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Lining a canal in the United Kingdom with a bituminous geomembrane

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ABSTRACT: As part of the continuing programme of improvements being carried out to the canal network in the UK by British Waterways, a section of the Llangollen canal in North Wales required relining due to leakage in the 200 year old structure. Engineers in British waterways' headquarters in Leeds specified a bituminous geomembrane liner system, which enabled a simpler design to be adopted compared to other commonly used systems. Added complications on the site were the construction of a new concrete retaining wall along one bank and access for cattle from a pasture above the canal to the water by means of watering hole structures constructed in concrete. The ability to bond the bituminous geomembrane directly onto the concrete was an important factor in its choice.

1 INTRODUCTION

1.1 *Background*

The 2,000-mile (3,219km) network of canals and river navigations throughout England, Scotland and Wales are managed by a Public Corporation known as British Waterways. An example of a "working heritage", the canals are currently being restored at the same rate they were built 200 years ago and the biggest ever programme of repairs is currently underway.

The canals have an important role to play in meeting leisure, community and ecological needs, and are used by over 25,000 boat owners per year. Additionally 7 million cyclists per year travel on its 1500 miles (2,400km) of towpaths. There are 1,000 wildlife sites on the canal network, some of which have been identified by the EU as important protection areas for breeding birds (SPAs) or Special Areas of Conservation (SACs).

The restoration scheme on the Llangollen canal described in this paper presented particular challenges to the design team with concrete structures abutting the liner and the need to retain a unique aquatic habitat following restoration.

1.2 *The Llangollen canal*

Opened in 1805 to connect with the Shropshire Union canal, it formed part of a vast network in the midlands to haul goods. Now enjoyed by holiday-makers in rented motorized canal "narrow boats" the Llangollen canal is reputedly one of the prettiest and certainly one of the busiest tourist canals in the UK. At one point the canal runs along the 1000 feet (305m) long Pontcysyllte aqueduct built 130 feet (39m) above the River Dee using interlocking cast iron sections by the famous engineer of the day, Thomas Telford. The aqueduct, the highest and biggest in the British Isles, is a scheduled ancient monument, and a candidate for World Heritage status.

1.3 *Canal use today*

Commercial traffic on the Llangollen canal ceased by the mid-1930's yet today it carries more traffic than at any other period of its history. In common with the rest of the network any maintenance work has to be undertaken during the winter months when there is less tourist traffic on the canal.

2 GENERAL DESCRIPTION OF THE SITE

2.1 *The section to be lined*

The site to be lined was a section approximately 400m in length running from just after a 200 year old arched stone bridge carrying vehicles over the canal, to a narrowed concrete channel. The canal runs in an elevated position along the side of a slope, with grazing land on the uphill slope and low density housing below the canal embankment on the downhill side.

2.2 *Construction*

The construction of the canal was in its original condition, not having changed since being built over 200 years ago. The bed of the canal was lined with clay as was typical for canal construction in the eighteenth Century. Having survived this not inconsiderable time there were some areas showing signs of leakage in the embankment that gave concern to the canal operators, and an investigation carried out to find the best solution.

3 DESIGN CRITERIA

3.1 *The purpose*

In order to prevent further deterioration of the retaining embankment and therefore the risk of collapse and flooding to properties on the hillside below the canal, repairs to the lining were required. The scheme also allowed the construction of a new reinforced concrete retaining wall to be cast in-situ to further strengthen the bank, and some areas for livestock to access the canal from the pasture above, for water.

3.2 *Ecological considerations*

The relining of this section of canal had to satisfy not only the technical, but also the ecological demands of the site. There is always great emphasis placed in maintaining the ecological balance on all canal refurbishment schemes, with many protected and rare aquatic animals such as the Water Vole and native Crayfish. Canals have become an ideal habitat and feeding ground for a diverse range of flora and fauna which British Waterways aims to maintain.

In order to reline the canal and reinstate the area sympathetically to the environment it was important that the canal did not become a sterile concrete channel. To this end the designers required the placement of 6-10inch (150-250mm) rip-rap stone over the bed to provide a habitat for freshwater crustacea such as Crayfish. Nesting boxes were installed in the bank above water level with entry pipes situated at levels varying from 50mm below to just above water level to provide for the Water Voles.

3.3 *Engineering concerns*

Additionally, there were three watering holes in the bank on the higher slope to enable cattle to gain access to the water for drinking, originally depressions in the bank that had formed over the years that allowed livestock to come to the waters edge. Relining the canal gave the designers the opportunity to engineer more suitable structures and also place a barrier around the watering holes to prevent cattle from straying too far into the water.

4 THE LINER

The designers chose to use a reinforced bituminous geomembrane for lining of this section of canal. The engineers, from British Waterways' Technical Services Department in Leeds, had experience of it before on a section of the Lancaster canal in Northern England. They had also seen it in use in France on the Canal de Nevers, where they had long discussions with their French colleagues of Voies Navigables de France (VNF). Amongst the reasons for using this type of geomembrane against the more commonly used polymeric sheet were:

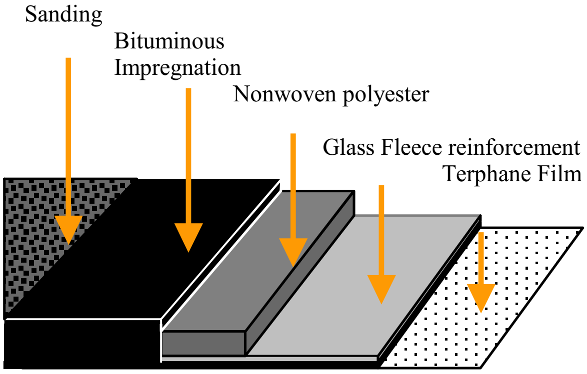
- The liner chosen was substantially thicker
- It is easy to fix and bond against concrete structures
- It has a proven in-service record
- It possesses a high puncture resistance
- All joints and welds are ultrasonically checked

4.1 *The structure of the geomembrane*

The structure of the geomembrane used is as follows (Fig 1):

- The core of the geomembrane is composed of
  - a non-woven polyester geotextile whose mass per unit area is 300 grammes per m^2
  - a glass fleece reinforcement which contributes to the strength of the geomembrane and stability during fabrication
  - the whole structure is impregnated with a compound including a blown bitumen of 100/40 pen plus filler
- The underside is coated with a Terphane film bonded when the membrane is hot, and designed to give resistance to penetration from tree roots
- Finally the upper surface is coated with a fine sand to a) provide greater traction on a slope, giving greater operator safety and security from slipping, and b) to give protection from the degrading effects of UV radiation

Figure 1: Typical cross-section



4.2 *Physical characteristics of the geomembrane*

The bituminous geomembrane used, Coletanche NTP2, possessed the following physical characteristics:

Table 1: Physical characteristics of the liner used

Characteristic	Property	Test Method
Roll length	80m	
Roll width	5.20m	
Thickness	4mm	ASTM D5199
Roll mass	2000 kg	
Mass per unit area	4850gr/m^2	ASTM D5261

5 THE SEQUENCE OF WORK

5.1 *Dewatering and gaining access*

The work involved dewatering the section of canal to be repaired and forming an access point for construction plant and materials from the pasture above the canal into the canal bed (figure 1). As the Llangollen canal forms part of the important local water resource, pumps were installed to maintain the flow of water and by-pass the closed off section whilst work was in progress.

Figure 2: Access to canal from pasture (before work commenced)

5.2 *Excavation*

Heavy excavation plant was used from both the bed of the canal and also from the bank to remove silt and defective materials. Where the original clay liner had broken down there were some areas that had become waterlogged. These were removed and replaced with new, sound, fill materials.

5.3 *Drainage under the canal*

The bed of the canal was then reinforced with a layer of 28mm single sized clean, crushed, durable stone to a depth of 250mm in order to carry the weight of construction traffic (see figure 3). A 100mm-diameter land drainage pipe was installed in order to take groundwater from underneath the canal, and reduce the possibility of water lying below the new construction.

5.4 *Retaining wall along the bank*

In order to provide additional protection and support an access road to properties below the level of the canal, a reinforced concrete retaining wall was constructed (see figure 3). Within this retaining wall were placed several "vole hole clusters" (see 3.2) designed to encourage the native Water Vole to re-colonize the canal and nest in the banks. The reconstruction of the retaining wall also enabled upgrading of the adjacent towpath for the use of pedestrians and cyclists.

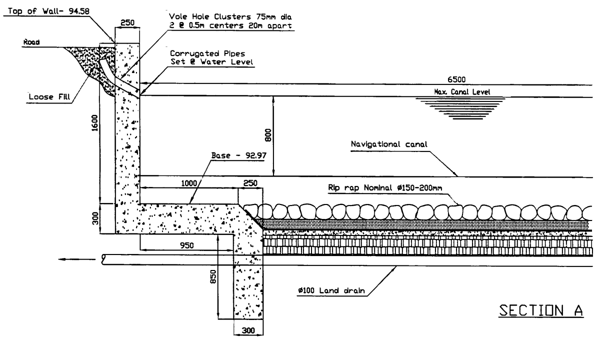


Figure 3: Section of canal showing retaining wall and drainage

5.5 *Tree clearance*

In order to enable effective waterproofing of the uphill side of the canal bank, it was necessary to remove a number of small saplings and scrub bushes. The hedgerow was also thinned to allow more light and thus encourage reed growth, the preferred food of Water Voles. Figure 4, below, shows the appearance of the bank beforehand. The old towpath and absence of retaining wall are also clear in this picture.

Figure 4: The old towpath and opposite bank showing tree growth.

6 THE LINING WORKS

6.1 *Preparation of the base*

It was very important to ensure the base of the canal and the bank was free of large stones and well compacted. Following on from the reconstruction of the bed a 2.5-tonne tandem roller was used to ensure correct compaction. However, even after this it was necessary to use a small vibrating plate to correct any disturbance caused by the tracked excavator used to place the rolls of geomembrane.

6.2 *The preparation of the concrete structures*

Unlike plastic lining materials, the geomembrane used can be bonded directly onto concrete structures - as well as steel, vitrified clay, etc. In order to carry this out the surface is prepared with a solvent-based bituminous primer. The gaps left by the water stop bars were filled with a special mastic which also permits a weld to be made under water if necessary.

6.3 *Geotextile protection*

Whilst not considered essential by the manufacturers of the geomembrane, the engineers of British Waterways specified a geotextile underneath and above the liner. This was in order to provide better protection of the liner as heavy plant would have to travel along the bed of the canal after completion. A non-woven polypropylene geotextile 8mm thick (750gr/m^2) was used under the liner, and a 4mm thick (400 gr/m^2) geotextile above it.

6.4 *Placing the liner*

The rolls of geomembrane were transported along the bed of the canal by the use of a 30-tonne 360˚-tracked excavator. A purpose-designed beam for unrolling the material was used; this allowed the heavy rolls to be maneuvered and the liner placed in position across the bed of the canal (see figure 5).

Figure 5: Unrolling the geomembrane

6.5 *Welding the liner*

The simplicity and effectiveness of the welding method for this type of liner are a major benefit on sites such as this. The edge of each roll of liner has a 200mm strip of kraft paper incorporated along the length, which is peeled off to expose a clean edge. This edge is lifted slightly, and a propane gas torch used to heat and liquefy the bitumen. The two layers are then brought together and rolled with a light hand held roller to produce a continuous seam. The very edge is then heated and trowelled over to remove any possibility of failure. Concrete structures are treated similarly, having been previously primed (see 6.2).

Figure 6: Bonding to the concrete wall

Additionally it is usual, when bonding the material to concrete structures, to reinforce the welds with a strip of aluminium or stainless steel approximately 2mm thick. This is designed to prevent the possibility of the edge of the liner becoming damaged and peeling back after time. In this case it was Hilti-Nailed to the concrete, and provides extra security for the edge at little cost (figure 7).

Figure 7: The geomembrane bonded to wall and reinforced

6.6 *Testing the welded seams*

All seams in the liner were tested for defective welds using an ultrasound device. With this it is possible to establish the integrity of all welds with complete confidence. An ultrasound pulse is generated by a hand held transducer, which also detects the reflected signal from the underside of the weld, displaying the readout on a monitor screen as two “peaks”. Any defects show up as a smaller peak between the generated and reflected peaks and the area can be marked for remedial action – repair is simple, by cutting, re-welding and then placing a patch over the repair overlapping by 200mm. The entire area of each seam is tested by a trained technician, traversing the width of each seam in a “zig-zag” fashion for the whole length. In a similar way any repairs carried out to the liner may thus be verified as secure.

A final visual inspection of the whole site was undertaken prior to its’ covering with stone to ensure there were no surface defects visible.

6.7 *Covering the liner*

The liner was covered firstly with a geotextile protection blanket (see 6.3), and then 100mm of type 1 crushed stone. This was leveled out with an excavator as it progressed along the bed. Following this operation nominal 150-200mm diameter rip-rap stone was placed along the bed of the canal and up the bank in order to provide additional protection for the liner and, equally important, provide an aquatic habitat for water-living creatures. The completed canal bed is shown in figure 8.

Figure 8: The rip-rap placed along the bed and up the bank

Following completion, the canal was refilled and opened up and returned to its normal use for the holiday season (figure 9).

Figure 9: The completed canal, opened to holiday traffic

7 CONCLUSIONS

This example of waterproofing a canal demonstrates the successful use of a bituminous geomembrane in a demanding situation, used where a more conventional material would have proved difficult to connect to structures. Easy to use, able to ensure good waterproofing characteristics and tough enough to be laid and covered over directly with stone to provide a diverse aquatic habitat, not covered with a sterile concrete slab.

REFERENCES:

Breul, B. and Herment, R 1995. Canals and Waterways: Maintenance and Repair using Bituminous Geomembranes

Breul, B. 2001 Technical Data of Coletanche NTP