USN											CMRIT

Internal Assessment Test 3 – June 2022

Sub:	REHABILITATION AND RETROFITTING					Sub Code:	18CV824	Branch:	CIVIL
Date:	17.06.2022	Duration:	90 mins	Max Marks:	50	Sem / Sec:	VIII A & B		OBE

Answer all questions. Provide neat sketches wherever necessary	MARKS	CO	RBT
1. Explain the design and construction errors and suggest suitable rehabilitation techniques.	10	CO3	L1
2. Explain the corrosion prevention methods in concrete structures.	10	CO3	L1
3. Write short notes on Jacketing technique used to strengthen structural elements in concrete.	10	CO3	L1
4. Explain the steps and guidelines in the seismic rehabilitation of existing building.	10	CO3	L2
5. Classify and explain different techniques for repair of concrete structures.	10	CO4	L3

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Solutions

1. Explain the design and construction errors and suggest suitable rehabilitation techniques.

Following are the different design and detailing errors in construction, their symptoms and prevention methods:

(1) Inadequate structural design

Due to inadequate structural design the concrete is exposed to greater stress than it can handle or strain in concrete increases more than its strain capacity and fails.

The symptoms of such kind of failures due to inadequate structural design show either spalling of concrete or cracking of concrete. Excessively high compressive stress due to inadequate structural design results in spalling of concrete. Also, high torsion or shear stresses results in spalling or cracking of concrete. High tensile stresses also results in cracking of concrete. To identify the inadequate design as cause of the structural damage, the structure shall be inspected and locations of the damage should be compared to the types of stresses that should be present in the concrete. For rehabilitation projects, thorough petrographic analysis and strength testing of concrete from elements to be reused will be necessary.

Prevention: Inadequate structural design can be prevented by thorough and careful review of all design calculations. Any rehabilitation method that makes use of existing concrete structural members must be carefully reviewed.

(2) Poor design details

Poor design details can cause localized concentration of high stresses in structural members even if the design is adequate to meet the requirements. These high stresses may lead to cracking of concrete that allows water or chemicals to pass through the concrete. Thus poor design detail may lead to seepage through the structural members. Poor design detail may not lead to structural failure, but it can become the cause of deterioration of concrete. These problems can be prevented by a thorough and careful review of plans and specifications for the construction work.

Types of poor design detailing and their possible effects on structures are discussed below:

(a) Abrupt changes in section:

Abrupt changes in section may cause stress concentrations that may result in cracking. Typical examples would include the use of relatively thin sections rigidly tied into massive sections or patches and replacement concrete that are not uniform in plan dimensions.

(b) Insufficient reinforcement at corners and openings:
Corners and openings also tend to cause stress concentrations that may cause cracking. In this case, the best prevention is to provide additional reinforcement in areas where stress concentrations are expected to occur.
(c) Inadequate provision for deflection:
Deflections in excess of those anticipated may result in loading of members or sections beyond the capacities for which they were designed. Typically, these loadings will be induced in walls or partitions, resulting in cracking.
(d) Inadequate provision for drainage:
Poor attention to the details of draining a structure may result in the ponding of water. This ponding may result in leakage or saturation of concrete. Leakage may result in damage to the interior of the structure or in staining and encrustations on the structure. Saturation may result in severely damaged concrete if the structure is in an area that is subjected to freezing and thawing.
(e) Insufficient travel in expansion joints:
Inadequately designed expansion joints may result in spalling of concrete adjacent to the joints. The full range of possible temperature differentials that a concrete may be expected to experience should be taken into account in the specification for expansion joints. There is no single expansion joint that will work for all cases of temperature differential.
(f) Incompatibility of materials:
The use of materials with different properties (modulus of elasticity or coefficient of thermal expansion) adjacent to one another may result in cracking or spalling as the structure is loaded or as it is subjected to daily or annual temperature variations.
g) Neglect of creep effect:
Neglect of creep may have similar effects as described for inadequate provision for deflections. Additionally, neglect of creep in prestressed concrete members may lead to excessive prestress loss that in turn results in cracking as loads are applied.
(h) Rigid joints between precast units:
Designs utilizing precast elements must provide for movement between adjacent precast elements or between the precast elements and the supporting frame. Failure to provide for this movement can result in cracking or spalling.
(i) Unanticipated shear stresses in piers, columns, or abutments:
If, through lack of maintenance, expansion bearing assemblies are allowed to become frozen, horizontal loading may be transferred to the concrete elements supporting the bearings. The result will be cracking in the concrete, usually compounded by other problems which will be caused by the entry of water into the concrete.
(j) Inadequate joint spacing in slabs:
This is one of the most frequent causes of cracking of slabs-on-grade.

2. Explain the corrosion prevention methods in concrete structures.
   Corrosion control of steel reinforcement is necessary to prevent damage and failure of concrete structures. Nearly 40% of failure of concrete structures is due to corrosion of embedded steel reinforcement. There can be many causes for corrosion of reinforcement, but mostly it is related to quality of concrete, environment and quality of construction practices. So, the first step in corrosion control of rebar is to provide good quality of concrete through good construction practices. The quality of concrete materials, mixing, placing and compaction techniques and good workmanship can help control the rebar corrosion.
   Methods of Corrosion Control of Reinforcement in Concrete:
   1. Cement-Polymer Composite Coated Rebars (CPCC)
   Cement polymer coated rebars embedded in concrete are surrounded by an alkaline medium, thus cement based coating is more compatible for reinforcement corrosion control. Two coats of cement polymer are applied on rebar - Primer coat and Sealer coat. Products involved in Cement Polymer Composite Coated rebar are:
   De-rusting Solution
   Alkaline Powder
   Phosphating Jelly
   Inhibitor Solution
   Sealing Solution
   2. Fusion Bonded Epoxy Coated Rebars (FBEC)
   Fusion bonded epoxy coated rebar is produced from 100% solid finely ground fused powder particles. These particles melt to form a continuous adherent film when heated. There is no passivating primer film provided in case

of FBEC rebars. Fusion bonded epoxy coating introduces a medium of weakness in the path of an intimate bond between rebar and alkaline concrete.

Epoxy coats the rebar in the following manner:

- Melts
- Flows
- Gels
- Cures
- Cools
- Adheres as coating

3. Corrosion Resistant Steel Deformed Rebars (CRSD)

Mechanism of resistance to corrosion begins with the formation of initial layer of protective oxide or rust. (Hypo oxides). Unlike common rust on normal rebars, the CRSD rust is passive, tenacious and self-renewing. The protective oxide is fine textured, tightly adherent and a barrier to moisture, oxygen, carbon dioxide, Sulphur dioxide and chloride effectively preventing further corrosion. Scale on normal bars of steel is coarse textured flaky oxide that does not prevent moisture or oxygen from reaching the underlying bars and continuing the corrosion. As corrosion resistance is in the chemistry of the grade, if the passive oxide layer gets removed somehow, a new passive layer is formed immediately.

3. Write short notes on Jacketing technique used to strengthen structural elements in concrete.

Column strengthening is a process used to add or restore ultimate load capacity of reinforced concrete columns. It is used for seismic retrofitting, supporting additional live load or dead load that not included in the original design, to relieve stresses generated by design or construction errors, or to restore original load capacity to damaged structural elements. There are several techniques which are used to strengthen reinforced concrete columns like reinforced concrete jacketing, steel jacketing, and FRP confining or jacketing.

When strengthening of R.C. Column is needed?

- The load carried by the column is increased due to either increasing the number of floors or due to mistakes in the design.
- The compressive strength of the concrete or the percent and type of reinforcement are not according to the codes' requirements.
- The inclination of the column is more than the allowable.
- The settlement in the foundation is more than the allowable.
- Strengthening Techniques for R.C. Columns

There are three major techniques for strengthening reinforced concrete columns which are discussed below:

1. Reinforced Concrete Jacketing

It is one of the techniques used to improve or restore capacity of reinforced concrete column. The size of the jacket and the number and diameter of the steel bars used in the jacketing process depend on the structural analysis that was made to the column.

Reinforced Concrete Jacketing Process

- Initially, reduce or eliminate loads on columns temporarily if it is required. This is done by putting mechanical jacks and additional props between floors.
- After that, if it is found out that reinforcements are corroded, the remove the concrete cover and clean the steel bars using a wire brush or sand compressor.
- Then, coat the steel bars with an epoxy material that would prevent corrosion.
- If reducing loads and cleaning reinforcement is not needed, the jacketing process begin by adding steel connectors into the existing column.
- The steel connectors are added into the column by making holes 3-4mm larger than the diameter of the used steel connectors and 10-15cm depth.
- The spacing of new stirrups of the jacket in both the vertical and horizontal directions should not be more than 50cm.
- Filling the holes with an appropriate epoxy material then inserting the connectors into the holes.
- Adding vertical steel connectors to fasten the vertical steel bars of the jacket following the same procedure in step 5 and 6.

- Installing the new vertical steel bars and stirrups of the jacket according to the designed dimensions and diameters.
- Coating the existing column with an appropriate epoxy material that would guarantee the bond between the old and new concrete.
- Pouring the concrete of the jacket before the epoxy material dries. The concrete used should be of low shrinkage and consists of small aggregates, sand, cement and additional materials to prevent shrinkage.

4. Explain the steps and guidelines in the seismic rehabilitation of existing building.

Seismic Retrofitting Techniques are required for concrete constructions which are vulnerable to damage and failures by seismic forces. In the past thirty years, moderate to severe earthquakes occurs around the world every year. Such events lead to damage to the concrete structures as well as failures. Thus the aim is to Focus on a few specific procedures which may improve the practice for the evaluation of seismic vulnerability of existing reinforced concrete buildings of more importance and for their seismic retrofitting by means of various innovative techniques such as base isolation and mass reduction. So Seismic Retrofitting is a collection of mitigation technique for Earthquake engineering. It is of utmost importance for historic monuments, areas prone to severe earthquakes and tall or expensive structures.

Seismic Retrofitting of Concrete Structures

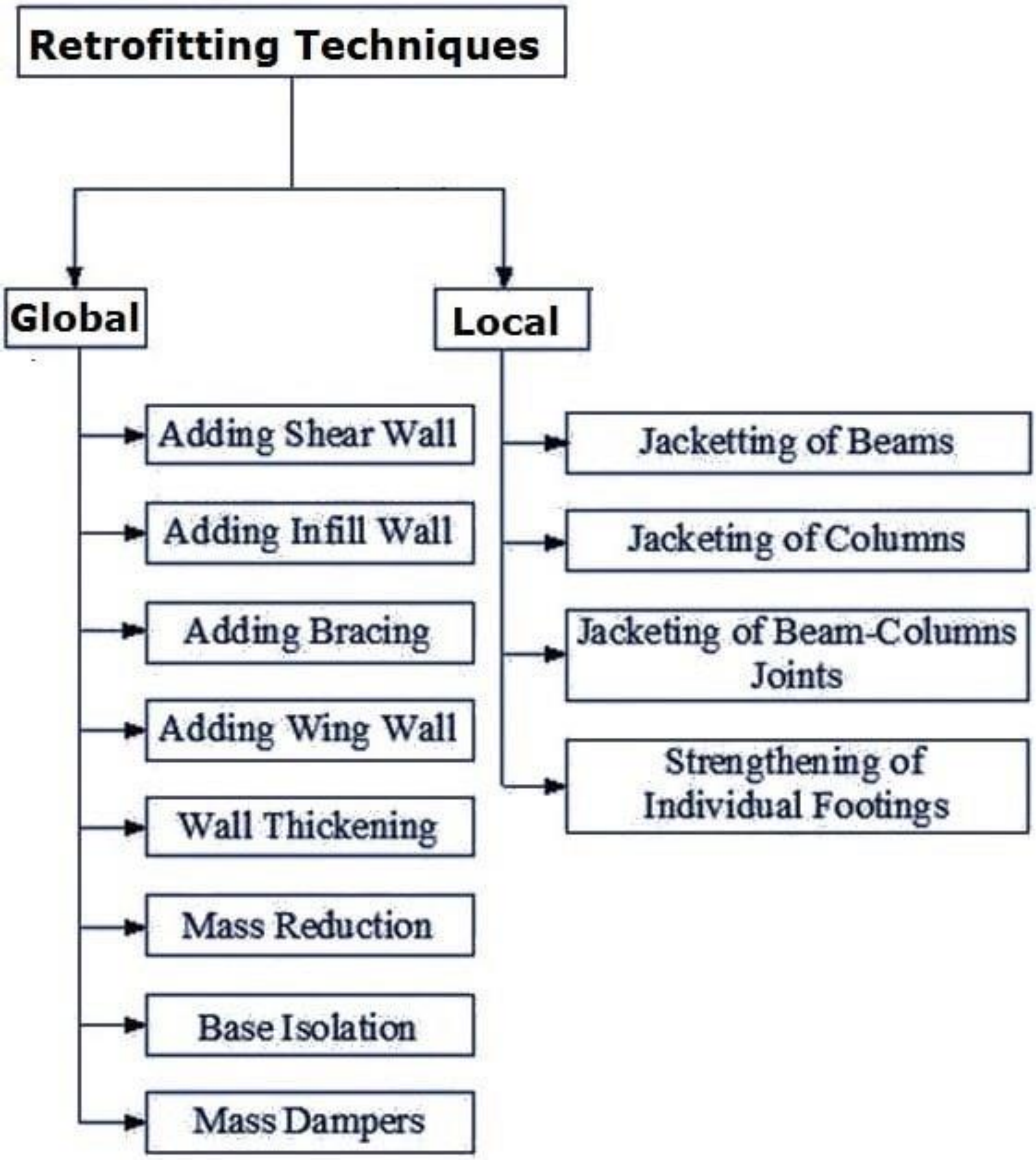
It is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes. The retrofit techniques are also applicable for other natural hazards such as tropical cyclones, tornadoes, and severe winds from thunderstorms.

Need for Seismic Retrofitting

- To ensure the safety and security of a building, employees, structure functionality, machinery and inventory
- Essential to reduce hazard and losses from non-structural elements.

predominantly concerned with structural improvement to reduce seismic hazard.

- Important buildings must be strengthened whose services are assumed to be essential just after an earthquake like hospitals.



Retrofitting Techniques for Reinforced Concrete Structures

5. Classify and explain different techniques for repair of concrete structures.

Methods of Concrete Crack Repair

Epoxy injection

Epoxy injection method is used for cracks as narrow as 0.002 inch (0.05 mm). The technique generally consists of establishing entry and venting ports at close intervals along the cracks, sealing the crack on exposed surfaces, and injecting the epoxy under pressure. Epoxy injection has been successfully used in the repair of cracks in buildings, bridges, dams, and other types of concrete structures (ACI 503R). However, unless the cause of the cracking has been corrected, it will probably recur near the original crack.

Routing and Sealing of Cracks

Routing and sealing of cracks can be used in conditions requiring remedial repair and where structural repair is not necessary. This method involves enlarging the crack along its exposed face and filling and sealing it with a suitable joint sealant (Fig.1). This is a common technique for crack treatment and is relatively simple in comparison to the procedures and the training required for epoxy injection. The procedure is most applicable to approximately flat horizontal surfaces such as floors and pavements. However, routing and sealing can be accomplished on vertical surfaces (with a non-sag sealant) as well as on curved surfaces (pipes, piles and pole). Routing and sealing is used to treat both fine pattern cracks and larger, isolated cracks.

Concrete Crack Repair by Stitching

Stitching involves drilling holes on both sides of the crack and grouting in U-shaped metal units with short legs (staples or stitching dogs) that span the crack. Stitching may be used when tensile strength must be reestablished across major cracks. The stitching procedure consists of drilling holes on both sides of the crack, cleaning the holes, and anchoring the legs of the staples in the holes, with either a non shrink grout or an epoxy resin-based bonding system.

Additional Reinforcement for Crack Repair

Conventional reinforcement

Cracked reinforced concrete bridge girders have been successfully repaired by inserting reinforcing bars and bonding them in place with epoxy. This technique consists of sealing the crack, drilling holes that intersect the crack plane at approximately 90^0, filling the hole and crack with injected epoxy and placing a reinforcing bar into the drilled hole. Typically, No. 4 or 5 (10 M or 15 M) bars are used, extending at least 18 in. (0.5 m) each side of the crack. The reinforcing bars can be spaced to suit the needs of the repair. They can be placed in any desired pattern, depending on the design criteria and the location of the in-place reinforcement.

Prestressing steel

Post-tensioning is often the desirable solution when a major portion of a member must be strengthened or when the cracks that have formed must be closed (Fig.5). This technique uses pre stressing strands or bars to apply a compressive force. Adequate anchorage must be provided for the prestressing steel, and care is needed so that the problem will not merely migrate to another part of the structure.

Drilling and Plugging Method

This technique is only applicable when cracks run in reasonable straight lines and are accessible at one end. This method is most often used to repair vertical cracks in retaining walls. A hole [typically 2 to 3 in. (50 to 75 mm) in diameter] should be drilled, centered on and following the crack. The grout key prevents transverse movements of the sections of concrete adjacent to the crack. The key will also reduce heavy leakage through the crack and loss of soil from behind a leaking wall. If water-tightness is essential and structural load transfer is not, the drilled hole should be filled with a resilient material of low modulus in lieu of grout. If the keying effect is essential, the resilient material can be placed in a second hole, the fiat being grouted.

Gravity Filling Method

Cores taken at cracks can be used to evaluate the effectiveness of the crack filling. The depth of penetration of the sealant can be measured. Shear (or tension) tests can be performed with the load applied in a direction parallel to the repaired cracks (as long as reinforcing steel is not present in the core in or near the failure area). For some polymers the failure crack will occur outside the repaired crack.

Grouting Method of Crack Repair

Portland cement grouting

Wide cracks, particularly in gravity dams and thick concrete walls, may be repaired by filling with Portland cement grout. This method is effective in stopping water leaks, but it will not structurally bond cracked sections. The procedure consists of cleaning the concrete along the crack; installing built-up seats (grout nipples) at intervals astride the crack (to provide a pressure tight connection with the injection apparatus); sealing the crack between the seats with a cement paint, sealant, or grout; flushing the crack to clean it and test the seal; and then grouting the whole area. Grout mixtures may contain cement and water or cement plus sand and water, depending on the width of the crack. However, the water-cement ratio should be kept as low as practical to maximize the strength and minimize shrinkage. Water reducers or other admixtures may be used to improve the properties of the grout. For small volumes, a manual injection gun may be used; for larger volumes, a pump should be used. After the crack is filled, the pressure should be maintained for several minutes to insure good penetration.

Dry packing

Dry packing is the hand placement of a low water content mortar followed by tamping or ramming of the mortar into place, producing intimate contact between the mortar and the existing concrete. Because of the low water-cement ratio of the material, there is little shrinkage, and the patch remains tight and can have good quality with respect to durability, strength, and water tightness. Dry pack can be used for filling narrow slots cut for the repair of dormant cracks. The use of dry pack is not advisable for filling or repairing active cracks. Before a crack is repaired by dry packing, the portion adjacent to the surface should be widened to a slot about 1 in. (25 mm) wide and 1 in. (25 mm) deep. The slot should be undercut so that the base width is slightly greater than the surface width. To minimize shrinkage in place, the mortar should stand for 1/2 hour after mixing and then should be remixed prior to use. The mortar should be placed in layers about 3/8 in. (10 mm) thick. Each layer should be thoroughly compacted over the surface using a blunt stick or hammer, and each underlying layer should be scratched to facilitate bonding with the next layer. The repair should be cured by using either water or a curing compound. The simplest method of moist curing is to support a strip of folded wet burlap along the length of the crack.