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Search for hidden construction shafts within the Welsh railway tunnels

Recherche pour les puits de constructions cachés dans les tunnels ferroviaries gallois

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ABSTRACT: There are currently in excess of fifty active railway tunnels in Wales many of which were constructed during the mid to late nineteenth century. Many of these tunnels are of significant heritage value with several having features, which are listed, such as the tunnel portals. During the construction of the railway tunnels, several shafts were often sunk in order to allow numerous faces to be worked at the same time. Following completion of the tunnelling works a number of these shafts were converted into air shafts, however many were infilled, bricked over or capped and forgotten. Following a collapse of one of these construction shafts, (referred to as hidden shafts), works have been ongoing to locate these shafts. This paper discusses the archival research into the historical construction of the tunnels and shafts and the subsequent site investigation works to prove the presence or absence of these shafts and potential remedial works required to protect the live railway.

RÉSUMÉ: Il existe plus de cinquante tunnels ferroviaires actifs au Pays de Galles dont beaucoup ont été construits du milieu à la fin du dix-neuvième siècle. Beaucoup de ces tunnels ont une valeur importante au patrimoine national avec un certain nombre ayant des caractéristiques telles que les portails de tunnel, qui sont répertoriés. Pendant la construction des tunnels ferroviaires plusieurs puits ont souvent été enfoncés afin de permettre le traitement simultané de nombreux faces. Suite à la construction des tunnels, un certain nombres de ces puits étaient transformés en puits de ventilation mais beaucoup ont été remplis, maçonnés ou couverts et oubliés. Suite à l'effondrement d'un de ces puits de construction (aussi appelle des puits cachés), des travaux sont en cours pour localiser ces puits. Cet article traite de la recherche archivistique sur la construction historique des tunnels et puits et l'enquête ultérieure sur le site avec le but de prouver la présence ou absence de ces puits et les travaux de réparation potentiels nécessaire pour protéger le chemin de fer en activité.

Keywords: Tunnels; Hidden; Construction; Collapse; Shafts

1 INTRODUCTION

At the time of the construction of the railways in the nineteenth century the methodolgy for tunneling had been established during the previous century following the construction of the extensive canal network across the United Kingdom (Simms 1896). The construction of a tunnel was an extremely labour intensive process with the majority of the work undertaken utilising picks, shovels and gunpowder charges through rock or hard strata. In order to increase the speed of construction the early canal builders decided upon the use of construction shafts to allow multiple faces to be worked at once rather than just one face at either end of the tunnel.

These construction shafts were positioned at varying intervals along the length of the tunnel, with the exact distance between shafts varying based on numerous factors such as, but not limited to, construction technique, geology, thickness of rock cover and accessibility of the site. In general for tunnels constructed in the 1830's numerous shafts where sunk, however the diameter of these shafts was kept to a minimum. In the 1850's due to the introduction of pneumatic rock drills and blasting the number of shafts required reduced, however the diameter of some shafts increased. From 1886 with the introduction of compressed air machines with air locks and shields the number of shafts sunk reduced further and again the shaft diameter increased (Mckibbins 2009). In addition, the main difference in tunneling techniques between the canal and railway tunnels was that for the canal tunnels a top heading was used, whilst for railway tunnels an initial bottom heading or haulage heading was constructed.

Once the location of the construction shafts had been determined and these had been progressed to the required depth, a small heading was driven in either direction from the base of the shaft towards the nearest shaft or portal. This way of working allowed multiple faces to be worked at once. Once the headings were progressed such that all headings were linked, these were widened to the desired tunnel size and shape and, if required, lined with either brick or stone (Pragnell 2016).

Once the tunnel neared completion the construction shafts were either incorporated into the tunnel as ventilation shafts, were used as pumping shafts (as in the case of the Severn Tunnel (Walker 1888)) or were abandoned. The abandoned shafts were usually obscured by the lining of the tunnel often with no evidence visible in the brick or stone work. The resultant shaft beyond the lining was then either left voided or partially or wholly infilled. There appears to be little consistancy with regards the infilling of these shafts or in the consitency of the provision of any sort of capping.

2 HIDDEN CONSTRUCTION SHAFTS

A number of these tunnels were constructed as early as 1845. Therefore it is no surprise that as time progressed the exact location and state of backfilling of these construction shafts was forgotten. It should be noted that the tunnel engineers often omitted the construction shafts from the "as built" drawings. Consequently over time, in a number of locations, the land use above the tunnels has changed dramatically from what was in most cases arable land to a range of residential, commercial or industrial uses, often with no prior knowledge of the potential presence of an infilled or voided construction shaft below.

On the 28th April 1953 at Clifton Hall Tunnel near Manchester the brick lining of the tunnel collapsed in the early hours of the morning beneath what turned out to be a hidden construction shaft (Figure 1). The contents of the shaft spilled out onto the railway line and caused a crater to appear at surface, aproximately 20 feet deep. Unfortunately, the area above the tunnel was occupied by a number of semi detached properties; a pair of which collapsed into the crater killing five of the occupants (Ministry of Transport 1954).

Figure 1 Clifton Hall Tunnel Shaft Collapse (Salford Voice 2017)

This incident and the resultant investigation highlighted the danger posed by these abandoned construction shafts and as such works have commenced sparodically since the 1960's to try to identify and locate any such hidden construction shafts.

3 DESK BASED ASSESSMENT

Currently there are fifty three railway tunnels still in active use across Wales, owned and managed by Network Rail, the majority of which were constructed by the Victorian's in the mid to late 19th Century. These tunnels range in length from as little as 105m (Cilmery Tunnel) up to 7008m (Severn Tunnel); all of which have the potential to contain hidden construction shafts.

As part of the initial assessment a high level review was undertaken of all 53 tunnels. This initial assessment removed three tunnels which would not contain construction shafts due to the method of construction such as cut and cover and those which were limited in length. In these case the distance to sink a shaft would be greater than the length of the tunnel.

As part of the main assessment, Network Rail Archives were contacted and all available historical documents relating to the construction of the various tunnels was requested. The quality of historical information available for each tunnel varied significantly with a number of tunnels having no historical construction information, whilst others such as the River Severn had significant records.

In addition to the archive data, the historical Ordnance Survey plans were obtained for all tunnels along with the Light Detecting and Ranging (LiDAR) data held by Network Rail as shown in figure 2.

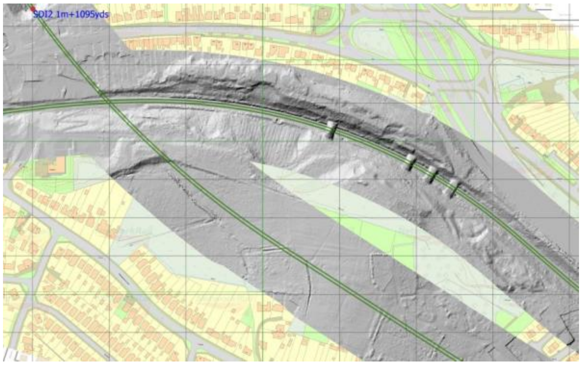

Figure 2 Example of LiDAR data for Lonlas Tunnel provided

As part of the archive review, some historical reports were located indicating that limited intrusive investigation works had been undertaken for a number of tunnels. In addition, a phase of geophysical survey investigations utilising Ground Penetrating Radar (GPR) had been carried out along the roof of the majority of the tunnels.

Whilst the GPR survey data did identify the potential presence of shafts the results were mostly inconclusive and the recommendations in all cases was that intrusive investigations were required in order to confirm the findings due to a low confidence in the results. This is in part due to the early blasting using gunpowder which could cause large overbreak of the tunnel making it difficult to determine the differnce between this and a hidden shaft.

In addition to the archive data, a site visit was made at each tunnel to walkthrough and over the tunnels. During the tunnel walkthrough, features which may potentially indicate the presence of a hidden shaft, were measured from both tunnel portals and recorded. This included areas of significant water ingress, bulging of brick work and large areas of brick repairs. As part of the tunnel walkover, features such as depressions (figure 3) and spoil mounds (figure 4) were recorded utilising hand held GPS.

Figure 3 Surface depression at Pembrooke Tunnel with mature trees growing within.

Figure 4 Radial spoil mound adjacent to an air shaft at Ffestiniog tunnel..

The information obtained from the site visit elements was combined with the historical information for each tunnel and a separate report was produced for each tunnel. During this process, each potential construction shaft was given a designation of either Open, Blind, Suspected or Hidden based on a designation system developed by Network Rail on other routes.

- Open Shafts: predominatly air shafts, which are clearly visible in the tunnel.
- Blind Shafts: a shaft that has been sealed or capped in such a way as to render the position of the shaft discernible. These shafts are regularly inspected but are not used as air shafts.
- Hidden Shafts: a shaft that has been sealed or capped in such a way as to render the position of the shaft indiscernible.
- Suspected Shafts: a shaft for which there are several pieces of information indicating the presence of a shaft although it has not been located (Teager 2004).

Following completion of the desk based works, 26 of the 53 Welsh tunnels were suspected to potentially contain shafts with a total of 86 shafts believed to be present. Of these 28 were recorded as Open Shafts, 7 were recorded as Blind Shafts, 18 were Hidden and a further 29 were Suspected. In addition a further 4 potential shafts were identified which could possibly be classified as suspected, however the confidence level in the information was insufficient to undertake further inestigation works at that stage. For the purpose of this paper the shafts under investigation are described as Suspected Shafts only from this point onwards.

As a result of this intial assessment, it was determined that a phase of intrusive investigation works was required in order to confirm the location of 51 of the shafts to allow appropriate risk measures to be put in place and if required allow for remedial action to be undertaken. This is in line with the Network Rail flowchart for locating suspected shafts.

4 INTRUSIVE INVESTIGATION

Recommendations were made within the desk based reports with regards to various intusive investigation methodologies. These recommendations were based on experience gained undertaking similar investigations on other rail routes and inline with well established methodologies for investigating abandoned mine shafts. Figures 5 – 7 show various investigation tewchnique undertaken.

Figure 5 - Spoil Mound Investigated Following Walkover Survey in South Wales (AMEY)

Wherever possible. the first option was to undertake a trial trenching investigation from the surface, targeting spoil mounds or depressions. This was deemed to be the only possible way to postively determine if a shaft cap was in place.

Figure 6 – Trial Trenching investigation (AMEY)

Unfortunately, further to the construction of a number of the railway tunnels, the land at the surface is often inaccessible, has been subsequently developed making trial trenching impossible or in environmentally sensitive areas. As such this option was only possible for a limited number of shafts.

The majority of the investigation works were targeted from within the railway tunnel itself with intrusive investigation holes positioned in the roof of the tunnel. In general the intrusive methodology allowed for drilling a total of 21 holes into the tunnel roof at 1m centres with the central hole situated at the anticipated shaft position and 10 holes drilled in either direction along the length of the tunnel at a spacing of 1m. The intrusive holes were required to prove either 1.5m of intact rock or 3m of soft ground or fill. Given the number of shafts to be investigated, Network Rail awarded this element to three separate contractors in order to speed up the process and as such two slightly different intrusive techniques were developed.

The first technique involved the use of a traditional coring rig similar to that which would be found on most investigation sites for undertaking concrete coring. In this instance, the contractor installed bolts at 1m centres into the roof of the tunnel, which allowed the rig to be bolted to the roof. The holes were then drilled utilising a 32mm core barrel with various extension rods used to achieve the required depth. Whilst this method was more time consuming, the equipment used was relatively mobile and could be moved to site on track trollies with the work area accessed via tower scaffold. In addition, multiple teams were able to work in close proximity to each other.

Figure 7 – Drilling coreholes into the tunnel roof of Lonlas Tunnel

An advantage of this technique is that the cost of equipment is relatively low due to the fact that heavy plant is not required on the railway to transport the equipment to and from site. This allowed works in some tunnels to be undertaken on shorter mid week night possessions as well as during the weekends. In addition, cores could be accurately logged as soon as they were recovered (figure 8), allowing a confident determination whether or not natural rock had been encountered. However progress was relatively slow with an average of six cores drilled per possession dependent on possession length and the geology encountered.

The second main technique used by one of the contractors was to use a large specialist drill traditionaly used in mining with a 30mm diameter drill bit and effectively drill an open hole. This technique, when used was extremely rapid allowing the possibility of drilling dozens of holes per shift. The drill rig was mounted on a track trolley which was manovered into place using a road railer (RRV). The trolley was then lifted to the roof of the tunnel to allow drilling to take place. Whilst this method can be extremely quick, mobilising the equipment on to site can be time consuming and expensive due to the type of plant required. In addition,, the logging of the holes can be extremely difficult with interpretation based on the drilling returns and the speed of drilling only.

Figure 8 – Example of core recovery from Lonlas Tunnel

Ultimately both techniques have advantages and disadvantages but results have been achieved with both methods. An example of sections produced are showwn in figure 9.

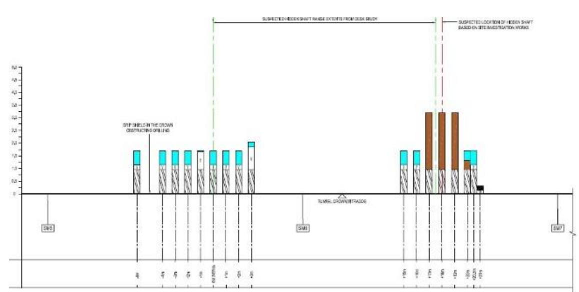

Figure 9 – Cross section of tunnel showing shaft location in brown. (COWI)

Following the completion of the drilling works the results were reported within an investigation report for each tunnel. These reports have concluded that in some cases there are no suspected shafts present and that the evidence such as heavy water ingress can be attributed to a separate cause such as faulting or weathering of the natural rock. In a number of reports further investigation works have been advised to target additional areas or the suspected shafts have been proven and recommendations for additional works have been provided for the purpose of designing appropriate remedial measures.

5 FURTHER WORKS

Currently the initial investigation works in the Welsh tunnels are nearing completion. The further phases of investigation are currently in the planning stage. This includes additional drilling based on the same principles as the works to date aimed at proving if the shafts sit centrally above the tunnel and confirming the shape and diameter of the shafts. Deeper, larger, intrusive holes are also required in order to determine if the shafts have been left open or partially or fully infilled. Figure 10 and 11 show examples of the type of data that will be recorded. In addition, the presence of a shaft lining and the type of capping if present needs to be determined. This is likely to require some top down investigation works or angled boreholes aimed at targeting the lining of the shafts.

Figure 10 – CCTV inside Hidden Shaft on LNW Route

Data is continuously collated and used to update the Tunnel Management Strategy with the risk to the tunnel and any potential properties above reguarly reviewed as additional data comes available. For example, in each Tunnel Management Strategy, a zone of influence drawing is provided, which shows the suspected location of the shafts and based on the shaft diameter and the amount of superficial deposits, predicts the zone which the shaft may affect. As the shafts are more accurately located, and the dimensions of the shafts become better understood, these drawings are updated and to allow Network Rail to more effectively manage any potential risks.

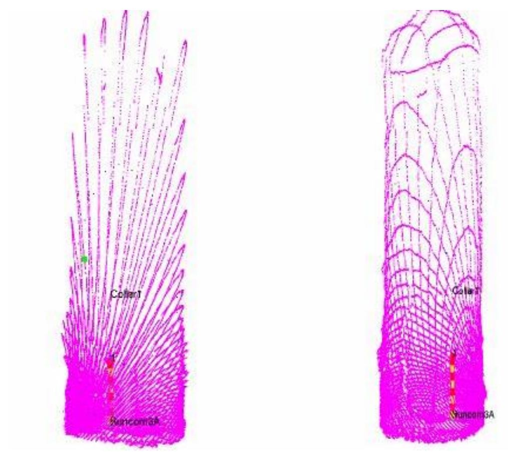

Figure 11 – Laser Scan of Hidden Shaft on LNW Route

6 CONCLUSIONS

From 2016 until the publication of this paper, Network Rail in Wales have undertaken a desk-based assessment of all 53 tunnels in their ownership and have concluded that there is the potential for 51 Hidden Shafts to be present. Further to the desk based assessments, initial intrusive works had been undertaken for 49 shafts with Hidden Shafts proven at 15 locations. Further investigations are still ongoing at several locations in order to collect additional data to aid in the design of remedial works, which are anticipated to be undertaken during the next control period with a target completion date of 2020.

During the original construction of these tunnels it is likely that the long term consequence of closing off these shafts was not considered. At that time, these were major construction projects involving, in some cases, thousands of workers over as long as a decade and it was probably inconceivable that the location of these shafts would ever be forgotten. In addition, at the time of construction, it was probably not considered that the tunnels would still be in active use in some cases 170 years following construction.

If we were to fast forward 170 years from now, will some of today's major projects such as HS2 cause similar issues for future generations and how many of our designer risk assessments today would take such a long term view.

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