



Left: Efflorescence and subsequent spalling on the Stwlan Dam
 Below: General view of the dam
 Photos courtesy of the author



A New Face on an Old Problem

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Stwlan Dam is the 34-metre-high buttress dam standing amongst the peaks of Snowdonia near Blaenau Ffestiniog in the slate-quarrying heart of North Wales and, once upon a time, the world. Stwlan [pronounced “stoolán”] impounds 2.2 million cubic metres of water, all for hydro-electric generation of a special kind: pumped-storage. Water from Stwlan falls 300 metres through shafts and tunnels to four 90-megawatt hydro-turbines in Ffestiniog power station, generating up to 360 megawatts within minutes of switch-on. This energy is crucial in helping the UK electricity grid system meet its rapid fluctuations in demand hour by hour, even minute by minute. The reservoir is refilled by pumping water back up the tunnels and shafts on cheaper electricity at times of lower demand, generally overnight.

When opened by Her Majesty the Queen in 1963, Ffestiniog Power Station was the first of its kind in the world. Assisted (but never superseded) by its larger sister station at Dinorwig, also in Snowdonia, it continues to operate efficiently and reliably.

The care and maintenance of the dam presents some challenges during this continuous use, especially when work is required on the lake-side face. This article highlights one particular problem with maintaining the dam and describes the solution reached.

The Problem

Like many mass concrete structures of its age, Stwlan’s downstream face became streaked with efflorescence soon after completion. What became called the “stale-bread” effect was due to a combination of too much cement content and overly slow rates of construction. This combination created high differential temperatures during early curing, which resulted in slightly un-bonded lift lines. Water seepage through the dam walls reacted with free lime and slowly sealed almost all the leakage.

Stwlan also had an unusual double-wedge contraction joint between its buttresses. These joints were generally never quite sealed, and seepage continued, freezing and thawing winter after winter, until eventually, fragments of concrete began to spall and fall off. The ground between the buttresses had then to be fenced off to protect the public and grazing animals from falling concrete.

Water loss was insignificant to reservoir safety and to the operation of the power station, but minimizing further structural deterioration was necessary, so the search began to find a material to seal the seepage and eliminate the frost damage. Then, effective concrete repairs could begin.

Sealing the more accessible downstream face of the dam was rejected; water would continue to enter the structure, and repairs were likely to fail under the high and cyclical water pressure coming from the reservoir. So the less accessible upstream face would be sealed.

The first major investment in coatings began in the early 1990’s with a polyurethane-based elastomeric material that required exacting environmental conditions for its successful application. A portable “environmental chamber” was suspended against the dam face within which the application was made. Unfortunately, the difficulty in creating the environmental conditions and the inconvenience of relocating this chamber for each area severely reduced productivity. After a whole summer of applications, the entire application budget was consumed, but only about 10% of the face at the top of the dam had been coated. The obvious difficulty of using a product of this type led to the search for more prac-

tical materials that were far more tolerant of varying weather conditions.

A material was therefore needed that could be applied to the upstream face and survive under the following conditions:

- no temperature control on an exposed mountain well over 500 m above sea level;
- no humidity control with an average rainfall of over 2.4 m a year; and
- wet concrete exposed for as little as two hours before being re-flooded.

The Trials

Product trials were initiated in 2000. Manufacturers were invited to prepare a patch of the dam face to their requirements and to apply their most suitable coating. Eight manufacturers took up the challenge, proposing a wide range of products, including elastomeric polymers, polymeric membranes, and cementitious-based products.

All were left on for a winter or two of daily exposure and submergence, then reassessed. By 2002, three materials looked promising: a) a cement-based product, b) an epoxy resin reinforced with glassflake, and c) an epoxy-based 100% solids epoxy incorporating polymer. The dam owners, First Hydro, decided to further assess these products.

One product seemed to be too good to be true. The weather was rough and the water level was high when it was applied, with application by roller continuing below the cold waves. "No problem," said the applicator. "No way!" retorted Bryn Williams, First Hydro's assistant civil engineer. When he returned the next day with civil engineer Owen P. Williams, Bryn expected to see the whole panel



Access platform suspended from special mobile rig on the dam crest for second round of coating trials

washed off, certainly where applied under water. But the trial was intact, and showed no sign of tide-mark at all—three years later, it still doesn't.

First Hydro's term maintenance

contractor, formerly Palmers but now Pyeroy of Rosyth and Newcastle, then applied the three best coatings from an access platform suspended from a special mobile rig on the dam crest road.

Each product was applied in a 4-metre-wide strip the full height of a double buttress joint, each under the direction and supervision of the coating manufacturer.

Preparation was by high-pressure washing of the concrete with no repairs to the slight concrete defects. Application rate, bridging of joints and defects, and waste varied considerably. These three trials were left for more than eight months and re-assessed in the spring of 2004. After exposure and

re-flooding more than 250 times, it was clear that, for adhesion, uniformity, residual thickness, crack and defect bridging, and edge integrity, only one product was virtually blemish-free: a 100% solids epoxy incorporating Kevlar® (aramid fibers). Moreover, wind, rain, temperature changes, and humidity problems during application

and early curing did not adversely affect the epoxy. In conjunction with no waste and no visual contamination of the lake water on first submergence, First Hydro considered the epoxy to clearly be the best performer. Despite its higher unit cost, it was also evaluated to be the best over all value. Accordingly, the product was specified for all the remaining joints on the dam.

Continued

Properties of the Successful Coating Material

A 2-pack liquid epoxy/polyamine with inert plasticiser and fibre incorporation

Volume solids	100%
VOC	zero
Flash point	> 100 C (200 F)
Typical dry film thickness	250–500 micron
Theoretical coverage	2m ² / litre (at 500 micron dft)
Application method	brush or roller
Pot life (15 C)	45 minutes
Drying times (15 C)	touch: 6 hours hard: 20 hours
Min/max recoating time (15 C)	20 hours / 8 days

The Solution

Balancing the opportunities created by ed, a further 1,150 square metres, again by Pyeroy, making an overall total of longer daylight hours with the lower 2,050 sq m.

operating lake levels and the restric The work was concentrated in bursts tions due to other station maintenance, of continuous shift work over long First Hydro planned to carry out the weekends whilst the power station was coating work on the face of the dam on “outage”; this meant the reservoir over two summers, 2004 and 2005. was kept empty, and the full face of

Accordingly, in the summer of 2004, Stwlan dam was therefore available 7 of Stwlan’s total of 19 buttress joints and accessible.

were prepared and coated, a total of Alex Brown, Area Director for 900 m². Pyeroy, commented: “Our first reaction

All surfaces were prepared by when speaking to First Hydro Company 10,000 psi water washing alone to regarding the proposals for the initial expose clean concrete surfaces and tdrils was one of scepticism. However, it remove loose laitance, small patches ofbecame clear at an early stage that the surviving bitumen paint (the original coating chosen was (from an application coating applied in 1961), silt, and bio- point of view) the way forward. Having film growth. now recoated over 2000 sq m of surface

The strips were increased in width area on the upstream dam face, we from four metres to eight metres, would conclude that the [coating select including the trial strips in place. ed] was the correct solution.”

Coated and uncoated areas would then First Hydro’s company civil engineer be in equal hit-and-miss strips so that, if Owen P. Williams, concluded, “For usit’ future monitoring dictated, the rest of a problem solved whilst keeping the dam could be sealed in single-pass’festiniog’ vital generating capacity infill strips also eight metres wide. almost continuously available. To date,

Early coating effectiveness was con performance is excellent and we now firmed by routine dam inspections plan to carry out the necessary repairs through the winter and in spring of to the concrete on the joints at the 2005. No seepage reaching the down downstream face.”

stream face through the treated joint The 100% solids, fibre-reinofced zones was identified. epoxy is manufactured under license by

In summer of 2005, the trials were Crosbie Casco, Manchester, UK, for TFT re-started, and the remaining ten but UK, Ltd (the UK affiliate of Thin Film tress contraction joint zones were coat Technology of Houston, TX, U.S.).