

## The New Studley Tunnel

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SCHOLEY, J. & INGLE, D. (1989). The New Studley Tunnel. *Proceedings of the Shropshire Geological Society*, **8**, 25–27. The New Studley Tunnel forms part of the Elan aqueduct. The site investigation at Clee Hill was outlined, enabling a description of the geological structure of the hill through which the tunnel leads. The construction of the project is explained, in particular how tunnelling methods were adapted to suit the diverse geology encountered.

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Sir John William and Partners' role in the project is that of Engineer. They are not a party to the contract which is between the Severn Trent Water Authority, the owners of the aqueduct, and Faircloughs. As the "Engineer", Halcrow had designed the project, prepared the contract and arranged the letting of the contract, though returned tenders were opened by the client who would decide whose tender to accept, with the assistance of recommendations from Halcrow.

Halcrow supervise the project and certify the amounts to be paid to the Contractor. Fairclough's role is the build the project and they have the experience, expertise and knowledge of methods to carry through the project.

The New Studley Tunnel will form part of the Elan Aqueduct. The aqueduct conveys water from a series of reservoirs in Wales the 118 km to Birmingham. In the late 19th century, Birmingham derived most of its water from boreholes. Birmingham is on high ground and had to pump to extract their water, and they were running short. They detailed a leading dam engineer of the time, James Mansergh, to identify an alternative supply for the city.

Mansergh was also a railway engineer and had been working on the Cambrian railways. While carrying out work near Rhayader he identified a site for a reservoir in an ideal position to supply Birmingham and he managed to persuade the Birmingham authorities that this would be the solution to their problem. He planned to run a conduit, keeping to higher ground for as much of its length as possible. It runs from Rhayader, past Ludlow and Clebury Mortimer, north of Bewdley and Wolverley and on to Hagley and Frankley.

Some third of its length is in Shropshire and most is gravity feed and free flowing and the conduit has a gently gradient of 1 in 4,000 overall. It has to cross a number of valleys; in particular it crosses the Teme thrice and the Severn Valley. Where it goes below the level of water surface it runs through a system of pipes in an inverted syphon designed so the head of water in the pipes is sufficient to flow in one end and out the other.

Where the aqueduct encountered high ground this was tunnelled through - some tunnels are up to 6 km in length and one tunnel, the Studley tunnel runs through the southern limb of Clee Hill. The original tunnel is shaped like a loaf of bread and is concrete lined with one layer of bricks lining the water channel which has become darkened by a layer of peat slime. There is a routine 72 hour cut-off of water supply every six months so that inspections and any necessary minor repairs can be carried out.

Repairs have been carried out several times over the century of the tunnel's use, nearly all of which have been in the central 500 m of the 1500 m long tunnel. Unfortunately the repairs that have been made restrict the flow of water in the tunnel and it became necessary to consider a final solution rather than another series of repairs.

Several possibilities were considered; the old tunnel could be rebuilt, but the water would have had to be overpumped during reconstruction at a considerable cost; a conduit running round the hill rather than through it, but the necessary extremely shallow gradient over the longer length would have meant construction of an impossibly smooth structure and the disruption to the local residents would have been immense.

The area is environmentally sensitive - it is a holiday area of outstanding beauty, so for economic and other reasons it was decided to build a new tunnel running parallel to the first.

A survey undertaken in 1967 had indicated that the geology of the hill caused the problems in the central section. The basic geological structure was known from Regional Memoirs and some records survive from the construction of the original tunnel. Clee Hill is a dolerite plug and has been quarried for over a century, but the southern limb is quite different, it is sedimentary.

However before the new tunnel could be designed and sited a full site investigation needed to be carried out. Halcrows undertook this contract and in 1985 ten boreholes were driven. Two of these had to be relocated as it was found impossible to drill through certain strata. These were usually mixtures of marl and sandstone or marl and clay. Pumping experiments were also conducted to try to determine the porosity of the strata. These experiments were not entirely successful and in some cases no back pressure could be obtained and the local residents became distressed to see their entire water supply being pumped down boreholes! From this investigation the structure of the hill was determined with some accuracy.

Underlying the hill are Devonian marls and sandstones which are dipping north. Unconformably overlying these is a syncline, at the base of which is Carboniferous limestone, interbedded by a series of shales. The limestone bands are hard but muddy. Above the limestone is a rather 'nasty' band of marl clay containing approximately 65% silt and a fair amount of clay containing the clay mineral smectite which is a potentially swelling clay mineral. It was pointed out that the term 'marl' is used to describe calcareous mudstones, and it says nothing about the strength of the rock and very little about its structure.

In the hill this band of clay marl acts as an impervious layer and there is a series of sandstones, conglomerates and mudstones above it, referred to collectively as the Cornbrook Series.

Once above the swelling marl there is no calcite present, the rocks are acidic and siliceous. Towards the top of the hill are Coal Measures, but it is not thought that these are very developed over the tunnel itself as they tend to be further up the syncline and further round the hill. There are coal

bands in the Cornbrook Series, these are bands of carbonaceous shale.

The structure of the syncline is more of a V-shape than a U-shape and strata go down nearly parallel for some way on both sides. The fold is concentrated into a narrow central zone which makes it difficult to define where the axis is located, and there tends to be shattered rock down the middle of the syncline.

A further 9 boreholes were sunk in 1986 and slides of the number 17 core were used to describe the rock sequence in some detail.

The construction methods used by the Contractors to overcome the difficult and variable geology can now be described. The work started in October 1987, and the first job was to improve access to the site. The new tunnel was to be 1330 m long with an internal diameter of 3.15 m which would be reduced to 2.65 m when lined. This final lining would be circular rather than the "D-shaped" excavated profile and it would be parallel to the original tunnel.

Faircloughs started a shaft excavation in November 1987 to dig down to the level of the original tunnel which lay at a depth of 9 metres below ground level. Using a special excavation machine they were able to proceed 150 m horizontally through the Devonian marl without the need for blasting. However, once into the sandstone the machine could not cope on its own and a drill and blast method of excavation was adopted.

One problem with the variability of the rocks is that of support and the New Austrian Tunnelling Method has been adopted which employs the use of concrete sprayed by pneumatic means with water being added at the nozzle of the spraying machine, the "shotcrete" method. It is an ideal method of support as a few metres of tunnel can be excavated and then immediately supported before the ground has a chance to relax, also support can be applied to various thicknesses, as little as 50 mm thick where the rock is good, but where the rocks are broken a mesh reinforcement material is applied and the concrete sprayed over it.

Where the rocks are shattered, steel or lattice ribs are used for support with up to 150 mm of shotcrete applied between them. Where the tunnel went through the swelling clay marl the floor and sides were well treated with supporting ribs and concrete as well as the roof. Checks are carried

out on this system of support by convergence checks. Three studs are placed in the tunnel and accurate measurements are taken to determine whether there is any movement between them over time and if movement exceeds 5 mm then more support is applied to guard against possible collapse.

There is, of course, a necessity for both ends of the New Tunnel to be joined into the existing aqueduct and new junction pieces have been designed and cast in concrete. One of these was fitted during a routine cut-off in September 1988. It is basically a 'Y-shaped' piece with one diameter designed to fit into the existing tunnel and a branch off that fits the new tunnel. The new tunnel branch is at present blanked off, but when the new tunnel is finished and the junction made at the other end also the flow through the aqueduct will be diverted from the old to the new tunnel.

At the time of writing the new tunnel was excavated to around 500 m, approximately one third of the total length. Once it is complete a circular concrete lining will be cast *in situ* to smooth and finish the tunnel to receive the water flow.

## ACKNOWLEDGEMENTS

Based on notes by Joan Jones prepared during a lecture given by John Scholey of Sir William Halcrow and Partners and Mr David Ingle of Fairclough to the Shropshire Geological Society on 12<sup>th</sup> October 1988.

John Scholey introduced the lecture and explain the roles of the two speakers' respective companies and then gave a history of the Elan aqueduct of which the New Studley Tunnel would form a part. He then talked about the site investigation of Clee Hill and the geological structure of the hill through which the tunnel leads.

Dave Ingle then continued by explaining the construction of the project and in particular how his company have adapted their tunnelling methods to suit the diverse geology in the tunnel.

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