SDMC Training Programme

Retrofitting Techniques of Existing Buildings

Masonry Buildings

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Behavior of Buildings

Under Earthquakes

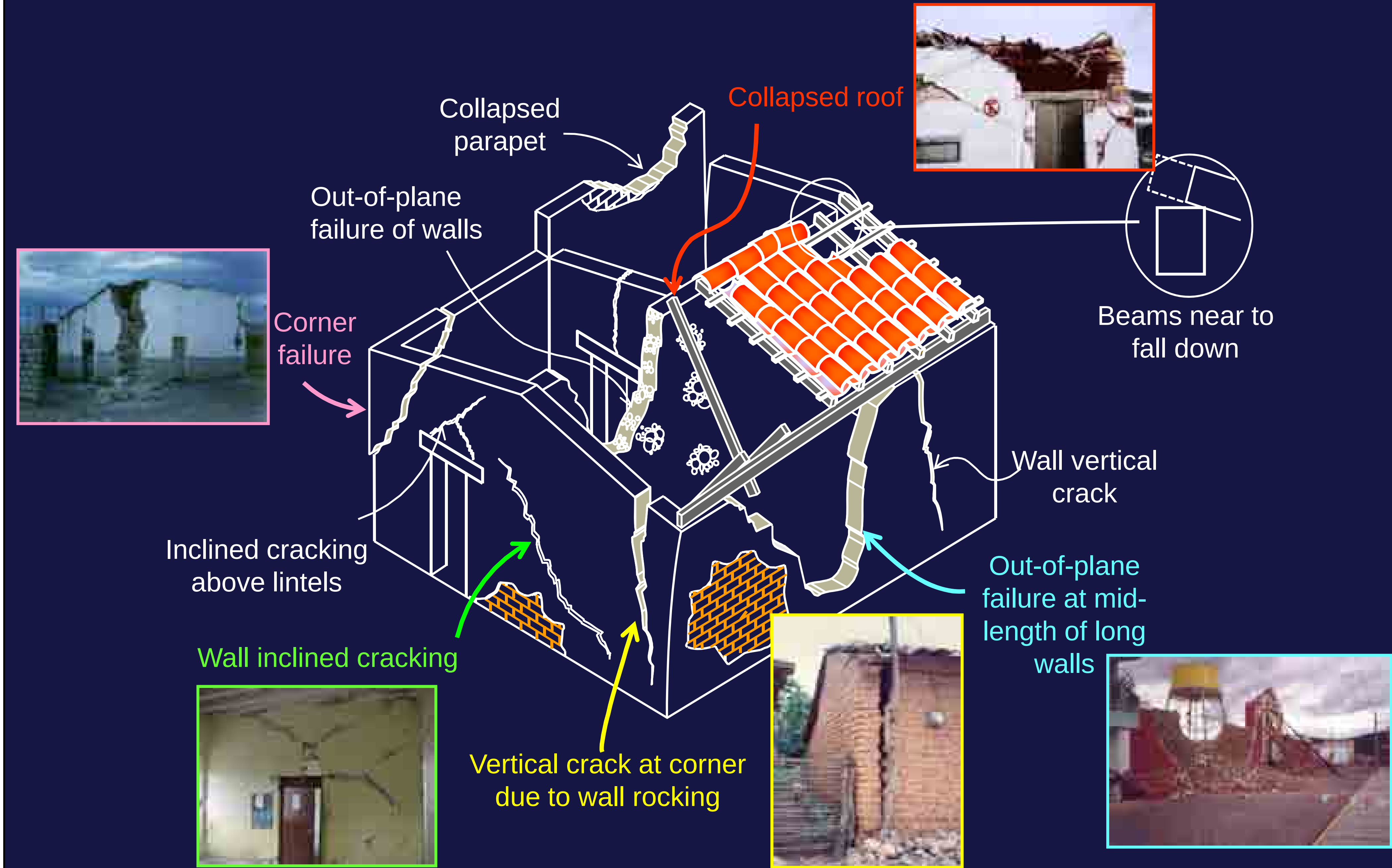
- In-plane failure
- Out-of-plane failure
- Failure mechanisms
- Lack of knowledge

Need to understand behaviour of Masonry Buildings under seismic action

Minimize the damage keeping the minimal stability conditions

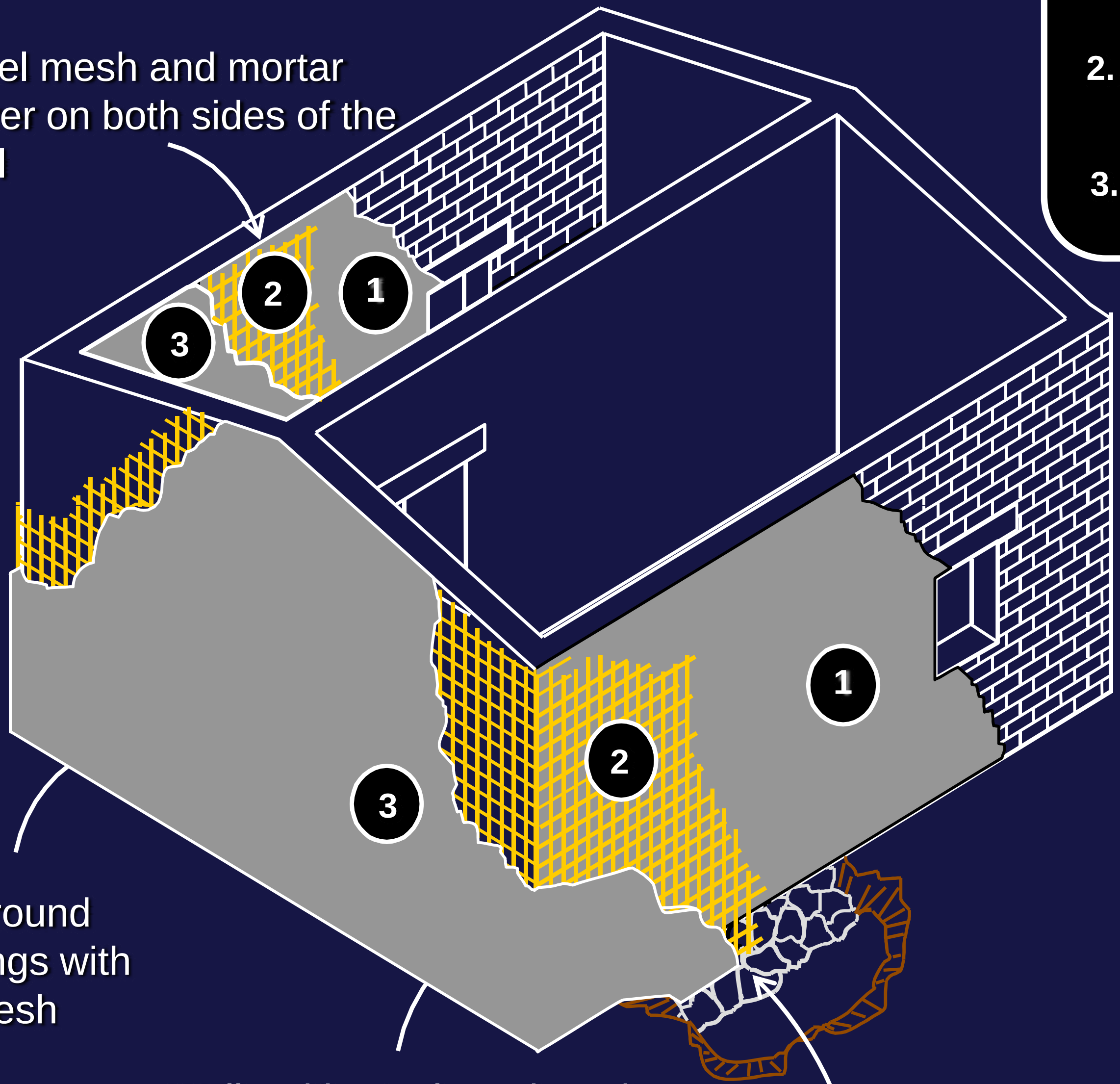
Rehabilitate / Retrofit

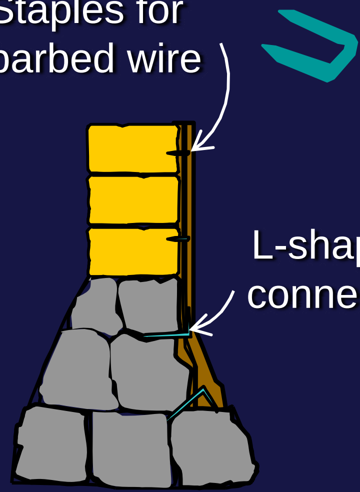
Typical damage patterns in rural housing –



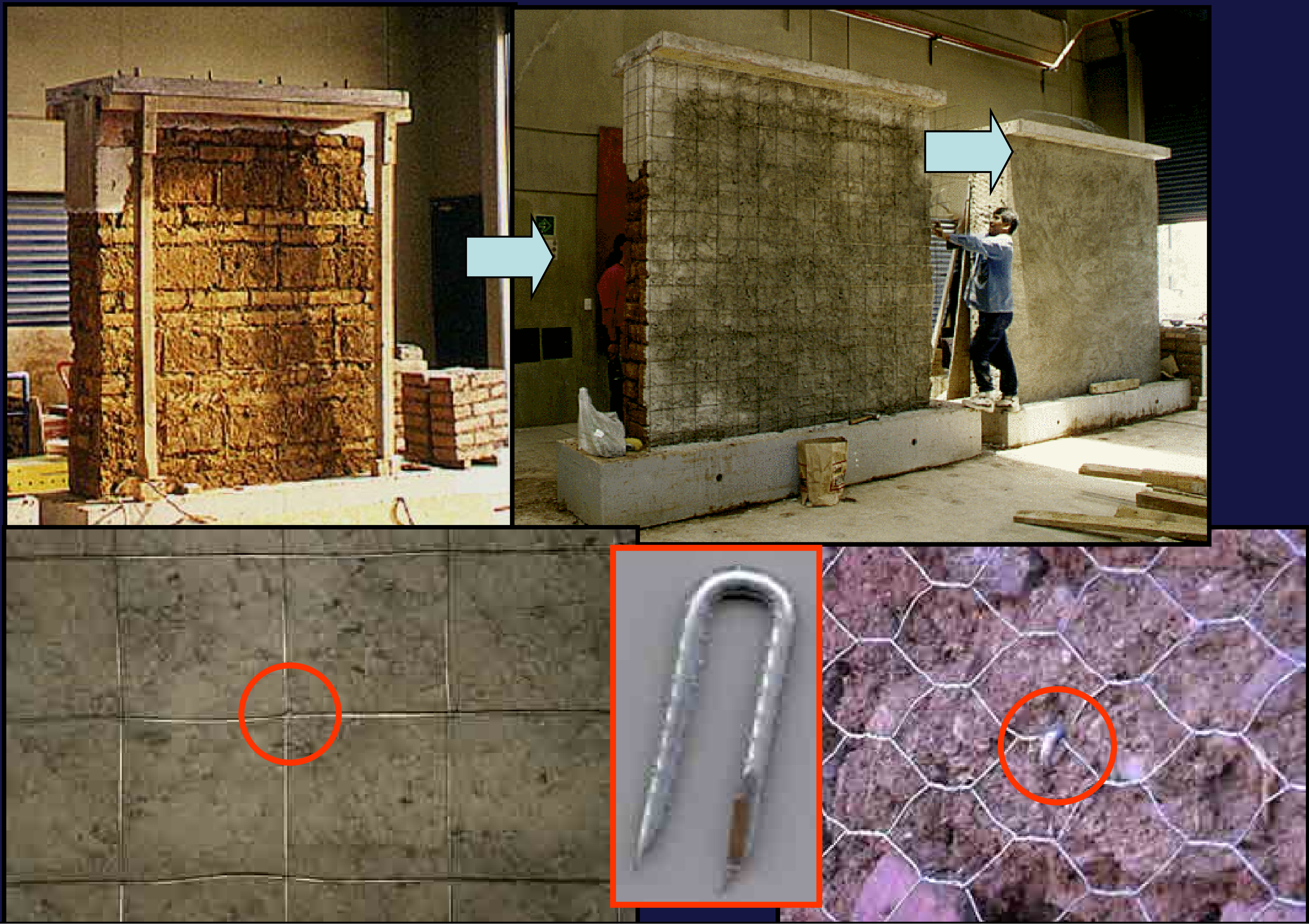
Rehabilitation Techniques – Global Level
wall jacketing

1. 10-mm cement mortar cover; cement : lime : sand 1 : ½ : 4½
2. Chicken wire or welded wire mesh, with 9 steel staples per m²
3. Final 15-mm cement mortar cover

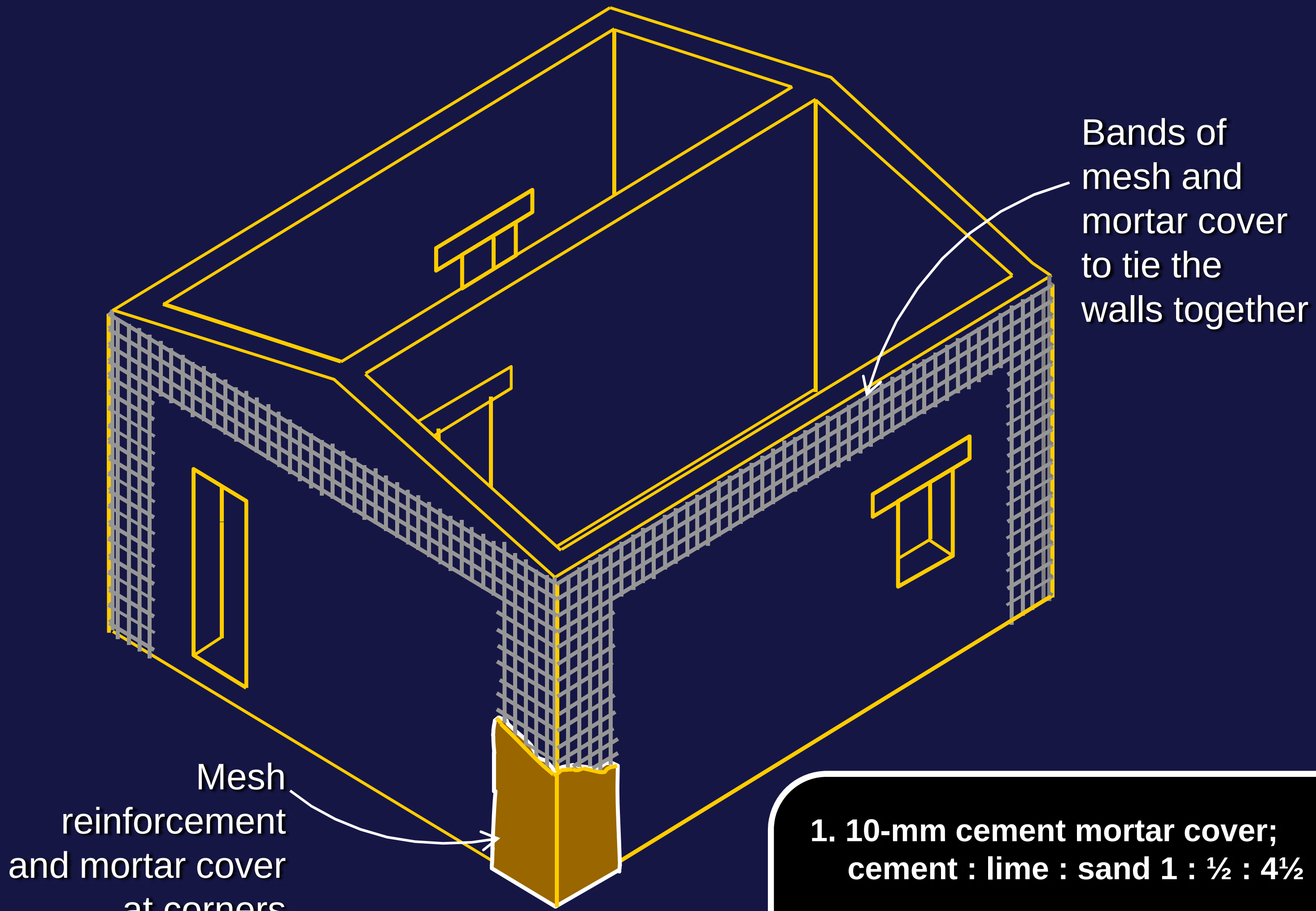


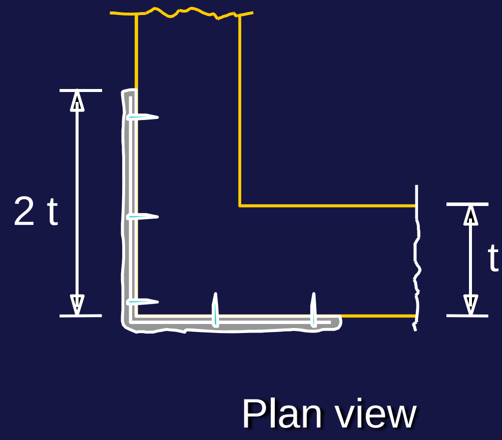


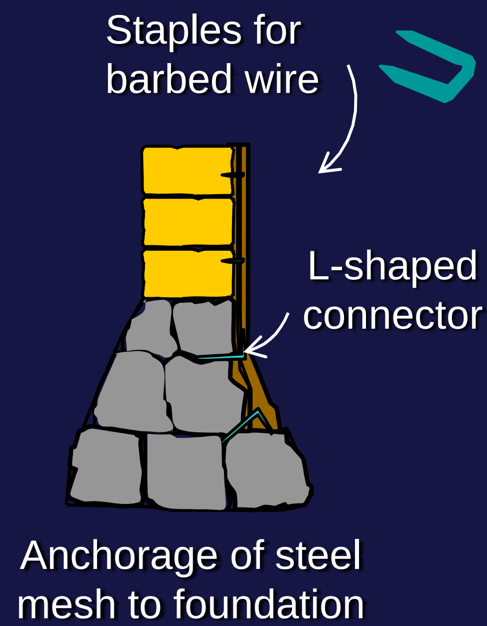
Wall Strengthening



Rehabilitation Techniques – Global Level
Example: Partial Wall Jacketing

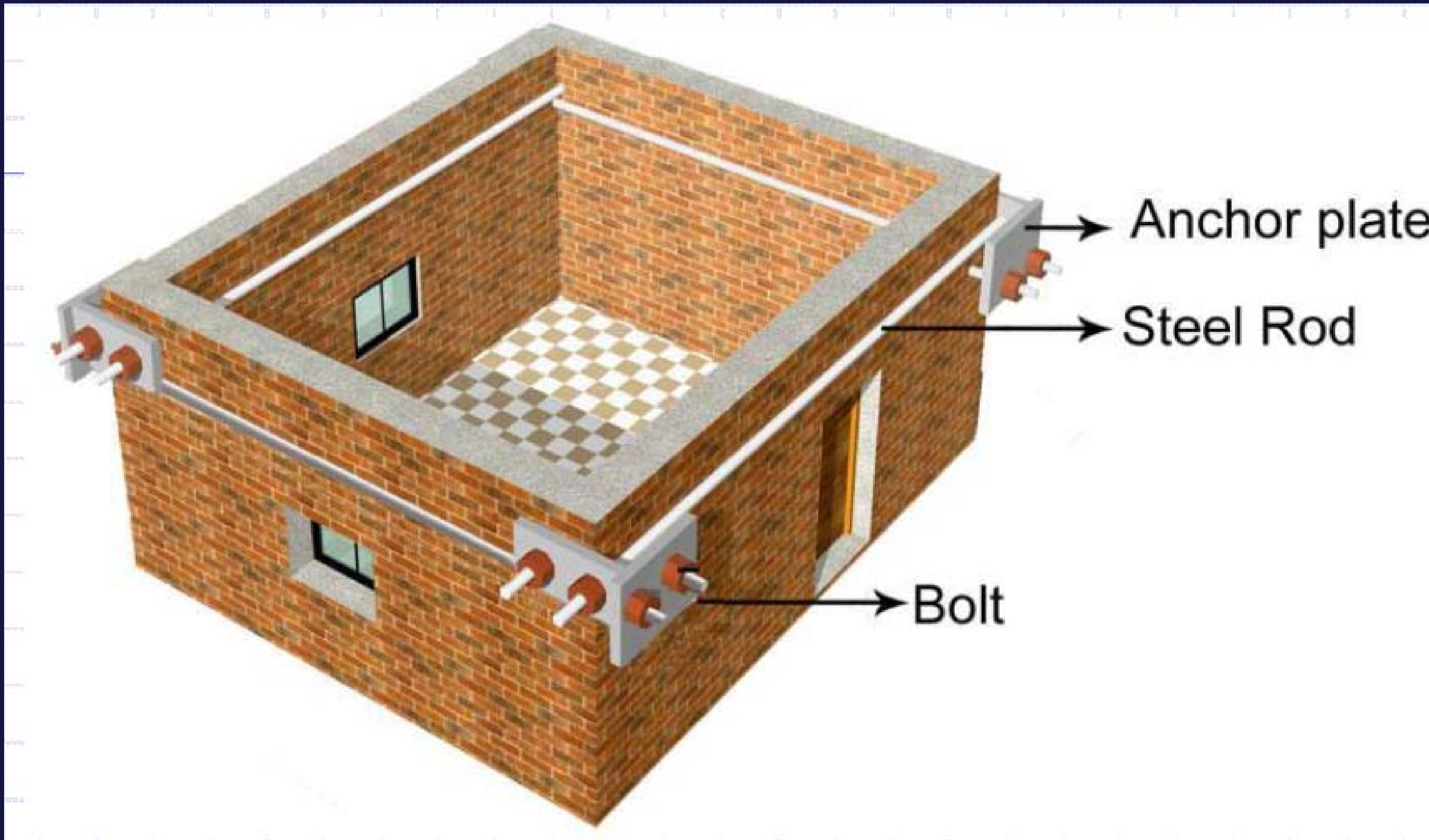






1. **10-mm cement mortar cover; cement : lime : sand 1 : ½ : 4½**
2. **Chicken wire or welded wire mesh, with 9 steel staples per m²**
3. **Final 15-mm cement mortar cover**

Rehabilitation Techniques – Global Level
Prestressing of Walls

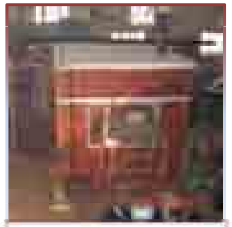


EXPERIMENTAL INVESTIGATIONS

URM : Unreinforced Masonry

URM_REP: Unreinforced (Repaired) Masonry

URM_RET: Unreinforced (Retrofitted) Masonry



RM: Reinforced Masonry

RM_RET: Reinforced (Retrofitted) Masonry

CM: Confined Masonry

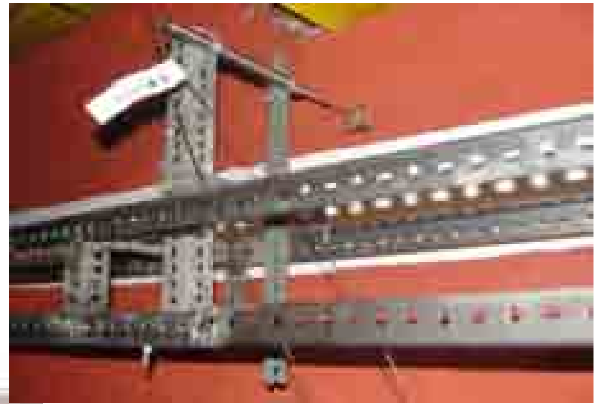
Rehabilitation Techniques – Global Level

Vertical Reinforcement at Corners and Prestressing by MS Plates

Confined Masonry : SEQUENCE OF CONSTRUCTION

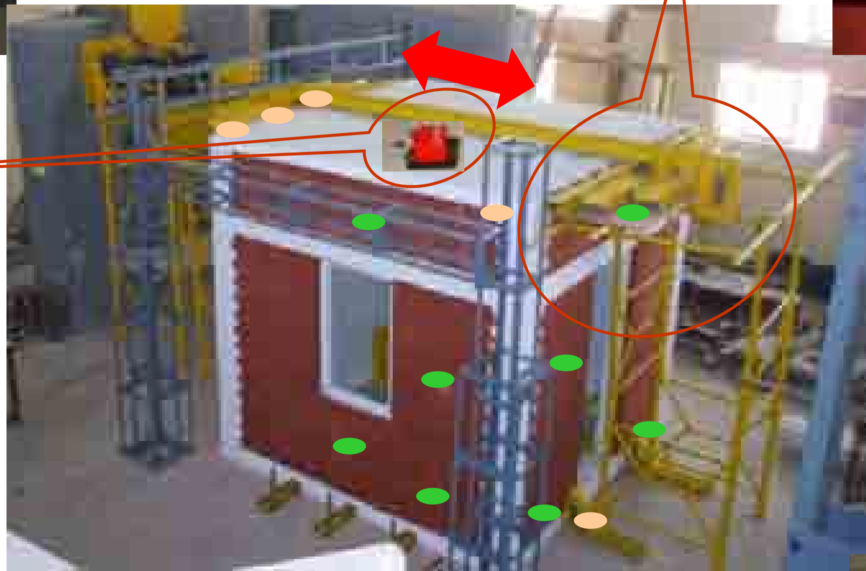
EXPERIMENTAL SET-UP

SUPPORTING FRAME
FOR LVDTs



8 POINT DISTRIBUTED LOADING

TRIAXIAL VELOCITY SENSOR



LVDTs

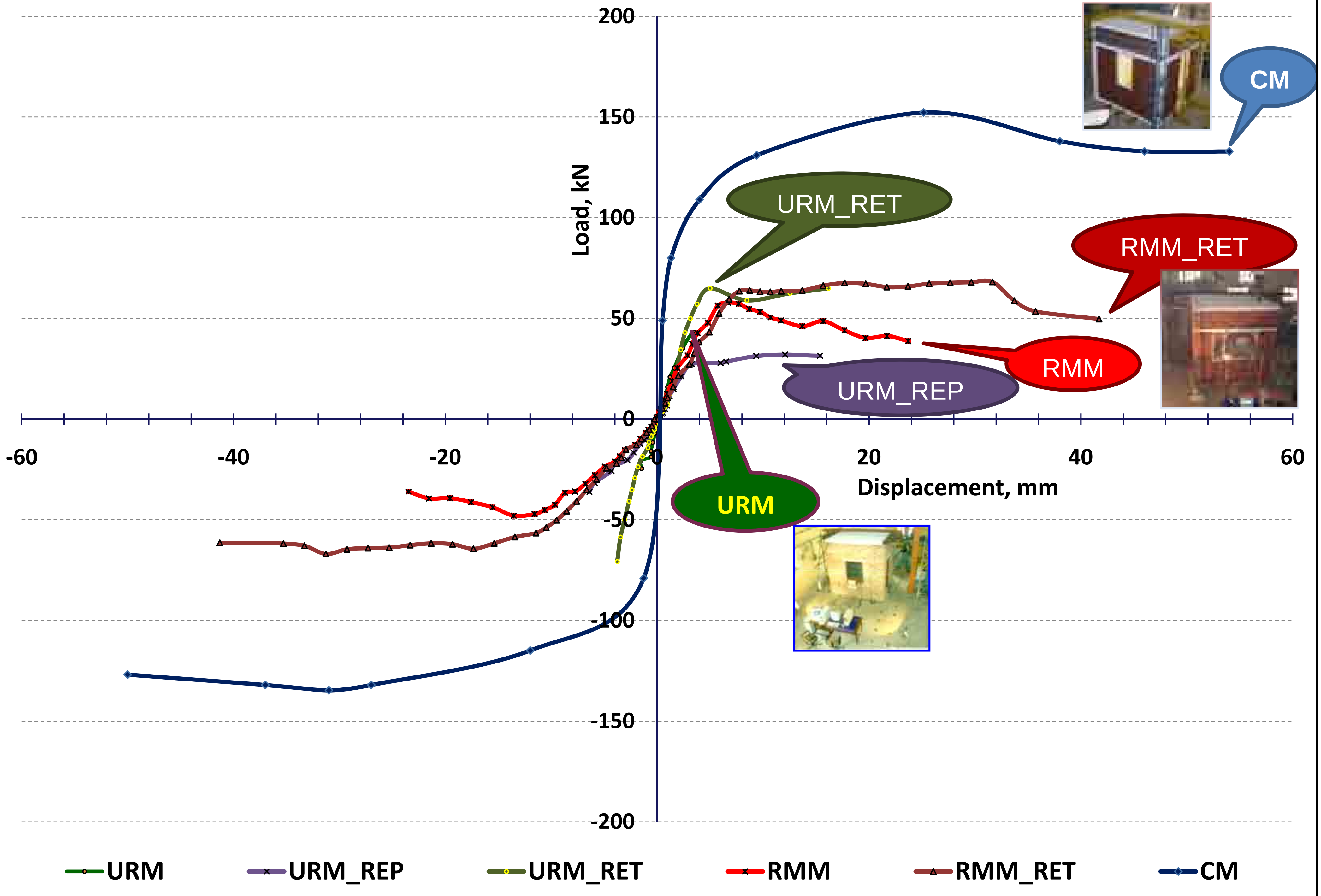
DIAL GAUGE

STRAIN GAUGE

500kN ACTUATOR

60 CHANNEL DATA ACQUISITION SYSTEM

AVERAGE LATERAL LOAD-DISPLACEMENT ENVELOPE
DIFFERENT MASONRY CONSTRUCTION SYSTEMS



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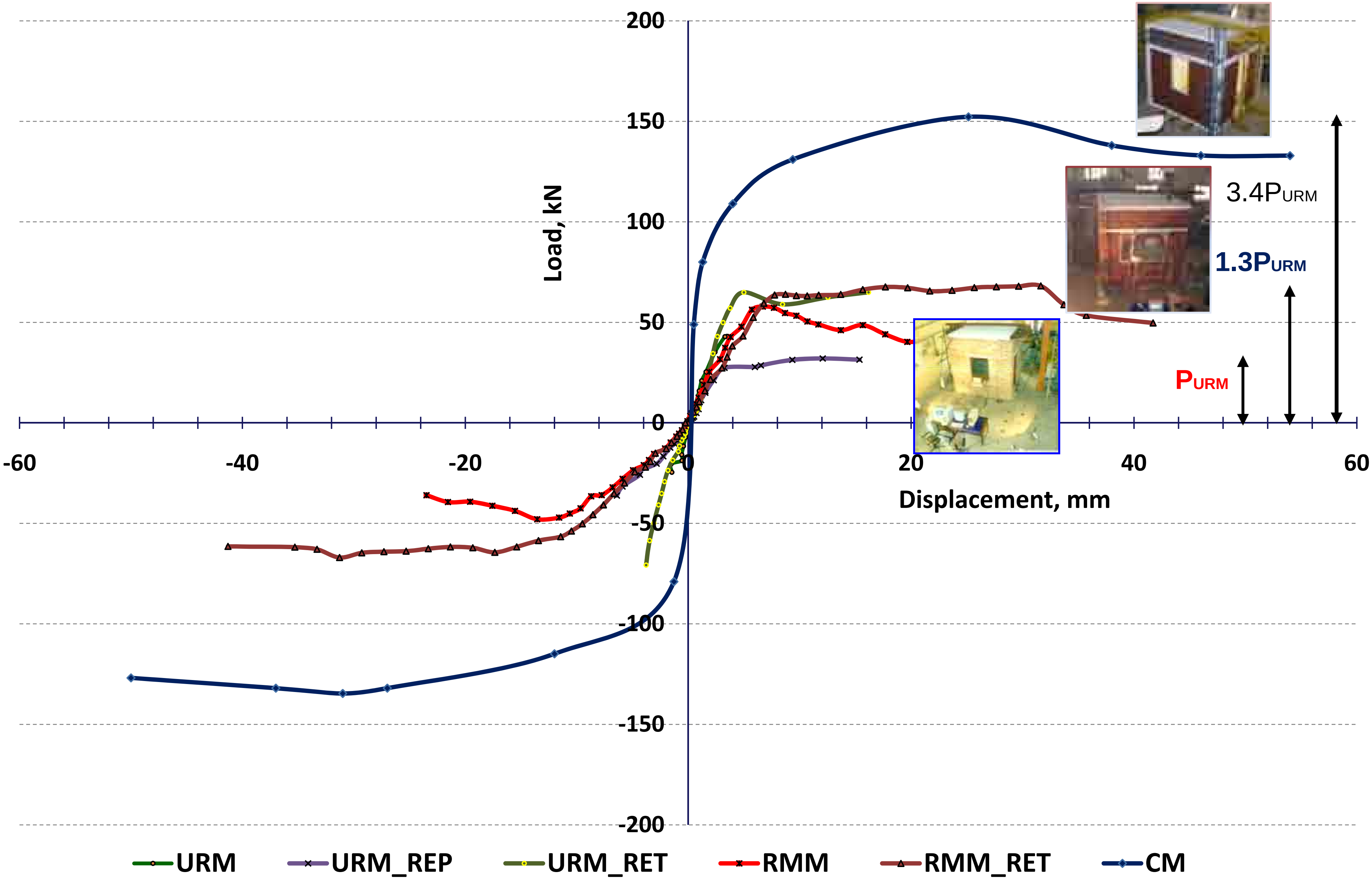
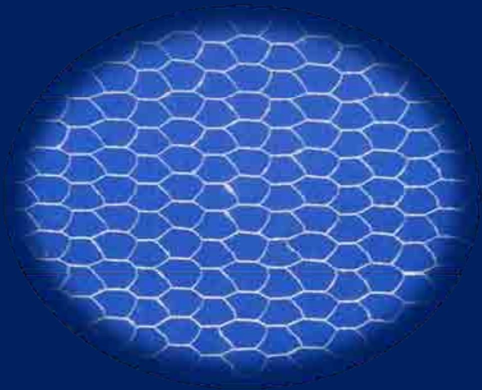


Rehabilitation Techniques –
Alternative Materials

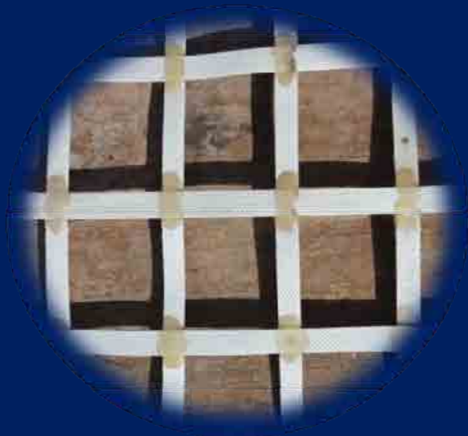
Welded wire Mesh (WWM)



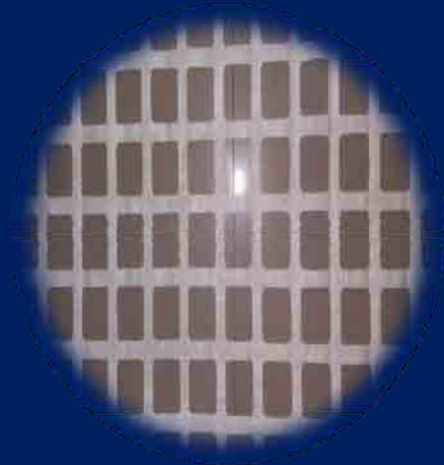
Chicken Mesh (CM)

Nylon Mesh (NM)

Industrial Geogrid Mesh (IGM)



Polypropylene Band mesh (PBM)



Plastic Cement Bag mesh (PCBM)

Evaluation of Alternative Materials

410 mm

220 mm

Masonry Prism Specimen

670 mm

670 mm

Masonry Wallet Specimen

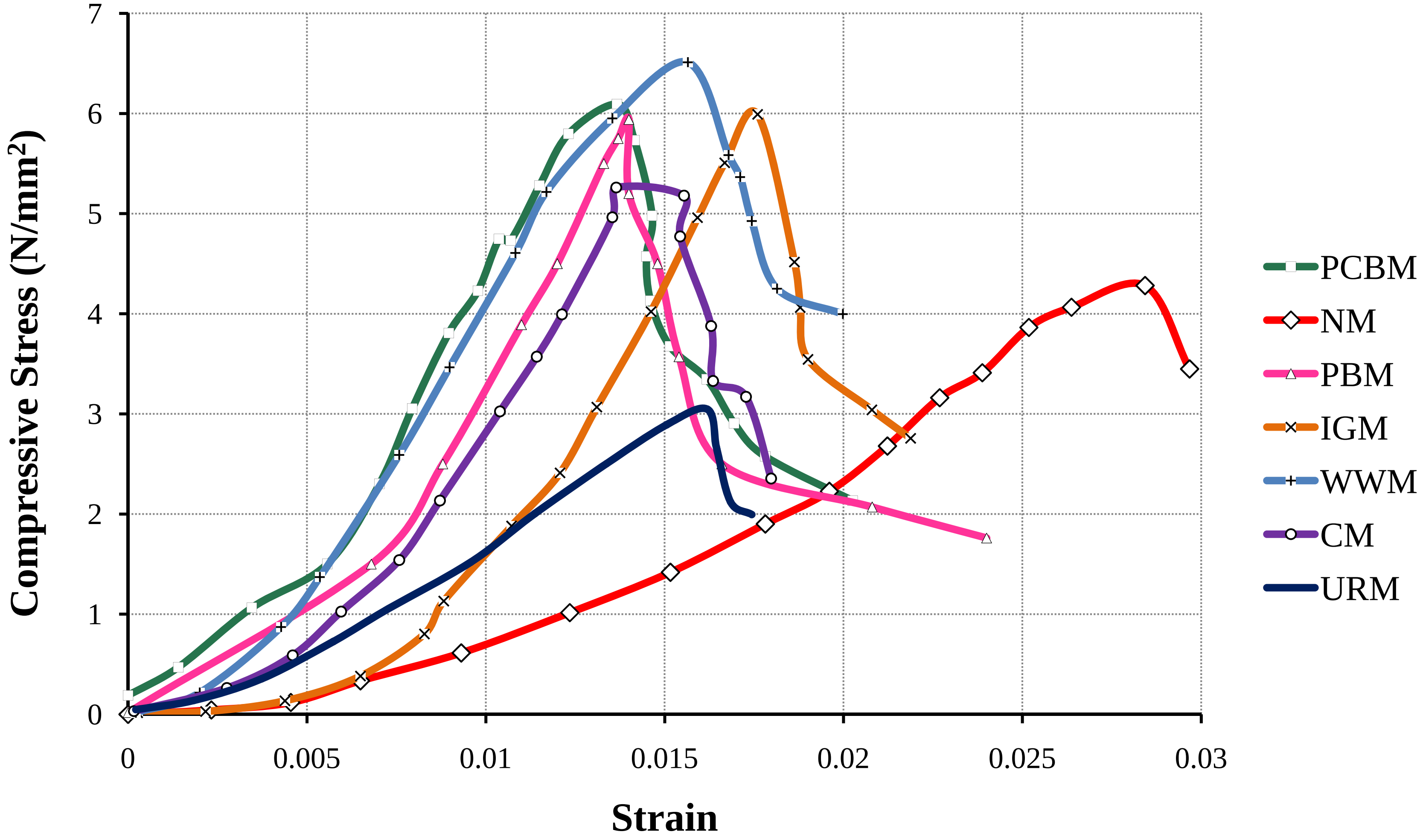
Evaluation of Alternative Materials : Compressive Strength






Evaluation of Alternative Materials: Damage Pattern

COMPRESSIVE STRESS-STRAIN CURVE FOR MASONRY PRISMS



PCBM – Plastic Cement Bag Mesh

NM – Nylon Mesh

PBM – Polypropylene Band Mesh

IGM – Industrial Geo-grid Mesh

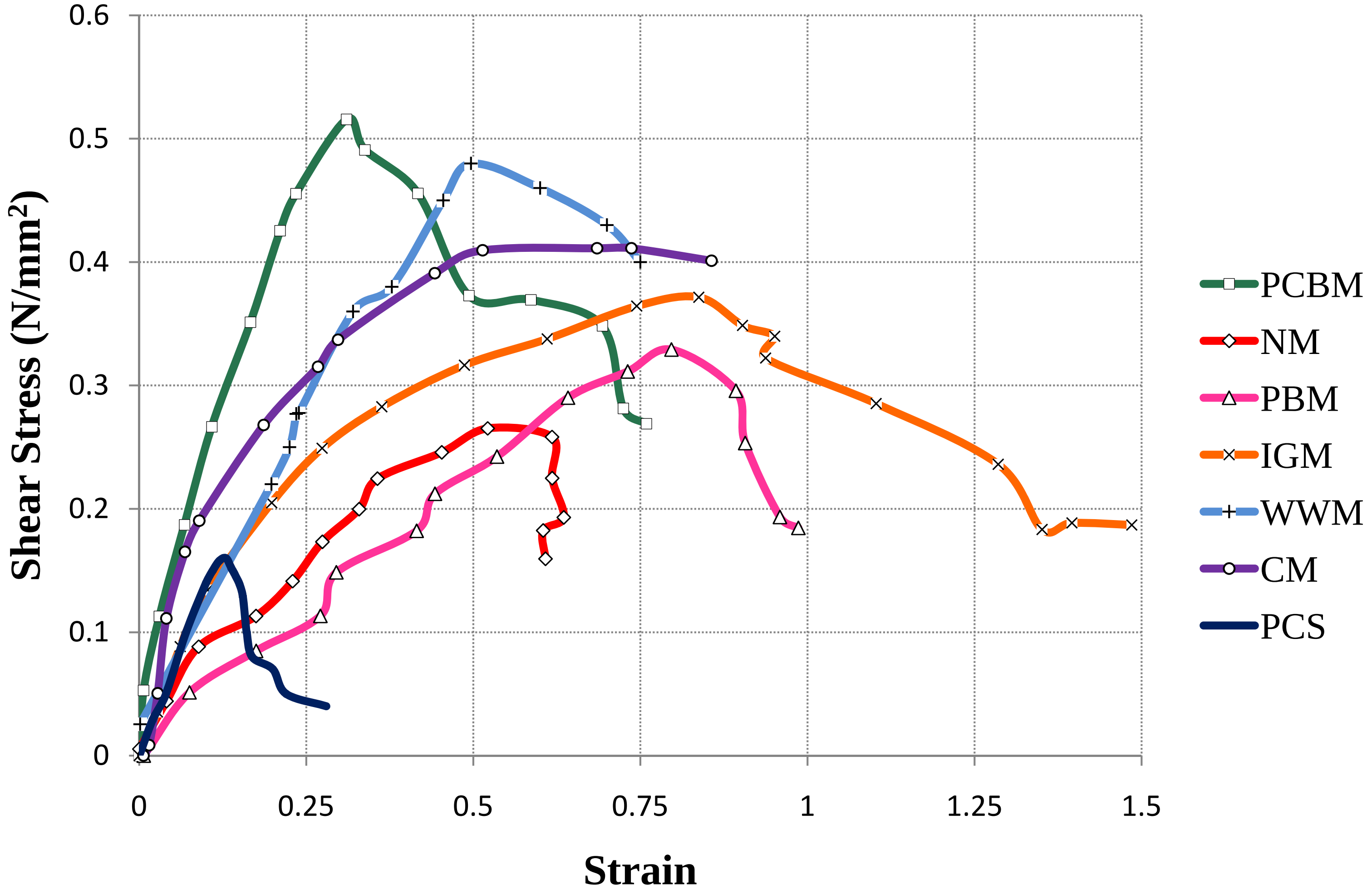
WWM – Welded Wire Mesh

CM – Chicken Mesh

URM – Unreinforced Masonry

DIAGONAL SHEAR TEST OF MASONRY PRISMS

SHEAR STRESS-STRAIN CURVE FOR MASONRY PRISMS



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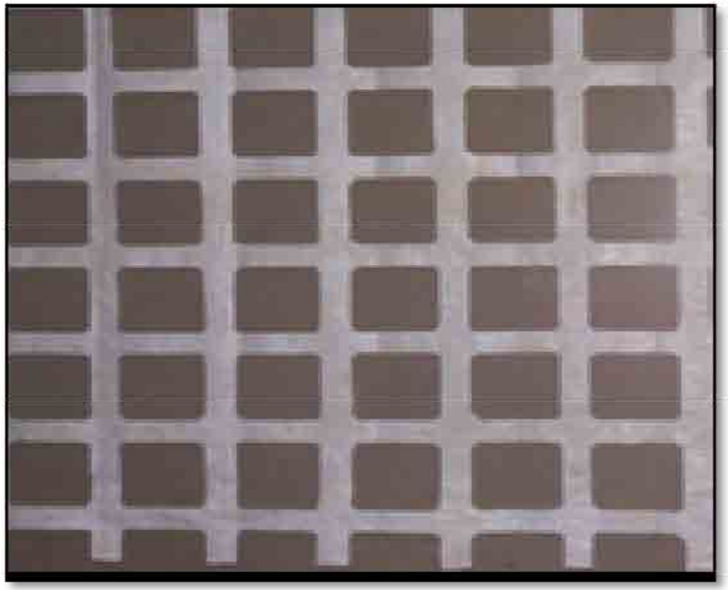
PROPERTIES OF PLASTIC CEMENT BAG MESH

- High compressive and shear strength
- Flexible
- Economical
- Reusable
- Non- corrodible
- Minimum thickness
- Adequate bonding with masonry



Preparation of plastic cement bag mesh by forming 25 mm wide strips and 50 x 50 mm holes in empty cement bags.

STRENGTHENING OF DAMAGED CM BUILDING

Cracks in CM building Model

Grouting in Cracks

Application of Plastic Cement Bag Mesh

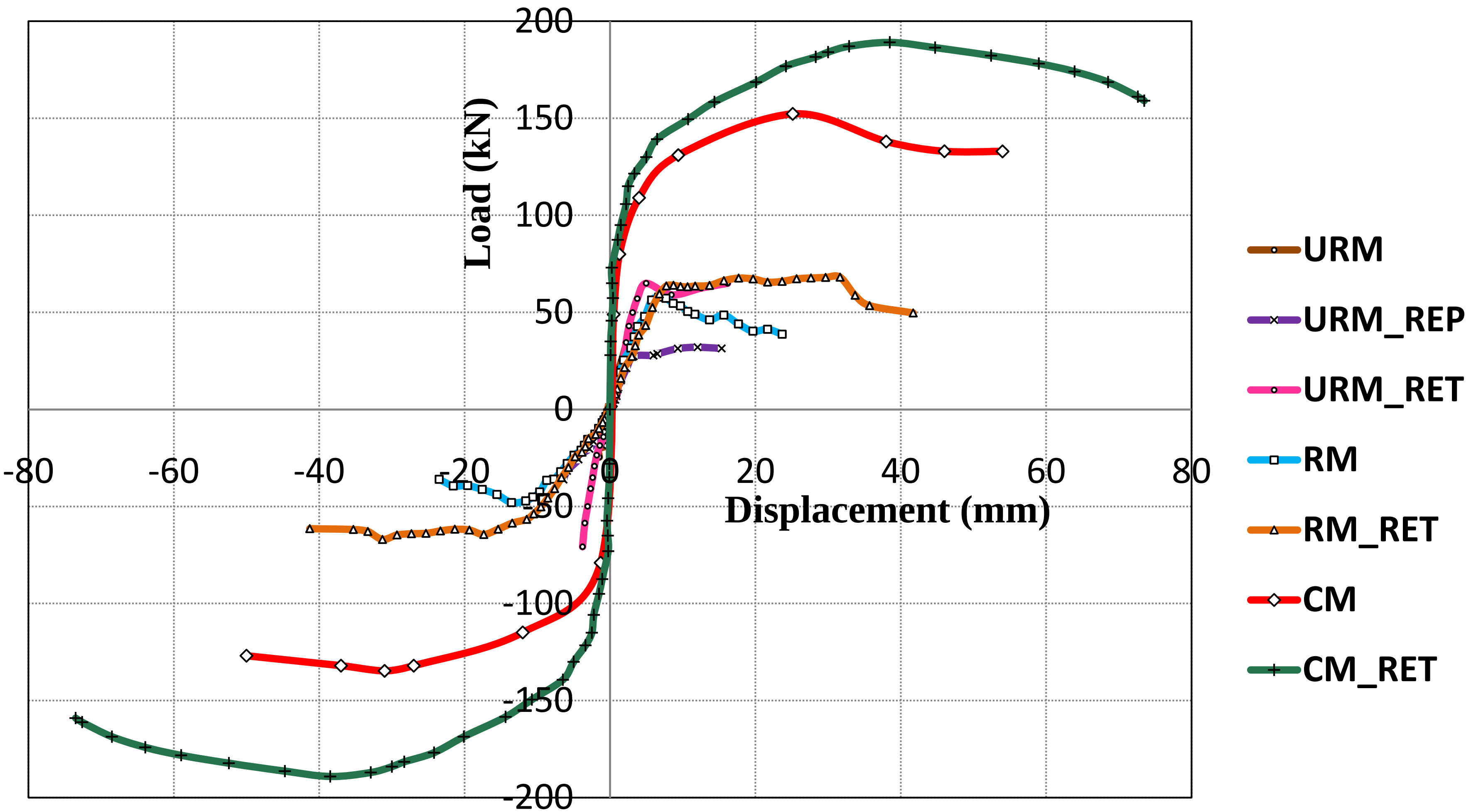
Plastering and Curing

TEST SETUP FOR RETROFITTED CONFINED MASONRY BUILDING MODEL

DAMAGED BUILDING

DAMAGED BUILDING

LATERAL LOAD-DISPLACEMENT ENVELOPE FOR TESTED MASONRY BUILDINGS



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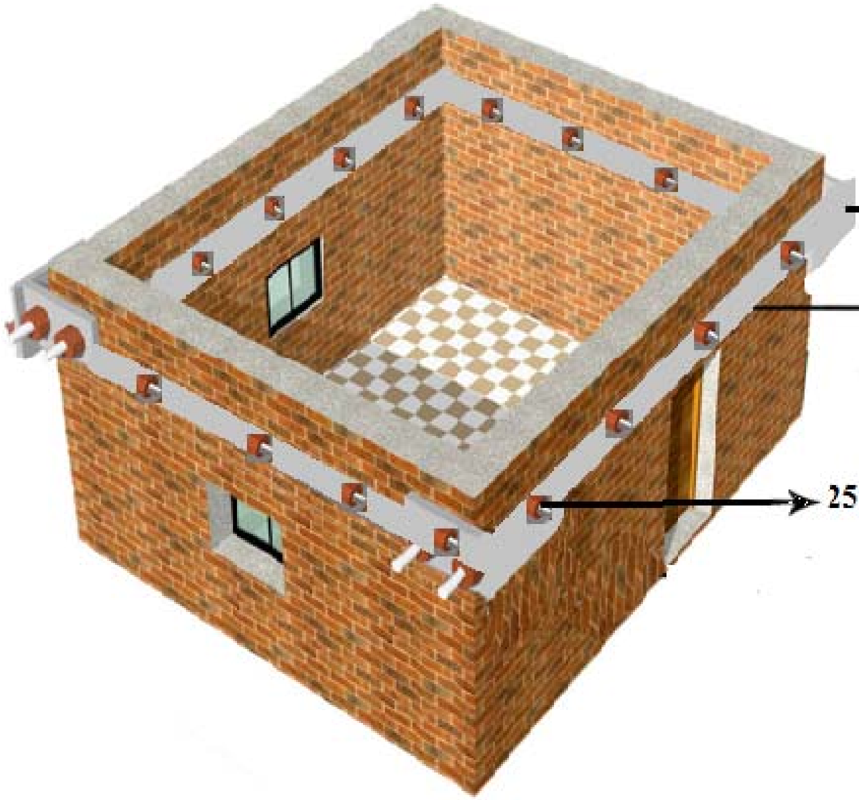
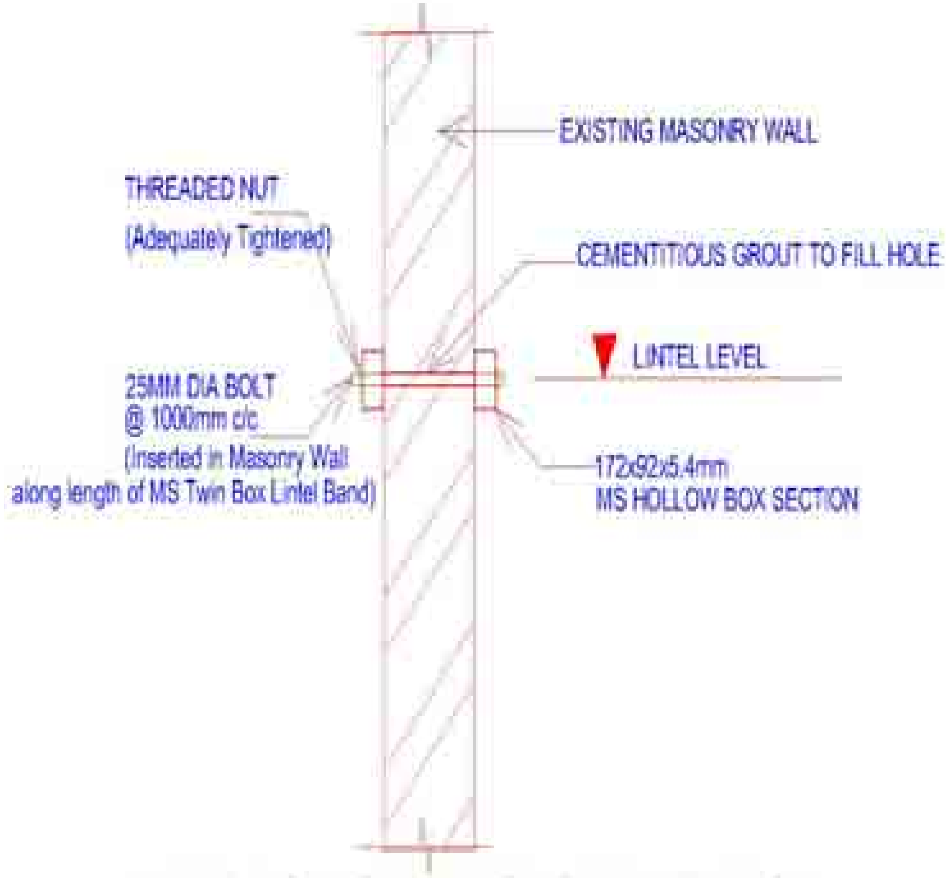
SEISMIC STRENGTHENING OF A BUILDING

- Computation of building weight
- Calculation of seismic base shear
- Design of MS twin box lintel band
- Design of shear wall
- Design of shear wall foundation

MS TWIN BOX LINTEL BAND



Typical Detail Showing Provision of MS Twin Box Lintel Band for Strengthening of Masonry Walls



Details of Bolt Connection of MS Twin Box Lintel Bands on either face of each masonry wall

Computation of Seismic Base Shear of Building

Calculate Building Weight (W) (Weight of walls + columns + beams + slabs)

↓

Consider Zone Factor, Importance Factor & Response Reduction Factor as per the building.

↓

Determine Sa/g as per IS 1893:2016

↓

Horizontal Seismic Coefficient, Ah $= \frac{Z\ I\ Sa}{2\ R\ g}$

↓

Seismic Base Shear = $A_h\ W$

Design of MS twin lintel box

Calculate Force on Lintel

$P = a\ A_h\ \gamma\ t_w$

(a = design fator, t is wall thickness, ϒ is density of wall, t_w is wall thickness

↓

Weight (w) = P x height at which load is calculated

↓

Calculate Moment

$M = \frac{wl^2}{2}$ **(l is wall length)**

↓

Compressive Force (C) = Tensile Force (T) $C = M \times LA$

(LA = Lever Arm = Wall Thickness)

↓

Required Sectional Area of Steel Member = $\frac{C}{0.6\ f_y}$

Assume Bolt Dia. & Spacing between Bolts and sectional properties of steel section

↓

Calculate Load carried by Lintel

$W_l = \gamma \, t_w \, h_t$

↓

Shear Force

$$V = \frac{w \text{ x } Max \text{ } unsupported \text{ } length}{2}$$

↓

$$Q = \frac{A_s \, LA}{2}$$

A_s is area of *selected* steel member

↓

Stress between member and wall

$$\tau = \frac{V \, Q}{I \, d}$$

(I = MOI of whole section, d = depth of selected steel member)

Force carried by bolts

$$F = \tau \text{ x } d \text{ x } 1000$$

Total area of bolts required

$$A_b = \frac{F}{\tau_s}$$

τ_s = Shear stress of bolts (shall be assumed to be 60% of their tensile strength)

Area of 1 bolt

a_b = л x r^2

r = Radius of bolt

Number of bolts required / meter of length

$$n = \frac{A_b}{a_b}$$

Spacing between bolts

$$s = \frac{1000}{n}$$

Shear Wall

Assume Material Properties of Shear Wall, Bar diameter and reinforcement percentage.

↓

Calculate Maximum Factored Shear Force (Vu)

↓

Find Nominal Shear Stress

$$\tau_v = \frac{V_u}{L\,t}$$

L is wall length, t is wall thickness

↓

Calculate Design Shear Strength (τ_c) as per IS 456:2000

Shear force to be resisted by horizontal reinforcement

$V_{us} = (\tau_v - \tau_c)\, t\, L$

Ratio of Area of Horizontal reinforcement (A_h) and Spacing (S_v)

$$\frac{A_h}{S_v} = \frac{f_{ck}}{0.87\, f_y\, L}$$

Minimum horizontal ratio required

$$\frac{A_h}{S_v} = 0.0025\ x\ t$$

Provide reinforcement in 2 layers if $\tau_v > 0.25(f_{ck})^{0.5}$ or $t \geq 200$ mm

Spacing between horizontal reinforcement

$$S_v = \frac{\pi \, x \, r^2 \, x \, rf}{A_h / S_v}$$

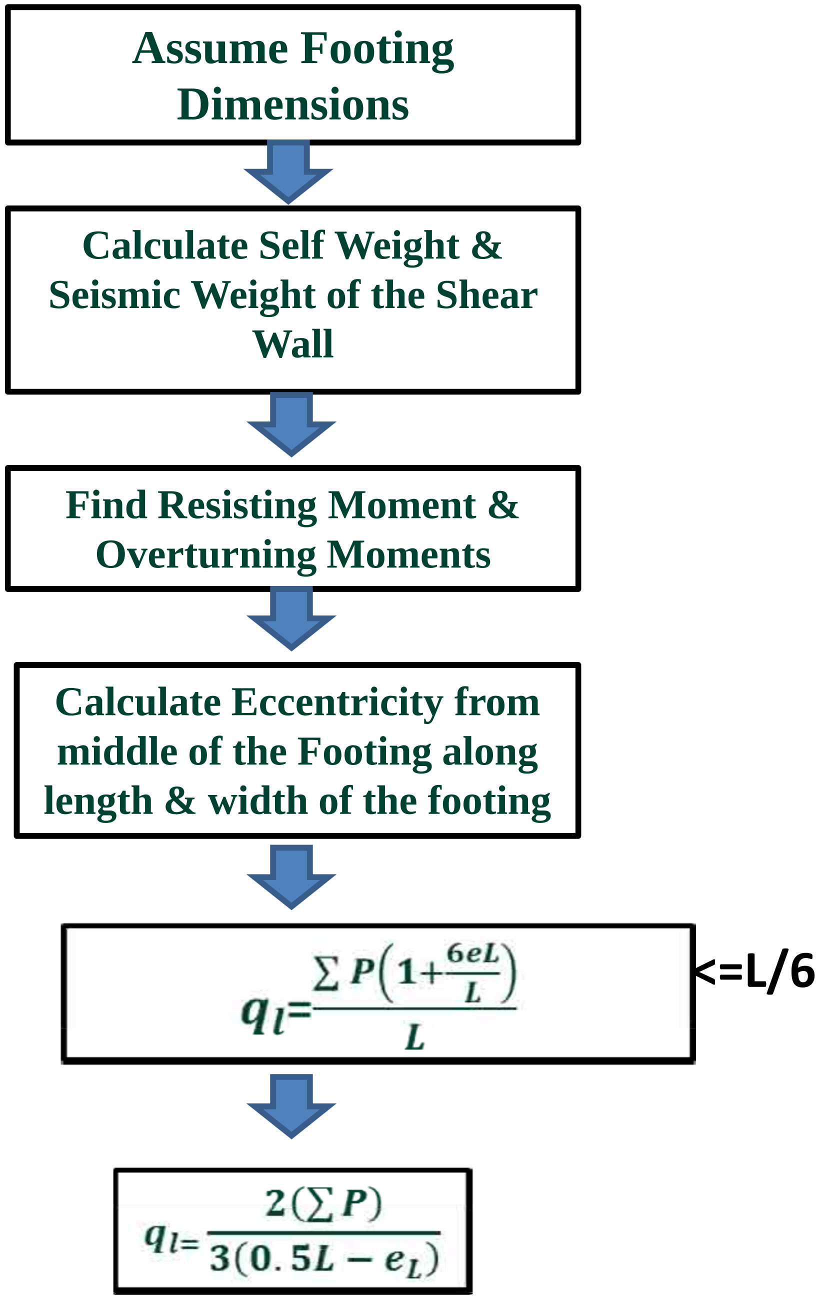
where

r = Radius of reinforcement bar

r_f = Number of reinforcement layers

Area required for vertical reinforcement,

$$Av = r_r \times t \times L$$


Assume Footing Dimensions
Calculate Self Weight & Seismic Weight of the Shear Wall
Find Resisting Moment & Overturning Moments
Calculate Eccentricity from middle of the Footing along length & width of the footing
$q_l = \frac{\sum P\left(1+\frac{6eL}{L}\right)}{L}$
<=L/6
$q_l = \frac{2(\sum P)}{3(0.5L - e_L)}$

$$Q_{max} = ql\frac{1 + \frac{6e_B}{B}}{B}$$

(If e_B<=L/6)

$$q_l = \frac{\sum P\left(1+\frac{6\,e_l}{L}\right)}{L}$$

$$Q_{max}=ql\frac{2}{0.5B-e_B}$$

(If e_B>L/6)

$$q_l = \frac{2(\sum P)}{3(0.5L - e_L)}$$

Find Factor of Safety (Resisting Moment/ Overturning Moment)

If Factor of Safety >= 1.5 & Maximum Bearing Capacity >= (4/3 X Bearing Capacity of Soil)

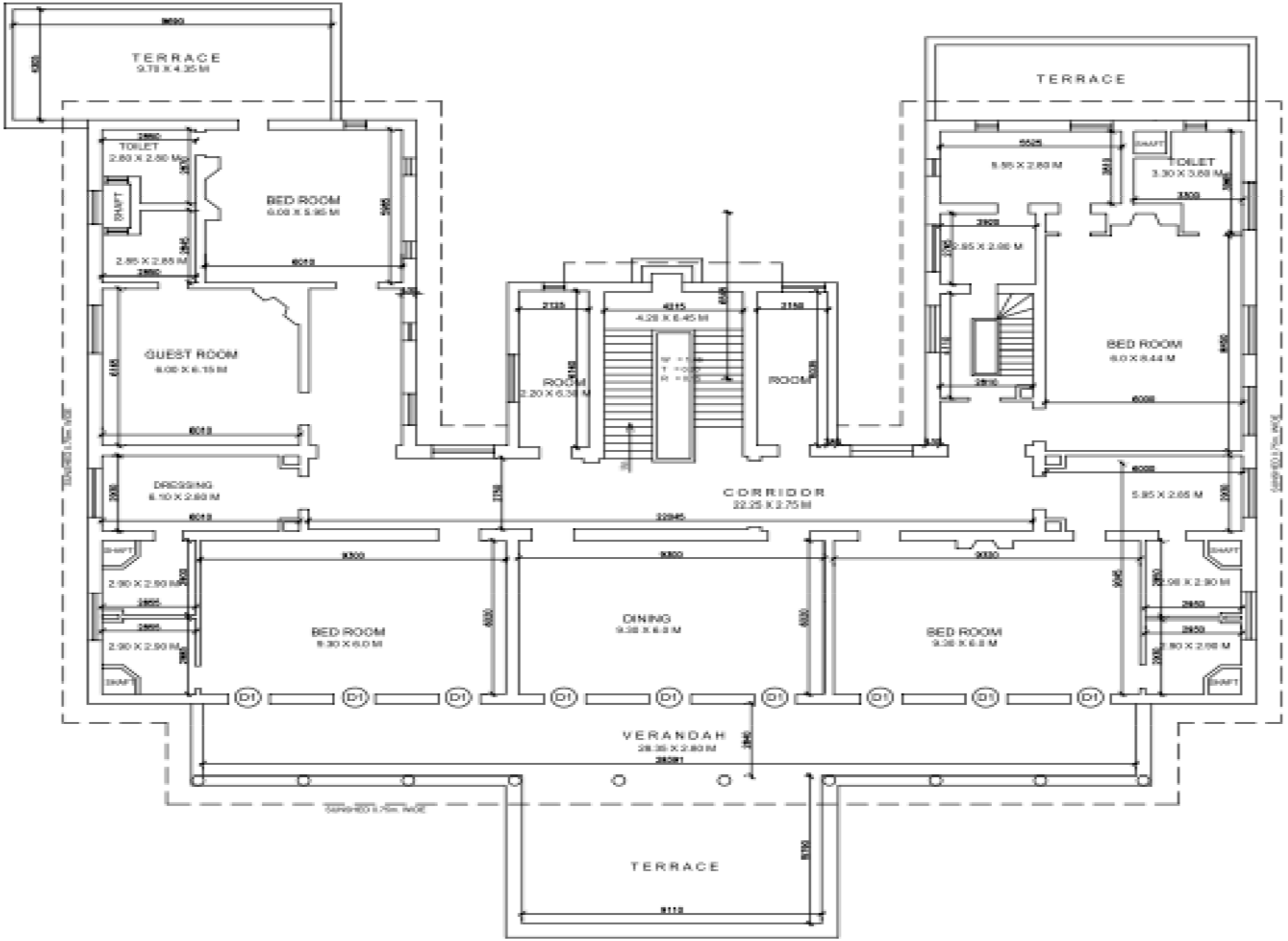
$$Q_{max}=\frac{q_l\,(1+\frac{6\,e_B}{B})}{B}$$

Assumed Footing Dimensions are OK

$$Q_{max}=ql\frac{2}{0.5B-e_B}$$

DESIGN EXAMPLE

Design calculations has been provided for the following building plan:



To Conclude

- Tremendous progress towards seismic safety
  - Vis-à-vis other developing countries
- Yet, a long way to go further
  - Rehabilitation & Retrofit
- Major earthquakes provide “window of opportunity” if plans are ready

Thank You !!