

Designing Superstructures for Earthquake Resilience

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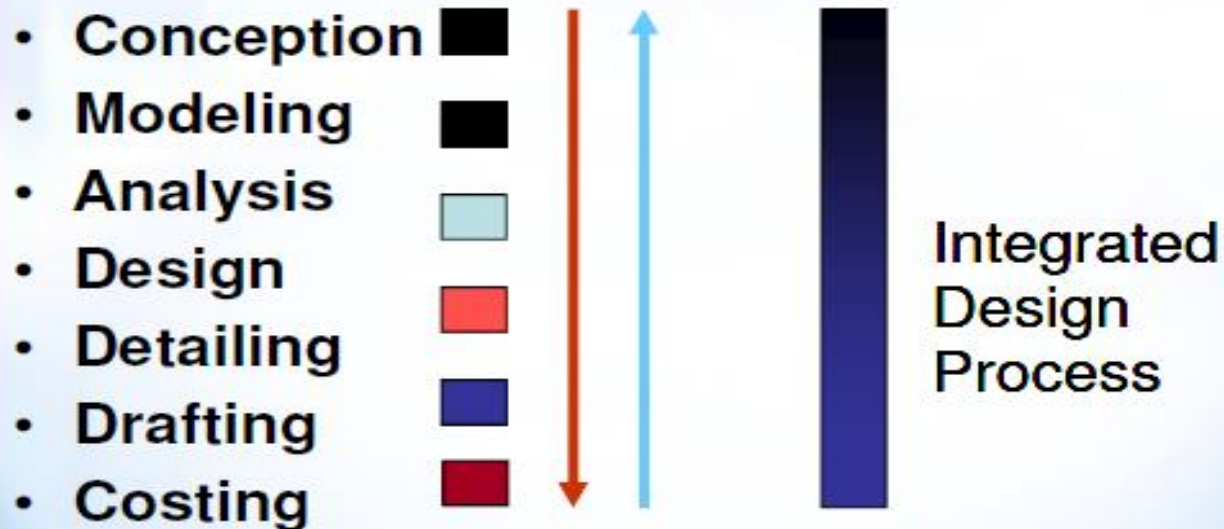
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Seismic Design Philosophy

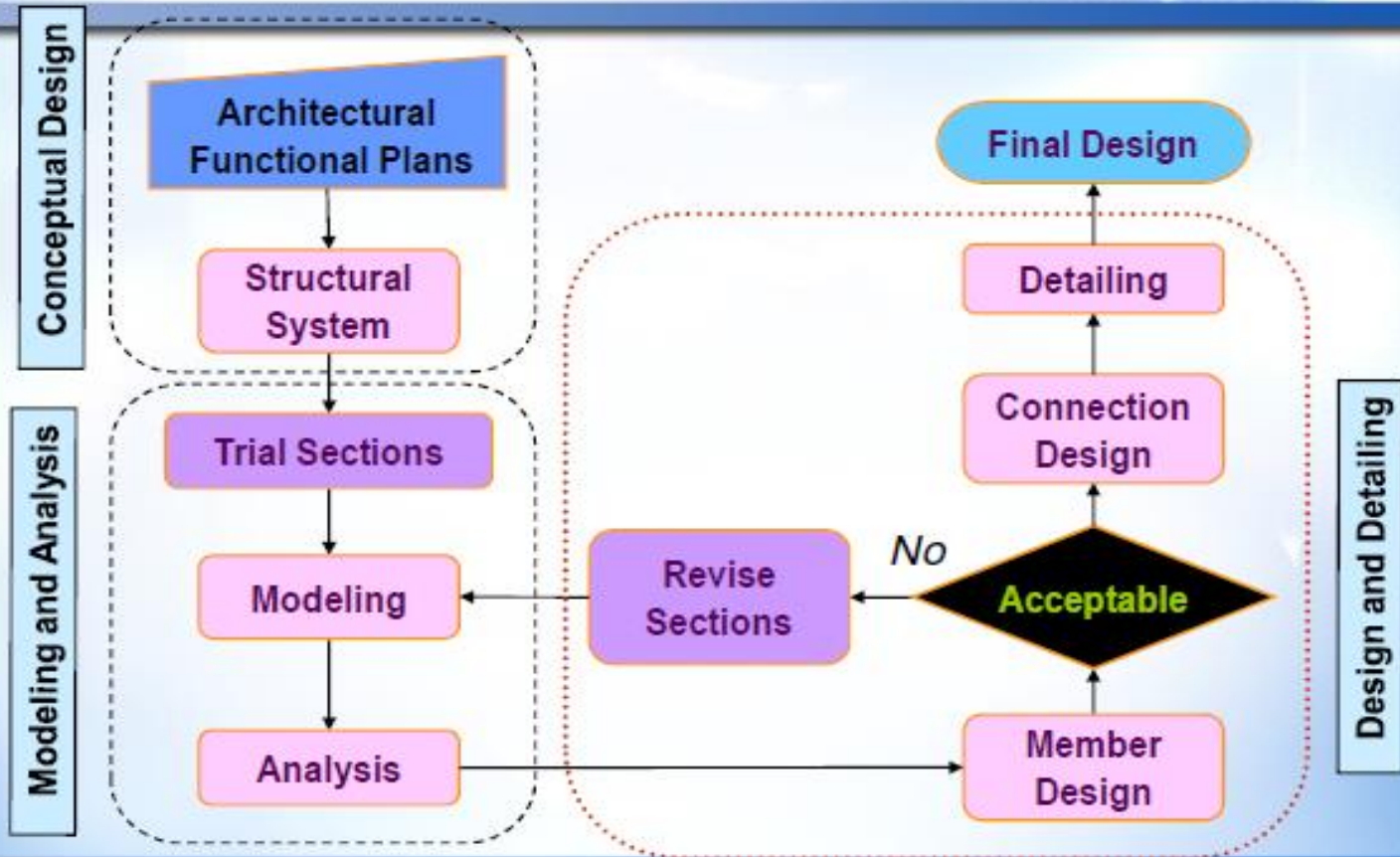
- The main goal of earthquake-resistant design is to attain a structure with sufficient strength and ductility to assure life safety, i.e., to prevent collapse under the most intense earthquake expected at a site during the life of a structure. In most structures that are subjected to moderate-to-strong earthquakes, economical earthquake-resistant design is achieved by allowing yielding to take place in some structural members.

- It is typically impractical as well as uneconomical to design a structure to respond in the elastic range to maximum expected earthquake-induced inertia forces. However, for certain types of structures such as nuclear containment buildings, hospital etc., yielding in the structure cannot be tolerated, and the design needs to be elastic.

Overall Design Process



Structure Design Process



Design Philosophy and Process

“Structural Design is the process of proportioning the structure to safely resist the applied forces in the most cost effective and friendly manner”



Conceptual Design Procedure

- ❑ **Structural Design of Foundation and Superstructure (Structural Framing System)Concept**
- ❑ **Code of Practice, Guidelines and Material Specification**
- ❑ **Design Load and Loading Combinations**

EARTHQUAKE EFFECTS TO STRUCTURES

GENERAL

EARTHQUAKES ARE NATURAL HAZARDS UNDER WHICH DISASTERS ARE MAINLY CAUSED BY THE DAMAGE TO OR COLLAPSE OF BUILDINGS AND OTHER MAN-MADE STRUCTURES.

UNTIL TODAY, THERE IS NOT MUCH THAT CAN BE DONE TO PREVENT THE OCCURRENCE OF EARTHQUAKES. HOWEVER, THE EARTHQUAKE-INDUCED DAMAGE CAN BE REDUCED WITH PLANNING AND CONSTRUCTING EARTHQUAKE RESISTANT BUILDINGS OR EVALUATING AND STRENGTHENING EXISTING BUILDINGS BEFORE AN EARTHQUAKE.

EARTHQUAKE DAMAGES DEPEND ON MANY PARAMETERS, SUCH AS:

1. EARTHQUAKE SHAKING CHARACTERISTICS:

INTENSITY, DURATION, AND FREQUENCY CONTENT OF GROUND MOTION

2. SOIL CHARACTERISTICS:

TOPOGRAPHY, GEOLOGIC, AND SOIL CONDITION

3. BUILDING CHARACTERISTICS:

BUILDING'S STIFFNESS, STRENGTH, DUCTILITY, AND INTEGRITY

BESIDE THE PARAMETERS MENTIONED ABOVE, EARTHQUAKE CASUALTIES DEPEND ON IMPORTANT SOCIOLOGIC FACTORS, SUCH AS:

- 1. DENSITY OF POPULATION**
- 2. TIME OF DAY OF THE EARTHQUAKE OCCURRENCE**
- 3. COMMUNITY PREPAREDNESS**

BASIC CAUSES OF EARTHQUAKE -INDUCED DAMAGE

1. GROUND SHAKING

GROUND SHAKING IS THE MAIN CAUSE OF DAMAGE BY EARTHQUAKES.

2. GROUND FAILURE

TYPES OF GROUND FAILURE:

- LANDSLIDE,**
- SETTLEMENT, AND**
- LIQUEFACTION.**

(Some)Important factors for Earthquake resistant Design

- Applied code of practice
- Structural framing system { Building configuration effects (symmetry, height, mass distribution.,) }
- Analysis and design method { Ductility, redundancy, and energy dissipation }
- Seismic detailing of RC structures
- Real-life case studies of well-performing and failed buildings

PROBLEM CLASSIFICATION

1. BEFORE A DAMAGING EARTHQUAKE:

THE REQUIRED STRENGTHENING TO BE DETERMINED BY A SURVEY AND ANALYSIS.

2. JUST AFTER A DAMAGING EARTHQUAKE:

TEMPORARY SUPPORTS & EMERGENCY REPAIRS ARE TO BE CARRIED OUT.

THOSE ACTIONS ARE NEEDED SO THAT THE BUILDINGS CAN BE RE-FUNCTION AND NOT COLLAPSED DUE TO AFTERSHOCKS.

3. AFTER A DAMAGING EARTHQUAKE WHEN THINGS START SETTLING DOWN:

DISTINCTION TO BE MADE IN THE TYPE OF ACTION REQUIRED:

- REPAIR**
- RESTORATION**
- STRENGTHENING**

REPAIR, RESTORATION, & STRENGTHENING

1. 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:

- A. PATCHING UP OF DEFECTS SUCH AS CRACKS, AND FALL OF PLASTER**
- B. REPAIRING DOORS, WINDOWS, REPLACEMENT OF GLASS PANES**
- C. CHECKING AND REPAIRING ELECTRIC WIRING.**
- D. CHECKING AND REPAIRING GAS PIPES, WATER PIPES & PLUMBING SERVICES**
- E. REBUILDING NON-STRUCTURAL WALLS, BOUNDARY WALLS, ETC.**
- F. RE-PLASTERING OF WALLS AS REQUIRED**
- G. REARRANGING DISTURBED ROOFING TILES**

2. 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 EPOXY 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.**

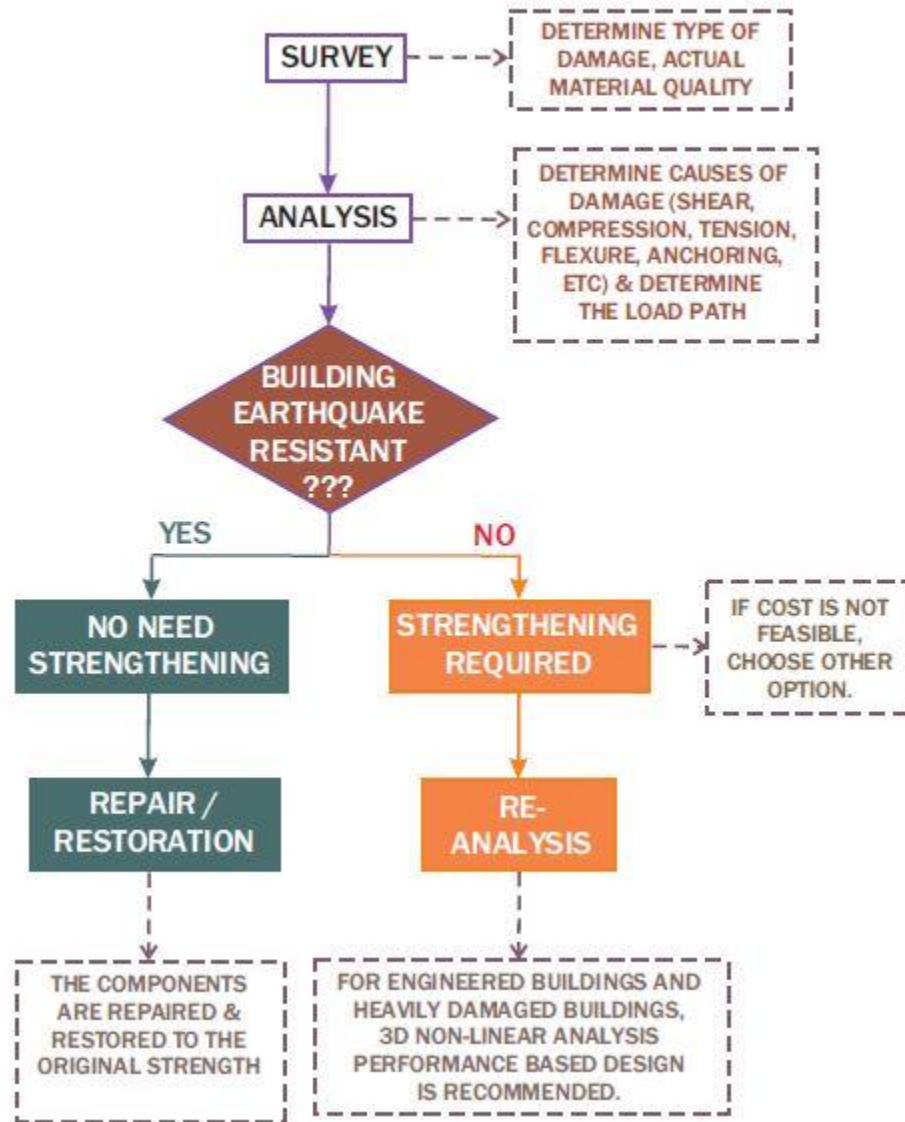
3. STRENGTHENING

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.**

RETROFITTING STEPS



RETROFITTING OF DAMAGED BEAMS AND COLUMNS

CRACKS IN CONCRETE:

1. HAIR-LINE CRACKS IN CONCRETE (WIDTH LESS THAN 0.2 MM) OR NO VISIBLE CRACKS INDICATE INSIGNIFICANT DAMAGE.
2. GENERALLY, CRACKS UP TO 2 MM WIDE IN CONCRETE COMPONENTS ARE NOT CONSIDERED SIGNIFICANT (AND MAY SIGNIFY LOW DAMAGE).
3. CRACKS UP TO 5 MM WIDE IN CONCRETE COMPONENTS MAY INDICATE MODERATE DAMAGE.
4. CRACKS GREATER THAN 5 MM INDICATE HEAVY DAMAGE (WITH SIGNIFICANT LOSS OF STRENGTH).
5. BUCKLING OF REINFORCEMENT IN CONCRETE COMPONENTS SIGNIFIES HEAVY DAMAGE, IRRESPECTIVE OF CRACK WIDTH IN CONCRETE.

GENERALLY, THE TECHNIQUES TO STRENGTHEN CONCRETE COLUMN / BEAM ARE AS FOLLOWS:

- 1. TO ADD REINFORCEMENT AND STIRRUPS OUTSIDE THE CONCRETE COLUMN / BEAM AND SUBSEQUENTLY COVER BY CONCRETE.**
- 2. TO BANDAGE THE CONCRETE COLUMN / BEAM WITH WELDED WIRE FABRIC AND SUBSEQUENTLY PLASTER WITH MORTAR.**
- 3. TO COVER THE CONCRETE COLUMN WITH RECTANGULAR STEEL PROFILE OR PIPE AND SUBSEQUENTLY THE GAP BETWEEN CONCRETE AND STEEL IS GROUTED.**
- 4. TO BANDAGE WITH STEEL PLATE WELDED TO 4 STEEL ANGLE PROFILES PLACED IN EACH CORNER OF THE COLUMN AND SUBSEQUENTLY THE GAP BETWEEN CONCRETE AND STEEL IS GROUTED.**

TO INCREASE THE COLUMN SHEAR STRENGTH WITHOUT INCREASING ITS FLEXURAL CAPACITY, A GAP MUST BE PROVIDED AT THE TOP AND BOTTOM OF THE COLUMN. THEREFORE, THE ADDITIONAL REINFORCEMENT IS NOT ANCHORED TO THE BEAM.

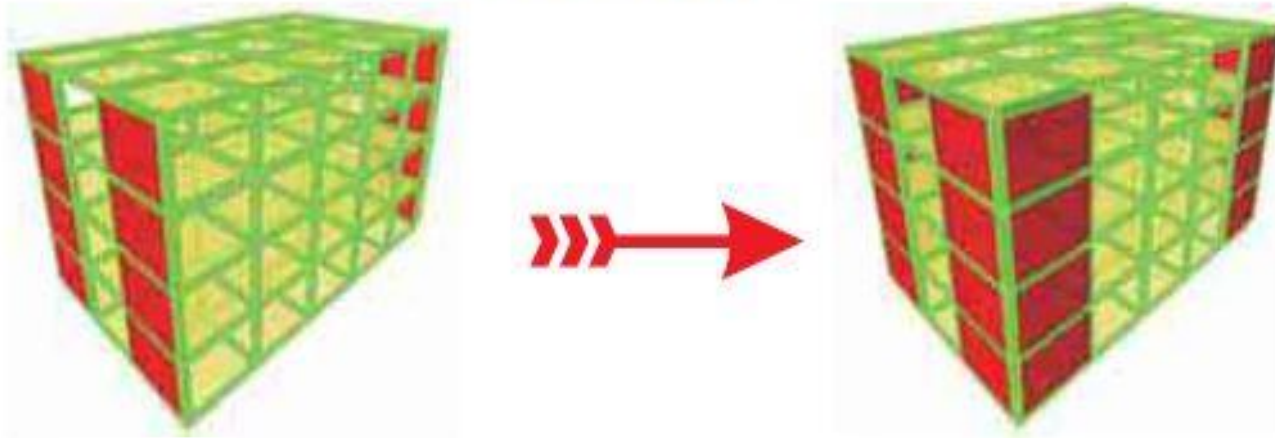
FOR COLUMNS WITH MODERATE CRACKS, REMOVE THE DAMAGE PART, CLEAN, AND POUR NEW CONCRETE. COLUMNS MUST BE SUPPORTED DURING RETROFITTING WORKS.

FOR HEAVILY DAMAGED COLUMNS, NAMELY COLUMNS WHERE ITS STRENGTH IS SUBSTANTIALLY REDUCED (BASED ON OBSERVATION AS WELL AS ANALYSIS). THE DAMAGED PART IS REMOVED AND IF THE ANALYSIS SHOWS THAT ADDITIONAL REINFORCEMENT MUST BE PLACED, ONE OF THE ABOVE EXPLAINED METHOD CAN BE APPLIED. BEFORE REMOVING THE DAMAGED PART OF THE COLUMN, BEAMS AND SLABS AROUND THE COLUMN MUST BE SUPPORTED.

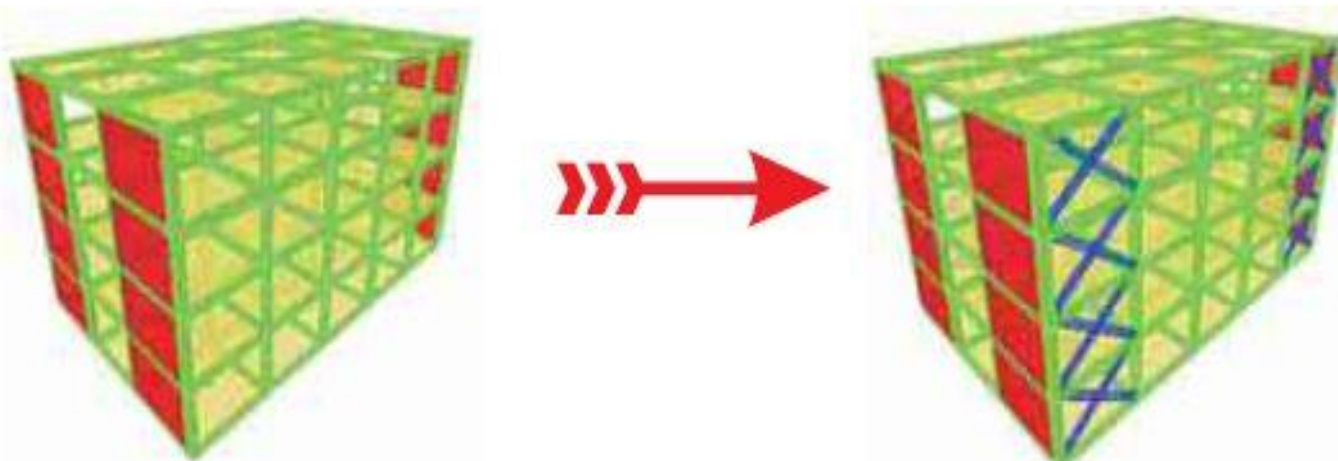
Consideration for Whole Building Unit

Example for Providing Wall & Frame

ADDITION OF NEW WALLS



ADDITION OF BRACED FRAMES



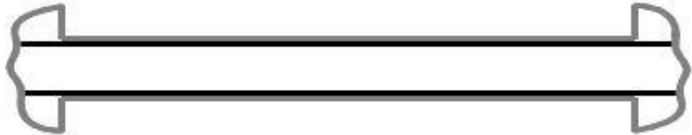
Structural Elements

- Slab
- Beam
- Column, Walls , Basement Walls
- Footing,etc.
- Staircase , Parapet Walls, Sunshade Fans

Strengthening Floor Beam Example

ACI 318-05, Overview of Frames: Beam Longitudinal Reinforcement

$$\frac{200}{f_y} \leq \rho \leq 0.025$$



At least 2 bars continuous
top & bottom

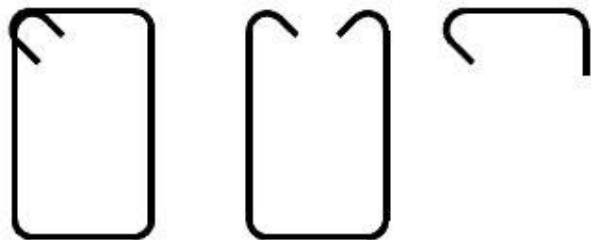


Joint face M_n^+ not less than 50% M_n^-
Min. M_n^+ or M_n^- not less than
25% max. M_n at joint face



Splice away from hinges and
enclose within hoops or spirals

ACI 318-05, Overview of Frames: Beam Transverse Reinforcement

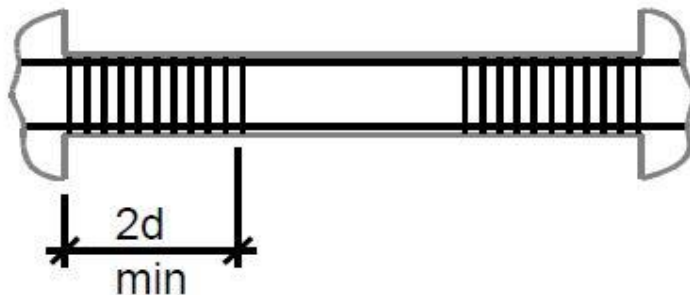


Closed hoops at hinging regions with “seismic” hook

135° hook, $6d_h \geq 3$ ” extension

Maximum spacing of hoops:

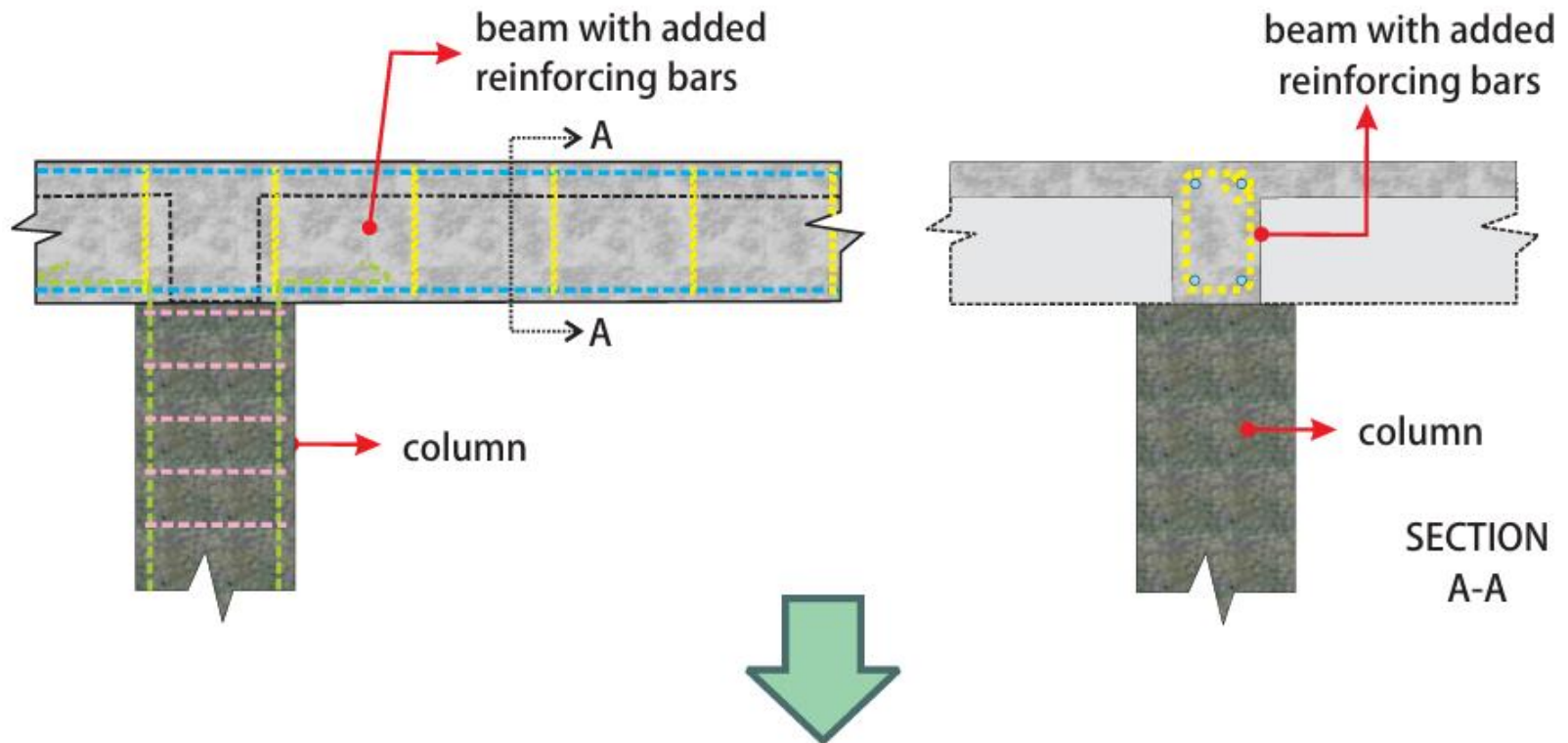
$d/4$ $8d_b$ $24d_h$ 12”

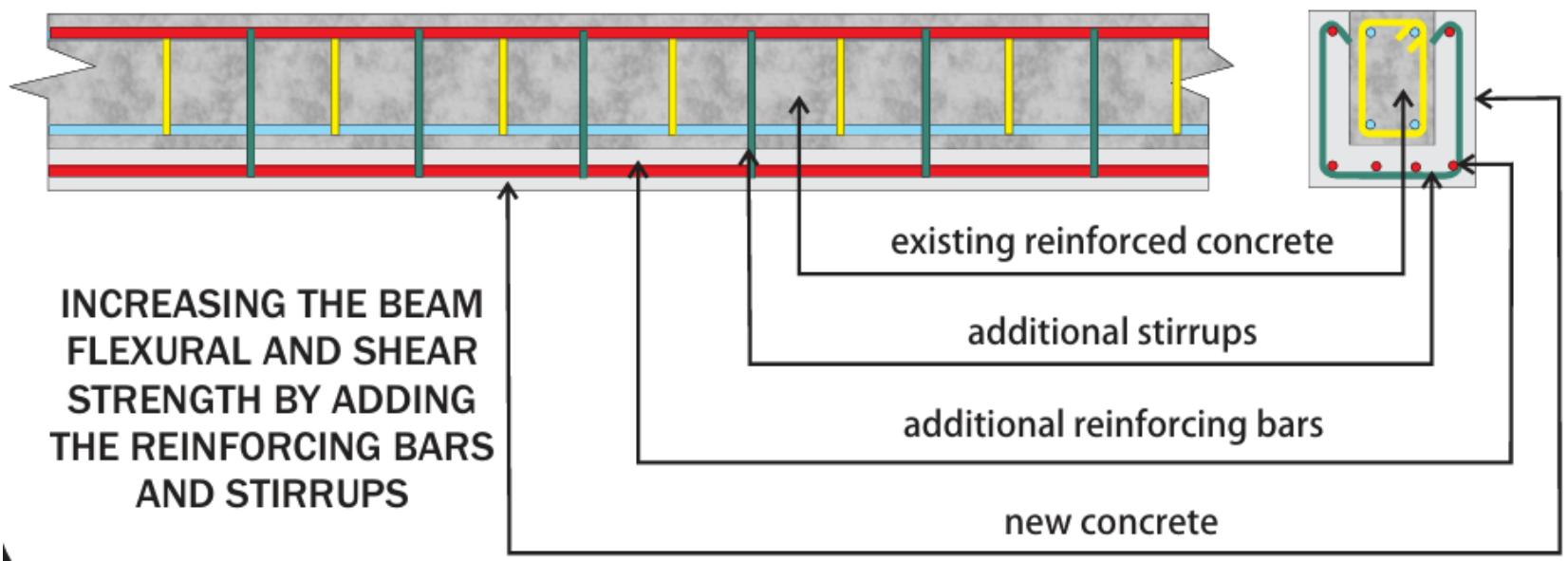
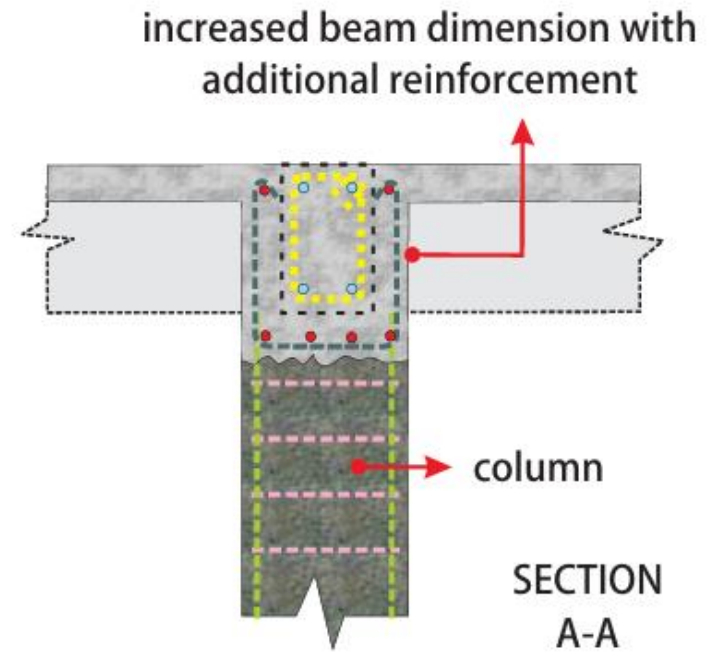
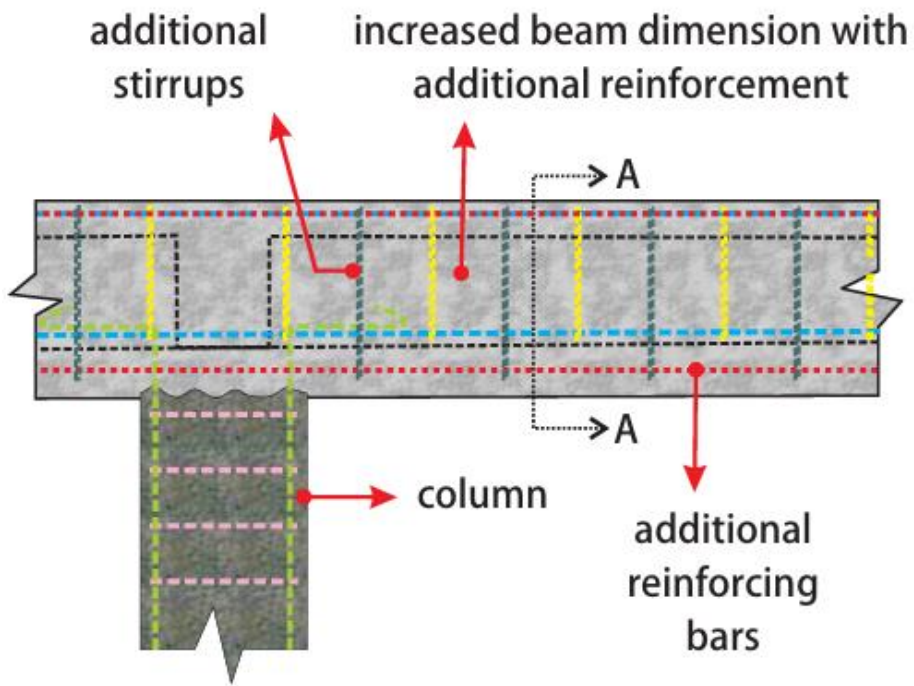


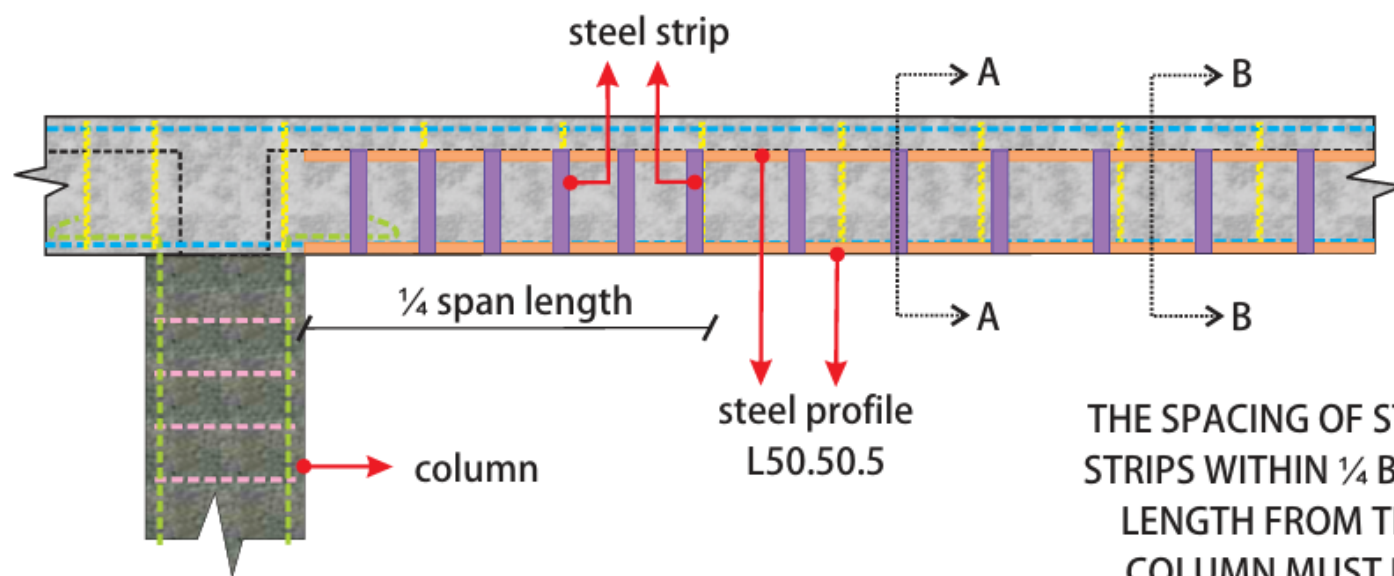
Longitudinal bars on perimeter tied as if column bars

Stirrups elsewhere, $s \leq d/2$

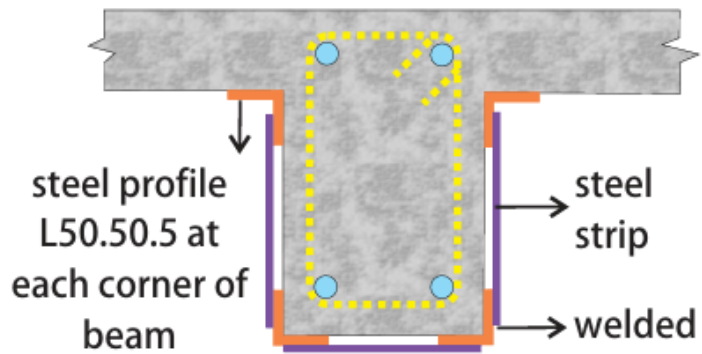
IF THE ANALYSIS SHOWS THAT THE BEAM REINFORCEMENT IS NOT ADEQUATE, ADDITIONAL REINFORCEMENT MUST BE PLACED AND THE DIMENSION OF THE BEAM CAN BE INCREASED (JACKETING).



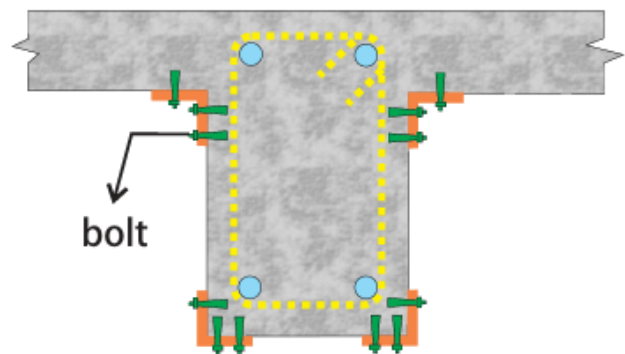




THE SPACING OF STEEL STRIPS WITHIN $\frac{1}{4}$ BEAM LENGTH FROM THE COLUMN MUST BE SMALLER



SECTION A-A



SECTION B-B

ADDING STEEL PROFILE & STIRRUPS TO INCREASE THE BEAM SHEAR STRENGTH WITHOUT INCREASING ITS FLEXURAL STRENGTH

Need for Steel-based Strengthening

- Reasons to choose steel over other materials:
 - Superior ductility and toughness
 - Familiarity in design codes (AISC, Eurocode 3)
 - High fire resistance compared to FRP
 - Ease of inspection and reversibility

Steel Bandaging Techniques

Overview

- External confinement using steel straps or plates.
- • Confinement for columns: circular and rectangular
- • Shear strengthening for beams
- • Retrofit of seismic regions

Materials for Steel Bandaging

- Key materials and specifications:
 - High-strength steel straps ($f_y \geq 250$ MPa)
 - Mild steel flat plates
 - Hydraulic jacks and turnbuckles
 - Bolts, washers, and steel anchor plates

Application Procedure – Bandaging

- Steps for installing steel bandages:
 - Surface preparation: clean and roughen concrete
 - Position and align steel straps/plates
 - Secure with anchor plates and bolts
 - Apply corrosion protection (galvanizing/paint)

Steel Jacketing Techniques

Overview

- Encasing members with steel plates or shells.
- • Full or partial steel jackets
- • Welded vs bolted connection methods
- • Suitable for columns and beams

Materials for Steel Jacketing

- Components for jacketing:
 - • Steel plates (eg.thickness 6–12 mm)
 - • Connection studs or welding rods
 - • Bolts and stiffeners
 - • Corrosion-resistant coatings

Application Procedure – Jacketing

- Step-by-step jacketing process:
 - Prepare substrate and remove loose concrete
 - Fit and align steel plate segments
 - Weld or bolt plates to existing member
 - Install internal reinforcement if needed
 - Seal joints and apply protective coatings

Design Example – Jacketing

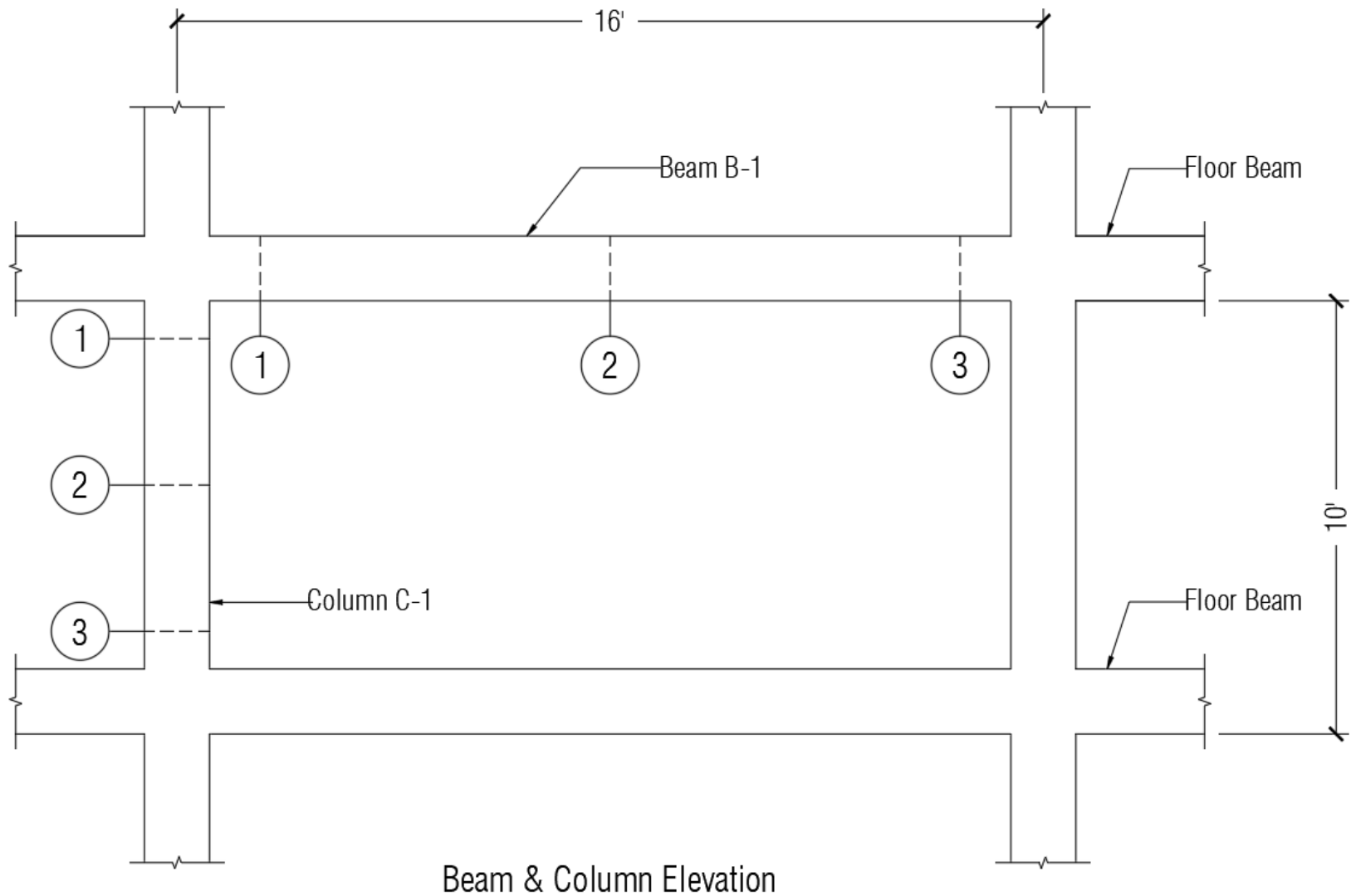
- Example: 500×500 mm column with steel shell (10 mm thick)
- • Compute composite area $A_c = A_o + A_s$
- • Evaluate increased moment capacity M_n
- • Check local buckling using slenderness λ
- • Verify overall section strength

Comparison: Bandaging vs Jacketing

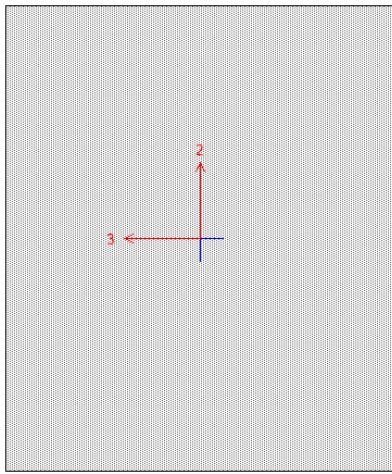
- Selecting the appropriate method:
 - Bandaging: quick, minimal weight, less invasive
 - Jacketing: higher capacity gain, more durable
 - Cost, site access, and desired performance
 - Combination approaches for optimal results

- Steel bandaging and jacketing offer robust solutions for structural strengthening.
- • Enhance capacity and ductility
- • Cost-effective and sustainable
- • Applicable to diverse structural elements

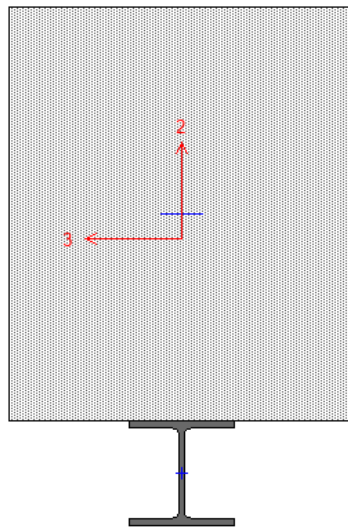
Example for Column & Beam in a Frame



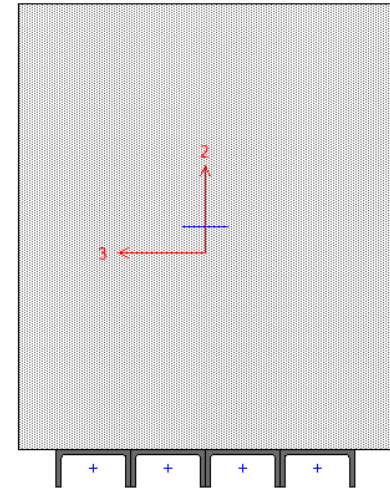
BEAM SECTION (20" x 24")



Existing R.C Beam Section
(20" x 24")



Strengthening
with H-Section (6" x 6")

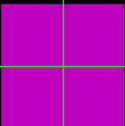


Strengthening
with C-Channel (4" x 2")

Longitudinal Reinforcing Steel Before Strengthening

	5.5264	2.0126	5.7437	
	2.6347	4.2608	2.8539	

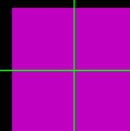
Longitudinal Reinforcing Steel After Strengthening

	4.8267	1.9089	5.0618	
	2.3715	3.4021	2.5828	

Shear Reinforcing Steel Before Strengthening

	0.1292	0.1157	O/S	
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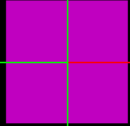
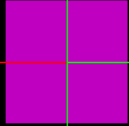
Shear Reinforcing Steel After Strengthening

	0.1016	0.1012	0.1157	
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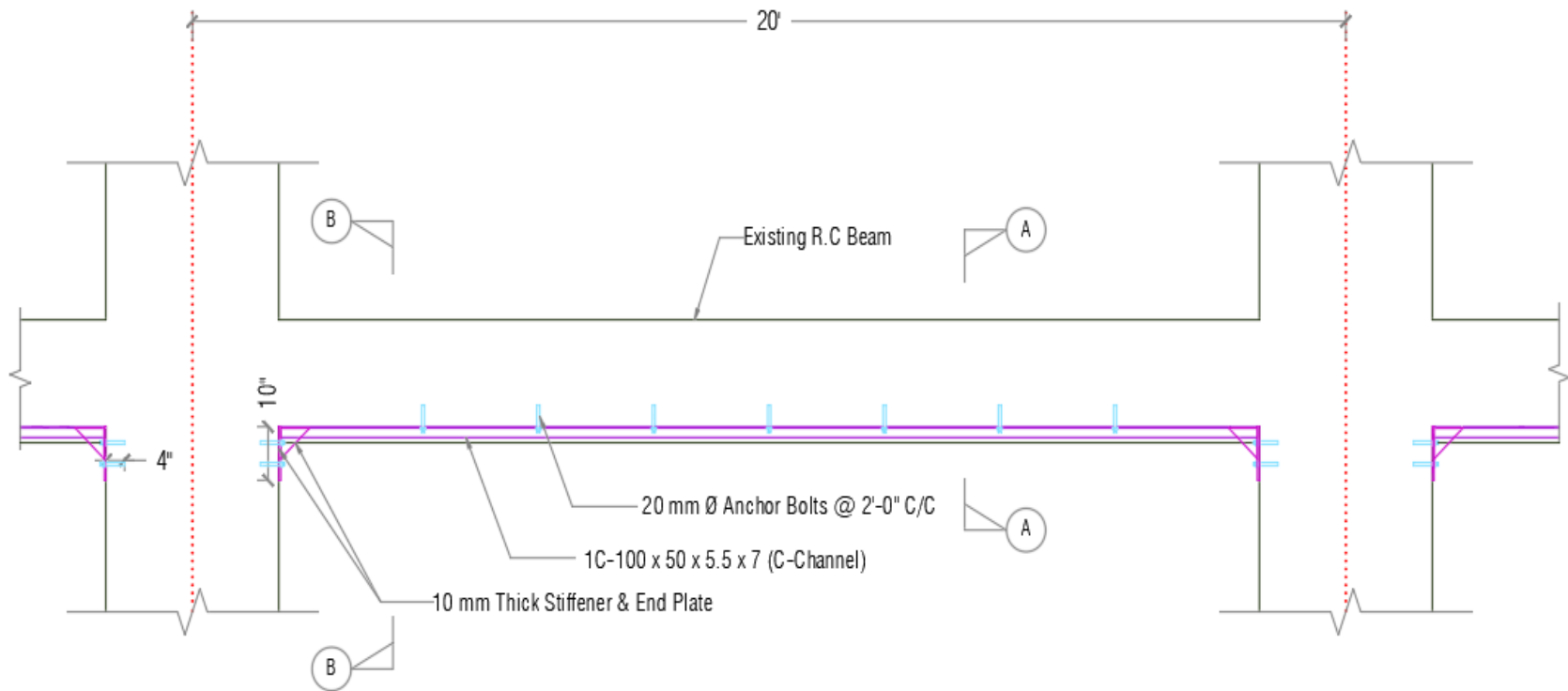
Torsion Reinforcing Steel Before Strengthening

	0.0157	0.0249	0.0300	
	2.4456	2.4456	2.4456	

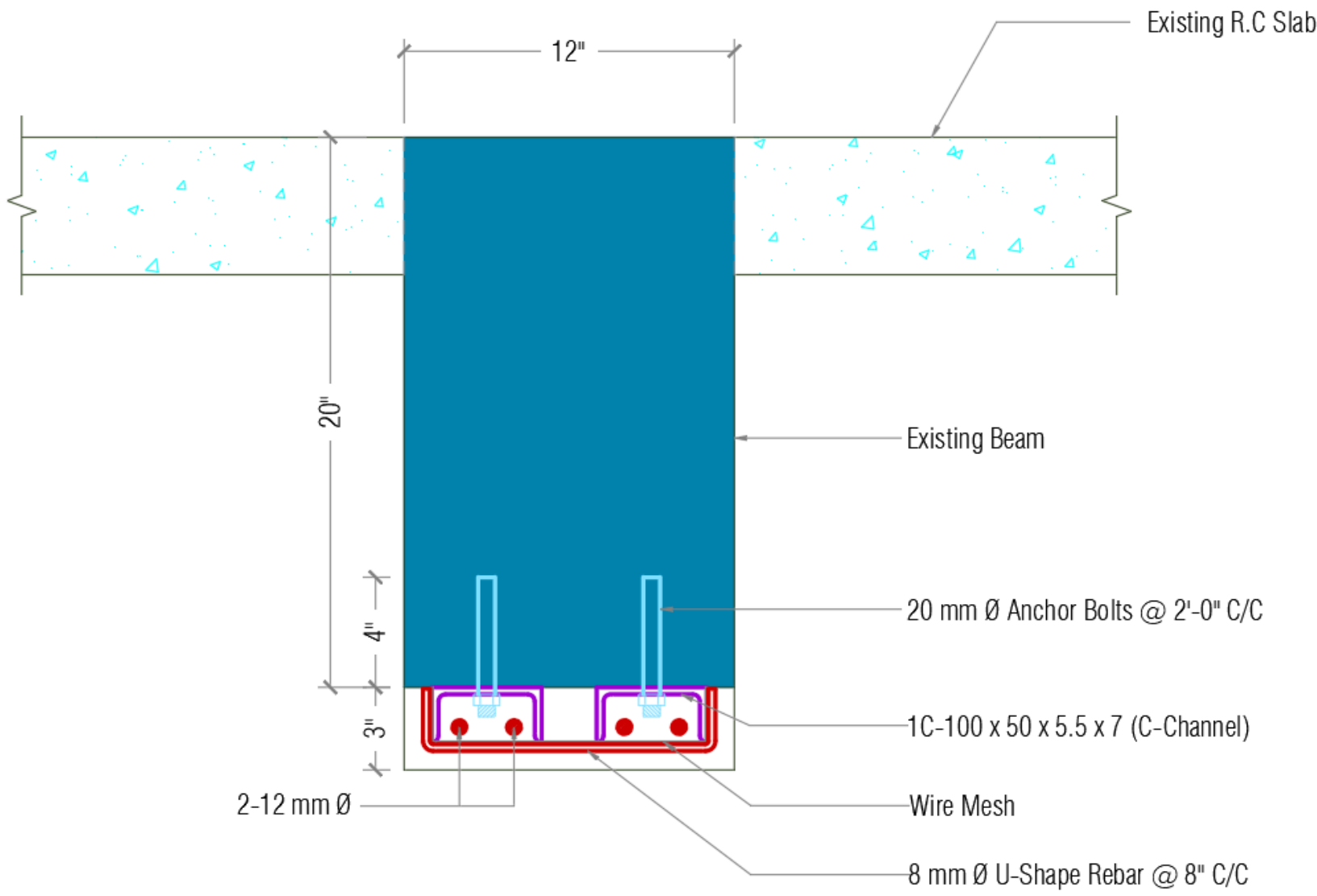
Torsion Reinforcing Steel After Strengthening

	0.0203	0.0308	0.0374	
	1.9132	1.9132	2.3035	

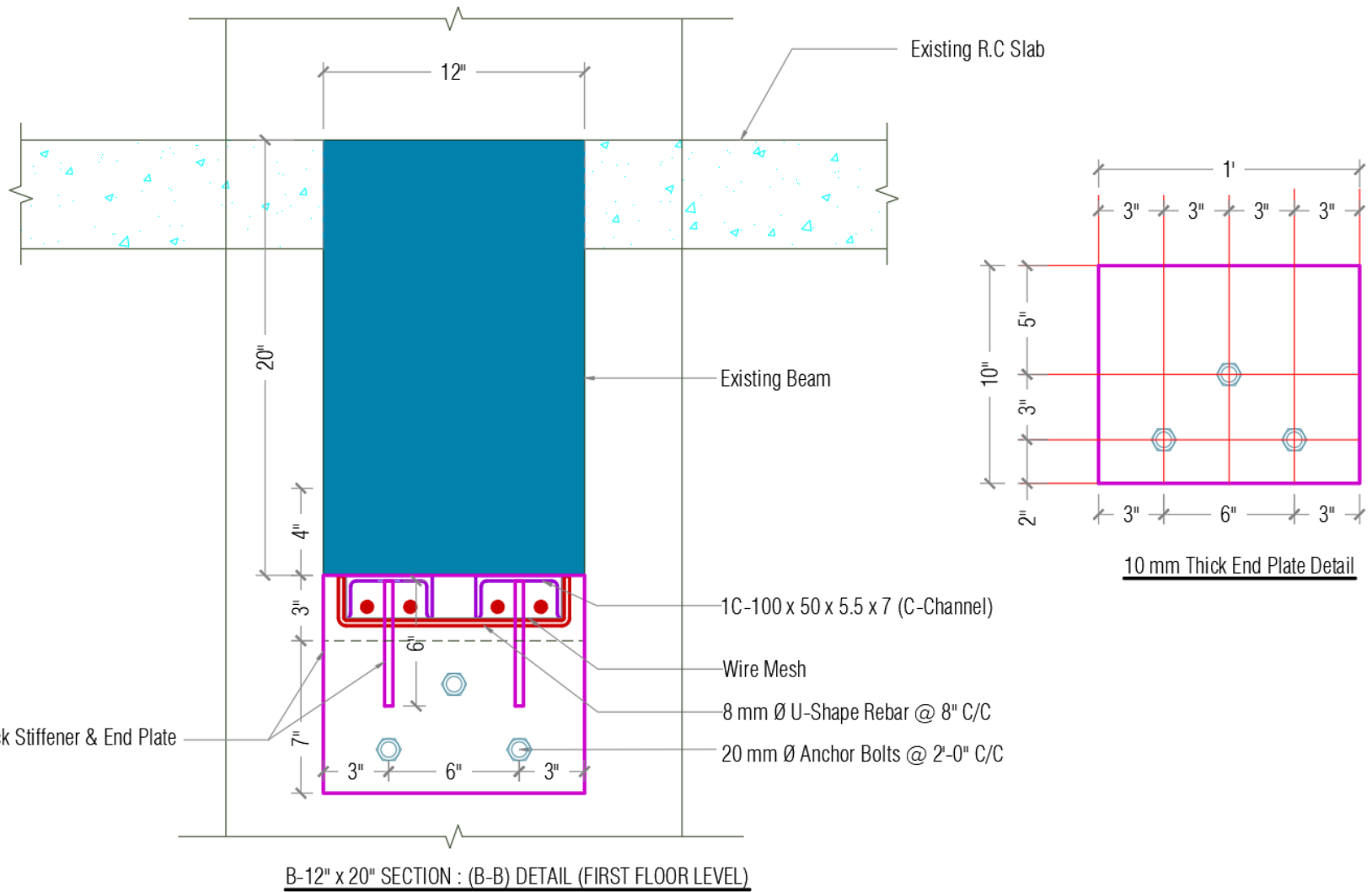
Strengthening Beam Detail (Elevation)

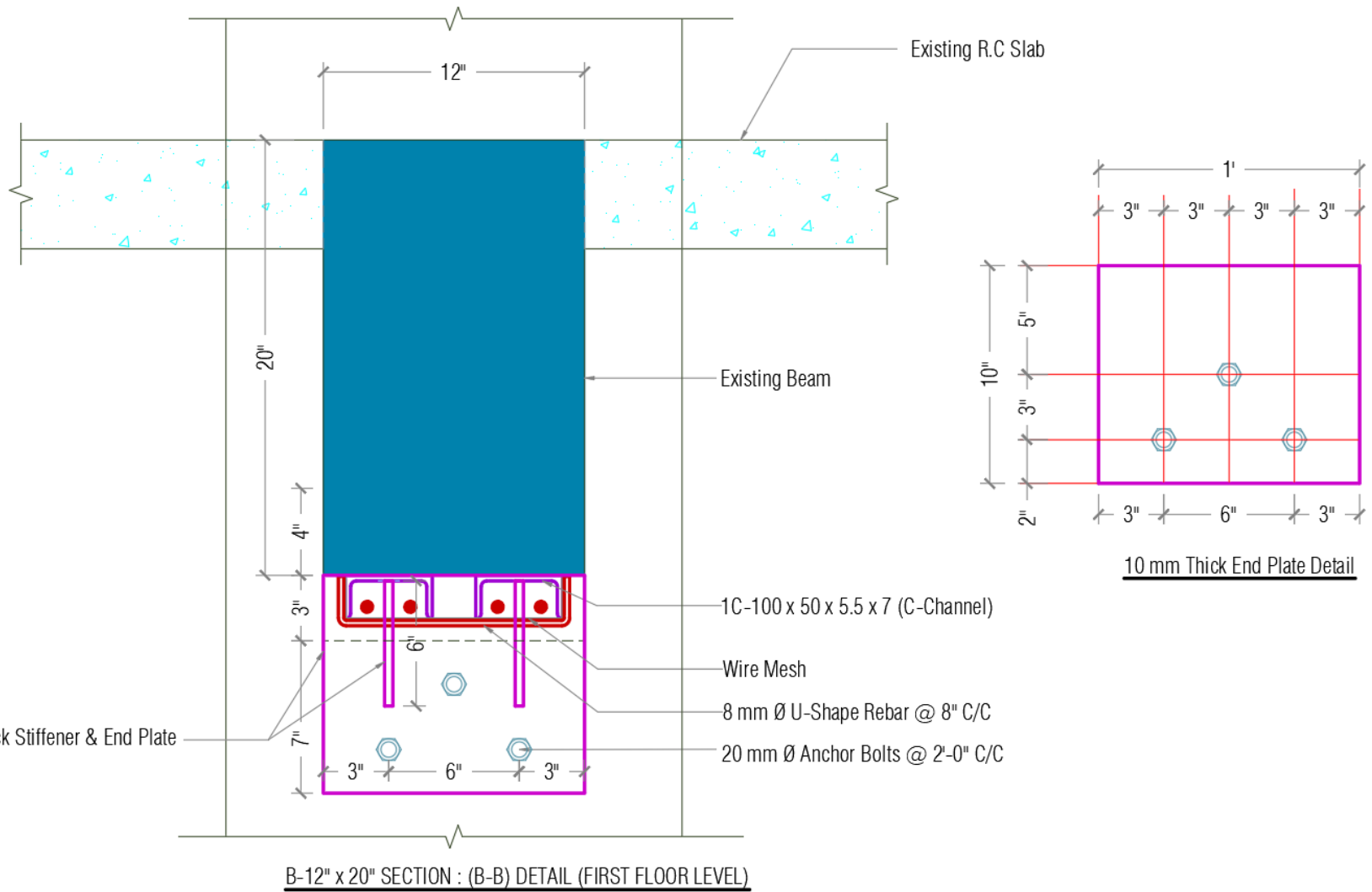


B-12" x 20" ELEVATION

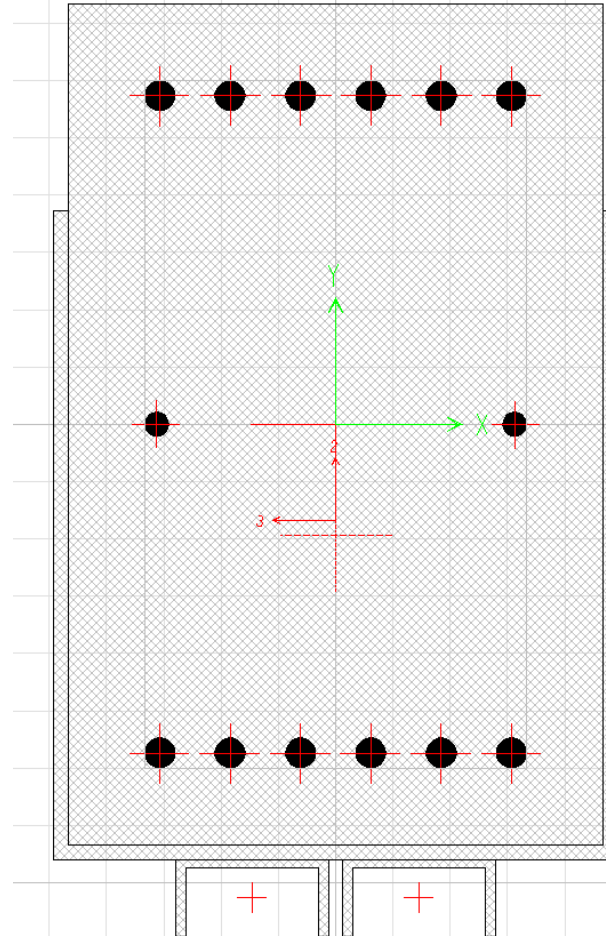
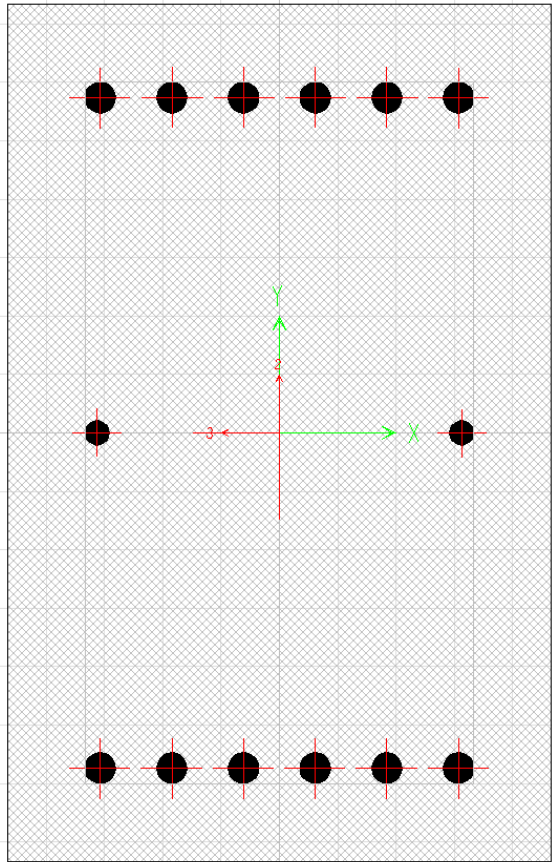


B-12" x 20" SECTION : (A-A) DETAIL (FIRST FLOOR LEVEL)

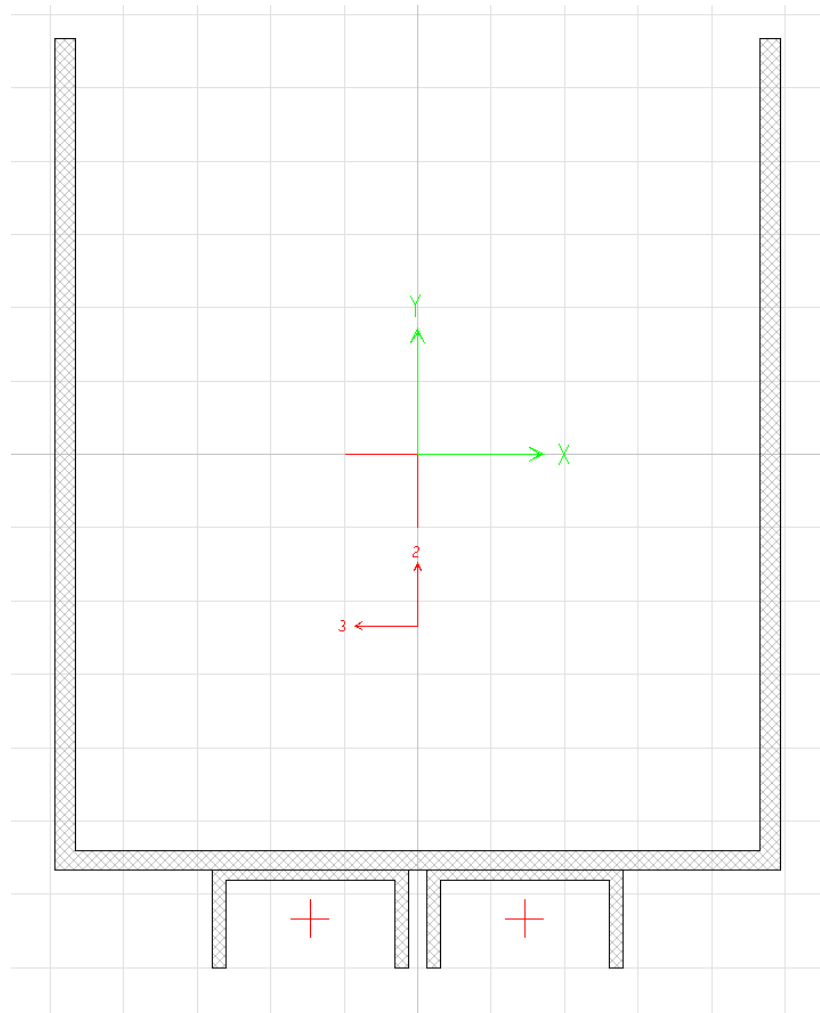




Strengthened Beam Section (example)



Strengthened Beam Section (example)



Beam No- B1

BEAM SIZE - 14" x 22"

Bending Moment(Kips - in)

Beam Section	Load Combination		Reinforcement		Remark
	1.2 DL + 1.6 LL	1.32DL+ 1LL+1EQX	1.2 DL + 1.6 LL	1.32DL+ 1LL+1EQX	
1	-1189	-1827	5 - 20mm Ø	5 - 25mm Ø	
2	770	771	5 - 20mm Ø	5 - 20mm Ø	
3	-1251	-645	5 - 20mm Ø	5 - 25mm Ø	

Beam No- B1

BEAM SIZE - 14" x 22"

Shear Force (Kips)

Beam Section	Load Combination		Reinforcement		Remark
	1.2 DL + 1.6 LL	1.32DL+ 1LL+1EQX	1.2 DL + 1.6 LL	1.32DL+ 1LL+1EQX	
1	-21	-25.97	2-10 mm Ø - 5 in c/c	2-10 mm Ø - 4 in c/c	
2	-4	-8.15	10 mm Ø - 6 in c/c	2-10 mm Ø - 5 in c/c	
3	22	18.40	2-10 mm Ø - 5 in c/c	2-10 mm Ø - 4 in c/c	

BEAM SIZE - 14" x 22'

Torsion Force(Kips - in)

Beam Section	Load Combination		Longitudinal Reinforcement (Top / Middle / Bottom)		Transverse Reinforcement		Remark
	1.2 DL + 1.6 LL	1.32DL+ 1LL+1EQX	1.2 DL + 1.6 LL	1.32DL+ 1LL+1EQX	1.2 DL + 1.6 LL	1.32DL+ 1LL+1EQX	
1	274	279.00	2 - 16mm Ø	2 - 20mm Ø	2-10 mm Ø - 5 in c/c	2-10 mm Ø - 4 in c/c	
2	137	149.00	2 - 16mm Ø	2 - 16mm Ø	10 mm Ø - 6 in c/c	2-10 mm Ø - 5 in c/c	
3	-309	-324.00	2 - 16mm Ø	2 - 20mm Ø	2-10 mm Ø - 5 in c/c	2-10 mm Ø - 4 in c/c	

COLUMN SIZE - 14" x20'

Column Design	Required reinforcement		Provided Reinforcement		Remark
	1.2 DL + 1.6 LL	1.32DL+ 1LL+1EQX	1.2 DL + 1.6 LL	1.32DL+ 1LL+1EQX	
Longitudinal Reinforcement(in ²)	2.70	8.70	8 - 18mm Ø	12 - 25mm Ø	
Shear Reinforcement(Major Shear)(in ²)	Minimum	0.028	2-10 mm Ø - 6 in c/c	2-10 mm Ø - 3 in c/c	
Shear Reinforcement(Minor Shear)(in ²)	Minimum	0.025	2-10 mm Ø - 6 in c/c	2-10 mm Ø - 3 in c/c	

Strengthening Reinforced Concrete Column Example



Column with Inadequate Ties

Joint Failure – No Shear Reinforcing

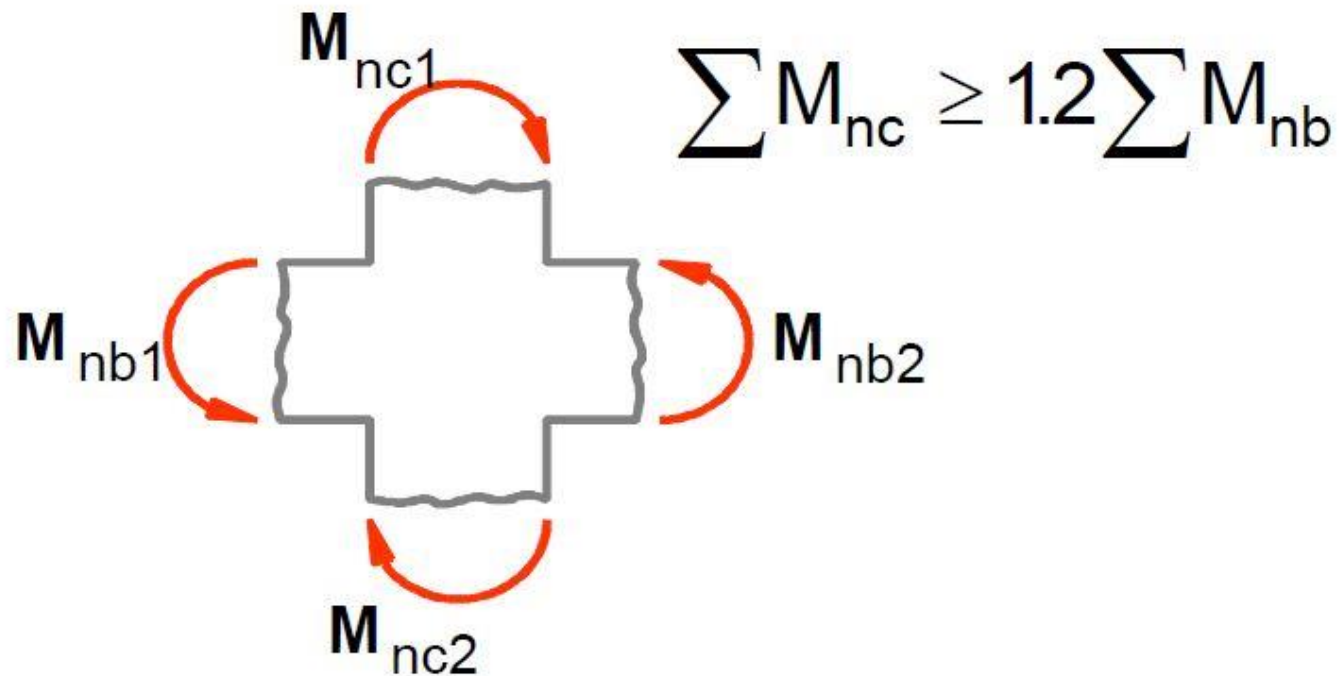




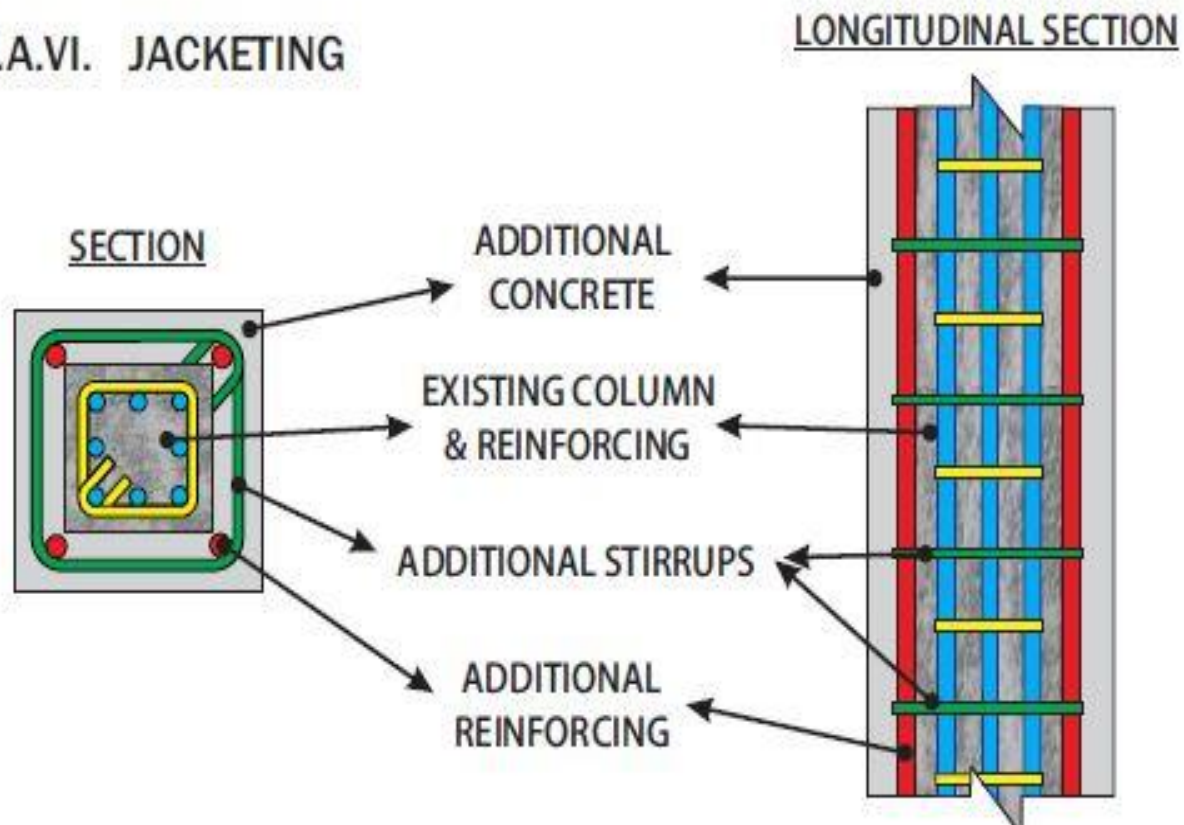
Splice in Hinge Region

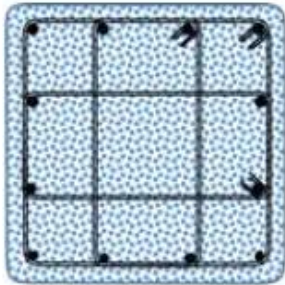
Terminating
bars

Required Column Strength

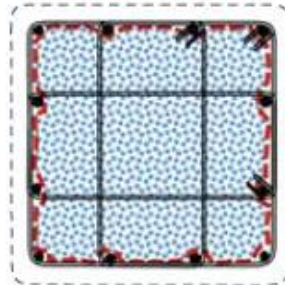


8.2.A.VI. JACKETING

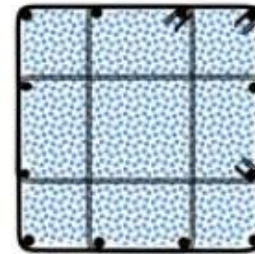




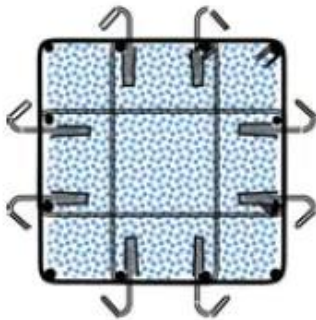
1: Original section



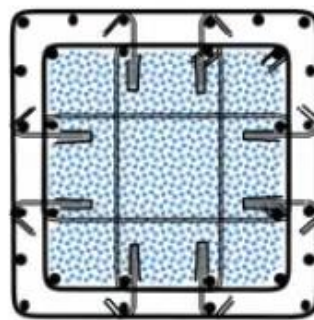
2: Concrete to be demolished



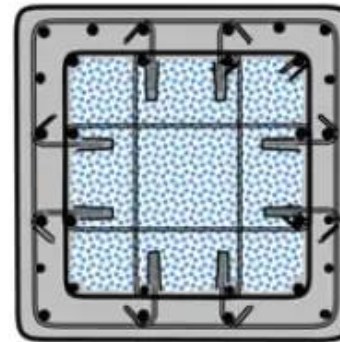
3: Cleaning steel reinforcement



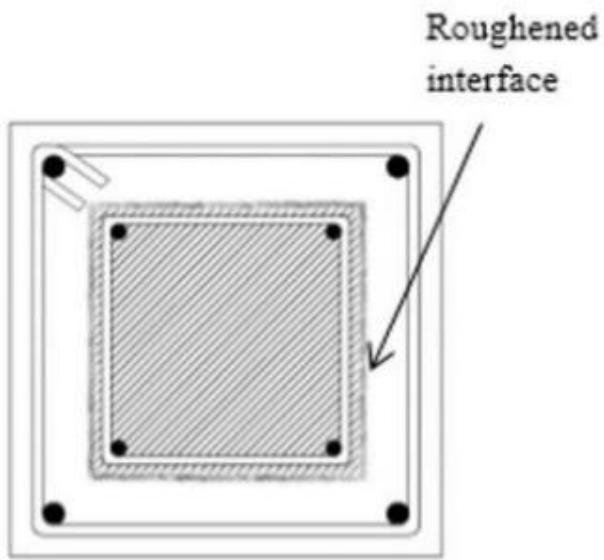
4: Inserting steel dowels



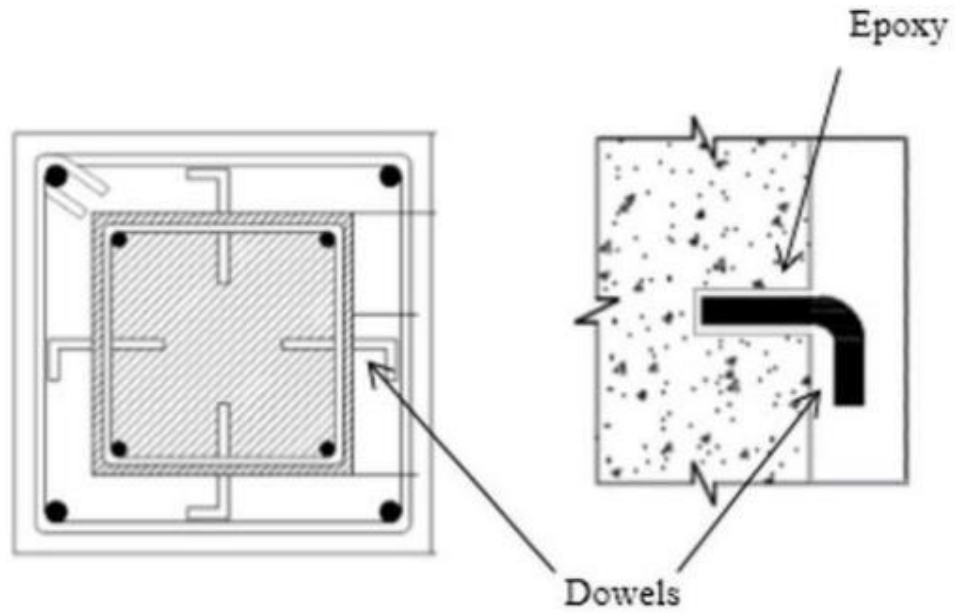
5: Fixing steel cage of the jacket



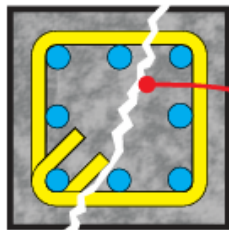
6: Casting new concrete



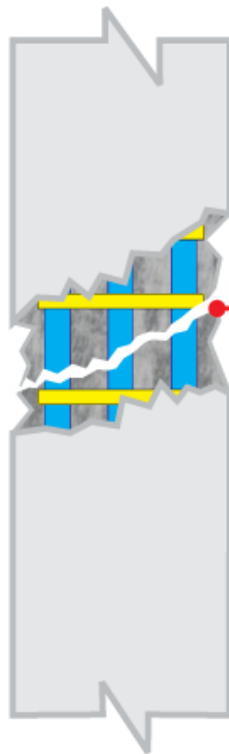
(a)



(b)

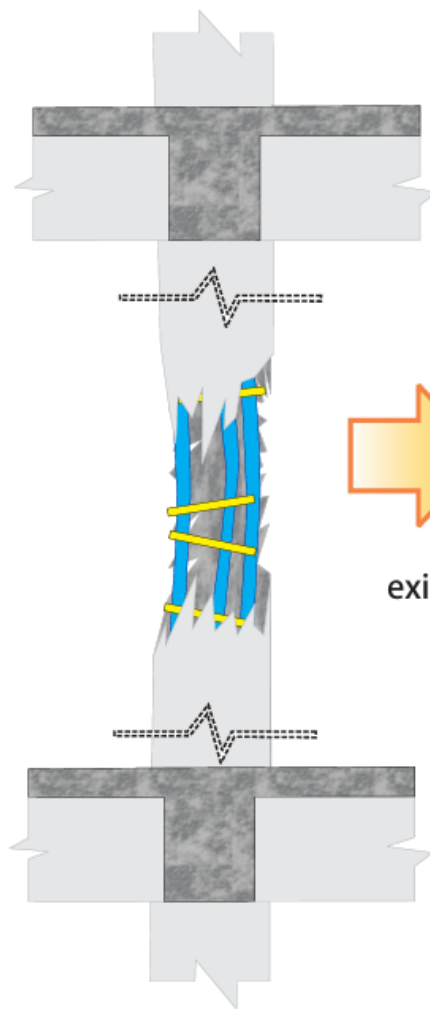


the cracked part is removed, cleaned, and subsequently pour new concrete



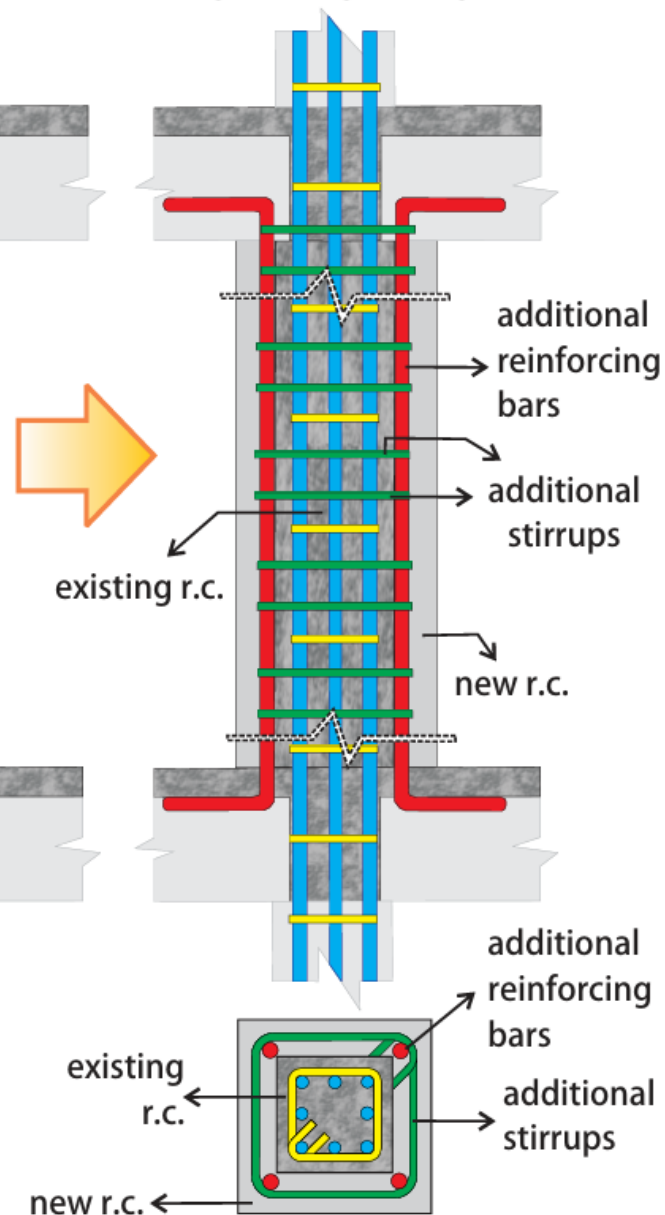
COLUMN WITH MODERATE CRACK

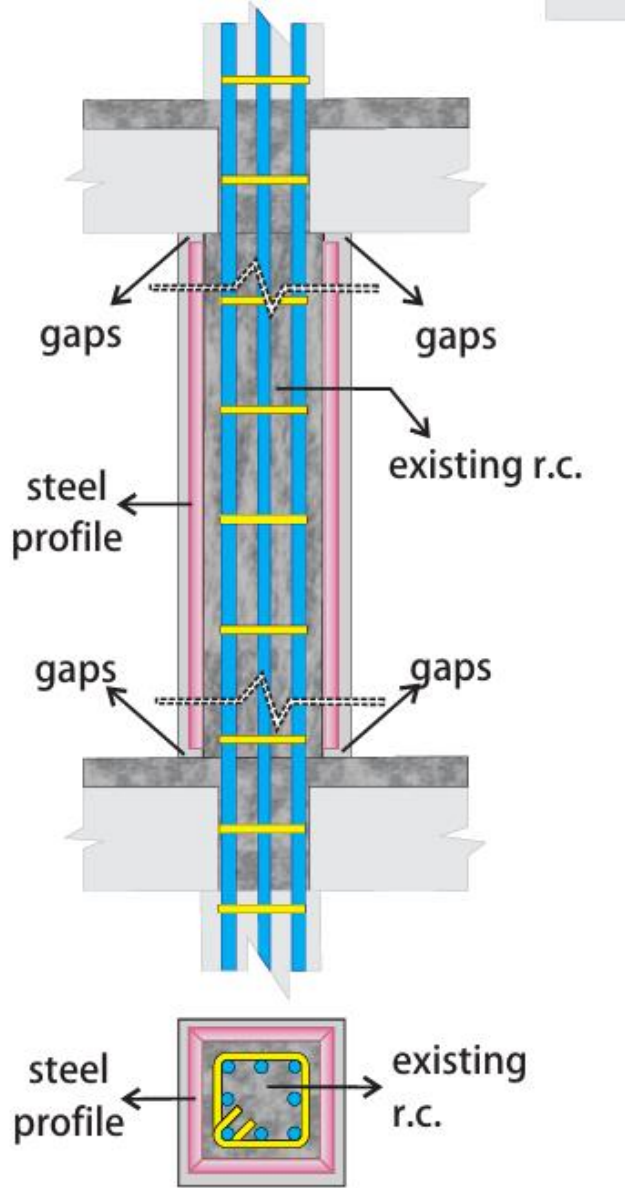
DAMAGED COLUMN



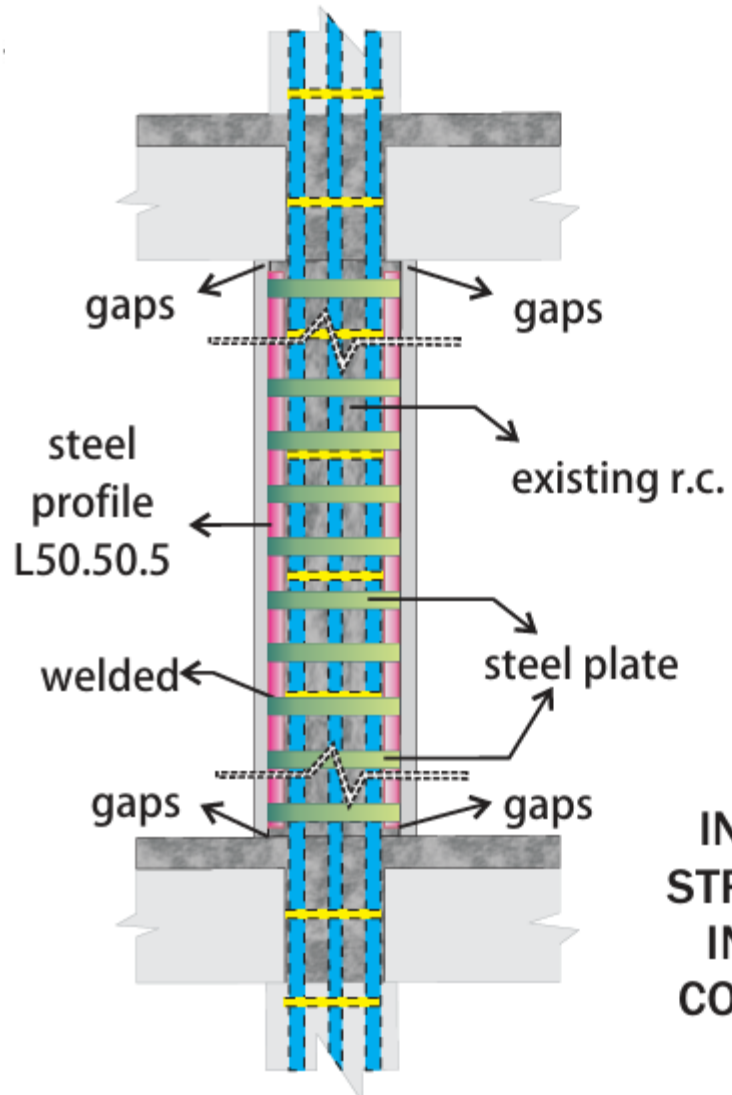
COLUMN WITH HEAVY DAMAGE

ADDING FLEXURAL & SHEAR STRENGTH





ADDING STEEL PROFILE TO INCREASE SHEAR STRENGTH WITHOUT INCREASING THE COLUMN FLEXURAL CAPACITY

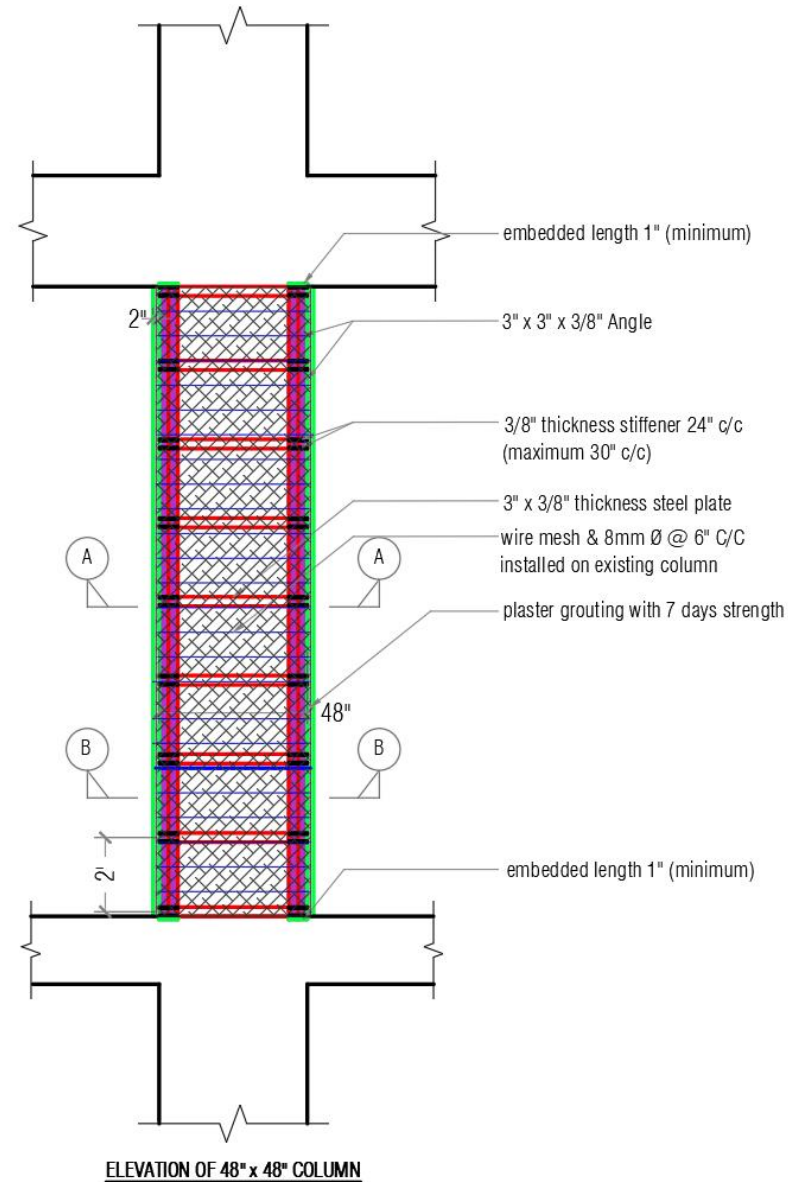


ADDING STEEL PROFILE TO INCREASE SHEAR STRENGTH WITHOUT INCREASING THE COLUMN FLEXURAL CAPACITY

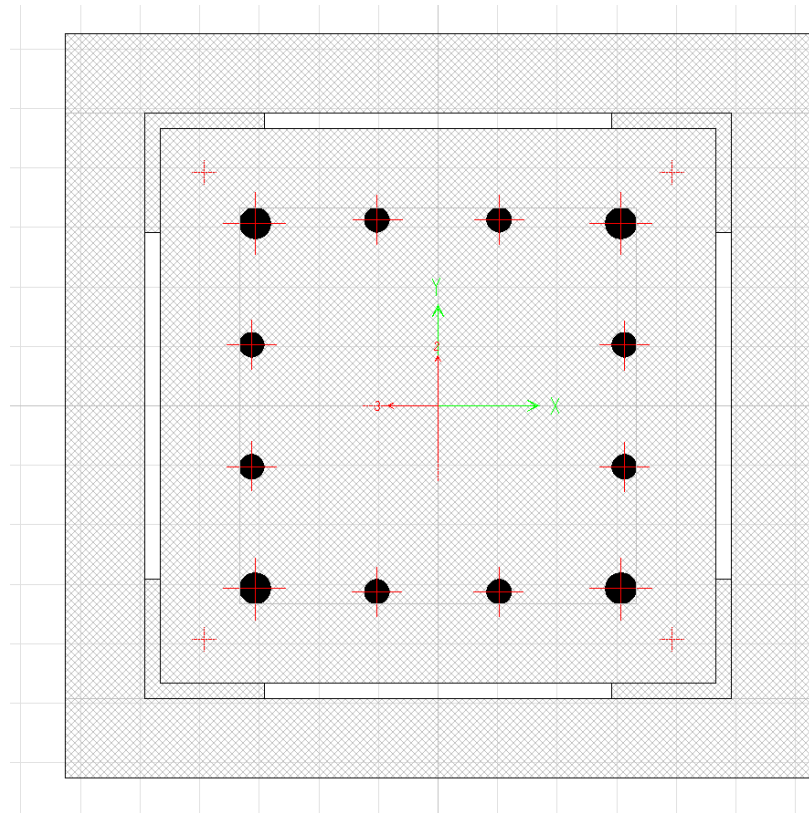
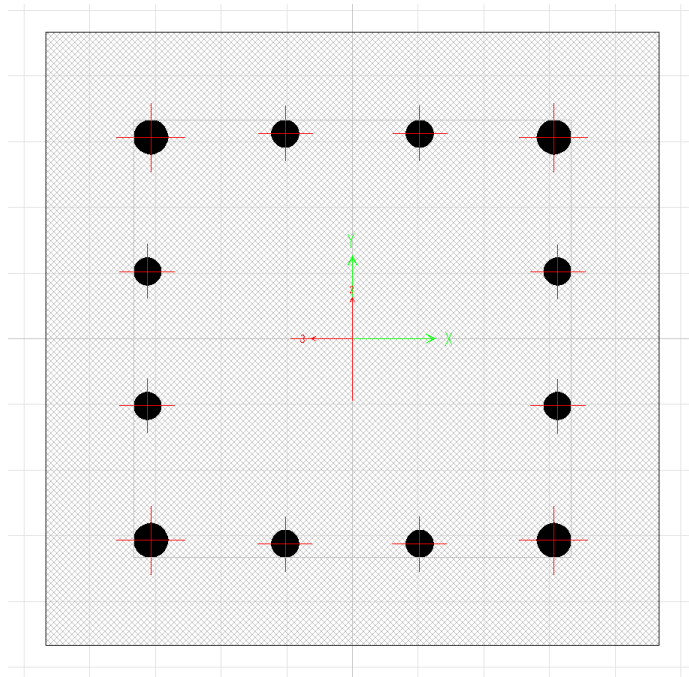
steel profile L50.50.5 at each corner of column

steel plate

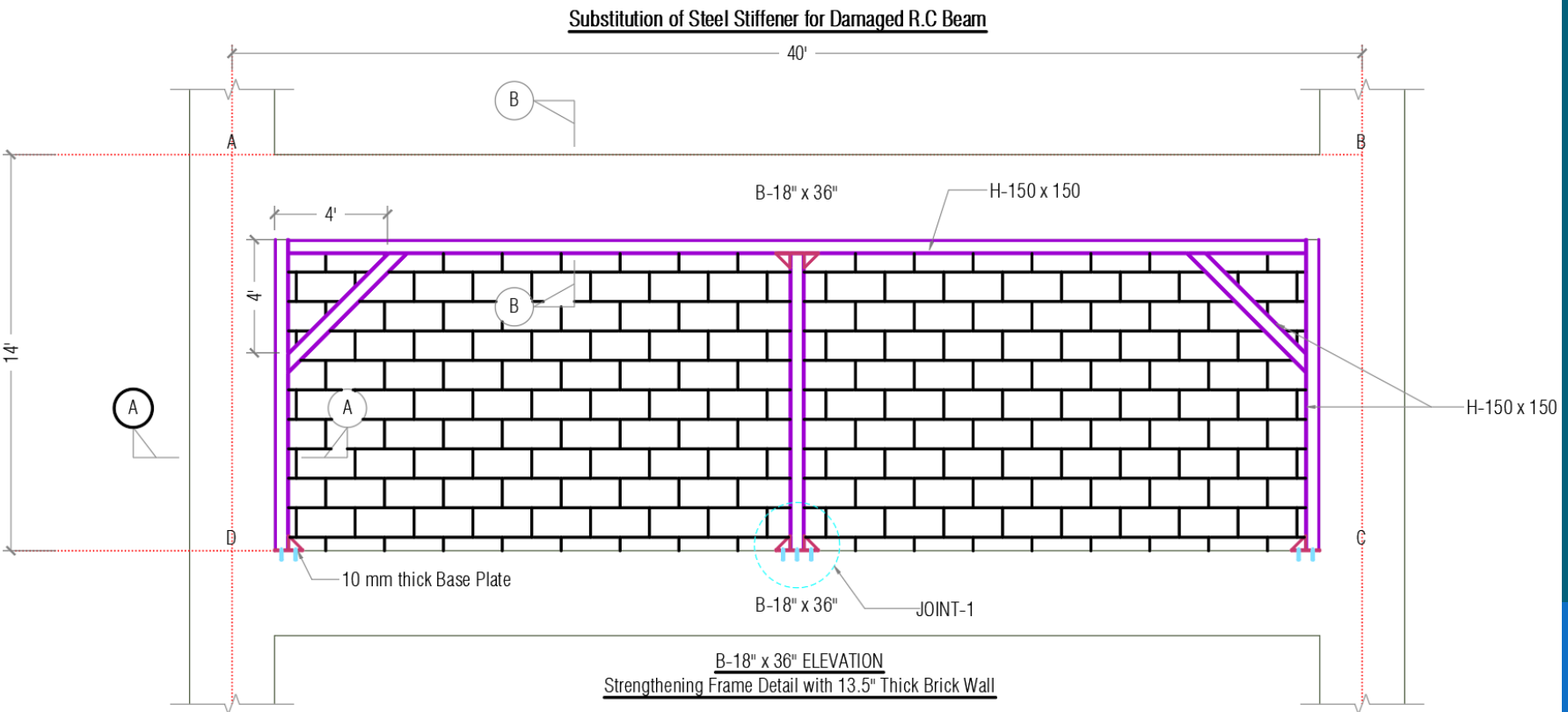
Strengthening Column Detail (Elevation)



Strengthened Column Section (example)



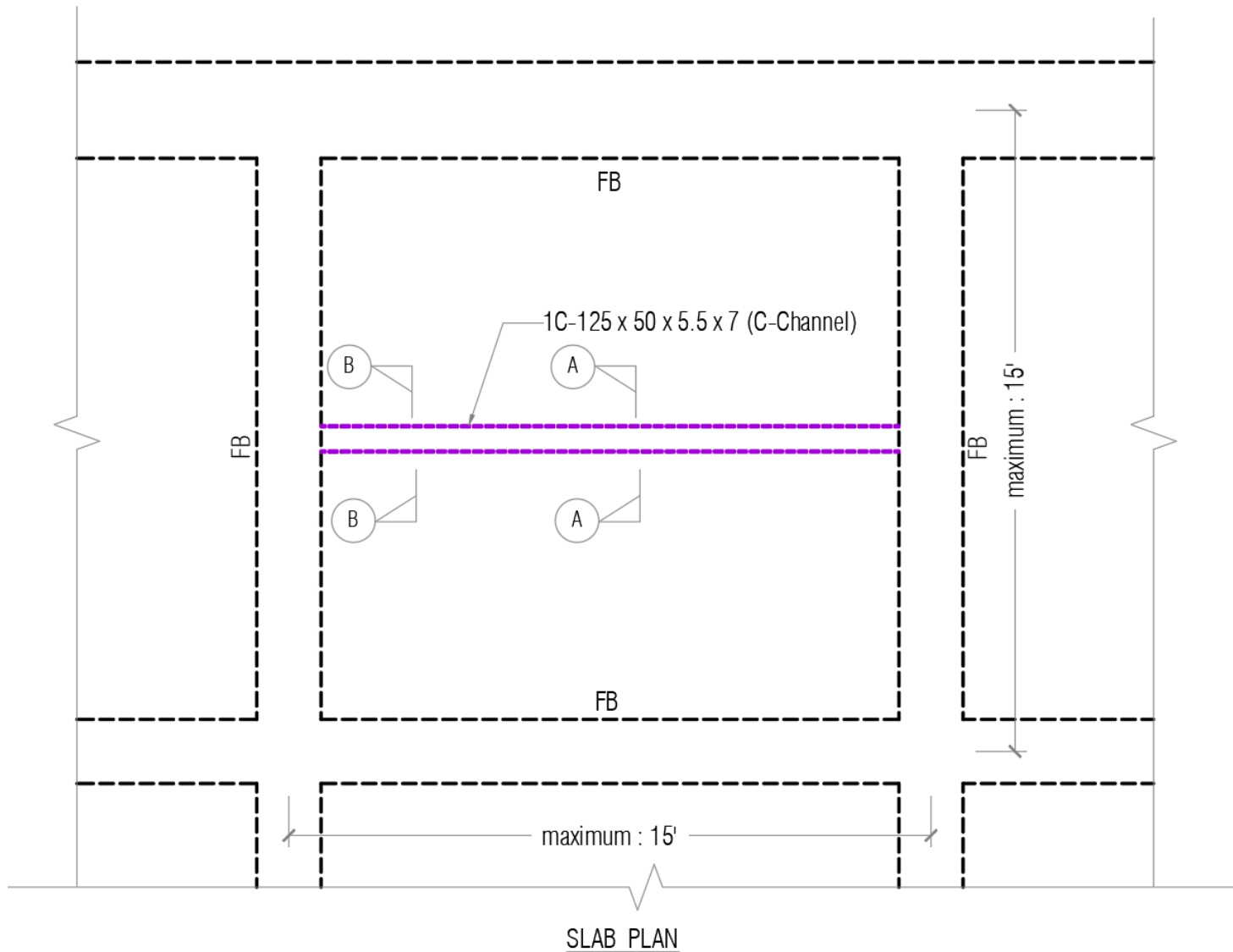
Strengthening Beam & Column with Steel Member and Providing vertical Stiffener for Brick wall



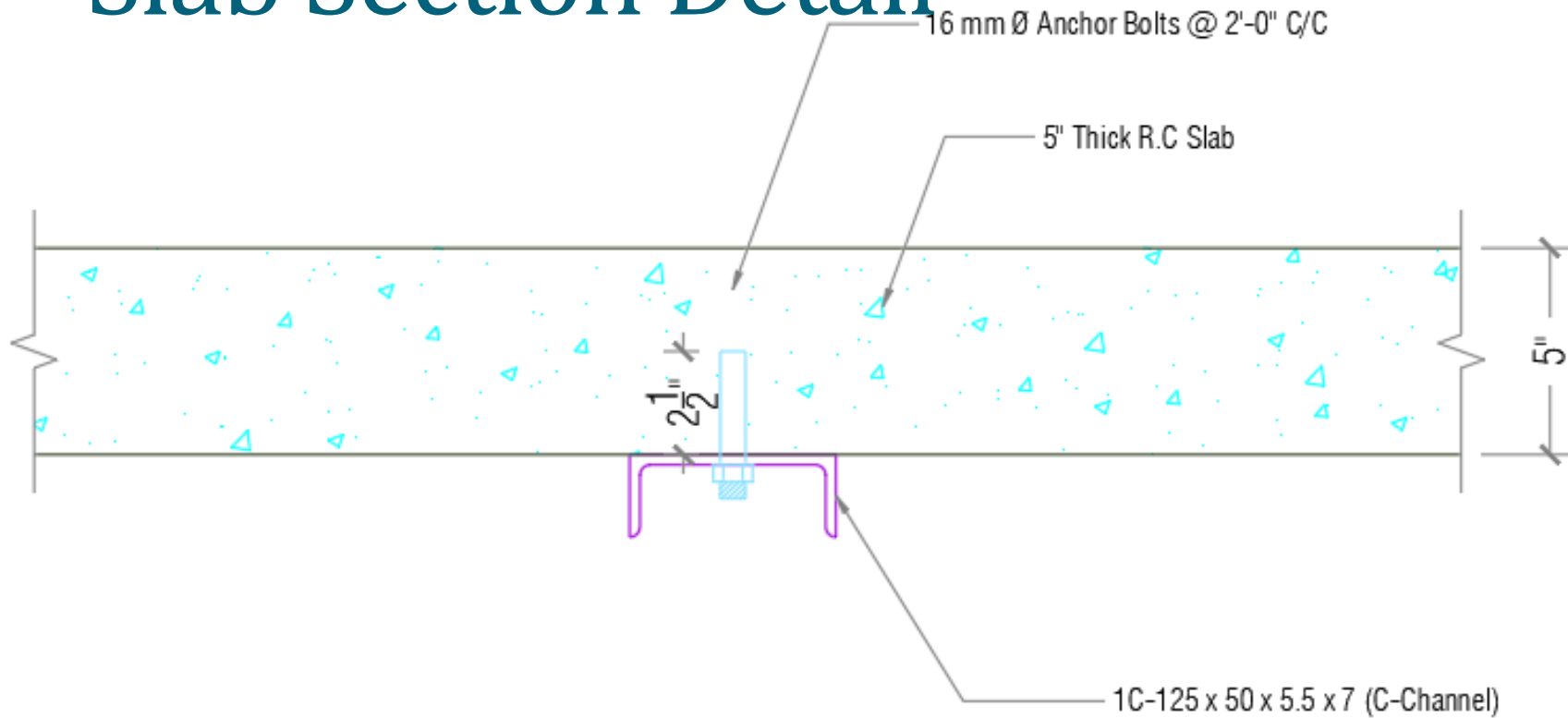
Strengthening Floor Slabs

- Providing Floor Beams to reduce slab span length (ie. To reduce bending & shear stress etc. ,)
- Before providing additional beam, check adequacy of strength & serviceability etc. of existing perimeter beams.

Additional (Steel) Beam to Reduce Slab Panel Area (ie. To lessen slab span length l_a & l_b)

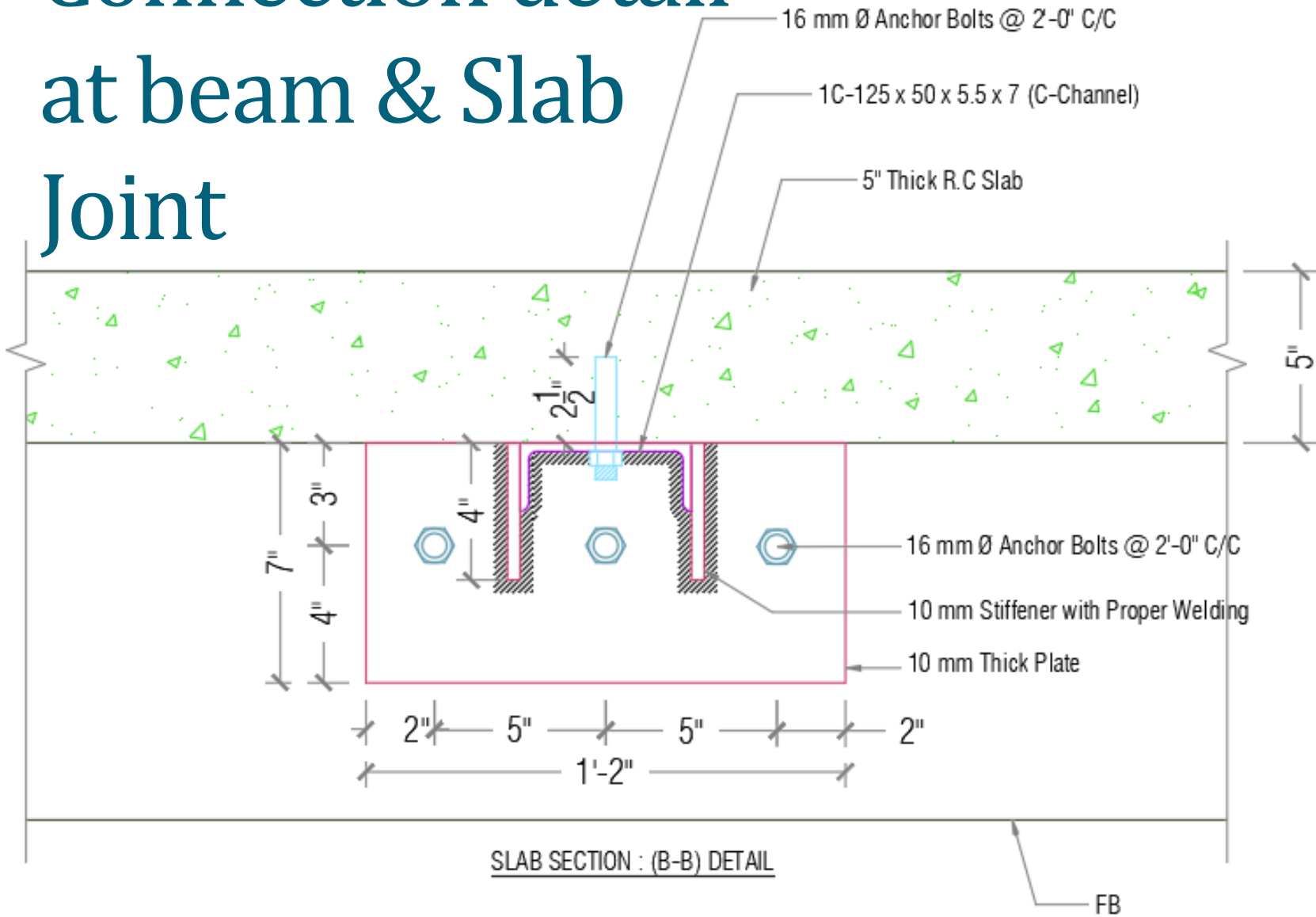


Slab Section Detail



SLAB SECTION : (A-A) DETAIL

Connection detail at beam & Slab Joint



From design aspect, a structure may fall under one of the following categories:

1. Undesigned structures
2. Underdesigned structures
3. Overdesigned structures
4. Optimally designed structures

Undesigned Structures

- The undesigned structures are those built without being designed following any of the well-established analysis and design procedures.
- Both the proportioning of members and the actual construction are done entirely based on rules of thumb or past experiences.
- The structure may thus be overstrong in one part while inadequate in another.

Underdesigned structures

- The underdesigned structures are those designed by engineers but are deficient in strength for using undersized members reinforcement too lightly. This is mainly due to a deliberate effort to get most profit out of the project, without regard for the consequences of structural failure in case of overloads or accidental understrength of members.
- The margin of safety is less than the internationally accepted norms.

Losses of life and property are at stake!!!

Overdesigned structures

- The overdesigned structures are those designed by engineers who are too eager to avoid making a bad name in their carrier through possible structural mishap caused by factors which are beyond their control.
- Another reason for overdesign is that the designer has no control over the quality of materials and construction.

Practice without theory is BLIND!!!

Optimally designed structures

- The optimally designed structures are those analyzed and designed according to logical and scientific concepts, principles and methods, with due consideration given to peculiarities of individual sites.
- The designer may often be called upon to make reasonable assumptions in analysis and design, to take calculated risk, to exercise judgement and to make decisions based on sound engineering principles in order to meet the requirements of safety, serviceability and economy.
- The designer under this category will always try to “trim the fat” from all parts of the structure in order to achieve economy without affecting safety and serviceability requirements.

As a Designer:

- You are responsible to try your best to protect the losses of life and property of the occupants or users of the structure. Human life is invaluable. The first rule is therefore SAFETY COMES FIRST.

- Strictly follow safety provisions of Codes. You are totally responsible for a failure due to design fault.
- You are responsible to try your best to save as much money as possible for the benefit of the client by cutting down unnecessary wastes. A RESPONSIBLE DESIGNER ALWAYS CARES ABOUT ECONOMY.



DAMAGED COLUMN,
STIRRUPS &
ANCHORING ARE NOT
ADEQUATE



ADDITION OF
STIRRUPS &
ANCHORING



FORMWORK



FORMWORK REMOVED
AFTER CONCRETING

EXAMPLE OF COLUMN RETROFITTING

Remarks (for existing damaged buildings)

- Diagnose all structural elements by using appropriate structural analysis and design method for considered load combinations.
- Check stability requirements for whole structural unit .

- To strengthen a structural member , determine forces (bending, shear, torsion, axial ,etc.,) at critical sections
- Apply suitable strengthening method (if necessary ,for existing structures)
- Check structural safety, serviceability, reliability , etc.,

References

- Reinforced Concrete Design..U Nyi Hla Nge
- Teddy Boen & Associates. (n.d.). *Retrofitting simple buildings damaged by earthquakes*. United Nations Center for Regional Development (UNCRD), Disaster Management Planning Hyogo Office.
- Federal Emergency Management Agency. (n.d.). *Seismic design of reinforced concrete structures*. Instructional material complementing FEMA 451, Design Examples. FEMA.

Thank You for Your Attention.

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