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HDPE Pipe Design and Construction:
Lessons Learned from the East Texas Fish Hatchery Incident

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An educational document from the American Concrete Pipe Association for users and specifiers

In April 2009, inspectors at the John D. Parker East Texas Fish Hatchery discovered that sections of 60-inch and 48-inch diameter high-density polyethylene (HDPE) drainage pipes had collapsed.[1] Ultimately, approximately 11,000 linear feet of 30-inch, 48-inch, and 60-inch diameter corrugated HDPE pipe were removed and replaced.

In May 2010, a Compromise and Settlement Agreement (Settlement) was signed by the Texas Parks and Wildlife Department (TPWD), HDR Engineering (Engineer), Allco (Contractor), and Travelers Casualty and Surety Co. of America.[2] Per this Settlement, the Engineer paid $3.18 million to TPWD and $213,000 to the Contractor. According to the Settlement, "certain issues arose regarding the HDPE drainage pipe on the project, which issues included certain portions of the HDPE pipe experiencing deflections beyond what should normally be expected." [2] It is noteworthy that the HDPE pipe manufacturer was not a party to the Settlement. The Contractor and Owner were severely delayed, and the Engineer bore all financial liability of the Settlement.

Design-Installation Failure of the Corrugated HDPE Pipe System

A third-party Construction Assessment and Failure Analysis cited professional opinions for the failure of the designed-installed corrugated HDPE pipe system, including:

- "The corrugated HDPE drain pipes collapsed or deflected excessively because the external forces imposed by soil and hydrostatic pressures exceeded the capacity of the pipe and surrounding soil to resist those forces."[3]
- These external forces should have been foreseen. For instance, geotechnical studies were available.[4]
- Soil boring analysis determined that on site materials were poorly suited for pipeline construction.[4]
- Insufficient compaction of backfill material was a significant factor in the collapse and excessive deformations.[3]
- Sufficient compactive effort was not achieved. The gap between the pipe and trench box wall was too narrow to allow proper compaction. Further, dragging the trench box loosened the backfill around the pipe.[3]
- The Contractor did not comply with the specification requirements for dewatering beneath the pipe trench, which led to difficulty achieving proper compaction of pipe embedment.[3]
- The pipe backfill and compaction specifications contained inconsistencies and were difficult to understand.[3]
- The Contractor should have resolved the specification inconsistencies by asking the Engineer to clarify what type of backfill material and how much compaction was necessary. This could have been done at a pre-construction meeting and/or through RFIs to the Engineer.[3]
- The Engineer had important construction phase responsibilities. However, the Engineer believed that its construction responsibilities were limited to progress assessment, monthly site observations, and responding to questions. Despite its on-site presence, albeit limited in scope, the Engineer was simply not aware of the pipe's failing conditions.[4]
- The Engineer "did not provide per their contract with TPWD sufficient services during construction … including sufficient site observations and review of field compaction and inspection records. As such, [the Engineer] fell below standard of care as the Engineer of Record."[4]
- The Engineer "should have more carefully chosen the type of backfill and degree of compaction. At a minimum, a Class II backfill compacted to a minimum of 95% relative compaction should have been used for pipe embedment for the 30-inch and 48-inch diameter pipelines."[4]

- The Engineer's "approach of designing the pipes solely by using a chart was improper given that the chart did not account for the contributions of groundwater that was known to exist at shallow depths at the site. As such, [the Engineer] fell below the standard of care for pipe design."[4]

What can we learn from this case study?

What can engineers and contractors learn from this corrugated HDPE design-installation failure? The mistakes and misunderstandings in the East Texas Fish Hatchery incident are commonplace in the civil engineering and infrastructure construction industry. Do not dismiss your level of risk based on the catastrophic scale of this incident. Some of the pipe issues discovered were not evident from above-ground casual observation and were not known until proper internal inspections were conducted. Listed below are some basic questions and fundamentals for civil engineers and underground utility contractors that choose to accept the risks and properly use corrugated HDPE and thermoplastic pipes.

Should engineers use fill height tables / design charts or a manufacturer's design suggestion without validating the actual geotechnical conditions?

In the Fish Hatchery incident, the Engineer misapplied a standardized design chart that was obtained through a plastic pipe association. Pipe design charts are commonly misused; however, it is possible to properly design and engineer the installation of plastic pipe based on American Association of State Highway and Transportation Officials (AASHTO) Load Resistance Factor Design (LRFD) standards. AASHTO LRFD Bridge Construction Specifications, Section 12 design standards incorporate in-situ geotechnical conditions, practical construction standards, and acceptable design service limits for buckling, wall thrust, combined strain, and a controlled deformation limit.

In order to properly design an engineered installation of plastic pipe, the engineer must obtain site geotechnical information (depth, groundwater elevation, AASHTO soil classification, soil modulus of elasticity, etc), pipe wall geometry data (e.g., moment of inertia, distance to neutral axis, wall area, etc), and plastic material properties (e.g., allowable tension strain, long term modulus of elasticity) as outlined in the AASHTO Section 12 procedure.

If a design chart is used, the engineer should certify that the assumptions and parameters used to develop the table are consistent with the in-situ geotechnical conditions, the plastic pipe properties, as well as with practical construction specifications.

Should engineers incorporate geotechnical studies into pipe designs?

Geotechnical engineering is often a minimal aspect of an overall project budget, but it can be critical. Meeting the standard of care in the design of pipe-soil systems requires knowledge of in-situ soil conditions. In this case, the Engineer overlooked available geotechnical studies for the East Texas Fish Hatchery site, which should have played a critical role in the design and specification of a suitable pipe material and installation. Standard design tables are often based on minimum in-situ soil strength and should be verified before use.

Do engineers need to consider the impacts of groundwater on thermoplastic pipe performance?

The plastic pipe association's design chart used for the East Texas Fish Hatchery project did not include the contributions of external stresses imposed by groundwater above the springline.[4] As it turns out, the hydrostatic pressures contributed to the excessive deflection and ultimate collapse of some sections of the HDPE pipes.

It is not uncommon for pipe to be installed in high groundwater conditions, even without dewatering, with little to no consideration given to the structural impacts. High groundwater can create pipe buoyancy issues, but groundwater can also impact structural performance of the pipe-soil system. Basic geotechnical analysis can determine groundwater conditions, and the hydrostatic impacts can then be properly evaluated. For engineers relying on standard design tables from a government agency or state department of transportation (DOT), it is suggested that you seek clarification about whether or not the DOT's suggested fill height limits for thermoplastic pipe consider groundwater impacts.

ASTM D2321 is a construction specification that applies to the contractor, not the engineer, right?

Actually, ASTM D2321 applies to both the contractor and the engineer. If you specify thermoplastic pipe as an engineer, or if you install thermoplastic pipe as a contractor, then you need to obtain a copy of American Society for Testing and Materials (ASTM) D2321 Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications.[5] A forensic analysis performed prior to resolution of the East Texas Fish Hatchery lawsuit determined that many of the project specifications appeared to have been derived from ASTM D2321. This specification provides compaction limits for AASHTO soil classifications, outlines numerous responsibilities of the engineer, and advises on groundwater and trench conditions, as well as other important factors.

Contractors should use the RFI process to clarify pipe design and installation concerns. Communication could be a major factor in project success.

The request for information (RFI) phase prior to bidding is an excellent opportunity to clarify concerns about such issues as pipe design, acceptance of in-situ materials as suitable backfill, dewatering, final internal inspection, and laser profiling. The engineer and contractor should communicate a mutual understanding of the factors impacting pipe performance on the project, and knowledge of these issues would provide for more accurate bids. For example, consider asking this question:

- If the contractor installs the thermoplastic pipe using in-situ soil for embedment and backfill to 95% standard proctor density compaction, does the engineer's analysis show that the pipe will pass or fail a 5% deflection limit?

If the contractor uses a pipe material allowed by the engineer and compacts to the specified quality limit, then the installed pipe is expected to perform within its design service limits. In the East Texas Fish Hatchery incident, a failure analysis indicated that excessive deflections could have resulted in the ultimate reverse curvature and collapse of the 60-inch corrugated HDPE pipe.

Why is final internal inspection and laser profiling so important?

All storm pipe systems should be inspected after final backfill. It is especially important to measure shape deformations and deflection in flexible pipes using laser profiling equipment. It does not appear that internal pipe inspections were performed in the East Texas Fish Hatchery project until pipe sections had already collapsed. At that point, internal pipe inspections were used to ascertain the extent of excessive deflections. Ultimately the conditions warranted removal and replacement of pipe sections that otherwise would not have been initially detected without internal inspection. The use of the pipe inspections and deflection assessments prevented further collapse and property damage or personal injury.

A contractor may elect to conduct periodic deflection checks during installation. However, ASTM D2321 states that deflection tests should be performed no sooner than 30 days after installation in order to allow for stabilization of the pipe soil system. Soil stiffness of the pipe embedment or native trench soils can change over time. Trench settlement can change loads on the pipe. Such time dependent changes typically add to initial deflections. Public agencies and private owners nationwide are recognizing that the use of final inspection and laser profiling is a cost-effective way to verify proper pipe performance and public safety, particularly when using highly installation-sensitive pipe materials.

How can I prevent structural failures on my drainage projects?

Although the scale of the East Texas Fish Hatchery incident was large in terms of the 11,000 feet of replaced corrugated HDPE pipe and a $3.2million settlement, the root causes of this incident are commonplace. The premise of flexible pipe design is *engineered installation*. Each flexible pipe installation warrants a site specific design. A thermoplastic pipe is essentially a liner that requires a contractor to carefully construct a soil embedment structure in accordance with a geotechnically-based design from the engineer. The concepts explained in this document and a further understanding of pipe design and installation will result in successful drainage projects.

References

1. Williams, Matt. *Back on track: Design firm bears brunt of repair bill on fish hatchery*, http://dailysentinel.com, August 29, 2010.
2. Compromise and Settlement Agreement, dated May 7, 2010, between Texas Parks & Wildlife Department, HDR Engineering, Inc., Allco, Inc. and Travelers Casualty & Surety Co. of America.
3. Exponent Failure Analysis Associates, *Construction Assessment and Failure Analysis, Drain Pipeline System, East Texas Fish Hatchery, Jasper, Texas*, TPWD Project No. 101690, Exponent Project No. 0904829.000, December 8, 2009.
4. Exponent Failure Analysis Associates, Design Assessment and Failure Analysis, Drain Pipeline System, East Texas Fish Hatchery, Jasper, Texas, TPWD Project No. 101690, Exponent Project No. 0904829.000, December 4, 2009.
5. ASTM D2321, *Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications*, ASTM International, www.astm.org, 2009