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Large Bore Rectangular Box Culvert and Non Circular Rehabilitation with CIPP

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Abstract: This paper addresses the site specific challenges that lie inherent in rehabilitating large diameter non circular pipe and concrete box culverts using the cured in place pipe methods described in ASTM F 1216¸ as well as ASTM F 1743. This paper details the pipe preparation requirements including corner grouting to allow for fully deteriorated design modeling as a large bore non circular case. It focuses on several case histories detailing the design thru installation including a triple barrel renovation of a 8'-8" x 6'-0" rectangular box culvert. At the time of its installation, the triple barrel box was the largest cured in place installation of this kind in the world. This direct inversion installation using methods described in ASTM F 1216 utilized over one million pounds of isophtallic polyester resin. Due to the tubes being too large to transport over the highway; three (3) tubes, each measuring twelve hundred foot, were installed in a period of less than one month using the "over the hole" method of field wet out and inversion.

INTRODUCTION

There are many benefits available when considering cured in place pipe in non circular application. This rehabilitation method not only offers maximum retention of hydraulic storage potential, but it has been proven to increase flow capacity by reducing the systems Manning's coefficient. The unique ability of this rehabilitation method to take the shape of its container most often precludes the need to bridge problematic gaps or annular spaces (post rehabilitation) with substances such as grout.

Generally speaking, the risk associated with relying on post applied grout materials regard unfilled spaces between the liner and host. These types of voids not only make the resultant structure suspect, but offer capacity for the storage and flow of unwanted or detrimental contaminants. In many rehab methods, the regulation of grout pressures and a continuous flow of grout material between the profile of a rough liner exterior and a host pipe is far from an exact science. An example of an undesirable condition which may occur should a gap remain between the rehabilitation and the host pipe is the infamous "annular space". The detrimental effects of this phenomenon include a condition known as "piping" where flow may continue within the utility after rehabilitation between the liner and the host pipe. Although an internal video inspection may seem to reveal all is well, external to the liner pipe; water, silt, and other effluents may continue to flow while eroding the host pipeline and potentially undermining the soil envelope. Given the objective in trenchless rehabilitation to renew the host pipe to a full service life expectation of fifty (50) years or more; it is important to disallow such phenomenon.

A tremendous advantage afforded the designer of CIPP rehabilitations is the ability to rely on this method to accommodate inline diameter and directional changes efficiently and economically. This paper shall document the successful fully deteriorated structural rehabilitation of large bore non circular pipeline and box culvert installations with both transitions and directional changes using cured in place pipe methods described in ASTM F 1216 and F 1743. Reliable grout methods for disallowing gaps, voids, and annular spaces shall be presented.

F 1216 vs. F 1743

With direct inversion becoming “public domain” in 1995, several experienced contractors were afforded the opportunity to obtain large bore experience with either method. There are some significant observations which should be noted as to where there may lie advantage in quality and/or installation efficiency when comparing these technologies.

ASTM F 1743 describes the pull in place of an impregnated tube followed by the inversion of a secondary constituent known as a calibration hose. ASTM F 1216 describes the direct inversion of an impregnated tube into the host pipe to be rehabilitated. Although, either method has been put to task in many large bore applications; the success of the repair invariably mirrors the experience of the installation crew, the quality of data extracted during the pre lining pipeline survey, pre lining pipeline preparation, and testing. This being stated, we point to Black Point WWTP, a Miami Dade Treatment Facility which was rehabilitated over ten (10) years ago using methods described in ASTM F 1743 (Figure 1). The failure mode in this 96” to 72” to 48” three tiered reducing concrete pipe oxygenation train was classic sulfide attack of the crown, “the father” of sanitary sewer pipe failures. This four hundred fifty (450) foot rehabilitation was allowed by staging a seven (7) day shutdown for each of the three critical treatment plants influent lines. Each pipe to be rehabilitated had three inline eccentric reducers, one ninety (90) degree, and two (2) forty five (45) degree bends. Further complicating matters was that each single shot transitioned from 44mm to 37.5mm to 24.0mm material containing approximately one hundred thousand (100,000) pounds of epoxy vinyl ester resin. Sufficed to say that attempting this rehabilitation with methods described in ASTM F 1216 could be compared to an Olympic gymnast coming off the uneven bars and “sticking the landing” after a routine with a difficulty factor of ten (10)!

After thorough cleaning and debris removal; pipeline preparation consisted of trowel filling all voids, cracks, and fissures with calcium aluminate cement. Although the structural properties of grout or cements utilized is not factored into the CIP tube design; it is important to achieve a continuous bearing surface insuring contact between the liner and host pipe at all places. The goal is to utilize a material which insures attaining the commonly achievable densities of compacted granular backfill or concrete.
The ASTM F 1743 installation method allowed for the liner to be winched into place while a careful comparison could be made, in the pipe, between the position of the different material stages and the pipeline anomalies themselves. Once the tube was properly positioned; the inversion of a calibration hose ensued and a precise rehabilitation product was assured.

Conversely, in an outfall installation called B 29 on the Detroit River we encountered a 72” x 54” x60” three tiered transition over a one thousand (1000’) foot distance rehabilitated using methods described in ASTM F 1216. A post rehabilitation inspection using both non destructive, as well as core sampling revealed the liner to be fully in contact with the host pipe throughout the length of the rehabilitation. The Judges…..9.9, 9.9, 10.0!

The parameters affecting successful inversion of a large bore rectangular box culvert or transitional CIPP installation include:

- Experience of the installation crew
- Pre inversion pipeline preparation
- Accurate survey data
- Testing

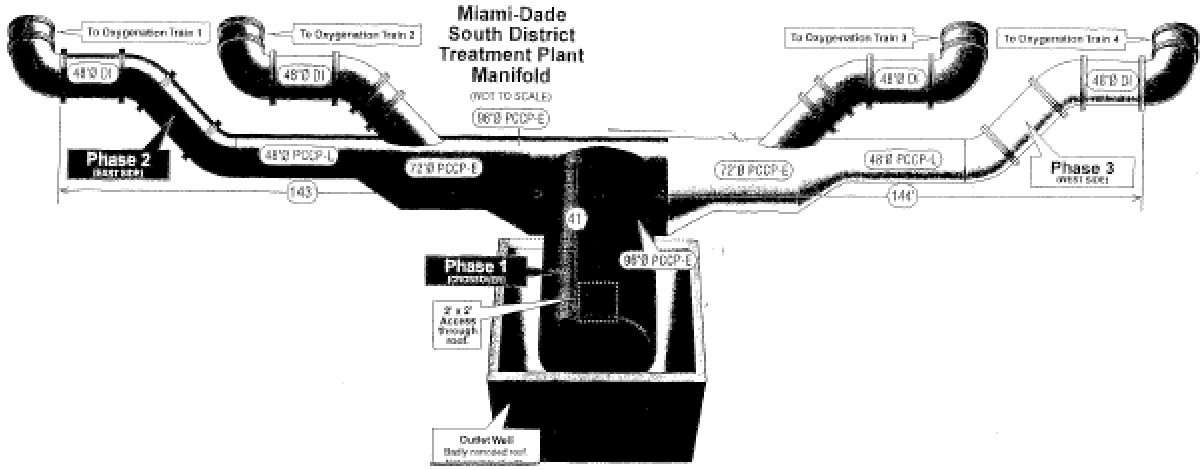

Figure 1 Transitional   96"x72"x48" Cured in Place Rehab favoring methods listed in ASTM F 1743

DESIGN CONSIDERATIONS

It is not the intent of this paper to spend a great deal of time rehashing the design methods stated in ASTM F 1216, ASTM F 1743, or the WRc Design Types 1 thru 3. Rather it is recommended that these designs be compared for applicability to the conditions encountered. There are many installations of CIP technology that have been in place for adequate duration to demonstrate the viability of this methodology in fully structural application meeting the criteria set forth in each of the afore mentioned design approaches.

In the rectangular shapes encountered during the box culvert rehabilitations presented it was extremely significant that full contact between the host pipe and liner was assured.   This was achieved by installing fillets in each of the corners allowing the tube to take on an elliptical configuration. Validation of the fully deteriorated structural design could then proceed by considering the liner as an ovalized non circular application, as opposed to a rectangle.   Fillet dimensions were calculated after a comparison of the areas between the rectangle to be rehabilitated and the circular tube to be utilized which, when inverted into a box culvert, took on the shape of an ellipse.

In all cases the loss of area did not exceed 12% which was then regained hydraulically due to the intrinsic efficiencies of flow characteristics in cured in place pipe. Ovality generally ranged in the 8% to 14% range which caused substantial wall thickness increases when compared with comparable circular rehabilitations; but none that proved prohibitive in handling or tube inversion ability. No rectangular box rehabilitated exceeded a span to rise ratio of 2:1.

Key design parameters

- Design Method ASTM F 1216 /1743 vs. WRc Type I, II, or III
- Span to rise ratio
- Ovality of the resultant Non circular Liner
- Capacity change and tolerance for area reduction
- Fillet design and dimensions
- Inversion length
- Wall thickness

- Weight of materials being installed
- Over the hole vs. factory impregnated

INSTALLATION

There can not be enough emphasis placed on pipe preparation prior to installation of any trenchless rehabilitation. The properties, quality, and life expectancy achieved are always dependant upon the clean and televise protocol adopted by the installer. Not only are these efforts the eyes and ears of the operation on a production basis, but they set the stage for the installation's ultimate efficiency and technical success. In the cases of rectangular box culvert, large bore, and transitional liner application; not only are the cleaning crews making the pipeline available for the critical survey step, but they prepare the pipe for placement of the fillets and tube installation.

During the pre installation survey; defects and dimensions catalogued are compared with visual and CCTV data collected. Prior to tube fabrication, analysis of the design dimensions and pipeline configuration must take place. With critical lead times as long as three (3) weeks in mammoth tube fabrication, the urge to rush the pre installation survey must be resisted.

The fillets are placed with a gravity fed trowel methodology at the inverts, while a mesh coping may be used to keep material at the crown locations. Since the tube will expand upwardly as it is being installed it may not be necessary to grout the crown prior to inversion. Alternatively, crown material may be either pumped from the inside of the tube at fifty (50) foot intervals, pumped from above ground through placement tubes (if access exists), or through placement tubes longitudinally which are extracted as pumping proceeds. Excessive grout pressures must be avoided since this may cause undue pressures on the liner application. Optimum results, however, are assured through gravity or mechanical pre inversion grout placement methods.

Once the host pipe is fully prepared and geometrically modified the stage is set for the non circular CIPP inversion. The installation may commence over the hole in cases where installation quantities exceed those which can be transported, or conventionally, out of a reefer trailer or low boy hauled "cool box".

An additional factor of safety may be implemented by increasing the anticipated resin consumption by a sacrificial quantity of between 5% and 15%. This additional material insures intimate contact between the liner and host pipe, while enhancing structural characteristics in the finished product and filling all cracks and voids.

In transitional liner applications (concentric diameter changes or eccentric increaser/reducer applications) it should also be noted that it takes a distance of approximately three times the largest diameter over a longitudinal distance within the host pipe to make the transition desired. In other words in a five (5') foot diameter equivalent round pipe it may take as much as fifteen (15') of longitudinal distance to make a diameter change. This is also significant when performing pre installation grout preparation on the host pipe.

The tube should generally be installed such as to overlap the smaller diameter liner into the larger diameter host. In this case the effects of grout and sacrificial resin may be counted on for support in order to avoid or minimize the phenomenon of fins. Fins occur when there is plainly more material than can be distributed over the hydraulic radius. Cut away investigation of fining has demonstrated that this is not a defect but rather the manifestation of excess material. This material may be cut, ground out or sanded if there remains concern that a hydraulic inefficiency or debris flow blockage might ensue.

Table 1. Boxes rehabilitated by methods described

	METHOD	WALL THICKNESS/LENGTH	FILLET DIMENSIONS	ROUND EQUIVALENT
72” X 48”	OVER THE HOLE	38.5MM / 1605LF	18”X12”	60”
84” X 60”	FACTORY IMPREGNATED	38.5MM / 910LF	18”X18”	72”
72” X 104”	OVER THE HOLE	47.5MM / 3600 LF	18”X24”	89”
63” X 72”	FACTORY INPREGNATED	36MM / 700LF	NONE REQUIRED	66”
78” TRAPEZOIDAL	OVER THE HOLE	42MM / 3525LF	18”X18”	72”

TESTING

The benefits of third party testing have been well documented and utilized over millions of feet of CIPP installation. The ability to demonstrate properties achieved in the field by flexural modulus and flexural strength testing of a composite resin/felt coupon not only validates the preliminary design basis but additionally:

- Proves the wet out phase was adequate
- Insures that the prescribed cure / cool cycle was thorough
- Serves as a secondary check of design wall thickness
- May be utilized for resin verification

Upon conclusion of a large bore non circular or rectangular box culvert installation it may also be advisable to do some internal pipeline verification of the corners using either destructive or non destructive means. The simplest is a core sample where a small tap is drilled to insure that there is an intimate contact between the host pipe and liner. A batch of ambient cure resin or epoxy and hardener may be utilized to fill these taps upon conclusion of the verification. Where tapping a good liner is not desired; a “sounding” of the area with a rubber mallet may be performed. Voids behind the liner will sound hollow when struck. Should voids be detected there are several methods which can be utilized to insure a suitable end result ranging from resin injection to cutting out the suspect area and performing a “hand lay up” or sectional repair. For comparison purposes, consider that in the over ten thousand (10,000’) lineal feet of large bore non circular and box culvert rehabilitation documented in this paper the need to perform this type of repair occurred twice while impacting only some forty (40’) feet of pipe.

CONCLUSIONS

In this paper we have documented the rehabilitation of over two (2) miles of non circular, transitional, and rectangular box culverts which were successfully renovated to fully deteriorated model stand alone structures with a renewed full service life expectancy using cured in place pipe methods described in ASTM F 1216 and ASTM F 1743. The successes were attributable to contractor experience, superior pre installation pipe preparation, accurate dimensional survey, and post installation testing. The pre lining grouting methods successfully utilized were explained while alternative methods were presented for consideration.

REFERENCES

Gelinas, M. (1999). Trenchless Repair of Larger Diameter Sewers. Proceedings of 1999 NoDig Conference, Orlando, Florida, May 23-26, 1999.