

3	PIPES AND FITTINGS MATERIALS.....	3
3.1	GENERAL.....	3
3.1.1	Scope	3
3.1.2	References	3
3.1.3	System Description	5
3.1.4	Submittals.....	6
3.1.5	Delivery, Handling and Storage	6
3.1.6	Pipe Materials.....	9
3.2	VITRIFIED CLAY PIPES AND FITTINGS	9
3.2.1	Standards	9
3.2.2	Manufacture.....	9
3.2.3	Inspection and Testing.....	10
3.2.4	Repair Couplings for VC Pipes	10
3.2.5	Perforated Clay Pipes and Fittings.....	10
3.3	CONCRETE PIPES AND FITTINGS	11
3.3.1	Standards	11
3.3.2	Pipe Materials.....	11
3.3.3	Manufacture.....	11
3.3.4	Plastic Lining	12
3.3.5	Epoxy Coating	13
3.3.6	Inspection and Testing.....	13
3.4	GLASS REINFORCED PLASTIC (GRP) PIPES AND FITTINGS	13
3.4.1	Standards	13
3.4.2	Design	15
3.4.3	Pipes and Fittings Manufacture.....	16
3.4.4	General.....	16
3.4.5	Buried GRP	16
3.4.6	Exposed GRP.....	22
3.4.7	Inspection and Testing.....	23
3.5	PVC-U PIPES AND FITTINGS	24
3.5.1	Standards	24
3.5.2	Manufacture.....	25
3.5.3	Joints	25
3.5.4	Inspection and Testing.....	26
3.5.5	Inspection and Testing.....	26
3.6	ACRYLONITRILE BUTADIENE-STYRENE (ABS) PIPES AND FITTINGS	26
3.6.1	Standards	26
3.6.2	Manufacture.....	26
3.6.3	Joints	26
3.6.4	Inspection and Testing.....	26
3.7	DUCTILE IRON PIPES AND FITTINGS.....	26
3.7.1	Standards	27
3.7.2	Exposed Joints	27
3.7.3	Buried Joints.....	27
3.7.4	Internal Lining	27
3.7.5	External Coating and Wrapping, Use and Materials.....	28

3.7.6	Factory Application of Tape Wrapping	29
3.7.7	Factory Applied Extruded Polyethylene Coating	29
3.7.8	Inspection and Testing.....	29
3.8	FLANGE ADAPTERS AND FLEXIBLE COUPLINGS.....	30
3.8.1	General.....	30
3.8.2	Flange Adapters	30
3.8.3	Flexible Couplings	30
3.9	PIPES FOR OTHER USE	30
3.9.1	Copper Tubes and Fittings.....	31
3.9.2	Hose and Appurtenances	31
3.9.3	Stainless Steel Pipes, Tubes and Fittings	31
3.9.4	Carbon Steel Pipes and Fittings.....	32
3.10	MEDIUM AND HIGH DENSITY POLYETHYLENE (HDPE) PIPES.....	32
3.10.1	Applicable Standards.....	32
3.10.2	Manufacture.....	33
3.10.3	Fittings.....	34
3.10.4	Pipes and Fittings for Gravity Applications	35
3.10.5	Testing of MDPE and HDPE Pressure Pipes and Fittings.....	36
3.11	POLYESTER RESIN CONCRETE (PRC)-PIPING SYSTEMS FOR NON-PRESSURE DRAINAGE AND SEWERAGE	38
3.11.1	General.....	38
3.11.2	Resin	38
3.11.3	Minimum strength	39

ARAB ENGINEERING BUREAU

3 PIPES AND FITTINGS MATERIALS

3.1 GENERAL

3.1.1 Scope

- 1 This Part includes the manufacture, factory testing and supply of pipes and appurtenances of different materials for use in pipelines.
- 2 Related Sections and Parts are as follows:

This Section

Part 1 General
Part 4 Pipeline Installation
Part 5 Valves, Penstocks and Appurtenances
Part 6 Miscellaneous Metal Works
Part 7 Miscellaneous GRP Works
Part 8 Protective Coatings and Painting
Part 11 Sewer Rehabilitation
Part 12 Vacuum Sewerage System

Section 5 Concrete
Section 19 Plumbing Works
Section 20 Drainage Works to Buildings.

3.1.2 References

- 1 The following standards or revised/updated versions are referred to in this Part:

ANSI B16.3 Malleable Iron Threaded Fittings
ANSI B16.5 Steel Pipe Flanges and Flanged Fittings
ANSI B16.9 Factory-Made Wrought Steel Butt Welding Fittings
ANSI B16.11 Forged Steel Fittings, Socket Welded and Threaded
ANSI B16.28 Wrought Steel Butt Welding, Short Radius Elbows and Returns
ANSI B 36.19 Stainless Steel Pipe

ASTM A53 Standard specifications for Pipe, Steel, Black and Hot-dipped, Zinc-coated Welded and Seamless
ASTM A105 Standard specifications for Forging, Carbon Steel, for Piping Components
ASTM A182 Standard specifications for Forged or Rolled Alloy-steel Pipe Flanges, Forged Fittings, Valves and Parts for High Temperature Service
ASTM A234 Standard specifications for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures
ASTM A240 Standard specifications for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plated, Sheet and Strip for Pressure Vessels
ASTM A312 Standard specifications for Seamless and Welded Austenitic Stainless Steel Pipes
ASTM A403 Standard specifications for Wrought Austenitic Stainless Steel Piping Fittings

- ASTM A774.....Standard specifications for As-Welded, Wrought Austenitic Stainless Steel Fittings for General Corrosive Service at Low and Moderate Temperature
- ASTM A778.....Standard specifications for Welded Unannealed Austenitic Stainless Steel Tubular Products
- ASTM D1000.....Standard Test Methods for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications
- ASTM D1004.....Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting
- ASTM D2412.....Standard Test Methods for External Loading Characteristics of Plastic Pipe by Parallel Plate Loading
- ASTM D2584.....Standard Test Method for Ignition Loss of Cured Reinforced Resins
- ASTM D3681.....Standard Test Method for Chemical Resistance of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe in a Deflected Condition
- AWWA C209Cold-Applied Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines
- BS 864.....Capillary and compression tube fittings of copper and copper alloy
- BS 2494Elastomeric seals for joints in pipework and pipelines
- BS 2782Methods of testing plastics
- BS 3063Dimensions of gaskets for pipe flanges
- BS 3396Woven glass fibre fabrics for plastics reinforcement
- BS 3532Method of specifying unsaturated polyester resin systems
- BS 3749"E" Glass fibre woven rovings for the reinforcement of polyester and epoxy resin systems
- BS 4027Specification for Sulphate-resisting Portland cement
- BS 4346Joints and fittings for use with unplasticised PVC pressure pipe
- BS 5391Acrylonitrile butadiene-styrene (ABS) pressure pipe
- BS 5392Acrylonitrile butadiene-styrene (ABS) fittings for use with ABS pressure pipe.
- BS 5556General requirements for dimensions and pressure ratings for pipe of thermoplastic materials
- BS 5911Concrete pipes and ancillary concrete products
- BS 5955Code of practice for plastic pipework (thermoplastic materials)
- BS 6076Tubular Polyethylene film for use as protective sleeving or buried iron pipes and fittings
- DIN 30674-3.....Coating of ductile cast iron pipes; zinc coating with protective covering
- EN 197Cement
- EN 295Vitrified clay pipes and fittings and pipe joints for drains and sewers
- EN 545Ductile iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods

- EN 598 Ductile iron pipes, fittings, accessories and their joints for sewer pipelines - Requirements and test methods
- EN 639 Common requirements for concrete pressure pipes including joints and fittings
- EN 642 Prestressed concrete pressure pipes
- EN 1057 Copper and copper alloys
- EN 1092 Flanges and their joints
- EN 1401 Plastic piping systems
- EN 12620 Aggregates for Concrete
- EN 13244 Plastic piping systems
- EN 14020 Reinforcements. Specification for textile glass rovings
- EN 14118 Reinforcement. Specifications for textile glass mats
- EN 14364 Plastics piping systems for drainage and sewerage with or without pressure - Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP) - Specifications for pipes, fittings and joints; (ISO 23856 Plastics piping systems for pressure and non-pressure water supply, drainage or sewerage — Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin)
- EN 1796 Plastics piping systems for water supply with or without pressure - Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP); (ISO 23856 Plastics piping systems for pressure and non-pressure water supply, drainage or sewerage — Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin)
- ISO 1456 Metallic and other inorganic coatings
- ISO 4179 Ductile Iron Pipes for Pressure and Non-Pressure Pipelines, Centrifugal Cement Mortar Lining, General Requirements
- ISO 4633 Rubber Seals - Joint Rings for Water Supply, Drainage and Sewage Pipelines - Specification for Materials.

3.1.3 System Description

- 1 Pipes and fittings, except for those used in treated sewage effluent pipelines, shall be suitable for carrying sewage at temperatures of up to 45°C with hydrogen sulphide concentrations up to 400 mg/l.
- 2 Treated sewage effluent pipelines shall be suitable for chlorine concentration up to 15 mg/l.
- 3 Pipes shall be suitable for immersion in corrosive groundwater conditions typically exhibiting the following characteristics unless otherwise specified:

SO ₃ Content	:	1.7 g/l
Cl Content	:	1.07 g/l
pH	:	8.6
Conductivity	:	4000 µs/cm

- 4 The Contractor's attention is drawn to the stringent limits on infiltration detailed in Clause 4.5.2 of this section.

5 The Contractor shall be responsible for providing a jointing system as recommended by the pipe manufacturer that enables the installation and use of the designated pipeline systems.

3.1.4 Submittals

1 The Contractor shall order materials to suit the construction programme and obtain the Engineer's approval of submittals before placing orders. The Contractor shall submit two copies of the following documents for the approval of the Engineer:

(a) product data

- (i) originals of catalogues and engineering data sheets for manufactured items. Each item and option to be provided shall be clearly marked and each item not to be provided shall be deleted
- (ii) literature to show that products provided meet the requirements for material, construction, operation, and tests
- (iii) information on the following items as a minimum:
 - pipes
 - flexible couplings
 - gaskets
 - isolating joints
 - sealant systems
 - linings and protective coatings
- (iv) manufacturer's installation instructions for all items
- (v) certified reports for all tests and inspections designated herein, signed and sealed, showing full compliance with referenced standards
- (vi) maintenance requirements and procedures
- (vii) period of guarantee for products
- (viii) Manufacturer's test reports for hydrostatic proof testing, sustained pressure testing and burst strength testing.

(b) shop drawings

- (i) Piping material, class, grade and joint type, thickness or schedule, seam or seamless, coating information if applicable.
- (ii) fittings, couplings, and joints
- (iii) for concrete pipes, details of reinforcement, concrete and joints for straight
- (iv) pipes, specials and connections

(c) design data

- (i) If glass reinforced plastic (GRP) pipes with a stiffness exceeding designated values by more than 30 percent are proposed, the Contractor shall include in his submittal complete structural design calculations indicating the effect of the proposed variation in pipe stiffness of the deformation modulus of the bedding material or any other related aspect

3.1.5 Delivery, Handling and Storage

1 Each pipe, fitting and special appurtenance shall be marked with permanent identification which shall include but not necessarily limited to the following:

- (a) nominal diameter
- (b) name or trade mark of manufacturer

- (c) serial number
 - (d) class of pipe, pressure rating in compliance with referenced standards
 - (e) date of manufacture
 - (f) type of service
 - (g) details on fittings such as angle of change and taper
 - (h) circular concrete pipes with asymmetrical reinforcement shall have the letter "T" clearly marked on the inside and outside to indicate the top of the pipe when laid.
- 2 The acceptability of the pipes and fittings on delivery to the Site will be based on the results of tests carried out by one or more of the following:
- (a) the manufacturer at the place of manufacturer
 - (b) the Engineer
 - (c) a third party on behalf of the Engineer
- 3 The Engineer shall be permitted at all reasonable times to visit places of manufacture to witness tests.
- 4 The Engineer may require checking of the dimensional accuracy of GRP pipes and fittings at the place of manufacture, the cost of such verification shall be borne by the Contractor.
- 5 Transport, handling and storage of pipes and fittings shall be carried out as follows:
- (a) in accordance with the manufacturer's recommendations subject to the approval of the Engineer
 - (b) effective precautions shall be taken to prevent damage to the pipe and fittings.
- 6 During transport
- (a) pipes and fittings shall be well secured and adequately supported along their length
 - (b) bolsters and binding of approved type shall be used
 - (c) nesting of pipes (placing a smaller pipe inside a larger) may be permitted for pipes of certain materials and size provided that methods statements demonstrate that effective precautions will be taken to protect all pipe surfaces and coatings from damage
 - (d) no pipe shall overhang the end of a vehicle
 - (e) pipes and fittings of plastic materials shall be covered.
- 7 Handling shall be carried out as follows:
- (a) pipes should be lifted singly and not handled as bunches
 - (b) pipes shall be handled only by means of
 - (i) approved hooks, of the type having a plate curved to fit the curvature of the inside of the pipe, on ends of sections
 - (ii) fabric slings not less than 250 mm wide
 - (iii) other methods approved for the pipe used
 - (c) use of wire rope, chains and fork lift trucks will not be permitted
 - (d) for strings of pipe longer than the standard length precautions shall be taken to avoid curvature and longitudinal stress in excess of allowable limits
 - (e) pipes and fittings of plastic materials

- (i) smaller than 300 mm diameter may be handled manually, larger than 300 mm diameter and greater than 4 metres in length shall be lifted using fabric lifting straps or large diameter rope slings positioned at a quarter of the pipe length from each end
 - (ii) there should be enough slack in the slings to keep the hook approximately 600 mm over the pipe
 - (iii) steel chain or hooks shall not come into contact with the pipe
 - (f) VC pipes and fittings shall be transported in pallets and handled only with suitable equipment
 - (g) pipes and fittings shall not be dropped or bumped
 - (h) pipes shall not be dragged over the ground
 - (i) if rolled, pipes shall be rolled only over adequate timber bearers to prevent damage
 - (j) where necessary, chocks shall be used to prevent lateral movement of pipes.
- 8 All pipes, fittings and materials shall be stored in accordance with the manufacturer's recommendations and the following:
- (a) pipes may be stored in the open on a flat level area and raised above the ground on timber bearers so that the lowest point of any pipe or fitting is not less than 150 mm above the ground
 - (b) timber bearers not less than 200 mm wide and 75 mm thick to be provided at 4 m intervals maximum
 - (c) if on pallets or crated, on the pallets or in their crates until required
 - (d) if not on pallets or not crated, stacked one above the other as follows:
in accordance with the manufacturer's recommendations but not to a greater number of tiers than the following:

pipes >1200mm diameter1 tiers
≤ 1200mm >= 900mm diameter2 tiers
< 900mm >= 600mm diameter3 tiers
< 600mm diameter4 tiers

 - (i) suitable protective packing shall be placed between tiers to the approval of the Engineer
 - (ii) wrapped pipes shall not be stacked
 - (e) if spigot and socket, stacked so that successive pipe layers have sockets protruding at opposite ends of the stack
 - (f) with pipes of different sizes and thickness stacked separately
 - (g) with maximum height of stacked pipes not exceeding 2 m, or that recommended by the supplier if less than 2 m.
- 9 Pipes and fittings of plastic materials including GRP shall be:
- (a) stored under cover and out of direct sunlight
 - (b) adequately supported along their length
 - (c) provided with a free flow of air around the pipe.
- 10 Storage of jointing materials shall be as follows:
- (a) under cover

- (b) rubber ring gaskets shall
- (i) be stored in their original packing
 - (ii) not be exposed to sunlight
 - (iii) protected from exposure to greases and oils
- (c) gasket lubricants shall be stored so as to prevent damage to the container.
- 11 Pipes and fittings shall be protected in storage to the approval of the Engineer by means of an impermeable membrane which shall cover the pipes and fittings and separate them from the ground on which they are supported. The membrane shall be strong and durable in the prevailing climate conditions.
- 12 Pipes and fittings shall be subject to visual inspections after off-loading at site and before installation.
- 13 The following procedures shall be followed for dealing with damaged pipes and fittings:
- (a) pipes and fittings damaged during transportation handling and storage shall be set aside and the damage brought to the attention of the Engineer
 - (b) pipes or fittings that show signs of corrosion or deterioration during storage shall immediately be treated to arrest and prevent the corrosion or deterioration or removed from Site, as the Engineer directs
 - (c) proposals for repair shall be submitted in writing for the Engineer's approval
 - (d) no attempt shall be made to repair damage without the Engineer's approval
 - (e) if in the Engineer's opinion the nature of any damage is such that the condition of a pipe has been impaired and cannot be repaired the pipe concerned shall not be incorporated in the Works
 - (f) all rejected pipes shall be immediately removed from the Site
 - (g) damaged pipe shall be replaced or repaired by the Contractor at his expense and such repairs shall be to the approval of the Engineer
 - (h) the Engineer may require that any GRP pipe or fittings found to be damaged to be subjected to a further hydraulic test which shall be carried out by the Contractor, at the Contractor's expense, in accordance with the requirements of Subpart 4.5 of this Section.

3.1.6 Pipe Materials

- 1 For the purposes of this specification the following shall apply:
- (a) Pipes of steel, glass reinforced plastic (GRP), PVC-U and polyethylene shall be deemed to be flexible pipes.
 - (b) Pipes of concrete and vitrified clay shall be deemed to be rigid pipes.
 - (c) Pipes of ductile iron shall be deemed to be semi- rigid pipes.

3.2 VITRIFIED CLAY PIPES AND FITTINGS

3.2.1 Standards

- 1 Pipes and fittings for foul sewerage and surface water applications shall be manufactured to EN 295.
- 2 Pipes and fittings for land drainage applications shall be manufactured to EN 295.
- 3 Sealing rings shall be to BS 7874, EN 681, EN 682, EN 681-2 or ISO 4633.

3.2.2 Manufacture

- 1 Pipes and fittings shall comply with the following:
 - (a) pipes shall have spigot and socket type joints.
 - (b) pipes shall be glazed both internally and externally.
 - (c) all pipes shall be free of cracks, blisters, broken ends and other imperfections.
 - (d) When tested in accordance with EN 295-3:2012, Clause 7, the crushing strengths (FN) for pipes or pipe sections shall be not less than the values given in Tables 5 to 7 of EN 295-1
- 2 Joints shall be as follows:
 - (a) Pipes and fittings shall be supplied with flexible mechanical joints of the spigot and socket type joints.
 - (b) Sealing rings shall be of elastomeric material suitable for foul sewerage and surface water drainage works, as the case maybe, conforming to BS 7874, EN 681, EN 682, EN 681-2 or ISO 4633.
 - (c) Acceptance of VC pipes on delivery is dependent upon the Contractor demonstrating that the joints are capable of meeting the water test requirement of Clause 4.6.2 of this Section.
 - (d) Polypropylene sleeve couplings shall not be used.
- 3 Fittings shall be capable of withstanding the same load as the adjacent pipes or shall be provided with concrete surround.

3.2.3 Inspection and Testing

- 1 Barrel impermeability, straightness, crushing strength and bending moment resistance and chemical resistances tests shall be carried out in accordance with EN 295 at the frequency designated for the crushing strength test.
- 2 All products complying with EN 295 shall be sampled in accordance with EN 295-2 and EN 295-3.

3.2.4 Repair Couplings for VC Pipes

- 1 Repair couplings shall be obtained from an approved manufacturer and shall consist of a moulded synthetic elastomeric sleeve which is fastened over the pipe ends by stainless steel clamping bands and be complete with a stainless steel shear ring. The repair coupling shall be suitable for use with vitrified clay pipes and shall include a bushing adapter when joining to a pipe of the same nominal bore but of a different outside diameter.
- 2 Repair couplings shall comply with the joint performance requirements of BS 295-1 and be capable of withstanding an external water pressure of 60 kPa without leaking.
- 3 Sleeves and bushes shall comply with the requirements of EN 681-1. Clamping bands and shear ring shall be made from 300 series austenitic stainless steel.

3.2.5 Perforated Clay Pipes and Fittings

- 1 Perforated clay pipes and fittings shall comply with the requirements of EN 295-5.
- 2 Ground water collection / transmission systems shall be $\frac{1}{2}$ perforated pipes in configuration LP, area of perforations Type B, in accordance with Clause 4.7.2 and Clause 4.7.3.
- 3 Trench soakaway / infiltration pipes shall be $\frac{3}{4}$ perforated pipes in configuration LP, area of perforations Type B, in accordance with Clause 4.7.2 and Clause 4.7.3.

4 When tested in accordance with EN 295-3:2012, Clause 7, with no perforations under the top bearer, the minimum crushing strengths (FN) for perforated pipes shall not be less than the values given in Tables 3 and 4.

5 When tested in accordance with EN 295-3:2012, Clause 7, with no perforations under the top bearer, the minimum crushing strengths (FN) for perforated pipes greater than 500mm diameter shall be calculated in accordance with Formula (1)

$$FN = (\text{Class} \times \text{DN}) / 1000$$

and shall be based on a minimum of Class 95.

Higher crushing strengths than those given in Table 4 can be declared providing that they conform to the requirements of the next higher class. Classes are restricted to 95, 120 and 160, thereafter in increments of 20.

6 Joint assemblies for perforated pipes shall be flexible joints (in accordance with EN 295-1) or used with other joints. Where necessary, the joint material requirements shall be agreed between the manufacturer and the specifier / purchaser.

3.3 CONCRETE PIPES AND FITTINGS

3.3.1 Standards

1 Except as otherwise designated, concrete pipes and fittings shall conform to the requirements of this Subpart following standard specifications:

- (a) reinforced and unreinforced, BS 5911
- (b) prestressed non-pressure concrete pipes, BS 5911.

2 The strength requirement and other features of particular application shall be as specified in this Subpart or designated in the contract specific documentation.

3.3.2 Pipe Materials

1 Cement used for manufacturing pipes and fittings shall be Ordinary Portland cement conforming to EN 197-1.

2 Aggregate shall conform to BS 882.

3 Reinforcement shall conform to BS 4449 or BS 4483 as appropriate.

4 Admixture shall be used only with the written permission of the Engineer. The methods of use and the quantities of admixtures used shall be subject to the approval of the Engineer. Admixture containing calcium chloride will not be permitted.

3.3.3 Manufacture

1 Pipes and Fittings:

- (a) Storage of concrete materials, mixing, curing and testing of concrete shall be in accordance with the appropriate Clauses in Section 5. Any deviation from these clauses shall be made only with the approval of the Engineer
- (b) unless stated otherwise crushing strengths of pipes shall not be less than those designated in BS 5911 for the designated classes of pipes.
- (c) Reinforced concrete pipes shall have a minimum effective length of 2.5 m except as otherwise designated or required for special purposes such as curves, closures or built in pipes.

- (d) Steel reinforcement shall be accurately placed in the concrete wall. The placement of all steel shall not vary from the designated position in the pipe wall by more than ± 6 mm from the nominal position. In no case shall the cover to the reinforcement be less than 25 mm.
- (e) The planes of the ends of the pipes shall be perpendicular to their longitudinal axis.

2 Joints

- (a) except as specified in other Parts of this Section, pipe joints shall be supplied with flexible mechanical joints of the spigot and socket type in accordance with BS 5911, double collar or sleeve type
- (b) gasket stock shall
 - (i) comply with BS 2494.
 - (ii) be a synthetic rubber compound in which the elastomer is exclusively neoprene.
 - (iii) solid compound shall contain not less than 50 % by volume of neoprene and shall not contain reclaimed rubber or deleterious substances.
 - (iv) stock shall be extruded or moulded and cured in such a manner that cross-sections are dense, homogeneous and free from porosity, blisters, pitting and other imperfections.
 - (v) stock shall be extruded or moulded with smooth surfaces to the designated size within a tolerance of ± 6 % measured on joint cross-section dimensions.
- (c) the sealing ring shall be confined in a contained groove on the spigot face of each pipe section to properly position and confine the rubber gaskets in the annular space
- (d) each joint shall contain a neoprene ring gasket as follows:
 - (i) the gasket shall be the sole element depended upon for watertightness of the joint.
 - (ii) the gasket shall be of circular cross-section unless otherwise approved by the Engineer.
 - (iii) the length and cross-sectional diameter of the gasket, the annular space
 - (iv) provided for the gasket, and all other joint details shall be such as to produce a watertight joint which shall not leak when pulled 13 mm over and above the initial jointing allowance.
- (e) the initial jointing allowance is the gap between the spigot and the shoulder of the socket measured parallel to the centre of the pipeline and shall not be less than 6 mm or greater than 12 mm.
- (f) Joints shall be capable of maintaining water tightness up to an angular deflection of 2° from true, in any direction.

3.3.4 Plastic Lining

- 1 Where designated concrete pipes shall be lined with polyvinyl chloride plastic (PVC) liner plate. The PVC liner plate material shall be as specified in Section 5 Part 14.6. The liner plate shall be securely fixed to the formwork before pouring concrete and all in-situ welding of the liner plate shall be carried out by skilled labour using the methods specified by the manufacturer. Purpose made units shall be used where required; e.g., at junctions.
- 2 The installation of liner plates in concrete pipes or structures, and the sealing and welding of joints, shall be carried out in strict compliance with all applicable specifications, instructions and recommendations of the plastic liner plate manufacturer. All welding of liner plate shall be carried out by properly trained and approved workmen.

- 3 Once cast into the pipe, the liner shall be permanently and physically attached to the concrete by the locking mechanism and shall not rely on an adhesive bond.
- 4 The lining shall withstand a 100 kPa hydrostatic back pressure applied to the under surface of the lining without losing anchorage or without rupture.
- 5 Damaged liner plate shall be repaired in accordance with the manufacturer's recommendation and to the approval of the Engineer.

3.3.5 Epoxy Coating

- 1 All exterior surfaces of concrete pipes shall be coated by the pipe manufacturer with a heavy duty, solvent free epoxy suitable for application to fresh concrete as specified in Section 5. A minimum of two coats shall be applied to attain a minimum total dry film thickness of 400 µm.

3.3.6 Inspection and Testing

- 1 Inspection procedures and tests shall be carried out at the place of manufacture. Pipes and joints shall be hydrostatically tested in accordance with BS 5911.
- 2 The performance of pipes shall be verified by the testing of random sample pipes in accordance with the type of inspection and batch size mentioned. The pipes shall be subject to rejection on account of non-compliance with the following:
 - (a) failure to pass hydrostatic test
 - (b) failure of the longitudinal concrete surfaces of joints to meet dimensional tolerances
 - (c) fractures or cracks
 - (i) passing through the shell, except that a single end crack that does not exceed the depth of the joint shall not be cause for rejection; however
 - (ii) if a single end crack that does not exceed the depth of the joint exists in more than 10 % of the pipes inspected, the defective pipes shall be rejected
 - (d) defects that indicate defective mixing and moulding
 - (e) surface defects indicating honeycomb or open texture
 - (f) spalls
 - (i) deeper than one half the depth of the joint
 - (ii) extending more than 100 mm around the circumference
 - (iii) smaller than one half the depth of the joint or less than 100 mm around the circumference exist in more than ten percent of the pipes
 - (g) insufficient cover to the reinforcement.

3.4 GLASS REINFORCED PLASTIC (GRP) PIPES AND FITTINGS

3.4.1 Standards

- 1 All activities relating to this section of the particular specification shall comply with the following or approved equal standard. The latest version of the standard indicated shall apply.

Statutory provisions shall always apply as amended from time to time.

Generally applicable standards:

ASTM D2997Standard Specification for Centrifugally cast "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe.

ASTM D3517-01Standard Specification for "Fiberglass"(Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe

- EN 681Elastomeric seals. Material requirements for pipe joint seals used in water and drainage applications.
- EN 1796Plastic piping systems for water supply with or without pressure – Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP)
- EN 14364Plastic piping systems for drainage and sewerage with or without pressure. Glass reinforced-thermosetting plastics (GRP) based on unsaturated polyester resin (UP). Specification for pipes, fittings and joints
- CEN TS 14632Plastics piping systems for drainage, sewerage and water supply, pressure and non-pressure - Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP) - Guidance for the assessment of conformity
- DIN 16869 - Part 2Glass-fibre reinforced polyester resin pipes (UP-GF) – Centrifugally cast – filled Part 2: General quality requirements, testing.
- DIN 16869 - Part 1Centrifugally cast and filled glass fibre reinforced polyester resin pipes - dimensions.
- DIN 16945Testing of Resins, Hardeners and Accelerators, and Catalyzed Resins
- DIN 16946 - Part 1Cured casting Resins - Testing DIN-16946- Part 2 Cured casting Resins - Types
- DIN 16966 -6.....Glass fibre reinforced polyester resin (UP-GF) pipe fittings and joint assemblies; collars, flanges, joint rings, dimensions
- DIN EN 1119Plastics piping systems – Joints for glass-reinforced thermosetting plastics (GRP) pipes and fittings – Test methods for leak tightness and resistance to damage of flexible and reduced articulation joints
- DIN EN 1447Plastics piping systems – Glass-reinforced thermosetting plastics (GRP) pipes – Determination of long-term resistance to internal pressure
- DIN EN 681-1Elastomeric seals – Material requirements for pipe joint seals used in water and drainage applications – Part 1: Vulcanized rubber
- DIN EN ISO 10468Glass-reinforced thermosetting plastics (GRP) pipes – Determination of the long-term specific ring creep stiffness under wet conditions and calculation of the wet creep factor (ISO/DIS 10468:1999)
- DIN EN ISO 14828Glass-reinforced thermosetting plastics (GRP) pipes – Determination of the long-term specific ring relaxation stiffness under wet conditions and calculation of the wet relaxation factor (ISO/DIS 14828:1999)
- DIN EN ISO 178Plastics – Determination of flexural properties (ISO 178:1993)
- DIN EN ISO 527-1Plastics – Determination of tensile properties – Part 1: General principles
- DIN EN ISO 527-2Plastics - Determination of tensile properties - Part 2: Test conditions for moulding and extrusion plastics
- DIN EN ISO 527-4Plastics – Determination of tensile properties – Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites
- DIN EN ISO 75Plastics – Determination of temperature of deflection under load

EN ISO 2078Textile glass — Yarns — Designation (ISO 2078)

- ISO 1172Textile-glass-reinforced plastics, prepgs, moulding compounds and laminates - Determination of the textile-glass and mineral-filler content - Calcination methods
- ISO 3126Plastic pipes. Measurement of dimensions wall thickness table.
- ISO 4633Joint rings for water supply, drainage and sewerage pipelines: Specification for materials
- ISO 7509Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes —Determination of time to failure under sustained internal pressure
- ISO 7685Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Determination of initial specific ring stiffness
- ISO 8513Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Determination of longitudinal tensile properties
- ISO 8521Plastic piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Test methods for the determination of the apparent initial circumferential tensile strength
- ISO 10466Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Test method to prove the resistance to initial ring deflection
- ISO 10928Plastics piping systems - Glass-reinforced thermosetting plastics (GRP) pipes and fittings - Methods for regression analysis and their use
- ISO 10952Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes and fittings — Determination of the resistance to chemical attack for the inside of a section in a deflected condition
- ISO 15306Glass-reinforced thermosetting plastics (GRP) pipes — Determination of the resistance to cyclic internal pressure
- ISO 25780Plastic piping systems for pressure and non-pressure water supply, irrigation, drainage or sewerage – Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin – Pipes with flexible joints intended to be installed using jacking techniques

3.4.2 Design

- 1 The design of GRP pipes, fittings and bedding shall be carried out by the pipe manufacturer to enable the pipe to meet the requirements of the Works. The following general requirements shall prevail for pipes and fittings:
- they shall be designed to achieve a minimum working life of 60 years under all applicable standard loadings, environmental and installation conditions
 - they shall have a minimum stiffness of $10,000 \text{ N/m}^2$
 - Non-pressure pipes and fittings shall be designed for a nominal pressure rating of PN 01 (1 bar)
 - Pressure pipes and fittings shall be designed for a normal operating pressure rating of PN16 (16 bar) to pressure ratings in ISO 25780, EN 14364 or EN 1796.

- (e) they shall convey a liquid with a temperature up to 45°C
- (f) they shall be designed to withstand up to 5% long term deflection in their installed conditions.
- (g) all bends shall be long radius bends unless otherwise approved by the Engineer.
- (h) they shall be capable of withstanding a 95% lower confidence strain of 0.85% over 60 years without failure or cracking when tested in accordance with the strain corrosion type test requirements specified herein.
- (i) sewerage and drainage pipelines and fittings shall be designed to carry septic sewage having a maximum hydrogen sulphide concentration of 50mg/l at a temperature of 45°C
- (j) irrigation pipelines and fittings shall conform to the water supply standards
- (k) The manufacturer shall provide a valid Certificate of Conformity to EN 1796, EN 14364 or ISO 25780 as applicable. The certificate shall be issued by an independent certification body or authority.
- (l) For direct jack GRP pipes, the allowable jacking force shall be based on the minimum wall thickness measured at the bottom of the spigot gasket groove where the wall cross section has been reduced, and the mean longitudinal compressive strength of the pipe. A minimum factor of safety of 3.5 in accordance with ISO 25780 shall be used for the jacking force on a straight alignment. A reduced jacking force shall be used when jacking to a curvature.
- (m) Direct jack GRP pipes can be used for pressure and non-pressure applications.

3.4.3 Pipes and Fittings Manufacture

- 1 The pipes and fitting shall conform to either EN 14364 or EN 1796 for sewage or water supply pipes. Jacking pipes shall comply with ISO 25780. The referenced test standards therein have to be fulfilled.

3.4.4 General

- 1 All GRP components shall be designed and fabricated by one manufacturer.
- 2 GRP pipes and fittings shall be manufactured by an approved process utilising a mandrel or rotating mould incorporating equipment to accurately control the quantities and placement of all resins, glass and aggregates.
- 3 Use resins, reinforcement and aggregates to produce pipes and fittings, which when combined as a composite structure will satisfy the performance requirements of this section of the specification.
- 4 Internal and external surfaces shall be free from irregularities, which would impair the ability of the component to conform to the requirements of EN 14364, EN 1796 or ISO 25780.

3.4.5 Buried GRP

- 1 The pipes and fittings shall be constructed using chopped and /or continuous glass filaments, strands or roving, mats, synthetic veils or fabric, and polyester / vinyl ester resin, aggregate and fillers. If applicable, additives necessary to impart specific properties to the resin may be used, subject to the approval of the Engineer.
- 2 Filament Wound (FW) GRP Pipes and Fittings
 - (a) ResinsVinyl ester shall be used in the internal resin rich liner of the pipes and fittings. Isophthalic or vinyl ester shall be used in the structural layer of the pipes and fittings. Vinyl ester or isophthalic resin shall be used in the outer layer of the pipes and fittings.

Resins shall be cured to achieve a minimum of 90% of the manufacturer's recommended Barcol hardness value.

(b) Additives

The use of additives such as fire retardants, UV inhibitors or coloured pigments or dyes shall only be used for specific project based applications and their use shall be subject to the approval of the Engineer.

(c) Glass reinforcement

The glass used for the manufacture of the reinforcement shall be type "E" (alumina-calciosilicate glass), type "C" (alkali-calcium glass) or type "ECR" (alumina-borosilicate glass).

The reinforcement shall be made from continuous drawn filaments of glass and shall have a surface treatment compatible with the resin to be used. It may be used in any form, e.g. as continuous or chopped filaments, strands or rovings, mat or fabric.

(d) Aggregates

Aggregates shall be clean, graded silica sand containing no impurities and a maximum moisture content of 2%. The maximum particles size of the sand aggregate shall not exceed 0.8mm.

The overall sand content of the pressure pipes and fittings shall not exceed 30% by weight.

The overall sand content of the non-pressure pipes and fittings shall not exceed 60% by weight.

(e) Fillers

Fillers (other than silica sand aggregate) shall only be permitted if required for a particular project application and be subject to the approval of the Engineer following satisfactory long term type tests (ISO 10952, ISO 10466), for a minimum of 10,000 hours.

(f) Wall construction

Lining Layer

- (i) The inner lining layer shall comprise a minimum 2.0mm thick rich vinyl ester layer suitably reinforced with C glass veil with a glass content not exceeding 10% by weight. The remainder of the lining shall consist of layers of vinyl ester resin and powder bound ECR acid resistant glass chopped strand mat or roving, depending on the method of manufacture, with a glass content of between 25% and 35% by weight.
- (ii) Sand aggregate shall not be used in the lining layer.

Structural Layer

- (iii) The structural layer shall comprise Type E or ECR glass reinforcement and a thermosetting isophthalic polyester resin with or without sand aggregate.
- (iv) The layer shall be built up in layers of Type E or ECR acid resistant glass chop roving or continuous roving.
- (v) The manufacturing process shall ensure that no aggregate becomes embedded in the internal resin rich liner layer.

Outer Layer

- (vi) Pipes shall be provided with a resin rich layer with C glass veil reinforcement.
- (vii) The resin used in the outer layer shall have a Glass Transition temperature of at least 75°C.

(viii) The use of special finishes is permitted when the pipe or fitting is expected to be exposed to extreme climatic, environmental or ground conditions. These may include the provision of a sand layer, pigments or inhibitors for UV protection or fire retardation, subject to the approval of the Engineer.

(g) Bends and Fittings

Bends and fittings shall be equal or superior in quality and performance to the corresponding pipes. Mitred bends and fittings shall be fabricated from pipes which have been hydraulically tested successfully.

3 Centrifugally Cast (CC) GRP Pipes and Fittings

(a) Resins

Vinyl ester shall be used in the internal pure resin liner of the pipes and fittings. Isophthalic or vinyl ester shall be used in the structural layer of the pipes and fittings. Vinyl ester or isophthalic resin shall be used in the outer layer of the pipes and fittings. Resins shall be cured to achieve a minimum of 90% of the manufacturer's recommended Barcol hardness value.

(b) Additives

The use of additives such as fire retardants, UV inhibitors or coloured pigments or dyes shall only be used for specific project based applications and their use shall be subject to the approval of the Engineer.

(c) Glass reinforcement

The glass used for the manufacture of the reinforcement shall be Type E or ECR glass.

The reinforcement shall be made from chopped glass filament in long and short fibres and shall have a surface treatment compatible with the resin to be used.

(d) Aggregates

Aggregates shall be clean, graded silica sand containing no impurities and a maximum moisture content of 2%. The maximum particles size of the sand aggregate shall not exceed the lesser of 1/5 the total wall thickness of the pipe or fitting, or 2.5mm.

(e) Fillers

Fillers (other than silica sand aggregate) shall only be permitted if required for a particular project application and be subject to the approval of the Engineer following satisfactory long term type tests (ISO 10952, ISO 10466), for a minimum of 10,000 hours.

(f) Wall construction

Lining Layer

- (i) The inner lining layer shall comprise a minimum 2.0mm thick pure vinyl ester resin without glass reinforcement and sand aggregates.
- (ii) The barrier and transition layers between the pure resin lining layer and the structural layer shall be to suit the manufacturing process.

Structural Layer

- (iii) The structural layer shall comprise glass reinforcement and a thermosetting isophthalic polyester or vinyl ester resin with or without sand aggregate.
- (iv) The layer shall be built up in layers of ECR acid resistant glass chopped fibres.
- (v) The manufacturing process shall ensure that no aggregate becomes embedded in the inner pure resin liner layer.

Outer Layer

- (vi) Pipes shall be provided with an outer layer formed of a mortar of resin and sand aggregates with no glass reinforcement.
- (vii) The resin used in the outer layer shall have a Glass Transition temperature of at least 75°C.
- (viii) An outer protection layer shall be provided which has a minimum of 60% sand for corrosion protection.
- (ix) The use of special finishes is permitted when the pipe or fitting is expected to be exposed to extreme climatic, environmental or ground conditions. These may include the provision of a sand layer, pigments or inhibitors for UV protection or fire retardation, subject to the approval of the Engineer.
- (x) The transition layers between the structural layer and the outer layer shall be to suit the manufacturing process.

(g) Bends and Fittings

Bends and fittings shall be equal or superior in quality and performance to the corresponding pipes. Mitred bends and fittings shall be fabricated from pipes which have been successfully pressure tested.

4 Direct Jack GRP Pipes

(a) Resins

Vinyl ester resin shall be used in the internal pure resin liner of the pipes. Isophthalic or vinyl ester resin shall be used in the structural layer of the pipes. Vinyl ester or isophthalic resin shall be used in the outer layer of the pipes.

Resins shall be cured to achieve a minimum of 90% of the manufacturer's recommended Barcol hardness value.

(b) Additives

The use of additives such as fire retardants, UV inhibitors or coloured pigments or dyes shall only be used for specific project based applications and their use shall be subject to the approval of the Engineer.

(c) Glass reinforcement

The glass used for the manufacture of the reinforcement shall be Type E or ECR acid resistant glass.

The reinforcement shall be made from chopped glass filament in long and short fibres and /or continuous glass filaments, strands or roving, mats, synthetic veils or fabric and shall have a surface treatment compatible with the resin to be used.

(d) Aggregates

Aggregates shall be clean, graded silica sand containing no impurities and a maximum moisture content of 2%. The maximum particles size of the sand aggregate shall not exceed the lesser of 1/5 the total wall thickness of the pipe or fitting, or 2.5mm.

(e) Fillers

Fillers (other than silica sand aggregate) shall only be permitted if required for a particular project application and be subject to the approval of the Engineer following satisfactory long term type tests (ISO 10952, ISO 10466), for a minimum of 10,000 hours.

(f) Wall construction

Lining Layer

- (i) The inner lining layer shall comprise a minimum 2.0mm thick rich vinyl ester layer suitably reinforced with C glass veil with a glass content not exceeding 10% by weight. The remainder of the lining shall consist of layers of vinyl ester resin and powder bound ECR acid resistant glass chopped strand mat or roving, depending on the method of manufacture, with a glass content of between 25% and 35% by weight, when the filament wound manufacturing process is used.
- (ii) The inner lining layer shall comprise a minimum 2.0mm thick pure vinyl ester resin without glass reinforcement and sand aggregates when the centrifugal manufacturing process is used.
- (iii) The barrier and transition layers between the pure resin lining layer and the structural layer shall be to suit the manufacturing process.

Structural Layer

- (iv) The structural layer shall comprise glass reinforcement and a thermosetting isophthalic polyester or vinyl ester resin with or without sand aggregate.
- (v) The layer shall be built up in layers of Type E or ECR acid resistant glass chopped fibres.
- (vi) The manufacturing process shall ensure that no aggregate becomes embedded in the inner pure resin liner layer.

Outer Layer

- (vii) Pipes shall be provided with an outer layer formed of a mortar of resin and sand aggregates with no glass reinforcement.
 - (viii) The resin used in the outer layer shall have a Glass Transition temperature of at least 75°C.
 - (ix) An outer protection layer shall be provided which has a minimum of 60% of sand for corrosion protection.
 - (x) The use of special finishes is permitted when the pipe is expected to be exposed to extreme climatic, environmental or ground conditions. These may include the provision of a sand layer, pigments or inhibitors for UV protection or fire retardation, subject to the approval of the Engineer.
 - (xi) The transition layers between the structural layer and the outer layer shall be to suit the manufacturing process.
 - (xii) The outer surface of the pipes shall be smooth with a resin rich topcoat 0.3mm thick.
- (g) Longitudinal Compressive Strength

Proof of compression strength shall be supplied by testing all pipe types using the procedure set out in Annex A of ISO 25780.

The test results of compressive properties obtained from coupon or spool test specimens may be used. As described in ISO 25780, the manufacturer shall show the correlation of the results obtained from coupons or full spools by means of initial type tests. The pipes shall meet the following requirements for the initial longitudinal compression properties:

Table 3.4.1 : Longitudinal compressive strength for direct jack GRP pipes

Specimen	Pipe quality	Minimum compressive strength (single value)	Mean compressive strength
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Rebated and grooved specimen	with filler	80 MPa	90 MPa
Coupon specimen	with filler	90 MPa	100 MPa
Rebated and grooved specimen	without filler	70 MPa	80 MPa
Coupon specimen	without filler	80 MPa	90 MPa

(h) Dimensions

The manufacturer shall confirm that the outside diameter of the pipe conforms to ISO 25780.

The outside diameter of the jacking pipe shall be compatible with the jacking machine.

The nominal length of the pipe shall preferably be 1m, 1.5m, 2m, 3m or 6m. Other lengths shall be permitted to suit a particular project requirement.

The jacking force shall be transmitted face to face on the pipe joint without the use of packer rings, unless required for a specific project application. The permitted deviation from squareness across the joints external diameter shall be as tabled below:

Table 3.4.2 : Permissible deviation from squareness across a joint's external diameter

Manufacturer's declared outside diameter d_{OD} mm	Deviation of squareness mm
$d_{OD} \leq 300$	0.5
$300 < d_{OD}$	1.0

(i) Marking of jacking pipes

Markings shall meet the requirements for the application and conform to ISO 25780. Designations to meet special quality requirements as item 6 below are permissible. The marking of the pipe shall be visible on the external and internal surfaces of the jacking pipe.

5 Wall thickness

The minimum total wall thickness, including the liner and outer protective layer shall be declared by the manufacturer, which shall be complying with the standard performance criteria.

The wall thickness at any point on the pipe and the spigot shall not be less than the manufacturer's declared values.

6 Abrasion resistance

The pipes shall be resistant to abrasion when tested according to CEN TR 15729 over 100,000 cycles. There shall be no evidence of free glass fibres on the inner surface of the pipe.

7 Markings

All pipes including cut lengths and all fittings before dispatch from the pipe manufacturer's works shall be indelibly marked as follows on the external and internal surfaces.

- (a) The manufacturer's name, initials, or identification mark.
- (b) The nominal internal diameter in millimetres.
- (c) The length in metres.
- (d) The classification i.e. pressure rating, stiffness.
- (e) The date of manufacture and batch number.
- (f) A stamp to show that they meet the required inspection requirements and hydraulic tests at the point of manufacturer.
- (g) Identification number stencilled on the inside and outside at each end. The same number shall appear on all record sheets and documents relating to the manufacture delivery and testing of that pipe.
- (h) The manufacturing standard.
- (i) The project or contract number.

8 Joints

- (a) Except where otherwise detailed on the Drawings, all buried pipes and fittings shall have non-end-load-bearing flexible joints of spigot type or GRP sleeved couplers with EPDM rubber in full faced elements or rings in accordance with BS / DIN EN 681; manufactured according to the individual manufacturing technique and supplied as an integral part of the pipe or as separate fittings. The elastomeric sealing gaskets shall provide the sole means of maintaining joint watertightness. The sealing gaskets shall be supplied by the pipe manufacturer.
- (b) Joints in direct jack applications (non-pressure application) can also be of stainless steel Grade 316 Ti (EN 1.4571) couplers with approximately the same outside diameter as the pipe so that the joints are essentially flush with the pipe outer surface.
- (c) The manufacturer shall declare the maximum draw for which each flexible joint type is designed.
- (d) The manufacturer shall declare the maximum allowable angular deflection and the maximum draw for which each locked joint type and flexible joint type are designed.
- (e) All joints shall remain watertight for all combinations of angular deflection and draw up to the maximum allowable values. In addition, pipe joints for pipelines laid in open cut trenches shall be capable of withstanding an external pressure differential equivalent to +10m head of water without leakage in the straight, deflected and drawn positions.
- (f) When a pipe is cut or turned down in order to form a joint, the exposed faces shall be fully sealed with a continuous coating of vinyl ester resin with a minimum of 1.5mm thick.
- (g) Wrapped or cemented joints shall only be used subject to the approval of the Engineer.

3.4.6 Exposed GRP

- 1 The use of GRP pipes and fittings for exposed service shall be subject to the approval of the Engineer. The exposed pipes and fittings shall be designed to resist all bending stresses, thrust forces, surge pressures, negative pressures, thermal and vibratory forces.
- 2 Exposed pipe and fittings shall be manufactured in the same manner and with the same materials as buried pipe, along with the following requirements unless otherwise approved by the Engineer.

- (a) An outer protective surface layer shall be provided consisting of a topcoat of UV inhibitor and resin with or without glass reinforcement to form a resin rich layer with a minimum thickness of 0.3mm. The outer protective surface layer shall be designed to resist other project specific extraneous causes (atmospheric conditions, mechanical damage and chemical stress etc.) as described in the project specification.
- 3 Exposed pipes and fittings inside treatment plant buildings, process structures, pumping stations, and valve chambers shall use PN 16 flanged joints:
- (a) Flanges shall be filament wound, tape wound, contact moulded, hot or cold pressed with epoxy or vinyl ester resins only.
 - (b) All bolts shall be stainless steel grade 316.
 - (c) Flanges shall be drilled to EN 1092 (metric units) resp. DIN 16966-1 type PN16.
 - (d) Flanged pipe joints shall incorporate an annular gasket covering the full face of the flange. Gaskets to be 3mm thick self-energised EPDM or nitrile rubber (NBR) with embedded stainless steel inlay O rings. The gaskets shall have a shore hardness of 60 ± 5 .
 - (e) When flanged joints are to be made, secure the bolts and the nuts initially to finger tightness. Thereafter the final tightening of the nuts shall be effected by torque spanners in such sequence that diametrically opposite nuts are tightened together to achieve the manufacturers recommended torque.
- 4 External exposed pipes and fittings shall use fixed laminated joints with expansion bellows and be supported in accordance with the manufacturer's requirements.
- 5 The exposed pipeline shall be protected by bollards, lateral sand bunds etc. where there is a risk of physical impact.
- 3.4.7 Inspection and Testing**
- 1 A pipe type test group consists of a range or family of products made such that the results of the long-term type tests are applicable to all products in the group. A pipe type test group shall be made of products:
- a) manufactured by the same process;
 - b) with the same material specifications;
 - c) with the same pipe wall construction (i.e. the sequence of layers, layer compositions, material properties and design method for using the results of the long-term type tests in determining the pipe wall for all combinations of DN, PN and SN);
 - d) tested with the same loading condition (i.e. uniaxial or biaxial load).
- 2 The pipe manufacturer shall submit type test results according to EN 14364 or ISO 25780 for each product group.
- 3 Strain corrosion tests shall be carried for each class and diameter range, where applicable, according to ISO 25780 and ISO 10467, as a type test generally in accordance with ASTM D3262 resp. ISO 10952. The strains shall be at levels at which failure can be predicted from the strain corrosion type test results to occur at 100 hours and 1,000 hours. No failures shall be below the lower 95% confidence limit of the type test regression line.
- 4 The calculated failure strain at 60 years from the results of the quality control test using the least squares method shall not be less than 0.85%. In the event that a specimen fails the strain corrosion test all pipes in that class and diameter range, where applicable, pertaining to that batch which has been manufactured or installed shall be rejected.

- 5 The pipe manufacturer shall carry out the following Inspection Tests. The results of these tests shall be made available to the Engineer who shall also be allowed to witness some or all of the tests.
- (a) One pipe in every 100 of each type and size of manufactured item shall be tested for loss of ignition in accordance with ASTM D2584 resp. ISO 1172.
 - (b) The liner thickness of pipes, fittings and couplings shall be measured in accordance with Section 6 of ASTM D3567 resp EN 3126. A liner check shall be carried out for one in every 100 of each type and size of manufactured item. A minimum of one item of each type and size shall be tested. The liner thickness shall not be less than 1mm at any pitted point.
 - (c) Data for the above tests shall be submitted to the Engineer. The data shall be traceable to the supplied pipes with a unique number as "Batch no", the test data shall hold all the above mentioned tests samples results under this batch no. The batch no. shall be clearly marked as ID on each length of produced pipes.
- 6 Checks will be carried out by the Engineer at Site. The Contractor shall destroy or indelibly mark as rejected and remove from Site any pipes or fittings found at any time failing to meet dimensional criteria or any of the following quality criteria:
- (a) scratches shall be no deeper than 0.3 mm and no reinforcing fibres shall be exposed
 - (b) no cracks shall be present on the inside of pipes. Hair cracks on the outside may be permitted with repair if not longer than 200 mm circumferentially or 6 mm longitudinally. Impact cracks shall not affect more than 3 % of surface area
 - (c) no delaminations shall be evident
 - (d) no impact or other damage to pipe ends shall be evident. The end surface of pipe or fitting shall be completely covered with resin and free from cracks, porosity, bubbles, voids, exposed reinforcement or extraneous matter
 - (e) no protruding fibres permitted on jointing surfaces
 - (f) no other protuberances. Small globules or resin projections permissible if not more than 25 % of area is affected. Jointing surfaces shall be completely free of any such flaws. Ridges formed by resin shall not exceed 1.5 mm in depth
 - (g) air voids, blisters, bubbles are not acceptable if greater than 5 mm diameter or 1 mm depth. Subject to the approval of the Engineer, if less than 0.5% of internal areas are affected, such defects may be ground out and repaired
 - (h) not more than 5 % of the internal or 10 % of the external surface shall be affected by pitting. No individual pit shall be more than 1 mm diameter or 0.5mm depth
 - (i) wrinkles and indentations shall not be more than 2mm deep and not more than 3 % of surface area affected. Subject to the approval of the Engineer, if not more than 5 mm deep and 0.5 percent of surface area is affected, such defects may be repaired
 - (j) any pipe which when resting freely on the ground and not subjected to any loads other than its own weight exhibits a deflection of more than 2%, measured along the diameter, shall be rejected and removed from the Site.

3.5 PVC-U PIPES AND FITTINGS

3.5.1 Standards

- 1 Except as otherwise indicated, materials and workmanship described in this section shall conform to the latest editions of the following standards:

ASTM D1599.....Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing and Fittings

AWWA M23 PVC Pipe - Design and Installation

BS 3505/3506 - Polyvinyl Chloride Pressure Pipe

EN 1401 - Plastic piping for non-pressurised underground drainage & sewerage

EN 1452Plastic piping systems for water supply (UPVC)

DIN 8061Unplasticised polyvinyl chloride pipes - general quality requirements & testing

DIN 8062: 1988Unplasticised polyvinyl chloride (PVC-U, PVC-HI) pipes – dimensions

DIN 8063: 1986Pipe joint assemblies & fittings for unplasticised polyvinyl chloride (PVC-U) pressure pipelines

ISO 1452Pipes and fittings in PVC –U pipes for water supply

- 2 The strength requirement and other features of particular application shall be as specified in this Subpart or designated in the contract specific documentation.

3.5.2 Manufacture

- 1 UPVC pipe shall be provided in standard 6 metre lengths, unless otherwise specified, detailed or required on the approved plans. Shorter lengths, up to 3 metres, will be permitted when authorised by the Engineer. Field cut lengths of pipe used as closures may not be shorter than 0.75 metre in length and must be approved by the Engineer. Solvent welded pipes may be permitted in sizes of 100mm and less.
- 2 For sewerage service, PVC-U pipes 200 mm in diameter may be supplied in lengths up to 4 m. PVC-U pipes 150 mm in diameter and less shall be supplied 50 percent in lengths not exceeding 2 m and 50 percent in lengths not exceeding 4 m.
- 3 UPVC Pipes shall be SDR17 as a maximum and shall have be designed to withstand a nominal operating pressure of PN16 at 250C (equivalent to PN10 at 450C) unless otherwise specified in the Contract Documents.
- 4 All joints for UPVC Pressure Pipe shall be integrally cast, spigot and socket joints, or plain end with EPDM rubber ring couplings. Joints shall be of the same pressure rating as the pipe. Solvent weld joints are not permitted for TSE Mains. Gaskets and lubricants shall be made from materials that are compatible with the plastic material and with each other when used together. They shall not support the growth of bacteria and shall not adversely affect the potable qualities of the water that is to be transported. One elastomeric gasket shall be furnished with each length of socket-end pipe.
- 5 Pipe shall have a minimum internal diameter equal to or greater than the pipe size shown on the Drawings and Bills of Quantities. SDR shall be defined as outside diameter divided by wall thickness. Acceptable PVC pipe shall have common profiles for interchangeability between rough barrel dimensions, couplings, ends and elastomeric gaskets so as to facilitate future repairs. When assembled, the pipe shall have only one gasket per socket and spigot end.
- 6 Pipes delivered to site shall be no more than 12 months old. The Engineer reserves the right to reject the pipes older than 12 months old.

3.5.3 Joints

- 1 Solvent welded joints shall not be permitted for sewerage pipelines and all jointing shall be by socket and spigots with sealing rings which shall conform to BS 2494.

- 2 Unless otherwise designated, irrigation pipework up to 100 mm in diameter shall be solvent welded in accordance with BS 4346 Part 1.

3.5.4 Inspection and Testing

- 1 Inspection and testing for sewer pipes shall be in accordance with an approved inspection and test plan.
- 2 Inspection and testing for irrigation pipes shall be in accordance with an approved inspection and test plan.
- 3 Test certificates shall be provided by the manufacturer.
- 4 All pipes may be subject to inspection at the place of manufacture in accordance with the provisions of the referenced standards as supplemented by the requirements herein. The Contractor shall notify the Engineer in writing of the manufacturing starting date not less than 14 calendar days prior to the start of any phase of the pipe manufacture.
- 5 During the manufacture of the pipe, the Engineer shall be given access to all areas where manufacturing is in process and shall be permitted to make all inspections necessary to confirm compliance with the Specifications.
- 6 The Contractor shall perform said material tests in accordance with the requirements of the Contract Documents. The Engineer shall have the right to witness all testing conducted by the Contractor, provided that the Contractor's schedule will not be delayed for the convenience of the Engineer.
- 7 In addition to those tests specifically required, the Engineer may request additional samples of any material for testing by the Engineer.
- 8 All expenses incurred in obtaining samples for testing shall be borne by the Contractor at no additional cost to the Contract.

3.5.5 Inspection and Testing

- 1 All fittings shall be push-on joint with mechanical fittings. Fittings shall be in uPVC material compatible with the above specified pipe and having the same minimum Class and Pressure Rating. The fittings when connected to the main pipe shall provide an integral system capable of withstanding the working and test pressure.

3.6 ACRYLONITRILE BUTADIENE-STYRENE (ABS) PIPES AND FITTINGS

3.6.1 Standards

- 1 Acrylonitrile butadiene-styrene (ABS) pipes and fittings for pressure pipes shall conform to BS 5391 and BS 5392.

3.6.2 Manufacture

- 1 Unless otherwise designated, ABS pipes and fittings shall be class E and manufactured in accordance with BS 5391 and BS 5392.

3.6.3 Joints

- 1 ABS pipes shall be provided with socket and spigot joints, sealed with elastomeric sealing rings conforming to BS 2494.

3.6.4 Inspection and Testing

- 1 Inspection and testing for pipes and fittings shall be in accordance with BS 5391 and BS 5392.

3.7 DUCTILE IRON PIPES AND FITTINGS

3.7.1 Standards

- 1 Unless otherwise stated in the Contract Documents ductile iron pipes and fittings for pipes shall comply with EN 545 and shall be suitable for an allowable operating pressure (PFA) of 16 Bar and an allowable maximum operating pressure (PMA) of 20 bar.
- 2 Unless otherwise stated in the Contract Documents, flanges on ductile iron pipework and fittings shall comply with EN 1092-2 and shall be PN16.
- 3 All puddle flanges shall be cast integrally with the wall piece.

3.7.2 Exposed Joints

- 1 Ductile Iron flanged pipes shall be furnished with either integrally cast flanges, welded flanges or screwed on flanges faced and drilled to class designation, which must be achieved at the manufacturers works, no "Site" fabrication of flanged joints shall be permitted. Steel bolts and nuts shall be supplied with two washers per bolt. Bolt length shall be such that after the joints are made up, the bolts shall protrude through the nut, but not more than 12 mm. Bolts shall be stainless steel grade to BS 970 Grade 316 S31.
- 2 Gaskets shall be compatible with the fluid to be conveyed. For treated sewage effluent pipelines, EPDM gaskets shall be used. Gaskets shall be able to withstand a pressure of PN 16 for a 24 h test period. Thickness of gaskets shall be such that, when jointed in accordance with manufacturer's instructions, the joint shall provide a positive seal for the range of pressures likely to occur in the pipeline under the maximum joint deflection permitted.
- 3 Pipes and fittings in chambers and pumping stations shall have flanged joints unless detailed otherwise. Flanges shall comply with EN 1092-2 and shall be PN16 unless a higher pressure rating is detailed elsewhere.

3.7.3 Buried Joints

- 1 Pipes and fittings to be buried shall have flexible joints unless detailed otherwise.

3.7.4 Internal Lining

- 1 Pipes and fittings shall be lined internally with one of the following linings:
 - (a) Polyurethane lining minimum thickness 1,000 micron
 - (b) Fusion bonded epoxy powder lining minimum thickness 500 microns
 - (c) Ceramic epoxy lining minimum thickness 1,000 micron
- 2 All coatings shall be factory applied in strict accordance with the lining manufacturer's specification. Pipes shall be blast cleaned or ground to the equivalent of EN ISO 8501-1, BS 7079:A1, SA 2.5 prior to application of the products.
- 3 All liners shall comply with the following standards:
 - (a) adhesion to pipe (ASTM D4541) Min 10 MPa
 - (b) impact resistance (ASTM2794) Min 10 J
 - (c) abrasion resistance (AST D4060, 1kg x 1000cycles) Max 100 mg
 - (d) vapour permeability (ASTM D1653, Wet cup method) 1.0g/m²/24hr
 - (e) immersion test 20% sulphuric acid (ASTM D-714-87) No effect after 2 years
 - (f) salt spray test (ASTM B117 – 1,000 hours) pass
 - (g) spark holiday test voltage V = 248T0.5, where T = thickness of lining in microns
 - (h) any defect found in the lining shall be repaired at the manufacturers plant before shipment.

- 4 Internal socket end of pipes shall be protected with a minimum thickness of 300 \pm m of epoxy.
- 5 All pipes shall be clearly marked to indicate the type of lining as follows:
- (a) PU – Polyurethane
 - (b) FBE – Fusion bonded epoxy
 - (c) CE – Ceramic epoxy

3.7.5 External Coating and Wrapping, Use and Materials

- 1 External coatings for ductile iron pipes shall be factory applied to the approved pipe manufacturer's standards and conform to one of the following specifications.

Table 3.2 External DI Pipe Coating Systems

Inner coat	Middle Coat	Final Coat	Applicable Standards
200g/m ² zinc	150 \pm m epoxy	Black fusion or hot melt adhesive bonded polyethylene sleeving of nominal thickness 1000 \pm m.	EN 598, 6076 and ISO 8179-1
200g/m ² zinc	150 \pm m epoxy	Black tape self adhesive bituminous resin on PVC backing layer complying with AWWA C2009 Section 24 Type 1. 55% overlap.	EN 598, ISO 817, AWWA C2009
Nil	Nil	Polyurethane as Part 3 – 3.7.4 minimum thickness 2000 \pm m	NF A48-851

- 2 Laminate tape shall have the following characteristics:

Table 3.3 Laminate Tape Properties

Parameter	Applicable Standard	Pipes □600mm dia	Pipes □600mm dia
Overall thickness	ASTM D 1000	1.1mm	1.6mm
PVC backing thickness	ASTM D 1000	0.3mm	0.7mm
PVC backing thickness if fabric reinforcement in bituminous layer	ASTM D 1000	0.5mm	0.5mm
Tensile Strength	BS 2782	7.5N/mm	12.0N/mm
Elongation	BS 2782	200%	200%
Tear Resistance	ASTM D 1004	19N/mm	50N/mm
Adhesion to steel	ASTM D 1000	1.0N/mm	2.0N/mm
Adhesion to self	ASTM D 1000	1.8N/mm	1.8N/mm
Impact resistance (single layer)	DIN 30672	8.0Nm	10.0Nm

Parameter	Applicable Standard	Pipes Ø600mm dia	Pipes Ø600mm dia
Dielectric strength	BS 2872	25,000V	30,000V
Insulation resistance	BS 2782	1,000,000 megohms	1,000,000 megohms
Water vapour permeability	BS 2782	□ 0.65 g/m ² /day	□ 0.65 g/m ² /day

- 3 Spigot ends of pipes that are tape or polyethylene wrapped shall not be wrapped over the depth of engagement of the spigot with the socket or mechanical coupling but shall be coated with a minimum thickness of 300±m of epoxy.

3.7.6 Factory Application of Tape Wrapping

- 1 Before primer application, all oil and grease shall be removed with an approved solvent. Surfaces to be coated shall be cleaned by mechanical brushing to remove loose corrosion products, welding slag, loose factory applied bituminous paint or any other foreign matter and achieve a surface finish equivalent to mechanical scraping and wire brushing as specified in Clause 8.3.5 of this Section. All surfaces shall be solvent wiped after blast cleaning.
- 2 Primer shall be applied to all surfaces to be wrapped immediately following completion of surface preparation.
- 3 Primer shall be allowed to dry before wrapping. Primer application shall be limited to the amount that can be wrapped during the working day.
- 4 Tape shall be applied spirally to provide a 55 % overlap and with sufficient tension to result in constant adherence without voids or wrinkles. On completion of the wrapping the surface shall be smoothed to ensure completely sealed overlaps and the absence of air pockets under the tape. The width of the tape shall be suitable to conform to the size and shape of the pipeline being wrapped.
- 5 On completion of the wrapping, all tape wrapping shall be checked for continuity by a "Holiday" detection unit. Any Holidays detected shall be repaired by over-wrapping with tape and the wrapping retested.
- 6 Bond/adhesion tests shall be carried out on all tape wrappings not more than 24 hours after completion of wrapping.
- 7 Test certificates shall be provided by the manufacturer.

3.7.7 Factory Applied Extruded Polyethylene Coating

- 1 Extruded polyethylene coating shall be factory applied to preheated epoxy primed pipes and fittings to provide a minimum finished thickness of 2.0 mm. The coating shall be resistant to peeling, free from imperfections, and shall be tested for continuity using a minimum 10 kV spark tester. The polyethylene coating shall be stabilised to prevent ultraviolet and thermal degradation.

3.7.8 Inspection and Testing

- 1 Inspection procedures and tests for DI pipes and fittings shall be carried out in accordance with BS 4772.
- 2 The Contractor shall provide Manufacturer's type and quality control test certificates to be traced to the pipe cast number, heat number or lot number.

- 3 Manufacturer's certificates shall state the relevant British or ISO standards to which the pipes and fittings supplied comply.
- 4 The repairs to cement mortar linings, if permitted by the Engineer, shall comply with the requirements of the designated thickness, minimum bore and surface conditions.
- 5 In addition to the prescribed testing, the pipes and fittings shall be subjected to visual inspection at the place of manufacturer and at Site and will be rejected if the pipes are incorrectly marked or have defects outside the ranges permitted.

3.8 FLANGE ADAPTERS AND FLEXIBLE COUPLINGS

3.8.1 General

- 1 In addition to the types of joints typically designated for each type of pipe, flange adaptors and flexible couplings may be designated particularly for pressure pipelines.

Flange adaptors and flexible couplings shall:

- (a) be manufactured from rolled steel or other approved materials
- (b) be capable of withstanding the pressure test of the pipeline in which they are incorporated
- (c) permit minimum angular deflection as shown below:

Table 3.3 – Minimum Angular Deflection

Pipe diameter (mm)	Deflection
□450	6°
450 – 600	5°
600 – 750	4°
750 – 1200	3°
1200 -1800	2°
>1800	1°

- (d) be capable of accommodating a movement of 10 mm between ends of pipes they connect.
- 2 Adaptors and couplings shall be joined as recommended by the manufacturer.
- 3 Where necessary to restrain movement at joints tied flange adaptors shall be used and the deflection criteria shall not apply.
- 4 All fasteners shall be stainless steel to BS970 Grade 316S31.

3.8.2 Flange Adapters

- 1 Flange adapters shall be used on PVC-U, GRP, cast and ductile iron, and joints between each of the materials as designated. Flanges shall be PN 16 rating and gaskets shall be to BS 3063.

3.8.3 Flexible Couplings

- 1 Flexible couplings shall be used with PVC-U, GRP, cast and ductile iron, and between joints between pipes manufactured from each of the materials.

3.9 PIPES FOR OTHER USE

3.9.1 Copper Tubes and Fittings

- 1 All tubes shall be clean, round, smooth and free from harmful defects and from deleterious films in the bore. Copper tubing shall conform to EN 1057 and shall be half hard, light gauge copper. Tubing shall be supplied in straight lengths by an approved manufacturer whose identification mark shall appear on each tube at about 0.5 m intervals. Approved dielectric isolation fittings or attachments shall be furnished where copper fittings, piping or tubing are connected to ferrous fittings or connections.
- 2 Copper tubes for internal use shall be in accordance with Table X of
- 3 EN 1057. Chromium plated copper tube shall be of plating quality in accordance with BS 1224, free of defects such as blisters, pits, roughness, cracks or unplated areas. Fittings shall be of the compression type complying with BS 864 Part 2 and shall be resistant to dezincification.
- 4 Copper tubes for external use shall be in accordance with Table Y of BS 2871 Part 1. Tubing shall have a factory applied green coloured polythene sheath with a minimum thickness of 1.0 mm. Fittings shall be of the compression or capillary type complying with BS 864 Part 2 and shall be resistant to dezincification. Joints shall be adequately protected with tape to the approval of the Engineer.

3.9.2 Hose and Appurtenances

- 1 Hose and hose reel shall be furnished for designated hose bibbs. Hose shall be 25 mm diameter minimum and provided with an adjustable nozzle. Hose pipes for wash water shall be matched to the operating head of the supply system, be constructed for heavy duty and be 50m long. Hose pipes shall have a certified test pressure of 1.5 times the maximum operating pressure. Hose pipes for fire fighting shall be in accordance with Section 23.
- 2 Couplings shall be furnished for each size hose, one for each 25 m length of hose provided; they shall be of cast brass quick fix type and shall have standard threads.

3.9.3 Stainless Steel Pipes, Tubes and Fittings

- 1 All stainless steel for pipes, tubes and fittings shall be Type 316L.
- 2 Stainless steel pipes and tubes shall conform to ASTM A312 and ASTM A688. Plate shall conform to ASTM A240; diameters and wall thickness to ANSI B36.19.
- 3 Stainless steel fittings and specials shall be compression type conforming to ASTM A234. Plate shall conform to ASTM A240; diameters, wall thickness and dimensions to ANSI B36.19, ANSI B16.9.
- 4 Pipe sizes 50 mm and smaller shall be of Schedule 40 and above seamless stainless steel with threaded ends, and shall conform to material specifications ASTM A312 and dimensional specifications ANSI B36.19. Fittings shall be threaded, 2,000 pound forged stainless steel, and shall conform to material specification ASTM A182 and dimensional requirements of ANSI B16.11.
- 5 Unless otherwise designated, pipe sizes over 50 mm shall be Schedule 10 and above, seamless stainless steel with bevelled ends for welding conforming to material specification ASTM A312 and dimensional specification ANSI B36.19. Unless otherwise designated, fittings shall be Schedule 10, seamless stainless steel with bevelled ends for welding and conform to material specification ASTM A403 and to the dimensional requirements of ANSI B16.9 and ANSI B16.28. Flanges shall be ANSI slip-on or welding neck type, with 150 pounds rating conforming to material specification ASTM A182 and to the dimensional specifications ANSI B16.5.

3.9.4 Carbon Steel Pipes and Fittings

- 1 Carbon steel pipes shall conform to :
- 2 ASTM A53, ASTM A106 for pipes, and ASTM A105 for fittings and flanges
- 3 Carbon steel fittings and flanges shall conform to ASTM A105.

3.10 MEDIUM AND HIGH DENSITY POLYETHYLENE (HDPE) PIPES

3.10.1 Applicable Standards

- 1 MDPE and HDPE pipes shall conform to the latest editions of the following standards.

ASTM D638-10Standard test method for tensile properties of plastics

AWWA C224Standard for nylon-11 based polyamide coating system for the interior and exterior of steel water pipe, connections, fittings and special sections

EN 12099Plastics piping systems – Polyethylene piping materials and components – Determination of volatile content

EN 12201Plastic piping systems for water supply and for drainage and sewerage under pressure – Polyethylene (PE)

EN 12666Plastic piping systems for non-pressure underground drainage and sewerage – Polyethylene (PE)

EN 1519Plastic piping systems for soil and waste discharge (low and high temperature) within the building structure – Polyethylene (PE)

EN ISO 527Plastics -- Determination of tensile properties

EN ISO 1133-1Plastics. Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics.

EN ISO 1167Thermoplastic pipes, fittings and assemblies for the conveyance of fluids – Determination of the resistance to internal pressure

EN ISO 2505Thermoplastics pipes – Longitudinal reversion – Test method and parameters

EN ISO 3126Plastics piping systems – Plastic components – Determination of dimensions

EN ISO 6259Thermoplastic pipes - Determination of tensile properties

EN ISO 9080Plastic piping and ducting systems – determination of the long term hydrostatic strength of thermoplastics materials in pipe form by extrapolation

EN ISO 1183-2Plastics – Methods for determining the density of non-cellular plastics – Part 2: Density gradient column method

EN ISO 12162Thermoplastic materials for pipes and fittings for pressure applications - Classification and designation – Overall service (design) coefficient

EN ISO 13479Polyolefin pipes for the conveyance of fluids. Determination of resistance to crack propagation.

EN ISO 15512Plastics – Determination of water content

- EN ISO 16871Plastics piping and ducting systems – Plastics pipes and fittings – Method for exposure to direct (natural) weathering
- ISO 4065Thermoplastic pipes – Universal wall thickness table
- ISO 4427Plastics piping systems - Polyethylene (PE) pipes and fittings for water supply
- ISO 6964Polyolefin pipes and fittings – Determination of carbon black content by calcination and pyrolysis – Test method and basic specification
- ISO 9624Thermoplastic pipes for fluids under pressure – mating dimensions of flange adaptors and loose backing flanges
- ISO 11357-6Plastics – Differential scanning calorimetry (DSC) – Part 6: Determination of oxidation induction time (OIT)
- ISO 11922-1Thermoplastic pipes for the conveyance of fluids – Dimensions and tolerances - Part: 1: Metric series
- ISO 13761Plastics pipes and fittings – Pressure reduction factors for polyethylene pipeline systems for use at temperatures above 20°C
- ISO 13953PE pipes and fittings – Determination of tensile strength and failure mode of test pieces from a butt-fused joint
- ISO 14236Plastics pipes and fittings – Mechanical joint compression fittings for use with polyethylene pressure pipes in water supply systems
- ISO 18553Method for the assessment of the degree of pigment or carbon black dispersion in polyolefin pipes, fittings and compounds.
- WIS 4-24-01Specification for mechanical fittings and joints for polyethylene pipes for nominal sizes 90 to 1000 mm OD
- WIS 4-52-01Specification for polymeric anti-corrosion (barrier) coatings
- WIS 4-52-03Specification for anti-corrosion coatings on threaded fasteners

3.10.2 Manufacture

- 1 MDPE and HDPE (PE) pipes and fittings shall be manufactured from virgin materials only. Recycled, re-ground or re-generated materials shall not be used.
- 2 HDPE pressure pipes and fittings shall be manufactured from material conforming to polymer classification PE100 having a minimum required strength value (MRS) of 10 MPa at 50 years and 20°C in accordance with ISO 4427. Design stress shall be 8 MPa. The pipe manufacturer shall identify the manufacturer of the resin, the resin type and classification.
- 3 The HDPE pipe material shall be certified as meeting the requirements of the PE100+ Association.
- 4 HDPE pipes to be installed using trenchless technology applications shall be manufactured from a PE100-RC material. Pipes manufactured from such material shall have undergone the Notched Pipe Test at an independent 3rd party laboratory in accordance with ISO 13479 and the time to failure shall have been a minimum of 8,760 hours (1 year). All other characteristics shall comply with the PE100 requirements of ISO 4427 and this specification.

- 5 HDPE pipes shall have a standard dimension ratio (SDR) of 11 unless indicated otherwise by the Engineer and shall have a pressure rating of 16 bar (PN16) at 20°C (de-rated to 11.8 bar at 40°C, in accordance with Annex A of ISO 4427 Part 1) unless indicated otherwise by the Engineer.
- 6 Pipes and fittings shall be designed to achieve a minimum working life of 50 years under all applicable loads, environmental and installation conditions.
- 7 MDPE pressure pipes and fittings shall be manufactured from material conforming to polymer classification PE80 having a minimum required strength value (MRS) of 8 MPa at 50 years and 20°C in accordance with ISO 4427. Design stress shall be 6.4 MPa. The pipe manufacturer shall identify the manufacturer of the resin, the resin type and classification.
- 8 MDPE pipes shall have a standard dimension ratio (SDR) of 11 unless indicated otherwise by the Engineer and shall have a pressure rating of 12.8 bar (PN12.8) at 20°C (de-rated to 9.5 bar at 40°C, in accordance with Annex A of ISO 4427 Part 1) unless indicated otherwise by the Engineer.
- 9 Pipes and fittings shall be homogeneous throughout and free of visible cracks, holes, foreign inclusions, voids and other injurious defects.
- 10 The resin from which the pipes and fittings are manufactured shall comply with the requirements of ISO 4427 Part 1 and be protected from UV attack by the addition of carbon black in accordance with the standard.
- 11 Straight lengths of PE pipe shall be supplied in standard lengths of 12m (-0/+50 mm) measured at 23°C ± 2°C. Unless otherwise specified, coil length shall not exceed 100m. Coiled pipes shall be coiled such that localised deformation is avoided and the minimum internal diameter of the coil shall not be less than 20 x outside diameter. Prior to jointing the degree of pipe ovality shall not exceed the permissible levels given in Table 1 of ISO 4427, Part 2 and the Contractor shall, if required, use mechanical re-rounding equipment to meet these requirements. Field cut lengths of pipe used as closures may not be shorter than 0.75 metre in length and shall be approved by the Engineer.
- 12 All pipes shall be indelibly marked at intervals of maximum 1m. The colour of the pipe marking shall always contrast with the colour of the pipe. Markings shall include the following information:
 - (a) Manufacturer's name, trademark
 - (b) Material and designation i.e. PE100
 - (c) The nominal pressure (PN) of the pipe / fitting
 - (d) Dimension of the pipe (nominal outside diameter x nominal wall thickness)
 - (e) Standard Dimension Ratio (SDR)
 - (f) Production period (date / batch code)
 - (g) International Standard to which the pipe / fitting has been produced to
 - (h) Designation of the medium for which the pipe is produced for (water, gas, sewage)
 - (i) Stencilled in legible letters the pipe identification number on the outside at each end. Ensure that the same number appears on all record sheets and documents relating to the manufacture, delivery and testing of that pipe.
- 13 Pipes shall be delivered in wooden frames or similar arrangement to avoid movement between pipes. Pipes shall not be stacked higher than 1m in each frame or packing arrangement.

3.10.3 Fittings

- 1 Unless otherwise specifically approved by the Engineer, all PE pressure pipe fittings for use with pipes of up to 355 mm OD shall be injection moulded with the same polymer classification, material type and pressure rating as the pipe to which they are to be connected. All joints between PE pipes and fittings shall whenever possible be by thermal butt fusion welding or electro-fusion welding process.
- 2 Connections of PE pipes and fittings to metallic fittings shall be made with PN16 backing rings with a stainless steel stiffener insert or as recommended by the pipe or fitting manufacturer and approved by the Engineer.
- 3 Transition fittings used to join the pipe to flanged fittings and pipes made of other materials shall be certified by an independent third party as being fully compliant with the Type 1 or Type 2 requirement of WIS 4-24-01 i.e. they shall prevent the pull out of the pipe at their rated operational and test pressures.
- 4 Metallic fittings shall be fully coated to provide protection against corrosion. The coating shall be a factory applied fusion bonded epoxy or a nylon 11 based polyamide coating system, have a minimum dry film thickness of 250 microns and comply with the requirements of either AWWA C224 or WIS 4-52-01. Any bolts, studs or nuts shall be of stainless steel (grade 304 or better) or else be protected with a coating that complies with the requirements of WIS 4-53-03. All buried metallic fittings shall be protected by petroleum impregnated primer, paste and tape prior to back filling.
- 5 Where their use is approved by the Engineer, all compression fittings shall be certified by an independent third party as being fully compliant with the requirements of ISO 14236. They shall be tested and certified as being class 1 end load bearing fittings i.e. they shall prevent the pull out of the pipe at their rated operational pressure. Only materials listed in Tables 1 and 2 of ISO 14236 shall be used in the manufacture of the fitting body.
- 6 Where the use of fabricated fittings has been specifically approved by the Engineer such fittings shall be designed and manufactured in accordance with the requirements of ISO 4427, Part 3, in particular Annex B. The pressure derating factors to be employed by the fittings fabricator shall be in accordance with annex sections B3 and B5 unless they can demonstrate that higher factors can be applied. The use of any higher factors shall be approved by the Engineer prior to commencement of fitting fabrication.
- 7 All PE fittings shall, as a minimum, be indelibly marked with the following information:
 - (a) Manufacturer's name, trademark
 - (b) International Standard to which the pipe / fitting has been produced to
 - (c) Material and designation i.e. PE100
 - (d) The nominal pressure (PN) of the pipe / fitting
 - (e) Outside diameter and Standard Dimension Ratio (SDR)
 - (f) Production period (date / batch code)
- 8 PE Fittings shall be individually packed in bulk, bag or individual protection against contamination. Electrofusion fittings shall always be packed in a sealed bag or container. The packaging shall, as a minimum, be labelled with the manufacturer's name, quantity, type and dimension.

3.10.4 Pipes and Fittings for Gravity Applications

- 1 Pipes and fittings for drainage applications shall be suitable for carrying potable water, treated sewage effluent, raw sewage and surface water at temperatures up to 40°C as dictated by the particular application and they shall comply with the requirements of EN1519 or EN 12666, as appropriate.

3.10.5 Testing of MDPE and HDPE Pressure Pipes and Fittings

- 1 The raw material and pipe manufacturers shall document and certify all products and shall undertake all testing required by ISO 4427 and this specification.
- 2 Prior to delivery of any pipes or fittings the pipe manufacturer shall provide the Engineer with a comprehensive Inspection and Testing Plan (ITP) for their approval. The ITP shall detail all the certificates and documents that shall be provided by the pipe manufacturer, together with details of the testing that they shall undertake, its frequency and associated test reports. Where the pipe manufacturer cannot themselves undertake the required testing they shall employ an independent third party laboratory to undertake the testing on their behalf.
- 3 Definition of material, pipe and fittings batches for the purposes of batch release testing:
 - (a) A raw material batch shall be considered as a batch of material supplied by the resin producer having an individual identification number or code. For the purposes of this specification it shall also be the raw material used to manufacture a particular pipe batch.
 - (b) A pipe batch shall be considered as a continuous production run of a particular pipe OD and wall thickness manufactured from one resin type with no change in the manufacturing process.
 - (c) A batch of fabricated fittings shall be considered as group of fittings of the same OD and wall thickness.
- 4 The pipe manufacturer shall undertake the following minimum batch release testing.

Table 1 –Release tests to be undertaken on each raw material batch

Characteristics	Reference	Sampling Frequency	No. of Tests or Inspections
Compound Density	ISO 4427-1 section 4	Once per raw material batch	1
Oxidation induction time	ISO 4427-1 section 4	Once per raw material batch	1
Melt mass-flow rate	ISO 4427-1 section 4	Once per raw material batch	1

Table 2 – Release inspections and tests to be undertaken on each batch of pipes

Characteristics	Reference	Sampling Frequency	No. of Tests or Inspections
Appearance and colour	ISO 4427-2 section 5	Continuously	-
Geometrical	ISO 4427-2 section 6	Continuously	-
Marking	This specification	Each pipe or coil	1
Melt mass-flow rate	ISO 4427-2 section 8	Once per pipe batch	1
Elongation at break	ISO 4427-2 section 8	Once per pipe batch	1

Characteristics	Reference	Sampling Frequency	No. of Tests or Inspections
Tensile strength at yield on a sample cut from HDPE pipe	ISO 6259 (Tensile strength to be $\geq 19\text{ MPa}$)	Once per pipe batch	1
Tensile strength at yield on a sample cut from MDPE pipe	ISO 6259 (Tensile strength to be $\geq 15\text{ MPa}$)	Once per pipe batch	1
Longitudinal reversion	ISO 4427-2 section 8	Once per pipe batch	1

- 5 Pipe wall thickness shall be measured and controlled on a continuous basis using an ultrasonic thickness gauge or similar device that shall be regularly calibrated in accordance with the gauge manufacturer's recommendations.
- 6 In accordance with the recommendations of ASTM D 638, the maximum thickness of the tensile strength test samples cut from the pipe wall shall be 14 mm. In the event of the pipe wall being thicker than 14 mm the pipe manufacturer shall machine the test samples in accordance with the Table 3.

Table 3 – Preparation of samples for tensile testing

Pipe Wall Thickness (WT) (mm)	Test Sample Thickness (mm)	No. of samples to be taken from the pipe wall
≤ 14	WT	1
$14 < WT \leq 28$	WT/2	2
$28 < WT \leq 42$	WT/3	3
$42 < WT \leq 56$	WT/4	4
$56 < WT \leq 72$	WT/5	5

- 7 All testing shall be undertaken in accordance with ISO 6259 and all HDPE samples shall achieve a minimum tensile strength at yield of 19 MPa in order for the pipe to successfully pass the test. MDPE samples shall have achieved minimum tensile yield strength at yield of 15 MPa.

Table 4 – Release inspections and tests to be undertaken on each batch of fabricated fittings

Characteristics	Reference	Sampling Frequency	No. of Tests or Inspections
Appearance and colour	ISO 4427-2 section 5	Continuously	-
Geometrical	ISO 4427-2 section 6	Continuously	-
Marking	This specification	Each fitting	1
Hydrostatic strength at 20°C , 100hrs & $12.4\text{ MPa} \times f$	ISO 4427-3 Annex B	Once per batch of HDPE fittings	1 piece only
Hydrostatic strength at 20°C , 100hrs & $10\text{ MPa} \times f$	ISO 4427-3 Annex B	Once per batch of MDPE fittings	1 piece only

- 8 The fabricated fitting to be hydrostatically tested shall be a tee or branch provided the batch in question contains this type of fitting, otherwise a bend shall be tested.
- 9 In the case of injection moulded fittings the manufacturer shall issue a certificate confirming compliance with ISO 4427 and providing details of the type testing undertaken by an independent third party in accordance with sections 7 and 8 of ISO 4427 – Part 3.
- 10 The pipe manufacturer shall provide the Engineer with a copy of the batch release tests i.e. all those tests listed above, with each batch of pipes or fittings that is delivered to site.
- 11 Prior to delivery of pipes the pipe manufacturer shall provide the Engineer with copies of all the test results and certification required by ISO 4427, this specification and the ITP, but which are not covered by the above batch testing requirements. These documents shall comprise the Type Test Report.
- 12 The Type Test Report shall include a copy of the raw material manufacturer's "Certificate of Quality Control Testing" covering each batch of raw material used for manufacturing pipes produced under this specification.
- 13 The pipe manufacturer shall ensure that all the applicable codes and standards are available at their facility for the Engineer's reference during any visit or inspection.
- 14 The pipe manufacturer shall provide full assistance and co-operation for any inspection, when required by the Engineer or by an inspector appointed by the Engineer.
- 15 The Engineer may reject any item that does not successfully pass the required tests or fully comply with the requirements of this specification. When a pipe or fitting is rejected, the items manufactured immediately before or after shall be carefully examined and tested at the direction of the Engineer. If further defects are found, the entire batch shall be rejected.
- 16 All pipes and fittings shall be visually inspected by the PE Welding Inspector before incorporation in the Works.
- 17 In addition to those tests specifically required, the Engineer may request additional samples of any material for testing by the Engineer and all expenses incurred in obtaining samples for testing shall be borne by the Contractor at no additional cost to the Contract.

3.11 POLYESTER RESIN CONCRETE (PRC)-PIPING SYSTEMS FOR NON-PRESSURE DRAINAGE AND SEWERAGE

3.11.1 General

- 1 Polyester resin concrete is a mixture formed from aggregates and fillers which are bound together using a polyester resin (also called Polymer concrete pipes), as defined in ISO 18672-1 or ASTM D 6783 with the amendments given below.
- 2 Polyester resin concrete is permitted for use in infrastructure drainage and sewage systems (pipes, manholes, soakways).

3.11.2 Resin

- 1 The resin used in the pipe system and manufactured as per ISO 18672-1 shall have a temperature of deflection of at least 85 °C, when tested in accordance with Method A of ISO 75-2 with the test specimen in the edgewise position. It shall also conform to the applicable requirements of EN 13121-1.
- 2 The resin used in the pipe system and manufactured as per ASTM D 6783 shall have a minimum deflection temperature of 85°C when tested at 1.82 MPa following Test Method D648. The resin content shall not be less than 7% of the weight of the sample as determined by test method D2584.

3.11.3 Minimum strength

1 The minimum strength classes for different pipe shapes are given below

Table 3.11.1
Minimum strength classes for pipes designated PRC-OC or PRC-TC

Nominal size DN	Strength class S_c N/mm	
	PRC-OC	PRC-TC
150 ≤ DN ≤ 500	180	180
600 ≤ DN ≤ 1000	145	160
1200 ≤ DN ≤ 3000	120	145

Table 3.11.2
Minimum strength classes for pipes designated PRC-OE or PRC-TE

Nominal width/height WN/HN	Strength class S_c N/mm	
	PRC-OE	PRC-TE
300/450 ≤ WN/HN ≤ 600/900	180	180
700/1050 ≤ WN/HN ≤ 1000/1500	145	160
1200/1800 ≤ WN/HN ≤ 1400/2100	120	145

Table 3.11.3
— Minimum strength classes for pipes designated PRC-OK or PRC-TK

Nominal size DN	Strength class S_c N/mm	
	PRC-OK	PRC-TK
800 ≤ DN ≤ 1000	145	160
1200 ≤ DN ≤ 1800	120	145

END OF PART