

SEISMIC RETROFITTING GUIDELINES OF BUILDINGS IN NEPAL

2013

**TRAINING
CURRICULUM
(Construction)**

PART II

**PRESENTATION
MATERIALS
&
EXERCISE
FOR TRAINEE**



April 2013

SEISMIC RETROFITTING GUIDELINES

of

Buildings in Nepal

TRAINING CURRICULUM
(Construction)
PART II

Presentation Materials
&
Exercise for Trainee



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:

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

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 be 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 desired 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

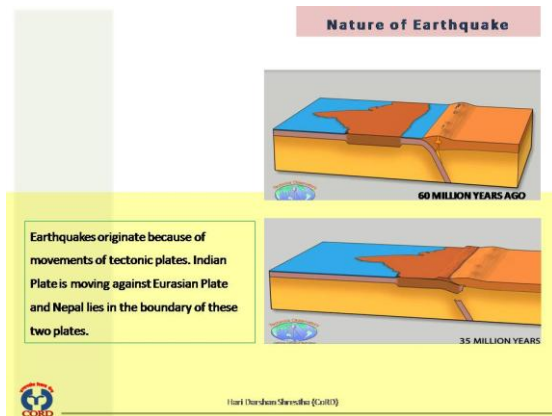
DAY 1

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

1. Presentation

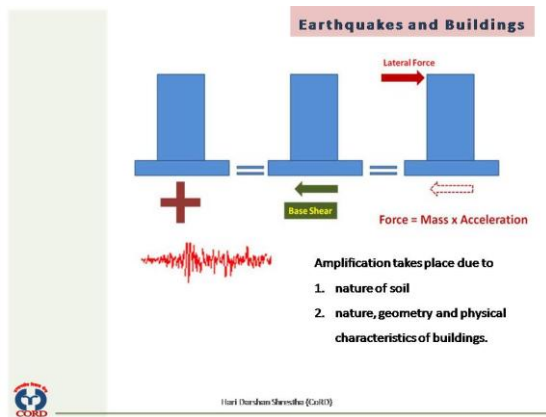
OVERVIEW / CONCEPT OF RETROFITTING

Slide no. 1



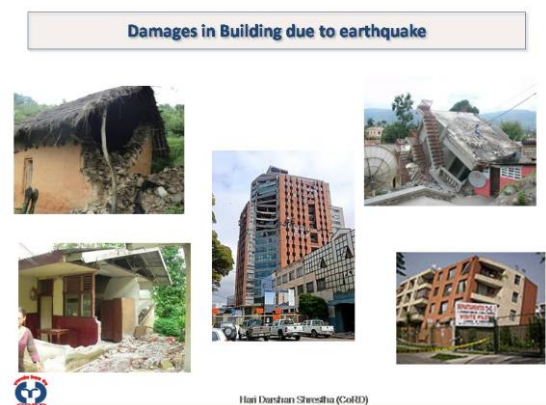
Nature of Earthquake

Slide no. 2



Earthquake and Building

Slide no. 3



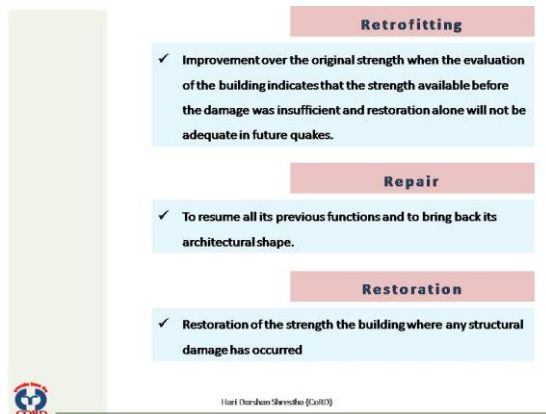
Damages in Building due to earthquake

Slide no. 4



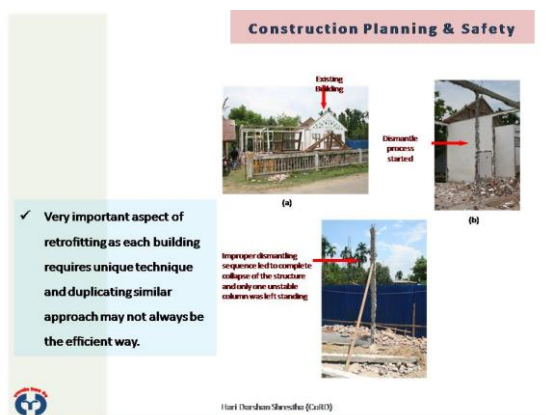
Damages in Building due to earthquake

Slide no. 5




Retrofitting/ Repair/ Restoration

Slide no. 6



Construction Planning & Safety

Slide no. 7



CORD


Safety is Important

- ✓ Know the building before you enter
- ✓ Do not open all the parts at once. Refer the design drawings and consult the site engineer before dismantling any part.
- ✓ Use helmet, boots and other personal safety devices
- ✓ Watch out for any falling hazards
- ✓ Inform the building occupants, if any, for necessary precautions
- ✓ Watch out for persons in the road and inside the building for falling hazards
- ✓ Put proper signs for workers, visitors, occupants and passersby.
- ✓ Try to assemble fitting units outside of the building as far as practicable.
- ✓ Improve visibility inside the building.
- ✓ Follow all safety first rules.

Harf Dardem Sirendur (2017)

Safety is Important

Slide no. 8



CORD


Retrofitting Techniques

1. Jacketing – Increasing size of existing members
2. Shear wall – providing additional shear walls in proper locations
3. Bracing
4. Dampers
5. Base Isolation
6. Addition of frames – Additional steel/concrete frames are added which contribute to the strength of the existing structure
7. Others – There are many other methodologies, such as use of Fibre Reinforced Polymers (FRP), which can be effectively used for retrofitting of existing RCC structures.

Harf Dardem Sirendur (2017)

Retrofitting Techniques

Slide no. 9



CORD

Retrofitting Techniques

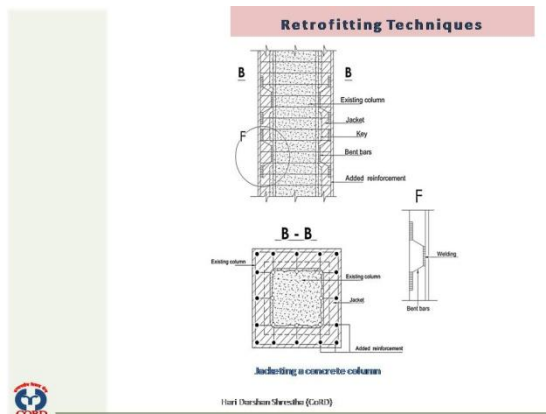
Similarly for masonry and adobe structures, following are some of the common methods:

1. Wall encasing wire meshing
2. Gabion wire
3. PP band
4. Introduction of bands and stitches
5. Strengthening/stiffening of roofs/floors
6. Anchorage of roofs/floors with walls
7. Strengthening of foundation
8. Grouting

Harf Dardem Sirendur (2017)

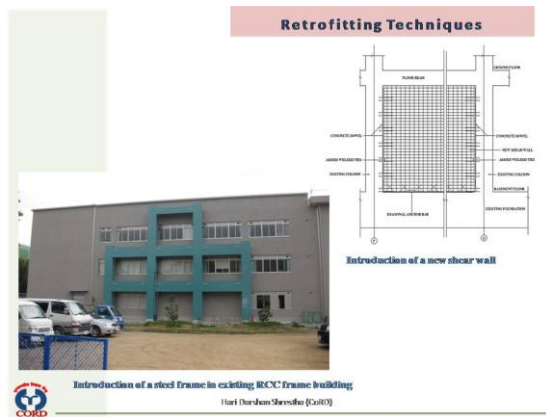
Retrofitting Techniques

Slide no. 10



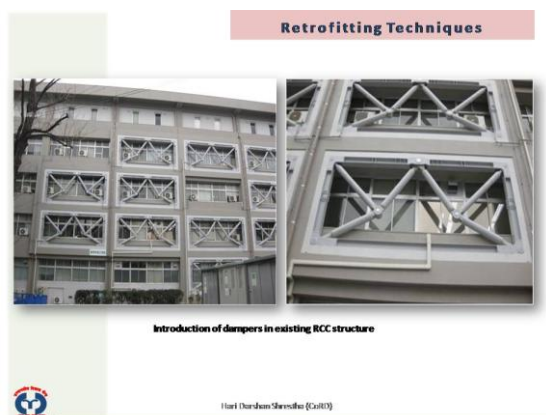
Retrofitting Techniques

Slide no. 11



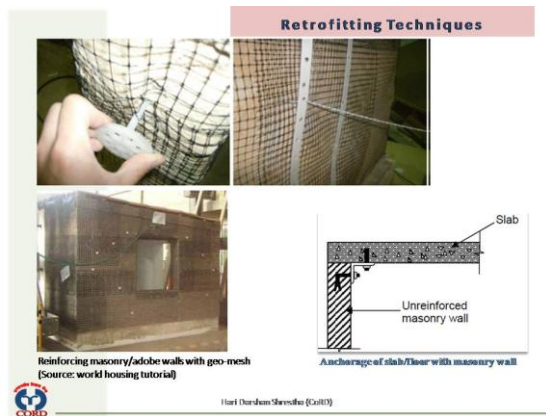
Retrofitting Techniques

Slide no. 12



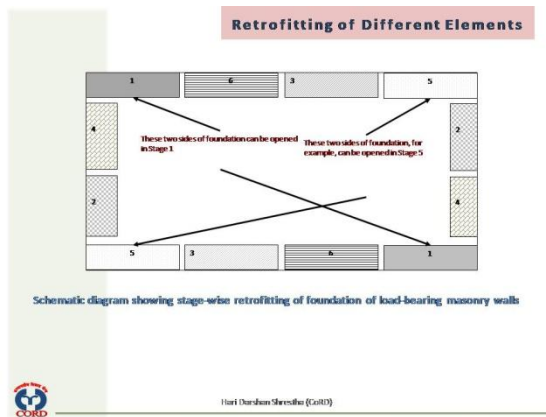
Retrofitting Techniques

Slide no. 13



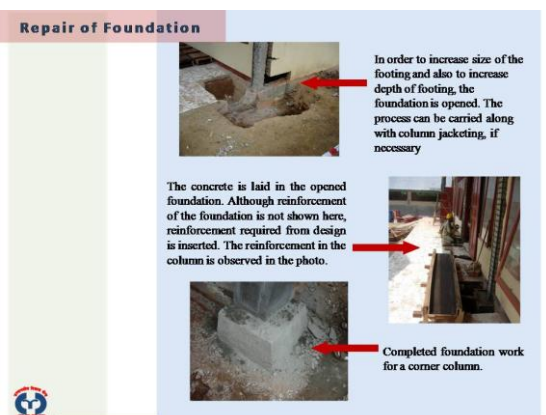
Retrofitting Techniques

Slide no. 14



Retrofitting of Different Elements

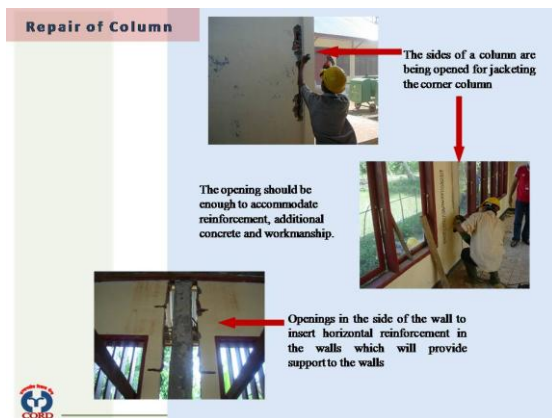
Slide no. 15



Repair of Foundation

Slide no. 16


Repair of Column



The sides of a column are being opened for jacketing the corner column.

The opening should be enough to accommodate reinforcement, additional concrete and workmanship.

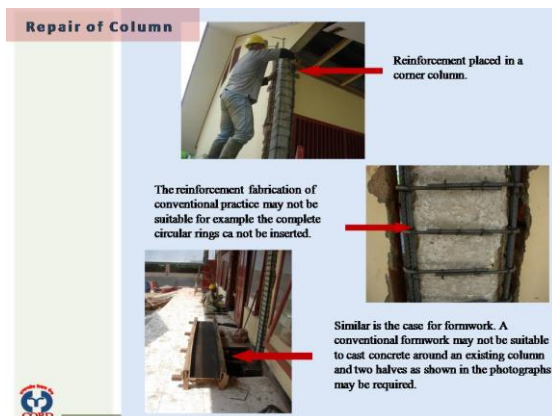
Openings in the side of the wall to insert horizontal reinforcement in the walls which will provide support to the walls.



Repair of Column

Slide no. 17


Repair of Column



Reinforcement placed in a corner column.

The reinforcement fabrication of conventional practice may not be suitable for example the complete circular rings can not be inserted.

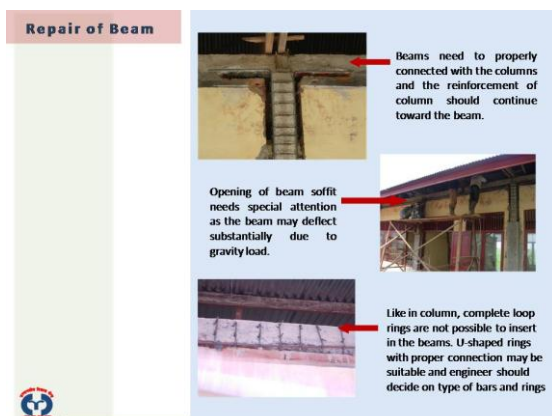
Similar is the case for formwork. A conventional formwork may not be suitable to cast concrete around an existing column and two halves as shown in the photographs may be required.



Repair of Column

Slide no. 18


Repair of Beam



Beams need to properly connected with the columns and the reinforcement of column should continue toward the beam.

Opening of beam soffit needs special attention as the beam may deflect substantially due to gravity load.


Like in column, complete loop rings are not possible to insert in the beams. U-shaped rings with proper connection may be suitable and engineer should decide on type of bars and rings.



Repair of Beam


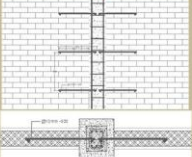

Slide no. 19

Repair 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.



Repair of Wall


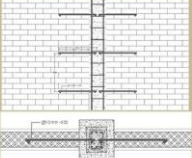

Slide no. 20

Repair 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.



Repair of Wall

Slide no. 21

Quality Control



Hardi Chandan Sharma (C/073)

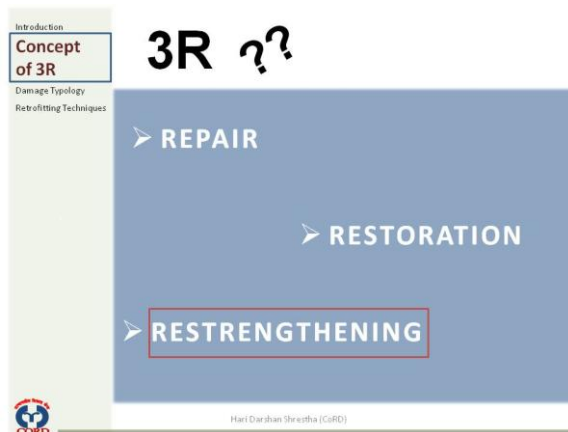


Quality Control

2.Presentation

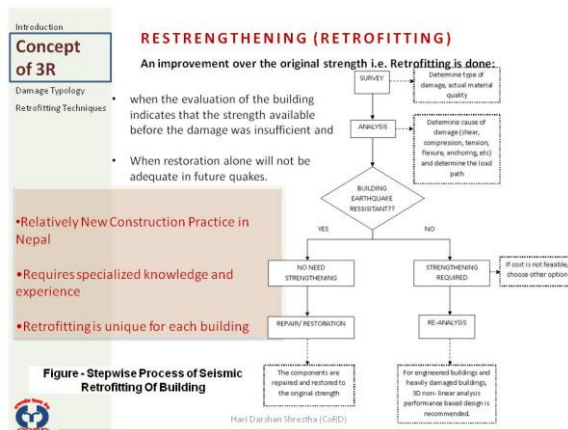
RETROFITTING TECHNIQUES: ADOBE AND MASONRY STRUCTURES

Slide no. 1



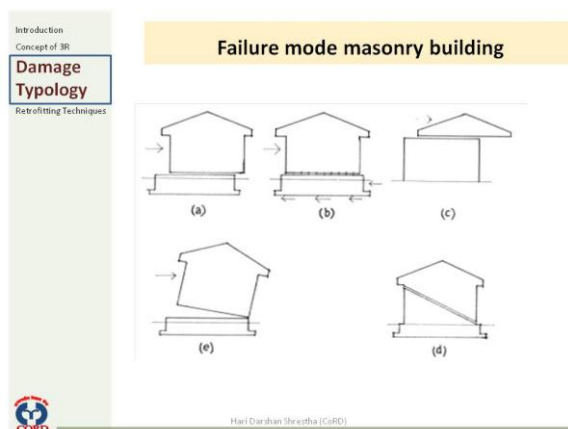
Concept of 3R

Slide no. 2



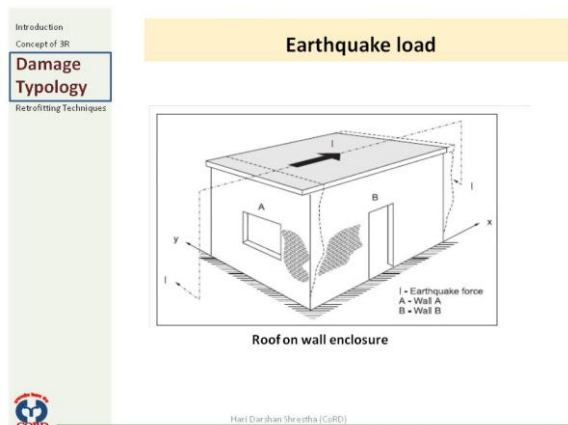
Stepwise Process of Seismic Retrofitting of Building

Slide no. 3



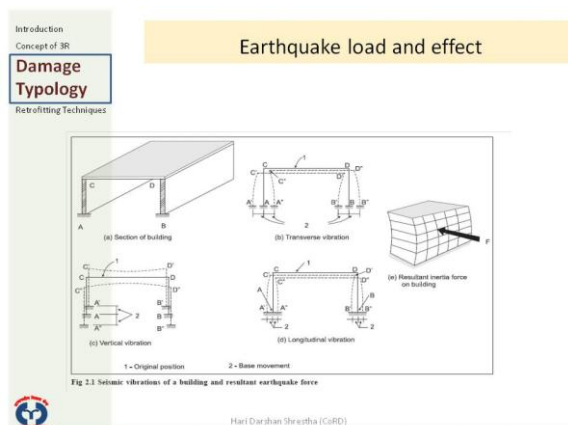
Failure mode of Masonry Building

Slide no. 4



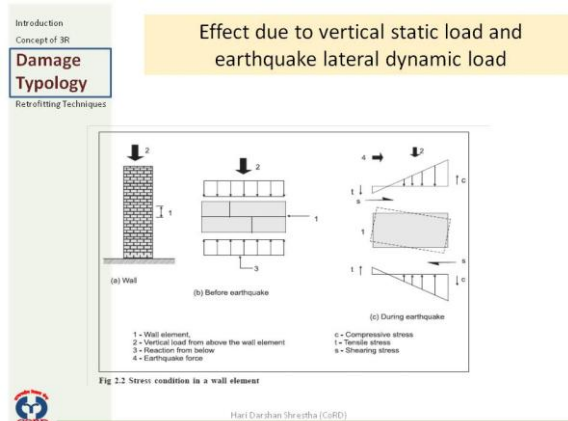
Earthquake Load

Slide no. 5



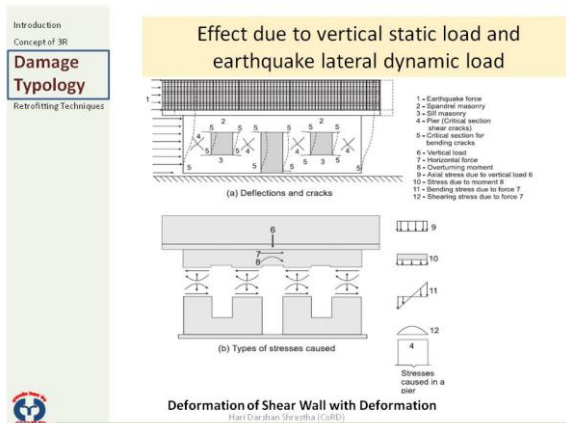
Earthquake load and its effect

Slide no. 6



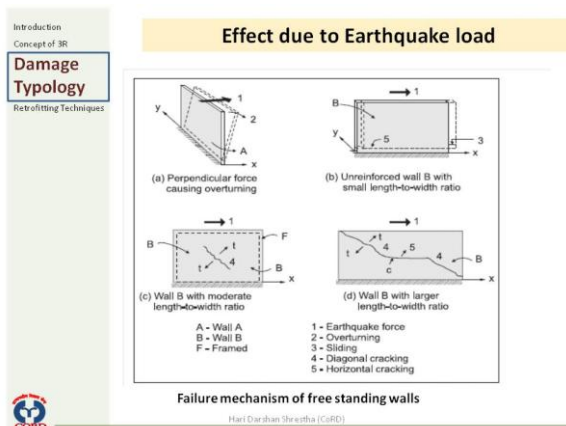
Effect due to vertical static load & earthquake lateral dynamic load

Slide no. 7



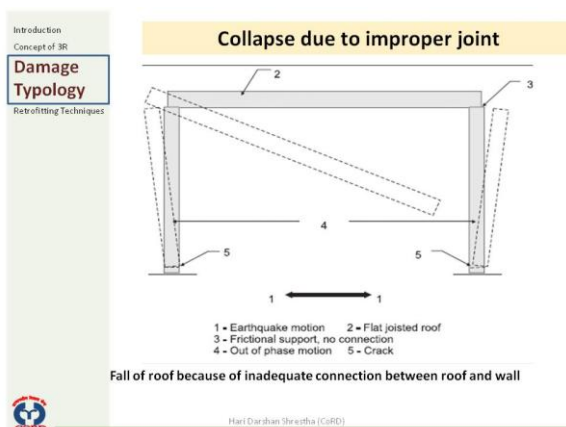
Effect due to vertical static load & earthquake lateral dynamic load

Slide no. 8



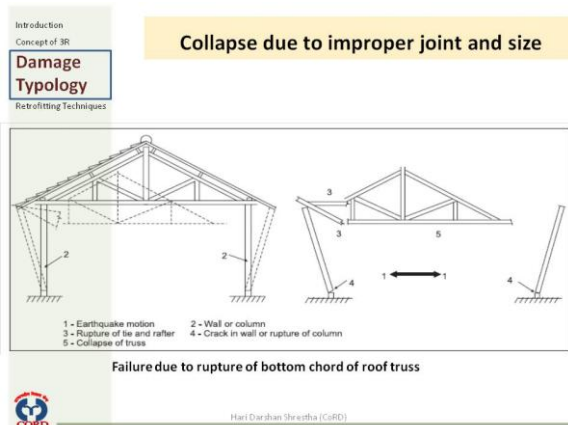
Effect due to earthquake load

Slide no. 9



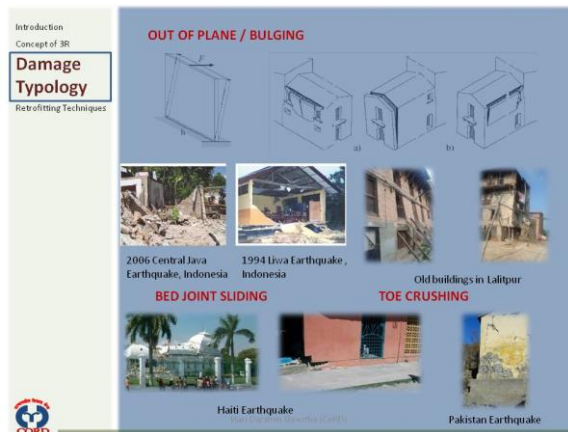
Collapse due to improper joint

Slide no. 10



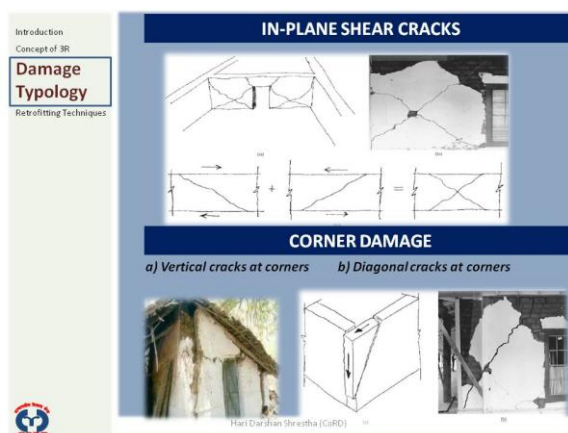
Collapse due to improper joint

Slide no. 11



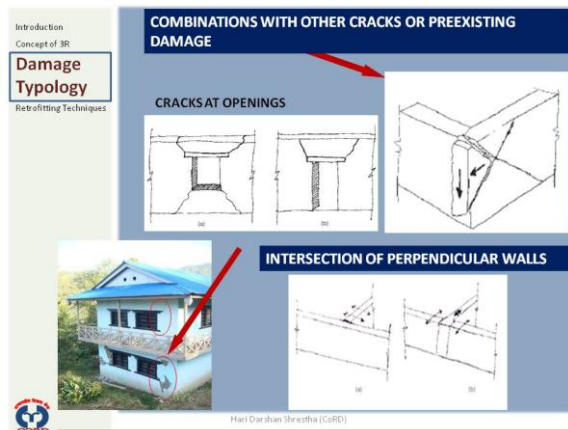
Damage Typology

Slide no. 12



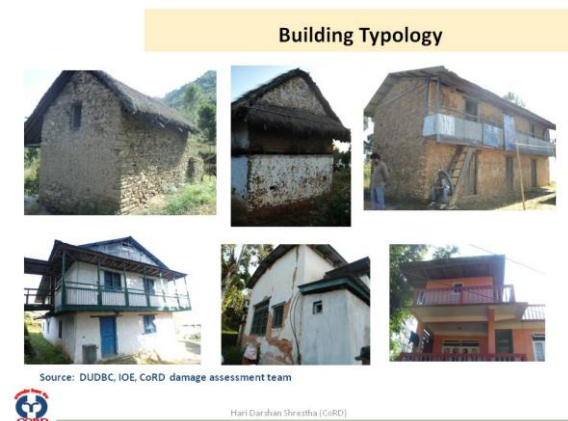
Damage Typology

Slide no. 13



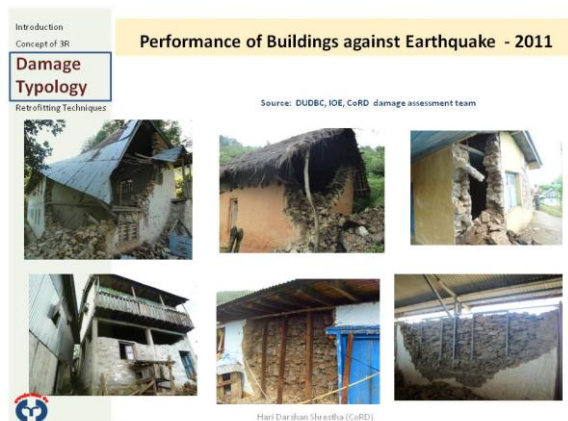
Damage Typology

Slide no. 14



Damage Typology

Slide no. 15




Performance of Buildings against Earthquake- 2011

Slide no. 16

Introduction
Concept of BR
Damage Typology
Retrofitting Techniques

Performance of Buildings against Earthquake - 2011



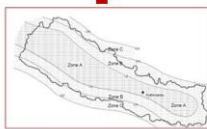
Source: DUGBC, IOE, CoRD damage assessment team
Hari Dardhan Shrestha (CoRD)

Performance of Buildings against Earthquake- 2011

Slide no. 17

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 Dardhan Shrestha (CoRD)

Retrofitting – General Requirement

Slide no. 18

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

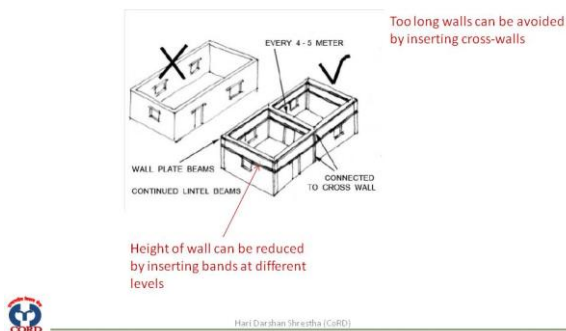


Hari Dardhan Shrestha (CoRD)

Retrofitting – General Requirement

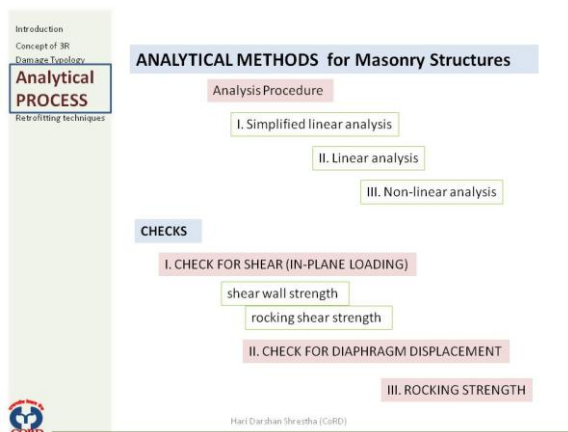
Slide no. 19

Retrofitting – General Requirements



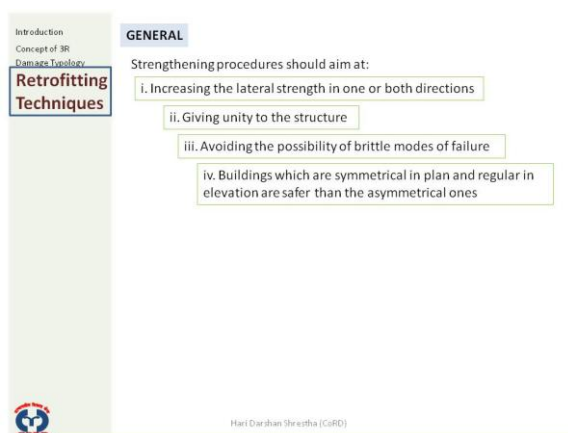
Retrofitting – General Requirement

Slide no. 20



Analytical Methods for Masonry Structures

Slide no. 21



Retrofitting Techniques - General

Slide no. 22

Introduction
Concept of SR
Damage Typology

Retrofitting Techniques

1. STRENGTHENING OF FLOOR/ ROOF

Aims:

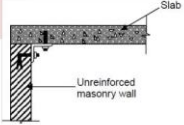
- Increasing in plane roof stiffness allows loads to be transferred more efficiently and evenly to the walls to which they are connected, enhancing wall to roof connection.
- Increase in-plane stiffness of horizontal diaphragms (floors and roof) so the seismic forces can be efficiently transferred to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



Slab
Unreinforced masonry wall

Hari Darshan Shrestha (CoRD)

Strengthening of Roof/ Floor

Slide no. 23

Introduction
Concept of SR
Damage Typology

Retrofitting Techniques

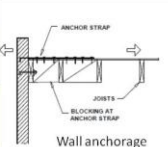
1. STRENGTHENING OF FLOOR/ ROOF

II. TIMBER FLOORS/ ROOFS

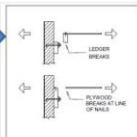
Wall shall be anchored at the roof and all floor levels at a spacing ≤ 6 foot (1.8 m) center to center.

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

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



ANCHOR STRAP
JOISTS
BLOCKING AT ANCHOR STRAP
Wall anchorage



WOODEN MEMBERS
PLANKS SPACED AT LINE OF WALL

Hari Darshan Shrestha (CoRD)

Strengthening of Roof/ Floor

Slide no. 24

Introduction
Concept of SR
Damage Typology

Retrofitting Techniques

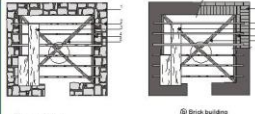
1. STRENGTHENING OF FLOOR/ ROOF

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.



Brick building
Brick building



1. Long plank
2. Diagonal metal strip
3. Nail
4. Nail
5. Nail
6. Nail
7. Nail
8. Nail
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Stiffening flat wooden floor / roof

Hari Darshan Shrestha (CoRD)

Strengthening of Roof/ Floor

Slide no. 25

Introduction
Concept of BR
Damage Topology

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 Dardhan Shrestha (CORD)

Strengthening of Roof/ Floor

Slide no. 26

Introduction
Concept of BR
Damage Topology

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

Slide no. 27

Introduction
Concept of BR
Damage Topology

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.	Mesh mm
One	One	10	N* B- **
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

Hari Dardhan Shrestha (CORD)

Wall Openings

Slide no. 28

Introduction
Concept of SR
Damage Topology

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

Hari Darshan Shrestha (CoRD)

Strengthening of Walls

Slide no. 29

Introduction
Concept of SR
Damage Topology

Retrofitting Techniques

3. STRENGTHENING OF WALLS

1. SEISMIC BELTS

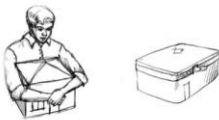
Aims:

- 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.



Upper wall element
Lower wall element

Figure: Seismic belt showing upper and lower wall elements

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Strengthening of Walls

Slide no. 30

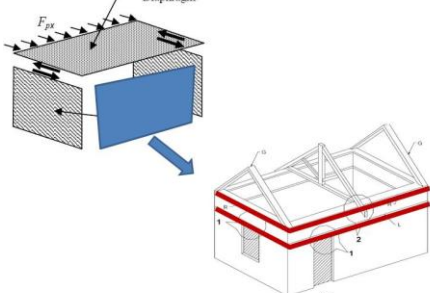
Introduction
Concept of SR
Damage Topology

Retrofitting Techniques

3. STRENGTHENING OF WALLS

1. SEISMIC BELTS

Horizontal Diaphragm

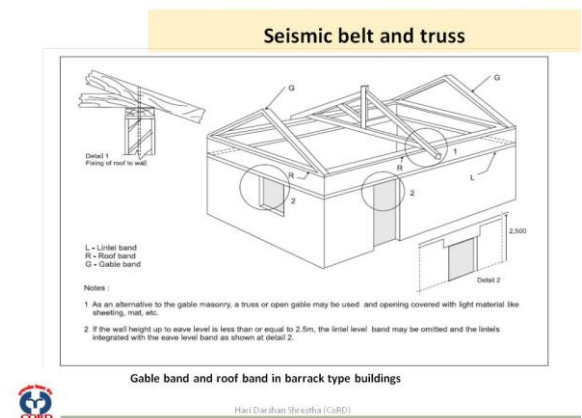


(a)

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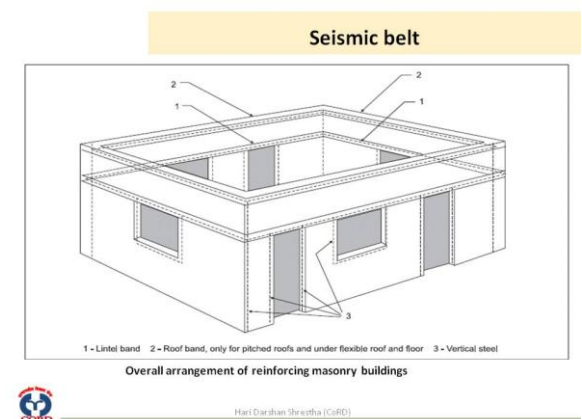
Strengthening of Walls

Slide no. 31



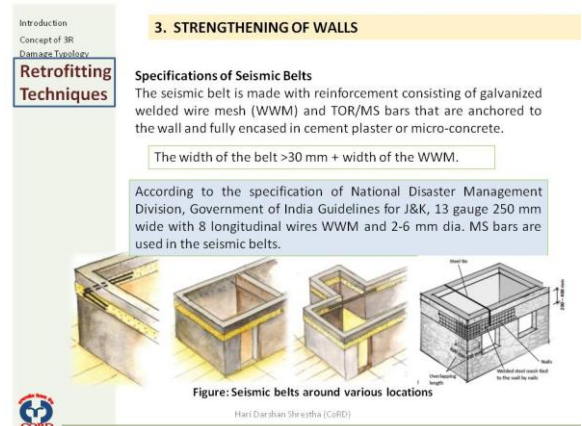
Seismic belt and truss

Slide no. 32



Seismic Belt

Slide no. 33



Specification of Seismic Belts

Slide no. 34

Introduction
Concept of BR
Damage Topology

Retrofitting Techniques

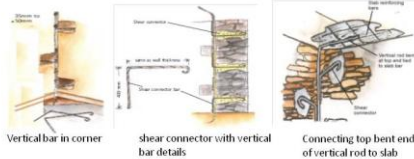
3. STRENGTHENING OF WALLS

Vertical Reinforcing

- Single vertical reinforcement
- Reinforcement with welded wire mesh, and
- 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. Generally 10-12 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

Slide no. 35

Introduction
Concept of BR
Damage Topology

Retrofitting Techniques

3. STRENGTHENING OF WALLS

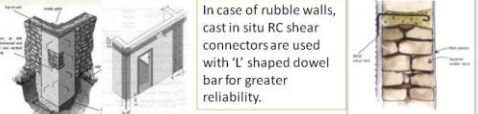
Vertical Reinforcing

- Reinforcement with Welded Wire Mesh (WWM)
- Post-tensioning

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.

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



Vertical reinforcement with WWM 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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Vertical Reinforcing

Slide no. 36

Introduction
Concept of BR
Damage Topology

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. 37

Introduction
Concept of 3R
Damage Typology

Retrofitting Techniques

3. STRENGTHENING OF WALLS

b. Bamboo Reinforcing



adobe wall is reinforced by bamboo straps with internal chicken wire mesh

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Stiffening Wall/ Wall Jacketing

Slide no. 38

Introduction
Concept of 3R
Damage Typology

Retrofitting Techniques

3. STRENGTHENING OF WALLS

c. External Cane and Rope Mesh

Vertical cane tied with horizontal ropes forming an approximately 450 mm square mesh.



d. External wire mesh reinforcement

Nailing wire mesh bands against the adobe walls and then covering them with cement mortar.

e. External polymer mesh reinforcement

- Polymer mesh (geomesh) is compatible with the earthen wall deformation
- Provide an adequate transmission of tensile strength to the walls up to the final state.
- The mesh forming a confinement prevents the total collapse.



CoRD

Stiffening Wall/ Wall Jacketing

Slide no. 39

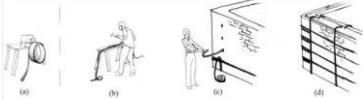
Introduction
Concept of 3R
Damage Typology

Retrofitting Techniques

3. STRENGTHENING OF WALLS


f. Used Car Tire Straps

- Uses circumferentially cut straps from the treads of used car tires for tension reinforcement.
- Enhances the in-plane and out-of-plane resistance of adobe walls.
- Improve life safety rather than preventing economic loss of property during an earthquake.



Potential crack
Horizontal straps
Vertical straps

At least one pair of straps, either vertical or horizontal, should cross every large potential crack that will open during an earthquake



Elevation

Hari Darshan Shrestha (CoRD)

Stiffening Wall/ Wall Jacketing

Slide no. 40

Introduction
Concept of BR
Damage Typology
Retrofitting Techniques

4. STRENGTHENING FOUNDATION

Retrofitting may require –
Evaluation of local soil condition
Foundation condition
Strengthening of foundation

- Soil Material Improvement
 - Improvement in vertical bearing capacity
 - Increase in friction
 - Increase in passive resistance

↓

- Retrofitting may be achieved by –
 - Soil Material Improvement
 - Treatment of foundation at shallow depth
 - Treatment of foundation by using piles

Hari Darshan Shrestha (CoRD)

Strengthening of Foundation

Slide no. 41

Introduction
Concept of BR
Damage Typology
Retrofitting Techniques

4. STRENGTHENING FOUNDATION

Strengthening existing foundations is a difficult and expensive task.
A special investigation is recommended before any such intervention.

Foundation structure with differential settlement can be supported by **UNDERPINNING**. (fig a)

Sliding movement of a foundation can be prevented by constructing **NEW RC SUPPORTING BEAMS** or **PROVIDING RC BELTS**. (fig b)

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Strengthening of Foundation

Slide no. 42

Good Practice – Survived in Eastern Earthquake

Hari Darshan Shrestha (CoRD)

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

1. Introduction on Concept Of Repair, Restoration And Retrofitting

Buildings are designed to perform at required performance level throughout its life. The material degradation due to aging and alterations carried out during use over time necessitates the operations like Repair, Restoration and Retrofit. The decay of building occurs due to original structural inadequacies, weather, load effects, earthquake, etc.



Reinforcing old concrete with surface for concrete bonding

Anchoring old concrete with new concrete

Grouting on seismic resistance

Carbon fiber retrofitting


Introduction to Repair, Restoration & Retrofitting

Slide no. 2

2. Required Performance Level
Immediate Occupancy (IO)
Life Safety (LS)
Collapse Prevention (CP)

3. Seismic Assessment
Rapid Assessment (Visual Survey)
Methodology For Rapid Seismic Assessment

Preliminary Evaluation
Site Visit
Acceptability Criteria
Detailed Evaluation



Schmidt Hammer

Ferro Scanner

Introduction to Repair, Restoration & Retrofitting

Slide no. 3

4. Seismic Evaluation
Categorization Of Damage
Overview Of Some Damaged RC Buildings And Its Cause




Fig. 3
The solid building tilted as a rigid body and the raft foundation rises above the ground

Soft Storey

Short Column due to partial masonry wall

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 masonry infill walls, water tanks, staircase, parapets.

Site Visit & Collection of Data


Slide no. 6

CONFIGURATION-RELATED CHECKS

❖ Geometry

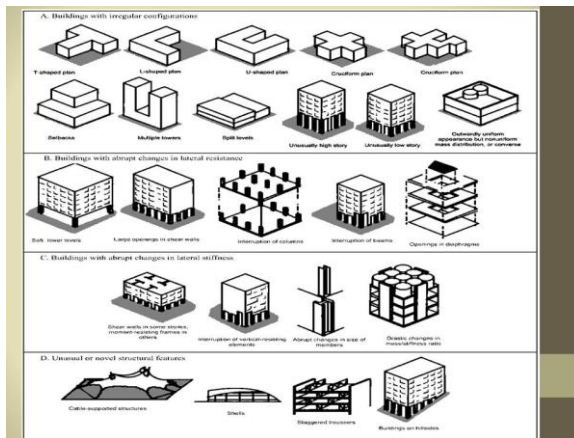
- Check for geometry of building along plan and elevation
- Check for Symmetry of the building

Vertical Irregularity Building in Kathmandu



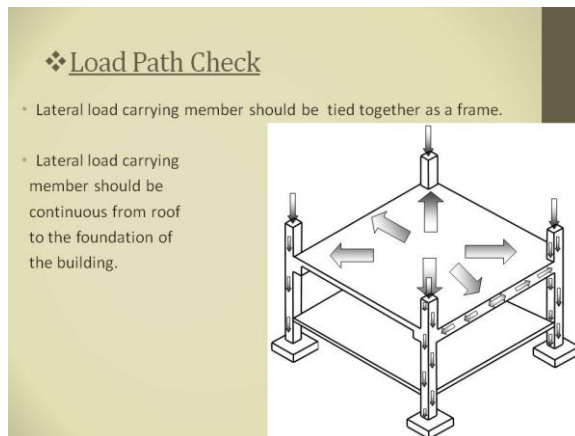
Configuration Related Check

Slide no. 7



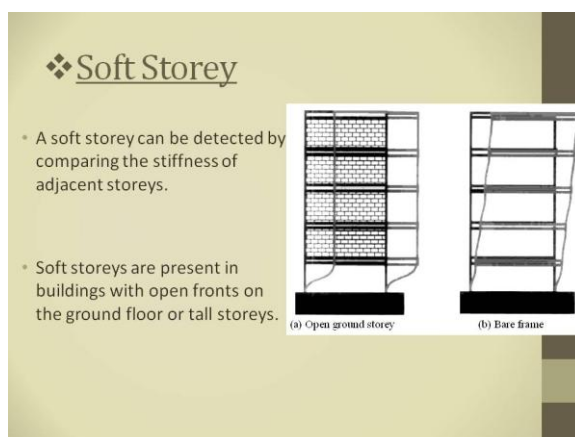
Configuration Related Check

Slide no. 8



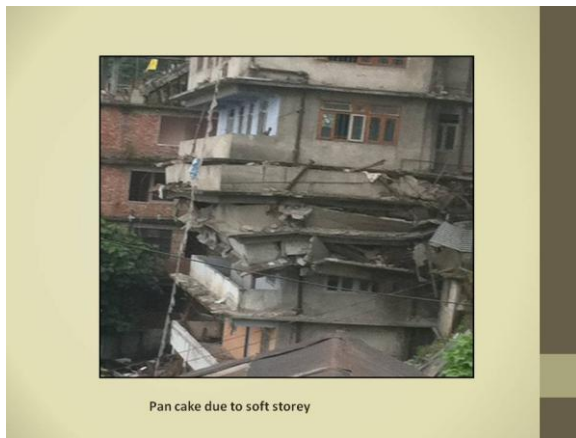
Load Path Check

Slide no. 9



Soft Storey

Slide no. 10



Soft Storey

Slide no. 11



Soft Storey

Slide no. 12

❖ Weak Storey

- The strength of the vertical lateral force resisting system in any storey shall not be less than 70% of the strength in an adjacent storey.

Weak Storey

Slide no. 13



Soft Storey

Slide no. 14

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.

MASS RATIO

WHEN $W_i > 2.0 W_{i-1}$
OR $W_i > 2.0 W_{i+1}$
Mass Irregularity

Mass Irregularity

Slide no. 15

❖ 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.

Short Cloumn

Slide no. 16



Short Cloumn

Slide no. 17

❖ Effect of Adjacent Building

- Buildings with same height and matching storeys will show similar behavior and pounding damages will be limited.
- Clear distance between two building is preferred to be 0.04 times the height of short building

❑ Pounding in situation (b) is far more damaging.

(a)

(b)

Effect of Adjacent Building

Slide no. 18

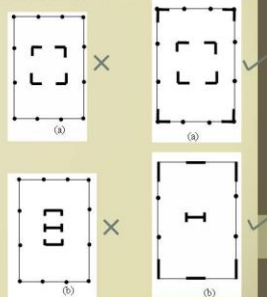


Pounding Damage due to Adjacent Building

Slide no. 19


❖ Torsional Effect

- Torsional failures are seen to occur where the symmetry is not planned in the location of the lateral structural elements.
- Center of mass and the center of stiffness of a storey shall be less than 30% of the building dimension at right angles to the direction of loading considered.



Torsion Effect

Slide no. 20



L shaped building at the street corners whose lift core is at one corner of building which is very unsymmetric.

Top Floor Collapse due to Torsion in Mexico City Earthquake in September 1985

Damages

Slide no. 21

Strength – Related Check

- Check axial stress, shear and moment in frame within allowable limit and its capacity.
- Check shear stress for RC masonry infill walls.

Strength Related Check

Slide no. 22

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.

Detailed Evaluation


Slide no. 23

❖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

Detailed Evaluation


Slide no. 24



Founding due to adjacent building



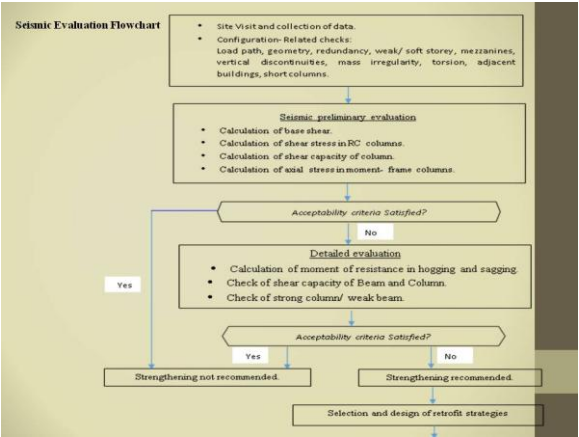
Column Tie spacing and hook



Strong Column Weak Beam

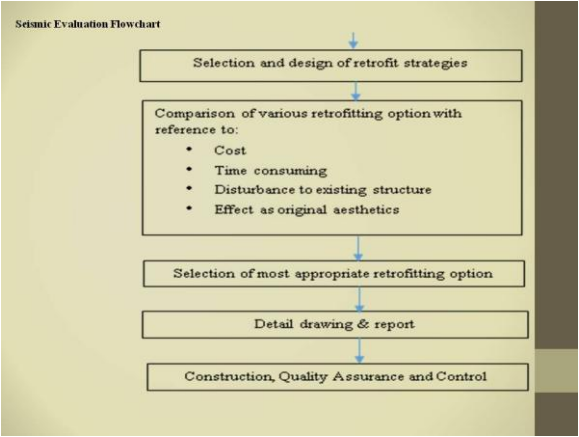
Damages

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

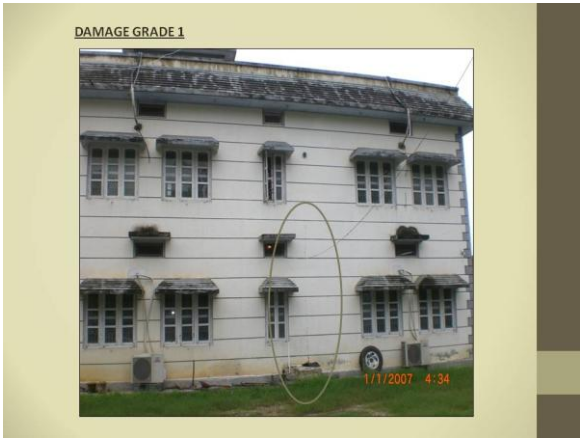
Slide no. 28

CATEGORIZATION OF DAMAGE GRADE (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

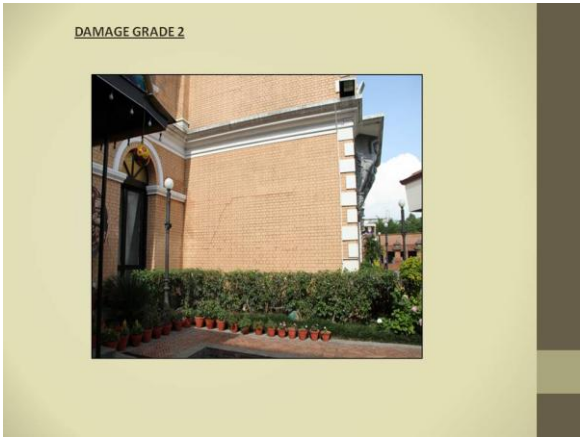
Categorization of Damage Grade

Slide no. 29



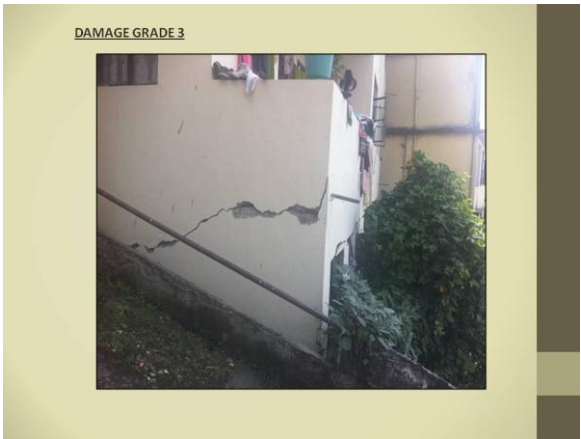
Damage Grade 1

Slide no. 30



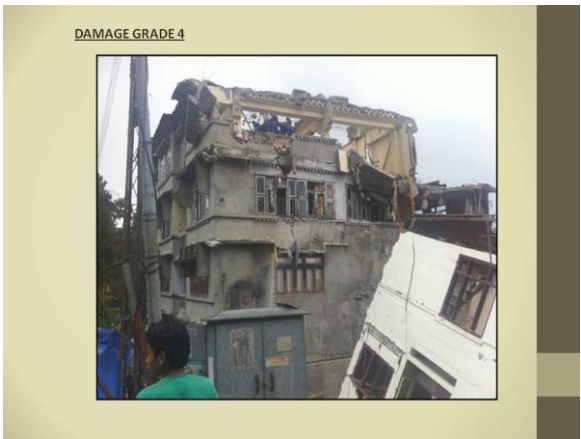
Damage Grade 2

Slide no. 31



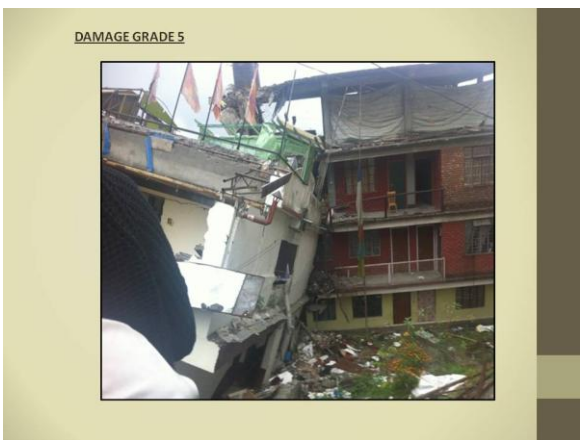
Damage Grade 3

Slide no. 32



Damage Grade 4

Slide no. 33



Damage Grade 5

Slide no. 34


5. Seismic Strengthening Strategy

a) System Strengthening and Stiffening

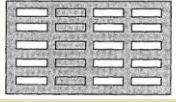
- Shear wall into an existing concrete structure
- Buttresses perpendicular to an external wall of the structure
- Moment resisting frames
- Infill walls
- Trusses and Diagonal Braces
- Diaphragm Strengthening
- Others

Seismic Strengthening Strategy

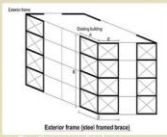
Slide no. 35



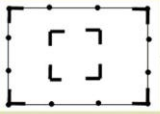
Buttress Addition



Infill Wall



Exterior frame (steel framed truss)
Girding on weak column




Shear wall Addition


Seismic Strengthening Strategy

Slide no. 36


b) Strengthening of original structural elements




Roughening of old surface by chipping of existing concrete surface



Anchorage of new reinforcement with the existing structure



Welding of new reinforcement with existing one



Quality control by testing concrete grade

Seismic Strengthening Strategy

Slide no. 37

6. Seismic Retrofitting Option

➤ RC Jacketing Of Columns and other elements

➤ Steel Jacketing Of Columns and other elements

➤ Addition of RC Shear Wall

➤ Addition of Steel Bracing

➤ Others

Seismic Retrofitting Option

Slide no. 38



Reinforcement layout for column jacketing



Steel jacketing of column



Reinforcement placing for beam jacketing



Reinforced concrete jacketing of column



Steel jacketing of column and beam



Top reinforcement detailing of beam jacketing

Seismic Retrofitting Option


Slide no. 39




Reinforcement layout at foundation for retrofit



Foundation retrofit with concrete




Shear wall addition with column jacketing



Reinforcement layout at foundation for retrofit



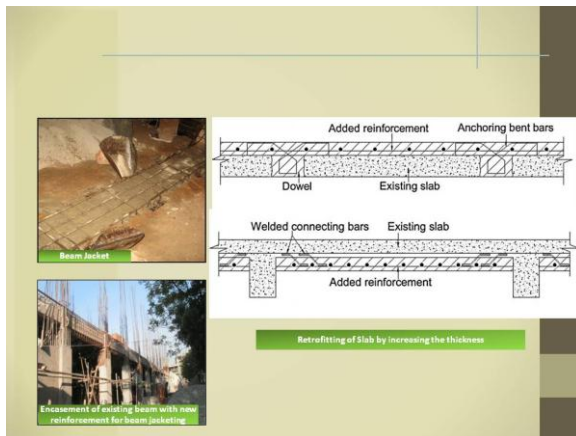
Reinforcement layout at foundation for retrofit



Shear wall addition with column jacketing

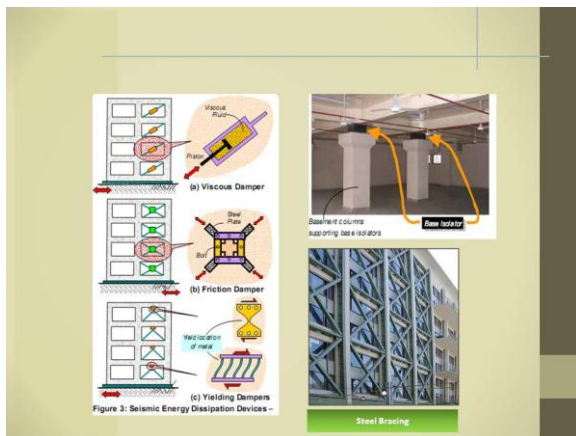
Seismic Retrofitting Option

Slide no. 40



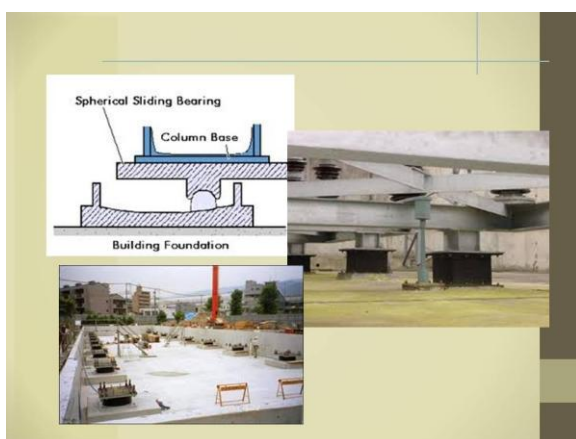
Seismic Retrofitting Option

Slide no. 41



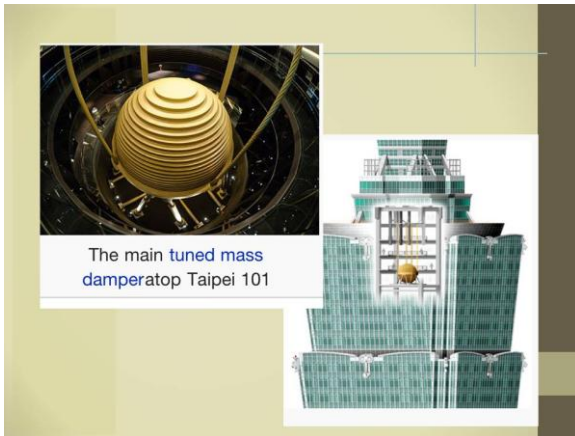
Seismic Retrofitting Option

Slide no. 42



Seismic Retrofitting Option

Slide no. 43



Example

1. Presentation:

INTRODUCTION TO NON-DESTRUCTIVE TEST

Slide no. 1



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

Overview and Introduction

Slide no. 2



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

Definition

Slide no. 3



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

Historical Background

Slide no. 4



Classification

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

Our Formula – Your Solution

Classification

Slide no. 5



Methods

- To estimate strength
- To evaluate conditions other than strength

Our Formula – Your Solution

Methods

Slide no. 6



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

In-place Tests to Estimate Strength

Slide no. 7



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

Non-Destructive Tests for Integrity

Slide no. 8



Durability Tests

- Core Sampling
- Strength Determination, Chemical Analysis, Excess Voidage Estimation, Petrographic Analysis
- Carbonation
 - pH
 - Moisture content
 - Resistivity

Our Formula – Your Solution

Durability Test

Slide no. 9



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

Techniques for Quality Assurance, Failure Investigation and Strengthening Techniques

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



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

Products and System for Repair and Strengthening RC Structures

DAY 3

6. Quality Control

7. Demolition and Retrofitting Techniques at Site

2. Presentation

QUALITY CONTROL

Slide no. 1

Quality Control in the field is essential

Building performs the way it is constructed !!!

Not the way it's designed



Not the way we wish **Not the way it looks**

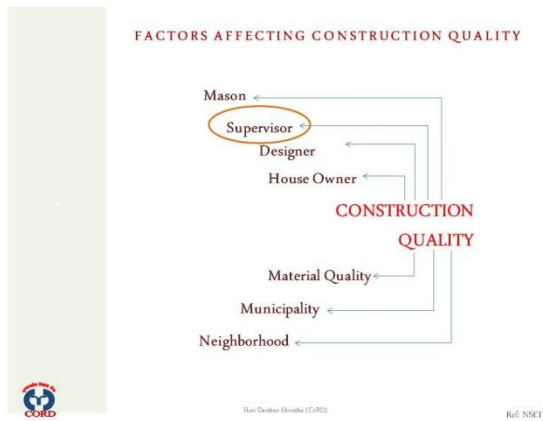


Hani Dattani Shrivastha (GPRD)



Quality Control in Field

Slide no. 2



Factors affecting construction Quality

Slide no. 3

QUALITY IN CONSTRUCTION MATERIAL

<p>SAND</p> <ul style="list-style-type: none"> -from rivers/quarries -clean from mud -Clean from organic materials 	<p>BRICKS</p> <ul style="list-style-type: none"> -completely burnt -flat, not warping -does not break easily -uniform size -corners not damaged -min. size 20x10x5 cm 
<p>CEMENT</p> <p>Portland Cement</p> <ul style="list-style-type: none"> -Not hardened -dry -in 45/50 kg bags -not mixed with other materials -uniform color 	<p>GRAVEL</p> <ul style="list-style-type: none"> -from rivers/ quarries -clean from mud -clean from organic materials -1-2cm dia 
<p>WATER</p> <ul style="list-style-type: none"> -Clean, clear without smell, potable -No oil, acid, alkali, salt, organic material that can affect the RC bars 	

Ref: Constructing Seismic Resistant Masonry Houses, Taddy Boon & Associates



Quality in Construction Material

Slide no. 4

Quality in Construction Material

CONCRETE BLOCKS

- best from concrete mix
- corners not damaged
- no cracks



RC BARS

- uniform size
- not rusted
- straight
- conform with standard bars
- diameter in accordance with drawings



TIMBER

- dry and straight
- no cracks, notch
- treated against termite
- well seasoned



RUBBLESTONE

- size as uniform as possible
- rough surface, not smooth





Ref: Constructing Seismic Resistant Masonry Houses, Taddy Bean & Associates


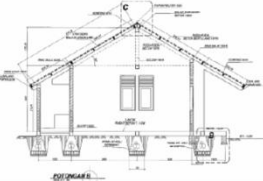
Quality in Construction Material


Slide no. 5

Gap between design and construction

Huge Gap between Engineering and Construction Works

- Survey in Banda Aceh
- Construction works does not meet the requirement of drawings and specifications






Gap between design and construction


Slide no. 6

Quality in Construction Material

BRICK

1. Compressive Strength : 7.5 N/mm²
2. Properly/evenly baked, smooth texture with red colour.
3. Even in Shape and Size
4. Should give mettalic sound when struck
5. Should not absorb more than 25% of water when soaked for 24 hours.





Ref: NSET

Quality in Construction Material- Brick

Slide no. 7

A. Bricks: Wetting test

- 1 Inch circle in brick with Wax Pencil
- 20 drops of water
- If all the water is absorbed within 90 seconds, brick wetting is necessary.

BRICK TEST

2 cm diameter balls, 48 hrs. dried should not break by pressing

4 weeks sun-dried adobe should support weight of a man

Brick Test

Slide no. 8

Bricks must be soaked min 10 minutes prior to laying & shall be laid immediately.

BRICK TEST

Mortar Mix
1 PC (cement) 4 Sand
Mix properly & add water appropriately

Mortar thickness 1.5 cm
Mortar mix 1 cement 4 sand
Surface must be horizontal

Curing : Brick must be sprayed periodically

Ref: Constructing Seismic Resistant Masonry Houses, Tolly Breen & Associates

Brick Test

Slide no. 9

Quality in Construction Material

CEMENT

1. Grades:
 - i. 33, 43, 53 and 55 grades
2. Should be used within two months from manufacture date
3. Should be properly packed in air tight container and without holes.
4. To be stored in dry and moisture free rooms
5. Should be in the state of free flow fine powder.
6. Should not be less than 43 grade for RCC or structural works



Ref: NSRF

Quality in Construction Material- Cement

Slide no. 10

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: NSIT

Quality in Construction Material- Cement

Slide no. 11

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: NSIT

Quality in Construction Material- Cement

Slide no. 12

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



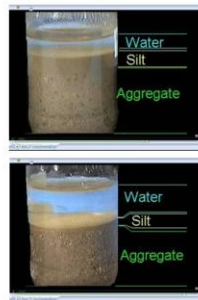
Ref: NSIT

Quality in Construction Material- Cement

Slide no. 13

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 %



Sand Silt Test

Slide no. 14

ORGANIC TEST

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



Organic Test

Slide no. 15

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

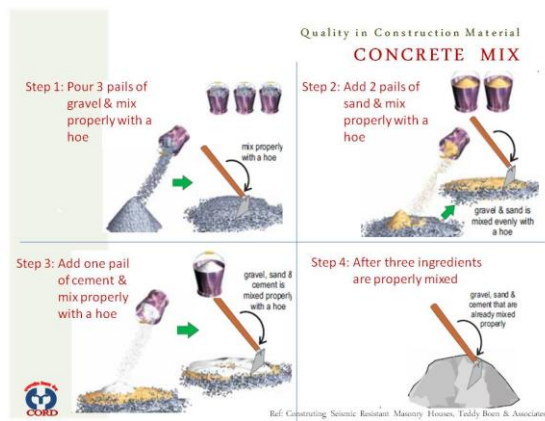
For other thickness, follow specification



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

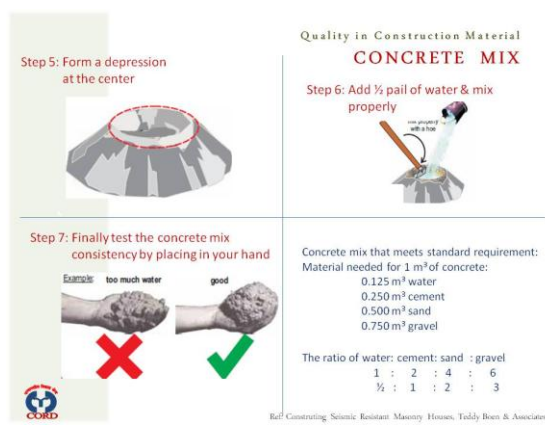
Quality in Construction Material- Gravel

Slide no. 16



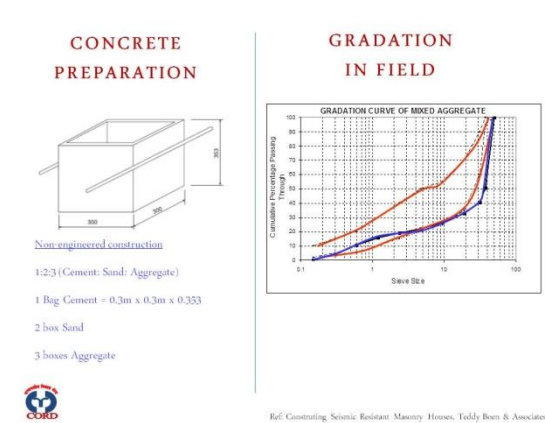
Concrete Mix

Slide no. 17



Concrete Mix

Slide no. 18




Concrete Preparation and Gradation in field


Slide no. 19

Quality in Construction Material

RC BARS

- 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





Quality in Construction Material- RC bars

Slide no. 20

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 : $2(A+B) + 2(C+E) - 8F$
 $2=(120+120) + 2(48+20) - 8 \times 15$
 $= 496 \text{ mm}$
 $= 49.6 \text{ cm}$



Ref: Constructing Seismic Resistant Masonry Houses, Todd Beem & Associates


Quality in Construction Material- RC bars

Slide no. 21

Quality in Construction Material

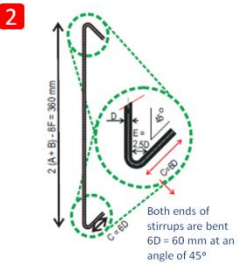
RC BARS- STIRRUPS

1




Concrete cover thickness 1.5cm from stirrup axis

2



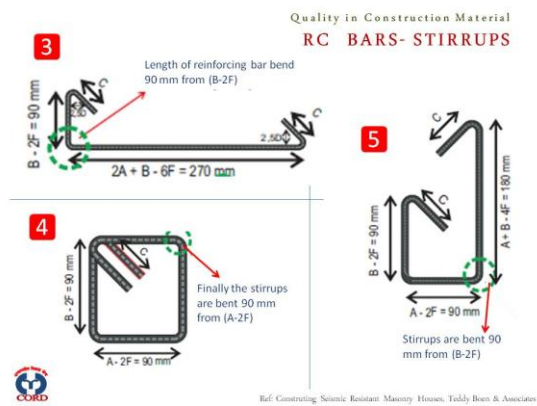
Both ends of stirrups are bent 60 = 60 mm at an angle of 45°



Ref: Constructing Seismic Resistant Masonry Houses, Todd Beem & Associates

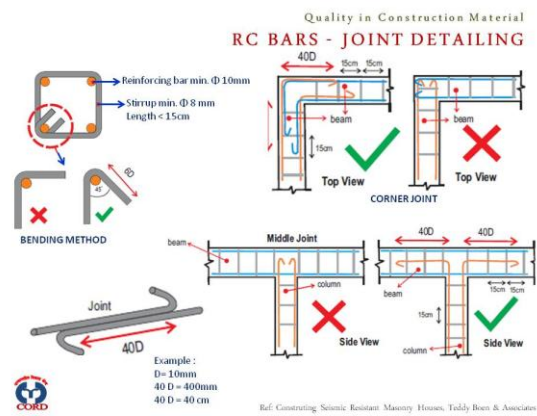
Quality in Construction Material- RC bars - stirrups

Slide no. 22



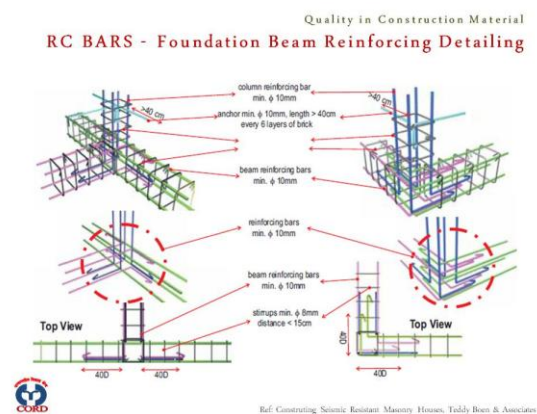
Quality in Construction Material- RC bars- stirrups

Slide no. 23



RC bars –Joint detailing

Slide no. 24



RC bars- Foundation Beam Reinforcing Detailing

Slide no. 25

Quality in Construction at site

Quality in Construction at Site

No proper mixing and placing

Improper Mixture of Concrete

- Improper mixture ratio/ too little cement
- Too much water
- Inadequate placing/ No compacting

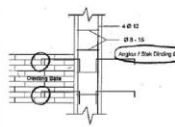


Slide no. 26

Quality in Construction at site

Quality in Construction at Site

Lack of Proper Detailing



Widely spaced hooks



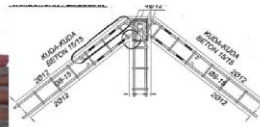
Slide no. 27

Quality in Construction at site

Quality in Construction at Site

Lack of Proper Detailing

Construction does not follow the drawing, which requires longitude rebars in columns bended and connected to beams



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

"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 Fillion, USGS retired, *New York Times*, December 27, 2004



Hani Ozkanli (CORD)

Natural hazards are inevitable, Natural disasters are not!

Slide no. 33



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.

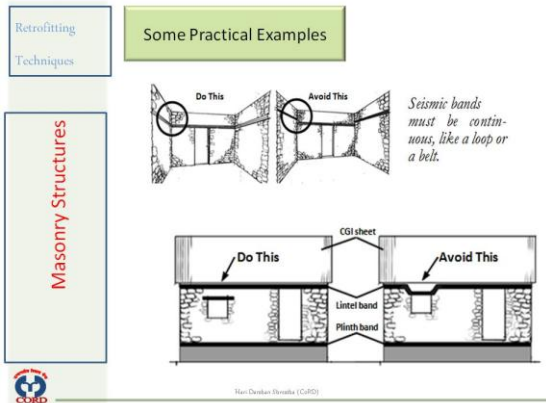
Continuous monitoring and supervision is required. Quality check of finished product is recommended.



Hani Ozkanli (CORD)

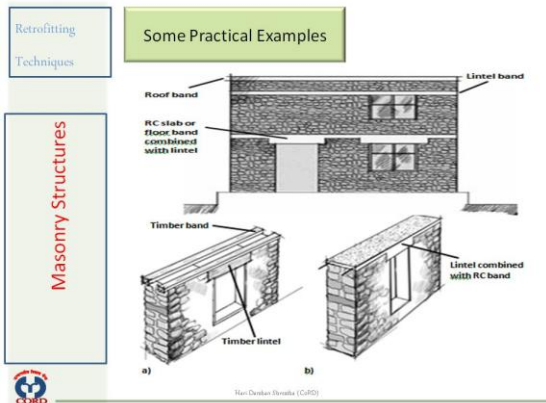
Quality control at site

Slide no. 34



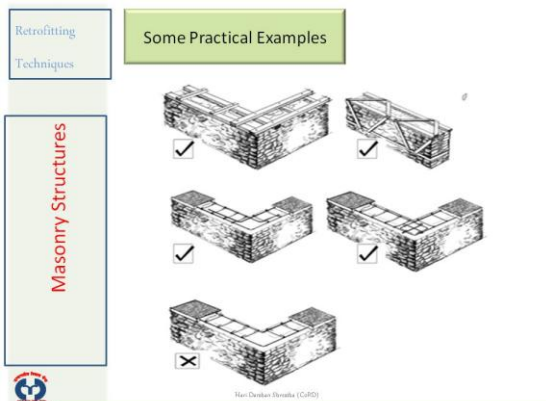
Practical Examples

Slide no. 35



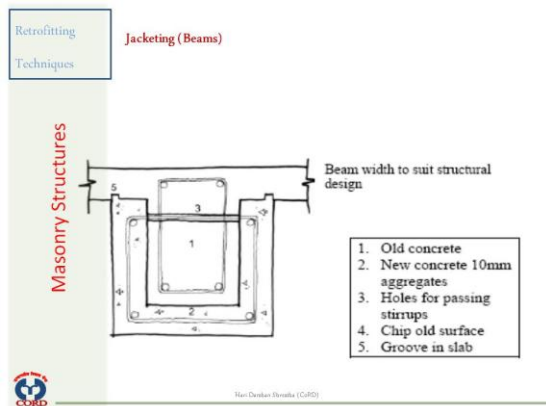
Practical Examples

Slide no. 36



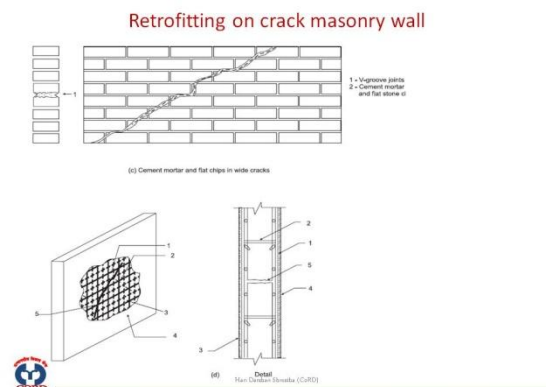
Practical Examples

Slide no. 37



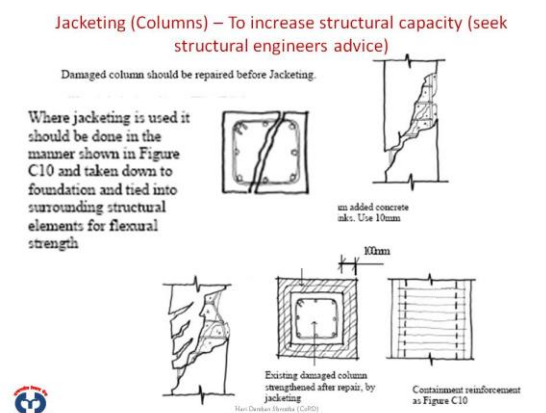
Practical Examples

Slide no. 38



Practical Examples

Slide no. 39



Practical Examples

Slide no. 40

Concrete strength to be 20 N/mm² (minimum)

Cover to bars to all sides: Beams – 35mm

Slabs - 25mm

Columns - 40mm

Ground beams – 50mm

Foundations – 75r

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 used to allow for ductile behaviour (sized after calculations). Minimum steel should be 0.12% diameter bars, less than 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.



Heri Darmasetyawan (CoED)

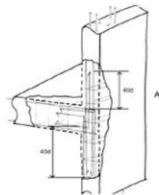
Practical Examples

[illegible]

Slide no. 41

Detail A: REPAIRS TO COLUMN BEAM JOINTS

- 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.



Hani Darmasetya (CoPI)

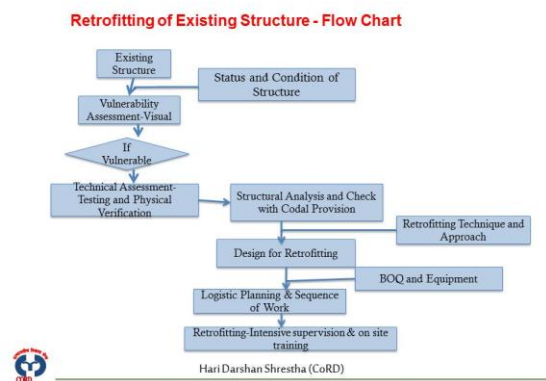
Strengthening of Foundation

[illegible]

7. Presentation

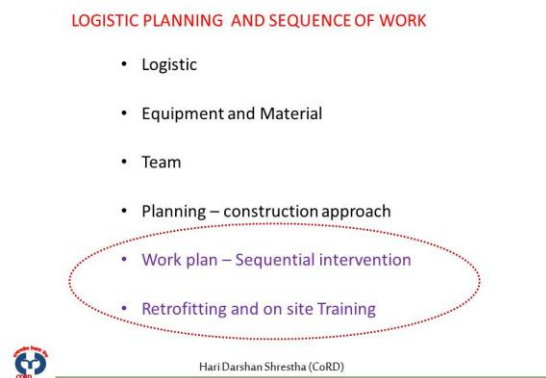
DEMOLITION AND RETROFITTING TECHNIQUES

Slide no. 1



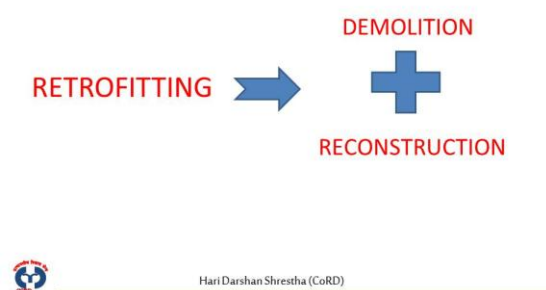
Retrofitting of Existing Structures

Slide no. 2



Logistic Planning and Sequence of Work

Slide no. 3




Retrofitting

Slide no. 4

EQUIPMENTS AND MATERIALS FOR RETROFITTING

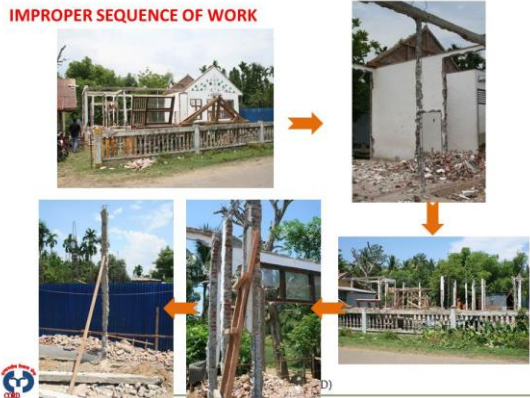
1. Concrete cutter	8. Vibrator
2. Electrical Drilling machine	9. Wheel Barrow
3. Jack Hammer	10. Other regular tools and equipment
4. Hammer	11. Material for form work
5. Chisel	12. Construction material- steel bar, cement, sand, aggregate, timber and others
6. Gun for adhesive	
7. Concrete mixtures	


 Hari Darshan Shrestha (CoRD)

Equipment and Materials for Retrofitting

Slide no. 5

IMPROPER SEQUENCE OF WORK

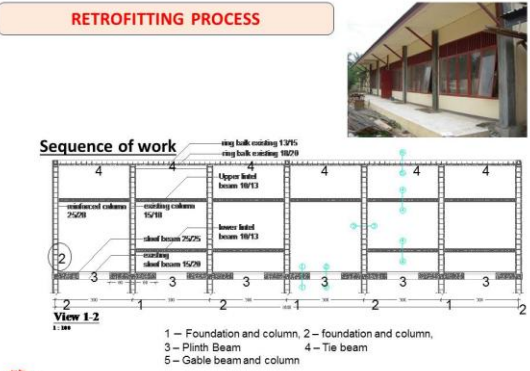




Improper sequence of Work


Slide no. 6

RETROFITTING PROCESS



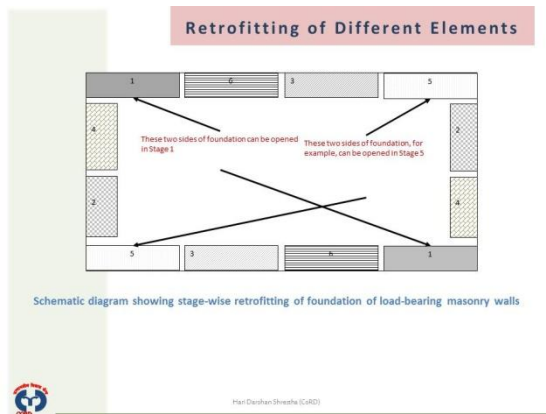
Sequence of work

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

 Hari Darshan Shrestha (CoRD)

Retrofitting Process

Slide no. 7



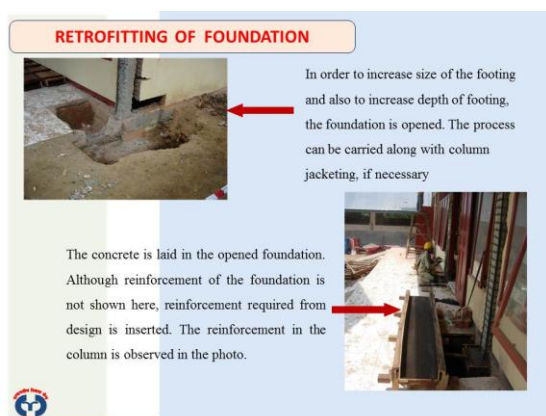
Retrofitting of Different Elements

Slide no. 8



Retrofitting of Foundation

Slide no. 9



Retrofitting of Foundation

Slide no. 10

RETROFITTING OF FOUNDATION

Cut the necessary part of the adjoining walls



Formwork for reconstruction





Completed foundation work for a corner column.

Retrofitting of Foundation

Slide no. 11

RETROFITTING OF COLUMN




Dismantling Process



Retrofitting of Column


Slide no. 12

RETROFITTING OF COLUMN




The sides of a column are being opened for jacketing the corner column

The opening should be enough to accommodate reinforcement, additional concrete and workmanship.



Openings in the side of the wall to insert horizontal reinforcement in the walls which will provide support to the walls




Retrofitting of Column


Slide no. 13

RETROFITTING OF COLUMN


Column Jacketing



Reinforcement placed in a corner column.



The reinforcement fabrication of conventional practice may not be suitable, for example the complete circular rings can not be inserted.





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Retrofitting of Column

Slide no. 14

RETROFITTING OF COLUMN

Anchorage to the wall







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Retrofitting of Column


Slide no. 15

RETROFITTING OF COLUMN

Preparation of Formwork



Similar is the case for formwork. A conventional formwork may not be suitable to cast concrete around an existing column and two halves as shown in the photographs may be required.



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Retrofitting of Column

Slide no. 16

RETROFITTING OF COLUMN

Connection with beam



Plastering of Column



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Retrofitting of Column

Slide no. 17

RETROFITTING OF BEAM

Dismantling Process

Opening of beam soffit needs special attention as the beam may deflect substantially due to gravity load.



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Retrofitting of Beam

Slide no. 18

RETROFITTING OF BEAM

Beam Jacketing

Like in column, complete loop rings are not possible to insert in the beams. U-shaped rings with proper connection may be suitable and engineer should decide on type of bars and rings



Beam- Column Joint

Beams need to properly connected with the columns and the reinforcement of column should continue toward the beam.




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Retrofitting of Beam


Slide no. 19


RETROFITTING OF BEAM

Formwork Preparation



Plastering






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Retrofitting of Beam

Slide no. 20

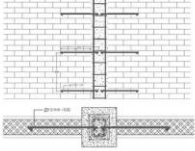
RETROFITTING OF WALL




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.





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Retrofitting of Wall

Slide no. 21

RETROFITTING OF WALL

Removal of Plaster



Surface Preparation





Hari Darshan Shrestha (CoRD)

Source: NSET

Retrofitting of Wall

Slide no. 22

RETROFITTING OF WALL

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



Retrofitting of Wall

Slide no. 23

RETROFITTING OF WALL

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



Retrofitting of Wall

Slide no. 24

RETROFITTING OF WALL

Placing Reinforcement
(Steel bar mesh / GI wire mesh)



Retrofitting of Wall

Slide no. 25

RETROFITTING OF WALL

Anchoring Reinforcing Bars

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



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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



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Retrofitting of URM building
