



Government of Nepal  
National Reconstruction Authority  
Singhadurbar, Kathmandu

**REPAIR AND RETROFITTING  
MANUAL  
For  
RCC STRUCTURE**

For earthquake damaged houses that needs to be repaired and retrofitted under  
HOUSING RECONSTRUCTION PROGRAMME

2017

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## FOREWARD



I would sincerely like to congratulate everyone involved in the development of “Repair and Retrofitting manual for RCC Structure” which has been published by National Reconstruction Authority. This manual is to support the partially households that needs repair and seismic retrofitting of partially damaged houses under reconstruction programme.

Thirty-one districts have been identified by the GoN Post Disaster Needs Assessment (PDNA) as being earthquake affected. To date, almost 25,000 households across the 31 districts have been identified with damage Grade 2 major and Grade 3 minor and being eligible to receive 100,000 NPRs housing reconstruction grant for repair and retrofit. The grant is disbursed in number of tranches based on compliant construction.

Every effort is required to support households to repair and retrofit unsafe structure so that they can receive the grant amount. This manual has been developed for technical staff to the structure that can be still be occupied without any risk also to go through the process of implementing required measures so that they could guide the households.

I look forward to seeing the manual implemented across the earthquake affected districts and to seeing the impact that it will have. This represents another positive step forward in the reconstruction process, and will support households to overcome non-compliance issues and secure approval to receive tranches of the reconstruction grant and to have safe, compliant houses.

Dr. Govind Raj Pokharel  
Chief Executive Officer, NRA

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## **PREFACE**



Under the housing reconstruction programme, houses that are partially damaged and falls under damage grade 2 major and 3 minor are eligible for getting grant under the repair and retrofit. For the household to receive the housing reconstruction grant the buildings need to comply with all the descriptions mentioned in the inspection check sheet which were formulated on the basis of MRs.

Hence, this manual is prepared to introduce the measure for the repair and retrofit measures along with their step by step procedures.

Beneficiaries whose houses were considered for repair and retrofit will get a chance to make their house safe if their house falls under the repair and retrofit criteria and adopt the appropriate measures mentioned in this manual.

On the other hand, this manual is helpful to all the engineers who are working for the reconstruction and are deployed by GoN for inspection. The manual has been divided into two parts and one annex.

PART- A: Seismic damage and intervention

PART- B: Seismic deficiencies and intervention

Annex 1: EMS Damage Grade of RCC buildings

Dr. Hari Ram Parajuli  
Executive member, NRA

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## **Standardization Committee, NRA for Reconstruction of Earthquake Resistant Houses**

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Our sincere thanks to the respected senior experts Prof. Dr. Prem Nath Maskey, Prof. Dr. Hikmat Raj Joshi, Prof. Dr. Gokarna Bahadur Motra, Er. Manohar Raj Bhandari, Dr. Narayan Marasini, Dr. Jagat Kumar Shresth for their support and suggestions during the discussions on critical issues which were required to finalize this manual.

We also thanks to senior structural engineers Er. Nabin Paudel and Er. Kuber Bogati, for their continuous work during the preparation of this manual.

We would like to congratulate all personnel involved, both directly and indirectly, for their valuable contribution to the preparation of this manual.

Standardization Committee, NRA  
for Reconstruction of Earthquake Resistant Houses

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## **BACKGROUND**

As per post disaster needs assessment, some of the identified damaged houses needs repair and retrofitting. Under the Government of Nepal (GoN) private housing reconstruction programme, a housing reconstruction grant is disbursed on the basis of repair and retrofitting of the damaged structures. The manual outlines the minimum intervention works that requires to the damages and to be eligible to get the tranches that will suppose to give under repair and retrofitting provision.

The manual discusses on two level of intervention works which are necessary for the damaged building that ensures life safety level of performance envision by Nepal National Building Code, NBC 105: 1994. First is basic level of intervention strategies which turns building into pre-earthquake condition only. Second level of intervention strategies ensures structural safety considering future earthquakes as well. Basic level of intervention works are mandatory only for receiving full tranches while second level of intervention works are advisory for the beneficiaries and is not mandatory for receiving full tranches.

There are various methods of repair and retrofitting for earthquake damaged masonry structures in different categories. Application of repair methods is expected to restore the structures to its pre-earthquake condition where as application of retrofitting methods to damaged structures is expected to increase strength and ductility of the structure. Considering the suitability of these methods in terms of material availability, beneficiaries' level of affordability and ease in skills, various methods are incorporated in this manual.

This manual has been developed to support engineers responsible for the compliance inspection process. The engineers will use this manual to provide advice and guidance to beneficiaries for the implementation of required repair and retrofitting strategies.

## SCOPE

### □ Applicability

The repair and retrofitting strategies set forth in this manual are applicable only for the residential houses that falls in repair and retrofitting categories after Gorkha earthquake 2015 under the GoN housing reconstruction programme. The manual intends to achieve the minimum acceptable structural safety envisioned in NBC 105 : 1994 after completing two level of intervention.

The designs mentioned in the manual are ready-to-use designs for all structural components, but some provisions mentioned are set as advisory measures.

### □ Limitations

***The repair and retrofitting strategies are only for damaged non-engineered residential buildings.***

This manual has certain limitations and is only relevant for buildings which are:

- I. Residential and fall under category 'C' and 'D' of NBC.

- ✓ Category "A": Modern building to be built, based on the international state-of-the-art, also in pursuance of the building codes to be followed in developed countries.
- ✓ Category "B": Buildings with plinth area of more than One Thousand square feet, with more than three floors including the ground floor or with structural span of more than 4.5 meters.
- ✓ Category "C": Buildings with plinth area of up to One Thousand square feet, with up to three floors including the ground floor or with structural span of up to 4.5 meters.
- ✓ Category "D": Small houses, sheds made of baked or unbaked brick, stone, clay, bamboo, grass etc., except those set forth in clauses (a), (b) and (c).

*\* If the basic level of intervention has already done and strategy is similar as mention in this manual or published documents by Government of Nepal or as per international practices and are based on codal provision ensuring life safety with quality construction then applications can be forwarded only after thorough engineering judgement.*

# What can we do on earthquake damaged houses.

Every earthquake damage building always need not to be demolished

- Some of them can be repaired, retrofitted and reused;

So before taking decision the building should be Evaluate carefully.

The general terms used for the improvement of the damaged buildings are :

## [General Terms]

### [Repair]:

The main purpose is to bring back the architectural shape of the building so that all services start working & the functioning of building is resumed quickly.

The actions will include the following:

- 1) Patching up of defects such as cracks and fall of plaster.
- 2) Repairing doors, windows, replacement of glass panes.
- 3) Checking and repairing electric wiring.
- 4) Checking and repairing gas pipes, water pipes and plumbing services.
- 5) Re-building non-structural walls, smoke chimneys, boundary walls, etc.
- 6) Re-plastering of walls as required.
- 7) Rearranging dislocated roofing tiles.
- 8) Relaying cracked flooring at ground level.
- 9) Redecoration - whitewashing, painting, etc.

### [Restoration]

The main purpose is to carry out structural repairs to load bearing components to restore its original strength.

The actions will include the following:

- a. Injecting rich mortar, epoxy's like material, which is strong in tension, into the cracks in walls, columns, beams, etc.
- b. Addition of reinforcing mesh on both faces of the cracked wall, holding it to the wall through spikes or bolts & then covering it suitably.
- c. Removal of portions of cracked masonry walls & piers and rebuilding them in richer mortar. Use of non-shrinking mortar will be preferable.
- d. Remove the damage column or beam, fix the reinforcing, add reinforcing if needed, and re-concreting.

### [Strengthening/Retrofitting]

The main purpose is to make buildings stronger than before.

The actions will include the following:

- a. demolish the weakness sources or sources that can make stress concentration in several parts:
  - ❖ columns distribution are not symmetric
  - ❖ walls distribution are not symmetric
  - ❖ different stiffness from one to another floors
  - ❖ excessive openings
- b. make the building as a unity by tying together all components of building
- c. Avoid brittle failure by re-arranging, adding reinforcing bars, and make the details in accordance with ductility requirement.
- d. Increasing the lateral strength by adding walls, columns, etc.

### Steps of retrofitting:

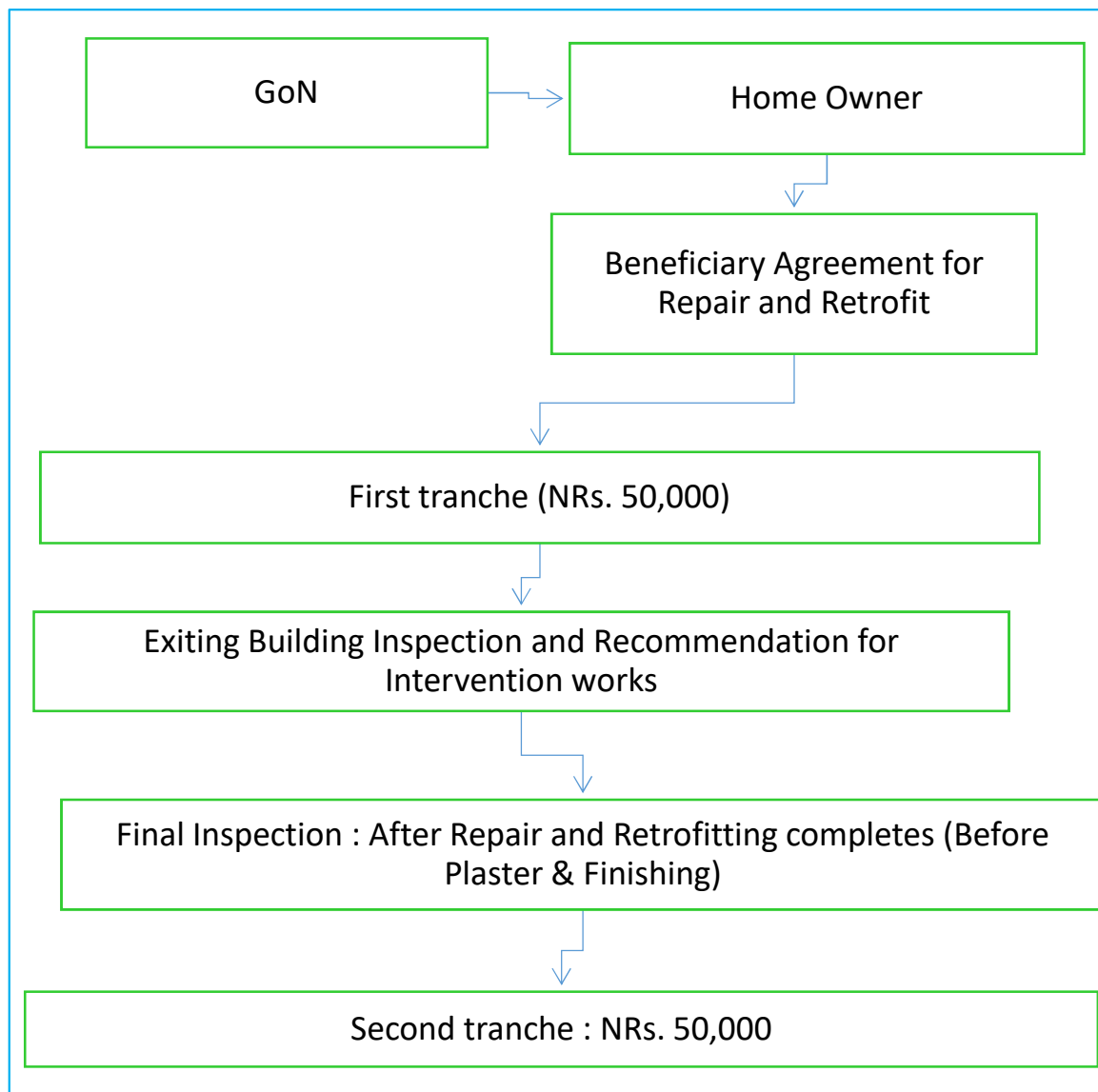
1. Determine as accurate as possible how the building behave when shaken by an earthquake
  - ❖ check the building
  - ❖ check building material quality
  - ❖ list all component of the building that are damaged
1. Perform a dynamic analysis for the building to get an idea of the causes of damage and determine the load paths when shaken by the earthquake.
2. Determine the causes of damage of components; caused by shear, compression, tension, flexure, anchoring, etc.
3. As soon as the type of damage can be identified, repair and restoration of the components can be done separately in order that the original strength of the components can be restored.
4. If results of analysis indicate that the building with restored components can withstand the maximum expected earthquake for that area based on the latest code, then there is no need to strengthen.
5. however, if the building with restored components was not designed or designed for a lower than the maximum expected earthquake Specified by the latest code, then the building needs to be strengthened
  - ❖ For strengthening, the restored building must be re-analysed to identify which component must be strengthen.
  - ❖ For engineered buildings with severe damage and if the building needs to be strengthened, 3d non-linear analysis performance based design should be done.
  - ❖ If cost for strengthening the building to its original function is not feasible, one option that can be chosen is to change the building function with less stringent requirement, therefore cost will be reduced.
  - ❖ After the strengthening works is completed, the building must be re-analysed to ensure that the strengthened building is earthquake resistant.

## Level of Intervention

### Level of Interventions required to receive the grant:

This guideline presents repair and retrofitting methodologies for Reinforced Cement Concrete buildings. The grant distribution process is presented on flow chart below.

### Grant distribution process:



Flow chart of Grant Distribution of Repair and Retrofitting



---

## PART-A: Seismic damage and intervention

This part deals with seismic damages and possible intervention that needs to turn the building in to pre earthquake condition.

# 1. Materials for the Repair and Retrofitting

The various materials used for repairs of cracks are:

## Ordinary material

- Cement Slurry
- Cement Mortar
- Expansive Cement
- Quick setting Cement
- Gypsum Cement
- Steel Reinforcement
- GI wires
- Rolled Steel sections

## Advanced material

- Epoxy resin/epoxy Mortar
- Polymer Modified Cementitious Products
- Fiber Reinforcement Polymers.

# 2. Basic Repair techniques

1. Repair of spalling or falling or minor cracks in RC members by cement slurry or mortar
2. Routing and Sealing
3. Stitching
4. Applying External Stress
5. Cement slurry Grouting/Epoxy-injection Grouting
6. Surface Overlay/ shotcrete or guniting
7. Removing buckled and yielded Reinforcement and adding new reinforcement
8. Infill wall repair

### 3. Floor Damage at Ground floor and mitigation work

[Key Problem]

F.1 Crack in Ground floor

F.2 Settlement of Ground floor



F.1 Minor cracks on floors of ground floor

#### Solution: Minor Crack on floor

Repair of ground floor crack can be done as follows:

1. If there is minor crack on the Ground floor it can be repair by cement slurry of 1:3 or by suitable joint sealant.

#### Solution: Settlement of floor of ground floor.



# 1. Floor Damage at Ground floor and mitigation work

## Solution: Settlement of floor of ground floor.

Repair of settled foundation floor can be done as follows:

1. If there is floor settlement then level the area first
2. In some case retaining wall may require before levelling the area of damaged floor.
3. Remove any loose materials from the damaged part and make the damaged area clean
4. Wash the damaged area with water and moist the whole area.
5. After levelling soling and concreting (1:1.5:3) of surface can be done as per necessary
6. Re-plaster the whole area
7. Use cement slurry(1:3) over the plaster.



---

## 4. RCC Beam and Column Damage and Mitigation works

### **[Key Problem]**

Potential damages in foundation are as follows :

- P.1 spalling or falling of outer cover of concrete
- P.2 minor structural cracks in column and beam
- P.3 Crushing of concrete with or without buckling of bars

### **[Repair Solution]**

Repair solution on corresponding damages in foundation listed above, are :

- S.1 Rich Concrete overlay:
- S.2 Epoxy Grouting in urban and semi-urban areas:
- S.3 Removing buckled and yielded reinforcement and adding new Reinforcement:



Problem : Crack or Crushing of Concrete with or without buckling of bars



**Picture: Damages on Column due to earthquake**

**Problem : Crack or Crushing of Concrete with or without buckling of bars**



**Picture: Damages on beam due to earthquake**

Problem : damages on RCC structures

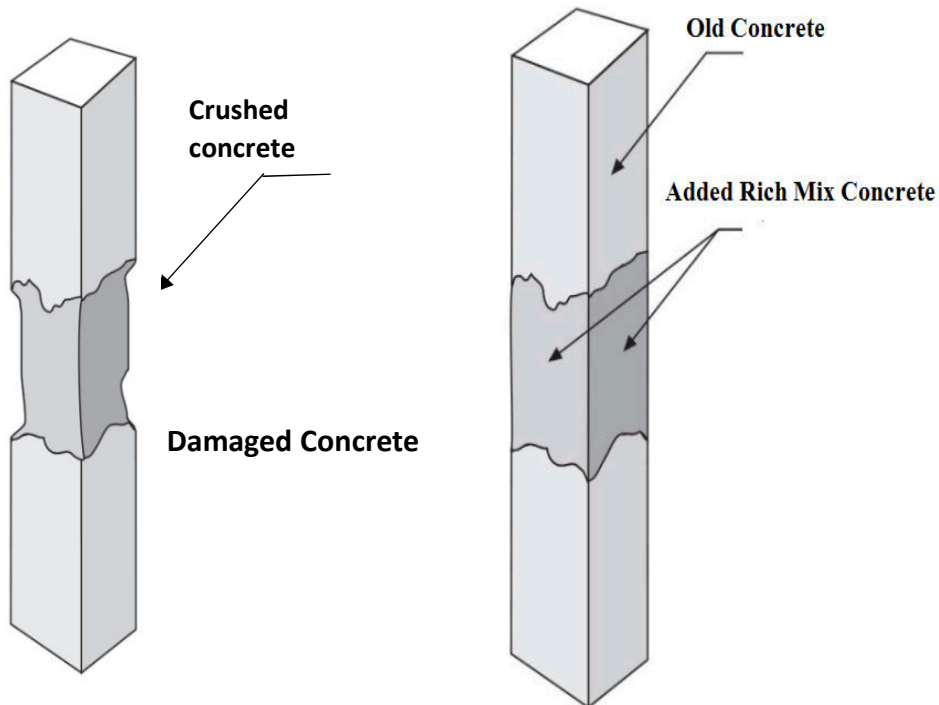


**Picture: Building affected by earthquake**



## Solution : Rich mix concreting Overlay

- In such case the damage can be repaired by removing the crushed concrete in the area and re-concreting with rich mix of concrete



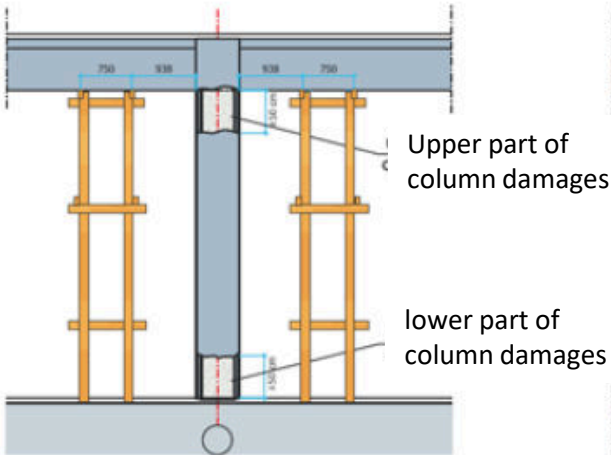
Rich mix concreting overlay

## Repair and Retrofitting of column and beam column Junction

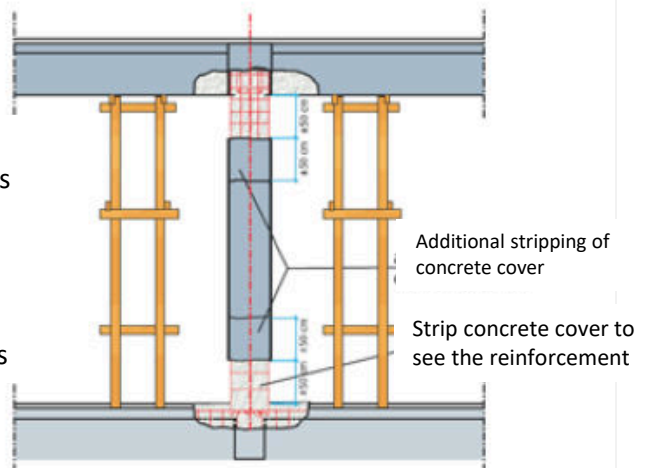
1. Support the beams around the column to be retrofitted with timber posts at suitable intervals. Timber size to be adjusted based on the load to be supported. Steel support can also be utilized. (Figure I)
2. Strip the concrete cover of columns / beams to know the number of reinforcement & stirrups. (Figure II)
3. If analysis shows that the number of column & beam reinforcement & stirrups are not sufficient, additional reinforcement must be placed. (Figure III.A.)
4. If the detail of the column-beam joint reinforcing is not in accordance with the seismic resistant requirements, additional anchoring from column to beam must be placed. In this case, part of the beam concrete must be removed for anchoring. (Figure III.B.)
5. If the column / beam reinforcement is not adequate, there are 2 choices that can be implemented:
  - a. Remove the entire column / beam concrete & install the additional reinforcement.
  - b. Additional reinforcement is installed outside the column / beam and concreted (jacketing).
6. If no additional reinforcement for the column is necessary, but the detailing of the joints must be rectified, the beam concrete must be removed and install the necessary anchoring. For additional column stirrups, strip the column concrete cover min. 1m length and subsequently place the stirrups with suitable size & spacing in accordance with the analysis result. (Figure III. B.)
7. For placing new concrete, the formwork must be shaped like a cone (figure IV.A and Figure IV.B). The upper part of cone formwork must exceed the boundary of old & new concrete.
8. Pour concrete with the desired strength up to the top of the cone.
9. If there is not enough space, concreting can be done by drilling a hole in the slab. (Figure IV.B)
10. After 24 hours, the formwork can be removed and the protruding concrete part (due to the cone shape) can be chipped. Figure (V.A. & V.B.).

# Retrofitting of top and bottom of column that are damaged and placing additional stirrups of beam and column

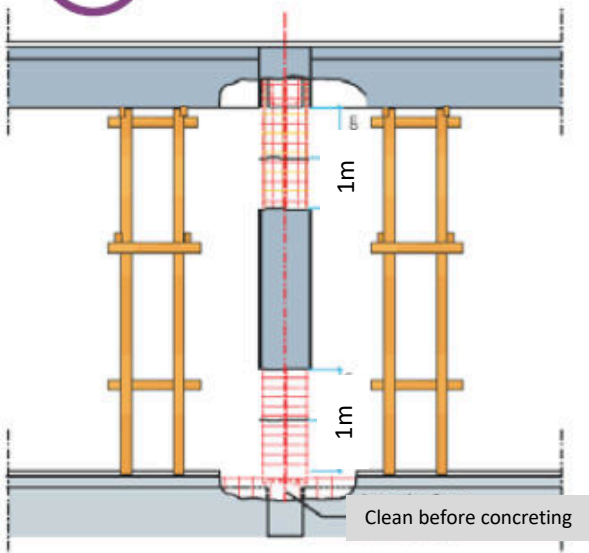
I



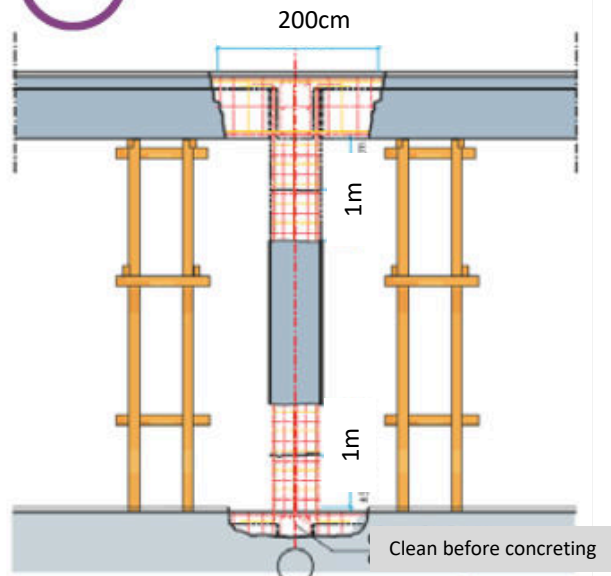
II



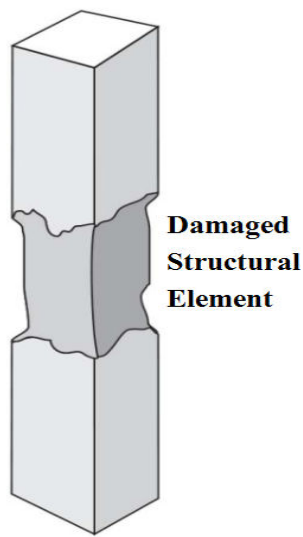
III.A



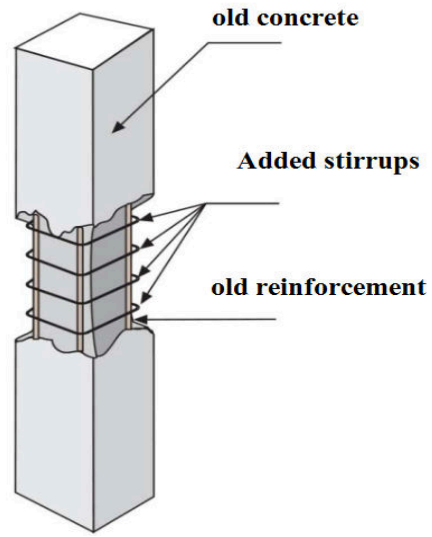
III.B



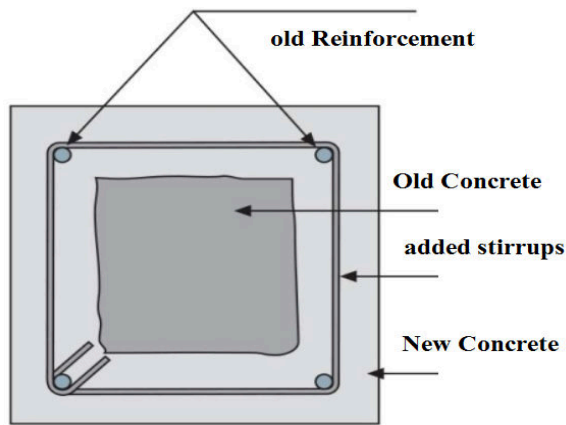
Solution : retrofitting of column by adding stirrups/reinforcement



Damaged structural column



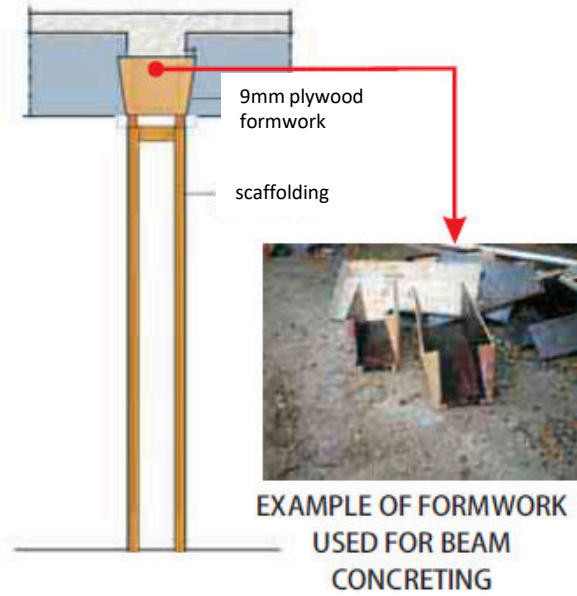
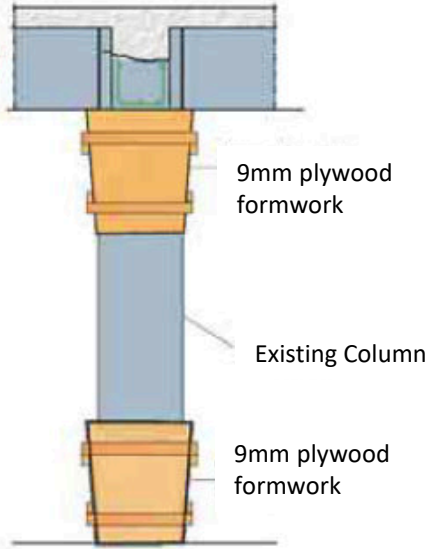
Repaired of structural Element



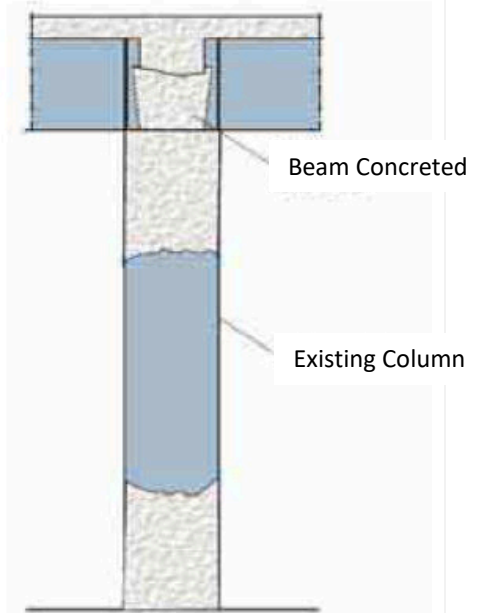
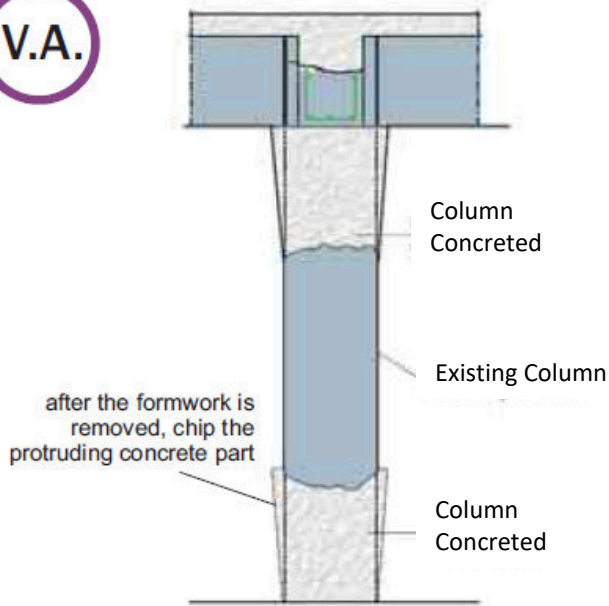
Section of repaired structural element

Repair and Retrofitting of top and bottom of column that are damaged and placing additional stirrups of beam and column

IV.A.

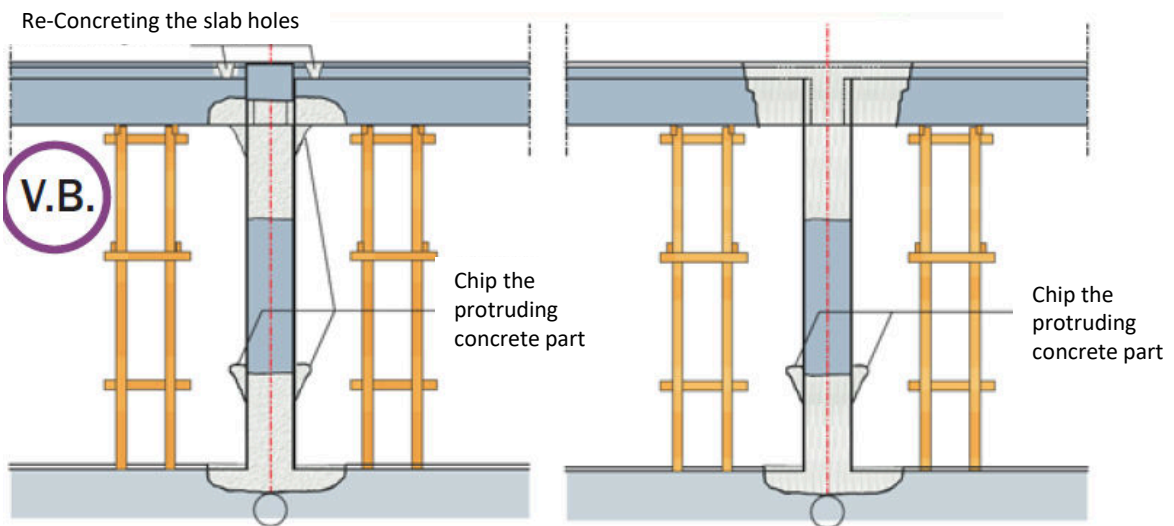
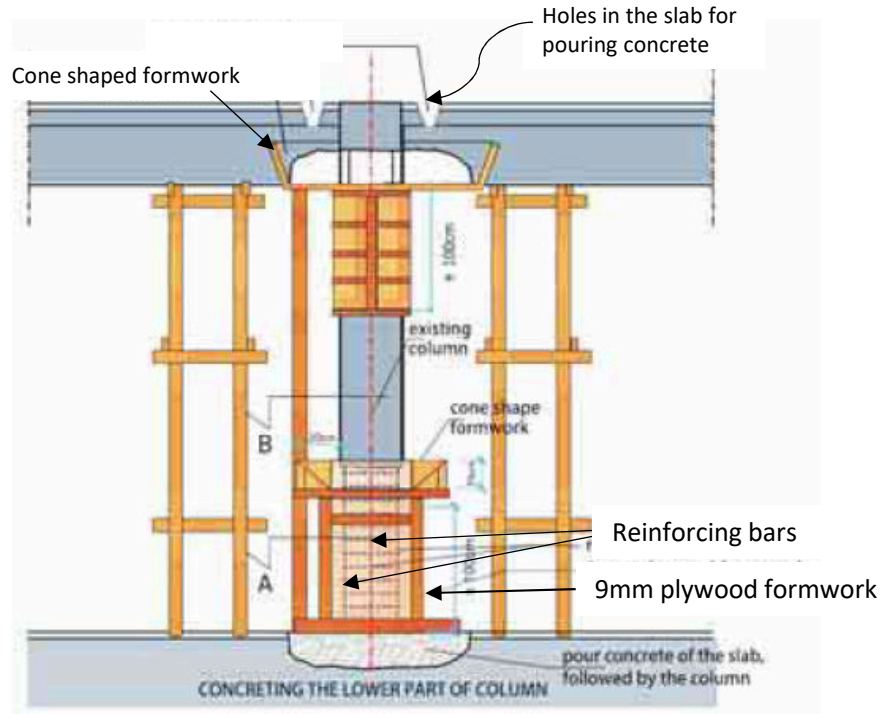


V.A.



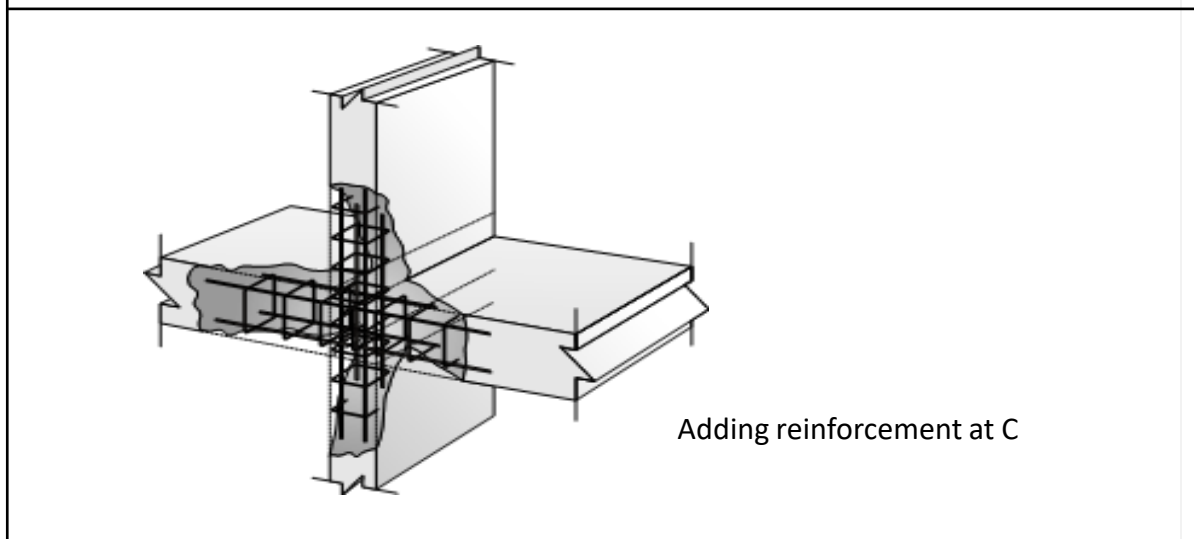
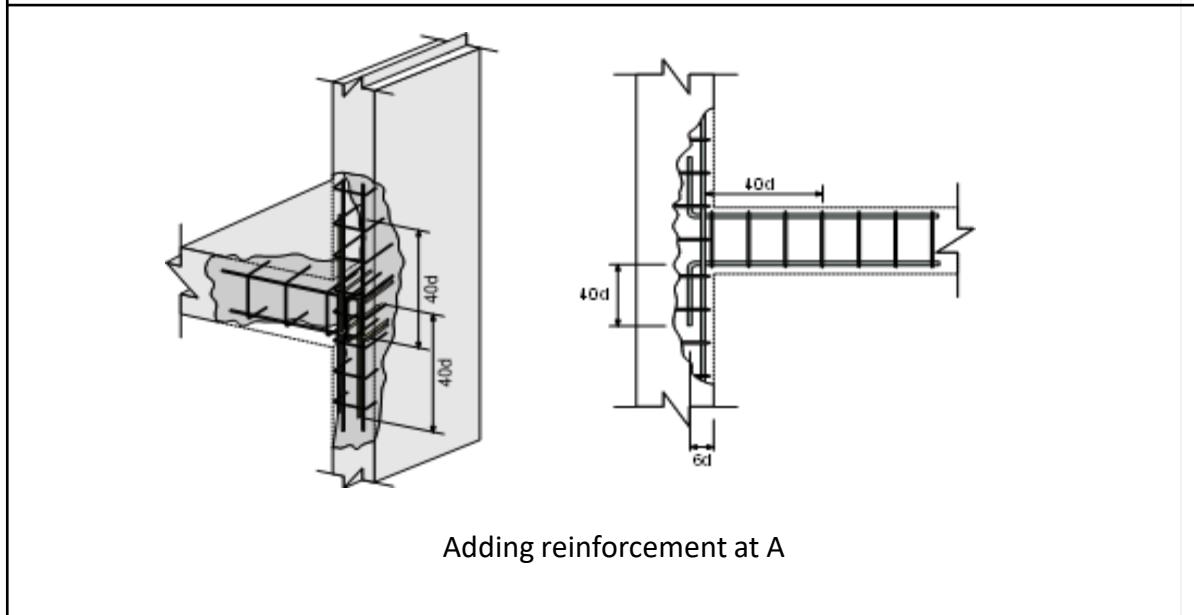
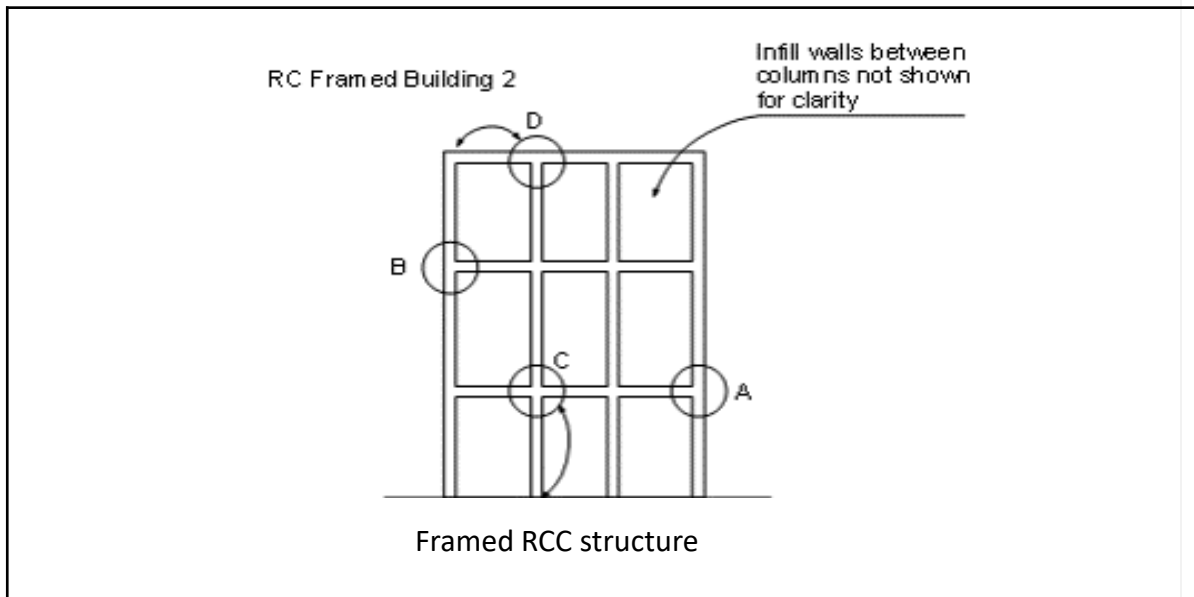
Retrofitting of top and bottom of column that are damaged and placing additional reinforcement stirrups of beam and column

IV.B.

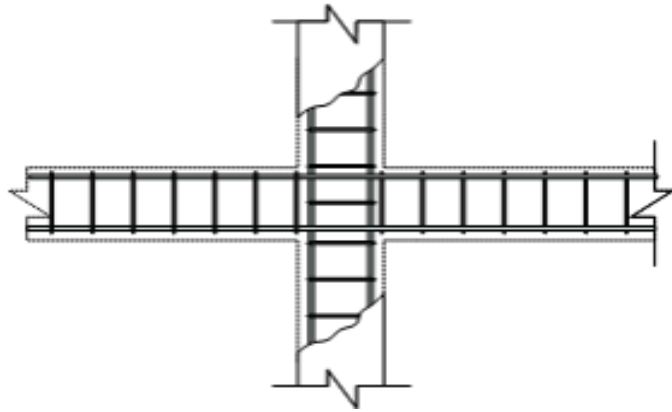


V.B.

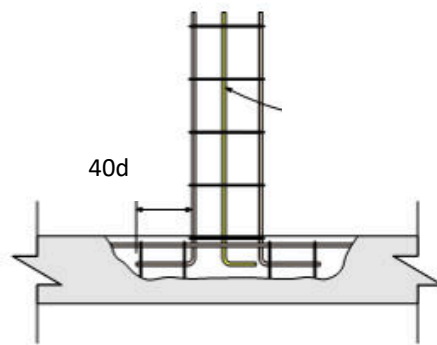
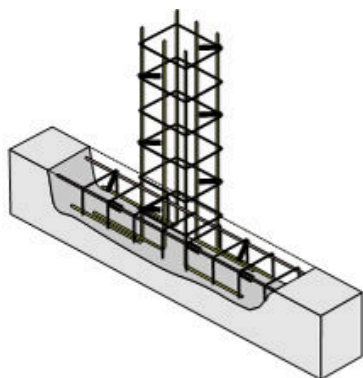
## Solution : Spalling of Concrete with buckling of bar



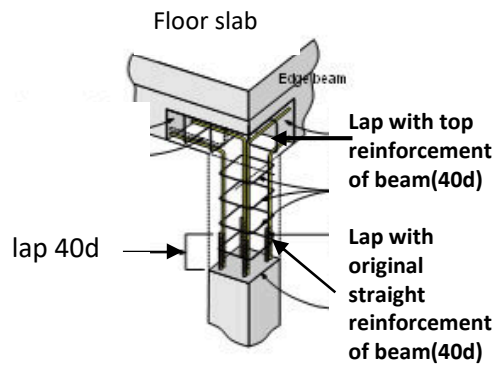
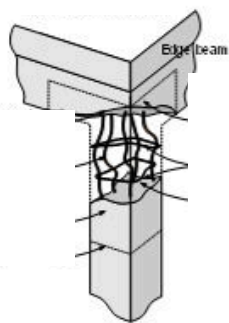
Solution : Spalling of Concrete with buckling of bar



Adding reinforcement at C



Detail at D: repair at column base

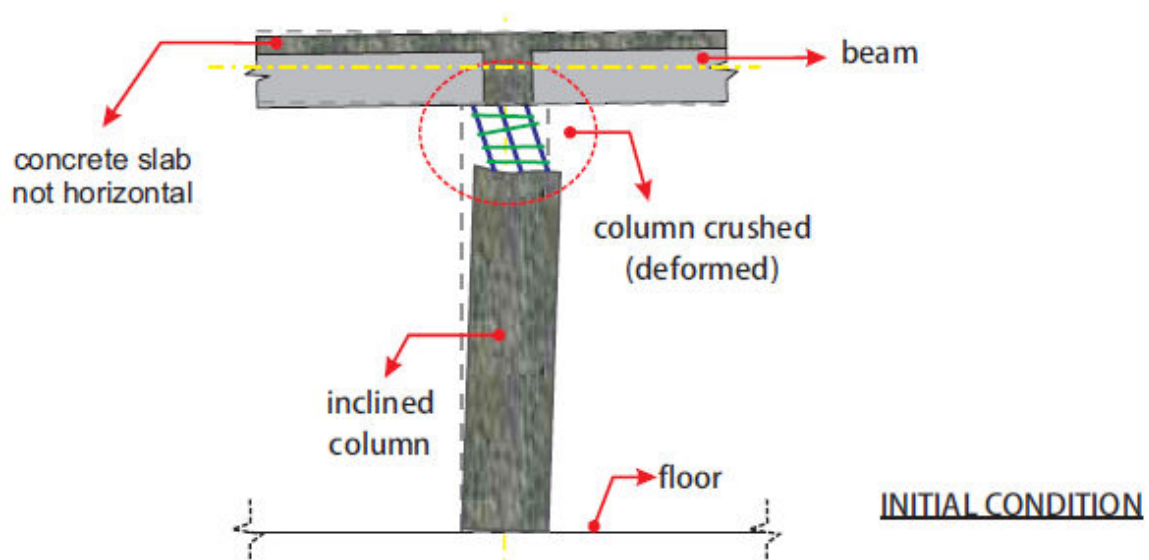


Detail at D: repair at column Head

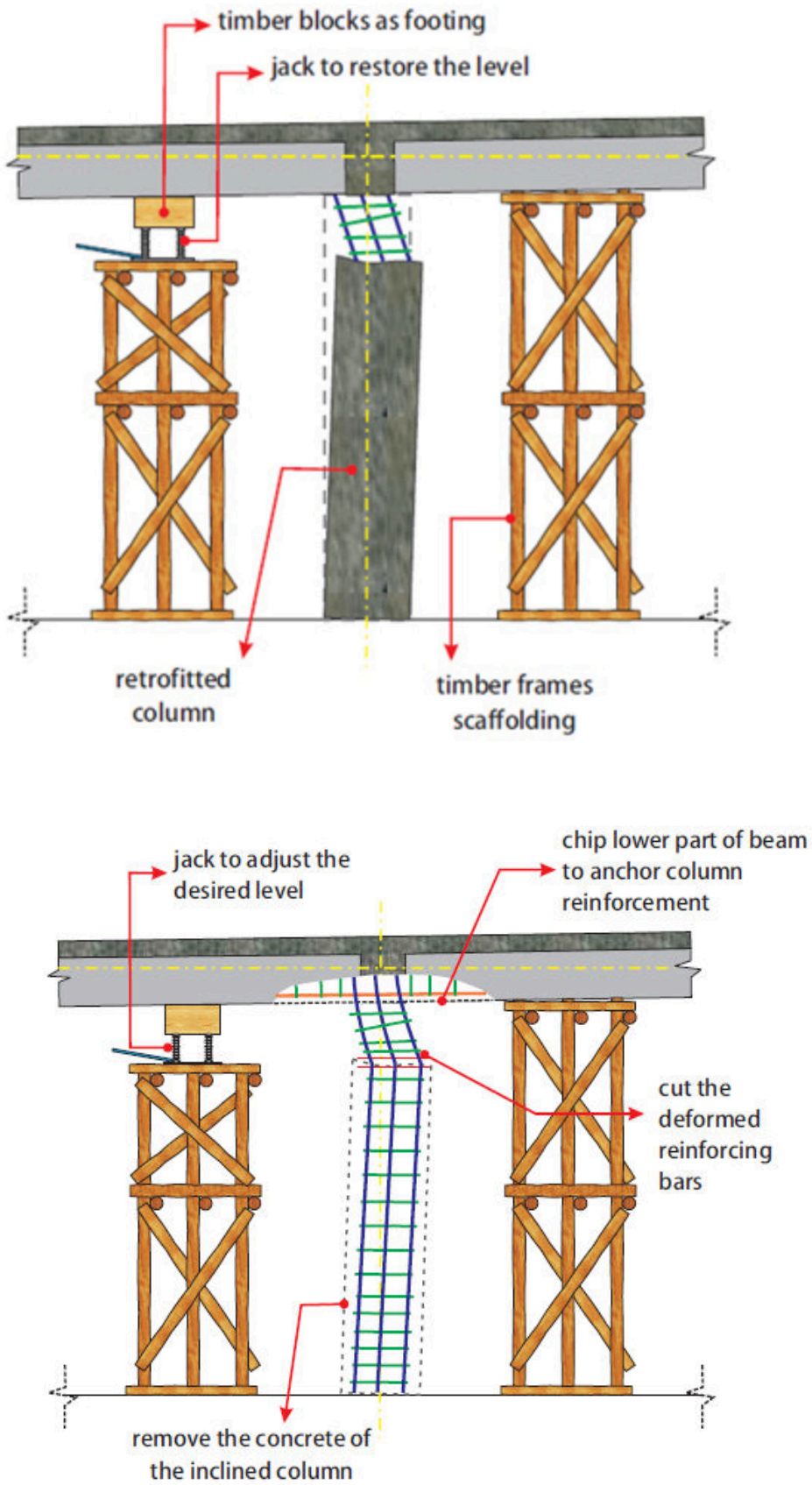


## Solution : Retrofitting of inclined columns damaged at the top

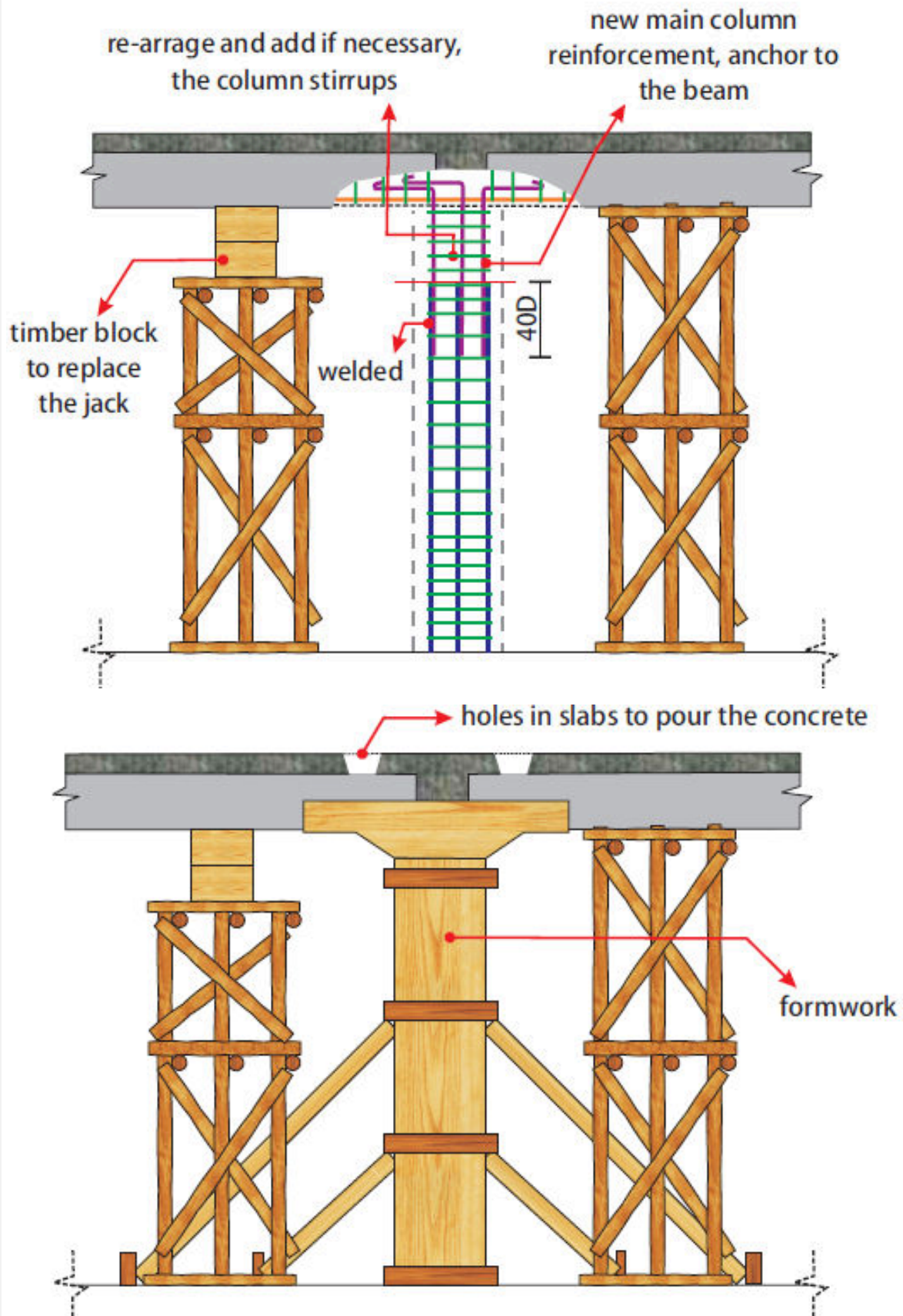
1. Support the beams around the column to be retrofitted during construction.
2. The slanted beam must be supported and jacked-up to restore the level. (figure i) Note: if jacking is difficult, the deformed column reinforcement can be cut first.
3. Remove the concrete of the inclined column.
4. Cut the deformed reinforcing bars. (figure ii)
5. Jack-up the beam until the desired level.
6. Remove the concrete of the lower part of the beam and for improving the joint reinforcement detail. (Figure ii)
7. After the structure is horizontal at the desired level, the jacks are replaced with timber or concrete blocks. (Figure iii)
8. Install the new column reinforcement and splice with the existing one. The length of splice between the existing and the new reinforcement is minimum  $40d$ . (Figure iii) Re-arrange and add, if necessary, the column stirrups.
9. Construct the formwork of 9 mm thick plywood. The formwork must be shaped like a cone (Figure IV).
10. Place the concrete as soon as the formwork is ready.
11. After 24 hours, the formwork can be removed and the protruding concrete part (due to the cone shape) can be chipped.



Solution : Retrofitting of inclined columns damaged at the top



## Solution : Retrofitting of inclined columns damaged at the top



## 5.RCC Floor Damage and Mitigation works

If the crack are of small size then it can be repair by rich concrete mortar over lay or by some epoxies. But if the slab has large crack with deteriorated reinforcement, they are repaired by providing additional reinforcements dowels bars as per building codes and concreting.



### Solution: Simple rich concrete and mortar overlay

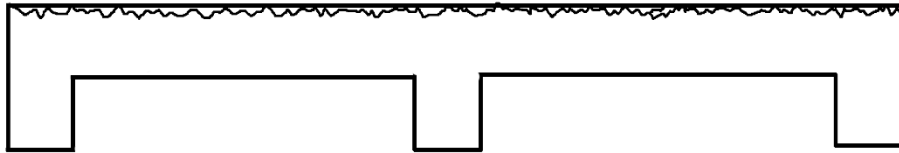
1. Chisel out the crack to create a backward-angled cut, using a cold chisel and a hammer.
2. Clean loose material from the crack using a wire brush, or a portable drill with a wire wheel attachment.
3. Apply a thin layer of rich cement slurry for bonding between old and new concrete
4. apply rich screed over the prepared surface/



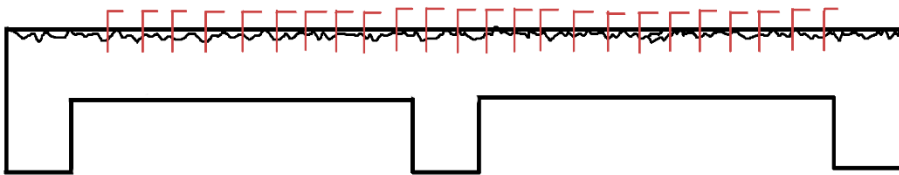
Slab repaired by concrete overlay



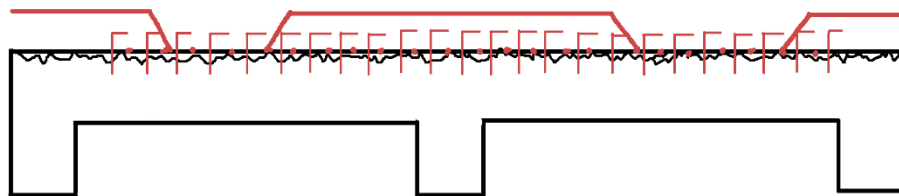
**Solution: RCC slab repair by adding reinforcement and dowels bars**



**Step #1: Supporting the slab, removing the concrete cover, cleaning the steel bars and coating them with epoxy**



**Step #2: Installing vertical and horizontal dowels at 10” spacing in each direction**

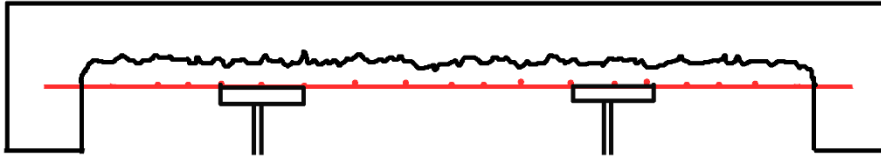


**Step #3: Installing the new steel mesh fasten it with dowels**

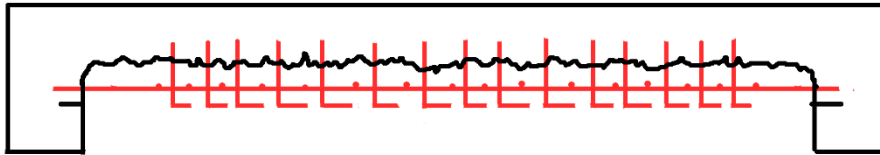


**Step #4: pouring the required new layer of concrete**

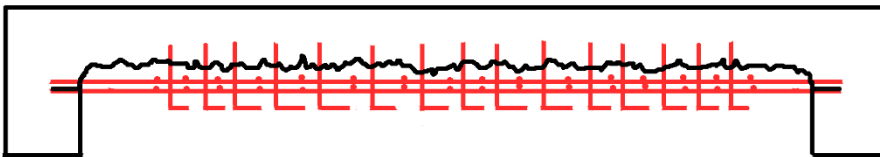
**Solution: RCC slab repair by adding reinforcement and dowels bars**



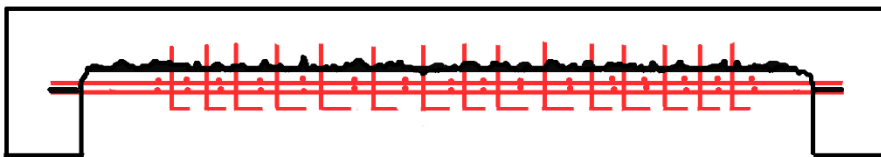
**Step #1: Supporting the slab, removing the concrete cover, cleaning the steel bars and coating them with epoxy**



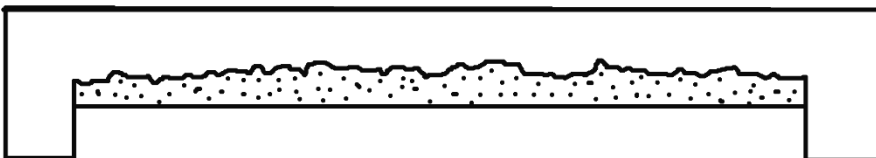
**Step #2: Installing vertical and horizontal dowels at 10" spacing in each direction**



**Step #3: Installing the new steel mesh and fasten it with the dowels**



**Step #4: Coating the surface with epoxy**



**Step #5: pouring the required new layer of concrete**

## 6. Other Crack Repair techniques for RCC Structures

### Grouting and micro-concreting(Repair of minor cracks in RC members )

#### For urban and semi-urban area

In case of minor cracking - the RC member can be repaired by injecting suitable grout as follows:

- Remove plaster and any loose material in the vicinity of crack
- Fix the grouting nipples in the cracks at spacing of 6 – 8 inch (150-200 mm) c/c;
- Inject water through the nipple so that the dust inside the cracks is washed off and the concrete is saturated with water
- Inject the grout till it comes out from the next nipple and then move to next nipple;
- After injection of grout through all the nipples is completed, re-plaster the surface and finish as required.

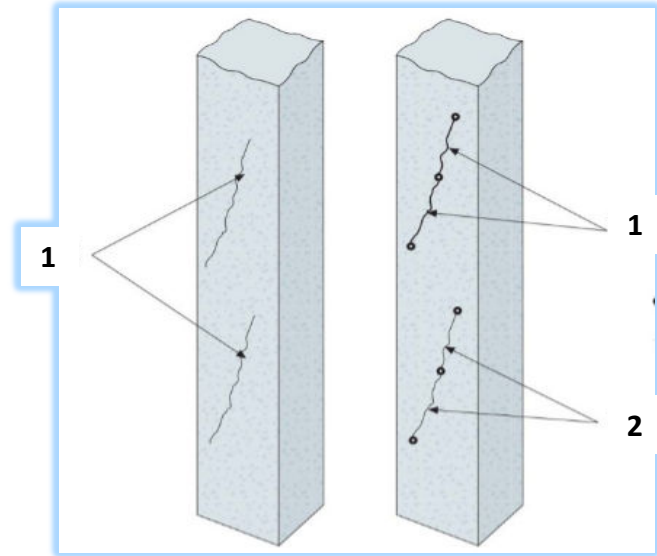


Fig: repair of damaged columns with sight crack (1. Cracks 2. Injection ports)

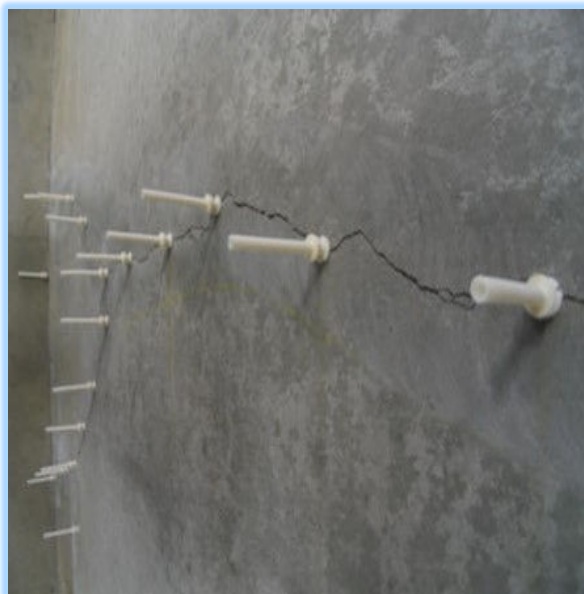
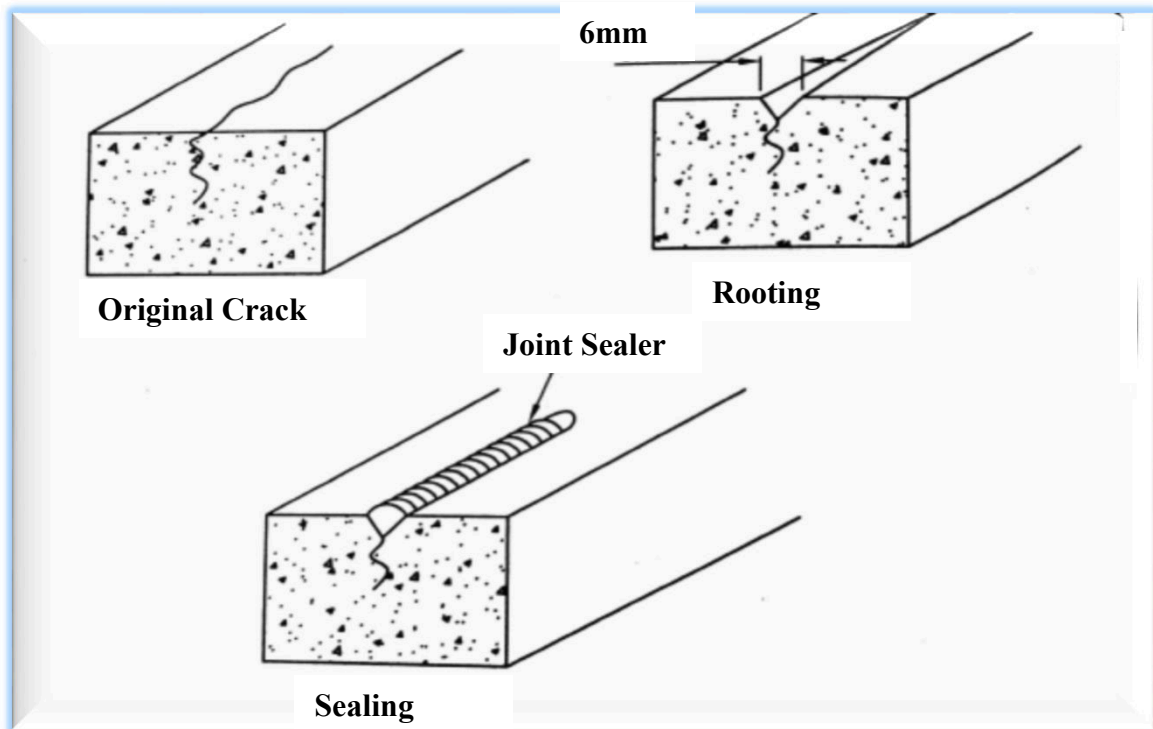


Fig: Nipple fixing for Grouting

## Routing And Sealing

- This is a Simplest , most common , inexpensive method
- It can be used for both fine and larger isolated cracks
- This method involves enlarging the crack along its exposed face and sealing it with a suitable joint sealant or rich mixed mortar.
- This techniques is mostly used for floors and pavements
- One of the defect of this method is swelling with time.



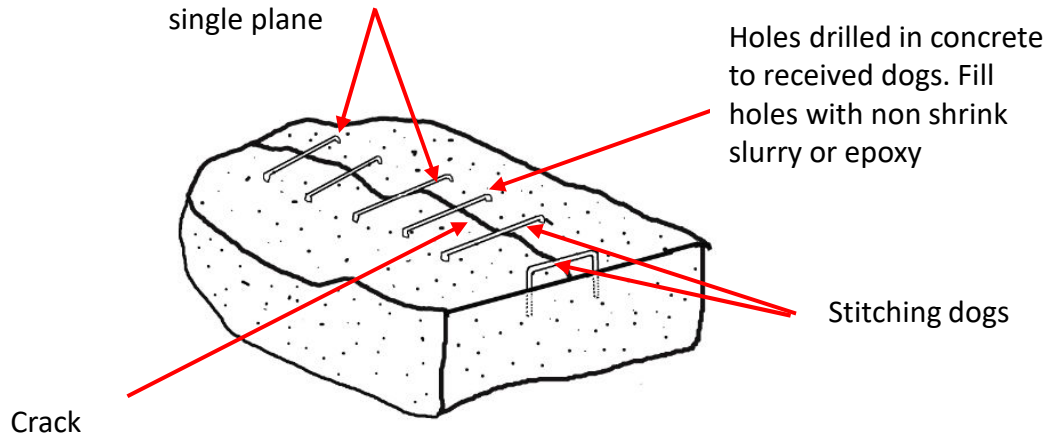
Cracks Repairs by Routing and sealing



# Stitching

- Stitching may be used when tensile strength must be re-established across major cracks.
- Stitching involves
- Drilling holes on both sides of the crack
- Grouting in U-shaped metal units with short legs called staples or stitching dogs or bolting with steel strips on both sides of crack

Note: Variable length, location and orientation of dogs so that tension across crack is distributed in the concrete rather than concentrated on a single plane

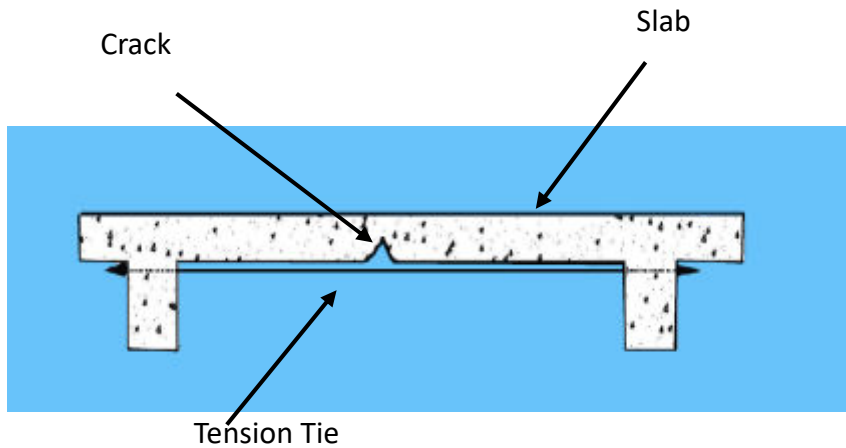


## Stitching

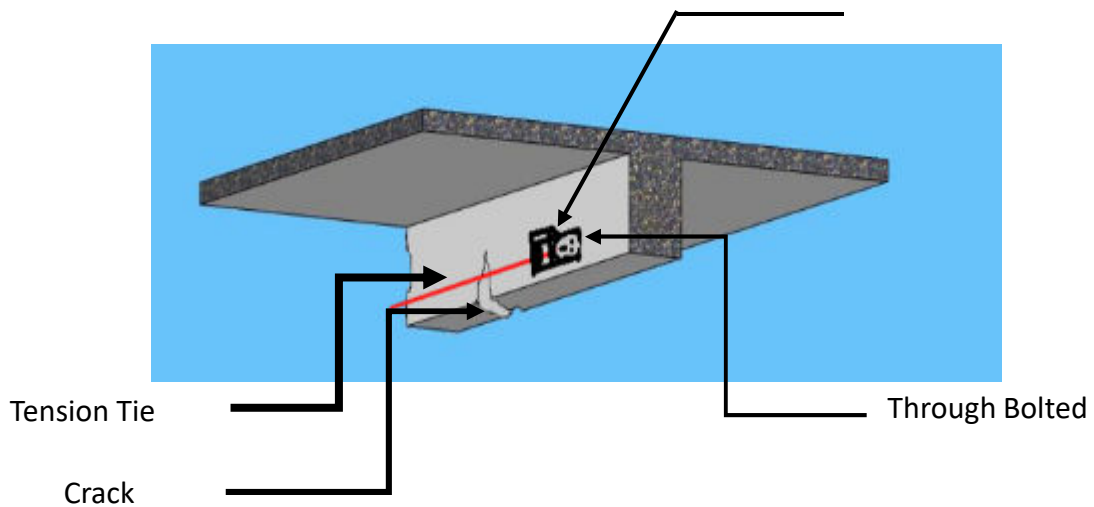


## Applying External Stress:

- The development of cracking is due to the tensile stress ,thus can be arrested by suppressing this stress
- Cracks can be closed by inducing a compression force to overcome the tensile stresses
- The compressive force is applied by
  - ✓ Pre-stressing wires or rods
  - ✓ Wedging – by opening the cracks and filling with expanding mortar, by jacking and grouting or by actual driving wedges



a). To Correct Cracking of Slab Anchorage-Both sides



b). To Correct Cracking of beam



Repair and strengthening of masonry infill of RCC building is similar to that of load bearing masonry. So refer following document for Repair and retrofitting of Masonry Infill in RCC buildings.

**Repair and Retrofit Manual for Masonry structures Published by:  
National Reconstruction Authority  
Singhadurbar, Kathmandu**

## PART-B : Seismic deficiencies and intervention

Additional intervention might required with respect to inherent structural deficiencies after turning the building in to pre earthquake condition as per part A. This part deals with possible deficiencies in the masonry buildings and possible deficiencies on.

### 1. Major Seismic Deficiencies of RCC Building

- 1) Inadequate depth and size of the footing
- 2) Inadequate size of Structural Members
- 3) Inadequate amount of reinforcement on structural member
- 4) Missing of bands on masonry walls
- 5) Vulnerable Parapet walls/staircase
- 6) Soft/ weak Storey

### Intervention for not meeting minimum Requirement

- ❖ Improvement for Foundation footing and providing retaining wall
- ❖ Intervention for Beam and column
- ❖ Intervention for slab
- ❖ Intervention for Masonry infill.

For those building which doesn't fulfil the current building code requirement and have seismic vulnerability needs advance level assessment and design for retrofitting. For this please refer the following Guidelines published by Government of Nepal. Any Similar government published documents for seismic retrofitting of RCC building can be taken for reference also.

**Seismic Retrofitting Guidelines of Building in Nepal RCC Published by:  
Ministry of Urban Development (MoUD)  
Department of Urban Development and Building Construction (DUDBC)  
Babarmahal, Kathmandu**

## 2. Structural Assessment Checklist

For the intervention of seismic deficient building different structural acceptability criteria have to be Checked which are tabulated below

Checks	Remarks
Load Path	The frame system provides a complete load path which transfer all inertial forces in the building to the foundation. Is there clear load path?
Redundancy	Is There are more than two bays of frame in each direction?
Goemetry	Is the plan of the building is same in all stories except at basement?
weak/ soft storey	Is there are weak/soft storey?
Vertical discontinuous	Is vertical elements in the lateral force resistant element system are continuous to the foundation except for the basement floor?
Mass	Is there change in mass in adjacent floor of the building?
Torsion	Is the eccentricity of the building within the limit?
Adjecent Building	Are there adjacent building?
short column	Is there short column effect?
deterioration of concrete	Is there deterioration of Concrete?

If there are structural deficiencies and not meeting the build code requirements then so sort of intervention have to be imposed to building. Some of the basic intervention techniques are

- [Strengthening of footings]
- [Jacketing of Beams]
- [Jacketing of Column]
- [Jacketing of beam Column Joints]

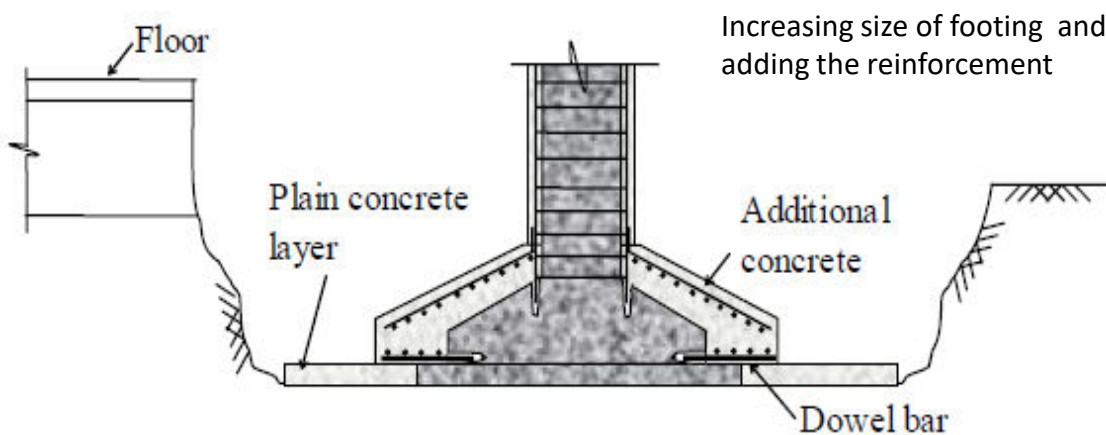


## Strengthening of original structural elements

Strengthening of reinforced concrete structural elements is one method to increase the earthquake resistance of damage or undamaged buildings. Repair of reinforced concrete elements is often required after a damaging earthquake to replace lost strength.

Establishing sound bond between the old and the new concrete is of great importance. It can be provided by chipping away the concrete cover of the original member and roughening its surface, by preparing the surface with epoxy prior concreting by additional welding of bent reinforcement bars or by formation of reinforced concrete or steel dowels.

### 3. Strengthening of Footing of RCC Building

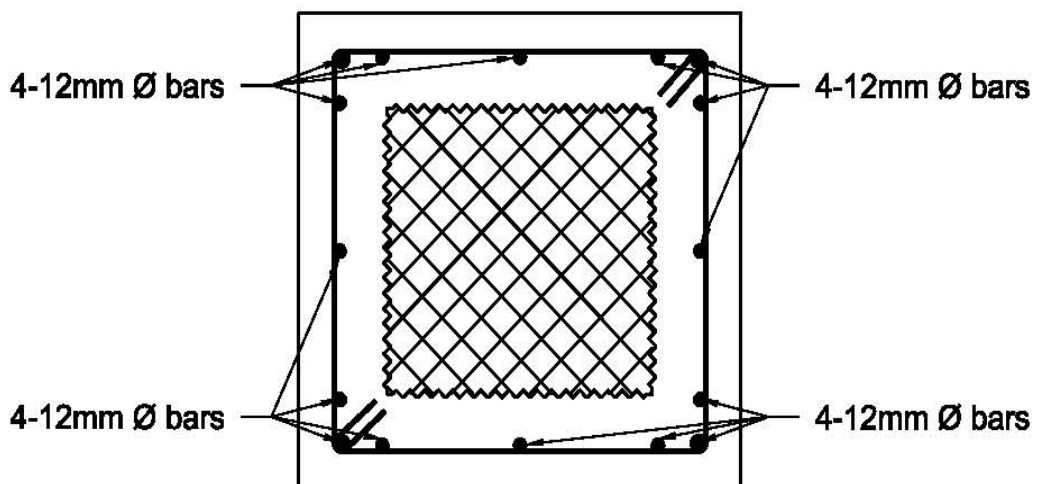


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## 5. Strengthening of Column and beam

1. Provide the required supporting system to the structure.
2. Remove weak concrete if exist.
3. Clean the surface and clean the rust of steel if exist.
4. Apply rust removers and rust preventers.
5. Provide additional steel **as per design** all around the section.
6. Provide required formwork.
7. Provide polymer based bonding coat or rich cement bonding between old and new concrete.
8. Place the concrete of required thickness and grade and workability admixed with plasticizers

## Concrete Jacketing



**Sample Reinforced  
concrete jacketing**

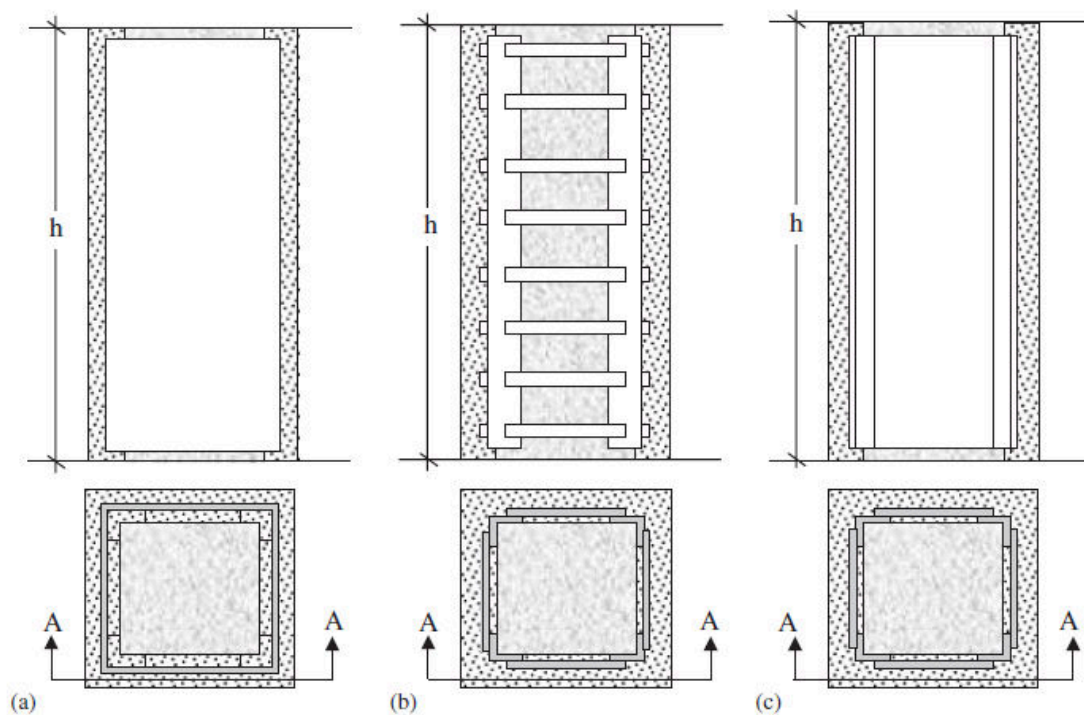


## Rolled Steel Jacketing

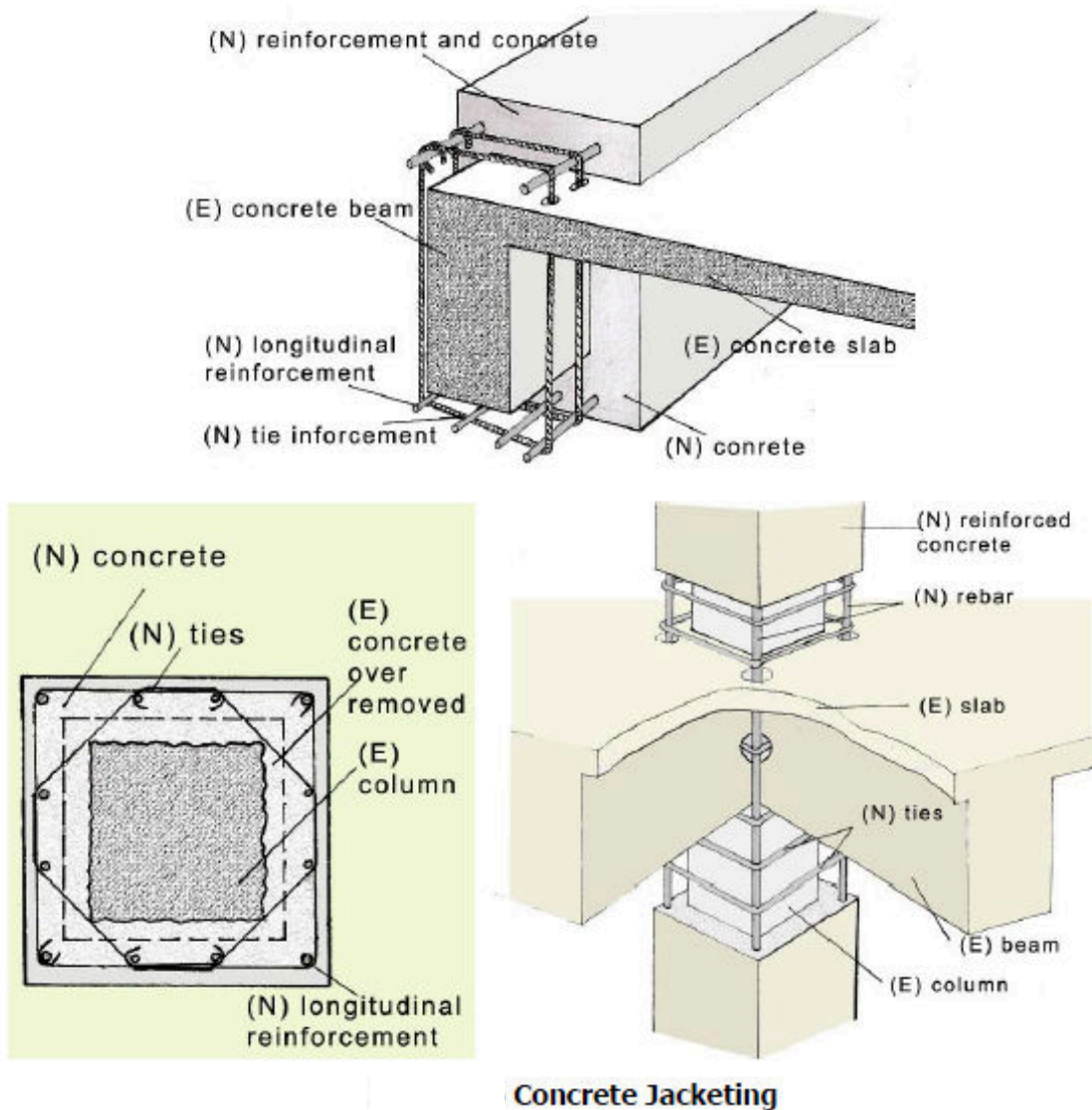
The steel jacketing option involves the total encasement of the column with thin steel plates placed at a small distance from the column surface, with the ensuing gap filled with non-shrink grout. An alternative to a complete jacket is the steel cage. Steel angles are placed at the corners of the existing cross-section and either transversal straps or continuous steel plates are welded on them. In practice, the straps are often laterally stressed either by special wrenches or by welding. Any spaces between the steel cage and the existing concrete are usually filled with non-shrink grout. When corrosion or fire protection is required, a grout concrete or shotcrete cover may be provided



**Retrofitting of columns by steel profile jacketing**

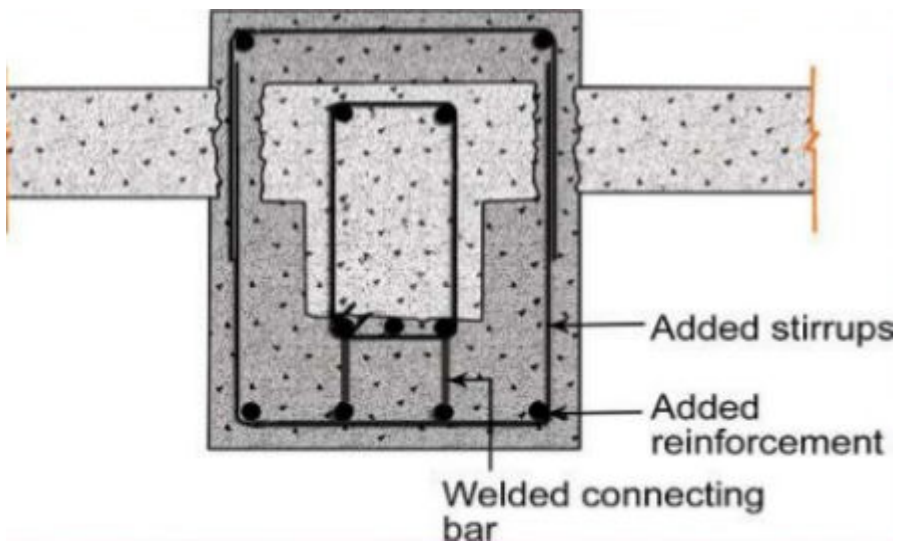
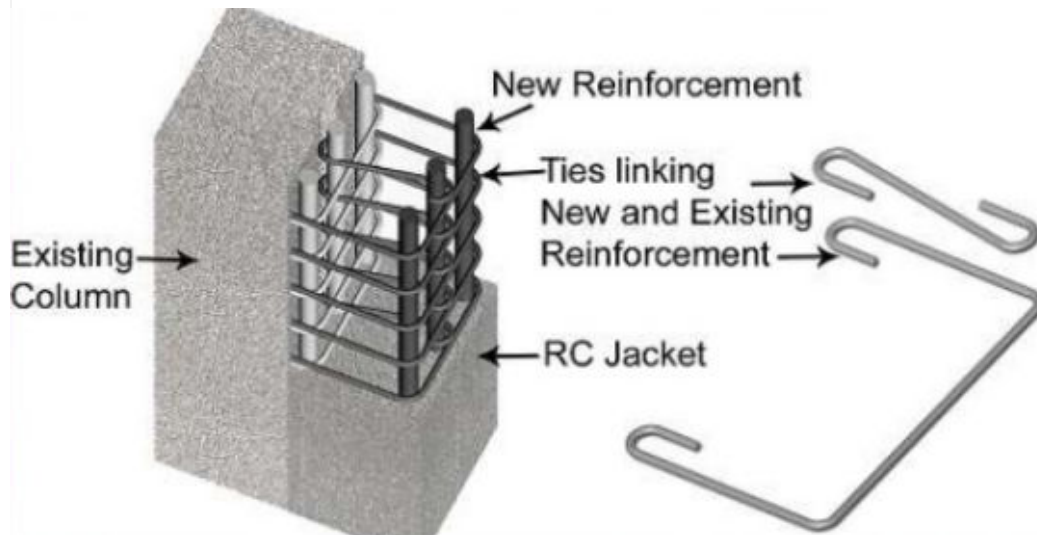


**Rolled steel sections jacketing(embedded inside concrete)**



### Option 1

The concept of concrete jacketing is an addition of a relatively thick layer of reinforced concrete in the form of a jacket around the existing structural elements (usually columns). Jacketing will enhance the flexural strength, ductility and shear strength of the structural elements.



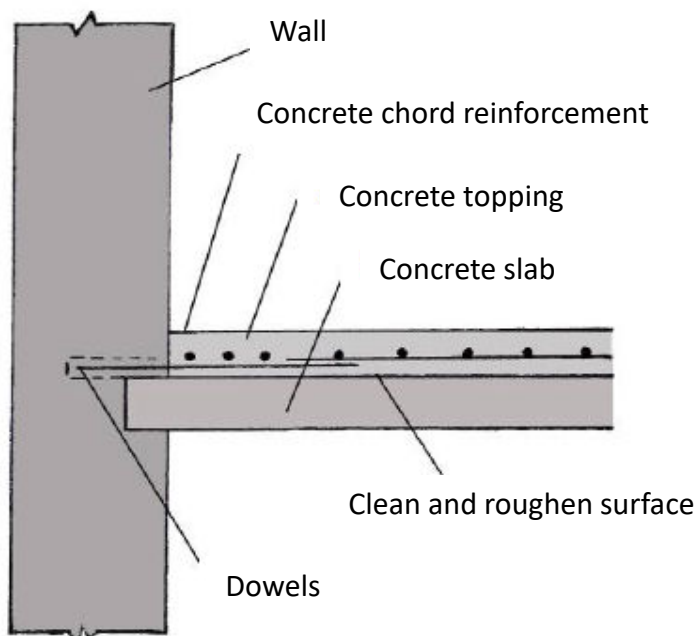
## Option 2

## 6. Strengthening of Slab/Diaphragm

Most of the concrete building have adequate diaphragms except when there occur large openings. Methods of enhancing diaphragms include the provision of topping slabs, metal plates laminated on to the top surface of the slab, or horizontal braced diaphragms beneath the concrete slabs.

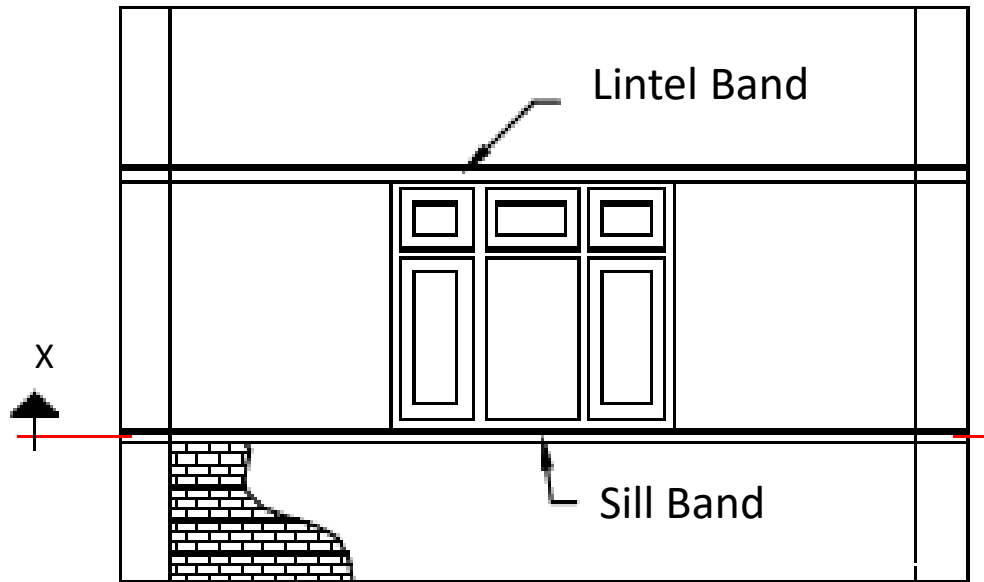


Fig: Diaphragm strengthening by steel sections

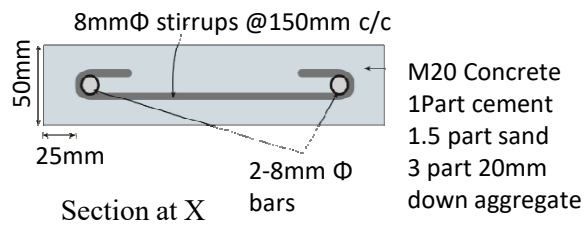


Strengthening concrete Diaphragm with new topping slab and chord

## 7. Strengthening of infill walls



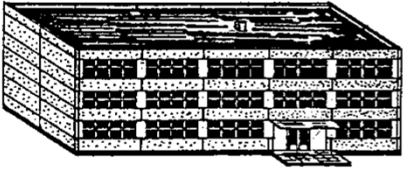
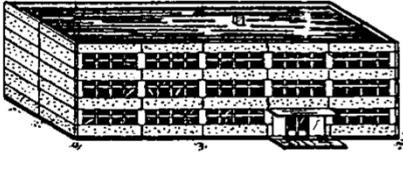



Elevation



Adding sill and lintel band externally on masonry wall (see Correction and exceptional manual for detail)



## Annex 1: EMS Damage Grade For RCC building

 <p><b>Grade 1: Negligible to slight damage</b></p>	<p><b>Structural damage : No</b> <b>Non-structural damage: Slight</b></p> <ul style="list-style-type: none"> <li>• Fine cracks in plaster over frame members or in walls at the base.</li> <li>• Fine cracks in partitions and infills.</li> </ul>
 <p><b>Grade 2: Moderate damage</b></p>	<p><b>Structural damage : Slight</b> <b>Non-structural damage: Moderate</b></p> <ul style="list-style-type: none"> <li>• Cracks in columns and beams of frames and in structural walls.</li> <li>• Cracks in partition and infill walls; fall of brittle cladding and plaster.</li> <li>• Falling of mortar from the joints of wall panels.</li> </ul>
 <p><b>Grade 3: Substantial to heavy damage</b></p>	<p><b>Structural damage: Moderate</b> <b>Non-structural damage: Heavy</b></p> <ul style="list-style-type: none"> <li>• Cracks in columns and beam column joints of frames at the base and at joints of coupled walls.</li> <li>• Spalling of concrete cover, buckling of reinforced bars.</li> <li>• Large cracks in partition and infill walls, failure of individual infill panels.</li> </ul>
 <p><b>Grade 4: Very heavy damage</b></p>	<p><b>Structural damage: Heavy</b> <b>Non-structural damage: Very heavy</b></p> <ul style="list-style-type: none"> <li>• Large cracks in structural elements with compression failure of concrete and fracture of rebars; bond failure of beam reinforced bars; tilting of columns.</li> <li>• Collapse of a few columns or of a single upper floor.</li> </ul>
 <p><b>Grade 5: Destruction</b></p>	<p><b>Structural damage: very heavy</b></p> <ul style="list-style-type: none"> <li>• Collapse of ground floor or parts (e.g. wings) of buildings.</li> </ul>

1. Teddy Boen and associates 2010 **“Retrofitting Simple Building Damaged By Earthquake”**
2. Shrestha Hari Darsan, Pribadi Krishna, Kusumastuti Dyah, Lim Edwin Manual on **“Retrofitting Of Existing Vulnerable School Buildings Assessment To Retrofitting”** Part I
3. **Nepal National Building Codes**
4. NICEE, India **“Guideline for Earthquake Resistant Non-Engineered Construction”**
5. CPWD, Government of India **“Handbook on Repair and Rehabilitation of RCC Buildings”**
6. MoUD, DUDBC Babarmahal Kathmandu, **“ Seismic Retrofitting Guidelines of Buildings in Nepal.**







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