Precast Segmented Tunnel Liners with Embedded PVC Liner Provide Single Pass Corrosion Protection in Segmented Concrete Tunnel

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1.1 Over the years several methods have been used from inserting a smaller secondary pipeline in the tunnel which greatly reduces the available flow or after completion, spraying on a coating, which for the most part is a temporary fix. Both of these methods require a second pass through the tunnel which makes for higher cost and requires a longer completion time. This paper discusses the use of a “T” ribbed PVC lining material that has been used for corrosion protection for over 60 years in reinforced concrete pipe and structures. This process requires very few modifications to the precast segmental tunnel liner manufacturing and the actual tunneling, this liner can theoretically provide a 100-year life to a finished tunnel in a single pass.

2.1 INTRODUCTION: The city of Sacramento has been upgrading their sanitary sewer system for several years. Even with the addition of several new interceptors, such as the Bradshaw Interceptor, the city has still been experiencing sewer over flows due to rapid population growth in the area. The current technology used for reducing the number of overflows has been introducing a large storage tunnel into the sewer systems. Such a tunnel would capture any overflow and then allow the city to process the stored sewerage at the rate in which the system could easily handle the increased amount.

2.2 The Sacramento Regional County Sanitation District decided on a new project named the Upper Northwest Interceptor, Section 1 & 2. This project was a new overflow tunnel that consisted of 3.6 miles of 144” Internal Diameter (5.79km X 3.65m), one 84” X 144” transition structure (3.31m X 3.65m), one 120” X 144” transition structure (4.72m X 3.65m), 20 each access manholes, one interceptor manhole and the connection of three (3) existing sewer lines. The project duration was 1,095 calendar days the liquidated damages was $10,000.00 per calendar day. The Engineer for the Project was URS. There was a non-mandatory pre-bid conference on May 8, 2007 and project was to be bid on July 12, 2007.

2.3 At the pre-bid conference it was suggested to use a “T” ribbed PVC liner for corrosion protection and have the liner cast directly into the precast segmented tunnel liner sections; thus making the tunnel useable with a one pass system. This had never been done before and there had to be several hurdles overcome before it could be tried. The Sacramento Regional County Sanitation District had many years using the “T” ribbed liner in their reinforced concrete pipe, manholes and structures but it had not been used in this application anywhere in the world. Because the “District” had such a long and good history with the “T” ribbed PVC liner, they decided to add this option to the bid documents in an addendum.

2.4 The project was bid on July 12, 2007; the low bidder for the project was Traylor Brothers/Shea JV. Traylor Brothers/Shea JV chose to use the precast segmented tunnel liner
with the “T” ribbed PVC liner option. They selected Ameron International, Protective Linings Division (Ameron PLD) for the liner manufacturer/supplier.

3.1 **FORWARD**: The first order of business was to re-do the segmental casting forms. Traylor Brothers went to France and worked with CBE to make new forms that would incorporate the liner in the forms. Ameron PLD was contacted and asked to supply several different configurations for the forms. The liner had to be made in such a way as not to interfere with the standard production of the segments and fit within the current guidelines for precasting the segments. CBE had no trouble implementing the liner in the forms and was able to use their current system with very few modifications. One change was to use a single lift/grout hole and incorporate solid plastic dowels in lieu of using the standard bolt-hole technology. This would minimize the need for cut-outs in the liner and streamline the PVC welding process to just the joints and the grout holes.

3.2 After the bid, the main topic with the contractor was the labor/time that involved welding the longitudinal and circumferential joints. Every joint needed a 4” joint strip and then 2 – 1” weld strips on either side of the joint strip. At bid time the contractors thought was to complete the tunnel and then go back through after the track was removed and weld the joints with the idea that one applicator is positioned at the end and another applicator be positioned at the beginning of the tunnel. Both would start and meet in the middle. They estimated that it would take 90 days to complete the welding. After several meetings with the liner manufacturer, the idea was to weld while the segments were being applied, allow the cutting head and the placement arm to go by then do the top and side welding to the tracks. This would enable the contractor to complete the welding as the track was removed, thus having the tunnel complete at the time of the TBM track removed. In addition to the welding, was the liner manufacturer’s idea to incorporate either a one or a two sided flap in the liner sheet to eliminate the need for the 4” joint strip that had to be used with the current liner configuration. The idea with the two flap liner was going to require a “buy in” from the District and the Project Engineer they felt the two flap liner may interfere with the segment placement so the two flap system had to be considered. However they did adopt a one flap liner that would have the flap on the longitudinal joints thus eliminating the need for the 4” joint strip and the 2 - 1” weld strips on that joint. The idea of welding the joints as the TBM is moving seemed to be the way to go. That idea was accepted. A special platform was made on the TBM for the top portion of the welding and the lower, they put two hot air welders at each station, top and bottom.

3.3 Production began on the segmented tunnel liners as soon as the new forms were received. To insure that the liners would hold the proper tolerance, the liner manufacturer kept the liner sheets at a constant 80 degrees during the cutting of the pieces. The liners had to maintain a tolerance of .0075” in the precast forms. The precut liners were palletized in the identical configurations, five (5) different shapes were made and kept separate (Fig. 1). After the liners were delivered to the precaster they were kept under thermal blankets at a temperature of 80 degrees so they would be at the same tolerance when cut.
3.4 The addition of the liners during the manufacturing phase did not present any problems. The liner was introduced during the mold cleaning phase and did not create any additional time for that position (Fig 2).

The liner also acts as a gasket during the pouring process and assists the mold in making sure all the edges are tight. After the mold is filled it is steamed for several hours and then taken out of the mold to be inventoried in the yard. The segments are cast in the order they are to be placed in the tunnel, so the casting process has five different molds in sequence. The segments are separated with wooden shims so that air flow is constant between the precast segments. The wooden shims do not cause any damage to the liners. (Fig.3)
Over 23,000 precast segmental liner pieces were cast. Not one was rejected due to using the “T” ribbed PVC liner. Also, mold cleanup was much easier with the liner in the form. It left less cement in the form to be cleaned. All-in-all, the introduction of the liner in the precasting process did not affect the process at all. No additional time was required to insert, cast and inventory the precast segment. A very successful pour resulted.

3.5 Before the precast segmented tunnel liners were put down the tunnel shaft, it was necessary to make sure they would go together without any problems, the District, URS and Traylor/Shea JV put together a mock tunnel on the surface to see how the segments would fit. (Fig 4) The pieces fit perfectly and the liner did not cause any problems during the placement. In addition to the segments being put together, the liner was checked for embedment into the concrete. The test run on the liner was to cut a flap above an embedded “T” three inches in length and apply 100 ponds per linear inch pull to the liner to check the embedment. The liner passed the test without any problems, the engineers decided to take the liner to ultimate, over 500 pounds of pull was exerted on the liner “T” before failure. That equated to over 167% of the standard performance was measured. This was due to using a plasticized concrete that was self consolidating along with having the proper vibration at time of pour. Ultimate concrete strength was over 10,000psi.

3.6 The TBM used for this tunnel was delayed because it was being used on another project; the Upper Northwest Interceptor was delayed two months waiting for the TBM. With the joint welding and several “unknowns” this was causing some concerns. However, after the delays the initial start up was smooth and the project was set on course, the TBM was put in place and the track was laid in the invert of the tunnel. A special design for track placement on the liner was made by the liner manufacturer. This would eliminate additional repair and welding when the track was removed during the cleanup of the final phases of the project.

3.7 The initial goal was to set 21 rings or 105 precast segments per day. This was achieved on the first day and that goal was broken time after time. Again the thought was the PVC liner would hinder the movement in the tunnel and the placement of the segmented rings. (Fig. 5)
Figure 5 – Segments waiting to be placed in tunnel

After the placement of the rings the welding was done, as stated earlier a special platform was created for the top 180 degree joint welds and the lower joint welds. Both the longitudinal and the circumferential joints were done. The circumferential joints were welded to the TBM track and a terminal strip was left to continue the weld once the track was removed. During the first ½ of the project the original one-flap liner configuration was used. After some discussion and trials, Traylor Brother began casting the new “two flap” liner configuration. This new design eliminated the need for any 4” joint strip and the dual 1” weld strip for all of the circumferential joints. In essence, over 60% of the welding was eliminated. What the “two flap” system did was to overlap all the joints with a ¾” flap. This was enough to heat seal it to the next segment and then apply the 1” weld strip. This small addition to the “T” ribbed PVC liner greatly increased the welding efficiency of the project. All the welded joints were tested by Project Inspectors from the District. A visual inspection of the weld and a probing of the joint was done for every weld made. The welds had a 100% accuracy on this project. (Fig. 6)

Figure 6 – Circumferential weld using the 4” Joint strip.

3.8 The Upper Northwest Interceptor Tunnel was completed two months ahead of schedule. With the welding being done as the TBM would progress this greatly increased the efficiency of the production and only having to finish the welds at the track line was a simple task.
4.1 SUMMARY: The Upper northwest Interceptor Section 1 & 2 marked the first time any segmented tunnel had been lined with a “T” ribbed PVC liner, it also marked the first time a tunnel had been competed for sanitary use with a “one pass system”. The use of the two flapped “T” ribbed liner proved to be effective and did eliminate over 60% of the time and materials to weld the joints. In addition the welding of the joints as the TBM progressed also proved effective and greatly increased the efficiency of the project. The initial thoughts that the liner would create additional time in the manufacture of the segmented liner pieces also proved to be wrong. This project proved that a true one pass segmented tunnel liner system could be done using a proven corrosion resistant “T” ribbed liner that had been used in reinforced concrete pipe, manholes and structures for over 60 years. The addition of the liner created the one pass system and gave the tunnel a 100 year life against corrosion. (Fig. 7)