UNIVERSITY OF CAMBRIDGE

FIF EPSRC Network Future Infrastructure Forum

Future Infrastructures Forum - II

Professor Priyan Dias

University of Moratuwa, Sri Lanka

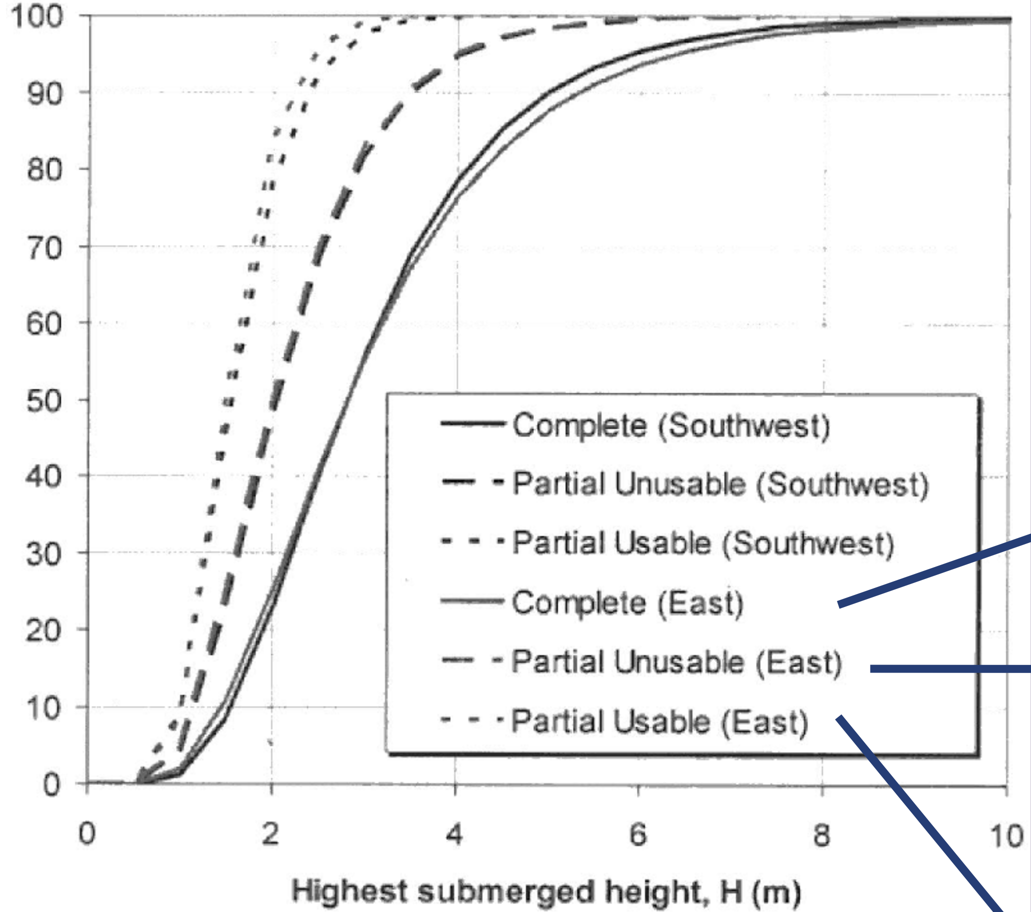
Nature of Presentation

- **APPROACH:** Snapshots; NOT Details
- **SCOPE:** Country paper; BUT personal choices
- **UNIVERSITIES:** Moratuwa, Peradeniya
- **FIELDS:** Structural, Materials & Geotechnical
- **TYPE:** Country specific; PLUS Cutting edge
- **COUNTRY**: Developing, Tropical, Historical
- **MOTIVATION:** Research partnerships, funding

a wise man who built his house on the rock (Matthew 7:24)

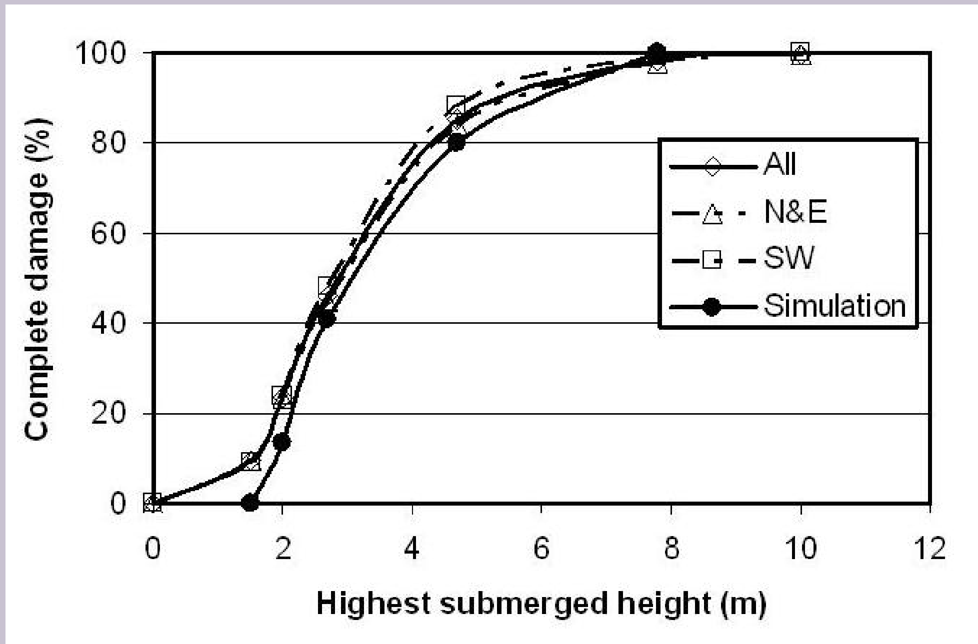
Tsunami Loads & Vulnerability

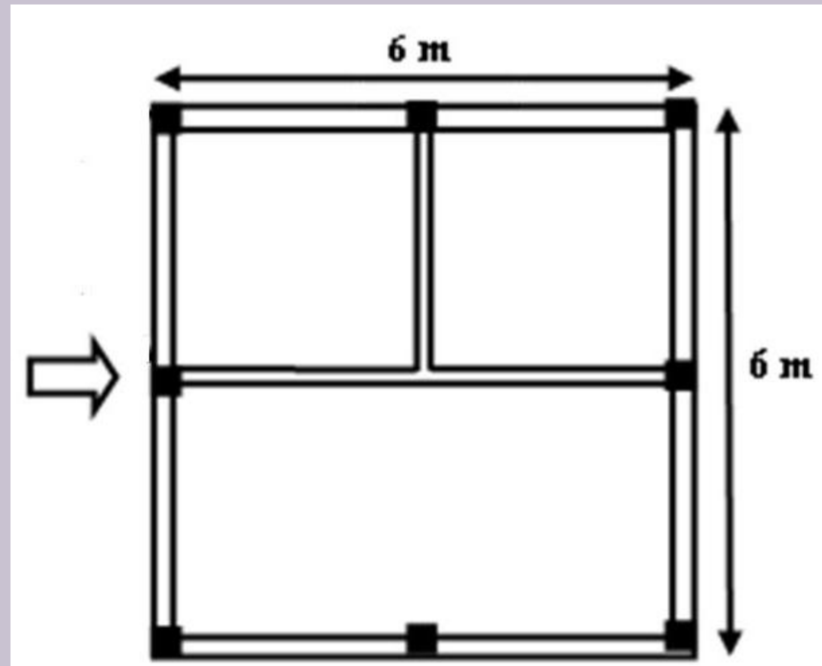
Priyan Dias, Hiran Yapa, Kosala Bandara, Nuwan Dewapriya,
(University of Moratuwa)
Navin Peiris (EEFIT, U.K.)



Vulnerability Curves – Survey (Peiris; Dept of Census & Statistics)

- Damage Classification
- Survey
- Curve Fitting

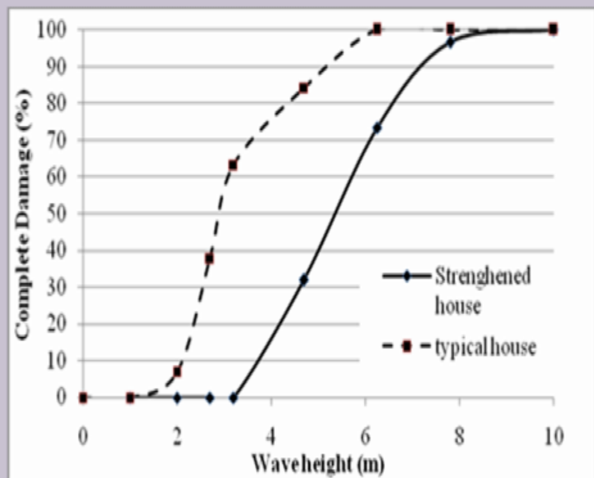


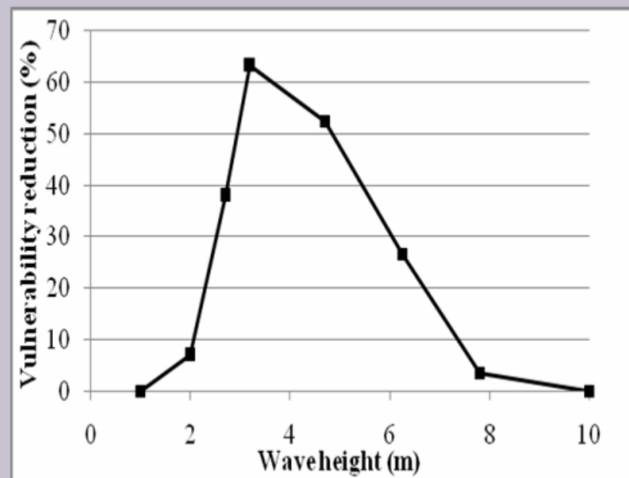


Simulations

- Monte Carlo (limited)
- Matching survey
- Exploring improvements

Parameter	Distribution
Roof Weight	Random Normal
Wall height	Random Normal
Wall system	4 Discrete States
Plastering	2 Discrete States





Tsunami Loads

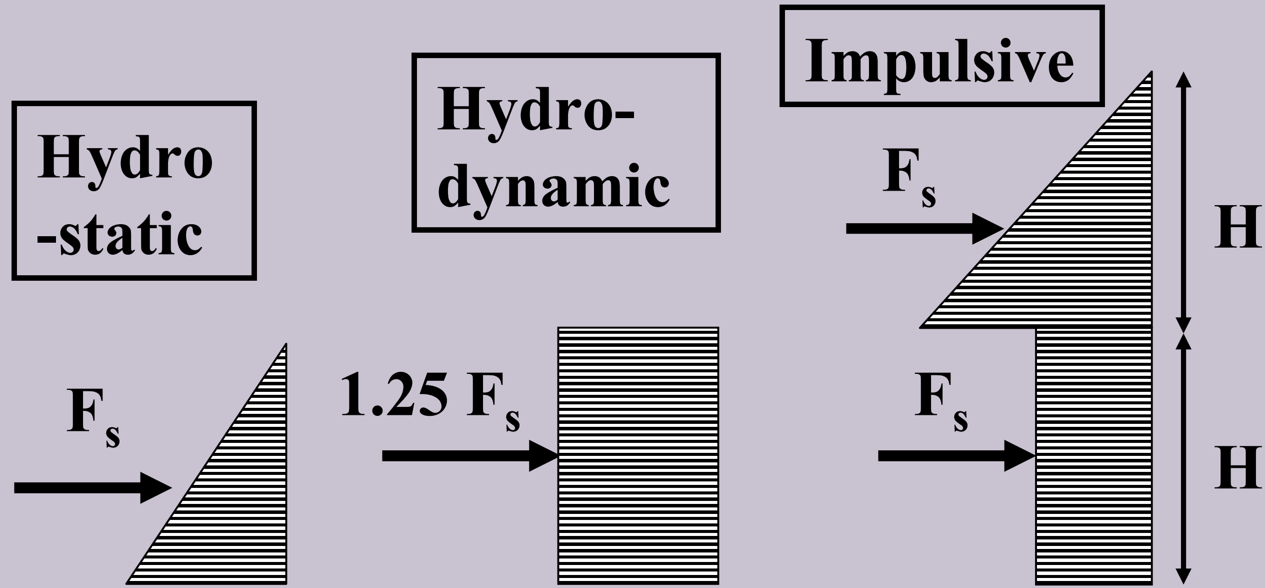
-Arriving at a routine design procedure

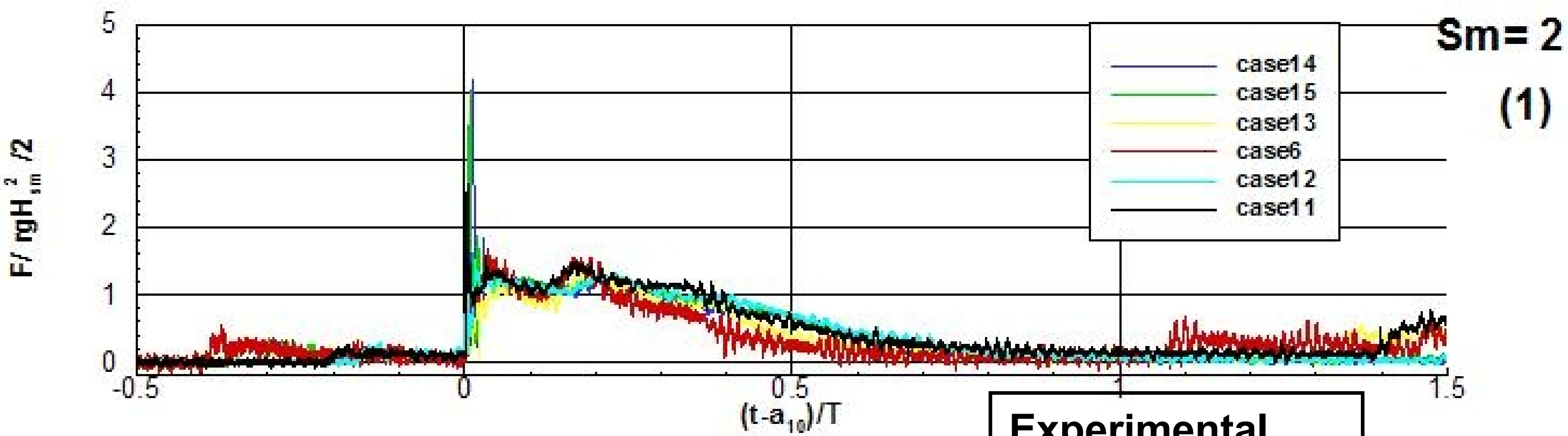
-Reconciling literature

-Obtain in terms of hydrostatic load

- $F_s = 0.5\ \gamma\ H^2\ B$

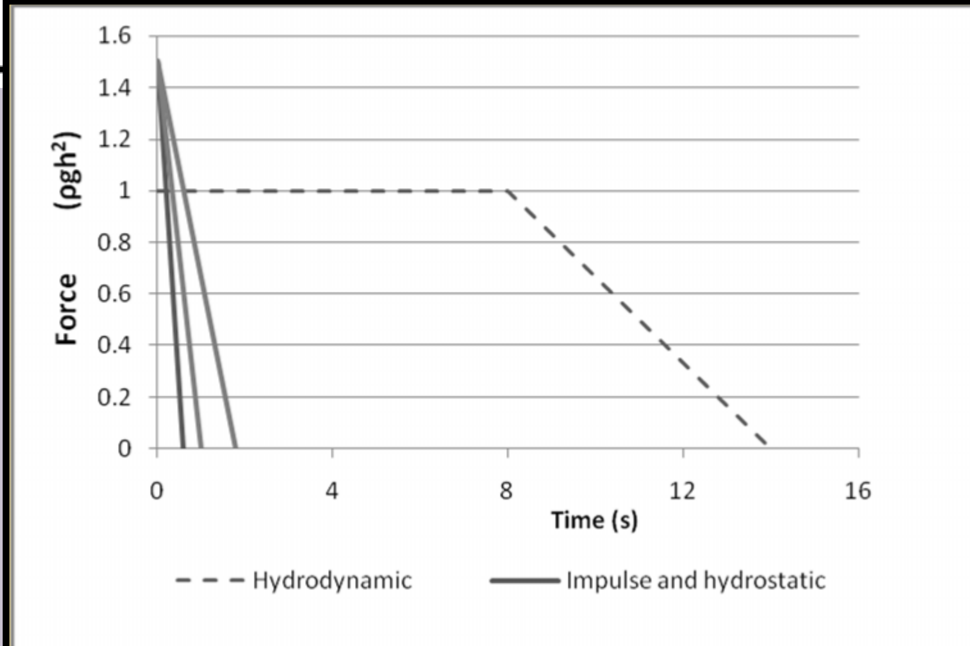
- H = inundation depth





Experimental (Arikawa, PARI)

Square Pile	Detached Building	Sea Wall
		
$3\ F_s$	$4.25\ F_s$	$9\ F_s$



Tsunami Loads

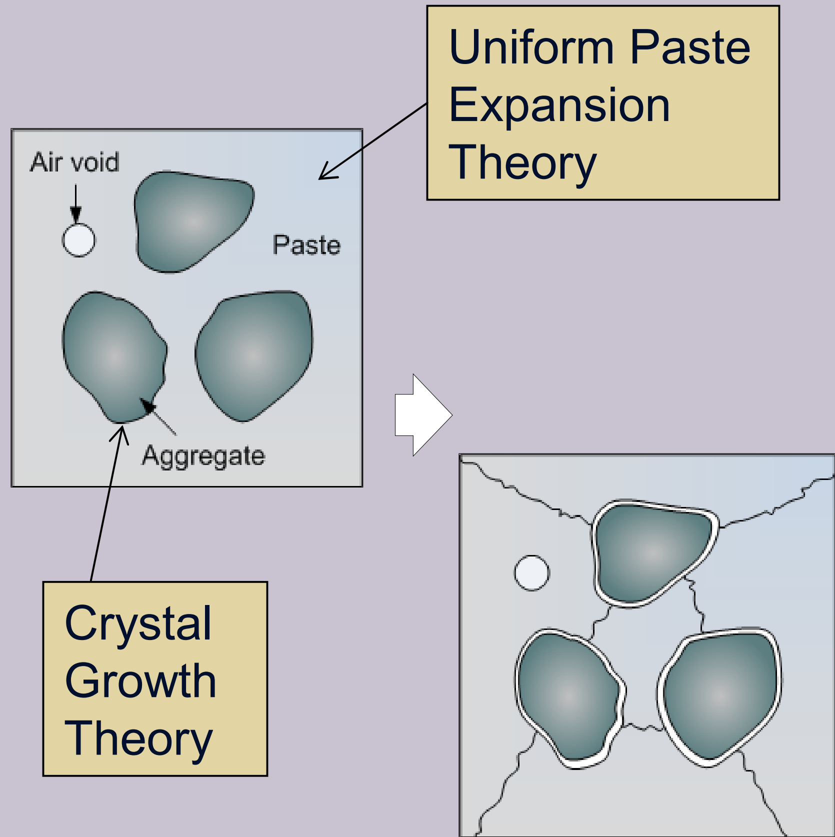
- Variation with structure type
-Time varying nature (wave period)
- CFD approaches
- **Effects on vegetation? (non-rigid)**

Cracking in concrete (& healing)

Will the line stretch out to the crack of doom?
– Macbeth, Act 4, Sc 1

Anura Nanayakkara

(University of Moratuwa)

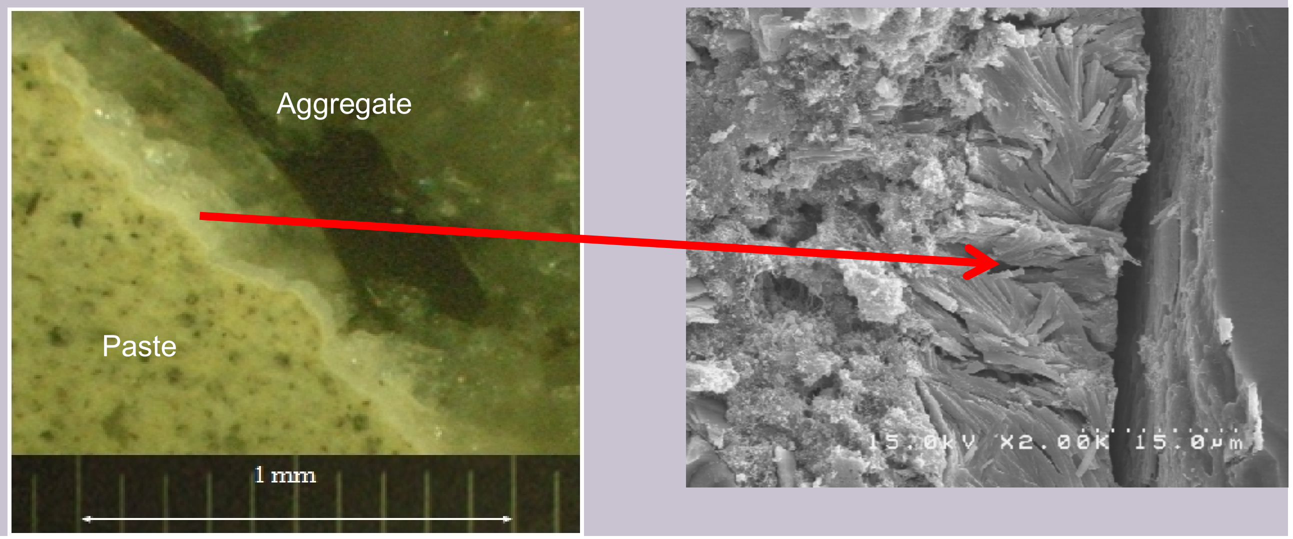


Delayed Ettringite Formation

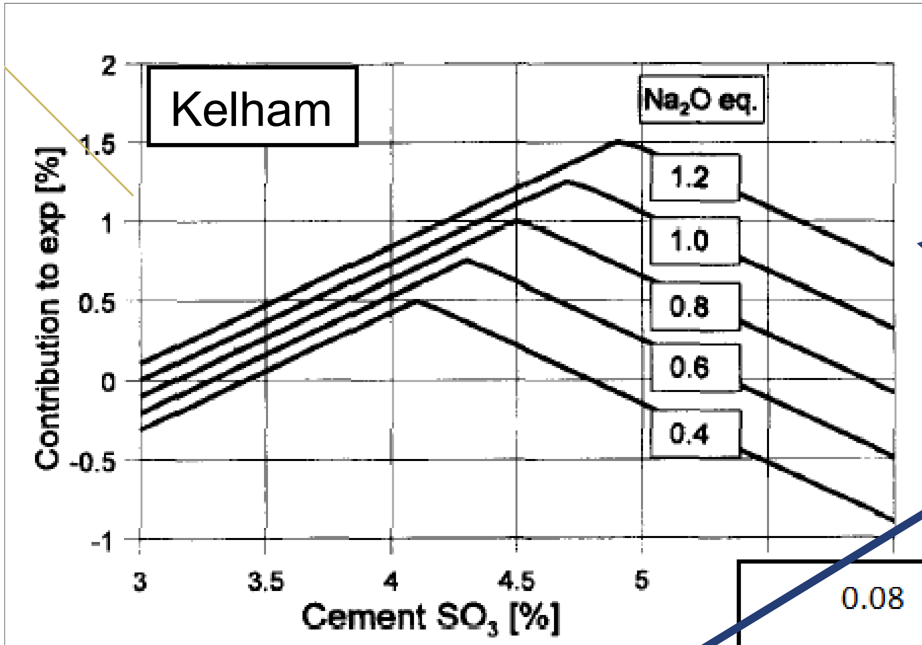
-Phenomenon

(High early temperature; moisture in service)

-Mechanisms



Delayed Ettringite Formation: causative factors

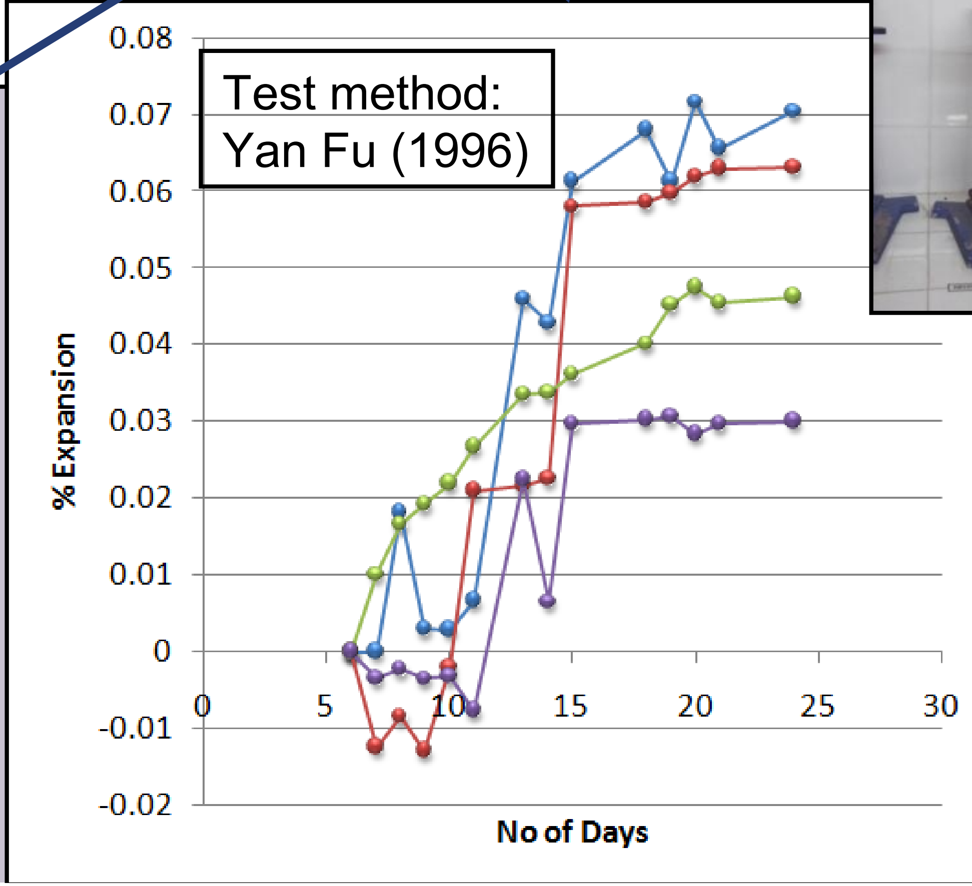


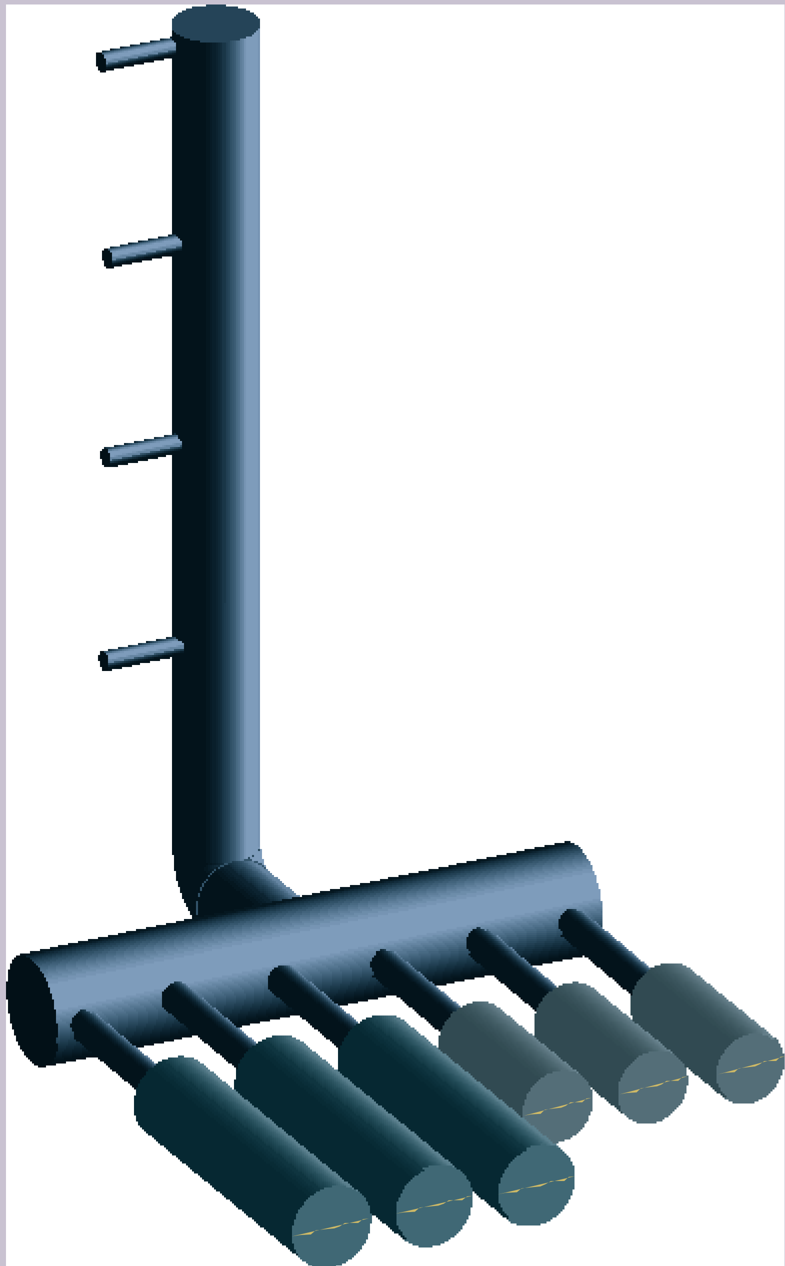
- Alkali & sulphate contents
- Early temperature rise
-Cement fineness

T < 60 °C no risk of DEF
T < 70 °C very low risk of DEF
T < 80 °C low risk of DEF

Blended cement with pfa > 20% or ggbs > 40% will prevent DEF-induced expansion in concrete subject to peak temperatures up to 100 C

[BRE IP11/01 :Delayed ettringite formation: in-situ concrete]





Self Healing of Concrete Cracks

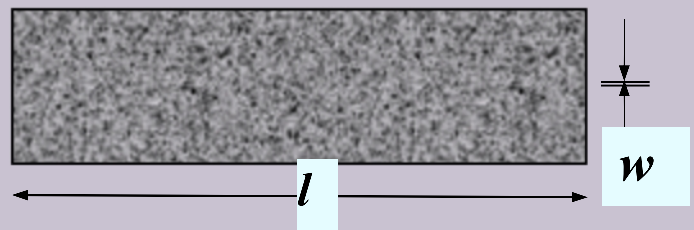
- **Mechanisms**
  - -Hydration of cracked cement grains
  - -Formation of Calcium carbonate
- **Factors**
  - -Crack width
  - -Hydraulic gradient (water head; specimen length)
  - -Fine particles within crack

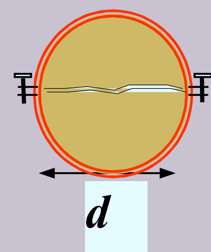
$$q = \Delta p\ d\ w^3 / 12\ \eta\ l$$

Flow through parallel plates

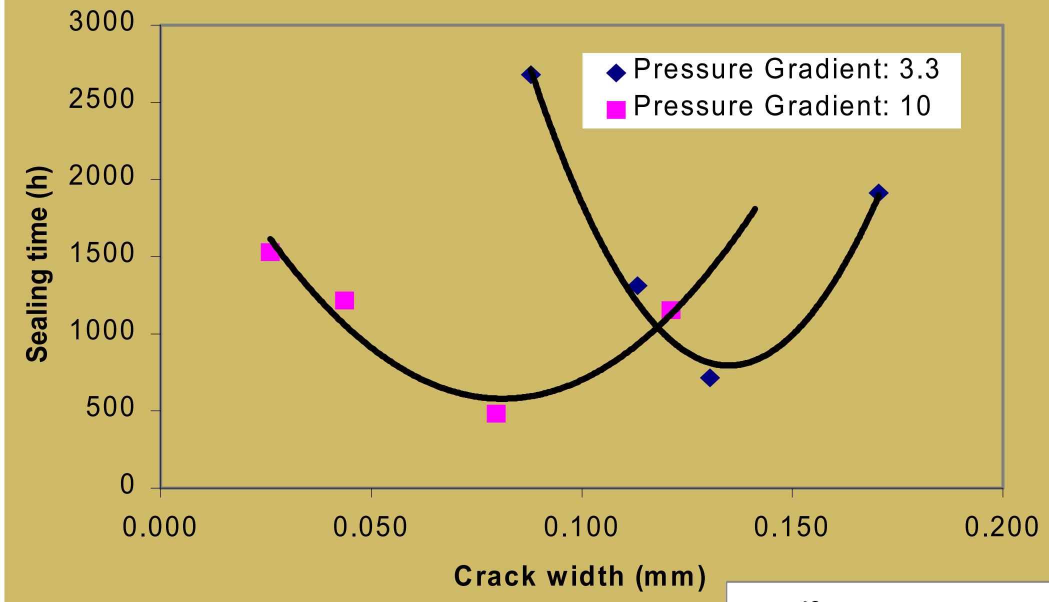
Equivalent Crack width

- q = initial flow rate
- Δp = pressure head
- d = surface crack length
- w = equivalent crack width
- l = path length
- η = viscosity of water



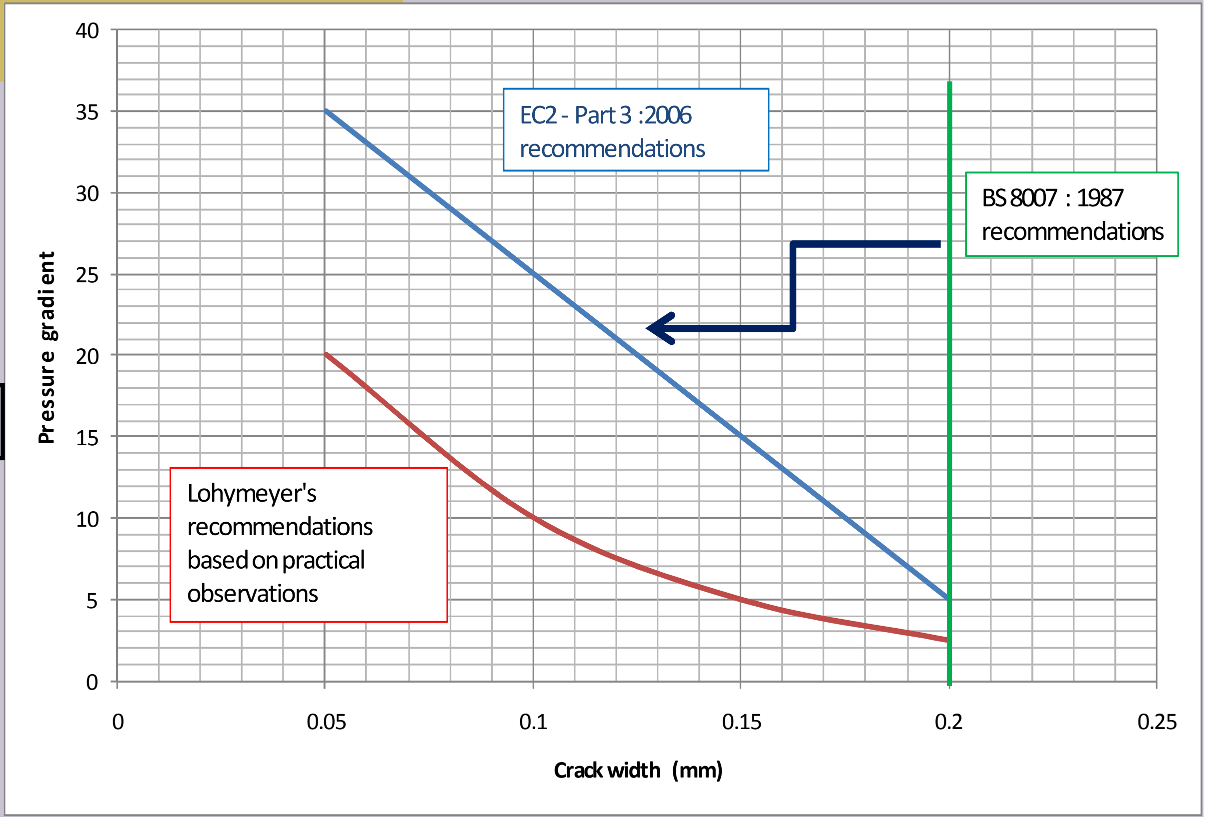


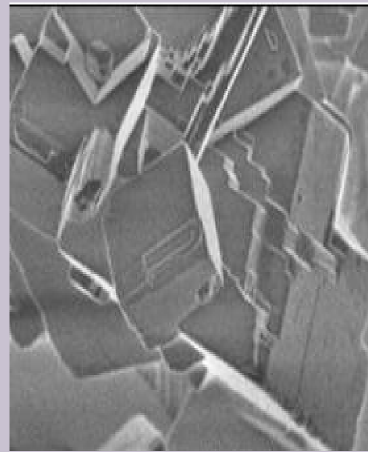
Design crack width

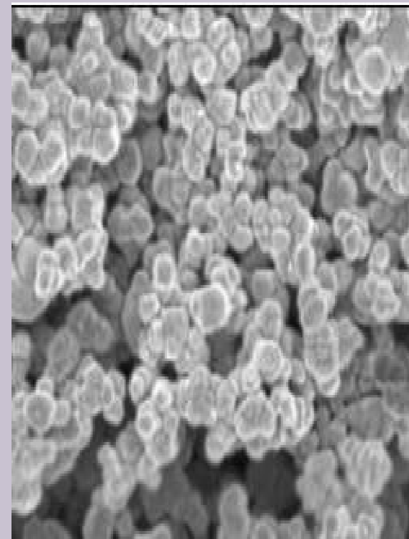


Experimental

EC2 Recommendation







There's plenty of room at the bottom – Richard Feynman

Micro & Nano Particles in Concrete

Priyan Dias, Anura Nanayakkara (University of Moratuwa)
Priyan Mendis (University of Melbourne)
K.R.B. Herath & S.R. Herath (University of Peradeniya)

Geopolymer Concrete

- **Constituents**
  - Fly ash (or Kaolin) – source of SiO_2 & Al_2O_3
  - NaOH (or KOH) – cation source for catalysis
  - Na_2SiO_3 – source of SiO_2, increases pH
  - **No OPC**
  - **Utilization of waste (fly ash)**
  - **Precasting application**

- **Process Variables**
  - amount of water used
  - pH of the mixture
  - mixing procedure
  - speed of mixing
  - mixing duration
  - reaction temperature
  - curing temperature
  - curing duration

Extrudable Mix

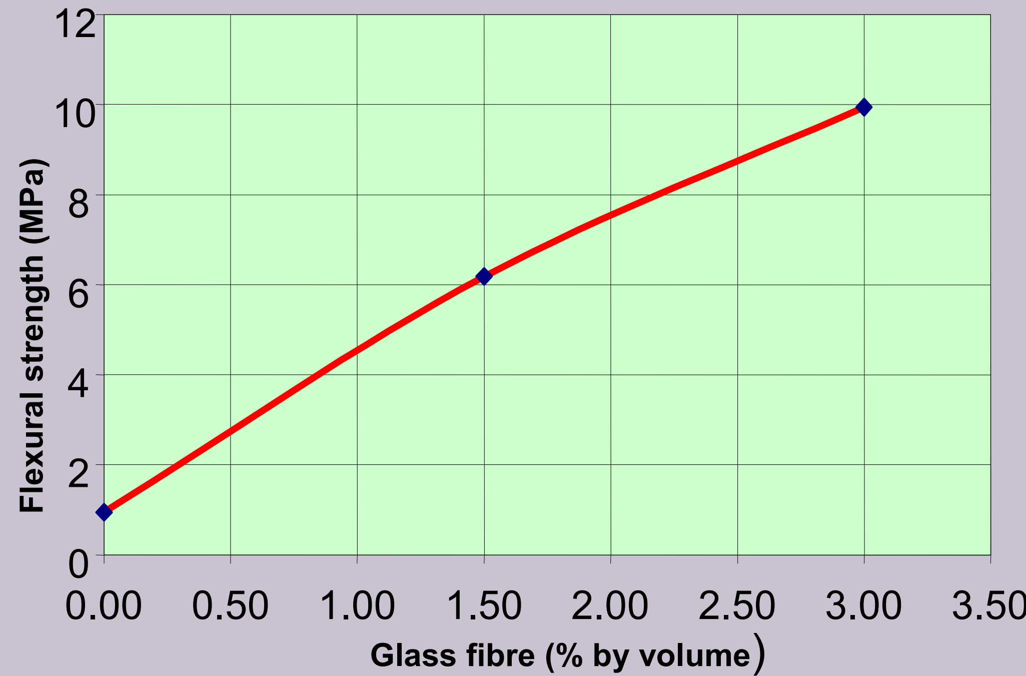
Self Compacting Mix

Cube Strength (MPa)

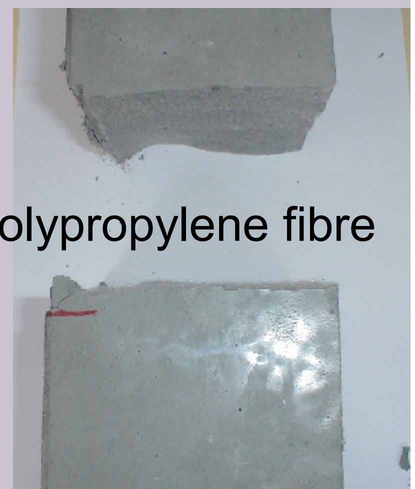
Temp (°C)				
100		**70**		
80	**50**	**87**		
60			**76**	
30				**81**
	2	3	24	168
	Duration (hrs)			

- Increases with duration
- Has a maximum wrt temperature
- Displays time-temperature trade-off

Flexural Strength (Extrudable mix)

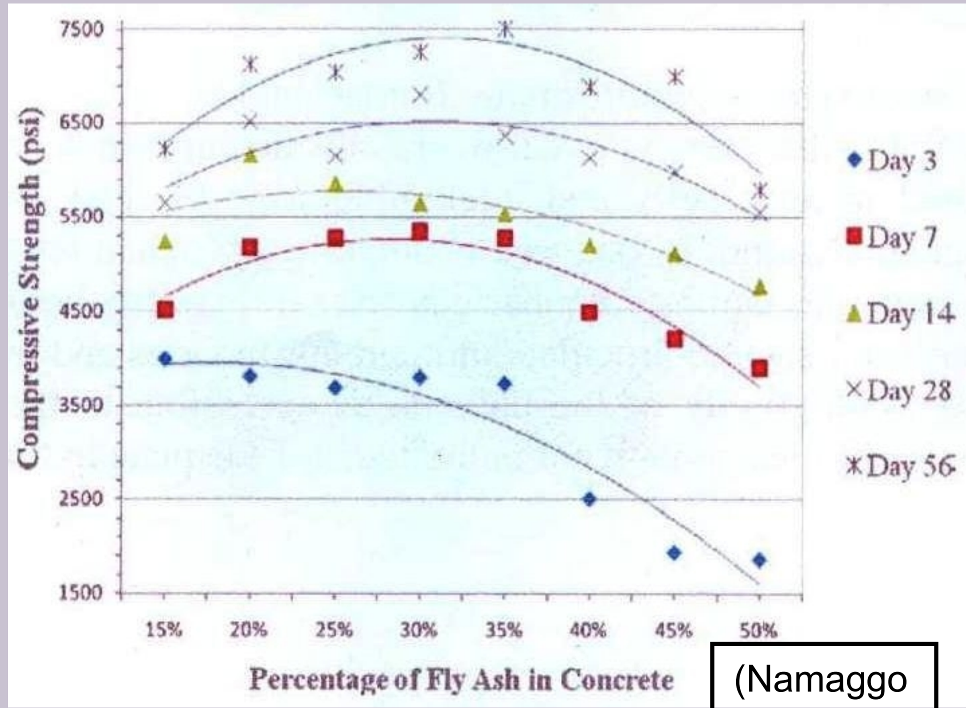


Steel > Glass > Polypropylene



Nanoparticles in Concrete

- **Motivation**
  - High pozzolan volumes will reduce strength
  - Strength can be restored by nanoparticles
- **Issues**
  - Cost of nanoparticles
  - Safety in use



(Namaggo & Atadero)

HVFA & Nano SiO_2

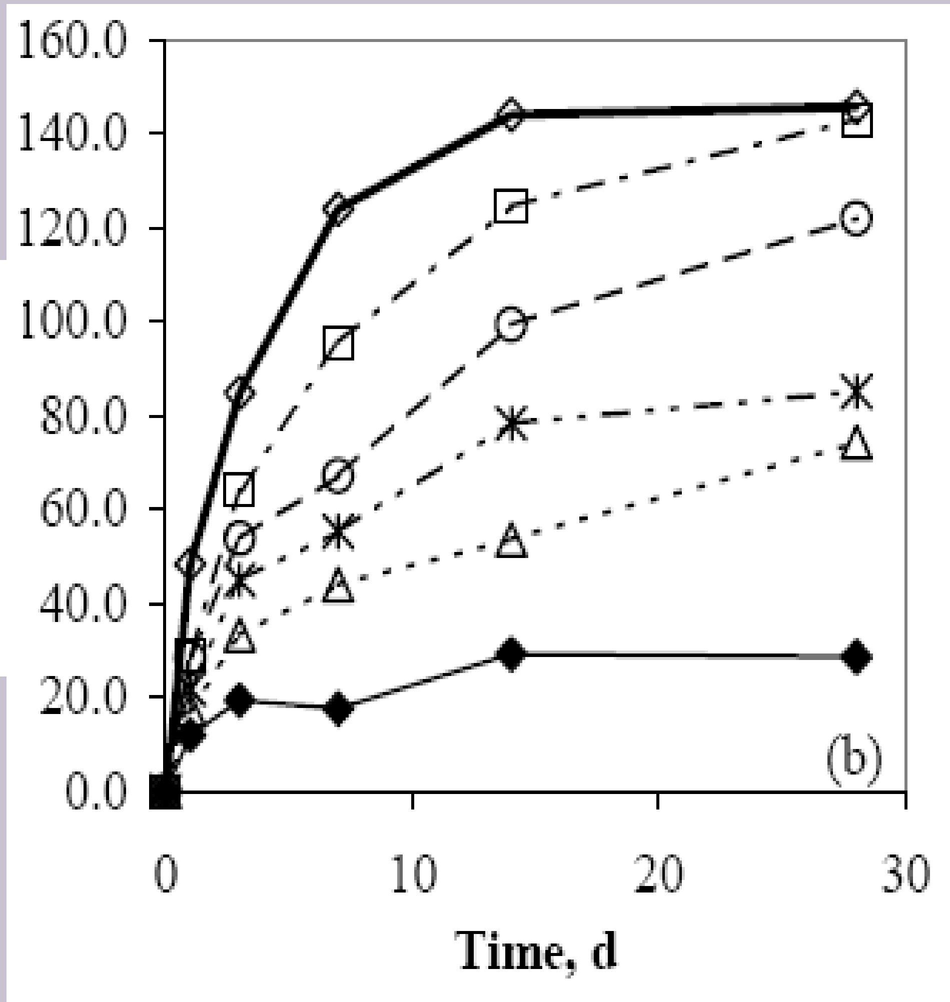
(Gengying Li, 2004)

Compressive strength gain of concretes

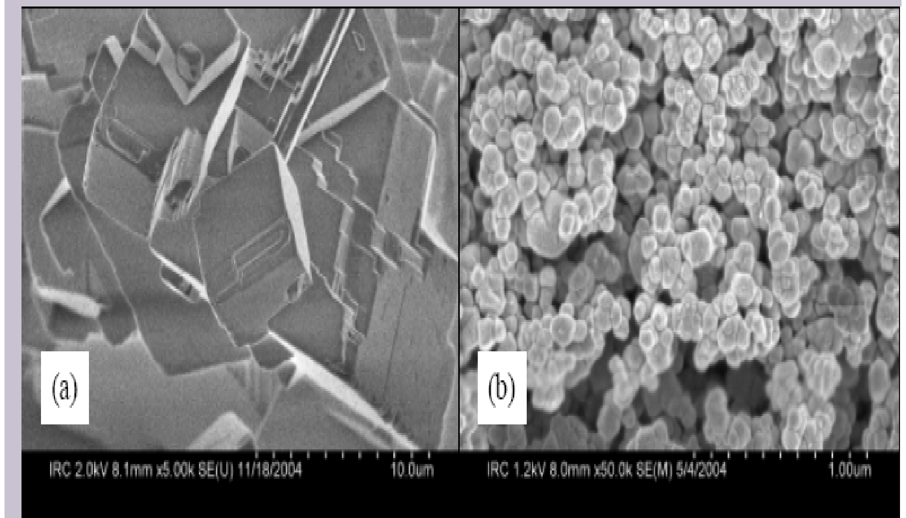
Binder combination	Cube compressive strength (MPa)							
	1 days	3 days	7 days	28 days	56 days	112 days	360 days	720 days
PCC	40.5	51.2	66.8	81.1	87.9	91.2	96.3	103.7
HFAC	16.8	27.6	35.0	54.4	71.6	85.7	95.4	108.5
SHFAC	30.4	43.9	59.0	75.8	85	92.2	104.5	115.9

HFAC = 50%PCC + 50%PFA; SHFAC = 46%PCC + 50%PFA + 4% nano-

Nano better than Micro ggbfs & $CaCO_3$ (Sato and Beaudoin, 2006)



OPC
OPC + GGBFS [50%]
OPC + GGBFS + Nano-sized $CaCO_3$ [10%]
OPC + GGBFS + Micro-sized $CaCO_3$ [10%]
OPC + GGBFS + Nano-sized $CaCO_3$ [20%]
OPC + GGBFS + Micro-sized $CaCO_3$ [20%]



Collaborations in Nanotechnology

Sri Lanka Institute of Nanotechnology (SLINTEC): http://www.slintec.lk

Focus on Sustainability

Initiative on Sustainable Construction (Nanoparticles in Concrete)

Partners: University of Moratuwa (Prof Priyan Dias – special projects advisor)

Experimental

University of Melbourne (Prof Priyan Mendis)

Numerical

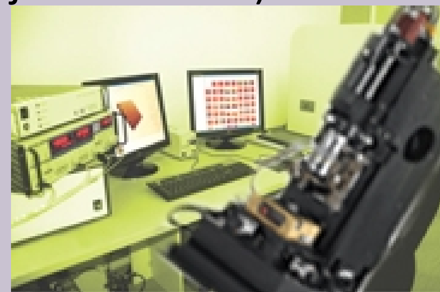
SLINTEC

Microstructural

Equipment: Atomic Force Microscope

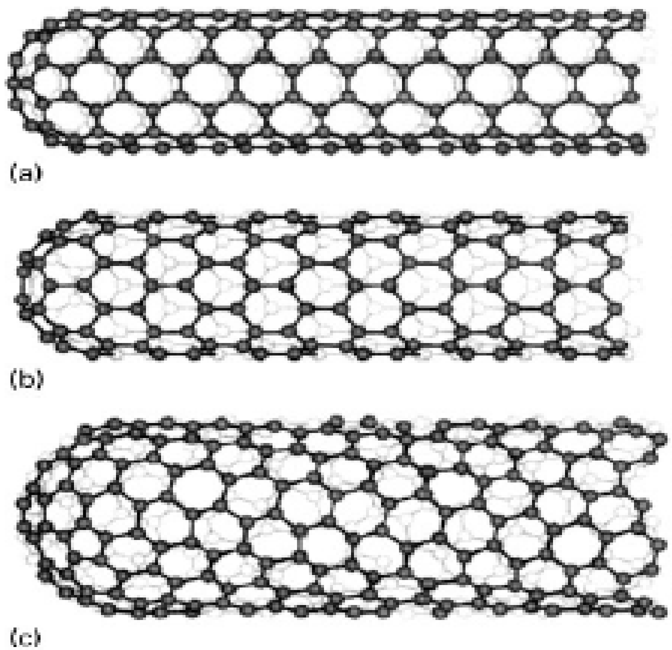
Particle Size Analyser

X-ray diffractometer

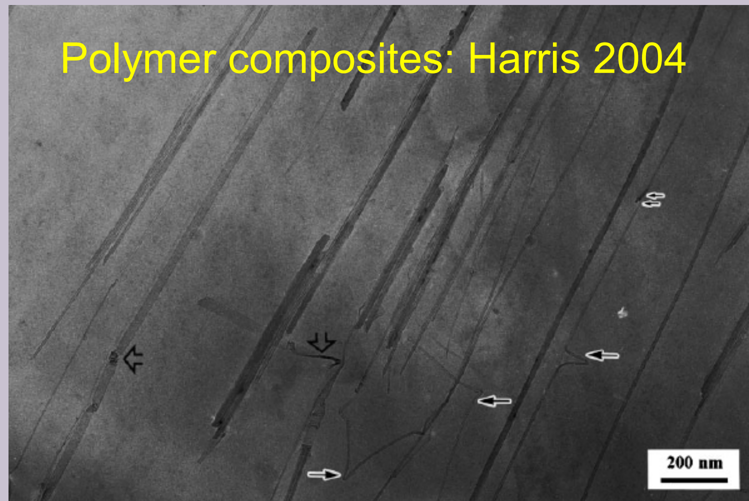


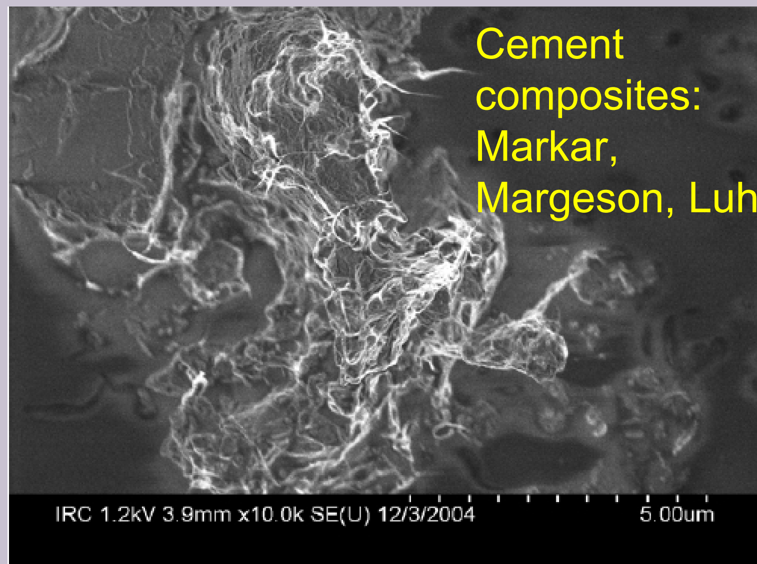
Note: Other collaborations are welcome

Carbon Nanotubes



a armchair (n, m)=(5, 5); b zigzag (n, m)=(9, 0); c chiral (n, m)=(10, 5)



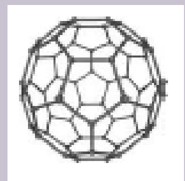


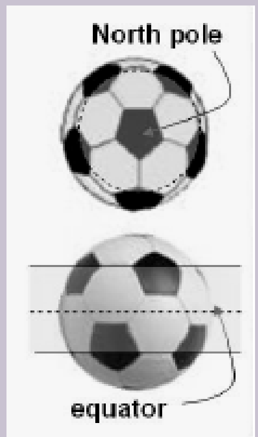
High strength (50 GPa)
100 times that of steel
High stiffness (1 TPa)
5 times that of steel
High elastic range (5-10%)
25 times that of steel
Large deformations out of plane

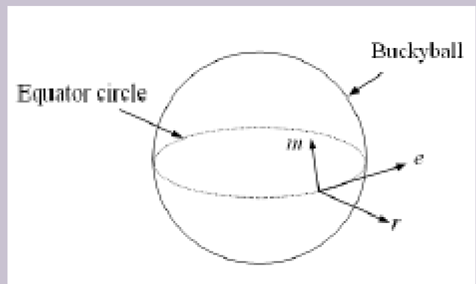
Nanomechanics

(K.R.B. & S.R. Herath, 2011

Buckyballs

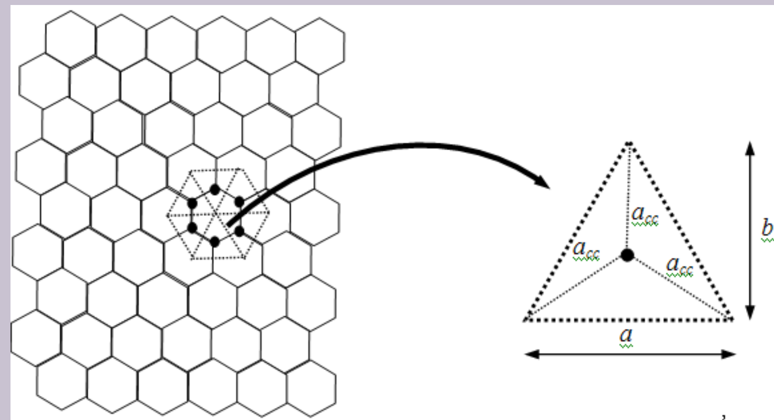


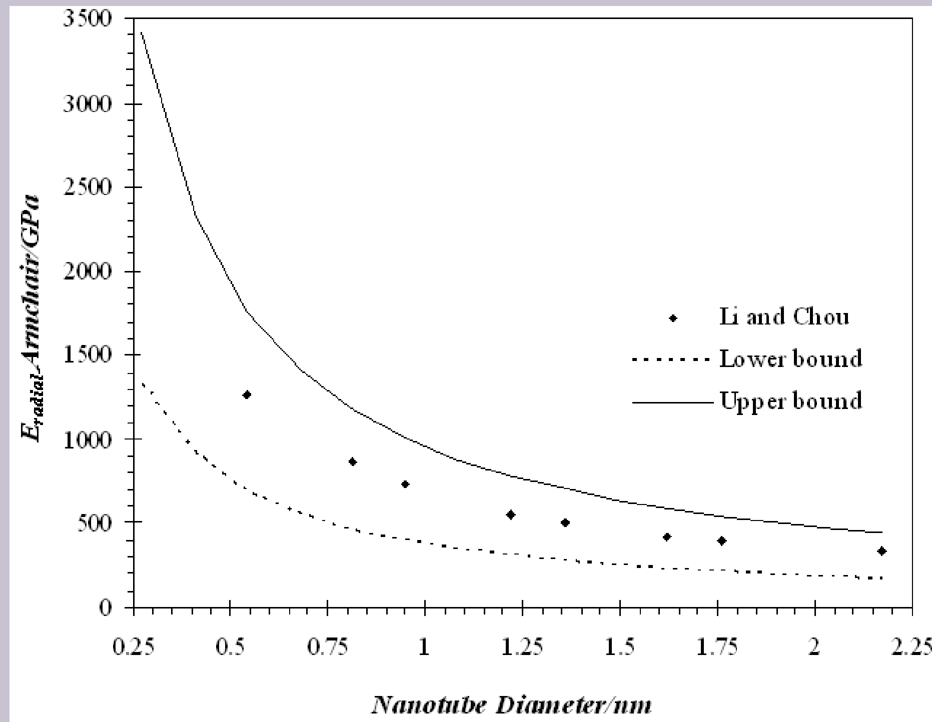




Modulus direction	Lower bound/(TPa)	Upper bound/(TPa)
Meridianal Modulus, E_m	0.532	1.358
Equatorial Modulus, E_e	0.341	0.870
Bulk Modulus, E_r	0.333	0.849

Carbon Nanotubes





Architecture aims at eternity
- Christopher Wren

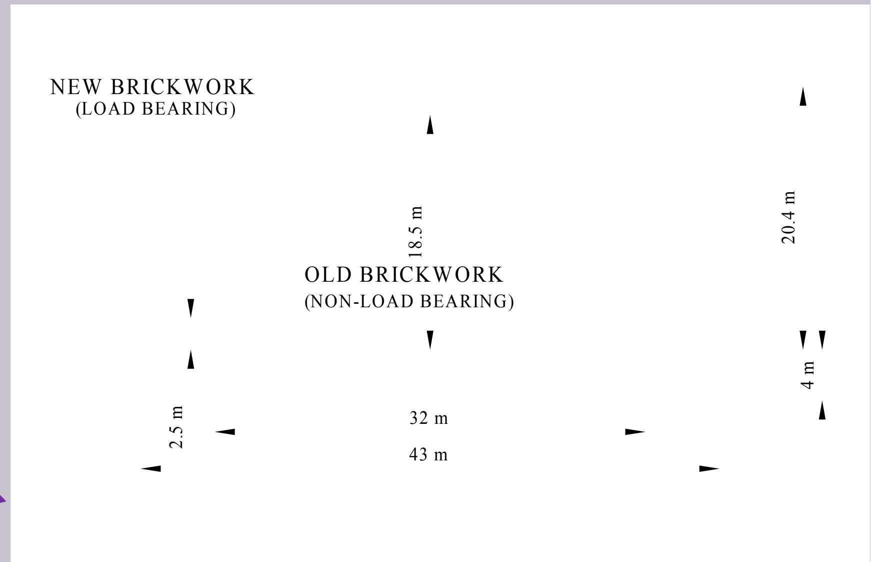
Ancient Structures

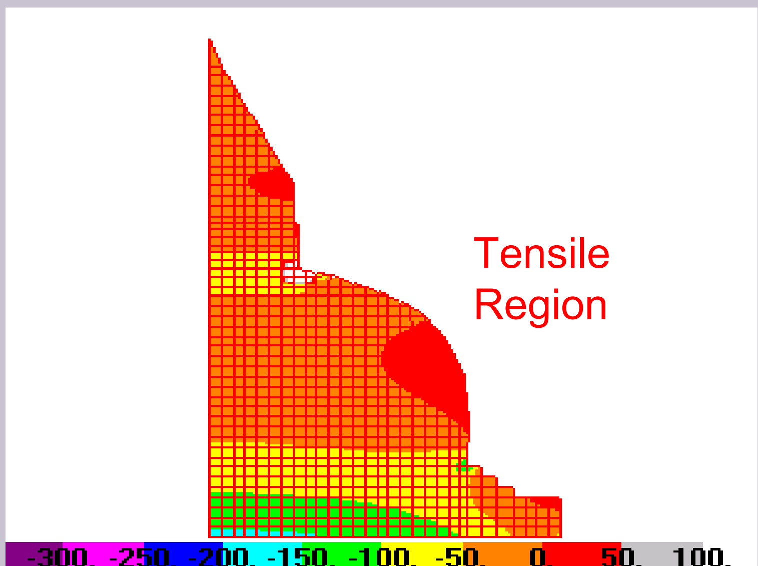
Munidasa P. Ranaweera
(University of Peradeniya)

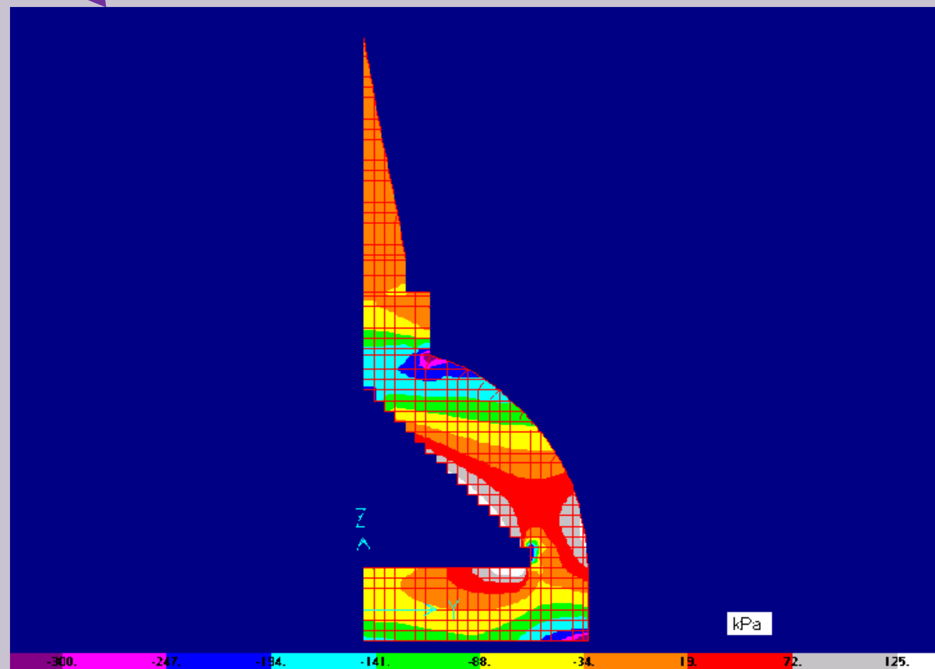
Stress Analysis

Diagnosis

Restoration





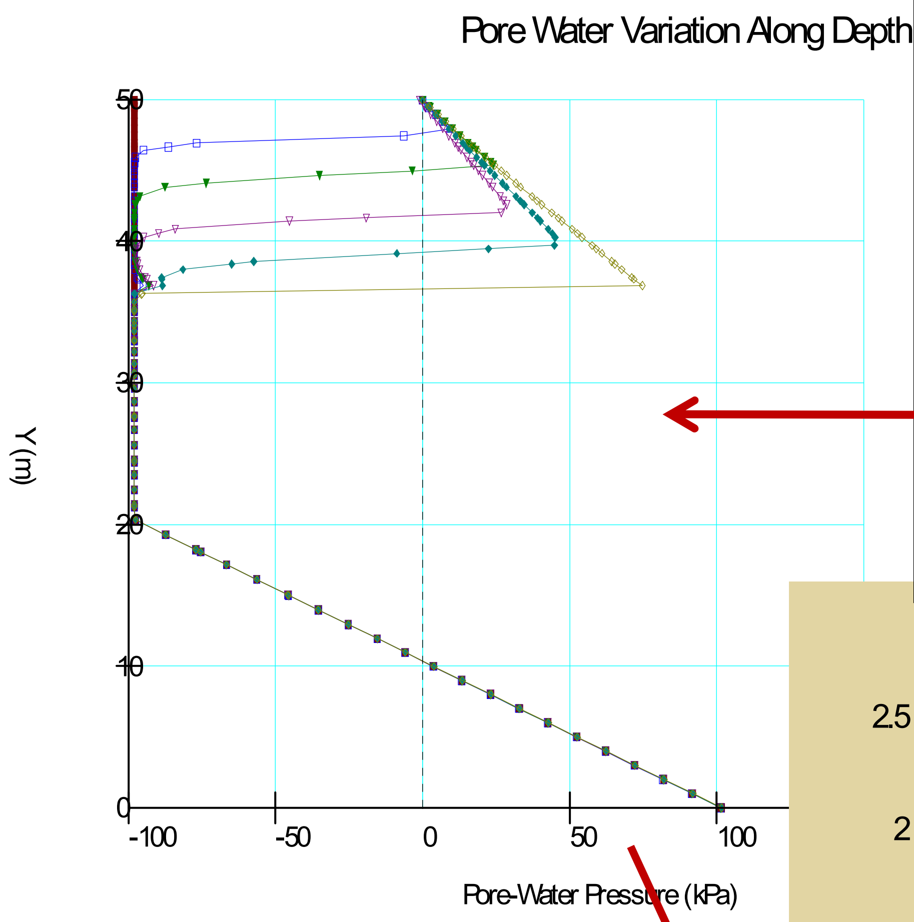


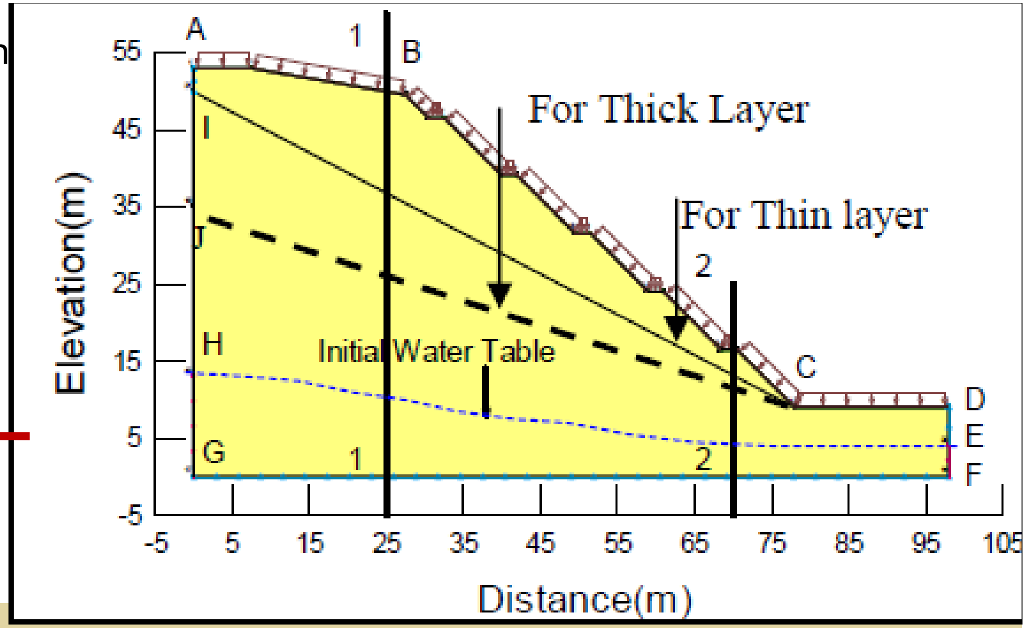
We know more about the
movement of celestial bodies
than about the soil underfoot
- Leonardo da Vinci

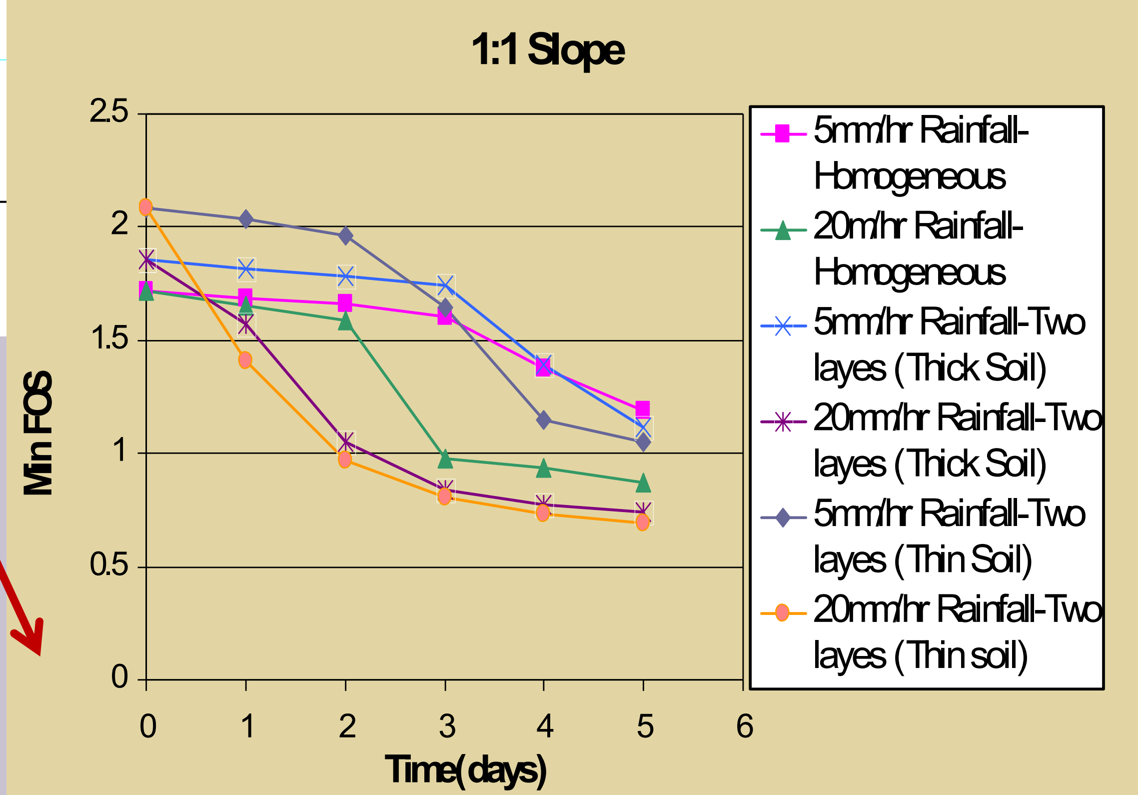
Geotechnical Engineering

Ground Improvement

Athula Kulathilake (University of Moratuwa)







Slope stability under rainfall

Electro osmotic improvement of peaty soils

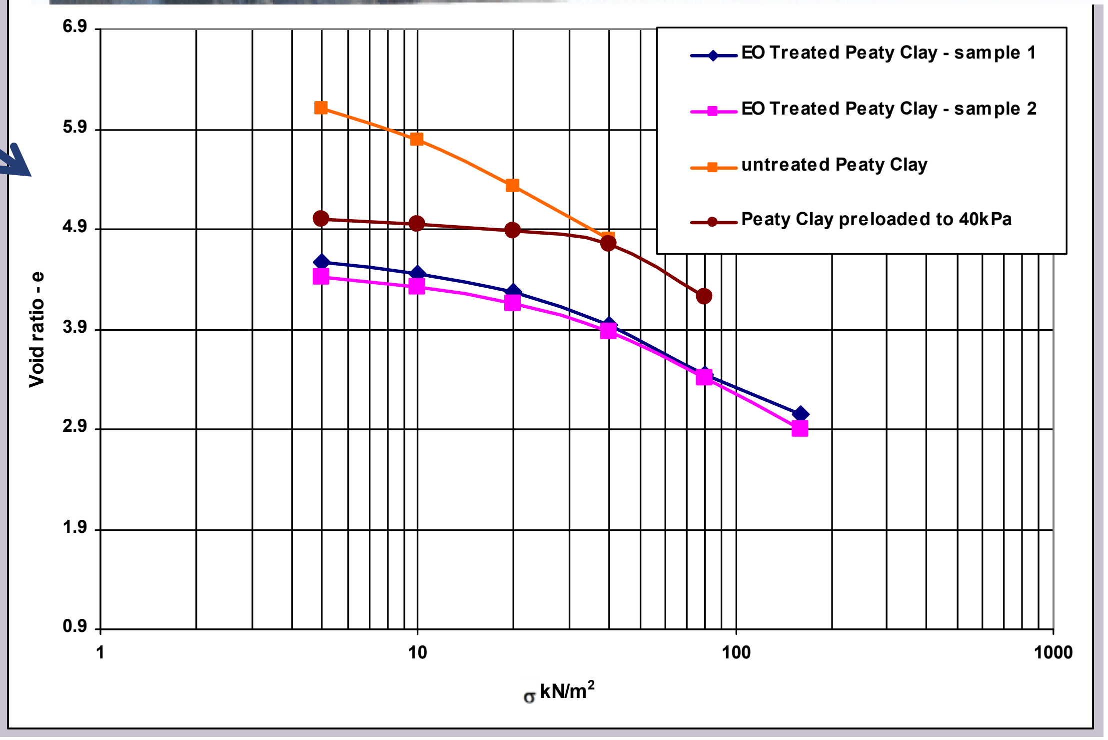
*When a DC Voltage difference is provided through a soil;
- Cations will move towards cathode
- Anions will move towards anode

*These ions with carry their hydration water with them

* More cations than anions; so net flow towards the cathode

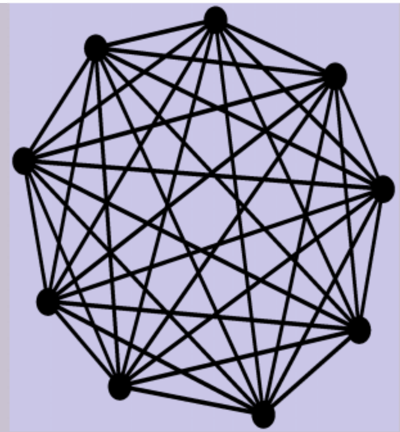
* Enhancements in consolidation characteristics and shear strength

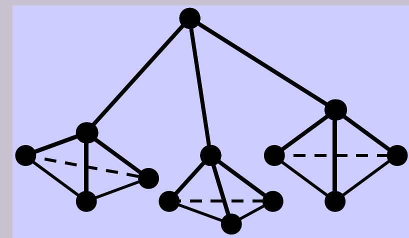
LOCATION	C_U(kN/m²)
Near Cathode	19.16
10 cm from Cathode	29.49
Near Anode	38.04



The practitioner is confronted with a choice. Shall he remain on the high ground where he can solve relatively unimportant problems according to his standards of rigor, or shall he descend to the swamp of important problems where he cannot be rigorous in any way he knows how to describe

- Donald Schon





Systems thinking

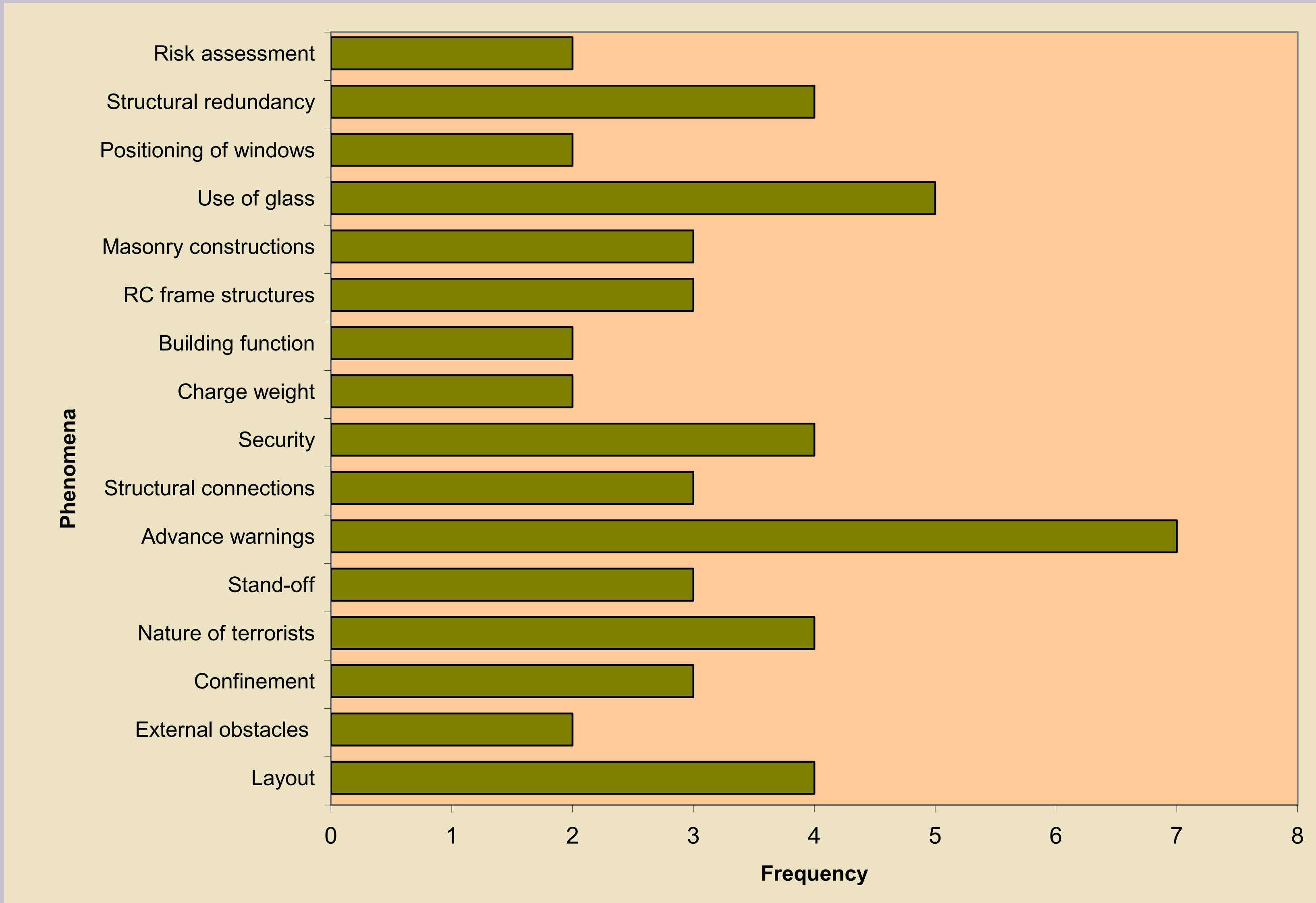
Case Study - Vulnerability to Bomb Blast

Priyan Dias & Ravihansa Chandratilake (University of Moratuwa)

David Blockley (University of Bristol)

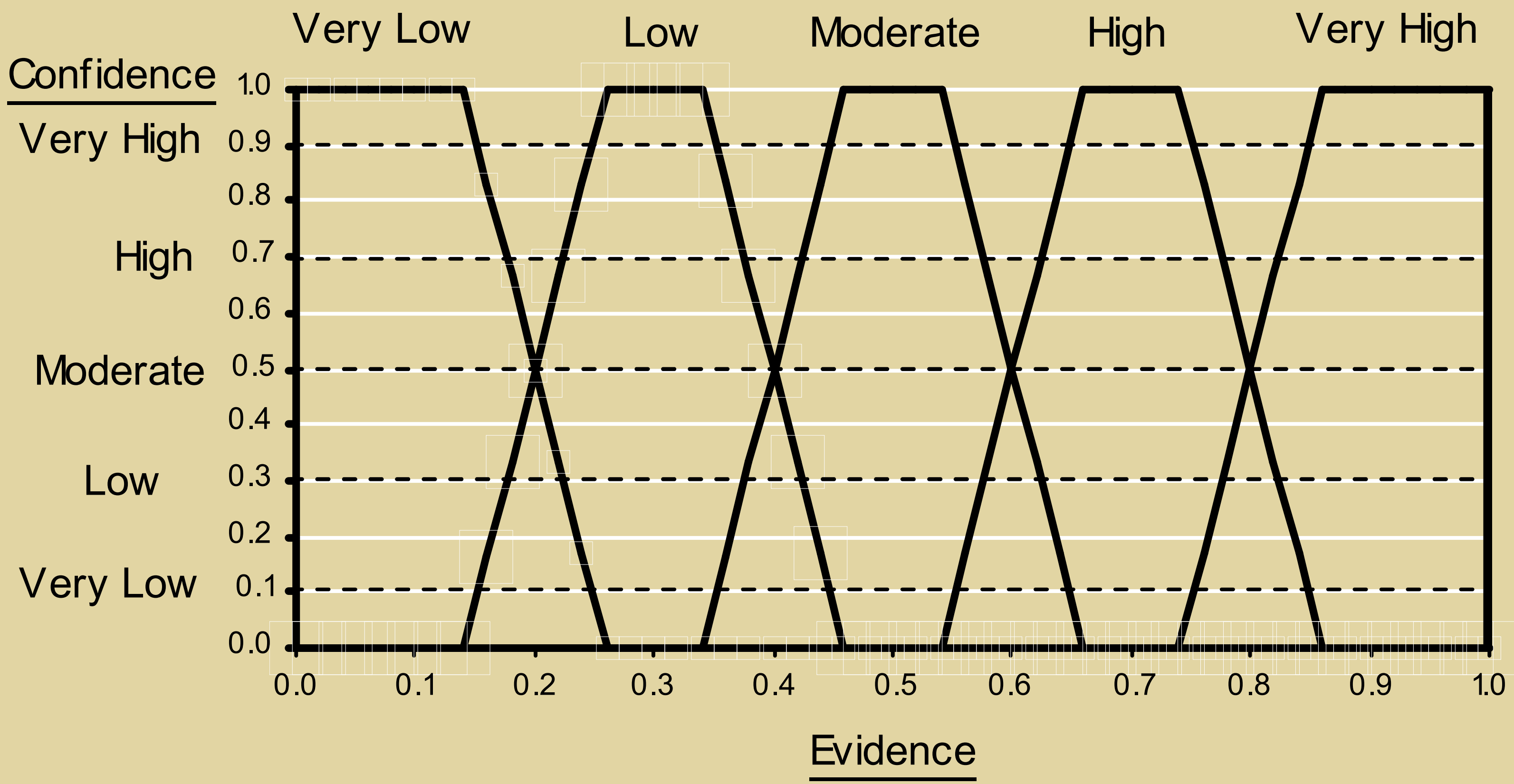
Socio-technical nature

- Grounded theory for generating key issues
- NOT "selective inattention"

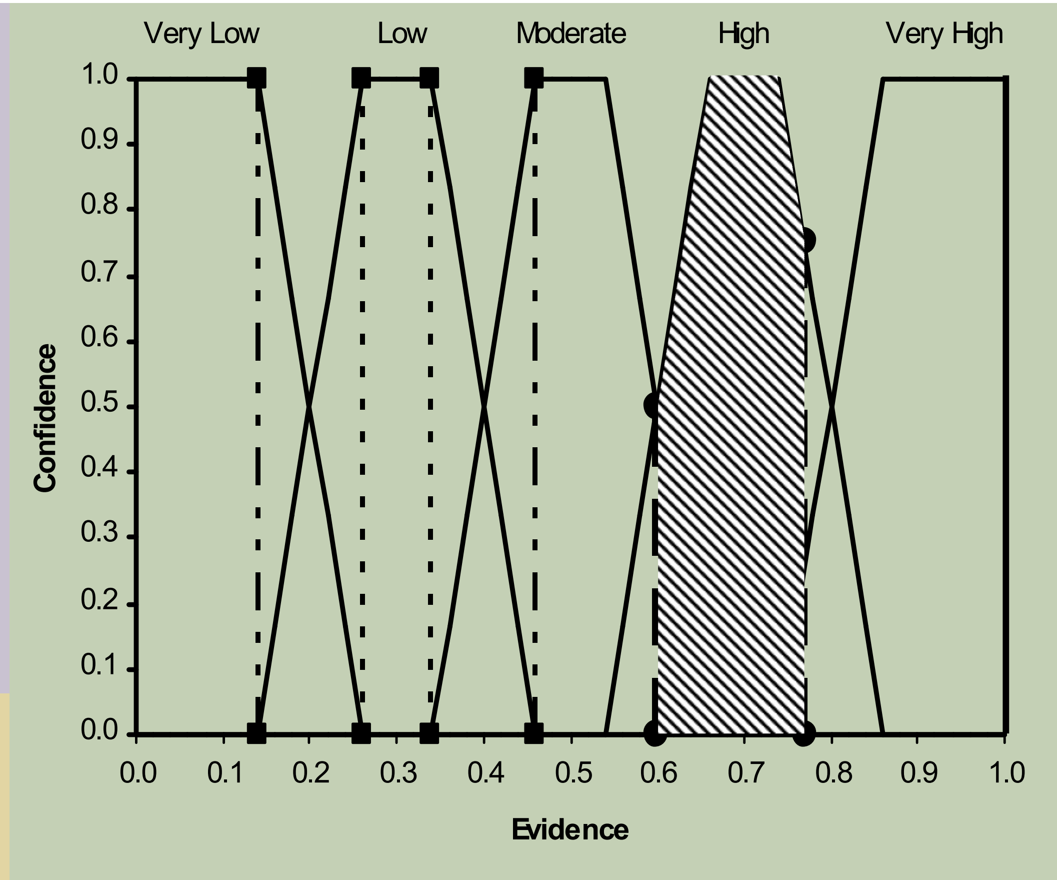


Uncertainty

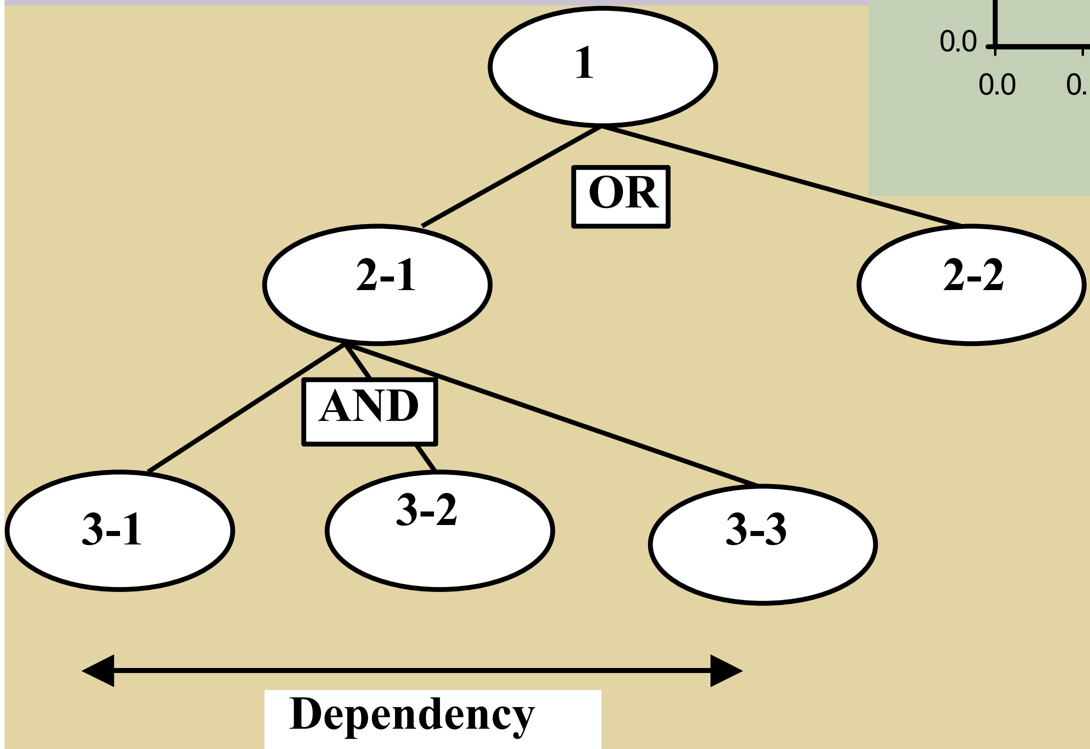
- Imprecision (Fuzziness); Incompleteness
- **Interval numbers**



Linguistic interpretation



Combining evidence



VULNERABILITY RATING

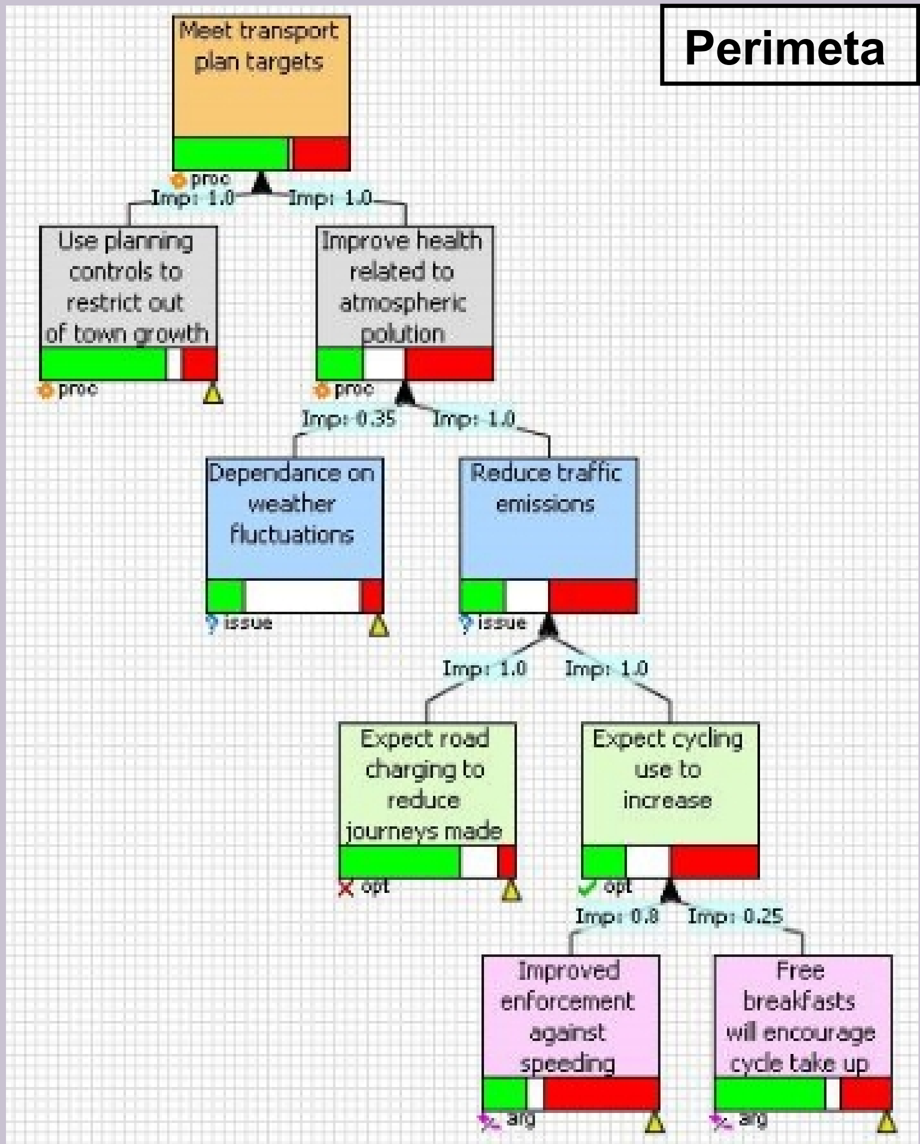
“very high” with a degree of confidence of “very low”;

“high” with a degree of confidence of *“very high”* ;

“moderate” with a degree of confidence of “very low”.

Interval Probability & Italian Flags

(Blockley & Davis, Bristol U.)



- Qualitative Factors
- Admission of Incompleteness
- Enables Conversation
- Multi-layer perception

S_n = "necessary" evidence for the holon

S_p = "possible" evidence for the holon

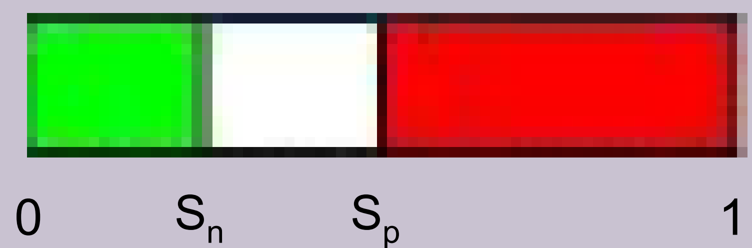
$S_p – S_n$ = uncertainty (incompleteness)

Hence (S_n,S_p)

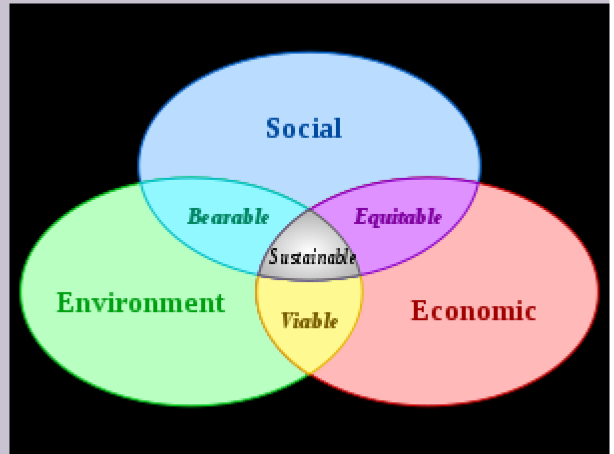
(0,0) ≡ certainly false

(1,1) ≡ certainly true

(0,1) ≡ completely uncertain



Treat the earth well: it was not given to you by your parents, it was loaned to you by your children
- African Indigenous



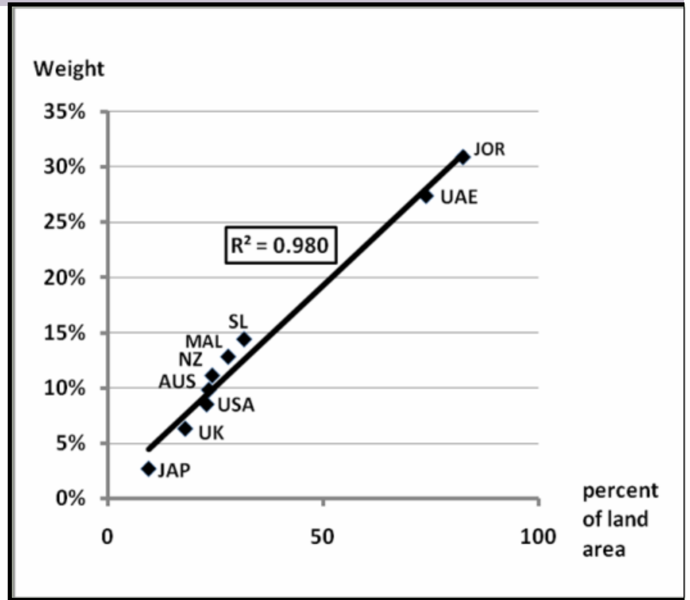
Sustainability

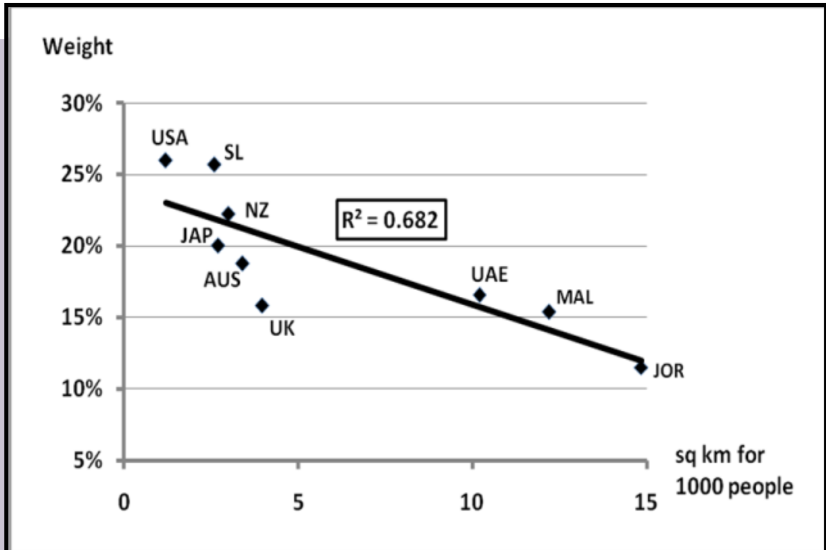
Priyan Dias & Ravihansa Chandratilake (University of Moratuwa)
Moratuwa University Design Team

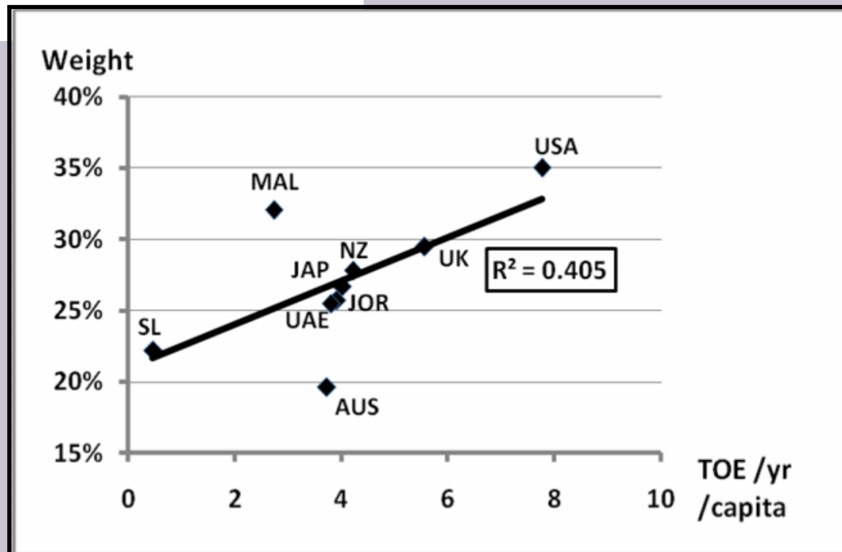
Sustainability Indicators

- Rating Systems
- Importance of Context

Scheme	Domain weight (%)					
	Site	Energy Efficiency	Water Efficiency	Material	IEQ	Waste & Pollution
LEED (USA)	**26.0**	**35.0**	08.5	12.0	14.0	04.5
BREEAM (UK)	15.8	**29.5**	06.3	**25.2**	11.6	11.6
SABA (Jordan)	11.5	**25.7**	**30.9**	11.5	13.2	07.2
Pearl Rating (UAE)	16.6	**25.5**	**27.4**	10.2	14.6	05.7
GBI (Malaysia)	15.4	**32.1**	12.8	07.7	**26.9**	05.1
Green Star (NZ)	**22.2**	**27.8**	11.1	11.1	**22.2**	05.6
Green Star (Australia)	18.8	19.6	09.8	**25.9**	**23.2**	02.7
CASBEE (Japan)	**20.0**	**26.7**	02.7	17.3	**26.7**	06.6
Sri Lanka Survey (SL)	**25.7**	**22.2**	14.4	14.5	12.3	10.9







MAS Holdings – Green Factory

LEED Platinum Award

Features:

Solar panels on roof

Evaporative cooling

Natural ventilation

Passive techniques

Rainwater harvesting

Result:

45% saving on energy

Rohinton Emmanuel,
Thishan Jayasinghe,
Chintha Jayasinghe,
Rahula Attalage,
Ajith de Alwis

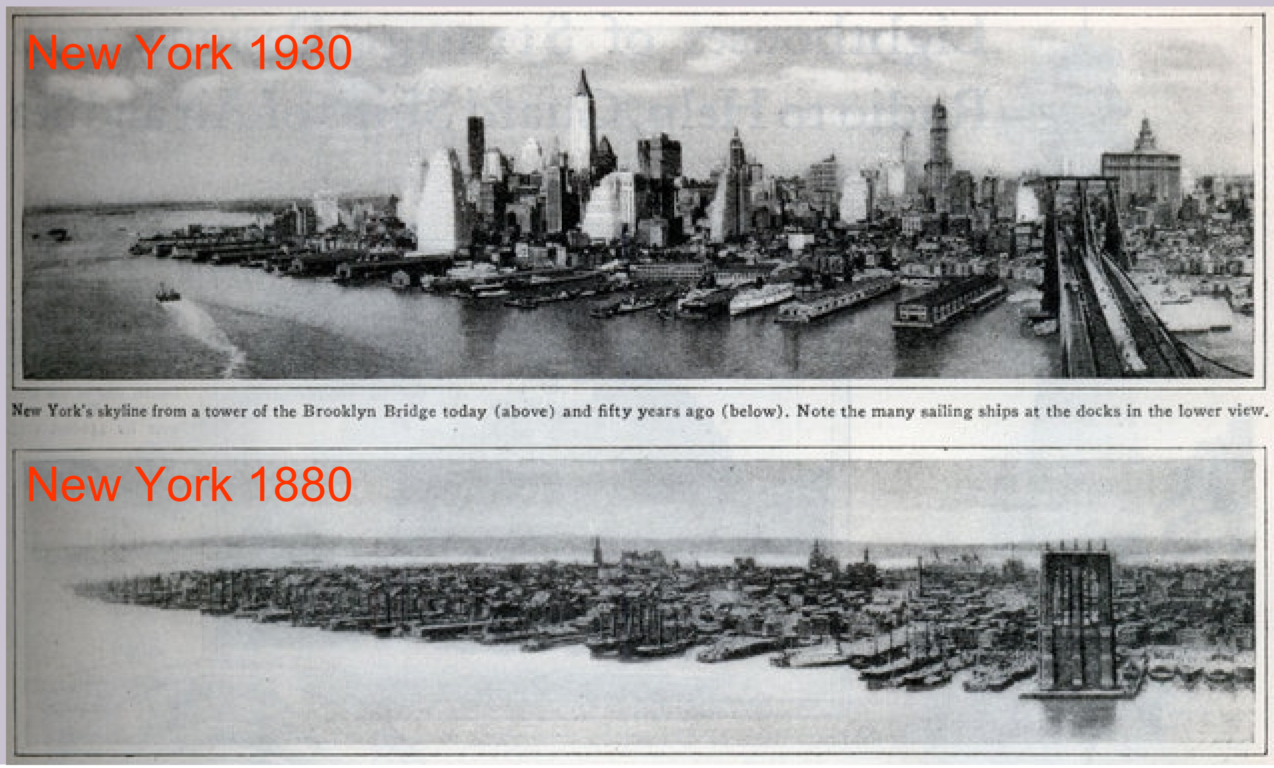
Service Life

-Technical constraints; Social requirements

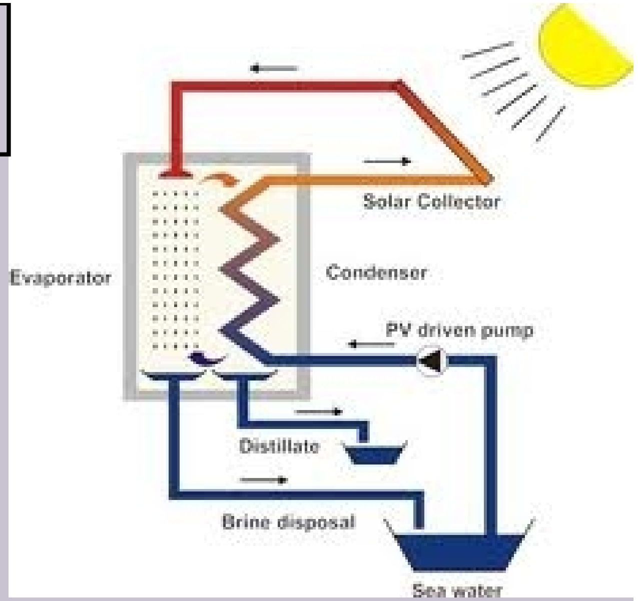
-Crossing threshold

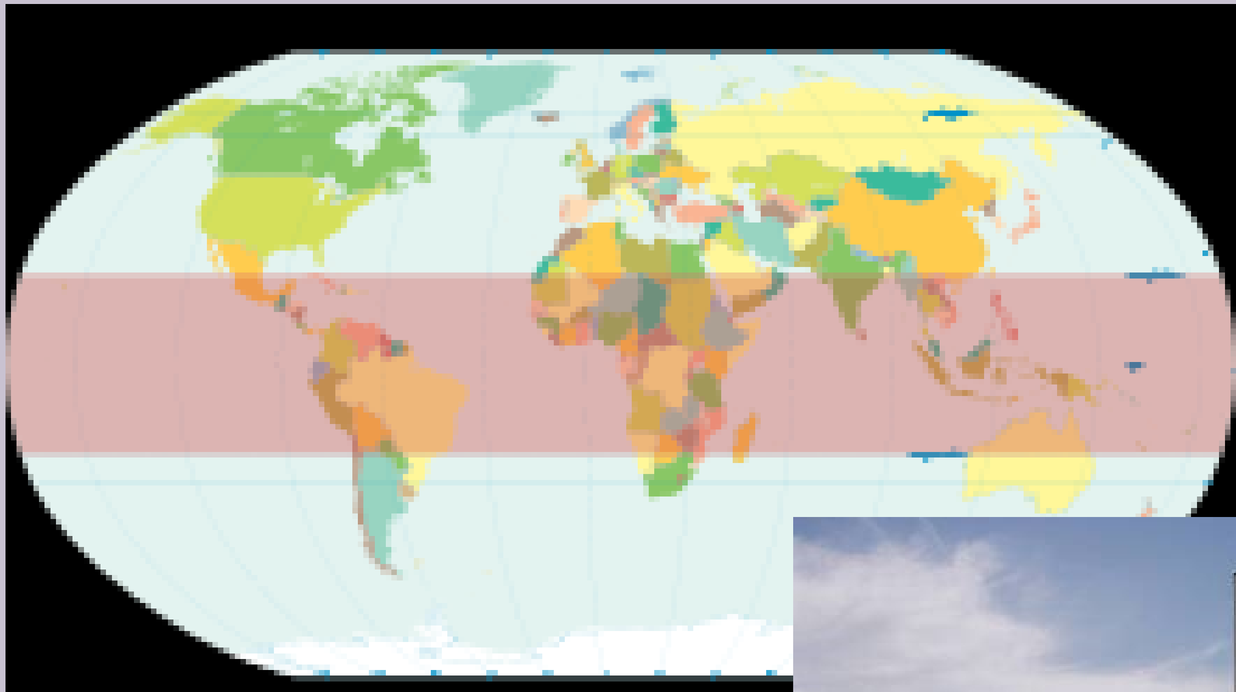
-**If it has lasted for n years, it will last for n more?**

Gaffoor Bldg, Colombo Fort; 125 yrs old



Solar distillation – water crisis





Global warming – Using the heat?

Solar chimney – energy crisis

Summary

Tsunami Loads & Vulnerability	Loads on vegetation shields
Cracking in Concrete & Healing	Autogenous crack healing
Micro & Nano Particles in Concrete	Enhancing properties of cement replaced concretes
Ancient Structures	Understanding deterioration & planning restoration
Geotechnical Engineering	Ground improvement
Systems Thinking	Addressing completeness; Tools to promote reflection
Sustainability	Solar radiation for energy and water crises; Service life