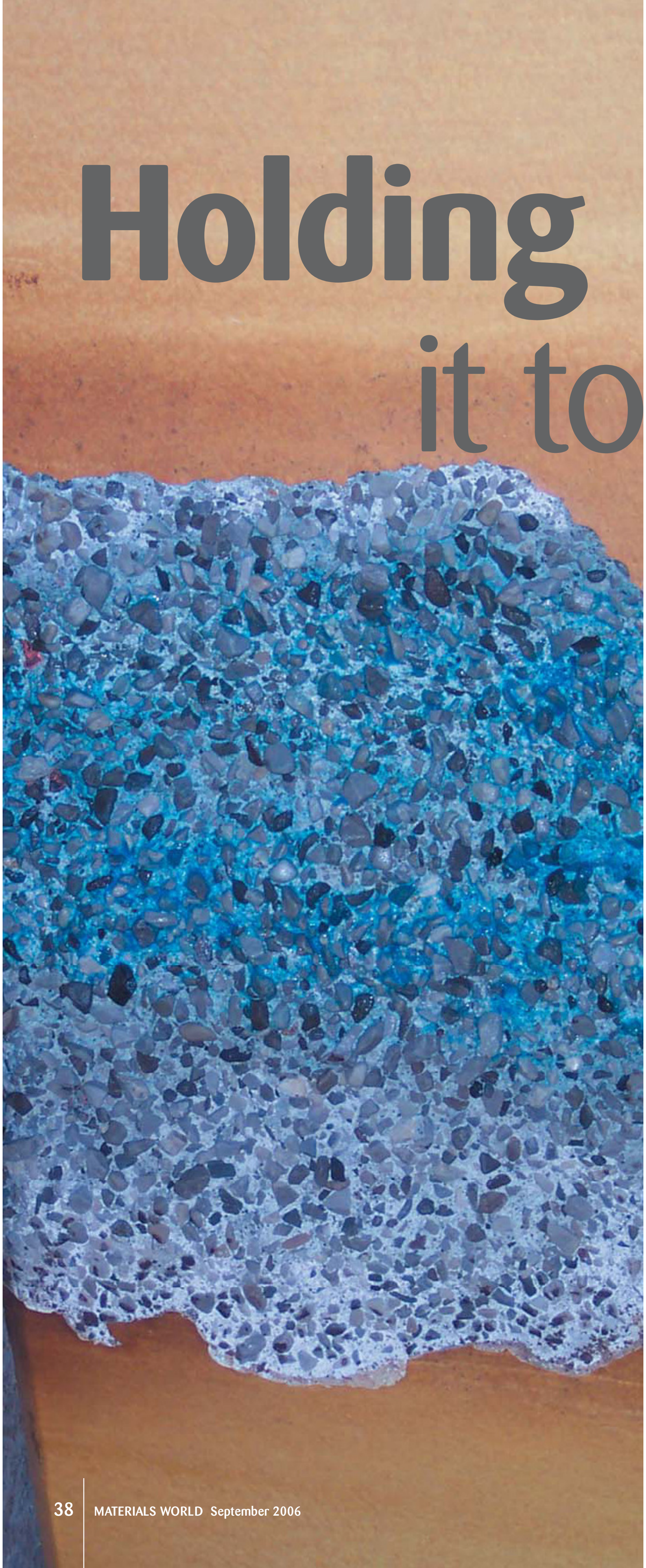
Holding it together



Michael Forrest examines new polymer technologies

Concrete is present in, and is almost responsible for, our modern infrastructure, from humble garden paving to spectacular bridges and skyscrapers. Its components are geologically some of the most frequently occurring – limestone, crushed rock and clay – yet it can be used to fabricate buildings that are anything but common. Concrete is also employed in structural beams and pillars, with the addition of steel reinforcing bars or rebars, one of the main products of the global steel industry.

Although concrete infrastructure can and has survived for centuries, if water penetrates pore spaces, it can cause premature corrosion and failure. If reinforcing bars come into contact with water, oxidation and swelling of the steel can take place, weakening the structure. The challenge therefore lies in repairing these faults. One solution is to cut out the damaged section and replace it. If this is not an option, then an entire rebuild may be the only alternative (see also *Materials World*, August 2006, p12).

Use and abuse

Mining is not only a provider of raw materials for concrete, it is also a user. Processing plants, retaining walls, ore shoots and fluid retaining tanks all use the material, usually reinforced. Often the surrounding environment is abrasive, subject to water percolation or holds chemically-active fluids and minerals. Failure of a concrete structure in mining can be expensive, not only in replacement costs but also in the downtime taken for repairs.

Bearing up

Modern materials science, developed for the aerospace industry to build stronger, lighter and more durable aircraft, has an answer. These materials are easy to apply and can improve the structural strength of load-bearing members several times over.

One company developing these advanced materials is HJ3, based in Tucson, Arizona, USA. The company uses patented composite materials in the form of fibre-reinforced polymers (FRP). The are the result of twenty years of research of HJ3 Composite Technolog for the repair of existing structures. In the past decade, the company has developed new composites for use in seismically active zones and to strengthen structures against explosions.

The FRPs developed by HJ3 Composite Techn-olgy are based on fibres coated with an interphase coupling agent. This is a polymer coating that promotes cross linking, ensuring good bonding to the epoxy resin. The fibres can be Kevlar, carbon or glass, according to the intended application.

The polymer epoxy resin acts as a developing medium to ensure the chemical and physical integrity of the material. It is uniquely formulated to bind together the reinforcing fibres and the substrate of steel, concrete or wood. The minimum thickness of the components is 1mm. The FRPs are flexible and ensure adhesion to the damaged area of the structure in the form of a coated wrap allowing the original shape to be maintained. The fibres have been specially developed by HJ3 to improve wetting and ease application.

The interplay between the fibres, coupling agent and epoxy resin adds strength that is at least equal to or exceeds the original design. In comparison with other materials such as steel and aluminium, FRP solutions are lighter, stiffer and have a greater fatigue resistance. They also possess a very low thermal expansion and chemical resistance.

HJ3 manufactures a number of wraps and laminates designed for specific applications. The most widely used in repairing structures and industrial plants are those where the laminate fibres are aligned vertically or horizontally to add tensile strength to concrete columns or beams. These can improve shear strength by 800% and reinforce weak points where columns are joined or extended. The unidirectional wrap enhances the tensile strength. Steel pipes can thus be strength-ened, increasing the pressure-bearing capacities beyond the original design specification, and concrete pipes can be fortified and made resistant to chemical corrosion.

Take the rough with the smooth

Mining is a tough business – its plant and machinery operate in abrasive and chemically-hostile environments. Mines and processing plants work in tandem and loss of production in one affects the other. Repairs therefore need to be made quickly and effectively.

One example is a copper mine and processing plant in the USA. The production method encompasses mining, grinding and flotation to produce a 28% copper concentrate, flash smelting to 70% copper, flash converting to 99.6% copper, followed by electrolysis in an acid solution to provide a 99.9% copper ingot.

It was in the latter stage that problems arose which threatened the entire operation. The electrolyte leaked from the processing tanks where the copper is refined through the ceiling and on to the column-to-beam connections. Exposure to electrolyte in the basement of the cell house caused the steel reinforcement within the concrete columns to corrode, making them susceptible to structural failure.

The solution involved chipping out loose material from the columns and sandblasting them to remove all traces of the corrosive electrolyte. A HJ3 polymer patching material that can withstand acidic attack from electrolyte was applied for resurfacing, and pre-cured strips of s-glass laminate, a high-strength chemically resistant glass, were placed against the surface of the column using a tack coat of rubber-toughened epoxy. Eight columns were repaired in two days. The tanks were quickly brought back into action.

Main image: corrosion at a beam column junction. Below (L-R): Corrosion at the base of a column. Corrosion sampled in the column. Preparation of the column for wrapping




Columns wrapped and repaired

Gift wrapped

Repairing infrastructure is not the only application for FRP wraps – they enable the strengthening of concrete, brick and steel structures beyond their initial design capacity obviating rebuilding. New patented Blastek technology offers a safety margin for constructions within the vicinity of explosions. Masonry block walls, one wrapped with the high strength composite Blastek, the other without, were tested. Using the equivalent of 100kg of TNT explosives at a distance of 10 metres, the standard wall was completely demolished while the Blastek-enhanced specimen remained undamaged. Sensors within the structures indicated that the pressure on the side of the wall facing the explosive charge registered 178psi while the inner surface registered 1.46psi.

Further information

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