Plimsoll CSO much more than just treading water

by Simon Watts & Andy Thomas

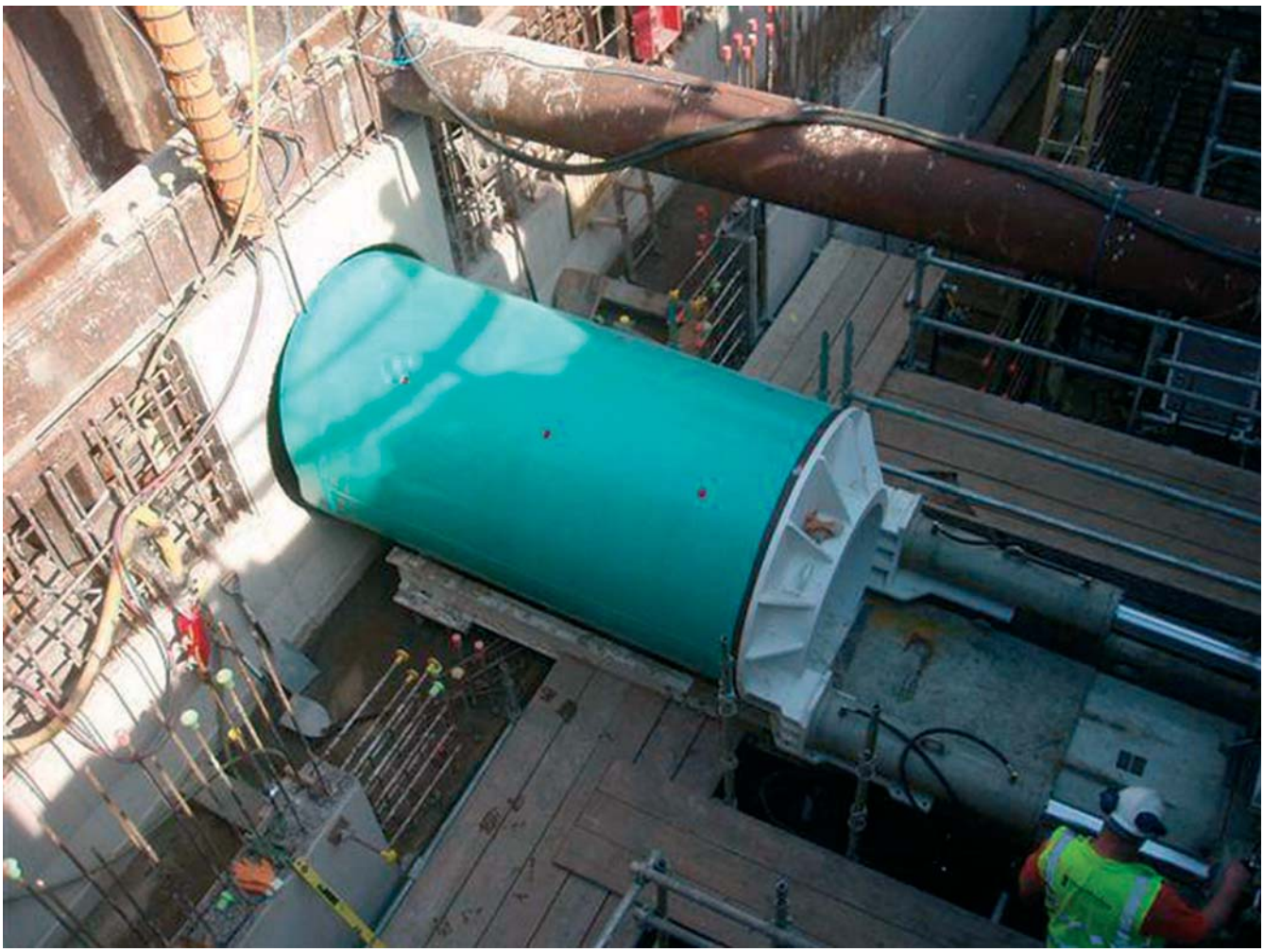
Alongside the Avon Gorge in the heart of Bristol, in the shadow of the Brunel's Clifton Suspension Bridge, sits the Plimsoll statue. Bristol born Samuel Plimsoll later became a Member of Parliament and during his time in the Commons he brought in legislation that later became known as the Plimsoll Line. This law required vessels to display a line around their hulls marking the safe loading limit; if only resolving sewer overloading was quite that simple. The Plimsoll Line legislation was imposed to prevent recurrence of a series of maritime disasters due to overloading of vessels. Wessex Water's sewer improvement works shared many of the concerns familiar to Samuel Plimsoll; how to create a safe working environment, how to maximise loads without risking overloading, how to ensure that buoyancy is controlled at all times. A lesser known, albeit it temporary, landmark for the residents and visitors has been created under the gaze of Plimsoll's statue; the site of one of Wessex Water's most high-profile projects.

Plimsoll CSO under construction - suspension bridge in background *photo courtesy Wessex Engineering & Construction Services*

Background

Much of Bristol's sewerage network dates back to the 19th century, when the population was only about a quarter of the current 550,000. The population growth in the Bristol catchment, combined with legislative efforts to achieve significant improvements in the environmental impact of wastewater discharges, has brought about a huge investment programme. Since privatisation of the water companies, investment has focussed on meeting this new legislation. The investment has led to significant and targeted improvements in the effluent standards of hundreds of sewage treatment works. Further investment in the sewerage system (which carries flow to this STW, mainly to reduce the frequency and aesthetic impact of storm water discharges) continues.

Combined sewer overflows (CSO's) are designed into the sewerage system to act as pressure relief valves, ensuring that excess flow is kept away from areas which might otherwise be harmed by sewer flooding. Alongside the Avon Gorge, numerous CSOs operated at times of heavy rainfall, discharging flows in excess of the sewer capacity directly into the river. A large diameter sewer was constructed in the 1980's, parallel to the River Avon, to intercept the many crude discharges and instead carry the flow directly to



Plimsoll CSO under construction *photo courtesy Wessex Engineering & Construction Services*

Avonmouth STW, to reduce the number of unsatisfactory intermittent discharges (UIDs) to the River Avon. Wessex Water chose to overhaul the interceptor both through reducing and improving a number of these CSOs and by providing fine screening to all discharge flows.

Six CSOs were to be eliminated by the development of a single CSO, whose site was carefully selected to achieve the best performance of the network. This site became known as the Plimsoll site.

The ground conditions at the CSO were known to be very difficult. Approximately four years prior to works commencing, a significant land-slip due to failure of a water main nearby caused part of the Portway (one of Bristol's main trunk roads carrying over 38,000 vehicles per day to the M5 motorway) to fall into the river.

Another significant challenge would be faced from dealing with the River Avon itself. Tidal ranges in excess of 12m would do their best to challenge any work on the riverbank, causing the site to flood and making the stability of any permanent structure a critical issue.

Need for the scheme

During periods of heavy rainfall and due to the historical prevalence of combined sewers (those that carry both surface and foul water) system inadequacies are relieved by the construction of Plimsoll CSO. To eliminate one such CSO and improve the performance of two others by reducing both the frequency and spill volume of storm flows, Wessex Water developed a range of improvements.

Proposals

Improvements to the Plimsoll CSO were agreed with the Environment Agency and would bring about the elimination of one downstream CSO entirely, with significant performance improvements in two further CSOs upstream of the Plimsoll CSO.

The new CSO was to be built upon the line of the existing trunk sewer that runs under or parallel to the Portway all within the confines of the Avon Gorge. The CSO would be capable of passing much of the flow forward on for full treatment at the nearby Avonmouth sewage treatment works, whilst the excess flow, up to 3.3m^3/s, would be discharged locally into the Avon.

Procurement

With its massive £800 million, five year investment programme, Wessex Engineering and Construction Services (WECS) is sharply focussed on delivering efficiency for its regulated client Wessex Water. In past years this has been achieved through the use of alliance designers and contractors working in collaboration to deliver an outcome. For three years now Wessex Water has adopted this principal but taken it to the logical, and fruitful conclusion. WECS is the result. A wholly owned contracting business. A dedicated and complete project delivery service.

WECS has the expertise to appraise, design, construct and commission schemes and for the Plimsoll CSO it was the perfect delivery vehicle. WECS worked within the confines of the project scope to achieve best value, not for itself, but for the Client. This is an important distinction as the Plimsoll CSO scheme was more liable than most to suffer from the risks thrown in its path. A traditional approach of employing external contractors (who would welcome these risks and the associated rising costs) would not deliver best value. This was anathema to WECS whose success would be judged on the whole cost, thereby ensuring that the extensive risk register would be managed efficiently and with the primary focus ensuring a high quality, low cost solution for Wessex Water.

Plimsoll CSO under construction

courtesy Wessex Engineering & Construction Services

Design

Through its extensive experience of infrastructure construction, WECS has developed a wide portfolio of standard designs to match the client requirements. These standards are in use in many of the client's assets, maximising efficiency and operator familiarisation, whilst reducing the cost of design, construction and stocks of spares.

Use of computer driven modelling for sewerage assessments and improvements is well established. Simulation of the behaviour of real systems, using packages such as Wallingford Software's INFOWORKS package allows engineers to understand both the causes of substandard sewer system performance (flooding/unsatisfactory overflow operation) and to develop solutions to these problems. WECS has a dedicated team of modellers who support the company's design, construction and operations arms.

Engineers develop models that simulate the actual behaviour of the system from asset data (pipes, manholes, pumping stations) combined with quantification of storm and foul flows into the system. Models are verified by collecting rainfall and flow data over an eight week period and comparing the predicted and actual system performance.

Although design of the permanent works was relatively straightforward, incorporating two screens and six pumps, the temporary works needed to permit deep excavation, anti-flotation and stability was a significantly more challenging task. WECS sub-let the design of the works to one of its framework consultants, permitting its own in-house design team to take an overview of the project and comment on the design as appropriate.

A sequential excavation technique was proposed, with rock anchors to hold the CSO in situ, sacrificial sheet piles to restrain the lateral loads imposed by the river and the adjacent ground and a series of props and bracing struts to retain the shape of the cofferdam.

The ground in which the excavation was formed was enormously varied. Alluvial deposits from the River Avon were combined with both fractured rock and rock of high integrity. A further band of hill-wash added to the complicated geological environment.

Construction

Construction began on the CSO in May 2006. In the limited space available between the Portway road and the River Avon, a tracked excavator began the task of reducing the ground level in the general area before commencing the installation of the upper 8no. rock anchors to support the Portway wall. The ground level was then reduced a further two metres and another 8no. rock anchors were installed. This enabled a piling rig to then be positioned on the footpath behind the wall to install 8no. piles for the crane slab to be constructed on. With this in place a 40 tonne crawler crane was brought to the site to install the sheet piled cofferdam.

15 metre long interlocking sheet piles were driven into the ground to form, when seen from above, a rectangle of 17m by 8m. The excavation then began in stages installing welded frames at four levels, finally reaching a level of 9m below footpath ground level and 8m below Highest Astronomical Tide.

As excavation progressed, the first two rows of rock anchors were connected into the framework of the cofferdam. The third row of anchors were installed before the final excavation could be taken to formation. These were installed as tendons and drilled using a rig from within the cofferdam at an angle of 22 degrees from the horizontal 18m down into the rock, before the an annulus between the steel cables and the remaining cased hole was grouted, securing the anchors in place.

In order to allow further excavation a grid of 20no. pressure relief wells were installed through the alluvium in the base to the bedrock below. Continuous monitoring of the cofferdam using the observational method was employed throughout the final stages of excavation works via a system of piezometers, extensometers, inclinometers, tilt meters, strain gauges and daily site engineering checks.

Excavation could then proceed to formation level, although this had to be constructed in a very controlled sequence which involved localised staged excavation in strips incorporating permanent props constructed of steel universal columns encased in concrete across the full base area of the cofferdam. With this robust structural blinding strut in place construction of the 36no. tension piles could be undertaken from this level. Once the piles and pile cap (base) had been constructed and achieved its designed strength the dewatering via the relief wells could be discontinued. This then allowed a dry working area for the installation of the permanent works, incorporating a reinforced concrete pumping station, which needed to be constructed in managed stages to allow the installation of 15m of 1500mm welded steel pipejack some two metres from the pumping station base to the existing brick sewer within the carriageway.

On completion of this the internal walls can be taken to mid-height before removal of the walling frames. The remainder of the structure and concrete soffit can then be completed allowing installation of 2No. Huber Rotomat screens, 2no. screening return pumps and 4no. 625ltr/secs Bedford Canister Pumps to enable discharge from the CSO at any tidal condition.

Note:***The Editor & Publishers wish to thank Simon Watts, Site Manager and Andy Thomas Construction Manager, both with Wessex Engineering & Construction Services for providing the above article for publication.***■