IAT 3 QUESTIONS

1. Explain in detail the different crack arresting techniques?
2. Briefly explain the different fibre reinforced polymers used in concrete strengthening.
3. What is meant by jacketing? Briefly discuss the different jacketing techniques.
4. What does guniting and shotcreting mean? Describe its advantages in detail.
5. Describe external bonding technique (EBT) and near surface mounting technique (NSM) in detail.

SOLUTION

1. Explain in detail the different crack arresting techniques?

The crack arrest approach can be adopted for determining the fitness for service of a structure. Many structural integrity assessment procedures are aimed at preventing the initiation of fracture. An alternative approach is to assume that unstable crack extension may start in a region of high stress and/or localised embrittlement, but that the surrounding material will have sufficient resistance to crack extension to arrest the running crack.The crack initiation approach relies on close attention to the workmanship and quality control during welding. However, it can be difficult to guarantee that no areas of local brittle zones exist. It is also difficult to know the exact stress distribution around a crack tip that experiences contributions from residual stresses and local stress concentration. For these reasons the crack arrest approach may be considered a viable alternative. The crack arrest concept is simple in principle, if not always in application: arrest of fast running brittle cracks, that have initiated in a region of low toughness, will occur if the applied crack driving force is smaller than the resistance to crack propagation. By looking at conditions of crack arrest, the focus can be taken away from localised stress concentration or brittle zones and back to the bulk properties of the parent plate, weld metal or heat affected zone and the nominal applied stress.

The conditions for crack arrest to occur can be expressed using one of the following approaches

REPAIR AND RETROFITTING TECHNIQUES

1. Rust eliminators and polymers coating for rebars during repair,

2. Foamed concrete,

3. Mortar and dry pack,

4. Vacuum concrete,

5. Gunite and shotcrete,

6. Epoxy injection,

7. Mortar repair for cracks,

8. Shoring

9. Underpinning

Rust Eliminators

- Cement paste normally provides a highly alkaline environment that projects embedded steel against corrosion.
- Concrete with a low water/cement ratio, well compacted and well cured, has a low permeability and hence minimizes the penetration of atmospheric moisture as well as other components such as oxygen, chloride ion, carbon dioxide and water, which encourage corrosion of steel bar.

- In very aggressive environments, the bars may be coated with special materials developed for this purpose.
- Coating on reinforcing steel, therefore, serves as a means of isolating the steel from the surrounding environment. Common metallic coatings contain galvanizing zinc.
- High chloride concentration around the embedded steel corrodes the zinc coating, followed by corrosion of steel. Hence, this treatment is used for moderately aggressive environments.
- For high corrosive atmospheres caused by chloride ions from the de-icing salts applied to protect against sodium chloride and calcium chloride, usually near seashores, epoxy coating is applied to protect steel reinforcing bars from corrosion.
- Such bars have acceptable bond and creep characteristics. The coat normally applied is 150um thick. The reinforcement is epoxied in the factory itself, where the steel rods are manufactured.
- Such reinforcement is known as fusion-bonded epoxy coated steel. Steel manufacturers also manufacture CTD bars with better corrosion resistance, termed as Corrosion Resistance Steel (CRS).
- The performance of the CRS CTD bars is better in resisting corrosion compared to plain CTD bars. However, the use of CRS CTD bars will only delay the process of corrosion. It will not prevent corrosion once for all.

Polymer Resin based Coating

These are generally of two types,

1. Resins blended with organic solvents and

2. Solvent free coating

Solvent-based coatings are subdivided into single and two component coatings.

- The coatings on drying produce a smooth dense continuous film that provides a barrier to moisture and mild chemical attack of the concrete.

- Because of the resistance to moisture penetration, staining, and ease of cleaning, they are preferred for locations of high humidity and those in which a lot of soiling occurs.
- Most products are low solids content materials which require multiple coats to produce a continuous film over concrete, since the materials are thermoplastic, and have a significant degree of extensibility they are capable of bridging minor cracks which may develop in the concrete surface if they are applied in sufficient thickness.
- The number of coats required depends on the surface texture, porosity and the targeted dry film thickness.
- Although some of the newer products have some moisture tolerance, enabling them to be applied over damp surfaces, in normal usage they should be applied over dry surfaces.
- Due to their relative in permeability to water vapor, they could blister when applied to concrete surfaces with high moisture content or where the opposite surface of the concrete is inconstant contact with moisture.
- Careful control of wet film thickness is therefore necessary during application.
- Two component polymer coatings consist of a solution of a compounded polymer with or without solvent and a reactive chemical component called the curing agent hardener or catalyst.
- The materials are usually mixed just prior to use in accordance with the manufacturer’s instructions. When using two components polymer based coatings the following items are of importance to the application of the materials.

1. Most produces are supplied as a kit containing the two components in the required proportions. Therefore, in order to realize the full potential of the product the correct mix ratio of the two components must be used.

2. To ensure a complete reaction of the two components they must be mixed thoroughly. 3. Some two component material requires an induction period of 15 to 40 min after mixing. Therefore, such products cannot be used immediately after mixing. 4. Viscosity reduction by the use of thinners should be resorted to only after the manufacturers are consulted.

5. The storage temperature of solvent based coatings is not critical. They should be stored are a temperature 16 to 32◦c just prior to use.

Foamed concrete

- Aerated concrete is made by introducing air or gas into slurry composed of Portland cement or lime and finely crushed siliceous filler so that when the mix set and hardens, a uniformly cellular structure is formed.
- Though it is called aerated concrete it is really not a concrete in the correct sense of the word.
- As described above, it is a mixture of water, cement and finely crushed sand. Aerated concrete is also referred to as gas concrete, foam concrete, cellular concrete.
- In India we have at present a few factories manufacturing aerated concrete. A common product of aerated concrete in India is Siporex.

There are several ways in which aerated concrete can be manufactured, (a) By the formation of gas by chemical reaction within the mass during liquid or plastic state.

(b) By mixing performed stable foam with the slurry

(c) By using finely powdered metal (usually aluminum powder) with the slurry and made to react with the calcium hydroxide liberated during the hydration process, to give out large quantity of hydrogen gas. This hydrogen gas when contained in the slurry mix, gives the cellular structure.

Powered zinc may also be added in place of aluminum powder. Hydrogen peroxide and bleaching powder have also been used instead of metal powder. But this practice is not widely followed at present.

In the second method performed, stable foam is mixed with cement and crushed sand slurry causing the cellular structure when this gets sets and hardened. As a minor modification some foam-giving agents are also mixed and thoroughly churned or beaten (in the same manner as that of preparing foam with the white of egg) to obtain foam effect in the concrete. in a similar way, air entrained agent in large quantity can also be used and mixed thoroughly to introduce cellular aerated structure in the concrete. however, this method cannot be employed for decreasing the density of the concrete beyond a certain point and as such, the use of air entrainment is nor often practiced for making aerated concrete.

Gasification method is of the most widely adopted methods using aluminum powder or such other similar material.

This method is adopted in the large scale manufacture of aerated concrete in the factory wherein the whole process is mechanized and the product is subjected to high pressure steam curing i.e., in other words, the products are autoclaved. Such products will suffer neither retrogression of strength nor dimensional instability.

The practice of using performed foam with slurry is limited to small scale production and in situ work where small change in the dimensional stability can be tolerated. But the advantage is that any density desired at site can be made in this method.

Properties

Use of foam concrete has gained popularity not only because of the low density but also because of other properties mainly the thermal insulation property. Aerated concrete is made in the density range from 300 kg/m3 to about 800 kg/m3, lower density grades are used for insulation purposes, while medium density grades are used for the manufacture of building blocks or load bearing walls and comparatively higher density grades are used in the manufacture of prefabricated structural members in conjunction with steel reinforcement.

Mortar and dry pack

Dry pack is a combination of Portland cement and sand passing a No. 16 sieve mixed with just enough water to hydrate the cement. Dry pack should be used for filling holes having a depth equal to, or great then, the least surface dimension of the repair area, for cone bolt, she holt, core holes, and grout-insert holes; for holes left by the removal of form ties; and for narrow slots cut for repair cracks. Dry pack should not be used for relatively shallow depressions where lateral restraint cannot be obtained, for filling behind reinforcement, or for filling holes that extend completely, through a concrete section.

For the dry-pack, method of concrete repair, holes should be sharp and square at the surface edges, but corners within the holes should be rounded, especially when water tightness is required. The interior surfaces of holes left by cone bolts and she bolts should be roughened to develop an effective bond; this can be done with a rough stub of 7/8-inch steel-wire rope, a notched tapered reamer, or a star drill. Other holes should be undercut slightly in several places around the perimeter. Holes for dry pack should have a minimum depth of 1 inch.

Preparation and application

Application of dry-pack mortar should be preceded by a careful inspection of the hole, which should be thoroughly cleaned and free from mechanically held loose pieces of aggregate. One of three methods should be used to ensure good bond of the dry-pack repair. The first method is the application of a stiff mortar or grout bond coat immediately before applying the dry-pack mortar. The mix for the bonding grout is 1: 1 cement and fine sand mixed with water to a fluid paste consistency.

All surfaces of the hole are thoroughly brushed with the grout, and dry packing is done quickly before the bonding grout can dry. Under no circumstances should be bonding coat be so wet or applied so heavily that the dry-pack material becomes more has slightly rubbery.

When a grout bond coat is used, the hole to be repaired can be dry. Pre-soaking the hole overnight with wet rags or burlap prior to dry packing may sometimes give better results by reducing the loss of hydration water, but there must be no free surface water in the hole when the bonding grout is applied.

The second method of ensuring good bond starts with pre-soaking the hole overnight with wet rags or burlap. The hole is left slightly wet with a small amount of free water on the inside surfaces. The surfaces have been covered and the free water absorbed. Any dry cement in the hole should be removed using a jet of air before packing begins.

The hole should not be painted with neat cement grout because it could make the dry-pack material too wet and because high shrinkage would prevent development of the bond that is essential to a good repair. A third method of ensuring good bond is use of an epoxy bonding resin. Epoxies bond best to dry concrete. It may be necessary to dry the hole immediately prior to dry packing using hot air, a propane torch, or other appropriate method.

The concrete temperature however should not be high enough to cause instant setting of the epoxy or to burn the epoxy when it is applied. After being mixed, the epoxy is thoroughly brushed to cover all surfaces, but any excess epoxy is removed. Dry-pack mortar is then applied immediately, before the epoxy starts to harden.

The epoxy must be either fluid or tacky when dry packing takes place. If it appears that the epoxy may become hard before dry packing is complete, fresh fluid epoxy can be brushed over epoxy that has become tacky.

If the epoxy becomes hard, it must be comes hand, it must be removed before a new coat is applied. The epoxy ensures a good bond between the dry-pack repair and the old concrete. It also reduces can loss of hydration water from the repair to the surrounding concrete, thus assisting in good curing; however, the epoxy-bonded dry pack still requires curing as discussed below. Where appearance is not important, epoxy has sometimes been used on the surface in place of a curing compound. This procedure is not recommended.

Vacuum Concrete It has been amply brought out in the earlier discussion that high water/cement ratio as harmful to the overall quality of concrete whereas low water/cement ratio does not give enough workability for concrete to be compacted hundred per cent. Generally, higher workability and higher strength or very low workability and higher strength do not go hand in hand. Vacuum process of concreting enables to meet this conflicting demand. This process helps a high workable concrete to get high strength.

In this process, excess water used for higher workability, not required for hydration, and harmful in many ways to the hardened concrete is withdrawn by means of vacuum pump, subsequent to the placing of the concrete. The process when properly applied, produces concrete of quality. It also permits removal of formwork at an early age to be used in other repetitive work.

The equipment essentially consists of a vacuum pump, water separator and filtering mat. The filtering consists of a backing piece with a rubber seal all round the periphery. A sheet of expanded metal and then a sheet of wire gauge also forms part of the filtering mat. The top of the suction mat is connected to the vacuum pump. When the vacuum pump operates, suction is created within the boundary of the suction mat and the excess of water is sucked from the concrete through the fine wire gauge or muslin cloth. At least one face of the concrete caused by loss of water must be vibrated.

The vacuum processing can be carried out either form the top surface or from the side surface. There will be only nominal difference in the efficiency of top processing or side processing. It has been seen that the size of the mat should not be less than 90 cm x 60 cm. smaller mat was not found to be effective.

Rate of Extraction of Water

The rate of extraction of water is dependent upon the workability of mix , maximum size of aggregate, proportion of fines and aggregate cement ratio. In general, the following general tendencies are observed:

(a) The amount of water which may be withdrawn is governed by the initial workability or the amount of free water. A great reduction in the water/cement ratio can, therefore, be obtained with higher initial water/cement ratio.

(b) If the initial water / cement ratio is kept the same the amount of water which can be extracted is increased by increasing the maximum aggregate size or reducing the amount of fines in the mix.

(c) Although the depression of the water/cement ratio is less, the lower the initial water/cement ratio, the final water / cement ratio is also less, the lower the initial value.

(d) The reduction in the water / cement ratio is very slightly less with mixes leaner than 6 to 1, but little advantage is gained with mixes richer than this

(e) The greater the depth of concrete processed the smaller is the depression of the average water/cement ratio.

(f) The ability of the concrete to stand up immediately after processing is improved if a fair amount of fine material is present, if the aggregate size is restricted to 19 mm and if a continuous grading is employed.

(g) Little advantage is gained by prolonging the period of treatment beyond 15 to 20 minutes and a period of 30 minutes is the maximum that should be used. It is found that there is a general tendency for the mix to be richer in cement near the processing face. This may be due to the fact that along with water, some cement gets sucked and deposited near the surface. It is also found that the water/cement ratio near the surface will be lower in value, anything from 0.16 to 0.13, than the original water /cement ratio. Because of the above reasons the vacuum processed concrete will not be of uniform strength.

The simultaneous vibrations or the subsequent vibrations will reduce this shortcoming to some extent and also increase the strength of the concrete. If vibration is not done, the continuous capillary channels may not get disturbed and the strength would not be improved in relation to decreased water/cement ratio. Table 12.15 shows the comparisons of strength of processed and unprocessed cubes.

Epoxy injection

Resin injection is based to repair concrete that is cracked or delaminated and to seal cracks in concrete to water leakage. Two basic types of resin and injection techniques are used to repair concrete; epoxy resins and polyurethane resins. Epoxy resins cure to form solids with high strength and relatively high module of elasticity.

These materials bond readily to concrete and are capable, when properly applied, of resorting the original structural strength to cracked concrete. The high modules of elasticity causes epoxy resin systems to be unsuitable for re-bonding cracked concrete that will undergo subsequent movement.

The epoxies, however, do not cure very quickly, particularly at low temperatures, and using them to stop large flows of water may not be practical. Cracks to be injected with epoxy resins should be between 0.005 inch and 0.25 inch in width.

It is difficult or impossible to inject resin into cracks less than 0.005 inch in width, while it is very difficult to retain injected epoxy resin in cracks greater than 0.25 inch in width, although high viscosity epoxies have been used with some success Epoxy resins cure to form relatively brittle materials with bond strengths exceeding the shear or tensile strength of the concrete.

If these materials are used to rebound cracked concrete that is subsequently exposed to loads exceeding the tensile or shear strength of the concrete, if should be accepted that the cracks will recur adjacent to the epoxy bond line. In other words, epoxy resin should not be used to rebond working" cracks.

Epoxy resins will bond with varying degrees of success to wet concrete, and there are a number of special techniques that have been developed and used to rebond and seal water leaking cracks with epoxy resins. These special techniques and procedures are highly technical and, in most cases are proprietary in nature.

Polyurethane resins are used to seal and eliminate or reduce water leakage from concrete cracks and joints. They can also be injected into cracks that experience some small degree of movement. Such systems, with the exception of the two-part solid polyurethanes, have relatively low strength sand should not be used to structurally re-bond cracked concrete.

Cracks to be injected with polyurethane resin should not be less than 0.005 inch in width. No upper limit on crack width has been established for the polyurethane resins at the time this is being written.

Polyurethane resins are available with substantial variation in their physical properties. Some of the polyurethanes cure into flexible foams.

Other polyurethane systems cure to semi-flexible, high-density solids that can be used to re-bond concrete cracks subject to movement.

Most of the foaming polyurethane resins require some form of water to initiate the curing reaction and are, thus, a natural selection for use in repairing concrete exposed to water or in wet environments.

At the time this is written, there are no standard specifications for polyurethane resins equivalent to the standard specification for Epoxy-Resin-Base Bonding Systems for Concrete. ASTM Designation C-881.

Shoring and underpinning

The arrangement employed to prevent a damaged structure, due to either foundation settlement or other reasons from collapse, is called shoring. It is also used for providing temporary support to a structure which is being remodeled.

The shores are of types:

Racking Shores : In this type, notches are cut in the walls of the building and inclined posts are property, while demolishing the building, are called horizontal or flying shores.

Horizontal of Flying Shores : The shores, which are employed to support the walls of adjoining property while demolishing the building are called horizontal or flying shores.

Vertical Dead Shores : The vertical shores used to support walls temporally are called vertical or Dead shores.

Underpinning

The operation of providing new permanent foundation is known as underpinning The under pining may be done by the following methods.

Pit Underpinning

In this method, a pit is dug to expose the foundation to b remodeled & the old foundation is either removed completely or strengthened suitably.

Pier Underpinning

In this method of underpinning, piers under foundations of structures are installed, filled with concrete and wedged up to transfer the load to a new pier. This method is most suitable in dry ground. In pier underpinning, proper care must be taken to prevent loss of ground installing the sheeting, otherwise the building structure mar sink.

The least size of the underpinning pits to provide working place, for workers is 1m x 1.3m. The pits are sunk to a stratum strong enough.

In this method piles are jacked into the ground with case for underpinning building, where underlying ground has water bearing strata.

2. Briefly explain the different fibre reinforced polymers used in concrete strengthening.

Fibre Reinforced Polymer (FRP) composites comprise of fibres of high tensile strength within a polymer matrix such as epoxy, vinylester or polyester thermosetting plastic, but most commonly epoxy resins. The polymer matrix, the original plastic which is usually stiff but relatively weak, is mixed with a reinforcing material of high tensile capacity to yield a final product which has the desired material or mechanical properties, i.e. large mechanical strength and elasticity. The fibres are usually made of carbon, glass, aramid, or rarely basalt, although other fibres such as paper or wood or asbestos have been used in the past.

FRP composites have evolved during the last 2-3 decades from being special materials used only in niche applications, to common engineering materials used in a diverse range of applications. FRP materials have a very high strength to weight ratio, and possess good fatigue, impact and compression properties. They also demonstrate impressive electrical properties and a high grade environmental resistance and durability, along with good thermal insulation, structural integrity, UV radiation stability and resistance to chemicals and corrosives. A key factor driving the increased number of applications of composites over the recent years is the significant drop in their price, as well as the development of new advanced forms of FRP materials, which include high performance resin systems and new styles of reinforcement, such as carbon nanotubes and nanoparticles.

FRP COMPOSITE MATERIALS

The properties of the composite materials are mainly determined by the mechanical properties of the fibres. The FRP systems are divided into carbon (CFRP), glass (GFRP), aramid (AFRP), and basalt (BFRP) systems [Triantafyllou 2004].

Carbon fibre reinforced polymers (CFRP). Carbon fibre reinforced polymers have the best mechanical properties amongst other FRP composites, and have the more favourable price to properties ratio. The carbon fibres have high strength and higher modulus of elasticity with respect to the other fibre materials, which make it more appropriate for the shear strengthening of RC members. As a result, they are the most widely used FRP systems, and all the main FRP providers offer a large variety of carbon-based sheets and laminates, in terms of size and weight.

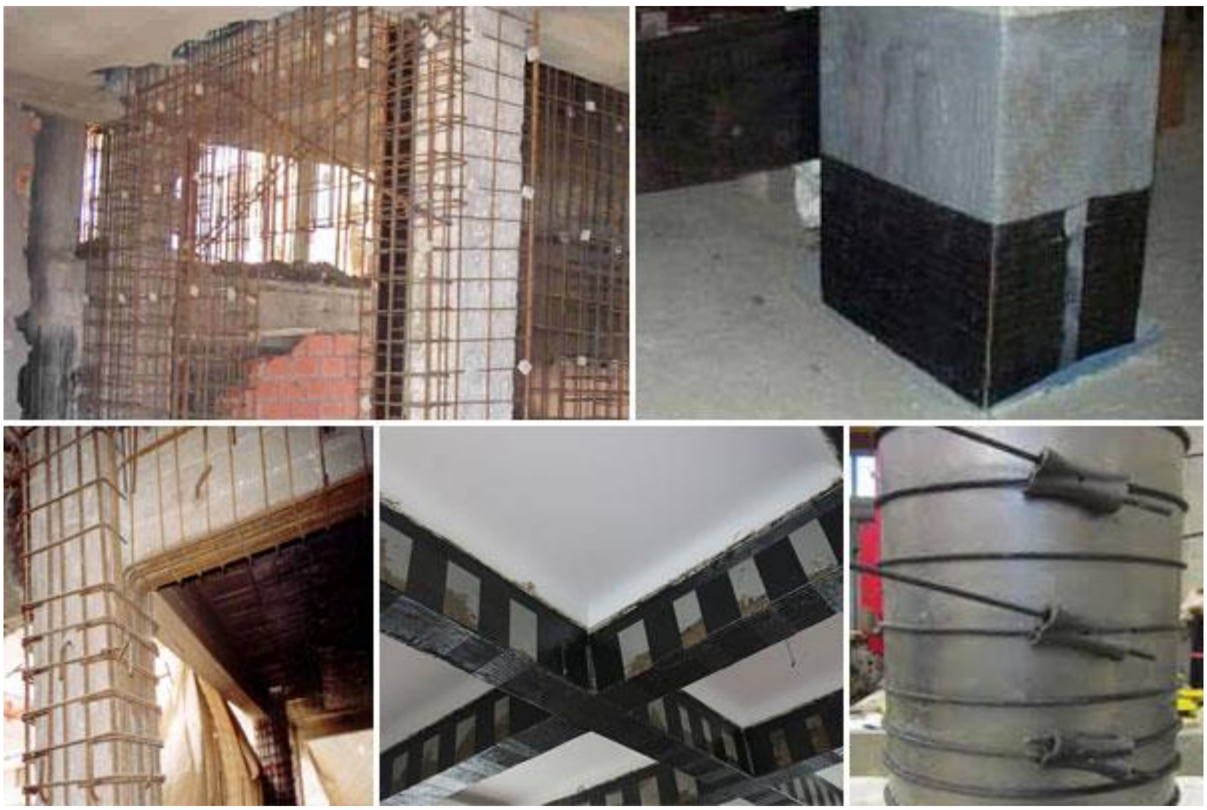
Glass fibre reinforced polymers (GFRP). Glass fibres have relatively lower cost with respect to the other types of FRPs, and they are the second (after carbon) most commonly used material in the construction industry. They come in three different types: (i) type E, which is the most common type. It has relatively low strength and modulus of elasticity, and its main drawbacks are that it has low humidity and alkaline resistance, (ii) type AR with increased alkaline resistance, but low strength and elasticity, and (iii) type S with high strength and elasticity modulus. Glass is more suitable for increasing the confinement of RC members, and it can also be used for flexural enhancement. Because of its low modulus, glass is seldom used for the shear capacity increase. The GFRP rebars are the most popular among other FRP rebar types, due to the combination of relatively low cost with environmental resistance.

Aramid fibre reinforced polymers (AFRP). These fibres have high static and impact strengths, which is why they are often used for the wrapping of bridge piers, where there is high danger of car crashes. Nevertheless, their use is limited by reduced long-term strength (stress rupture) as well as high sensitivity to UV radiation. Another drawback of aramid fibres is that they are difficult to cut and process.

Basalt fibre reinforced polymers (BFRP). Such fibres have excellent resistance to high temperatures possess high tensile strength, as well as good durability. Other advantages are high resistance to acids, superior electro-magnetic properties, resistance to corrosion, resistance to radiation and UV light and good resistance to vibration [Gudonis et al. 2013]. All the same, basalt FRPs are seldom used in practical applications. In terms of mechanical properties and production complexity, basalt (BFRP) and aramid (AFRP) bars are somewhere in the middle, but they are seldom used in practice.

3. What is meant by jacketing? Briefly discuss the different jacketing techniques.

Jacketing is a technique used to increase the strength of existing structural members (e.g. Columns, Beams etc.) by providing a "Jacket" of additional material around the existing member. This additional material can be of several types e.g. concrete, steel or FRP etc.



Jacketing is a method of structural retrofitting and strengthening It is used to increase bearing load capacity following a modification of the structural design or to restore structural design integrity due to a failure in the structural member. This technique is used on vertical surfaces such as walls, columns and other combinations such as beam sides and bottoms. It consists of added concrete with longitudinal and transverse reinforcement around the existing column. Jacketing is the process whereby a section of an existing structural member is restored to original dimensions or increased in size by encasement using suitable materials. A steel reinforcement cage or composite material wrap can be constructed around the damaged section onto which shotcrete or cast-in-place concrete is placed.

Jacketing is particularly used for the repair of deteriorated columns, piers, and piles and may easily be employed in underwater applications. The method is applicable for protecting concrete, steel, and timber sections against further deterioration and for strengthening. Jacketing improves axial and shear strength of columns and a major strengthening of the foundation may be avoided.

When is jacketing needed?

Jacketing is the process of strengthening weak RCC columns which have deteriorated over some time due to adverse atmospheric conditions or due to poor maintenance of the structure. Other reasons during the construction phase include design errors, deficient concrete productions, bad execution process. During the service life, the need may arise due to an earthquake; an accident, such as collisions, fire, explosions; situations involving changes in the structure functionality; the development of more demanding code requirements**.**

- The load carried by the column is increased.
- When there is an error in design.
- Deterioration of column due to weathering action.
- Dilapidation of columns.
- Heavy damage due to other causes like earthquake and fire

Advantages of jacketing

- It increases the seismic capacity of columns.
- Amount of work is less as foundation strengthening is not required.
- It increases the shear strength of the column.
- It also increases the confinement of concrete in circular columns.
- Does not increase the significant weight of the column and also saves construction time (curing).

Different types of jacketing

Reinforced concrete jacketing

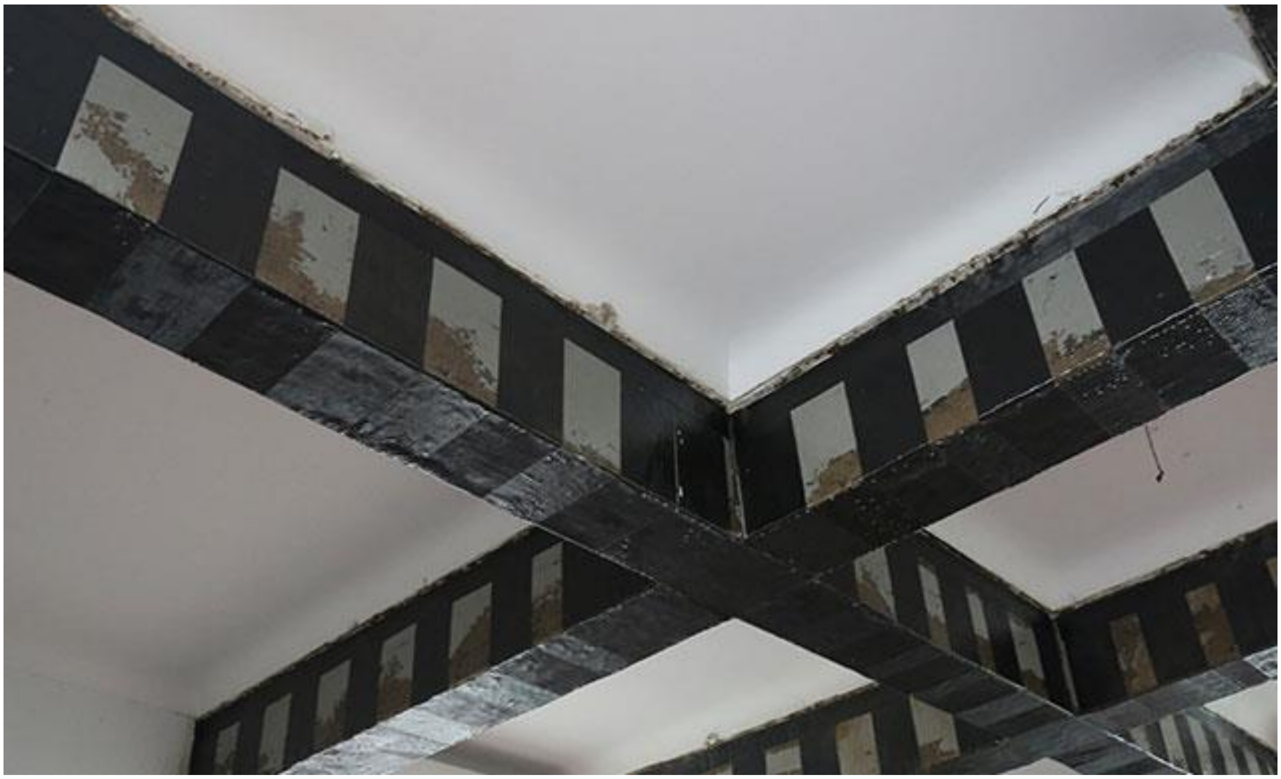
The strengthening of reinforced concrete members is a task that should be carried out by a structural engineer according to calculations. Here only a few suggestions are included to illustrate how the strengthening could be done. RC columns can best be strengthened by jacketing, and by providing additional cage of longitudinal and lateral tie reinforcement around the columns and casting a concrete ring. Jacketing a reinforced concrete beam can also be done in the above manner. For holding the stirrup in this case, holes will have to be drilled through the slab.

Steel jacketing

Steel jacketing is also an effective method to increase basic strength capacity. Steel jacketing not only provides enough confinement but also prevents deterioration of shell concrete, which is the main reason for bond failure and buckling of longitudinal bars. Steel jacketing refers to encasing the section with steel plates and filling the gap with non-shrink grout. It is a very effective method to remedy the deficiencies such as inadequate shear strength and inadequate splices of longitudinal bars at critical locations. But, it may be costly and its fire resistance has to be addressed. In practice, the most commonly used strengthening technique is by steel strips and angles. Steel jacketing helps to restore the strength, ductility, and energy absorption capacity of columns thus it seems to be effective in retrofitting columns. And also the steel jacket helps to increase the flexural strength and ductile behavior of the lap-spliced column thus increasing the lateral performance of columns

Fiber Reinforced Polymer (FRP) jacketing

One of the most commonly used methods for retrofitting is Fiber Reinforced Polymer (FRP) jacketing. FRP is widely used for its properties such as high strength to weight ratio, stiffness, good impact properties, high resistance to corrosion in harsh environmental and chemical condition, and also it causes only a minimum alteration to the geometry of structural elements than other methods FRP is used to strengthen the corroded rectangular columns considering different levels of corrosion and various volumetric ratios and the test results indicate that shear resistance of FRP and column increases with the increase in volumetric ratio and decreases with increase in different levels of corrosion. Shrinkage is one of the factors responsible for the formation of cracks in structural elements like beams and slab. To reduce the shrinkage hybrid fiber-reinforced polymer (FRP) reinforced shrinkage compensating concrete is used.

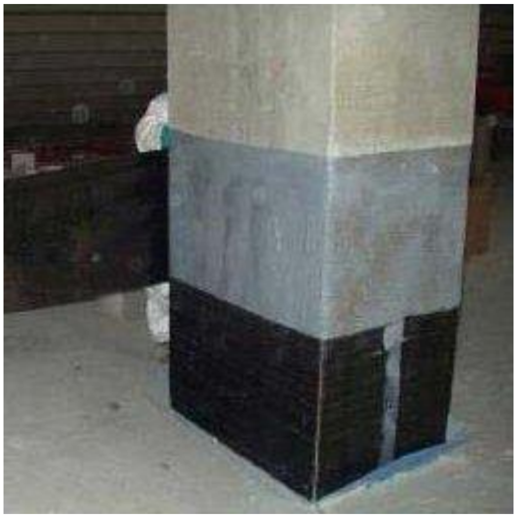


Glass Fibre Reinforced Polymer Jacketing

The application of composite materials for jacketing has been developed in strengthening and retrofitting of concrete structures through recent years so that many concrete structures would be strengthened by these materials. One of these applications is Glass Fibre Reinforced Polymer (GFRP) material used in strengthening and retrofitting of reinforced concrete columns. The design of glass-fiber-reinforced contains basic properties under tensile, compressive, bending and shear forces, coupled with estimates of behavior under secondary loading effects such as creep, thermal response and moisture movement. Glass fiber-reinforced concrete consists of high-strength, alkali-resistant glass fiber embedded in a concrete matrix. In this form, both fibers and matrix retain their physical and chemical identities, while offering a synergistic combination of properties that cannot be achieved with either of the components acting alone. In general, fibers are the principal loadcarrying members, while the surrounding matrix keeps them in the desired locations and orientation, acting as a load transfer medium between the fibers and protecting them from environmental damage. Glass fibers can be incorporated into a matrix either in continuous or discontinuous lengths.

Near-Surface Mounted (NSM) Fiber-Reinforced Polymer (FRP) Jacketing

In the NSM method, grooves are cut into the cover concrete, and FRP bars are placed in the grooves and bonded using an appropriate filler, such as epoxy paste or cement grout. NSM FRP bars are usually used in the longitudinal direction to enhance the flexural strength of the column. Mostly, the NSM method is used in conjunction with externally bonded FRP jacketing, resulting in a hybrid jacketing.



Hybrid Jacketing

Hybrid jacketing involves a combination of two or more different strengthening methods/materials for enhancing the seismic performance of a column and, thus, benefits from the advantages of both methods. This section summarizes the experimental studies utilizing the hybrid jacketing approach for the strengthening and repair of RC columns.

Shape Memory Alloy (SMA) Wire Jacketing

Shape memory alloys, that are characterized by their superelasticity, durability and shape memory effect have been considered for the strengthening of structural elements by different researchers. Moreover, SMA alloys are considered a more viable solution to FRP retrofitting due to the advantages such as no need for adhesive, easy installation and no danger of peel off.

Conclusion

Concrete Jacketing is pivotal for strengthening 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 is 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.

4. What does guniting and shotcreting mean? Describe its advantages in detail.

Gunite or Shotcrete

Gunite can be defined as mortar conveyed through a hose and pneumatically projected at a high velocity on to a surface. Recently the method has been further developed by the introduction of small sized coarse aggregate into the mix deposited to obtain considerably greater thickness in one operation and also to make the process economical by reducing the cement content.

Normally fresh material with zero slumps can support itself without sagging or peeling off. The force of the jet impacting on the surface compact the material. Sometimes use of set accelerators to assist overhead placing is practiced. The newly developed ‘Redi-set cement” can also be used for shotcreting process.

There is not much difference guniting and shotcreting. Gunite was first used in the early1900 and this process is mostly used of pneumatically application of mortar of less thickness, whereas shotcrete is a recent development on the similar principal of guniting for achieving greater thickness with small coarse aggregates.

There are two different processes in use, namely the ‘Wet-mix” process and the ‘dry-mix” process. They dry mix process is more successful and generally used.

Dry-mix process

The dry mix process consists of a number of stages and calls for some specialized plant. Atypical plant set-up is shown in Fig

The stage involved in the dry mix process is given below:

(a) Cement and sand are thoroughly mixed.

(b) The cement/sand mixture is fed into a special air-pressurized mechanical feeder termed as “gun”.

(c) The mixture is metered into the delivery hose by a feed wheel or distributor within the gun.

(d) This material is carried by compressed air through the delivery hose to a special nozzle. The nozzle is fitted inside with a perforated manifold through which water is sprayed under pressure and intimately mixed with the sand/cement jet.

(e) The wet mortar is jetted from the nozzle at high velocity onto the surface to be gunited.

The Wet-mix Process

In the Wet-mix process the concrete is mixed with water as for ordinary concrete before conveying through the delivery pipe line to the nozzle, at which point it is jetted by compressed air, onto the work in the same way, as that of dry mix process.

The wet-mix process has been generally discarded in favours of the dry-mix-process, owing to the greater success of the latter.

The dry-mix methods make use of high velocity or low velocity system. The high velocity gunite is produced by using a small nozzle and a high air pressure to produce a high nozzle velocity of about 90 to 120 metres per second. This results in exceptional good compaction. The lower velocity gunite is produced using large diameter hose for large for large output. The compunction will not be very high.

Advantages of Wet and Dry process

Some of the advantages and disadvantages of the wet and dry processes is discussed below. Although it is possible to obtain more accurate control of the water/cement ratio with the wet-process the fact that this ratio can be kept very low with the dry process largely overcomes the objection of the lack of accurate control.

The difficulty of pumping light-weight aggregate concrete makes dry process more suitable when this type of aggregate is used. The dry process on the other hand, is very sensitive to the water-content of the sand, too wet a sand causes difficulties through blockade of the delivery pipeline, a difficulty which does not arise with the wet process.

The lower water/cement ratio obtained with the dry process probably accounts for the lesser creep and greater durability of concrete produced in this way compared with concrete deposited by the wet process, but air-entraining agents can be use to improve the durability of concrete deposited by the latter means. Admixtures generally can be used more easily with the wet process except for accelerators.

Pockets of lean mix and of rebound can occur with the dry process. It is necessary for the nozzelman to have an area where he can dump unsatisfactory shotcrete obtained when he is adjusting the water supply or when he is having trouble with the equipment.

These troubles and the dust hazard are less with the wet process, but wet process does not normally give such a dense concrete as the dry process. Work can be continued in more windly weather with the wet process than with the dry process. Owing to the high capacities obtainable with concrete pumps, a higher rate of laying of concrete can probably be achieved in the wet process than with the dry process.

5. Describe external bonding technique (EBT) and near surface mounting technique (NSM) in detail.

Near surface mounted reinforcement

The technique of near-surface mounted reinforcement for strengthening concrete structures is currently being developed as an alternative to externally bonded fibre composite materials. The process involves cutting a series of shallow grooves in the concrete surface in the required direction. (The depth of the groove must obviously be less than the cover so that the existing reinforcement is not damaged.) The grooves are partially filled with epoxy mortar into which pultruded carbon fibre composite rods or strips are pressed. The remainder of the groove is then filled with epoxy mortar and the surface levelled. The approach can be used to increase the flexural (bending) of beams and slabs, or the shear capacity of beams. It can also be used for strengthening concrete masonry walls.

As the fibre composite material is embedded in the concrete, it is less susceptible to damage, for example by fire or vandalism, than material bonded to the surface. It is obviously very appropriate for strengthening the top surfaces of slabs, where externally bonded fibre composites would require a protective layer; damage may be caused to the composite if it is necessary to remove the protective layer at a later date. A further potential advantage of the technique over the use of externally bonded fibre composite is that no preparation of the concrete surface is required. Clearly one limitation on the technique is the need to have sufficient cover to the existing reinforcement to allow the grooves to be cut without the risk of damaging the steel.

EXTERNAL BONDING tECHNIQUE

The first application of FRP strengthening was made to reinforce the concrete beams. The beams are load bearing structural elements that are designed to carry both vertical gravity loads and horizontal loads due to seismic or wind. The structurally deficient beams fail during such events. There are mainly two types of failure of beams i.e., flexural and shear.

Hence, the strengthening of such beams is needed in flexure or shear or both zones and the use of external FRP strengthening to beams may be classified as:

Flexural strengthening

Shear strengthening

Flexural strengthening

Beams are strengthened in flexure through the use of FRP composites bonded to their tension zone using epoxy. The direction of fibers is parallel to that of high tensile stresses. Both prefabricated FRP strips, as well as sheets are applied.

Shear strengthening

The shear failure of an RC beam is distinctly different from the flexural failure. The flexural failure of a beam is ductile in nature, whereas shear failure is brittle and catastrophic. When the RC beam is deficient in shear, or when its shear capacity is less than the flexural capacity after flexural strengthening, shear strengthening must be considered. Both FRP composite plates and sheets can be used in shear zone to enhance the capacity of beam, but the latter are more popular because of their flexible nature and ease of handling and applications. There are various FRP bonding schemes which can be applied to increase the shear resistance of RC beams. These include:-

Bonding FRP to the sides of the beam only,

Bonding FRP U-jackets covering both the sides and the tension face, and
Wrapping FRP around the whole cross section of the beam.

FRPs are strong only in the directions of fibers. The fiber directions in FRP composites may be unidirectional, bi-directional or multi-directional. The use of fibers in two directions can be beneficial with respect to shear resistance even if strengthening for reversed loading is not required, except for unlikely case in which one of the fiber directions is exactly parallel to the shear cracks.

Modes of failure of FRP strengthened beams are:

Fiber failure in the FRP

It occurs when the tensile stress in the fibers exceeds the tensile strength. It is characterized by a rapid progressive fiber failure in the composite, particularly for sheets, but the failure is brittle in most of the cases. The orientation of the fibers with respect to the principal strain in concrete affects the ductility of the composite.

Bond failure

Bond failure is governed by the properties of the weaker materials in contact, i.e. concrete and adhesive. When the shear strength of one of these exceeds the force then transfer cannot be ensured anymore and a slip is produced. The deboning can take place in the concrete, between the concrete and the adhesive, in the adhesive, between the adhesive and the fibers. The use of side- bonded FRP sheets enhance the shear capacity of the flange beam, but strength of FRP sheets in fullest extent may not be utilized due to the bond failure between the FRP and the concrete. U-jacketing is currently the most popular shear strengthening solution due to its high practicality, but it is limited by end peeling of the U-jacket legs. These drawbacks have opened up a new area of research on development of anchorage system.