The Forgotten St. Clair Tunnels, Toronto, Ontario

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1.1 Introduction

In 1888 the world tunneling community was taking a keen interest into the proposed subaqueous tunnel being constructed beneath the St. Clair River. The purpose of this tunnel was to provide a much needed rail link between Sarnia in Ontario and Port Huron, Michigan. At 6.522m it was the largest shield driven tunnel of its time, completing the drive in 14 months. This great tunneling feat was again repeated in 1992, and is today known as the Paul M. Tellier tunnel.

In 1914, and over 285kms away, at the City of Toronto’s Department of Works, plans were being prepared for the construction of a series of combined brick sewers along St. Clair Ave. West between Symes Rd. and Station Rd. The purpose of these brick sewers was to provide greater sewer capacity to the district known locally as the “Stockyards”. The area was also known amusingly as “Hogtown” due to the presence of livestock holding pens and numerous abattoirs along St. Clair Ave. W. such as Swifts, Gunn’s and Harris’s. This sewer alternated from a circular section to an egg-shaped section along its route and provided service for almost 93 years until 2009 when the City of Toronto became aware of certain internal condition issues and decided to replace the worst affected section with a new cast-in-place concrete tunnel. The tender to build the new tunnel along St. Clair Ave. W. from Symes Rd. to Keele St was awarded to McNally Construction Inc. in March of 2009. The focus of this paper is to provide the reader with an account of how the original brick sewers were built and then concluding with details of the challenges facing the project team during the construction of the new tunnel in 2009.

1.2 Local Geology

The sub-surface geology along St. Clair Ave. W. was formed during the later stages of the Wisconsin glacial period. The lowland Lake Ontario became inundated by a body of water which became known as Lake Iroquois. This vast meltwater body gave rise to the creation of large deposits of beach sands and gravel. These deposits are termed “Baymouth Bars” [3] with one such bar occurring along St. Clair Ave. W. (Fig.1). The majority of the tunnel drives both in 1915 and 2009 were excavated within the compact to dense silty fine sand harboring an undrained shear strength of 150Kpa. This predominant soil stratum exhibited Standard Penetration Test (S.P.T.) N – values of 30 blows per 300mm, an angle of internal friction (c’) of 30°. The moist silty fine sand typically contained a moisture content of 6%, although this progressively increased to 20% as the tunnel entered the watertable on its approach to the Keele St. Exit shaft. Local boreholes at Keele St. indicated wet seams and traces of gravel, thus presenting a condition at the tunnel face whereby the risk raveling/sloughing increased. Thus a 2.844m O.D. LOVAT TBM (Tunnel Boring Machine) with full face control doors was selected to build the new sewer, extruding an expandable rib and lagging primary lining along its drive. Furthermore advance plans were made to install in-shaft dewatering for a short period, to complete the TBM exit shaft, TBM extraction and subsequent manhole construction. In order to construct the original brick sewers in 1915, evidence suggests that the mining crews used either compressed air or an invert sub – drain or possibly a combination of both to counteract the watertable.
1.3 The 1915 Brick Sewer Tunnel Contracts.

The contractual history on the construction of the St. Clair Ave. W. brick sewer makes rather interesting reading. On February 4th 1915 [4] five tenders were received and opened for the construction of the District No.2 Outlet of the West Toronto sewer system on St.Clair Ave. W. from Mulock Ave. to the Grand Trunk Railway Lines (G.T.R). or Station Street. However a study of local street maps revealed multiple railway sidings and two separate G.T.R rail lines, but no account of a “Station Street” could be found. Further investigation revealed that in the late 1890’s the City of Toronto undertook a major street re-naming programme in order to emphasize prominent streets in the downtown Toronto core. Thus, Station Street was renamed Caledonian Park Rd, which today is 880m due East of Mulock Ave. This 936m sewer varies in cross section starting in a tunnelled 1.200m circular brick sewer built and terminates in a 300mm vitrified pipe constructed in an open cut trench. Eleven manholes were also required to be built along the sewer at 90m centres. Tenders were opened on the 4th of February 1915 and out of five bids for the work, the lowest was submitted by the Connolly-Agnew Construction Company Ltd. at $28,653 ($538,300 in 2009 - Consumer Price Index). However on the 8th of February 1915 Connolly-Agnew made application to the City Clerk requesting that their tender be withdrawn and bid deposit returned, claiming that the “borings taken on the tunnel section of this work was incomplete and misleading”.

Six boreholes were drilled along St. Clair Ave. W. in 1913 as part of the West Toronto Drainage System site investigations down to a depth of 5.600m below ground surface, and yielded dry brown sandy soil. Groundwater was noted at the bottom of two boreholes within the tunnelled portion of the work. The 302m tunnel sections were to be driven 10.600m below ground surface, and it appears that after discussions with a local competitor on the day that the tenders were opened, representatives from Connolly-Agnew realized that they had not allowed for potential compressed air tunnelling. They also had not undertaken to drill any borings to confirm the ground conditions prior to submitting their bid. It may be noted that while the borings did not detail the material to within the tunnel horizon a clause in the contract stated that the City “does not warrant the plot of underground objects to be even approximately correct”. On the 22nd February the Commissioner of Works, Mr. Roland C. Harris, instructed Connolly-Agnew to execute the conditions of contract, and failing in this, that the deposit accompanying their tender be forfeited and that that be subject to all of the conditions and penalties under which they bid. Soon after on the 8th of March 1915 the original contract was made void and the City immediately invited new tenders for the contract.

On the 31st of March three bids were received and opened with the lowest at $34,777 ($653,351 in 2009 C.P.I.) being submitted by Fussell – McReynolds Co. Ltd. Thomas Fussell signed the contract on the 19th April 1915 with construction commencing shortly after. On 18th of June 1915
Fussell – McReynolds made a submission to the city requesting the 1.220m diameter circular tunnelled portion of the contract be extended by 120m in order to complete the work satisfactorily. The City accepted citing benefits to the traffic flow along St. Clair Ave. W. however no additional allowance was made to Fussell – McReynolds for the design change.

In early October 1915 a second sewer contract was put out for tender for a brick lined sewer to be built completely in tunnel along St. Clair Ave. W. commencing at Mulock Ave and terminating 900m away at Symes Rd. This sewer alternated in section from a 1.905m circular quadruple lined brick to a 1.200m x 0.750m triple lined egg shaped brick sewer and included 8 manholes at 150m centre’s approximately. Six tenders were opened on the 14th October 1915, with Fussell – McReynolds again being the lowest at $43,977 ($826,190 in 2009 C.P.I.) Fussell – McReynolds clearly had the upper hand, considering that were already mobilized and tunnelling the neighboring contract towards Caledonian Park Rd. Thomas Fussell signed the contract with the City on the 18th of October 1915 in the presence of Mr. G Powell the acting Deputy City Engineer.

1.4 Construction of the Egg-Shaped / Circular Brick Sewer – The Crutch System

In the early 1900’s whilst the shield method of tunneling was gaining popularity globally, it is known that tunnelling methods incorporating timber were still very much in use. A number of these methods were applied in Toronto such as the English Method and Belgian Method [5]. The sandy soil along St. Clair Ave. W. would have been approached cautiously as it was well understood that dry sand would run like fluid if uncontrolled. The presence of groundwater would have called for a change of face attack with possible options such as the laying of an invert sub-drain, establishing the excavation and subsequent brick work upon a timber deck/sill or the introduction of compressed air. The compressed air alternative would have been the last resort. Records from 1915 state that during the construction of the 2.438m circular brick sewer tunnel that was been driven south along Mulock Ave, the contractor Donnelly & Graham experienced major face control issues. The reason being was that the compressed air was being lost both through the sandy soil medium, influenced by the presence of a 300mm sewer and adjacent tile drains over the tunnel. Thankfully, due to the existence of one black and white picture out of three taken on January 14th 1916 within one of the headings being driven west of Keele St., we can factually determine that the St. Clair Ave. W. brick sewer tunnels were built using the “Crutch System” [6,7] (Fig. 2). This system is also known as the Polygon Method [8] or rather unusually as the “Horse Cups Method” [9]. The method is very similar to the English Method in that it allowed the full face to be mined with the brickwork being built from invert to tunnel crown. A typical mining cycle is best described as follows:

1.4.1 Mining Shift: The mining crew would have consisted of four men, two miners and two muckers. At the heading the brickwork from the nightshift would have been laid right up to the first crutch. The miners would have then set to work, firstly removing the bulkhead, screwjack and digging out the heading in such a manner that the 250mm square, 75mm thick wallplates could be laid into each side of the cutting. Upon these wallplates rested pairs of suitably long 150mm x 200mm timbers thus forming an inverted V, known as the crutch. These crutches were spaced at 0.914m centre’s typically. The roof of the tunnel was held up by longitudinal timbers better known as “crown bars”. These crown bars covered the upper arc/roof of the tunnel from 9 o clock to 3o clock and most written texts from the era suggest that they were made from evergreen wood such as pine 300mm x 75mm in section. The primary reason being that softwoods yield prior to fracture unlike most hardwoods, thus conveying advance warning of impending danger. One end of the crown bars rested on the brickwork whilst the other lay on the crutch, blocked in place with a combination of heavy arch blocks and wedges, which peculiarly were nicknamed “horse cups”. It is known that in situations two sets of crown bars were used, one over the other which allowed one set to telescope over the other as excavation proceeded. Any gaps between respective crown bars were filled with hay or straw, this also had the effect of moving the crown bars forward during bricklaying, a bit easier once the wedges were knocked.

It has been often asked, how was the muck hauled out in brick tunnel particularly an egg-shaped sewer? Though no written records exist that describe how this element of the mining was dealt with under St. Clair Ave. W., research indicates that the following unique method was commonly
employed in Toronto. Basically a steel monorail (Fig. 4) was laid at the invert of the tunnel, upon which a muckskip was set down on. The muckskip had two wheels which ran on the rail, and two sets of horizontally adjustable springline stabilizing wheels, which allowed different sizes of muckskips to be hauled easily through the completed brick sewer. The muckskip itself rested on a frame, and was readily hoisted from the frame once the skip reached the shaft. Man power was used to shunt the muck skip on short drives, and air or hydraulic powered winches were used on the longer drives. An average daily advance for the mining crew was 3.048m – 3.657m.

1.4.2 Bricklaying Shift: The St. Clair Ave. W. sewer tunnel contained several different brick tunnel sections ranging from a quadruple skinned circular brick sewer to a double skinned egg-shaped brick sewer. The laying of the tunnel brick was a very skilled operation, which commenced at the invert. The brick used was red in colour and would have come from one of the many local brick manufacturers such as the Don Valley Brick Company. Once the brickwork was laid to springline a timber arch centre was installed and firmly wedged in place, upon which the brick arch was laid. While laying the arch the crew would have brought the crown bars forward and filled the ensuing void with compacted broken brick. If the soil moved during the moving of the crown bars they were left in place, with instructions left for the mining crew to bring in a new set of crown bars the following day. The brick in the immediate invert was typically composed of red hard shale, to counteract the effects of scouring. Typical bricklaying advances ranged from 1.829m to 2.438m.

A “technical note” is referenced on the contract drawings indicating that wherever ground water is encountered and not eliminated by compressed air the contractor was instructed to lay 100mm timber deck, upon which Class B concrete was to be formed to springline at his own expense. It is unlikely that such a clause would be included in today’s contracts. The tunnel crown was then to be built from brick. At the intersection of St. Clair Ave. W. and Keele St. the water table is known to be approximately 1.000m above tunnel invert, considering that the only picture of the works was taken here in 1916 shows no signs of concrete forming we’re led to believe that Fussell – McReynolds either introduced compressed air or laid a subdrain to stem the effects of the groundwater. Unfortunately no records exist to indicate the length of time it took to build the St.Clair brick sewer from Mulock Ave. to Symes Rd. However, applying an average daily advance of 3.657m, the estimated date of completion would have been July/August 1916.

1.5 Construction of the Egg-Shaped / Circular Brick Sewer – Shafts

Multiple mining shafts at the future manhole locations would have been sunk to construct the St. Clair Ave. W. sewer and allow several headings to be driven at once. It is thought that the shafts would have been exclusively timbered, rectangular in plan and made from heavy timbers with walers/struts often being 300mm square. Vertical forepoling or timber sheet piling may have been introduced wherever ground water proved troublesome. Once tunneling was complete the shafts themselves were stacked out in circular brickwork, and capped with a cast-iron lid.

![Fig. 2 The Crutch System of Soft Ground Tunnelling](image-url)
St. Clair Ave. W. is presently undergoing major urban regeneration, with the former abattoir buildings being demolished and replaced by large residential complexes. The Toronto Transit Commission (T.T.C.) is currently replacing the existing surface rail track bed and adjacent street furniture. Thus, in 2008, the City of Toronto aware of service issues in the old brick sewer between Symes Rd and Keele St. decided to replace this section with a 1.800m dia. cast-in-place concrete sewer (Fig. 5). The City Of Toronto then contracted RV Anderson Associates Limited to design the new cast in place tunnel. McNally Construction Inc. successfully tendered and on March 6th 2009, signed the contract to construct the sewer in tunnel for $8.1m. The original scope of the work included the following:

- 660m of steel rib and lagging tunnel, followed by 1.800m ID cast in place concrete and a benched low-flow invert.
- A twin 1.800m diameter manhole chamber with cast-in-place base incorporating flow control appurtenances.
- One 3.600m diameter precast manhole, with a transition from 900mm precast pipe to the 1.800m cast-in-place concrete tunnel.
- 26m of hand tunnel to accommodate a 1.800mm ID cast-in-place tunnel, followed by a tie-in to and existing 1.524m ID tunnel built in 1967.
- 227m of open-cut, with the precast pipe ranging from 300mm to 900mm ID, including two 2.400m diameter precast manholes.
- Plugging and abandonment of nine existing manholes along the existing brick sewer.

Prior to construction, a series of value engineering studies were undertaken to fully assess project elements. Subsequent field and site investigations yielded information that allowed a number of design changes to be developed and presented to the City of Toronto. The ultimate goal of such changes was to provide the owner with cost effective solutions with applicable credits while reducing construction risk to the health and safety of the workforce. A list of the changes is listed herewith:

- Relocation of TBM launch shaft to avoid by-pass pumping of a 250mm existing sanitary sewer.
- The twin 1.800m diameter chamber at the TBM exit shaft was changed to a single 1.800m diameter manhole and constructed entirely from precast.
- The 3.600m precast concrete manhole at the TBM launch shaft was reduced to 2.400m.
- The 26.000m of 1.800m ID cast-in-place hand tunnel was reduced to 6.000m with a 600mm ID PVC sewer pipe tie-in, as a result of relocating the TBM exit shaft 16.000m West of its original location.

The last item warrants further explanation as it was an item of work that understandably presented the most concern to the project team. The original plan involved hand mining a liner plate tunnel from the TBM exit shaft, heading Northeast to an existing bulkhead inside a 1.524m cast-in-place sewer built in 1967. This 1.524m ID sewer aligns north-south at the intersection of St.Clair Ave. W. and Keele St. In order to do this, the hand mined liner plate tunnel would have to traverse beneath numerous sub-surface utilities and the egg shaped brick sewer. The risk of potentially undermining the live brick sewer was a serious threat and would have required advance ground improvement techniques. Fortunately, after studying the 1967 sewer contract drawings, an alternative solution was found. In 1967 as part of the contract, a manhole was built encompassing the brick sewer, thus connecting the 1.524m cast-in-place tunnel to the brick sewer. The manhole was approximately 16.100m due west of the original TBM Exit shaft location. If this manhole could be found, the requirement to tunnel under the brick sewer could be effectively eliminated. Intensive field investigations including GPR (Ground Penetrating Radar) finally revealed the manhole which was confirmed via inspection on the 13th of May 2009. The proposal, involved the connecting of the new cast-in-place tunnel into the existing manhole via a 600mm ID PVC sewer pipe, was then reviewed and accepted by the consultant and client.

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**Fig. 5 Geography of Tunnel Projects.**

1.7 Construction of the 2009 Tunnel

The TBM selected to build the rib and lagging tunnel (Fig. 6) was a 2.844m Lovat, which was recently refurbished at the McNally workshop in Toronto. The TBM launch shaft was a typical soldier pile and lagging shaft 9.400m x 4.000m in plan and 8.300m deep. This shaft was located adjacent to a busy pharmacy and due to the small compound size, material deliveries were scheduled on a “just in time” basis. Muck and material hoisting at the mining shaft was done by a veteran LinkBelt 108B crane and after eleven days working on a double shift basis the shaft was ready to accept the TBM for launching. The TBM was delivered on the 28th of April 2009 launched
in short mode with power being provided via an insulated trailed diesel generator located outside the shaft. Once the tailcan and full length conveyor were installed, mining rates increased to 14,600m per shift. Mining was on a double shift basis with an approved amendment to the Noise By-Law for 24hr work if required. The rolled steel ribs were designed by McNally Construction Inc. and fabricated locally by Kube Steel Ltd. of Stoney Creek, Ont. Two in-line drop manholes were installed ahead of the TBM by drilling and when passed by the TBM, care was taken to ensure that a tunnel rib did not conflict with the subsequent tie-in.

The TBM exit shaft presented a few issues as the shaft compound was located at a very busy intersection, requiring a comprehensive traffic plan so as to not cause any unnecessary disruption. This soldier pile and lagging shaft, measured 6.500m x 4.100m in plan and was 13.100m deep. The shaft was constructed in 4 weeks on a single shift basis which included the time required to install an internal dewatering system for the last 1.500m. It was also decided to install a horizontal plane of interlocking 102mm steel channels as spiling above the tunnel crown to prevent ground loss during TBM breakthrough. The TBM arrived at the shaft on the 5th June 2009 on line and grade. Once the TBM was removed the 6.000m hand mined 1.800 OD liner plate tunnel commenced. Again, channel spiling was applied to the crown and after 5 days of mining the chamber was reached, and a 0.750mm core taken out by Graff Concrete Coring and Cutting (Fig. 7). A 600mm SDR35 PVC sewer pipe was then inserted and concreted in place, followed immediately by the stacking out of the 1.800m precast concrete manhole.

1.8 Cast in Place Tunnel and Low-Flow Invert.

The installation of EFCO collapsible forms began as soon as the tunnel was cleared of rail and service lines. Once the “slick lines” were laid and surface pumps set up the daily concrete pour rates averaged 36.500m; the tunnel concreting was completed in 20 days. The finished tunnel ID was 2.080m thus giving a minimum of 300mm of 35Mpa monolithic lining. A benched low-flow invert was specified in the contract to cater for fluctuations in the effluent flow velocity; McNally proposed a 600mm SDR35 PVC sewer pipe cut in half and braced to the tunnel invert. Once the cast-in-place concrete was complete the crews commenced the low flow benching, achieving daily progress rates of 60m. Once all the tunnel concrete benching was completed the 2.400m precast manhole at the mining shaft was stacked out and the transition between the 900mm precast and the tunnel completed. The open-cut sewers, in-line drop structures and abandonment of the old manholes were all undertaken by local sub-contractor Dom Meridian Ltd., thus completing the new St.Clair Ave. W. combined sewer on time and within budget.

Fig.6  2.844m OD Rib & Lagging Tunnel  Fig.7 Coring into the existing Manhole Built in 1967.
1.9 Conclusion

Although separated by 94 years these two “St. Clair” tunnels shared a number of similarities. Both were constructed within the same tunnel horizon and consisted of a timber support system for the primary lining. The fact that the two tunnels differ greatly in terms of cross-section and final lining, clearly represents just how far tunneling technology has advanced. The proactive approach adopted by the project team, in identifying and developing solutions resulted in the successful construction of the new tunnel. Now with the retiring of the old brick sewer (Fig. 8), the new concrete sewer (Fig. 9) is ready to service the St. Clair Ave. W from Symes Rd to Keele St. in an area formerly known as “Hogtown” for the next few decades.

Fig. 8 St. Clair Ave Brick Sewer 2009

Fig. 9 Completed Cast-In-Place Sewer 2009

1.10 Acknowledgements

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1.11 References

[4] City of Toronto – City Council Minutes 1915 – Vol.1 & Appendix A