Rigid vs. Flexible Material

	Precast Concrete Pipe	CMP & Spiral Rib	HDPE	PVC
Applicable Material Specifications	ASTM - Nonreinforced Pipe C 14, C 985; Reinforced Pipe C 76, C 655; Arch Pipe C 506; Elliptical Pipe C 507, AASHTO - M86, M170, M206, M207, M242, M262.	ASTM - Manufacture A 760 (galv), A 762 (poly), B 745 (alum), Design A 796 (galv), B 790 (alum), AASHTO - M36, M218, M190, M245, M246, M274; Aluminum M196, M197, M289.	Manufacture AASHTO M294, ASTM F 2306. Cell Classification ASTM D 3350, NCLS ASTM F 2136, Stiffness ASTM D 2412.	ASTM - Manufacture D 3034 (4" to 15"), F 679 (18" to 36"), F 949, Cell Classification D 1784, Stiffness D 2412, AASHTO - M264, M278, M304.
Significant Material Requirements	Composed of cement, aggregates, and water in accordance with national and local specifications, approved suppliers' lists, and submittals.	Sheet thickness (gage) adequate for structural and durability needs. Coating thickness and integrity after manufacture and handling.	Virgin resins should be used. Cell class 435400 C. Material must have ability to withstand stress cracking.	HDB rated resins. Minimum cell class 12364 or 12454.
Hydraulics	Laboratory values for Manning's "n" of 0.010. Recommended design value 0.012. Lower entrance loss coefficient because of pipe bell which can result in smaller diameter (compared to alternate materials) in culvert inlet control situations.	Lab Manning's "n" for Spiral Rib = 0.013, Corrugated = 0.022-0.028. Recommended design value for Spiral Rib = 0.016, Corrugated 2 2/3" x 1/2" = 0.022-0.027, 3" x 1" = 0.027-0.028, 5" x 1" = 0.025-0.026.	Laboratory values for Manning's "n" of 0.009 - 0.015. Installed pipe has shown values of 0.015 to 0.021. Liner buckling is assumed in AASHTO design. Design n value = 0.012 - 0.016 possibly higher, varies with I.D. and corrugation growth of liner from loading. Manning's formula calculations should reflect that the base I.D. (minimum) is promoted and is less than nominal I.D.	Laboratory values for Manning's "n" of 0.009. Recommended design value 0.011. Manning's formula calculations should reflect that the pipe will have less than nominal I.D.
Required Pipe Strength or Pipe Stiffness	Calculate load on pipe by determining dead load, live load, and bedding factor, then determine the required pipe strength.	Requires support of soil envelope. Pipe stiffness determined by gauge (thickness), material type, and corrugation profile. Modified Iowa Formula used to determine deflection and relationship of structural soil support and pipe support.	AASHTO LRFD Bridge Specs., Section 12. Pipe stiffness decreases with increase in diameter. (P.S. of 15" pipe = 42; P.S. of 48" pipe = 18).	AASHTO LRFD Bridge Specs., Section 12. Minimum pipe stiffness = 46.
Applicable Installation Specifications	ASTM C 1479, AASHTO Highway Bridge Specifications (Section 27), ASCE 15.	ASTM A 798 (galv), A 796, B 788 (alum), AASHTO Highway Bridge Specifications (Section 26).	ASTM D 2321, AASHTO Highway Bridge Specifications (Section 30).	ASTM D 2321, AASHTO Highway Bridge Specifications (Section 30).
Soil Stiffness	E' is not a factor in the design of rigid culverts.	Modified Iowa Formula determines theoretical deflection. Pipe parameters and soil stiffness interact.	Soil stiffness relative to pipe stiffness is critical. Min. E' 1000.	Soil stiffness relative to pipe stiffness is critical. Min. E' 1000.
Backfill	Compact to required density up to spring line according to installation type (1, 2, 3, or 4). Critical only up to springline. Normal installations - native soil with little or no compaction.	Compact to 90% of maximum density in 6" to 12" lifts to 12" above top of pipe. Material should be granular with little or no plasticity. Trench: Min. 2' each side of pipe. Embankment: Min. one diameter each side of pipe.	Compact to required density in 6" lifts to 6" - 12" above top of pipe. Removal of trench box must not allow movement of compacted material. Usually requires select material.	Compact to required density in 6" lifts to 6" - 12" above top of pipe. Removal of trench box must not allow movement of compacted material. Usually requires select material.
Installation Testing	Visual inspection for alignment and grade. Deflection not significant. Less sensitive to installation.	Installation sensitive. Check for alignment and grade. Deflection should be less than 5%.	Check for alignment and grade. Deflection should be less than 5% certified actual I.D. Require laser profile or mandrel test. Pipe performance determined by soil envelope and installation. Deflection (creep) continues at reduced rates over long term.	Check for alignment and grade. Deflection should be less than 5% certified actual I.D. Require laser profile or mandrel test. Pipe performance determined by soil envelope and installation. Deflection (creep) continues at reduced rates over long term.
Service Life - Life Cycle Cost Analysis	100 years or more confirmed. Longer life and no expected replacement costs.	Max. 50 years (with coatings under favorable conditions). Shorter life = higher replacement costs.	Not known - extrapolated. Shorter life = higher replacement costs.	Not known - extrapolated. HDB rated pipe - max. 50 years. Shorter life = higher replacement costs.
Corrosion Resistance	Generally not applicable unless installation is to be in extremely "hot" soils with acid or high percent of sulfates in replenishable solution, which can be countermeasured with changes in mix design, backfill, etc.	Low pH (<6) and Resistivity of 2,000 - 10,000 ohm cm will corrode. Damaged coating allows metal to oxidize, reducing design life. Metallic (galvanized and aluminized) and other coatings especially susceptible to bed load abrasion.	Low susceptibility to corrosion. Interaction of stress and environment is determinant of durability to some chemicals or common materials such as strong oxidizing acids, oils, polar reagents such as detergents, alcohols, esters, ketones, and silicones (exposures to these polar reagents may also accelerate stress cracking).	Low susceptibility to corrosion. Interaction of stress and environment is determinant of durability to some chemicals or common materials such as esters, ketones, aromatic and chlorinated hydrocarbons, and vegetable oils (exposures to latter two may also accelerate stress cracking).
Flammability	Not applicable. Non-combustible. Structural integrity not destroyed.	Not generally applicable. Coatings may be flammable.	Flammable and self-fueling. Once burning, does not need external fuel source. Emits toxic fumes when burning.	Flammable. Needs external fuel source. Emits toxic fumes when burning.
Flotation	Resists buoyancy forces best of all products. Specific gravity = 2.40.	Pipe is lighter than the fluid/soil weight it displaces. Buoyancy forces can affect line and grade.	Specific gravity of material is 0.91 - 0.96 (less than water). Buoyancy force will affect line and grade.	Specific gravity of material is 1.4. Buoyancy force will affect line and grade.
Miscellaneous Considerations	Protect crown of pipe from construction equipment. Ensure proper installation of joint material.	Repair coatings prior to installation. Bed load (abrasion) may damage coating and accelerate deterioration.	Susceptible to ultraviolet deterioration. Deflection at structures. Very flexible in relation to other "flexible" pipe. High % of strength attained from soil envelope.	Differential deflection at joints and structures. High % of strength attained from soil envelope.