Methods of Repair

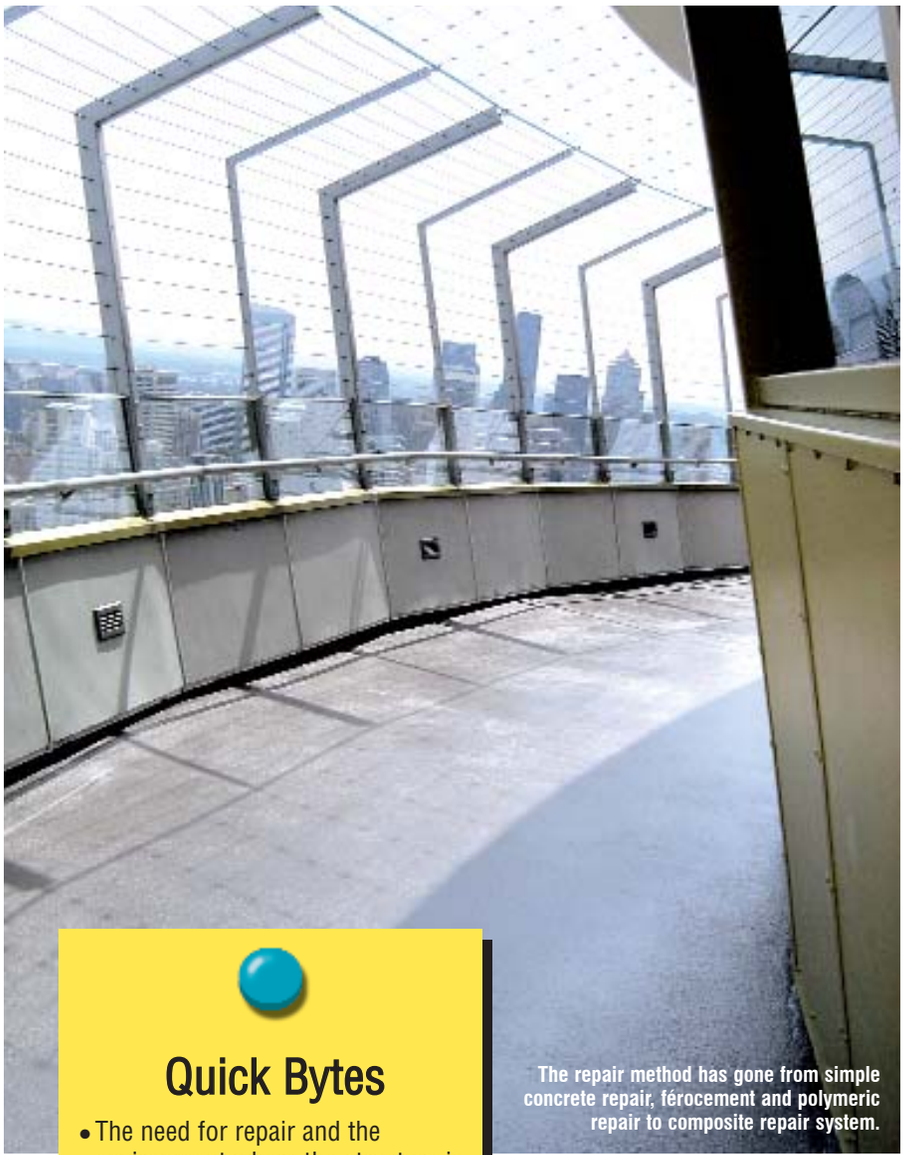
SURESH CHANDRA PATTANAIK and RP GARG undertake a comparison of fibre-reinforced composites (FRC) and fibre-reinforced polymers (FRPs) with other repair materials for deteriorated concrete structures.

All concrete structures deteriorate with time, a process that becomes much faster in aggressive environmental conditions. Broadly, methods to repair them can be classified under structural repair and non-structural repair. Structural repair is carried out by repair, renovation and retrofitting of the entire system as a whole for structural strengthening to carry additional loads or for seismic retrofitting. FRP wrapping, introduction of shear walls and external bracing are some of the methods used for structural strengthening. Non-structural repairs are carried out to repair and restore the damaged members of the structure to increase service life. Repair of column or ceiling of slab owing to spalling of concrete is an example of localised repair.

Making a choice

However, choosing the right material

The compressive strength of the column and flexural strength of the beam can be improved by using wraps.



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Quick Bytes

- The need for repair and the environment where the structure is located have to be clearly understood before opting for a particular repair system.
- Modulus of elasticity and bond strength are the two most important properties for durability of concrete repair.
- Fibre-reinforced composites of cement, cementitious material or polymer are being widely used for structural strengthening.
- The use of polymeric material has become very successful for repair, restoration and retrofitting of concrete structures. But for structural rehabilitation and strengthening, FRCs have proven to be more effective.

and methodology for deteriorated concrete structures depends upon serviceability and application conditions. The most important factors to be considered for durability of repair material are compatibility with existing concrete and method of application. The compatibility of repair material with existing substrate may be chemical and electrochemical compatibility and dimensional compatibility. The dimensional compatibility may be of drying shrinkage, elastic modulus, coefficient of thermal expansion, etc.

Modulus of elasticity and bond strength are the two most important properties for durability of concrete repair. Sometimes higher compressive strength of repair material leads to reversal of stresses causing failure of the original concrete. Spalled and disintegrated concrete can be repaired by any suitable compatible material. But structural repair has to be properly designed along with failure diagnosis.

The repair method has gone from simple concrete repair, férocement and polymeric repair to composite repair system. Fibre-reinforced composites (FRCs) of cement, cementitious material or polymer are being widely used for repair and structural strengthening and retrofitting of structures owing to their higher corrosion resistance, ultimate strength and modulus of elasticity unaffected by electromechanical deterioration and light weight. But it has become very difficult to choose the right material and methodology on the part of repair structural consultants. A comparison of properties of FRCs with other repair materials shows that FRCs are a more versatile repair material. Let's read on and see how.

Deterioration of the structure

There are many causes of deterioration: physical (cyclic freezing, thawing), chemical (acid attack, sulphate attack, alkali-aggregate reaction) and electrochemical (corrosion of steel). Of these, corrosion of steel single-handedly results in almost 90 per cent of structural deterioration. Coastal environments with high levels of carbon dioxide and humidity also contribute significantly to deterioration. Hence, it is essential to identify the cause of deterioration of the structure the way a doctor diagnoses a patient before treatment.

The need for repair and the environment where the structure is located have to be clearly understood before opting for a particular repair system. It has been observed that maximum failure of repaired structures takes place owing to improper surface preparation and wrong method of application rather than the material itself. Repair materials should be chemically and electrochemically compatible with the existing concrete. Depending upon serviceability and lifecycle cost, the right material and methodology have to be selected.

Polymeric materials

Polymer-modified mortar/concrete: Different types of polymers like liquid resins, latex, water-soluble polymers and re-dispersible powders are used in cement mortar or concrete to improve strength, adhesion and chemical resistance.

Maximum safety precautions need to be taken while applying polymer concrete.

Extremely low permeability helps against chloride and carbon dioxide ingress, offering excellent resistance to moisture ingress with shrinkage being compensated. Polymer-modified mortar can be applied to repair up to 50 mm thickness only. Strength gain at 28 days is less than normal water-cured cement mortar or cement concrete whereas 90-day strength is more because hydration or polymerisation takes place for a longer period. At the same time, epoxy-based polymer-modified mortar has better compressive and flexural strength than acrylic-based and other polymer-modified mortar. Epoxy-modified cement mortar and concrete are more suitable for highly humid conditions and industrial environments.

Polymer mortar/concrete: This matrix of liquid resin of epoxy and other polymer and fine and coarse aggregate sets quickly and has good bond, tensile, flexural and compressive strength, and good chemical resistance. It is useful for pothole repairs on highways, runways of airports, and repair of tunnel linings. It cannot be applied when temperature is below 10°C and is also very expensive. Acrylic and polyester polymer concrete are used for patch repair. Polyester resins are economical and very moisture-sensitive. Maximum safety precautions should be taken while applying polymer concrete.

Polymer impregnation: This is used for repair of fine cracks. The surface should be fully dried otherwise it will fail. This method requires skilled manpower and is not so popular.

Epoxy injection: Cracks can be repaired from 1 mm to 6 mm in width with this. Owing to its low viscosity, it can be injected deep into concrete joints, hairline cracks and fissures. It has high bond and compressive strength, no volume change and no shrinkage. It can be applied underwater to the negative side of water pressure. The only disadvantage is that it cannot be applied to moving cracks and to stop active water leakage that is possible by polyurethane resin injection.

Shotcrete: This is applied to concrete or mortar pneumatically at high velocity to the repaired surface area. It is suitable for repairing hydraulic structures, bridges, tunnels and buildings. Surface preparation is very important and highly skilled people are required for the job.

Migrating corrosion inhibitors (MCI) technology: This is gaining importance for prevention of corrosion. Inhibitor molecules migrate deep inside porous concrete and form a mono molecular film, thus preventing corrosion.

The use of polymeric material has become very successful for repair, restoration and retrofitting of concrete structures. But for structural rehabilitation and strengthening, FRCs have proven to be more effective.

Epoxy-modified cement mortar and concrete are more suitable for highly humid conditions and industrial environments.

Fibre-reinforced material

For some years now, fibre-reinforced

Fibre-reinforced cement based composites are used for pavement repair, repair of hydraulic structures, etc.

concrete — where different fibres of steel, glass and polypropylene are added along with fibre dispensers — are being used for the repair of structures. Steel fibres up to 1.5 to 2 per cent by volume are commonly used. Fibre-reinforced cement based composites are used for pavement repair, repair of hydraulic structures, etc.

Fibre-reinforced composite (FRC)

FRCs may be cement-based or polymer-based, while the latter is known as fibre-reinforced polymer (FRP) composite. Plates and wraps are used for repair and rehabilitation. Plates are used to improve the tension of the member while wraps are used for improving the compressive strength of the column and flexural strength of the beam. Commonly used fibres are glass, aramid and carbon. Epoxy resin is used to form the matrix along with the fibre to form the FRP. The main advantages of such type of material are corrosion-resistance against acid, alkalis and salts, higher ultimate strength, higher Young's modulus, freedom from electro-mechanical deterioration, very good fatigue properties and light weight. Carbon fibre gives the higher strength but it is very expensive. Glass fibres of thin wrap have lower stiffness but higher ultimate strain that makes them better for seismic retrofitting. Glass fibres are also cheaper than carbon fibres.

FRCs are the most versatile material for repair and rehabilitation when the lifecycle cost and efficacy are considered.

Summing up

Fibre-reinforced composites are now being increasingly used for repair, rehabilitation, retrofit and structural strengthening. But the system has to be designed properly by a structural consultant for bond, flexure, shear and axial load by choosing the type of fibres and layer of wrapping required in a resin system to make it a more composite, durable system. The only drawback for the use of these composites is the unavailability of standard codes and higher cost of fibre. But considering the lifecycle cost and efficacy, they appear to be the most versatile material for repair and rehabilitation. CW

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