SEISMIC RETROFITTING GUIDELINES OF BUILDINGS IN NEPAL

2013

TRAINING CURRICULUM (Construction)

PART II

PRESENTATION MATERIALS & EXERCISE FOR TRAINEE

UNDP

CORD

MRB & Associates

April 2013

SEISMIC RETROFITTING GUIDELINES of Buildings in Nepal

TRAINING CURRICULUM (Construction) PART II

Presentation Materials & Exercise for Trainee

Empowered lives.
Resilient nations.

FOREWORDS

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ACKNOWLEDGEMENT

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TRAINING FOR MASONS

SEISMIC RETROFITTING OF BUILDINGS IN NEPAL

Introduction

This training curriculum has been developed for providing an extensive theoretical and practical knowledge to the masons about the seismic retrofitting techniques and procedures for different types of buildings in Nepal. In order to improve the overall safety of the building, good retrofitting design alone is not adequate. It is very important that those designs are appropriately implemented at the construction site. Therefore, masons are the key actors who translate designs into reality, especially in Nepal mason are the "best technical hand" on construction/retrofitting works. Unless the practicing masons are equipped with required skills and knowledge in proper retrofitting techniques and tools disaster risk reduction through seismic retrofitting of existing building will not be successful.

The training material is prepared with technical assistance of Centre of Resilient Development (CoRD) with intensive consultation of Ministry of Urban Development (MOUD) and Department of Urban Development and Building Construction (DUDBC) with the support of Comprehensive Disaster Risk Management Programme (CDRMP), UNDP.

This concept note consists of goals and objectives, course contents schedule and requirements for the mason training purpose.

Objective of the Training Program

The main objective of training program is to provide the practicing masons with basic knowledge of retrofitting technique, tools and quality control of material and works and equip them with required skills on retrofitting of existing vulnerable building.

This training is expected to:

- Make the masons aware of the importance of appropriate working procedure at site.
- Make them aware about the quality control and tests that can change the performance of the built structure.
- Enhance their skills and knowledge of masons in retrofitting technique and tools and quality works.
- Motivate the masons in retrofitting works.
- Familiarize them with the Guideline on Seismic Retrofitting of Building in Nepal and relevant safe construction practices to ensure earthquake safe construction

Course content: The course content is as follows

TRAINING FOR CONSTRUCTION

SEISMIC RETROFITTING OF BUILDINGS IN NEPAL

(Schedule)

Date: **Venue:**

<table>
<tr><th>Time</th><th>Day 1</th><th>Day 2</th><th>Day 3</th><th>Day 4</th><th>Day 5</th></tr>
<tr><td>9:30 – 10:00</td><td>Registration</td><td></td><td></td><td></td><td></td></tr>
<tr><td>10:00 – 10:30</td><td>Inauguration and Speech</td><td>Review of previous day</td><td>Review of previous day</td><td>Review of previous day</td><td>Site Demonstration: Demolition and Retrofitting Techniques at Site</td></tr>
<tr><td>10:30- 10:45</td><td>Brief introduction of participants</td><td>Tea</td><td>Tea</td><td>Tea</td><td>Tea</td></tr>
<tr><td>10:45-11:15</td><td>Tea</td><td rowspan="2">Retrofitting techniques -RCC Structures</td><td rowspan="2">Quality Control</td><td rowspan="3">Site Demonstration: Quality Control</td><td rowspan="3">Site Demonstration: Demolition and Retrofitting Techniques at Site</td></tr>
<tr><td>11:15–12:30</td><td>Introduction, Overview Concept of Retrofitting</td></tr>
<tr><td>12:30- 1:00</td><td>Discussion</td><td>Discussion</td><td>Discussion</td></tr>
<tr><td>1:00 – 2:00</td><td>Lunch</td><td>Lunch</td><td>Lunch</td><td>Lunch</td><td>Lunch</td></tr>
<tr><td>2:00 - 3:30</td><td>Retrofitting techniques - MASONRY, ADOBE</td><td>Introduction to Non-Destructive Test</td><td>Demolition and Retrofitting Techniques at Site</td><td rowspan="3">Site Demonstration: Quality Control</td><td rowspan="2">Site Demonstration: Demolition and Retrofitting Techniques at Site</td></tr>
<tr><td>3:30-4:00</td><td>Discussion</td><td rowspan="2">Site Demonstration: Non-Destructive Test</td><td>Discussion</td></tr>
<tr><td>4:00 – 5:00</td><td>Q/A session</td><td>Demolition and Retrofitting Techniques at Site</td><td>Evaluation / examination</td></tr>
</table>

Training Duration:

The duration for the proposed trainings is of five days. It includes seven hours per day in which there are 45 minutes session, two fifteen minutes tea break and one hour lunch break each day.

Participants:

- 20-25 numbers of masons who already got the mason training (as possible) are proposed in one classroom.
- They should have at least one year working experience as masons, bar-benders and should be literate.

Resource persons:
The resource person should have minimum diploma in civil or architectural engineering with completion of 5 days Training of trainers course (TOT) in Seismic Retrofitting of Building and adequate experience as trainers in safe construction, capable of delivering training to masons.

Training Venue:
Any available space within the easy locality which fulfills the requirements of a training venue can be chosen. It should however have comfortable sitting arrangements with proper light and ventilation and the size of the hall should be suitable for project presentation with 20-25 numbers of participants. Drinking water, lunch, refreshments and wash rooms facility shall be available for the participants during the training session. The venue also consists of open space of at least 40'X30' for practical experiments/exercise and full scale construction of model during training. Alternatively, visit and onsite training in nearby ongoing retrofitting works as possible.

Training conduction:
The training shall be conducted according to the schedule provided.
For practical exercise and workshops, the participants will divided into smaller groups for with at least three resource persons. Enough time has been allocated for group work/discussion and hands on exercises. Class room teaching is proposed for clarification and demonstration of different issues related to earthquake safety.
If possible, the equipments used during dismantling and retrofitting shall be shown to the participants with short description.

Logistics: Logistics required for training purpose are as follows:

Stationaries

Flip chart	20 nos
Thumb pins	1 pack
Boards	1 nos
Projector	1nos
Laptops	1nos
Temporary Markers	5 red,5 blue,5 green,5 black
Notebook	25 nos
Pen/pencils	25 nos
Erasers	25 nos
Scale	25 nos
Stitch	1 nos
Punching	1 nos
Marking tape	2 roll
Double tape	2 roll
Curtain for projector	1 nos

Volt guard	1 nos
Multi plug	2 nos
Scissor	1 nos
Paper cutter	1 nos
Certificate writing pen	1 nos
First aid Kit	1 set

Construction Materials for practical exercise required for Mason Training (Trainer will suggest before training, if retrofitting works are not nearby Venue)

SN	Description	Quantity	Unit	Remarks
A	**Construction Materials**			

Accessories to be distributed for Masons (Trainer will suggest addition to this)

SN	Description	Quantity	Unit	Remarks
A	**Accessories for participants**			
1	Bags	25	nos.	
2	Plump bob	25	nos.	
3	Trowel	25	nos.	
4	Thread	25	nos.	
5	Measuring tape 5 m	25	nos.	
B	**Publications**		nos.	
1	IEC material on retrofitting and safe construction	25	nos.	

Training Evaluation:

a. Participants performance evaluation

- At the end of the training session, there shall be a group discussion and question/answer with individual participants on the lessons learnt during past four days. There shall be a test for all the participants to know their level of understanding from the five days training.

- No formal evaluation would be done besides this. However, the trainer shall clear all the queries of participants before concluding the session. After confirmation of desire knowledge level of participants, Certificate of training will be provided to each participant.

Reporting:

A brief report on training along with feedback will be presented within the week after the completion of the training course with the number of participants and the training details.

TRAINING

DAY 1

1. Presentation: Overview / Concept of Retrofitting
2. Presentation: Retrofitting Techniques for Masonry and Adobe Structures

DAY 2

3. Presentation: Retrofitting Techniques for RCC Structures
4. Presentation: Introduction to Non-Destructive Structure

DAY 3

5. Presentation: Quality Control
6. Presentation: Demolition and Retrofitting Techniques

DAY 4

7. Demonstration : Quality Control

DAY 5

8. Demonstration : Demolition and Retrofitting Techniques

DAY 1

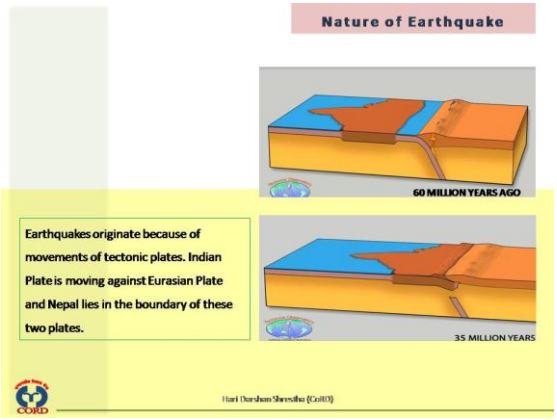
1. Presentation: Overview / Concept of Retrofitting
2. Presentation: Retrofitting Techniques for Masonry and Adobe Structures

1. Presentation

OVERVIEW / CONCEPT OF RETROFITTING

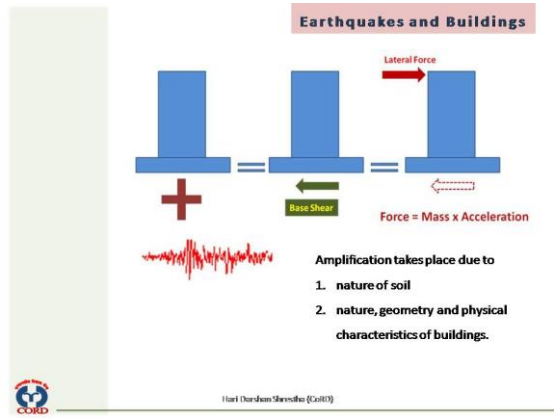
Slide no. 1

Nature of Earthquake



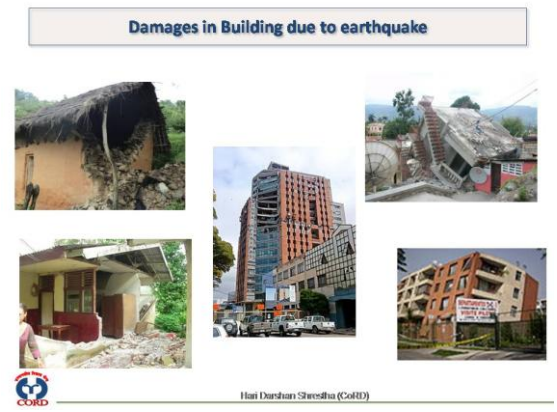
Slide no. 2

Earthquake and Building



Slide no. 3

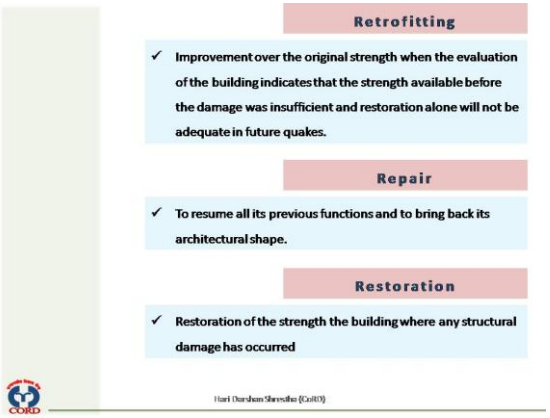
Damages in Building due to earthquake



Slide no. 4

Damages in Building due to earthquake

Slide no. 5



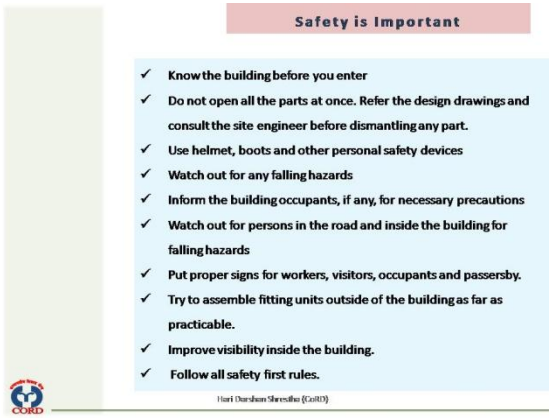
Retrofitting/ Repair/ Restoration

Slide no. 6

Construction Planning & Safety

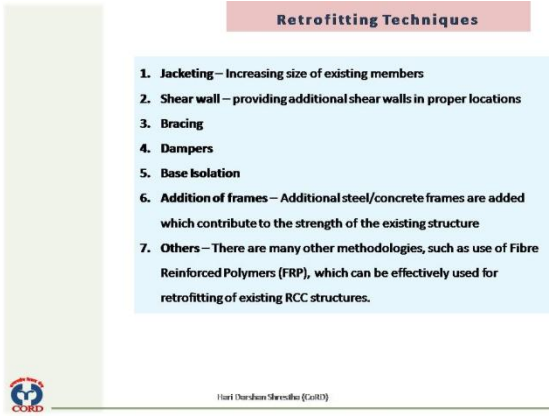
Slide no. 7

Safety is Important



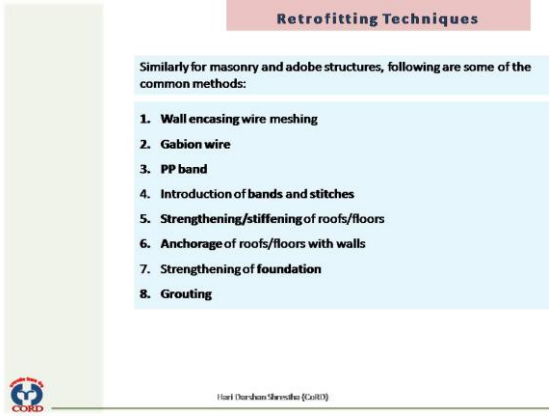
Slide no. 8

Retrofitting Techniques



Slide no. 9

Retrofitting Techniques



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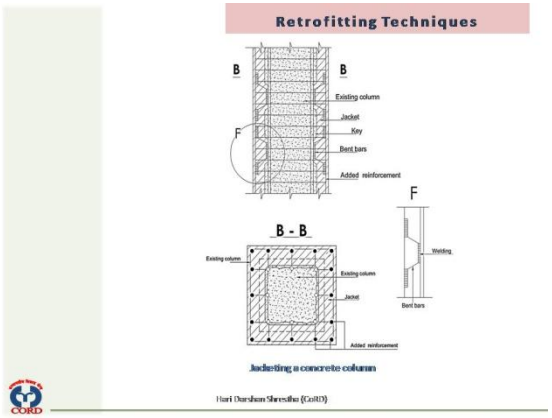
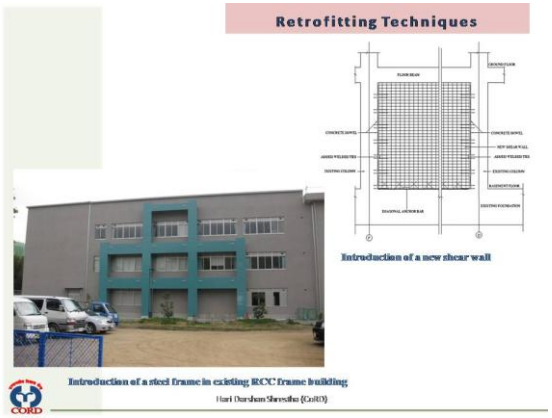


Retrofitting Techniques

Slide no. 11



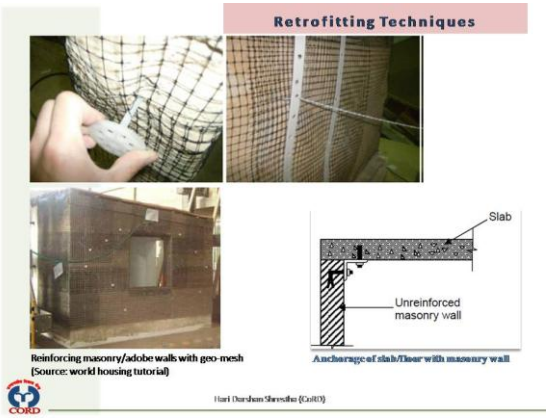
Retrofitting Techniques

Slide no. 12

Retrofitting Techniques

Slide no. 13

Retrofitting Techniques



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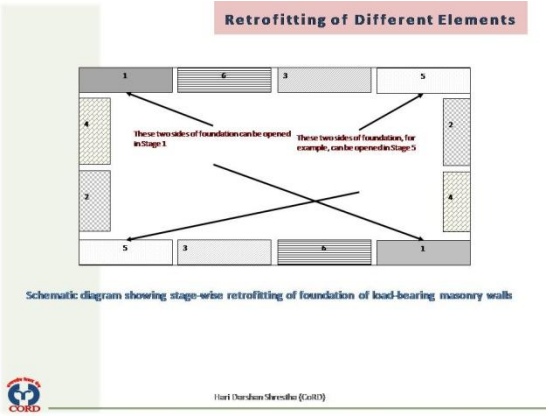
Retrofitting of Different Elements



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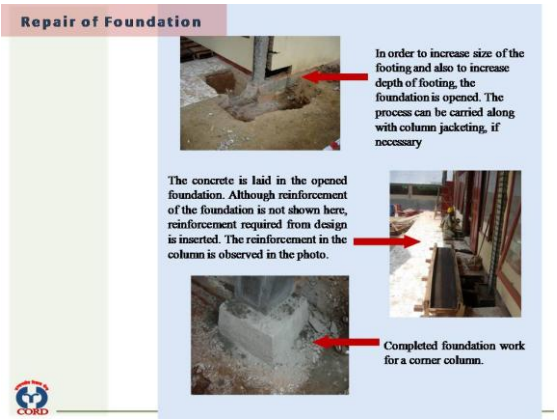
Repair of Foundation



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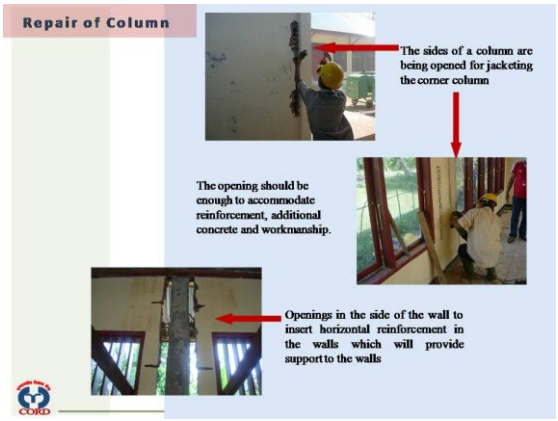
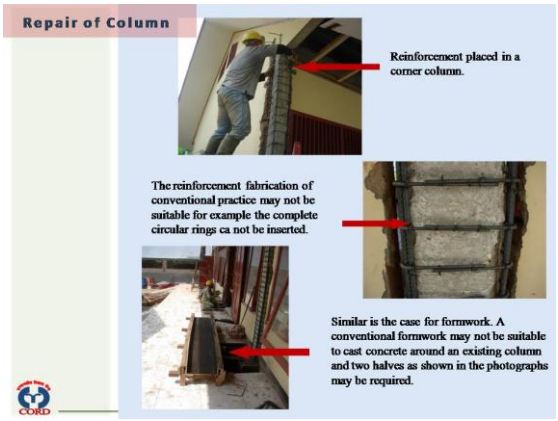


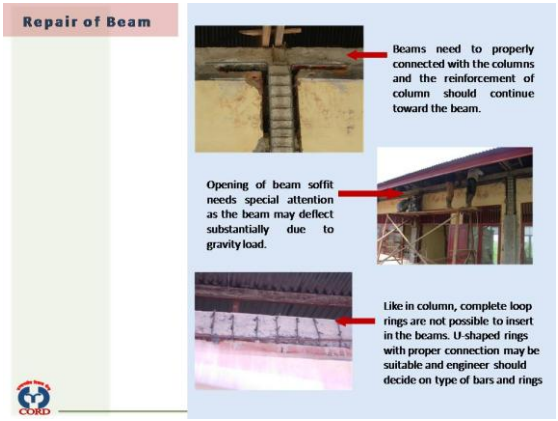
Repair of Column

Slide no. 17



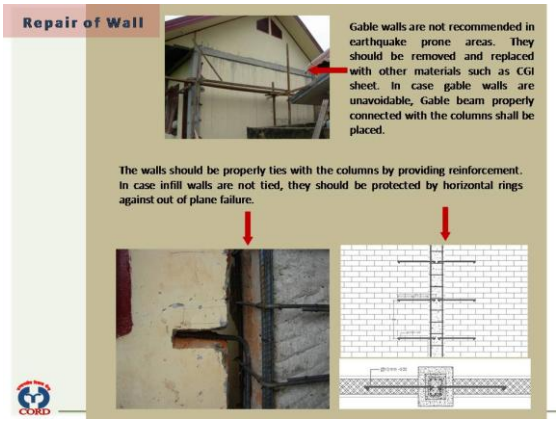
Repair of Column

Slide no. 18



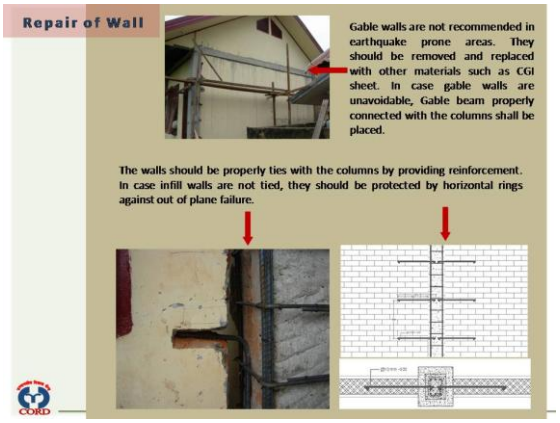
Repair of Beam

Slide no. 19



Repair of Wall

Slide no. 20



Repair of Wall

Slide no. 21

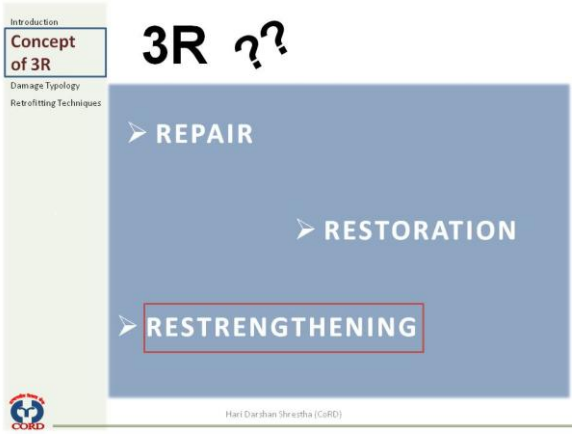
Quality Control

2. Presentation

RETROFITTING TECHNIQUES:

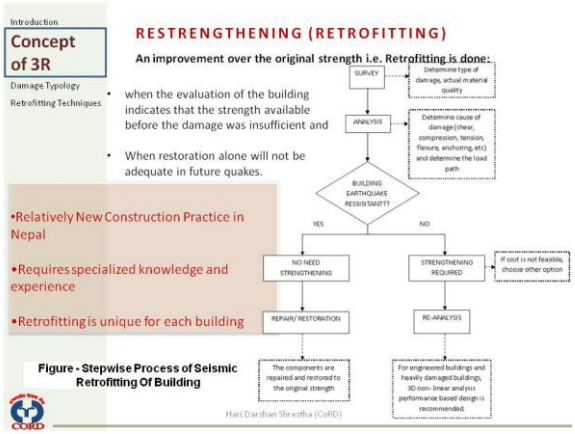
ADOBE AND MASONRY STRUCTURES

Slide no. 1



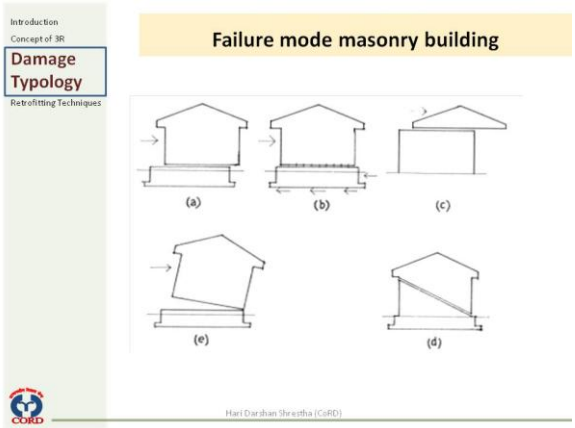
Concept of 3R

Slide no. 2



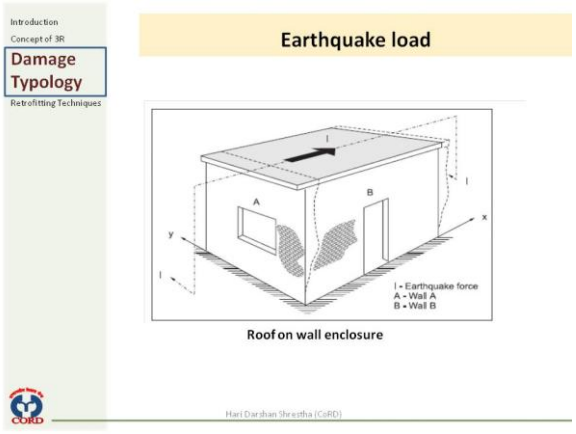
Stepwise Process of Seismic Retrofitting of Building

Slide no. 3



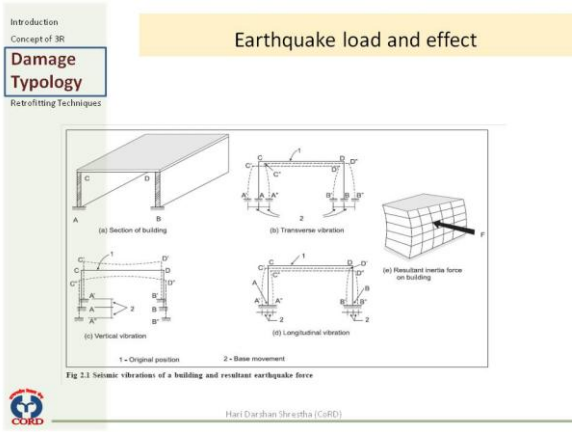
Failure mode of Masonry Building

Slide no. 4



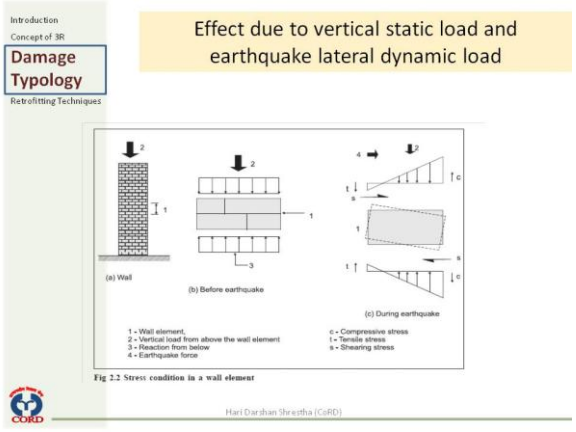
Earthquake Load

Slide no. 5



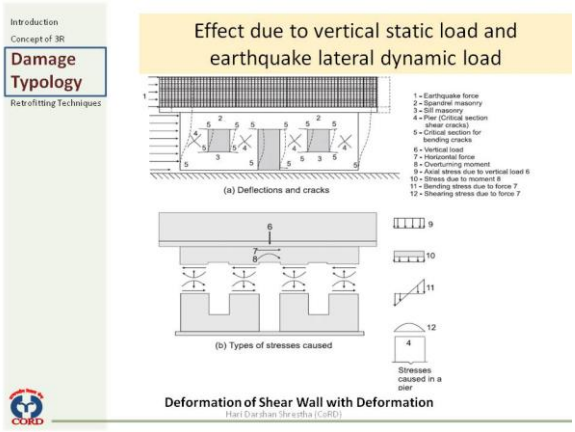
Earthquake load and its effect

Slide no. 6



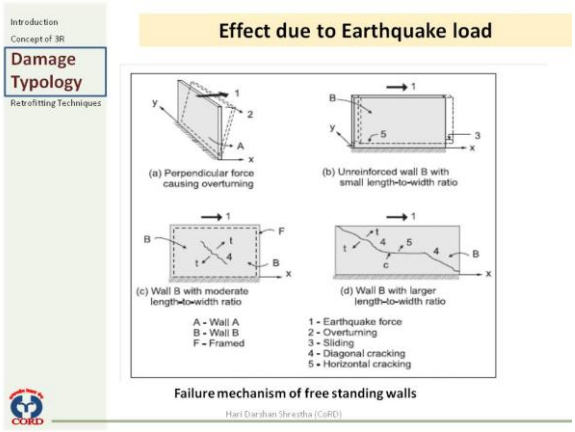
Effect due to vertical static load & earthquake lateral dynamic load

Slide no. 7



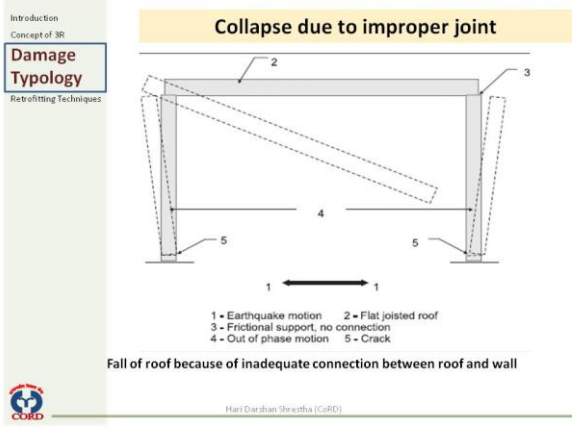
Effect due to vertical static load & earthquake lateral dynamic load

Slide no. 8



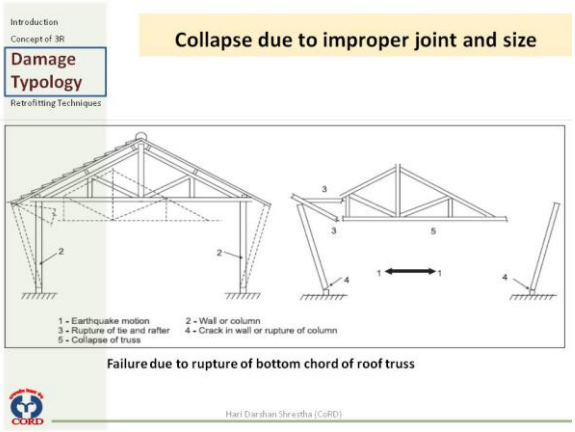
Effect due to earthquake load

Slide no. 9



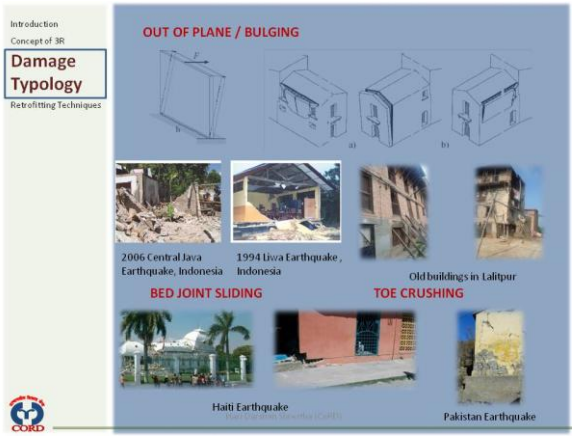
Collapse due to improper joint

Slide no. 10



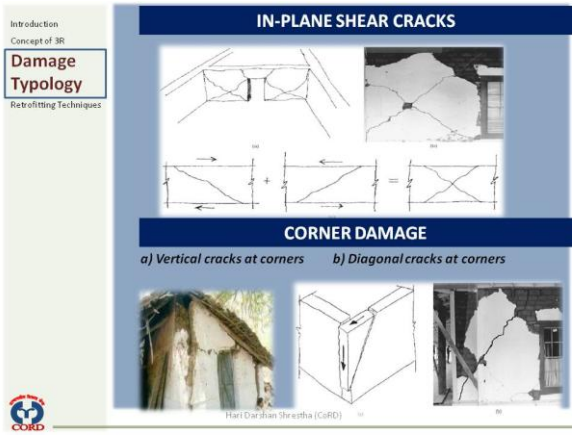
Collapse due to improper joint

Slide no. 11



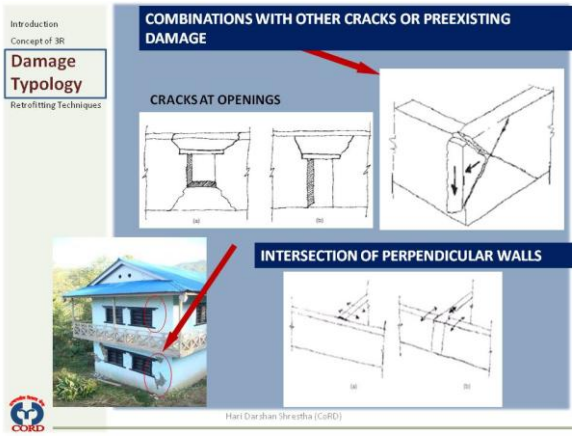
Damage Typology

Slide no. 12



Damage Typology

Slide no. 13



Damage Typology

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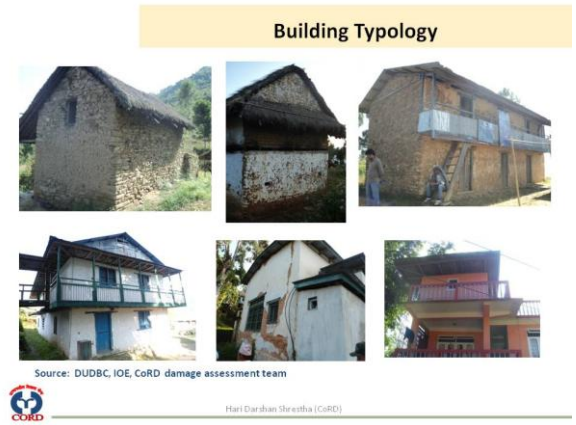
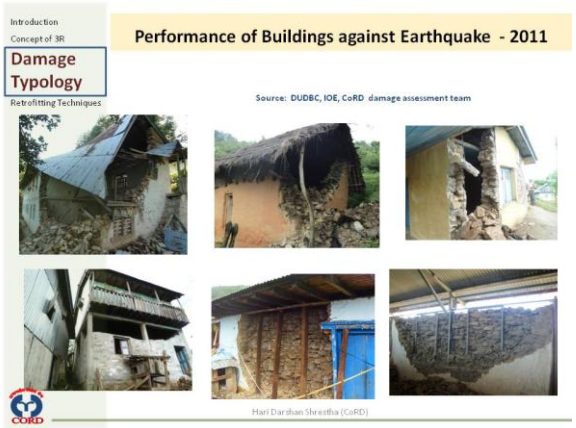


Damage Typology

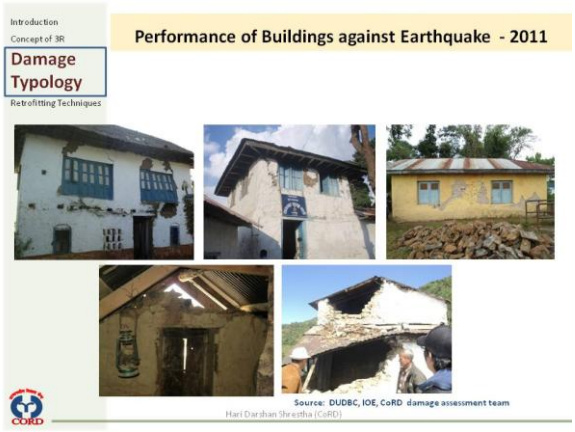
Slide no. 15



Performance of Buildings against Earthquake-2011

Slide no. 16

Performance of Buildings against Earthquake- 2011

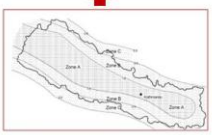


Slide no. 17

Retrofitting – General Requirement

Retrofitting – General Requirements

Building type	Maximum Storey height according to seismic zone		
	A	B	C
Masonry with rigid diaphragm	3	3	3
Masonry with flexible floors	2	3	3



In case of buildings not meeting the above criteria, the provisions in this guide can be applied but building specific detailed analysis must be carried out.

Hari Darshan Shrestha (CoRD)

Slide no. 18

Retrofitting – General Requirement

Retrofitting – General Requirements

HEIGHT TO THICKNESS RATIO OF WALLS

Wall type	Zones		
	A	B	C
Top storey of multi-storey building	9	14	14
First storey of multi-storey building	15	16	18
All other conditions	13	16	16

Based on FEMA and IITK Guidelines

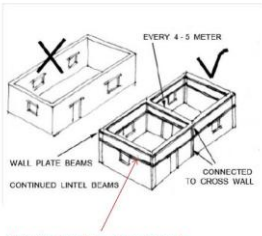
Wall Height – Unsupported wall should be taken as 1.5 times the H

Hari Darshan Shrestha (CoRD)

Slide no. 19

Retrofitting – General Requirement

Retrofitting – General Requirements



Too long walls can be avoided by inserting cross-walls

Height of wall can be reduced by inserting bands at different levels

Hari Darshan Shrestha (CoRD)

Slide no. 20

Analytical Methods for Masonry Structures

Introduction
Concept of 3R
Damage Typology
Analytical PROCESS
Retrofitting techniques

ANALYTICAL METHODS for Masonry Structures

Analysis Procedure

- I. Simplified linear analysis
- II. Linear analysis
- III. Non-linear analysis

CHECKS

- I. CHECK FOR SHEAR (IN-PLANE LOADING)
  - shear wall strength
  - rocking shear strength
- II. CHECK FOR DIAPHRAGM DISPLACEMENT
- III. ROCKING STRENGTH

Hari Darshan Shrestha (CoRD)

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Retrofitting Techniques - General

Introduction
Concept of 3R
Damage Typology
Retrofitting Techniques

GENERAL

Strengthening procedures should aim at:

i. Increasing the lateral strength in one or both directions

ii. Giving unity to the structure

iii. Avoiding the possibility of brittle modes of failure

iv. Buildings which are symmetrical in plan and regular in elevation are safer than the asymmetrical ones

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Slide no. 22

Strengthening of Roof/ Floor

Introduction
Concept of 3R
Damage Typology
Retrofitting Techniques

1. STRENGTHENING OF FLOOR/ ROOF

Aims:

- *Increasing in plane roof stiffness allows loads to be transferred more efficiently and evenly to the walls to which they are connected, enhancing wall to roof connection.*
- *Increase in-plane stiffness of horizontal diaphragms (floors and roof) so the seismic forces can be efficiently transferred to masonry shear walls*

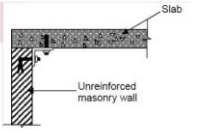
DIAPHRAGMS

I. RCC slabs

Masonry walls shall be connected using reinforcement or anchors to the roof

RCC slabs IF NOT CONNECTED with the masonry walls

shall be anchored with the wall with suitable connection



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Strengthening of Roof/ Floor

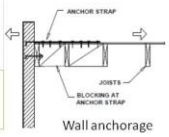
Introduction
Concept of 3R
Damage Typology
Retrofitting Techniques

1. STRENGTHENING OF FLOOR/ ROOF

II. TIMBER FLOORS/ ROOFS

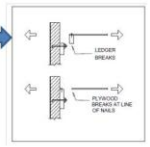
Wall shall be anchored at the roof and all floor levels at a spacing ≤ 6 foot (1.8 m) center to center.

However, anchors shall be provided within 2 feet (0.6m) c/c horizontally from the inside corners of the wall



Wall anchorage

The connections between the walls and the diaphragm shall not induce cross-grain bending or tension in the wood members.



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Strengthening of Roof/ Floor

Introduction
Concept of 3R
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Retrofitting Techniques

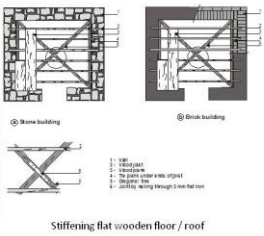
1. STRENGTHENING OF FLOOR/ ROOF

STIFFENING THE FLAT WOODEN FLOOR / ROOF

Flat floor or roof made of wood logs or timber joists covered with wooden planks and earth.

FOR MAKING RIGID FLOOR/ ROOF

- long planks 100 mm wide and 25 mm thick should be nailed at both ends of the logs/joists from below.
- Additionally, similar planks or galvanized metal strips 1.5 mm thick 50 mm wide should be nailed diagonally also.



Stiffening flat wooden floor / roof

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Strengthening of Roof/ Floor

Introduction
Concept of 3R
Damage Typology
Retrofitting Techniques

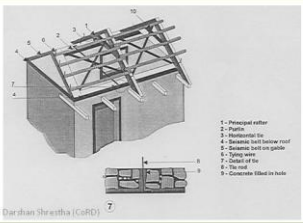
1. STRENGTHENING OF FLOOR/ ROOF

STIFFENING THE SLOPING ROOF SURFACE

Roofs push the walls outward during earthquakes

Timber roofs must be braced in plane with seismic belt.

The opposite rafters, on both sides of the ridge need to be connected near about mid-height of the roof through cross ties nailed to the rafters (Fig a).
The collars should be provided to prevent roof spreading (Fig b).



Hari Darshan Shrestha (CoRD) 7

Slide no. 26

Wall Openings

Introduction
Concept of 3R
Damage Typology
Retrofitting Techniques

WALL OPENINGS

CONTROL ON DOOR AND WINDOW OPENINGS IN MASONRY WALLS

I. INFILL OPENINGS ⇒ Reduction of openings

prevents stress concentrations from forming at the corners of openings that initiate cracks

THING TO CONSIDER

is to INTERLACE the new units with the existing or to provide some type of shear connection between the two.

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Wall Openings

Introduction
Concept of 3R
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Retrofitting Techniques

2. WALL OPENINGS

II. SEISMIC BELTS AROUND DOOR / WINDOW OPENING

Jambs and piers between window and door openings require vertical reinforcement

No. of Storeys	Storeys	Reinforcement		
		Single Bar. mm	Mesh	
			N*	B-**
One	One	10	20	500
Two	Top	10	20	500
	Bottom	12	28	700
Three	Top	10	20	500
	Middle	12	28	700
	Bottom	12	28	700

Mesh and reinforcement for covering the jamb area

* N = Number of longitudinal wires in the mesh.
**B = Width of the micro concrete belt, half on each all meeting at the corner of T-junction

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Strengthening of Walls

Introduction
Concept of 3R
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Retrofitting Techniques

3. STRENGTHENING OF WALLS

Encasement belt around opening

Aims:
- *Prevents rocking or diagonal cracking*

Generally **280 to 300 mm** wide encasement belts are used around the openings .

Window Encasement Door Encasement

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Strengthening of Walls

Introduction
Concept of 3R
Damage Typology
Retrofitting Techniques

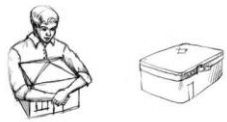
3. STRENGTHENING OF WALLS

1.SEISMIC BELTS

Aims:
- *Prevents failure due to overturning providing anchorage to the roof-floor, out of plane strength and stiffness.*
- *Establish in plane continuity.*
- *Prevent cracked wall section from kicking out in plane*

Seismic belts hold the walls together and ensure integral box action of an entire building.

Provided on all walls on both faces
(a) just above lintels of door and window openings
(b) just below floor or roof.



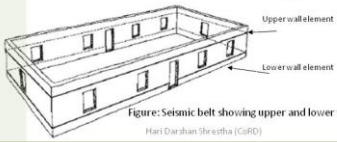


Figure: Seismic belt showing upper and lower wall elements

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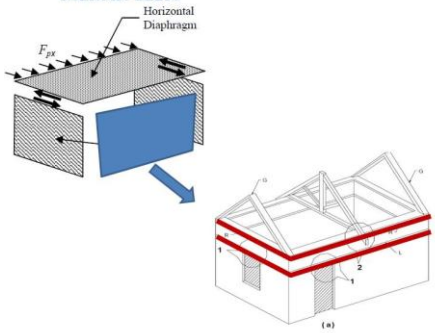
Strengthening of Walls

Introduction
Concept of 3R
Damage Typology
Retrofitting Techniques

3. STRENGTHENING OF WALLS

1.SEISMIC BELTS



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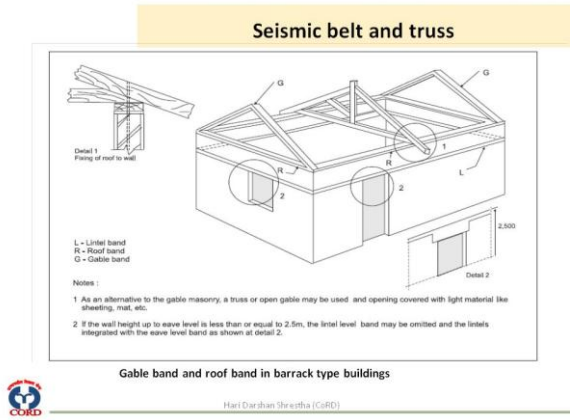
Seismic belt and truss



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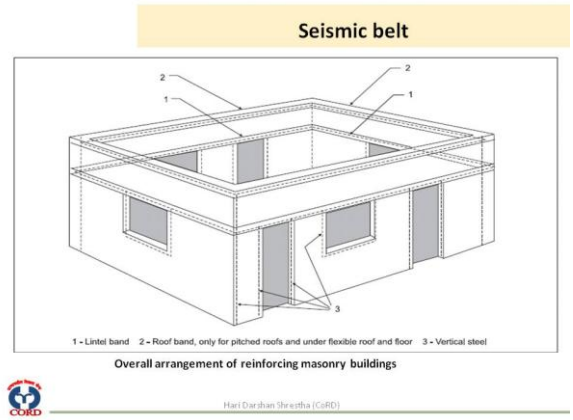
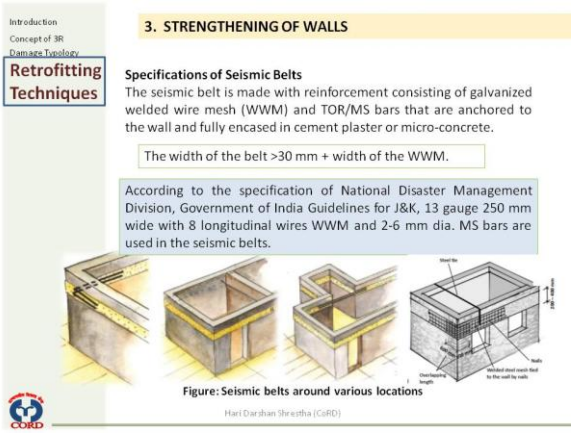
Seismic Belt



Slide no. 33

Specification of Seismic Belts



Slide no. 34

Vertical Reinforcing

Introduction
Concept of 3R
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Retrofitting Techniques

3. STRENGTHENING OF WALLS

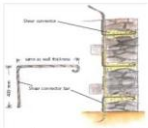
Vertical Reinforcing

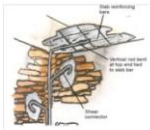
i. Single vertical reinforcement
ii. Reinforcement with welded wire mesh, and
iii. Post-tensioning

i. Single vertical reinforcement

Installed at the inside corner of a wall-to-wall 'L' type junction. In the case of a 'T' junction it may be installed on either side of the junction. Generally10-12 dia TOR bar is used.


Vertical bar in corner


shear connector with vertical bar details


Connecting top bent end of vertical rod to slab

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Vertical Reinforcing

Introduction
Concept of 3R
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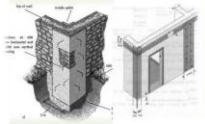
Retrofitting Techniques

3. STRENGTHENING OF WALLS

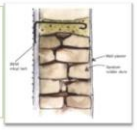
Vertical Reinforcing

ii. Reinforcement with Welded Wire Mesh (WWM)

Installed in an 'L' configuration on the outside of 'L' type wall-to-wall junction and on the outside of a 'T' type junction.
The belt will start from 300 mm below plinth level and continue up to the top of wall at roof level.


Vertical reinforcement with WWM

In case of rubble walls, cast in situ RC shear connectors are used with 'L' shaped dowel bar for greater reliability.


Anchoring WWM with shear Connector

iii. Post Tensioning

Can be applied externally or be installed internally by drilling vertical cores through the middle of a wall.
Steel rods are inserted into these cores and then tensioned.
It also increases the shear capacity of the wall.

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Stiffening Wall/ Wall Jacketing

Introduction
Concept of 3R
Damage Typology
Retrofitting Techniques

3. STRENGTHENING OF WALLS

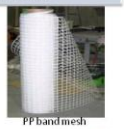
2. STIFFENING WALL/ WALL JACKETING

Aims:

- *Provide out-of-plane stability to unreinforced adobe walls resisting out-of-plane flexure*
- *provide in-plane continuity limiting the relative displacement of cracked walls section preventing extensive wall deterioration*

a. Polypropylene (PP) Band

- simple and low-cost method
- consists of confining all adobe walls with a mesh of PP-bands.
- Increase the structure ductility and energy dissipation capacity through controlled cracking.
- Practical application in Nepal, Pakistan and Peru with positive reception from the communities.


PP band mesh


PP band retrofitted house before mortar laying

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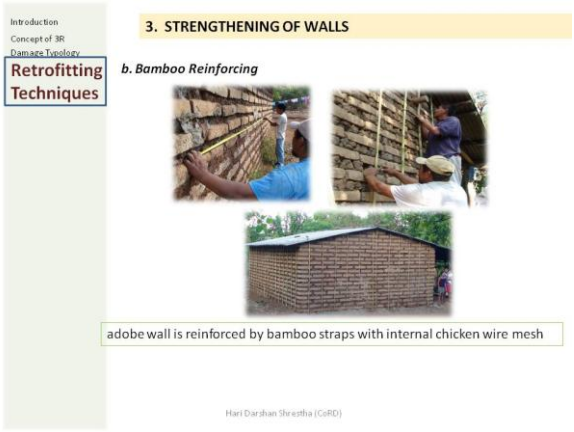
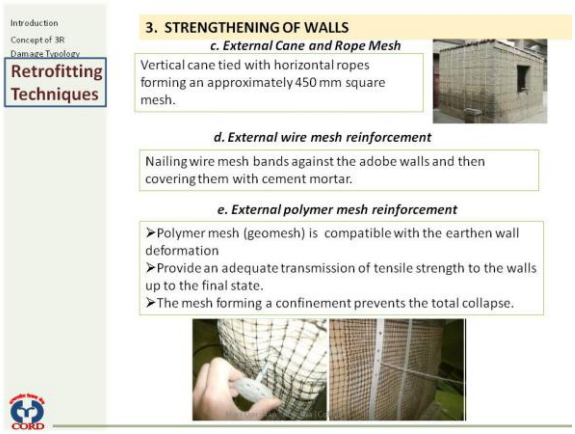
Stiffening Wall/ Wall Jacketing



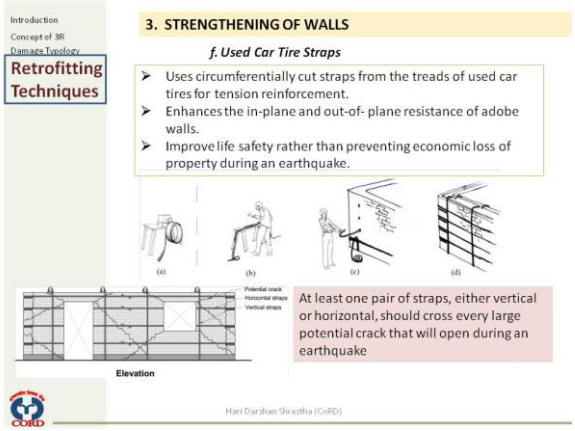
Slide no. 38

Stiffening Wall/ Wall Jacketing



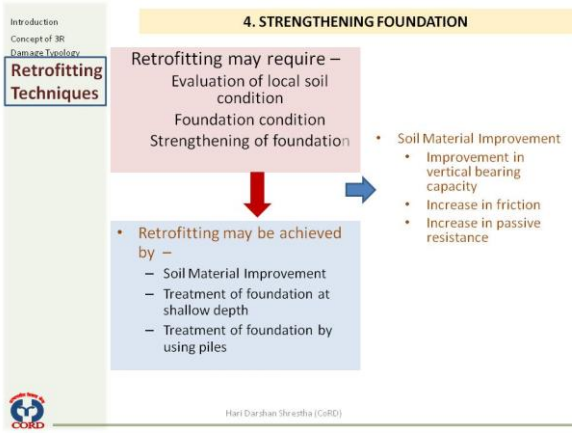
Slide no. 39

Stiffening Wall/ Wall Jacketing



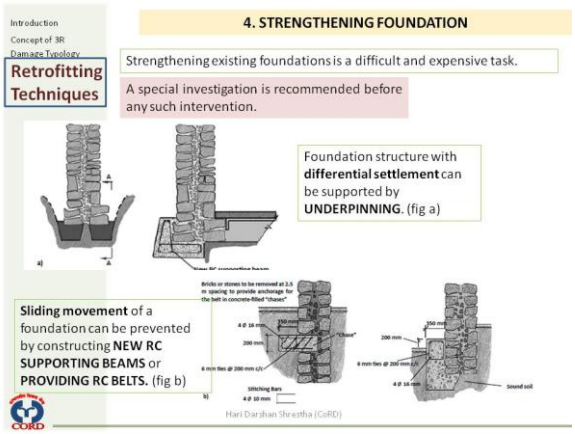
Slide no. 40

Strengthening of Foundation



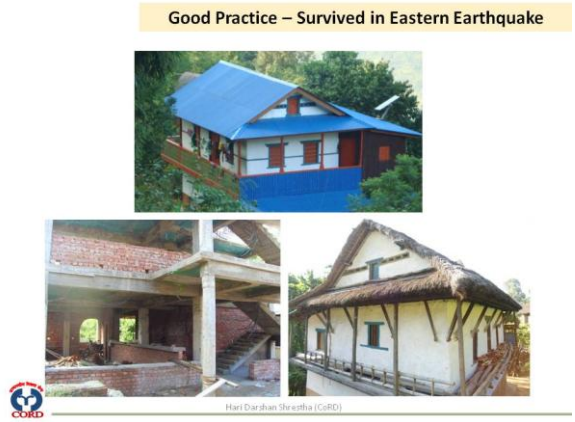
Slide no. 41

Strengthening of Foundation



Slide no. 42

Good Practices



DAY 2

3. Presentation : Retrofitting Techniques: RCC Structures
4. Presentation: Non- Destructive Test

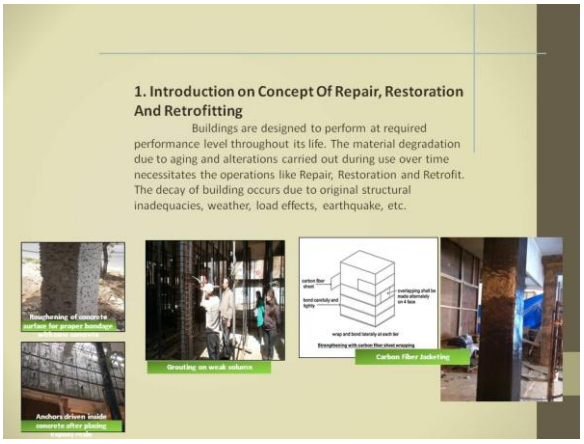
Day 2

3. Presentation

RETROFITTING TECHNIQUES:

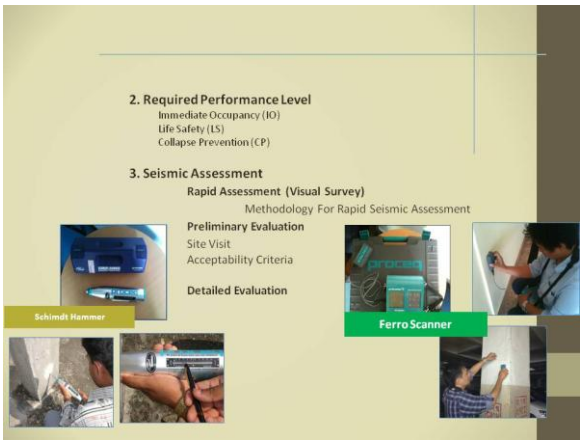
RCC STRUCTURES

Slide no. 1



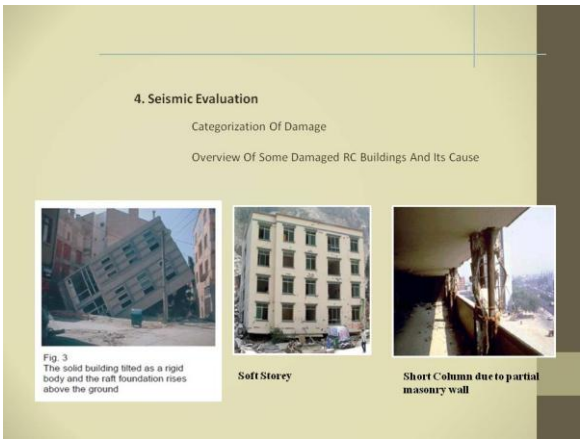
Introduction to Repair, Restoration & Retrofitting

Slide no. 2



Introduction to Repair, Restoration & Retrofitting

Slide no. 3



Introduction to Repair, Restoration & Retrofitting

Slide no. 4

PRELIMINARY EVALUATION

- Site Visit & Collection of All Available Data
- Configuration-Related Checks
  - Load Path
  - Geometry
  - Weak/Soft Storey
  - Mass Irregularities
  - Short column
  - Effect of Adjacent Building
  - Torsion
- Strength-Related Checks

Preliminary Evaluation

Slide no. 5

❖Site Visit & Collection of Data

- Get all the drawing, if it is not available prepare as built drawing.
- Site soil classification
- Identify building type and its use.
- Study the effect of certain architectural features that may affect the seismic performance especially location of masonary infill walls, water tanks, staircase, parapets.

Site Visit & Collection of Data

Slide no. 6

CONFIGURATION-RELATED CHECKS

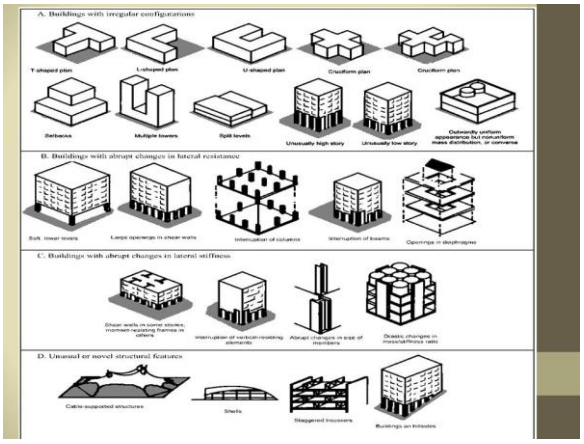
❖**Geometry**

- Check for geometry of building along plan and elevation
- Check for Symmetry of the building

Configuration Related Check

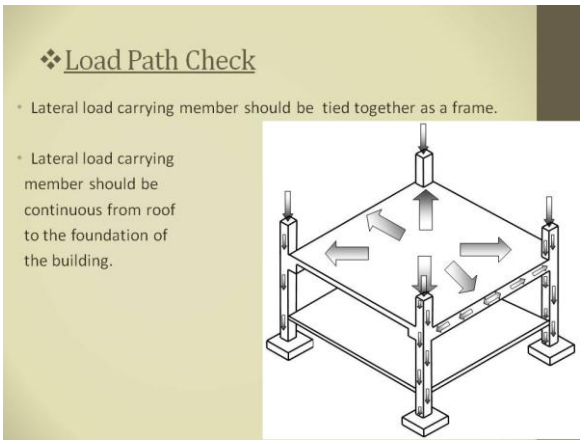
Slide no. 7

Configuration Related Check



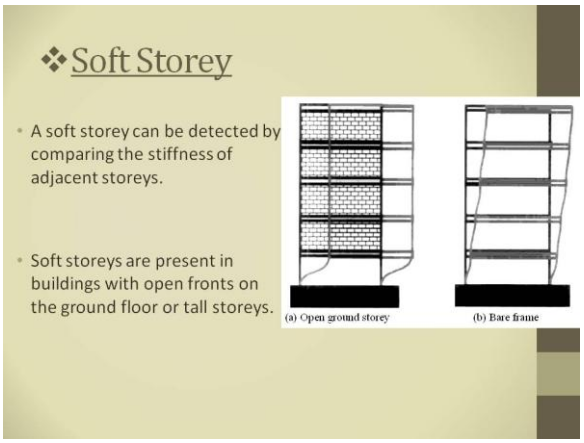
Slide no. 8

Load Path Check

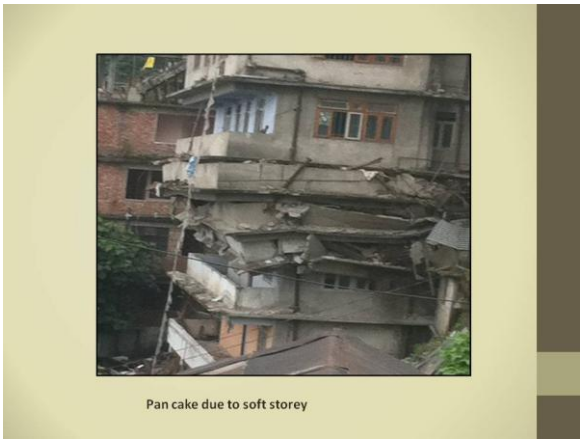


Slide no. 9

Soft Storey



Slide no. 10

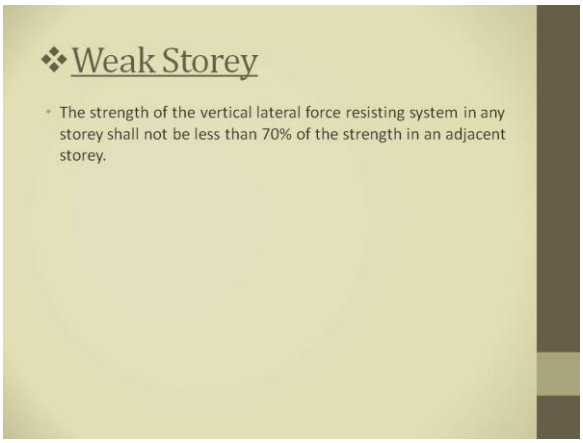


Soft Storey

Slide no. 11

Soft Storey

Slide no. 12



Weak Storey

Slide no. 13

Soft Storey

Soft Upper Storey

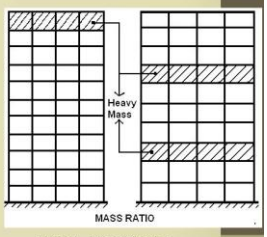
Soft Ground Storey

Slide no. 14

Mass Irregularity

Mass Irregularities

- Mass of a storey should not be double the mass of next storey.
- In case of unavoidable situations or non-compliance the ratio of mass to stiffness of two adjacent storeys should be made equal.



WHEN Wi > 2.0 Wi-1
OR Wi >2.0 Wi+1
Mass Irregularity

Slide no. 15

Short Cloumn

❖Short column

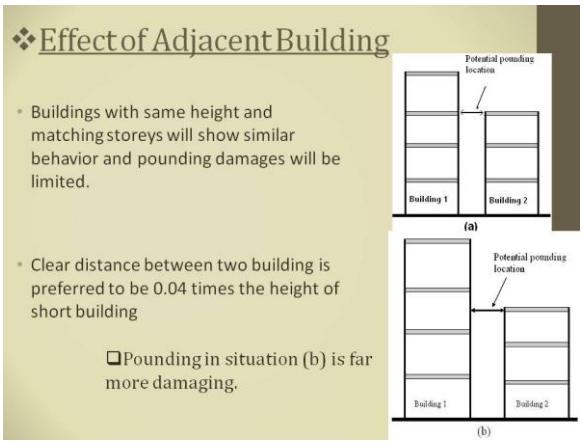
- Short column should be avoided as they are relatively stiffer than other columns in a storey and tend to attract higher seismic forces.
- A flexible joint between infill wall and concrete column should be provided.
- Provide special confining reinforcement along full height of column.

Slide no. 16

Short Cloumn

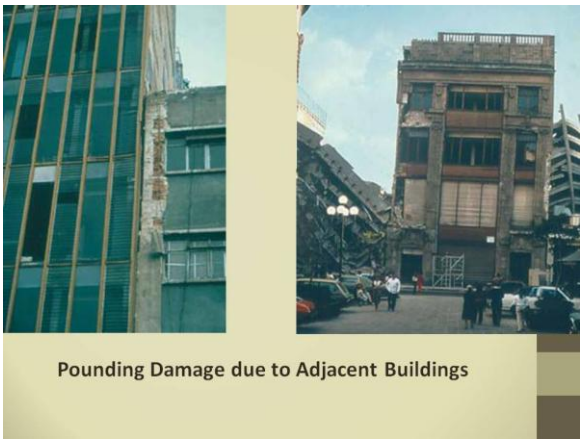
Slide no. 17

Effect of Adjacent Building



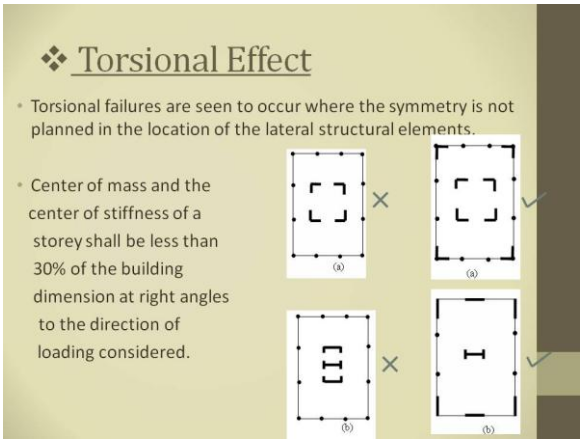
Slide no. 18

Pounding Damage due to Adjacent Building



Slide no. 19

Torsion Effect

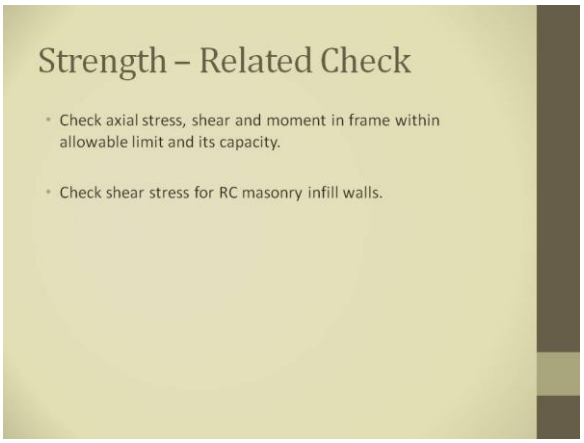


Slide no. 20

Damages

Slide no. 21

Strength Related Check



Slide no. 22

Detailed Evaluation

DETAILED EVALUATION

❖ **Condition of building component and material**

- There should not be any deterioration of concrete and reinforcement steel.
- There should not be any diagonal crack wider than 3mm in concrete column
- Present day strength of the material can be obtain on site testing using rebound hammer.

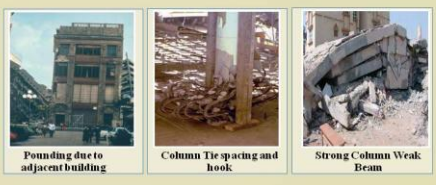
Slide no. 23

Detailed Evaluation

- Shear capacity of frame members shall be adequate to develop the moment capacity at the ends, and shall be in accordance with provisions of IS: 13920 for shear design of beams and columns.
- Strong Column/Weak Beam

Slide no. 24

Damages

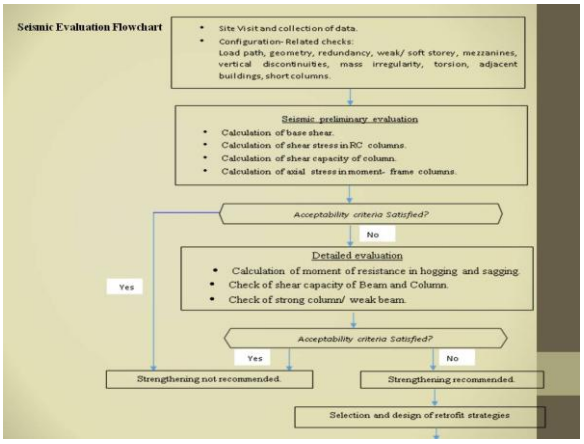


Pounding due to adjacent building

Column Tie spacing and hook

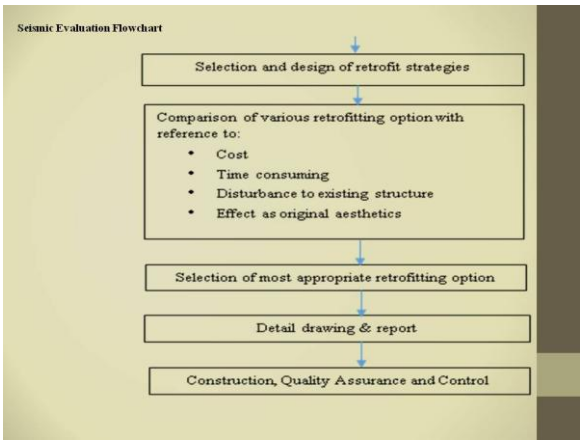
Strong Column Weak Beam

Slide no. 25



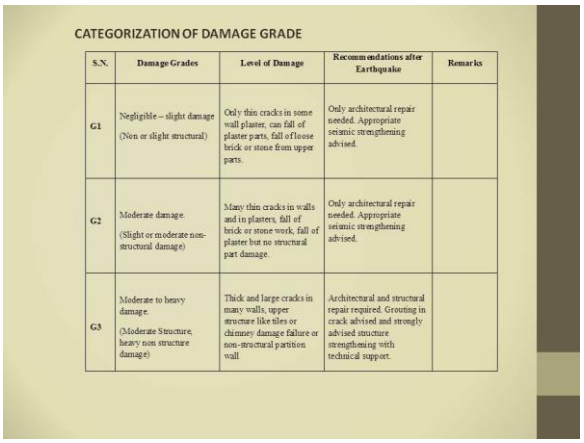
Evaluation Flowchart

Slide no. 26



Evaluation Flowchart

Slide no. 27


CATEGORIZATION OF DAMAGE GRADE

S.N.	Damage Grades	Level of Damage	Recommendations after Earthquake	Remarks
G1	Negligible – slight damage (Non or slight structural)	Only thin cracks in some wall plaster, can fall of plaster parts, fall of loose brick or stone from upper parts.	Only architectural repair needed. Appropriate seismic strengthening advised.	
G2	Moderate damage. (Slight or moderate non-structural damage)	Many thin cracks in walls and in plasters, fall of brick or stone work, fall of plaster but no structural part damage.	Only architectural repair needed. Appropriate seismic strengthening advised.	
G3	Moderate to heavy damage. (Moderate Structure, heavy non structure damage)	Thick and large cracks in many walls, upper structure like tiles or chimney damage failure or non-structural partition wall.	Architectural and structural repair required. Grouting in crack advised and strongly advised structure strengthening with technical support.	

Categorization of Damage Grade

Slide no. 28

Categorization of Damage Grade

CATEGORIZATION OF DAMAGE GRADE (CONTINUED.....)

G4	Very heavy damage (Heavy structure, very heavy non structure damage)	Large gap occurs in main walls, wall collapses, some structural floor or roof damage.	Immediately vacate the building, demolish and construct with seismic designs. In some case extensive restoration and strengthening can be apply.	Technical Assistance Recommended
G5	Destruction (Very heavy structure Damage)	Floor collapse due to soft storey, partial or total collapse of building.	Immediately clear the site and reconstruction the building following seismic design.	Technical Assistance Recommended

Slide no. 29

Damage Grade 1

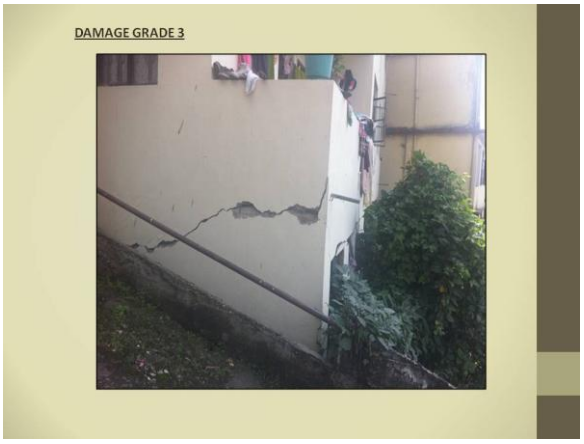
DAMAGE GRADE 1

Slide no. 30

Damage Grade 2

DAMAGE GRADE 2

Slide no. 31



Damage Grade 3

Slide no. 32

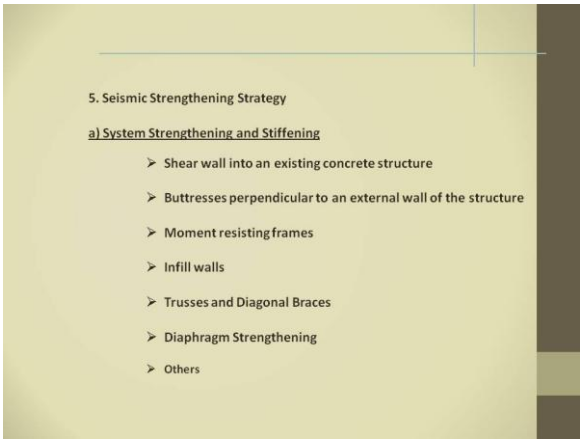
Damage Grade 4

Slide no. 33

Damage Grade 5

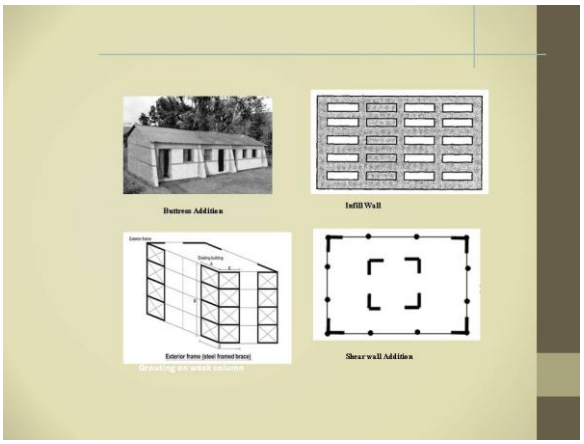
Slide no. 34

Seismic Strengthening Strategy



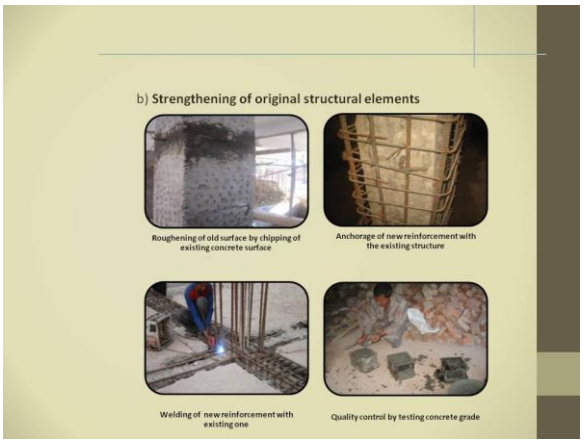
Slide no. 35

Seismic Strengthening Strategy



Slide no. 36

Seismic Strengthening Strategy



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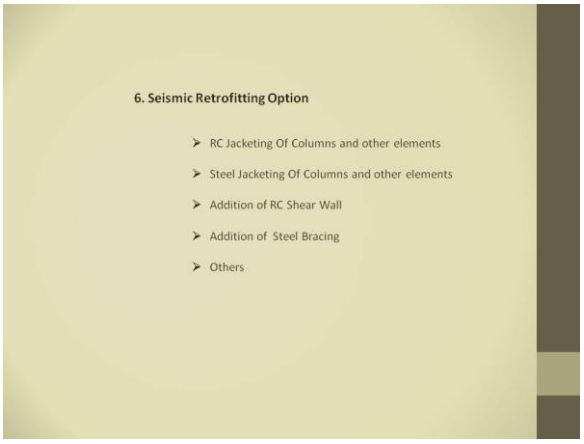


Seismic Retrofitting Option

Slide no. 38

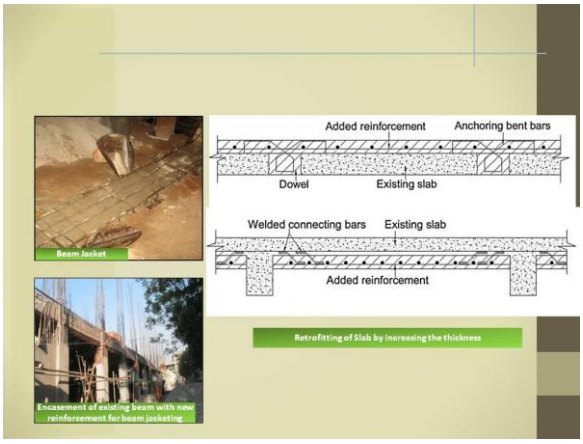
Seismic Retrofitting Option

Slide no. 39

Seismic Retrofitting Option

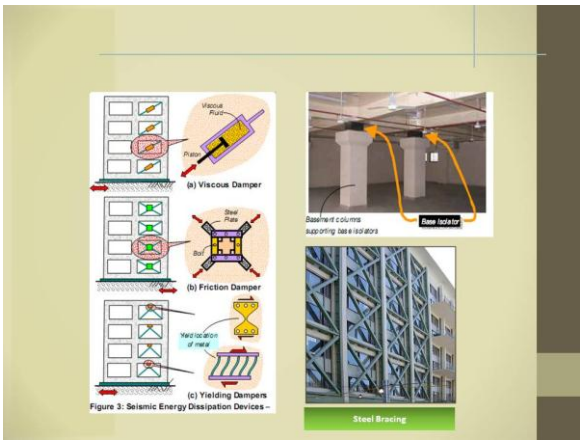
Slide no. 40

Seismic Retrofitting Option



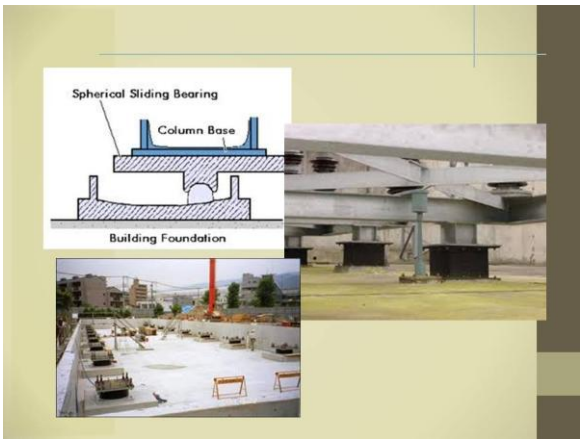
Slide no. 41

Seismic Retrofitting Option



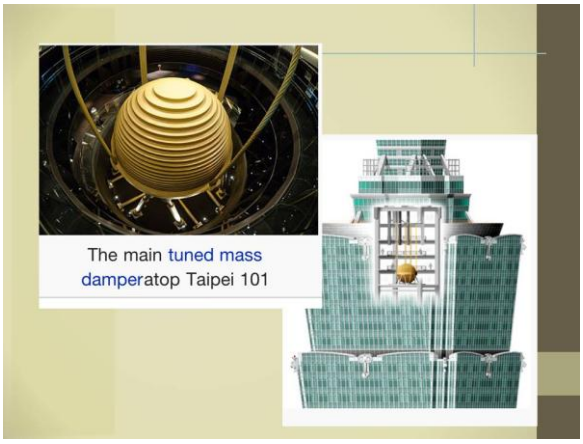
Slide no. 42

Seismic Retrofitting Option



Slide no. 43

Example



1. Presentation:

INTRODUCTION TO NON-DESTRUCTIVE TEST

Slide no. 1

Overview and Introduction

Service Life Evaluation of RC Structures & Assessment of Strength of existing Concrete Structures by Non Destructive Testing

- What it is ? Definition & Historical Background
- Why is it used ? Classification
- Methods
- ACME's Techniques for Investigation
- ACME's Technical Specification - Repair / Strengthening
- ACME's Products & Systems for Rehabilitation

Our Formula – Your Solution

Slide no. 2

Definition

Definition

- NDT stands for "Non Destructive Testing" and is defined as a method used to investigate the integrity of an object, material or system without impairing its future usefulness.

Our Formula – Your Solution

Slide no. 3

Historical Background

Historical Background

- Some of the first methods to evaluate the in-place strength of concrete were adaptations of the Brinell Hardness test for metals

Our Formula – Your Solution

Slide no. 4

Classification

ACME CONCRETE SYSTEMS

Classification

- To assess in-place strength
- To locate hidden defects

Our Formula – Your Solution

Slide no. 5

Methods

ACME CONCRETE SYSTEMS

Methods

- To estimate strength
- To evaluate conditions other than strength

Our Formula – Your Solution

Slide no. 6

In-place Tests to Estimate Strength

ACME CONCRETE SYSTEMS

In-place Tests to estimate Strength

- Surface Hardness: Rebound Hammer
- Homogeneity: Ultrasonic Pulse Velocity
- Probe penetration
- Pullout
- Break-off
- Maturity method

Our Formula – Your Solution

Slide no. 7

Non-Destructive Tests for Integrity

Non Destructive Tests for Integrity

- Visual Inspection
- Ground Penetrating Radar
- Electrical / Magnetic Methods

  Cover Survey/ Rebar Orientation / Half Cell Potential
- Infrared Thermography

Our Formula – Your Solution

Slide no. 8

Durability Test

Durability Tests

- Core Sampling

Strength Determination, Chemical Analysis, Excess Voidage Estimation, Petrographic Analysis

- Carbonation
- pH
- Moisture content
- Resistivity

Our Formula – Your Solution

Slide no. 9

Techniques for Quality Assurance, Failure Investigation and Strengthening Techniques

ACME's Techniques for Quality Assurance, Failure Investigation & Strengthening Techniques

- Quality Evaluation
- Failure Investigation
- Degree of Deterioration
- Repair, Rehabilitation & Strengthening Strategy
- Selection & Evaluation of Repair Materials

Our Formula – Your Solution

Slide no. 10

Non-Destructive Test -1

Slide no. 11

Non-Destructive Test -2

Slide no. 12

Non-Destructive Test -3

Slide no. 13

Non-Destructive Test -4

Slide no. 14

Products and System for Repair and Strengthening RC Structures

ACME CONCRETE SYSTEMS

ACME's Products & Systems for Repair & Strengthening of RC Structures

- High Performance Admixtures & Adhesives
- New Generation Polymers
- Protective Coatings
- Electrochemical Repairs
- Advanced Composite Materials [FRP – Carbon, e-Glass]
- Expansion joints [Strip Seal/ Modular]

Our Formula – Your Solution

DAY 3

6. Quality Control

7. Demolition and Retrofitting Techniques at Site

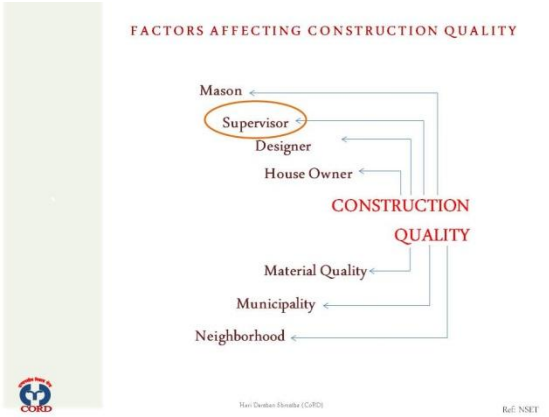
2. Presentation

QUALITY CONTROL

Slide no. 1

Quality Control in Field

Slide no. 2



Factors affecting construction Quality

Slide no. 3

Quality in Construction Material

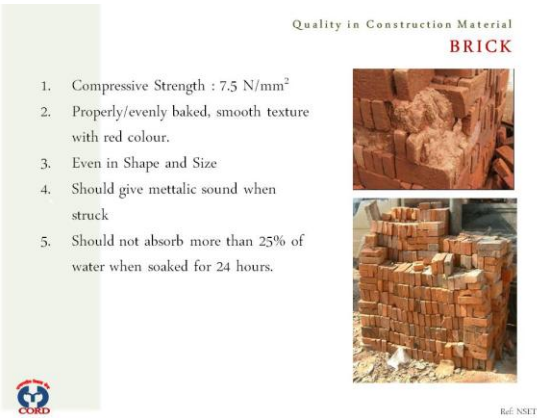
Slide no. 4

Quality in Construction Material

Slide no. 5

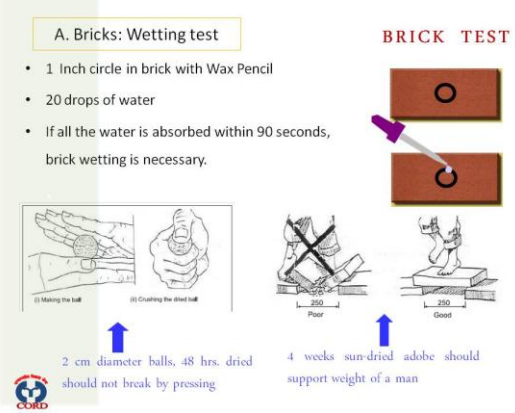
Gap between design and construction

Slide no. 6



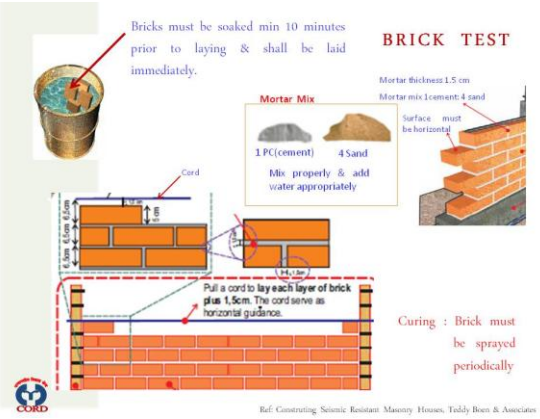
Quality in Construction Material- Brick

Slide no. 7



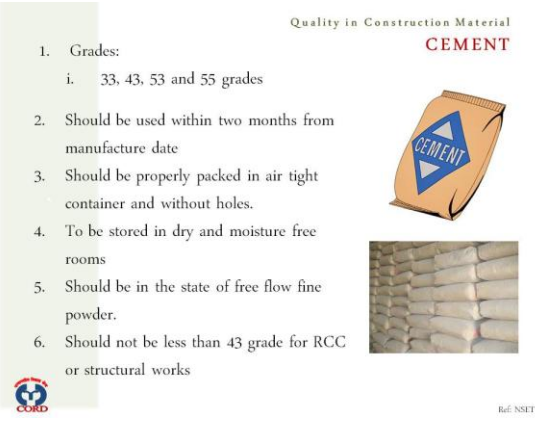
Brick Test

Slide no. 8



Brick Test

Slide no. 9



Quality in Construction Material- Cement

Slide no. 10

Quality in Construction Material- Cement

Quality in Construction Material

CEMENT

1. **Good Quality Cement:**
   i. Which sets and hardens within given time frame
   ii. Gains appropriate load bearing capacity within given time
   iii. Absorbs moisture of specified amount
   iv. In the state of fine powder

2. **Bad Quality Cement:**
   i. Which does not set and harden within given time frame
   ii. Absorbs excess dampness
   iii. Not in the state of fine powder

Ref: NSET

Slide no. 11

Quality in Construction Material- Cement

Quality in Construction Material

CEMENT

Decreasing load carrying capacity of cement due to prolonged storage

Storage Duration	Decrease in Load bearing capacity in 28 days(%)
Fresh	0
3 months	20
6 months	30
1 year	40
2 years	50

Strength of fresh and stored cement

Duration	Cement concrete (1:5) from fresh cement	Cement concrete (1:5) from 6 months old cement
7 days	100	73
28 days	100	75
6 months	100	84

Ref: NSET

Slide no. 12

Quality in Construction Material- Cement

Quality in Construction Material

SAND

1. **Test for Sand**
   i. Take a handful of sand in clean hands
   ii. Rub with both hands
   iii. If the hands are clean, then the sand is of good quality

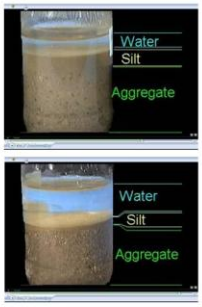
Ref: NSET

Slide no. 13

Sand Silt Test

SAND-SILT TEST

- Place 5 cm of aggregate + 2 Cm Water
- Add ½-1 Spoon salt
- Shake well
- Allow the container to stand for an hour
- More than 3 mm silt is not desirable
- Should be less than 5-6 %



Slide no. 14

Organic Test

ORGANIC TEST

- Sand 150 ml
- Add Caustic Soda instead of Salt (3% -120 mL)
- Dark color water means presence of organic matter

Slide no. 15

Quality in Construction Material- Gravel

Quality in Construction Material

GRAVEL

Hard, clean similar in shape but not round.
Not easily broken.
Should be free from minerals and other impurities
Should be of various sizes

Sizes of gravel for various thickness of cast:

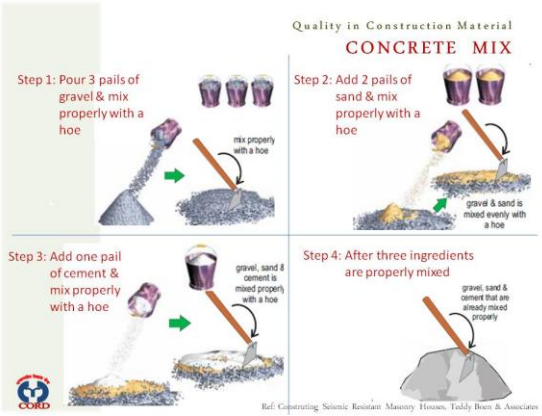
Thickness of slab	Gravel size
100mm	≤ 40 mm
40- 100mm	≤ 20 mm
< 40 mm	≤ 6 mm

For other thickness, follow specification

Ref: Constructing Seismic Resistant Masonry Houses, Teddy Boen & Associates

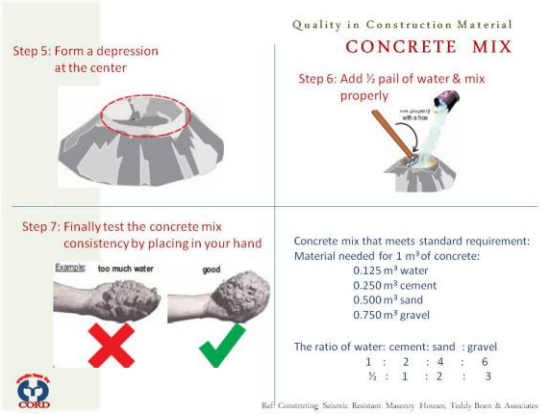
Slide no. 16

Concrete Mix



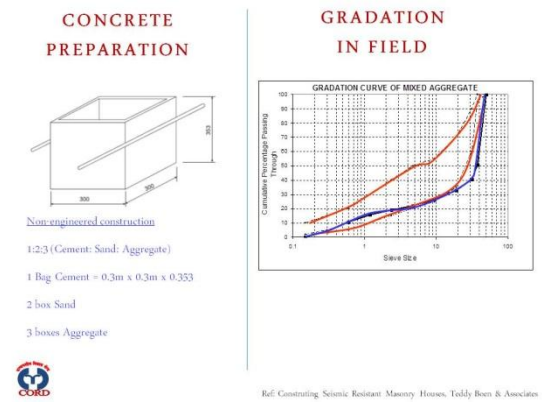
Slide no. 17

Concrete Mix



Slide no. 18

Concrete Preparation and Gradation in field



Slide no. 19

Quality in Construction Material- RC bars

Quality in Construction Material

RC BARS

- Free of rust
- Should not break when bent
- Should not have nay cracks in overall length
- Should have uniform thickness and diameter
- Should be of trusted quality and company

Slide no. 20

Quality in Construction Material- RC bars

Quality in Construction Material

RC BARS- STIRRUPS

Prior to cutting, stirrup reinforcing bar length to be measured from construction drawings, including the bends & hooks. The length is determined based on the stirrups axis with formula:
Perimeter of column/ beam + 2X hook length – 8 concrete cover from stirrup axis

Example: Stirrup of Column 12X12 cm using bar Φ 8mm:

A= column width at one side = 120 mm
B= column width at other side = 120 mm
C= 6D = 48 mm
D= bar diameter = 8mm
E= 2.5 D = 20 mm
F= concrete cover from stirrup axis = 15mm

Formula : 2(A+B) + 2(C+E)- 8F
2=(120+120) + 2(48+20) – 8X 15
= 496 m
= 49.6 cm

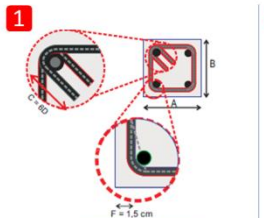
Ref: Construting Seismic Resistant Masonry Houses, Teddy Boen & Associates

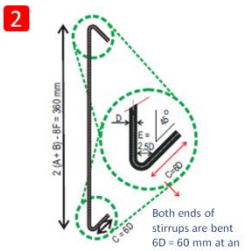
Slide no. 21

Quality in Construction Material- RC bars - stirrups

Quality in Construction Material

RC BARS- STIRRUPS

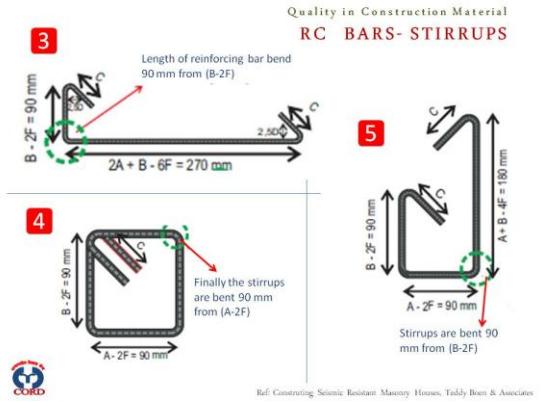




Concrete cover thickness 1.5cm from stirrup axis

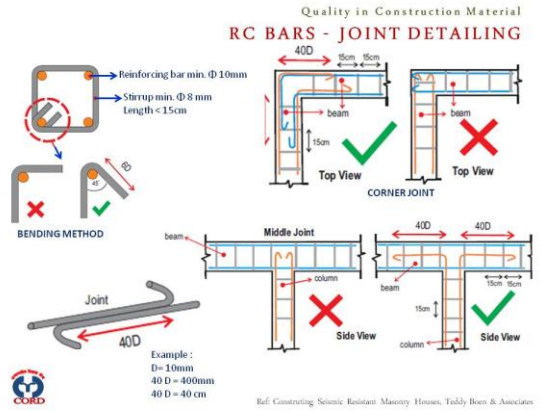
Ref: Construting Seismic Resistant Masonry Houses, Teddy Boen & Associates

Slide no. 22



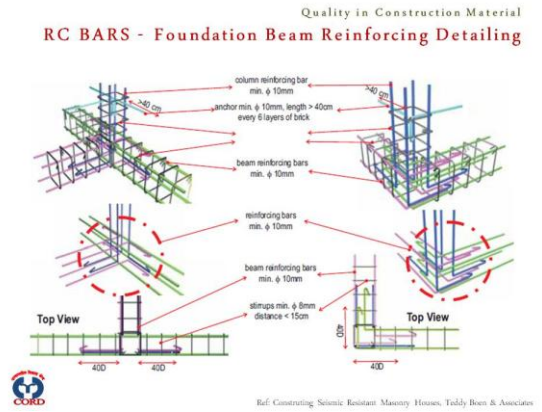
Quality in Construction Material- RC bars- stirrups

Slide no. 23



RC bars –Joint detailing

Slide no. 24



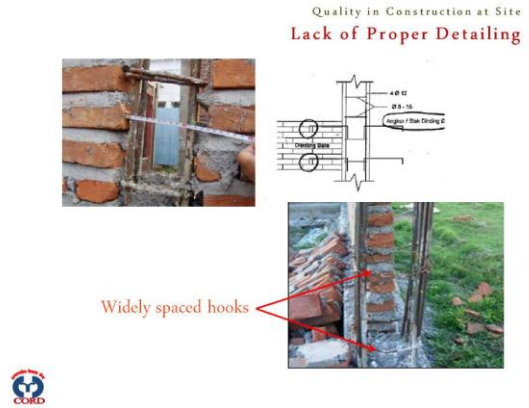
RC bars- Foundation Beam Reinforcing Detailing

Slide no. 25

Quality in Construction at site

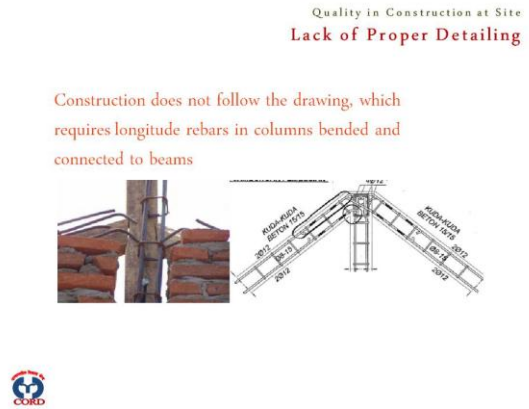
Slide no. 26

Quality in Construction at site



Slide no. 27

Quality in Construction at site



Slide no. 28

How can we assure quality in the field?

Can we assure quality in the field?

Slide no. 29

Field inspection form: Material

S. No	Description	Observation in the field	Remarks
1	**Sand**: Storage Water content General Quality		
2	**Brick**: Brick quality Cleanliness Water absorption		
3	**Cement**: Storage Purchased date		
4	**Aggregates**: Grading Cleanliness Shape		
5	**Reinforcement bar**: Quality Rust and physical condition		

Field Inspection form

Slide no. 30

Field inspection form: Concrete

S. No	Description	Observation in the field	Remarks
1	**Concrete mix:** Ratio Procedure for concrete mixing Water cement ratio Is strength check done?		
2	**Placement of concrete:** Pouring of concrete Compaction Shear key in column		
3	**Framework/ Centering/ Shuttering :** Quality Safety		
4	**Curing:** Done properly?		
5	**Reinforcement:** Bending Fabrication Placement		
6	**Detailing:** Stirrups Beam/column joint Lap length		
7	**General :** Eccentricity Member Connectivity		

Field Inspection form

Slide no. 31

Construction quality control at site

CONSTRUCTION QUALITY
CONTROL
AT
SITE

Slide no. 32

Natural hazards are inevitable, Natural disasters are not!

"It has long been acknowledged that the configuration, and the simplicity and directness of the seismic resistance system of a structure, is just as important, if not more important, than the actual lateral design forces."

Structural engineer - William Holmes, 1976,

"Natural hazards are inevitable.
Natural disasters are not."

John Filson, USGS retired, ***New York Times***, December 27, 2004

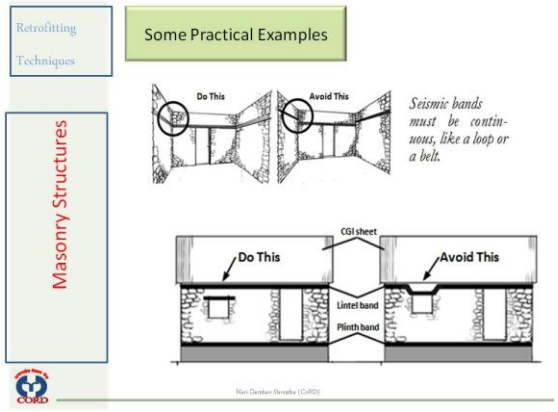
Slide no. 33

Quality control at site

Quality control in field is very important to achieve the required performance of a building. Simple and easily available measures such as slump test are very effective in the field.

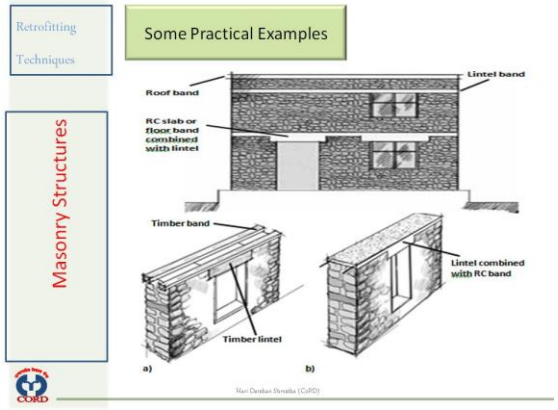
Continuous monitoring and supervision is required. Quality check of finished product is recommended.

Slide no. 34



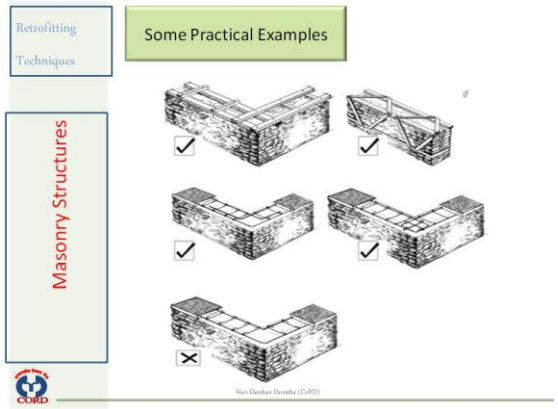
Practical Examples

Slide no. 35



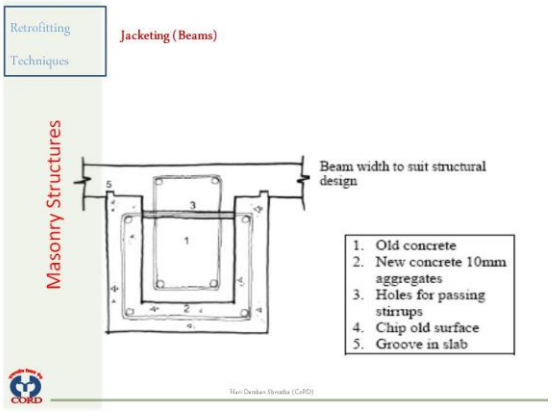
Practical Examples

Slide no. 36



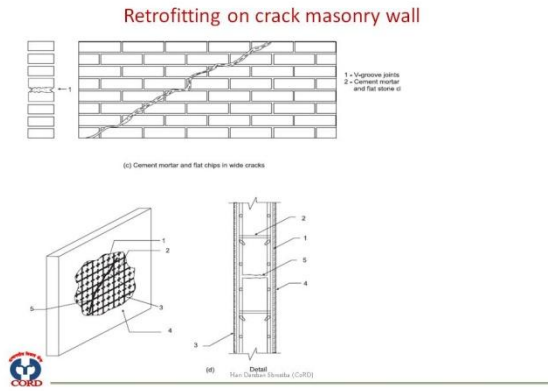
Practical Examples

Slide no. 37



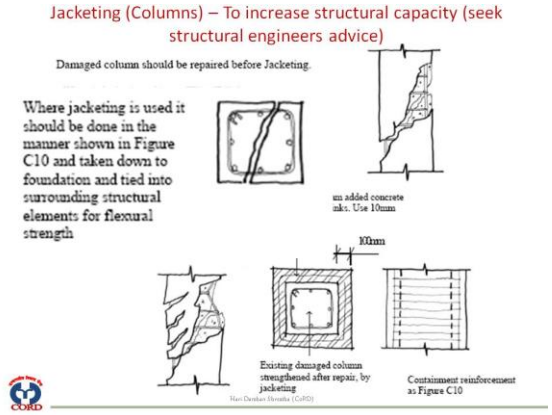
Practical Examples

Slide no. 38



Practical Examples

Slide no. 39



Practical Examples

Slide no. 40

Practical Examples

Concrete strength to be 20 N/mm^2 (minimum)
Cover to bars to all sides: Beams – 35mm
Slabs – 25mm
Columns – 40mm
Ground beams – 50mm
Foundations – 75mm
All reinforcement to be high yield (ribbed bars)

REASONS FOR USE AND COMMENTS

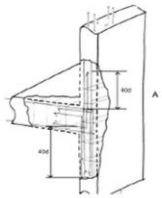
- Provide adequate temporary supports to all damaged columns and beams down to foundations.
- Cut out damaged concrete
- Columns should be reinforced with a minimum of 8 bars, with links as recommended. Bars should be lapped at mid height of column with full tension laps (40d min). **Bars must be continued and anchored into adjoining members**.
- Reinforcement sized to allow for ductile behaviour (sized after calculations). Minimum steel should be 8 No. 16mm diameter bars, links 10mm diameter bars
- Link spacing to be as specified by design (note, must be close spacing at ends and at lap positions).
- Full continuity should exist for reversal of forces.
- Bar spacing to be restricted to 200mm maximum. All bars to be tied with links
- Jacketing thickness should be 100mm minimum. Aggregate size should be restricted to 10mm.

Slide no. 41

Strengthening of Foundation

Detail A: REPAIRS TO COLUMN BEAM JUNCTIONS

1) Provide adequate temporary supports to beam and column
2) Cut out damaged concrete to a square edge
3) Cut out damaged bars and provide new bars with adequate laps and anchorage
4) For spacing of links refer to Figure C3

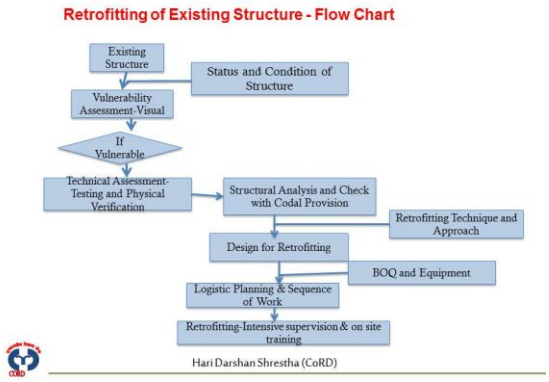


- Increases strength of column / beam junction
- Restores and improves ties
- Improves bending and shear resistance at junctions, particularly for reversal of loads.
- It is important that columns and beams are continuous through the connection and are not at an offset.

7. Presentation

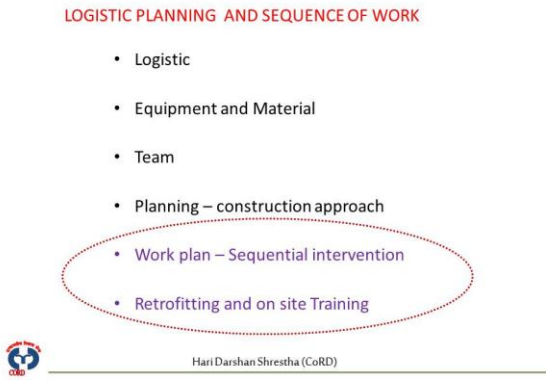
DEMOLITION AND RETROFITTING TECHNIQUES

Slide no. 1



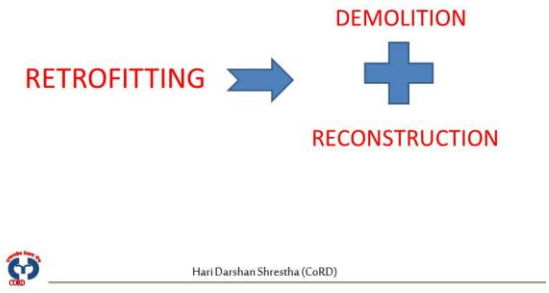
Retrofitting of Existing Structures

Slide no. 2



Logistic Planning and Sequence of Work

Slide no. 3



Retrofitting

Slide no. 4

Equipment and Materials for Retrofitting

EQUIPMENTS AND MATERIALS FOR RETROFITTING

1. Concrete cutter
2. Electrical Drilling machine
3. Jack Hammer
4. Hammer
5. Chisel
6. Gun for adhesive
7. Concrete mixtures
8. Vibrator
9. Wheel Barrow
10. Other regular tools and equipment
11. Material for form work
12. Construction material- steel bar, cement, sand, aggregate, timber and others

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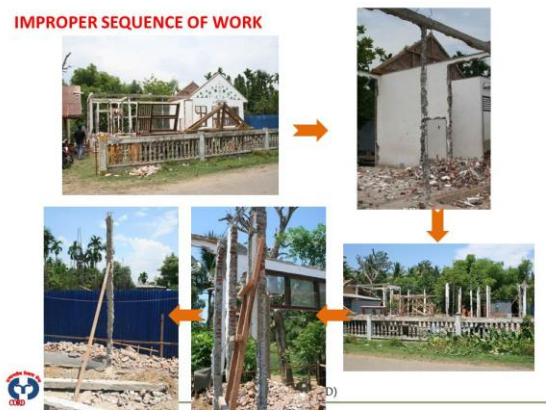
Slide no. 5

Improper sequence of Work

IMPROPER SEQUENCE OF WORK

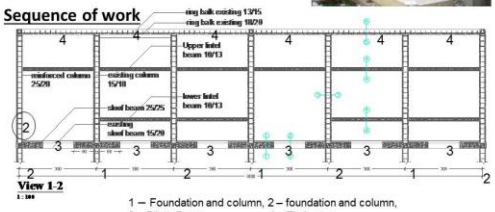


Slide no. 6

Retrofitting Process

RETROFITTING PROCESS

Sequence of work



1 – Foundation and column, 2 – foundation and column,
3 – Plinth Beam 4 – Tie beam
5 – Gable beam and column

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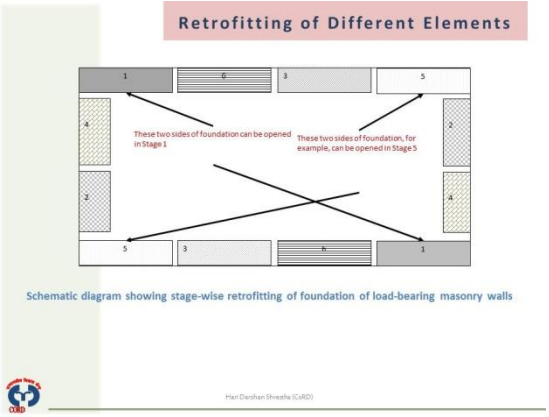
Slide no. 7

Retrofitting of Different Elements

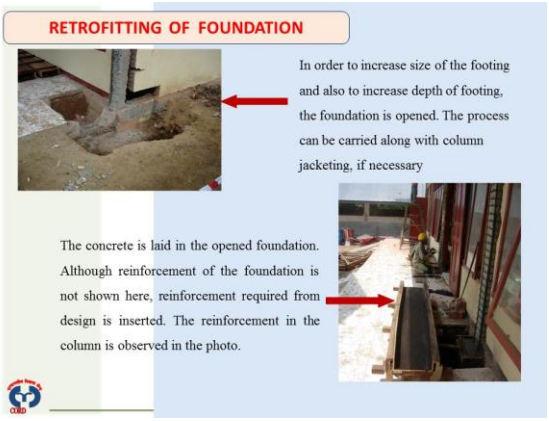


Slide no. 8

Retrofitting of Foundation

Slide no. 9

Retrofitting of Foundation



Slide no. 10

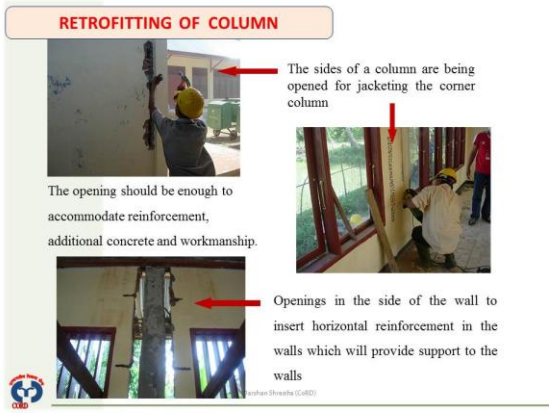
Retrofitting of Foundation

Slide no. 11

Retrofitting of Column

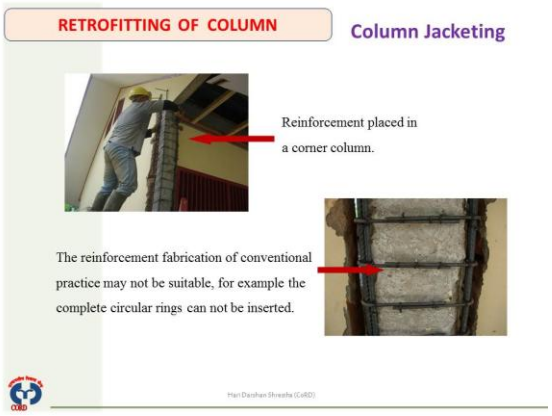
Slide no. 12

Retrofitting of Column



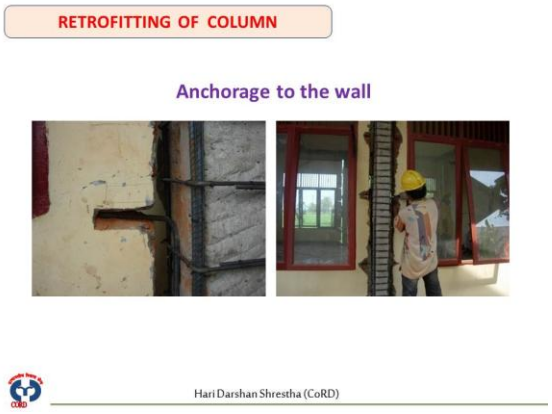
Slide no. 13

Retrofitting of Column



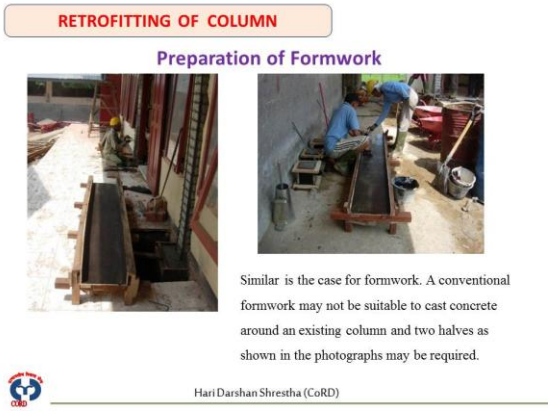
Slide no. 14

Retrofitting of Column



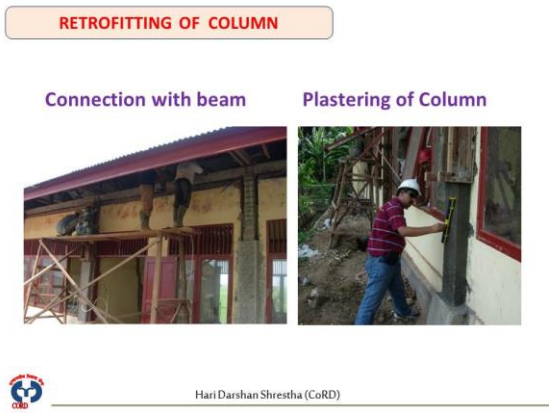
Slide no. 15

Retrofitting of Column



Slide no. 16

Retrofitting of Column

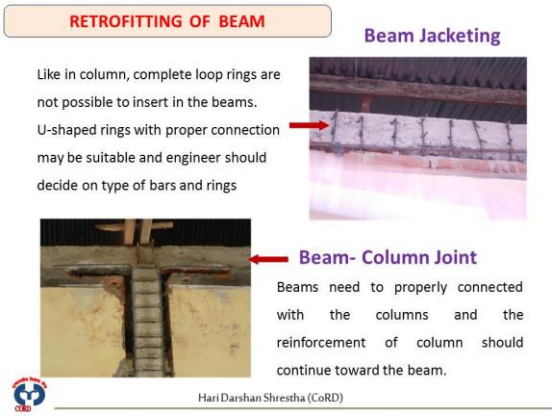


Slide no. 17

Retrofitting of Beam

Slide no. 18

Retrofitting of Beam



Slide no. 19

Retrofitting of Beam

RETROFITTING OF BEAM

Formwork Preparation

Plastering

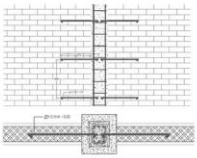
Hari Darshan Shrestha (CoRD)

Slide no. 20

Retrofitting of Wall

RETROFITTING OF WALL

Gable walls are not recommended in earthquake prone areas. They should be removed and replaced with other materials such as CGI sheet. In case gable walls are unavoidable, Gable beam properly connected with the columns shall be placed.



The walls should be properly ties with the columns by providing reinforcement. In case infill walls are not tied, they should be protected by horizontal rings against out of plane failure.

Slide no. 21

Retrofitting of Wall

RETROFITTING OF WALL

Removal of Plaster

Surface Preparation

Hari Darshan Shrestha (CoRD) Source: NSET

Slide no. 22

Retrofitting of Wall

RETROFITTING OF WALL

Insertion of Anchorage bars or GI wires (at suggested interval) by drilling holes on walls

Hari Darshan Shrestha (CoRD) Source: MRB and

Slide no. 23

Retrofitting of Wall

RETROFITTING OF WALL

If surface is not smooth, apply protective coat of 12mm thick cement plaster

Hari Darshan Shrestha (CoRD) Source: NSET

Slide no. 24

Retrofitting of Wall

RETROFITTING OF WALL

Placing Reinforcement (Steel bar mesh / GI wire mesh)

Hari Darshan Shrestha (CoRD) Source: MRB and

Slide no. 25

RETROFITTING OF WALL

Anchoring Reinforcing Bars

Fix reinforcing bars into wall using inserted G.I wires or steel anchorage bars

Hari Darshan Shrestha (CoRD) Source: NSET

Retrofitting of Wall

Slide no. 26

RETROFITTING OF WALL

Plastering

Curing

Retrofitting of Wall

Slide no. 27

Retrofitting of URM Building – After Iran Eq, 2006

- Adding external bracings
- Decreasing the weights of the building
- Increasing the rigidity of the floors and the roofs.
- Increasing the widths of the foundations,
- Improve integrities of the diaphragms

Retrofitting of URM building