Bloomfield Road Tunnel Sleeving

an innovative solution to secure a key asset

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The Bloomfield Road Storage tanks sit in the heart of Blackpool, Lancashire, providing 60,000m^3 of storm storage during periods of high flow in the United Utilities sewer network. The tanks were constructed in the late 1990s and are of diaphragm wall construction, with each being some 36m diameter and 36m deep. When flows in the network increase, the tanks fill via a weir penstock into tank 1. There is an 1,800mm diameter interconnecting tunnel, 5m above the invert level of tank 1 which transfers flows into tank 2. From here, flows are pumped back into the network when hydraulic capacity is available. In November 2011, a maintenance project whose scope was to grout voids beneath tank 1 and strengthen the headwall to tank 1 was nearing completion when a routine inspection identified a leak within the tunnel.

Work nearing completion, the steel pipe has been inserted and staging is being dismantled - Courtesy of Guzelian

Introduction

The tunnel consists of bolted segments with an internal GRP liner and 100mm grout infill. The tunnel was known to be distorted and had been surveyed previously to monitor both its geometry and condition. When the leak was detected, concerns were raised for the integrity of the tunnel. Because of the severe consequence should the tunnel collapse, the project scope was extended to effect a repair to the tunnel.

Initial considerations were to grout externally around the tunnel, however, there was a realisation that the grouting operation may need to be extended along the line of the tunnel to ensure its security by infilling any voids around it. The potential infiltration of groundwater, under some 3 bar of pressure, brought the risk of sand and gravel fines migrating into the tunnel which could result in asymmetrical loading on the tunnel from further ground loss. Grouting pressures would need to be in the order of 6 bar to overcome groundwater pressures and penetrate the surrounding material effectively. These two issues brought real concerns that the tunnel would not be able to withstand the loads to which it may be subjected.

Pipe sleeve

After further detailed consideration, the design team concluded that the risks of undertaking any grouting work were simply too high. Determining the residual strength of the tunnel was effectively impossible with the local conditions and the implications of failure were grave. The team concluded that the best solution would be to sleeve a pipe into the tunnel which would effectively be structurally independent. With ductile iron, polyetheylene and steel options, the key decision centred on whether the pipe would be structural with an infill grout, or a liner with a structural grout surround. Following further investigations the project team chose the structural pipe as the safer option. The integrity of the liner solution would be completely reliant on sealing the ingress into the tunnel, which had the potential to deteriorate further and crucially, prove too high a risk for the operatives who would have necessarily had to work in the tunnel.

Material selection

Supply chain research lead to steel being selected as the preferred material. There was a desire to maximise the diameter of the pipe for hydraulic reasons, whilst also being mindful of construction tolerances for installation. The distortion of the tunnel was also to play a crucial part. Outline design considered the potential effect of a 6 bar point load onto the pipe, acting as a beam over a potential void of indeterminate size. This lead to the selection of a pipe manufactured from Grade 50 steel, 20mm thick. Choosing steel helped from a programme perspective as procurement of the supplier and plate could commence whilst the tunnel was being surveyed and design finalised.

Whilst nominally 1,800mm diameter, the minimum clear diameter was of 1,580mm was determined following a laser survey. Consideration of tolerances and the need for external flanges to allow the pipe to be assembled 30m below ground led the project team to conclude that an 1,100mm internal diameter was the maximum size which could be accommodated without significant risk to the insertion process.

No risk solution

The original design intention was to travel the pipe into the tunnel on castors but, as the surveys and 3D modelling of the tunnel were developed, it became clear that the tunnel had a high point which would attract an 11T point load from the pipes as they were inserted. This raised concerns as to the effect of this load on the tunnel. Since it was not feasible to quantify the residual strength of the tunnel, and with the requirement to bring the tanks back into operation for the bathing season in May 2012, site work was stood down; the risk to the tunnel was deemed to be too great for work to proceed.

Following further survey work, the integrated design and site team identified that, given the geometry of the tunnel, the only way to eliminate any further damage and risk to the tunnel was to develop a no-contact solution. The site team developed the idea of an innovative travelling beam system, whereby the pipe was supported by rollers on a primary and secondary beam system and winched through the tunnel. The beam system comprised a 762mm x 267mm x 192mm primary beam fitted with inclined castors on the top edge to carry the pipe *(as shown in the photograph bottom right)*. The system was inserted into the tunnel using two smaller beams, which were on skates, and then fixed to end plates which carried the primary beam.

Trial run

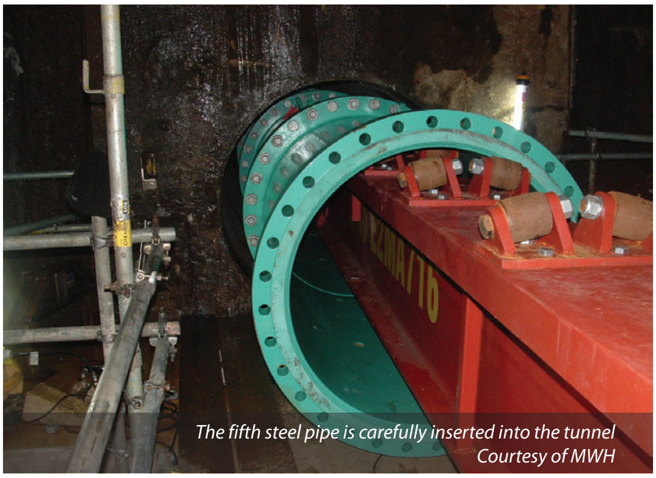
Due to the bespoke nature of the system and the difficulties with accurately assessing deflections, the system was built at ground level to trial run the full pipe assembly and gain confidence as to how the system would operate. A twin trestle and jack arrangement, at the insertion side, allowed pipes to be carefully introduced into the tunnel.

A ground penetrating radar survey was also undertaken during this time which indicated that no discernible voids were present under the tunnel. After further analysis the team agreed not to carry out the proposed grouting from ground level along the line of the tunnel, a saving of some £300,000.

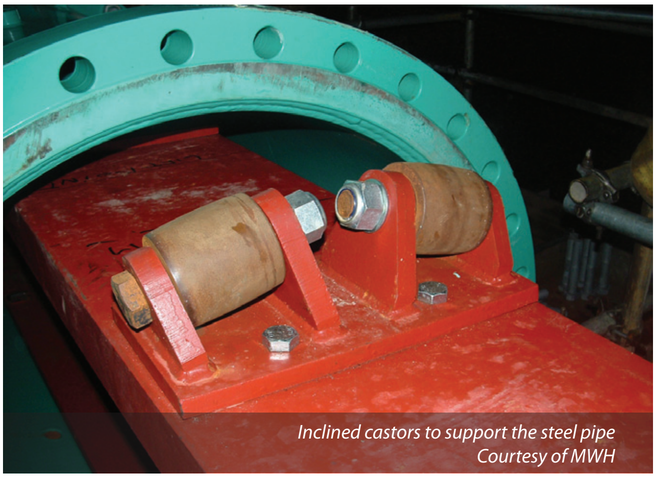
A crucial part of the solution was the trial of the jacking system at ground level on site. This was invaluable for the site team as it gave them a key understanding as to how the system behaved and

Tanks under construction in the late 1990s

The site set up needed careful consideration within the limited space



The fifth steel pipe is carefully inserted into the tunnel Courtesy of MWH



Inclined castors to support the steel pipe Courtesy of MWH allowed method statements to be fully reviewed. Static deflection of the system was estimated at some 100mm, but clearly this would not necessarily cater for the transient conditions as installation proceeded. Time here was spent very wisely with some key modifications and knowledge learned by the site team;

1. A single jack did not provide sufficient lateral stability to the primary beam so these were doubled up.
2. The primary beam needed some additional stability to its top flange. This was accomplished by the introduction of additional SHS stiffeners *(see photo 3 on previous page)*. The capability to undertake these modifications on site proved to be invaluable as the team learned how the system was behaving under transient conditions.
3. A better understanding of the beam deflection was gained. This would prove to be critical in setting the initial line in the tunnel. The final design incorporated 11 (No.) 1,840mm long pipes, each weighing 1.63T. The design team were aware that as installation proceeded, deflections of the beam decreased as the relative stiffness of the pipe was greater. Thus the greatest deflection occurred as the fifth pipe was strung in.

Pipe insertion

Works resumed on site in October 2012 and a period of development took place to overcome the complex deflections, sequencing and safety of the exercise. With Christmas looming the site team moved onto a twelve hour day, seven days a week working practice. With continuing difficulties being overcome, the final pipe was installed at 9pm on Friday 21 December 2012. The following weekend was utilised to fill the void between the pipe and tunnel via a grout in three lifts, leaving the tunnel secured just before Christmas.

Undertakings

The project team was formed from specialists within the various partner organisations, consisting of a United Utilities project manager and geotechnical engineer, an MWH civil engineer and a GHA Livigunn structural engineer. Input from principal contractor KMI+ was invaluable in developing a deliverable solution.

Interaction between the design and site teams was particularly important for the project as it was clearly very high risk with an untried solution. KMI also engaged key members of the supply chain who, likewise, played an integral part:

- **Burwood Supply**: Procurement and delivery of steel pipes.
- **Alken Pipe Fabrications**: Design and fabrication of steel pipes.
- **Rossendale Group Ltd**: Design and fabrication of beam support system.
- **Kier Engineering Services:** Design of platforms and staging
- **NW Total Engineered Solutions**: Site trial and pipe installation.
- **RAM Ltd**: Grout around steel pipes.

Detailed scope, methods and risks clearly evolved with the project. The team arrangements were flexible to ensure the desired outcome was met.

The cost for this element of work was £750,000 and what started out as a simple request proved to be an enormously difficult project. With the introduction of an innovative travelling system, seldom, if ever, used in this application before, the site team were able to secure the tunnel and deliver a successful solution and thereby secure a key asset for the client.

The Editor and Publishers would like to thank Brian Sharp, Senior Project Manager with United Utilities, David J Morgan, Principal Civil Engineer with MWH and Graham Collinson, Site Manager with KMI+, for preparing the above article publication.

With the pipeline inserted and grouted in, the staging is dismantled
Courtesy of Guzelian and MWH