# POWER STATION PROTECTION

Enhancing the durability of reinforced concrete in the nuclear industry.

*By Chris Lloyd, Director, Flexcrete Technologies Limited*

Since the world's first full-scale nuclear power station was opened some 60 years ago at Calder Hall in Cumberland in the UK, reinforced and prestressed concrete have formed an integral part of the containment structure within nuclear plants. In essence, the primary function of concrete is to separate the reactors and other safety and control systems from the external environment.

When many nuclear power plants were first constructed, concrete was typically specified for its versatility and ability to achieve the primary functions of shielding and containment to prevent the release of fission products to the environment, whilst offering protection from floods, storms and even scenarios such as aircraft impact. It provided a cost-effective, durable solution, offering the required typical design life of 30 years whilst fulfilling the engineering requirements of the Design Engineer.

Irrespective of reactor technology, a myriad of reinforced concrete structures can be found in nuclear power stations, providing foundation, support, shielding and containment functions. The durability of many of these structures has been commendable, but over the passage of time, concrete ages, it is susceptible to degradation and remedial work becomes necessary to ensure that leak tightness is maintained.

Although many of the original nuclear power stations in the UK have now been decommissioned with plans for remaining operating stations to close by 2025, there is increasing commercial pressure to see their design life extended to meet our increasing demand for electricity. Many nuclear power plants are situated near the coast to make use of seawater for cooling, with buildings often below the water table exposing structures to the risk of chloride induced corrosion of the reinforcement.

## LEAK PREVENTION

Therefore, it is often necessary to prevent leaks both from and into the structures, with construction joints and cracks being particularly vulnerable areas with the most serious risk of nuclear fluid escaping and contaminating the surrounding area. The massive economic costs associated with forced unplanned shutdowns, where the plant is brought offline, let alone the risk to public safety, highlights the criticality of maintaining the integrity of the concrete.

The rate of concrete degradation can often be dependent upon the structural design, the original materials selection, the quality of construction and the aggressiveness of the environmental exposure. By far the most critical factor is the cover to the reinforcement, as premature failure of corroded steel reinforcement is one of the primary causes of concrete degradation. Reinforced concrete structures require an adequate thickness of concrete cover over the steel reinforcement to combat corrosion.

The depth and quality of the cover concrete is absolutely vital, as this relatively thin layer

of concrete protects the reinforcing steel from corrosion by maintaining an alkaline environment and preventing the ingress of chloride ions and all the other fuels for corrosion. If left untreated, low or inadequate cover will most certainly lead to a legacy of unplanned shutdowns and expensive maintenance bills with the likelihood of the design life of the structure being drastically reduced. It is important to take swift action, otherwise the lack of protection to the re-bars will lead to premature de-passivation of the steel and subsequent corrosion. Inadequate concrete cover will not only speed up the damaging effects of carbonation but also allow even more rapid ingress of chlorides, moisture and oxygen.

Low concrete cover is not a problem just limited to existing reinforced concrete structures. At Flexcrete, we encounter it with many new build structures as a direct result of construction deficiencies or detail modifications. With today's complex designs, the sheer density of reinforcement can provide supreme challenges for contractors in achieving the specified quality. In such instances, the mix design of the concrete may be such that it is difficult to access confined spaces with congested steel. Poor workmanship can also lead to low cover problems. Errors may occur when formwork is fixed, inadequate spacers may be used or reinforcement may become displaced when concrete is poured and compacted. Whilst in new build situations, precast elements can be rejected during quality control checks on-site. With major spending plans in place for new reactors at various power plants across the UK and further afield, this presents a very real scenario.

Once low cover has been identified, various options may be open. These could range from the drastic and costly measures of demolishing sections that fail to meet the required specifications, or partial recasting with new concrete. This involves removal of the concrete back to behind the level of reinforcement using mechanical or ultra high pressure water jetting techniques, repositioning the formwork to achieve the desired cover and recasting the concrete. However, not only is this a costly procedure, it can often prove difficult to access the area to carry out the remedial work.

## PROTECTIVE COATING

A more practical and cost-effective means of reinstating cover is to apply a protective coating. There are many different products available on the market and it is important to assess factors such as substrate compatibility, life span and the film thickness required to provide the necessary cover, not to mention successful track record of use on nuclear structures and independent approvals such as CE Marking in accordance with BS EN 1504, the pan European standard for concrete repair.

One product which is frequently specified for reinstating effective cover on precast and in-situ reinforced concrete is Cementitious Coating 851 – a waterborne, cementitious modified polymer coating. Independent tests show that a 2mm coating of 851 is equivalent to 100mm of good quality concrete cover, as well as providing a complete barrier to water under 10 bar pressure. Being cement based, it chemically reacts with the substrate to form an integral part and will have a design life equivalent to that of the concrete to which it is applied. 851 can also be applied to green concrete by brush or spray and exhibits minimal hazard during application due to its water-based composition; it releases no strong odours, is non-toxic when cured and can be applied in confined areas. This is critical in locations such as nuclear power plants, as environmental considerations are paramount and no downtime is required, so normal daily routines can continue unhindered.

The ability to combat chloride ingress is a critical factor and the VINCI Construction Technology Centre has assessed the chloride ion diffusion of Cementitious Coating 851 for the past 28 years. To-date, no steady state of flux of chloride ions has been detected, whereas the control concrete achieved this in just 28 days. Cementitious Coating 851 is well proven at power stations, having been specified for use at Chapelcross Power Station near Dumfries in Scotland, Dinorwig Power Station in Snowdonia National Park, North Wales, and Marchwood Power Station in Hampshire to name a few applications.

## SEVERAL CONSIDERATIONS

When selecting repair products for concrete, there are several factors to take into

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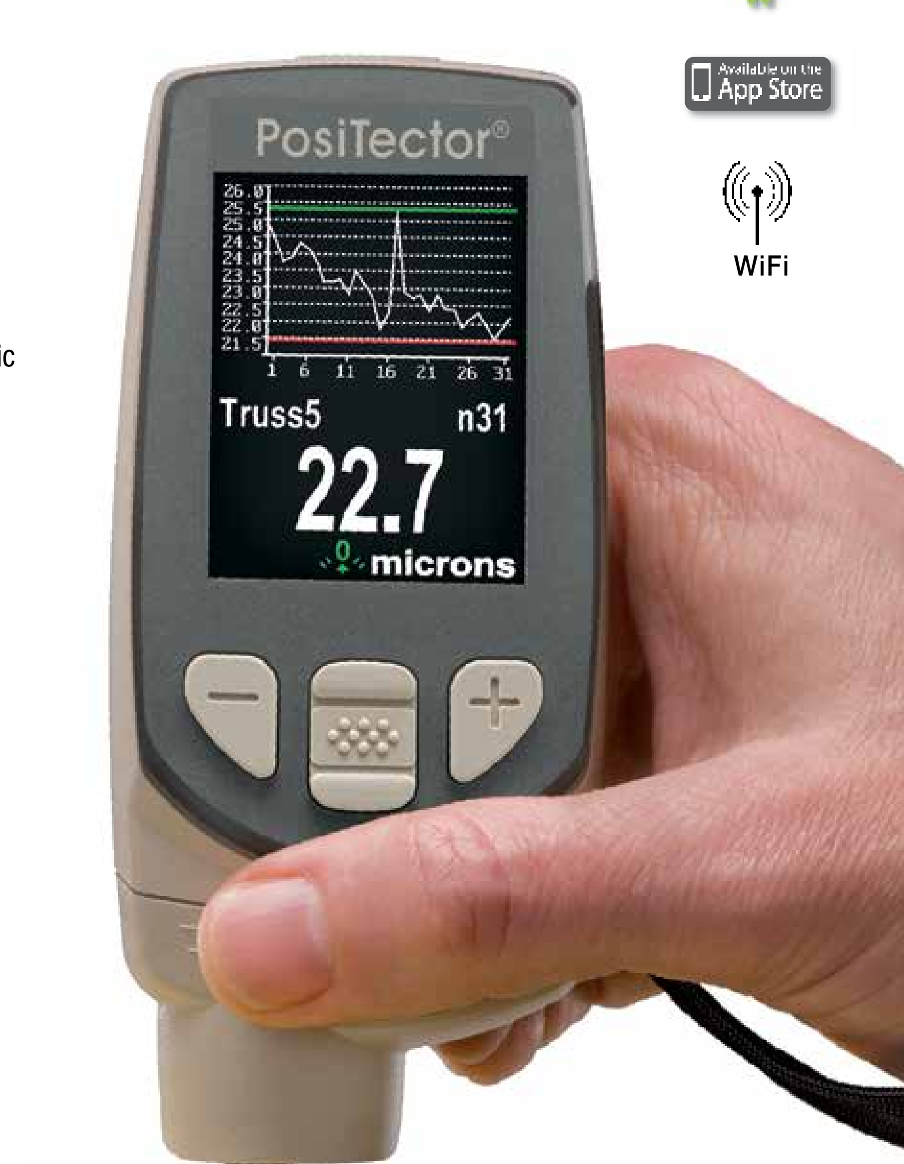


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consideration. For example, it is important that materials offer effective waterproof protection, particularly for sub-structure works or applications exposed to external weathering. Leading manufacturers will be able to provide evidence that products are proven to resist positive and negative water pressure and are independently approved by the likes of the British Board of Agrément (BBA).

Water seepage through construction joints and cracks can have a number of consequences, including leaching of the concrete, corrosion of the reinforcement, attack on the concrete matrix from aggressive elements in the ground and ultimately, leakage of fluids either into or out of a facility. The specification of effective concrete repair materials can halt future deterioration and prevent unacceptable fluid migration.

Some projects may also demand a temporary waterproofing system, for example during basement construction. One product well proven for this type of application is Cemprotec E-Floor, an epoxy and cementitious modified, self-smoothing polymer topping which is designed for the protection of concrete floors in highly demanding environmental conditions. A 2mm coating of Cemprotec E-Floor resists 10 bar hydrostatic pressure, providing equivalent waterproofing to more than two metres of good quality concrete.

## A RANGE OF PRODUCTS

Leading manufacturers should also be able to offer a range of different products to suit the application in question – for example fast setting repair mortars designed for use in areas which cannot be taken out of service for long periods, elastomeric coating membranes that can withstand thermal or structural movement and products that can be applied in damp environments with minimal levels of surface preparation.

Products available include Fastfill, a rapid setting repair mortar which sets in as little as 10 minutes and Cemprotec Elastic, a two component, cementitious modified, polymer rich coating which is especially suited for applications where further movement is expected and can be applied in temperatures as low as 5°C. It hydrates and chemically cross-links to form a durable, highly alkaline, permanently flexible coating which not only protects concrete from water penetration and carbon dioxide diffusion, but also accommodates movement in cracks. Chemical attack can also be of concern in power stations and there are products available which offer exceptional chemical and abrasion resistance.

A series of new reinforced concrete waste storage tanks and a salt store have been constructed at Dounray Image Credit: DSRL and the NDA

Flexcrete Tiefill was specified to provide a rapid curing, high strength, waterproof filler in the waste storage tanks

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If manufacturers are able to offer a range of products for various applications – whether this be general concrete finishing, concrete repairs, tie hole filling or bund linings – they can offer a single source solution and clients can avoid the cost and inconvenience associated with sourcing alternative products from a mass of different suppliers. Leading manufacturers will work with clients to help determine which products are best suited to the technical and budgetary parameters of a given project.

### DOUNREAY POWER STATION

Dounreay, located in the Highlands on the north coast of Scotland, was the centre of the UK fast breeder reactor research programme from 1954 until 1994. Some 180 facilities, including three reactors, chemical reprocessing plants and various waste facilities, were built on approximately 136 acres. Around the 1950s, fast breeders were seen as the solution to Britain's energy needs and three fast breeder reactors were subsequently built at Dounreay. However, by the 1980s, the fissile form of uranium was no longer in scarce supply and fast reactors were deemed more expensive than conventional forms of electricity generation. The Government decided the technology would not be needed for the foreseeable future and announced an end to research in 1998.

As part of a £1.6 billion project carried out by Dounreay Site Restoration Ltd on behalf of the Nuclear Decommissioning Authority, Dounreay is currently being decommissioned, whereby each of the 180 facilities is being cleaned out, the waste managed safely and the structure dismantled before the site closes. New plant is also needed to manage the waste.

By 2022-25, all radioactive waste will have been packaged in a form that makes it safe for long-term storage or disposal. Low level waste will also have

Cemprotec E942 was chosen as the ideal solution to line the chemical bunds at the Tamar Valley Power Station

been deposited in a series of shallow vaults next to the site and capped. The more hazardous intermediate level waste will be held securely in purpose-built stores.

Part of the decommissioning activities includes the construction of a new disposal facility for low level waste, of which up to 175,000m of solid low level waste is expected to be generated during the decommissioning work. A series of new reinforced concrete waste storage tanks and a salt store have been constructed and a high performance filler was required for application to the tie holes formed by formwork bolts on the new structures. This was critical to ensure leak containment and to guarantee that the structures are watertight.

Flexcrete Tiefill, a polymer modified, fibre reinforced, cementitious repair mortar, was specified to provide a rapid curing, high strength, waterproof filler. Due to its exceptional waterproofing properties, being able to withstand 10 bar water pressure after just 72 hours' curing, Tiefill ensures the tanks are watertight, preventing water ingress both into the tanks and leakage from them. Tiefill is supplied as a single component system, requiring only the addition of clean water on-site, and it maintains high bond strength to the substrate, setting in only 30 minutes at 20°C. Tiefill has several independent accreditations, including certification to BS EN 1504. Over 5 tonnes of Tiefill was applied by the principal contractor Graham Construction. Tiefill can also be used for sealing grout holes and voids around fixings in precast elements.

## TAMAR VALLEY POWER STATION

Tamar Valley Power Station is a 210MW LNG-fired gas turbine combined-cycle power plant. The single largest generating plant in Tasmania, it is located at Bay Bell near George Town on the Tamar River and was commissioned in October 2009 after two years' construction. Originally owned and operated by Aurora Energy, the government-owned power distributor and largest energy retailer in Tasmania, ownership has since been transferred to HydroTasmania, another state owned enterprise.

With tight deadlines to meet, the designers were keen to embrace fast track methods to ensure prompt completion of the power station, however one area of concern was the 28 day cure period required for the concrete bunds. Cemprotec E942, an epoxy and polymer modified cementitious coating, was chosen as the ideal solution to line the chemical bunds. To reduce time on-site before installation of chemical storage tanks, Cemprotec E942 was applied by MRJ Industrial Services Pty Ltd directly to the concrete bunds after only seven days' curing. This allowed

the application of a chemically resistant top coat within one more week. By adopting this approach, the normal 28 day cure period for freshly cast concrete can be waived, thus saving valuable time. Cemprotec E942 is certified to EN 1504-2 for Protection against Ingress and is in use worldwide.

## LATEST APPLICATION

Cemprotec E942 has also been used to provide anti-corrosion protection to steel at a new materials handling facility under construction at Lynemouth Power Station in Northumberland.

Cemprotec E942 has been specified by Sir Robert McAlpine to protect new steel piling totalling 1,500m$^2$ to ensure that the 20 year design life of the steelwork is achieved. Cementitious technology was chosen for this project due to the ability of Cemprotec E942 to provide enhanced chemical and abrasion resistance, whilst ensuring rapid completion of the coatings work due to limited preparation requirements of the steelwork.

Originally constructed in 1972 to generate electricity from coal, Lynemouth Power Station is currently under conversion to a biomass-fuelled power plant. The Power Station is being converted from coal burn generation to biomass in order to supply the National Grid with up to 390 megawatts of low carbon electricity, supplying enough power for almost half a million residential homes. The biomass conversion will save 1.5 tonnes of carbon dioxide in comparison to coal.

Sir Robert McAlpine is constructing the materials handling facility at the power plant and an anti-corrosion coating was needed for protection of the sheet piling in the new rail offload areas. CSC Services UK Ltd, a specialist repair and coatings contractor to the power and water industries, was appointed to carry out the application work. The interlocks between the sheet piles and any voids were first filled with Cemprotec Clutch Filler, a uniquely formulated cementitious material for sealing the surface gaps between piles prior to the application of a Flexcrete cementitious anti-corrosion coating.

A 1mm stripe coat of Cemprotec E942 was then applied over welds, flanges, cut edges, plates and all fixings including nuts and bolt heads. Cemprotec Edge Scrim was embedded on all welds and cut edges before a 1mm coat of Cemprotec E942 was spray applied to the complete surface area of the sheet piles. Just 30-60 minutes later a second 1mm coat was applied to provide excellent anti-corrosion protection.

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