COMPARING RCP WITH PLASTIC PIPE

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When a little bit of knowledge is a dangerous thing: criteria for selecting RCP and HDPE pipe for stormwater drainage applications.

By Sue McCraven

Have you ever felt that you have been dropped in the middle of a battle zone? If not, start asking questions about which is the better product – corrugated high-density polyethylene (HDPE) pipe or reinforced concrete pipe (RCP) – and watch the dust fly. There is probably not another arena in the construction industry that can compare to the dead-serious competition between the gladiators and lions who vie for market share in the precast concrete and plastic pipe industries.

Amazing assortments of weapons are wielded by these intensely motivated competitors, both legitimate and incredible. On both sides, there are arsenals of research data purporting to prove many positions. Legitimate instruments are also in evidence, such as valid study data, guidelines from state departments of transportation (DOTs), documents from standards-writing organizations (AASHTO, ASTM) and memoranda from the U.S. Federal Highway Administration. This article takes an objective look at the current pros and cons of corrugated HDPE and RCP materials in order to provide engineers and specifiers with some well-founded rationales and references for selecting materials for stormwater drainage applications (this article does not address other profile configurations of HDPE pipe, such as ribbed and solid wall).

What to look for in selecting pipe materials

Data from state transportation agency specifications were used to create the following criteria to consider when selecting RCP or HDPE pipe for stormwater drainage systems. Please note that this list is not all-inclusive, and examples given in each category are only some of the many factors to consider in selection of RCP or HDPE for drainage materials.

1. Application

2. Cost

3. Strength

4. Liability

5. Service life and joint integrity

6. Installation and inspection

7. Sustainability

8. Material competition

9. Engineer's knowledge of materials

Application

Will a cross drain be running under a high-traffic road? The Wisconsin DOT (WIDOT) uses average daily traffic (ADT) as a barometer for selecting material; if ADT is greater than 7,000 vehicles, for example, RCP is used for its proven service life and to avoid potential road closures for repairs. ADT as a determining factor for materials selection varies throughout the nation. Historically, some states have not allowed the use of plastic pipe for cross drains while some agencies have no ADT restrictions on HDPE pipe.

What is the depth of cover over the culvert? If the culvert is beneath an existing or proposed roadway and the depth of cover is 0 feet to 3 feet, Michigan DOT requires AASHTO M 86 Class IV RCP. Corrugated plastic pipe (CPE) less than 36 inches in diameter is acceptable under roadways with greater than 3 feet to 10 feet of cover. Are there concerns about reactive/corrosive soil or groundwater conditions? Materials engineers often choose HDPE pipe for its inert chemical properties. Yet RCP stands up very well in these environments and also offers equally high material impermeability, especially when mix designs include fly ash, silica fume and other cementitious materials.

Because of the variability of its native soils, current culvert design procedures and standard specifications, WIDOT limits the maximum diameter for plastic pipe to 36 inches. Allowable diameter for plastic pipe varies among the state agencies. Some DOTs allow use of 60-inch diameter, the maximum HDPE size manufactured at this time. In many cases, fill height tables determine the pipe material and class. Samples of pipe specifications may be found at these Web sites:

- http://www.extranet.vdot.state.va.us/locdes/electronic%20pubs/iim/IIM121.pdf
- http://mdotwas1.mdot.state.mi.us/public/specbook
- http://roadwaystandards.dot.wi.gov/standards/stndspec/index.htm

Geotechnical engineers in Georgia evaluate the soil conditions (pH and resistivity) and prepare a modified table that is project-specific. The project-specific (or modified) allowable materials table is then used in state transportation construction plans for contractors to use when selecting suitable pipe material (see the online version for an example).

Type of Pipe Installation	Reinforced Concrete	Corrugated Steel ASHTO M-36 Aluminum Coated (Type 2) **Note	Corrugated Steel, ASHTO M-36 Plain Zinc Coated	Corrugated Aluminum AASHTO M- 196 M *Note	Corrugated HDPE AASHTO M-252	Corrugated Smooth Lined HDPE AASHTO M-294 Type “S”	PVC Profill Wall AASHTO M-304	PVC Corrugated Smooth Interior ASTM F-949
Longitudinal Interstate and Travel Bearing	Yes	No	No	No	No	No	No	No
Longitudinal Non-interstate and Non-travel Bearing	Yes	Yes (3)	No	Yes (2)	No	Yes	Yes	Yes
Cross Drain ADT < 250	Yes	Yes (3)	Yes (1)	Yes (2)	No	Yes	Yes	Yes
Cross Drain 10% or Less Grade 250 < ADT < 15,000	Yes	No	No	No	No	Yes	Yes	Yes
Cross Drain 10% or Less Grade ADT > 15,000	Yes	No	No	No	No	No	No	No
Cross Drain 10% or Less Grade ADT > 250	No	No	No	Yes (2)	No	Yes	Yes	Yes
Side Drain	Yes	Yes (3)	Yes (1)	Yes (2)	No	Yes	Yes	Yes
Permanent Slope Drain	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Perforated Underdrain	No	Yes	Yes	Yes	Yes	Yes	No	Yes

*Corrugated Aluminum AASHTO M 196 pipe is also allowed as Cross Drain in the Coastal Plains, Piedmont, and Blue Ridge provinces when 250 < ADT < 1,500 (2).

**Corrugated Steel AASHTO M 36 Aluminum Coated (Type 2) is also allowed as Cross Drain in the Piedmont and Blue Ridge provinces when 10% or less grade and 250 < ADT < 1,500 (4).

THIS TYPE CAN BE USED IF:

- Resistivity is greater than 8,000 ohms/cm and the pH is between 6.0 and 10.5.
- Resistivity is greater than 1,500 ohms/cm and the pH is between 4.5 and 9.0.
- Resistivity is greater than 3,000 ohms/cm and the pH is between 5.0 and 9.0.
- Resistivity is greater than 3,000 ohms/cm and the pH is between 5.0 and 9.0 (Note: the addition of Type "B" Coating "AASHTO M-190, Half Bituminous Coated with Paved Invert" is required).
    - If environmental conditions fall outside the specified requirement listed above, the Office of Materials and Research will make recommendations concerning allowable high performance corrosion protection systems.
    - Structural requirements of storm drain pipe will be in accordance with Georgia Standard 1030-D or 1030-P, whichever is applicable, and the Standard Specifications.
    - Procedure for designating pipe culvert materials according to the Standard Specifications:
        - Regardless of funding on all projects where a soil survey is not made, the Office of Materials and Research will furnish, upon request, a recommendation of allowable materials.
        - The Summary, Detailed Estimate, and Proposal will include the item in accordance with Georgia Standard 1030-D or 1030-P using a non-specifying nomenclature.
        - Allowable pipe materials for the project will be noted on the Plan Summary Sheet.
        - Other acceptable pipe materials and/or high performance corrosion protection systems will be noted on the Plan Summary Sheet.
        - If steel structural plate for pipe, pipe arches, and arches are required on a project, the materials and coating requirements will be noted on the Plan Summary Sheet.

Cost

Engineers for private developers may consider HDPE pipe for drainage to comply with an owner's desire to keep costs at a minimum, with little consideration for service life. State DOTs, as publicly funded agencies, also must weigh the material costs of available pipe materials. The general perception seems to be that the initial cost of RCP is higher in most applications for pipe under 60 inches in diameter than the initial cost for plastic pipe. The installed cost of plastic pipe (which may include engineered backfill, inspection and laser testing), however, may prove equal to or greater than RCP costs.

Strength

RCP arrives on site as a proven structure with a tested concrete compressive strength that is known to the engineer, usually having attained greater than 90 percent of its maximum strength. Plastic pipe arrives on site as a non-structure, at about 10 percent of the installed system's required strength, and requires proper contractor installation and recommended fill materials to reach its manufacturer-specified service strength.

Liability

Dr. Patricia Galloway, P.E. (see sidebar "Engineer's Liability: The Difference between RCP and HDPE," page 13) provides sobering information on the engineer's liability in specifying materials for pipe installation. Some view the engineer's liability to be greater when selecting HDPE pipe, because ASTM D 2321 indicates that the engineer is responsible for ensuring proper backfill of plastic pipe installation. It is important that the installing contractor has an established reputation for following recommended installation procedures for plastic pipe and that the engineer be present or have inspectors on site during construction. Because RCP goes into the ground as a structural element with known bearing strength, the vagaries of contractor installation and soil conditions are not as critical as they can be for HDPE pipe installation.

Service life and joint integrity

Concrete has an established historical record for long service life as a construction material. As a much more recently developed material, HDPE obviously does not have as long a history of performance, yet the plastic pipe industry has made claims that extrapolates a service life of nearly 3,000 years for some applications (www.acppubs.com/article/CA6452939.html). Service life specifications for both HDPE and RCP vary throughout the United States. Some DOTs specify a 50-year service life for both products, while other agencies look for a 100-year service life for stormwater drainage pipe. Florida's DOT has probably done more research on HDPE pipe than other state agencies and specifies the most restrictive protocol of those agencies surveyed for predicting service life for plastic pipe. See the following Web sites:

- www.dot.state.fl.us/rddesign/dr/PAG/Final-report08-15-05Indexed.pdf
- www.dot.state.fl.us/specificationsoffice/2007BK/430.pdf

It is important to remember that HDPE is a relatively new product, while concrete pipe has been in use for centuries. Old concrete pipe systems are often incorrectly criticized for having poor-quality joints, and a brief history of these early installations explains why. Connections for these older concrete pipe systems were not designed to prevent soil/water infiltrations or to stop leakage from the pipe to surrounding soils, but simply to keep the pipe in line.

In fact, engineers often desired subsurface water infiltration into and through concrete stormwater pipes, because this process lowered local water tables and allowed for increased surface development. Thousands of miles of concrete pipe, built and installed with these original design considerations, are still used today performing exactly as specified.

In the 1950s and 1960s, soil tightness and watertightness started to become important design considerations for water mains with high internal pressures. With the onset of new design requirements, the concrete pipe industry developed new joint designs along with ASTM performance specifications to satisfy engineering needs.

The reinforced concrete pipe industry has kept pace with these modern expectations of joint integrity. Harland Couillard, plant manager with Upper Peninsula Concrete Pipe Co., Escanaba, Mich., and Jim Skinner, president of Press-Seal Gasket Corp., Fort Wayne, Ind., offer these 10 rules of thumb for the pipe specifier:

1. Specifier knowledge of material properties for all pipe products is critical to prevent leakage in stormwater installations.

2. Much of the older concrete pipe installed decades ago was not intended to have watertight joints; stormwater pipe that helped to lower water tables was, in fact, desirable.

3. When properly specified, installed and inspected, concrete pipe and flexible pipe have the ability to deliver joint integrity and watertightness.

4. While HDPE pipe cost is generally lower than that for RCP, the installed condition of flexible pipe can be more costly.

5. Because soils are variable, the engineered installation details for flexible pipe must include bedding materials, bedding width and compaction requirements below the pipe, at the sides of the pipe and above the pipe. In poor soils, bedding width becomes critical (ASTM 2321).

6. Concrete pipe is a load-bearing structure requiring bedding control from the spring line to the bottom of the pipe only (ASTM C1479).

7. HDPE pipe comes with pre-mounted gaskets. Joint seals for RCP are supplied separately from the pipe or cast into the product. Both systems require proper installation to achieve good joint integrity.

8. Most regional-based standards (like those for the Great Lakes region) allow for some leakage from stormwater pipes.

9. In general, contractors installing flexible pipe need to be more careful. Because stormwater pipes are typically of a large diameter, greater loads must be supported by the pipe and the surrounding soil. Contractors must take greater care in installation of flexible pipe than for rigid pipe to ensure that the fill material or stone is properly placed and compacted to provide required lateral support.

10. If pipe stiffness values are low and installed soil stiffness is low, deflection of HDPE pipe will likely increase.

Installation and inspection

Installation of RCP and HDPE pipe must be performed according to the manufacturer's specification and be in compliance with relevant standards (ASTM C 1479 and D 2321, and AASHTO Section 30 of the highway bridge specifications). Because flexible, or HDPE, pipe transfers loading to the surrounding support soil, the type of backfill used, the width of the installation trench and the resulting soil strength must be carefully determined, approved and inspected during installation by the specifying engineer.

RCP, on the other hand, is much less reliant on the surrounding soils for its structural strength. Deflection testing of HDPE pipe, usually 30 days after installation, is now required by some state transportation agencies for underground drainage piping. Mandatory mandrel testing, visual inspection, video taping and laser testing of the interiors of drainage culverts for ovality are becoming standard DOT requirements. While laser testing for deflection is a relatively new protocol, most transportation officials believe it offers the best data, especially for inspection of pipe bends and intersections.

Deflections exceeding 5 percent to 7 percent usually constitute structural failure and require removal. Current research from field laser testing of HDPE pipe (see the sidebar "Research on Field Laser Testing of HDPE Pipe," page 14) indicates that certain plastic pipe installations may result in failed ovality tests if proper installation is not performed.

Sustainability

Environmental factors are now assessed in determining cost effectiveness of a structure's service life. Engineers must consider a project's sustainability when selecting materials for construction. The onus of responsibility to ensure that maximum sustainability is obtained for public projects is a serious professional engineering obligation that will only increase in the future. The sustainability value in specifying RCP with supplementary cementitious materials (SCMs are industrial byproducts such as fly ash, slag and silica fume) is clearly commendable. While state engineers are interested in learning more about concrete pipe with SCMs for reactive site conditions, engineers can be assured that these products are both locally available and have a record of good performance.

Material competition

The U.S. Federal Highway Administration (FHWA) requires that all agencies using federal funds develop pipe selection policies that consider all available pipe products judged to be of satisfactory quality and equally acceptable on the basis of engineering and economic analysis (www.fhwa.dot.gov/construction/cqit/culvert.cfm). This means that state DOT specifying engineers must consider competing materials in selection of underground pipe. The idea of promoting product competition in the marketplace is based on the strongly held American belief that free enterprise ensures the best quality products at the lowest price for the consumer.

In reality, however, this concept places even more responsibility on the specifying engineer to evaluate the total system, acknowledging that the initial costs of pipe material are only a percentage of the total cost of installing stormwater drainage. With regard to how state transportation engineers will determine the cost effectiveness and design of RCP or HDPE pipe in the future, the FWHA further mandates that all new culverts (and other structures) shall be designed by LRFD Specifications after Oct. 1, 2010 (www.fhwa.dot.gov/bridge/062800.htm). It seems likely that the more design time required for a particular product, the less likely the product will be specified.

Engineer's knowledge of materials. Most civil engineers do not study plastics as a structural material in college. Concrete and steel courses are offered in engineering programs with a construction emphasis, but these courses are not required in most civil engineering undergraduate programs. Whether or not an engineer/specifier has academic training in reinforced concrete or polyethylene materials, recognition and understanding of the differences in the fundamental material properties between available products and their life-cycle cost analyses are no longer optional tasks. As technology advances, more and more state transportation departments are ensuring that their engineers are adequately trained in new product technologies and relevant material science.

RCP versus HDPE pipe:

If you can't stand the heat …

There are engineers who would agree that reinforced concrete is the preferred product for large stormwater drainage systems under high-traffic roads and that RCP is a proven structural product with a long service life. While some have selected HDPE pipe for its perceived low initial price, ease of installation and inert qualities, plastic pipe is structurally sound only when it is properly installed within its soil envelope and tested for deflection. Beyond the ongoing structural integrity debate between RCP and HDPE, if the bottom line is cost, the specifying engineer is well-advised to assess the total, not just initial, cost of both products and to be knowledgeable of competing products, including service life and strength. It remains for the specifying engineer to continually learn about the material properties of available construction products, be aware of the relevant standards, understand the ramifications of installation and inspection, and to keep an eye focused on sustainable design.