sitharam, S. Kolathayar, and N. James (2015) In **Geoscience Frontiers (2015)**, Volume 6, Issue 6, Pages 847–859. **(IF: 4.28)**

# Seismic studies at a Power Plant at Chittagong Bangladesh



# Population and Land Use exposure to Seismic hazard



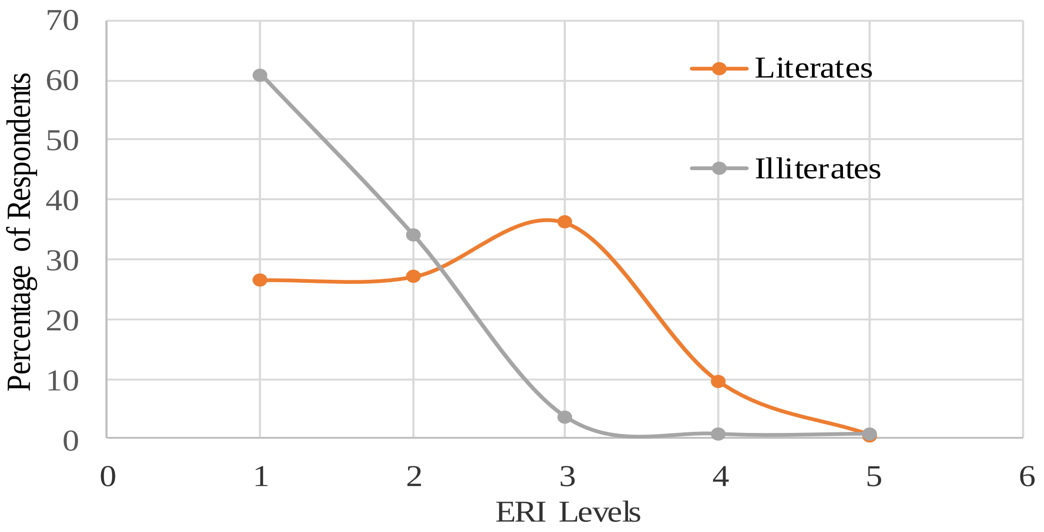




Proceedings of the Geotechnical Earthquake Engineering and Soil Dynamics V, GSP 291Book set: GEESD V 2018ISBN: 9780784481462, pp 135-145

# Earthquake Readiness Index: Valid and reliable tool to assess household and community preparedness

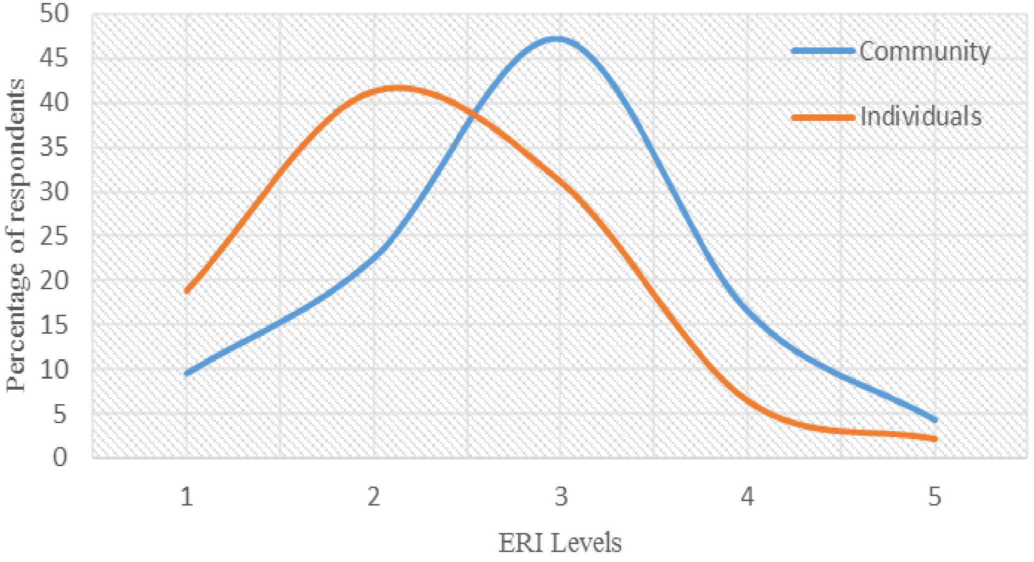
| Sl No. | Factors for ERI for Individuals | Item | Variance | Factors for ERI for Community | Item | Variance |
|---|---|---|---|---|---|---|
| 1 | Emergency needs | x12, x14 ,x17 ,x20 ,x22 ,x26 | 23.96 | Community Participation | y1, y2, y3, y4, y5 | 20.1 |
| 2 | Personal Safety | x9, x10, x11, x16 ,x27 | 12.3 | Trust | y13, y14, y15, y16, and y17 | 12.38 |
| 3 | Outdoorr Safety | x21, x23, x24, x25 | 7.24 | Collective Efficacy | y8, y9, y10 | 10.99 |
| 4 | Indoor Safety | x4, x5, x7, x8, x13 | 4.86 | Willingness | y18, y19, y20 | 7.98 |
| 5 | Structural Safety | x1, x2, x3, x6 | 4.33 | Empowerment | y11,y12 | 5.54 |
| 6 | Mitigation | x15,x18, x19 | 3.91 | Intension | y6,y7 | 5.37 |

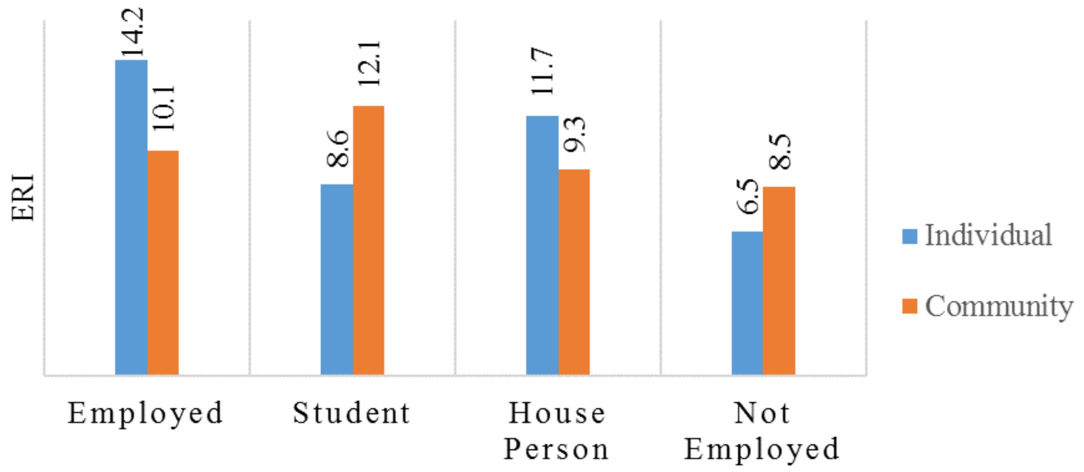
| Level | % activities completed | Degree of preparedness | ERI range for Individuals | %respondents for ERI for Individuals | ERI range for community | %respondents for ERI for Community |
|---|---|---|---|---|---|---|
| 1 | upto 20 | Very poor | 0-5 | 18.89 | 0-4 | 9.5 |
| 2 | upto 40 | Poor | 5-10 | 41.30 | 5 -8 | 22.5 |
| 3 | upto 65 | Moderate | 11-17 | 31.11 | 9-13 | 47.25 |
| 4 | upto 85 | Good | 18-23 | 6.48 | 14-17 | 16.5 |
| 5 | above 85 | Excellent | 24-27 | 2.22 | 18-20 | 4.25 |




Kolathayar et al. (2018) Development of Earthquake Readiness Index Tool to assess Individual Earthquake Preparedness Level, ASCE India Conference, New Delhi.

# Community preparedness

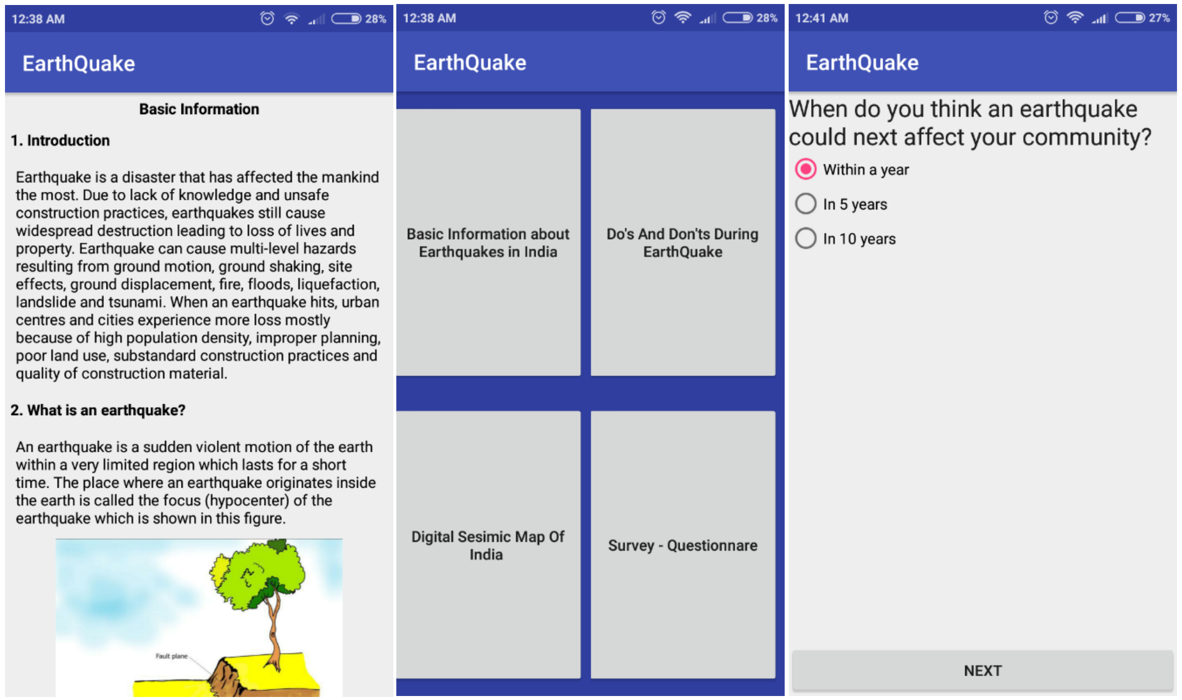


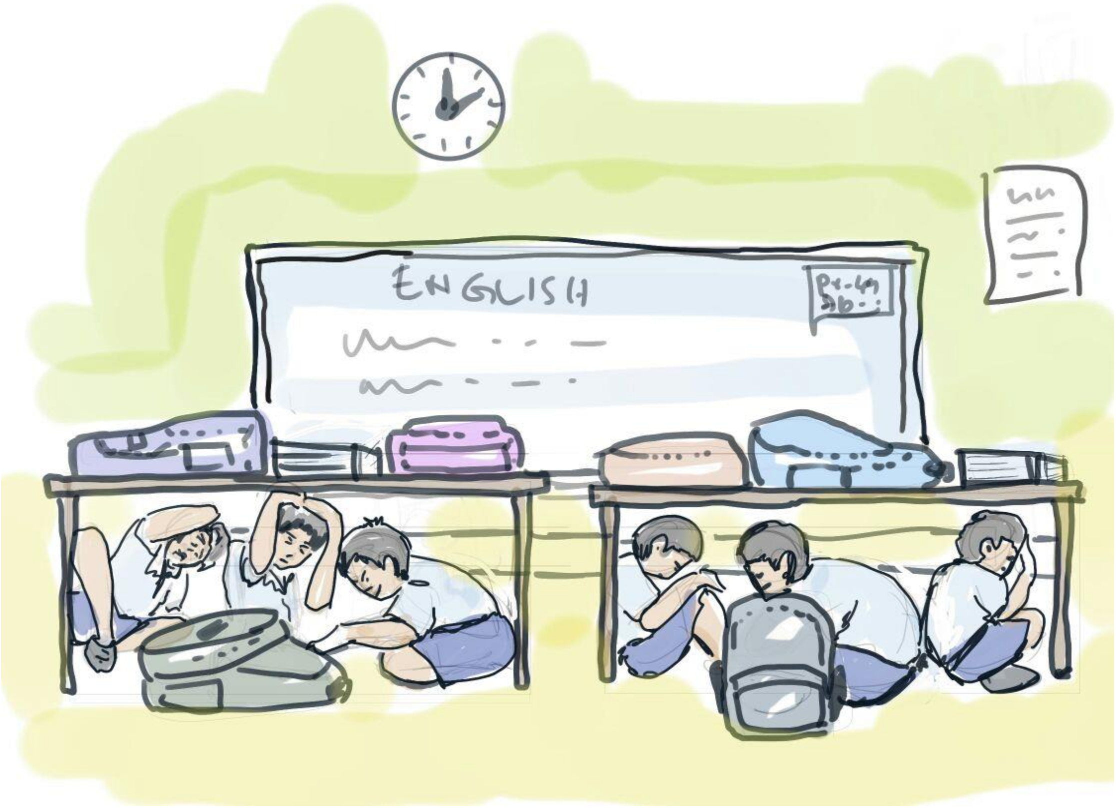

d) Employment Status

In book: Preparing for Earthquakes

# BhookampRaksha Mobile app




Kolathayar et al (2018). Development of Mobile Application to Assess and Enhance Earthquake Preparedness Level of Individuals and Community in India. Proceedings of 5th GeoChina International Conference (Springer)


ENGLISH

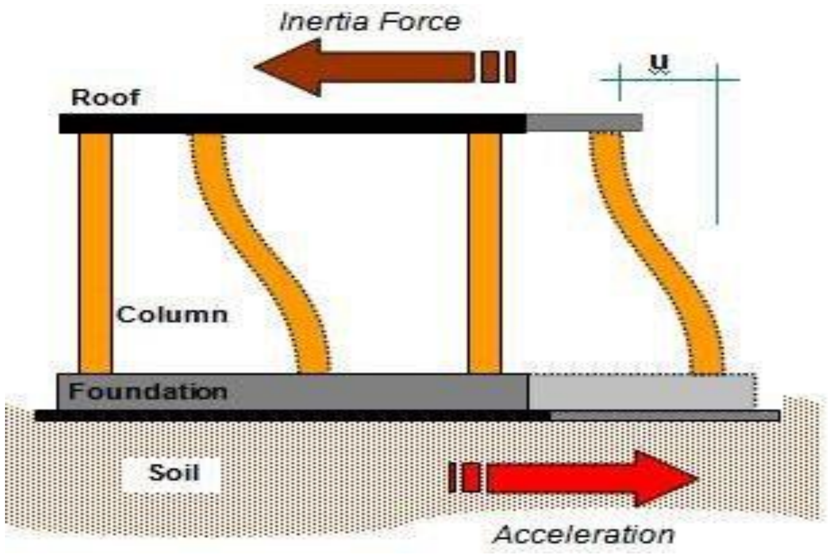

DROP
COVER
HOLD

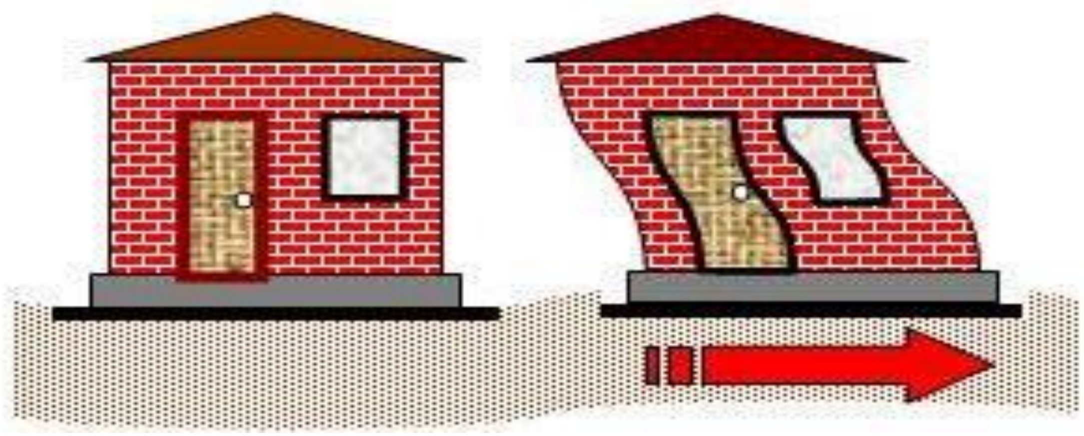
# Earthquake Effect: Inertial Forces

**Inertial force** is created by the structure's tendency to remain at rest, though the ground beneath is moving.

This inertial force imposes **strains** upon the structural elements. If these strains are large enough, the structural elements suffer damage of various kinds

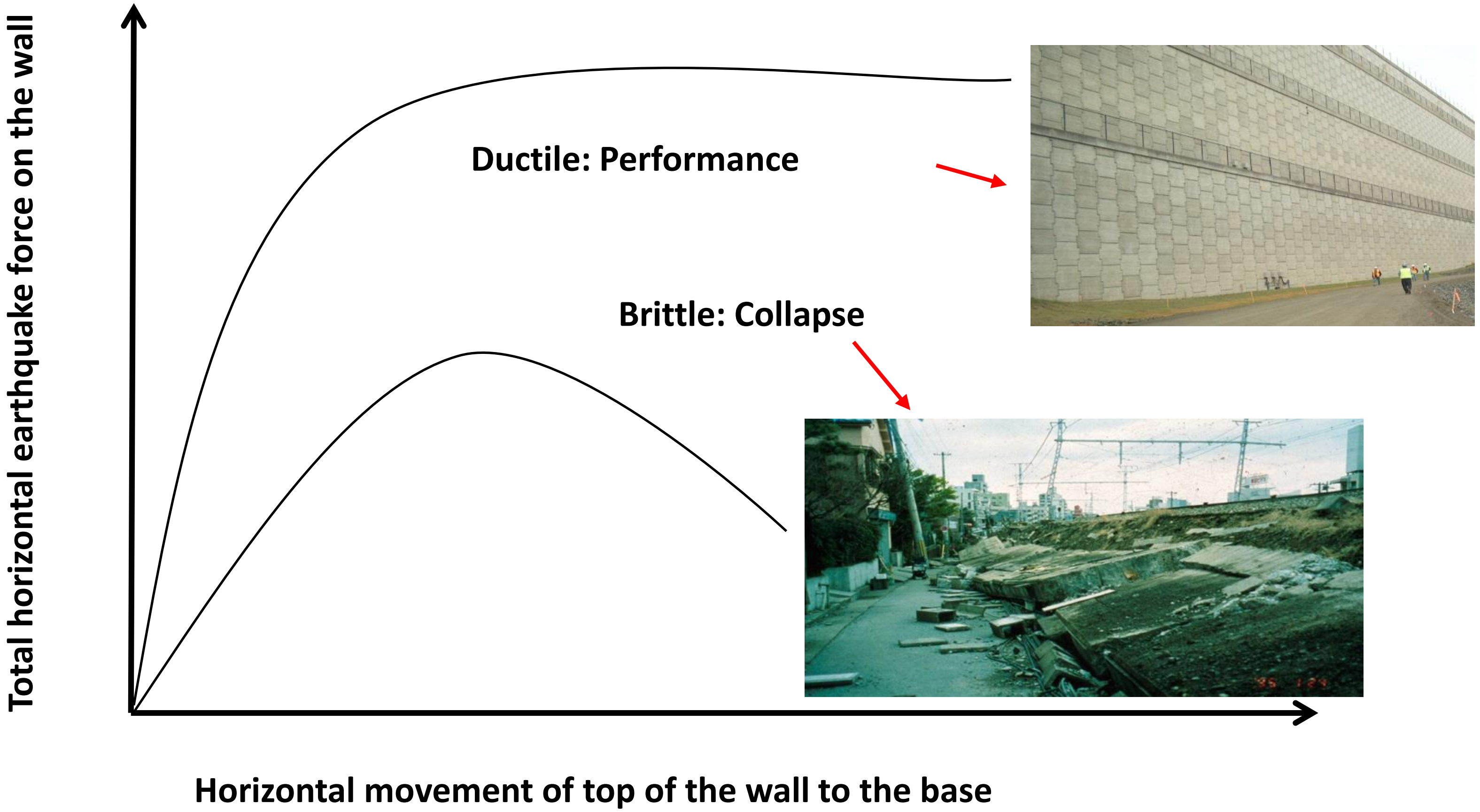
Obviously, it is far more desirable for a structure to sustain a limited amount of deformation than for it to suffer a complete breakage failure.

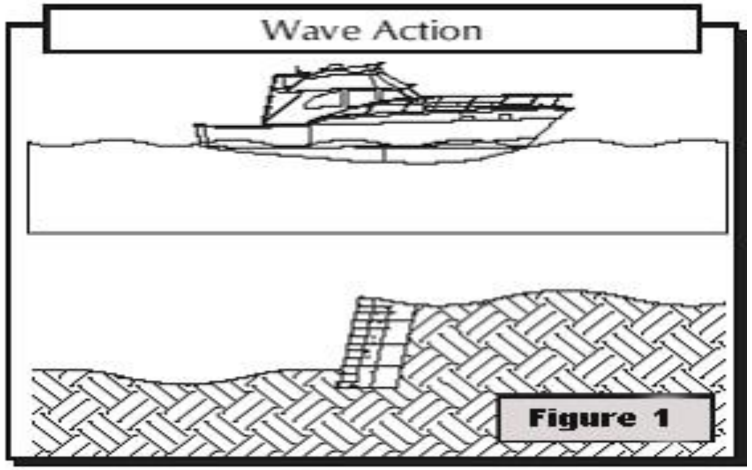


**Thanks to NICEE IIT Kanpur & Prof. Madhavi Latha G**

# Earthquake Resistance: Ductility




**Ductility** is the key property for earthquake survival. It's like a defense that will **bend but not break.**

**Thanks to Prof. Madhavi Latha G**

# Geogrid Reinforced Earth Retaining Wall Before Earthquake (Kobe)

Geogrid-reinforced soil RW along JR Kobe Line (1992)

Retaining Wall

springer.com/in/book/9783319595214

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# Preparing for Earthquakes: Lessons for India

Authors: **Sitharam**, T. G., **Kolathayar**, Sreevalsa

Presents an earthquake risk reduction and management plan developed by the Authors which is endorsed by Indian Society of Earthquake Technology

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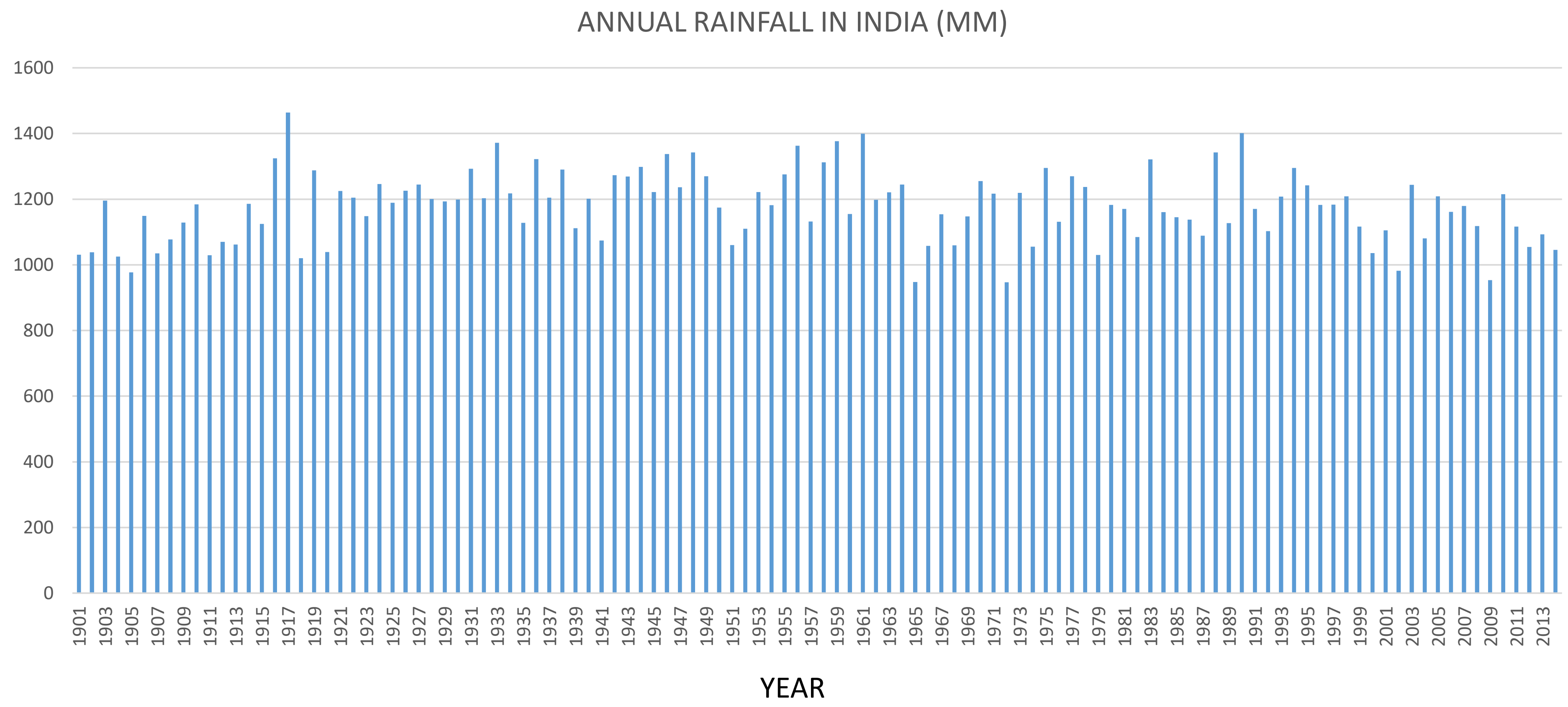
5:54 PM

# Geotechnical Schemes for Water Security

**Dr. Sreevalsa Kolathayar,** M.Tech IIT Kanpur, PhD IISc

**Secretary, India Chapter, International Association for Coastal Reservoir Research (IACRR)**

# India – A country of rivers

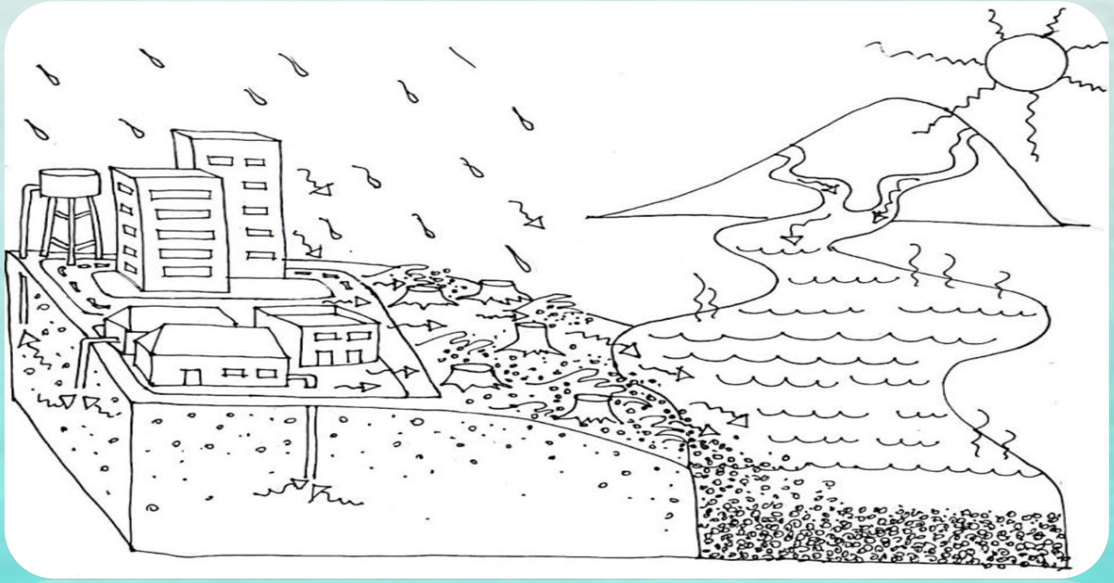



AVERAGE ANNUAL RAINFALL IN INDIA IS 1176 MM

# Reducing water potential and its relation to the changing processes:

**In past:**

**Nature used to recharge surface and ground water on its own**



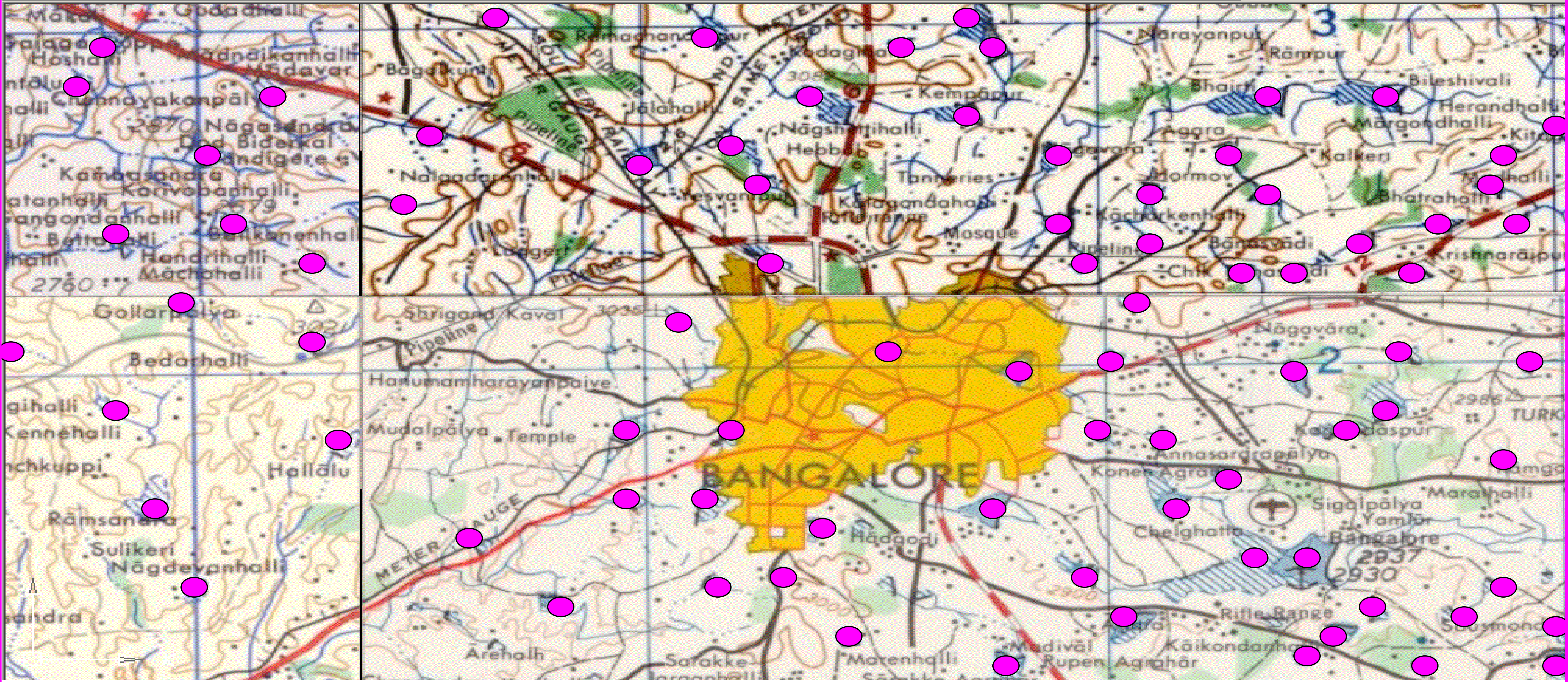
**Now:**

**Due to soil erosion and siltation water bodies lose their capacities to store water**

Degradation of forest, increased soil erosion have reduced the resident time of water in the different layers of the earth (ground water).

Thanks to Dr Lingaraju, Art of Living

# Old tanks in Bangalore – Topo Sheet of 1960

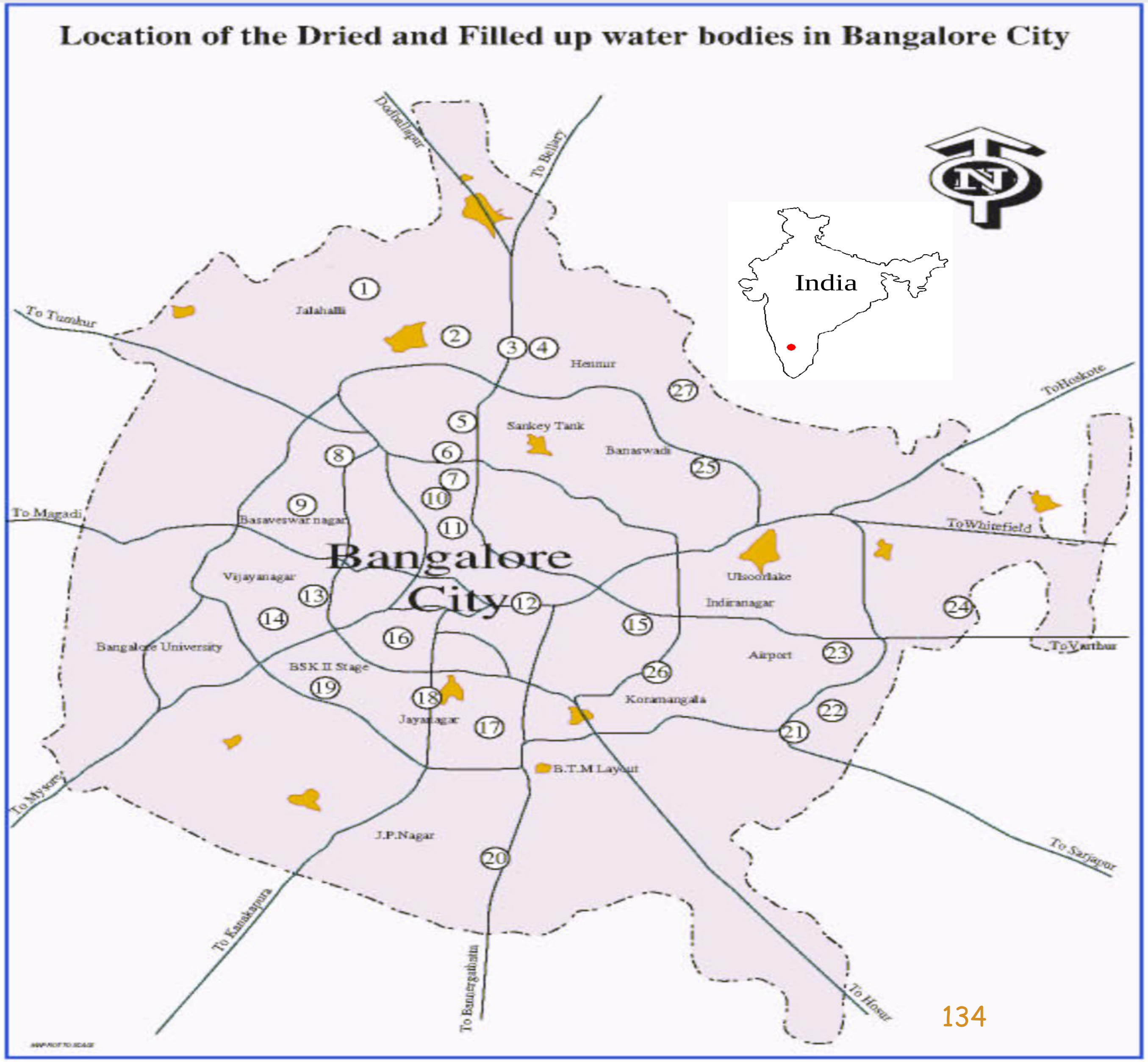



within Corporation boundary

Thanks to Prof Sitharam, IISc

# Tanks/ponds/lakes in Bangalore and present status

| | | |
|---|---|---|
| 1 | Vidyaranyapura Lake | Vidyaranyapura(Jalahalli East) |
| 2 | Gokula Tank | Mattikere |
| 3 | Geddalahalli Lake | RMV 2nd Stage, 1st Block |
| 4 | Nagashettihalli Lake | RMV 2nd Stage, 2nd Block |
| 5 | Tumkur Lake | Mysore Lamps |
| 6 | Ramshetty Palya kere | Milk Colony (Playground) |
| 7 | Oddarapalaya Lake | Rajajinagar (Industrial Area) |
| 8 | Ketamaranahalli Lake | Rajajinagar (Mahalakshmipuram) |
| 9 | Kurubarahalli Lake | Basaveshwaranagar (Chord Road) |
| 10 | Agasana Lake | Gayathri Devi Park |
| 11 | Jakkarayana kere | Krishna Floor Mills |
| 12 | Dharmambudhi Lake | Kempegowda Bus Terminal |
| 13 | Vijayanagar Chord Rd Lake | Vijayanagar |
| 14 | Marenahallli Lake | Marenahalli |
| 15 | Sampangi Lake | Kanteerva Stadium |
| 16 | Kalasipalya Lake | Kalasipalya |
| 17 | Siddapura Lake | Siddapura/Jayanagar 1 stBlock |
| 18 | Tyagarajanagar Lake | Tyagarajanagar |
| 19 | Kadirenahalli Lake | Banashankari 2nd Stage |
| 20 | Sarakki AgraharaLake | JP Nagar 4th Phase |
| 21 | Koramangala Lake | National Dairy Research Institute |
| 22 | Chinnagara Lake | Ellpura |
| 23 | Domlur Lake | Domlur Second Stage |
| 24 | Kodihalli Lake | New Thippasandra /Government Buildings |
| 25 | Banaswadi Lake | Subbayapalya Extension |
| 26 | Shule Tank | Ashok Nagar, Football Stadium |
| 27 | Hennur Lake | Nagavara (HBR Layout) |




**About 150 lakes now reduced to 64**

Thanks to Prof Sitharam, IISc

# Water scarcity hits paddy transplantation

## Coverage of wheat, pulses also lower

# 'Water scarce in 566 villages'

## 70 Villages Get Drinking Water Through Tankers

Times News Network

**Gandhinagar:** As the temperatures rise, the Gujarat government declared 566 villages to be suffering water scarcity and put relief measures in place. The government has started providing drinking water through tankers in 70 villages.

State revenue minister Bhupendrasinh Chudasama reviewed the water scarcity situation in the state. The state government has started providing fodder at Rs 2 per ... ges are in Surendranagar, Kutch, Rajkot and Botad districts.

Chudasama said, "Compare to 42% at this time last year, water levels in the 204 major dams is at 37.85% this year and there is no need to panic. Wherever required, ...

PYASA GUJARAT

## Kutch industries to work on saving water

Times News Network

**Ahmedabad:** Faced with water shortage and subsequent production losses, industrial units in Kutch have themselves taken up initiatives to address their water woes by setting up water storage facilities, sea water desalination plants, rain water harvesting and sewage treatment plants.

As against the requirement of 150 million litres per day (MLD) requirement, industries get less than 60 MLD. "Shortage of water causes production loss to the tune of Rs. 10,000 crore annually to industrial units operating in ... deration of Kutch Industries Associations (FOKIA).

In order to combat water shortage many companies have themselves started taking various steps. Some of the companies have set up their sea water desalination plants, while another corporate group has established sewage treatment plant.

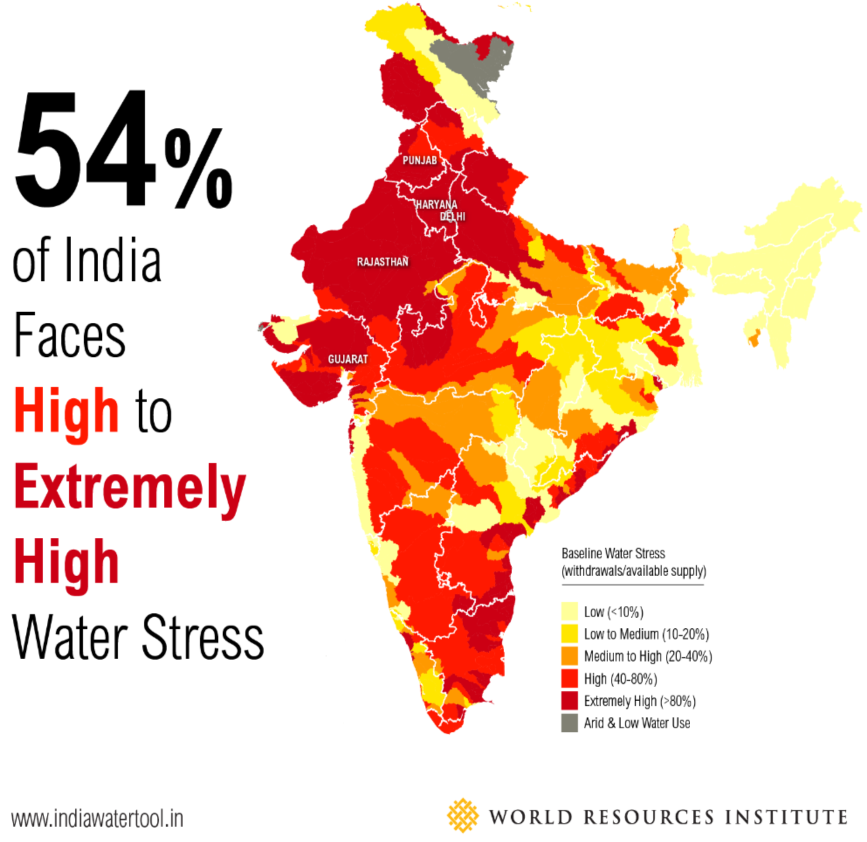
Other initiatives include rain water harvesting and creation of surface water storage facilities.

"A Rs. 1,300 crore sea water desalination plant near Bhadreshwar in Kutch has also been planned. We have identified a number such projects under our Rs. 3,000 ...

vardhmanenvirotech.com

# Fresh Water Shortage

- Availability of freshwater per capita is declining
- WATER STRESS – Developing world
- Water demand in coastal regions is also increasing
- India is not running out of water but Water is running out of India



India is not running out of water.

Water is running out of India

# India’s traditional water harvesting structures


REDMI NOTE 8
AI QUAD CAMERA

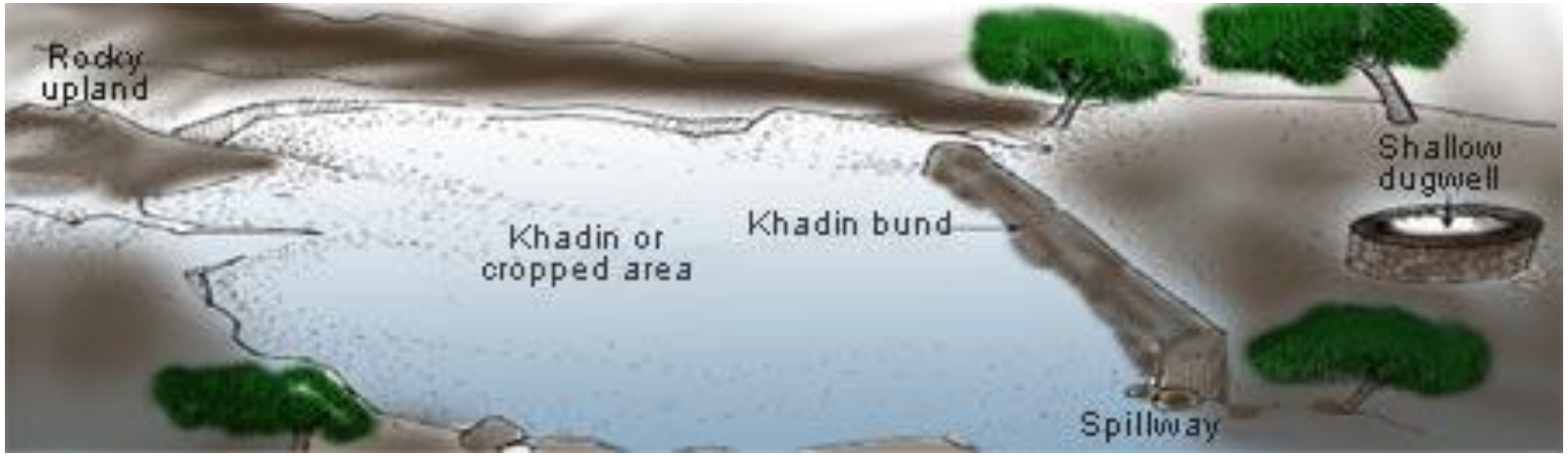
# Kulam (Ponds) in Northern Kerala

- Steps made of laterite stones
- For bathing, washing and irrigation purpose
- Water recharged from underground aquifers.

# Tankas (Rajasthan)

- A Tanka is a cylindrical underground rainwater storage cistern, wherein rainwater from rooftops, a courtyard or natural or artificially prepared catchment flows into the paved underground pit, through filtered inlets made on the external wall of the structure,
- Once fully filled, the water is sufficient for a family of 5-6 members for a period of 5–6 months, and saves it from everyday-water-fetching-drudgery
- The water was used only for drinking.
- The *tanka* system is also to be found in the pilgrim town of Dwarka where it has been in existence for centuries.
- It continues to be used in residential areas, temples, *dharamshalas* and hotels.

# khadin/dhora (Western Rajasthan)




- An ingenious construction designed to harvest surface runoff water for agriculture.
- Its main feature is a very long (100-300 m) earthen embankment built across the lower hill slopes lying below gravelly uplands.
- Sluices and spillways allow excess water to drain off.
- Based on the principle of harvesting rainwater on farmland and subsequent use of this water-saturated land for crop production.

# Jhalaras, 17th Century AD

stepwells that have tiered steps



***Jhalaras*, Jodhpur, 1660 AD**

Source: Sanchari Pal, The Better India (2016)

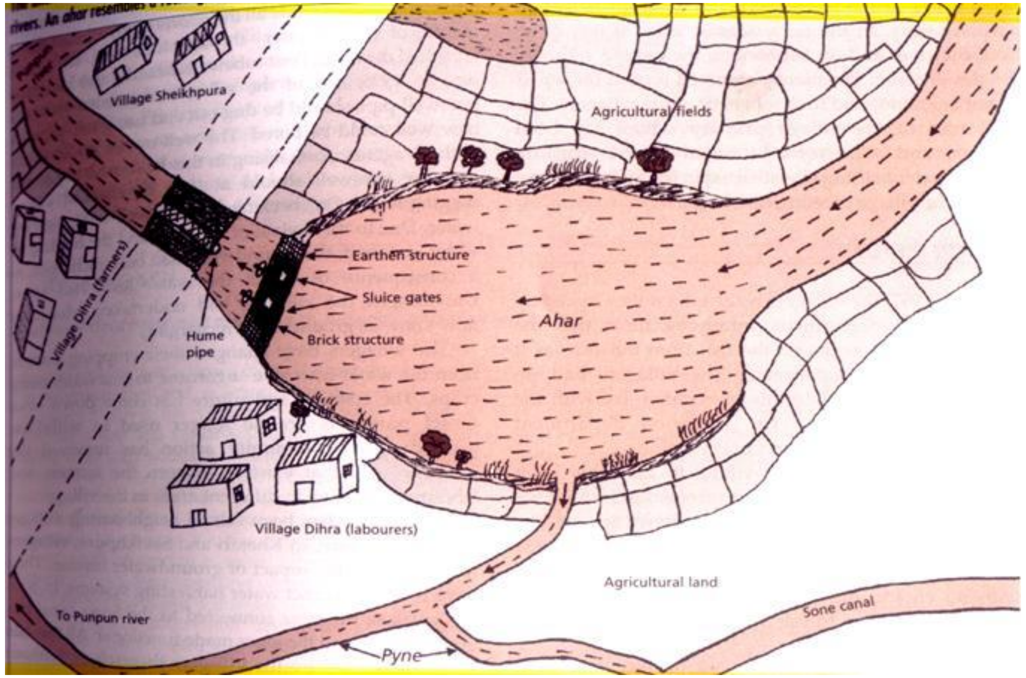
# Bavadi (Gujarath and Rajasthan)

- Traditional stepwells. Secular structures from which everyone could draw water.
- The construction date from four periods: Pre-Solanki period (8th to 11th century CE); Solanki period (11th to 12th century CE); Vaghela period (mid-13th to end-14th century CE); and the Sultanate period (mid-13th to end-15th century CE).
- Sculptures and inscriptions in stepwells demonstrate their importance to the traditional social and cultural life.

- When a stepwell was located within or at the edge of a village, it was mainly used for utilitarian purposes and as a cool place for social gatherings.
- When stepwells were located outside the village, on trade routes, they were often frequented as resting places.
- Many important stepwells are located on the major military and trade routes from Patan in the north to the sea coast of Saurashtra.
- When stepwells were used exclusively for irrigation, a sluice was constructed at the rim to receive the lifted water and lead it to a pond, from where channeled into the fields.

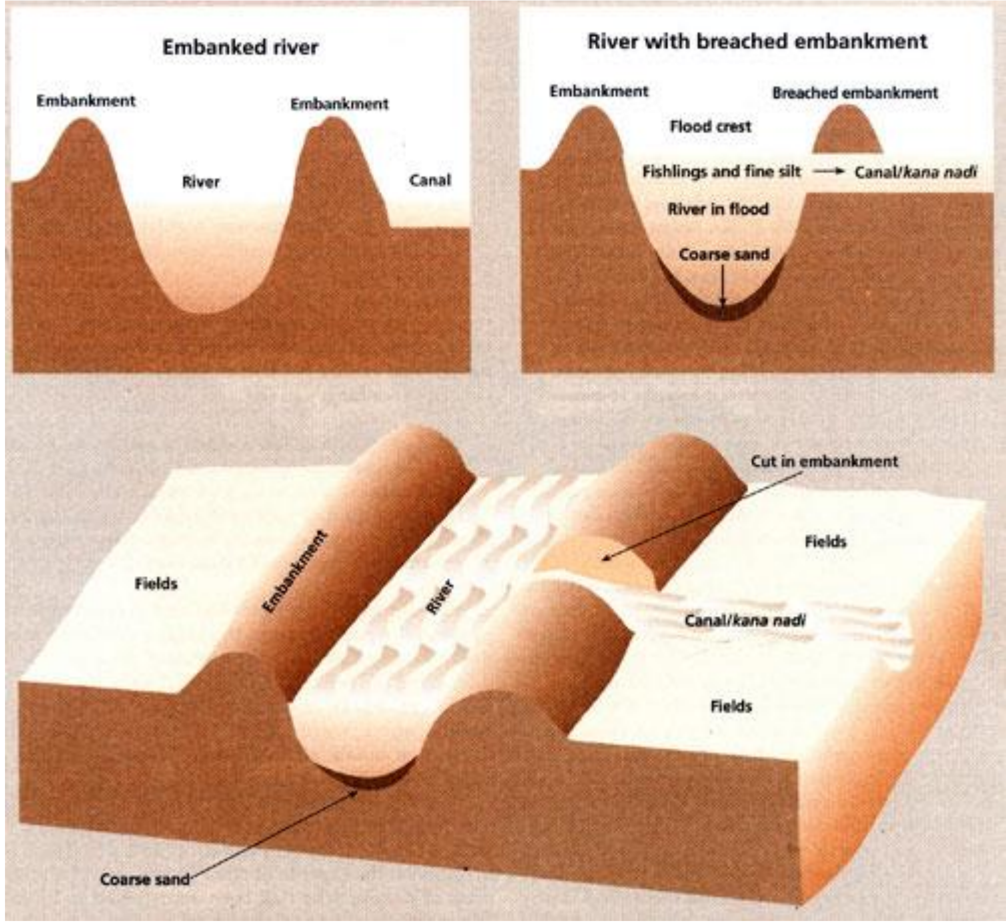

KANKARIA
State Bank of India (SBI) atm

# Ahar-Pynes




- Ahar pynes are traditional floodwater harvesting systems indigenous to South Bihar and have been the most important source of irrigation in this region.
- Ahars are reservoirs with embankments on three sides and are built at the end of drainage lines such as rivulets or artificial works like pynes.
- Pynes are diversion channels led off from the river for irrigation purposes and for impounding water in the ahars.
- In 1949, a Flood Advisory Committee investigating continuous floods in Gaya district came to the conclusion that "the fundamental reason for recurrence of floods was the destruction of the old irrigational system in the district.

# Bengal's Inundation Channel




Bengal once had an extraordinary system of inundation canals.

- The distinguishing features of the irrigation system were:
- the canals were broad and shallow, carrying the crest waters of the river floods, rich in fine clay and free from coarse sand;
- the canals were long and continuous and fairly parallel to each other, and at the right distance from each other for purposes of irrigation;
- irrigation was performed by cuts in the banks of the canals, which were closed when the flood was over.

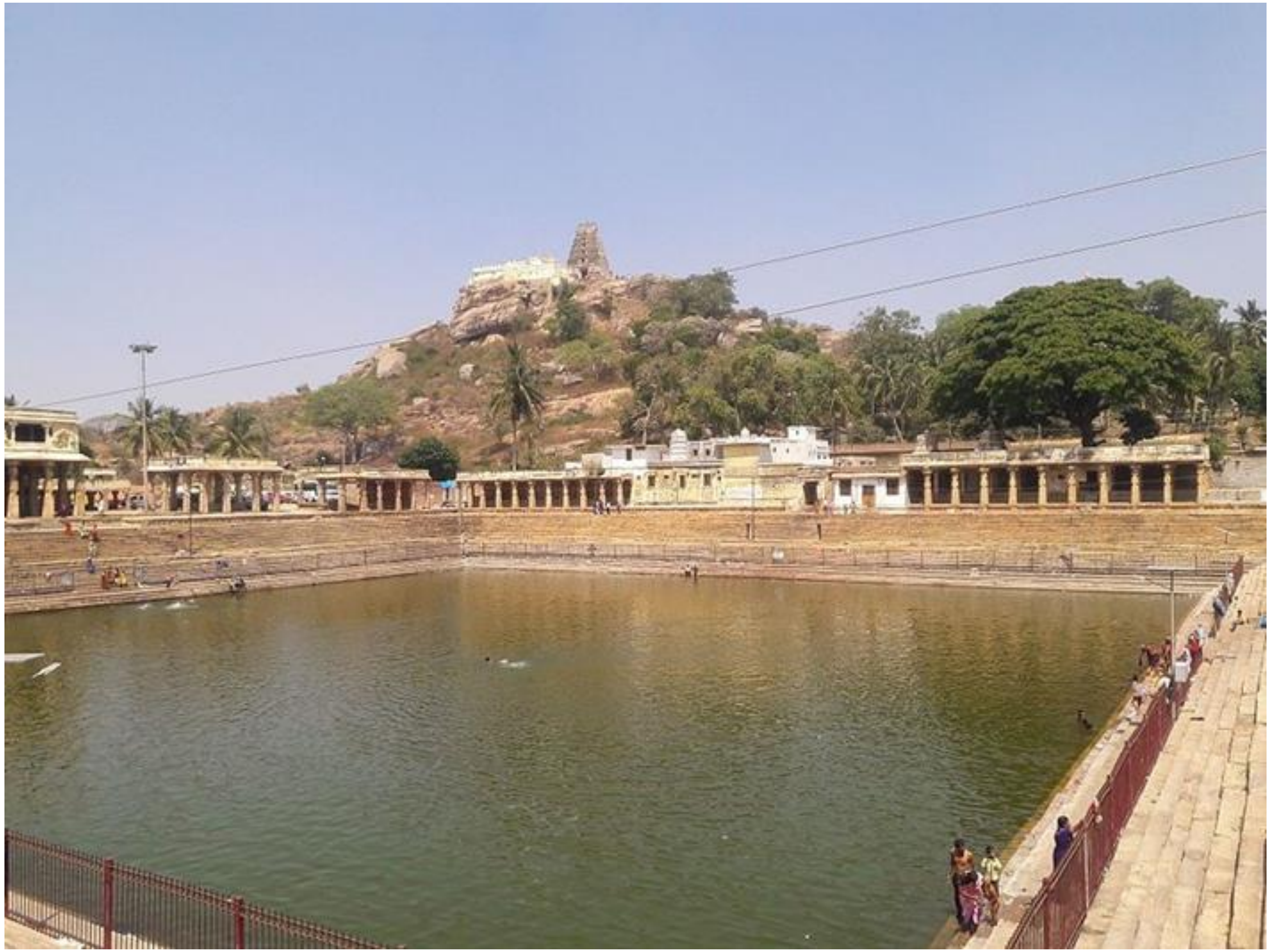
# Bhanadaras

- These are check dams or diversion weirs built across rivers. A traditional system found in Maharashtra, their presence raises the water level of the rivers so that it begins to flow into channels. They are also used to impound water and form a large reservoir.
  Where a *bandhara* was built across a small stream, the water supply would usually last for a few months after the rains.

*Cheruvu* are found in Chitoor and Cuddapah districts in Andhra Pradesh. They are reservoirs to store runoff. *Cheruvu* embankments are fitted with *thoomu*(sluices), *alugu* or *marva* or *kalju* (flood weir) and *kalava* (canal).

Tanks, called kere in Kannada, were the predominant traditional method of irrigation in the Central Karnataka Plateau, and were fed either by channels branching off from anicuts (chech dams) built across streams, or by streams in valleys. The outflow of one tank supplied the next all the way down the course of the stream; the tanks were built in a series, usually situated a few kilometres apart. This ensured a) no wastage through overflow, and b) the seepage of a tank higher up in the series would be collected in the next lower one.

# Kalyani (Melukote)



## Zings

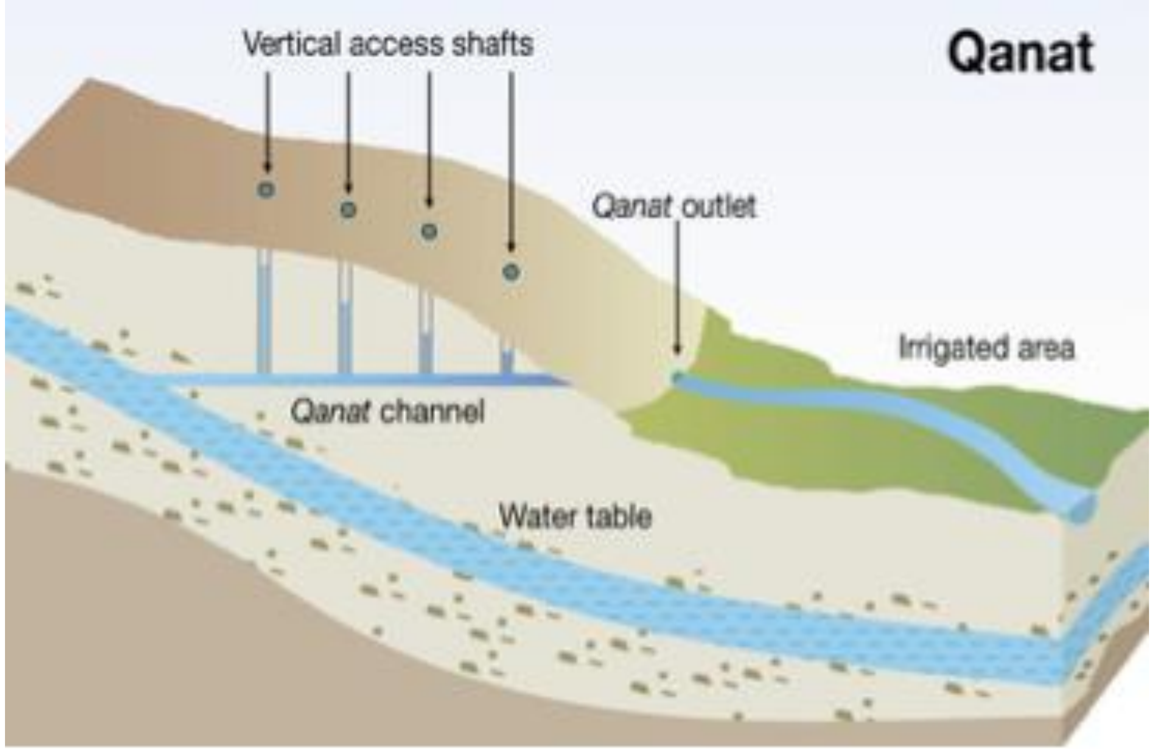
- Ladakh is a dryland where cultivation is very difficult
- Entire cultivated area of 19,000 ha depends on irrigation from the waters of melting snow through long, winding streams from upper mountain reaches.
- At sowing time, it is still cold, water from the snow-melt is very limited.
- Owing to short growing period, all farmers need irrigation almost at the same time.
- Water is diverted from streams with the help of guiding channels.
- Towards the evening, it is taken to a small tank, locally known as a *zing*.
- The stored glacier water is used the following day in the fields. Each village has a large network of canals and *zings*.

11

# Suranga

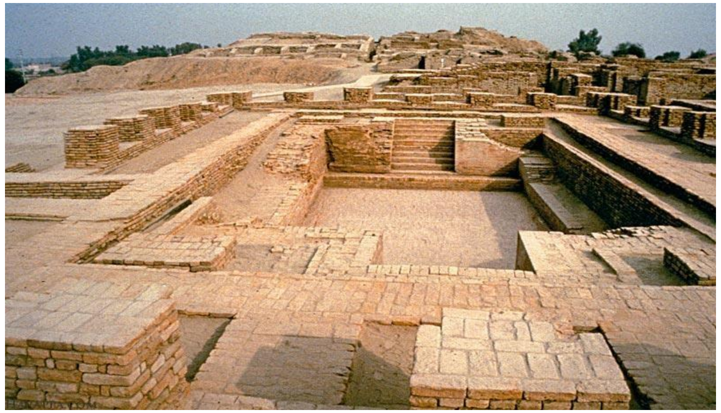
- A suranga is a narrow horizontal tunnel, dug into laterite hills until a water spring is found.
- The porous laterite has a capacity to store water. The clay in the laterite mud holds the water, which is the key in the process of suranga

# Surang
a


Vertical access shafts
Qanat
Qanat outlet
Irrigated area
Qanat channel
Water table

# Hydraulic Engineering in Ancient India

**First major human settlements in Indus Valley (3000-1500 BC)**



**Great Bath of Mohenjodaro**

**Dock-yard in Lothal, Gujarat**

**Dholavira, Gujarat**

**Brick Well, Satvahan Dynasty**

(1st Century B.C.-2nd Century A.D)

Sudarshan Lake, Gujarat,3rd Century BC

# Kallanai Dam), 1st Century AD

- Built by **Chola King Karikalan** during the **first century**, it is the **world's fourth oldest dam, still in use.**

- The dam plays an important role in the irrigation system in the Cauvery delta.

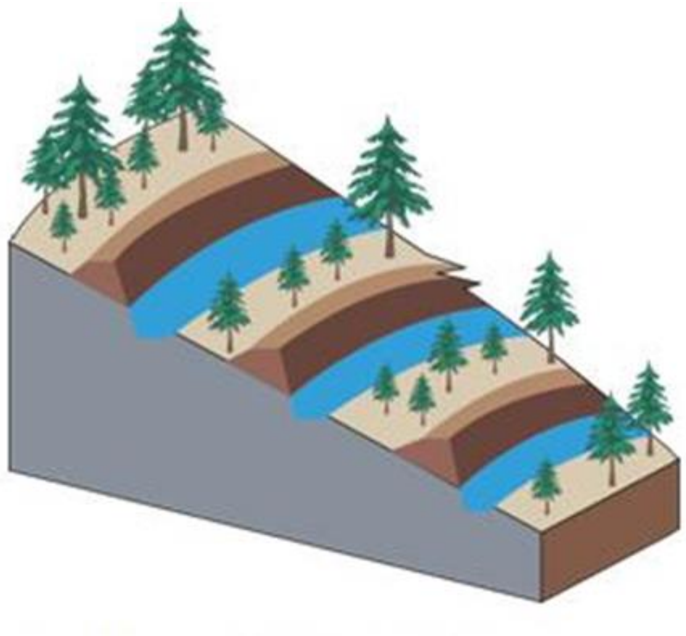
- **Grand Anicut is a massive structure constructed with uneven stones to a length of 329 metres and a width of 20 metres across the main stream of the river.**



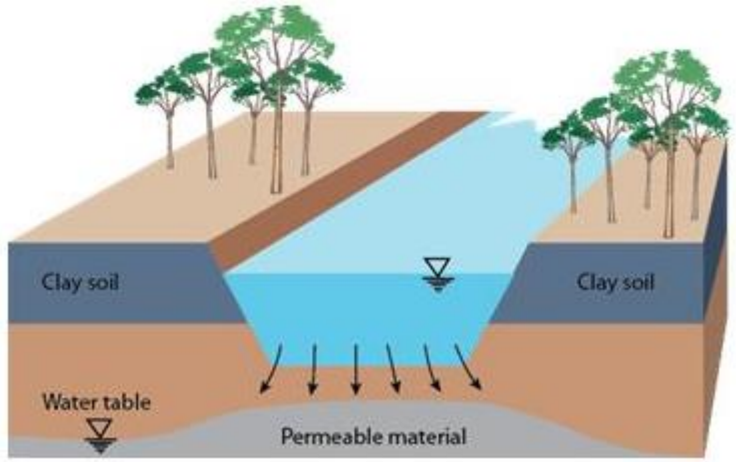
- The dam was meant to divert water across the fertile delta region for irrigation through canals.

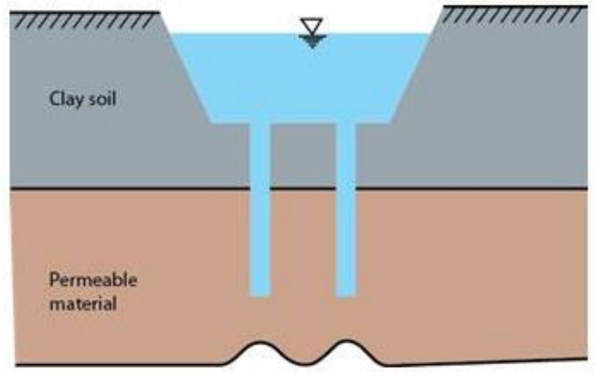
# Rain water harvesting Structures

**Contour bunds**



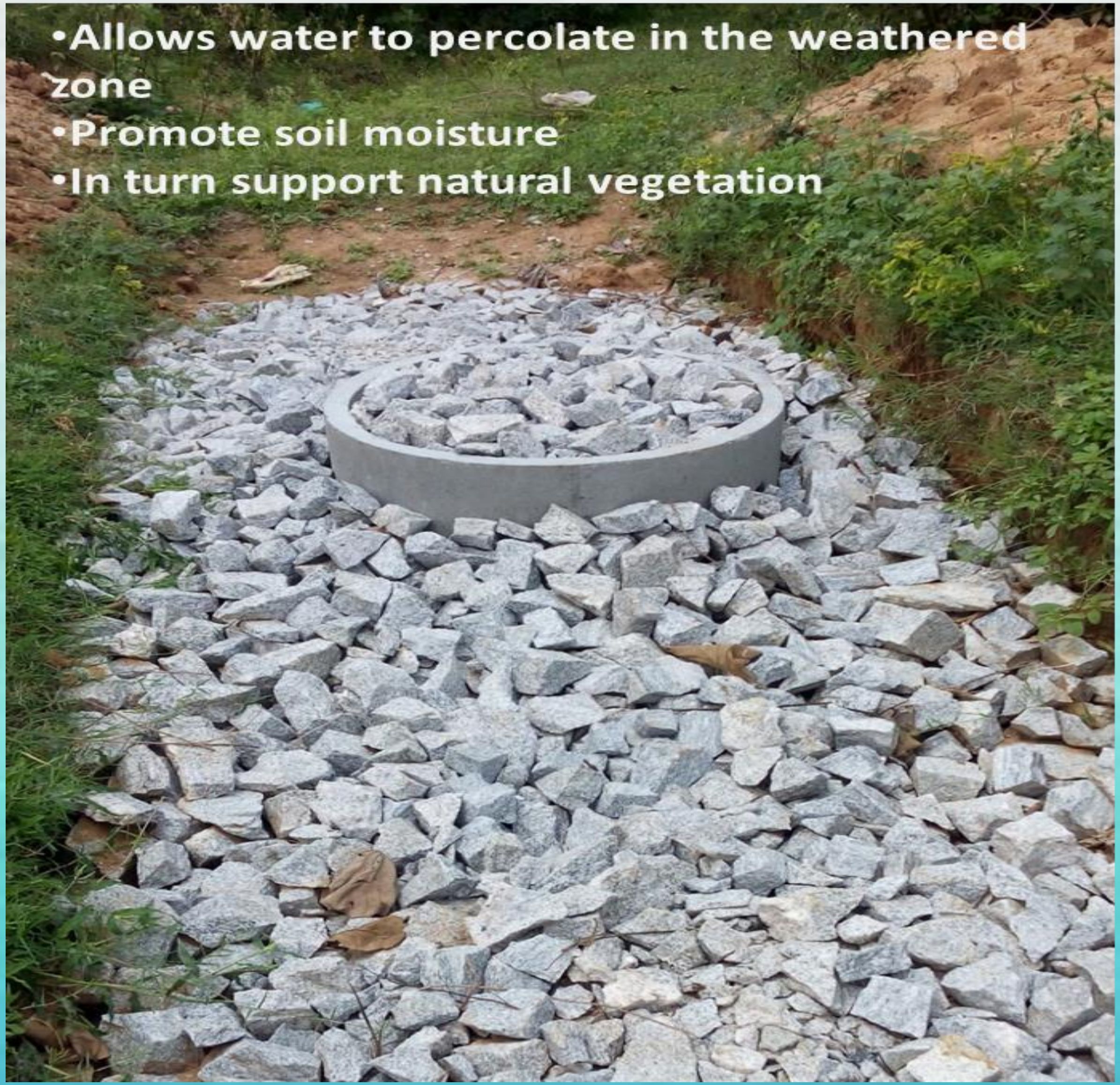
**Pits and shafts**



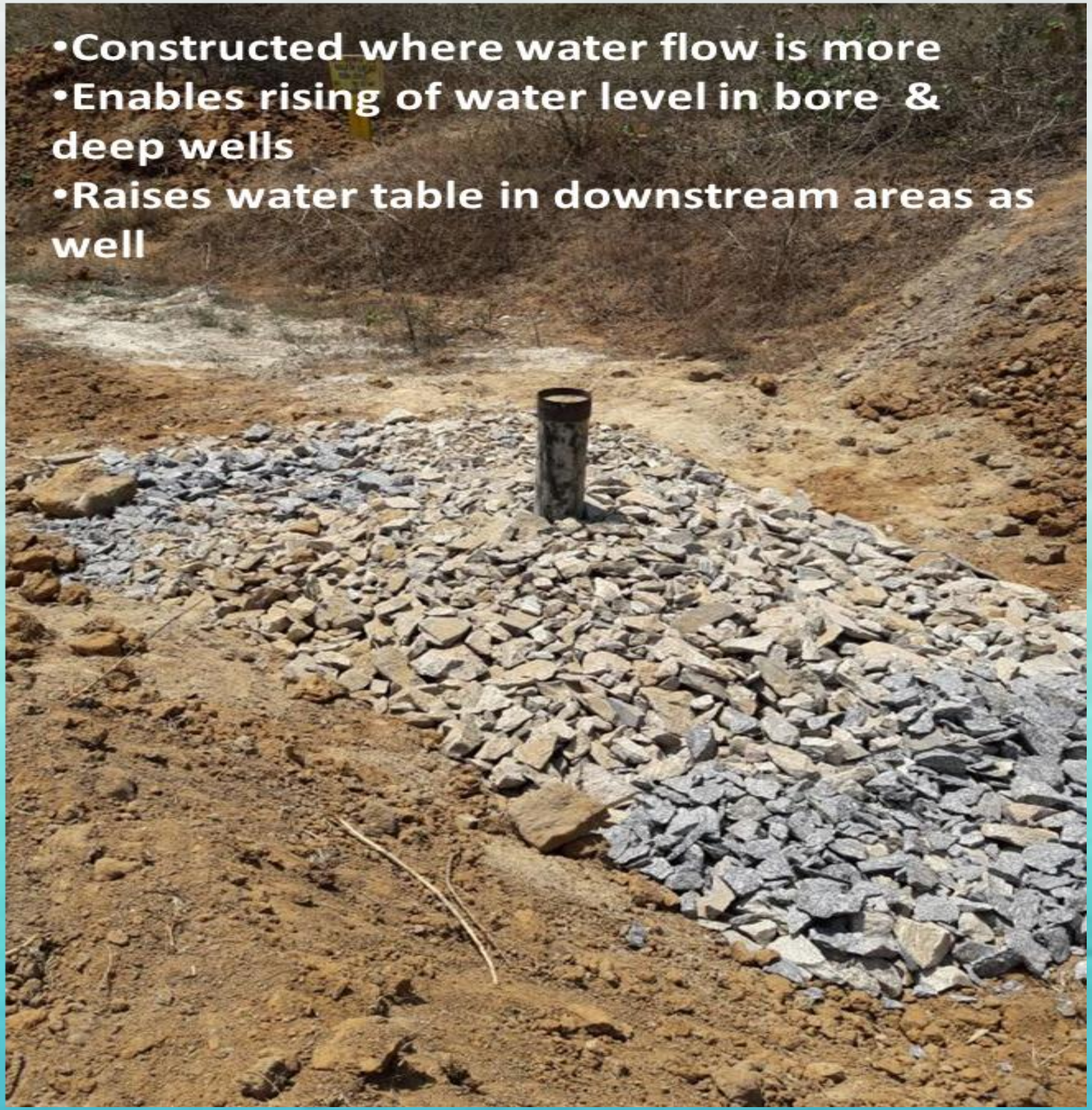



# Boulder Check

# Recharge Well




# Recharge Bore Well




Water Pool
•Water storage in a column with minimum spread area
•Reduce evaporation
•Source of water for human, cattle and birds

# Afforestation

- Prevents soil erosion,  Accelerates water infiltration
- Attracts water molecules to the gravity zone
- Enhances water retention through capillary action
- Long term permanent solution for water problem

**Case Study from Jharkhand**

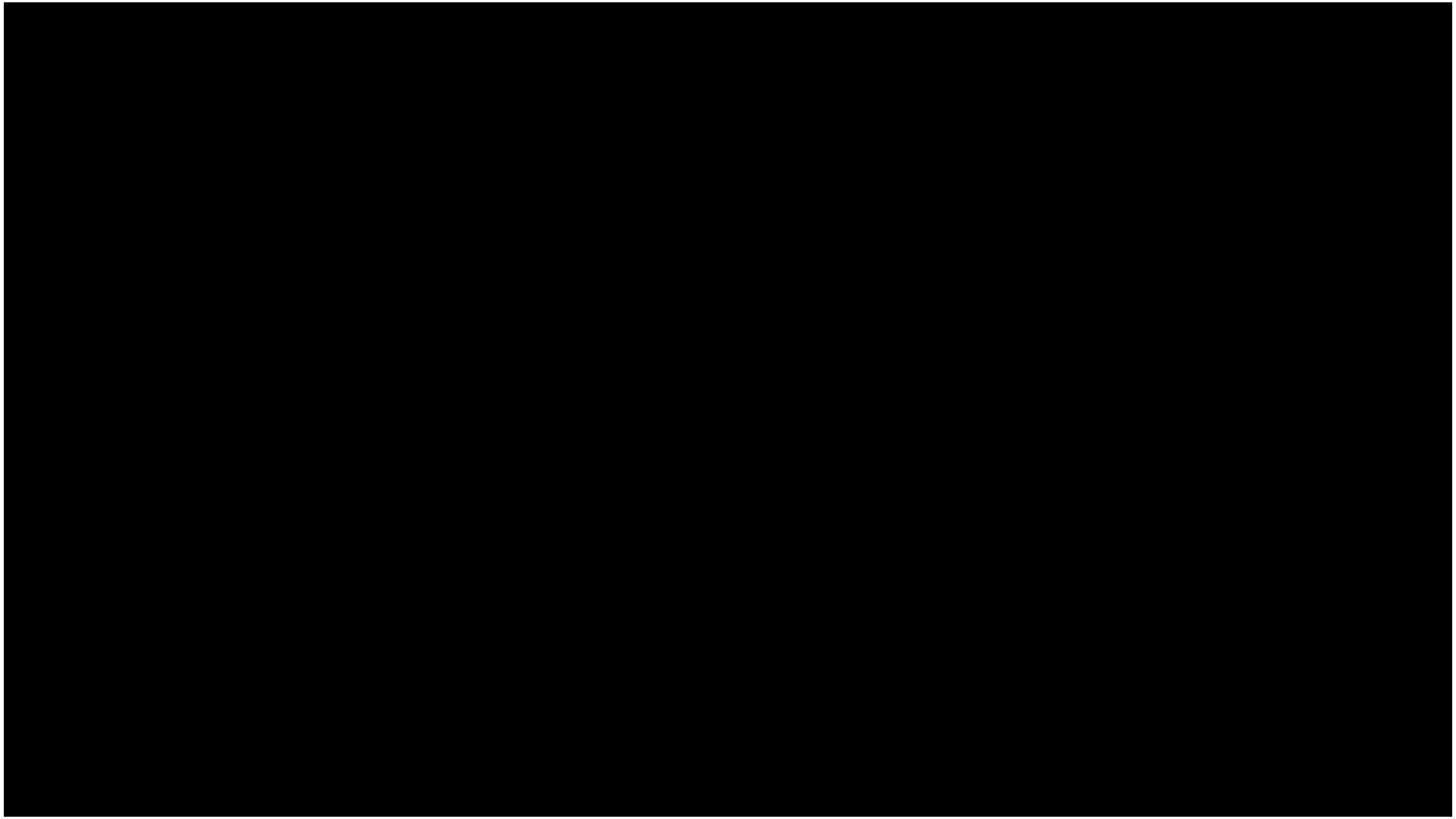
Water ponds and recharge wells at Farmland in Jharkhand.

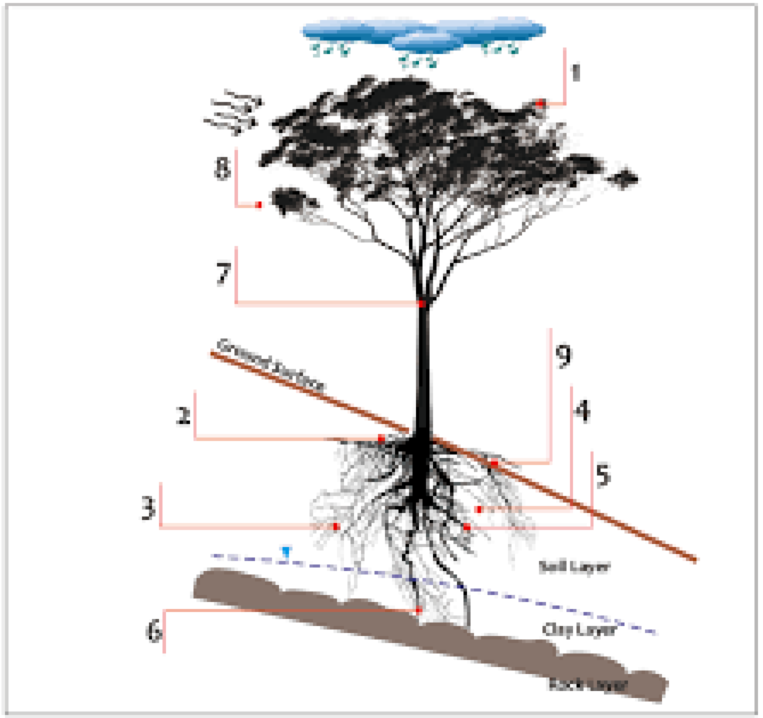
In association with Divvyayan Krishi Vigyan Kendra, Ranchi

**Case Study from Dunda, Uttarakashi**

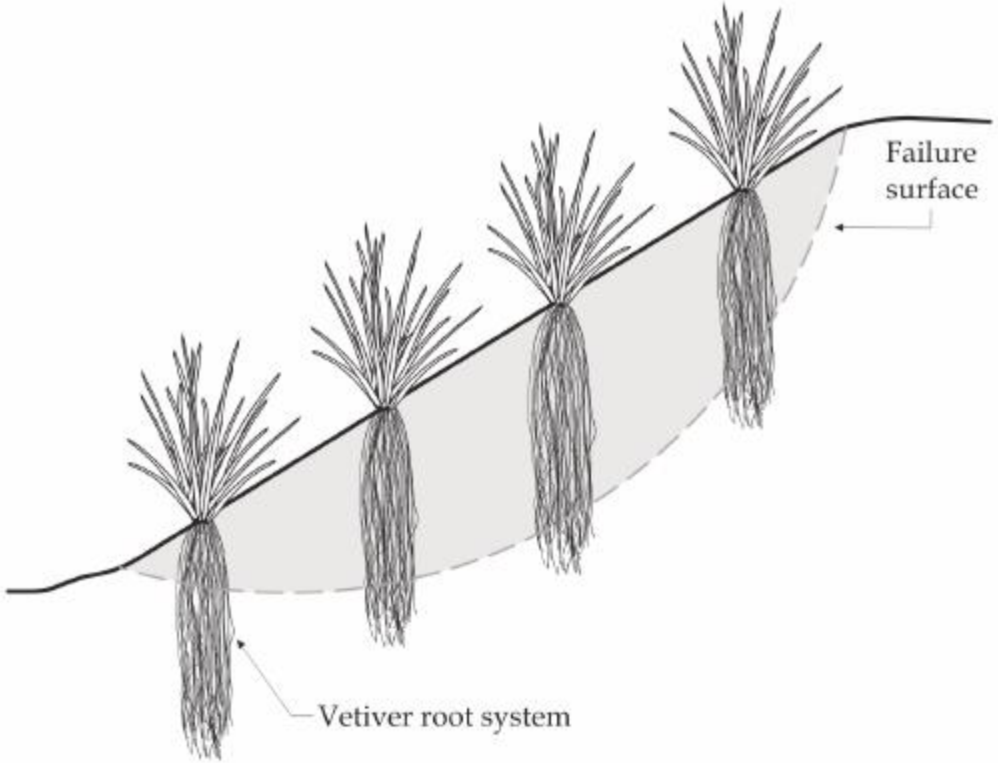
Water ponds and recharge wells at Farmland in Jharkhand.

# World is not running out of water
# but water is running out of the world




1
8
7
9
2
4
5
3
6
Ground Surface
Soil Layer
Clay Layer
Rock Layer


Fibres as roots
70 mm


Failure surface
Vetiver root system

# Soil Stabilization and Reinforcement with Fibers


Soil

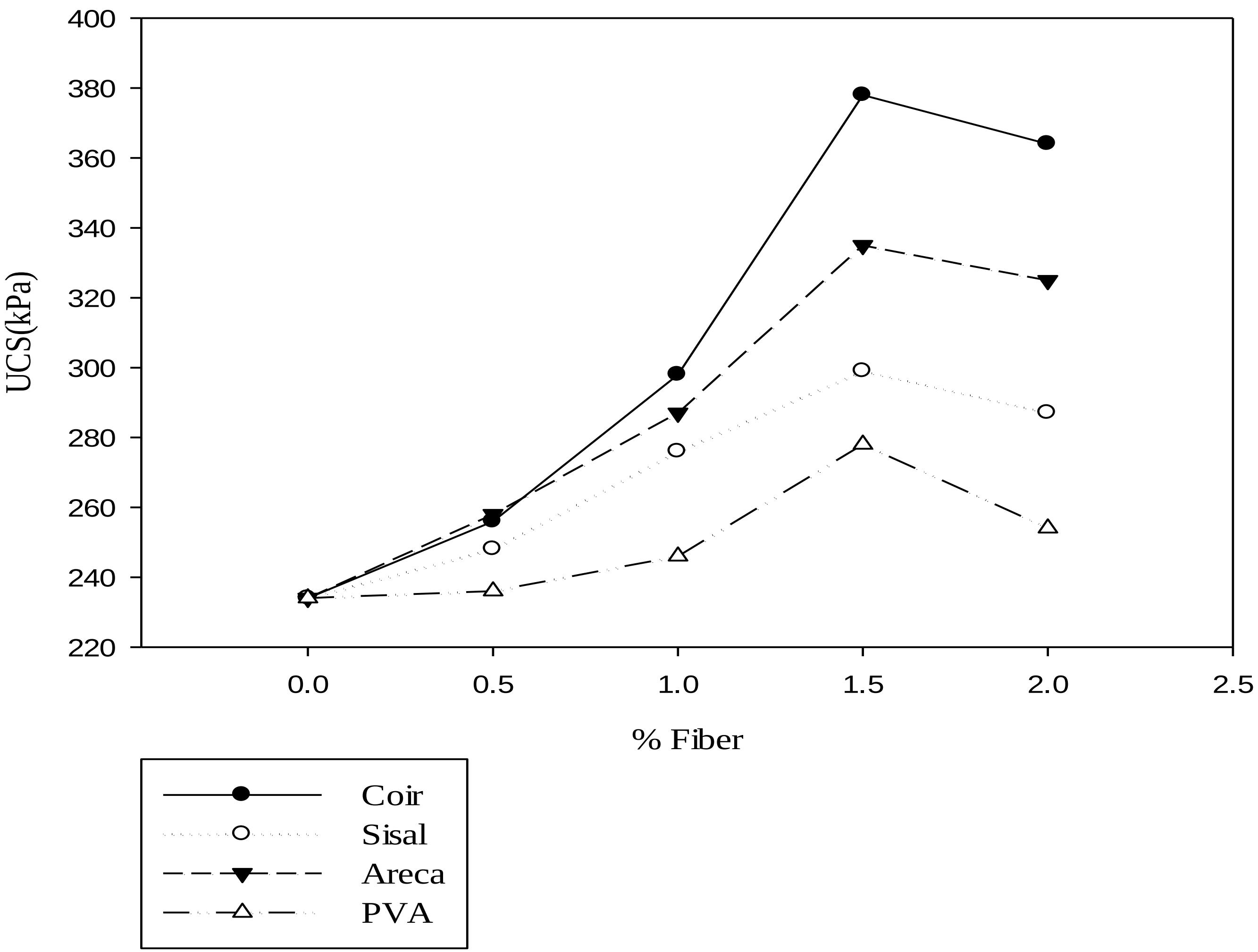

Bottom Ash

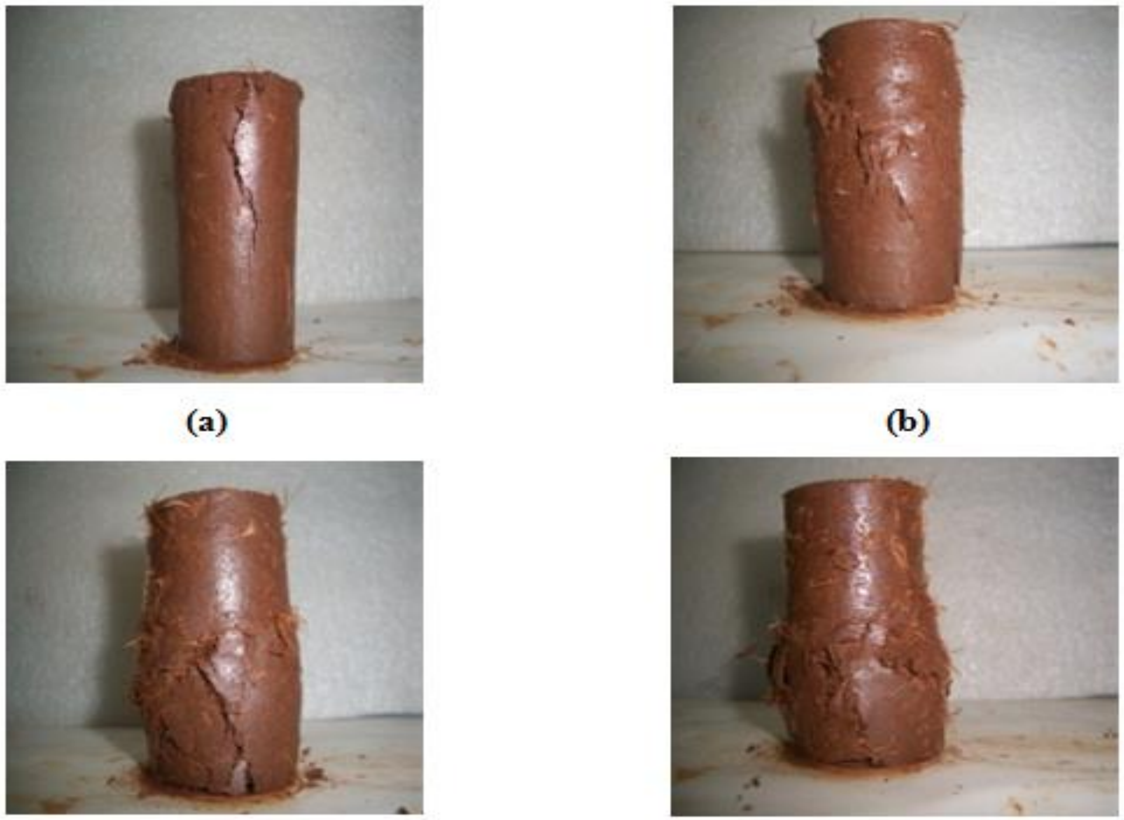

Coir fiber


Sisal fiber


Areca fiber


PVA fiber



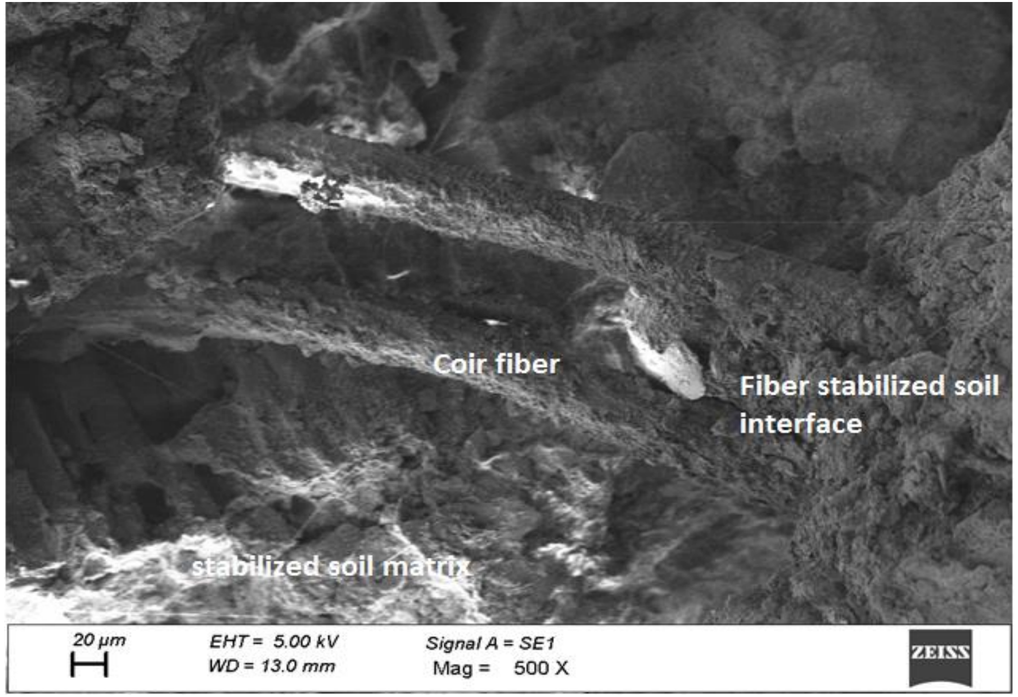



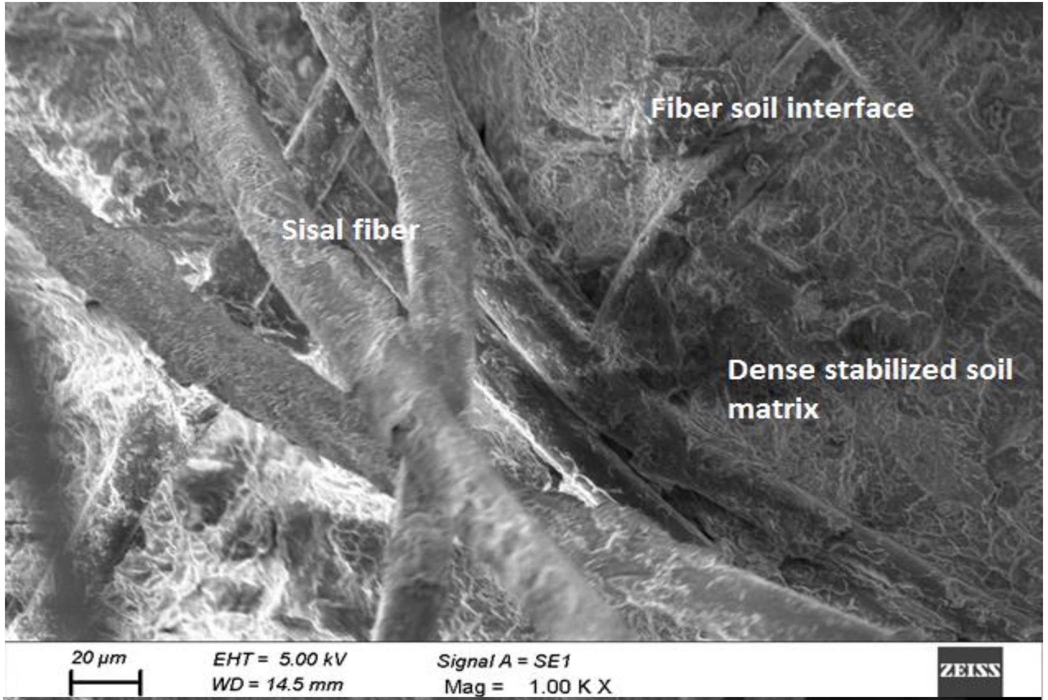
(a) (b)

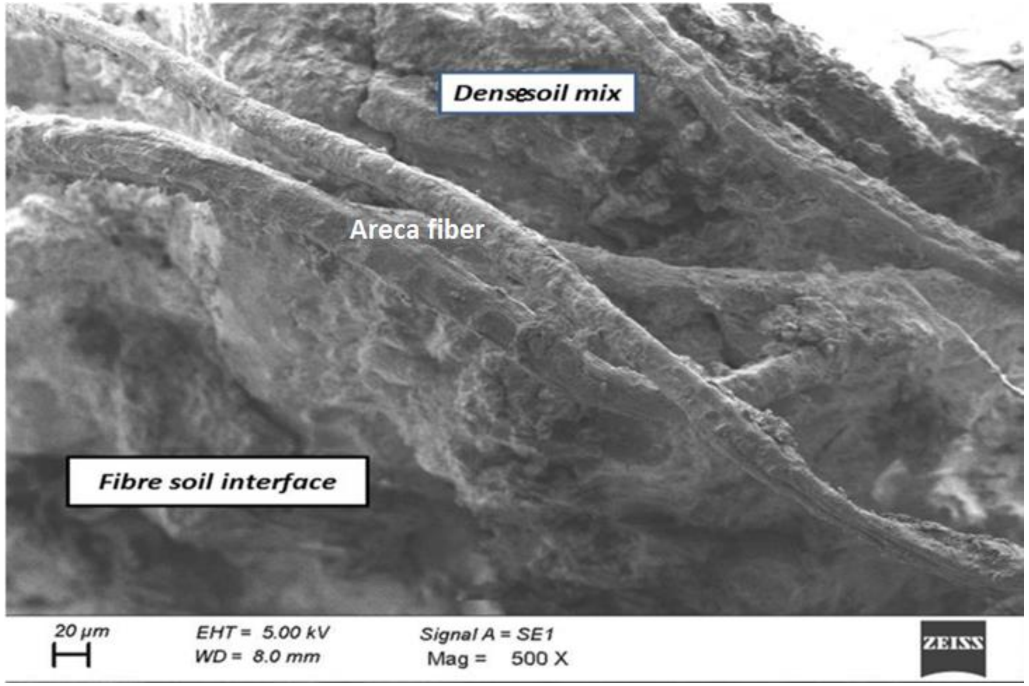
(b) (d)

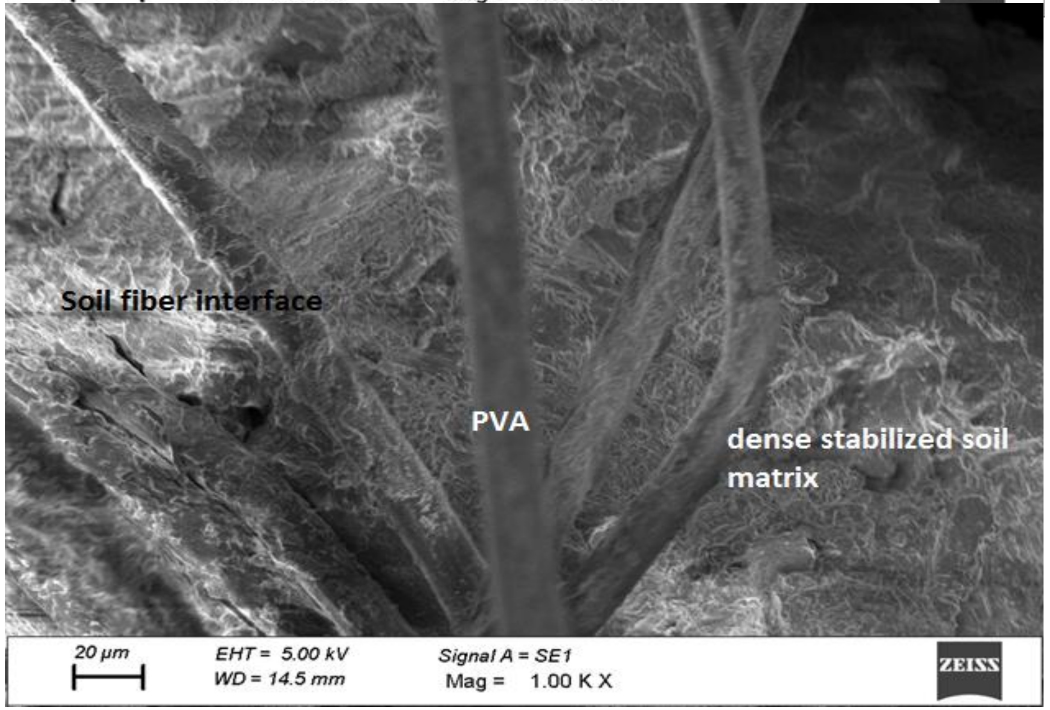
Sooraj S, Sharma A and Kolathayar (2018), J. Mat Civ Engg., ASCE

Swetha P, Kolathayar S and Sharma (2020), ACEM, ASTM


Coir fiber
Fiber stabilized soil interface
stabilized soil matrix
20 µm
EHT = 5.00 kV
WD = 13.0 mm
Signal A = SE1
Mag = 500 X
ZEISS

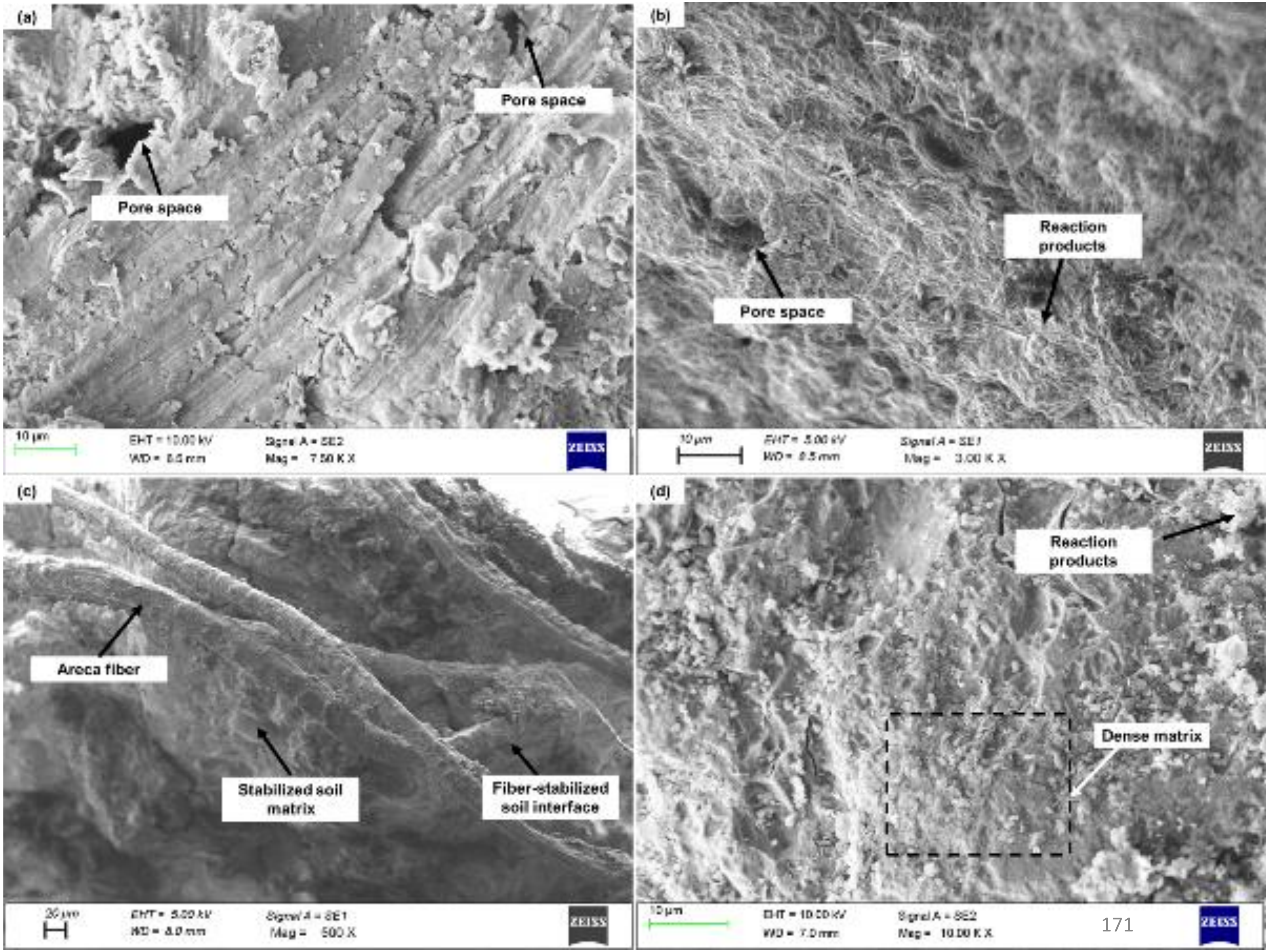

Fiber soil interface
Sisal fiber
Dense stabilized soil matrix
20 µm
EHT = 5.00 kV
WD = 14.5 mm
Signal A = SE1
Mag = 1.00 K X
ZEISS


Densesoil mix
Areca fiber
Fibre soil interface
20 µm
EHT = 5.00 kV
WD = 8.0 mm
Signal A = SE1
Mag = 500 X
ZEISS


Soil fiber interface
PVA
dense stabilized soil matrix
20 µm
EHT = 5.00 kV
WD = 14.5 mm
Signal A = SE1
Mag = 1.00 K X
ZEISS

**SEM micrographs of**

a) untreated soil
b) stabilized mix cured for 28 days
c) fiber-stabilized mix interface cured for 28 days
d) stabilized mix cured for 90 days



# GEOSYNTHETICS

- The term ‘Geosynthetics’ has two parts:
- the prefix ‘geo’, referring to an end use associated with improving the performance of civil engineering works involving earth/ground/soil

- and the suffix ‘synthetics’, referring to the fact that the materials are almost exclusively from man-made products. The materials used in the manufacture of geosynthetics are primarily synthetic polymers generally derived from crude petroleum oils; although rubber, fiberglass, and other materials are also sometimes used for manufacturing geosynthetics.

- Land Engineering

Subgrade Stabilization using Tensar Biaxial Geogrids
Talasari - Udhava Major Dist. Road, PWD, Maharashtra

# Coastal Protection

After installation - During High Tide

# Rock fall protection

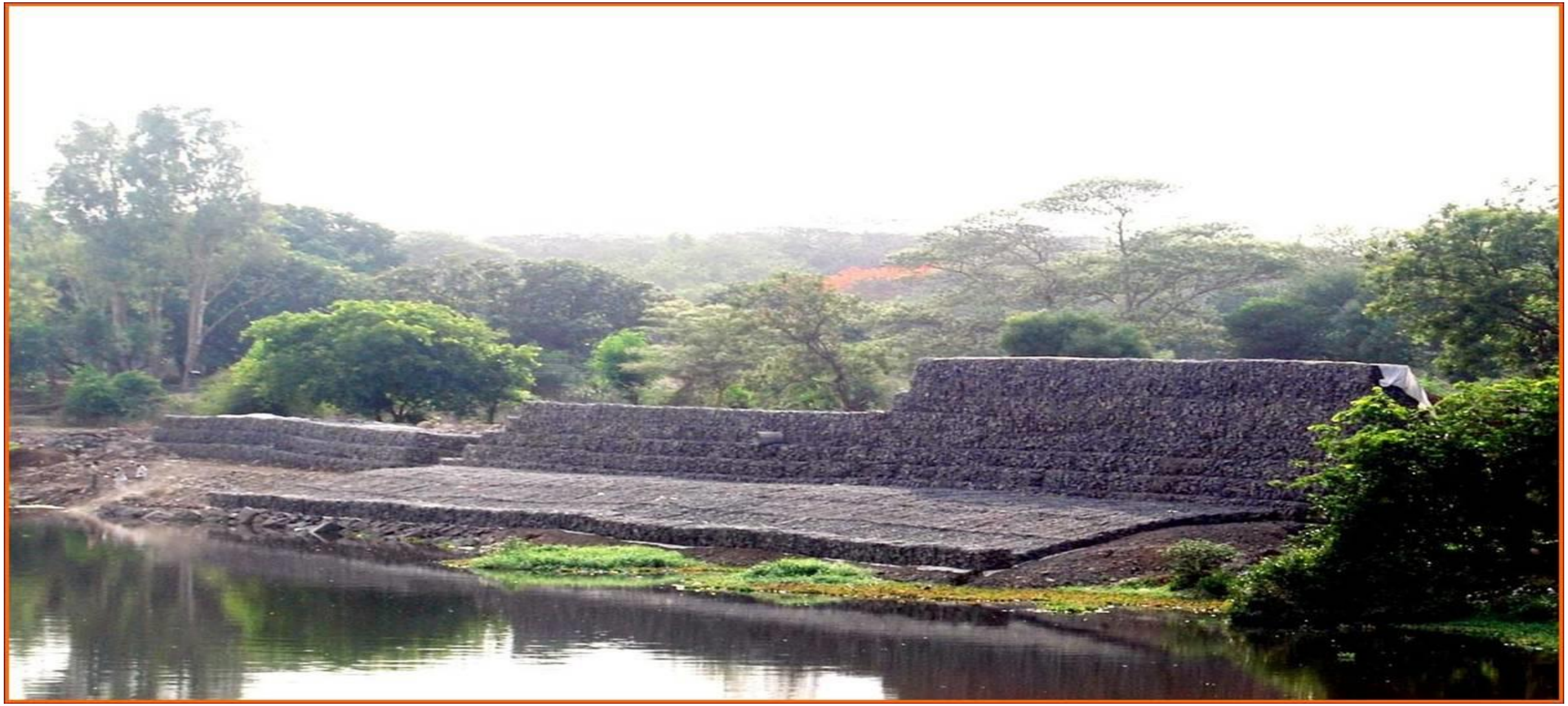
Gabion Retaining Wall – Lavasa

# Canal Lining

Canal Lining

Revetment - Anti Erosion Sea Bund
Morbhagwa, Gujarat, India

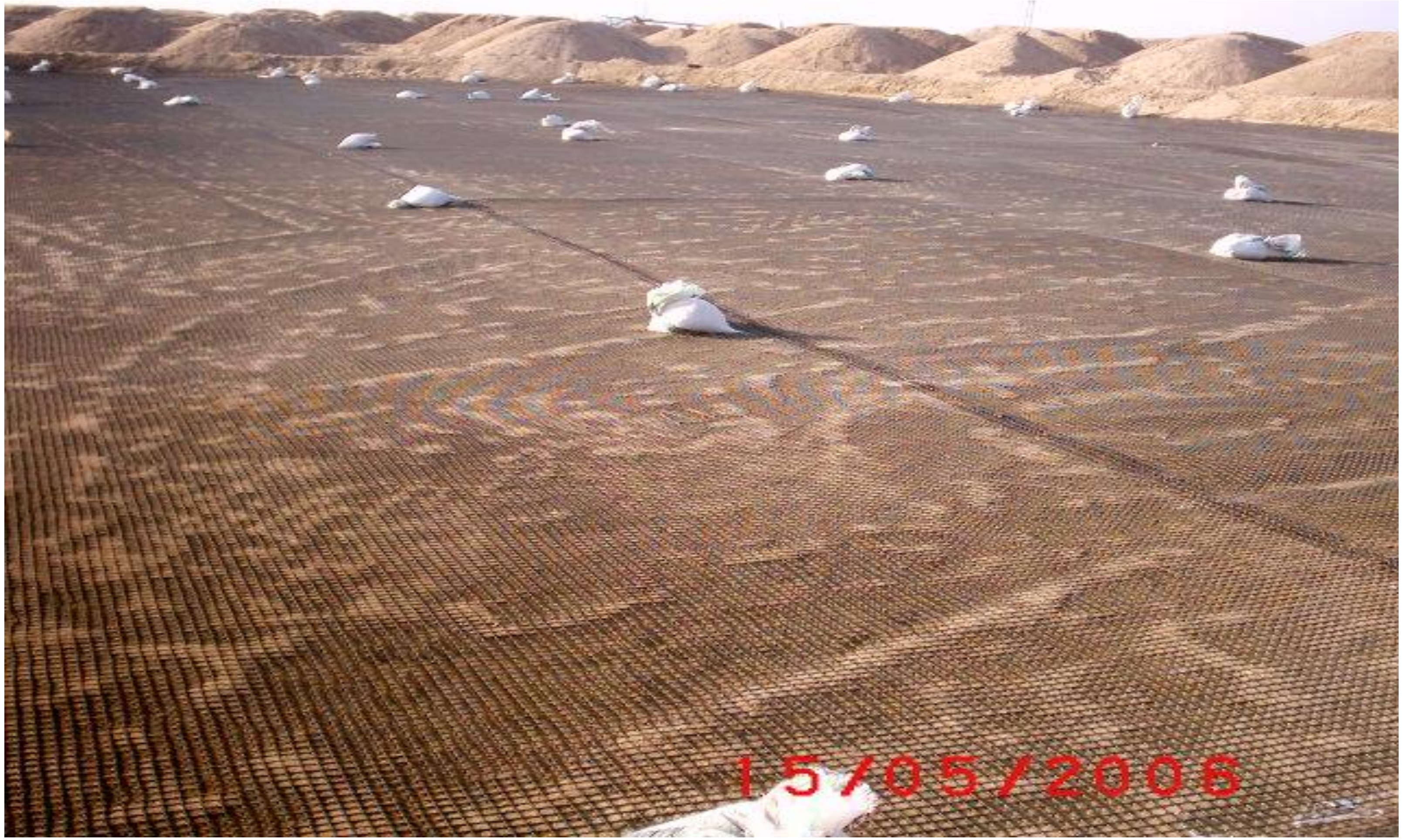
# Flood Control



Flood Protection Works, Mula River, Pune

Slope Retention works at Sakleshpur – Subhramanya Road Section, South Western Railways, Mysore Division

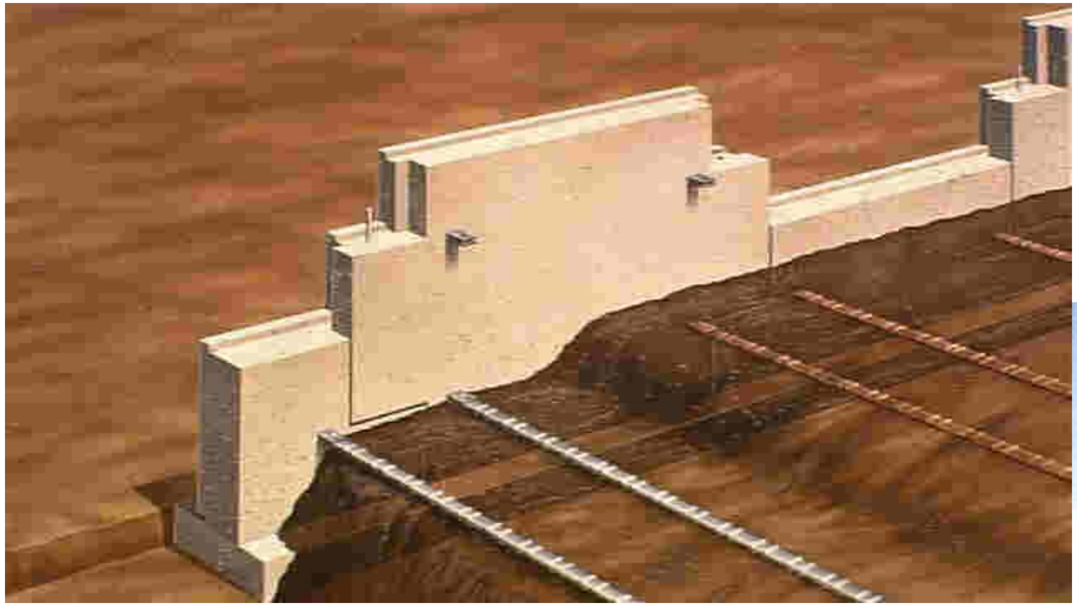
# Ground Improvement




Ground Improvement for Tank Foundation,
HPCL, Mundra, Gujarat

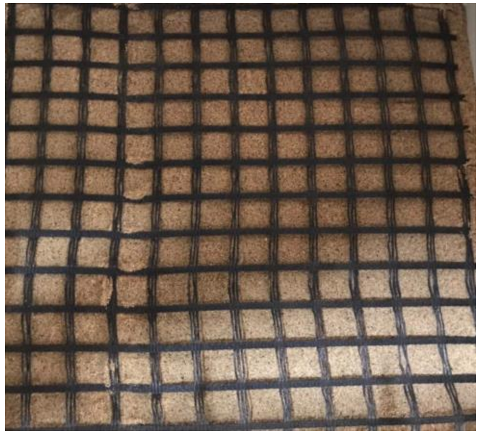

Reinforced Soil System with Gabion Facia, MRPL, Mangalore

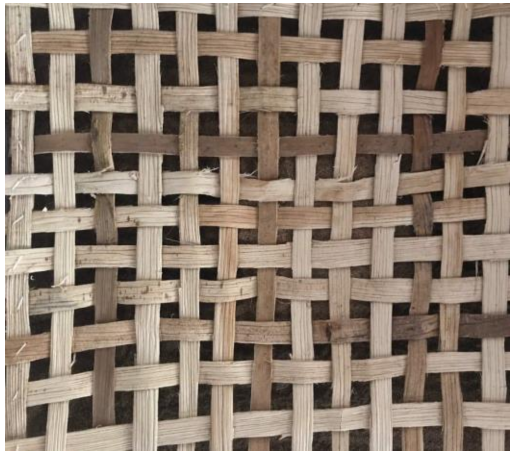
# Types of GRS Walls: concrete panel walls



# Natural planar grids for soil reinforcement

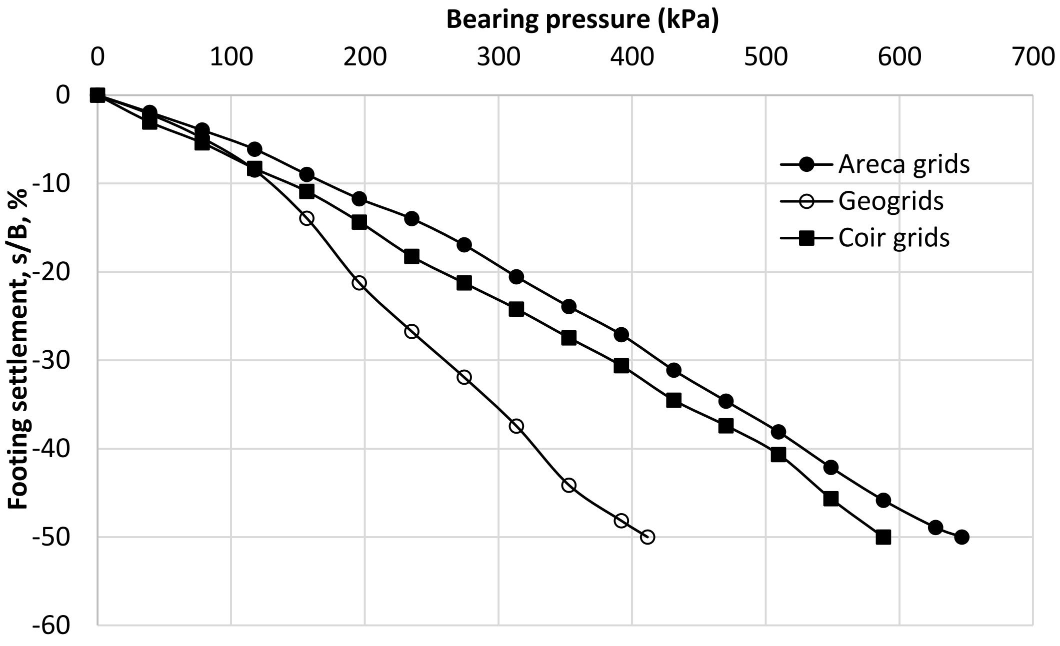


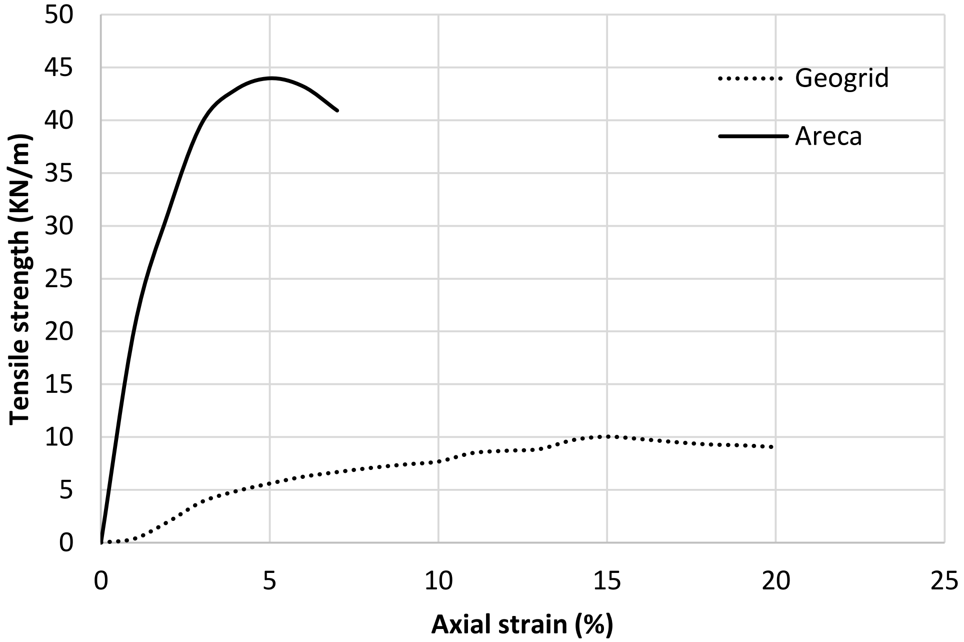


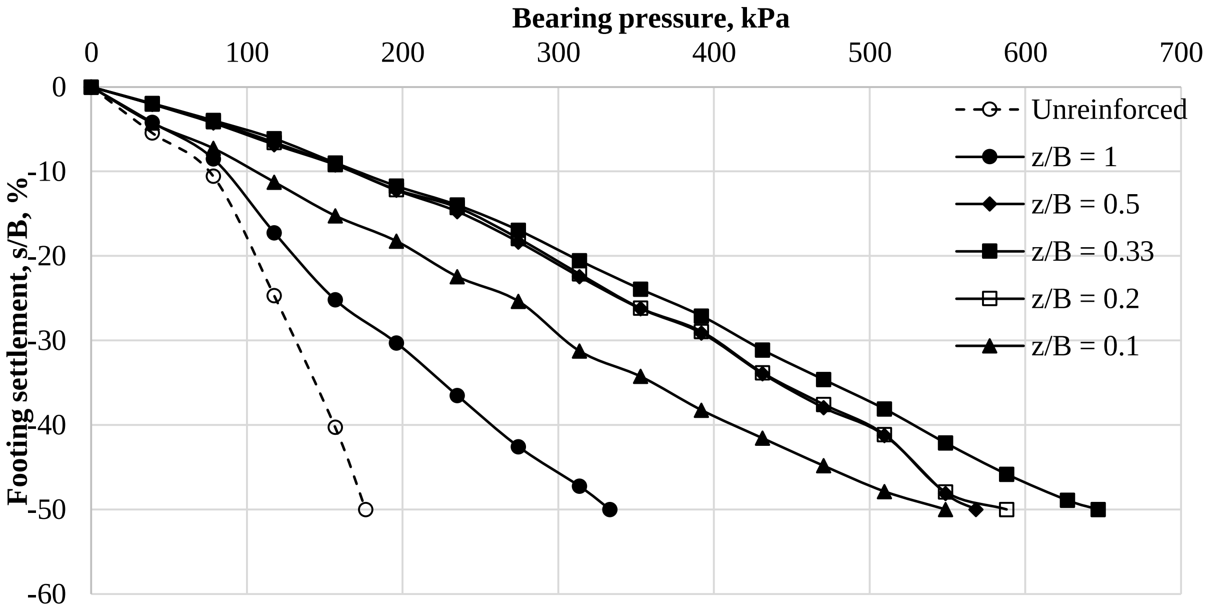


Model Footing Test Setup Fabricated

| Parameter | Value |
|---|---|
| Specific gravity | 2.65 |
| Fineness modulus | 3.62 |
| Effective size, $D_{10}$ (mm) | 0.215 |
| Coefficient of uniformity, $C_u$ | 3.67 |
| Coefficient of curvature, $C_c$ | 0.919 |
| Soil Classification (USCS) | SP (Poorly graded sand) |



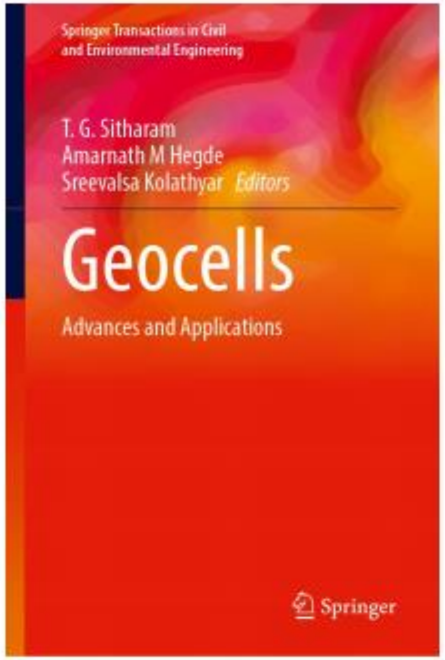




Ref: Kolathayar S, Aravind CA and Shukla SK (2019) In J. Nat Fibers

Springer

springer.com




1st ed. 2021, XIX, 489 p. 280 illus., 156 illus. in color.

**Printed book**

Hardcover

159,99 € | £139.99 | $199.99
[1]171,19 € (D) | 175,99 € (A) | CHF 189,00

**eBook**

T. G. Sitharam, Amarnath M. Hegde, Sreevalsa Kolathyar (Eds.)

# Geocells

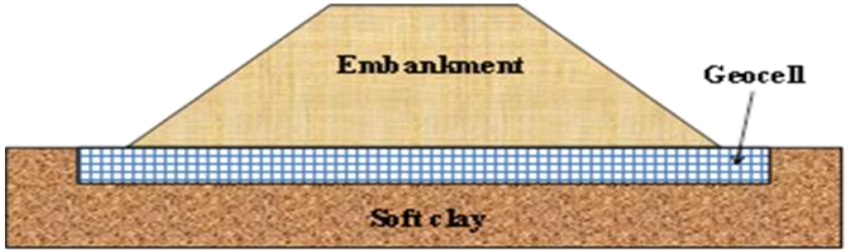
## Advances and Applications

### Series: Springer Transactions in Civil and Environmental Engineering

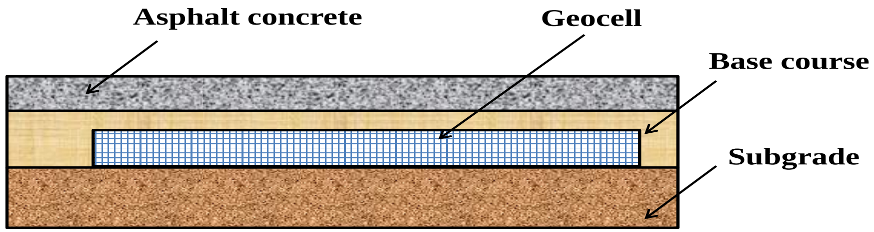
- First ever comprehensive resource on geocells
- Industry case studies with color photographs
- Catalogs geocells manufactures and applications

This book is designed to serve as a comprehensive resource on cellular confinement systems or geocells, covering technologies and their applications in geotechnical engineering. The book discusses all aspects of geocells and related technologies, and covers the subjects from conceptual basics to recent advances. The chapters of this book are written by renowned international experts and its contents include detailed case studies from both academic and industry experts. This book is a one-stop reference work foracademicians, students, and practicing engineers in the global geotechnical community.

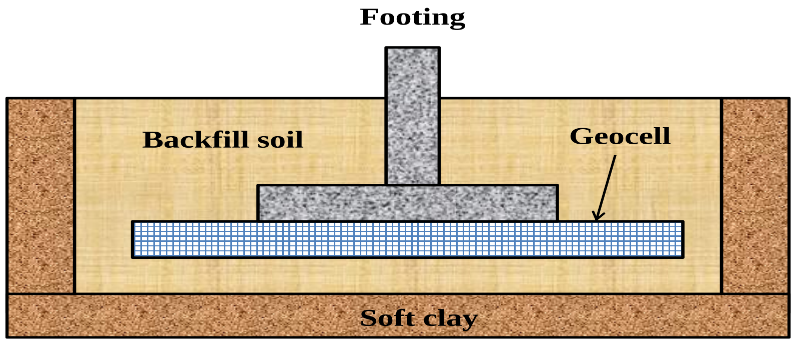
# Geocell Applications



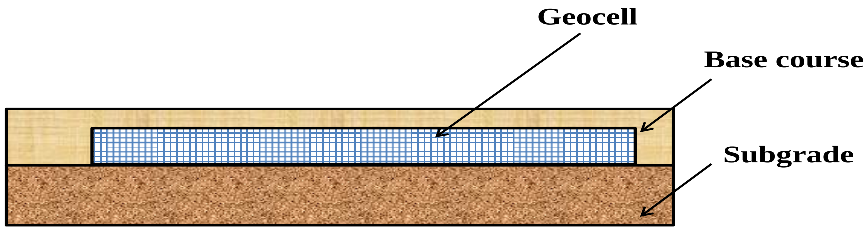

(a) Embankment foundation



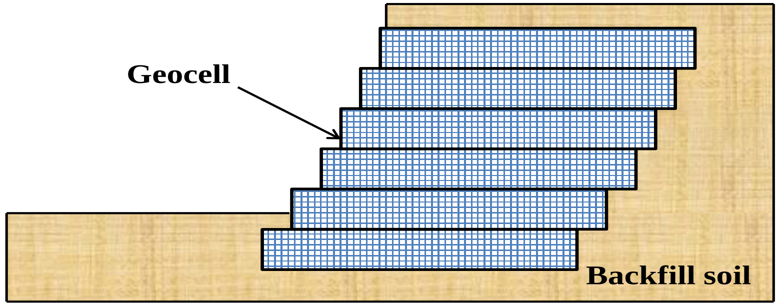

(b) Paved road



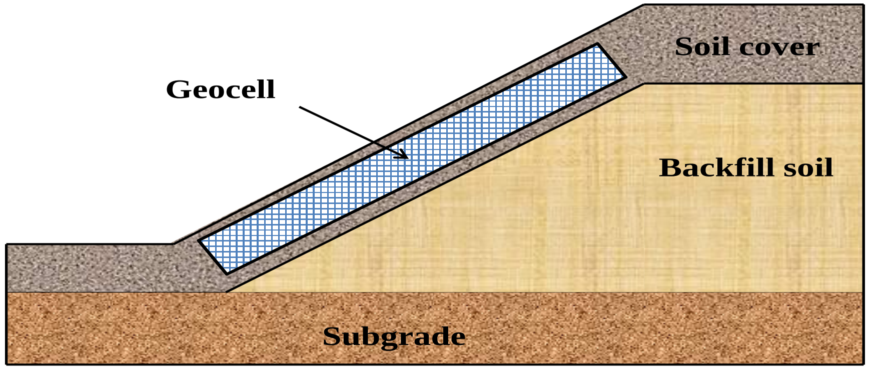

(c) Spread footing foundation




(d) Unpaved road




(e) Earth retaining wall




(f) Slope erosion control

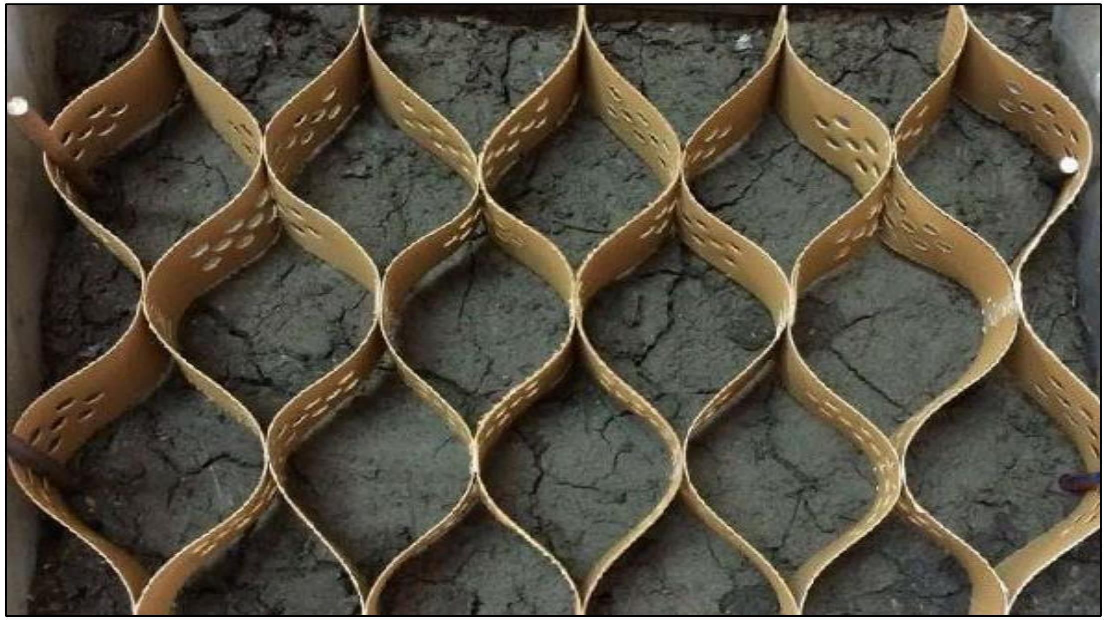
# 1 year after completion.

Areca leaf sheath

Areca grids

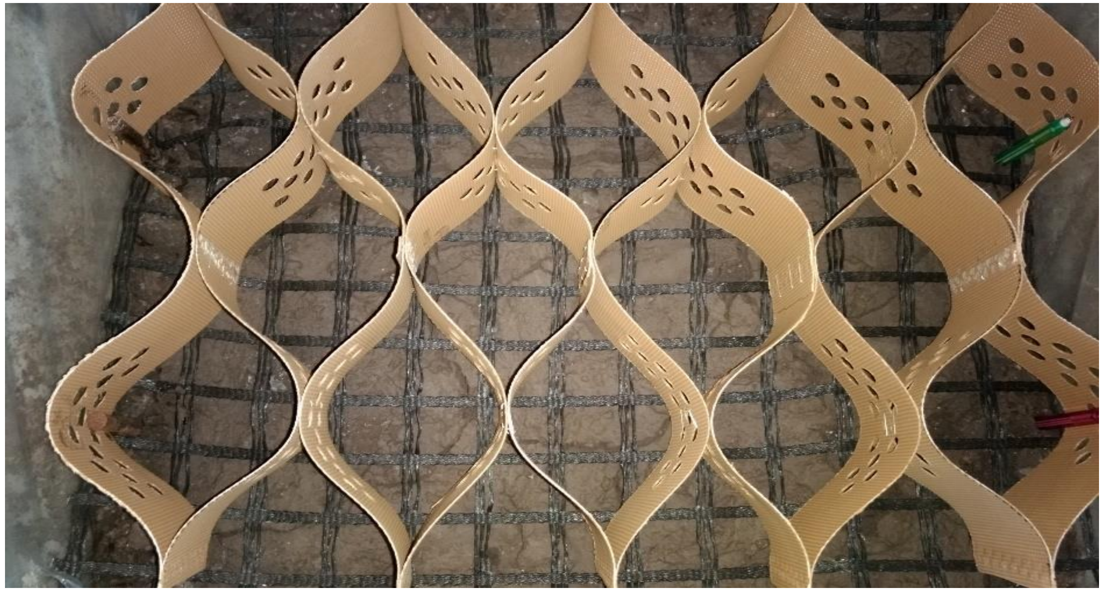
Areca cells

Kolathayar et al. (2019a), Kolathayar et al. (2019b)



Geocell reinforced clay bed

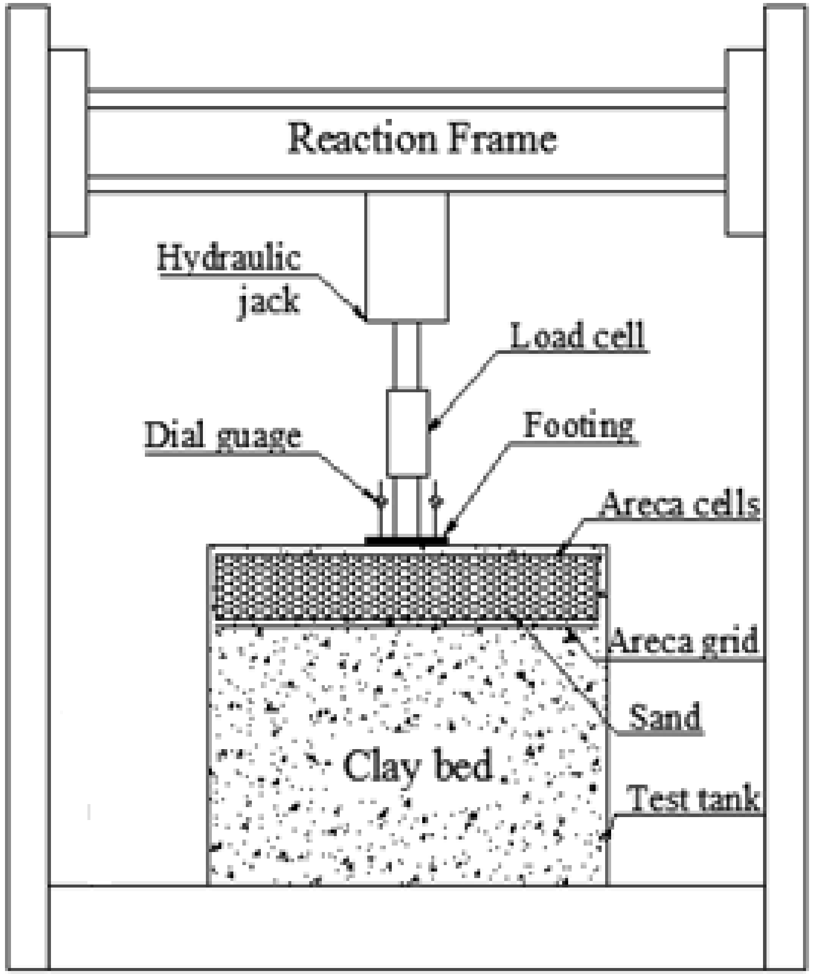
Areca cell reinforced clay bed



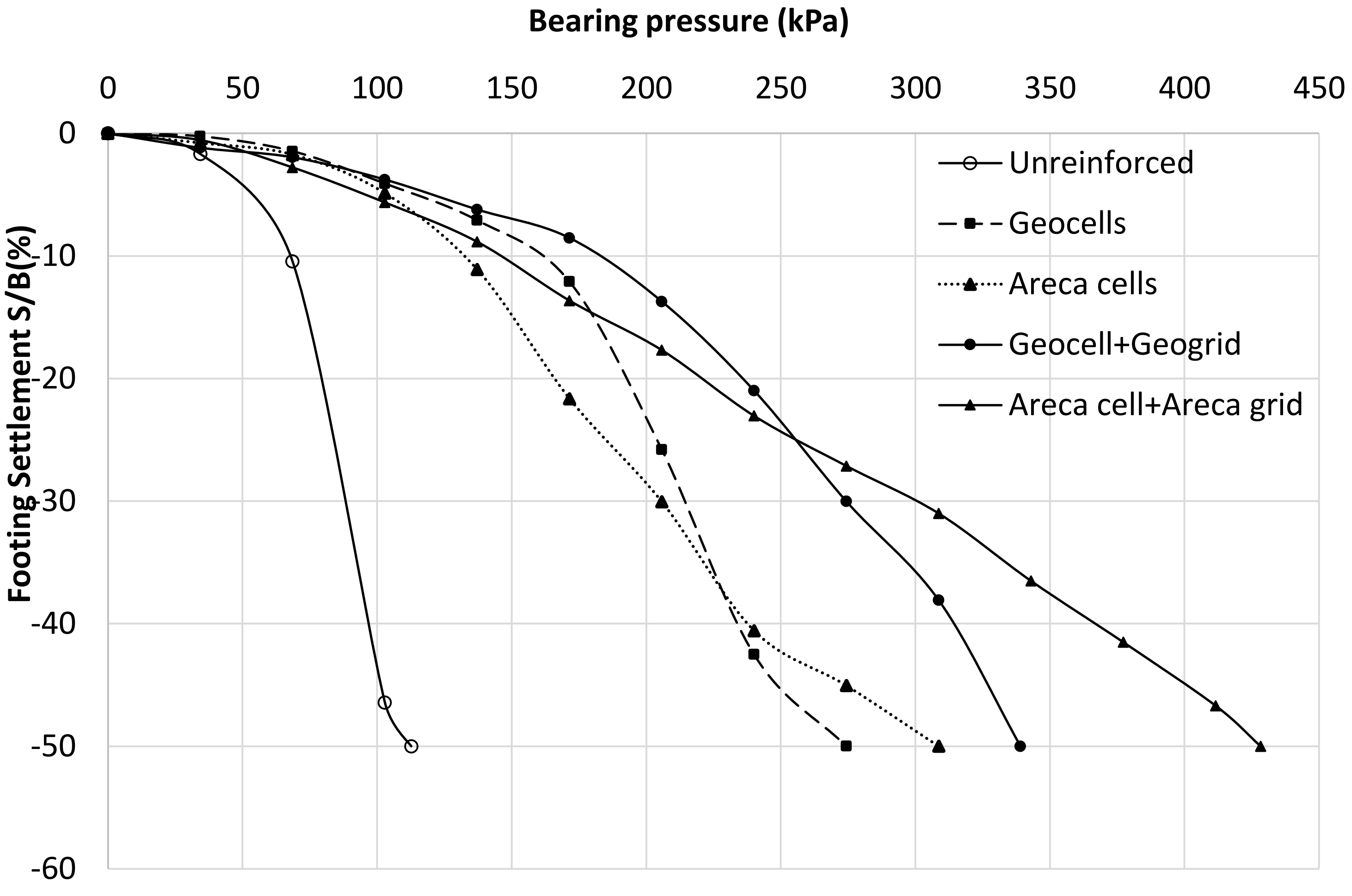
Geocell + Geogrid reinforced clay bed

Areca cell + Areca grid reinforced clay bed

Four-fold increase in bearing capacity with areca cell & grid!




Model footing test set up

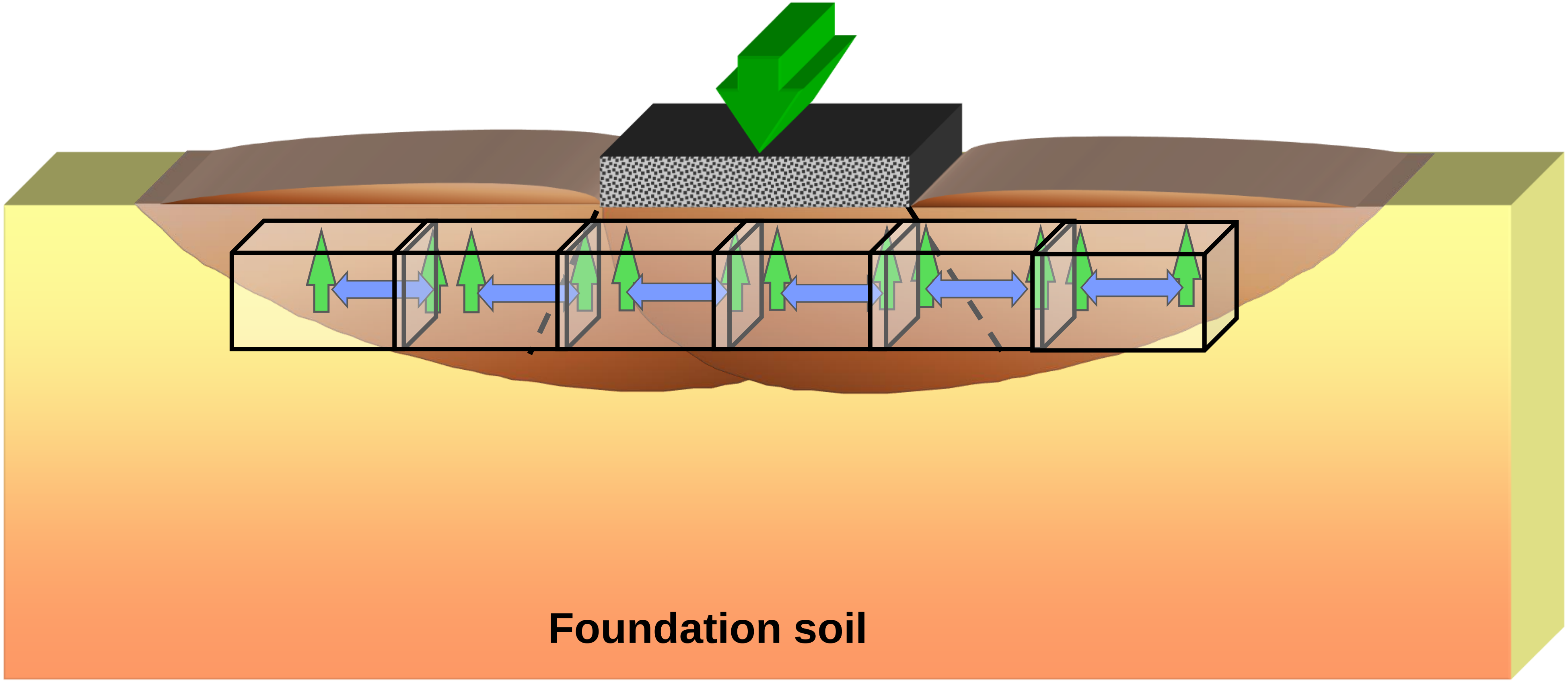



Bearing pressure vs settlement behaviour

Ref: Kolathayar S, Aravind CA and TGS (2019) Geomechanics and Geoengineering

# GEOCELL REINFORCED SOIL BED

## Mechanism of Geocell Reinforcement in foundations



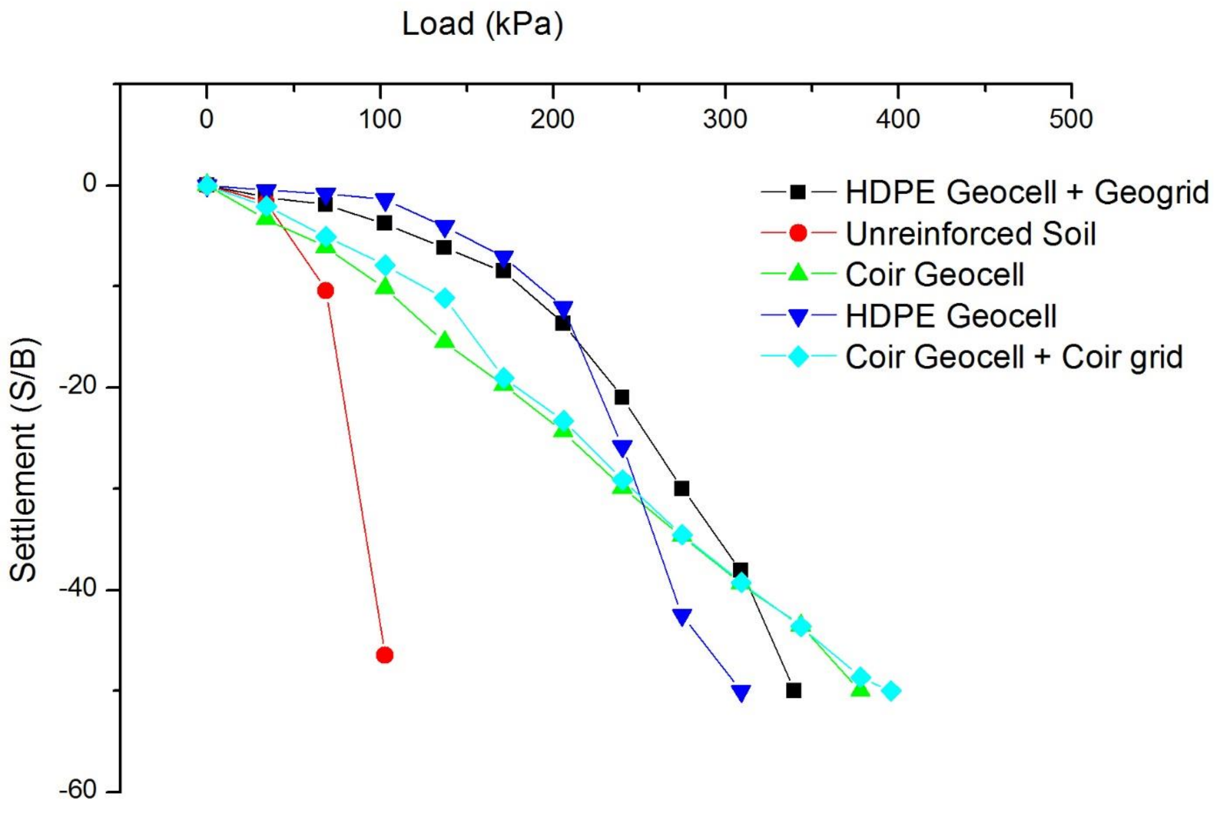
**Areca geocell**

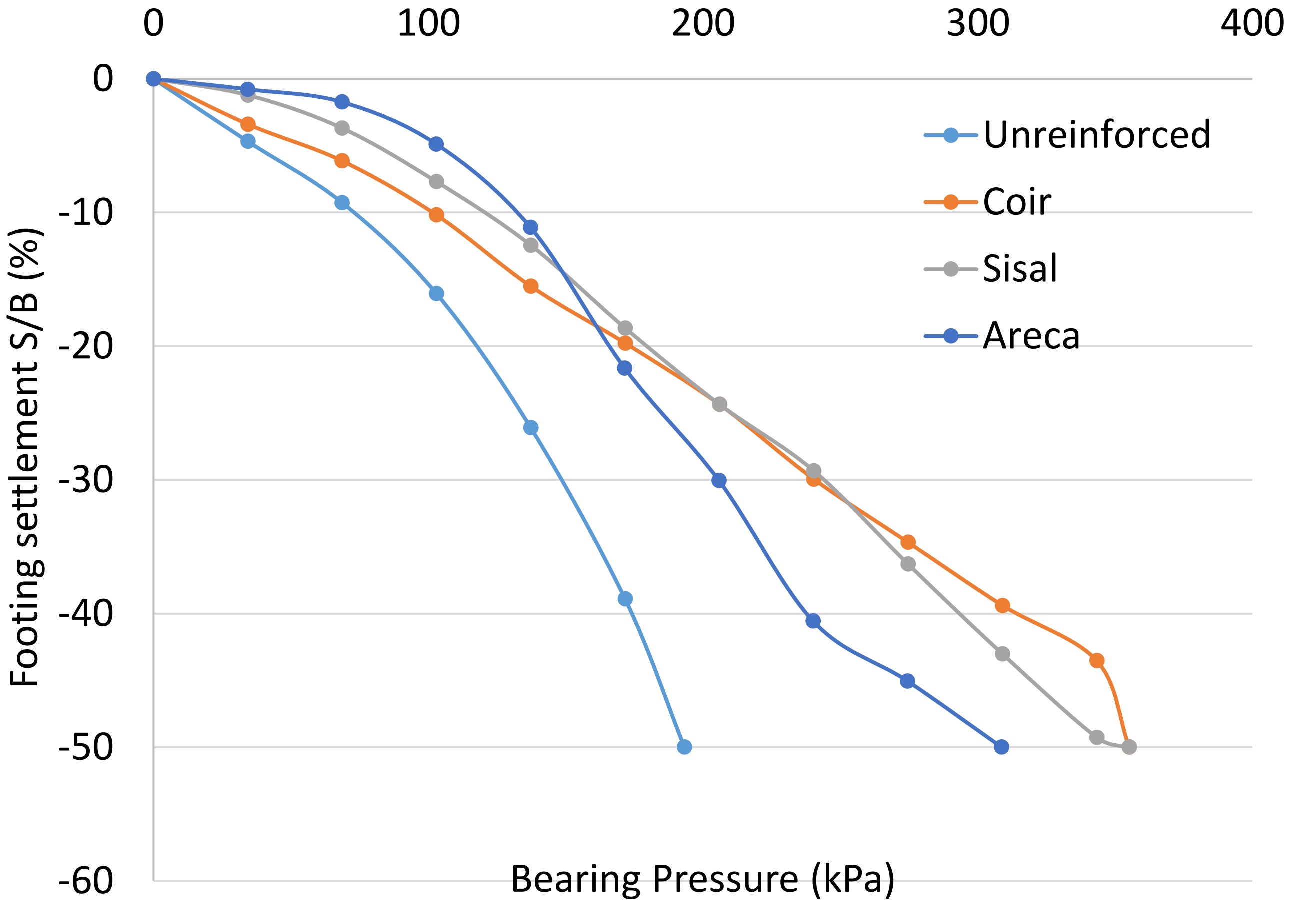
**Coir Geocell**

**Jute Geocell**

**Sisal Geocell**

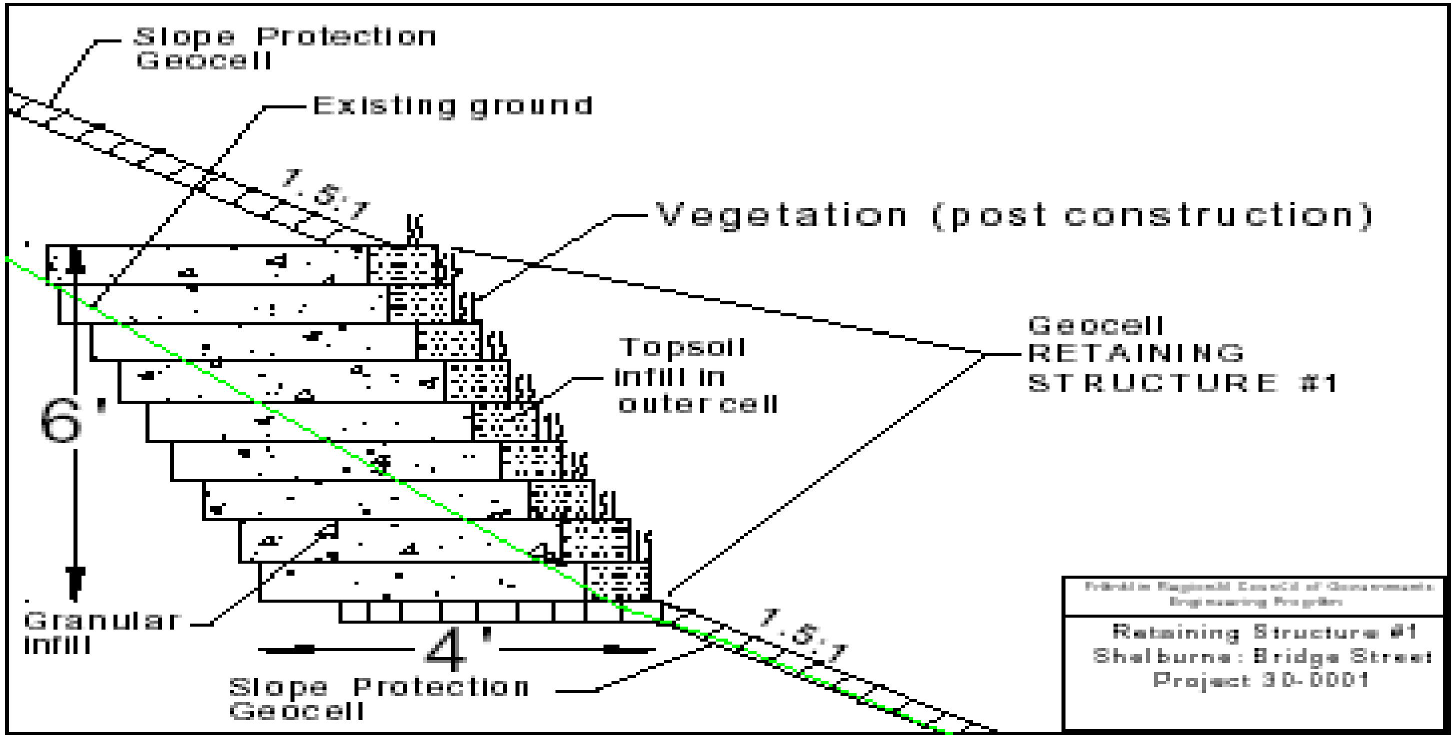
# Bearing pressure - Settlement behavior of Natural Geocell reinforced soil

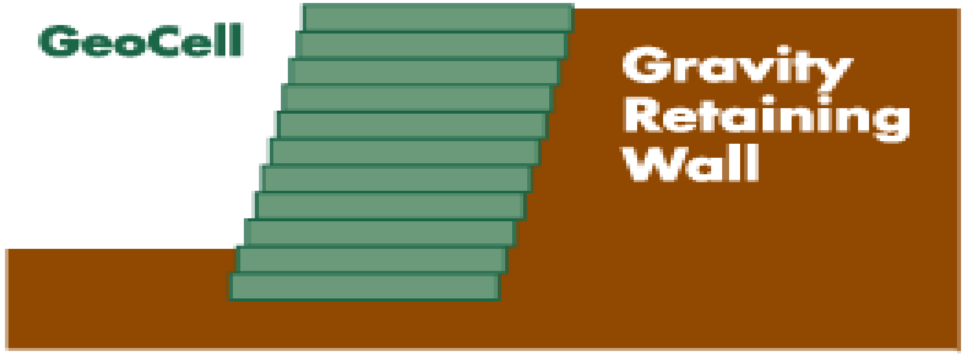



**Kolathayar et al. (2020), Intl. J. Geomech., ASCE**

# Geocell Retaining Walls



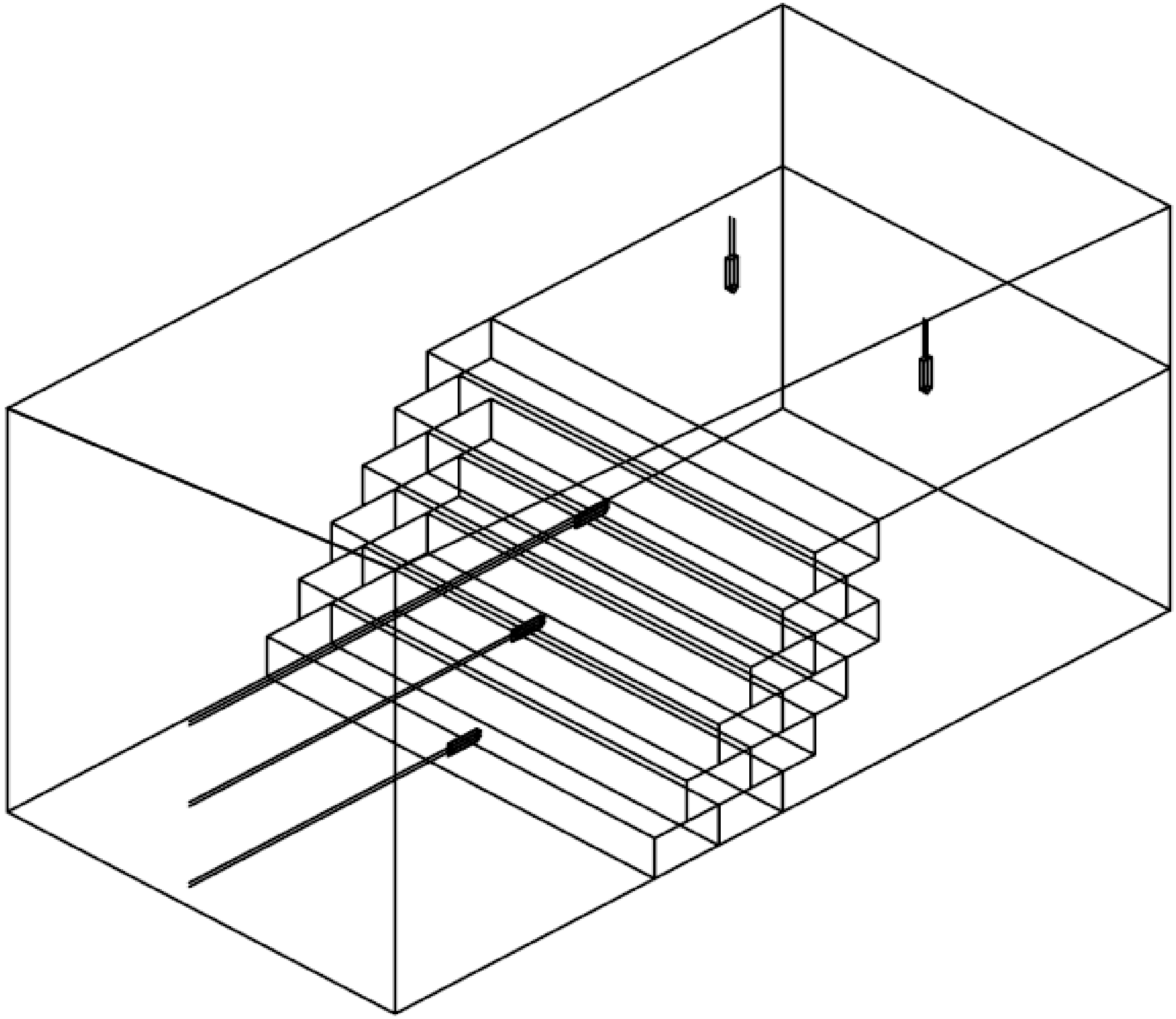




**Primarily constructed using the GeoCell as a stabilizer for the soil, able to retain materials behind it by virtue of it's own weight.**

# Natural Geocells as Soil etention systems

## Model Retaining Wall Test Set up created

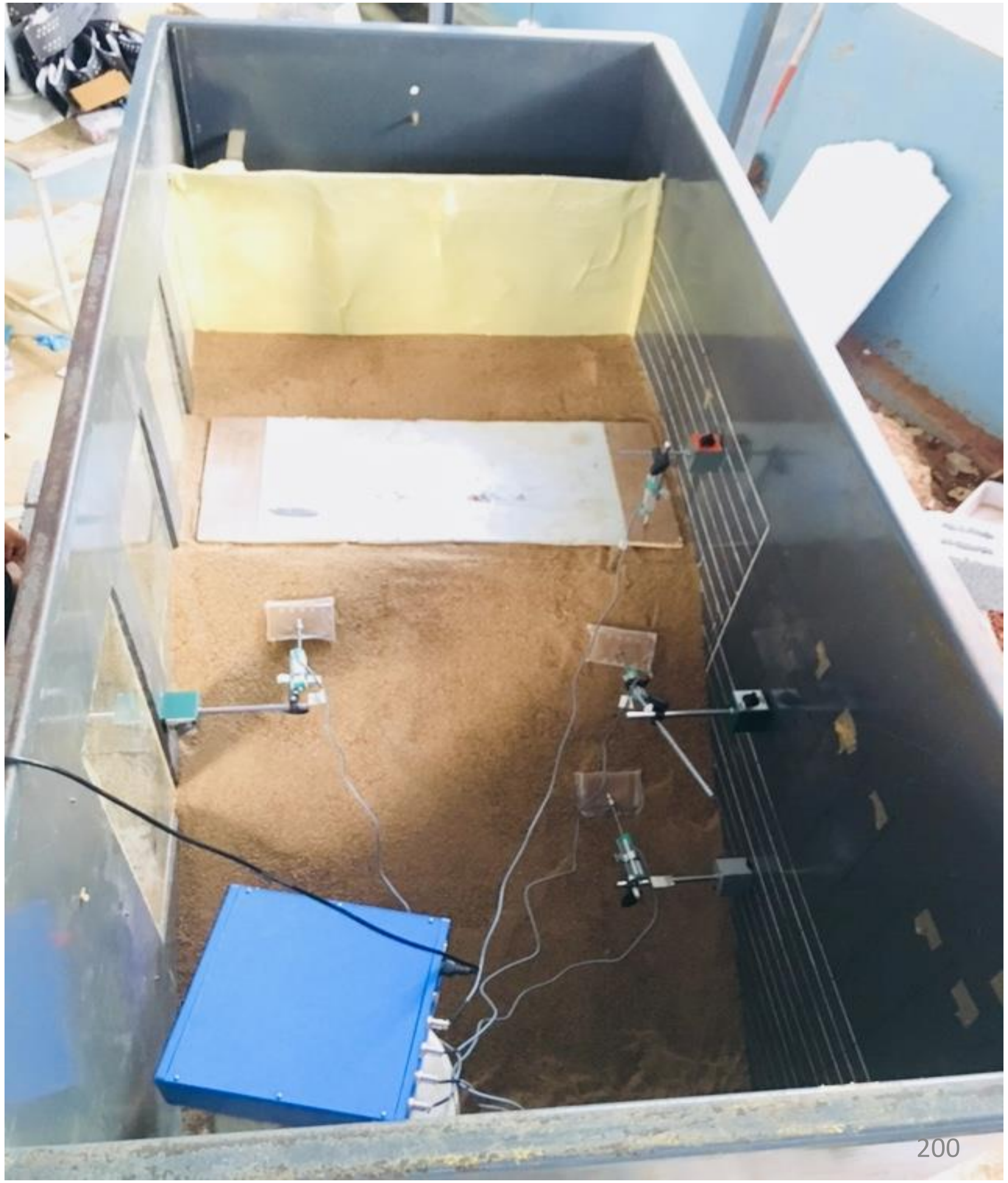
- Static load tests were performed on retaining walls of height 0.6 m, bottom dimensions 1.3 m × 1 m and top dimensions 0.95 m × 1 m.
- For the uniform application of the load, a wooden panel of dimensions 0.40 m × 0.98 m was used.
- Even though the length of backfill at the top portion was 0.80 m, to reduce the confinement effect 0.55 m top length of model was considered.

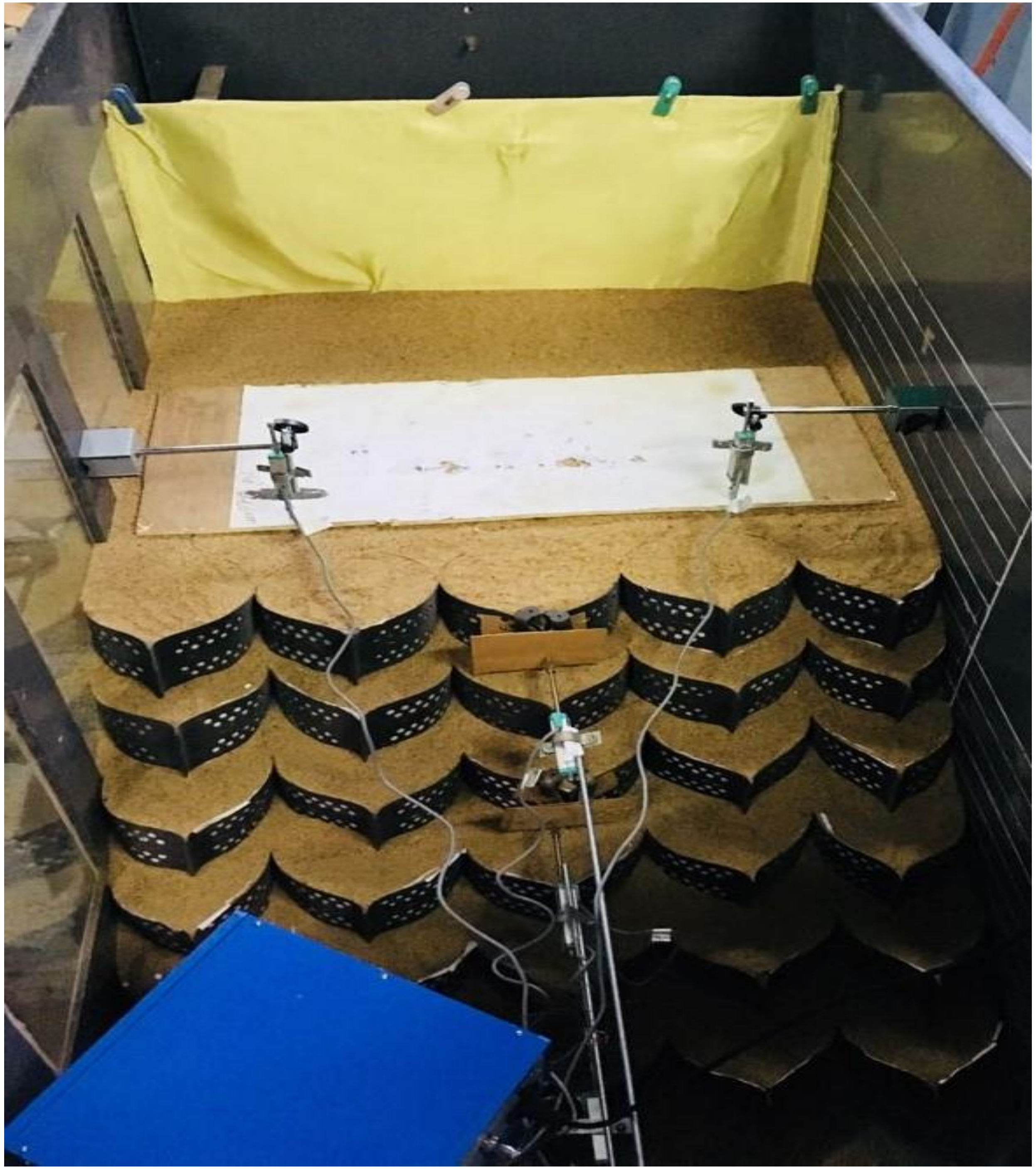


***Model retaining wall***



# *Unreinforced slope (RW 1)*





*HDPE Geocell Retaining Wall (RW 2) – infill material (Sand)*

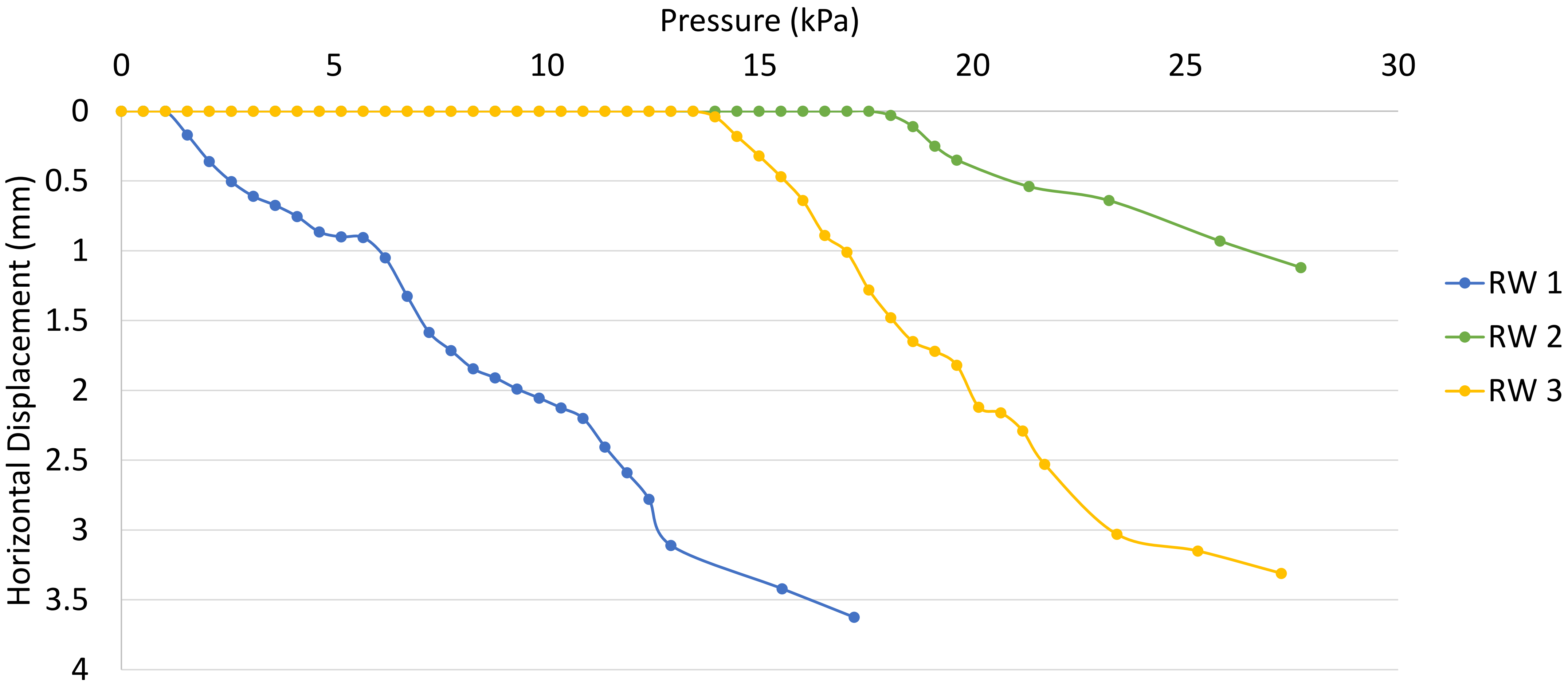
# *Coir Geocell Retaining Wall (RW 3)* *– infill material (Sand)*

# *HDPE Geocell Retaining Wall (RW 4)* *– infill material (ST mixture)*

# *Coir Geocell Retaining Wall (RW 5) – infill material (ST mixture)*

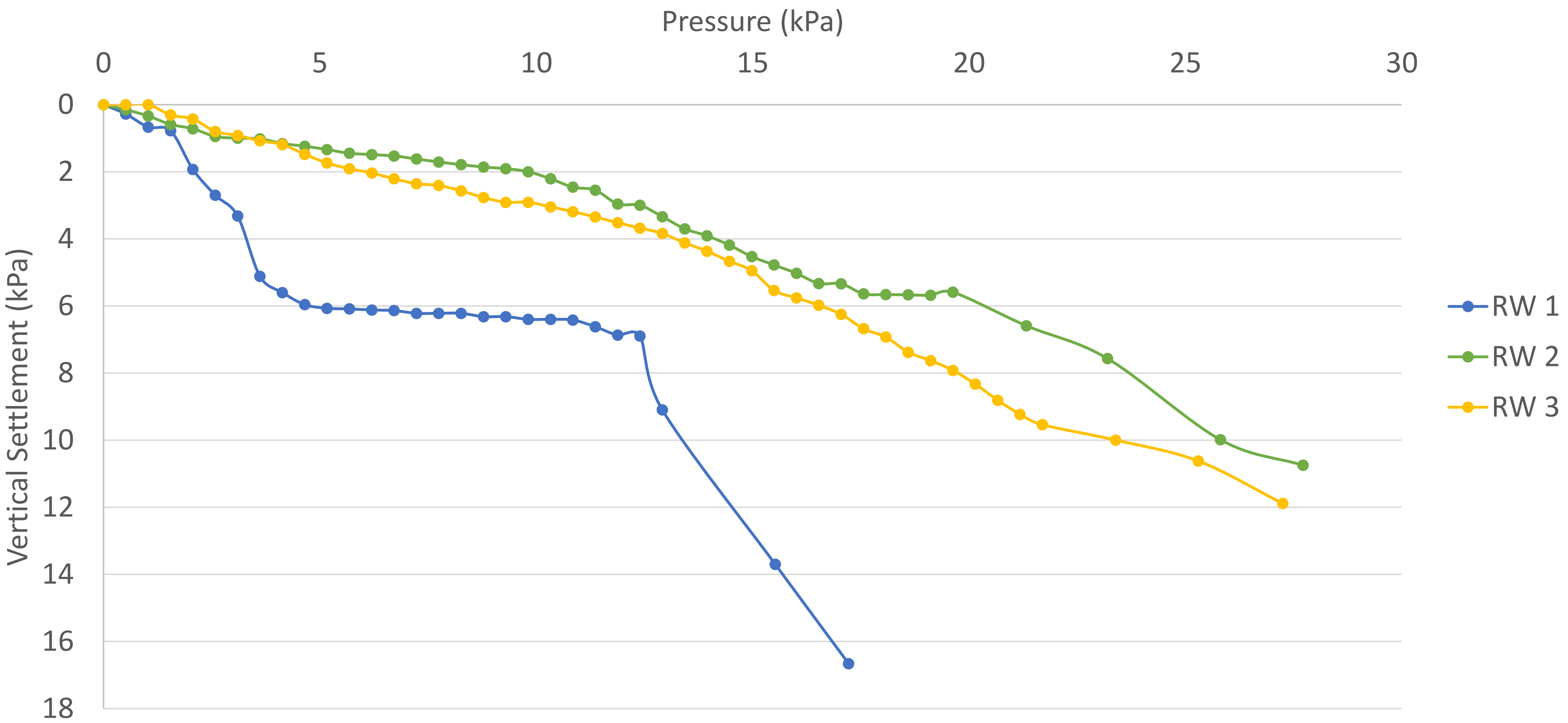
# Observations

***Horizontal displacement with respect to pressure exerted on the face of RW***

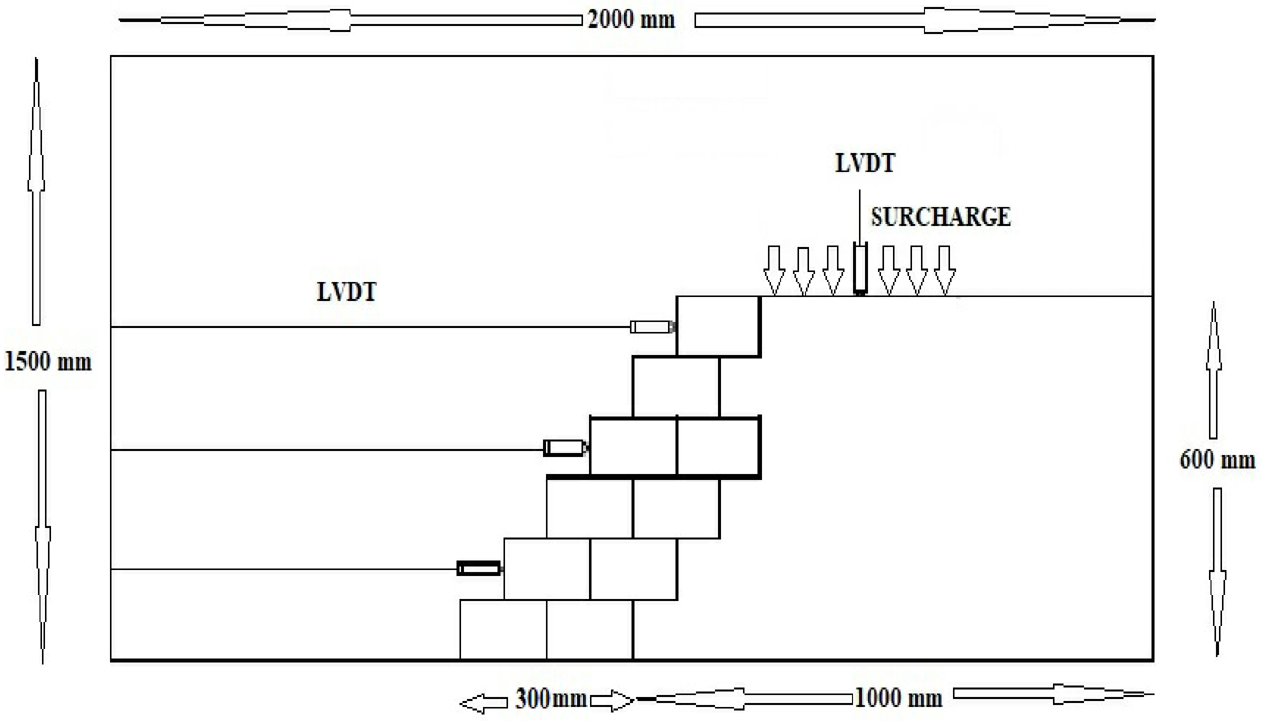


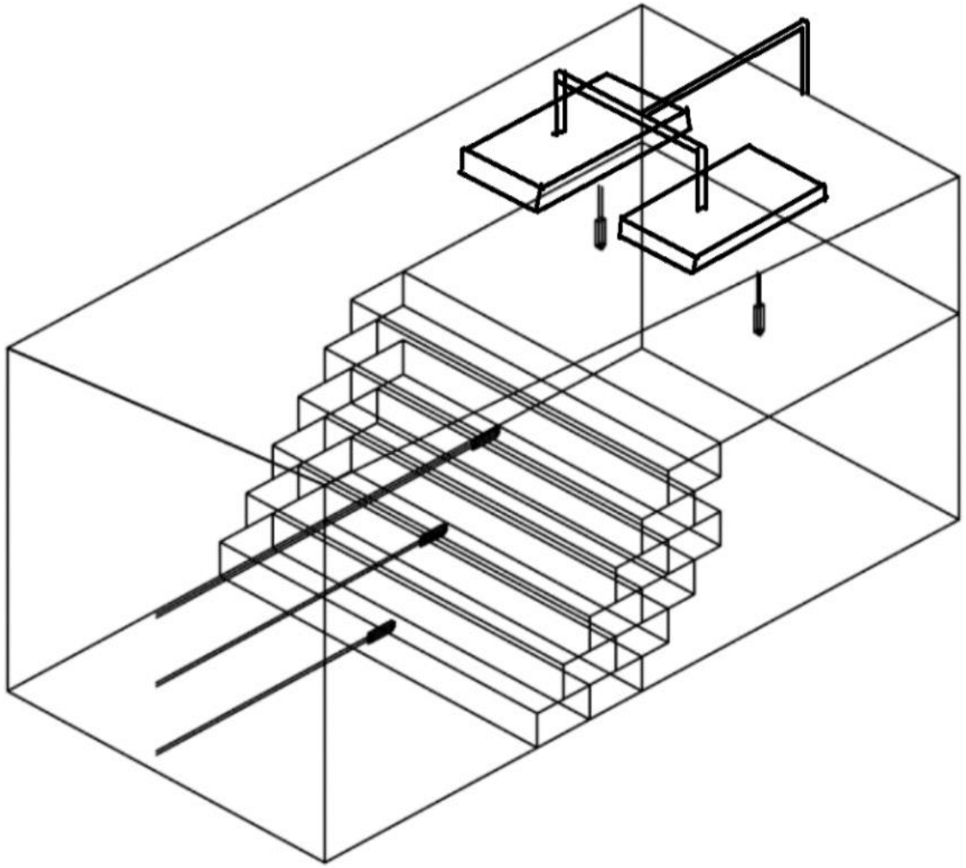

Ref: Kolathayar S and Rajesh Kumar (2019) In GeoCongress 2019

# *Vertical Settlement with respect to pressure exerted on the face of RW*

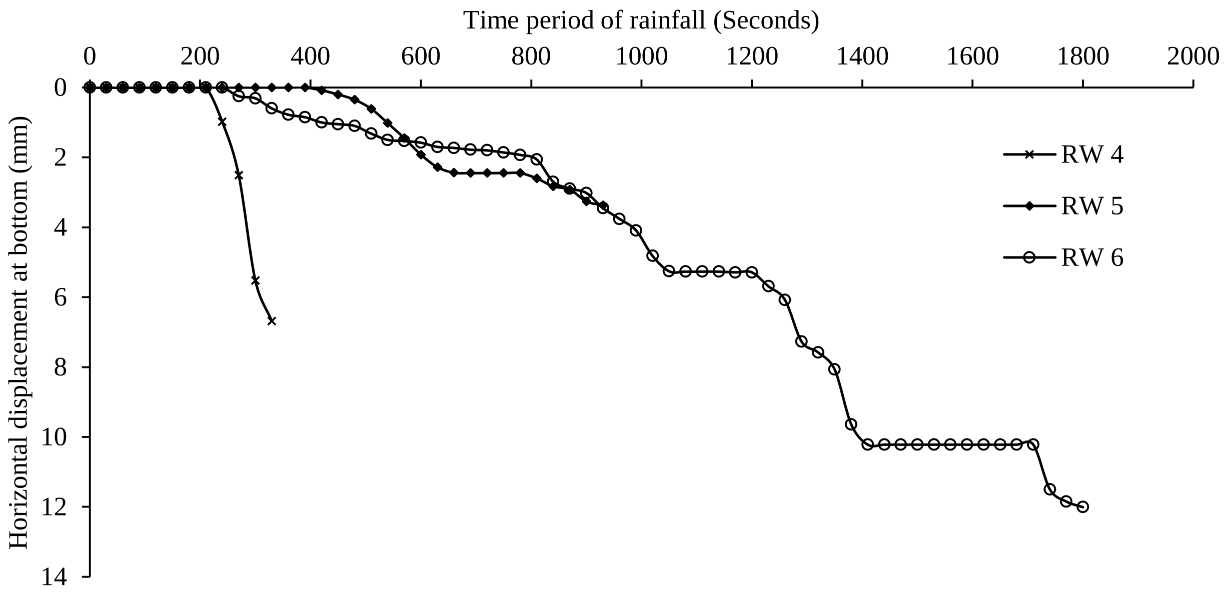


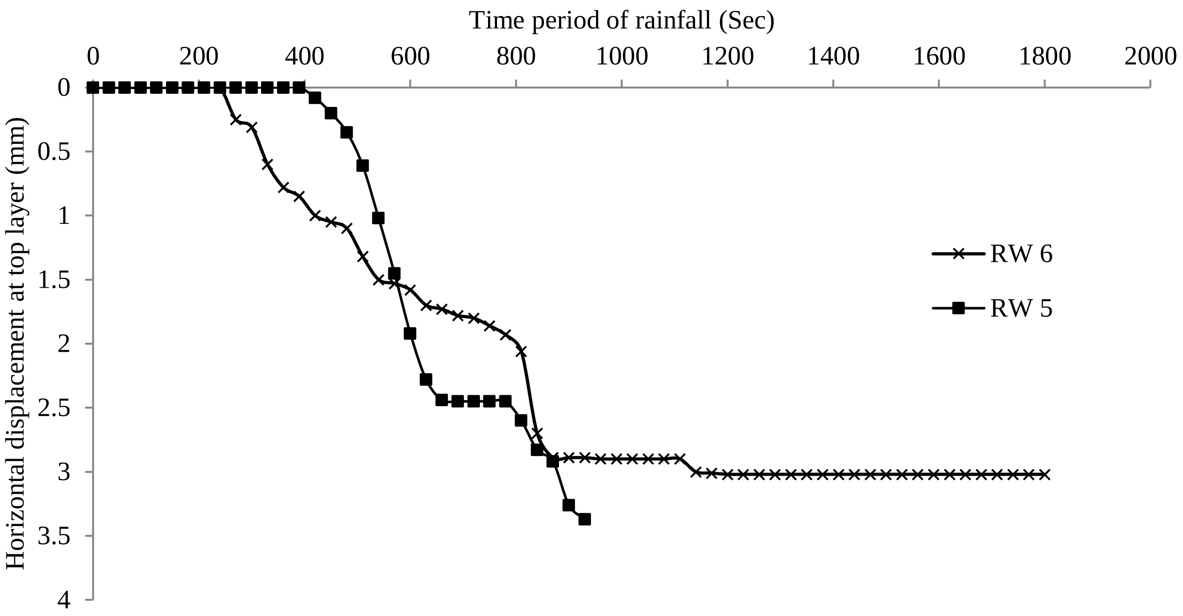
- Static load tests were performed on retaining walls of height 0.6 m, bottom dimensions 1.3 m × 1 m and top dimensions 0.95 m × 1 m.
- For the uniform application of the load, a wooden panel of dimensions 0.40 m × 0.98 m was used.



# Rain replicated – Wet Condition



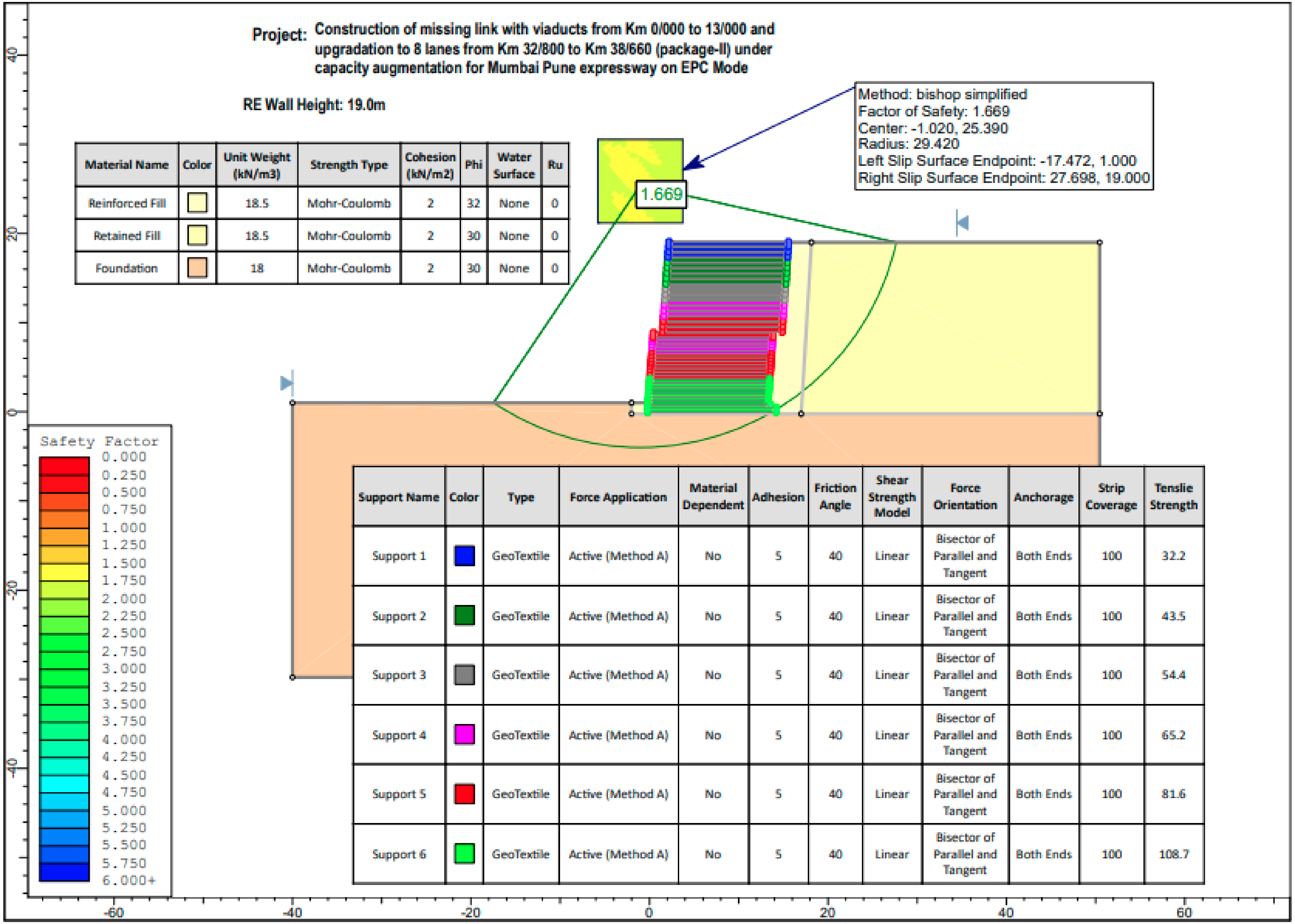

Comparison of Horizontal displacement for different walls for wet condition with surcharge of 6kPa a) at toe b) at top

Chitrachedu and Kolathayar (2020)

**Project:** Construction of missing link with viaducts from Km 0/000 to 13/000 and upgradation to 8 lanes from Km 32/800 to Km 38/660 (package-II) under capacity augmentation for Mumbai Pune expressway on EPC Mode

**RE Wall Height: 19.0m**

| Material Name | Color | Unit Weight (kN/m3) | Strength Type | Cohesion (kN/m2) | Phi | Water Surface | Ru |
|---|---|---|---|---|---|---|---|
| Reinforced Fill | | 18.5 | Mohr-Coulomb | 2 | 32 | None | 0 |
| Retained Fill | | 18.5 | Mohr-Coulomb | 2 | 30 | None | 0 |
| Foundation | | 18 | Mohr-Coulomb | 2 | 30 | None | 0 |




| Support Name | Color | Type | Force Application | Material Dependent | Adhesion | Friction Angle | Shear Strength Model | Force Orientation | Anchorage | Strip Coverage | Tenslie Strength |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Support 1 | | GeoTextile | Active (Method A) | No | 5 | 40 | Linear | Bisector of Parallel and Tangent | Both Ends | 100 | 32.2 |
| Support 2 | | GeoTextile | Active (Method A) | No | 5 | 40 | Linear | Bisector of Parallel and Tangent | Both Ends | 100 | 43.5 |
| Support 3 | | GeoTextile | Active (Method A) | No | 5 | 40 | Linear | Bisector of Parallel and Tangent | Both Ends | 100 | 54.4 |
| Support 4 | | GeoTextile | Active (Method A) | No | 5 | 40 | Linear | Bisector of Parallel and Tangent | Both Ends | 100 | 65.2 |
| Support 5 | | GeoTextile | Active (Method A) | No | 5 | 40 | Linear | Bisector of Parallel and Tangent | Both Ends | 100 | 81.6 |
| Support 6 | | GeoTextile | Active (Method A) | No | 5 | 40 | Linear | Bisector of Parallel and Tangent | Both Ends | 100 | 108.7 |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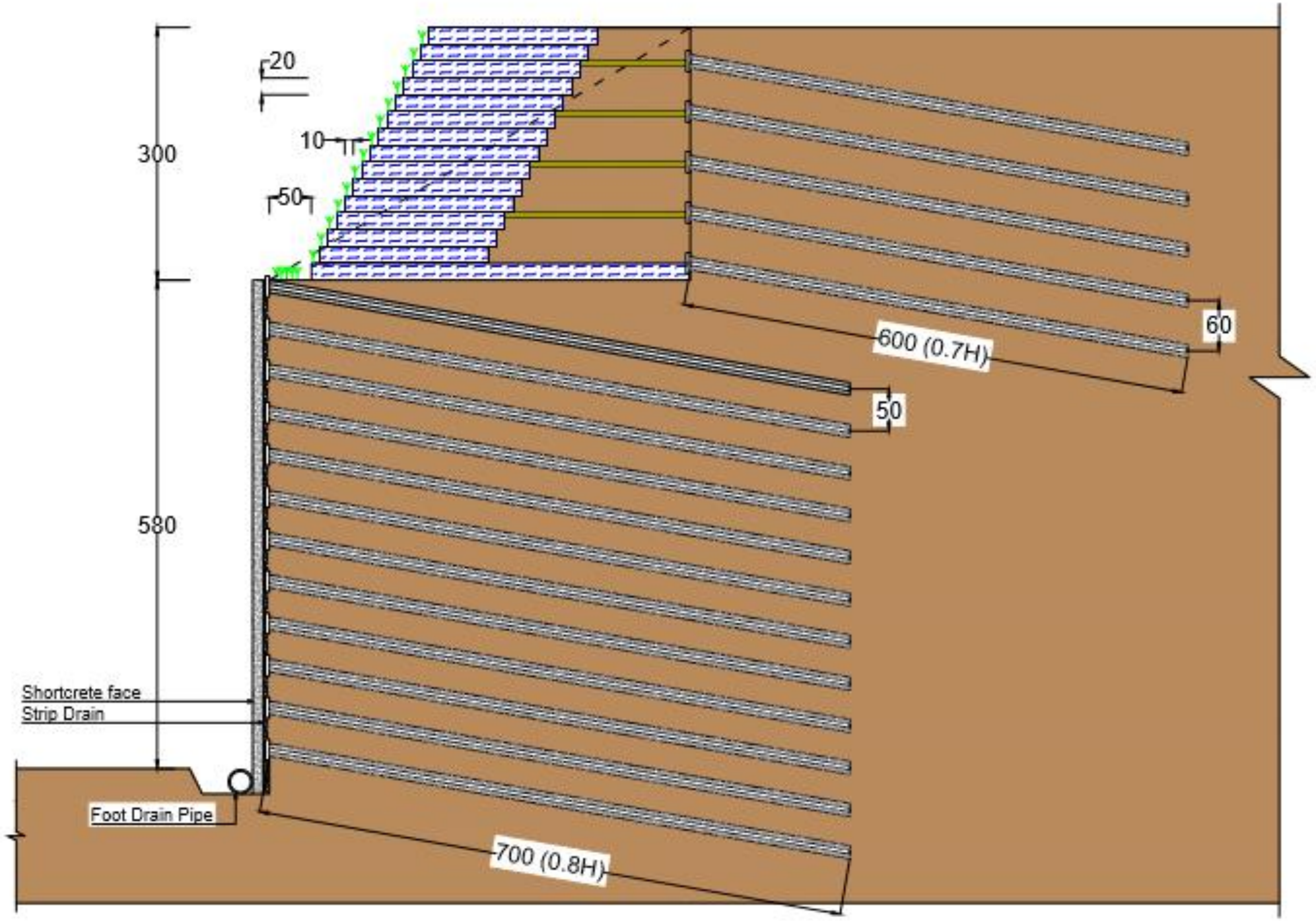


Section BH06

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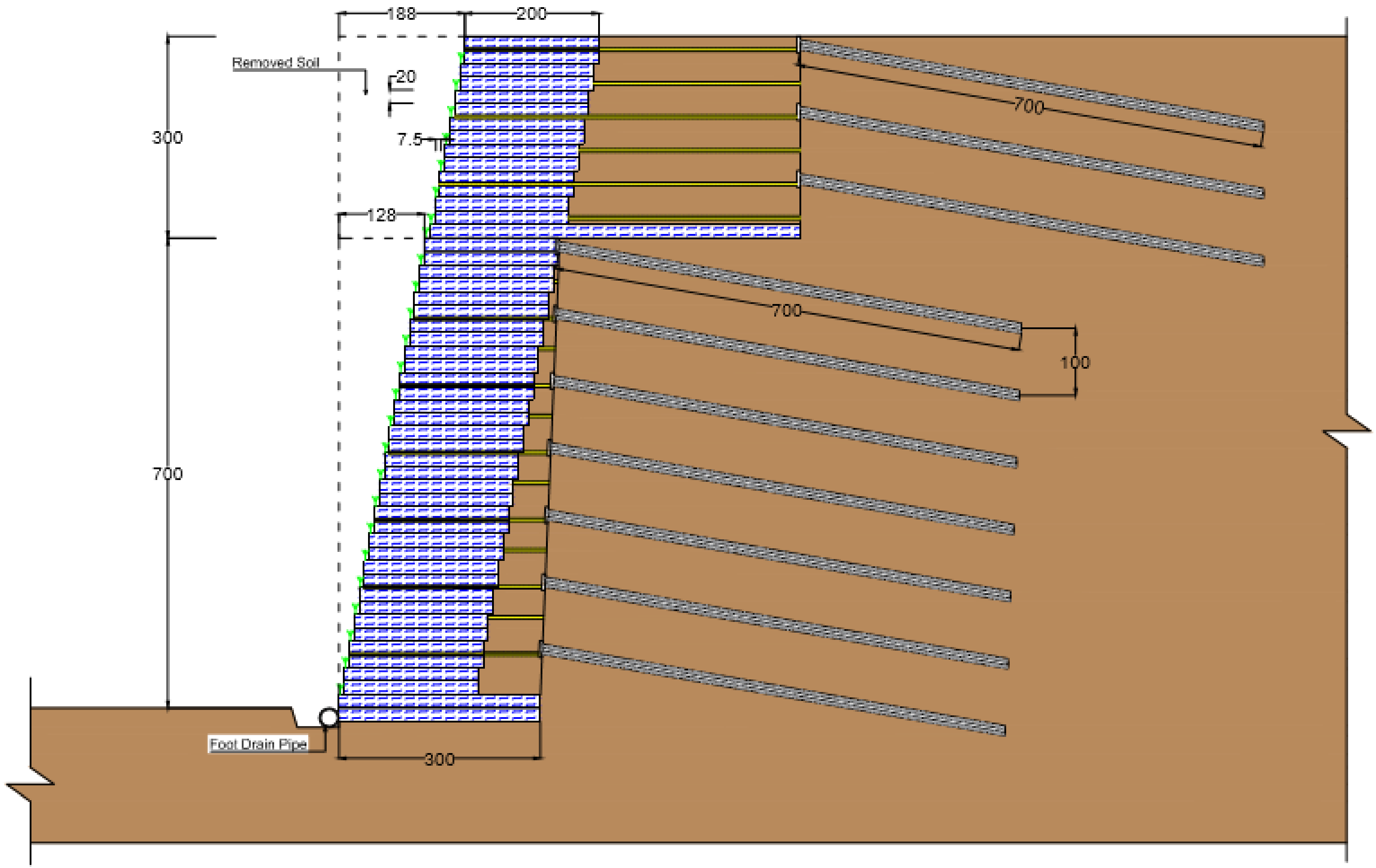
|---|---|---|---|
| (yellow) | Geogrids | (grey) | Shortcrete/Grouting works/Nailing work |
| (green symbol) | Vetiver grass | (blue) | Geocells |




Section BH__

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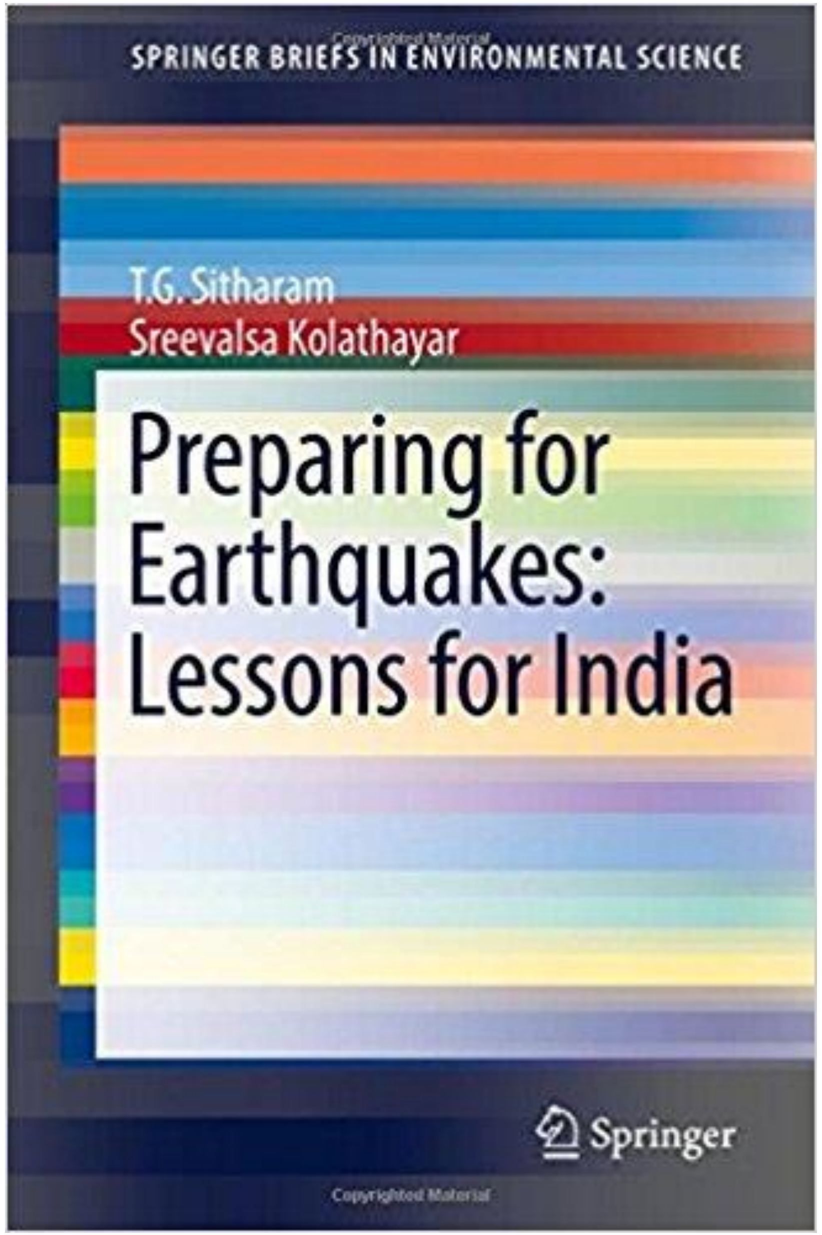
|---|---|
| Geogrids | Shortcrete/Grouting works/Nailing work |
| Vetiver grass | Geocells |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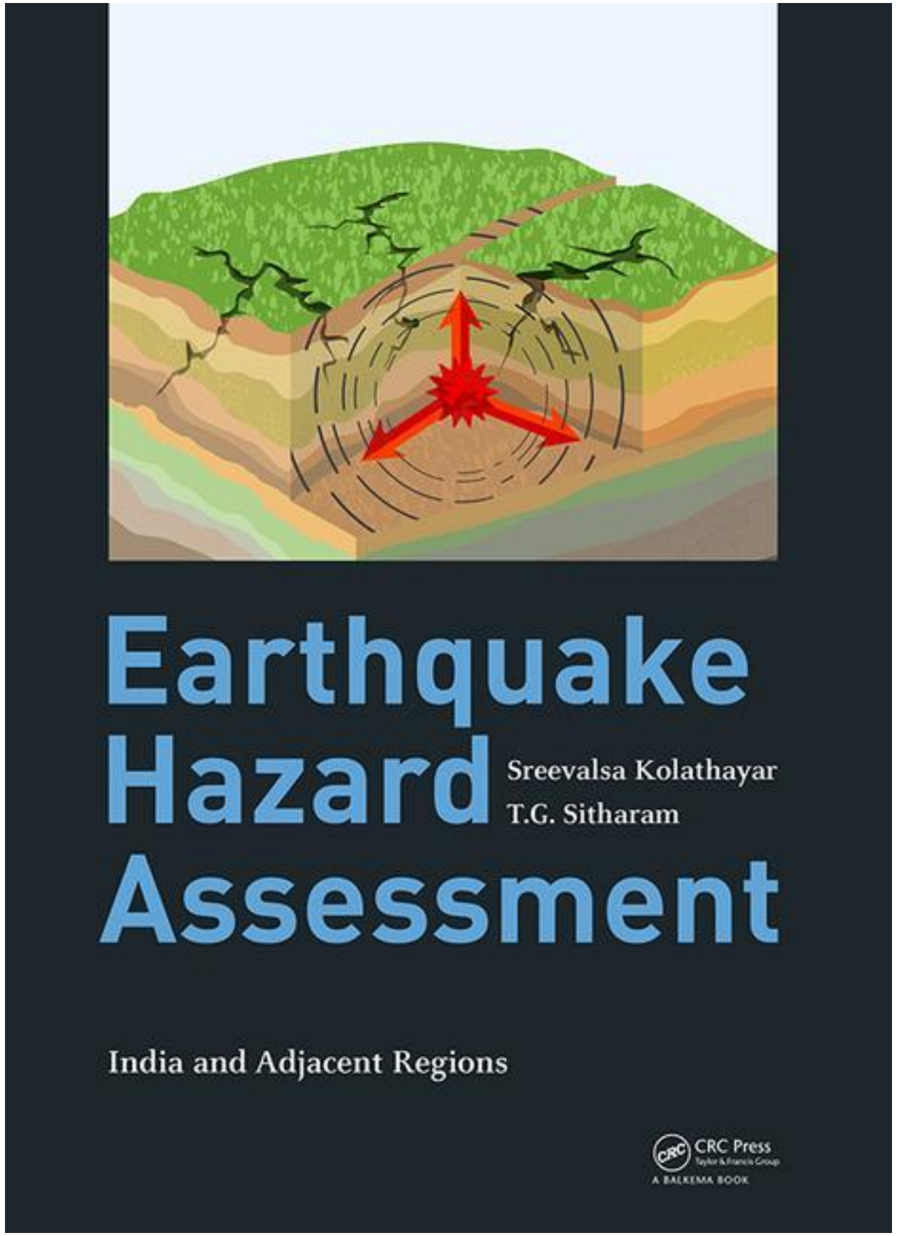
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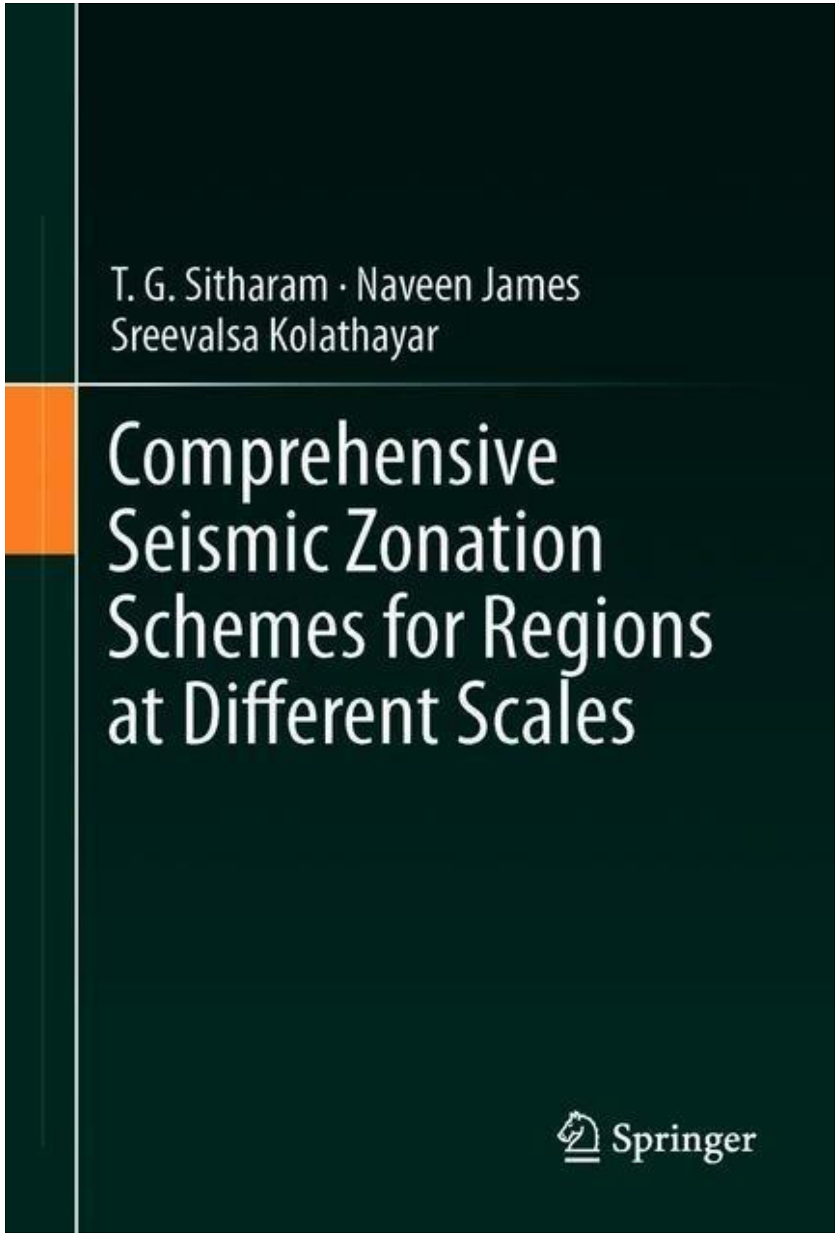
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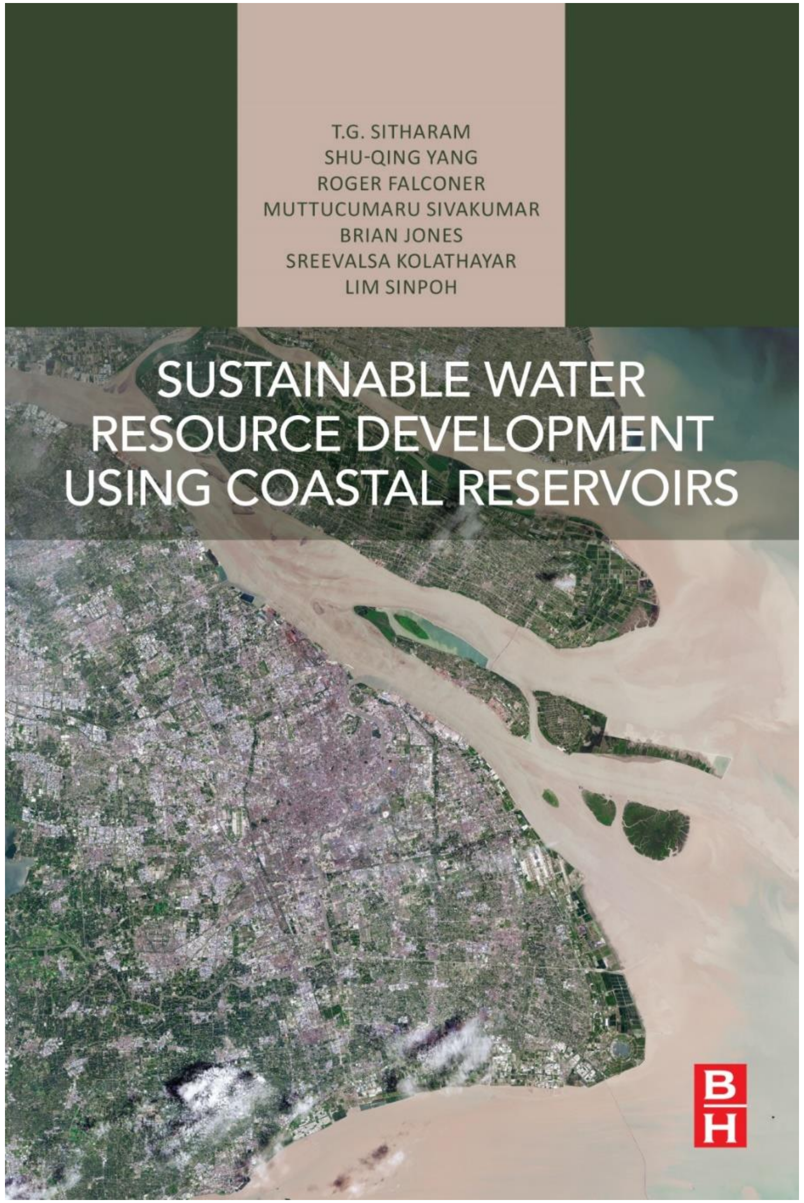
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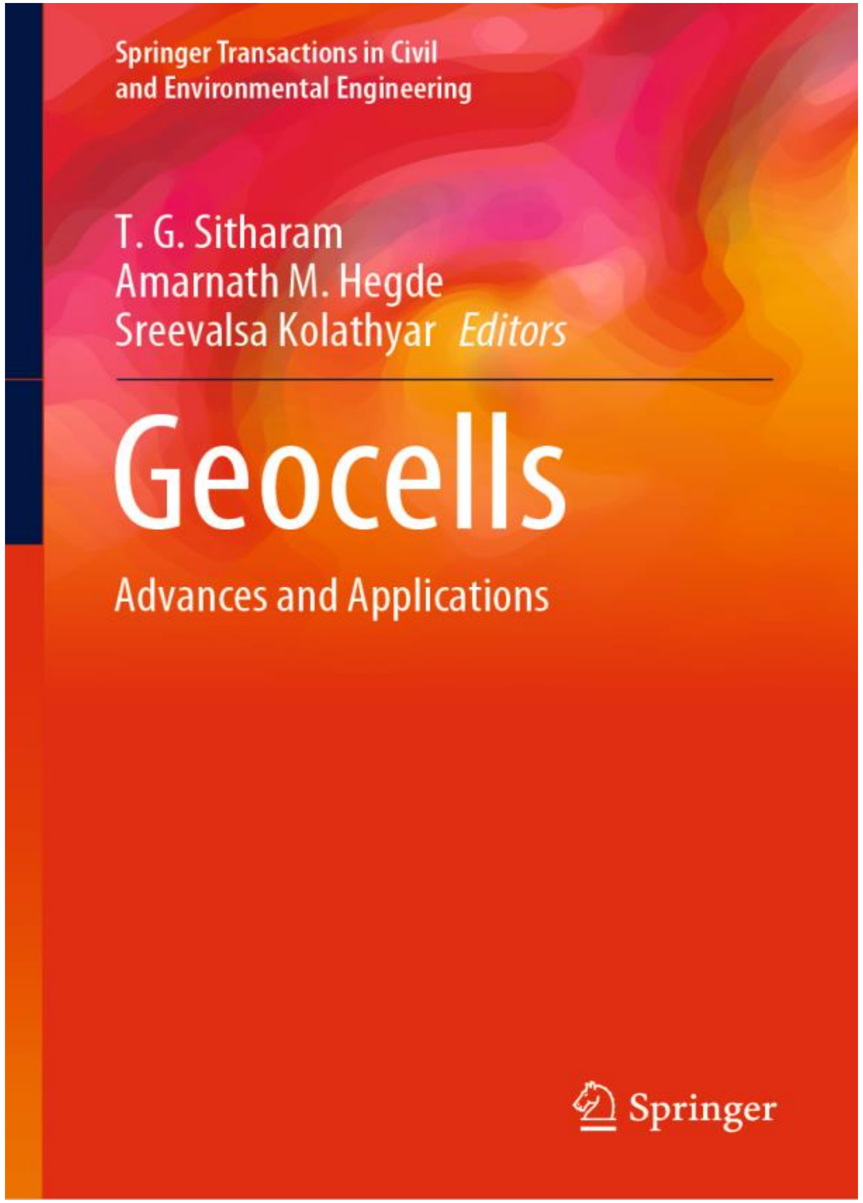
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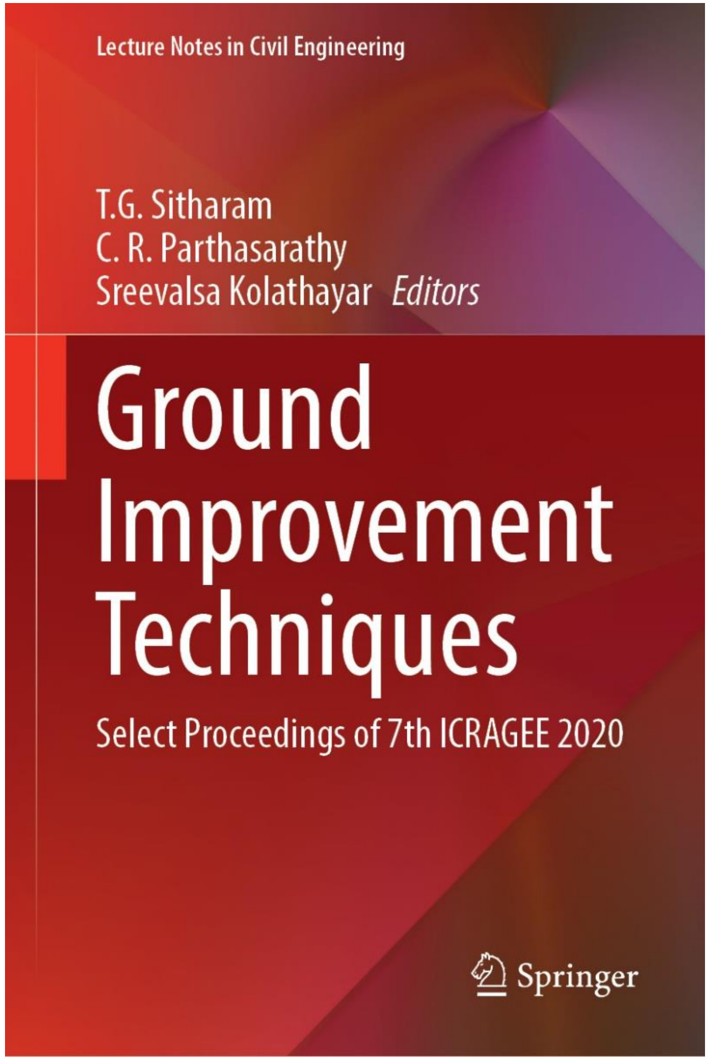
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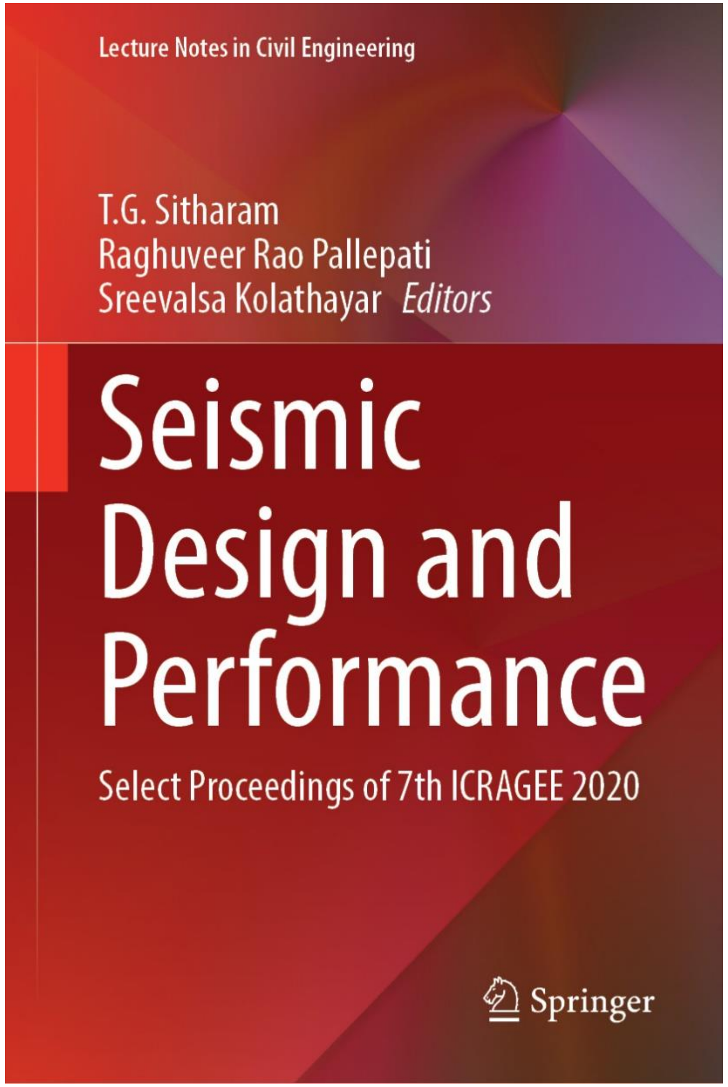
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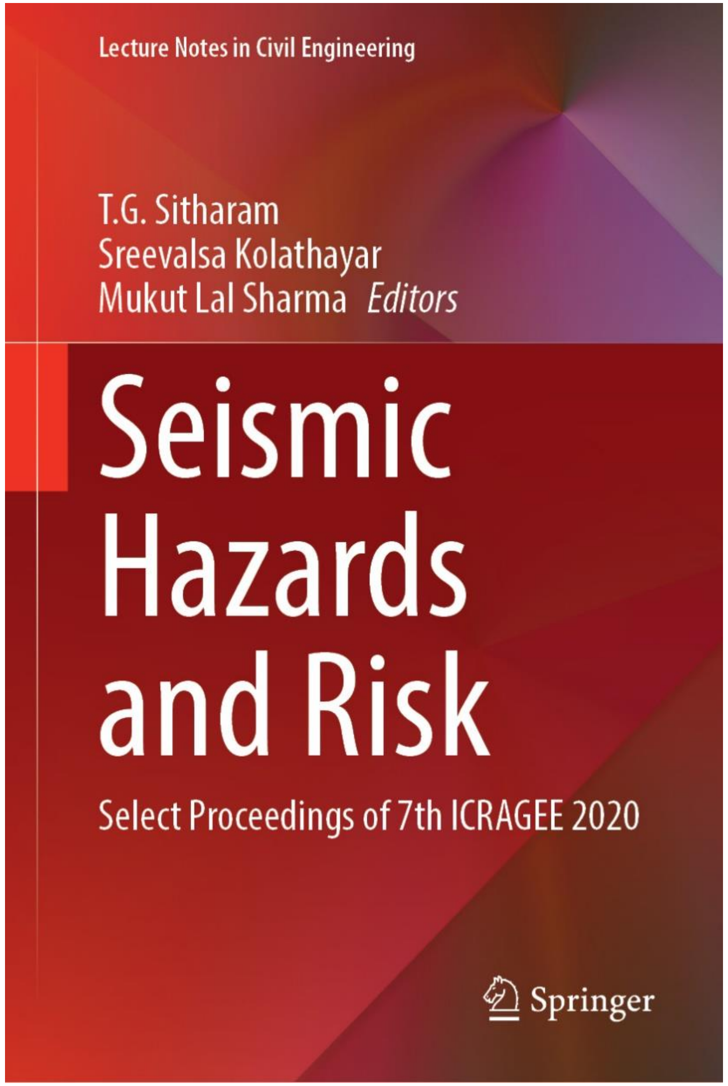
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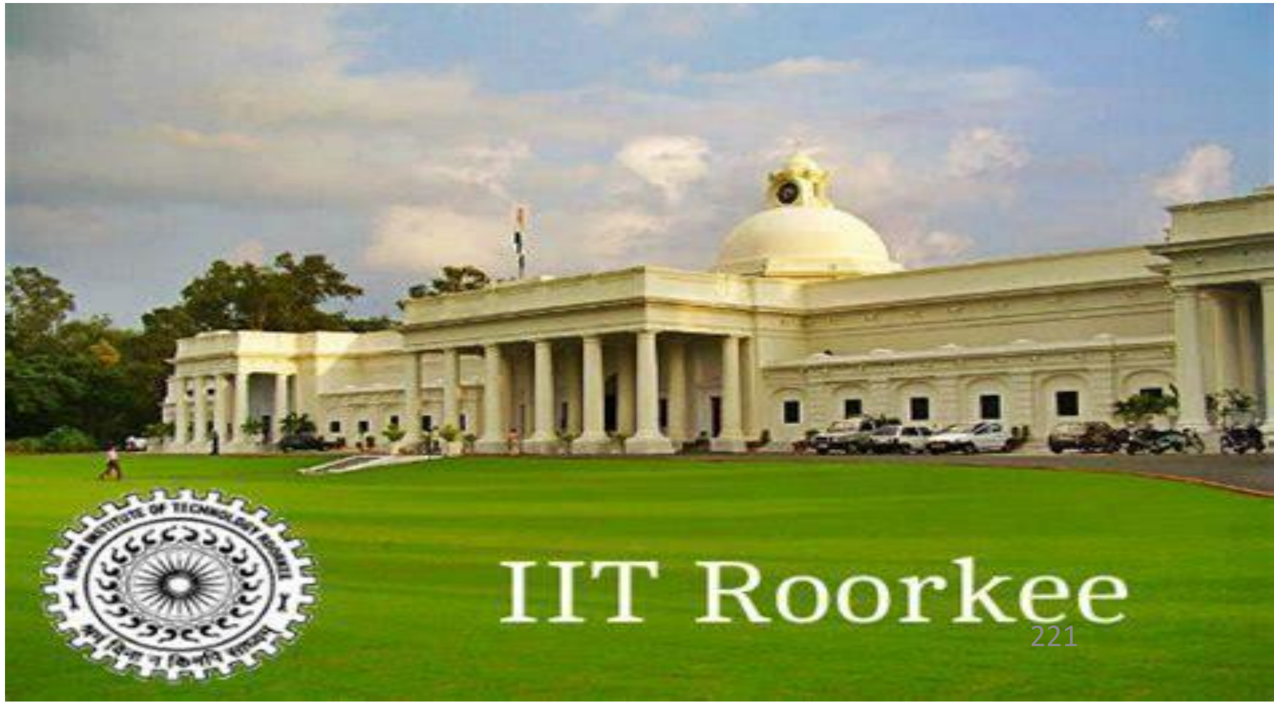

# Thank You