GREEN HOMES

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Sustainable Construction Materials: EARTH CONSTRUCTION

Dr. Santosh Shrestha

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Earth Construction - limitation

- Unreinforced structures is weak in seismic activities
- Few undesirable properties or limitation
    1. Loss of strength when saturated with water,
    2. Weathering /erosion due to wind or driving rain and
    3. Poor dimensional stability.

As well as,

4. Social acceptation

Can we be eliminated the limitations ?

Yes!

Can be eliminated significantly by stabilizing the soil

Earth Construction

- three stabilization procedures
  - Mechanical stabilizer -

    in changes in its density, mechanical strength, compressibility, permeability and porosity
  - Physical stabilizer

    in changes in its density, mechanical strength, compressibility, permeability and porosity
  - Chemical stabilizer

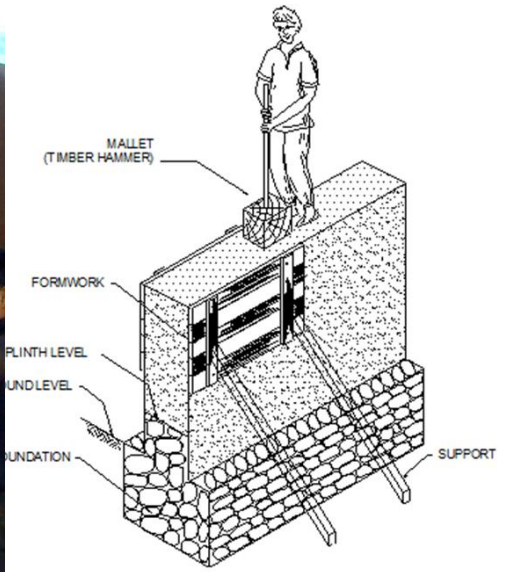
    modifying its properties, either by a physic-chemical reaction between the grains and the materials or the added product, or by creating a matrix which binds or coats the grains

Rammed Earth Wall

Rammed earth walls

Monolithic wall panels, usually cement stabilised earth, are compacted between stiffened shutters well supported to prevent lateral spread.

Compaction is normally done in 100-150mm layers by pneumatic tamper or hand rammers



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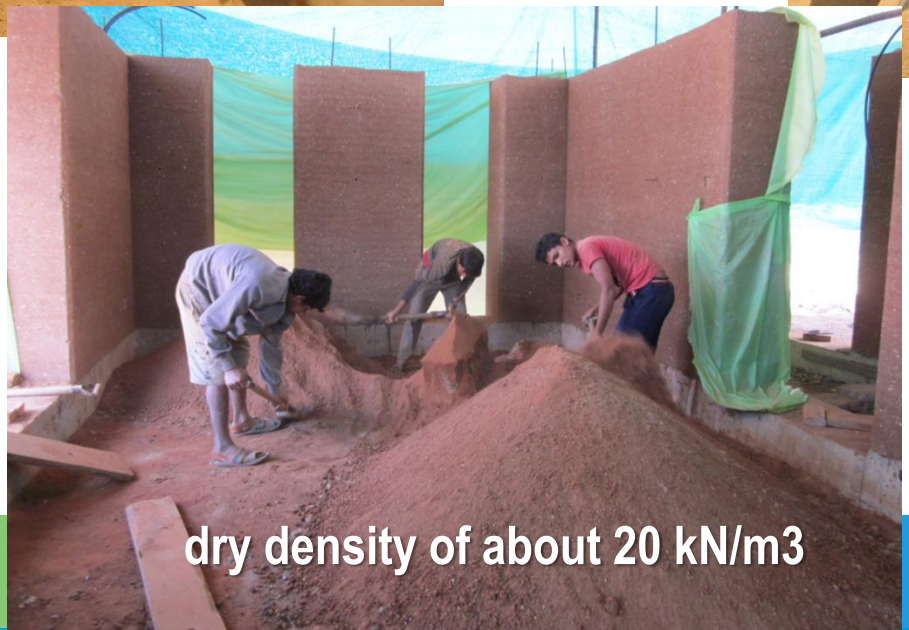
Rammed earth walls

clay and silt particles < 0.06 mm should be 20% - 30%

the optimum water content is about 9.5–11.0%.



dry density of about 20 kN/m3

not contain particles larger than 38 mm

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Rammed earth walls

unit weight of rammed earth is in the range of 1800–2000 kg/m3.

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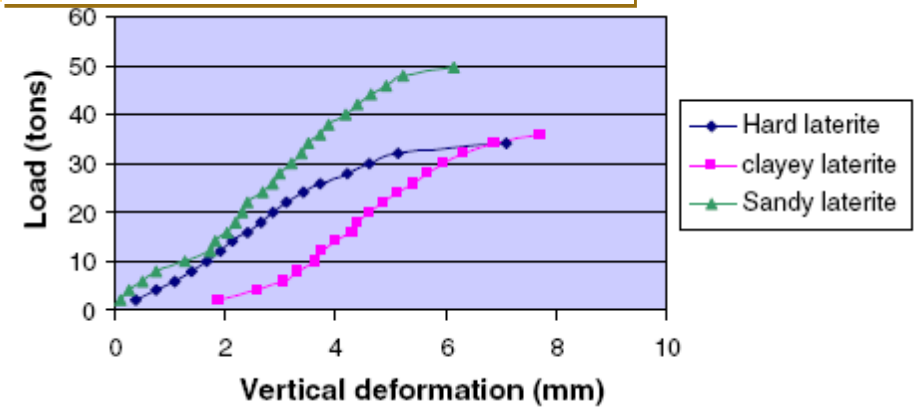
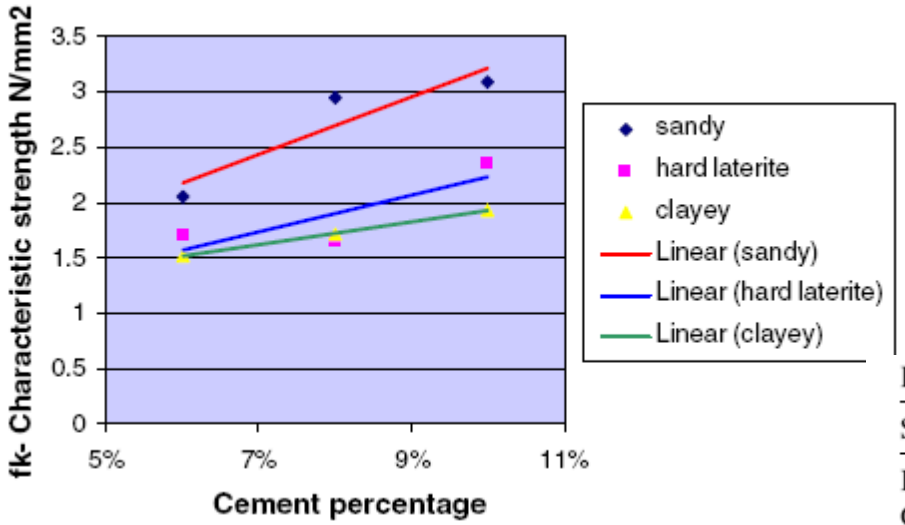
Rammed earth walls

Strength characteristics in compression





Ratio of wet/dry strength of rammed earth panels

Soil type	Cement (%)	Dry strength	Wet strength	Ratio
Hard laterite	6	2.03	1.30	0.64
Clayey	6	1.82	0.85	0.46

a ratio more than 0.33. Therefore, the strength of rammed earth walls under adverse conditions will be adequate

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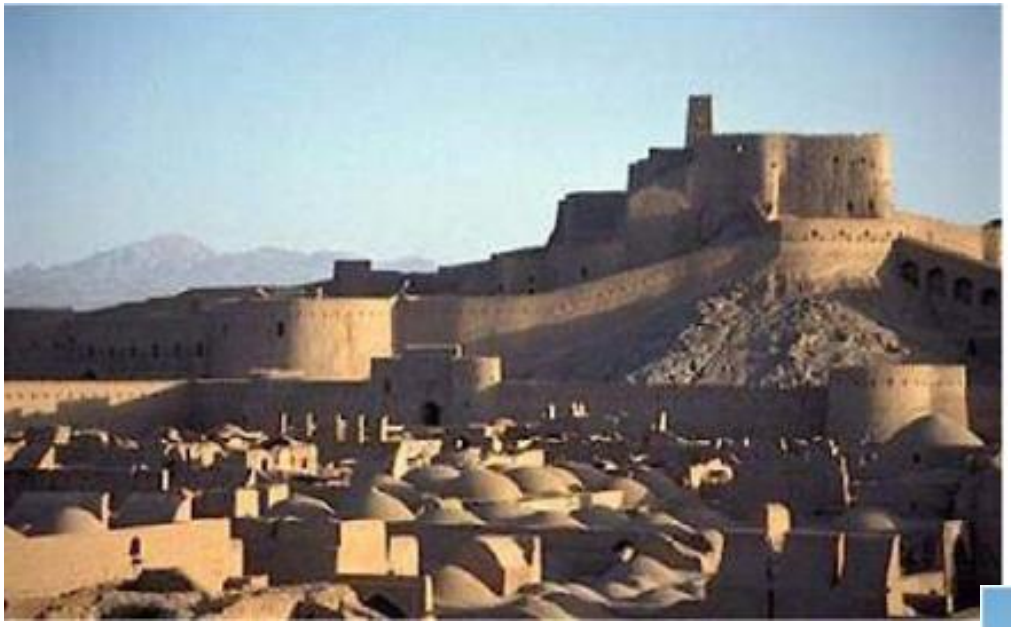
Rammed earth walls – EQ damage

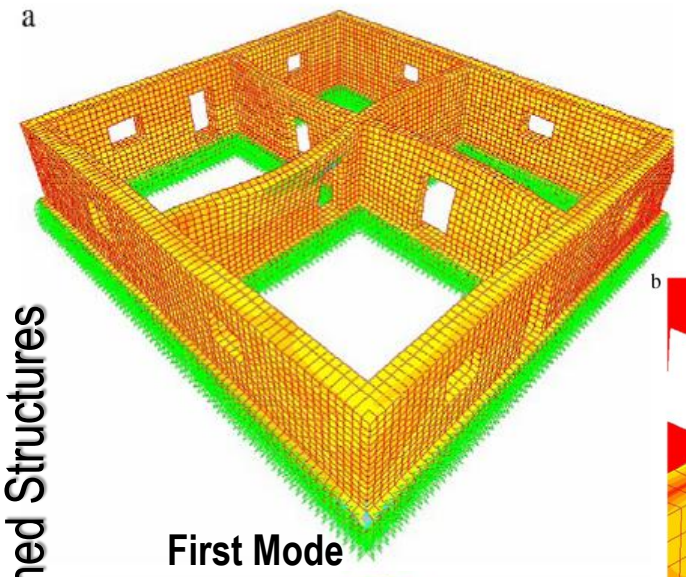


Bam City, Iran before the Dec. 2003 Earthquake

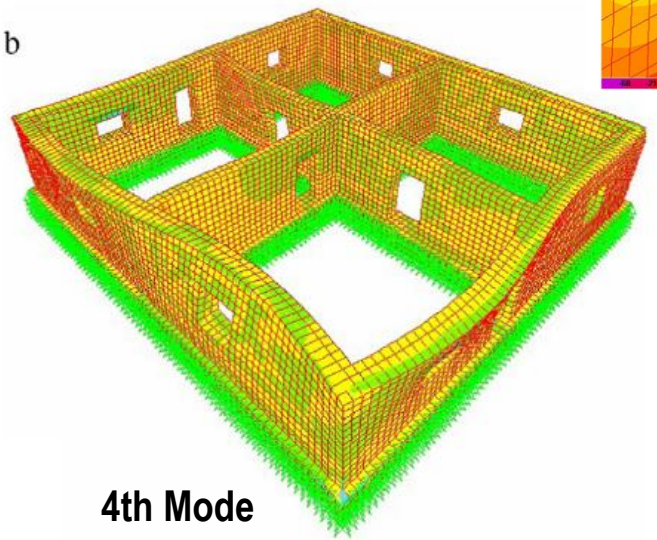
Bam City, Iran after the Dec. 2003 Earthquake

Rammed earth walls - Simulation

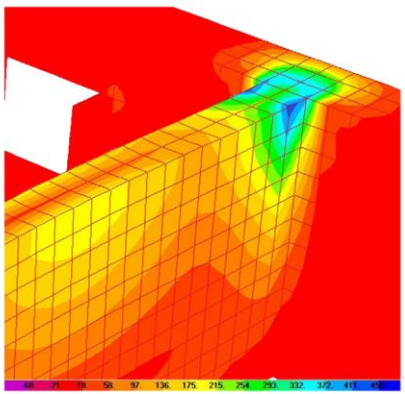
Un-strengthened Structures

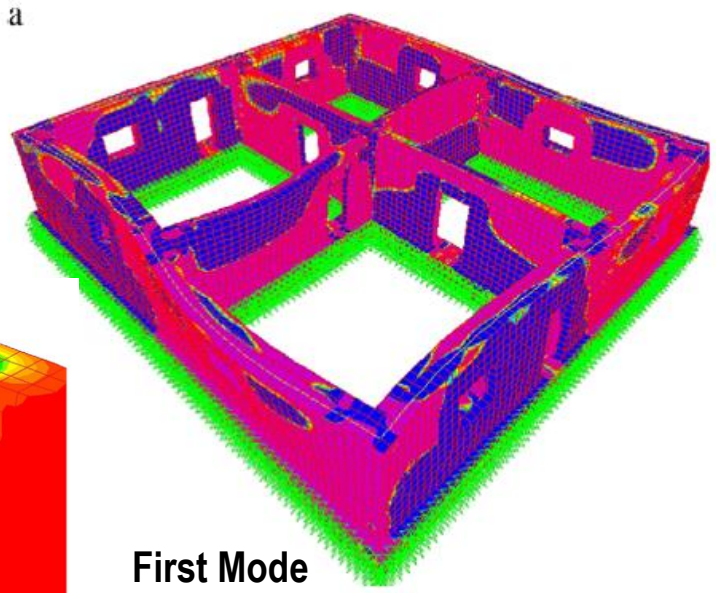


First Mode

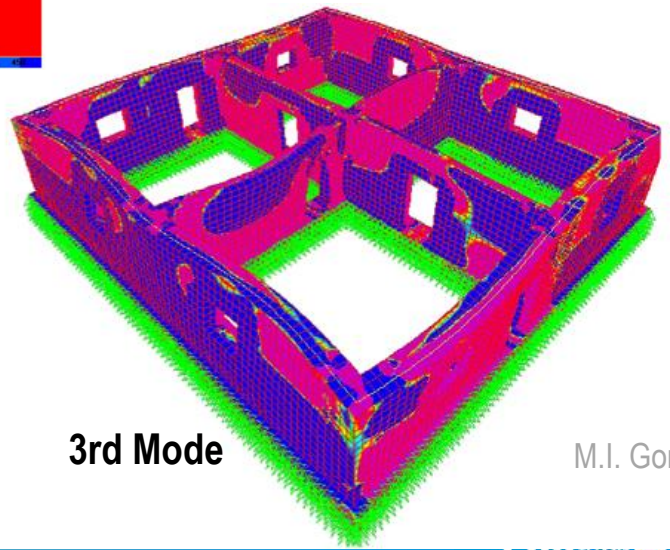


4th Mode





First Mode



3rd Mode

Strengthened Structures

M.I. Gomes et al. /

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Rammed earth walls - Findings

Unstrenghtened Structures

- the difference between the maximum tensile stresses (σ = 0.450 MPa) and the allowablevalues (σ = 0.130 MPa) in several locations is very high and clearly indicates that damage would be extensive, eventually leading to collapse
- The strengthened structures showed much lower levels of displacements and stresses in the earth elements than the non-strengthened structure
- The most effective reinforcement strategy is adding RC beams at the top of all walls, and adding RC columns at all wall intersections.
- All this indicates that earth structures may survive strong earthquakes with moderate damage if properly designed and reinforced.

Rammed earth walls

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Mato ko Ghar @ Budhanikanth

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Nov 2011, Minimum Shadows in Winter

June 2012, Full Shadow on Facade

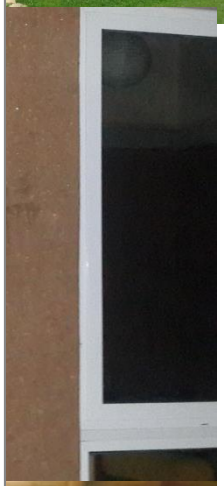
Sept. 2012, Partial Shadow on Facade

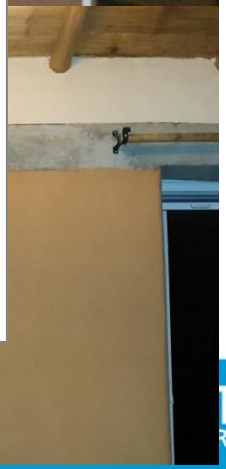
Floor Thermal Mass, radiant floor heating with XPS insulation

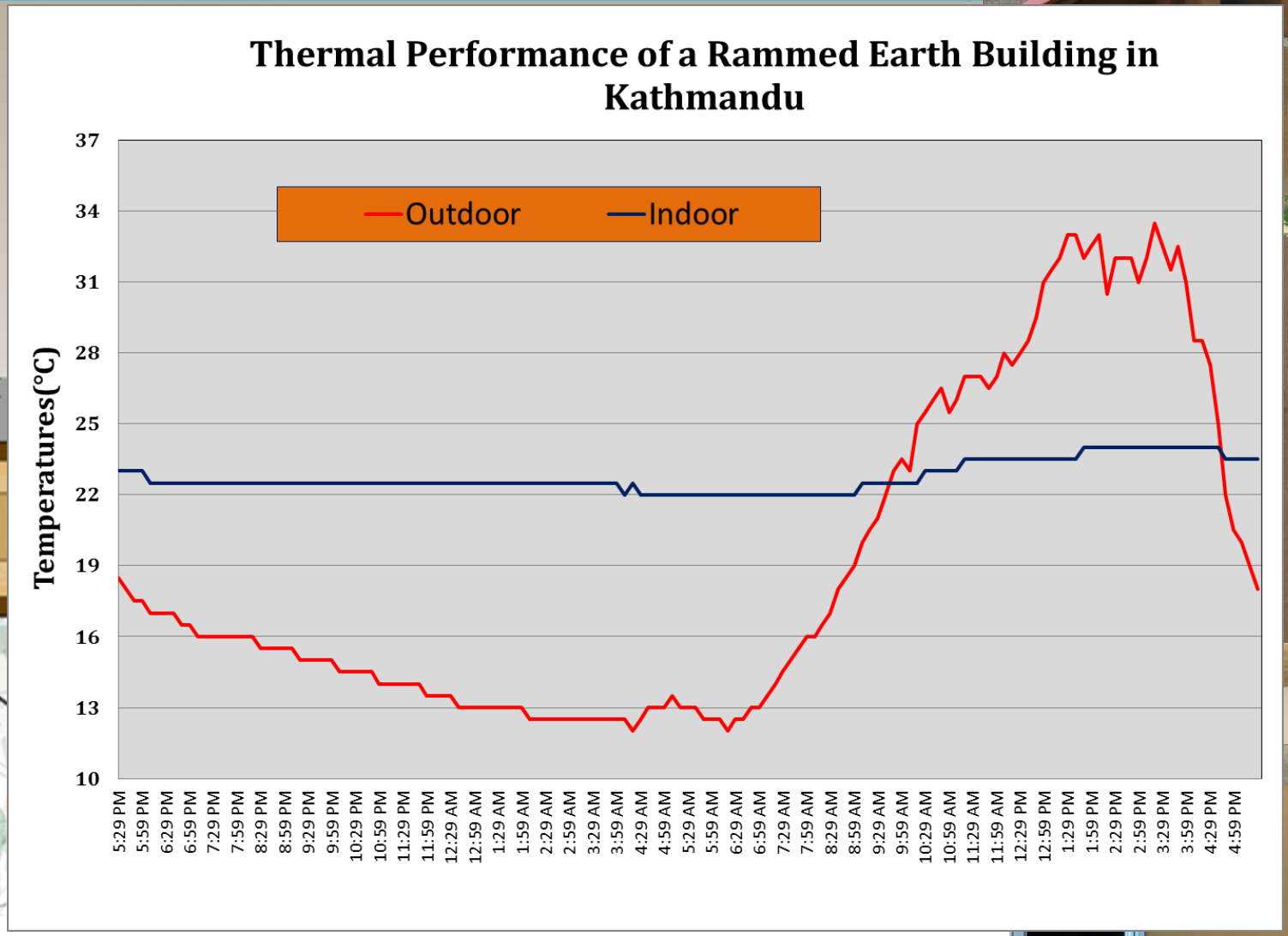
Dark colour of floor enhances heat absorption

Insulated and ventilated roof
XPS sheets, radiative aluminium sheet,

Mato Ghar - Performance







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– More sustainable, ecofriendly and healthy !

Compressed Stabilised Earth Block (CSEB)

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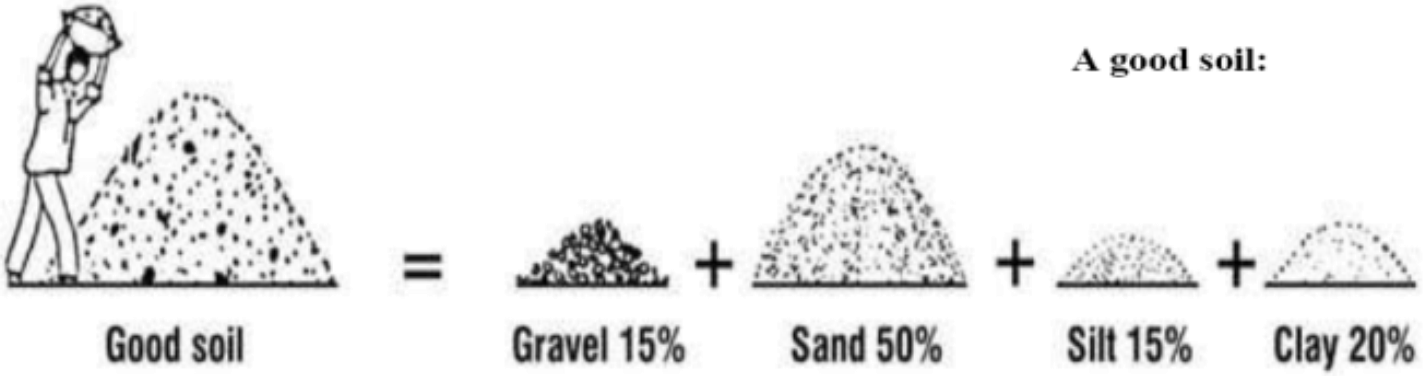
Earth Construction - CSEB

- **CSEB**
  - ✓ **Compressed Stabilizered Earth Block**
  - ✓ **Use cement or lime as a stabilizer**

Soil Stabilization – reduction of soil plasticity (permeability of soil)
- Increase strength and cohesion of the soil
- Improvement its workability and also resistance of erosion



5-7 % Cement as a Stabilizers

Soil Identification –

No Top soil and soil with organic matter.

Grain size distribution - more of sandy

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CSEB/Soil-Cement Block

CSEB Production process

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Compaction Machine

- Auroville Earth Institute, India

Aurum press 3000

HI – CSEB Block machine – Habitech centre, Thailand

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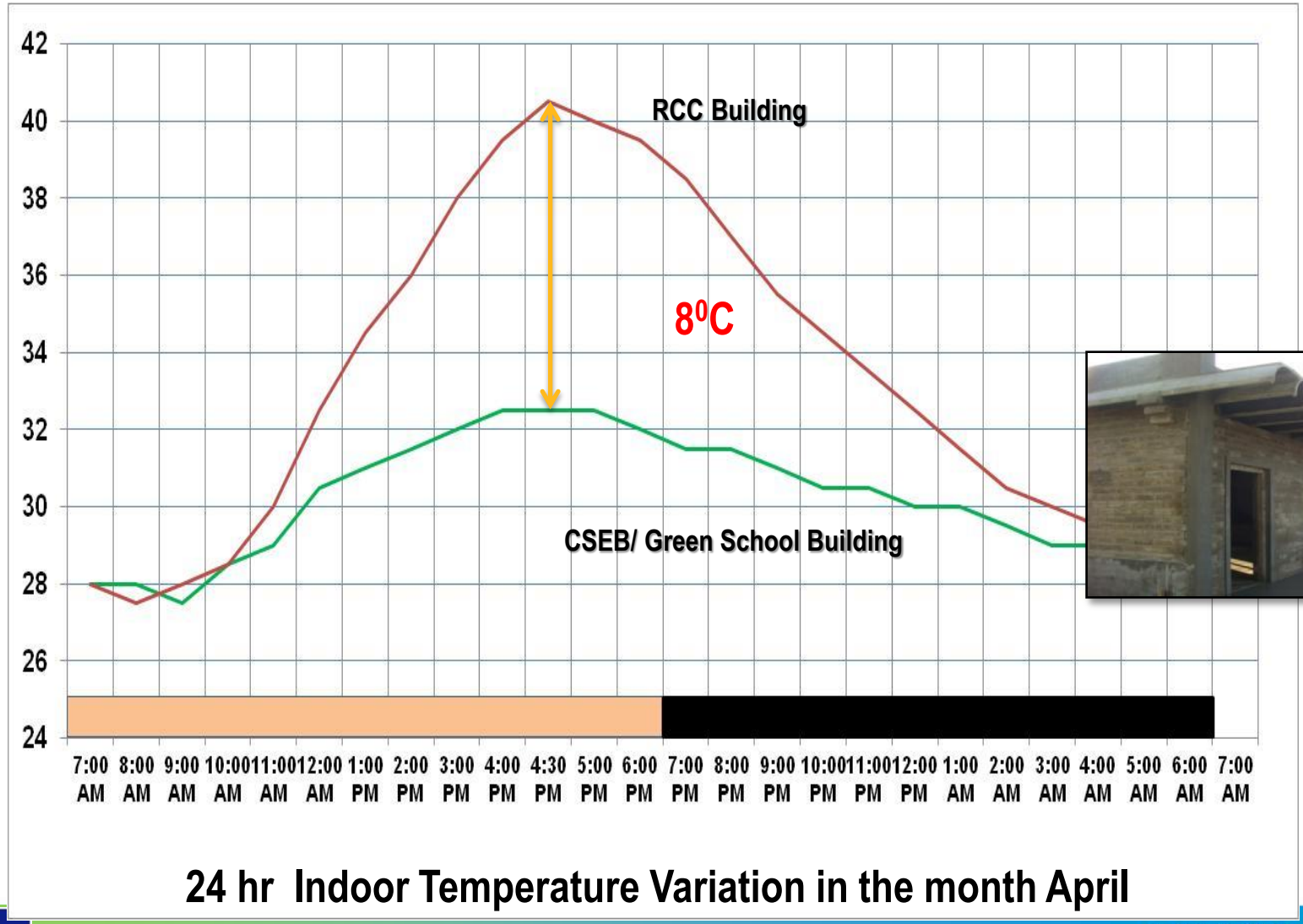
Soil-cement block / CSEB



24 hr Indoor Temperature Variation in the month April

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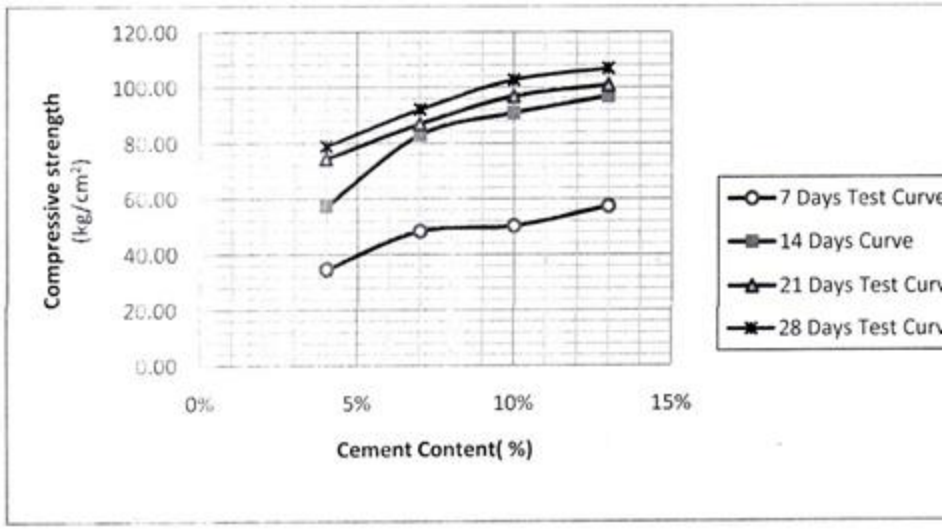
CSEB – Test result

- **Effect of cement contains (Sun dried back case)**

Increase compression strength with cement contains as well as pressure



igure 3-7 Effects of cement content on the Sun dried compressive strength of soil bl
200kg/cm^2 compaction pressure

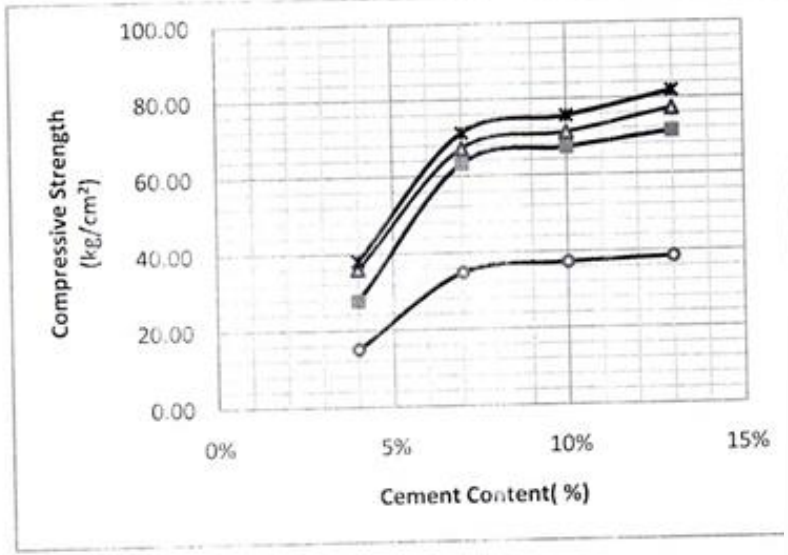


Figure 3-5 Effects of cement content on the Sun dried compressiv
100kg/cm^2 compaction pressure

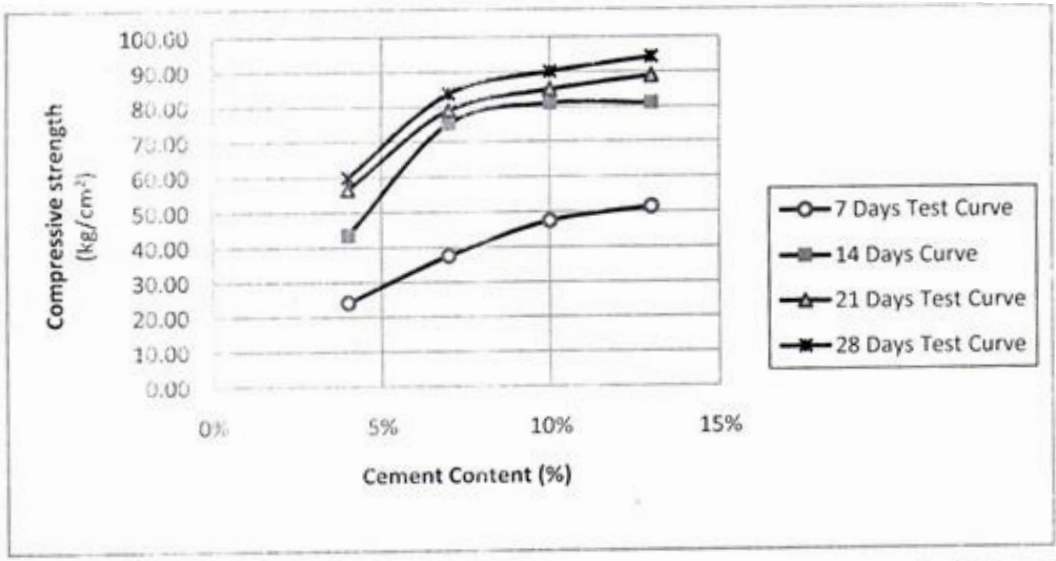


Figure 3-6 Effects of cement content on the Sun dried compressive strength of soil block
150kg/cm2 compaction pressure

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CSEB – Test results

- **Effect of cement contains (Wet compressive strength)**

Increase compression strength with cement contains as well as pressure

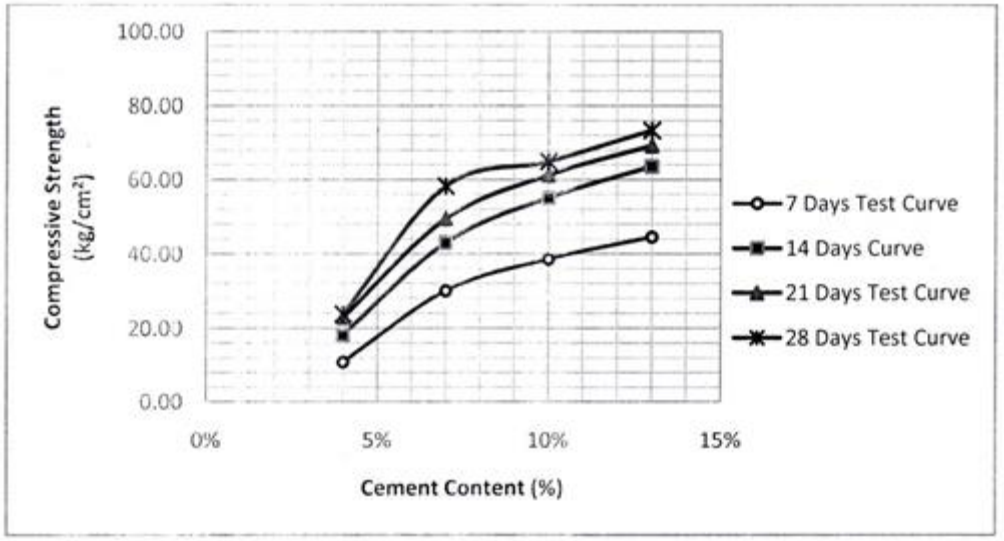

Figure 3-8 Effects of cement content on the Wet compressive strength of soil block for 100kg/cm^2 compaction pressure

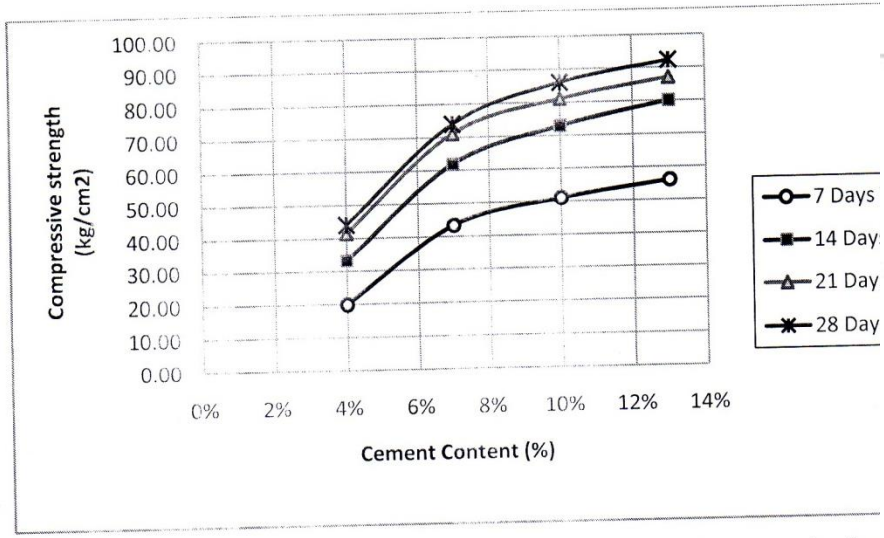

Figure 3-10 Effects of cement content on the wet compressive strength of so 200kg/cm^2 compaction pressure

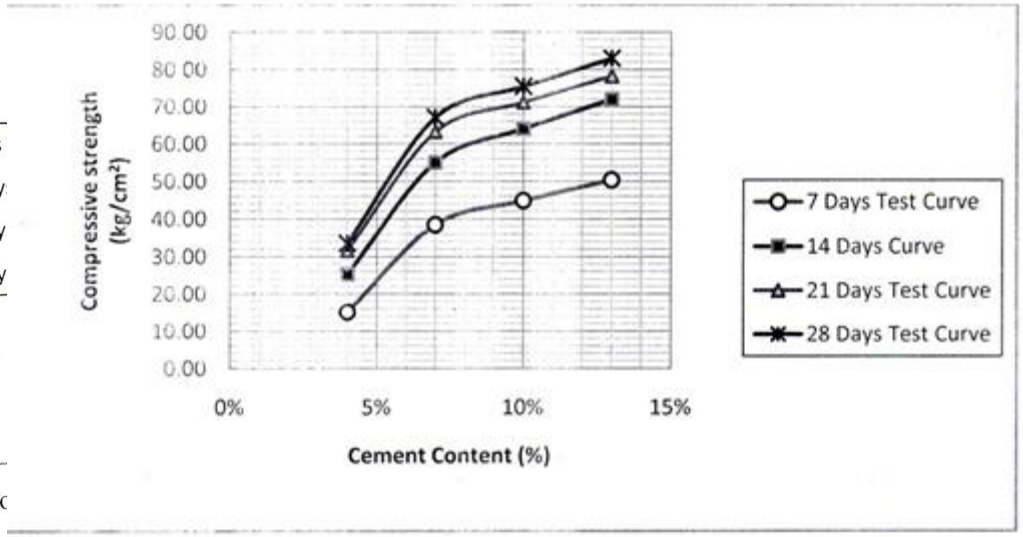

Figure 3-9 Effects of cement content on the Wet compressive strength of soil block for 150kg/cm^2 compaction pressure

CSEB – Test Results

Higher the compaction higher the compressive strength

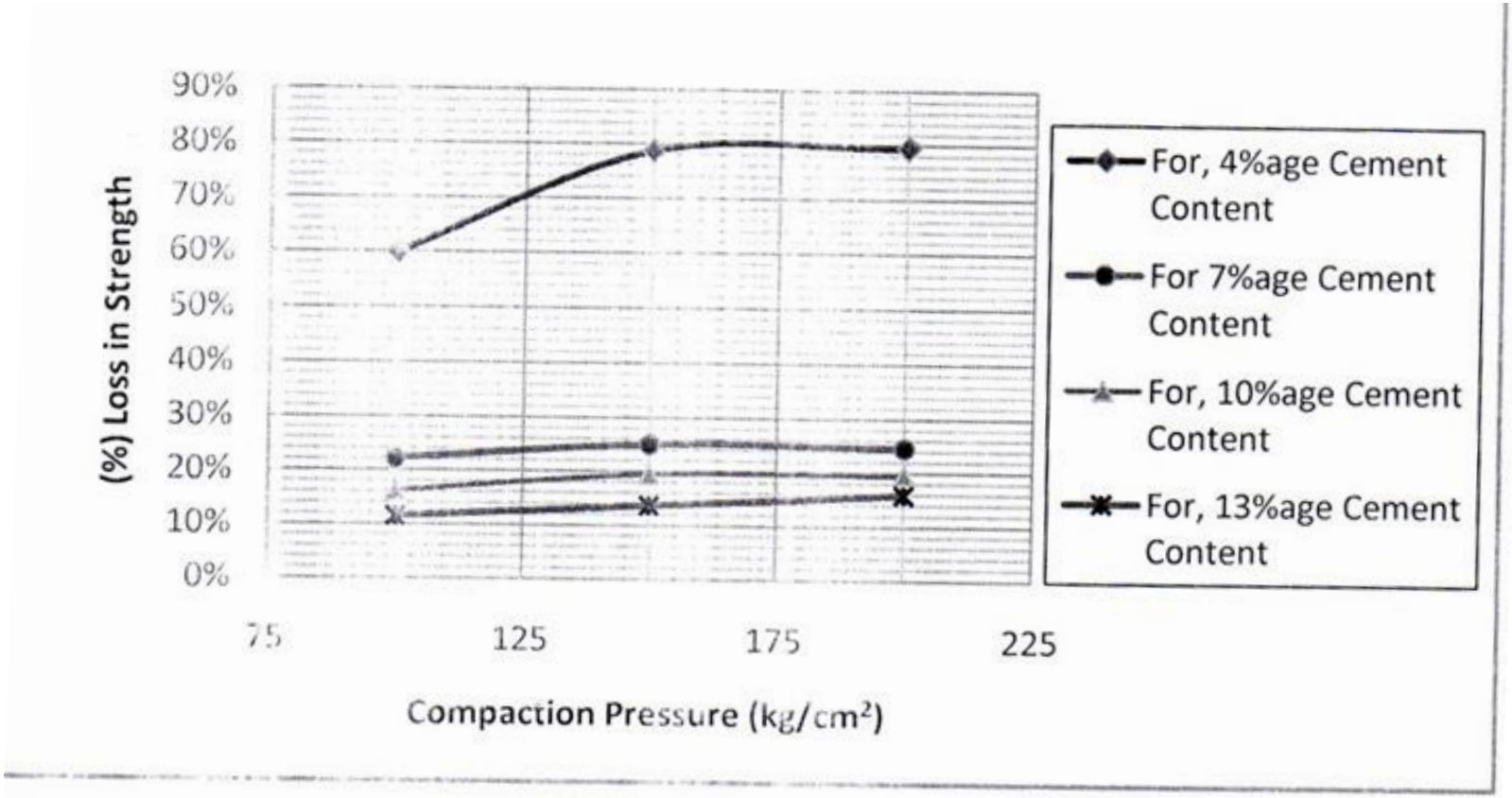

Figure 3-11 Compaction pressure with respect to loss in strength of CSEB

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CSEB – Test Result

- Water absorption

Water absorption capacity decreases with increase of cement content and compaction pressure

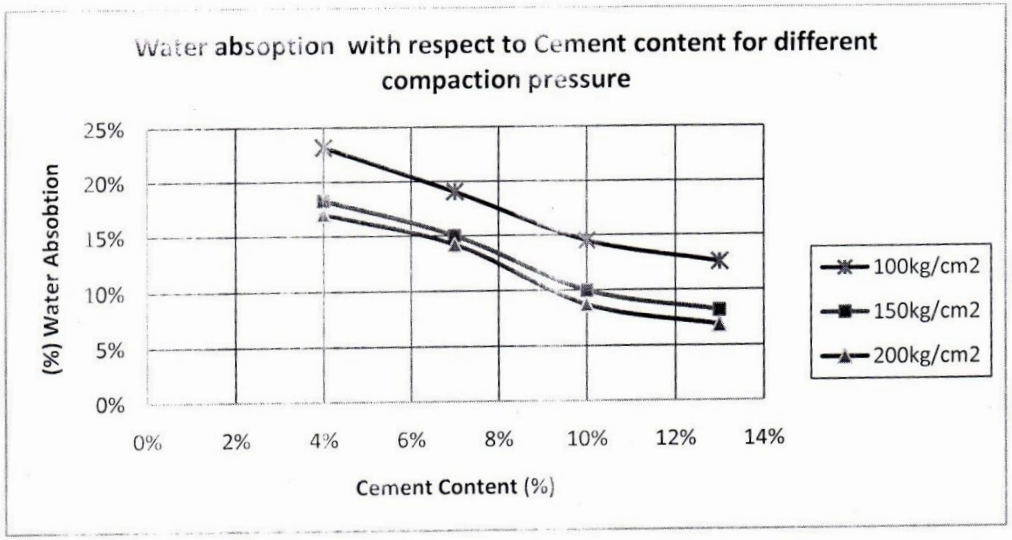

Figure 3-12 Water absorption with respect to Cement content percentage for different compaction pressure (casting)

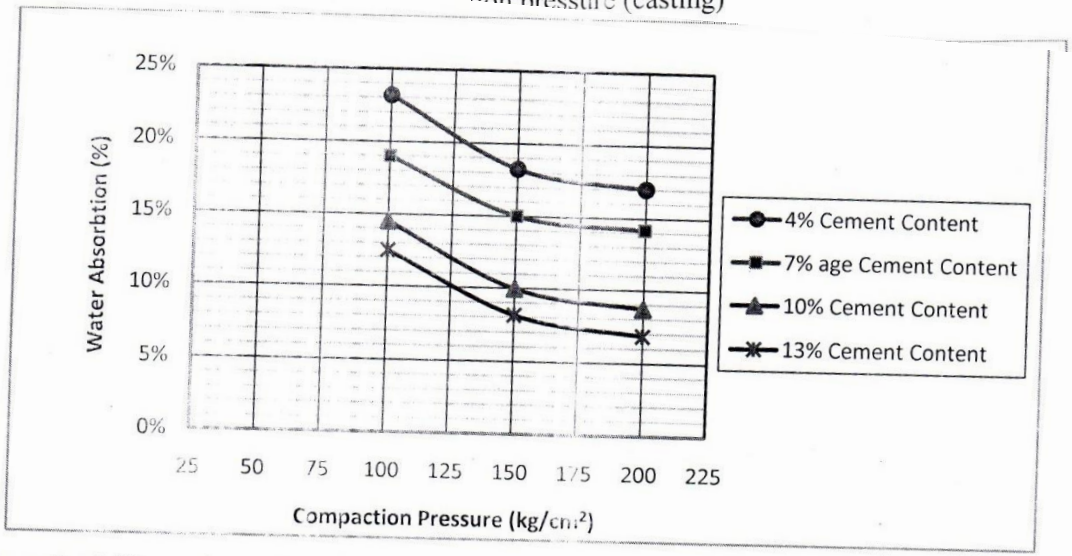

Figure 3-13 Water absorption with respect to compaction pressure for different cement content percentage

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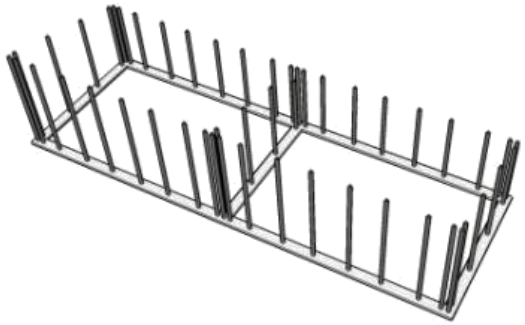
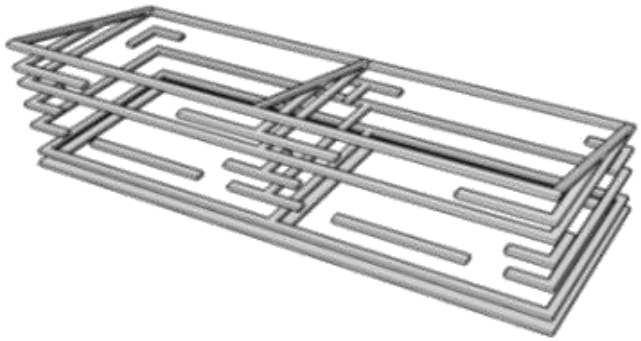
Earth Construction - CSEB

28- Days compressive strength (Kg/cm^3)			
Cement content %	Compressive Strength of CSEB at Different Casting Pressure		
	10 Mpa	15 Mpa	20 Mpa
4%	23.84	33.52	43.99
7%	58.3	67.04	73.99
10%	64.94	75.42	85.89
13%	73.32	82.96	92.17

Strengthening





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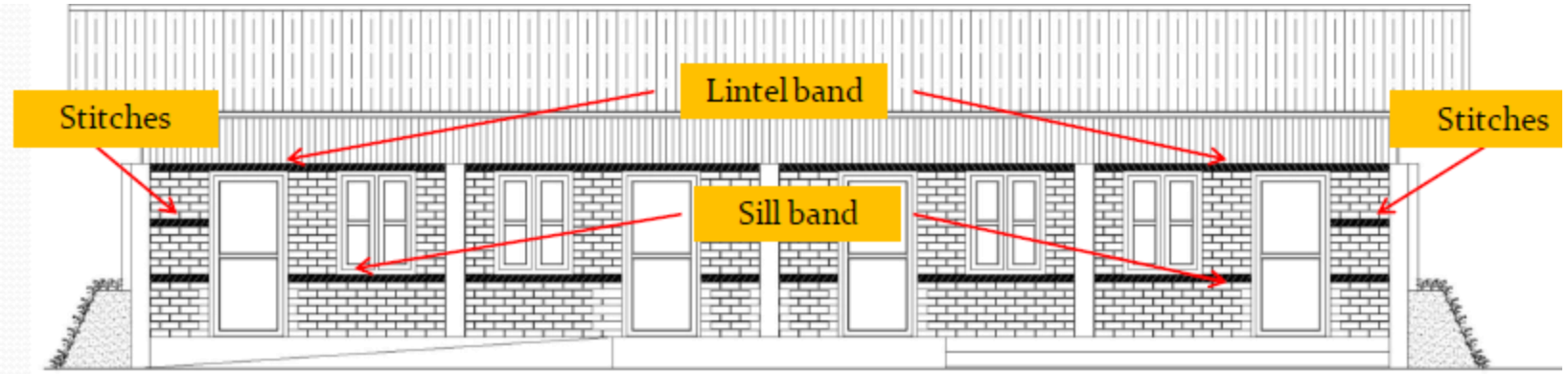
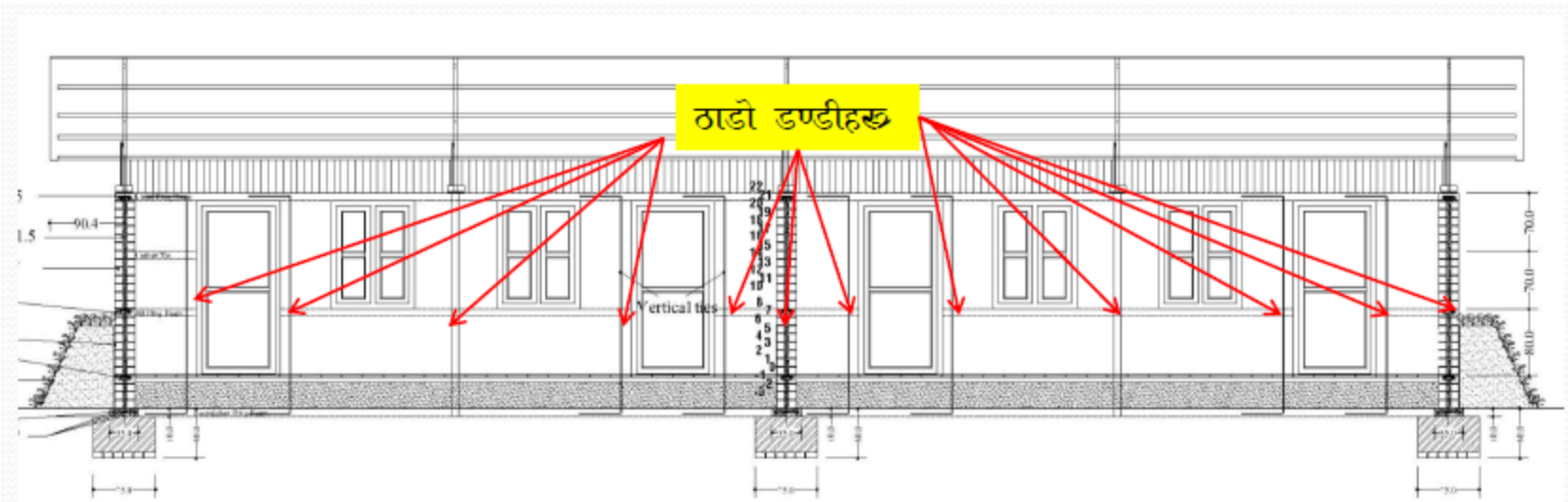

Stitches
Lintel band
Stitches
Sill band


ठाडो डण्डीहरू
Vertical ties

Some Example

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Model Building at IOE, Kathmandu

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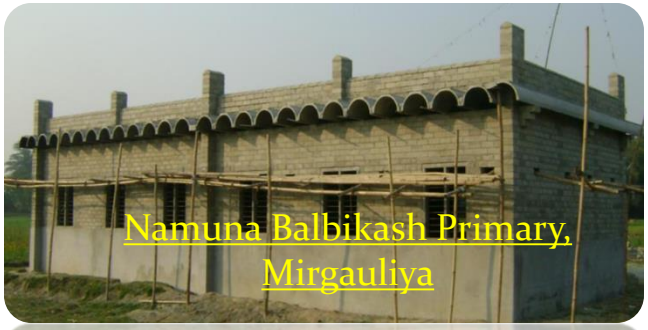
Green Schools in Morang

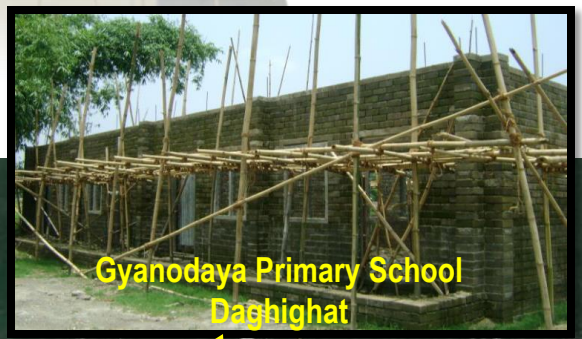
CSEB Technology

2 # FC Channel Roofing
2 # CGI Roofing with local material false ceiling


Namuna Balbikash Primary, Mirgauliya


Laxmi Lower Secondary School, Rajghat


Khanda Lower Secondary School, Dulari


Gyanodaya Primary School Daghighat

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Compressive Strength Test for Individual Block

–

Dry Block is 7.58 MPa and Wet Block is 4.99 MPa

Flexural Tensile Strength Test for Individual Block

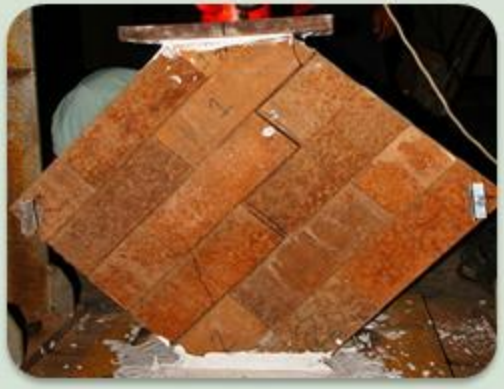
–

1.10 MPa which indicates the better quality of masonry

Direct Shear Strength Test

–

0.29 MPa



Compressive Strength Test for Block Unit – Compressive Strength is 2.71 MPa

Diagonal Compression Test – Diagonal tensile strength is 0.48 MPA

Modulus of Elasticity is 1830 MPa

Straw-bale

Stawbale Construction

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Straw-bale Pannel for urban housing

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Strawbale wall –test results

Strawbale

Embodied Energy - 25 MJ/m3
Embodied CO2 - 1 Kg/m3

http://www.youtube.com/watch?v=x8Uz-2PonEk

Shake table test done by The University of Nevada (Source: http://www.youtube.com/watch?v=MMIL9HE6Yus

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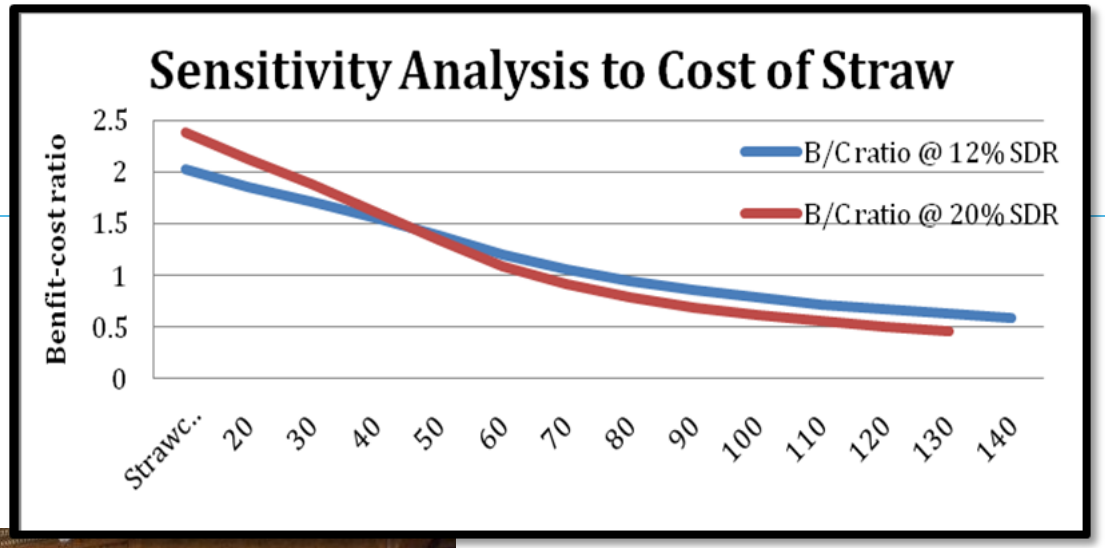
Strawbale


Sensitivity Analysis to Cost of Straw
Benfit-cost ratio
2.5
2
1.5
1
0.5
0
B/C ratio @ 12% SDR
B/C ratio @ 20% SDR
Strawc..
20
30
40
50
60
70
80
90
100
110
120
130
140

Limitation

- Moisture protect is a challenging .
- Straw-bale construction is a cost-effective option if straw is not readily available and needs to be transported over large distances.
- Straw-bale houses require thicker walls due to which the carpet area is reduced for the same floor area as compared to a conventional building.
- It is not suitable for extremely wet and humid climates. If a good roof is not provided then the straw-bale walls are subject to rotting and deterioration.
- Being a completely new building technology, it might not be easily accepted by the society

Strawbale House in Boulder, USA

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Fero Cement Channel

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FC Channel

Compared to normal RCC slabs,

- ✓ decreases total cost by about 15% to 20%,
- ✓ CO2 emission - saving around 10% to 15%
- ✓ 60% to 70% lighter


Thank you


LET US ADJUST THIS A BIT GREENER!