UNIT 5-REPAIR, REHABILITATION AND RETROFITTING OF STRUCTURES

2Marks

1. **What is overlay? (Nov/Dec 2018)**

Overlays may be used to restore a spelling or disintegrated surface or to protect the existing concrete from the attack of aggressive agents. Overlays used for this purpose include concrete or mortar, bituminous compounds etc. Epoxies should be used to bond the overlays to the existing concrete surface.

2. **How to overcome low member strength?(April/May 2018)**

The distress is due to inadequate stirrups either due to deficiency in the of provision of C- stamps, U-clamp fixed externally along the length of beam to provide adequate these will be protected by covering with rich mortar or concreting as the a later stage.

3. **What is the techniques required for repairing cracks? (Nov-2013)**

- Bonding with epoxies
- Routing and sealing
- Stitching
- Blanketing
- External stressing
- Grouting
- Autogenous healing

4. **Write the ranges of thermal conductivity , thermal diffusivity, specific heat , coefficient of thermal expansion of concrete (April/May 2017)**

- Thermal conductivity ranges from 1.4 to 3.6 joule/meter square per second.
- For a normal concrete value of diffusivity lies in between 0.002 to 0.006 m2h
- Coefficient of thermal expansion of concrete is about 10 millionths per degree Celsius (10x10-6/C), although values ranging from 7 to 12 millionths per degree Celsius have been observed.

5. How will you develop demolition strategy (Nov/Dec 2018)

The controlled demolition ensures minimum disruption to the general public and transportation systems. Road closures and waterway traffic halts are put in place for preparation, detonation, and debris clearing. Depending on the size of the bridge, clearing the debris can usually be completed in a matter of days so that diversions can be lifted.

6. List the methods of demolition used in construction methods (Nov/Dec 2017)(April/May 2018)

- Controlled Demolition Technique
- Explosive Demolition method

7. **List any two methods of retrofitting of structures subjected to leakage(Nov/Dec 2017)**

The most common methods of pressure management include establishing zone boundaries, fixed outlet pressure control valves, pump and level control, time modulated control valves and flow modulated control valves

8. List the pre planning activities to be done before demolition of buildings (April/May 2017)

- Get the building inspected.
- Acquire the necessary permits.
- Disconnect existing services.
- Tear down the house.
- Haul away the debris.
- Learn more about house demolition:
- Keep reading about house demolition costs:

9. How to repair a crack repair by routing and sealing (April/May 2019)

This method simply involves enlarging the cracks on the surface and then filling and sealing it with a joint sealant. It is important to take care of the width to depth aspect ratio when sealing the joint so that there is enough room left for the movement.

10. Suggest the guidelines for construction in different seismic zones (April/May 2019)

One way to to make a simple structure more resistant to these lateral forces is to tie the walls, floor, roof, and foundations into a rigid box that holds together when shaken by a quake. The most dangerous building construction, from an earthquake point of view, is unreinforced brick or concrete block.

11. Define stitching.

The tensile strength of a cracked concrete section can be restored by stitching

in a manner similar to sewing cloth.

12.Whatdo you mean by blanketing? (Nov-2013)

This is the simplest and most common technique for sealing cracks and is applicable for sealing both fine pattern cracks and larger isolated. The cracks should be dormant unless they are opened up enough to put in a substantial paten in which case the repair may be more property termed as "Blanketing”.

13.Defineexternal stressing. (Nov-2009)

Development of cracking in concrete is due to tensile stress and can be arrested by removing these stresses. Further the cracks can be closed by including a compressive force sufficient to overcome the tension a residual compression.

14.Write short notes on Autogenous healing.

The inherent ability of concrete to heal cracks within "autogenous healing”. This is used for sealing dormant cracks such as precast units cracked in handling of cracks developed during the precast pilling sealing of cracks in water hands and sealing of cracks results of temporary conditions.

15. Give short note on Jacketing. (Nov-2013)

Jacketing consists of restoring or increasing the section of an existing member by encasing it in a new concrete. This method is useful for protection of section against further deterioration by providing additional to in member.

16.Givean account on how metal bonding is done on concrete member.

On the tension side of the beam 2to 3mm steel plates are to the existing beam to increase its capacity. The glue or adhesive should compatible with the existing concrete with behavioral characteristics under load addition to providing integrity with parent member.

17.Definegrouting. (Apr/May 2011)

Grouting can be performed in a similar manner as the injection of an epoxy. However the use of an epoxy is the better solution except where considerations for the resistance of cold weather prevent such use in which case grouting is the comparable alternative.

18.Give a short note on epoxy coatings.

These are organic compound which when activated with suitable hardening agents form strong chemically resistant structures having excellent adhesive properties. They are used as binders or adhesives to bond new concrete patches to existing surfaces or hand together cracked portions. Once hardened, this compound will not melt, flow or bleed. Care should be taken to place the epoxy within the pot life period after mixing.

19.Whatare protective surface coatings?

During of concrete can be substantially improved by preventive maintenance in the form of weather proofing surface treatments. These treatments are used to seal the concrete surface ad to inhibit the intrusion of moisture or chemicals.

20.Listsome materials used as protective surface coatings. (Apr/May 2009)

Materials used for this purpose include oils such as linseed oils, petroleum etc.

21. Define dry pack. (Apr/May 2012)

Dry packing is the hand placement of a very dry mortar and subsequent tamping or ramming of the mortar into place producing an intimate contact between the old and new concrete work.

22.Givea brief account on routing and sealing.

This method involves enlarging the cracks along its exposed surface, filling and finally sealing it with a suitable material. This is the simplest and most common technique for sealing cracks and is applicable for sealing both fine pattern cracks and larger isolated.

23.List any four causes of cracks?

- Use of unsound material
- Poor & bad workmanship
- Use of high water-cement ratio
- Freezing & thawing Thermal effects
- Shrinkage stresses

24.Whatare the types of cracks? (Apr/May 2012)

i) Class-1: Cracks leading to structural failure
ii) Class-2: Cracks causing corrosion
iii) Class-3: Cracks affecting function
iv) Class-4:Cracks affecting appearance

25.Whatis pneumatically applied mortar?

Pneumatically applied mortar is used for the restoration of when the location of deterioration is relatively at shallow depth. It can be used on vertical as well as on horizontal surfaces and is particularly restoring surfaces spalled to corrosion of the reinforcement. Damaged concrete elements also retrofitted using this method. This also has known as gunning or shotcreting techniques.

26.What is caging with steel?

A steel caging is prepared and made to surround the existing masonry so that lateral expansion when it is loaded in compression. The confinement of masonry will steel cage increases its capacity and ductility.

27.Give a brief note on dogs in stitching. (Apr/May 2012)

The dogs are thin and long and to cannot take much of compressive force. The dogs must be stiffened and strengthened by encasement in an overlay or some similar means.

28 .Give some concrete materials used to overcome weathering action on concrete.

The two concrete repair materials used were (/) a flow able concrete with 16 mm aggregate and containing a plasticizer and a shrinkage-compensating additive, to be cast against forms in heights up to 1.5m, and (//) a patching mortar to be applied b rendering, for areas less than .01

29. What is dry pack?

Dry packing is the hand placement of a low *wlc*ratio mortar which is subsequently rammed into place to produce a dense mortar plug having tight contact to the existing concrete, because of the. low*wlc*ratio, there is little shrinkage and the patch remains tight, with good durability, strength, and water tightness.

30. What are the characteristics of good coatings?

A wide range of surface penetrating sealers and coatings are available. They ranges from purely cosmetic treatments to thick membranes and can be applied to cracked concrete. If cracking has reached a stable condition, then a can usually be applied successfully. Low viscosity, low solid resistance solutions such as epoxies haven been used to seal the surface of concrete in areas that are not subjected to wear.

31. How the jacketing **is done?**

Jacketing is the process of fastening 8 durable material over concrete and filling the gap with a grout that provides needed performance characteristics, the materials used for jacket are metals, rubber, plastics, ferrocement and concrete. A steel reinforcement cage is constructed around the damages section onto

which shotcrete or cast-in-place concrete is laid. Sometimes brackets are cast externally along with jackets to encase the damaged members.

32. Discuss about the process of guniting?

The guniting process applied to damaged concrete structures is as follow: The cement and sand are batched and are mixed in the usual way and conveyed through a hosepipe with the help of compressed air, a separate pipe line brings water under pressure and. the, water and cement aggregate mix are passed through and intimately mixed in a special manifold and then projected at high velocity to the surface being repaired.

33. Differentiate between: "shoring and underpinning"?

Underpinning Shoring

Underpinning	**Shoring**
Underpinning in foundation should be addressed and supervised by an engineer. The underpinning process must be started from the corners and the working inwards. Underpinning ·must be', made only on load bearing walls.	Shoring supports the forms, workers, and fresh concrete at the top level. The shore posts may be wood, aluminium, or steel. Shores distribute the loads from the form to the slab below which is the top surface of the reshore system. Shoring and reshoring at the ground level is a special condition

34. Give any four characteristics of coatings to concrete?

- Surface Coatings
- Anti Carbonation Coatings
- Surface Impregnation coatings
- Coatings to protect from Acidic environment.

35. Explain about vacuum concrete.

For concrete surfaces that contain a large number of cracks vacuumimpregnation may be used. The part of structure to be repaired is

enclosed withinas air tight plastic cover and then the aim from all cracks within coverer is sackedby applying vacuum, after exhausting the air from all cracks. The monomer of resingrout is forced under one atmosphere pressure in cracks and pores of the concretesurfaces.

36. Define stitching?

The cracks are bridged with U shaped metal units called stitching dogs beforebeing repairs with a rigid resin material. This can establish restoration of thestrength and integrity of cracked section. Stitching may accentuate restraintscausing cracking. Strengthening of adjacent areas of the structures to take theadditional stress may be required.

37. Advantages of slab jacking technique.

- II Cost effectiveness-grouts leveling is frequently the most economicalmethod.
- Down time it's generally faster than other methods of repair.
- Surface maintenance - for concrete pavements, the repair maintains thesurface of texture and appearance, provides a smooth riding surface, andextends the useful life of the concrete surfacing.

38. Define FRC; explain the effect of volume fraction on fresh concrete properties?

Define:

Fibre reinforced concrete can be defined as a composite material consistingof mixtures of cement, mortar or concrete and discontinuous, discrete, uniformlydispersed suitable fibres.

Volume of fibres:

The strength of the composite largely depends on the quantity of fibres, theeffect of volume on the toughness and strength. The fibre volume at which thissituation is reached depends on the length and diameter of the fibre.

16 Marks

1. How do you strengthen the various structural elements? Explain in detail with sketches.(Nov/Dec 2018)

Repair/Strengthening Columns, Beams and slabs

These form the basic structural elements in most of the building structural systems,which are deteriorated and require attention to improve the load carrying capacity.

Their structural modification or strengthening would give the required relief to thestructure and enhance its performance as under:

1. COLUMNS: The strengthening of columns may be required for the following

a. Capacity: The load carrying capacity of the column can be enhanced bysection enlargement. Different types of arrangement for section enlargementare shown in Fig. 6.11

b. Ductility/confinement: The ductility of the column can be enhanced byproviding additional tiles, steel plate bonding, and fibre wrap.

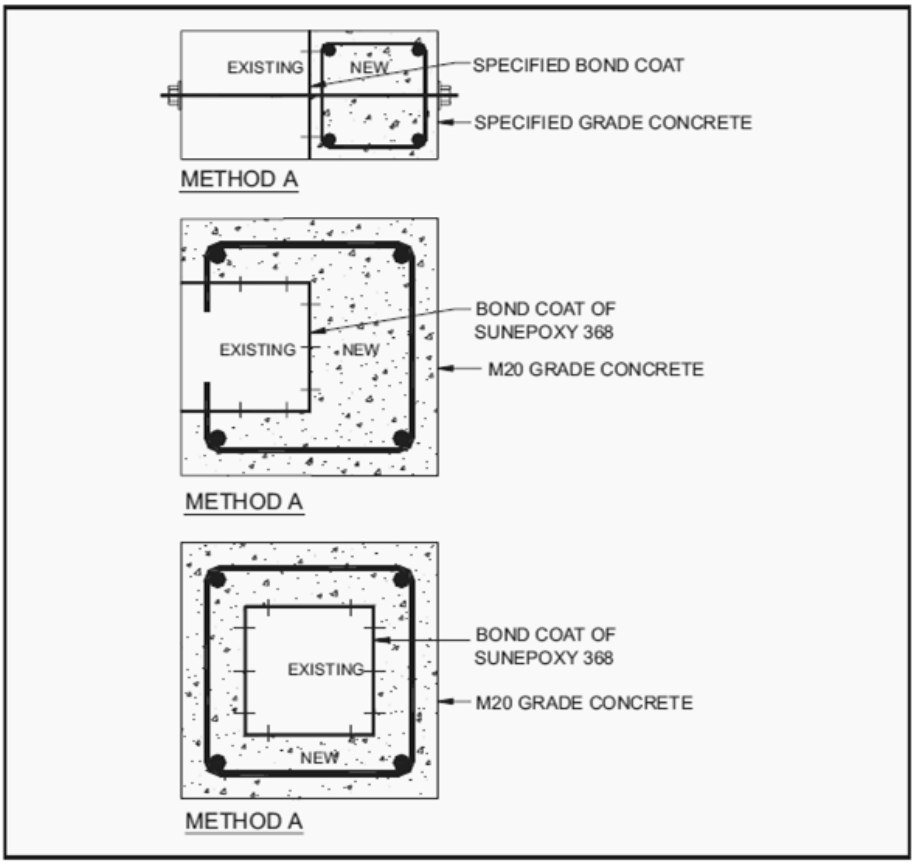


Fig. 6.11 Column Compressive Strengthening by Section Enlargement

c. Joints: The joints play crucial for resisting earthquake forces. The joints can bestrengthening by enlargement, jacketing by steel collar and fibre wrap.

2. BEAMS: These can be strengthened for:

a. Flexural Strength: The flexural strength of the beam can be enhanced by

- Section enlargement in compression,
- Additional reinforcement in the tension. Caution shall be exercised toensure that section is not over reinforced while providing additionalreinforcement to compensate loss of reinforcement due to corrosionetc.

- The provisioning for enhanced tensile strength if being undertaken,this should be accompanied with corresponding increase in compressionas well .Due to such increased flexural capacities extra shear capacitiesrequired to ensure ductile behaviour during earthquake shall alsoconsidered for provision.
- MS plate bonding
- High Strength Fibre Fabric Wrap Technique (without sectionenlargement)

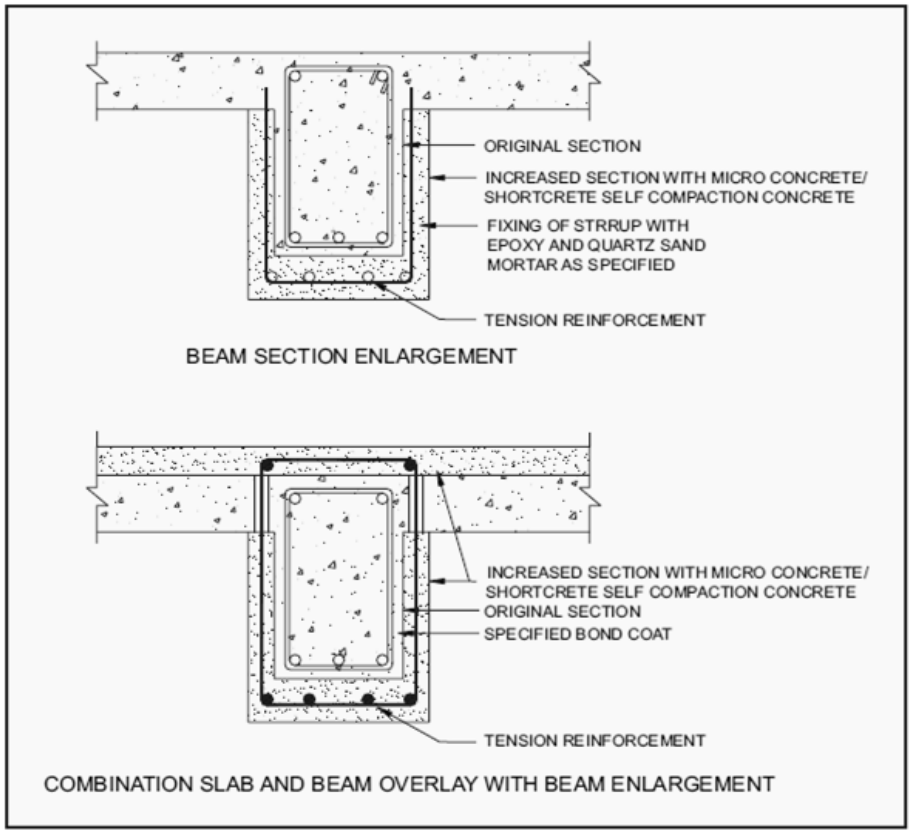


Fig. 6.12 Beam Strengthening : Concrete Overlay And Section Enlargement

b. Shear Strength:

The shear strength of the beam can be enhanced by any of thefollowing:

- Section enlargement
- Shear ties anchored in compression zone of beam.
- Post tension strap around the section
- Diagonally anchored bolts (the holes are drilled perpendicular to the
- possible shear cracks)

- MS Steel plate bonding
- Fibre wraps

3. SLABS:

The performance of the slab can be improved by providing overlays(in case of negative moment deficiency) or underlay (in case of positive momentdeficiency). The addition of overlay/underlay will also increase the stiffness ofthe slabs and control the excessive deflections problems.

The slabs are generallysafe in shear and as such no need is likely to occur for shear strengthening exceptflat slabs near column capital.

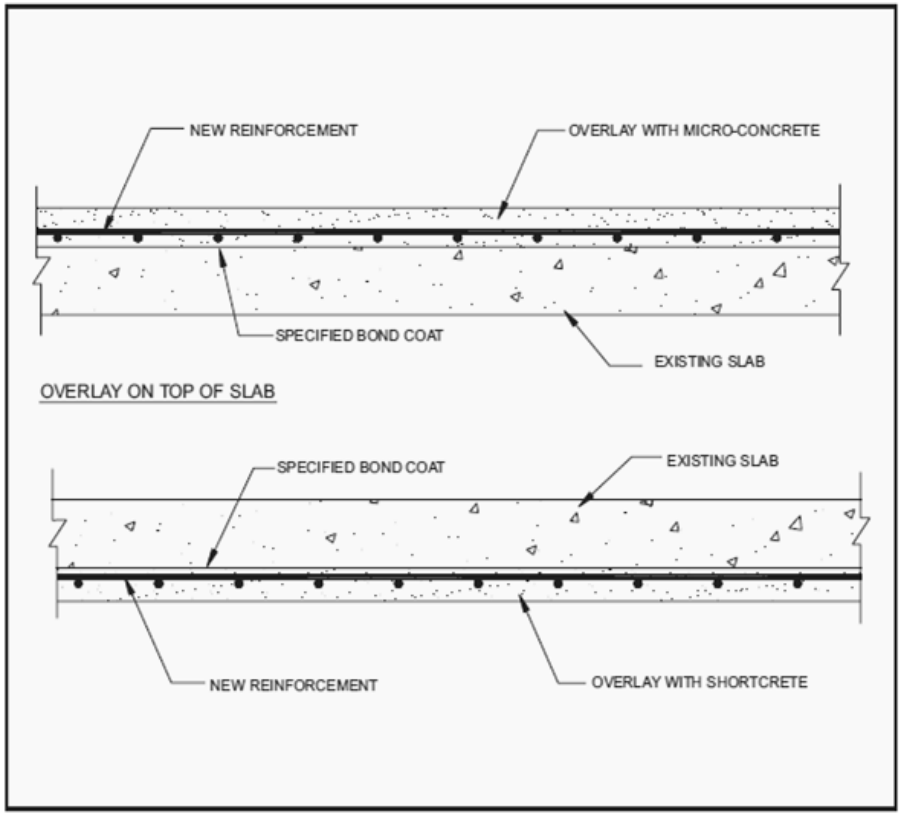


Fig. 6.13 Slab Strengthening : Concrete Overlay

2. **Elaborate the preliminary consideration for strengthening of foundation(Nov/Dec 2018)**

- Pick a site, making sure to investigate the conditions of the soil.
- Have your lot surveyed. This is to determine and locate the actual corners of the foundation so the entire foundation can be formed.
- Start digging. Your excavation contractor carries out this step in the process.
- Install the footings. Keep in mind that you may be pouring concrete into wood forms or directly into trenches to create the footings.
- Seal the footings to protect them from moisture. Be sure to purchase a high quality sealer, and experts recommend that you to a ready mix producer and ask where they would recommend a high quality sealer.
- Once the concrete has cured, use concrete block to create the stem walls if you're building a basement.
- Treat your foundation walls with another round of sealer to keep moisture out.

3. **Explain how cracked reinforced concrete elements are repaired by providing additional steel?(April/May 2019)**

(or)

With sketches explain how doyou improve the load carrying capacity of columns and beams.(April/May 2017)

(or)

State and explain the various options for strengthening a concrete with low member strength.

1. PLATE BONDING

- Plate bonding is an inexpensive, versatile and advanced technique for rehabilitation,up gradation of concrete structures by mechanically connecting MS plates by boltingand gluing to their surfaces with epoxy
- Plate bonding cansubstantially increase strength, stiffness, ductility and stability of the reinforced concreteelements and can be used effectively for seismic retrofitting.
- In this method the bolts, which are first used to hold the plates in position during construction,act as permanent shear connectors and integral restraints.
- The bolts are also designed toresist interface forces assuming the epoxy glue used as non-existent assuming it as destroyed by fire, chemical break down, rusting or simply bad workmanship.
- Since epoxy is prone to premature deboning, use of mechanical anchorage along with epoxy bonding is considered more reliable.

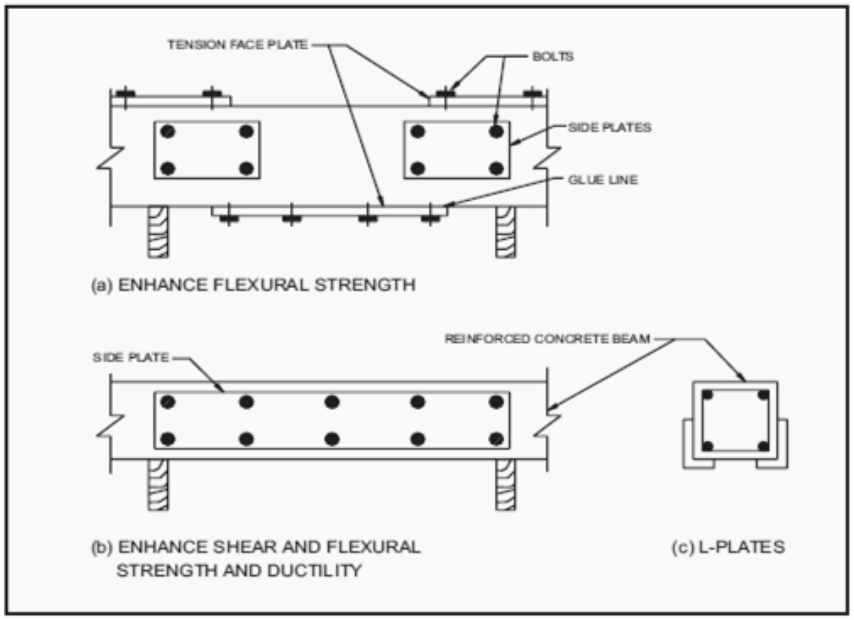


Fig 6.7 Tension Face Plates

- Since the steel plates are unobtrusive, with this technique original sizes of the structural membersare not increased significantly.

- This method is preferred where enlargement of the membersis going to affect the headroom, existing windows, doors and other fixtures.

2. RCC JACKETING

- ✓ Reinforced concrete jacketing increases the member size significantly. This has the advantageof increasing the member stiffness and is useful where deformations are to be controlled. Ifcolumns in a building are found to be slender, RC jacketing provides a better solution foravoiding buckling problems.
- ✓ Design for strengthening/repair work is based on compositeaction between the old and the new work. Strain compatibility calculations may have to becarried out carefully giving due accounts to factors such as creep.
- ✓ As the new jacket is tobehave compositely with the parent member, the new jacket can take additional loads onlywith the increase in the stresses & strains in the old one.

The problem arises if the;

- Old concrete has reached limiting strain and is not likely to sustain any more significantstrain
- Old concrete is weak and porous and started deteriorating due to weathering actionand corrosion of reinforcement.

- ✓ The question then arises as to whether the composite action should be abandoned and the new jacket (plate or RC) designed to carry the entire load. It is perhaps best todesign the strengthening in this manner, but detailing must be right to ensure transfer of load tothe new jacket, if the old concrete fails.
- ✓ It is however, necessary to ensure perfect bond alsobetween the old and new concrete by providing shear keys and effective bond coat with the use of epoxy or polymer modified cement slurry giving strength not less than that of newconcrete.

- ✓ Plate bonding and RC jacketing are the common methods of strengthening RCC structures(detail procedure and stages given in Fig 6.8). The cost difference between the two methodsis not significant.
- ✓ A choice has to be made between the two methods based on actual needsand the suitability of each method with respect to the structural /architectural and other detailsof buildings.

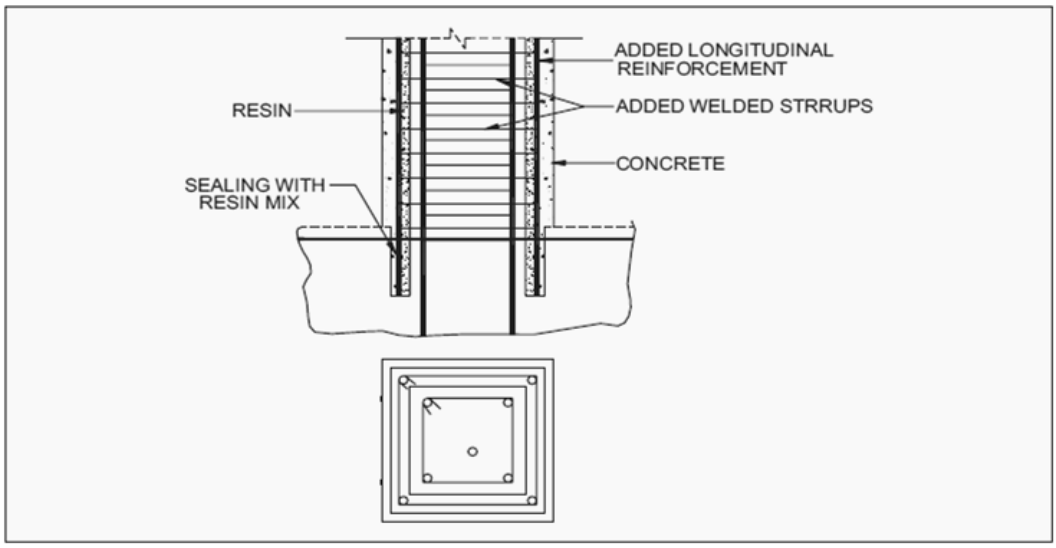


Fig 6.8(a) Column Strengthening Concrete Jacket

3. FIBRE WRAP TECHNIQUE:

The fibre wrap technique, also known as Composite Fiber System is a non-intrusive structural strengthening technique that increases the load carrying capacity (shear, flexural, compressive) and ductility of reinforced concrete members without causing any destruction or distress to the existing concrete. (Refer Fig 6.10)

There are two systems followed in adopting this technique:

a. Bi-directional Woven Fabric
b. Uni-directional E-glass Fibres:

a. Bi-directional Woven Fabric:

- This system comprises of woven fabric presoaked in specially formulated epoxy and applied over prepared surface after application of epoxy primer.

- Woven fibre fabric is composed of bi-directional high strength fibers that are combined with specially formulated epoxy in a pre-determined proportion to form a composite-Material.
- This composite material is wrap applied onto the reinforced concrete or steel member requiring strengthening or protection and left to cure at ambient temperature.
- The subsequent layer/s of unidirectional fibre fabric could be applied after giving the required overlap along the direction of fibres as per design requirements

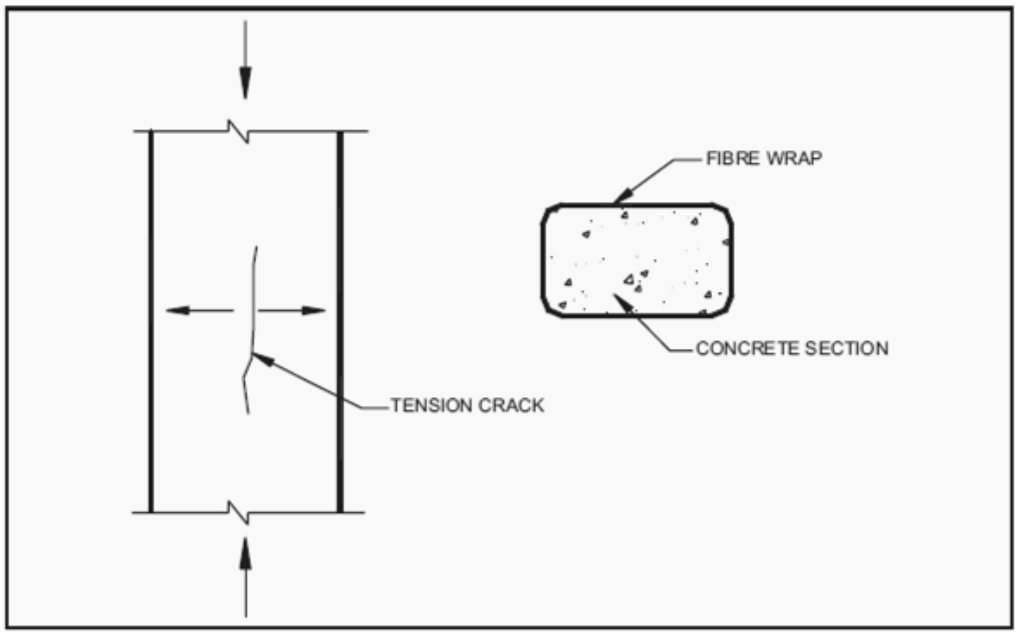


Fig 6.10 Fibre wrap technique for improving load carrying capacity of a column.

b. Uni-directional E-glass Fibres:

- This system comprises of precut unidirectional E-glass fibre wrapped over epoxy primer applied prepared surface of member requiring structural strengthening and/or surface protection.
- Subsequent to its wrapping, it is saturated with epoxy using rollers and stamping brushes manually to remove air bubbles, if any and left to cure at ambient temperature. The subsequent layer/s of unidirectional fibre fabric could be applied after giving the required overlap along the direction of fibres as per design requirements.
- Though the underlying principle of the above two methods is more or less identical, but the application techniques and basic materials

adopted are at slight variance. Each of the above systems has their own merits.

- Enhancement in lateral drift ductility and horizontal shear carrying capacities of a concrete member can also be obtained by confinement of the member by this method. The flexural, shear and axial load carrying capacities of the structural members can be enhanced by appropriate orientation of primary fibres of the composites.

- The resulting cured membrane not only strengthens the reinforced concrete member but also acts as an excellent barrier to corrosive agents, which are detrimental to concrete and the reinforcement.

- Ingress of water,oxygen and carbon dioxide through the external surface of concrete member is prevented by the application of composite jacket.

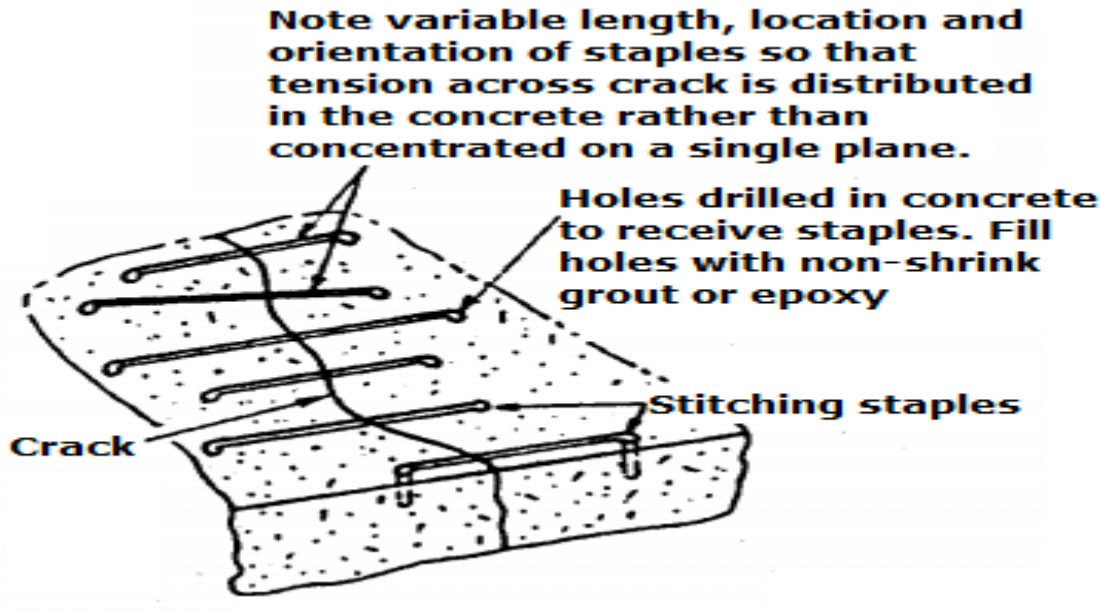
- The system is useful for its structural enhancement and protection capabilities under severe environmental conditions.

- It can be used for retrofitting of a wide variety of structures that include bridges, flyovers, chimneys, water tanks, buildings, large diameter pipes, industrial plants, jetties, sea-front and underwater structures

4.**Illustrate the stitching procedure to repair a crack**

Stitching of Cracks

Stitching of cracks seems to be simple and a durable method. In this method, holes are drilled in a way that entry and exit points are made across the cracks. Through the holes, a number of U-shaped metallic staples are passed through and at the ends, the holes are anchored strongly. Grout or epoxy can be used to anchor the ends.



5. **Explain the different methods of strengthening the concrete structures against cyclone? (April/May 2019)**

System based strengthening techniques

- Most of the strengthening strategies have recently been based on global strengthening schemes as per which the structure is usually strengthened for limiting lateral displacements in order to compensate the low ductility.
- In these methods causing a change in the global behavior of a building, as explained above, a behavioral change takes place when new members are added to the building.
- For a building which is currently used, it is important that the new members which are to be added to the structure are few in number and they are designed to ensure a significant increase in the load capacity and stiffness of the structure.

- It is well known by construction engineers that this target may most easily and economically be achieved through reinforced concrete and steel shear walls.
- Shear walls that are to be added to the building can be designed in the form of infill shear wall or external shear wall.
- Below are presented some of the most frequently applied system based strengthening methods.

Infill shear walls

- Among the global strengthening methods, addition of RC infill is the most popular one.Many researchers have focused on the addition of infill RC walls and found that theinstallation of RC infill walls greatly improves lateral load capacity and stiffness of thestructure.
- Even in cases of application to damaged buildings, the infill method can yieldsatisfactory results.
- In the strengthening method with infill walls, the existing partition walls in the building areremoved and high strength reinforced concrete shear walls are built instead.
- Insuch a strengthening application, the shear walls bear majority of the earthquake loads andlimits the displacement behavior of the building while the frame system resists very lowamounts of the earthquake loads.
- Reinforced concrete infill walls can also be used as partial walls and wing walls. Door and window openingsmay also be provided in these walls to allow the building to deliver its architecturalfunctions although they reduce stiffness and strength of the wall.
- In such applicationspreventing the construction of infill walls in the form of a full-fill wall, many experimentalstudies indicated that these walls develop more brittle damages compared to full-fill walls.

Fig. 3. Infill wall application in an RC building

External shear walls

- Although the use of shear walls becomes widespread due to the fact that they are effective strengthening elements, they are also known to result in some difficulties hence they require a great deal of demolition and construction works in the existing structure.
- Application of external shear walls is an approach introduced to diminish such difficulties. In this approach, shear walls are applied to the external facade of a building without demolishing the existing infill walls.
- In that case, the shear wall can be placed in parallel with or perpendicular to the existing frame members.

Fig. 6. Wide infill walls and anchored crossties confining the longitudinal reinforcements

- In case the shear walls are located perpendicular to the building façade, large openings are needed in the building facade. The shear walls installed function like a buttress.
- In cases where pile foundation is not applied for the shear wall foundation, such shear walls are effective in only one direction.
- In order to create a positive effect on earthquake resistance of the building, they must be installed at opposite facades.
- This increases the required amount of shear walls and costs. For all these reasons, external shear walls that located perpendicular to the external facade are not preferred in the application.

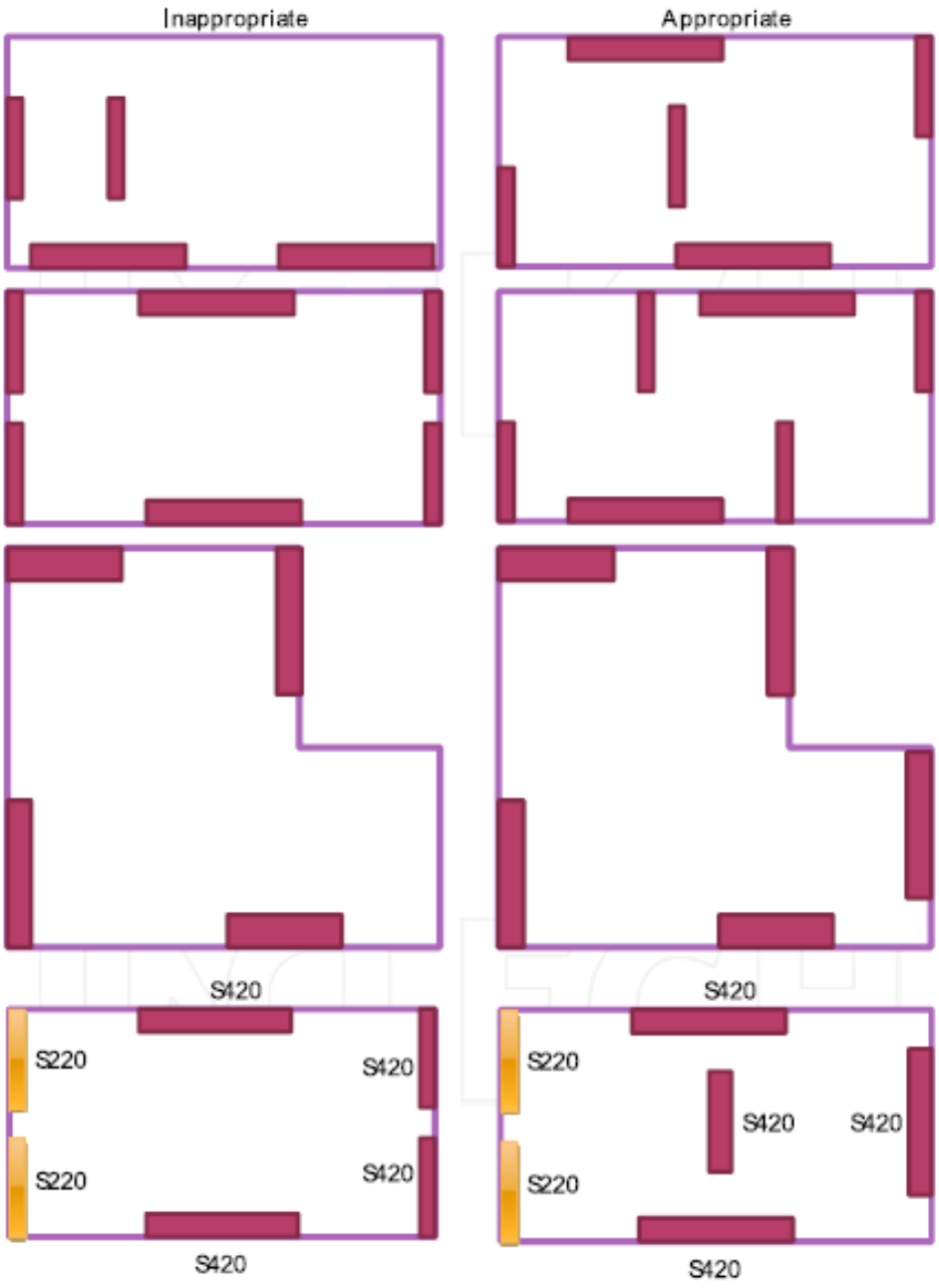


Fig. 7. Inappropriate and appropriate shear wall layouts

Steel bracing

- Steel bracing for RC frames has also been used to reduce drift demands. Bracing can either be implemented inside the frame or applied from outside of the system like RC walls. Post-tensioning can also be applied to bracing elements.

- In either case, steel bracing offers more suitable solutions in aesthetical terms for numerous applications. Although its application inside the building is not easy for those buildings with small openings, it particularly allows easy installation across the axes on external facades. Research on various types of bracing styles is available in the literature.
- Architectural characteristics and functionality can be less disturbed by using an appropriate bracing style. Figure 11 presents the use of buttress type steel shear wall constructed on the building's external facade as a different example.
- Design of steel elements must be made in conformity with the details specified in steel standards and codes. For the connection between the existing structure and steel members, the anchor design principles given in the subsequent section may be utilized.
- Another mode of damage that must especially be considered in the buttress type steel shear walls is to be the out-of-plane buckling of the compression elements of the buttress type shear wall placed.
- If possible, it is recommended to install lateral supports at storey levels to prevent lateral buckling. Use of such elements may also economize design of shear walls to a certain extent.

Fig. 11. Buttress type external steel shear wall (Photo by Dr. Yavuz Selim Tama)

Infill strengthening

- Another method that can be used apart from adding new ductile shear walls to a building with an inadequate earthquake resistance is to improve both capacities and ductility of the existing brittle partition walls which are constructed between columns and beams in the form of fills.
- Those walls of which effects on the behavior are not considered during structural design can generally produce a certain bracing effect and make a positive contribution to the behavior.
- There are too many uncertainties regarding the behavior of these members and they are not likely to produce a desired bracing effect at all times.
- Partition walls may also lead to brittle damages across the surrounding columns by exhibiting many different behaviors.
- In addition, these walls are the members that are first damaged and lose their bearing capacity in a building under earthquake loads. A wide range of methods were developed to enhance capacity and ductility of these walls.

6. **How do you repair and rehabilitate a structure distressed due to fire? (April/May 2018)**

Surface Preparation

- The original concrete cover was chipped off to expose the existing reinforcing bars. Cleaning of the reinforcing bars proceeded immediately using a wet type sand blasting equipment until all the reinforcing bars were to bare white metal finish.
- High pressure water spraying is used immediately before epoxy application in order to remove all loose and defective concrete and for final cleaning of reinforcing bars. This utilized a 6,000 psi (41.3 Mpa)

High Pressure washer. The quality of bonding surface and rough texture was assured by this final surface preparation procedure.

- The tight spaces and reinforcing bars cages required epoxy application by hand brushing. It was therefore necessary to require that the epoxy would have an adequately long "overlay time" of at least six (6) hours to allow application, erection of forms and pouring of concrete. This requirement meant that the forms would have to be collapsible and allow for easy installation.
- Prefabricated laminated plywood forms were specified to eliminate the need to refinish the stripped surfaces.

Concreting

- It was necessary to pour the concrete columns in two lifts with the last lift being poured monolithically with the upper Beam Column joint . Maximum 3/8" (9.5mm) aggregate was specified to ensure that the congested areas are effectively filled by concrete.
- Breather holes were punched in the slabs to prevent entrapment of air that could block the flow of concrete. Very small diameter hand held electric Driven Pencil Poker Vibrators were utilized in most instances due to the tight spaces involved.
- The Concrete Mix required the use of a plasticizer because of the low water cement ratio (0.42) required on top of the minimum guide specification of fc'=4000 psi (27.6 Mpa) Concrete Cylinder Compressive Strength.
- The low water cement ratio was required to reduce shrinkage to a minimum. Wet curing of the poured concrete elements also helped to reduce shrinkage. The more than liberal distribution of new and old reinforcing bars in a way prevented shrinkage movements that would have otherwise caused concrete to crack.

7. **Explain the methods used for fire protection in RC building. (April/May 2019) (Nov/Dec 2017)**

- If the bottom side of the slab is subjected to fire, the strength of the concrete and the reinforcing steel will decrease as the temperature increase. However, it can take up to three hours for the heat to penetrate through the concrete cover to the steel reinforcement.
- As the strength of the steel reinforcement decreases, the moment capacity of the slab decreases. When the moment capacity of the slab is reduced to the magnitude of the moment caused by the applied load, flexural collapse will occur.
- It is important to point out that duration of fire until the reinforcing steel reaches the critical strength depends on the protection to the reinforcement provided by the concrete cover.
- Fire resistance in concrete structures will vary in relation to the type of aggregate used. Table 1 shows a summary of the minimum thickness requirements for floor slabs and cast in place walls for different concrete types and for different
- Fire resistance ratings. Table 2 summarizes the minimum column dimensions for different concrete type s and different fire resistance ratings.
- Another factor to be considered in complying with fire-resistive requirements is the minimum thickness of concrete cover for the reinforcement. The minimum concrete cover to the positive moment reinforcement is given in Table 3 for one-way or two-way slabs with flat undersurfaces. The minimum concrete
- Cover to the positive moment reinforcement (bottom steel) in reinforced concrete beams is shown in Table 4.

Table 1 Minimum thickness for cast in place floor and roof slabs, in.

	Fire resistance rating				
Concrete type	1 hr.	1.5 hr.	2 hr.	3 hr	4 hr.
Siliceous aggregate	3.5	4.3	5.0	6.2	7.0
Carbonate aggregate	3.2	4.0	4.6	5.7	6.6
Sand-lightweight	2.7	3.3	3.8	4.6	5.4
Lightweight	2.5	3.1	3.6	4.4	5.1

Table 2 Minimum concrete column dimensions, in.

	Fire resistance rating				
Concrete type	1 hr.	1.5 hr.	2 hr.	3 hr	4 hr.
Siliceous aggregate	8	9	10	12	14
Carbonate aggregate	8	9	10	11	12
Sand-lightweight	8	8.5	9	10.5	12

Table 3 Minimum cover for floor and roof slabs, in.

	Fire resistance rating					
	Unrestrained					Restrained
Concrete type	1 hr.	1.5 hr.	2 hr.	3 hr	4 hr.	4 hr. or less
Siliceous aggregate	0.75	0.75	1	1.25	1.625	0.75
Carbonate aggregate	0.75	0.75	0.75	1.25	1.25	0.75
Sand-lightweight	0.75	0.75	0.75	1.25	1.25	0.75

Table 4 Minimum cover requirements to main reinforcement in beams (All types), in.

		Fire resistance rating				
Restrained or unrestrained	Beam width, in.	1 hr.	1.5 hr.	2 hr.	3 hr	4 hr.
Restrained	5	0.75	0.75	0.75	1	1.25
	7	0.75	0.75	0.75	0.75	0.75
	≥ 10	0.75	0.75	0.75	0.75	0.75
Unrestrained	5	0.75	1	1.25	-	
	7	0.75	0.75	0.75	1.75	3
	≥ 10	0.75	0.75	0.75	1	1.75

* Minimum cover for reinforcement in columns, for all aggregate types, is the smaller of, 1 in. times the number of hours of required fire resistance, or 2 in. (Reference 1)

COLUMNS

- The fiber reinforcing on the columns was applied transversely and designed to increase the ultimate compressive load of the members by confining the concrete.
- The insulation completely covered the fiber reinforcing and hence the entire surface of the column. The applied thickness of the insulation on the round column was 15mm and the applied thickness on the square column was 20mm.

BEAM SLAB ASSEMBLIES

- The fiber reinforcing on the beams consisted of a longitudinal strip along the bottom of the beam's web designed to increase the flexural strength and a stirup on each end. The stirrup on the ends was designed to show shear reinforcing.
- Although both beams received identical fiber reinforcing, the insulation was applied to the beams in two different configurations. This was to address the goal of reducing the amount of required surface area that has to be covered.

- The first beam assembly consisted of the insulation being applied over the underside of the beam as well as continuing up the web and extending onto the underside of the flange for a small distance.
- Insulation on this specimen was applied at 15mm thickness. This is the layout that would be anticipated for beams strengthened for both flexure and shear. The second specimen consisted of the insulation being applied to the underside of the beam and then terminating a short distance upto the web.
- Insulation on this specimen was applied at 20mm thickness. This layout was designed for beams strengthened with FRP to increase flexural capacity only. The amount of the insulation system was optimized to be the most cost effective solution.

- Both beam assemblies and both columns passed the requirements of the testing for 4 hours. They sustained the applied load without failure and met all the internal steel temperature requirements.
- In the United States and Canada, this testing meets the requirements to provide up to a 4 hour rating and demonstrates that the FRP strengthened section can take higher design loads during the fire event.

8. **Explain the different repair methods of various types of cracks:(April/May 2019)**

I. REPAIR OF DORMANT CRACKS:

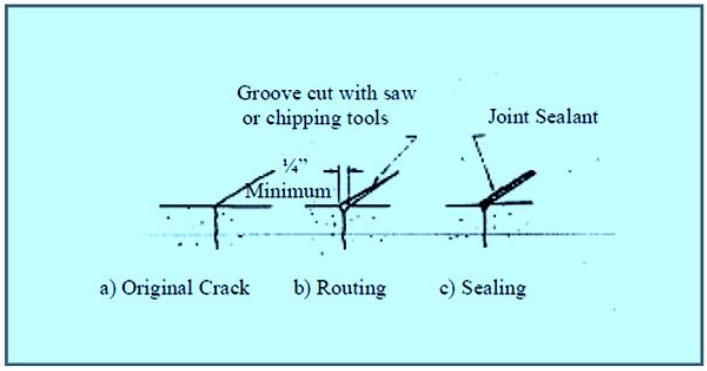
Sealing of Cracks:

- Sealing of cracks as stand alone repair should be used in conditionswhere structural repair is not necessary. Isolated cracks whetherextending through the concrete section or partially into it, should be sealedat the concrete surfaces.
- For this a slot of approx. 25mm wide should besaw cut upto 10mm deep along the crack keeping crack at the center ofthe slot.
- The concrete should be chiseled out from between the two sawcut edges and concrete should be further undercut beyond the 10mmdepth up to say 20mm depth so that the base width is slightly greater thanthe surface width.
- After the slot is thoroughly cleaned, soaked with waterfor 10 hrs. and surface dried, a bond coat/ primer coat, of an approximatelatex bonding compound should be applied.
- Once the primer becomestacky, high strength polymer modified cementitious mortar withspecification mentioned in Para 10.1 should be filled in the slot, properlytamped and surface finished.

- Curing compound should be applied assoon as surface becomes touch dry. 7 days wet curing should be done bycovering with wet Hessian and polythene sheet.

Routing and Sealing of Cracks:

- Alternatively a V-groove should be prepared along the crack at the surfaceranging in depth from 6 to 25mm and minimum opening at surface of6mm Fig.



- A concrete saw, hand tools or pneumatic tools may be used. The grooveis then cleaned by air blasting, sand blasting or water blasting and dried.A sealant is placed into the dry groove and allowed to cure.
- The sealant may be any of several materials, including epoxies,urethanes, silicones, polysulphides, asphaltic materials or polymermortars.
- A bond breaker may be provided at the bottom of the groove toallow the sealant to change shape, without a concentration of stress onthe bottom. The bond breaker may be polyethylene strip or tape which willnot bond to the sealant.

Bond Breaking:

- In some cases over bonding (strip coating) is used independently of or inconjunction with sealing. For this an area approx. 25 to 75mm on eachside of the crack is sand blasted or cleaned by other means, and a

coating(such as urethane) 1 to 2mm thick in a band is applied over the crack.

- Abond breaker may be used over the crack or over a crack previouslysealed (Fig. 12). Cracks subject to minimal movement may be overbanded, but if significant movement can take place, sealing must be usedin conjunction with over banding to ensure a water proof repair.

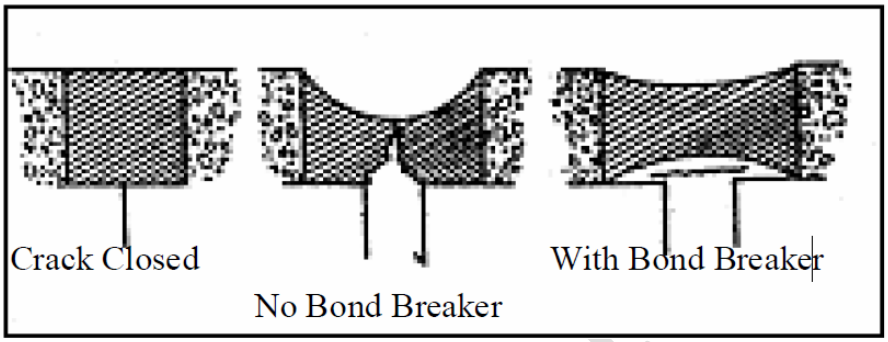


Fig. Effect of Bond Breaker

Epoxy Injection:

- Cracks as narrow as 0.3mm can be bonded by the injection of epoxysuccessfully in buildings, bridges and other concrete structures. However,unless the cause of the cracking has been corrected, it will probably recurnear the original crack.
- If the cause of the crack cannot be removed and itis not causing reduction in strength of the structure, then either the crackcould be sealed with flexible sealant thus treating it as a joint or establisha joint that will accommodate the movement and then the crack should begrouted with epoxy.
- With the exception of certain moisture tolerantepoxies, this technique is not applicable if the cracks are actively leakingand cannot be dried out. Epoxy injection requires a high degree of skill forsatisfactory execution, and the ambient temperature may limit applicationof the technique.

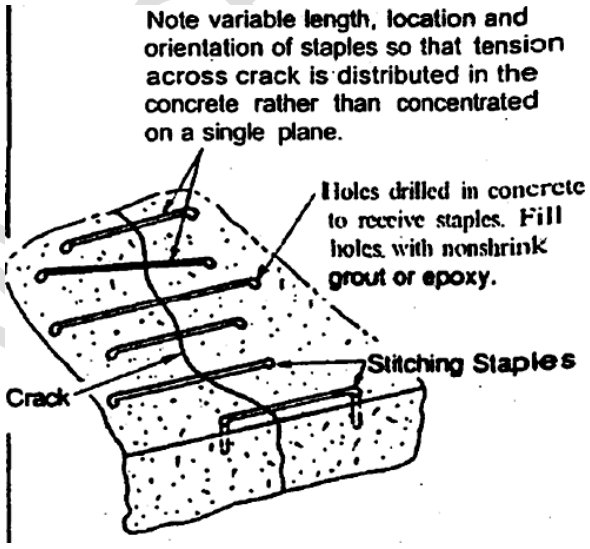
II. REPAIR TO ACTIVE CRACKS:

Drilling and Plugging through Crack:

- One of the approximate methods would be to drill holes normal to cracks, fillthem with a suitable epoxy or epoxy-mortar formulation and then placereinforcement bars (of predetermined sizes and lengths) in them to stitchacross the cracks.
- The bars may be placed in the clean holes prior to fillingthe epoxy (so as to save loss of epoxy) but then great care is needed not toentrap any air.

Stitching:

- Stitching involves drilling holes on both sides of the crack and grouting inU-shaped metal units with short legs (staples or stitching dogs) that spanthe crack as shown in Figure.



- Stitching should be used when tensile strength has to be restored backacross major cracks. Stitching a crack tends to stiffen the structure andthe stiffening may increase the overall structural restrain, causing theconcrete to crack elsewhere.
- Therefore, it is necessary that properinvestigation is done and if required, adjacent section or sections arestrengthened using

technically designed reinforcing methods. Becausestresses are often concentrated, using this method in conjunction withother methods may be necessary.

- The procedure consists of drilling holes on both sides of the crack,cleaning the holes and anchoring the legs of the staples in the holes, witheither a non-shrink cement grout or any epoxy resin-based bondingsystem.
- The staples should be variable in length, orientation, or both andthey should be located so that the tension transmitted across the crack isnot applied to a single plane within the section but is spread over an area.

External Prestressing:

- The flexural cracks in reinforced concrete can be arrested and evencorrected by the 'Post –tensioning' method. It closes the cracks byproviding compression force to compensate for tensions and adds aresidual compression force.
- This method requires anchorage of the tierods(or wires) to the anchoring device (the guide – bracket- angles) attached to the beam Fig.

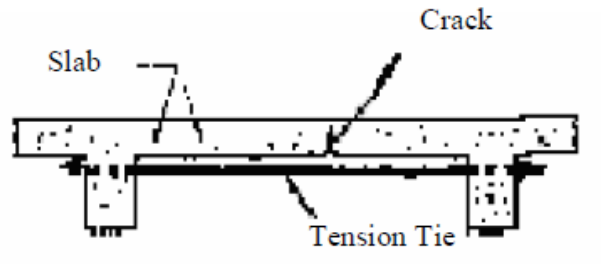
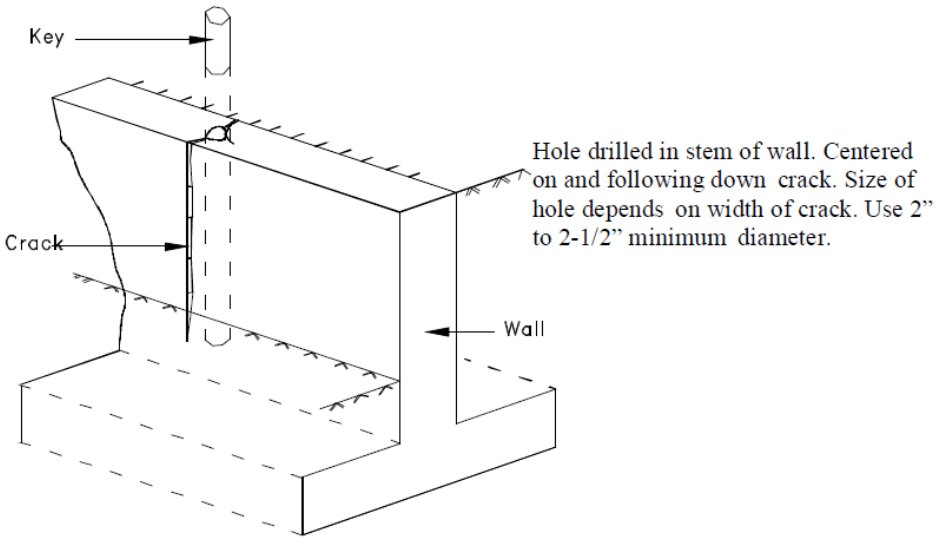


Fig.14 Post tensioning crack beam

- The rods or wires are then tensioned by tightening the end-nuts or byturning of turnbuckles in the rods against the anchoring devices.However, it may become necessary in certain critical case to run at leastan approximate stress-check to guard against any possible adverseeffects.

Drilling and Plugging:

- When cracks run in reasonable straight lines and are accessible at oneend, drilling down the length of the crack and grouting it to form a key as shown in Fig. couldrepair them.



- A hole of 50 to 75mm dia depending on width of crack should be drilled,centered on and following the crack. The hole must be large enough tointersect the crack along its full length and provide enough repair materialto structurally take the loads exerted on the key.
- The drilled hole shouldthen be cleaned, made tight and filled with grout. The grout key preventstransverse movements of the sections of concrete adjacent to the crack.The key will also reduce heavy leakage through the crack and loss of soilfrom behind a leaking wall.
- If water tightness is essential and structuralload transfer is not, the drilled hole should be filled with a resilient materialof low modulus in lieu of grout. If the key effect is essential, the resilientmaterial can be placed in a second hole, the first being grouted.

Gravity Filling:

- Low viscosity monomers and resins can be used to seal cracks with widthof 0.03mm to 0.3mm by gravity filling. High molecular-weightmethacrylates, urethanes and some low viscosity epoxies could be usedsuccessfully.
- Lower the viscosity, finer the cracks that can be filled. Firstthe surface should be cleaned by air blasting and/ or water blasting.
- Wetsurfaces should be permitted to dry several days to obtain the best crackfilling. The monomer or resin can be poured on the surface and spreadwith brooms or rollers

Cement Grouting:

- Wide cracks, particularly in mass concrete abutments/piers and masonrysubstructures may be repaired by filling with portland cement grout. Thismethod is effective in sealing the crack in concrete, but it will notstructurally bond cracked sections.

Chemical Grouting:

- It consists of solutions of two or more chemicals, such as urethanes,sodium silicates, and acrylomides that combine to form a gel, a solidprecipitate, or foam. Cracks in concrete as narrow as .05mm could befilled with grout.

9. **Discuss the sea water attack on concrete? /Marine exposure (April/May 2019)**

Effects of Continuous Immersion of Concrete in Sea Water.

- Concrete that is totally and continuously immersed in water, even ifthe water contains dissolved salts such as are found in sea water generallymay be regarded as being in a protected exposure.

- Continuous immersionusually provides a uniformity of environment with respect to temperatureand moisture content that prevents the immersed concrete from being subjectedto such deteriorating influences as frost action, volume change dueto wetting and drying, and differential volume change due to moisture content differences between the surface and the interior.
- Continuous immersionalso tends to reduce the potential for chemical reaction by removingchanges in degree of saturation as a mechanism for the flow into and outof the concrete of solutions containing ions that are capable of attacking'constituents of the concrete, and leaving only concentration gradients asthe means of ingress of such ions.
- The aggressiveness of water increases withincreasing concentration of the relevant substances, but that aggressivenessis also increased by higher temperatures, higher pressures, wetting and drying, or mechanical abrasion by fast-flowing or turbulent waters.

Effects of Intermittent Immersion of Concrete in Sea Water

- Most concrete structures exposed to sea water are partially or whollysituated so that they are sometimes immersed in sea water and sometimesexposed to the air.
- If the structure is located where the temperaturesfall below freezing, then the concrete that is exposed to the air withfalling tide is probably subjected to as severe frost action as is any concretein natural exposure.
- The second important effect on concrete related to wetting and dryingis the volume change relations due to changes in, or changes in uniformityof, moisture content. Thesephenomena often referred to as "dryingshrinkage" effects.

10. What are the different methods of demolition (or) Explain the procedure for demolishing main structural members(Nov/Dec 2018) (April/May 2017) (Nov/Dec 2017) (April/May 2018)

There are two types of demolition

A. Non explosive demolition method

B. Explosive demolition method

A. Non explosive demolition method

Demolition of a structure done with some or other equipment without use of any explosive. Different equipments used for the demolition activity are

A.1 Sledge Hammers and rammers

- A sledge hammer and rammers, equipment used for removing a stone wall or a single column. It consists of a long stem with a metallic head. It is used to give impacts on the surfaces and that cause the demolition of structure. It cannot be used for removal of large buildings.

A.2 Excavators and Bulldozers

- Hydraulic excavators may be used to topple one-or two-story buildings by an undermining process. The undermining process means erode the base or foundation, i.e., dig or excavate beneath the foundation so as to make it collapse.
- The strategy of excavation is to undermine the building while controlling the manner and direction in which it falls.
- The demolition project manager will determine where under mining is necessary so that the building is pulled into the desired manner and direction.
- Safety and cleanup considerations are also taken into account in determining how the building is undermined and ultimately demolished.

A.3 Wrecking Balls or Spilling Balls

- In case of buildings have greater heights 5 onwards story machineries like normal excavators and bulldozers are not sufficient. In such cases crane with wrecking balls or spilling balls are used to perform the demolition activity.
- The wrecking balls are steel balls hanging from a steel rope which is attached to the crane.
- This method is more effective only for high rise masonry structures because of the uncontrolled backward movement of steel ball after the impact on the wall surface.
- Nowadays this method is not commonly used because of this uncontrolled behavior of wrecking balls which may cause some other accident.

B. Explosive Demolition method

- The basic idea of explosive demolition is quite simple, easy and fast. If we remove the support of the structure of a building at a certain point, the section of the building above the point will come down on the part of the building below that point from where it is exploded.
- If this upper section is heavy enough, it will collide with the lower part with sufficient force to cause significant damage. The explosives are just trigger for the demolition. It's gravity that brings the building down.
- Demolition blasters or blasting expert ("Blasting expert" means a person who is the holder of a valid mine blasting certificate.) load explosives on several different levels of the building so that the building structure falls down on itself at multiple points.
- When everything is planned and executed correctly, the total damage of the explosives and falling building material is sufficient

to collapse the structure entirely, so cleanup crews are left with only a pile of rubble.

The main challenge and risk in bringing a building down is controlling which way it falls. There are mainly two ways to bring down a building,

1. Falling like a tree
2. Falling from crest to foot

B.1 Falling like a Tree

- In this method the blasting crew to collapses the building over on one side, into a parking lot or other open area with the help of blast.
- This sort of blast is the easiest to execute, and it is generally the safest way to perform demolition which is something like felling a tree.
- For example to topple the building to the north, the blasters detonate explosives on the south side of the building first , in the same way you would chop into a tree from the south side if you wanted it to fall in that direction .
- Blasters may also secure steel cables to support columns in the building, so that they are pulled a certain way as they crumble.

B.2 Falling from crest to foot

- Many times, a building is surrounded by numbers of structures that must be preserved. In this case, the blasters are used for true implosion, demolishing the building so that it collapses straight down into its own foot (that means the total area of building is removed into the base of the building).
- This requires great skill that only some handful of demolition companies in the world attempt it.

Mainly there are two methods of dismantling:

1. Primary dismantling
2. Secondary Dismantling

1. Primary Dismantling:

(a) To break up the structure with an aim to reduce the height and size of the elements.

(b) To break the structural elements into pieces that can be easily handled for immediate removal from on site location.

2. Secondary Dismantling:

To reduce the size of the demolished debits for disposal, salvage of scrap or processing elsewhere.

Primary dismantling methods:

- Speitters
- Non explosive cracking agent
- Controlled demolition.
- Thermal lancing
- Crane and Ball method
- Diamond sawing
- Robotic machines.

Secondary dismantling methods:

- Rock breaker
- Jack hammers
  - Pneumatic
  - Electrical
  - Hydraulic
  - Petrol Engine
- Concrete Pulveriser
- Hand held clippers
- Hydro demolition
- Hydraulic Rock Breakers
- Diamond sawing and Drilling

- Diamond wire s.awing system
- Silent expansive chemicals
- Controlled Demolition (Implosion)
- Hydraulic Bursting/splitting
- Thermal lancing
- Hydro demolition
- Robotic demolition.

Controlled Demolition Technique

Implosion is a term coined by the internationally renowned company "Controlled Demolition International" USA (CD!) for their specialised method of demolition of tall structures. concrete, steel and wood.

The CDI Technique:

Implosion Technology involves careful and detailed study of the structure to Identify critical locations for placing explosives, to calculate the amount. of charge required to plan the sequence of explosion etc. It presents debris of concrete flying outside the defined area.

When combined with carefully timed explosive charges and gravitational energy, the CDI Implosion Technology allows unbelievable control over the failure of complex structures while maximizing fragmentation of debris.

Basic Diamond Tools:

(a) Diamond Segment

- Man made arsenal to attack concrete
- Can be molded in many shops to suit base weapon.

(b) Common shapes of Diamond Tools

- Circular Blade dia range from 100 mm to 300 mm or more
- Core drill dia range from 10 rnm to 2000 mm

- Wire String of beads to form endless Wire
- Special shapes Cup grinders. Disc grinders

(c) Diamond Techniques

- Flat sawing
- Wall sawing
- Core drilling
- Wire sawing
- Hand Sawing
- Diamond Grinding

(d) Special Diamond Tools

- Cup Grinders and discs
- Diamond chain saw
- Diamond crack saw
- Span saw
- Multiple wheel saws for grooving and grinding.

(e) Flat Sawing:

Use floor saw

Machines with circular diamond blade to cut horizontal members like slabs, beams and flooring

(f) Wall sawing

Wall sawing uses circular Diamond blade with Hydraulic / Electric / Pneumatic drive motor mounted on tracks ideal for cutting RCC walls.

(g) Core drilling

Core drilling uses diamond tipped Bits with Hydraulic /Electric / Pneumatic drill motors.

Used for modelling holes or cutting long openings by stitch drilling

Wire Sawing: Ultimate Demolition Tool:

In wire sawing, a diamond beaded wire is reared around the RCC members to be cut The wire is rotated at a high speed (10 km/hr) by a special machine while constantly applying a pulling force. The diamond wire penetrates and cuts through the steel and concrete.

- Water is used as a lubricating coolant
- Wire sawing has no limitation on the size of RCC member to be cut.
- This technique is ideal for fast primary demolition.

Hand Sawing:

Hand sawing uses a light weight hand held machine with diamond Blade to cut RCC ill any direction. By this technique even over head cutting is possible.

Hydraulic Splitters / Busters

Creates enormous stresses within the concrete bars producing tensile cracking of concrete.

Dismantling Tools:

- Hand operated Machines
- Crane mounted Machines
- Excavator mounted Machines
- Special Machines
- Robotic Machines.

11. What are the precaution to prevent water leakage in roofs and sunken floors(April/May 2017)

1. Replace Missing Shingles Immediately.

2. Fix Ponding Surfaces.
3. Regularly Clean Your Gutters.
4. Inspect Flashing Around Vents, Valleys, Chimneys, Pipes, Skylights.
5. Inspect Your Attic **Ceiling**.
6. Remove Ice Buildup During Heavy Snows.
7. Find the Leakage Source
8. Fill Cracks
9. Regular Professional Maintenance

12.Explain pre-planning activities of demolition activity. (April/May 2019)

The different steps before the start of a demolition process are:

A. Surveying of site

B. Removal of hazardous materials from the site

C. Preparation of plan along with strategy to implement

D. Stability report from local authorities

E. Safety measures to be used.

A. Surveying of Site

1. Building surveying
2. Structural surveying

A.1 Building surveying

(a) Record Drawings

(b) Survey of Buildings

(c) Hazardous Materials on and in surrounding

A.2 Structural surveying

(a) Record Drawings

(b) Survey Items

(c) Special Structures

(d) Investigation and Testing at site

B. Removal of Hazardous Materials from site

B.1 Asbestos Containing Material if any on site

B.2 Presence of Soil Contamination Material

C. Preparation of plan and strategy

C.1 A detail plan showing:

C.2 A detail layout plan of all floors of the building to be demolished,

C.3 A Detail plan showing the structural arrangement

C.4 A Detail plan showing the steps for the demolition

D. Detail Stability Report

E. Safety Measures

E.1 Training to workers

E.2 Maintenance of equipment from time to time

E.3 Electrical appliances Safety

E.4 Fire and fire extinguishers

E.5 Occupational Health a priority

E.6 Emergency Exit in Demolition Sites for safety

E.7 Vibration and its Effect

13. Consider a RC structure in a marine environment, discuss the possible types of distress likely to affect the structure and suggest suitable remedy/protection for the structure.

Suitable remedy/protection for the structures:

a) cathodic protection

b) impressed current system

a. Titanium Anode Mesh Encapsulation
b. Titanium Anode Mesh integral pile jacket system
c. Titanium Ribbon Mesh Slotted system
d. Discrete Anode system

c) sacrificial system

a. Arc sprayed aluminum zinc Indian
b. Zinc Mesh integral pile jacket system
c. Cast Zinc Anodes