Generally, rigid pipes have the following characteristics:
- made in discrete lengths
- use gaskets in joints to form a water-tight seal
- often produced from composite materials
- minor trench deflections are accommodated by joint deflections

Rigid pipe design assumptions include:
- a sufficiently stable trench bottom to keep the pipe aligned
- bedding and primary backfill help distribute the load and minimize stress concentrations
- inherent pipe strength will primarily support imposed loads
- the gasket will be held to the desired compression by the geometry of the bell
- the pipe’s structural integrity is constant over time

Flexible pipes have few common characteristics. They may be manufactured in discrete lengths or welded together on site (infinite length). And gasketed joints may or may not be present.

FLEXIBLE PIPES
“Flexible pipes” rely upon their deformation of the pipe from imposed loads to mobilize the support of embedment materials on both sides of the pipe. Their primary structural function is distributing the imposed vertical loads to the surrounding soil. Some standards define a flexible pipe as one that can deflect more than 2% without cracking.

Only a small portion of imposed loads are actually carried by the flexible pipe itself. Instead, load is transferred to the surrounding bedding material. A pipe system’s load carrying capacity increases significantly with an increase in the stiffness of embedment materials. Consequently, embedment is often composed of a well-graded, angular, granular material that is well compacted.

Flexible pipes have few common characteristics. They may be manufactured in discrete lengths or welded together on site (infinite length). And gasketed joints may or may not be present.

EVALUATING PIPE PERFORMANCE
If all design factors are well understood, a suitable piping system can be created using either “rigid” or “flexible” pipe design methodology. Both methods are supported by academic review and industry standards (ASTM, AWWA, CSA, etc.) for pipe testing, qualification, and installation. However, design factors and assumptions are often not well known, incorrect, or they may change over time.

A piping system’s performance under load or embedment conditions that vary from the design assumptions is a good way of evaluating rigid versus flexible pipe.

Let’s examine a few scenarios:
INADEQUATE/IMPROPER BEDDING AND BACKFILL

A rigid piping system’s carrying capacity is the total load that can be supported by the pipe itself. For concrete pipe, this is determined by a three-edge bearing test multiplied by a bedding factor (between 1.5 and 4.4). Bedding factors between 1.5 and 2.3 apply to the four standard installation types in a trench application.

When the bedding is improperly installed, and the backfill is not properly compacted, the pipe's strength will initially support the imposed dead and live loads.

The trench walls will support the weight of the backfill (Marston effect). But any theoretical increase in pipe strength resulting from a properly bedded and backfilled installation is compromised. Over time, the pipe will experience more and more of the trench load. Eventually, the pipe’s capacity will be exceeded and it may fail. Cracks exceeding the design limits will develop and the pipe’s steel reinforcement will be exposed to its internal atmosphere. In sanitary sewer and industrial applications, this may be corrosive to the reinforcing steel. This failure is most likely to occur well after the installation period, when the system is not being monitored as carefully.

Flexible pipe, on the other hand, relies on initial bedding, which conforms to the project's standard requirements. For most sewer applications, this would be well-graded, granular materials that are appropriately compacted.

Limiting pipe deflection is the main factor in the design of a flexible piping system. Even when it isn’t, the expected pipe deflection is calculated. But this anticipated deflection increases substantially when the project-specified bedding is not provided. Monitoring pipe deflection during the construction process will effectively ensure compliance with project requirements. Installation problems are readily apparent and can be corrected before the pipe is put into service.

UNSTABLE TRENCH BOTTOM

Rigid pipes will move when the trench bottom is unstable. Because of pipe rigidity, the joints will move and gasket compression (plus the joint seal) will be affected. Sufficient joint movement can cause the seal to be lost.

If localized loads exceed the rigid pipe’s structural limit, wall failures (cracking) may occur. Either infiltration or ex-filtration will result (flow direction will be from the higher to lower pressure area). If cracking continues, the rigid pipe may collapse.

By contrast, flexible (especially plastic) pipes will deform when the trench bottom is unstable. As such, joint area movement is minimized, reducing occurrences of seal loss. Generally, flexible pipes come in longer lengths than rigid pipes, so there are fewer joints “at risk.” Plus, fused or welded HDPE pipe systems are joint-less and are therefore not subject to this problem.
SECTION 2
WEHOLITE VS. CONCRETE

PIPE STRUCTURE AND SCOPE
Concrete pipe is formed by encasing reinforcing steel inside a concrete pipe wall. The steel can be optimally located to provide resistance to the anticipated loads. The concrete is produced from different source materials to take advantage of local conditions and/or to obtain the desirable strength or chemical resistance properties.

This product can be designed to limit small crack formation in tensile sections of the pipe to less than 0.3 mm. The 0.3 mm crack classifications are 40-D, 50-D, 65-D, 100-D, or 140-D. Alternatively, concrete pipe can be designed to support an ultimate anticipated load, with appropriate factors of safety. The D load classifications using this method are 60, 75, 100, 150, and 175. The specifications covering this design are ASTM C76 M and CSA A257.2.

Weholite pipe is a profile, or structural, HDPE pipe wall. Fabricating the pipe with a profile allows for desirable stiffness properties at overall weights that are 40% less than solid wall HDPE pipe. Weholite typically weighs less than 10% of an equivalent concrete pipe. The pipe’s structural capacity is classified in accordance with ASTM F894. The Ring Stiffness Constant (RSC) rating for the pipe is an empirical measurement of its load carrying capacity.

JOINING SYSTEMS
Concrete pipe joints are gasketed bell and spigot connections. The pipes are supplied in 2.4 m (8') lengths, to limit the weight of large diameter individual pipe sections. Weholite is also available with bell and gasket connections (in sizes up to 36" in 20' lengths). However, a welded (fused) connection is recommended for all Weholite pipe in sewer (storm or sanitary) applications.

Sewer specifications typically include a pressure test and/or leak test with acceptance criteria. The same “leakage” criteria apply to all gasketed pipe systems, regardless of pipe material. For welded HDPE sewer pipes, the joint’s anticipated leakage rate is zero. It has uniform structural properties along its entire length.
In general, concrete and corrugated steel pipes are more vulnerable to chemical and biological attack than PVC and HDPE Pipe. High resistance to chemical attack is the most attractive feature of plastic pipe."

From a study by NRC Institute for Research in Construction

"Both domestic and industrial sewers contain many aggressive chemicals that can cause the corrosion of reinforced-concrete pipe. For instance, inorganic and organic acids may be present in effluents or in the subsoil of an industrial area, or they may be formed above the water line in the sewage, because of two-stage bacterial activity (Park, 1950, Ramaswamy and Jain, 1984). Sulfate ions and other chemicals may also exist in the soil and potentially cause chemical corrosion of concrete on the outside walls."

"The low abrasion resistance of concrete pipe is attributed to the brittle nature of the material."

<table>
<thead>
<tr>
<th>Standards (USA)</th>
<th>Concrete</th>
<th>Weholite</th>
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<tbody>
<tr>
<td>ASTM C507M</td>
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<td>ASTM F894</td>
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<td>CSA B182.6</td>
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<td>ASTM D2312</td>
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<tr>
<td>Manning's n</td>
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<td>0.01</td>
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</table>

CHEMICAL RESISTANCE

Generally, concrete is more chemically resistant than carbon steel pipe, but much less than HDPE. Concrete is vulnerable to hydrogen sulfide, which forms when solids in sanitary wastewater are unable to stay in suspension. This often occurs in collector sanitary sewers during periods of low flow.

Concrete pipe gaskets conform to the requirements of ASTM C443 and F877. Gaskets for HDPE Weholite pipe conform to the requirements of ASTM F477. Both piping systems can offer gaskets in a variety of materials. Generally, gaskets are more vulnerable than the pipe material to chemical attack. This is a significant concern for concrete pipe systems, which have a gasket every eight feet.

Extrusion welded Weholite systems are not subject to gasket degradation. HDPE has excellent chemical resistance to most industrial and domestic wastes. With the exception of exposure to apolar solvents (such as some alcohols, halogens, and aromatics), the chemical resistance of HDPE is superior to concrete.

Polyethylene is used as a lining to rehabilitate concrete pipe or on new concrete pipe installations where high resistance to corrosion is required.

ABRASION COMPARISON

Abrasion resistance is a material's ability to withstand mechanical erosion. Pipes used in sanitary, storm sewer, and culvert applications require significant abrasion resistance, since grit and suspended solids continuously impact on the pipe wall. As flow velocity increases, so does abrasion.

The abrasion resistance of concrete pipe may be adversely affected by corrosion. As such, the specific application must be evaluated.

Plastic pipe is highly resistant to abrasion. This is because its molecular composition creates a "trampoline" response when impacted by tumbling aggregate (such as grit and solids).
HDPE is three to five times more abrasion resistant than concrete pipe when tested in a Darmstadt abrasion test. In fact, HDPE often ranks first in wear resistance among pipe materials.

Dr. Louis Gabriel conducted a widely recognized comparison of abrasion resistance in 1990 at California State University. The project assessed abrasion alone and in concert with chemical corrosion. It concluded that HDPE outperformed concrete pipe.

**HYDRAULIC COMPARISON**

Manning's n value for new concrete pipe is 0.010 – 0.009. The concrete pipe industry promotes the use of 0.012 – 0.013 as appropriate long-term values. This 20-30% difference accounts for a long-term deterioration in "n" value due to corrosion and abrasion. The reduction in flow capacity is anticipated, particularly in hostile environments.

Manning's tested n value for Weholite is between 0.0097 and 0.0092. For pipe exceeding 36" ID, this will approach the 0.09 value associated with solid wall HDPE pipe.

A design value of 0.010 is recommended, to provide for limited deterioration while recognizing Weholite's excellent corrosion and abrasion resistance. Still, even by conservative estimates, Weholite's flow capacity in a gravity sewer application is 30% greater than comparably sized concrete pipe.

**INSTALLATION**

Concrete and Weholite pipe have very similar trenching, bedding and backfill requirements. The only notable difference is the primary backfill's upper limit.

According to ASTM C1479-01 ("Standard Practice for the Installation of Pre-cast Concrete Sewer...") the clearance between pipe and trench wall must sufficiently allow for the specified compaction. In any case, it must be at least 1/6th of the pipe's outside diameter (OD). ASTM D2321, ("Standard practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity flow Applications"), on the other hand, specifies a trench width wider than the compaction equipment required plus a minimum clearance of “8 inches” or “1/2 of the pipe's OD times 1.25 plus 6 inches.” But most user specifications, such as the OPS, require a minimum side clearance of 12 inches (300 mm) — regardless of pipe material.

Practically then, there's no difference in trench widths for bedding and initial backfill requirements between concrete or Weholite pipe. However, standards require that the initial backfill for concrete pipe must extend to the pipe spring-line, while the initial backfill for plastic (Weholite) pipe should extend to a minimum of 6" (150mm) over the top of the pipe. The initial backfill is the zone that must be compacted to achieve the pipe's bedding support.
"The light weight of plastic pipe, compared to that of concrete pipe, permits the use of longer sections, and the pipes can be cut at the job site for length adjustment, resulting in less effort and added flexibility during installation."

Where trench settlement isn’t a concern, some minor additional effort is needed to meet the initial backfill requirements for Weholite and other plastic pipes. But most trench applications in roadway cuts require careful selection and compaction of the trench backfill materials, anyway. So there is no additional effort (or cost) involved.

**SERVICE LIFE AND COST**

The popular concrete design software, “PipePac 2000,” compares the life cycle costs between concrete and HDPE (generally presumed to be circular corrugated polyethylene pipe). The software presumes a service life of 100 years for concrete pipe in all storm sewer, sanitary sewer and culvert applications. And it presumes a service life value of 70 years for HDPE pipe, despite the material’s superior hydraulic, corrosion resistant, and abrasion resistant properties. Although one can override the software’s service life values, many users will accept the program’s default settings. Doing so, however, will produce a result that is not supported by realistic service life values.

Concrete pipe failures (due to corrosion or abrasion) often result in a reduced service life. And joint degradation or failure may determine the effective useful life of a pipe system. Welded Weholite has no joints.

In general, Weholite’s service life will be at least 50% greater than concrete. In corrosive applications, it will be double. Although service life for both pipe materials must be carefully evaluated, concrete should never exceed the service life of Weholite pipe.

A fair cost comparison between the two materials will show similar capital costs, where the nominal pipe size is the same. But in many applications, smaller Weholite pipe will be used because of its superior Manning’s n value. Installation costs will vary. In areas where the trench can be open cut and where longer lengths of Weholite can be used, its installation costs should be lower.