TECHNO-COMMERCIAL HANDBOOK

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EFFECTIVE FILAMENT WINDING® PIONEERS

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THE AIM OF THIS HANDBOOK

Our experience has demonstrated that the sales of products, which are made of the non-traditional materials, require a general knowledge of all technical aspects regarding the product, the fabrication technology, and its application.

The sales activities are, rather than on the economic aspect, based on the popularisation of the characteristics of the GRP and on the promotion of the advantages this material is able to offer to the end-user in comparison with the traditional solutions.

The promotional aspect is even more important in those markets that have only in recent years begun to look with interest at Glass fibre Reinforced Plastics - GRP and to the advanced processing technologies.

The aim of this handbook is to summarize all the information necessary for the technical and sales staff and to provide an understanding of what GRP actually is.

TERMINOLOGY

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Unless otherwise indicated, the terminology used in this handbook shall conform to the definitions given in the ASTM Designation D 883- 92d (the standard nomenclature for plastic materials). Here we list the most important terms and their relative explanations (in part taken from the mentioned American Standard).

A

Accelerator	Also called the "*promoter*" or "*hardener*". It is a chemical compound used together with a catalyst to shorten the polymerization time at the ambient temperature. It is an additive to the polyester resin and it reacts with the catalyst to speed up the polymerization. This additive is required for the resins that are cured at a room temperature. See ***Promoter***.
Acetone	A ketone group solvent, used to dissolve the polyester resins. It is largely used for cleaning up the tools in the fibreglass operations.
Adapter	A fitting used to join two pieces of a pipe, or two pipe fittings which have different joining systems.
Additive	Any number of materials used to modify the properties of the polymer resins. Categories of additives include reagents, fillers, viscosity modifiers pigments and others.
Aggregate	A siliceous sand, conforming to ASTM C33, except that the requirements for the gradation do not apply.
Aliphatic Amine Curing Agent	Aliphatic amines are the curing agents for the epoxy resins. Aliphatic amine cured epoxy resins cure at a room temperature, a property that makes them especially suitable for use in adhesives. Some filament-wound pipes use the aliphatic amine cured epoxy resins. The properties of these pipes depend on the specific amine used in manufacturing.
Alligatoring	A visible cosmetic defect in the exposed gel coat, which looks like wrinkled skin or alligator skin.
Anhydride Curing Agents	Anhydrides are widely used curing agents for the fibreglass reinforced epoxy pipe. The properties of these pipes depend on the specific anhydride used in manufacturing.

Antimony Trioxide	A fire retardant additive, used with resins.

B

B-stage	An intermediate stage in the reaction of a number of thermosetting resins in which the material swells when in contact with certain liquids and softens when heated, but may not entirely dissolve or fuse. The resin in an uncured thermosetting moulding compound is usually in this stage.
Bag Moulding	Using an elastic or woven material to apply an atmospheric force to a laminate. See ***Vacuum Bag Moulding*** and ***Pressure Bag***
Barcol Hardness	A measure of surface hardness made with an instrument called Barcol Impressor, in accordance with ASTM D-2583. The hardness value can be used as an indication of the degree of cure of the GRP laminates.
Binder	It ensures the glass bonds to the resin. It is one of the glass reinforcement size purposes.
Barrier Cream	A cream used to protect the skin from contact with the resins.
Bell & Spigot	A joining system in which two cylindrical surfaces come together to form a seal by adhesive bonding or by compression of an elastomeric gasket. The bell is the female end and the spigot is the male end. Elastomeric gaskets are generally O-Ring type and can also be doubled for increasing the sealing and to allow hydrotesting.
Bending radius	The allowable deflection of the pipe's centreline before damage occurs. The radius refers to an imaginary circle where the pipe length would be an arc.
Benzoyl Peroxide (Bpo)	One of the two initiators generally used for curing the polyester resin. BPO is used with the aniline accelerators or where heat is used to cure the resin. See ***MEKP***.
Bi-Directional	The reinforcing fibres which are arranged in two directions, usually at right angles.

Binder — A resin soluble adhesive which secures the random fibres in a chopped strand mat or in a continuous strand roving.

Bisphenol-A — A major ingredient used to make the most common type of the epoxy resin, the bisphenol-A epoxy resin. Also used as an intermediate to produce some of the polyester resins.

Blister — An imperfection, a rounded elevation of the surface, with boundaries which are more or less sharply defined. In shape it looks like a blister on the human skin. A flaw, either between layers of laminate, or between the gel coat film and laminate.

Buckling — Also called a “collapse”. In engineering, buckling is a failure mode, characterized by a sudden failure of a structural member subjected to high compressive stresses, where the actual compressive stresses at failure are smaller than the ultimate compressive stresses that the material is capable of withstanding. This mode of failure is also described as a failure due to the elastic instability. For GRP pipe, the failure is caused as the result of the application of a uniform pressure around the total circumference of the pipe. The force may be caused by an externally applied pressure or a vacuum inside the pipe. The mode of failure is usually related to stability and it results in the flattening of the pipe but can be caused by a compressive (shear) failure of the pipe wall.

C

Casting — The process of pouring a mixture of resin, fillers and/or fibres into a mould, as opposed to building up layers through the lamination. This technique produces different physical properties compared to lamination.

Catalyst — Also called the "initiator" or "hardener". It is an organic compound which, when added to the resin in the presence of the accelerators, determines the polymerization reaction at ambient temperatures.

	Technically considered an initiator, catalyst is the colloquial name given to the substance added to the resin or gel coat in controlled quantities to initiate a cure.
Caulk	An elastic material used to protect joints or connections from the external elements, particularly moisture.
Cavity	The space between a male and female mould set in which the part is formed. It is sometimes also used to refer to a female mould.
Centipoise	A unit of measure used to describe the viscosity of a liquid. The centipoise of a resin is measured with a Brookfield Viscometer for most polyester resin applications.
Collar	See ***Coupling***.
Compressive Force	The force that occurs when the opposing loads act on a material, thus crushing or attempting to crush it. In a pipe, the circumferential compressive forces happen due to the external pressure. The longitudinal compressive forces may happen due to heating of the end-restrained fibreglass pipe.
Coupling (collar)	A short, heavy-wall cylindrical fitting, used to join two pieces of the same sized pipe in a straight line. The coupling always has the female connection ends that can be threaded or that use the adhesive bonding or elastomeric seals. Couplings can be made from GRP or other materials (plastic, or steel).
CFW	The continuous filament winding process applied in the continuous GRP pipes manufacturing line.
“C” Glass	A borosilicate glass with marked inertness to chemicals, which is used in the reinforced polyesters in the form of a mat with a very low unit weight, or to fabricate surfaces in direct contact with aggressive liquids.
Chalking	A surface phenomenon indicating the degradation of a cosmetic surface. Chalking is a powdery film which appears lighter in colour compared to the original colour.
Chopped Strand Mat	A fibreglass reinforcement, consisting of short strands of fibre, arranged in a random pattern and held together with a binder. The mat is generally used in rolls consisting of 300 g/m^2 to 600 g/m^2 material.

Circumferential Filament Winding Filament winding with the filaments arranged perpendicularly to the axis of the tank or the pipe (winding angle towards 90° but not less than 80°).

Cloth A fibreglass reinforcement made by weaving strands of glass fibre yarns. Cloth is available in various weights measured in ounces per square yard or Kg/m2.

Composite A solid product consisting of two or more distinct phases, including a binder material (matrix) and a particulate or fibrous material.

Composite A chemical or mechanical bonding of dissimilar materials, such as glass fibre and the polyester resin, where the cumulative properties are superior to the individual materials.

Compression Mould A closed mould, usually a steel mould, used to form a composite under heat and pressure.

Contact Moulding A procedure for moulding the reinforced polyester products, where the raw materials are applied to the mould without pressure and are cured with the accelerator/catalyst system with or without the application of heat.

Compressive Modulus A description of a mechanical property, which measures the compression of a sample at a specified load. It is described in ASTM D-695.

Compressive Strength The stress a given material can withstand when compressed.

Connection Where two panels are attached to each other or a panel is attached to the building.

Contact Moulding Refers to the use of a single or open mould, onto which layers of polymer and reinforcement materials can be applied. Contact moulding is characterized by one finished cosmetic side.

Continuous Filament Strand An individual rod of glass with a small diameter, flexibility and a great or indefinite strength.

Also used when referring to gun roving where it stands for a collection of string like glass fibre or yarn, which is fed through a chopper gun in the spray up process.

Continuous Strand Roving	A bundle of glass filaments which are fed through a chopper gun in the spray up process.
Continuous Laminating	A process for forming panels and sheeting in which the fabric or mat is passed through a resin bath, brought together between covering sheets, and passed through a heating zone for cure. Squeeze rolls control the thickness and the resin content as the various plies are brought together.
Core	A low-density material used between the two FRP skins. Examples of the core materials are: the end-grain balsa wood, urethane foam, PVC foam and the various honeycomb materials.
Cracks	The thin fissures in a laminate, usually caused by the impact or excessive concentrated loads.
Crazing	The cracking of the gel coat or resin due to stress or strain.
Creep	The time dependent part of the strain, resulting from stress.
	Deformation or strain that occurs over time when a material experiences sustained stress. Creep is expressed in inch per inch (or millimetre per millimetre) per interval of time. A fibreglass pipe is subjected to creep at all temperatures when it is subjected to stress.
Cross Filament-Winding	Two or more helical windings, crossed at the design angle.
Cross-Linking	The formation of a three-dimensional polymer by interchain reactions, resulting in changes in the physical properties.
Cross-Linking	The chemical bonding of molecules which occurs in polymers during the curing transition from a liquid to a solid state.
Cure	The hardening of a thermoset resin system by heat and/or chemical action. It is the completion of the cross-linking process during which a composite develops its full strength.
Curing Agents	See ***Hardener***, ***Promoter***.
Cure Stages	The degree to which a thermoset resin has cross-linked. The three stages (in increasing cross-linking order) include: the B-stage, gelled stage, and fully cured stage.

Cure Time	The time span between the introduction of a catalyst or initiator to a polymer and the final cure.
Curing	Curing is a chemical process employed in polymer chemistry and process engineering that produces the toughening or hardening of a polymer material by cross-linking of polymer chains.
Cut and Mitred Fittings	Fittings manufactured by cutting, assembling, and bonding the pipe sections into a desired configuration. The assembled product is then overlaid with the resin-impregnated roving, mat or glass cloth, to provide the required strength.
Cyclic Pressure Rating	The pressure rating obtained as the result of performing the tests in accordance with ASTM D2992, procedure A. This method rates a pipe on the basis of 150 million cycles. This conservative approach results in lower pressure ratings for the pipes than the static testing but is useful in comparing the competitive products. It is generally required for the pipes used in industrial piping systems, rather than for the civil applications.

D

Delamination	A physical separation with loss of adhesion due to creep in two neighbouring plies within the laminate. It is the separation of the composite layers from each other.
Density	A comparison of weight per volume, measured in pounds per cubic foot.
Design Factor (Factor of Safety)	A number equal to (or greater than) 1.0. it expresses how much stronger a system is than it needs to be for an intended load. Test data is divided by the design factor to obtain the allowable values. It is also called the ***Safety Factor***.
DFW or DW	The Discontinuous Filament Winding. It is the process or the machine for the reciprocating (discontinuous) cross and hoop filament winding of the impregnated rovings. Also called **FW.**

Dielectric Strength	The value of a material as an electrical insulator or the resistance to the flow of the electrical current.
Dimensional Stability	A description of the change in size of an object during the melding process, or in varying temperature conditions, or under various loads.
Distortion	The alteration of the original shape (or other characteristic) of the laminate. It may happen due to the laminating and curing problems, or resin shrinkage.
Distortion Temperature	The temperature at which a laminate, when subjected to a given load, undergoes a pre-established deflection.
Draft	The angle of the vertical components of a mould which allows the part to be the removed.
Drift Diameter	A measure of the effective minimum internal diameter of a pipe, including ovality and longitudinal warpage.
Dry Spot	An imperfection in reinforced plastics, an area of an incomplete surface film where the reinforcement has not been wetted out with the resin.

E

"E"- Glass	A borosilicate glass with a special chemical composition, which has an excellent mechanical strength and dielectric rigidity. The E-glass is the most common glass formulation used in fibreglass reinforcements and it was originally formulated to be used in electric circuitry.
Elastic Limit	See ***Proportional limit***.
Elastic modulus (Modulus of Elasticity)	In solid mechanics, Young's modulus (E) is a measure of stiffness of a given material. It is known as the Young modulus, modulus of elasticity, elastic modulus, or tensile modulus (the bulk modulus and the shear modulus are different types of elastic modulus). For small strains, it is defined as the ratio between stress and strain. This can be experimentally determined from the slope of a stress-strain curve, created during the tensile tests, conducted on a sample

of the material. It can also be defined as the slope of the stress–strain curve within the elastic range. For the composite materials such as GRP, different E-modulus are generally defined, either in relation to the fibres orientation (for example, we can consider the pipe's circumferential modulus and axial modulus), or to the type of the applied stress (tensile, flexural, compressive).

Elongation — It is the standard measure of how much a sample can stretch, as a percentage of the original length, before it fails or breaks.

Encapsulating — Completely surrounding an object with the resin or a fibre resin composite.

Epoxy Resin — A polymer resin, characterized by the epoxide molecule groups. Epoxies generally have higher physical properties than polyester resins. They are also costlier, more difficult to process, and less capable of enduring the exposure to sunlight.

Exothermic Heat — The internally developed heat which accompanies a chemical reaction. It is generally created when curing a thermosetting resin.

F

Fabricator — A manufacturer of reinforced plastic products.

Fatigue — The permanent structural damage in a material which has been subjected to the fluctuating stress and strain.

Female Mould — A concave mould used to precisely define the convex surface of a moulded part.

Fibre — A reinforcement material which is a major component in a composite matrix.

Fibreglass — The glass which has been extruded into extremely fine filaments. These filaments vary in diameter and are measured in microns. Glass filaments are treated with special binders and processed similarly to the textile fibres. These fibres come in many forms such as roving, woven roving, mat and continuous strands.

Fibreglass Pipe	A tubular product containing glass-fibre reinforcements, embedded in or surrounded by the cured thermosetting resin. The composite structure may contain an aggregate, granular, or platelet fillers, thixotropic agents and pigments or dyes. Thermoplastic, thermosetting liners, or coatings may be included.
Filament	A single thread-like fibre of extruded glass. Typically, microns in diameter.
Filament	An elementary thread of indefinite length, obtained by drawing molten glass.
Filament Winding	A procedure for fabricating the composite structures. During the procedure, a reinforcement, consisting of the continuous glass filaments, is applied to the rotating mould. The reinforcement has previously been impregnated or undergoes impregnation when it is in position.
Filament Winding In The Dry State	An operation during which the generally rich in resin filaments are applied to a ply, without previous impregnation, to increase the mechanical strength.
Filler	An inert, non-fibrous material added to the resin to modify the certain characteristics of the resin (for instance the stiffness, workability, viscosity, cost and so on).
Fire Retardants	Compounds mixed with the resin to reduce flammability.
Fish-Eye	The effect of the surface contamination which causes a circular separation of a paint or gel coat. It is a small globular mass that has not completely blended into the surrounding material.
Fitting Types	The classification of fittings by the method of manufacturing (i.e., moulded, cut and mitred, filament wound).
Flame Retardant Resin	A polyester resin which has been specifically formulated to reduce the flame spread and/or smoke generation.
Flammability	A measure of how fast a material will burn under controlled conditions. The ASTM D-635/UL E-84 tests.
Flange	A flange is an external or internal ridge for the purpose of stiffening or connecting two components.

Flash Point — The lowest temperature at which a substance gives off enough vapours to form a flammable mixture.

Flexibilizing Agent — A material added to the resin to improve the characteristics of the resin in regard to flexibility and elongation at break.

Flexural Modulus — An engineering measurement which determines how much a sample will bend when a given load is applied. ASTM D-790.

Foam — A lightweight, cellular plastic material containing gas-filled voids. Typical foams include: urethane, PVC, and polyester.

Foam-In-Place — It is the process of creating a foam by combining two liquid polymers. See ***In-Situ***.

FRP — Fibre Reinforced Plastics, also known as GFRP (Glass Fibre Reinforced Plastics), or GRP (Glass Reinforced Plastics) or RP (Reinforced Plastics).

FWM — The machine for the reciprocating (discontinuous) cross and hoop filament-winding of the impregnated rovings. Also ***DFW.***

G

Gel — The initial gelatinous state, developed during the polymerization of a thermosetting resin. It is the irreversible point at which a polymer changes from a liquid to a semi-solid state. Sometimes called the ***B-stage***.

Gel-coat — A thin ply of an unreinforced resin, formulated to ensure maximum resistance to chemical attacks by creating an impermeable barrier. It is a surface coat made of a specialized polyester resin, either coloured or clear, which provides a cosmetic enhancement and weatherability to a fibreglass laminate.

Gel-time — The time span, when a resin, which contains the accelerator and the catalyst, maintains viscosity that is low enough to be worked. The time span from the catalysation to gel or B-stage.

Gelation — The formation of a gel.

Glass Fabric	A bi-directional reinforcing material made by weaving glass-fibre yarn.
Glass fibre	A filament of glass, chopped to a measurable size.
Glass roving	An assemblage of parallel or slightly twisted glass filaments.
Glass transition temperature	The approximate mid-point of the temperature range when the glass transition takes place, i.e., the reversible change from a hard and relatively brittle condition of the polymer into a viscous or rubbery one.
Good Side	The side of a moulding in contact with a mould surface.
Green	A resin which has not completely cured and is still rather soft and rubbery.
GRP	Glass Reinforced Plastics. Generally based on polyester resin. See ***Fibreglass***, ***FRP***.

H

Hand Lay-Up	A procedure for lay-up, impregnation, and processing of the successive reinforcing plies by hand. It is the process of manually building up layers of fibreglass and resin, using hand rollers, brushes, and spray equipment.
Hardener (accelerator, catalyst, curing agent, promoter)	Any number of chemicals added to the resin, individually or in combination, that speed up the curing process or cause the occurrence of hardening.
Heat Distortion Point (HDT)	The temperature at which the strength of a material begins to degrade.
Helical filament winding	Winding an assembly of filaments with a different angle in respect of the axis of the mandrel.
HET-Acid Resin	A polyester resin with exceptional fire resistant qualities.
Honeycomb Core	Strips of paper, plastic, metal, etc., joined together to form a honeycomb pattern. They are used as a lightweight core in sandwich mouldings.
Hoop Stress	A circumferential stress in a pipe. See also ***Burst strength***.

Hydrostatic Design Basis (HDB)	The long-term hydrostatic hoop strength of a specific fibreglass pipe material for water service, as determined by the tests and detailed evaluation procedures in accordance with ASTM D2992.

I

Impregnation	In the case of reinforced plastics, it indicates saturation of the glass reinforcements with the resin.
Impregnate	To saturate with the resin. The most common application is saturating fibreglass with a catalysed resin.
Inhibitor	An additive to the polyester resin or styrene, used to slow the chemical reaction which leads to curing. It is a material added to a resin to reduce its reactivity at the ambient temperature.
Insert	A piece of material put into a laminate during or before moulding to serve a definite purpose.
Integral joint	A joint configuration in which the connection is an integral part of the pipe. A length of pipe with integral joints will have one male end and one female end. This is for example the Bell & Spigot Joint.
Intumescent	A fire-retardant technology which causes an otherwise flammable material to foam and so forms an insulating barrier when exposed to heat.
In-situ	A Latin phrase that translates literally to "on site" or "in position." It can mean "locally", "on site", "on the premises", or "in place" to describe where an event takes place, e.g. moulding.
Isophthalic **Isopolyester**	A polyester resin based on the isophthalic acid, generally with higher properties than a general-purpose resin, e.g. orthophthalic polyester resin.
Isotropic	Having an equal strength property which has the same value when measured in all orientations. Isotropic composites are usually achieved by random fibre orientation.

Isotropic Laminate	A laminate with a mechanical strength which is equal in all directions on the plane of the laminate.

J

Jackstrawing	A visual effect of the glass fibre turning white in a cured laminate. This may not affect the strength of a laminate but could be an indication of entrapped air or water contamination.
Jig	Any fixture for holding parts in position while joining them together or to maintain their shape.
Joining (connecting) systems	Any of a variety of methods for connecting two separate components of a piping system. For example, the bell-and-spigot, threaded, coupling, and mechanical devices.
Joint	A term used to describe an individual length of a pipe as well as the actual joining mechanism (i.e., adhesive-bonded bell-and-spigot, threaded, gasketed bell-and-spigot, gasketed coupling, etc.).
Joint	A line or distinction which forms when two panels are connected. Also referred to as a seam.

L

Laminate	A product obtained by successive lay-ups of glass reinforcements impregnated with resin.
Laminate	To place/lay-up a series of layers of polymer and reinforcement into a mould. The act of applying the FRP materials to a mould.
Laminant	The product of lamination. A composite consisting of a layer, or layers, of a thermoset polymer and a fibre reinforcement.
Lamination	To apply layers of glass and resin to a mould. Also used to describe a single ply of laminate.

Layer	A single ply of lay-up or laminate.
Lay-Up	The act of building up successive layers of the polymer and reinforcement. Layers of the catalysed resin and fibreglass, or other reinforcements, are applied to a mould to manufacture a part.
Liner	The continuous corrosion-resistant lining, which is rich in resin and forms the inner wall of the pipe, to ensure its hydraulic tightness and inertness to chemicals. Liner can be a filled or an unfilled thermoplastic or a non-reinforced or reinforced thermosetting resin.
Low-Pressure Laminates	Laminates which are moulded and cured using pressures up to 400 psi.

M

Male Mould	A convex mould where the concave surface of the part is precisely defined by the mould surface.
Mandrel	The rotating mould on which the lay-up and/or filament winding operations are carried out.
Master	A full-scale representation of the intended part, usually retained as a reference, and the part from which the production moulds are made.
Mat (Chopped Strands Of Glass Fibres)	The glass fibres arranged isotropically (randomly oriented) flattened into a sheet with a bonding agent soluble in the resin, to form a mat of varying lengths and widths. The mat is available in several unit weights of glass per unit of surface (gr/sq. metre). See ***Chopped Strand Mat***.
Matched Die Moulding	A technique for producing long runs of identical parts with two finished sides.
Matched Moulds	Two or more tools arranged in a set as a male and female mould. Normally used in a press.
Matrix	The liquid component of a composite or laminate. It is the resin material used to bind the reinforcements and fillers together. This resin may be epoxy or polyester and, to a large

	extent, dictates the temperature and the chemical performance of a pipe or fitting.
Mek Peroxide (Mekp)	Methyl Ethyl Ketone Peroxide is one of two initiators, often referred to as a catalyst, used to initiate the polymerization of the resin. (See ***Benzoyl Peroxide***).
Mek Solvent	Methyl Ethyl Ketone is a colourless, flammable liquid, sometimes used in clean up procedures.
Microballoons	Microscopic bubbles of glass, ceramic, or phenolic, used as a filler or to create a syntactic foam or putty mixtures.
Mil (Mil Thickness)	The unit used to measure the film thickness. One mil equals one thousandth of an inch. (1 mil = .001” = 25.4 micron).
Milled Fibres	The glass fibre processed by a hammer mill into lengths of 1/32” (0.8 mm) to 1/8” (3.2 mm). Commonly used as a reinforcement in a polyester putty.
Mitred fittings	See ***Cut and Mitred Fittings***.
Modulus Of Elasticity	An engineering term, used to describe the material’s ability to bend without losing its ability to return to its original physical properties. See ***Elastic Modulus***.
Mould	The tool used to fabricate the part in the desired shape. Also used to describe the process of making a part in a mould.
Moulding	The process of using a mould to form a part.
Mould Release	A wax or polymer compound that is applied to the surface of the mould and acts as a barrier between the mould and the part, thus preventing the part from bonding to the mould.
Moulded fittings	Pipe fittings formed by the compression of resin, chopped fibre, and other ingredients in a mould under heat and pressure.
Monomer	One of the components of the polyester resin. It is a low-molecular weight substance, usually liquid, which is capable of providing polymers with a high molecular weight. In the case of the polyester resins, the monomer links the linear chains of polyester to give molecules with a three-dimensional structure.

N

Net	A thin net of cotton or synthetic fibres.
Npg Gel Coat	Neopentyl glycol gel coat has an enhanced weatherability compared to the non-NPG gel coat.
Non-Air-Inhibited Resin	A resin in which the surface cure will not be inhibited or stopped by the presence of air.

O

Orange Peel	A gel coated finish or a painted finish which is not smooth and is patterned similarly to an orange's skin.
Orthophthalic Resin Ortho	A polyester resin based on the orthophthalic acid, also known as a general purpose resin (GP).
Orthotropic Laminate	A laminate with the mechanical strength which is localized in two directions at right angles to each other, on the plane of the laminate.

P

Parting Agent	See ***Mould Release*** and ***PVA***.
Parting Line	In industrial casting of moulds, it is the border line in which draft angles change direction. It is the dividing line that splits the core and cavity halves of a moulded part
Pattern	The initial model for making the fibreglass moulds. See ***Plug***.
Pigment	A colorant added to the gel coat or resin.
Pigment Separation	It occurs when the pigment is not thoroughly mixed into the gel coat during the formulation or when the gel coat is improperly mixed prior to use. It is characterized by a nonhomogeneous surface colour.

Pin	The male end of a pipe or fitting that matches with the female end of another pipe or fitting.
Pinholes	Small holes on the exposed gel coated surface. They have the diameter of common pins and can be easily counted.
Pipe Stiffness	The force required to deflect a pipe ring for a certain mount. According to the US standards, it is defined as: $$PS = \frac{F}{\Delta y} \text{ [psi]}$$ According to the European standards, it is defined as: $$S = \frac{EI}{D^3} \text{ [Pa].}$$ The relation between *PS* and *S* is: $$S \text{ [Pa]} = 128\ PS \text{ [psi]}$$ Please see the Engineering Handbook, chapter – "General Design Specification" for further details.
Plastics	Organic chemical compounds, called polymers, which can be formulated to produce a wide range of properties.
Plug	A composite industry name for a pattern or a model.
Poisson's effect (ratio)	The property of a material that causes a change in its dimensions due to a force applied perpendicular to the plane of the dimension change. Expressed as the ratio of the lateral strain to the load direction strain. For the GRP it is widely variable with the glass to resin ratio and with the fibre reinforcement orientation.
Polyester Resin	The family of thermosetting synthetic resins obtained by esterification of the polybasic organic acids or the respective anhydrides with polyalcohols. They are used as a bonding agent for the reinforcing material in the reinforced polyester. They are resins that are normally cured by cross-linking with styrene. The physical and chemical properties of the polyester resins vary greatly. Some have excellent chemical and physical properties, while others do not. Vinyl esters are a specific type of polyester resin. Polyester resins with

	properties that are suitable for the manufacturing of a fibreglass pipe include: the orthophthalic, isophthalic, bisphenol-A fumarate, and chlorendic anhydride acid polyesters. Each type of resin has strengths and weaknesses for a given piping application.
Polyester (unsaturated)	The product of an acid-glycol reaction, commonly blended with a monomer to create a polymer resin. In its thermosetting form it is the most common resin used in the FRP industry.
Polymer	A chemical compound, normally organic and with a high molecular weight, consisting of one or more simple units which are repeated in a regular manner.
Polymer	A chain molecule composed of many identical groups, commonly found in plastics.
Polymerization	The chemical bonding of the polymer molecules during the curing reaction.
Polyvinyl Alcohol (PVA)	A parting film applied to a mould to release the part.
Porosity	Entrapped gas bubbles or voids in a gel coat film.
Post-Cure	To cure by applying heat after the chemical exothermic reaction has subsided.
Post-Curing	A heat treatment normally carried out without pressure. It follows the initial curing of the reinforced polyester resin. Its purpose is to increase the inertness to chemicals and the mechanical strength.
Pot Life	The time during which the catalysed resin remains liquid or "workable." retaining its physical-chemical properties (life in the tin) unaltered (viscosity, reactivity, colour, etc.). See also ***Gel Time***.
Premix	Reinforcing material mixed with resin, and usually with pigment, filler and catalyst, before placing it in the mould.
Prepreg	Reinforcing material impregnated with resin prior to the moulding process and cured by the application of heat.

Pressure Bag	A membrane which conforms to the inside of a laminate laid up on a mould. The membrane or bag is then inflated to apply the pressure which consolidates and densifies the laminate.
Pressure class	The maximum sustained pressure for which the pipe is designed. It refers to the short-term burst pressure and to the long-term pressure resistance of the pipe. Different safety factors are applied: generally 4x for the short term burst test and 1.8x (or 2x) for the long term pressure resistance.
Print Through	A distortion in the surface of a part, allowing the pattern of the core or the fibreglass reinforcement to be visible through the surface. Also known as "print out", "telegraphing", or "read through".
Promoter	A reagent which speeds the curing of the resin, also called the *hardener*. See ***Accelerator***.
Proportional (elastic) limit	The greatest stress a material can sustain for a short period of time without causing permanent deformations. It is defined by the point at which the stress–strain curve deviates from linearity. For the composite materials, this point is called the apparent elastic limit, since it is an arbitrary approximation on a nonlinear stress–strain curve. See the ***Stress–strain diagram***.
Putty	A thickened mixture of resin made by adding fillers, thixotrophs, and reinforcing fibres.
Pva	See ***Polyvinyl Alcohol***.

R

Reducer	A pipe fitting used to join two different-sized pieces of a pipe. With the same centreline in both pipes, the reducer is concentric; if centrelines are offset, it is eccentric
Reinforced Polyester	A composite material, consisting of the various kinds of reinforcements bonded with the polyester resins to make structures, which possess much greater mechanical strengths than the basic resins.

Reinforced Moulding Compound	A compound consisting of a polymer and a reinforcement fibre or filler, supplied by a raw material producer in the form of the ready-to-use materials.
Reinforcement	A fibre which, when encapsulated in a polymer resin matrix, forms a composite or the fibreglass laminate. Also refers to a structural member designed to stiffen a moulded part. The glass fibres are used to provide strength and stiffness to a composite material. The form of the reinforcement plays a major role in determining the properties of a composite, as well as the fibre diameter and the type of sizing. Terms relating to the physical form of the reinforcement include: • Chopped fibre - continuous fibres cut into short (30 mm to 70 mm) lengths; • Filament - a single glass fibre (e.g., a monofilament); • Mats - a fibrous material consisting of random-oriented, chopped or swirled filaments, loosely held together with a binder; • Milled fibres - glass fibres which are ground or milled into short (0.81 mm to 3.2 mm) lengths.; • Roving - a collection of parallel glass strands or filaments and coated with a finish or a coupling agent to improve compatibility with the resins, gathered without mechanical twist. Roving may be processed in a continuous or chopped form; • Yarn - glass-fibre filaments, twisted together to form textile type fibres; • Yield – the amount material in yards, made from one pound of product.
Release Agent	A compound used to reduce the surface tension or adhesion between a mould and a part. A compound which prevents adhesion of the laid-up product to the mould.

Resin	A liquid polymer which cures to a solid state when catalysed. They are solid or pseudo-solid organic materials, often with a high molecular weight and with no definite melting point. In the broad sense, the term is used to designate any polymer that is a basic material for plastics.
Resin Tearing	The separation of pigments in a gel coat which affects the cosmetic appearance.
Roving	A collection of bundles of continuous filaments in untwisted strands. Used in the spray-up (chopping) process.
RPMP	Reinforced Polymer (or Plastic) Mortar Pipe - A fibreglass pipe with an aggregate.
RTRP	Reinforced Thermosetting Resin Pipe - A fibreglass pipe without an aggregate.

S

Sandwich Construction	A laminate with two composite skins separated by the structural core material, but also bonded to it. They are used to create stiff, lightweight structures.
Seam	See ***Joint***.
Self-Extinguishing	The ability of a material to stop burning once the source of the flame has been removed.
Self-Tapping Screws	Hardened screws which cut their own thread as they are set.
Service factor	A number less than (or equal to) 1.0, which takes into consideration the variables and degree of safety involved in a design. The service design factor is multiplied by the test values to obtain the design allowables. It is the reciprocal of the design factor.
Shear	An engineering term referring to the forces that are normally applied to the surface of a given material. The movement between the plies of a laminate is referred to as the interlaminate shear.

Shelf Life	The allowable length of time that a product may be stored for, without becoming unfit for use.
Ship Lap	Method of joining two panels together. One panel has a recessed shelf to receive the other panel on top of it, leaving a flush surface.
Size	An assemblage of compounds used during the extrusion of the glass to make the individual fibres workable and to protect them. The size usually contains the binder.
Skin Coat	The first layer of a laminate next to the gel coat, generally, one ply of chopped strand mat.
Specific Gravity	The ratio between the density of a given substance and the density of water.
Split Mould	An open mould made in two or more pieces.
Spray Up	The process of spraying glass fibres, resin and catalyst simultaneously into a mould using a chopper gun. It is a process for laying-up reinforced plastics, which is carried out with a suitable equipment that sprays the accelerated resin, catalyst and roving threads, which are chopped at pre-determined lengths. The sprayed-up material assumes an isotropic lay-out and is worked either mechanically or by hand.
Static pressure rating	The recommended constant pressure at which a pipe can be continuously operated for long periods of time without failure. It is determined by conducting tests in accordance with ASTM D2992, procedure B.
Stiffness / Stiffness Class	See ***Pipe stiffness***.
STIS	See ***Stiffness***.
Strand	See ***Roving***.
Strain	The dimensional change per unit of length resultant from the applied force or load. It is measured in inch per inch (or millimetre per millimetre).
Stress	The force per unit of the cross-sectional area. Measured in inch per square inch (or kilopascals).

Stress–strain diagram	A graphic presentation of unit stress versus the corresponding unit strain. As the load increases, elongation or deformation of the material also increases. The slant of the diagram is the E-Modulus.
Styrene Monomer	A component of the polyester resin that provides cross linking sites and reduces the polyester to a workable viscosity.
Support spacing	The recommended maximum distance between the pipe supports to prevent excessive pipe deformation (bending). *This is valid for the above ground installation.*
Surface layer	A filled or unfilled resin layer, non-reinforced or reinforced, applied to the exterior surface of the structural wall of the pipe.
Surface Mat	A lightweight tissue of glass or synthetic fibre (10-30 mils thick), which is used to provide a resin-rich surface. It is a mat with a low unit weight which consists of the continuous C glass fibres. A surfacing mat can also consist of synthetic fibres. See ***Veil***.
Surfactant	Chemicals used to modify or change the surface of a layer of the resin or polymer. Usually used to form a film on a curing resin, producing a tack-free surface.
Surge allowance	The portion of the surge pressure that can be accommodated without changing the pipe pressure class. The surge allowance is expected to accommodate the pressure surges usually encountered in the typical water distribution systems.
Surge pressure	A transient pressure increase, which is greater than the working pressure, sometimes called water hammer. It is anticipated in a system as a result of a change in the velocity of the water, such as when valves are operated or when the pumps are started or stopped.
Syntactic Foam	Foam made by mixing the micro spheres with a resin.

T

Tack	Surface stickiness.
Tack Free	A surface which is not sticky after cure.
Tape	A narrow width reinforcing fabric or mat. It is a unidirectional glass-fibre reinforcement, consisting of rovings which are knitted or woven into ribbon form.
Tensile Load / Force	A stretching force that acts on an object along its length, causing tension, opposite of compression.
Tensile Elongation	An engineering term referring the stretching that a material undergoes as it is pulled in tension. ASTM D-638.
Tensile Strength	A measurement of the tensile load a sample can withstand. ASTM D-638.
Tex	A standard of measurement, generally used for measuring the weight of the glass roving (1 tex = 0.001 g/m).
Thermal Coefficient of Expansion	Measures the dimensional change of a material when it is heated or cooled. It is measured in inches per inch per degree.
Thermal Conductivity	Measures the transfer of heat through a material. It is the rate at which a material transmits heat from an area of high temperature to an area of lower temperature. A fibreglass pipe has low thermal conductivity.
Thermal expansion	The increase in dimensions of a material resulting from the application of heat. Thermal expansion is positive as the temperature increases and negative as the temperature decreases.
Thermoplastics	A group of plastic materials which become elastic or melt when heated and return to their rigid state at room temperature. Examples of these materials are: PVC, ABS, polystyrene, polycarbonates, nylon, etc. These plastics can be repeatedly softened by heating and hardened by cooling. In the softened state they can be fused or shaped by flow.
Thermoset	Materials that undergo a chemical cross-linking reaction, going from a liquid state to solid or semi-solid state. This reaction is irreversible. The polymeric resin is cured by heat

or chemical additives. Once cured, a thermoset resin becomes essentially infusible (cannot be remelted) and insoluble. The thermosetting resins used in a pipe generally incorporate reinforcements.

Typical thermosets include:

- epoxies;
- amine cured materials;
- anhydride cured materials;
- aliphatic polyanhydrides;
- cycloaliphatic anhydrides;
- aromatic anhydrides;
- novolac or epoxy novolac;
- unsaturated polyesters;
- orthophthalic polyester;
- isophthalic polyester;
- bisphenol-A fumarate polyester;
- chlorendic acid polyester;
- vinyl esters;
- bisphenol-A methacrylates;
- bisphenol-F methacrylates.

Thixotropic A term describing the rheology (or characteristics) of a liquid that resists flowing or drainage during the application.

Thixotropic Index (T.I.) A measure of thixotropy using a Brookfield Viscometer. It is the low speed viscosity divided by the high speed viscosity.

Thixotropy The characteristic of a liquid which has a low dynamic viscosity and at the same time, a high static viscosity.

Thrust forces It is commonly used to describe the forces resulting from changes in direction of a moving column of fluid. It is also used to describe the axial or longitudinal end loads at fittings, valves, etc., resulting from the hydraulic pressure or thermal expansion.

Tooling Gel Coat A gel coat formulated for mould surfaces.

Torque Used to quantify a twisting force (torsion) in a pipe. Torque is measured as a force times the distance from the force to the

	axis of rotation. Torque is expressed in foot-pounds (ft-lb) or inch-pounds (in.-lb), or Newton meters (N-m).
Translucent	It permits a percentage of light to pass through, but it is not optically clear like window glass.

U

Undercut	An area of a part (or a mould), which has an acute angle between two surfaces. If a part has an undercut, a split mould is necessary.
Unidirectional	Strength lying mainly in one direction. A glass reinforcement in which the fibre is oriented in one direction.
UV Stabilizer	A chemical compound which improves the resistance to degradation from the ultraviolet radiation.

V

Vacuum Bag Moulding	It is a process for eliminating voids and forcing out the entrapped air and the excess resin from lay ups, by drawing a vacuum from a plastic film which blankets a laminate.
Vinyl ester	A premium resin system with an excellent corrosion resistance.
Viscosity	The liquid properties of a material. Resistance to flow.
Void Free	A moulding containing no entrapped air cavities, blisters, or voids.

W

Water Absorption	The amount of water which a laminate will absorb.
Wax	A compound used as a release agent. See ***Release Agent***.

Weeping	Leakage of extremely small amounts of fluid through the pipe wall.
Wetting-Out	The action of saturating a glass fabric with the resin. It is also a measure of speed with which the fabric soaks up the resin.
Winding Tension	The force of traction exerted by the threads of roving during the filament-winding, at the point of their contact with the mould.
Working pressure	The maximum anticipated, long-term operating pressure of the water system, resulting from a normal system operation.
Woven Roving Fabric	Heavy fabrics woven from the continuous filament in roving form. They usually weigh between 500÷1000 g/m^2.

Y

Yarn	Twisted strands of roving, used to weave the textile reinforcements.

GRP PIPES

GRP PIPES

The Only Satisfactory Solution

in Many Applications

TABLE OF CONTENTS

1. INTRODUCTION

Considerable experience has been gained in how to make the GRP pipes, which are used in the chemical, petrochemical and industrial processing plants. This experience is a result of many years of engagement in the design and research in the field of applications of the fibreglass reinforced polyester resins. In the chemical, petrochemical and industrial processing plants, pipes have the specific task of conveying fluids which usually exert an abrasive and corrosive action.

In an industrial plant, the initial investment costs are very high, because of the dimensions occupied by the pipelines. But further costs, such as the maintenance work, are often present. It is precisely for these reasons that GRP pipes can offer truly worthwhile alternatives, and in many cases, they present the only valid solution from the technical and the economical point of view, compared to pipelines made of traditional materials.

GRP pipes are nowadays very competitive, because they ensure specific qualities, such as an intrinsic corrosion resistance, and functionalities, such as low hydraulic roughness and light weight, which are distinctly superior. Moreover, they provide these qualities at a cost that is comparable to the cost of the traditional pipes.

In addition, the costs of handling and installation are extremely low for above or below ground GRP pipelines, due to their well-known light weight and the ease with which they can be manipulated. Their weight is 3 to 5 times lower compared to the weight of the steel pipes and up to 20 times lower compared to the weight of the concrete pipes.

Because of the excellent results, achieved with the GRP pipes, their use has extended to many industrial applications, such as:

- energy production, with a particular reference to the sea water cooling systems or geothermal plants;
- water treatment;
- submarine pipelines;
- firefighting systems for industrial installations;
- any other field where reliability and long lifetime of the pipes is required.

GRP pipes have recently also became commonly used in the non-highly specialized fields, which are connected with the improvement of the manufacturing technologies and a consequent costs reduction. The development of the jointing systems has made pipe laying fast, economic and reliable, which has favoured the wide application of the GRP pipes. This is especially true for the applications where pipes are commonly used in big quantities, such as for the drinking water systems, irrigation and in sewage systems.

It is important to remember that the GRP pipes permit lower losses of pressure compared to the pipelines made of the traditional materials. Pressure losses are constant for short- and long-term periods. Therefore, this characteristic enables the GRP pipes with a smaller diameter to be used for the same application, considerably reducing the costs, which is especially important where big throughput is involved.

Last but not least, because of the thermosetting nature of the material itself and the presence of the glass reinforcement, GRP pipes possess a mechanical strength which is 3 to 5 times greater compared to the commonly used thermoplastic pipes.

GRP has a huge field of applications because it is inert to most industrial substances. It also does not release polluting substances, making it the recommended choice for conveying fluids where a high level of purity or suitability for human consumption is required.

GRP provides a very high thermal and electrical insulation, which makes any special cladding or energy consuming heating systems unnecessary. This is especially valuable when GRP is used to carry heat, or for the overland pipelines which carry chemicals, especially the ones subjected to freezing temperatures or increased viscosity.

Laying the GRP pipes above and below ground is a simple procedure which can be done in a short period of time, because sleeve joints and spigot and socket joints are generally used. Butt joints are limited to specials or to applications in the chemical industry.

Severe tests, which comply with the ASTM and other international standards and rules regarding thickness, stiffness, weights, and lengths of the individual pipe sections, ensure a high, constant quality in the entirety of the production.

2. WATER MAINS

In this very broad field, the most commonly used pipes are made of the following materials:

- steel;
- cast iron;
- high density polyethylene;
- GRP.

All these materials have some advantages and some disadvantages with regards to their characteristics and costs.

Upon closer examination of the nature of these four materials, it is easy to notice that GRP pipes, with comparable costs of investment, include all of the advantages offered by the other materials and at the same time, do not present any of the disadvantages.

2.1. Steel Pipes

Steel pipes, which are used for conveying drinking water, are often coated with the epoxy resins, applied in successive layers on the inside. In this situation, the only possible joint between the individual sections of the pipes is a flanged joint, which makes it necessary to use special arrangements during the transportation and handling to avoid damages of the inside coating or of the flange itself. Welded joints with reconstruction of the coating on site (which is possible only for the large diameter pipes) is a solution which is unacceptable from a technical point of view.

Internal epoxy coatings have a limited life (about 5 years), after which an extensive and concentrated pitting, due to corrosion, will become apparent. Expensive maintenance works or even replacement of the sections of the pipeline will be necessary.

The inner coating is fragile and stiff and therefore, the axial and circumferential stresses caused by the internal pressure in the line or by the setting of the ground, will result in flaking or small separations of the coating. This will then lead to corrosion.

Corrosion on the inner surface without treatment leads to an increase in roughness and facilitates the formation of deposits, additionally reducing the flow. New pipes have an average roughness of 0.03 to 0.05 mm, but the roughness of the used pipes may increase up to 0.2 ÷ 0.4 mm or more.

Protection: Corrosion of the steel pipes is caused by an electrochemical occurrence. In humid conditions, an electrical current is generated between the pipe and the external environment, causing the current to transition into a metallic solution as an ionic bond.

This removal of particles from the unprotected pipes causes a progressive thinning of the pipe wall, whilst in the protected pipes, it leads to the formation of holes in the liner at the points of any imperfections, even the microscopic ones.

The environmental conditions, which lead to corrosion in an underground steel pipeline, are mainly two:

- the aggressive nature of the soil: corrosion takes place due to the formation of galvanic cells, caused by the differences in potential, which is generated on the surface of the pipes;
- stray current: the pipe behaves like a conductor. In the area, where the current goes from the pipe to the earth (anode), a migration of ions happens, resulting in corrosion.

The protection of the steel pipes may be passive or active:

The purpose of the **passive protection** is to prevent the exchanges of electrical currents between the pipes and the ground. It is provided by insulation and waterproof coatings (bitumen or polyethylene coatings) and by inserting the insulating joints at the suitable positions, to interrupt the electrical continuity of the pipeline.

The passive type of protection provides an insufficient guarantee, because small defects or damages in the coating are enough to make it useless. Coating can be easily damaged during the transportation and laying of the pipes, which starts the corrosion that can very quickly perforate the pipe.

Active protection is achieved by sending a current through an appropriate auxiliary electrical circuit from the ground to the pipe, in the opposite direction of the corrosive currents. In this way there is no current passing from the pipe to the ground and corrosion is neutralized.

Active protection can also be achieved by connecting the pipeline to the elements sunk in the ground, which have a lower electrical potential than the pipeline. In this way, the electrical currents leave the pipeline through these elements, which undergo the corrosion instead of the pipe and are therefore also called the “sacrificial anodes”.

Both types of protection require constant maintenance of the power plant that imparts the opposite current, and maintenance of the consumed sacrificial anodes.

Active protection is always provided together with the passive protection.

Passive internal protection is particularly required for pipes which are used for sewerage and are empty most of the time. The protection is provided with bituminous and epoxy coatings and has the same shortcomings as the external protection, which is worsened by the inability to overlay the welds in small diameter pipes.

Laying of the buried steel pipes does not include any special problems, when modern equipment is used. Special care should be taken to avoid scratches on the outer, protective, anti-corrosion coatings. It is best to lay the pipes on a bed and between the side support backfilling, consisting of properly riddled materials or preferably sand, especially if the bottom of the trench is uneven or rocky.

2.2. Cast Iron Pipes

In spheroidal cast iron pipelines with a rapid joint, the joints are usually clamped with bolts or rings to suit the static working conditions. The material used for these connections must be corrosion resistant and must not damage the protective coating of the seating.

In the grounds where clayey loams and geological electric piles are present, the outer coating needs additional protection, besides an insulating film, which protects the pipe from the mechanical action of the ground, especially from the swelling and shrinking of the clay against the protective film. Because of that, experts in cast iron recommend an outer polythene protective reinforcement, to avoid tearing and uncovering of the cast iron pipe.

The inside protection generally consists of a mortar lining. This lining may stress crack, especially in the buried pipes with large diameters, which are installed in unstable grounds with important external loads.

A cathode protection system is not needed if rubber packing is included in the joints.

If epoxy resin coating is used for the special requirements, the defects in the inner liner will be the same as encountered in the steel pipes.

Due to a heavy weight and to a relatively short length of the sections of the cast iron pipes, the laying is rather slow and the site operations quite difficult. Moreover, cast iron pipes are very often imported. Their production is limited to medium diameters, while large diameters are not available on the market.

Using cast iron pipes involves the following shortcomings:

- in the areas of reduced stability, the erection of concrete anchoring blocks makes the outer protection discontinuous. This lack of continuity can lead to corrosion, which activates the breakdowns in the structures in the unity of the pipe with the anchoring blocks;
- as with the steel pipes, pipelines which cross soils consisting of eroded chalks can undergo corrosion due to infiltrations through the protective outer liner.

The hydraulic properties of cast iron pipes depend on the quality and the condition of the inner cement liner, which is applied for protection and to improve the hydraulic properties.

The recommended absolute roughness coefficients for the pipes intended to be used as the water mains are as follows:

1. 0.05 mm for internally lined, new pipes for the supply mains;
2. 0.10 mm for internally lined secondary pipes that have smaller lengths and diameters;
3. 1.00 mm for internally lined distribution pipes that have a reduced length and a great number of special parts, or for the pipes without a liner or with a deteriorated liner

For sewage, it is recommended to use the Kutter formula with a 0.45 coefficient.

2.3. High Density Polyethylene Pipes

Technology for producing the high-density polyethylene pipes requires sophisticated and rather expensive plants and, above all, perfected control systems for pipes with large diameters. Besides the reliable manufacturers, who form part of the large Italian and European groups, there are also small producers who do not always provide the desired reliability.

The products available on the market are generally reliable and comply with their stated specifications, but there is always a risk, as with all thermoplastic materials, that the pipes have been made from recycled raw materials. This will result in an unsatisfactory performance, especially in the long term, and if they are incorporated in quantities greater than the smallest admissible percentage.

It should be noted that their mechanical properties relate to the short term and to the ambient temperature (20°C).

A pipe's elasticity modulus and the tensile strength decrease considerably with time and with increase in temperature, resulting in the material demonstrating a remarkable viscoelastic behaviour. Deformations increase in the long term due to an applied and constantly maintained stress: this occurrence is also called internal creep.

During the initial period, the breakages happen by yielding and the internal creep curves develop linearly. After some time, the pipe undergoes a sharp deterioration which is accompanied by brittle fractures.

The presence of the knee in the curve of breakages stresses, depending on the time length of the application of the stress and different ductile and brittle behaviours before and after the knee, indicate a deterioration of the material together with an alteration of its physical and chemical structure, which may be deemed to be the actual ageing.

Therefore, we must assume that the working life of the material should not be considered greater than the one identified by a knee in the curve. At the ambient temperature, this point is at about 100,000 hours or 11.4 years, but it is reduced to a little more than one year at a temperature of only 30°C.

At the ambient temperature, the chemical resistance of a high-density polyethylene to majority of the corrosive chemical compounds and solvents, can be described between good and excellent. High density polyethylene also does not undergo the electrochemical and bacterial corrosion. However, the degree of chemical resistance depends on the state of the stress of the material and decreases when the material undergoes great elongation (stress corrosion).

The combination of the ageing effect and brittling and the effect of the stress-corrosion, has been the cause for many failures (lengthwise cracks) in the upper generating line of the sections of the sewerage pipes. In fact, this zone is the most stressed one, due to the external loads, and it is where the heaviest concentrations of sulphur dioxide are developed.

Careful controls are recommended during laying of the line and the supporting of sides of pipes to keep the deflection values low.

Mention must be made, that due to a considerable thickness of the high-density polyethylene pipes, small deflection values lead to high deformation values (elongation) at the inner wall at the upper and lower generating line.

The impact strength and abrasion resistance of the high-density polyethylene pipes are very good. But an impact on a pipe, even though no damage can be seen, may cause structural weakening, which will lead to breakages in a long term, even of a great extent.

Flow and speed can be calculated with the Prandtl-Colebrook method. The ATV directive lists the roughness value as the long-term value, which is estimated to be 0.25 mm for the straight single section lines, and 0.40 mm for the networks. The Plastic Institute also proposes the Chezy formula, with the second expression of Bazin and a roughness coefficient of 0.06.

The length of HDPE pipe sections is generally 12 meters.

Welded joints are made with the equipment called the thermal elements or thermal mirrors, which heat the ends of the pipes that are going to be connected, to a temperature of 200°C. The ends are then pressed against each other until the material has cooled down and hardened.

The welding operation should be carried out by skilled personnel, with suitable equipment and in perfect conditions. The steps to prepare and clean the elements which are going to be connected (the temperature and the heating time to suit the thickness and the welding pressure) are particularly critical. The reliability of the joint is good, but it depends considerably on the skill of the workers performing the jointing.

A high-density polyethylene sleeve is also available and includes an electrical resistor, which produces the heat, needed to melt the material. The sleeve is normally only used for the repairs when it is impossible to bring the welded sections in an alignment.

High density polyethylene pipes, like other plastic pipes, belong to the so-called flexible pipes. This means that during their service, they can support a relatively high deformation of their cross section, generally limited to 5% of the diameter, so the hydraulic properties pertaining to that diameter are not altered.

On the other hand, they cannot sustain the vertical loads of the ground and traffic by themselves and, therefore, rely on the passive thrust of the ground to support their sides and help resists the tendency of the pipe to become oval.

The admissible value of ovalization is determined by the limit imposed on the stresses or strains on the pipe wall and it also takes the considerations of the stress corrosion into account.

The type of the ground used for the bed and the sides supports, as well as the methods used to arrange the ground around the pipe and to compact it, are decisive.

Based on the Italian Plastics Institute recommendations, high density polyethylene pipes should be laid on a bed and within the side supporting ground, consisting of a clean granular material, preferably sand, compacted to a 90% Proctor density.

Because the high-density polyethylene has a high expansion coefficient, it is advisable to carry out backfilling when the temperature of the pipe is as close as possible to the one normally encountered during its service. In particular, the pipes which have been exposed to the sun should not be buried.

Transporting, unloading and storing of these pipes does not present any particular problems other than those linked to the prevention of buckling and deformation, which might render the future welding operations difficult.

Due to the fact that polyethylene can be to cut and welded with relative ease, pieces of non-standard shapes and sizes can be produced with it, as well as a wide range of standard fittings (bends, reducers, flanges and tees).

2.4. GRP Pipes

GRP is a composite material, which means that its physical and mechanical properties vary considerably according to the production technology, type of the resin, and type and quantity of the used reinforcement.

The GRP properties are applicable to a wide range of temperatures. The mechanical behaviour of the thermosetting resins does not actually change considerably up to temperatures close to the vitreous transition point of the resin, in other words, to the point where the resin passes from a vitreous to a rubbery state. The reactions which take place, unlike those of the thermoplastic resins, are irreversible with deterioration of the resin.

GRP, like the thermoplastic materials, is also characterized by viscoelastic behaviour, but it is less emphasized and not very affected by the temperature, even when under a wide range of temperature variations (up to 70 –80°C).

Moreover, the regression curves obtained with the long-term cracking tests (for instance according to ASTM D2992), show a linear development on a bilogarithmic representation, without the typical knee of the thermoplastic materials and therefore without alteration in the behaviour of the material. This means that it is possible to foresee a very long working life of these products.

The strength values at 50 years are about 65¸70% of the short-term values. The modulus of elasticity shows an even smaller deterioration.

Due to the fibrous nature of the material, the breakage mechanism is rather complex and the figures for unit loads on cracking depend on the wall composition and the manufacturing technology. The breakage load is defined as the load at which a pipe, undergoing a bursting test, begins to leak, even without the occurrence of the macroscopic damages in the pipe wall.

GRP possesses an excellent chemical and electrochemical resistance. Its stability at high temperatures are definitely better than the ones shown by other plastic materials.

Various types of the polyester resins are used to produce the GRP pipes. The main ones, arranged according to an increasing degree of the chemical resistance, are: the orthophthalic, isophthalic, bisphenolic, and vinylester resins.

Orthophtalic resins are not recommended for the applications where a working life of more than 10 years is envisaged. In any case, they should not be used in the layer which is in direct contact with the conveyed fluid.

Isophthalic resins are excellent for conveying water, including sea water, for urban sewerage lines and for the majority of corrosive chemical substances dissolved in water in low concentrations.

Other resins are suitable for specialized plants and/or high temperature services ranging from 80°C to 100°C.

GRP is subjected to the stress corrosion as well. The considerations regarding the PVC and HDPE are also applicable to this material.

Since GRP pipes generally have inferior thicknesses, greater deflections of the cross section are generally acceptable when they are laid underground.

Impact resistance: the polyester resins have a more brittle behaviour compared to thermoplastic materials, but in a composite, the inclusion of the fibrous reinforcements prevents the spreading of cracks and imparts an excellent impact strength to the material. Moreover, the transparent nature of the material enables a visual detection of even small damages, enabling repairs, replacements, or disregard of the unimportant damage.

Abrasion resistance: because the surface toughness of the resins is high, the abrasion resistance of the GRP is better than that of the thermoplastic materials.

Hydraulic properties: GRP pipes have a very smooth flowing surface, especially when produced on a mandrel. Hydraulic calculations can be done with the formulas which consider the absolute roughness of the pipe wall, such as the Colebrook formula.

The calculated roughness, including the localised discontinuity at the joints, is normally between 0.05 and 0.10 mm for a new pipe, as well as for a pipe that has been in service for many years. The Hazen-Williams formula, with a 140¸150 roughness coefficient, gives a good approximation when determining the head loss.

Standards for GRP pipes generally do not list their thickness, since there are many variables which take part in determining it. For example: the manufacturing technological process, the characteristics of the used raw materials, the pressure class, and the stiffness class.

The inner diameter is the same as the nominal diameter of the GRP pipes produced on a mandrel with the reciprocal filament winding technology. The nominal diameter of the pipes produced with the CFW process does not correspond to the inner diameter because, with reference to the outside diameter, the internal diameter varies according to the thickness of the pipe.

The lengths of the sections of GRP pipes are generally 6 or 12 meters, but with the CFW manufacturing line, it is possible to obtain any desired length.

GRP pipes are available with different jointing systems. They can be joined by welding, by using adhesives, by mechanical systems using spigot and socket (bell) joints, or by sleeves with the elastomeric sealing gaskets. Moreover, the reciprocal filament winding technology allows for the mechanical jointing systems (lock joints). By using a suitable locking device, lock joints ensure the axial continuity of the pipeline and eliminate the risk of detachment of the joints and the need for anchoring blocks for the lines under pressure.

Although welded or adhesive joints do not require special equipment and heat treatment, they must be carried out by skilled personnel.

Mechanical joints enable easy and rapid laying of the pipeline and almost completely assure the efficiency of the inwards and the outwards hydraulic seal, even at high pressures.

GRP belongs to the class of the so-called flexible pipes. A certain care is required when preparing the bedding for the pipeline, lateral supports, and backfilling. However, due to the more elevated mechanical properties of GRP pipes you do not need to be as careful with them as with the PVC and HDPE pipes.

A full range of specials and fittings, including the inspection pits, are available for the GRP pipelines.

To sum up, GRP pipes provide the following advantages in water mains:

- a complete assurance that the material will not pollute the conveyed water (non-toxic pipes);
- negligible roughness of the surface, even in the long term, and an assurance that the maximum performance will be maintained for a long period of time;
- inertness to aggressive ground agents and complete resistance to attacks by mildew and micro-organisms;
- inertness throughout the whole thickness of the pipe, meaning that any damage to the pipe, causing a local breakdown, will not lead to any propagation of the corrosive effects;
- very little ageing, which has already been taken into account in the safety factors during the design;
- no need for the secondary coatings, which would require periodical inspection and maintenance;
- no need for a passive protection;
- pipeline has a structural continuity due to the uniformity of the joints;
- pipes are easy to transport, handle and lay.

3. URBAN AND INDUSTRIAL WASTES

In water treatment, GRP pipes are used to carry the liquids, which need to be purified, to the tanks and from the tanks to the treatment plants, and finally to the discharge point into the sea or river.

The chemical and physical properties of GRP pipes assure complete safety, low costs of the maintenance, when they are used to transport the industrial waste waters

GRP pipes have become an economical alternative (also when compared to the concrete pipes for urban waste waters), because of their intrinsic characteristics, their easy handling and laying, as well as because they present a considerable reduction in costs, due to the decisive progresses in design and the manufacturing processes (CFW and sand filled pipes).

Furthermore, in gravity applications, compared to other pipes of the same diameter, GRP pipes provide a higher flow rate, due to their very smooth internal surface. This means higher flow speed and no danger of sedimentation. On the other hand, they require a smaller slope.

4. CHEMICALS AND PETROCHEMICALS

Large, modern factories were the first to experience how to profitably take advantage of the exceptional characteristics of GRP pipes. They rapidly embraced GRP pipes and started using them for transporting and conveying raw materials, intermediates, and finished products, where an absolute assurance of proper conservation of the purity of the content, resistance to the inside and outside chemical attacks, and an excellent mechanical behaviour was needed.

This was the case with the pharmaceutical and petrochemical industries, as well as with the chemical industry. The total chemical inertness of GRP pipes to a huge range of products and their complete resistance to weathering, demonstrated their exceptionally long life and their ability to continuously convey various products.

All GRP pipes, which are intended for use in an industrial plant and are likely to come into contact with the aggressive and dangerous products, must be fabricated with a double corrosion resistant chemical barrier.

Due to this barrier, the safety of the GRP products has increased outstandingly. Accidental breakdowns, which can happen due to the cleaning operations or inspections and result in a formation of the small, undetectable cracks, do not impair the functional nature of the product, since the presence of the second liner prevents chemical attacks by the contained liquid.

5. IRRIGATION

A continuous increase in the world population and the resulting need to provide the production of foodstuffs in ever greater quantities, require an even more rational use of the cultivable ground and careful conversion of the vast areas without natural water resources into intensively exploited areas. Nowadays, the areas which have been abandoned as being non-productive in the past, are being converted into fertile, cultivated land, thanks to the delivery of irrigation water from the reservoirs which are several kilometres away.

In this field of application, all properties and favourable features of GRP pipes are proven. The length and their light weight considerably reduce the required installation time as well as the time required for the completion of the project.

A vast range of available diameters ensures an all-covering distribution throughout the territory, as well as the design of the well-balanced networks of pipelines.

Excellent hydraulic properties, which remain unchanged in a long term, allow higher flow rates without increasing the pumping costs. Because of that, it is possible to build plants that do not require maintenance work.

6. COOLING WATER

Desalination plants and power production plants, which are based on the combustion of mineral oils, petroleum gas or coal or which use atomic energy, require huge quantities of cooling water.

These plants are generally located near great water resources, which can supply cold water and absorb the re-circulated warm water. The plants are normally set up near the coastline, where sea water is available in unlimited quantities, at no costs.

Sea water, however, when transported through pipelines made with the traditional materials, practically presents unsurmountable problems, for example:

- concrete pipelines, which possess good corrosion resistance, are not only very heavy and therefore difficult and costly to lay, but they lose their hydraulic properties after a short time. They are affected by scale, micro-organisms and by the formation of algae;
- pipelines made from ferrous materials cannot be used for such applications, unless they are of the Bonna type. Bonna type have an elevated weight and a complete lack of resilience. Their joints are their weak points;
- recently, expensive pipelines which have an inner cupronickel liner have been used. These pipelines have partially overcome the problems related to corrosion, but their joints and specials remain a weak point.

Problems, which are present due to the sea water and brine (produced by these type of plants), have not been acceptably resolved with traditional materials, but they have been overcome with GRP pipelines. Furthermore, with GRP pipes, using a special resin for corrosion resistance is required only in very special cases.

TECHNICAL REPORT SAMPLES

TECHNICAL REPORT SAMPLES

TABLE OF CONTENTS

THESE ARE TWO MODELS FOR THE TECHNICAL REPORT THAT THE CLIENT CAN EDIT, CUSTOMIZE AND SUBMIT TO HIS CUSTOMERS.

FIELDS MARKED WITH [ ], CONTAINING TEXT IN ITALICS, HAVE TO BE EDITED AND CUSTOMIZED AS PER SPECIFIC PROJECT REQUIREMENTS.

TO RECEIVE THE EDITABLE WORD FILES, PLEASE CONTACT TOPFIBRA.

BURIED PIPE DESIGN REPORT

BURIED PIPE DESIGN REPORT

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1. UNDERGROUND PIPELINE DESIGN

The ANSI/AWWA Standard C950-01 and the AWWA Manual M45 are the basic references of this guide for selecting an appropriate GRP pipe for the underground installation.

The AWWA Manual M45 gives the design requirements and criteria for a buried fibreglass pressure pipe.

This Technical Report complies with the design requirements of the AWWA Manual M45 (Second edition - 2005), possibly using the same symbols. The results of the calculations are shown in the attached tables, taken from the computer program:

[INSERT THE RESULTS OF THE AWWA M45 PROGRAM CALCULATIONS

LIST OF TABLES;

LIST OF TABLES;

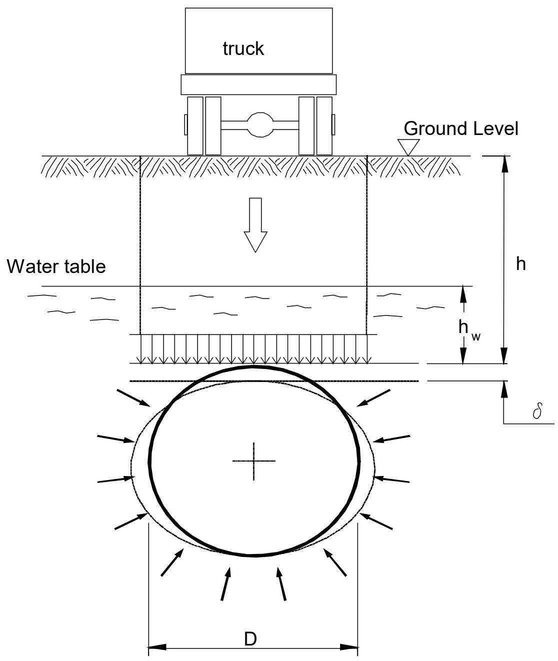
LIST OF TABLES.]

2. PRELIMINARY REMARKS

Fibreglass pipes are characterized by their flexibility and can sustain large deformations without any damages to the material.

Vertical loads (covering soil, traffic and water table) determine the deflection, depending on the soil compaction around the pipe and on the ring stiffness of the pipe's cross-section.

The following figure shows the load distribution and mobilization of the soil reaction, caused by the soil compression in interaction with the pipe flexibility and deformation.



3. DESIGN CONDITIONS AND INSTALLATION PARAMETERS

Development of the interaction between the soil and pipe and the resulting deflection of the pipe, depends on the pipe and soil composition as well as the installation procedure.

The pipe deflection is mainly affected by the following parameters:

- the hoop flexural modulus of elasticity;
- the wall cross-section geometry.

The soil condition and the installation procedure determine the deflection limitation through the pipe backfilling zone. Here, the main criteria are:

- soil composition and the material: soil specific weight γ_s, depth of cover (min/max);
- bedding and backfilling of the pipe and compaction of the soil material;
- vehicular traffic load, P;
- internal vacuum pressure, P_v.

Combination of the type and the degree of compaction for the native and pipe zone soils and the trench width will determine the following installation parameters for the design calculation:

- Deflection coefficient, K_x;
- Modulus of soil reaction, M_s;
- Deflection lag factor, D_L.

4. DESIGN REQUIREMENTS

The AWWA Manual M45 allows the pipe design to follow two different procedures, based on the stress or on the strain.

[INSERT THE NAME OF YOUR COMPANY] follows the strain procedure.

The design procedure involves the following steps:

4.1. Check the Working Pressure P_w

The working pressure should not exceed the pressure class P_c of the pipe $P_w \le P_c$

4.2. Check the Surge Pressure P_s

The maximum pressure should not exceed 1.4x the pressure class of the pipe $P_w + P_s \le 1.4 \cdot P_c$

4.3. Check the Ring Bending

The maximum allowable long-term ring bending strain leads to the allowable long term vertical deflection:

$$\varepsilon_b = D_f \left(\frac{\Delta y_a}{D} \right) \left(\frac{t_t}{D} \right) \le \frac{S_b}{FS}$$

Where:

D_f - the shape factor, function of the pipe stiffness and installation, given by Table 5.1 of the AWWA Manual M45. On the safety side the following values can be used, depending only on the pipe stiffness (S S according to the European standard; see below):

Stiffness [Pa]	1250	2500	5000	10000
D_f	8.0	6.5	5.5	4.5

For the present project, the value of the shape factor will be [INSERT VALUE], which is [INSERT STIFFNESS] Pa of the pipe stiffness.

t_t - the total pipe wall thickness;
D - the pipe diameter [mean];
Δy_a - the allowable deflection;
S_b - long term ring bending strain for the pipe;
FS - the design factor, 1.5.

The allowable long-term deflection is:

$$\left(\frac{\Delta y_a}{D}\right) \le \frac{1}{D_f}\frac{S_b}{FS}\left(\frac{D}{t_t}\right)$$

4.4. Check Deflection

The external loads (dead and live) should not cause a long-term decrease in the vertical diameter higher than 5%, or the one allowed by the pipe specification, whichever is lower:

$$\frac{\Delta y}{D} \le \min\left(5\%, \left(\frac{\Delta y_a}{D}\right)\right) = \left(\frac{\delta d}{D}\right)$$

The predicted long-term vertical deflection is calculated as follows:

$$\frac{\Delta y}{D} = \frac{(D_L W_c + W_L)K_x}{8S + 0.061M_s}$$ (for the European Pipe Stiffness)

or

$$\frac{\Delta y}{D} = \frac{(D_L W_c + W_L)K_x}{0.149PS + 0.061M_s}$$ (for the US Pipe Stiffness)

Where:

Δy = the predicted vertical pipe deflection;

D_L = the deflection lag factor [dimensionless].
After the soil has been placed around the pipe, it continues to consolidate with time. The deflection lag factor converts the immediate deflection of the pipe to the deflection of the pipe after many years. For shallow burial depths with a moderate or high degrees of compaction D_L = 2.0, and for a dumped or slight degrees of compaction D_L = 1.5;

W_c = vertical soil load on the pipe [N/m2] = $\gamma_S \times H$;

γ_s = specific weight of the soil in N/m3;

H = burial depth to the top of the pipe in m;

W_L = live load on the pipe [N/m2] = $M_p(P \times I_f)/(L_1 \times L_2)$;

P = the wheel load in N;

[SELECT THE TYPE OF THE LOAD, FOR EXAMPLE:
= 16000 lbs for the AASHTO HS-20 truck [72.57 kN];
= 100 kN for the DIN 1072 SWL60 heavy lorry.

IF A DIFFERENT LOAD IS REQUIRED, THE CALCULATION MUST BE MADE SEPARATELY AND THE RESULT CAN BE INPUTTED INTO THE DESIGN PROGRAM IN THE SPECIAL FIELD "Specific pressure due to other live loads (calculated separately)"];

I_f = the impact factor [dimensionless] = $1 + 0.33[(2.44 - h)/2.44] \geq 1$;

L_1 = load width parallel to the travel direction = $t_l + LLDF \cdot h$;

t_l = length of the tire footprint = 0.25 m;

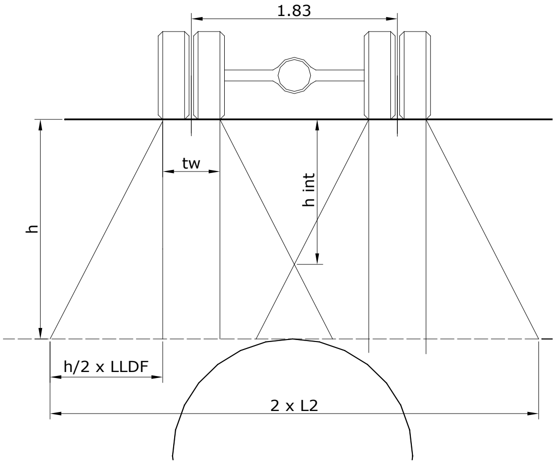
h = depth of the cover in m;

$LLDF$ = live load distribution factor = 1.15 for SC1 and SC2 backfill, otherwise 1;

L_2 = load width perpendicular to the travel direction = $t_w + LLDF \cdot h$;

t_w = width of the tire footprint = 0.5 m.

If $h > h_{int} = (1.83m - t_w)/LLDF$ then $L_2 = (t_w + 1.83m + LLDF \cdot h)/2$, since there is interaction and overlapping of the pressures coming from the two wheels, as shown in the following figure.



1.83
tw
h int
h
h/2 x LLDF
2 x L2

Where:

K_x = the deflection coefficient, which reflects the degree of support provided by the soil at the bottom of the pipe, over which the bottom reaction is distributed. Values of K_s are based on the description of the type of the installation:
(a) 0.083 for the uniform shaped bottom support;
(b) 0.1 for the direct bury;
[SELECT (a) OR (b) - GENERALLY 0.1 IS USED]

PS = pipe stiffness as defined by the ASTM and AWWA standards;

S = stiffness as defined by the BS 5480 or ISO standards.

For the American and European standards, the pipe stiffness (*PS*) and the stiffness (*S*) are measured with the parallel plate loading test. The relation between the two parameters is:

$$PS = \frac{1}{0.149}\frac{EI}{r^3} \qquad S = \frac{EI}{D^3}$$

$$0.149PS = \frac{EI}{r^3} \qquad 8S = 8\frac{EI}{D^3} = \frac{EI}{r^3}$$

$$\therefore 0.149PS = 8S$$

Where:

E = the pipe ring modulus of elasticity in MPa;

I = the moment of inertia of the pipe wall for ring bending in mm4/mm.

The product EI is also called the stiffness factor per unit of circumference and is determined by the parallel plate loading test, carried out for a deflection equal to 5% of the diameter, with the equation:

$$EI = 0.149 \cdot r^3 \left(\frac{F}{\Delta y}\right)$$

where F is the force per unit length and Δy the vertical pipe deflection.

To calculate M_s - the composite constrained modulus of soil reaction in MPa, the following formula is used:

$$M_s = S_c M_{sb}$$

Where:

M_{sb} = the constrained modulus of the soil reaction for the pipe zone embedment, from AWWA M45 Table 5-4, for different soil stiffness categories (SC).

For the present project, soil for the pipe zone embedment is SC [INSERT VALUE]; and is compacted to [INSERT VALUE] SPD.

S_c = the soil support combining factor, depending on the ratios between:
(a) the trench width and the pipe diameter and
(b) modulus of the soil reaction of the native and embedment soils;

B'_d = the trench width [at the pipe spring-line];

M_{sn} = modulus of the soil reaction for the native soil at pipe axis, according to the Table 5-6 of AWWA M45.

In most cases, the soil support combining factor equal to 1 is used. Only in a case of a very bad native soil or very hard loading conditions, a more careful calculation has to be performed.

[EDIT AS NECESSARRY: For the present project, where the native soil modulus is certainly in the upper part of the above table, and the bedding and primary backfilling will be made with dune sand with a very low fine content (less than 12 %/ 5% according to …), which stands for the soil category SC2 or SC1, a composite soil modulus E' of 13.8 MPa, can be used in the calculation.

The trench width, with the natural soil modulus higher than the backfilling modulus, is not critical and should be the minimum necessary to make joints and to let the workers compact the backfilling material under the haunches of the pipe. Enlargements of the trench shall be foreseen around the laminated joints.]

4.5. Check Combined Loading

In case of a deflection and the internal pressure, the next two equations should be verified:

$$\frac{\varepsilon_{pr}}{HDB} \leq \frac{1-\left(\frac{\varepsilon_b r_c}{S_b}\right)}{FS_{pr}} \qquad (5\text{-}19)$$

$$\frac{\varepsilon_b r_c}{S_b} = \frac{1-\left(\frac{\varepsilon_{pr}}{HDB}\right)}{FS_b} \qquad (5\text{-}20)$$

Where:

r_c = re-rounding coefficient = 1 - Pw/3 (Pw<3 N/mm2);

ε_{pr} = strain due to the internal working pressure = $\frac{P_w D}{2E_H t}$;

ε_b = bending strain due to the maximum allowed deflection

=; $D_f\left(\frac{\delta d}{D}\right)\left(\frac{t_t}{D}\right)$

FS_b = design bending factor 1.5;

FS_{pr} = design pressure factor 1.8.

4.6. Check Buckling

The sum of the external loads should be equal to or less than the allowable buckling pressure. The allowable buckling pressure *qa* is determined by the equation:

$$q_a = \frac{1}{FS} \cdot 1.2 \cdot C_n \cdot (8 \cdot S)^{1/3} \left(\varphi_s \cdot M_s \cdot 10^6 \cdot k_v\right)^{2/3} R_h$$

Where:

FS = design factor 2.5;

C_n = scalar calibration factor 0.55;

φ_s = factor for variability of the soil stiffness 0.9;

k_v = factor for the Poisson's effect on the soil 0.74;

M_s = constrained modulus for the composite soil in MPa (defined earlier);

S = a pipe specific stiffness in Pa;

R_h = the correction factor for depth of fill = $11.4/(11+D/h))$.

The actual load, which has to be compared with the allowable load, is calculated as:

with live loads: $q_L = \gamma_w h_w + R_w W_c + W_L$

and

with the internal vacuum: $q_V = \gamma_w h_w + R_w W_c + P_V$

Where:

the permanent soil load W_c and the live load W_L were defined earlier;

P_V = the internal vacuum pressure 1 bar [100,000 Pa] for the full vacuum;

R_w = the water buoyancy factor $= 1 - 0.33(h_w / H) \quad for \quad 0 \le h_w \le H$;

h_w = the height of the ground water surface, above the top of the pipe;

H = the burial depth [the height of the ground from the top of the pipe to the surface].

If the internal vacuum is not a transient condition but a permanent working condition, the traffic load, if any, should be added to the load q_V given previously.

The above equation is valid for the following conditions: *[CHOOSE THE CONDITION:*

- Without the internal vacuum 0.6 m $\leq$ h $\leq$ 24.4 m;
- with the internal vacuum 1.2 m $\leq$ h $\leq$ 24.4 m.

For burial depths lower than 0.6 m, the von Mises critical load can be used as the ultimate load, without applying a safety factor.]

4.7. Buoyancy

If the pipe is submerged in the ground water and is not filled with water, it receives buoyancy equal to:

$$P_B = \pi \left(\frac{ID}{2} \right)^2 \cdot 9810 \quad \text{[N/m]}$$

ID is the inside diameter in *mm*.

The buoyancy shall be balanced by the weight of the soil above the pipe, plus the weight of the pipe itself and other permanent loads.

The weight of the soil above the pipe (W_c) shall be reduced for the part submerged [below the water table], using the water buoyancy factor (R_w) as per section 4.6 - Buckling.

A safety factor of 2 is recommended:

$$P_B \leq \frac{1}{FS}\left(w_p + R_w \cdot W_c \cdot D + w_{c2} \right).$$

The pipe weight w_p [N/m], if not available directly, can be calculated on the basis of the relative density of 1.85.

The other extra permanent load w_{c2} [N/m] should be taken into account only in case it is really present.

If the permanent load w_{c2} is not applied immediately after the filling of the trench, a reduced safety factor may be allowed for the transition period. The Project Engineer will analyse the risk.

5. CALCULATION

The calculation sheets for the present project for a ND [*INSERT VALUE*] and a ND [*INSERT VALUE]* pipe are enclosed in the following pages.

[*CUT AND PASTE OR DIRECTLY ATTACH THE OUTPUT OF THE CALCULATION PROGRAM.*]

[Insert Client name]	**[Insert Company name]**
[Insert Project name]	[Insert Doc. No.: ______________] [insert Date __/__/____]
Calculation/report on the buried pipe, static verification.	

[Insert Client name]	**[Insert Company name]**
[Insert Project name]	[Insert Doc. No.: ______________] [insert Date __/__/____]
Calculation/report on the buried pipe, static verification.	

SUBMARINE PIPE DESIGN REPORT

TABLE OF CONTENTS

[Insert Client name]	**[Insert Company name]**
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Calculation/report on the buried pipe, static verification.	

[*INSERT CLIENT'S NAME*]

[*INSERT A MAP, PICTURE OR LOGO*]

[*INSERT PROJECT NAME*]

[*INSERT THE PROJECT DETAILS*]

GENERAL REMARKS

In the last twenty years, the applications of the submarine pipes for conveying different fluids have increased considerably.

The use of fibreglass pipes for the aqueducts, seawater intakes and, above all, wastewater discharge, has increased. The availability of this composite material for water pipes manufacturing, has led to the elimination of the disadvantages related to a limited resistance of the structure in an "aggressive" environment, such as seas and oceans.

This technical report takes into consideration the following problems, related to the sea out-fall of the sanitary and storm wastewater flows:

- techniques for disposal by dispersion through the sea outfalls;
- construction and the technological aspects (pipe materials);
- comparison between different materials for large diameter sea out-falls;
- properties of the Glass-Reinforced Plastics (GRP);
- methods for the sub-sea pipe laying;
- design of GRP for this project;
- reference list.

DISPOSAL TECHNIQUES BY DISPERSION THROUGH THE SEA OUTFALLS

The final disposal of the effluent in the coastal urban areas, when it is not recycled, can be performed at sea, at a certain distance from the coastline. This is done by a submarine out-fall and diffuser, in order to assist the final dispersion of the effluent in the sea areas which are physically and biologically more suitable for it than the coastal strip. This dispersion technique has clear advantages over discharging in the coastal waters, namely:

- *it protects the cleanliness of the shores without the need for disinfecting processes (thus avoiding related costs, as well as the toxicity caused by some disinfecting processes);*
- *it prevents the eutrophication phenomenon of the coastal waters which have a slowly water flow;*
- *it presents the possibility for disposal when the purification plant is not in operation. The urban effluent is merely pre-treated, but the satisfactory environmental and aesthetic conditions, even in the area surrounding the discharge point, are still maintained.*

Health and Hygiene Aspects

When disposing the sewage a certain distance and depth from the shore, it ensures that the strictest hygiene standards are followed in respect to bathing and shellfish cultivation. There is also no need for the disinfecting treatments, even when the purification plant is not in operation.

The Italian standard, which is one of the strictest in the world, requires a reduction in the concentration of the faecal coliform bacteria in sewage by a factor of 10^6 (a million times).

In order of magnitude, the natural bacterial disappearance phenomenon enables a reduction from 1000 to 10.000 times. The initial dilution allows for a reduction which is generally 100 times higher. The dilution in the second phase (or the surface dilution or the subsequent dilution), generally allows for a further reduction in the concentration of coliform by 10 times.

This reveals the importance of the initial dilution to protect the cleanliness of the waters. In this respect, it should be remembered that a good initial mixing could generally be achieved by a long diffuser.

Controlling Eutrophication

Where tertiary treatment of the effluent is not provided, the offshore dispersion in the open and oligotrophic waters helps to achieve the dilution ratios of nutrients, which are hundreds or thousands of times higher than those obtained by discharging on the shore. The open sea has a smaller concentration of nutrient substances and the phytoplankton biomass, compared to the coastal waters. Therefore, the dispersion by a submarine out-fall aids in solving the possible coastal eutrophication without producing a considerable clouding of the offshore waters, or negative effects on the marine environment.

It has to be mentioned that when it comes to the nutrients dispersion, the benefit of a high ratio of the initial dilution is less remarkable, compared to what has already been mentioned regarding the hygiene and health aspects or to what is to be described in the paragraph below concerning the disposal of the organic load and the aesthetic features of the marine waters surrounding the diffuser.

Controlling eutrophication requires the overall dilution ratio to be of the order of some thousands of times, which can only be achieved by sufficiently extensive dispersion or the total dilution processes (initial plus subsequent dilution) which involve periods of times lasting several days and, in general, correspondingly extensive marine surface areas (tens of kilometres).

A high degree of the initial dilution, generally possible only through a long diffuser, encourages a subsequent dilution process in the vertical direction (thanks to a reduction in the vertical gradient of density between the mixing area and underlying seawater). At the same time, however, a subsequent dilution in the horizontal direction takes place, downstream of the discharge location and slower in the central zone of the mixing area, when the latter is initially very wide.

The degree of the overall achieved dilution after a few days, is not decisively affected by the degree of the initial dilution. Vice versa, the positioning of the discharge location in the sufficiently open waters far from the shores, which encourage later transport to the open sea (or a wider total dispersion of the discharged effluent), which are relatively poor in nutrients, was found to be critical for controlling eutrophication.

From this point of view, a long out-fall is useful (and a long diffuser is not), because it makes the space and time scale of eutrophication go way beyond the zone in the immediate vicinity of the outlet.

It is possible that the seabed slopes very steeply. In this case, it is not feasible to construct an outlet which is a considerable distance from the shore or outside of any bays or coves. To prevent eutrophication, a mechanism of trapping the jets in deeper water layers can be adopted. This is because the circulation of the deep waters is separate from the surface water circulation and because deeper layers have a smaller flow of light energy compared to the upper layers, resulting in a slower exploitation of the discharged nutrient substances.

Disposal of the Organic Load

It is decisive and essential to use a long diffuser in order to maintain the discharge zone in the satisfactory environmental conditions, even when the purification plant is not in operation.

An initial 1 to 200 dilution ratio can easily be achieved in most cases, by appropriately dimensioning and positioning the end diffuser. 1 to 200 dilution ratio also means that the concentrations of BOD (biochemical oxygen demand), dissolved oxygen, surface-active agents, and ammonia, will comply with the strictest standards of the aquatic environment protection in the receiving area, surrounding the outlet.

From an aesthetic viewpoint, an adequate initial mixing process enables the disposal area to stay unchanged, provided that at least one adequate pre-treatment process is performed on land (very fine screening or, better, sieving followed by oil extraction) in order to trap the floating substances, scum, and particles which would in come to the surface.

The unacceptable appearance of the sea areas above various diffusers is normally due to the lack of pre-treatment structures.

These shortcomings refer not only to the disposal of the particles or floating substances in the sea, which jeopardise the appearance of the marine surface, but also to the usage of diffusers with bigger outlet holes in order to avoid frequent clogging which would otherwise occur when using smaller holes.

One cannot but underline, that a rapid initial dilution process does not solve possible problems caused by the accumulation of the sedimentary substances in the areas surrounding the discharge point. If the sedimentation treatment is not performed on land, mud banks of varying consistencies will form around the outlet. In shallow waters, this may lead to the re-suspension of these sediments during the sea storms.

1) 

2) *Figure 1: A typical GRP intake.*

3) 

4) *Figure 2: V-type diffusor.*

CONSTRUCTIONAL AND TECHNOLOGICAL ASPECTS: PIPE MATERIALS

In the past, almost all of the materials used for the land pipes were equally used for the submarine pipes. Nowadays the choice is influenced by the physical-mechanical properties of the materials and by other features such as: the depth of laying, dimensions of the pipes, extension and limits of the yard areas, installation potential, and laying time.

The advantageous features for a submarine pipe are:

- *excellent mechanical resistance;*
- *excellent corrosion resistance;*
- *flexibility of installation;*
- *laying safety;*
- *excellent efficiency of joining systems;*
- *minimum internal roughness;*
- *high impact strength;*
- *high resistance to wear and abrasion;*
- *minimum maintenance.*

The materials which completely or partially guarantee these properties and which are currently more competitive in constructing the large diameter submarine outfalls are reduced to:

- *the GRP (glass-reinforced polyester);*
- *steel.*

GRP is the subject of this study. It is a composite plastic material, which fulfils almost all of the above pipe requirements. It has an excellent mechanical resistance to impact and a chemical resistance to corrosion. These properties are long lasting, stable and provide the optimal possibilities to use this material for construction of the submarine pipes. They are a positive addition to the flexibility of GRP pipes, different techniques that can be used to install them and “zero” maintenance is required for them.

Steel is a widespread material for submarine pipes which carry all types of fluids. It is also used for the wastewater disposal. High mechanical properties of the material offer a high potential of adaptation of the outfalls to the most varying environmental conditions.

The negative aspects linked to steel are: the need to provide complex protection systems against corrosion, high bending rigidity of the outfalls which prevents their free adaptation to uneven sea beds, and the difficulty in protecting the pipe’s inner wall from incrustation and corrosion.

Compared to GRP, steel offers less freedom of choice when it comes to the installation procedures. Almost all steel outfalls are, in fact, installed by the bottom pull technique.

COMPARISON BETWEEN STEEL AND GRP

Steel Pipeline

Construction and installation: the pipeline continuity requires a detailed preparation of the laying plan and an extensive preparation of the sea bottom (trenching, excavation), due to the high stiffness of the material, which does not allow the pipeline to follow the natural profile of the sea bed. Moreover, the continuous laying method, which is usually adopted for the steel pipelines, requires an onshore construction yard, involving vast areas.

Steel pipe must be protected internally and externally from corrosion. Several methods are possible to achieve that: various paint coatings, epoxy coatings, concrete coatings etc. Protection against corrosion must be carefully restored after the various pipe section have been welded together.

An active or passive cathodic protection system could be required.

Despite all the protection systems, the steel service life is quite short and the maintenance costs due to the cathodic protection are very high.

Steel pipes are joined together by welding. All the welds have to be checked and the internal and the external protection restored. This operation is only done manually, and its internal and external efficiency is not guaranteed.

Laying of the pipes: for handling and laying operations of the steel pipes with thick external concrete layer, a crane and other big sized equipment is required, which results in high costs.

Fibreglass Pipelines (GRP)

Selecting GRP for the installation of the submarine pipelines offers various advantages related to the material's characteristics.

GRP is completely resistant to internal corrosion (to the sanitary fluids) and externally (sea water). It doesn't require protective layers or other systems.

Hydraulics: the inner finish of the pipes has an extremely low roughness, meaning no incrustations are possible.

Structure: GRP is an elastic material that can easily withstand considerable stresses. The elasticity of GRP pipes allows for better laying on the uneven profile of the seabed.

The bell and spigot lock joint provides a quick and reliable joining method and, if possible, a continuous pulling method.

PROPERTIES OF THE GLASS-REINFORCED POLYESTER

General Remarks

Glass-reinforced polyesters (GRP) belong to the group of composites and represent the latest generation of structural materials. Pipes made from this material, consist of a continuous thermosetting part (matrix) which incorporates a fibre part. The function of the matrix is to hold the fibres in the orientation and density defined by the designer, and to give the product the required shape and rigidity. The matrix is composed of polyester resins.

The fibre reinforcement, which provides the mechanical properties of the product, consists of glass fibres. Glass fibres that are normally used in the production of the GRP pipes develop a tensile strength of approximately 1800 N/mm². These pipes are an ideal solution for building the submarine outfalls, since they offer features that take the maximum advantage of the material's typical properties.

The main properties include:

- *flexibility of installation;*
- *safety of laying;*
- *high chemical resistance to corrosion;*
- *excellent mechanical resistance;*
- *low coefficient of friction;*
- *considerable resistance to wear and to abrasion;*
- *minimal maintenance.*

GRP Pipes Produced by Filament Winding

Of the various production technologies for GRP pipes, the one that allows the maximum mechanical performance consists of winding the continuous threads of glass on a male mould (**filament winding**). In this way, a higher quantity of fibre reinforcement can be incorporated in the matrix. The fibres are arranged parallel to each other in superimposed layers, thus reducing the empty spaces between each fibre to a minimum.

The best pipes are produced by using the thermosetting polyester resins, reinforced with the glass fibres, using the technique of continuously winding threads of glass (**filament winding**).

GRP pipes correspond to the following classifications of the ASTM (American Society for Testing Materials), according to the type and use:

ASTM D 2996	*Standard Specification for FILAMENT- WOUND REINFORCED THERMOSETTING RESIN PIPE*
ASTM D 3262	*Standard specification for REINFORCED PLASTIC MORTAR SEWER PIPE*
ASTM D 3517	*Standard specification for "FIBREGLASS" (GLASS-FIBRE-REINFORCED THERMOSETTING RESIN) PRESSURE PIPE*
ASTM D 3754	*Standard specification for "FIBREGLASS" (GLASS-FIBRE-REINFORCED THERMOSETTING RESIN) SEWER AND INDUSTRIAL PRESSURE PIPE (EX ASTM D 4161-82).*

In relation to the **principles of the GRP pipes inspection**, reference is made to the prescriptions of the ANSI/AWWA (American National Standard Institute/American Water Works Association):

ANSI/AWWA C950	*Standard for FIBREGLASS PRESSURE PIPE*
AWWA Manual M45	*Fibreglass Pipe Design*

GRP Pipe Wall

Liner or the chemically resistant layer

The liner is placed in direct contact with the conveyed fluid. It guarantees maximum resistance to the aggressive chemical agents contained in the fluid. It further increases the impermeability of the whole pipe wall.

The liner has a particularly smooth surface, free of defects, flaking or cracks. This reduces the losses in pressure of the conveyed fluids and the formation and growth of deposits. This layer is usually 1.2 mm thick.

Filament or the mechanically resistant layer

Filament guarantees the mechanical resistance of the pipe's wall to operation stresses (stresses from the internal or the external pressure, bending stress etc.), as well as to the stresses that the pipe will undergo during the transport and installation.

The laminate that makes up this layer, is achieved by winding it on the previously layered and partially polymerised liner of the continuous glass filaments, which are impregnated with the polyester resin, along spirals with a predetermined pitch and controlled tension.

This layer can contain siliceous inserts in order to increase the rigidity in the pipe wall. The stiffness of the pipe may be achieved by adding silica sand as a filler, which helps save on the glass filament. The thickness of this layer depends on the dimensions of the pipe and the desired characteristics.

Gel coat or the external layer

This layer is a few tenths of a millimetre thick. It consists of a pure isophthalic polyester resin without the glass reinforcement.

The gel coat ensures the complete impregnation of the peripheral glass fibres, to form an external pipe surface which is free from the surfacing fibres.

Raw Materials

Resins

Resins, used for the production of the GRP pipes generally belong to the thermosetting polyester resins.

A thermosetting resin is the one that can no longer be melted after the polymerisation reaction. In contrast, administering heat to the thermoplastic resins, makes the molecular bonds break and the resin soften. The polymerisation reaction of the thermosetting resins is not reversible and their stability at high temperatures is much higher.

Various types of resin belong to the polyester resins and are chosen according to the project conditions and the required performances.

The isophthalic polyester resins are generally used for the submarine applications.

Catalysts and accelerators

Suitable chemical agents, mainly catalysts and accelerators, have to be mixed with the resin in order to promote the polymerisation reaction. The function of the catalyst is to trigger the hardening process in the resin. The function of the accelerator is to adjust the speed of the hardening process.

The type of the catalyst and accelerator are chosen based on the type of resin and the required polymerisation trend.

Fibre reinforcement

Glass fibres, generally the "E" type, are used for the reinforcement in the form of:

- **Roving**: continuous and parallel fibres, gathered in bunches and wound on reels. Their weight is expressed in tex (gr/km). This glass type is used for the mechanically resistant layer, produced by filament winding.
- **Fabrics**: interlaced or woven roving of various weights. They are used in the production of fittings by manual or mechanical layering.
- **Mats**: composed of the continuous or cut lightweight roving, which is arranged with a random orientation and held together by special sizing. They are used for fittings and for the second liner layer.
- **Surface coat**: a very lightweight mat (33gr/m^2) made of the "C" glass fibres with superior chemical properties. Surface coat is suitable for absorbing large quantities of resin and is used as a reinforcement for the first liner layer.

Hydraulic Characteristics

The mandrels, on which the resin impregnated glass filaments are wound, have a high degree of finish. The state of their surface is frequently controlled and restored to the specified levels.

In order to prevent the resin adhering to the mandrel, a 23 microns thick tape of polyester film (Mylar) is wound on the mandrel with a slight overlapping, in order to act as a release agent.

The internal surface of the pipe allows:

- a Hazen–William flow coefficient: C = 150;
- a Manning coefficient: n = 0,009.

For more details about the coefficients, refer to the Engineering Handbook.

The hydraulic behaviour of GRP pipes is very similar to the smooth pipes. The losses of pressure due to friction is reduced to the minimum values.

GRP pipes retain their hydraulic properties over time since they do not suffer any form of corrosion. Due to the smooth internal surface, the formation of scale and incrustations is reduced.

5) 

6) *Figure 3: Behaviour of the GRP pipe under water.*

Joining Systems

Double O-ring bell and spigot joint

The joint, which is normally used for the installation of the submarine GRP pipelines, is a bell and spigot joint with a double O-ring.

Setting up a mould, the one end of the mandrel forms the bell (socket), while the male connector (spigot) is obtained by increasing the thickness of the opposite end. The housings for the two toroidal rubber seals (O-rings) are formed on the male connector by the mechanical machining at the precision lathe (calibration).

Hydraulic test of the joint

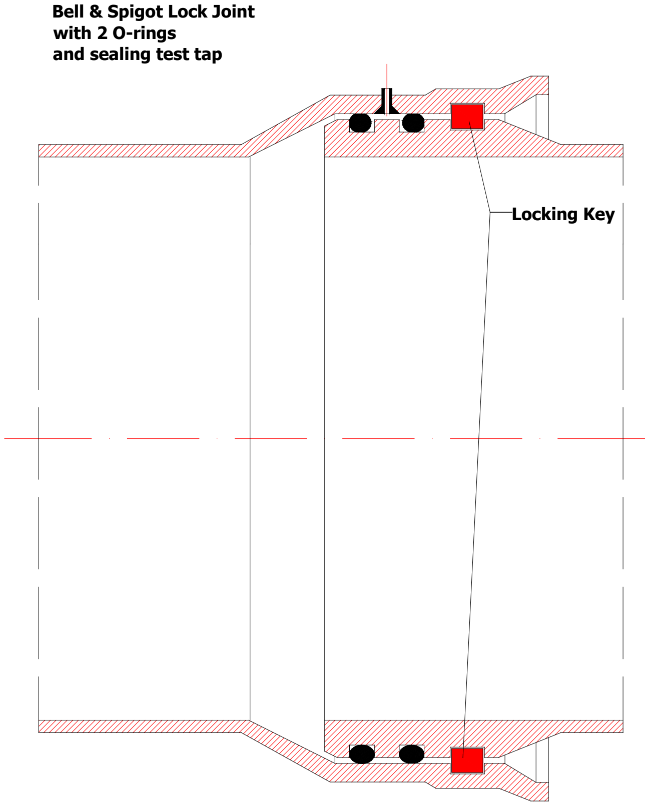
The double seal, in addition to a double guarantee of water tightness, enables the joint to be tested pneumatically or hydraulically. Through a threaded intake on the socket, the annular cavity between the two seals can be compressed with air or water.

This type of joint is the only one that allows the hydraulic test to be performed during the joining procedure and does not require skilled labour.

Lock joints

Bell and spigot joints, with a locking insert, are fitted with a device that prevents the bell from slipping out.

The locking device consists of a small cable, or a section bar, made from nylon, which is inserted between the male connector and the socket in a seat formed by both parts.



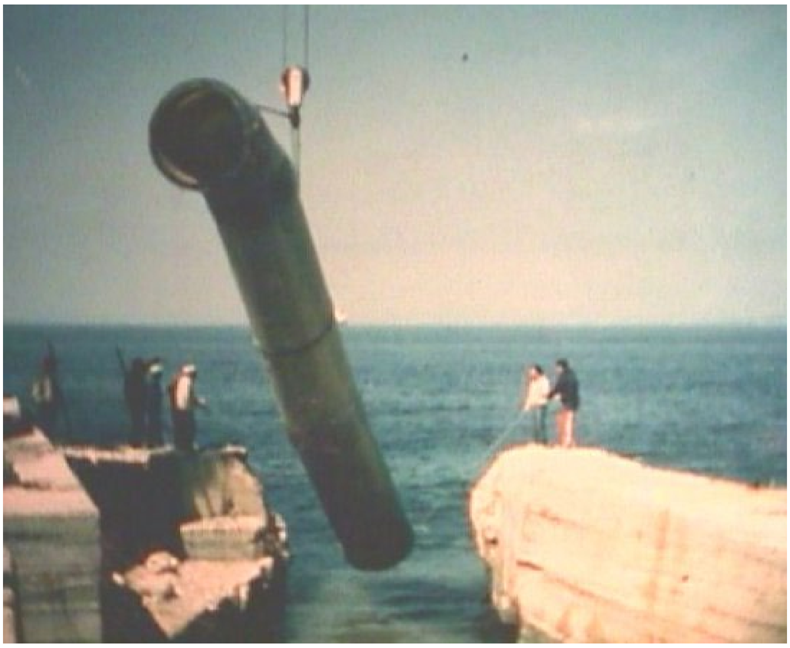
Flanged joint

This joint is used in the submarine pipelines to connect the diffusers to the pipes, for inspecting the manholes, and for connecting to the pumps or it is used where the joint has to be frequently disassembled. Flanges are available with bolt holes, complying to the main standards.

Figure 4: Flanged manhole.

Fittings in GRP

The whole range of bends, reducers, union tees, flanges, diffusers and other fittings are available for GRP pipes.



7)

Figure 5: Special spools.

8)

Installation

The light weight advantage of GRP pipes allows them to be considerably easy to handle. In the case of submarine outfalls, this makes the operations for installing the structure much easier, even in the environmental conditions that are far from ideal.

Generally speaking, regarding the installation techniques that are normally used, we can mention the following:

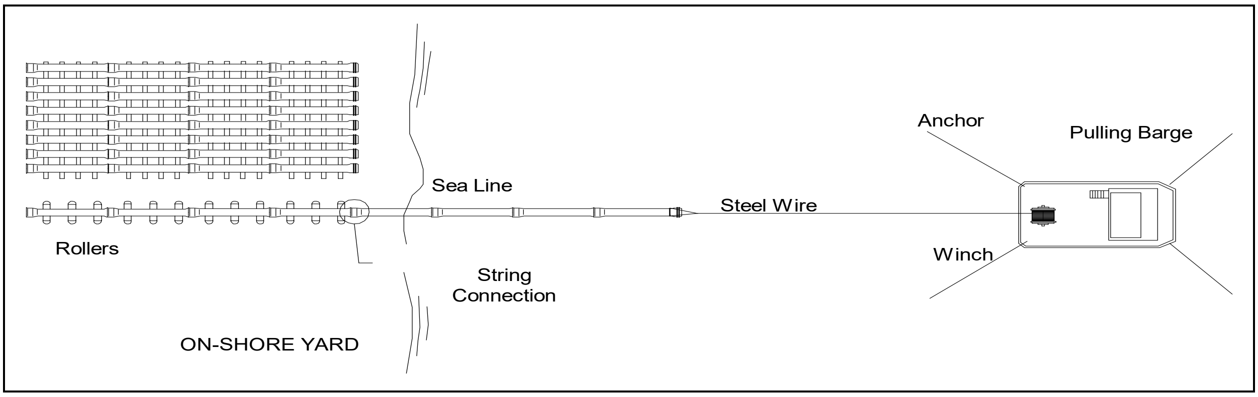
A) assembly of the out-fall on land and installation by the bottom pull, using winches which are normally on boats;

B) pre-assembly of the out-fall sections on land, which are composed of one or more bars (strings), followed by towing the floating string into the water, sinking it and connecting the generic string underwater to those that have already been installed;

C) transporting the bars on a pontoon and then installing them from the pontoon.

For the project under discussion, “METHOD C“ is the best course of action.

A) BOTTOM PULL



A requisite for this technique is the availability of a levelled area where adequately long columns of pipes can be prepared side by side. Pipes will be installed in series, slid on the support saddles and guide systems. The hook is extended with winch and generally installed on an anchored pontoon. The hook is then attached to a pulling head, which is fastened to the front of one column.

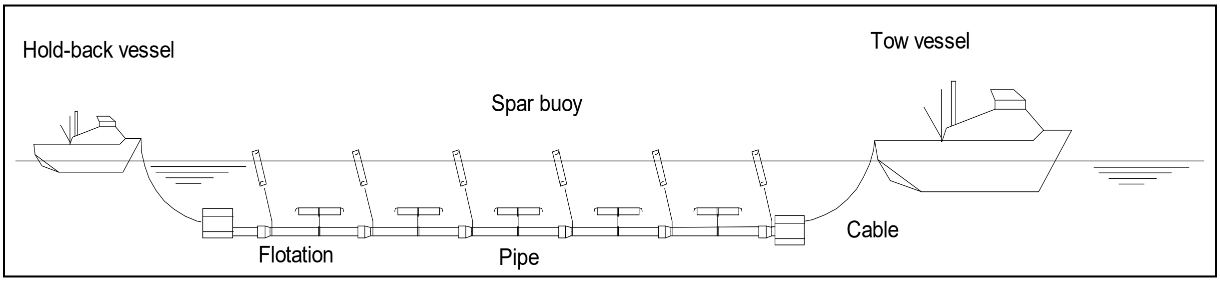
9)

Figure 6: Continuous pull from the beach.

Figure 7: Launching and Jointing machine.

Once a column has been installed, the pulling stops and the next column is positioned and joined to the end of the previous one. Joining is carried out on land at a special station, at the end of the installation line. The system can also be used for the simultaneous parallel installation of several outfalls. On certain projects, the pipes may be installed empty, sunk, or held up by floats. They may be placed on a natural bed that has been levelled or in a pre- excavated trench.

B) SURFACE TOW



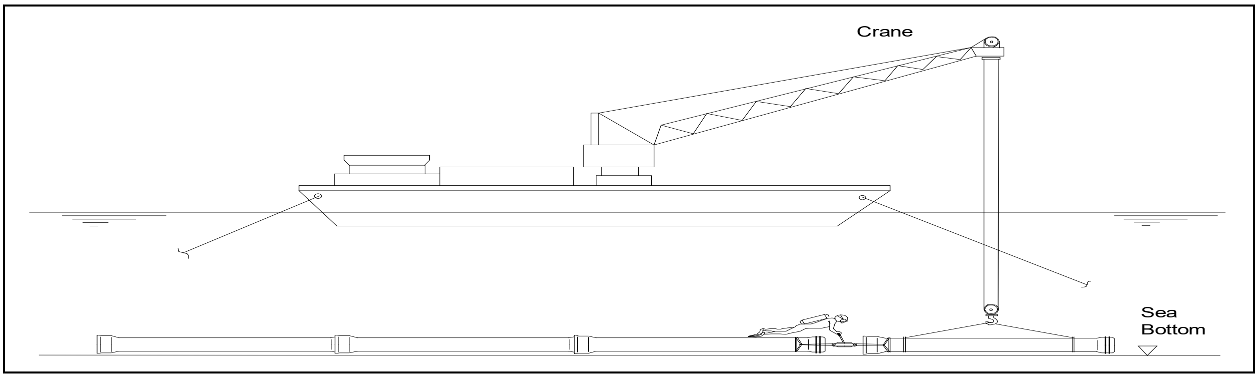
The outfall sections, which float due to their arrangement or with the aid of floats, are pulled or dragged to the correct position on the route. According to the design criteria, the sections may either be joined on the surface or on the bed.

10) 

Figure 8: Pre-assembling of the pipeline on the beach.

11)

C) INSTALLATION FROM A PONTOON



This is nowadays possibly the most commonly used method, particularly for pipes with large diameters. The size of a self-mobile or towed pontoon must be suitable for stowing sufficient quantities of pipes and holding all the required equipment for joining. The size of the pontoon affects the assembly and installation, as well as the progress of the work. The pontoon crane raises each bar and immerses it into the sea, where it is rested on the previously prepared bed, in the proximity of the already installed pipe section.

Coupling the pipe to the installed outfall section is performed underwater by diving specialists, who use the come-along jack and slings to join the pipes. The special “bell configuration” on one end of the pipe, provides a “self-aligning” joint and eases the underwater operations.

12) 

figure 9: Lowering a single pipe section from the pontoon.

DESIGN OF THE GRP PIPES FOR THIS PROJECT

The present project is relevant for the construction of:

The Sewerage and Stormwater Outlet to the Sea

Located in [*INSERT LOCATION*] for [*INSERT THE DESCRIPTION OF THE PROJECT*].

[*INSERT THE DESCRIPTION OF THE PROJECT*]

[*INSERT THE DESCRIPTION OF THE PROJECT*] is made of No. 3 ND 2000 pipelines (1 sewerage, 2 stormwater) from an onshore box culvert.

The starting pipe bottom level is -5.5 m.

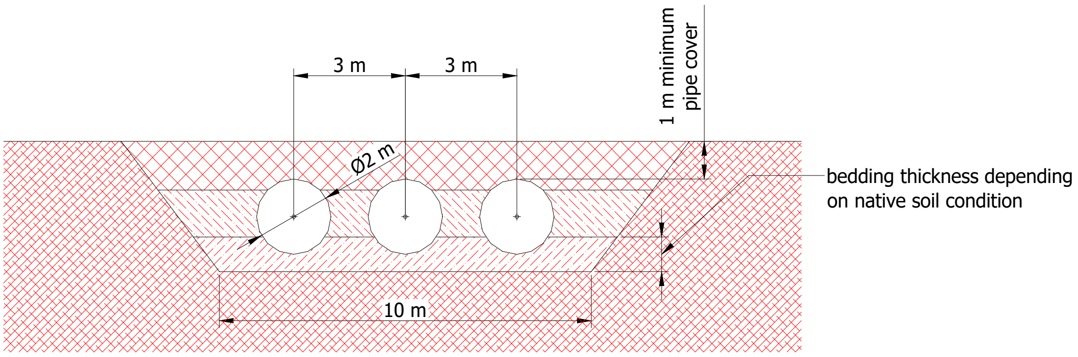
The outlet of the 2 stormwater pipelines is at a distance of 250 m, and the pipe bottom level is –15.50 m. The slope of the pipeline is 4%.

The sewer pipeline is 130 m longer than the stormwater pipelines, and the final bottom level of the pipe is -20.70 m. The slope is the same.

The first part (approximately 75 m long) is onshore, laid in an open trench, with a pipe bottom level up to -8.5 m and the ground level of +3 m. The soil cover on the top of the pipe ranges from 6.5 m to 9.5 m. The type of bedding and backfilling has to be defined according to the native soil conditions, the trench shape, and the availability of the material for bedding and backfilling. The design will be made by following the AWWA M45 Manual recommendations.

The second part (approximately 40 m long) is under the breakwater barrier and is installed into three steel tunnels (∅ 2.5 m).

The rest is offshore, laid in a wide trench, with a 1 m soil cover.



Mechanical characteristics of the pipe

[Insert Client name]	**[Insert Company name]**
[Insert Project name]	[Insert Doc. No.: _____________] [insert Date __/__/____]
Calculation/report on the buried pipe, static verification.	

The recommended pipe for this project possesses the following characteristics:

Pipe Nominal (internal) Diameter	2000	mm
Pipe Wall Thickness	23.5	mm
Pipe Section (12 m) Weight	3800	kg
Pipe Specific Transversal Stiffness	2500	Pa
Pipe Nominal Pressure Class	6	bar
Pipe Axial Strength	870	N/mm
Allowable Pulling Force	80	ton

The pipe's characteristics should be checked for:

- the vertical pipe deflection under the external load;
- critical buckling load;
- longitudinal stresses during the joining operations;
- safety against buoyancy.

Soil load

The soil load, which covers the pipe, is calculated as:

$$W_c = Rw \times \gamma_s \times H = 0.67 \times 20000 \times 1 = 13400\ Pa$$

Where:

Rw = the buoyancy reduction factor of the soil density;

γ_s = dry soil density [20000 N/m^3];

Hw = soil cover on the top of the pipe.

Deflection calculation

Pipe deflection under the load is calculated according to the AWWA M45 Manual Equation No. 5-8:

$$\frac{\Delta y}{D}=\frac{D_L W_C K_x}{8S+0.061E'}=\frac{1.5\times 13400\times 0.1}{8\times 2500+0.061\times 1.38\times 10^6}=\frac{2010}{10000+84180}=1.93\%$$

Where:

Δy = shortening of the vertical diameter;

D = pipe diameter;

D_L = "deflection lag" factor, to compensate for the time-consolidation rate of the soil [=1.5, dimensionless];

W_C = soil load from the previous equation;

K_x = bedding coefficient [=0.1, dimensionless];

S = pipe specific transversal stiffness [2500 Pa];

E' = modulus of the soil reaction [200 psi = 1.38e+006 Pa];

a low soil reaction modulus is assumed, due to the difficulty of compacting the dumped soil for the submarine application. Granular soil shall be used for the bedding and backfilling, up to the crown of the pipe.

The allowed value for this calculation is 5%.

[CHANGE AS NEEEDED] When the calculated deflection is lower than the allowed one, the pipe is verified.

Buckling calculation

The permissible load (safe against the critical buckling) is calculated according to the equation No. 5-21 of the AWWA Manual:

$$q_a=\left(\frac{1}{FS}\right)\sqrt{32R_W B' E' S}=\left(\frac{1}{2.5}\right)\sqrt{32\times 0.67\times 0.24\times 1.38\times 10^6\times 2500}=52295\,Pa$$

Where:

FS = the design factor, required by the Standard (2.5);

B' = the empirical coefficient of the elastic support [dimensionless], calculated as:

$$B'=\frac{1}{1+4e^{-0.213H}}=0.24$$

(H is in meters)

[*CHANGE AS NEEEDED*] *When the applied soil load is lower than the allowed load, the pipe is verified.*

Tensile strength

Since the pipe will be laid section by section, no axial tensile strength will be exerted on the pipe or on the joint.

In this case the verification is not required.

The pipe and the joint axial strength are very high and an [*INSERT THE AMOUNT*] tons axial load can be applied to both, with complete safety.

Buoyancy

To avoid displacements during the installation and the backfilling, sandbags will be put on the either side of the pipe.

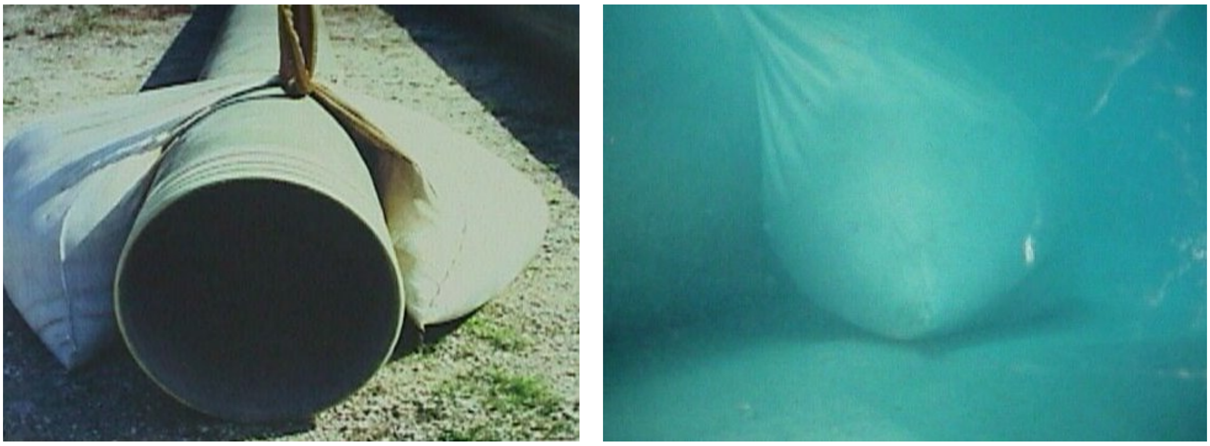


Figure 10: Sandbags on GRP pipes

The pipe should never be empty while operating.

The sewer could generate gas in the hot climate and compressed air needs to be used to clean the pipe culvert from the deposits inside. Once the maximum entity of gas/air in the pipeline is specified, a check must be done. If 1 m soil cover is not enough to prevent buoyancy of the pipeline, sandbags will be increased in number and dimensions in order to satisfy the safety criteria.