# Winscar Reservoir – a case study
## membrane repairs to a leaking reservoir

**by J R Claydon, BSc(Eng), ACGI, DMS, FICE, All Reservoirs Panel Engineer**

**Winscar Reservoir, located just south of Holmfirth, W.Yorkshire, was constructed between 1972 and 1975 for water supply. It has a capacity of 8 million cubic metres and the yield is 22 Ml/d. The reservoir is formed by a rockfill dam with a maximum height of 53m and a crest length of 520m. The embankment is made of compacted sandstone with an upstream slope of 1V on 1.7H and 1V on 1.4H downstream. A two-layer membrane of dense asphaltic concrete covers the 25,000m² upstream face of the dam. A cement grout curtain extends beneath the upstream toe to depths of up to 70m**

Winscar Jan 2001-leak measurement by stopwatch *(courtesy Yorkshire Water Services Ltd)*

**The Problem**

In January 2001 a large spring issued from the toe of the dam with a flow of about 15 litres/second. The reservoir was drawn down as a precaution and the response of seepage flows was closely monitored. Flow reduced at approximately half-depth of the reservoir, suggesting a major defect at this level.

The upstream face of the dam was inspected using roped access and about sixty defects were observed in the upper half of the asphaltic membrane. Most were blisters and small cracks but there were also more persistent cracks that coincided with construction joints between panels. This type of defect had not been previously encountered at Winscar and initially seemed to be the most likely explanation for the new leak. However, core drilling at crack locations was unable to confirm full-depth cracking.

The lack of conclusive evidence as to the location of the leakage meant that the reservoir had to be drawn down completely. A range of measures were needed to avoid environmental damage, which included blending of different quality waters; filtration through straw bales, geotextiles and hessian, settling basins; and timing of discharges. Emptying of the reservoir took over six months and the care continued during the repair works with the old submerged Dunford reservoir brought back into use to settle water before discharge to the river.

**The solution**

The uncertain condition of the asphaltic membrane prompted the decision to reject patch repairs in favour of major refurbishment of the entire water proofing element with all works completed before the winter rains of 2001/2002.

The technical feasibility of various engineering solutions was investigated by YWS and its consultant, *Montgomery Watson Harza and Arup.* The logistics, environmental and planning aspects were considered and the costs estimated. Two options gained high evaluations:

* removal of part of the existing facing and its replacement with a dense asphaltic concrete membrane over a bituminous bound drainage layer;
* installation of a geomembrane liner over the existing face of the dam.

Compliant tenders were received from main contractors on the YWS select list for both the asphaltic concrete and the geomembrane solutions.

The construction schedule was very challenging, because of the fast track nature of the project. The mobilisation of the necessary specialist plant was a problem, as was the timing of the works, which might have extended into a second year if inclement weather conditions prevented completion. The geomembrane was less influenced by these factors than the asphaltic concrete and on this occasion there was also a clear cost advantage.

It was decided that the geomembrane solution should be adopted and a contract was awarded to *Morrison Construction Ltd,* with *Carpi Tech* as specialist sub-contractors.

**Grouting operations during 2001**

A possible explanation for the increase in seepage beneath the dam over the life of the reservoir was that the grout curtain had been subject to leaching. Attention was directed at the foundation to the left of the culvert, since the new leakage was concentrated in that compartment of the foundation. Two phases of grouting were undertaken with an interim review to allow methods to be evaluated and modified. Over 20T of microfine cement were injected and the average consumption was 35kg/m. The grouting work was carried by *Skanska-Cementation* as a sub-contractor to *Morrison.*

**Geomembrane**

The compliant tender submitted by *Morrison/Carpi* was based on an HDPE membrane approved by the Drinking Water Inspectorate under Section 25 (1) (a) of the Drinking Water Regulations, 1989. An alternative PVC based geomembrane proposed by *Carpi Tech* had been used on over 60 dam projects worldwide but had never been used previously in a water supply reservoir in the UK and had not been submitted for approval. Product details and performance were presented to the DWI who stated that this was an issue that should be dealt with by YWS under the provisions of Regulation 25 (1) (b) ie the company might well consider that approval is unnecessary because of the small risk posed by use of the unapproved material. The PVC based material was adopted - modified for use in the Peak District by colouring it dark green.

**Geocomposite liner**

Sibelon CNT 3750, a Flag S.p.a Italian product was specially manufactured in Italy for Winscar over a period of a week in July 2001. The geocomposite liner was supplied by the factory to length in standard 2.10m wide rolls. Three rolls were then welded by automatic twin track machines in a prefabrication yard to construct wider panels in order to maximise quality and minimise installation time on site.

The geocomposite liner is mechanically fixed to the dam using watertight anchorages around the periphery and by tensioning devices on the face. Tensioning prevents wrinkle formation that may ultimately lead to cracking. The tensioning assembly, which is patented by *Carpi* comprises coupled stainless steel profiles. The lower profile is fastened to the upstream face by anchor rods embedded in epoxy resin. The embedment depth was determined on the basis of a fifty year return gust wind speed. The liner covers the lower profile and is clamped and fastened by the upper profile. A PVC cover strip overlies the coupled profile and is welded to the underlying liner. The liner was installed between August and December 2001.It could have been installed more quickly but the programme was interrupted by work on the grout curtain.

**Leak detection system**

The underside of the geomembrane is drained into the culvert through the dam. Any leakage is measured over 'V' notch weirs and transmitted through the telemetry system A leak detection system has been installed to pinpoint the source of any future leakage through the new liner. A network of fibre-optic cables was fastened to the asphaltic concrete surface and installed under the liner in a series of loops. The system uses a laser source to measurer the wavelength of light reflected back down the cable and sense temperature. The temperature at any point along the cable route varies depending on the season, reservoir temperature profile and other factors. However, passing a current through the external sheath of the fibre optic cable can induce an artificial increase in temperature. In dry conditions the temperature rise would be constant but energy is lost in the presence of water and anomalies can be detected.

**Performance**

The performance criteria for the design of the geocomposite liner was that it should be capable of reducing leakage through the face of the dam below 1 litre/sec against full reservoir head. Flow from the primary compartment which covered the original asphaltic concrete facing is very small, It has shown a faint increase with reservoir level and seepage was less than 0.02 litres/sec at three quarter full reservoir head.

The current indications are that total seepage flow has reduced considerably. It is estimated that the daily leakage during January 2001 of over 4,000m$^3$ will be reduced to 500m$^3$.

**Acknowledgments**

Thanks are due to all staff at Yorkshire Water, its consultants and contractors who worked as a team to investigate and repair this major asset successfully.■

**Note:** *The author of this paper, J R Claydon is Solutions Manager Yorkshire Water Services Ltd.*