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Use of HDPE Drainage Pipes by DelDOT

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1.0 Introduction

Acceptance of new construction materials in infrastructure applications is typically slow, especially in the public sector. This can be attributed to an understandable conservatism when a substantial amount of money needs to be invested, when long-term performance is uncertain, and when safety is an issue. In recent years, however, acceptance of new materials has accelerated, mainly due to the increasingly high cost of construction combined with the availability of less expensive newly developed, custom-made, engineered materials. The ability to better predict the performance of these materials, which has resulted from sophisticated lab testing and the use of powerful computers, facilitates the acceptance process. A prime example of rapid acceptance in critical applications is the use of cost-effective polymeric materials (geosynthetics) in soil reinforcement, filtration, and separation. The acceptance of geosynthetics has evolved over less than 30 years, whereas during the past 10 years national design guidelines allow for permanent applications in critical structures such as retaining walls, bridge abutments, dams, and landfills.

Three important aspects must be considered in the application of any construction materials: installation, maintenance, and durability. This can be achieved only if a reasonably conservative design exists in which the relevant long-term material properties can be identified. The term *design* pertains not only to the mechanics of the structure (e.g., induced stresses and reactive displacements) but also to consideration of environmental conditions (i.e., degradation due to environmental aspects such as temperature, electrochemical parameters), local experience of contractors (constructability), and other relevant elements.

To be economical, new materials are engineered to take advantage of beneficial interaction with the environment in which they are installed (e.g., utilize or account for mobilized compressive strength of the surrounding soil). While this may allow for reduced material strength, it relies on strong interaction with the environment. An example of such a case is a flexible buried drainage pipe. When embedded in soil and subjected to vertical live load, the circular pipe will tend to deform and attain an oval shape. However, the pipe must exert compressive pressure against the compacted soil on both its sides as it deforms. Since compacted soil is strong and stiff under compression, it will resist the pipe deformation. The end result is a pipe with reduced structural section capable of supporting large vertical dead and live loads through mobilization of the strength of the embedding compacted soil. The performance of such buried pipes hinges on uniformly well-compacted granular soil on both sides of the pipe. Soft soil or compacted soil on only one side will allow for deformation, leading to possible collapse or buckling of the pipe. Clearly, proper *installation* is then critical.

While installation is one important aspect, the frequency and cost of maintenance of an in-service structure is equally important. For example, maintenance operations may require the temporary closure of traffic lanes, which may not be affordable even if the cost of maintenance is relatively low. In drainage pipe applications, it may mean frequent repair of failed joints, replacement of collapsed pipes resulting from erosion of supporting soil as a result of open joints, or simply deformed pipe detected during inspection that implies impending collapse and thus requiring immediate repair. Poor installation may result in increased maintenance; however, a product having, for example, leaking joints or a structure that is too weak to support the load will require excessive maintenance even if the installation is adequate.

Finally, because the materials are new, there is always a question of their durability during the required life span of the structure. The environment in which the product has to perform may not be friendly (e.g., freeze-thaw cycles, acidity or alkalinity, ultra-violet radiation, or even possible fire), causing accelerated deterioration. Designed life spans of most structures related to the infrastructure typically vary from 20 to 150 years and thus may require an extrapolation of predictive life. There is a risk of failure in such extrapolation, and the economics should clearly justify taking such a risk.

2.0 Background: Interaction Between Pipes and Embedding Soil

The distinction between the behavior of flexible pipes and that of rigid buried pipes was made many decades ago. It is based on the interaction between the pipe and the embedding soil. Since the short- and long-term performance of flexible pipes is dependent on proper interaction with the confining soil, this section briefly presents related background information on that topic. Later on, this should lead to obvious conclusions regarding construction and long-term aspects of HDPE corrugated pipes.

Buried drainage pipes are capable of supporting vertical live and dead loads as a result of two elements:

a. The inherent strength of the pipe shell.
b. The lateral pressure of the embedding soil on the sides of the pipe produce stresses in the shell directly opposite to those generated by the vertical loads and therefore assists the pipe in supporting these loads.

In a rigid pipe, such as one made of concrete, cast iron, or clay, the inherent strength is the predominant source of load supporting capacity. Lateral soil pressure on the pipe is limited, since this type of pipe deforms very little under vertical load; consequently, its sides do not move outwards enough to mobilize any appreciable passive soil resistance. In flexible pipe, such as HDPE or PVC, considerable strength is obtained in shell compression; however, bending (flexural) resistance is low. As a result, the ability of such pipes to support vertical loads is derived from lateral passive pressure mobilized in reaction to outward movement of sides against the surrounding soil. That is, the pipe assumes an oval shape under load and thus must “push” against the confining soil mobilizing its strength indirectly reacting to the vertical load. The ability of a flexible pipe to deform readily without failure and thus utilize the reactive passive soil pressure on the sides is its principal distinguishing structural characteristic. This characteristic accounts for the fact that a relatively lightweight pipe of low inherent strength can support vertical loads without evidence of distress. In a sense, a composite material (polymer-soil) is created that through interaction allows for lighter end product. In fact, reinforced concrete pipes are also composite structures (concrete-steel), where the concrete provides the necessary compressive strength, while the steel contributes tensile strength.

The performance of flexible pipes is derived from strong interaction with the embedding soil. Hence, it is apparent that proper installation is crucial for satisfactory performance. Consequently, the dimensions of the excavated trench, type of natural soil, bedding, backfill material and its level of compaction, sequence of layers backfilling, and embedment depth below live loads, are all critical elements for the long-term performance of the corrugated HDPE pipe.

3.0 Designing with HDPE Pipes

This section provides an overview of design related to HDPE pipes. An excellent reference book (serving as the source for this overview) is *Designing with Geosynthetics*[1]. This book provides a perspective that enables one to see the entire process without being overwhelmed by the details. The details, however, are very important for the actual design and are provided by AASHTO. DelDOT requires AASHTO guidelines for design.

3.1 General

Current polymer resins used to fabricate plastic pipes are High Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Polypropylene (PP), Polybutylene (PB), Acrylonitrile Butadiene Styrene (ABS), and Cellulose Acetate Butyrate (CAB). Advanced extrusion processes allow for the fabrication of corrugated large-diameter HDPE pipes. Corrugation stiffens the pipe section, increases its resistance to buckling, and allows for less material to be used. The end product is low in initial cost and light weight. Handling of HDPE pipes is easy, joining pipes together is quick, their flow regime is good, and they *can be* durable. A number of feasible potential failure modes for HDPE pipes need to be addressed in design:

- Excessive pipe deflections due to improper backfilling leading to localized material overstressing.
- Seam separation of joined pipe ends due to ring compression stress.
- Wall crushing due to high overburden stress.
- Wall buckling due to external pressure.
- Impact cracking of pipe in extremely cold environment.
- Brittle stress cracking of pipe and pipe connection.

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[1] R. M. Koerner, Prentice Hall, 4^{th} Edition, 1998.

- Polymeric material degradation.

There are numerous books, reports, scientific papers, test methods, and manufacturers' guides that deal with plastic pipes. Much of this information is relevant to proper drainage application of HDPE pipes. Some of this literature implies that the HDPE pipe industry is maturing, recognizing past poor manufacturing and application, and attempting to improve its products and their specifications. AASHTO committees dealing with drainage pipes periodically modify the specifications to reduce the risk of failure.

3.2 Properties

In design calculations, one ensures that the "supply" (i.e., capacity of the pipe to produce a certain resistance such as strength) meets the "demand" (i.e., the actual load imposed by such stresses due to live and dead load). Quantification of the demand is quite established, especially in a mechanical sense. However, the supply aspect needs proper characterization of the HDPE pipe material and structure. Hence, a vital component of any design is knowledge of the relevant material properties. Only then can the issues associated with HDPE pipe be properly addressed in design calculations.

There are a variety of test methods to establish the relevant properties of plastic pipes, many of which are continuously being refined. Tests are developed by ASTM (Committees F-17 and D-20), AASHTO, AWWA (American Water Works Association), and NSF (National Sanitation Foundation). The test methods relevant to drainage are those in AASHTO and ASTM:

- **Physical Properties***:* These properties are for the pre-installation pipe and are used for identification, conformance, and quality assurance. The properties include the thickness of smooth walls (e.g., ASTM D2447), the wall geometry for corrugated pipe, the diameter, the standard dimension ratio, density (e.g., ASTM D792, D1505), and polymer identification (which is important for durability if low-quality polyethylene is used).
- **Mechanical Properties***:* Most failures of HDPE pipes are due to mechanical stressing. The ability of plastic pipes to withstand overburden stresses is based on the following properties:
    - Concentrated line load test (e.g., ASTM D2412) to determine the compressive stiffness, distributed load test (in-soil loading which is more relevant for plastic pipes, but not yet a standard test)
    - Hydrostatic pressure test (ASTM D1598; typically not relevant for drainage pipes)
    - Sustained load resistance (there is no specific test approach yet for creep unless one adopts the procedure used in geosynthetics; currently there are long-term full-scale field tests)
    - Environmental stress cracking resistance (i.e., while the existing standard test is relevant to geomembranes, its use in pipes is an extrapolation)

  - Impact resistance (i.e., ASTM D256), and
  - Connection test (i.e., ASTM 3212; may not be relevant in drainage pipes).

- **Chemical Properties***:* Drainage pipes used by DelDOT do not carry aggressive chemicals, and therefore some of the established degradation tests are not relevant. Ultraviolet light resistance should not be of concern unless the pipe is exposed to direct sunlight (ASTM D4355; additives to the polymer such as carbon black and antioxidants slow UV degradation).

Note: At present, quantifying the environmental stress cracking resistance of HDPE pipes is controversial. The ASTM D1693 test is not considered to be challenging enough. Also, it does not allow for quantification as to the relative ranking of resins. An alternative test, ASTM D5397, does not give the minimum value required. Stress cracking is likely a problem in very cold parts of the U.S. (e.g., Minnesota). Field experience in Delaware should tell whether this is a problem in HDPE drainage pipe local applications. Furthermore, a test for creep, especially under compressive stresses, does not seem to be readily available for pipes. However, large reduction of the short-term ultimate strength is used and, based on experience with geosynthetics, is likely to produce a conservative long-term allowable strength.

3.3 Design Calculations

Calculations to ensure the performance of buried HDPE drainage pipes are detailed in AASHTO M294 and are beyond the scope of this report. The AASHTO guidelines are evolving continuously. This evolution process is common to all applications for which AASHTO issues guidelines. The guidelines are further refined as more field experience is gained.

3.4 Construction

Joining and placement of plastic pipes is simpler than for most other pipe materials because of their light weight. However, proper procedures are paramount for pipe performance. Several organizations have installation guidelines. Besides AASHTO, it is recommended to follow the Plastic Pipe Institute guidelines, PPI TR8: "Installation Procedures for Polyethylene Plastic Pipe."

It is important to excavate a trench of proper dimensions. Too wide an excavation is costly, possibly disturbing a large volume of the natural soil. A trench that is too narrow will make it impossible to properly compact the backfill soil. If the natural soil is soft, a large volume of this soil has to be replaced with granular soil to ensure good lateral resistance to the flexible pipe deflections. The base of the trench should be compacted, even if it is the natural soil, to minimize deformations during the service life of the pipe. Compaction of the bedding soil should be at least 8 inches deep, yielding a minimum of 95% of Standard Proctor.

Backfilling is done in stages. The backfill should be granular so that it can be compacted with ease. Special attention should be paid to the placement of fill in the haunch areas beneath the pipe. When voids are left under the pipe, it will deform excessively. Inattentive compaction ("too much compaction," called *slicing* because it is done by shovels) will lift the pipe off and cause its misalignment. Also, the fill should be placed and compacted on both sides simultaneously. That is, lifts of 4 to 6 inches (could be larger if clean gravel is used) should be placed and compacted in an alternating fashion, each lift on the opposite side of the pipe. This will prevent excessive lateral push, thus ensuring aligned installation as well as symmetrical lateral support of the buried pipe.

Proper type of soil should be used as backfill. To ease placement of backfill soil on the sides of the pipe (a critical element in successful performance of HDPE pipe), no material that is classified as "fine soil" (i.e., over 50% passing sieve 200) should be used. That is, no clayey or silty soils should be used. Crushed rock or gravel with maximum particle size of 1.5 to 2 inches is best. Coarse-grained soils with a trace of fines (less than 12%), such as clean sands, are also good. Large stones against the pipe should not be used at all, since they could cause a large stress concentration. Secondary backfilling above the pipe could be the same as at the sides of the pipe; if economical, it could be of slightly lower quality. This fill should cover the pipe by a thickness of at least one diameter of the pipe. It should be well compacted. Before mechanical compaction of the secondary backfill, a layer of at least 12 inches should be placed to minimize any external compaction load from the pipe. Generally, backfill should not be simply dumped; it should be carefully placed and compacted in a sequential fashion.

Finally, pipe sections should be properly connected. Poor connection often triggers failure. As water flows rapidly through the drainage pipes, it can gradually wash away the backfill soil if a joint is open. That is, the soil particles around the joint will progressively be washed away, thus creating, over time, a void. Such a process can eventually cause a collapsing "sinkhole," which is costly to repair. This potential problem is common to *all* types of pipe.

4.0 Potential Weaknesses

This section refers to potential weaknesses of the HDPE corrugated drainage pipe system. It uses the term *potential* because some of the weaknesses are either uncertain (i.e., speculative at this stage) or will definitely happen if improper procedures are used. Possible remedies and precautions related to some of the weaknesses are proposed later on. The following items were identified:

- **Mixed track-record**. There were many installations in which the HDPE drainage pipes are performing well. There were also some spectacular failures, mainly in the private sector where adherence to design guidelines is not always followed and construction is often cavalier in nature. Such a mixed record is quite common to all new technologies. Based on forensic studies, most of the failures can be attributed to poor installation. However, some are related to specific products that will not be allowed by today's AASHTO design guidelines.
- **Rapidly evolving design**. Similar to application of any new product, design guidelines are dynamic, undergoing refinement as experience and knowledge

are further gained. It cannot be stated that HDPE pipes are in their infancy; they have been in use for over 20 years. However, it seems that the application has not fully matured yet (be it by virtue of the fact that critical applications have not reached yet their design life). AASHTO is continuously refining the design process (including material characterization), and its guidelines are comprehensive. Acceptance of new materials is currently made by extrapolation invoking relevant similar applications; such a process necessarily involves risks that diminish over time as experience is gained.

- **Short track-record**. The HDPE large-diameter drainage pipe is a new application relative to its expected life. Hence, legitimate questions about its durability are valid. Designs try to accommodate aspects such as creep, environmental stress cracking, and UV light by requiring a larger "sacrificial" sectional area of the wall (i.e., higher strength). The design is based on extrapolation from accelerated lab tests and experience with HDPE application in other areas (e.g., geomembranes, electric wire insulation exposed to sun light). As long as the data is extrapolated, such design can be "precise," wasteful, or unconservative. If it is overly conservative, the economics will hinder its application. However, if it is unconservative, it may pose a risk of premature failure. The availability of sophisticated lab tests, advances in knowledge in polymeric science, and the availability of advanced computational tools all reduce the level of risk. AASHTO committees on HDPE are good "watchdogs," keeping the design guidelines up-to-date.
- **Accidents and vandalism**. Although not easy, HDPE material can be damaged by accidents and vandals (e.g., fire). By the same token, other highway installations are susceptible to similar damage (e.g., traffic lights). This is a risk that needs to be considered by the owner.
- **Variety of products**. There are several manufacturers fabricating HDPE products that look similar but yet may possess different properties. Such competing products keep the cost down but can be confusing. To reduce the level of confusion, a 3rd party product certification should be required ensuring that all specified requirements are met or exceeded.
- **Designers' inexperience**. Drainage systems are typically designed by civil engineers. Most civil engineers are inexperienced with polymeric materials. Hence, they tend to shy away from such an application or may use it incorrectly. Education and proven field performance (product track record) may accelerate the required time for the learning curve. This has been happening in the area of polymeric soil reinforcement (geosynthetics).
- **Criticality of construction**. HDPE pipe has a relatively delicate structure that derives its in-situ strength from interaction with the embedding soil. It is easy to install (not requiring heavy equipment and skilled labor) and thus, it "creates" many "instant" contractors. Such contractors are more likely to be unqualified, which may result in improper installation. The end result is quick failure. It must be noted that, objectively, it is difficult to compact soil along the lower half of the pipe wall. However, proper procedures and backfill soil can alleviate this potential problem.

- **High water table**. If the water table is high (i.e., within the installation trench), it would difficult to place the HDPE pipe because of the uplift pressure against its lightweight structure. Such conditions require another type of pipe system.
- **Tight and aligned joints**. Connection of two adjacent pipes must be tight and aligned for any type of drainage system. If not, soil supporting the pipes near the joint can progressively be eroded by water flowing through the pipe, resulting in a void. It is easier to obtain a tight connection with HDPE pipes than with other materials. However, a void near the outside wall of the pipe will lead to a quicker failure with HDPE than with rigid pipes. In the long run, any type of drainage pipe will fail in one way or another (e.g., sinkhole collapse) if a large void is near its wall.

5.0 DelDOT Guidelines

The following are highlights from DelDOT guidelines (1999) for HDPE corrugated drainage pipes:

a. Design (and material) should follow AASHTO M294.

b. No damaged pipe or coupling shall be installed.

c. Minimum stiffness, measured at 5% deflection, based on ASTM D-2412 is specified for diameters ranging from 12 to 48 inches.

d. Joints for all pipes and fittings shall use watertight bell/spigot or bell/bell couplers. Gaskets shall meet the requirements of ASTM F477, and the joint system shall be certified to meet ASTM D3212 with a modified test pressure of 2 psi.

e. Joint should provide sufficient longitudinal strength to preserve pipe alignment and prevent joint separation.

f. Manufacturer's certificate stating the product was fabricated, tested and supplied in accordance with all the applicable requirements of AASHTO M294.

g. Class "C" bedding shall be incorporated at installation.

h. Contractor should use "whatever means to prevent displacement of the pipe horizontally or vertically" during installation.

i. Backfill materials and placement shall conform to the applicable requirements of Section 208 of the Standard Specifications.

A memorandum by Chao Hu (dated August 27, 1999) amends DelDOT applications as follows:

- Maximum allowable pipe diameter is 42 inches.
- *Installation is allowed only in subdivision streets where alternate access is available (i.e., no installation is allowed at cul-de-sacs or at the entrance to a development with a single entrance).*

- If a pipe is improperly installed, the contractor will receive a "strike." If two strikes are accumulated, the contractor will not be allowed to use HDPE in any future projects. The memo defines what constitutes improper installation.
- All closed drainage systems are subjected to video inspection.
- All contractors that intend to use HDPE must certify that they have attended a training session presented by the pipe manufacturer. A training session for district inspectors and contractors is held to ensure that each is aware of the proper installation for the product.

DelDOT's Policy Implement S-22, "Inspection of Subdivision Drainage System," requires that any storm drainage system of subdivision must be inspected using video and Mandrell deflections measurements before acceptance. The video should clearly show no defects in the installed drainage pipe. Defects must be repaired with a follow-up video. Using the Mandrell, deflections of all flexible pipes must be within the specification limit (per AASHTO, no more than 5% of the pipe diameter).

6.0 Suggested Improvements

Most state DOT's are using HDPE drainage pipes. Use of HDPE drainage pipes by DelDOT started on an experimental basis in mid-1997. Two test installations were under periodical inspection (1 and 4 years after installation); inspections showed good performance. The use of HDPE drainage pipes was allowed in subdivisions in August 1999. DelDOT personnel went through two training sessions. In 2000 and 2001 there were two additional training sessions open to the public. Clearly, DelDOT has used a cautious and responsible approach in adopting a new technology: starting with field tests that are monitored for long-term performance, limiting use to non-critical applications, adopting design guidelines developed by a reputable organization (AASHTO), and offering/requiring training courses for its own personnel as well as installers. The required video inspection of *all* pipes by DelDOT is an excellent tool to detect defects before serious problems arise. DelDOT should be commended for their rational and reasonably conservative approach, which allows for the introduction of new technologies that are potentially more economical while minimizing the risk associated with such adaptation.

At present, there are only a few suggestions for improvement. Following are these suggestions:

I. AASHTO is refining its guidelines continuously. DelDOT should always refer to the latest guidelines. DelDOT guidelines should not conflict with AASHTO except to use *stricter* rules when needed based on local experience.

II. Revisit periodically selected existing installations of HDPE drainage pipes to see whether degradation occurs. This will enable DelDOT to create its own database, facilitating future local modifications and revisions. One extreme could be to exclude the use of such pipe; the other would be to allow its use in critical applications (e.g., major roadways). In particular, these inspections should reveal whether the design and installation result in long-term excessive deflections, creep rupture, environmental stress cracking, UV surface deterioration in segments exposed to direct sun light (if relevant), joint misalignment, and progressive washing of backfill soil through the pipe, which may potentially lead to sinkholes.

III. Based on interviews with DelDOT personnel, it appears that so far the performance of HDPE drainage pipes has been good. The five-year mark of non-experimental installation could be used as a milestone in which DelDOT should explore whether to expand the scope of the current very restricted applications, i.e., applications beyond subdivisions.

IV. DelDOT should continue inspection using video. To facilitate the inspection process, DelDOT could consider phasing out Mandrell deflections measurements if the video alone proves to be effective. However, initial acceptance of a pipe should include deflection measurements, since this approach quantifies a limit for acceptance (i.e., if deflection is more than 5% of the diameter, the installation should be rejected). To keep the database in a modern and manageable fashion, the pipe location should be identified by its global coordinates (using a GPS), and the video should be digitized.

V. DelDOT should organize training sessions that also include a demonstration of good *and* poor installation. Such training should be required for all DelDOT inspectors and contractors who install HDPE pipes.

VI. DelDOT requires all contractors that intend to use HDPE to certify that they have attended a training session presented by the pipe manufacturer. It is recommended that DelDOT representative will attend the training session for the contractors to ensure it is properly presented and properly received.

VII. The two 'strikes and out' for a contractor who performs poorly is a good idea but seems to be difficult to monitor and enforce. It is recommended that DelDOT find a more practical way to ensure proper construction. One option would be to exclude such a contractor after one strike; there is little bookkeeping needed for such a penalty. Alternatively, a proper financial penalty can be imposed.

VIII. DelDOT should require third-party certification for HDPE corrugated pipes. Such certification is the result of a process by which a manufacturer states that a product meets or exceeds the requirement of AASHTO M294 standards, and a third party validates it, through testing and inspection, that the product does, in fact, meet the requirements. The third party is an independent body. The HDPE pipe industry has such a certification program, as do many other trade organizations. This will reduce any possible confusion about the products available in the market and eliminate inferior products.

IX. DelDOT should avoid installation of HDPE pipes when the water table is above the bedding in the trench.

X. Proper backfilling is critical to the performance of flexible pipes. Compaction of backfilled soil in the trench is of paramount importance. To ease compaction, it is recommended that:

   a. Based on ASTM D-2321, use only Class I to III type of backfill (AASHTO designation is A1, A-2-4, A-2-5, A3). Do not use fine grained material as backfill, since it makes compaction more difficult. It is easiest to compact poorly graded soil (i.e., most particles are of the same size), especially Class I to Class II (e.g., railway ballast is poorly graded mainly to minimize the energy needed for compaction).

b. Specify compaction of 95% Standard Proctor (not 90%) in maximum layer lifts of 8 inches. The base of the trench should be compacted, even if it is in the natural soil, to minimize deformations during the service life of the pipe. Close field supervision is recommended.

c. It is recognized that placement and compaction of soil along the lower half of the pipe diameter, the haunch zone, can be problematic. The soil is pushed into this tight space with the aid of a shovel. Compaction may cause horizontal and vertical misalignment of the pipe; lack of compaction will not provide sufficient lateral support and thus will allow for excessive deflections of the flexible pipe. To achieve high compaction while not affecting the pipe alignment, a restraining fixture is suggested. It should be pointed out that the proposed approach is an original concept that should enable proper construction in a practical way. An *inexpensive* woven or nonwoven geotextile strip is placed around the pipe, making one spiral loop with two horizontal flat ends, resembling an Omega (Ω) shape – see Figure 1. The two horizontal tails of the strip are placed on the bedding, stretched to the sides of the trench. The strip wraps the pipe, and its horizontal tails tie (anchor) it down as vertical load is applied. Geotextile strips can be 12 inches wide and be placed at 5-foot intervals. The larger the vertical load due to compaction, the larger the force that pushes the pipe sideways and up; however, the anchorage resistance of the horizontal tails and the friction along the interface between the wrapping geotextile and pipe circumference increase simultaneously with the load, thus keeping the pipe in place. The backfill is placed in lifts as currently specified by DelDOT. At the end of each lift on both sides of the pipe, the backfill is compacted to achieve the desired density. The wrapping spiral geotextile strips restrain the pipe from moving during compaction while enabling a high level of compaction. It seems that the added cost of this anchorage arrangement would be very little compared with the cost of pipe installation while the potential benefits are significant. By demonstrating the feasibility of this construction scheme, DelDOT may affect the practice of drainage pipe installation.

d. The fill should cover the pipe by at least one diameter of the pipe. It should be well compacted. In applications where no external load is expected over the pipe (e.g., off road), the cover should be at least ½ diameter. However, the classification of “off road” should be carefully evaluated. If there is a possible future traffic over the pipe (e.g., temporary ‘road’ needed for construction or bypass), a one diameter cover should be placed during the initial installation of the pipe.

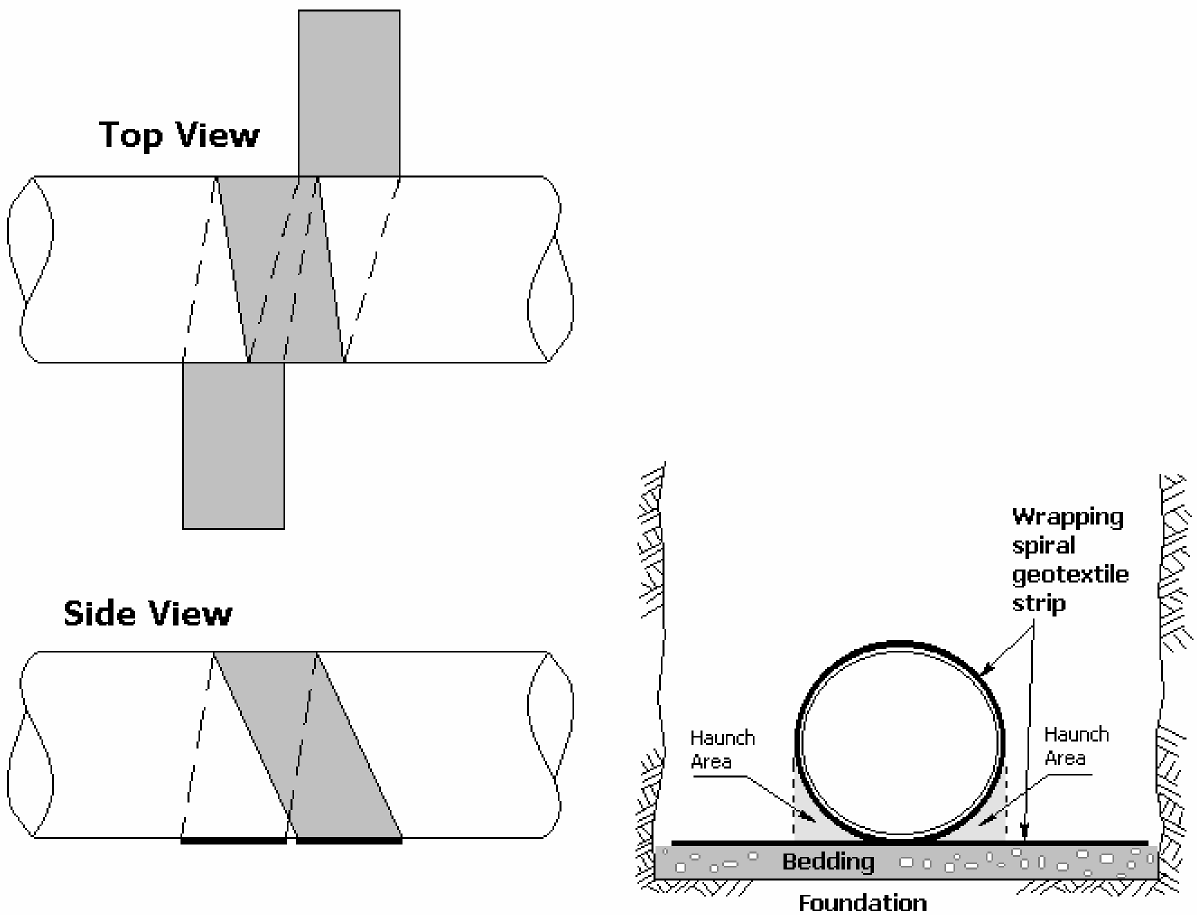

Figure 1. Spiral geotextile strip tying down the pipe to facilitate compaction of backfill

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