Val De La Mare Dam

design and installation of a geomembrane lining

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Val De La Mare Dam (VDLM) was constructed between 1958 and 1962, and is situated in the west of the Island of Jersey, on the boundary between St Peter and St Ouen. The dam is of mass concrete construction and is 193m long and 24.3m high. It was constructed from 27 (No.) main mass concrete monoliths or 'blocks', together with a reinforced concrete draw-off tower. The reservoir holds 940,000m^3 of raw water. In 1971 it was first recorded that differential displacement of some of the mass concrete blocks had occurred. Upon subsequent investigation, it was apparent that the dam was suffering from Alkali Silica Reaction (ASR). Differential movement of up to 35mm has now occurred due to the characteristic swelling of the highly alkali aggregates in the presence of water. This paper describes how the rehabilitation of the dam was carried out by installing 3,200m^2 of a specialist geomembrane lining to the upstream face.

Aerial view of Val De La Mare Dam, Jersey, Channel Islands - Courtesy of Jersey Water

Background

Jersey Water operates seven dams which are under the Reservoirs Act (Jersey) Law 1996. These serve two potable water treatment works at Handois and Augres with daily maximum outputs of 28ML/d and 18ML/d respectively.

Jersey has an annual (133 year average) rainfall level of just 851mm. The total available storage is 2,678ML with a maximum summer demand of 28ML/d. The Island's resident population is approximately 93,000 which rises to around 120,000 in the summer months. During extended droughts, the Company can operate La Rosiere Desalination Plant with a maximum 6ML/d output.

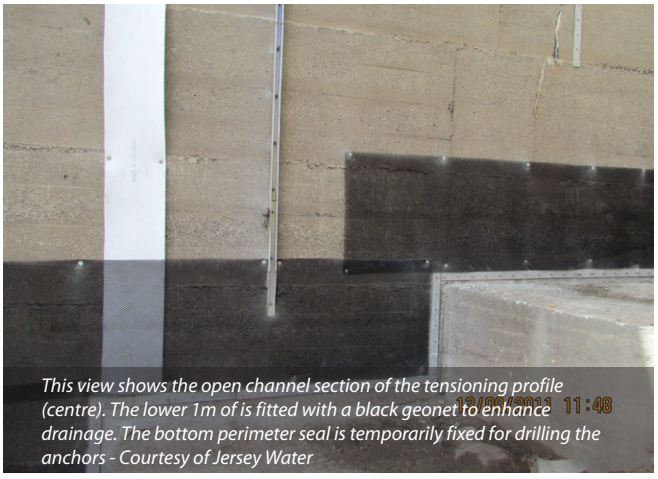
Water from the reservoir is drawn off via 3 (No.) 15" (380mm) diameter cast iron pipes each with guard and operating valves. A separate 18" (457mm) scour pipe and valves are available to draw down the reservoir in case of an emergency.

In his report in June 2010, the Inspecting Engineer for the dam recommended that a geomembrane lining be placed on the dam's upstream face prior to September 2014. The principal reasons were to prevent leakage through the mass concrete joints of the dam which cause uplift within the mass concrete, thus reducing the overall stability, especially in the case of a seismic event. Secondly, the membrane would also remove water from the fabric of the concrete, one of the key contributors to the Alkali Silica Reaction.

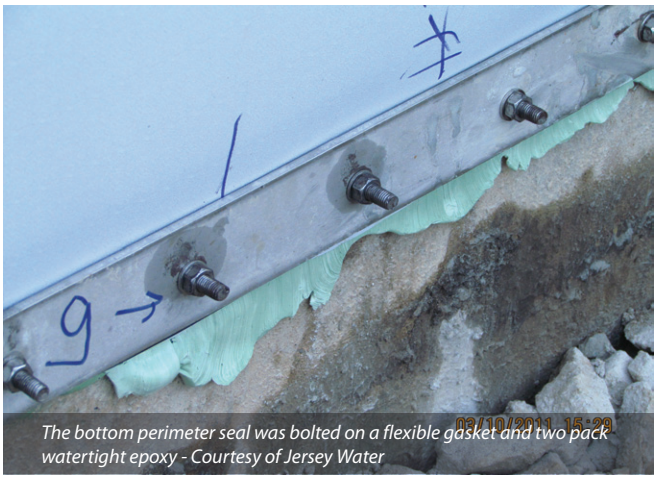
A Water Resources Management Plan in 2010 recommended that one option to meet future demand was to raise VDLM dam by 9m in order to double the available storage volume of the reservoir. However, prior to these works being undertaken it was essential that a geomembrane should be applied to the existing dam.

A stability analysis was updated in 2011 and it was shown that with the provision of a full face geomembrane, the dam would

This view shows the Alkali Silica Reaction (ASR) damage at Blocks 6 and 7 - Courtesy of Jersey Water



This view shows the open channel section of the tensioning profile (centre). The lower 1m of is fitted with a black geonet to enhance drainage. The bottom perimeter seal is temporarily fixed for drilling the anchors - Courtesy of Jersey Water



The bottom perimeter seal was bolted on a flexible gasket and two pack watertight epoxy - Courtesy of Jersey Water

withstand a maximum Horizontal Peak Ground Acceleration of 0.2g with a corresponding Vertical Peak Ground Acceleration of 0.1g. This condition equates to a seismic event with a return period of 1 in 20,000 years.

Geomembrane lining

A contract was tendered, evaluated and awarded to Carpi Tech SA based in Balerna, Switzerland with their head office in Amsterdam. Carpi have a worldwide patent on their geomembrane lining system and over 100 large raised dams have now been lined worldwide. Two dams in the UK have previously had a membrane application; Winscar in 2000 for Yorkshire Water and Seathwaite Tarn in 2008 for United Utilities.

In order to provide waterproof protection to the dam, 3,200m^2 of Sibelon CNT3750 500 polyvinylchloride (PVC) liner was proposed. This consisted of a 2.5mm PVC geomembrane sheet bonded to a 500g/m^2 impermeable geotextile. The lining is a patented design by Carpi Tech SA. The membrane has a strain value of 2.5 thus allowing the membrane to stretch significantly before failure.

During installation, the liner was suspended from the top of the dam and allowed to stretch before being permanently fixed in place. The membrane was supplied in 2.1m wide strips which were heat welded to give a completed width of 5.8m between adjacent tensioning profiles. The profiles and all fixings were stainless steel grade AISI 304 to prevent long term corrosion. A channel section was fixed vertically to the dam with epoxy resin anchors and was then overclamped with a trapezoidal section to pull the membrane flat to the dam and tension the membrane in place. The tensioning positions were then covered in a PVC over-strip, heat welded to cover the whole joint.

At the perimeter of the upstream face of the dam, the membrane was secured in place with an 80mm wide x 8mm deep stainless steel strip, drilled and chemically anchored into the dam. The membrane securing strip was laid on a two-pack epoxy resin mortar and gasket, to ensure that water cannot penetrate through the joint.

At the lower section of the membrane, an open polyethylene geonet was placed approximately 1m deep to allow drainage to the lowest point of the dam. Four 80mm diameter core holes, up to 3m long were drilled at the lowest feasible positions from the front face of the dam to the gallery and the lower level draw-off tower. This allows any seepage flows behind the membrane to drain and be monitored to assess the effectiveness of the waterproofing system.

The joints between the major monoliths/blocks of the dam, at the bottom fixation level, were diamond drilled on a 10 degree incline and grouted up with a waterproof non-shrink grout. The holes were 63mm diameter and drilled just into the existing bitumen core. This procedure ensured that water could not pass under the joint and penetrate behind the lining.

At the top of each inter-block joint, additional treatment was carried out to seal voids between the bituminous core and face of the dam, using Thoroflex 600 flexible sealants.

The tender award was on 9 March 2011 with the access gantry installation commencing on 22 June with completion in early August. The whole of the face of the dam was jet washed and concrete repairs carried out throughout August and into early September.

During the latter stages of the draw-down of the reservoir, approximately 17,500 fish were caught and re-located into other reservoirs. The reservoir is stocked each year with brown and rainbow trout, although the most abundant species was Perch and Carp. Intense fishing is carried out each year by a resident cormorant population!

Carpi mobilised to Jersey on 4 September 2011 with a seven man crew from the Czech Republic. The labour team was supplemented with three additional operatives sourced locally, to assist with drilling works and cradle operations etc. Carpi's programmed works was from 5 September until 28 October with re-filling of the reservoir programmed to be six weeks after commencement. Carpi worked a six day, sixty hour week with only Sundays as a rest day. Fortunately the Carpi site manager was fluent in English and Czech, to enable effective communication. Carpi were extremely efficient and hard working with excellent production rates throughout the tight construction programme. With excellent cooperation between all parties involved, the reservoir was handed back for re-filling ahead of programme. All of Carpi's works were completed by 14 October, a full two weeks ahead of the main works programme.

Enabling works

An enabling works/civil engineering contract was simultaneously tendered for and awarded to run concurrently with the Carpi works. The contract included the provision of a complete gantry/access structure to allow full access to the face of the dam, with four industrial cradles 8m long and one specially designed five-sided tower cradle.

This contract was won by Jayen Limited (Jersey), who appointed Harsco as their access specialist. An extensive structure was commissioned which allowed all loadings to be transferred into the main upper structure of the dam, not affecting the relatively fragile walkway and balustrades. The structure was assembled by a specialist rope access abseiling team, together with an 80 Tonne mobile crane at full extension, which was required to lift I-beams and cradles into position.

The fixed gantry structure supported a 260mm deep x 150mm wide I-beam to allow the cradles to traverse horizontally and vertically across the face of the dam. A power rail was integral and adjacent to the beam to allow 415/110 volt power to be distributed to all areas of the dam for drilling and heat welding works.

Part of the remit was to provide a clean and safe working area for the installation of the lower portion of the membrane. This involved excavating several thousands of cubic metres of shale on site and forming a pervious access bund upstream of the dam. This was required as the resultant silt levels in the reservoir were significantly higher than anticipated by a previous survey, carried out by a diving team.

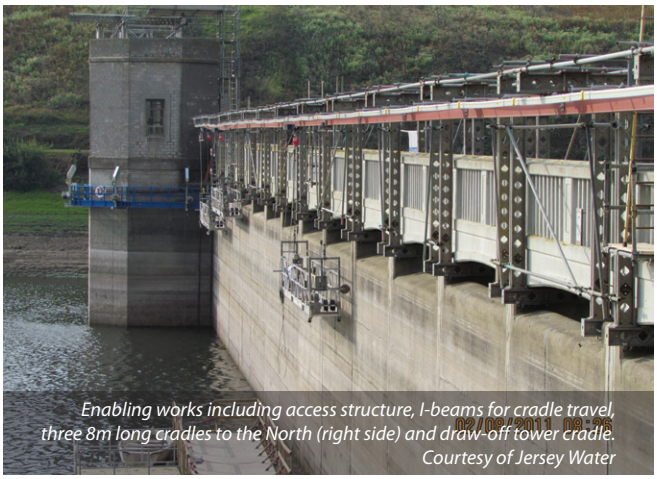
The bund was formed by extending existing access roads from the South abutment and pushing this towards the draw-off tower and onwards to the North abutment. The bund was required to hold back several metres depth of silt. The bund also acted as an excellent filter to allow constant dewatering of the incoming stream flows. The bund was created to leave sufficient freeboard in case of flood events. Dewatering of the works was carried out with a maximum pumping capacity of 6ML/d.

The geomembrane requires a relatively smooth surface, free from any projections of 5mm or above which could puncture the membrane. Extensive grinding and scabbling was carried out to prepare the surfaces. Where the surface was unsuitable, a sacrificial 'underlay' type material was placed to protect the lining from damage. This work was carried out by Concrete Repairs Limited of Bristol.

Site Safety was of paramount importance and extensive Risk Assessments and Method Statements were carried out and monitored. One major risk was presented by deep silts, several metres thick. The reservoir which is normally open to the public for recreation, was closed after it was apparent that the public were ignoring gates, fences and signage and trespassing onto the floor of the reservoir.

Hanging the geomembrane on the draw-off tower. The membrane was lifted upwards from the base of the tower. Note sacrificial textile was placed on the corners of the tower to protect the geomembrane. Courtesy of Jersey Water

The south (left) abutment partially completed. Sacrificial textile and drainage geonet is in place - Courtesy of Jersey Water



Enabling works including access structure, I-beams for cradle travel, three 8m long cradles to the North (right side) and draw-off tower cradle. Courtesy of Jersey Water

Val De La Mare Dam, Jersey : the completed project - Courtesy of Jersey Water

Part of the early works for the project included improvements to the site access roads. This generally involved recycling site excavated shale by grading and crushing materials on site. Tensar Geogrids were laid with up to 200mm of graded shale on top with a hoggin inter-void filler. This provided a very economic solution to strengthening the haul roads.

Whilst the reservoir was empty, Jersey Water took the opportunity to refurbish all the existing 15" and 18" operating and guard valves within the draw-off tower. The condition of the Glenfield gate valves was good with no apparent damage or wear. All valves were thoroughly cleaned, re-greased and fitted with new gland packings and bolts etc and tested.

Conclusion

The 3,200m^2 of geomembrane lining installed by Carpi Tech SA of Balerna, Switzerland has provided a major improvement to the safety of Val De La Mare Dam. The lining will allow the dam to dry out, and in doing so, will reduce existing uplift pressures and prevent further alkali aggregate reactions. The seismic resistance of the dam has been dramatically improved to withstand a 1 in 20,000 year event.

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Photograph showing the temporary works bund and access road Courtesy of Jersey Water

Stainless steel trapezoidal section tension profile being fixed in place. Jointing in progress - Courtesy of Jersey Water