Gujarat University

TECHNICAL SPECIFICATIONS

Additional Items

Tender No: GU/ESTATE/CC/2023-24/03

Tender Document
Of
Renovation, Repair & Refurbishment of Convention Centre & Exhibition hall at Gujarat University, Ahmedabad.

A. Repairing Structural Cracks with injecting cement slurry grouting in R.C.C.

- **Technical Specification**

Providing and injecting cement slurry grouting by fixing 10 to 20 mm dia. suitable nozzle of suitable length, over the surface of PCC/RCC/ beam/ etc and along the construction joint line, cracks, wherever required. Fixing of nozzle shall be in the required portion and the Nozzles shall be fixed with suitable size holes preferably by using repercussive hammer drill (electrically operated) including neat cement slurry admixed with water. Soluble non - shrink based chemical shall be injected through the network of nozzles with low pressure grout pumps (PDP) at a pressure of about 2.0 Kg /cm2, preparing cement slurry by mixing cement with non-shrink @ 500 gms/50 kg bag of cement and water, ensuring that Water : Cement ratio does not exceed 2 (by weight). The viscosity of the resultant solution water/cement/non-shrink should not be more than 1.2 centipoises. Plasticizing agent shall be added wherever required. The grouting shall be started at very low pressure and increased gradually to a required pressure. The grouting shall be continued till the hole refuses to take any further grout, even at an increased pressure. Applied pressure shall not be more than the strength of the PCC/RCC/brick masonry. After completion of grouting operation, the nozzles shall be sealed properly to the satisfaction of the Engineer-in-Charge. Quoted rate shall be inclusive of all government tax.

Applications of Cement Grouting for Cracks

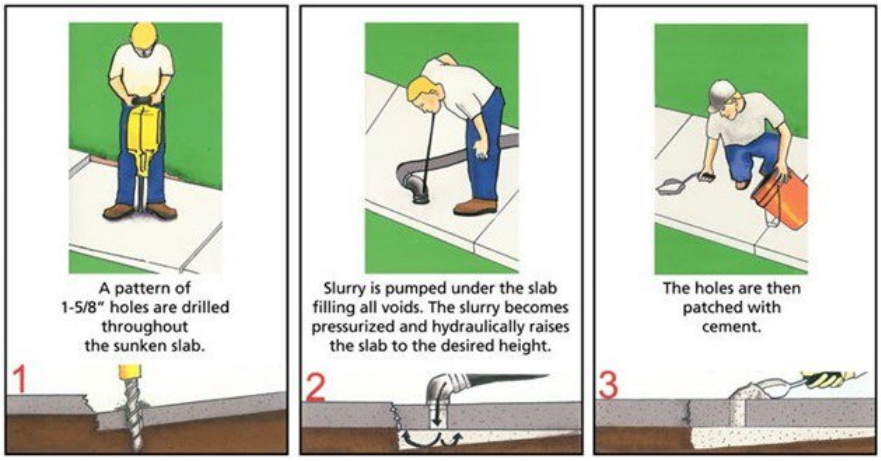
- When cracks are dormant
- Cracks are active but cause of cracking has been determined and remedial action has been taken.
- When honeycombing is present in concrete structures.
- When masonry is hollow.
- When deep leached mortar joints are present.

Materials Proportion and Pressure of Grouting

Ordinary Portland cement to IS:269, sand and water are required. Admixtures to impart non-shrinkable properties and to improve flow ability of grout may be added. The method of using admixture may be as per the manufacturer's recommendations.

The water-cement ratio (by weight) for the grout should be 0.4 to 0.5, the lower ratio being used when crack width exceeds 0.5mm. In atypical mix proportion for grout, 20 litres of water to be mixed with 50 kg of cement along with 225 gms of non-shrink admixture, such as conbex 100 (of M/s Fosroc), should be used.

The grouting pressure should be 2 to 4 kg/cm^2



Equipment for Cement Grouting in Cracks

The equipment required for cement pressure grouting are:

i) Air compressor with a capacity of 3 to 4 cum/ per minute and with a pressure of 2 to 4 kg per sq.cm.

ii) Grout injecting machine or grouting pump with inlet and outlet valves and pressure gauges. It should be capable of injecting cement grout up to 4 kg/cm^2(Now up to 20 kg/cm^2 pumps are available).

iii) An air tight, pressure mixer chamber, with stirrer for proper mixing of the grout and keeping it in proper colloidal suspension during grouting.

iv) Flexible pressure hose pipes for transmitting grout from pressure chamber to ports embedded in the masonry.

v) Drilling equipment, pneumatic or electric, for drilling of holes up to 25mmdia.

vi) 12-20mm dia G.I. pipes with couplers, or lockable type PVC nozzles.

B. Repair of cracks in masonry wall by cement grouting:

Providing and executing injection/pressure grouting in cracks in the parent concrete by fixing PVC nipples at 150mm to 200mm distance or specified distance as per design and detailed specifications. Pressure grouting using polymer cement grout Cebex 100 of FOSROC make or equivalent of MC Bauchemie make as per detail specification shall be done at required pressure etc. complete as per specification and approvals, labour, tools, tackles, curing etc. complete as directed by EIC.

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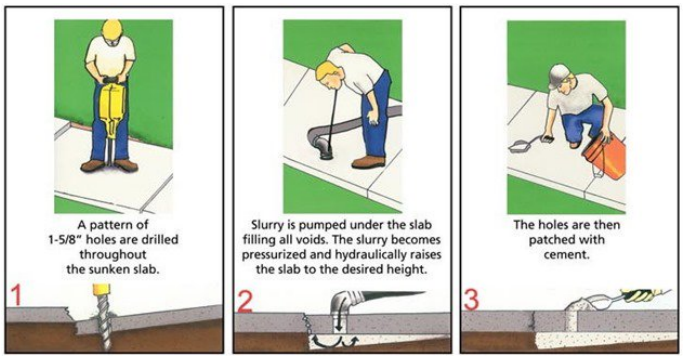

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v) Drilling equipment, pneumatic or electric, for drilling of holes upto 25mmdia.

VI) 12-20mm dia G.I. Pipes with couplers, or lockable type PVC nozzles.

c. Surface Preparation Work:

Surface preparation of concrete in RCC columns & beams by using wire brush, scrapper and finally using high pressure water jet to completely remove dust, debris, unwanted particles etc., complete including disposing the debris at designated locations outside the client premises. The rate shall include labour charges, cost of tools, cost of hire charges of high pressure water jet pump etc., to carry out the complete work.

Surface preparation is very important in all repair work, this should be carried out as per following procedure and using material as mentioned below:

Material: -

a) Electric light duty Chipper b) Hand Grinder

c) Wire brush d) Compressor

e) Electric Motor/water pump. f) Chisel & hammer.

Methodology: -

a. Chip off entire loose gunite, if any, from the concrete elements, such as columns, beams, external walls as per requirement for internal walls, slabs soffit and other structural elements of concrete to be repaired.

b. Chip off loose concrete from structural elements using chisel and hammer. Electrically operated chisel (Light duty Mechanical breaker / hammer) may be used. Debris should also be cleared once a day and area be kept clean. The loose concrete behind reinforcement, if any should be carefully removed. Corroded reinforcement should not be bent using chisel in order to create access. Only loose concrete should be taken out. This can be checked by lightly sounding the hammer over chipped area to ascertain any hollow sound on substrate.

c. Removal of corrosion scales on corroded reinforcement bars should be done manually using sharp tools such as chisel to scrape rust scales form the surface. Thereafter use wire brushes to clean the surface of rebar. Since the brush would not be able to access behind the bars use emery paper to clean exposed surface as well as areas with difficult access. Rotary wire brushes, shaft type rotary wire brushes can be used in place of hand held brushes. Exposed concrete surface is also to be cleaned with wire brush/ rotary wire brush to remove all the loose material, dust, dirt oil etc.

d. Finally clean the area with high pressure water jet of suitable pressure and allow to surface dry.

TYPICAL IMAGE OF SURFACE PREPARED RCC MEMBER

Mode of Measurement & Payment:

a. Surface area prepared for carrying out repair or treatment shall be measured in sq.mt for payment and shall be paid as per rates approved.

D. Rust Removal & Steel Protection.-

Cleaning as directed & specified all corrosion / rust / scales from reinforcement bars using rust remover Reebaklens RR of Fosroc make or Rust clean of BASF or equivalent of leaving to dry for 30 mins & washing surface with fresh water as required to exposed reinforcement bars complete as specified also providing & applying inhibition coats/system to exposed reinforcement bars after drying & also new bars after cleaning & removing scales and rust completely as specified. Two component inhibitor Concresive ZRI equivalent material of BASF make as approved by engineer shall be used as per manufacturers specification in two coats including all labour tools tackles, necessary surface preparation & necessary protection after & during repair work.

Cleaning of rust / scales/ corrosion from reinforcement bars should be carried out using rust remover, Reebakleens RR of Fosroc. The material to be applied to the rusted metal bar, using brush

and leaving it to dry for 30 mins. & washing surface with fresh water as required to exposed reinforcement bar including labour, tools, scaffolding, electricity, plant and machineries complete as per detail specification and as directed by Engineer-in-charge.

Corrosion protection of existing (OLD) reinforcement is very necessary in order to carryout durable repair of concrete structure, first the existing corrosion has to be removed and protection of rebar shall be done by using protective coating on rebar using specification as per relevant items.

Material:-

1) **Rust Removal:**

Reebakleens RR (Fosroc) or **Rustoclean** (BASF) : -

Reebakleens RR a cleaning agent is combination of acid based material, corrosion inhibitors and dispersing agents and is supplied as a clear green solution. with specific gratvity of 1.16 -

1.22 @ 25^0C or equivalent shall be used.

Methodology: -

a. All exposed old reinforcement shall be cleaned using rust remover Reebakleens RR of Fosroc or equivalent and then washed with clean water to remove traces of rust remover and finally allowed to dry.

Mode of Measurement & Payment:

a. Surface area prepared for carrying out repair or treatment shall be measured in sq.mt for payment and shall be paid as per rates approved.

E. Providing and fixing extra Reinforcement to corroded bars reinforcement with TMT bars in slab, Beam, Column, Raft, Foundation Footing at any height/level as per site design requirement having a minimum yield strength of 500 N/mm2. Anchor the steel rebar in sound concrete body up to desired depth by structural GRADE pure epoxy resin based cartridge filled and applied adhesive of approved make or equivalent including joggling, straightening, cutting, bending, placing in position, binding with G.I. wire of 18 gauge etc. complete in all respects. Additional reinforcement with adequate lap length & rings at required spacing shall be tied with existing reinforcement using binding wire or welded complete as per site requirement and directions of Engineer-InCharge. The rate shall be inclusive of scaffolding, propping, disposing-off all the debris etc. Complate as Directed by EIC (actual measurement shall be liable to pay)

Additional TMT Steel:

Providing & placing in position TMT bar reinforcement including cutting, bending, hooking and tying complete for solid slab as per detailed drawing or as directed by engineer-in-charge.

Purpose:-Providing additional reinforcement to the existing RCC Structure for the reinforcement lost due to corrosion or providing reinforcement in new RCC members and for Jacketing of Pier.

Materials and T&P: -HYSD reinforcement of minimum 415 grade, conforming to IS 1786, Galvanized

/ PVC coated binding wire, welding machine, generator and other incidental tools etc.

Procedure:

Step 1: The additional reinforcement shall be provided as directed by the Engineer's Representative.

Step 2: While carrying out the repairs to the existing RCC members, new rebar shall be fixed to the shear / rebar connectors (already driven into the concrete) by welding. The new rebar shall also be welded with the old rebar. In case, welding is not feasible, binding wire will be permitted, at the discretion of the Engineer's Representative. The new rebar shall be secured rigidly so that the vibration resulting from the deposition of repair material shall not impair or displace them. Minimum requirement of lap length of bars and Minimum cover to the reinforcement shall be as specified in I.S. 456.

Step 3: The rebar shall be provided for new RCC members as per the direction of the Engineer's representative.

Measurement:

The measurement of payment shall be in Kg for Payment.

F. Anchoring of new re-bars in the RCC Column, Beam, Slab, Flooring , Plinth Beam, Lintel Etc wherever required by using pure epoxy resin anchoring mortar (B18FOSROC/SIKA) with appropriate diameter of drilling of holes required for proper bonding into the concrete etc., complete. The rate shall include labour charges & hiring charges of drilling machine, cost of grouting compound etc., to carry out the complete work.

What is epoxy resin?

Epoxy is a type of chemical resin, which is the overall term for the different types of resin available. These include polyester resin, epoxy acrylate resin, vinylester resin and pure epoxy resin. All of these have different applications so it's important to make sure the resin you choose is the most appropriate for your application.

Epoxy resins are a group of prepolymers and polymers that contain epoxides, which react with the hardeners or curing agents added. The chemical process that takes place is referred to as curing, where the previously soft epoxy is converted into a stiff material. This hardened epoxy is incredibly waterproof, which is why it is widely used in the production of coatings and waterproofing.

At Anchor Fixings, we stock the Buffalo brand of resins, which are manufactured to a consistently high specification. Among this range are two epoxy resins, **Buffalo EPSF** (Epoxy Acrylate) and **Buffalo PUR** (Pure Epoxy).

Buffalo EPSF Epoxy Acrylate

Buffalo EPSF is an epoxy acrylate designed as a fast-curing resin fixing anchor for high loads and medium loads and is particularly advantageous for fixings in damp environments or with chemical exposure.

It can be used with all grades of **threaded rod** and rebar and is also suitable for bolts, posts, studs and **anchors**. EPSF is great for use in both dry and wet concrete applications, including those that are load bearing.

Buffalo PUR Pure Epoxy

Buffalo PUR is a pure epoxy fixing resin designed for high load bearing applications in concrete. This product is solvent free with virtually no odour, making it safe for use in contained areas. It's suitable for fixing rebar, threaded studs and anchors to install a massive variety of applications.

It can be used in any kind of solid substrate, for example, concrete, stone, granite, marble or brick. This resin has ETA, WRC and Fire Rated approvals.

Our Buffalo resins are independently tested and have the following certifications/approvals:

- **ETA ETAG 029 for Masonry Size M10**
- ITB approved AT-15-6835:2011 – ITB-974/W
- Tested by **Imperial College London**

What is epoxy resin used for?

Epoxy chemical resin is particularly useful for anchoring applications. It's used in areas where a higher strength fixing is required, or where a standard 'manual' fixing can't be used.

The **Epoxy Acrylate** and **Pure Epoxy** resins from the **Buffalo resin range** share some similar applications but also have features that lend themselves to particular applications.

Buffalo EPSF Epoxy Acrylate Applications:

- Used with all grades of threaded rod and rebar
- Suitable for bolts, posts, studs and anchors
- Used in concrete (both dry and wet), including load bearing applications
- European approval for use in masonry with nylon sleeves
- Good for confined spaces as it's styrene free
- Can be used indoors as well

Pure Epoxy Applications:

- Ideal for diamond drilled holes due to maximum adhesion to smooth surfaces
- Great for rebar usage due to slower gelling action
- Suitable for areas of high chemical exposure (e.g. swimming pools)
- Can be used in wet holes or underwater
- designed for deep embedment and large diameter holes due to its zero shrinkage and longer working times
- For highest ultimate loads
- Can be used in granite, marble etc.
- Good for confined spaces as it's styrene free

How does epoxy resin work?

Epoxy resins are combined with a hardener or curing agent in order to achieve polymerisation. It then reacts with the hardener or curing agent and cures into a very strong adhesive, which is why it's such a popular option for the building and construction industry. It's imperative that it is mixed thoroughly to ensure an even cure. Epoxy is thermosetting, which means that it cures depending on the surrounding temperature and once it is cured it cannot be uncured.

Tips for Epoxy Resin installation:

To gain maximum adhesion, ensure the drill hole is cleaned out and free from dust. This can be achieved using a blowout pump. If you have a number of **chemical anchors** to install, ensure you have all holes drilled, ready for applying resin. The resin hardens quickly in the nozzle, therefore it is important to install all anchors within as short a timescale as possible.

You can use our **chemical resin volume calculator** to determine how much you will need for your task.

What are the advantages of epoxy resin?

In the building, construction, manufacturing and engineering industries it's crucial to use an adhesive that is strong and reliable. It may need to handle heavy loads and maintain structural integrity, and you'll need a resin that has high bonding strength and resistance to external influences so that you prevent repairs being needed in the future. Epoxy resin has the highest durability of all the resins, with a longer shelf life, water resistance and chemical resistance.

Let's look at these properties in more detail:

1. Long shelf life
The resin component has a longer shelf life compared to other resins. This is because the hardener part in the resin is more active. Buffalo EPSF Epoxy Acrylate has a shelf life of 12 months from the manufacture date (Should be stored between +5˚C & +25˚C) and Buffalo PUR Pure Epoxy has a shelf life of 24 months from the manufacture date (Should be stored between +5˚C & +35˚C). This means you can keep the resin on hand for longer and you'll spend less time and money purchasing more.

2. Superior bonding properties

Epoxy resins can be a more expensive option compared to resin glue or other chemical resins; however, their excellent bonding capabilities surpass all other types of adhesive. The Buffalo PUR resin benefits from zero shrinkage, which maintains the ultimate bond strength.

3. Chemical resistant
Epoxy resins possess higher chemical resistance to common products like acids, alcohol, diesel and oils when compared to other types of resin, hence it's capable of withstanding extreme conditions.

4. Heat resistant
The strength of epoxy adhesives is degraded at temperatures above 350°F (177 °C), which means it has impressive heat resistance. This is a great benefit, as it's unlikely that the resin will have to encounter temperatures high enough to affect it. The result is a resin that's extremely long-lasting and durable.

5. Styrene free with low odour
The Buffalo epoxy resins are designed without styrene; hence they are low-odour and great for use in confined areas.

What are the gelling and curing times of epoxy resin?

Resins will react differently depending on the environment, and temperature is a key parameter for the gelling and curing times you can expect. The below examples for Buffalo EPSF and PUR are based on a temperature of 15°C.

Buffalo EPSF Epoxy Acrylate:
Gelling (working) time = 8 minutes
Minimum curing time = 60 minutes (dry concrete) and 120 minutes (wet concrete).

Buffalo PUR Pure Epoxy:
Gelling (working) time = 60 minutes
Minimum curing time = 300 minutes

The longer working time of Pure Epoxy makes it suitable for deeper and larger diameter fixings.

How strong is epoxy resin?
Epoxy resin provides one of the strongest bonds and is considered one of the strongest of all types of adhesives. Not only this, but it's also excellent at protecting materials such as metal, wood, steel, concrete, glass and some plastics. The impressive compressive, flexural and peel strength of epoxy resins makes them the ideal choice for the building and construction industry.

Compressive strength
This is the epoxy's ability to handle weight, which is especially important if the resin is going to be under heavy loads or used as a structural adhesive. High loads are possible with Buffalo EPSF, with a compressive strength of 45 N/mm2 and even more so with Buffalo PUR with an impressive compressive strength of 82.48 N/mm2 (test method EN ISO 604 / ASTM 695).

Flexural strength (bend strength)
This refers to the bending strength, which is the epoxy's ability to resist deformation under a load. Buffalo EPSF has a flexural strength of 15.4 N/mm2 (test method EN ISO 178 / ASTM 790) and Buffalo PUR has a flexural strength of 41.64 N/mm2 (test method EN ISO 178 / ASTM 795). The high flexural strength of epoxy resins means that once they are cured they will stay in place and will not warp or bend**.**

Peel Strength
This refers to the epoxy's adhesive bond strength ie. The material's ability to resist forces that can pull or peel it apart at a predetermined angle and rate. If an adhesive has very high peel strength they have a fantastic

bond, making it flexible enough to withstand cracking. High peel strength epoxides provide excellent physical strength properties, toughness and resistance to vibration, impact and shock.

F. Providing, Drilling and fixing of Shear Connector

Providing, Drilling and fixing of Shear Connector/Shear Stud of mimumum 450 mm long reinforcement at spacing as per drawings and detail to a depth of 75 mm to 100 mm. Fixing shear connectors using reinforcement rebar's in the drilled holes using polyester resin grout for RCC beams, slabs etc., as per the specifications including lead & lift, men, machinery & materials etc., complete as per the directions of engineer -in - charge. Note: Reinforcement steel is measured and paid separately.

Drilling holes into existing concrete structure for anchoring of new rebars with 10 mm dia shear connectors at 0.5 mtr c/c and fixing with pure epoxy resin based cartridge form chemical anchor material Masterflow 935 of BASF or approved equivalent product as per NF P 18-831 and NF P 18-

836. Drilling hole diameter: 14 mm, Drilling hole depth: 100 mm including cleaning, cutting, fabricating, chemicals, tools, plants, machineries, labour, electricity, etc. Complete as directed by Engineer-in-charge.

Material: -

a) Masterflow 935 (BASF make) or approved equivalent product as per NF P 18-831 and NF P

18-836

Master Flow 935 is a t w o -component, thixotropic, pure epoxy resin based chemical anchoring mortar. The product is specially designed for applications where heavy loads under critical conditions are to be fixed in concrete. Both components of Masterflow 935, packed in a single cartridge with separate compartments, are correctly mixed in the mixing nozzle during application.

Advantages: High adhesive power, Fast curing time – saves time and money, Easy to extrude, Styrene free formulation – low odour, High mechanical strengths, Can be used in diamond drilled holes, Applicable in slightly damp conditions, Can be used at high temperatures, Very low shrinkage, even on big diameters, For interior and exterior use, Specially suitable for technical applications, For fixing in solid material like concrete or brickwork

Methodology: -

Provision of Shear Connector

a) Wherever the reinforcement is reduced by corrosion for more than 20% of its original diameter, extra main steel is to be provided by welding a suitable dia. bar to existing steel or lapping it suitably (lap = 50 times the bar dia.). While doing this it may be necessary to take anchorage in sound concrete in case length beyond damaged portion is not adequate to provide lap and welding is not feasible. In such cases drill a slightly oversize (4 mm more in dia.) hole adjacent to existing main reinforcement, to a depth of 80-150 mm depending upon dia. of rebar and anchor new reinforcement using anchor resin grout of approved manufacturer.

b) New reinforcement can be clamped on soffit of damaged concrete slabs and anchored into supporting beams or at the end of the slab by making L shape bend.

c) For strengthening of columns and beam by jacketing methodology, new reinforcement shall be provided as per drawing and structural consultant recommendation by rebar grouting for Main steel. Stirrups and shear connector as per Item no. 5 & 6 above.

Mode of Measurement & Payment:

Measurement shall be taken in Numbers of shear connector fixed in Nos. and shall be paid as per rates approved.

G. **Providing and fixing seismic strap**

Providing and fixing seismic strap, made of G.I. Weld wire mesh of required size (25x25mm, 3mm nominal diameter Weld mesh, Hot dip galvanizing at the rate of 220 gm per Sqm (Heavy grade) as per IS code 4826, Table 1) on walls with the help of Steel Plate 200 x 75 x 6 mm thk with Minimum six numbers of M16 grade expansion bolts with walling material and Minimum six numbers of 100 mm long nails (Fe250) with Floor member of anchor bolts/bars/ binding wires etc. including cutting, bending and binding etc. complete as per direction of Engineer-in-Charge. Overlaps of 100mm shall be allowed in transverse direction. Minimum 10 mm cover on all side of the strap shall be given while Jacketing The same width shall be taken for measurement The Rate Shall Including of including, Stretching, joggling, straightening, cutting, bending, trimming ,placing in position, welding of wire mesh with old reinforcement/Shear Stud, Anchors, steel plates as per drawings and instruction, making of holes, jacketing , including Supply of necessary tools and tackles with taking necessary safety precaution scaffolding, PPE, all complete as per Instruction of Structure Engineer/ Engineer In Charge. If reinforcement need to place for certain section/geometry/are shall be paid separately

H. :Chip-off/Breaking, corrosion damaged /cracked/spalled concrete including plastering along the cracks on masonry wall , slab, projection or any other suspended/slopped structural slab carefully by low impact Hammer Breaker (electrically operated)/Manual Hammer Breaker without damaging the structure and make sure that the contaminated and loosen concrete are removed completely, including removing and stacking of all unserviceable material at earmarked dump yard at site, simultaneous transportation and disposal of debris outside the office premises at Local municipal dump yard. Then, exposing and cleaning the reinforcement thoroughly by light tapping / wire brushing and using strong emery paper and finally applying rust remover acetone and keep for 24 hours. Cleaning the reinforcement and the concrete surface thoroughly with potable water and make sure that there are no traces of rust on the surface of existing rebars and keeping the surface for drying. After Cleaning Installation of Wire mesh/Reinforcement as per site requirement or Instruction of Structure Engineer/Site Engineer. After Installation of Wire mesh/Additional Reinforcement application of mortar as per instruction by mix the base and hardener of the zinc rich epoxy resin mechanically using a slow speed heavy duty drilling machine fitted with mixing paddle. Apply the mixed materials with brush on the cleaned rebar in two coats with time interval of minimum 4 hours between each coat and allow it to dry for 24 hours till it dry complete as directed. Wet the concrete/Masonry Wall surface with potable water and make sure that the surface is kept moist so that the water cement ratio in the polymer modified mortar is maintained during the application. Repairing the surface after carrying out above operations by supplying and applying polymer modified mortar upto 20-40 mm thick in layers not exceeding 20 mm in a day in the proportion 1:5:15 (1 Polymer :5 cement : 15 Quartz Sand by volume) as approved by the Consultant followed by a smooth finish after applying (by brushing) polymer based jointing compound by mixing the polymer with cement in the ratio of 1:1 by weight to the prepared surface and each layer of plaster before applying the subsequent layer as per specification of manufacturer or as directed. The rate shall be for the work at all levels of floors including proper covering of the floors / windows/fixtures/furniture with tarpaulin or equivalent covering material, cleaning after repairs, curing as per standard etc. including

costs of all materials, labour charges, double scaffolding , Wiremesh Installation, cleaning the site, removing the debris out of premises etc. complete. Excluding of Cost of Wire mesh/Additional Reinforcement which will paid additional as per measurement (All measurement in Sq.mt in all floors Final and Net Measurement will be paid)

How Polymers Improve Mortar Properties

1. Strength and Durability
Time and again, it has been demonstrated that polymers improve tensile strength, flexural strength, impact and abrasion resistance, water resistance, and chemical resistance of polymer modified mortar in comparison to mortars without polymers. Added to that, polymers restrict the micro-crack propagation which improves the overall toughness of the mortar.

2. Workability
Polymers make mortar more fluid and easier to handle and apply. It acts as a water-reducer, eventually leading to a stronger mortar with fewer voids. Specific types of polymers extend the hydration period which increase working time. This is considerably advantageous in hot climates.

3. Adhesion
Due to the fact that Polymers act as an adhesive, it improves the adhesion of mortar to different surfaces like concrete, masonry, brick, wood, rigid polystyrene and polyurethane foam, glass, and metals. This property is specifically crucial in thin section overlay mortar applications and applications with excessive vibration and heavy traffic.

4. Cement Curing
Curing of mortar is one of the major factors that controls its strength. It is required to provide adequate water to have proper curing especially during the early stages of curing process; roughly the first five to seven days.

It has also been demonstrated that polymers improve mortar curing because it reduces the rate of water evaporation. This reduced rate of water evaporation is especially important in thin applications, where the surface area for evaporation is high, relative to the volume of the mortar.

Finally, since polymer modified mortar requires less water compared to ordinary mortar, it does not experience drying shrinkage as much as traditional mortar.

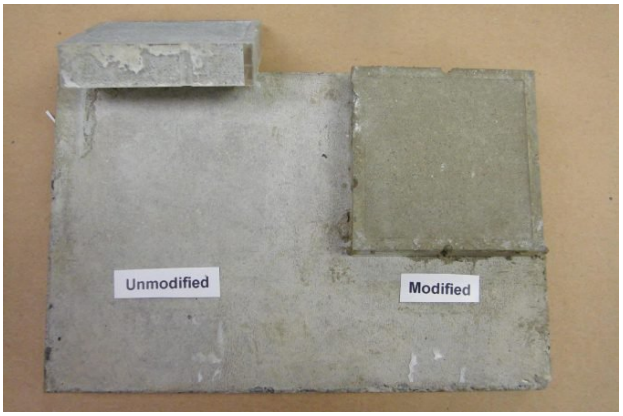

Fig. **1: Polymer Modified Mortar**

Types of Polymers
There are different types of polymers which are used to make polymer modified mortar :

1. Latex polymers

2. Redispersible dry polymers (such as ethylene vinyl acetate)

3. Water soluble polymers like polyvinyl alcohol

Applications

1. Grouting Walls and Floor Tiles
It is the most widely used application of polymer modified mortar. Reduced water and salt ingress makes polymer-modified mortar ideal for masonry exposed to weathering and other exterior conditions. Polymer-modified thinset mortar is designed to adhere tile to concrete and cement board substrates without needing to soak the tiles beforehand.

2. Patch and Repair
Polymer-modified mortars are widely used for repair purposes because of their minimized shrinkage and ability to bond with the densest surfaces. It is used for repairing cracks and delamination of concrete structure and cracks.

Fig. 2: Repair Cracks in Reinforced Concrete Beams using Polymer Modified Mortar

Fig. 3: Polymer Modified Mortar Used for Restoration of Piles

3. Waterproofing
Its application during the construction of basements, bulk water storage tanks, septic tanks, ship decks, roof decks, and concrete walls helps provide a strong resistance towards water and chemicals.

4. Flooring and Pavements
Polymer modified mortar can be utilized for commercial flooring overlay formulations, warehouses, factories, hospitals, stairways, and garages.

Fig. 4: Use of Polymer Modified Mortar for Installing Tiles

Mode of Measurement & Payment:

Surface area prepared for carrying out repair or treatment shall be measured in sq.mt for payment for thickness of average 60mm and shall be paid as per rates approved.

i. Epoxy thermoset Resin injection grout

Supplying and applying High molecular weight weight Super low viscous (3 to 5 cps) 0.56 Kg./Cm2 Epoxy thermoset Resin injection grout Monopol of Krishna Conchem or Conbextra EP10 of Fosroc or equivalent as approved by Consultant for Slab/Beam/ Column in appropriate proportion as per manufacturer's specifications into cracks/ honeycomb area of concrete including drilling of holes of 14mm- 16mm dia and depth of 75mm-100 mm in concrete, Fix PVC new nipples of 12 -14 mm using neat cement or M-Seal for proper anchorage. Injecting grout by electrically operated grouting machine/ manual pump at pressure of 1.0 to 2.0 Kg. /Cm2 until proper filling the voids and refuses the grout further in the nipple and subsequent cutting/removal of the nipple and sealing of the hole and groove after completion of grouting with cement/ epoxy mortar as directed by the Consultant including costs of all materials, labour charges etc complete.

Objectives

1. The structural improvement such as strength and ductility of concrete cube with a series of experiment.
2. The main aim of this study is to identify the characteristics strength of cube by epoxy injection and different grouting materials.
3. And restore the structural integrity and resistance to the concrete element

Scope :

1. To design a model cube with self-induced crack on it for Injection technique using the existing models available in the literature.
2. To identify various materials available for sealing the cracks in concrete structures.
3. To study the properties of different grouting materials and their behaviour under various circumstances.
4. To conduct an experimental study by injecting these self-in duced crack in cube model by various grouting material.
5. To summarize the effect of Epoxy grouting in the cracked structure and also compare other grouting materials.
6. When a structural repair is required, conditions that cause the crack must be corrected prior to proceeding with the epoxy injection.

2. MATERIALS

A. General:

The properties of different materials used namely cement, fine aggregate, coarse aggregate, Cement mortar and Epoxy resin were studied. As per IS 383-1970, Sieve analysis was done for fine aggregate, Coarse aggregate to test their suitability

D. Water: Casting and curing of specimens were done with the potable water that is available in the college campus.

E. Epoxy: Epoxy is known as polyepoxide, is a thermosetting polymer formed from reaction of an epoxide "resin" with polyamine" hardener". Epoxy is a co-polymer, means that it is formed from two different chemicals. These are referred to as the "resin" or "compound" and the "hardener" or "activator".

Sr. no.	Types of grouting material	Quantity (No.of cubes)

1	Normal testing cubes (without filling)	9
2	Epoxy grout	9
Total No of cubes		**18**

Epoxy resin is a kind of thermosetting (solid) resin. When main agent is blended with the hardener of appropriate ratio, after cross linkage for hardening, a network structure of three dimensional space is formed. Therefore, this product has equipped with a special physical property, mechanical property, and chemicals-resistant, etc

Properties of epoxy resin:

1. Viscosity.
2. Epoxy equivalent.
3. Oxyhdrogen equivalent.
4. Average molecular weight and its distribution.
5. Softening point.
6. Temperature of heat deformation after erosslinkage

3. METHODOLOGY

- Review of literature
- Preliminary test on cement, fine and coarse aggregates.
- Concrete mix design
- Casting of concrete specimen. (cube, cylinder, and prism)
- Test on harden concrete
- Comparison of results with controlled specimens
- Discussion
- Conclusion

4. SPECIMEN DETAILS

A Concrete mix is prepared with the proportions suggested such as 1:1.5:3 with water cement ratio 50% by mechanical mixer. A tested cube is prepared make sure that they are clean and greased or oiled thinly. Metal moulds should be sealed to their base plates to prevent loss of water. The Cubes are filled in three layers, tamping each layer with 25 strokes using a tamper, occasionally stir and scrape together the concrete remaining in the mixer to keep the materials from separating. Fill the moulds completely, smooth off the tops evenly, and clean up any concrete outside the cubes. Mark the specimen by a slip of paper on which is written the date and the specimen identification. The specimens are leaved in the curing room for 24 hours. After that open the moulds and immersed the concrete cubes in a water basin for 7,14 and 21 days. After Curing period, the specimens take out from the water and place it separately.

Compression Test

A. It is the most common test conducted on hardened concrete and an easy test to perform. Most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The tests were carried out on 150x150x150 mm size cube, as per IS 516-1959.

4. PREPARATION OF SPECIMEN

5. Before placing the concrete in the mould, its interior surface should be oiled. The concrete is filled into the mould in layers of approximately 5cm deep. Each layer is compacted either by hand or by vibration. For compaction by hand, the standard tamping rod should be used for 25 blows in each layer.

Curing of Specimen

After preparation of specimen, the specimen should be cured for 28 days in the curing tank.

Injection of the Specimen

After the curing of the cubes the injection of the specimen is to be conducted. Injection materials are epoxy, latex and cement mortar with Cebex 100.

J. Fiber Wrapping System

Strengthening structural elements with non-metallic composite fiber wrapping system comprise of uni-directional glass fibre sheet (900 GSM) and compatible saturant, by wet layup system including, as per following specification

1) Surface preparation: Grinding/ moulding concrete substrate, cleaning it with wire brush removing oil, laitance if present, rounding sharp edges to min 25 mm radius etc. complete.

2) Profiling: Applying compatible primer on prepared substrate, Filling the holes and uneven surface with thixotropic putty etc. Complete

3) Wrapping: Wrapping the fibre sheet to structural element at desired orientation using tamping roller to avoid any air voids etc. repeat the same procedure for multiple layer with the interval of 8 hrs

4) Sand pasting: Applying second coat of saturant after min. 12 hrs, rectify air voids if any paste the river sand on it to make surface rough to take any further finishes

(Mode of measurement: Per sq.mt of glass fibre sheet consumed and not surface area of application)

Materials

The materials and installation direction for this work shall be supplied by one of the following manufacturers.

1. Fyfe Co. LLC
2. Quake Wrap, Inc.
3. Sika Systems

Materials used to repair or patch portions of the concrete structural member, or to restore the concrete structural member to the section shown on the plans shall be as recommended by the manufacturer of the fiber reinforced system.

Materials shall be delivered to the project site in factory-sealed containers with the manufacturer's labels intact and legible with verification of date of manufacture and shelf life. Products shall be stored according the manufacturer's requirements and shall be protected from contact with moisture. All Materials supplied shall have a Type B certification in accordance with 916.

Submittals

The following items shall be submitted by the Contractor prior to beginning this work:

1. ASTM E84 flame and smoke test results. The minimum of a Class 1 rating for the system shall be provided.
2.Independent test report showing system environmental durability on the proposed composite to be used; including a minimum of 10,000 h resistance to salt water, alkali soil, and 100% humidity. Material shall maintain design properties as described herein.
3. Freeze-thaw resistance tests with a minimum of 20 cycles. Material shall maintain design properties as described herein.
4.Certification from the manufacturer of the system's material properties including previously completed ASTMD3039 test results of the proposed system.

5.Complete working drawings containing details of the number and thickness of layers, joint and end details and locations to satisfy project requirements.
6. Applicator project references from at least 10 previously completed projects using the proposed FRP system in the last two years.
7. The names of at least three individuals who have been certified and trained by the FRP system manufacturer and who will be on site during all phases of the project.
8. Written certification from the composite system manufacturer showing the names of at least three trained personnel who will be on the jobsite during all phases of the installation.
9. A list of at least two different qualified testing laboratories that can perform the required ASTM D3039 tests as per this specification.

The Contractor shall receive written approval of the plan and personnel prior to beginning work.

Construction Requirements

The portions of the concrete structural members to be repaired shall be cleaned. Deteriorated, delaminated, or otherwise unsound concrete and other deleterious substances shall be removed and the portions of the concrete structural members to be repaired shall be restored to their original cross sectional shape or to the shape shown on the plans prior to installing the fiber reinforced composite system.

The fibre reinforced composite system shall be field applied to the concrete areas shown on the plans or as directed by the Engineer.

This work shall be performed by an applicator with proven past experience applying the approved composite system for a minimum of 10 projects in the past two years. The applicator shall supply the names of at least three individuals who have been certified and trained by the FRP system manufacturer and who will be on site during all phases of the project. In accordance with 108.07, the Engineer will have the right to approve or reject the personnel qualifications as submitted. The Engineer may suspend the work if the Contractor substitutes unauthorized personnel for authorized personnel during construction.

The composite system applicator shall submit a written description of the proposed epoxy, including VOC levels, and a complete written description of the application procedures for review by the Engineer. The applicator shall be certified by the manufacturer and provide a quality control procedure in accordance with this specification.

The supply and installation of the composite system shall meet the performance criteria of this specification and as stated on the contract drawings

This work shall be completed per manufacturer requirements.

Field Quality Control Procedures

The application and testing of this work shall be done in accordance with the following field quality control procedures:

(a) Installers

Installers shall record batch numbers for fabric and epoxy used each day, and note locations of installation. The square footage of fabric and volume of epoxy used each day shall be measured and the complete report shall be submitted to the Engineer and the system manufacturer.

(b) Inspection

A manufacturer's representative shall periodically observe all aspects of preparation, mixing, and application of materials, including the following:

1. Material container label

2. Surface Preparation
3. Mixing of epoxy
4. Application of epoxy to the fibre
5. Application of composite system
6. Curing of composite material
7. Preparation and labelling of test samples.
8. Supervise all ASTM D4541 adhesion testing, if required.
9. Visual inspections and sounding of the installed composite.

The composite casing shall be completely inspected by the manufacturer's representative during and immediately following application of the composite. The Contractor shall monitor the mixing of all epoxy components for proper ratio and adherence to manufacturer's recommendations.

(c) Visual Inspection and Sounding of Installed Concrete

All installed areas shall be visually inspected by the manufacturer's representative. The installed composite shall completely adhere to the concrete substrate with no bubbles or voids. Any suspect areas shall be sounded with a ball peen hammer. A light tapping will indicate the presence of any voids behind the installed composite. All defects shall be reported to the Engineer and repaired as described below in this specification.

(d) Laboratory Testing

The lot number of fabric and resin used, and location of installation shall be recorded. A sample batch shall consist of two 12 in. by 12 in. samples of cured composite. A minimum of two sample batches shall be made daily. The two sample batches shall be taken at appropriate times during the day so as to ensure the maximum material deviance in the components of the composite. The testing laboratory shall pre-condition samples at 140ºF for 48 h before testing. Samples shall be taken, at random, at the Department's discretion.

Tested samples shall be tested per ASTM D3039. The 12 in. by 12 in. panel shall have five coupons, 3/4 in. by 9 in., removed and tested for their material properties in the longitudinal, primary fiber, direction. Tests shall conform to ASTM procedures and the manufacturer's published testing methods. Only pre-qualified testing laboratories shall be used.

Testing results shall be made available within three weeks of sample submission. The testing shall provide average values of the following:

1. Ultimate tensile strength
2. Tensile Modulus
3. Percent elongation

Fifteen percent of all sample batches shall be tested. If one 12 in. by 12 in. sample fails, specimens from the same sample shall be tested. If these specimens also fail, the other 12 in. by 12 in. from the same sample batch shall be tested. If this sample also fails, the remaining sample batch for that day shall be tested and appropriate remedial measures shall be taken, as described herein, to ensure integrity of the system from the failed sample batch. In addition, 25% of the remaining sample batches shall then be tested by the same criteria.

(e) Substrate Adhesion Testing

Direct tension adhesion testing of cored samples shall be conducted using the method described by ASTM D4541. A minimum of three tests shall be performed for each day of production or for each 500 sq ft of FRP application, whichever is less.

Pull-off tests shall be performed on a representative adjacent area to the area being strengthened. Tests shall be performed on each type of substrate or for each surface preparation technique used.

The prepared surface with one layer of the bonded FRP system shall be allowed to cure a minimum of 48 h before execution of the direct tension pull-off test. The locations of the pull-off tests shall be representative and on flat surfaces. If no adjacent areas exist, the tests shall be conducted on areas of the FRP system subjected to relatively low stress during service. The minimum acceptable value for any single tension test is 175 psi. The average of the three tests at each location shall not be less than 200 psi. Additional tests may be performed to qualify the work. The tension adhesion tests shall exhibit failure of the substrate indicated by a layer of concrete or masonry on the underside of the test puck following the test.

(f) Repairs

All defects, including bubbles, delaminations, and fabric tears, spanning more than 5% of the surface area, or as specified by the Engineer, shall be repaired. Two types of repairs shall be performed:

1. Small defects on the order of 3 in. diameter shall be injected or back filled with epoxy.
2. Large defects shall be repaired as required by this specification and by the manufacturer's specifications.

Small entrapped air pockets and voids naturally occur in mixed resin systems and do not require repair or treatment. Defect repair shall be provided by the manufacturer and shall be submitted to the Engineer for approval. Additional payment will not be made for repairs.

(g) Remedial Measures

In the event that material testing determines a sample batch to possess insufficient material properties, remedial measures shall be taken. If the tested composite system has material properties determined to be below the minimum specified values, additional layers shall be installed until the final composite thickness is increased by the same percentage as the deficiency of the material's elastic modulus. Additional payment will not be made for any required additional material.

Method of Measurement

Complete cleaning, removal of concrete, preparation of the structural member, patching of the structural member, and other incidentals and the fibre reinforced polymer concrete casing system will not be measured for payment.

K. Glass Fibre laminates

Applying procured glass fibre laminates (2.5 mm thick and 50 mm wide) with compatible structural adhesive including, as per following specification

1) Surface preparation: Grinding/moulding concrete substrate, cleaning it with wire brush removing oil, laitance if present, rounding sharp edges to min 25 mm radius etc. complete.

2) Profiling: Applying compatible primer on prepared substrate, Filling the holes and uneven surface with thixotropic putty etc. Complete

3) Wrapping: Wrapping the fibre sheet to structural element at desired orientation using tamping roller to avoid any air voids etc. repeat the same procedure for multiple layer with the interval of 8 hrs

4) Sand pasting: Applying second coat of saturate after min. 12 hrs, rectify air voids if any paste the river sand on it to make surface rough to take any further finishes

(Mode of measurement: Per running Mt. of 50 mm wide and 2.5 mm thick plate applied)

1.7. APPLICATION OF GFRP OVERLAYS FOR STRENGTHENING OF RC BEAMS

1.7.1. Fiber Reinforced Polymer (FRP)

Fiber reinforced polymer (FRP) composites are formed by embedding continuous Fibers in a resin matrix That binds the Fibers together.

1.7.2. Types of FRPs

Depending on the Fibers used, FRP composites are classified into three types: Glass FRP composites (GFRP), Carbon FRP composites (CFRP) and Aramid FRP composites (AFRP). Although FRP composites are expensive and more susceptible to physical damage than steel, they have become an attractive substitute for steel in strengthening systems for concrete structures due to their many advantages, high strength to weight ratio, corrosion resistance, High fatigue resistance, easy and reliable surface preparation.

1.7.3. FRP Composite

Fiber Reinforced Polymer composite is defined as a polymer (plastic) matrix, either thermo set or thermoplastic, that is reinforced (combined) with a fiber or other reinforcing material with a sufficient aspect ratio(length to thickness) to provide a discernable reinforcing function in one or more directions

1.7.4. GFRP Sheets

Application of GFRP overlays is the one of the simplex methods for wrapping the existing structures. GFRP has high strength ratio high stiffness to weight ratio, flexibility in design, non-corrosiveness, high ultimate strength and lower density.

1.8 ADVANTAGES AND LIMITATIONS OF GFRP OVERLAYS FOR

STRENGTHENING OF BEAMS/COLUMNS

1.8.1 Advantages

1. Low cost when compared to other FRPs
2. High Strength to weight ratio
3. Corrosion resistance

1.8.2. Disadvantages

1. The main disadvantage of externally strengthening structures with Composite materials is the risk of fire, Vandalism or accidental, damage, unless the strengthening is protected.
2. Compressive strength is lower than tensile strength.
3. The lack of experience of the techniques and suitably qualified staff to

1.10. GFRP WRAPPING PROCESS

While doing the wrapping process, first the beams were washed with acetone to remove the dust, dirt and were made clean. The surfaces of the beams were rubbed with paper to make the surface rough. Then wrapping of GFRP sheets on the surface of the beams were done. The wet lay up or hand layup technique will be adopted. Concrete beams strengthened with glass Fiber fabric were cured for 48 hours at room temperature before testing.

3.2. MATERIALS

3.2.1. Cement

Portland Pozzolona Cement (PPC)-53 grade was used for the investigation. It was tested for its physical properties in accordance with Indian Standard specifications.

3.2.2. Fine Aggregate

The sand used for experimental program was locally procured and conforming to zone II. The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm. It was tested as per Indian Standard Specification IS: 383-1970. The specific gravity coarse aggregate are 2.6

3.2.3. Coarse Aggregate

Locally available coarse aggregates were used in this work. Aggregates passing through 20mm sieve and retained on 16mm sieve were sieved and tested as per Indian Standard Specifications IS: 383-1970. The specific gravity coarse aggregate are 2.65

3.2.4. Water

The tap water available in the campus was tested for its suitability. Necessary properties such as pH value, chloride content, total hardness and total dissolved solids were evaluated.

3.2.5. Reinforcing Steel

HYSD bars of 8 mm ϕ were used as main reinforcement. 6 mm ϕ mild steel bars were used for shear reinforcement

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3.2.6. Fiber Reinforced Polymer (FRP)

Continuous fiber-reinforced materials with polymeric matrix (FRP) can be considered as composite, heterogeneous, and anisotropic materials with a prevalent linear elastic behaviour up to failure. They are widely used for strengthening of civil structures. There are many advantages of using FRPs: lightweight, good mechanical properties, corrosion-resistant, etc. Composites for structural strengthening are available in several geometries from laminates used for strengthening of members with regular surface to bidirectional fabrics easily adaptable to the shape of the member to be strengthened.

3.2.6.1. Glass fiber

Glass fibers are also available as thin sheets, called mats. A mat may be made of both long continuous and short fibers (e.g., discontinuous fibers with a typical length between 25 and 50 mm), randomly arranged and kept together by a chemical bond. The width of such mats is variable between 5 cm and 2 m, their density being roughly 0.5 kg/m2. Glass fibers typically have a Young modulus of elasticity (70 GPa for E-glass) lower than carbon or aramid fibers and their abrasion resistance is relatively poor; therefore, caution in their manipulation is required. In addition, they are prone to creep and have low fatigue strength. To enhance the bond between fibers and matrix, as well as to protect the fibers itself against alkaline agents and moisture, fibers undergo sizing treatments acting as coupling agents. Such treatments are useful to enhance durability and fatigue performance (static and dynamic) of the composite material. FRP composites based on fiberglass are usually denoted as GFRP.

3.2.7. Resin

Epoxy resin is used for wrapping the specimens with GFRP.

3.2.7.1. Epoxy Adhesive

The Sikadur 30 epoxy resin is a thixotropic adhesive mortar, based on a two-component solvent free epoxy resin. The mixing ratio was 3:1 of Component A (resin) and Component B (hardener) by weight. The elastic modulus, tensile strength, and shear strength as provided by the manufacturer are 11.7 GPa, 24.8 MPa, and 15 MPa, respectively.

3.2.9. Accelerator

It is used along with catalyst to harden the resin from liquid states to solid states.

3.2.9. Catalyst

Catalyst increases the rate of a chemical reaction of two or more reactants and helps in rapid hardening of the mix.

3.2.10. Pigment

A pigment is a material that changes the colour of mix. White pigment is used for wrapping the specimens with GFRP.

3.3. TEST PROGRAM

3.3.1.

In nominal mix concrete, properties of ingredients are not considered and same is limited up-to M20 grade Only. For present work, Portland Pozzolana Cement (PPC) was used in nominal and design mixed M20 grade Concrete and required angular aggregate and zone III river sand, nominal mix concrete (1.0 : 1.60: 2.75) was Prepared. Density and cement content of fresh concrete were 2217.00 kg/m3 and 413 kg/m3 respectively.

3.3.2. PREPERATION OF MOULD

Fresh concrete, being plastic requires some kind of form work to mould it to the required shape and also to hold it till it sets. The form work has, therefore, got to be suitably designed. It should be strong enough to

take the dead load and live load, during construction and also it must be rigid enough to withstand any bulging, twisting or sagging due to the load.

L. Injection Grouting for Densification and Honeycombed area:-

Providing and Fixing Injection ports/nozzles in staggered manner on all sides of shell at @ 500mm spacing after drilling holes, to facilitate injecting grout, using Renderoc Plug of Fosroc or equivalent and carrying out injection/pressure grouting in prefixed nozzles/ports using Micro fine cementations material Tamcrete MFC of Normet or equivalent of MC Bauchemie make and adding water for required consistency till no further grout is accepted by ports using grout pump etc. complete.

Note: Quantity of Micro fine cement-used shall be considered for measurement & Payment.

In case it is noticed that the beams, columns or slab elements have honeycombing inside after removal of loose concrete material, it is necessary to inject Microfine cement GROUT in the honeycombed areas and all part of bridge's concrete structure in order to fill all the voids/gap and make concrete denser.

a. First of all a hole of about 16 mm dia. is to be drilled into the honeycombed area, construction joints, and in grid pattern of 0.75 to 1.0 Mt distance in all area. The depth of the drilled hole should be about 200 mm. (in case of slabs, walls and such thin elements the drilled hole depth to be 40-60 % of the element thickness). Use compressed air to clean the hole, as well as honeycombed area to remove dust and dirt. Then a 12 mm dia. Flexible PVC injection nipple is to be fixed into the hole. Seal the surface around the nipple with Pre-packed material like Renderoc Plug of Fosroc or equivalent or using Pre packed Polymer modified mortar, These would ensure that the injected grout does not leak from the gaps.

b. In case of the honeycombed areas fix nipples and repair the honeycombed patch with pre-packed Polymer modified mortar of approved manufacturer:

c. The preparation done as above should be allowed to cure for 24 hours.

d. Prepare the polymer modified cementitious grout with following mix proportion. i. 25 kg Alcofine 1108 SR Microfine cement bag

ii. 10 to 12.5 ltr. Water

The above mix should be mixed in a container and stirred well for 5 minutes and used before setting of material.

d. Use 140 PSI grade Killick Nixon make injection grout pump or equivalent.

M. Rebarring Main steel:

Drilling holes of min 4mm larger than new rebar diamater into existing concrete substrate for anchoring of new rebars and depth 10 times the diameter of rebar and fixing with pure epoxy resin based cartridge form chemical anchor material Masterflow 935 of BASF or approved equivalent product confirming to NF P 18-831 and NF P 18-836 including cleaning, cutting, fabricating, chemicals, tools, labour, plants, machineries, scaffolding etc. complete as directed by Engineer-in-charge.