BUILDING REPAIRS AND MAINTENANCE

PART-II

Dr. S. THIRUGNANASAMBANDAM

ASSOCIATE PROFESSOR

DEPT. OF CIVIL & STRUCTURAL ENGINEERING

ANNAMALAI U NIVERSITY

ANNAMALAINAGAR-608 002

REPAIR

- Action taken to reinstate to an acceptable level the current functionality of a structure or its components which are defective or deteriorated, degraded or damaged in some way is called repair

The actions will include the following:

(i) Patching up of defects such as cracks and fall of plaster.

(ii) Repairing doors, windows, replacement of glass panes.

(iii) Checking and repairing electric wiring.

(iv) Checking and repairing gas pipes, water pipes and plumbing services.

(v) Re-building non-structural walls, smoke chimneys, boundary walls, etc.

(vi) Re-plastering of walls as required.

(vii) Rearranging disturbed roofing tiles.

(viii) Relaying cracked flooring at ground level.

(ix) Redecoration, whitewashing, painting, etc.

REHABILITATION

- It is the process of bringing the structure to its original level of function including durability and strength. It incluldes:
- Removal of portions of cracked masonry walls and piers and rebuilding them in richer mortar. Use of nonshrinking mortar will be preferable.
- Addition of reinforcing mesh on both -faces of the cracked wall, holding it to the wall through spikes or bolts and then covering it suitably. Several alternatives have been used.
- Injecting epoxy like material, which is strong in tension, into the cracks in walls, columns, beams, etc.

RETROFITTING

- Action to modify the functionality of a structure and to improve future performance in terms of load carrying capacity is called retrofitting.

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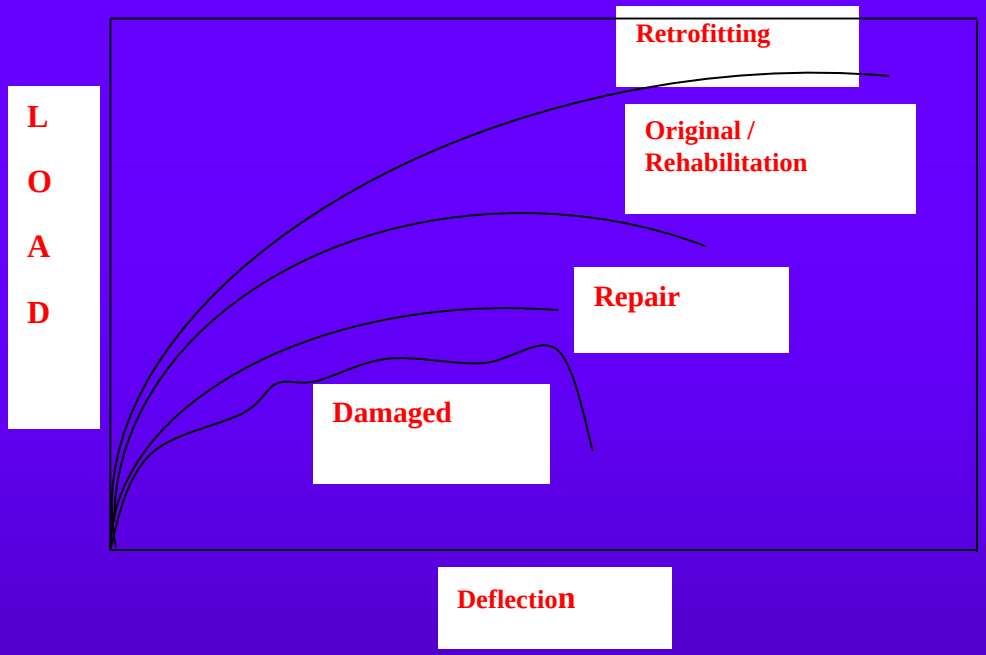
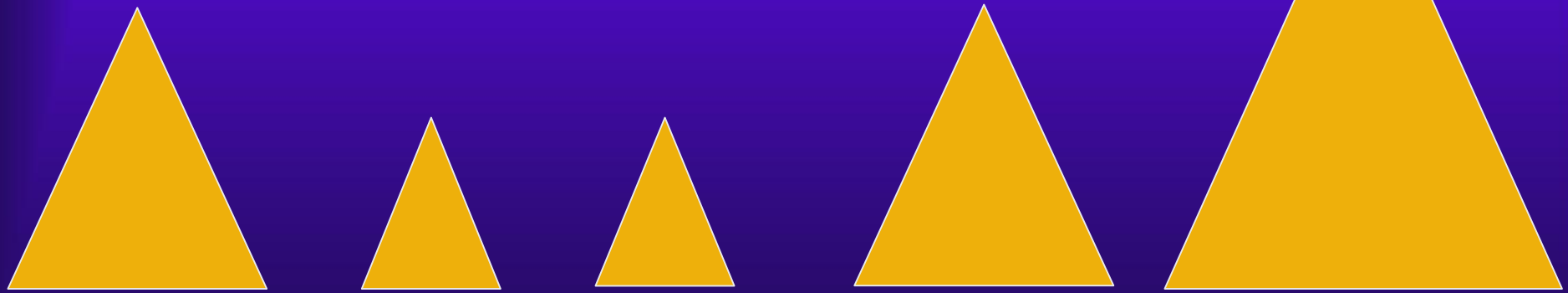
Effects of repair, rehabilitation and retrofitting





DESIGNED/ ORIGINGAL

DAMAGED

REPAIR

REHABILITATION/ ORIGINGAL

RETROFIT

- The expected economic life of the building under normal occupancy and maintenance conditions is considered to be as below:

(i) Monumental buildings 100 years.

(ii) RCC Framed construction *75* years

(iii) Load bearing construction *55* years.

(iv) Semi permanent structures 30 years

(v) Purely temporary structures *5* years

Criteria for selection of repair materials

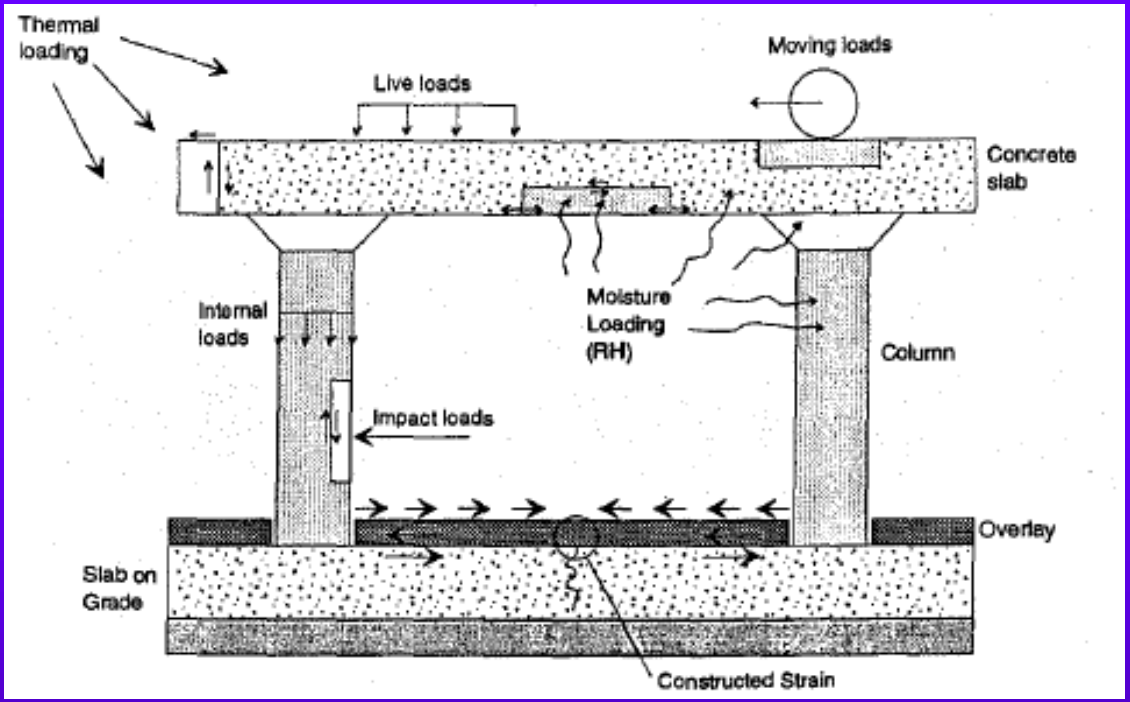
A careful selection of repair material is necessary for the following reasons (Shan Somayaji, 1995 and ACI. 1980)

1.Almost every repair job has unique condition and special requirements

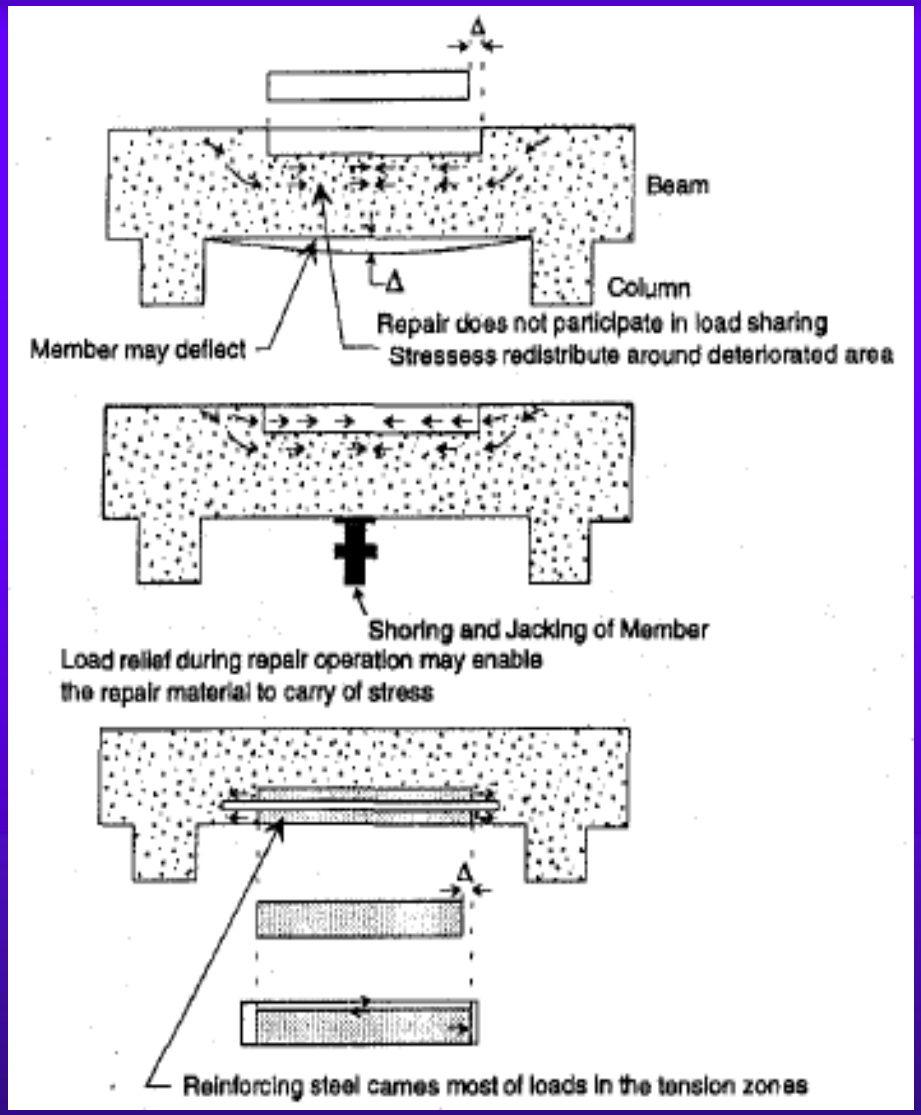
2.The composition and properties of repair materials have a profound effect and cured on the performance and durability of a repair.

3.The repair materials perform adequately only if they are prepared, applied and cured as per the specified procedures, which may necessitate the use of appropriate tools and considerable skill.

4.Repair materials, being generally proprietary in nature, are very costly.



Possible loads acting on a repair



Repair in Tension and Compression Zones

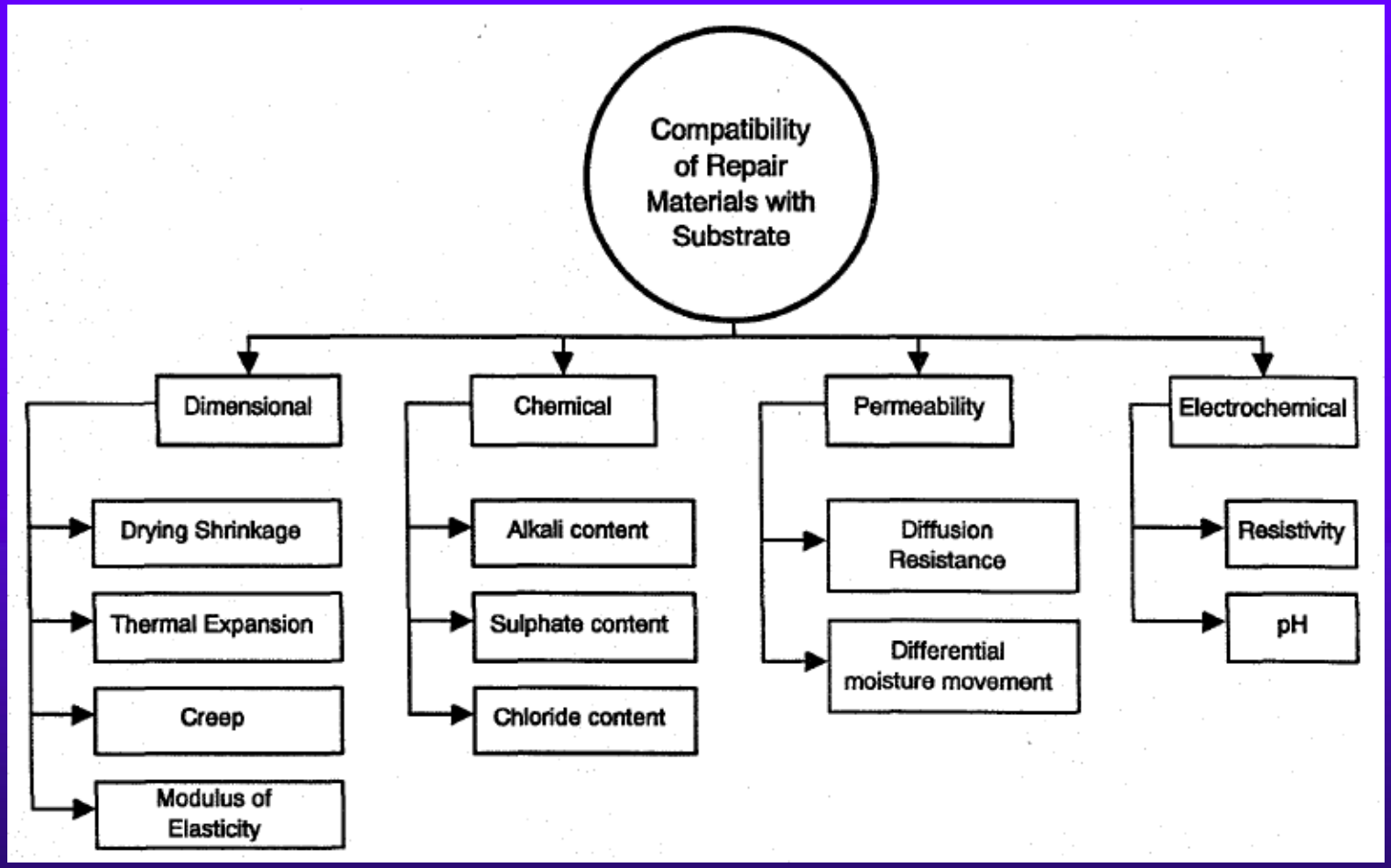
Compatibility

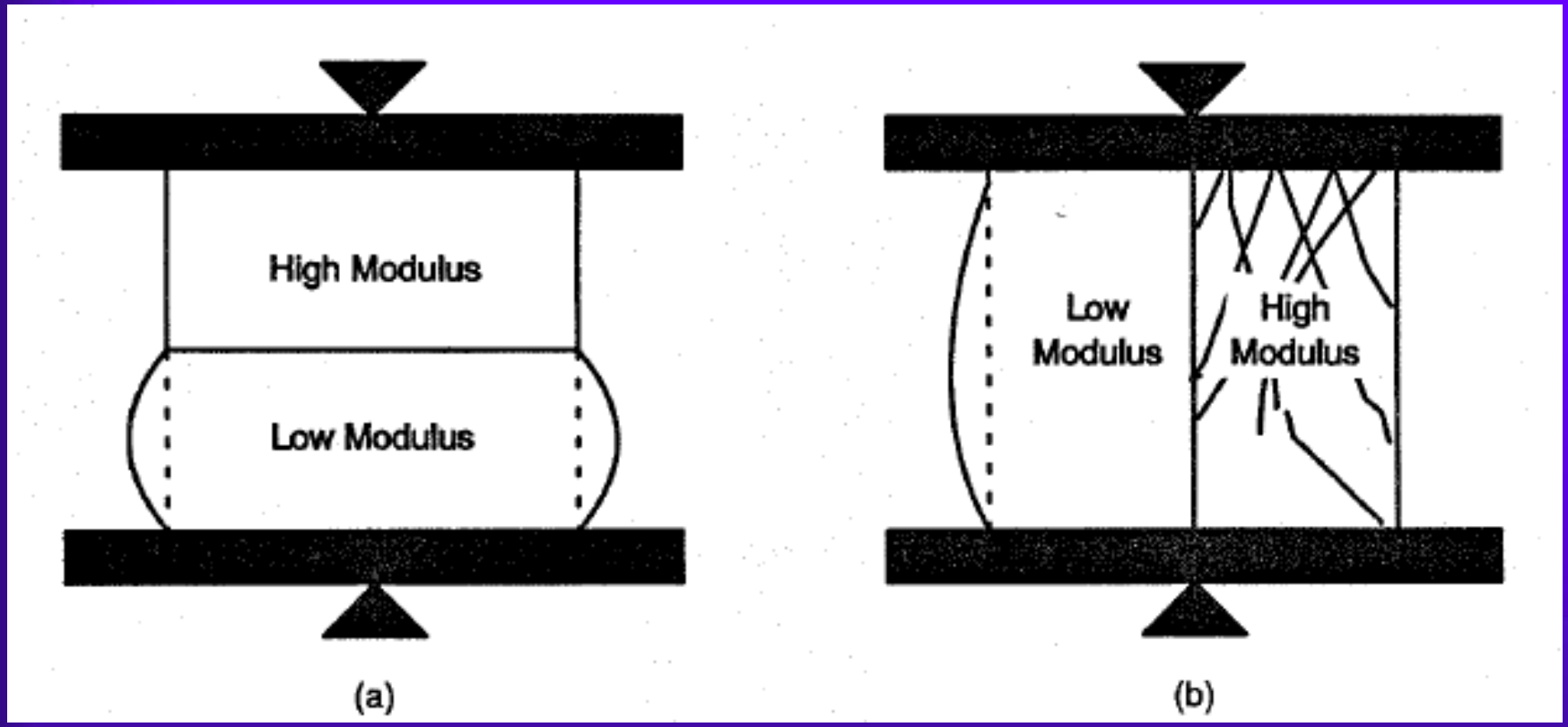
- Compatibility for a structural repair may be defined as that combination of properties and dimensions which ensures that interface bond strength is not exceeded and that the repair material carries its design load.

General Requirements of Patch Repair Materials for Structural Compatibility

Property	Relationship of repair mortar (R) to concrete substrate (C)
Strength in compression, tension and flexure	$R \geq C$
Modulus in compression, tension and flexure	$R \sim C$
Poisson's ratio	Dependent on modulus and type of repair
Coefficient of thermal expansion	$R \sim C$
Adhesion in tension and shear	$R \geq C$
Curing and long term shrinkage	$R \leq C$
Strain capacity	$R \geq C$
Creep	Dependent on whether creep causes desirable or undesirable effects
Fatigue performance	$R \geq C$
Chemical reactivity	Should not promote alk/agg reaction, sulphate attack or corrosion of embedments in substrate
Electrochemical stability	Dependent on permeability of patch material and Chloride ion content of substrate

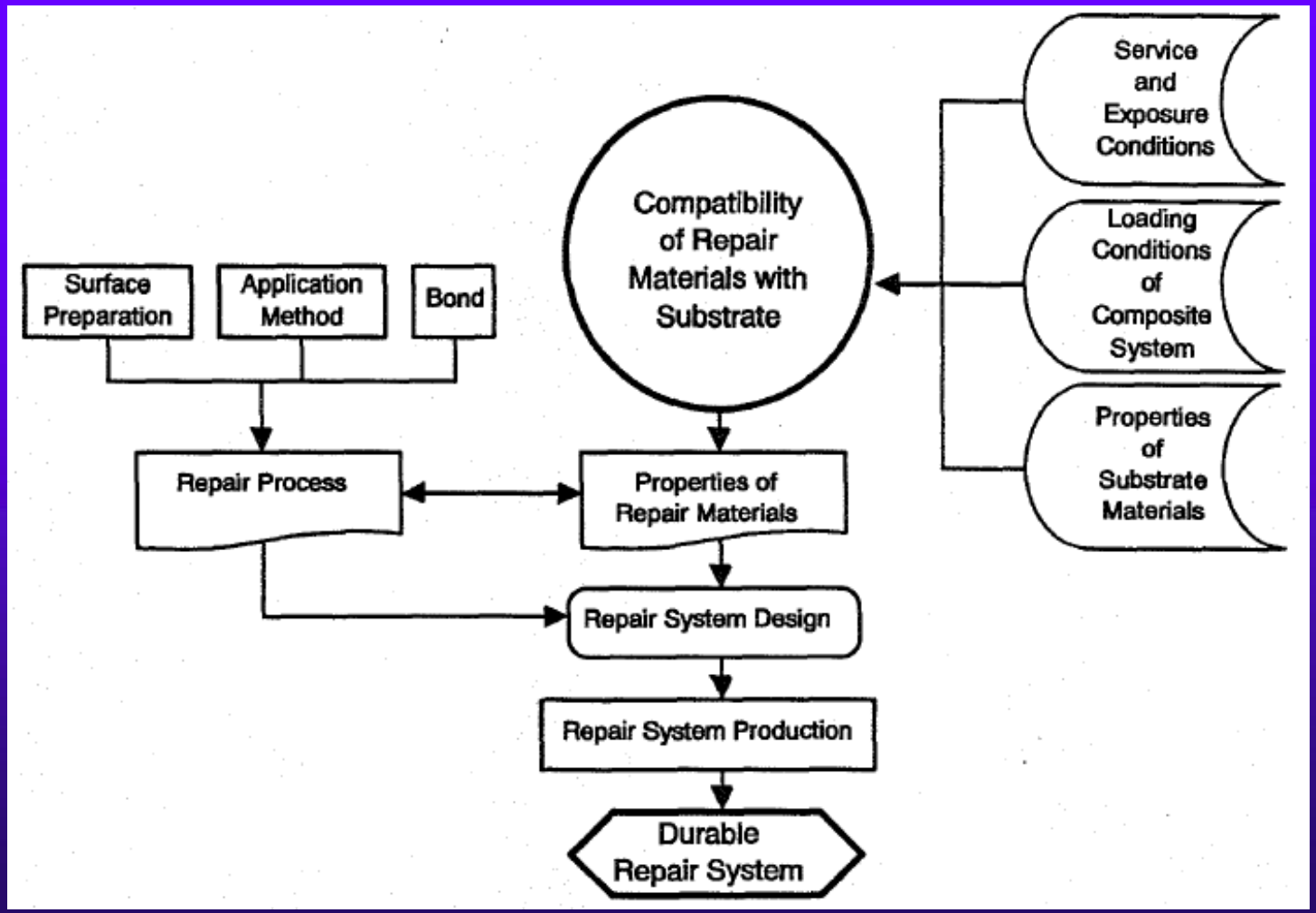
Various factors affecting the compatibility of repair materials





Materials with low modulus of elasticity deform more under given unit load

Factors affecting durability of concrete repair systems



Essential parameters for repair materials

1.Low shrinkage properties
2.Requisite setting / hardening properties
3.Workability
4.Good bond strength with existing sub-strate
5.Compatible coefficient of thermal expansion
6.Compatible mechanical properties and strength to that of the sub-strate
7.Should allow relative movement, if expected, particularly in case of sealing of cracks or dealing with expansion joints
8.Minimal or no curing requirement
9.Alkaline character
10.Low air and water permeability
11.Aesthetics to match with surroundings
12.Cost
13.Durable, non degradable or non-biodegradable due to various forms of energy, life, UV rays, heat, etc.
14.Non-hazardous / non – polluting.

Classification of repair materials

1. Patch Repair Materials

- Cementitious mortar / concrete
- Polymer modified cementitious mortar / concrete
- Polymer mortar / concrete
- Quick setting compounds
- High alumina cement based
- Calcium sulphate based
- Magnesium phosphates
- Sulphur concrete

2. Injection Grouts

- Cementitious grouts (with or without fibres)
- Gas forming grouts
- Sulpho-aluminate grouts
- Polymer grouts

3. Bonding Aids

- Polymer emulsion type
- Polymer resin type

4. Resurfacing Materials

- Protective coatings and membranes
- Impregnants and hydrophobic sealers
- Toppings / screeds
- Overlays
- Gunite / shotcrete

5. Other Repair Materials

- Corrosion inhibitors
- Rebar protective coatings
- Cathodic protection
- Re-alkalization
- Materials for surface preparation
- Chemical rust removers for corroded reinforcement
- Joint sealers
- Surface coatings for protection of RCC

Patch Repairing

Once the deterioration process is initiated, repair is an important factor in extending the life span of structures.

The replacement of defective and spalled concrete to reintroduce a protective and durable environment around reinforcement is great importance.

Therefore, deteriorated, reinforced concrete should be repaired with impermeable, highly alkaline cement-based materials, closely matched in properties to the parent concrete.

Patch repair consists of removal of the damaged concrete, cleaning of rust, and restitution of the original geometry with a patch material. Patch repairing is one of the common concrete repair technologies, especially when a localized corrosion occurs

The following are the requirements of a good patching material:

- Durable as the surrounding material
- Require minimum site preparation
- Resist wide range of temperature and moisture content
- Chemically compatible with the substrate
- Possess a similar colour and surface texture to the surrounding material.

The three major types of patch materials available in the market are Cement mortars and concretes, Polymer mortar and concrete and Epoxy-resin mortar and concrete.

The plain cement mortar repairing is not suitable for structural repair works because of their dimensional instability, weak adhesion, and durability.

The resin mortars including acrylics, polyurethanes, polyesters, and epoxies have superior properties as repair mortars. But the use of these mortars is restricted because of their cost and incompatibility with most of the substrate concretes.

The cement-polymer mortar has better adhesive properties, crack resistibility and compatibility. Styrene Butadiene Rubber (SBR) latex is being effectively used to modify cement mortar to be used as a repair system in practical application. Some additional reinforcements are added partially or totally to restore the original area of bars.

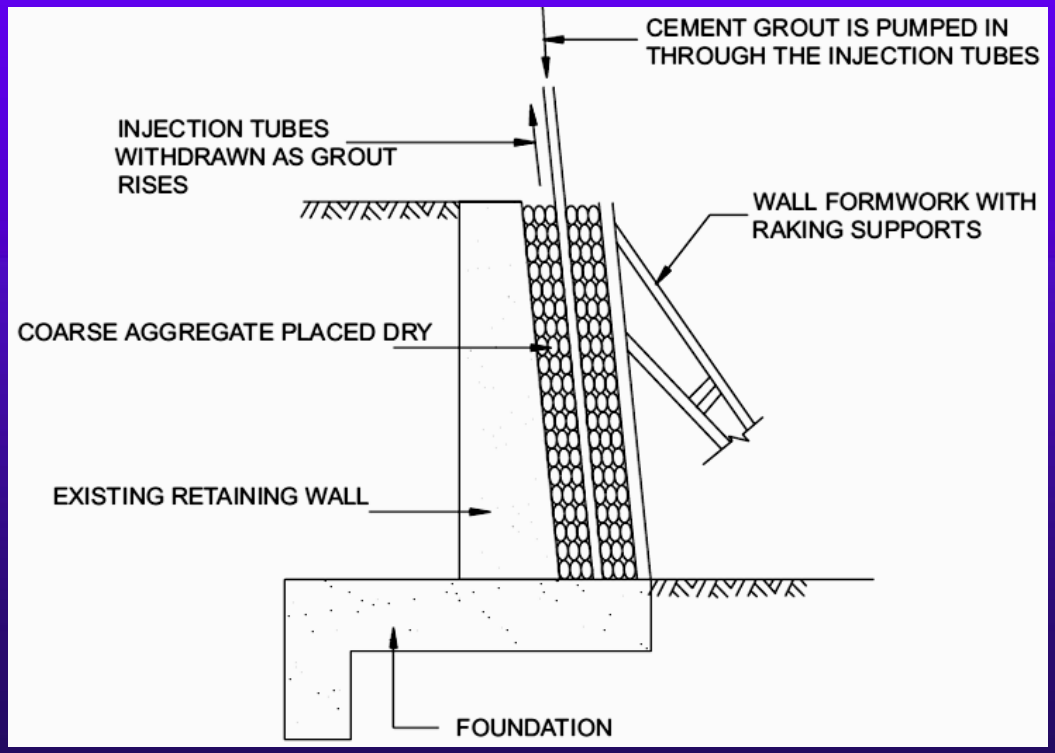
Prepacked concrete

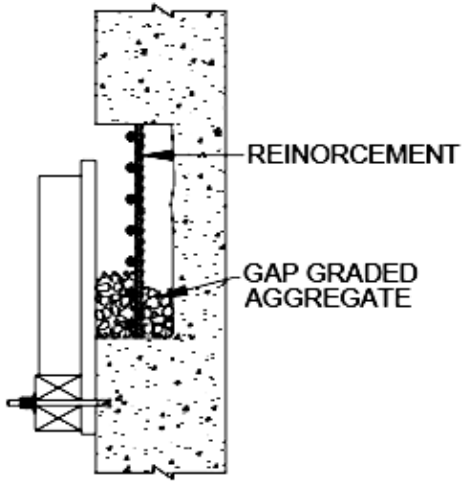
- This method is particularly useful for carrying out the repair under water and elsewhere where accessibility is a problem

- Prepacked concrete is made by filling forms with coarse aggregate and then filling the voids of the aggregate by pumping in a sand-cement grout

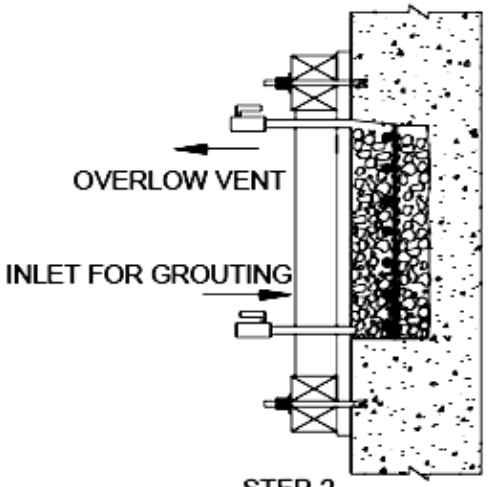
- Prepacked concrete is used for refacing of structures, jacketing, filling of cavities in and under structures, and underpinning and enlarging piers, abutments, retaining walls and footings
- Pumping of mortar should commence at the lowest point and proceed upward
- Placing of grout should be a smooth, uninterrupted operation

Preplaced concrete: It is technique in which the aggregates are placed first and then cemented together by introduction of intruded grout (cement –sand grout). It requires some special skills to carry out effectively. Pre-placed aggregate concrete (PAC) is concrete that is made by forcing into the voids of a mass of clean, graded coarse aggregate densely pre-packed in formwork

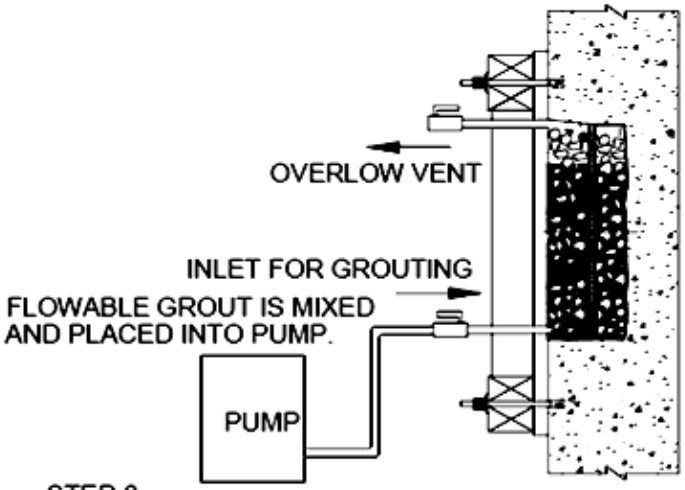




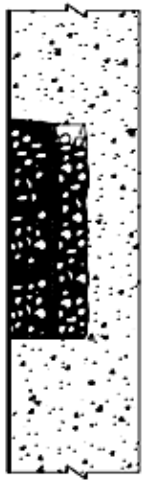
STEP-1
GAP GRADED AGGREGATE WASHED,FREE OF FINES AND BOND-INHIBITING MATERIALS ARE PLACED IN CAVITY.



STEP-2
FORMS ARE FITTED WITH PIPES AND NIPPLES AND VALVES FOR PLACEMENT OF GROUT.



STEP-3
FLOWABLE GROUT IS MIXED AND PUMPED INTO FORAMED CAVITY, FILLING SPACE BETWEEN AGGREGATE.



STEP-4
FORMS ARE REMOVED AND SURFACE IS FINISHED

Drypack

- Drypacking is the hand placement of a very dry mortar and the subsequent tamping of the mortar into place, producing an intimate contact between the new and existing works

- Because of the low water-cement ratio of the material, there is little shrinkage, and the patch remains tight. The usual mortar mix is 1:2.5 to 1:3

Dry Pack

Fibre Reinforced Concrete (FRC): FRC is a concrete containing small embedded reinforcements called fibres which ensures the concrete to delay the formation and propagation of internal micro cracks. Fibres include steel fibres, glass fibres, synthetic and natural fibres.

Polypropylene and Nylon fibers can:

Improve mix cohesion, improving pumpability over long distances

Improve freeze-thaw resistance

Improve resistance to explosive spalling in case of a severe fire

Improve impact resistance

Increase resistance to plastic shrinkage during curing

Steel fibers can

Improve structural strength

Reduce steel reinforcement requirements

Improve ductility

Reduce crack widths and control the crack widths tightly thus improve durabili

Improve impact & abrasion resistance

Improve freeze-thaw resistance

Polymer concrete and mortar

1. polymer impregnated concrete; 2. polymer cement concrete and
3. polymer concrete.

Polymer Impregnated Concrete (PIC)

Polymer impregnated concrete is made by impregnation of precast hardened Portland cement concrete with low viscosity monomers (in either liquid or gaseous form) that are converted to solid polymer under the influence of physical agents (ultraviolet radiation or heat) or chemical agents (catalysts).

Impregnation of concrete results in a remarkable improvement in tensile, compressive and impact strength, enhanced durability and reduced permeability to water and aqueous salt solutions such as sulfates and chlorides. The compressive strength can be increased from 35 MPa to 140 MPa, the water absorption can be reduced significantly and the freeze-thaw resistance is considerably enhanced.

Polymer modified Cement Concrete (PMC)

Polymer cement concrete is a modified concrete in which part (10 to 15% by weight) of the cement binder is replaced by a synthetic organic polymer.

Modification of concrete with a polymer latex (colloidal dispersion of polymer particles in water) results in greatly improved properties, at a reasonable cost. Therefore, a great variety of latexes is now available for use in polymer cement concrete products and mortars. The most common latexes are based on poly (methyl methacrylate) also called acrylic latex, poly (vinyl acetate), vinyl chloride copolymers, poly (vinylidene chloride), (styrene-butadiene) copolymer, nitrile rubber and natural rubber.

Polymer Concrete (PC)

Polymer concrete (PC) is a composite material formed by combining mineral aggregates such as sand or gravel with a monomer. Cement and water are completely eliminated in this of concrete.

Due to its rapid setting, high strength properties and ability to withstand a corrosive environment, PC is increasingly being used as an alternate to cement concrete in many applications, construction and repair of structures, highway pavements, bridge decks, waste water pipes and even structural and decorative construction panels.

Epoxy-resin mortar and concrete

Epoxies also come in the category of polymer but in the case the of epoxies, the polymerization process take place when tow materials called the epoxy resin and hardener come in contact by thoroughly mixing in specified proportion.

The epoxy resin materials have good mechanical strength, chemical resistance and ease of working.

Field of applications:

Anti corrosive and water proofing coatings: Fusion bonded epoxy powder (FBEP) coatings are being used for protection of reinforcing bars against corrosion in RC structures located in highly aggressive areas. FBEP process provides a tough film, which can withstand bar bending without cracking.

Bond coats and grouts: Epoxies are used as bond coats and grouts due to their excellent adhesive qualities on cementitious as well as metallic surface. An epoxy film is brushed or sprayed onto the surface of the cleaned substrate and the new concrete is placed as the epoxy becomes tacky but before it hardens.

Structural repair to concrete: Due to their excellent mechanical properties and bond characteristics with most of the materials, epoxy mortars / concretes are used to make up the damaged or lost cover concrete, etc.

POLYESTER RESINS

A two-part polyester resin (unsaturated polyester such as methylmethacrylates) based material suitable for the repair, surfacing, jointing and bedding of concrete, brickwork and masonry. Available in summer and winter grades, the mixed mortar will harden to give rapid strength gain and can be placed in section thicknesses of 5mm to 50mm in single layers. Thicker sections can be achieved by placing multiple layers. The bond strength developed is stronger than the tensile strength of most construction materials. Typical uses include bedding and fixing of precast concrete units, fixing of concrete barrier units, patch repairs to concrete floors, bedding of coping stones and infills where rapid service use is required.

ACRYLIC CONCRETE AND MORTAR

In this type, aggregates are mixed together with acrylic polymer to make concrete / mortar. Methylmethacrylate (MMA) and high molecular weight methacrylate (HMWM) monomers are used to make concrete.

All components of the product can be mixed together and placed over a patch area filled with preplaced aggregates. Due to its rapid strength gain and high ultimate strength, it is widely used in bridge slabs, parking garage decks, industrial warehouse floors and tanks.

QUICK SETTING COMPOUNDS

Repairs in heavy trafficked areas are possible using faster setting and curing materials such as high alumina cement containing compounds, magnesium phosphates, molten sulfur and calcium sulphate based materials.

BITUMINUOUS MATERIALS

Hot mixed, densely graded asphalt concrete is widely used for patch repair works. It is cheaper material and easy to apply. Care should be taken against the poorly graded aggregate and unconsolidated patches that are prone to water pick up, which accelerate deterioration of surrounding concrete.

FERROCEMENT

Ferrocement is a technical term, not to be confused with ordinary reinforced concrete. It might be defined as a composite material consisting of a matrix made from hydraulic cement mortar and a number of layers of continuous steel mesh reinforcement distributed throughout the matrix. It is relatively cheap, strong and durable, and the basic technique is easily acquired. The basic parameters which characterise ferrocement are the specific surface area of reinforcement, the volume fraction of the reinforcement, the surface cover of the mortar over the reinforcement and the relatively high quality of the mortar. The thickness of ferrocement is in the range between 12 to 30mm. The wire mesh is mechanically connected to the parent surface by U shaped nails fixed with suitable epoxy bonding system.

SLURRY INFILTRATED FIBROUS CONCRETE (SIFCON)

Slurry-infiltrated fibrous concrete (SIFCON) can be considered as a special type of fiber concrete with high fiber content. It is also sometimes termed as ‘high-volume fibrous concrete’. The matrix usually consists of cement slurry or flowing mortar. SIFCON has excellent potential for application in areas where high ductility and resistance to impact are needed.

(i) Mould filled with fibres (ii) Fibre pack well rammed (iii) Pouring of slurry

Making of SIFCON

Applications of SIFCON:

Pavement rehabilitation and precast concrete products

Overlays, bridge decks and protective revetments

Seismic and explosive-resistant structures

Security concrete applications (safety vaults, strong rooms etc)

Refractory applications (soak-pit covers, furnace lintels, saddle piers)

Military applications such as anti-missile hangers, under-ground shelters

Sea-protective works

Primary nuclear containment shielding

Aerospace launching platforms

Repair, rehabilitation and strengthening of structures

Rapid air-field repair work

Concrete mega-structures like offshore and long-span structures, solar towers etc.

SLURRY INFILTRATED MAT CONCRETE (SIMCON)

SIMCON can also be considered a pre-placed fibre concrete, similar to SIFCON. However, in the making of SIMCON, the fibres are placed in a “mat form” rather than as discrete fibres. The advantage of using steel fibre mats over a large volume of discrete fibres is that the mat configuration provides inherent strength and utilizes the fibres contained in it with very much higher aspect ratios. The fibre volume can, hence, be substantially less than that required for making of SIFCON, still achieving identical flexural strength and energy absorbing toughness.

SIMCON is made using a non-woven “steel fibre mats” that are infiltrated with a concrete slurry. Steel fibres produced directly from molten metal using a chilled wheel concept are interwoven into a 0.5 to 2 inches thick mat. This mat is then rolled and coiled into weights and sizes convenient to a customer’s application (normally up to 120 cm wide and weighing around 200 kg). Since the mat is already in a preformed shape, handling problems are significantly minimised resulting in savings in labour cost. Besides this, “balling” of fibres does not become a factor at all in the production of SIMCON.

GROUTS

Grout is a type of mortar used to fill joints, cracks, and cavities in tiles, masonry, and brickwork. It typically consists of water, cement, and sand; or cement and water. Used in semi-liquid form, it may be pumped, spread, or poured into cavities and allowed to harden, creating a tight, water-resistant seal.

The three main types of grout are epoxy, Portland cement - based, and furan resin. The epoxy type is strong and water resistant. It is available in 100 percent epoxy resin and modified epoxy emulsion form. Epoxy grout is generally more expensive than other types and can be difficult to find.

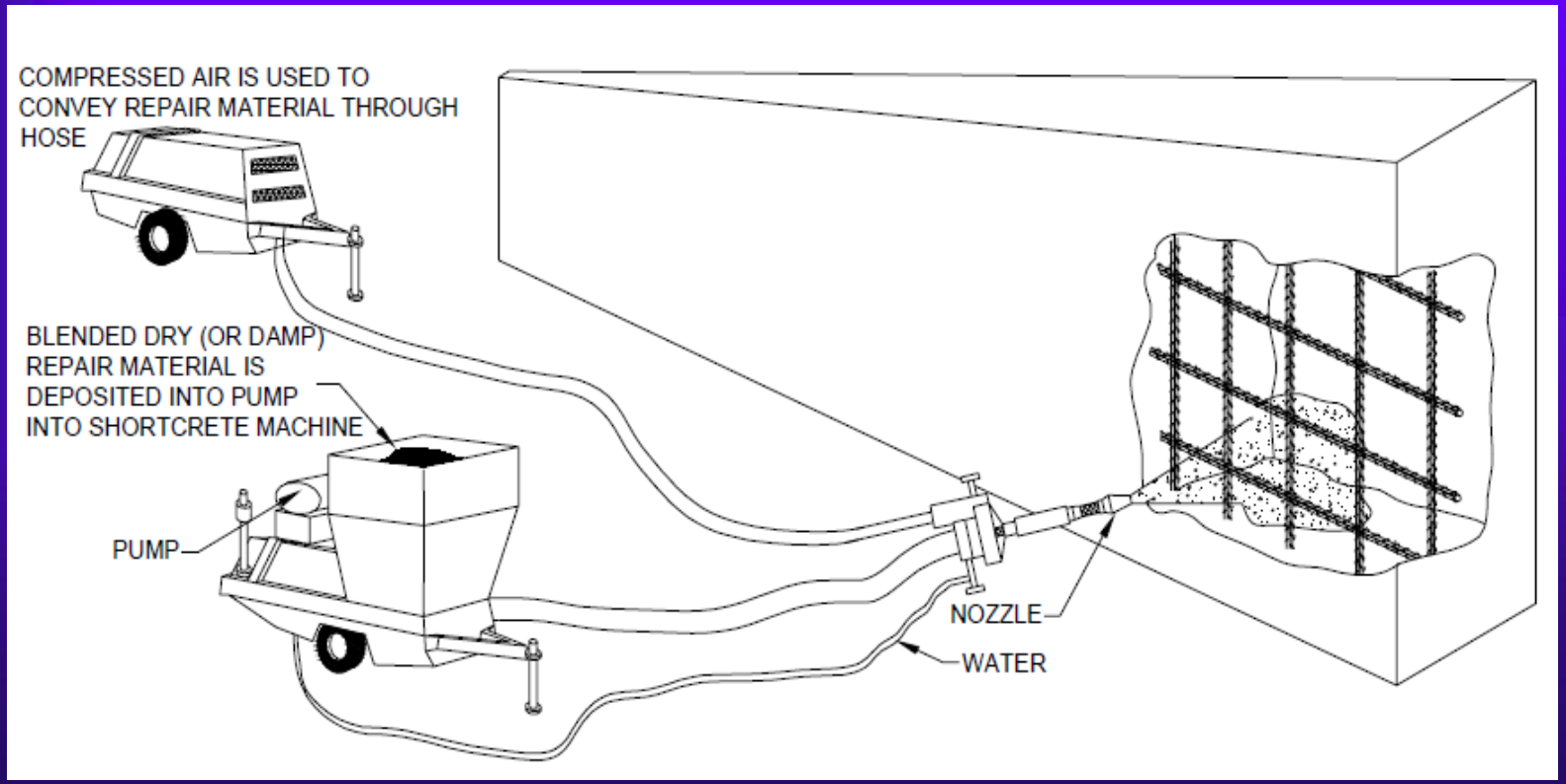
Grouting formulations are comprised of three basic elements: binder (clay types and properties, lime, synthetic), aggregate (sand, synthetic materials) and dispersant (water).

Essential Properties of grout:

- Viscosity
- Fluidity
- Penetration/Injectability
- Set time (initial and final)
- Stability
- Shrinkage
- Dilation (Spread out – wider - expand)
- Cohesion
- Bonding
- Crack formation within grout
- Compatibility (similar material if possible)
- Durability

Shotcrete [GUNITE]

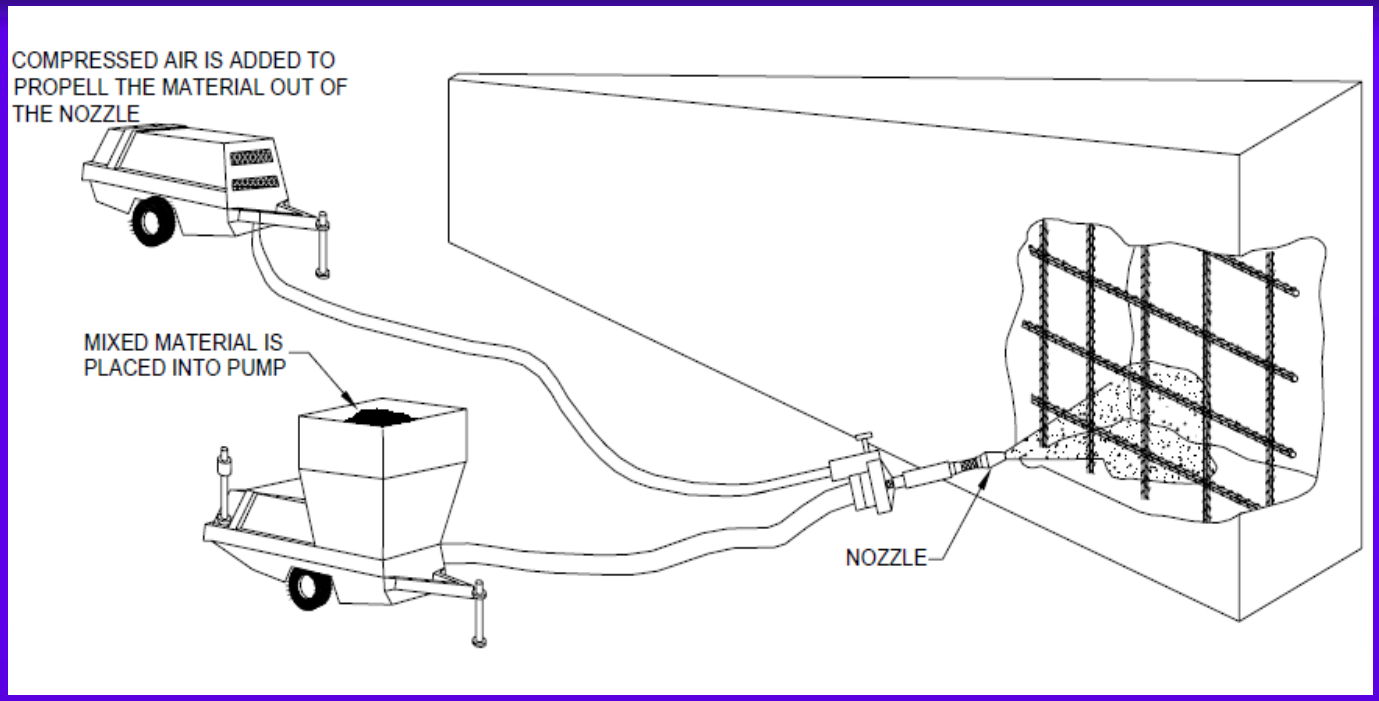
Shotcrete is a method of applying a combination of sand and Portland cement which mixed pneumatically and conveyed in dry state to the nozzle of a pressure gun, where water is mixed and hydration takes place just prior to expulsion. A maximum coarse aggregate size of 10mm is used. It can be applied by either a ‘dry mix’ or ‘wet mix’ process.



The dry process involves the following steps:

- Thoroughly mixing the dry materials;
- Feeding of these materials into mechanical feeder or gun;
- Carrying the materials by compressed air through a hose to a special nozzle;
- Introducing water at nozzle point and intimately mixing it with other ingredients at the nozzle;
- Jetting the mixture from the nozzle at high velocity on to the surface to receive the shotcrete

In the **wet process**, a predetermined ratio of cement, aggregate and water is batched, mixed and transferred to a pump. The concrete is pumped along a flexible hose to a discharge nozzle from where it is projected at high velocity on to the surface to be coated. A rapid setting admixture like sodium aluminate or metasilicate solution is commonly added at the nozzle to enable buildup of thick layers. The wet process is similar to the use of mix design procedure suited for pumping. The cement content and aggregate to cement ratio, maximum aggregate size and grading is limited to what will give a pumpable mix with the equipment used. A higher water cement ratio than in dry process is usually necessary to provide pumpable mixes. It is more suited to the application of large quantities of material, typically in new construction. It is less suited for restoration works.



The wet process involves the following steps:

- Thoroughly mixing all the materials except accelerating agents (if used)
- Feeding of these materials into the delivery equipment
- Delivering the mixture by positive displacement or compressed air through a nozzle
- Jetting the mixture from the nozzle at high velocity on to the surface to receive the shotcrete

BONDING AGENTS

When applying conventional concrete, sprayed concrete, cement mortar, polymer modified mortar or epoxy mortar, bonding of repair material to the existing concrete is often a problem. Bonding agents are usually used to make perfect bond of new concrete to old concrete. Two of the critical factors affecting the bonding between new and old concrete are

(i) the strength and integrity of the old surface and

(ii) the cleanliness of the old surface. The use of epoxy resin or polymer latex bonding agent can assist in achieving a reliable bond.

Polymer Latex Emulsions

The latex emulsions generally used in cementitious compositions are of the oil-in-water type, and sometimes contain more than 50% water. They are generally stable in the cement/water system. However, not all emulsions are compatible with cement, and the selection of an appropriate product for a given application requires an understanding of its chemistry or, alternatively, consultation with the manufacturer.

Three methods can be used to modify a latex to make it a useful bonding agent:

(i) Prepare a neat cement slurry utilizing the latex as part of the mixing water;

(ii) Use a 1:1 water : latex diluted material;

(iii) Use re-emulsifiable latex, which can be softened and re-tackified upon contact with water.

Styrene Butadiene (SBR) latex, which is compatible with cementitious compounds, is a copolymer. This type of latex shows good stability and is unaffected by the addition of relatively large amounts of electrolytes. SBR latex may coagulate if subjected to high temperatures, freezing temperatures, or severe mechanical action for prolonged periods of time.

Polyvinyl Acetate Latex (PVA)

Two main types of PVAs are used in repair: non-re-emulsifiable and emulsifiable. Non-re-emulsifiable PVA forms a film that offers good water resistance, ultraviolet stability, and aging characteristics. Because of its compatibility with cement, it is widely used as a bonding agent and as a binder for cementitious water-based paints and waterproofing coatings. Emulsifiable PVA produces a film that can be softened and re-tackified with water. This type of latex permits the application of a film to a surface long before the subsequent application of a water-based overlay.

Acrylic latex

Acrylic ester resins are polymers and copolymers of the esters of acrylic and methacrylic acids. Their physical properties range from soft elastomers to hard plastics. This type of emulsion is used in cementitious compounds in much the same manner as SBR latex.

Epoxy Bonding Agents

Various epoxy products are available for the bonding of freshly placed concrete to cured concrete and of concrete to steel. Most products contain resins that are 100% solids. In severe drying conditions, the open time for bonding coats may be too short to ensure a good bond and such situations epoxy resin bonding is preferable.

Epoxy concrete repair

SURFACE COATINGS

The protective coatings of concrete surface generally improve the durability and greatly help to protect concrete deterioration due to environment effects. The protective coatings properties are:

1. Possess excellent bond to substrate
2. Be durable with a long useful life normally 5 years
3. Little or no colour change with time
4. Little or no chalking
5. Should have maximum permeability to allow water vapour escape from concrete substrate
6. Should sufficient impermeability against the passage of oxygen and carbon dioxide from air to concrete
7. Should be available in a reasoning range of attractive colours.

8. The properties of concrete which affect the successful application and performance of a coating are (i) porosity (ii) moisture content (iii) presence of contaminants on the surface. Most of the protective coatings used are (i) Bituminous coatings and mastics (ii) Polyesters and Vinylesters (iii) Urethanes (iv) Epoxies (v) Neoprene (vi) Coal Tar Epoxy (vii) Acrylics.

Resin based toppings are used to protect the industrial floors subjected to heavy loadings. It consists of three components such as resin, curing agent (hardener) and aggregate fillers. Epoxies, polyurethane, polyester, polyacrylate and phenolic materials are used as resins. Epoxy mortar and glass fibre reinforced multicoat can also be used as toppings.

Surface Hardeners and Overlays:

These are used to upgrade the floor's wear resistance, reduce dusting and increase chemical resistance.

Application fields: (i) Pavements of garages, parking, shopping malls, sport installations, schools, hospitals, subjected to moderate or medium traffic. (ii) Dock slabs in warehouses, industries, fuel stations with moderate erosion.

Advantages:

1. Increases the durability of the pavement
2. Reduction of formation of superficial dust
3. Improves the resistance against impacts
4. Provides colour to pavement
5. It bonds structurally into the surface becoming part of the slab
6. Easy application by powdering over the fresh concrete
7. Low installation costs. Without maintenance
8. Easily cleaning of the treated surface

Surface Hardener: Surface hardeners are used to repair and upgrading of industrial floors. Two types of surface hardeners are generally used. One is shake hardener and the other is liquid hardener. In shake hardener, high aggregate (mineral and metallic aggregates) to cement ratio (2:1) are used. In liquid hardener, sodium silicate or silicofluorides are used.

Overlays: It is applied as a second stage of construction on a new floor or deck, as preventive maintenance on a deck that has been open to traffic for a short time. The commonly used materials are (i) High early strength OPC concretes and mortars using superplasticizers (ii) Polymer latex concrete (iii) Epoxy mortars (iv) Fibre reinforced concrete incorporating steel or polypropylene fibres (v) Silica fume concrete.

Thin Polymer Overlays: These are used to improve the abrasion resistance and for creating waterproofing barriers on the surface and act as protective coatings. These are applied in less than 10mm thickness. It is quite suitable for improving surface characteristics and also it acts as protective coatings. It comprises of one coat of primer and one or more coats of sealent. The primer coat shall consist of the same material as in the primer but with the addition of silica filler, titanium dioxide pigment and carbon black pigment.

Thin Epoxy Overlays: These are used to improve the abrasion resistance of surface and for creating waterproofing / protective coating. Thin epoxy overlays are applied in 2 to 3 mm thickness. It consists of resin and hardener. The strength gain is much faster than polymer overlays. There are several types for epoxy overlays available to suite different performance requirement. Epoxy overlays require protective coating in exposed locations subjected to ultra violet exposure.

SEALANTS

Sealants are used to seal the concrete surfaces and joints to prevent the ingress of moisture, solid matters such as dust and sand into the structures. Concrete sealers are finish coatings used to protect the concrete and to accommodate joint movements. Sealers act to prevent damage from traffic, water and chemical agents. Sealers reduce the porosity of concrete and prevent water and dirt from getting into the concrete.

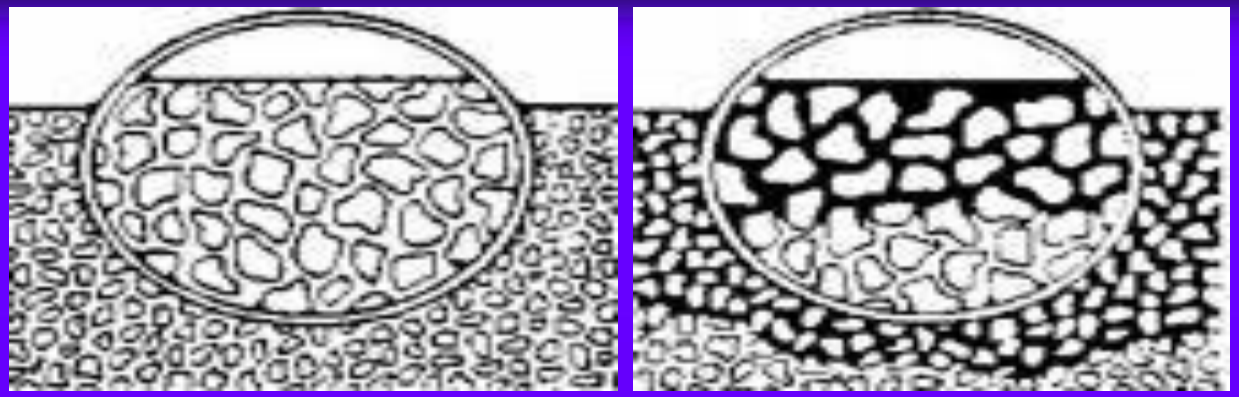
Types of Sealers:

Film Formers:

It creates a barrier on the concrete's surface. It is used for enhancing exposed aggregate colored concrete since they are shiny.

Penetrates:

These sealers penetrate into the concrete (Figure 6.14). They get 1 to 4 millimeters into the concrete to increase water repellency. Unlike the film formers, they do not leave a sheen or gloss.



Application of penetrate

Which Type of Sealer to Use?

It depends on: (i) Surface finish and (ii) Type of maintenance

film formers → glossy finish

penetrate → matte finish OR slip-free surface

Examples on sealers:

Acrylic, Silicone, Mastics, Latex, Urethane, silane , siloxane Epoxy Resin, wax forms

Sealer Application:

1. Surface Prepration:
2. clean the concrete surface before sealing.
3. coat the floor for 10 to 15 minutes.

Apply Sealer:

Clean Up:

Wash up with warm soap and water immediately.

1. INTRODUCTION

- 3 Basic symptoms of distress in a concrete structure
- Cracking, Spalling and Disintegration
- Reasons for their development may be poor materials, poor design, poor construction practice, poor supervision or a combination

- repair of cracks usually does not involve strengthening
- repair of a structure showing spalling and disintegration, it is usual to find that there have been substantial losses of section and/or pronounced corrosion of the reinforcement

2. Repairing cracks

- In order to determine whether the cracks are active or dormant, periodic observations are done utilizing various types of telltales
- by placing a mark at the end of the crack
- a pin or a toothpick is lightly wedged into the crack and it falls out if there is any extension of the defect

- A strip of notched tape works similarly :

  Movement is indicated by tearing of the tape
- The device using a typical vernier caliper is the most satisfactory of all.

  Both extension and compression are indicated
- If more accurate readings are desired, extensometers can be used
- Where extreme accuracy is required resistance strain gauges can be glued across the crack

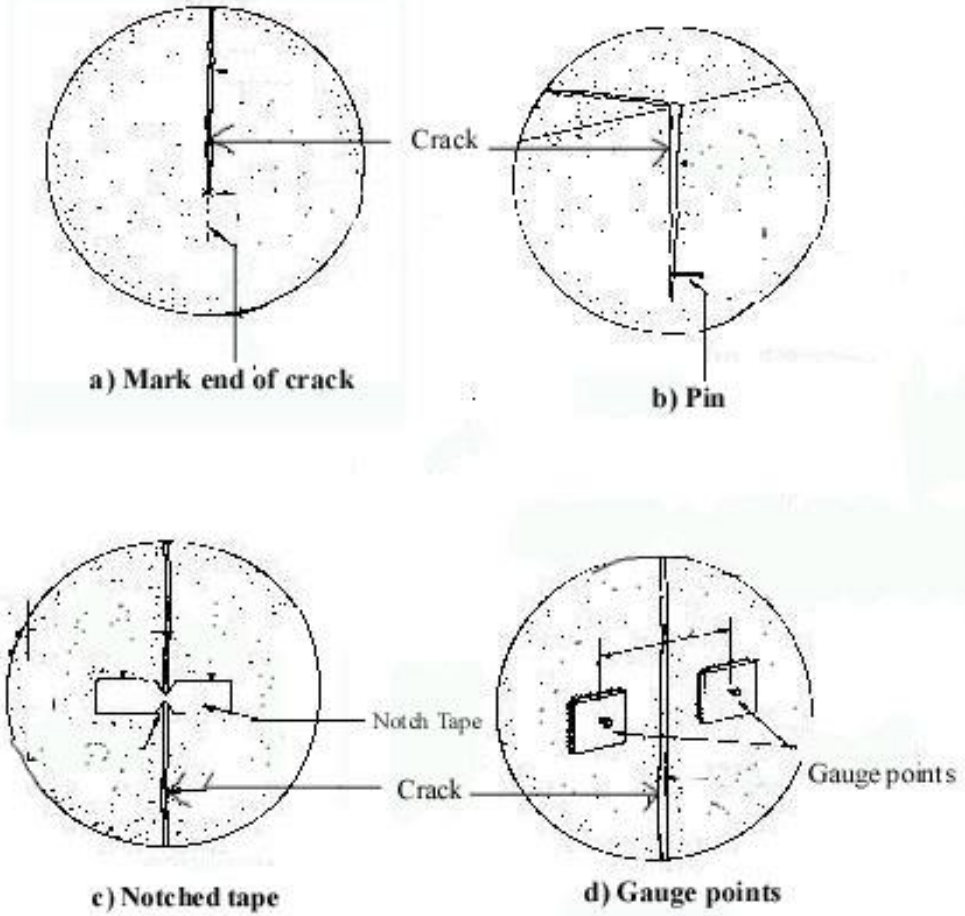


Fig. 1 Tell Tales

2.1 Types of cracks

- active cracks and dormant cracks
- the proper differentiation between active and dormant cracks is one of magnitude of movement, and the telltales are a measure of the difference

- If the magnitude of the movement, measured over a reasonable period of time (say 6 months or 1 year), is sufficient to displace or show significantly on the telltales, we can treat the crack as an active one.

- If the movements are smaller, the crack may be considered as dormant.

- Cracks can also be divided into solitary or isolated cracks and pattern cracks
- Generally, a solitary crack is due to a positive overstressing of the concrete either due to load or shrinkage
- Overload cracks are fairly easily identified because they follow the lines demonstrated in laboratory load tests

- In a long retaining wall or long channel, the regular formation of cracks indicates faults in the design rather than the construction, but an irregular distribution of solitary cracks may indicate poor construction as well as poor design

- Regular patterns of cracks may occur in the surfacing of concrete and in thin slabs. These are called pattern cracks

Methods of repairing cracks

1. **Bonding with epoxies**

- Cracks in concrete may be bonded by the injection of epoxy bonding compounds under pressure
- Usual practice is to
  - drill into the crack from the face of the concrete at several locations

- inject water or a solvent to flush out the defect
- allow the surface to dry
- surface-seal the cracks between the injection points
- inject the epoxy until it flows out of the adjacent sections of the crack or begins to bulge out the surface seals

- Usually the epoxy is injected through holes of about ¾ inch in diameter and ¾ inch deep at 6 to 12 inches centers

- Smaller spacing is used for finer cracks

- The limitation of this method is that unless the crack is dormant or the cause of cracking is removed and thereby the crack is made dormant, it will probably recur, possibly somewhere else in the structure

- Also, this technique is not applicable if the defects are actively leaking to the extent that they cannot be dried out, or where the cracks are numerous

2. Routing and sealing

- This method involves enlarging the crack along its exposed face and filling and sealing it with a suitable material

- The routing operation
- placing the sealant
- This is a method where thorough water tightness of the joint is not required and where appearance is not important

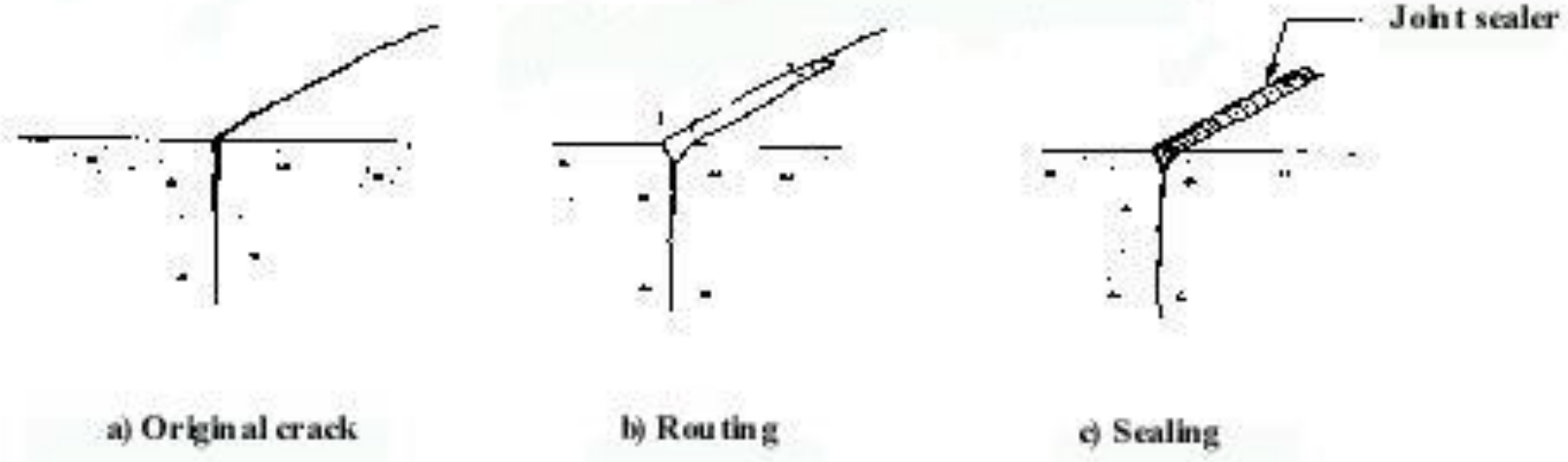


Fig. 2 Routing and sealing

3. Stitching

- Concrete can be stitched by iron or steel dogs
- A series of stitches of different lengths should be used
- bend bars into the shape of a broad flat bottomed letter U between 1 foot and 3 feet long and with ends about 6 inches long
- The stitching should be on the side, which is opening up first

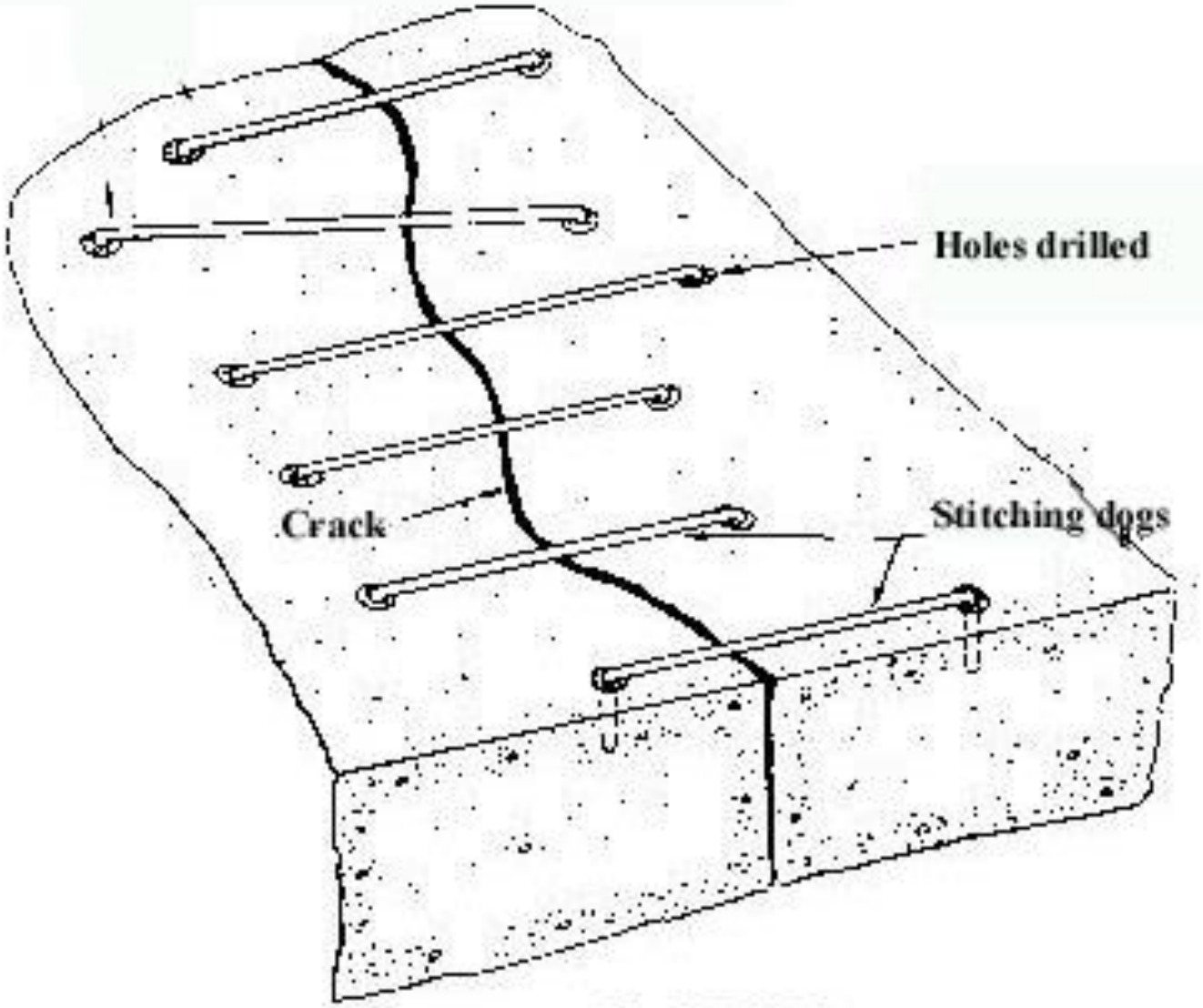
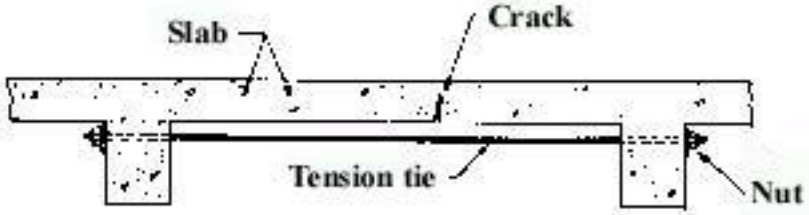


Fig. 3 Stitching

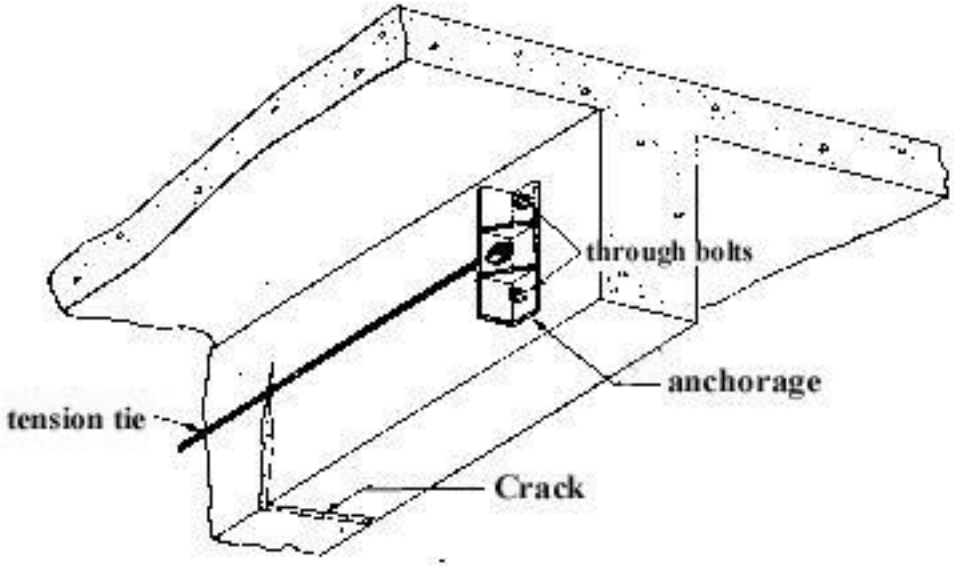
- if necessary, strengthen adjacent areas of the construction to take the additional stress
- the stitching dogs should be of variable length and/or orientation and so located that the tension transmitted across the crack does not devolve on a single plane of the section, but is spread out over an area
- In order to resist shear along the crack, it is necessary to use diagonal stitching
- The lengths of dogs are random so that the anchor points do not form a plane of weakness

4. External stressing

- cracks can be closed by inducing a compressive force, sufficient to overcome the tension and to provide a residual compression
- The principle is very similar to stitching, except that the stitches are tensioned; rather than plain bar dogs which apply no closing force to the crack
- Some form of abutment is needed for providing an anchorage for the prestressing wires or rods



a) to correct cracking in beams



b) to correct cracking in slabs

Fig. 4 External stressing

External Pre stressing

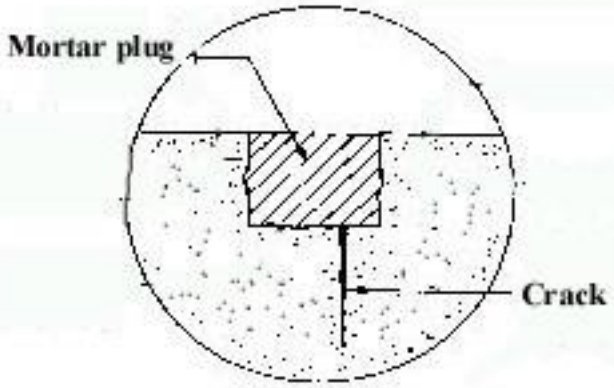
5. Grouting

- same manner as the injection of an epoxy
- cleaning the concrete along the crack
- installing built-up seats at intervals along the crack
- sealing the crack between the seats with a cement paint or grout
- flushing the crack to clean it and test the seal; and then grouting the whole

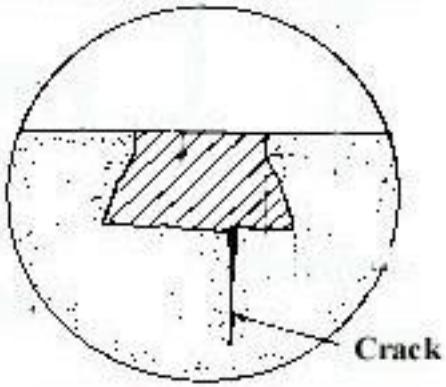
6. Blanketing

- similar to routing and sealing
- applicable for sealing active as well as dormant cracks
- Preparing the chase is the first step
- Usually the chase is cut square
- The bottom should be chipped as smooth to facilitate breaking the bond between sealant and concrete

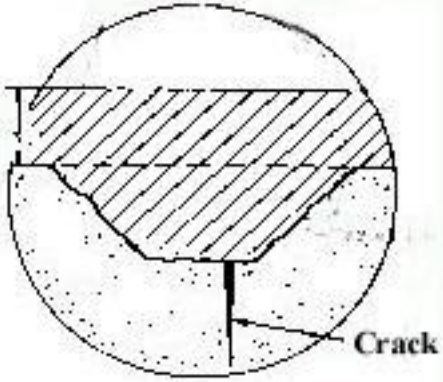
- The sides of the chase should be prepared to provide a good bond with the sealant material
- The first consideration in the selection of sealant materials is the amount of movement anticipated
- and the extremes of temperature at which such movements will occur
- elastic sealants
- mastic sealants
- mortar-plugged joints



a) Squarecut chase



b) Undercut chase



c) Beveled chase

Fig. 5 Types of chase

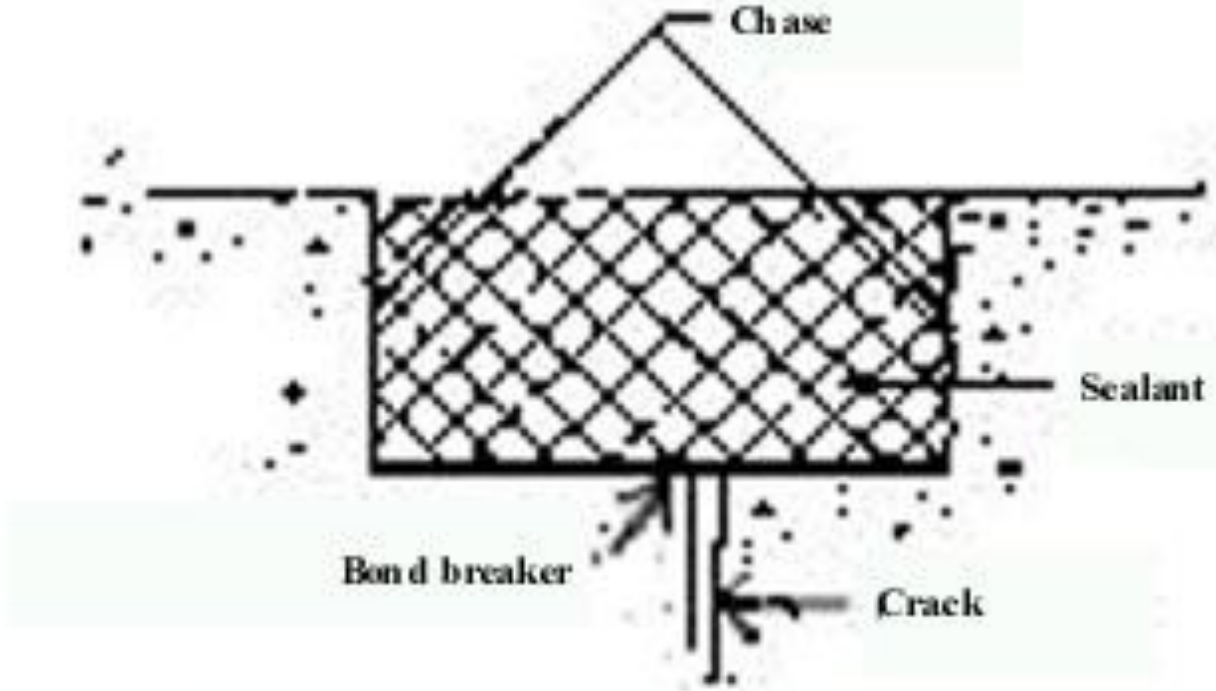


Fig. 6 Sealed chase

7. Use of overlays

- Sealing of an active crack by use of an overlay requires that the overlay be extensible and not flexible alone

- Accordingly, an overlay which is flexible but not extensible, ie. can be bent but cannot be stretched, will not seal a crack that is active

- Gravel is typically used for roofs
- concrete or brick are used where fill is to be placed against the overlay
- An asphalt block pavement also works well where the area is subjected to heavy traffic

Repairing spalling and disintegration

- In the repair of a structure showing spalling and disintegration, it is usual to find that there have been substantial losses of section and/or pronounced corrosion of the reinforcement
- Both are matters of concern from a structural viewpoint, and repair generally involves some urgency and some requirement for restoration of lost strength

1. Jacketing

- primarily applicable to the repair of deteriorated columns, piers and piles
- Jacketing consists of restoring or increasing the section of an existing member, principally a compression member, by encasement in new concrete
- The form for the jacket should be provided with spacers to assure clearance between it and the existing concrete surface

- The form may be temporary or permanent and may consist of timber, wrought iron, precast concrete or gauge metal, depending on the purpose and exposure

- Timber, Wrought iron Gauge metal and other temporary forms can be used under certain conditions

- Filling up the forms can be done by pumping the grout, by using prepacked concrete, by using a tremie, or, for subaqueous works, by dewatering the form and placing the concrete in the dry

- The use of a grout having a cement-sand ratio by volume, between 1:2 and 1:3 , is recommended
- The richer grout is preferred for thinner sections and the leaner mixture for heavier sections
- The forms should be filled to overflowing, the grout allowed to settle for about 20 minutes, and the forms refilled to overflowing
- The outside of the forms should be vibrated during placing of the grout

2. Guniting

- Gunite is also known as shotcrete or pneumatically applied mortar
- It can be used on vertical and overhead, as well as on horizontal surfaces and is particularly useful for restoring surfaces spalled due to corrosion of reinforcement
- Gunite is a mixture of Portland cement, sand and water, shot into the place by compressed air

- Sand and cement are mixed dry in a mixing chamber, and the dry mixture is then transferred by air pressure along a pipe or hose to a nozzle, where it is forcibly projected on to the surface to be coated

- Water is added to the mixture by passing it through a spray injected at the nozzle

- The flow of water at the nozzle can be controlled to give a mix of desired stiffness, which will adhere to the surface against which it is projected

3. Prepacked concrete

- This method is particularly useful for carrying out the repair under water and elsewhere where accessibility is a problem

- Prepacked concrete is made by filling forms with coarse aggregate and then filling the voids of the aggregate by pumping in a sand-cement grout

- Prepacked concrete is used for refacing of structures, jacketing, filling of cavities in and under structures, and underpinning and enlarging piers, abutments, retaining walls and footings
- Pumping of mortar should commence at the lowest point and proceed upward
- Placing of grout should be a smooth, uninterrupted operation

4. Drypack

- Drypacking is the hand placement of a very dry mortar and the subsequent tamping of the mortar into place, producing an intimate contact between the new and existing works

- Because of the low water-cement ratio of the material, there is little shrinkage, and the patch remains tight. The usual mortar mix is 1:2.5 to 1:3

5. Replacement of concrete

- This method consists of replacing the defective concrete with new concrete of conventional proportions, placed in a conventional manner
- This method is a satisfactory and economical solution where the repair occurs in depth (at least beyond the reinforcement), and where the area to be repaired is accessible
- This method is particularly indicated where a water-tight construction is required and where the deterioration extends completely through the original concrete section

- **Overlays**
- In addition to seal cracks, an overlay may also be used to restore a spalled or disintegrated surface
- Overlays used include mortar, bituminous compounds, and epoxies
- They should be bonded to the existing concrete surface

- When repairing cracks, do not fill the crack with new concrete or mortar
- A brittle overlay should not be used to seal an active crack
- The restraints causing the cracks should be relieved, or otherwise the repair must be capable of accommodating future movements

- Cracks should not be surface-sealed over corroded reinforcement, without encasing the bars

- The methods adopted for repairing spalling and disintegration must be capable of restoring the lost strength

Strengthening of an existing reinforced concrete structure

- **The owner of a residential building wanted to convert his building to a commercial building.**
- **According to change in the use of existing structure, the structural system of the building will be modified to fit the new changes.**
- **PROBLEM: The old building cannot carry the new loads that come from the changes.**
- **DESIGN BRIEF : Design a strengthening system that can increase the capacity of the existing structural system to be able to carry the new loads that come from the changes.**

Problems Facing Reinforced Concrete Structures

- Load increases.
- Damage to structural parts.
- Improvements in suitability for use.
- Modification of structural system.
- Errors in planning or construction.

STRENGTHENING REINFORCED CONCRETE STRUCTURES BY BONDING STEEL PLATES:

- **Strengthening** is the process of adding capacity to a member of structure.

- **Attachment of steel to concrete:**

1. Adhesive connecting mechanism.
2. Bolting connecting mechanism.

Explanatory Sketch

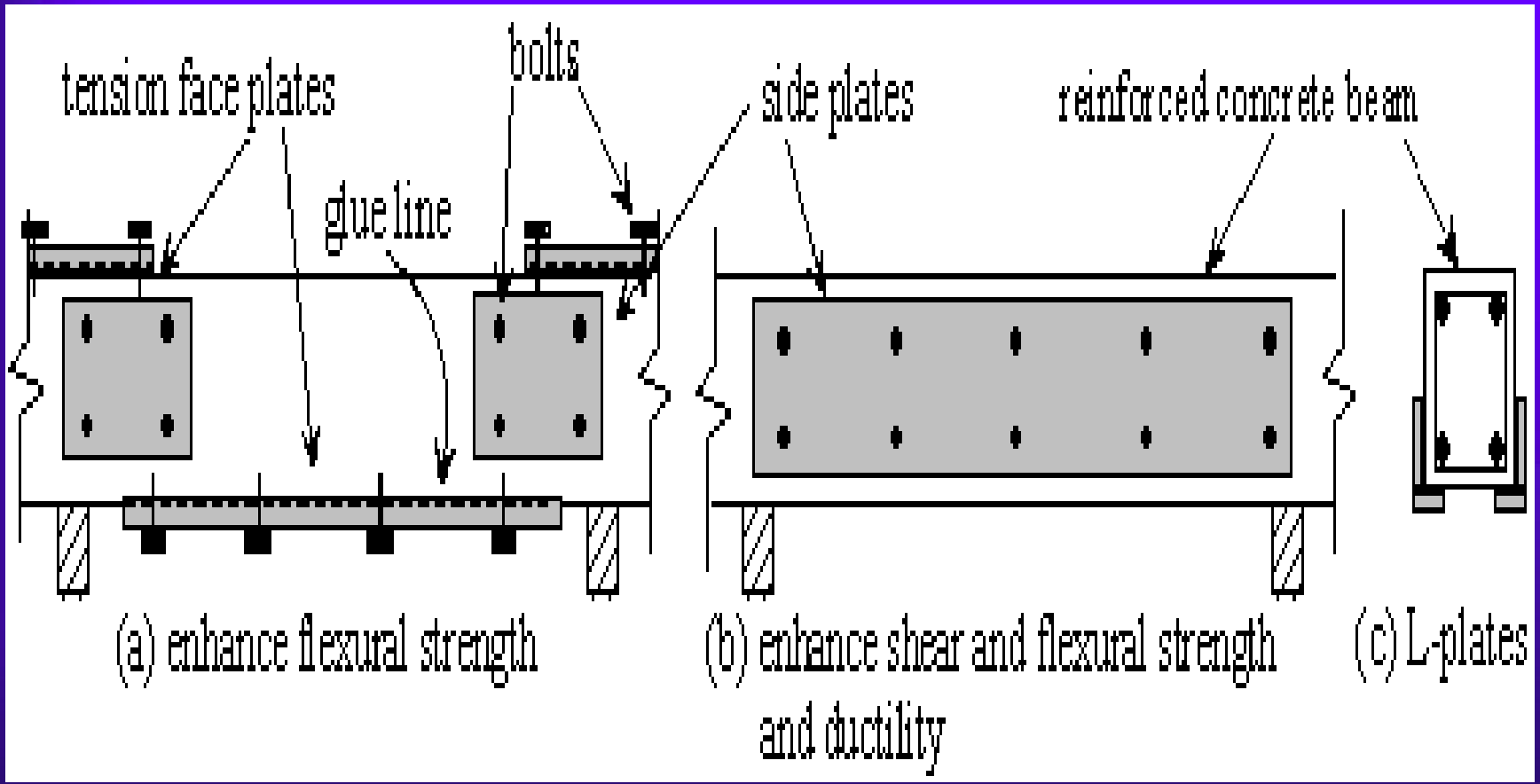


Fig. 1 Techniques of plating reinforced concrete beams.

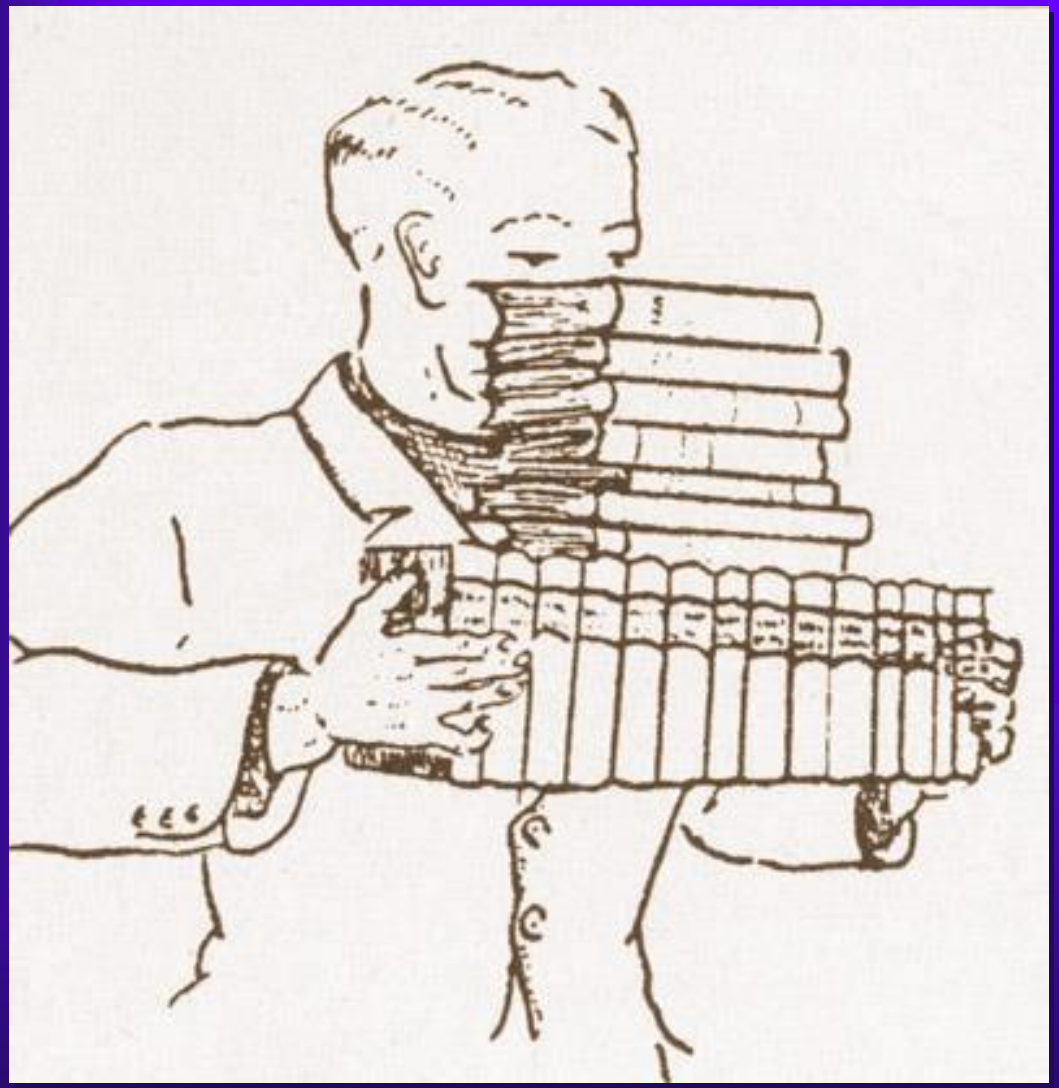
STRENGTHENING REINFORCED CONCRETE STRUCTURES BY PRESTRESSING CABLES:

- **Post-tensioning** is a technique used to prestress reinforced concrete after concrete is placed.
- The tensioning provides the member with an immediate and active load-carrying capability.

GROWTH IN THE DEMAND FOR PRESTRESSED CONCRETE BRIDGES

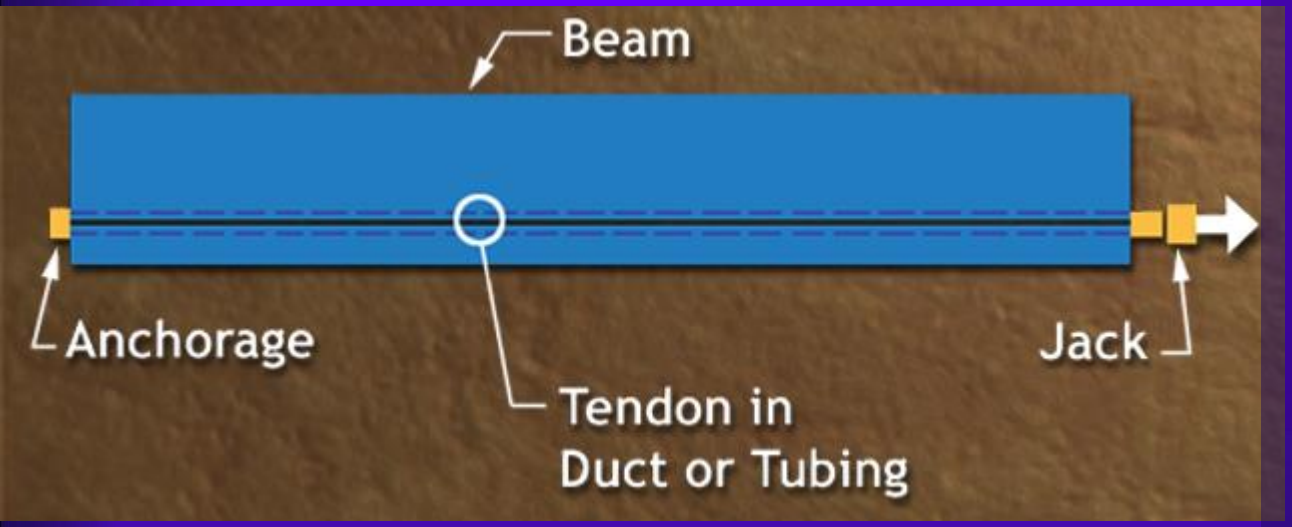
- One was Professor Gustav Mangel from the University of Ghent in Belgium.
- He described the concept of pre-compressed concrete to his students using his well-known illustration of a stack of books…

GROWTH IN THE DEMAND FOR PRESTRESSED CONCRETE BRIDGES



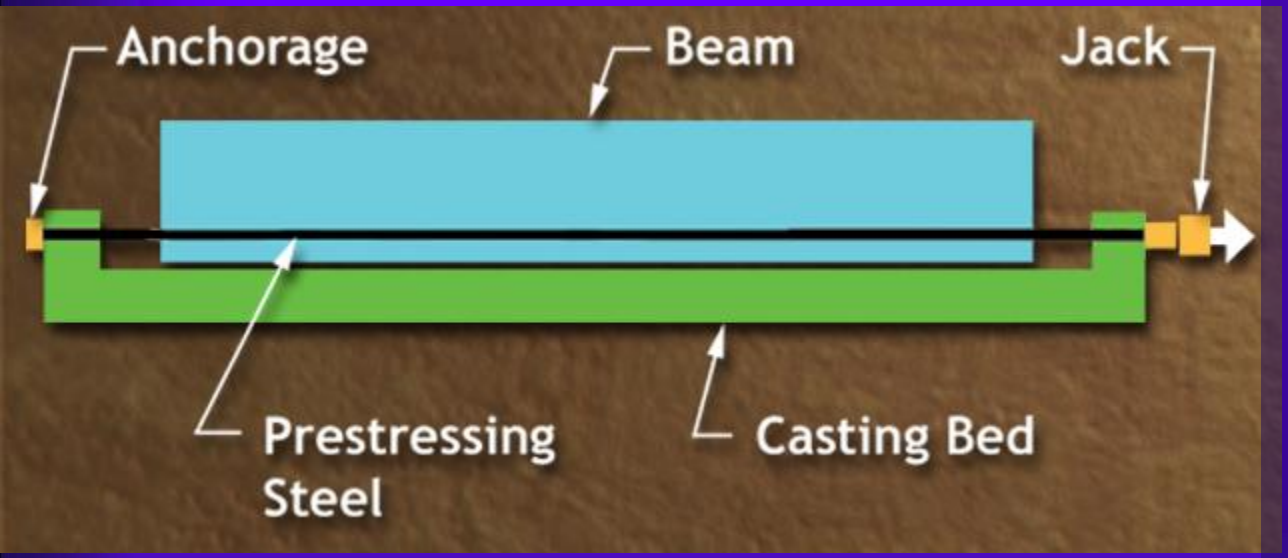
- The books on the bottom are like pre-compressed concrete: using a compressive force, they support their own weight… plus significant superimposed loads, represented by the books on top.

GROWTH IN THE DEMAND FOR PRESTRESSED CONCRETE BRIDGES



- The combination of high strength steel – to resist tensile stress – and concrete – to provide compressive strength and durability – make this composite material adaptable to many situations, especially the design and construction of bridges.

GROWTH IN THE DEMAND FOR PRESTRESSED CONCRETE BRIDGES



- A number of technological innovations followed the success of the Walnut Lane Bridge, including the establishment of precasting plants and in-plant pretensioning…

GROWTH IN THE DEMAND FOR PRESTRESSED CONCRETE BRIDGES

- … and the development of 7-wire strand to replace individual wires.

GROWTH IN THE DEMAND FOR PRESTRESSED CONCRETE BRIDGES

Long-Line Casting Beds

Permanent Steel Forms

Admixtures

High Early-Strength Concrete

Accelerated Curing

- Other early innovations included long-line casting beds; high-quality, permanent steel forms; specialized chemical admixtures; high early-strength concrete; accelerated curing with heat; and more…

External Post-tensioned picture

The advantages of External Prestressing

- Ability to restress, destress and exchange any external prestressing cable.
- Crack free members.
- Reduce deflection.
- High fatigue and impact resistance.

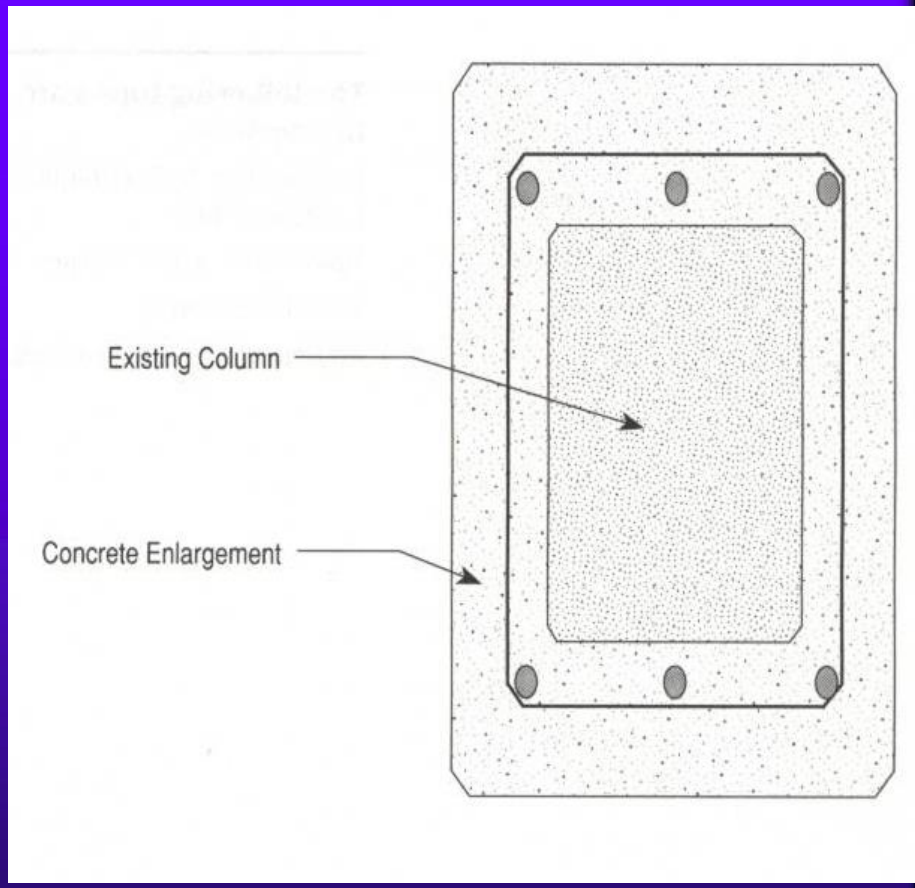
The Disadvantages of External Prestressing

- Usually requiring a greater section depth.
- More exposed to environmental influences (fire, vandalism, aggressive chemicals etc.).
- Handling of the tensioning devices may be more difficult.
- High cost.

Concrete Jackets (Section Enlargement)

Concrete Jackets (Section Enlargement)

- Enlargement is the placement of additional concrete and reinforcing steel on an existing structural member.
- Beams, slabs, columns, and walls, if necessary, can be enlarged to add stiffness or load-carrying capacity.

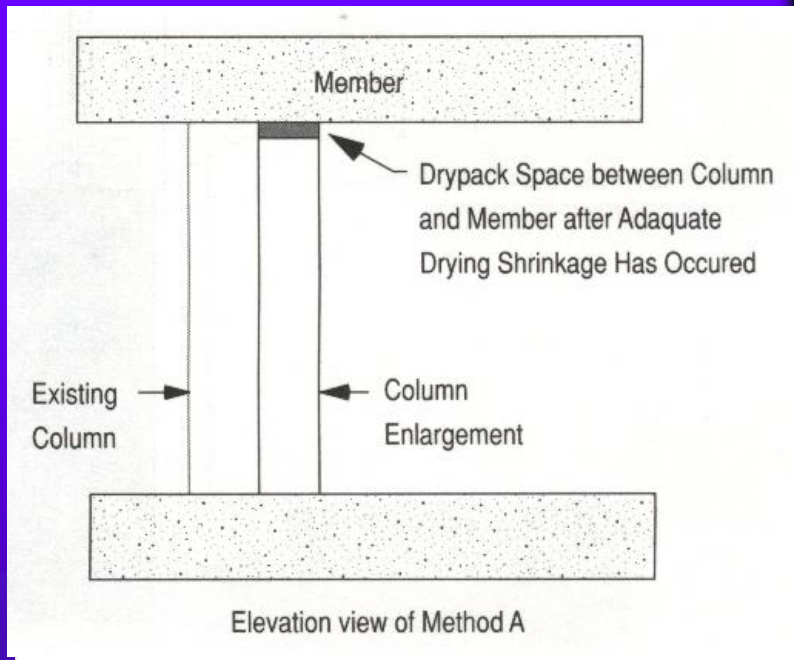


Concrete Jackets

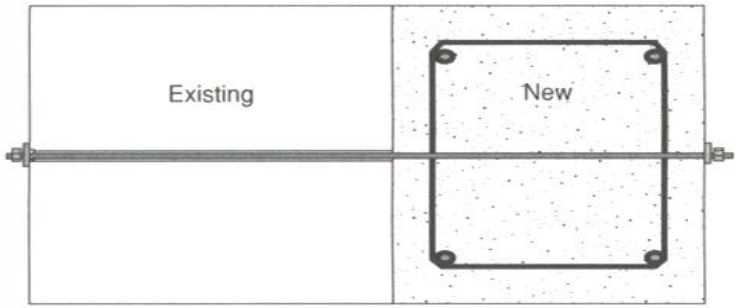
- In most cases, the enlargement must be bonded to the existing concrete to create a monolithic member for additional shear or flexural capacity.

Column Compressive strengthening by Section Enlargement

- Enlarging the cross section of an existing column will strengthen the column by increasing its load carrying capacity.
- A column can be enlarged in various configurations.
- The drying shrinkage effects in the concrete used to enlarge the column must be considered.



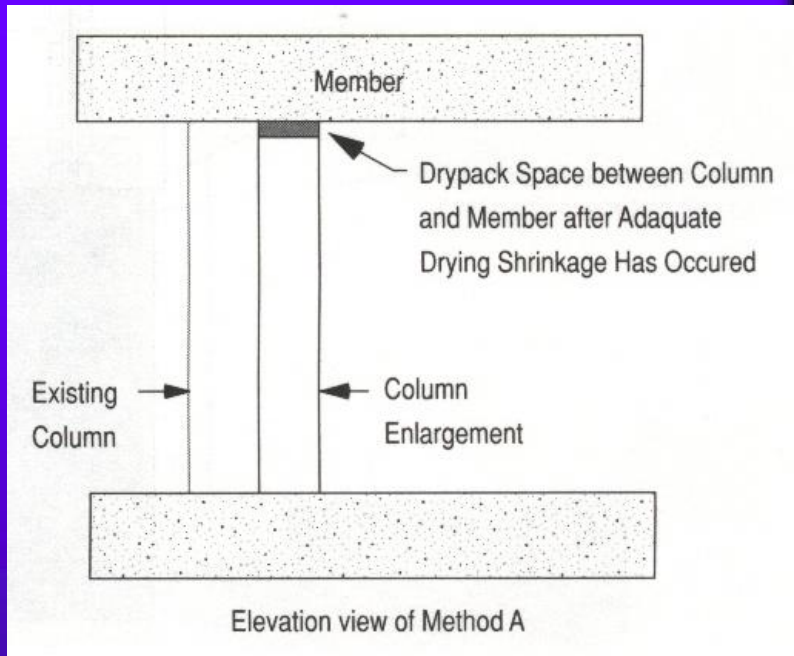
Elevation view of Method A



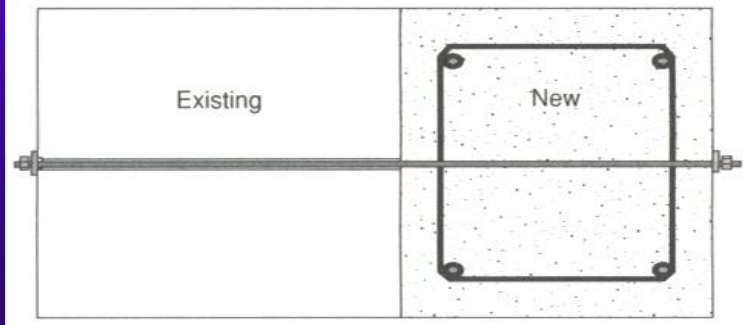
Method A

Section Enlargement Method A

- In the illustration, Method A will accomplish efficient load transfer if the new portion is cast with a bond breaker between the new and old concrete.
- After most of the drying shrinkage has occurred, the ties that link the old and new concrete can be installed.



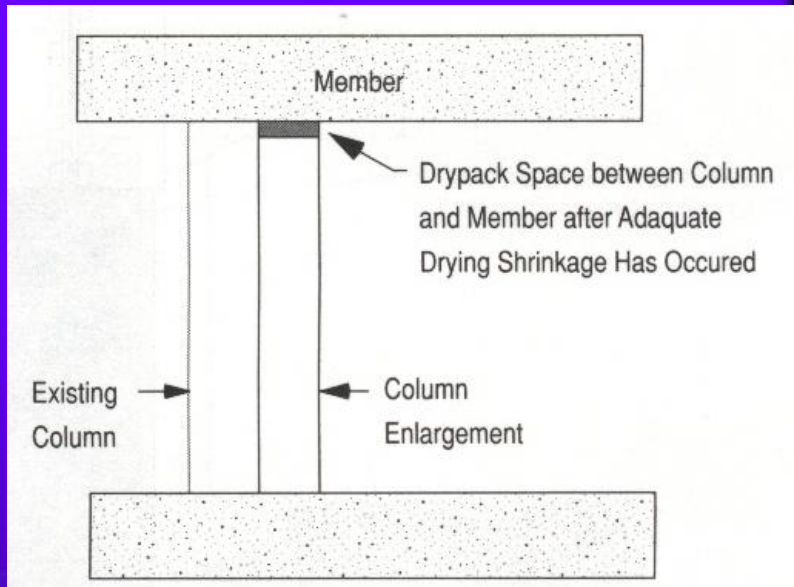
Elevation view of Method A



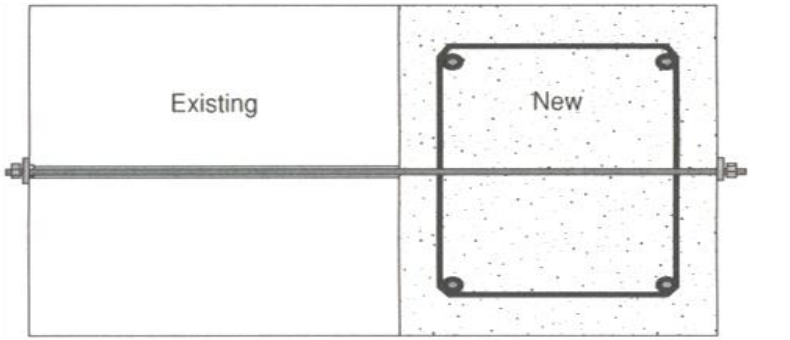
Method A

Section Enlargement Method A

- The gap between the new portion of the column and the existing member (to be partially supported by this column) can be filled with dry packing material.
- This will allow the new material to share its portion of the load.



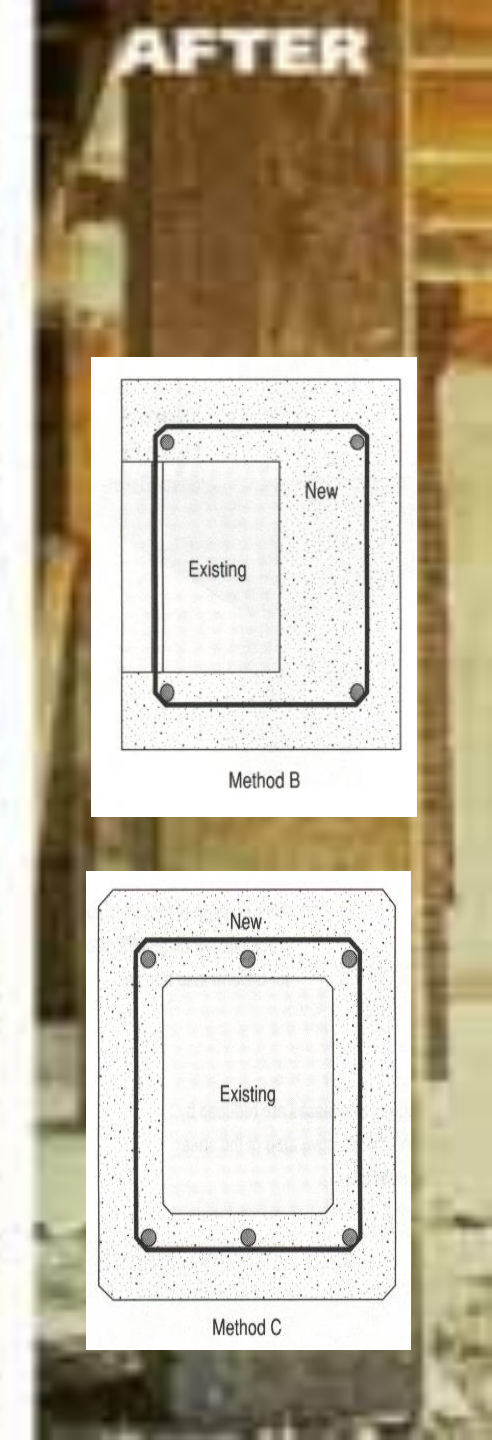
Elevation view of Method A



Method A

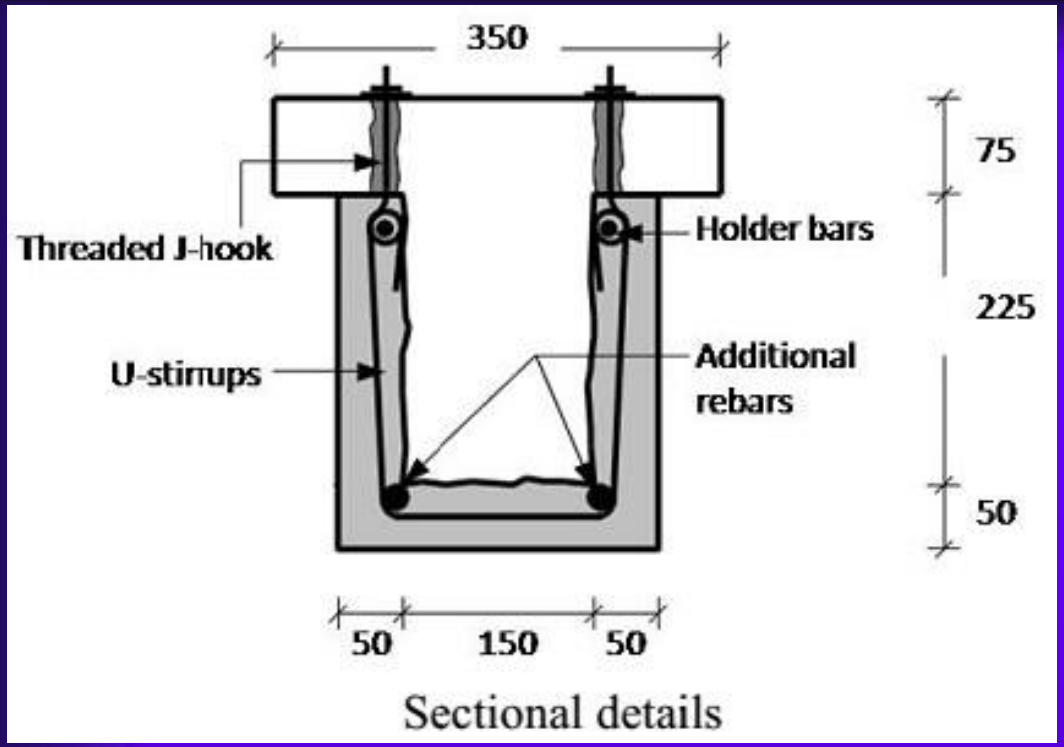
Section Enlargement Methods B & C

- When Methods B and C are used, extreme care should be exercised to select concrete mix designs with very low shrinkage rates.
- Pre placed aggregate concrete generally offers the lowest drying shrinkage; it is, therefore, an excellent material for column enlargements.



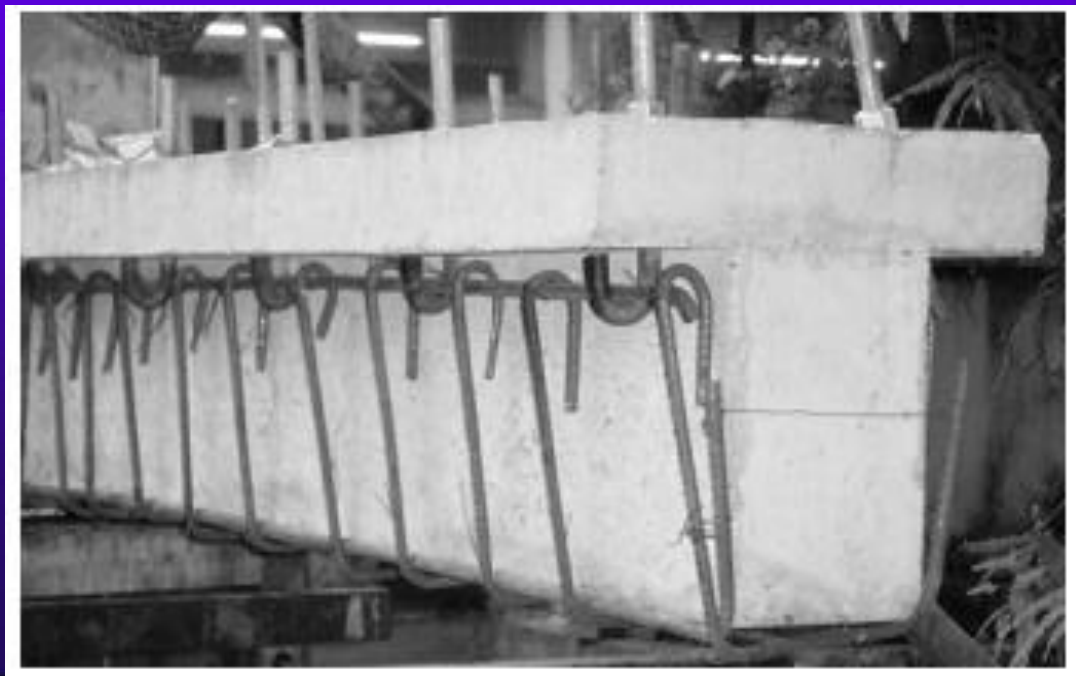
Disadvantages of the concrete jackets

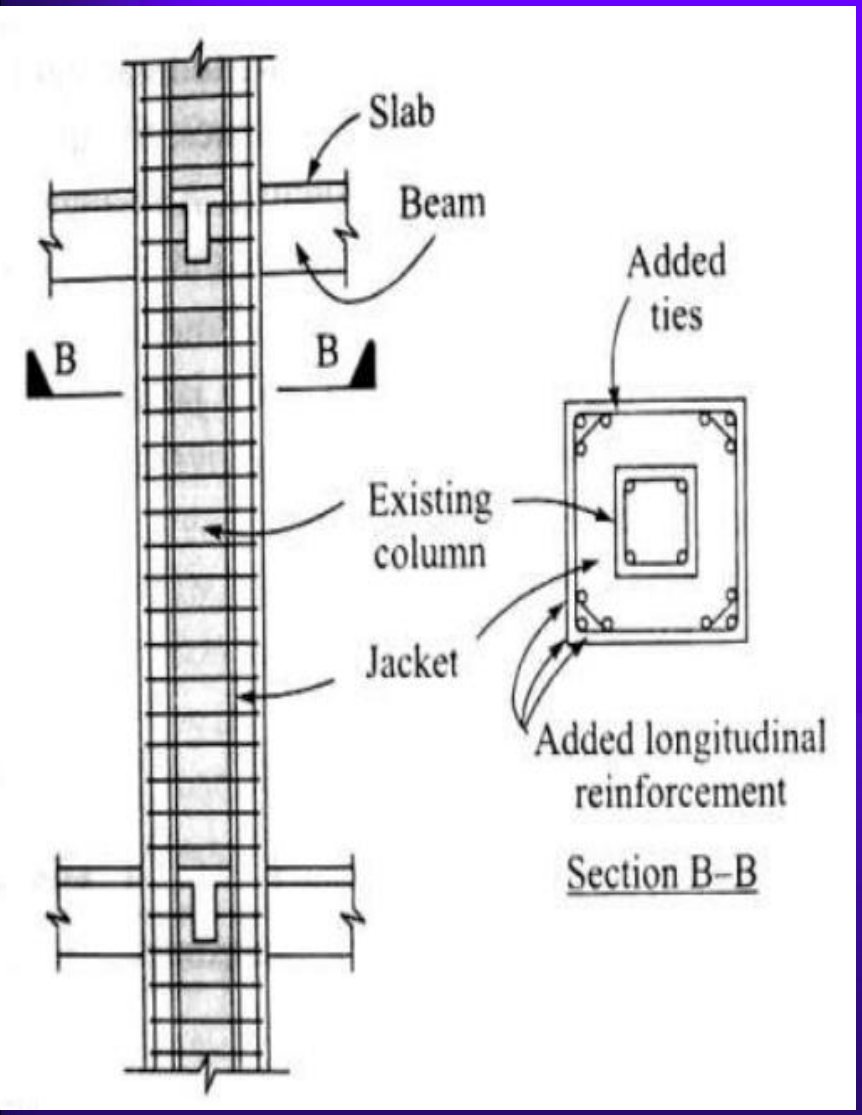
- Increasing the size of the element, which make its usage very limited.
- Difficult to construct in some active buildings such as hospitals, schools because of the noise of equipments.
- Needs shuttering, formworks, reinforced steel, concrete, concrete pumps, vibrators, …etc.



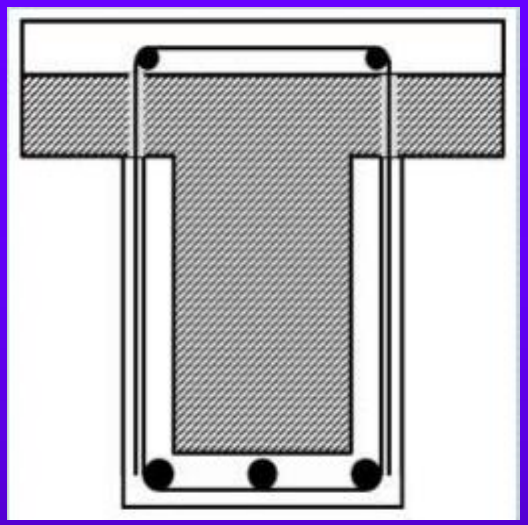
Sectional details

Reinforcement cage for the Concrete jacketing





Column Jacketing



Beam Jacketing

Fiber Reinforced Polymer

DEFINITION

Fiber Reinforced Polymer (FRP) Composites are defined as:

"A matrix of polymeric material that is reinforced by fibers or other reinforcing material"

Fiber Reinforced Polymer (FRP)

- FRP is a new class of composite material for the development and repair of new and deteriorating structures in Civil Engineering.
- Search for alternatives to Steel and alloys to combat the high costs of repair and maintenance of structures damaged by corrosion and heavy use.

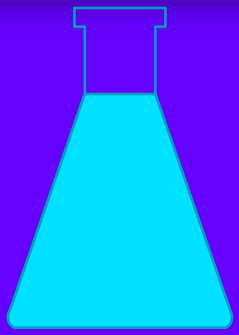
FRP Laminate Structure

- FRPs are organized in a laminate structure.
- each lamina (flat layer) contains an arrangement of unidirectional fibers fabrics embedded within a thin layer of light polymer matrix material.
- FRP consists of two main components:
  1. Fibers.
  2. Resin or Matrix.

FRP COMPOSITE CONSTITUENTS

- RESINS (POLYMERS)
- REINFORCEMENTS
- FILLERS
- ADDITIVES

MATERIALS: RESINS

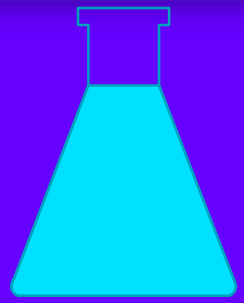


- PRIMARY FUNCTION:

  "TO TRANSFER STRESS BETWEEN REINFORCING FIBERS AND TO PROTECT THEM FROM MECHANICAL AND ENVIRONMENTAL DAMAGE"

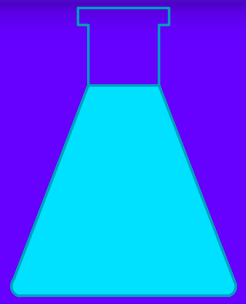
- TYPES:
  - THERMOSET
  - THERMOPLASTIC

RESINS



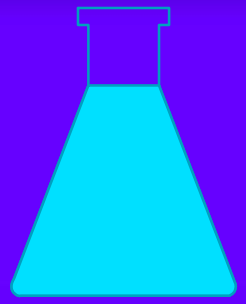
- THERMOSET
  - POLYESTER
  - VINYL ESTER
  - EPOXY
  - PHENOLIC
  - POLYURETHANE

RESINS



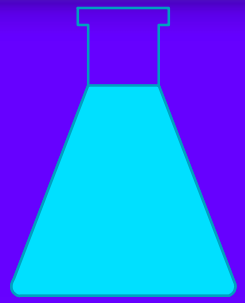
- THERMOPLASTIC
  - ACETAL
  - ACRYRONITRILE BUTADIENE STYRENE (ABS)
  - NYLON
  - POLYETHYLENE (PE)
  - POLYPROPYLENE (PP)
  - POLYETHYLENE TEREPHTHALATE (PET)

RESINS



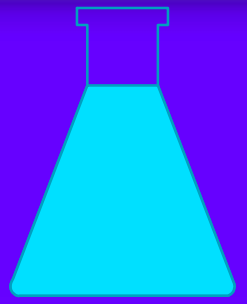
- THERMOSET ADVANTAGES
  - THERMAL STABILITY
  - CHEMICAL RESISTANCE
  - REDUCED CREEP AND STRESS RELAXATION
  - LOW VISCOSITY- EXCELLENT FOR FIBER ORIENTATION
  - COMMON MATERIAL WITH FABRICATORS

RESINS



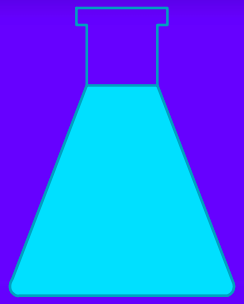
- THERMOPLASTIC ADVANTAGES
  - ROOM TEMPERATURE MATERIAL STORAGE
  - RAPID, LOW COST FORMING
  - REFORMABLE
  - FORMING PRESSURES AND TEMPERATURES

POLYESTERS



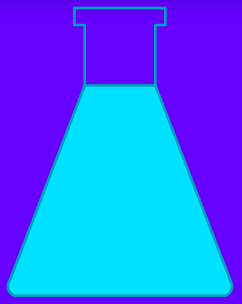
- LOW COST
- EXTREME PROCESSING VERSATILITY
- LONG HISTORY OF PERFORMANCE
- MAJOR USES:
  - Transportation
  - Construction
  - Marine

VINYL ESTER



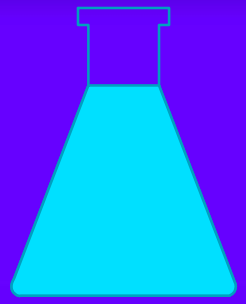
- SIMILAR TO POLYESTER
- EXCELLENT MECHANICAL & FATIGUE PROPERTIES
- EXCELLENT CHEMICAL RESISTANCE
- MAJOR USES:
  - Corrosion Applications - Pipes, Tanks, & Ducts

EPOXY



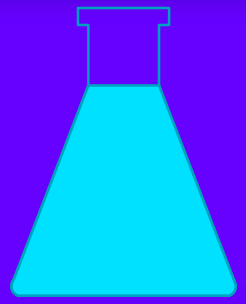
- EXCELLENT MECHANICAL PROPERTIES
- GOOD FATIGUE RESISTANCE
- LOW SHRINKAGE
- GOOD HEAT AND CHEMICAL RESISTANCE
- MAJOR USES:
  - FRP Strengthening Systems
  - FRP Rebars
  - FRP Stay-in-Place Forms

PHENOLICS



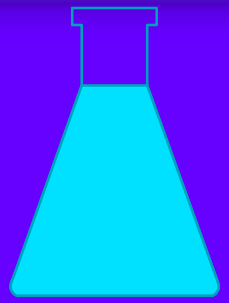
- EXCELLENT FIRE RETARDANCE
- LOW SMOKE & TOXICITY EMISSIONS
- HIGH STRENGTH AT HIGH TEMPERATURES
- MAJOR USES:
  - Mass Transit - Fire Resistance & High Temperature
  - Ducting

POLYURETHANE



- TOUGH
- GOOD IMPACT RESISTANCE
- GOOD SURFACE QUALITY
- MAJOR USES:
  - Bumper Beams, Automotive Panels

SUMMARY: POLYMERS



- WIDE VARIETY AVAILABLE
- SELECTION BASED ON:
  - PHYSICAL AND MECHANICAL PROPERTIES OF PRODUCT
  - FABRICATION PROCESS REQUIREMENTS

MATERIAL: FIBER REINFORCEMENTS

- PRIMARY FUNCTION:

  "*CARRY LOAD ALONG THE LENGTH OF THE FIBER, PROVIDES STRENGTH AND OR STIFFNESS IN ONE DIRECTION*"

- CAN BE ORIENTED TO PROVIDE PROPERTIES IN DIRECTIONS OF PRIMARY LOADS

REINFORCEMENTS

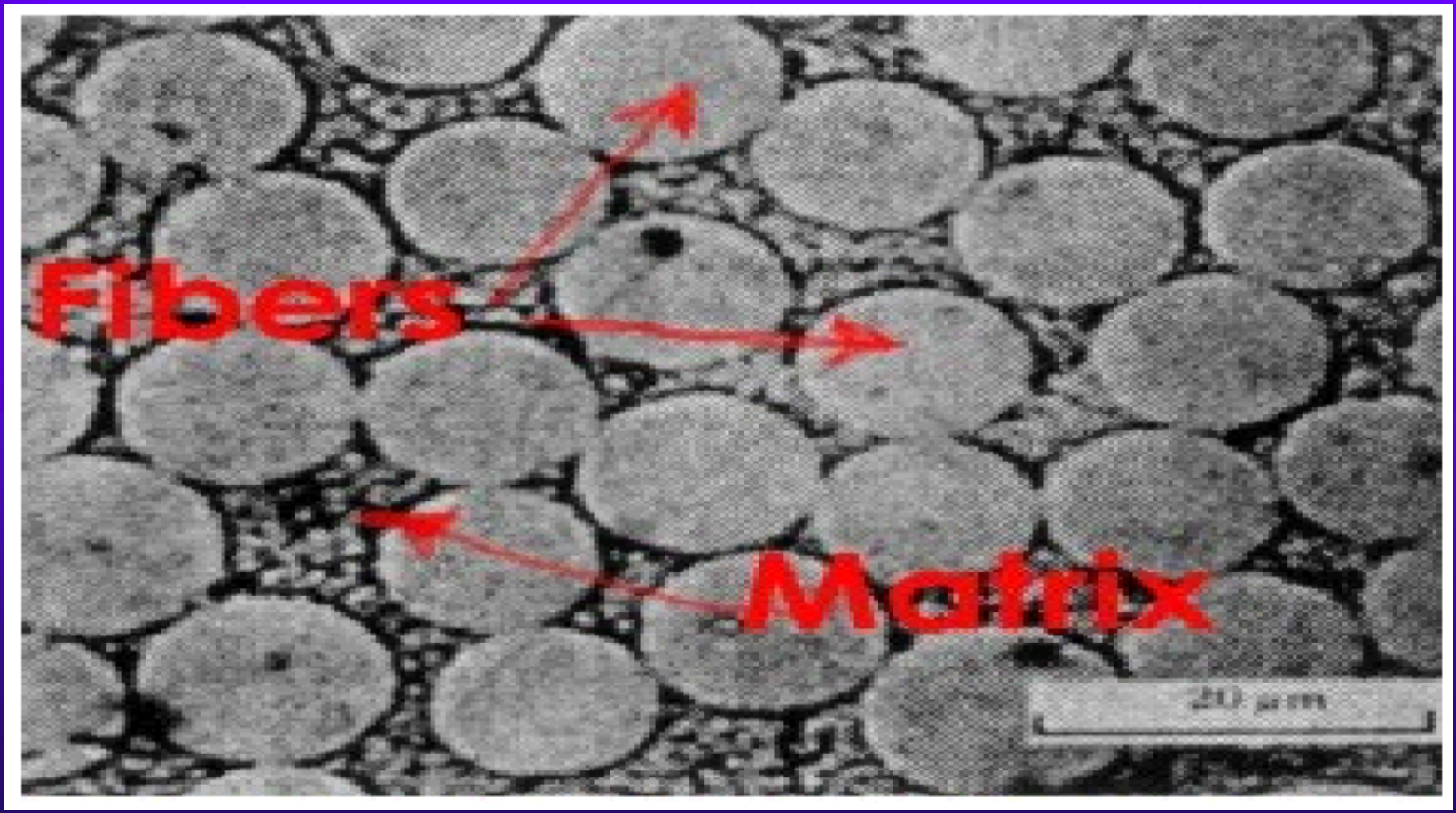
- NATURAL
- MAN-MADE
- MANY VARIETIES COMMERCIALLY AVAILABLE

MAN-MADE FIBERS

- ARAMID
- BORON
- CARBON/GRAPHITE
- GLASS
- NYLON
- POLYESTER
- POLYETHYLENE
- POLYPROPYLENE

FIBER PROPERTIES
DENSITY (g/cm^3)

FRP Laminate Structure



Types of FRP

The three main types of fibers used are:

- Carbon.
- Glass.
- Aramid.

Suitability of FRP for Uses in Structural Engineering

- FRP properties and advantages makes it ideal for wide spread applications in construction worldwide.
- FRP has a few disadvantages.

Advantages of FRP:

- Corrosion Resistance.
- Lightweight.
- Ease of installation.
- Less Finishing.
- Less maintenance.
- Ductility of FRP wrapped members improves dramatically.
- They are ideal for external application.

Advantages of FRP

- They are extremely durable.
- They are available in various forms: sheets, plates, fabric, etc.
- They are available in long lengths that eliminates joints and splices.
- They cure within 24 hours.
- Versatility.
- Anti-seismic behavior.

Disadvantages of FRP

- High cost, susceptibility to deformation under long-term loads
- Temperature and moisture effects, lack of design codes, and most importantly, lack of awareness.

Decision

Steel plates	Concrete jacketing	FRP
High Corrosion	Medium Corrosion	Corrosion resistance
Low Cost	High Cost	High Cost
High Installation cost	High Installation cost	Ease of installation.
more Maintenance	more Maintenance	Less Maintenance
Heavy Weight	Heavy Weight	light Weight

CONSTRUCTION PROCESS

- Typical RC Beam in Need for Repair
  - corroded steel
  - spalling concrete

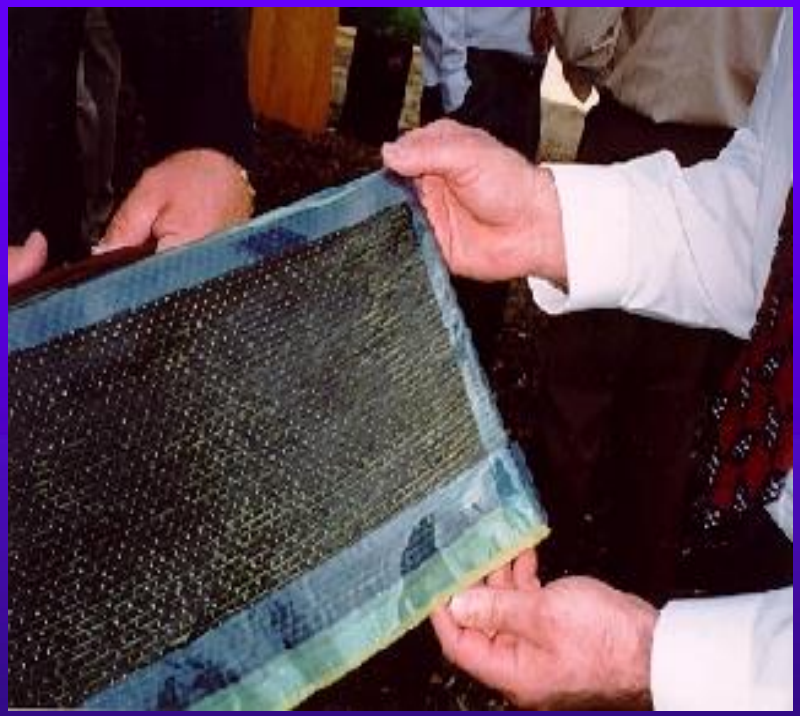
CONSTRUCTION PROCESS

- Deteriorated Column / Beam Connection

CONSTRUCTION PROCESS

- **Concrete Surface Preparation**
  - **Smooth, free of dust and foreign objects, oil, etc.**
  - **Application of primer and putty (if required by the manufacturer)**

CONSTRUCTION PROCESS



- **Preparation of the FRP Composites for Application**
  - **Follow manufacturer's recommendations**

CONSTRUCTION PROCESS

- Priming of the Concrete Surface
- Application of the Undercoating epoxy Layer (adhesive when FRP pultruded laminates are used)

CONSTRUCTION PROCESS

- Application of CFRP Fiber Sheet on a Beam- Wet Lay-Up Process
- Similar for Application of Pultruded Laminates

CONSTRUCTION PROCESS

- Column Wrapping with Automated FRP Application device

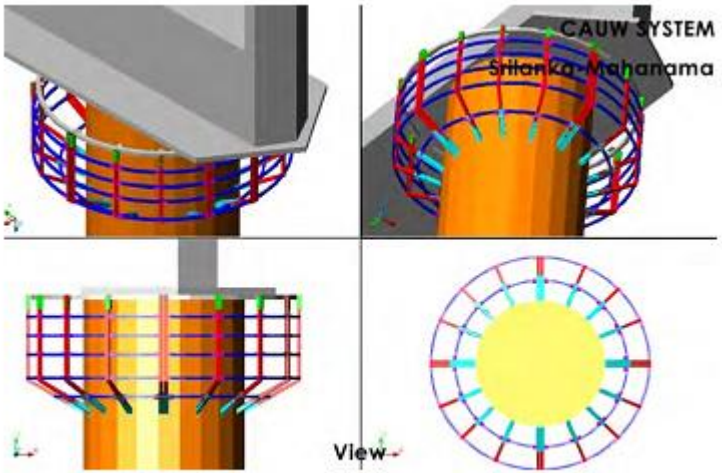
CONSTRUCTION PROCESS

- Robo Wrapper by Xxsys Technologies

CONSTRUCTION PROCESS

- Column Wrapping Device

Repair and Retrofit method



1. Design cofferdam

2. Installation cofferdam

3. Scaling and cracks

4. Rehabilitation

5. After GFRP application

Steel encasement for foundation

Sheet pile protection for foundation

FRP encasement for foundation

FRP Application procedure underwater

Crack Repair

1. Clean

2. Check crack

3. Sealing with UW epoxy

4. Installation packer

5. Injection UW epoxy

6. Surface grinding

Rehabilitation for Erosion and corrosion

1. Erosion and corrosion problems

2. Dry Shotcrete application

3. GFRP application

4. After coating

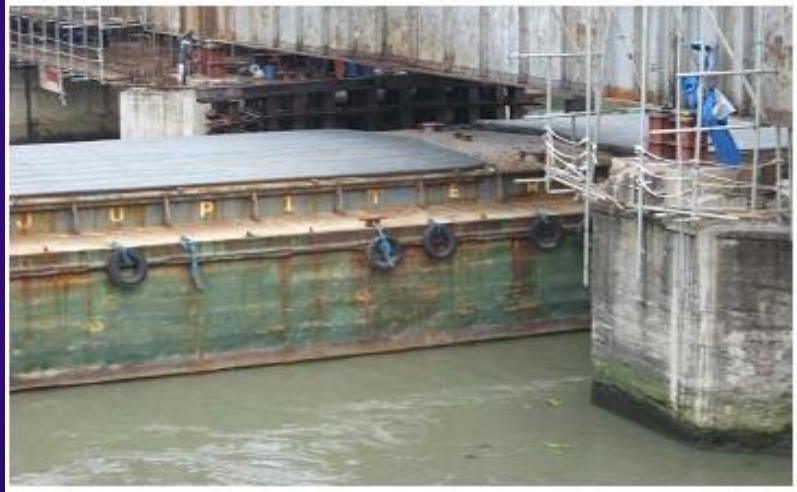
1. Railway bridges without maintenance

2. Pier #2 was broken by ship

3. Wire-saw underwater cutting

4. After rehabilitation

Before



After 1m raised up

1. Jetty

2. Rebar corrosion

3. Strengthening with GFRP

4. After

1. Before construction

2. Surface treatment

3. Priming

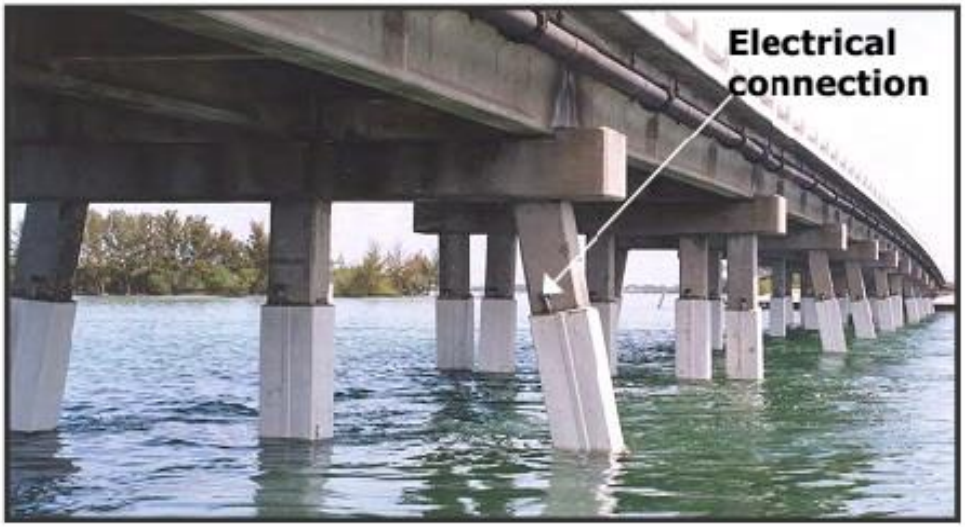
4. FRP Installation

5. Completion

Before

Rebar & FRP
Form Installation

Grout with Conductive
Mortar

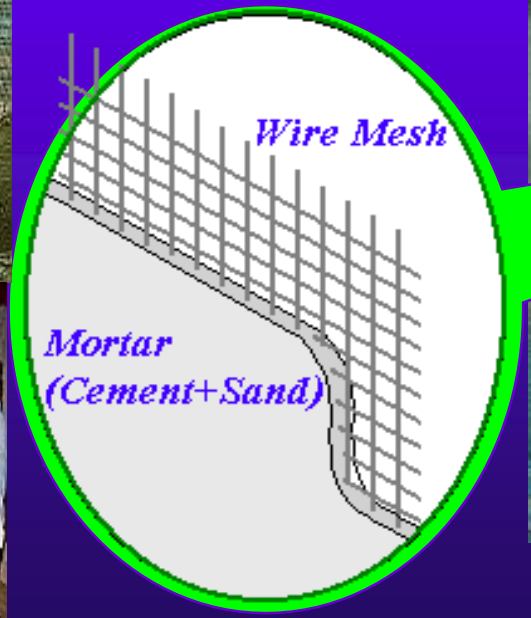


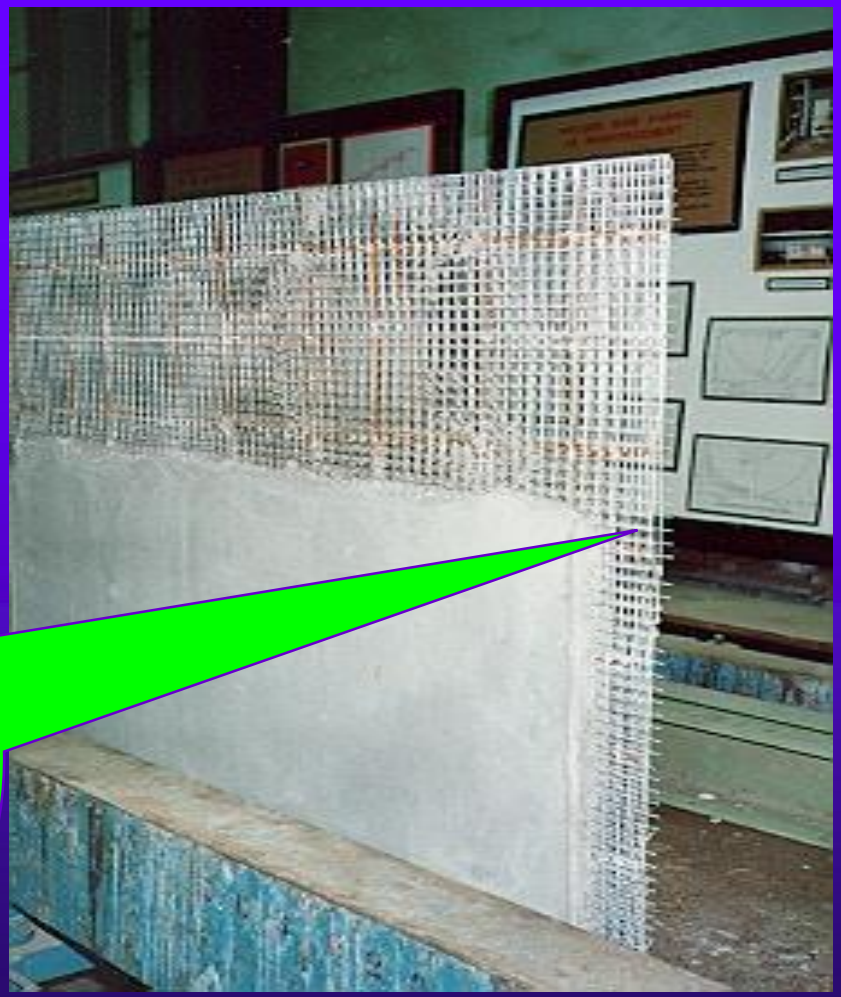
Zinc mesh is used
as sacrificial
anode


before
after

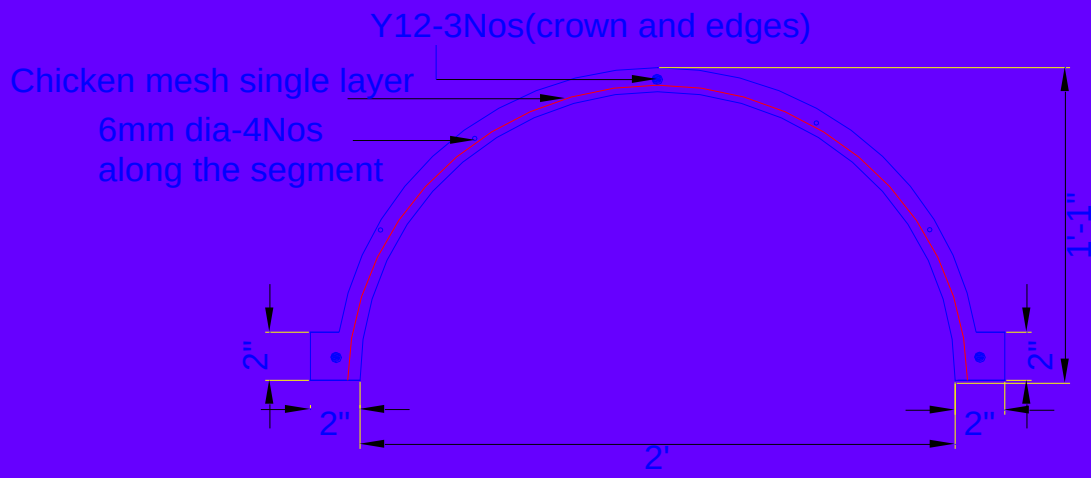
Ferrocement

A type of thin composite material made of *cement mortar* (cement + sand) reinforced with uniformly distributed layers of continuous and relatively *small diameter wire meshes*





FERRO-CEMENT CHANNEL ROOFING OF MUD MORTER HOUSING UNIT

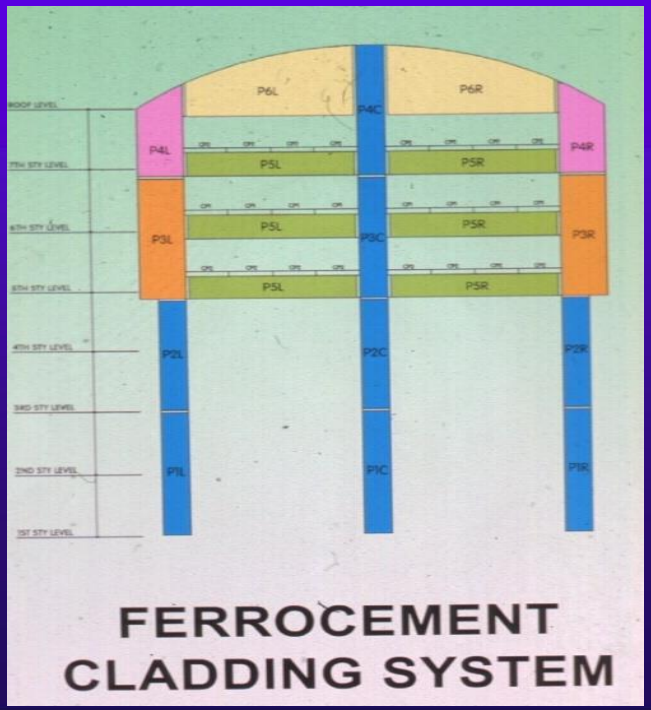


Cross Section of Ferrocemnt Roofing Channel

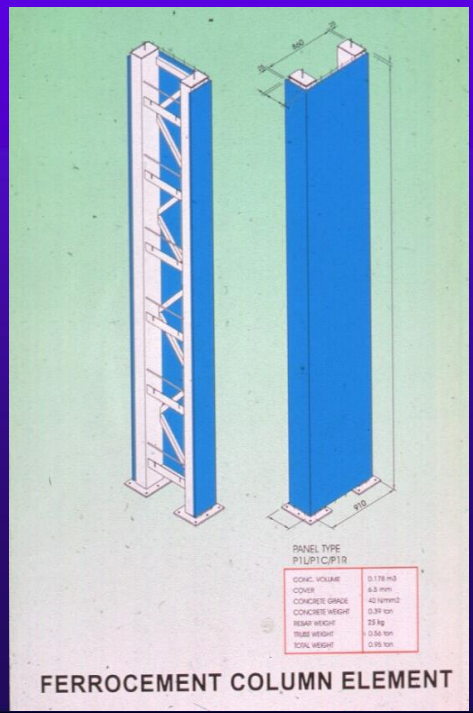
Ferro cement Roofing Channels

- 30% cost saving over RCC roofing
- Lower dead load on the walls
- Usable as an intermediate floor
- High strength to weight ratio
- Elegant profile and uniform sites

Secondary Roofing Slabs



FERROCEMENT CLADDING SYSTEM



FERROCEMENT COLUMN ELEMENT

New appearance of a typical block after upgrading

Current Epoxy Floor Application

Concrete Pour

Wait 28 Days

Shot Blast

Prime Floor and Topcoat

What If…

Concrete Pour

Wait 28 Days

Prime Floor and Topcoat

Shot Blast