RIVER MERSEY CLOSURE EMBANKMENTS APPLICATIONS OF GEOBAGS AND GEOSYNTHETICS

D.M. Tonks
EDGE Consultants UK Ltd

D. Parry
British Waterways

R. Howells
Manchester Ship Canal Co

D. M. Smith

EDGE Consultants UK Ltd

SYNOPSIS: substantial river closure embankments, each some 6m high and 40m wide have been constructed with the aid of various geosynthetics including use of geobags for underwater fill construction. They were formed across an abandoned loop of the River Mersey, in up to 3m depth of flowing water, on soft bed materials. Geotextile reinforcement was placed underwater on the river bed to provide construction stability. Enquiries revealed no comparable works of this nature or scale in UK or elsewhere, but did find some useful related experience. Comprehensive trials were therefore carried out to evaluate various products and construction methods. The Contractor developed special, purpose designed, handling equipment in close co-operation with the geotextile suppliers. The scheme allowed use of locally available sands and gave significant cost savings and environmental benefits compared to having to import stone, cofferdam or other difficult working techniques needed for a major river environment.

1 INTRODUCTION

The Mersey Closure Bunds form part of the Manchester Ship Canal, New Woolston Weir Scheme. Since construction of the Ship Canal in the 1890s, flood waters from the Rivers Mersey and Irwell and their catchment systems flow down the Ship Canal, before the Mersey separates again at Rixton. Fig. 1 shows the location and layout of this river / canal system. The flows had been controlled by a major 16 gate weir, requiring full time manning. As this was aging, the best option was replacement by an automated air-entrained siphon weir. Construction took place in the dry, in a newly cut diversion channel, some 80m wide and 800m in length. This also included various significant uses of geosynthetics. Full details can be found in Tonks et al (2002).

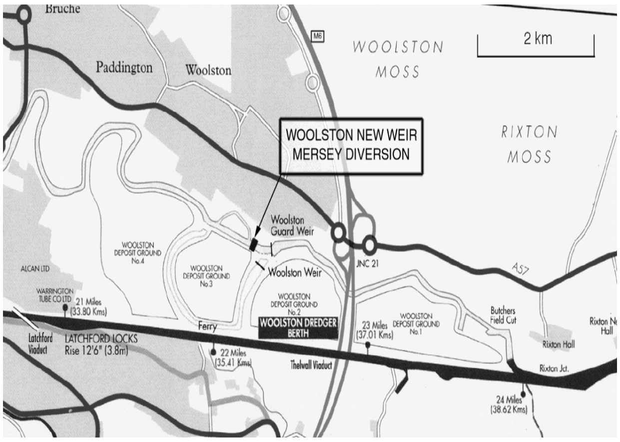


Figure 1 Schematic Plan showing site location and River Mersey / Manchester Ship Canal System.

The new weir and diversion led to the need for closure of the bypassed ox-bow, giving the opportunity for subsequent use for dredgings disposal. This required closure bunds at the eastern and southern ends of the site.

The initial section of Eastern Closure was constructed in September to October 1999 by way of closely monitored trials to assess and optimise construction methods. Photographs 1 – 6 show some of the main activities of interest from initial placing of the basal liner through to completion.

Filling below water level was by sandfilled geobags. Details of these are given in Table 1. The bags were typically filled to a volume of about 0.8 cu.m. and then closed by sewing prior to placement. A composite basal geotextile provided separation and filtration functions and also gave important short term reinforcing strength during construction until the soft river bed materials had time to consolidate and strengthen. Further geotextiles (Table 2) were incorporated as filters and separators within the embankment section and the stone protection

The Eastern Closure was constructed at the most suitable location immediately upstream of the abandoned Woolston Old Weir point. This entailed raising some 6m from river bed on soft ground with a significant amount of construction below water. Operation of the gated “guard weir” upstream, made it possible to control flows and lower the water level by about 2m, allowing construction to proceed in 2 to 3m of water. However, this could only be allowed for a few weeks and had to be co-ordinated with other maintenance works. It was therefore essential that the works were well planned in advance, to maximise use of the available window of time

The Southern Closure was constructed in sequence and closely followed the scheme for the Eastern Closure, programmed to optimise continuity of construction operations. It was located immediately to the upstream of the outfall of an inverted siphon which takes a small river beneath the Ship Canal to discharge into the lower level downstream Mersey.

This closure was raised some 6.5m from riverbed at 2.25m AOD. Typical downstream water level was around 5.5m AOD, but this could rise to over 7m AOD with high flows and tidal conditions downstream. The closures were designed to allow for further raising in due course, eventually to in excess of 20m. The scheme optimised use of available dredged sands and stone stockpiled nearby during the earlier construction of the new weir, used to provide erosion protection.

2 INITIAL APPRAISALS

Initial appraisals included extensive discussions with various geotextile suppliers and others with experience of similar work in UK and elsewhere, together with review and development from the authors' existing experiences experiences of similar works Moo-Young et al (1998), Tonks (1990, 2003).

A wide variety of construction techniques was considered. Pilarczyk K.W et al (1998) give a useful overview of the applications, benefits and limitations of various geosynthetic containment systems currently available. They considered the range of systems including geobags, mattresses, tubes and containers filled with sand and concluded these can provide satisfactory and cost-effective alternatives to more traditional materials and systems such as rock or concrete units or asphalt. They have been applied successfully in a number of countries and warrant application on a larger scale.

The use of large geocells filled from a dredger was investigated in some detail, as there was the option to link in with ongoing dredging operations in the area. This included discussions with various Dutch and German specialists. However all relevant experience encountered related to offshore applications. Geocells involve considerable amounts of off-take waters which can be only partially desilted. In the event it was concluded that it would not be practical to achieve control of suspended solids appropriate to the site's inland waterway constraints by such methods.

Development of the scheme therefore focussed on the practicalities of effectively and safely managing geobags and other key operations in the river environment.

3 DETAILS OF MATERIALS AND GEOSYNTHETICS

The closures were designed to be constructed with use of geotextile bags (geobags) filled with locally obtained sand from adjacent dredging deposit grounds. There proved to be little current UK experience of suitable construction techniques. Trials were designed to assess the suitability of the geobags and construction methods generally, with a view to optimising final design and construction. They were also designed to assess the relative merits of some differences in detail of the products, with technical support from suppliers, to evaluate and document experience for the main works.

Following consideration of the range of available products and discussions with a wide variety of suppliers and others with experience of similar work in the UK and overseas, two main types of geobags were selected. Summary details are presented in Table 1.

Table 1 Geobag Specification.

Ref	Size cu.m	Strength kN/m run	O_{90} μm	Comment.
B1	0.8	≥20 kN	80	600g/m^2 needle punched non-woven
	2	≥20 kN	80	600g/m^2 needle punched non-woven
B2	1	≥20 kN	80	woven polypropylene

Joint strength to be equal or better than geotextile.
Suitable detailing to allow dry filling from hopper.
Suitable lifting provision, hooks or suchlike to assist placement.

B1 "Sandcontainer" (Naue) is a purpose made bag for filling operations in waterways. Bags are formed from a folded and stitched rectangle of Secutex R601, a 600g/m^2 needle punched non-woven geotextile. The 0.8m capacity geo-bags proved quite easy to fill and place, using purpose-designed equipment (Photograph 2). No significant damage was encountered despite the need for some quite rough handling on occasions. Photograph 3 shows the geobags being placed below water, using a grab purpose-designed by the contractor.

Similar 2 cu. m capacity geobags were tried in the initial stages, but found to be significantly more difficult to fill, handle and place with the plant available, to the extent that they were not pursued for the main works. In essence, they proved too large and heavy for ease of filling and for handling by the types of plant appropriate for the site location and project requirements.

B2 Geobag (MMG) is a general-purpose fill container, formed from stitched Geolon 120, a woven high strength polypropylene geotextile. Although less costly for supply, these proved significantly more difficult to fill and particularly to place without damage in this quite challenging environment.

Several sand fill sources were readily available adjacent to the site. Fine to medium sized, dredged sands on the nearby deposit grounds were tested and found suitable for use in the works. Conventional crushed stone submersible fill and rip-rap were used where appropriate for bank protection, having been stockpiled for use during the earlier works.

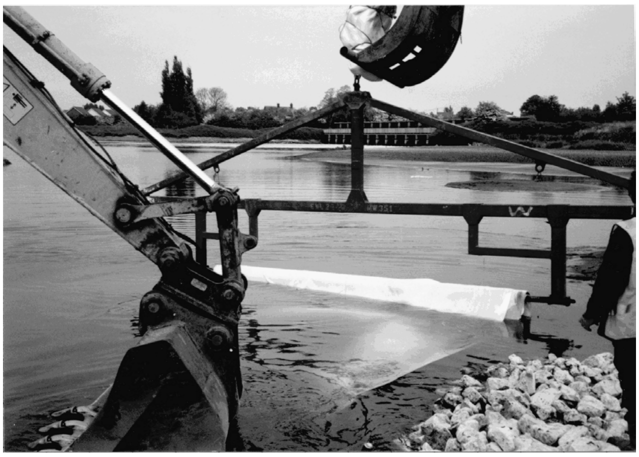
Various other geotextiles were used in the works, mainly for basal reinforcement and filtration, Table 2.

Table 2 Geotextile Specification:

Ref	Strength KN/m	O_{90} μm	Weight g/m^2	Comment
M1	≥20 kN		500	Composite geotextile sand ballast
R1	≥200 kN			High strength polyester
F1		80	≥200	
F2		80	≥800	

The Basal Geomat M1 used was a multi-layered, geotextile mat, self weighted and specifically designed for placement under water in such applications as this. Terrafix B813 "Sandmat" (Naue) was used here. This was a composite of 800g/m^2 and 300g/m^2 geotextiles, sandwiching a layer of sand ballast. Its tensile strength was some 20 kN / m run. This proved very adequate for placement and general usage.

A Basal Reinforcement Geotextile R1 was required for stability (see below), capable of giving some 200 kN / m run strength at strain ≤10%, for the short term only. A high strength polyester geotextile, Stabilenka 200/45 was used for this application. This would float and be difficult to place underwater. It was therefore combined with the geomat M1 in a composite roll and placed underwater, beneath the geomat. A purpose-made boom was developed by the contractor for this underwater placing, based on his experience on previous projects for the consultant (Photograph 1).



Photograph 1 Eastern Closure Placing Basal Geomat

Filter Geotextiles (F1 and F2) were incorporated into the embankment cross section as shown (Fig. 2), to provide a continuous filter against migration of fines.

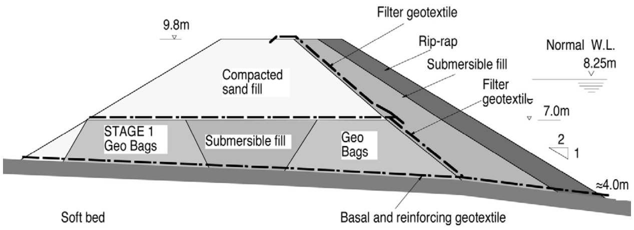


Figure 2 Cross section of Eastern Embankment

4 STABILITY

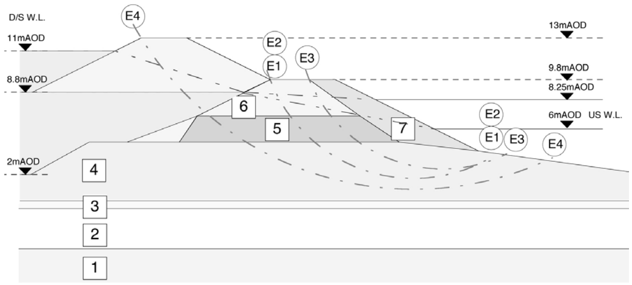
The most challenging overall design issue was stability of the closure bunds during construction. With the relatively high cost of materials, maximising the stable angle was of considerable economic benefit. This was also important to minimise construction time. Stability analyses for the embankments and foundations were undertaken using slope stability analysis program STABLE, which could incorporate the effects of the geotextile reinforcement. Typical details are shown on Fig. 3.

There were significant soft bed deposits of river silts overlying hard bed materials of mainly dense sands, but firm to stiff glacial clays in places . The soft deposits were of variable thickness, particularly for the Eastern Closure, due to the complex flow regimes associated with operations of the old gated weirs. The distribution and details of soft bed could not be defined with any great certainty. Excavating the silts was not an attractive, or indeed realistic, proposition. Stability analyses allowing for the soft deposits remaining in place indicated the possibility of instability during construction raising of the bunds, e.g. Case E1 with factors of safety less than 1.0.

Reinforcement geotextile provided the cost-effective means of addressing this. The reinforcement effectively halved the volume of fill required for stability and equally importantly halved the construction time. This was of particular significance, since the river levels could be reduced by operation of weirs for short periods only. Design provided for factors of safety of 1.3 during construction, with the reinforcement.

Long term strength (effective stress parameters) of the foundation and bank materials showed adequate factors of safety (> 1.4) without need for the geotextile reinforcement, post construction. This included assessing stability for the range of upstream and downstream water levels which could occur for these banks. E3 gives an example.

The design also provided factors of safety in excess of 1.4 for the planned further stages of raising (E4).



Ref.	FOS	U/S W.L.	D/S W.L.	Bank Height	Notes
E1	0.73	6	8.8	9.8	Total stress, analysis
E2	1.32	6	8.8	9.8	Total stress analysis, reinforced (T=200kN)
E3	1.38	8.25	8.8	9.8	Effective stress, analysis.
E4	1.59	8.25	11	13	Effective stress, analysis.

Ref.	Ø'	γ	Soil Description
1	30	18	Firm / Stiff CLAY
2	30	18	SAND & GRAVEL
3	28	16	Sandy SILT
4	30	16	Clayey silty SAND
5	36	18	Geosacs and stone fill.
6	36	18	Engineered fill
7	40	18	Stone fill
8	33	18	Dredging deposits

Figure 3 Eastern embankment. Stability analyses.

5 INITIAL CONSTRUCTION WORKS AND TRIALS.

Preliminary works were undertaken for the Eastern Closure with a view to making appropriate preparations and evaluating preferred options for the main works. The principal objectives were:-

- Preparatory Works and geotextile / geobag trials.
- As much preparation and investigation as practical / beneficial.
- Must not adversely affect final design options.
- Investigate plant, practicalities and aim for future economies.
- Evaluate procedures for filling and placing geobags for range of likely conditions.
- Start with simplest working through to more difficult conditions.
- Develop Method Statements with technical support and discussions with suppliers.

The main initial works involved:

- Lower upstream water level as far as practical, (from about 8m AOD normal to about 6m AOD)
- Form access bund across river immediately in front of Woolston Old Weir.
- Form trial bund approx 50m length, to 7m AOD
- Return water to normal operating river levels.
- Leave stable and secure for incorporation into main works

The initial works were undertaken over a six week period in September to October 1999. The main construction plant used was 2 No. Komatsu PC210 (23 Tonne class) excavators and 2 No. Hydrema (10 Tonne load) dumpers. One of the PC210 excavators was fitted with a modified grab (photograph 3) for bag placing and handling.

Water levels in the trial area were normally at around 8.2mAOD but subject to variability of River Mersey flows. These were controlled by closing sluice gates on the Guard Weir upstream and opening gates on the Old Weir and sluices on Woolston New Weir. The water was thus lowered to 6.2 - 6.5m AOD range (photograph 3); still requiring working in some 2 - 3m of water. Towards the end of the first stage construction, flood water from exceptionally heavy rain overtopped the guard weir and completely flooded the work area overnight. However this left no significant effect on the partially completed works.

Geobags B1 filling and handling proved somewhat difficult in the early stages. It took several days to establish an effective working system, with various modifications to the filling frame (photograph 2) and grab attachment (photograph 3). Once developed, production rates of up to 40 bags / day (per frame) were achieved in the initial construction works and up to twice this in the main works.

Photograph 2 Bag Filling Frame

Geobags B2 were easier to fill requiring only simple posts as support. However, the bags held less material and proved less robust. Various handling and placing methods were tried, but without achieving consistency or confidence, particularly for the more difficult areas of extended reach. These geobags were found useful in the less demanding applications for general infilling.

Placing bags was generally accomplished easily but with only limited control in the pattern of laying being practical, due to the irregular and variable shapes the bags took up during handling. After the initial learning process, progress was reasonably good, constructing up to10m length of bank / day. The construction layouts adopted varied as works progressed into the river. Hard bed below the silts was checked and proved with care as works advanced to ensure safety of working for the operational plant. A track was formed across the top of the bags using sand to protect the geotextiles from damage during tracking. Some river bed silts were displaced as the works progressed.

Fig.2 shows a cross section through the first stage embankment, as evolved through the trial works. The key objective here was to provide a safe and stable access across the river for operational plant. The basal geotextile mat was quite heavy, but it handled satisfactorily and significantly assisted the constructability of the works. The bund was constructed with outer walls of geobags B1 laid in a “stretcher bond” pattern with bags B2 infill in rows 4 bags wide. The height of this bund was up to 2m in the centre of the channel. A layer of submersible fill (stone) was placed on top of the bags for protection from excavator tracking. The ends of the structure were temporarily completed by folding the basal liner over the top of the leading faces of the bund, secured in place with submersible fill, to be uncovered and incorporated in the main works.

6 MAIN WORKS, SUMMER 2000

Based on the experience of the trials, works were programmed to commence in early May 2000, and be completed by the end of August 2000 (18 week construction period). In the event, progress was significantly better and was completed some 6 weeks early. The photographs 3- 6 show the main construction works.

Photograph 3 Southern Closure Placing Geobag Below Water

The eastern closure was constructed with upstream pond level as low as practical, around 6.5m AOD. The methods used enabled this period to be kept to a minimum at around 3 weeks. The main works entailed:-

- Lower upstream water level to c 6.5m AOD.
- Complete bank to full width at 7.0m AOD level using geobags.
- Place filter / separator geotextiles.
- Place bank protection.
- Place sands to level 9.8m AOD.
- Complete bank protection.
- Final landscaping / fencing.

Photograph 4 Southern Closure – Geobag Base with Sand Protection

Photograph 5 Construction above water level.

The southern closure was constructed with the downstream pond level around 5.5m AOD and bed level 2.25m AOD. With the rate of bag filling optimised this work was completed in 9 weeks. The main works entailed:-

- form access ramp to closure location
- raise bank to level 7.0m AOD using geobags.
- place filter / separator geotextiles.
- construct balancing pipe (including inlet/outlet).
- place bank protection.
- place sands to level 8.8m AOD.
- complete bank protection.
- final landscaping / fencing.

Photograph 6 Completed eastern embankment.

7 COMMENTS AND CONCLUSIONS

The works have successfully developed and implemented suitable design and construction techniques for river closure and other works. Use of the various geosynthetics gave major savings on other methods, which would have involved substantial import of submersible fill.

Geobags with other geosynthetics allow construction within the water environment in a suitably controlled manner. However, there are significant differences between different geobags. As might be expected, the higher cost bags were more robust and necessary for the more demanding applications. The lower cost bags were found useful for some applications, but not sufficiently robust for the main works.

There are some indicative design criteria from work on large offshore geocells. The main properties required are adequate strength for handling and filter size for containment. Criteria depend on the plant used and conditions of placement. Speed of filling and sewing, and ease of handling, are important to overall cost-effectiveness.

The construction method developed during the first stage trial embankment works was found easiest by the contractor and produced a suitably structured bund, within the practical constraints of placing the geobags below water.

Geotextile reinforcement provided a cost-effective means of addressing short term stability of substantial banks constructed under water on soft river bed silts. Alternatives would have entailed removal of the silts or much flatter embankments requiring far more fill which could well have doubled the cost and time of the works.

Design provided for factors of safety of 1.3 during construction, with the geotextile reinforcement. Stability improves to factors of safety exceeding 1.4 without the need for reinforcement in the long term, as the foundation soils consolidate and strengthen (i.e. the reinforcement becomes redundant post construction).

This approach also opens up the possibility of using a wider range of reinforcement including natural fibres (“geonaturals”) for reinforcement and for some of the geo-bag applications in the future,Tonks (2002).

8 ACKNOWLEDGEMENTS.

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