



Exploration & Production

GENERAL SPECIFICATION

PIPELINES - RISERS

GS PLR 410

Concrete coating for submarine pipelines

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1. Scope

This specification defines general requirements for the concrete weight coating for submarine pipelines (in sea, river and estuary conditions). This specification will apply also for concrete weight coatings of temporary submerged pipelines such in partially flooded areas or permanently submerged pipelines such in swamps.

Pipes are assumed to have already been anti corrosion coated either in the same plant or alternatively arriving coated from an other location or plant.

This specification is to be used conjointly with general specification **GS STR 101** and the documents referenced herein.

2. Reference documents

The reference documents listed below form an integral part of this General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

Standards

Reference	Title
NF P 18-303	Béton: Mise en œuvre - Eau de gâchage pour béton de construction
NF P 15-317	Liants hydrauliques - Ciments pour travaux à la mer
XP P 15-319	Liants hydrauliques - Ciments pour travaux en eaux à haute teneur en sulfate
NF P 18-370	Adjuvants
XP P 18-540	Granulats
EN 196	Methods of testing concrete
EN 197	Cement
Pr EN 197-4	Cement - Part 4
EN 12620	Aggregates
BS 1881	Method of testing concrete
BS 4027	Specification for sulphate resisting Portland cement
BS 4482	Specification for cold reduced wire for the reinforcement of concrete
BS 4483	Steel fabrication for the reinforcement of concrete
ISO 8501-1	Surface preparation Swedish Standard
ISO 1920	Concrete tests
ISO 2736	Concrete tests
ISO 4012	Concrete - Determination of compressive strength on test specimens

Reference	Title
ASTM C 31	Std Method of making and curing concrete tests specimens
ASTM A 82	Specification for cold redwood steel wire for reinforcement of concrete
ASTM C 33	Concrete Aggregates
ASTM C 39	Standard method for compressive strength
ASTM C 150	Portland Cement
ASTM C 227	Standard method for potential Alkali reactivity of cement aggregate
ASTM C 309	Liquid membrane. Forming compounds for curing concrete
ASTM C 171	
ACI 357 R	Guide for the design and construction of fixed offshore concrete structures
ACI 311.4 R	Guide for concrete inspection

Professional Documents

Reference	Title
API 5LW	Recommended practice for marine transportation of line pipe
API 5L	Specification for high-test line pipe

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
BS 8010.3	Code of practice for pipelines
DNV OSF 101	Submarine pipeline systems

Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
GS COR 220	Three layer polyethylene external coating for pipelines
GS COR 221	Three layer polypropylene external coating for pipelines
GS COR 223	Hot enamel pipe coating
GS COR 401	Installation of anodes on submerged pipelines
GS STR 101	Design of offshore jacket and subsea structures
GS STR 201	Materials for offshore steel structures
GS STR 301	Fabrication of offshore steel structures

3. Definitions

The Inspector: The COMPANY's representative or a member from an inspection agency duly appointed in writing by the COMPANY to act as his representative for the purpose of the contract shall be referred to herein as the "Inspector".

4. Concrete weight coating design

4.1 General

Such concrete coating is intended to:

- Achieve the required pipeline negative buoyancy
- Provide additional mechanical protection to the pipeline.

The particular project specification (PPS) - see also Appendix 1 - will give for each category of pipe of each project the main information of the required concrete coatings:

- Kind of reinforcement required (wire cage or mesh)
- Concrete density
- Concrete thickness
- Value of negative buoyancy required (with tolerances)
- Etc.

Note 1: In close liaison with Engineering, to get best economical compromise, CONTRACTOR may proposed to COMPANY approval an alternative concrete coating thickness by balancing concrete thickness and ingredient material to achieve the required standard gravity and submerged weight necessary for the stability of the pipeline.

Note 2: This specification is covering continuous cylindrical concrete coating. In some circumstances, stability of the submerged pipelines may be achieved by other means or tools (concrete blocks, concrete poured ins situ into mini cofferdams, etc.).

4.2 Service conditions

The coating materials shall be designed to meet the following general service conditions, of underwater pipeline i.e. unless other wise specified in the particular specification:

- Installation shall be by the lay barge method
- Temperatures during storage may vary from -15°C to 40°C
- Air temperature during installation may vary from 5°C to 30°C
- Pipeline may be laid in a trench or on the sea bed
- Pipeline may be thermally insulated.

The particular specification (see Appendix 1) will give other needed information as for instance pipeline operating temperature range.

4.3 Concrete coating materials

4.3.1 Cement

All cement used for the preparation of the concrete shall conform to [ASTM C 150](#) Type V or alternatively Type II (if sulphate contents of sea water is less than 1000 ppm).

Type I is acceptable in fresh water.

Sulphate contents shall be indicated in the PPS.

The tricalcium aluminate content (C3 A) of the cement shall be within the range of 3 to 5% for cement type V and between 3 to 7% for cement type II (% cement weight).

The cement shall be adapted for "sea water hardening" and shall resist the effects of sulphates. The cement dosing shall be equal or larger than 400 kg/m³ of concrete mix.

Cement that has hardened, partially hardened or become lumpy shall not be used.

Cement must not be stored in the open.

4.3.2 Sand (Silica type)

Sand used shall be grain rounded and shall be obtained by sieving. Clayey or schistose sands shall not be used. It shall be free of injurious amounts of salt, alkali, deleterious substances or organic impurities.

Suitability of the natural sand for making of concrete shall be determined in accordance with the requirements of [ASTM C 33](#).

Sand grading shall be within the range of values determined by the granulometric analysis curve:

Sieve		Passing	
ASTM C 33	Mesh size (mm)	Total weight of sand %	
		Minimum	Maximum
2	9.5	100	100
4	4.75	90	100
8	2.36	80	100
16	1.180	50	80
30	0.600	25	55
50	0.300	5	30
100	0.150	0	10

Sand shall be cleaned by washing or de-dusting process in order to meet above mentioned Standards.

Washing will be performed with fresh water. Sand shall be washed so as not to remove the smaller grains as defined (refer with [ASTM C 33](#)).

4.3.3 Coarse aggregate

Selected according to the type of concrete to be produced, coarse aggregate shall be crushed granite or equivalent material.

Grading shall be as follows:

Sieve		Passing	
ASTM C 33	Mesh size (mm)	Total weight of aggregate %	
		Minimum	Maximum
2	9.5	100	100
4	4.75	90	100

Coarse aggregates shall not contain any materials which may react with alkalies in the cement.

4.3.4 Heavy aggregate

The aggregate may be granite or approved equivalent material. Iron ore may be added to achieve the required density and required negative buoyancy after submersion and saturation with sea water. In that case this aggregate should be crushed to the following gradation:

Modulus ASTM C 33	% of Total weight of aggregate	
	Minimum	Maximum
N° 2 or 9.52 mm	100	100
No.4	80	90
No.16	40	70
No.50	10	30
No.100	0	10

The final granulometry must be approved by COMPANY. The heavy aggregate shall be clean and free of clay.

This shall be stored on rolled hard core or other paved area approved by COMPANY.

The cleanliness of the aggregate must be controlled by screening at the crusher and must be clean and free of deleterious material.

Aggregates shall be cleaned by washing or de-dusting process in order to meet above mentioned Standards.

Washing will be performed with fresh water.

4.3.5 Reinforcement

Galvanized steel poultry netting or chicken wire is not allowed for internal reinforcement of concrete coating for pipelines.

Two kinds of reinforcement may be used: welded cage or wire mesh.

4.3.5.1 Welded cage

The reinforcement should be "square grip" conforming to [BS 4483](#) and constituted of non continuous cage. The overlap shall be 100 mm minimum.

Characteristics of the welded cage shall be the following:

	Longitudinal reinforcement	Circumferential reinforcement
Steel bar diameter	3 to 8 mm	5 to 12 mm
Bar spacing	75 to 400 mm	75 to 150 mm
Percentage of coating sectional area	0.1 to 0.2%	0.45 to 1.0%

Detailed positioning of the reinforcement shall be provided.

4.3.5.2 Wire mesh

Wire mesh (spot welded mesh made of galvanized low carbon steel wire) shall be designed, manufactured and tested according to [BS 4482](#) and [BS 4483](#).

Characteristics of the wire mesh shall be the following:

	Longitudinal reinforcement	Circumferential reinforcement
Steel bar diameter	2 to 4 mm	2 to 4 mm
Bar spacing	50 to 300 mm	65 to 100 mm
Percentage of coating sectional area	0.08%	0.4%

One layer of mesh is required for concrete coating thickness up to 50 mm. One additional mesh layer is required per 50 mm of additional concrete thickness.

The overlap shall be 25 mm minimum.

In both cases, the distance between anti corrosion coating and reinforcement shall be 15 mm minimum, the reinforcement shall be covered by 19 mm minimum of concrete unless otherwise specified in the particular specification.

4.3.6 Mixing water

The mixing water shall be of potable quality. The water shall be clean and free from injurious oils, acids, alcohols, salts or organic materials.

Water analysis shall be provided to COMPANY approval.

The water to cement ratio shall be 0.28 to 0.35 in the mixed concrete applied on the pipe.

4.3.7 Fibre reinforcement

To possibly increase the tensile strength of concrete (thickness in the range of 40 to 60 mm) use of fibre reinforcement may be proposed to COMPANY.

4.4 Properties of the concrete coating

4.4.1 Concrete mix design

Mixes using the above mentioned concrete coating materials must obtain the required densities and strength.

Reuses of concrete shall not exceed 10% by weight of the total mix.

Full details shall be provided with regard to:

- The propositions and weights of the respective dry aggregates
- The cement weight per cubic meter of concrete
- The volume of water, per cubic meter of concrete
- The results of the preliminary tests for water absorption and resistance
- The density of the proposed mix.

The component parts of the concrete must be properly mixed in order to provide an homogenous and consistent mix.

The proposed composition shall meet the minimum mechanical strengths and water absorption specified and shall ensure easy and satisfactory application of the concrete coating.

Proposed composition may be changed during coating operation. Such change needs the written approval of the COMPANY.

The proposals shall be presented in the form of a detailed report and shall be submitted to COMPANY for approval prior to the application. It should be taken into account for mix design that during production the following tolerances by weight will be allowed:

- 3% for each type of aggregate
- 2% for the aggregate as a whole
- 1% for the total quantity of water
- 1% for the cement.

4.4.1.1 Proportion of water

To take into account the variations in water addition due to variations and aggregate moisture content, a diagram must be prepared indicating the weight or volume of sand to be added or deducted and the quantity of water to be added or deducted from the theoretical mix composition for each moisture content. The water content shall meet the requirement of 4.3.6. This shall be approved by the COMPANY.

4.4.1.2 Display of composition

At the start of each production shift, the following information shall be determined, measured and displayed:

- Theoretical composition as defined previously
- Actual composition, taking into account the daily moisture content of the aggregate and the humidity of the day.

4.4.2 Strength of the concrete

Unless otherwise specified the concrete coating shall have a strength of not less than:

- 255 kg/cm² (3626 psi) for cylinder samples or 287 kg/cm² (4168 psi) for cube samples after 7 days
- 408 kg/cm² (5803 psi) for cylinder samples or 460 kg/cm² (6668 psi) for cube samples after 28 days.

The strength of the concrete shall be measured during extensive tests (see details in Section 6.6).

The strength shall also be measured on specimen cubes with a minimum requirements of two cubes for each sample taken every four operation hours or mix change or after all shutdown periods.

4.4.3 Water absorption

Concrete water absorption is measured following a process described in Section 6.6.4, and shall not exceed 4%.

5. Fabrication

5.1 Working area and concrete coating plant

All arrangements for the COMPANY and/or the Inspector to have free access to the working area must be granted.

Without limitation all temporary and permanent facilities and services for the execution of the works, including materials, storage, fabrication, transportation, out loading, and for all transport craft and equipment of every kind required for the movement of his employees, equipment, and materials must be provided.

Complete drawings of the yard, layout of storage and working areas and any temporary works giving overall dimensions of the area shall be submitted to the COMPANY for approval.

Yard surface shall be wide enough to allow safe handling, proper curing area and safe storing area of the non concrete coated pipes and concrete coated pipes.

Full descriptive of the Process of the concrete coating must be described in a document detailing the various steps and proposed storing arrangements.

Efficiency, safety and maintenance there of until all the coated pipes have been delivered FOB to the pipe laying CONTRACTOR's supply barge are under the whole and entire supervision of the concrete yard coating.

Concrete coating yard employees shall comply with all relevant safety and other regulations and so shall Inspectors and staff.

Facilities (office, phone, fax, telex, etc.) for the COMPANY's representative(s) shall be provided. Description of these facilities will be given in the particular specification.

On the site, and to the satisfaction of the COMPANY's representative, sufficient, proper, and efficient life and first aid appliances shall be provided.

5.2 Weather conditions

Concreting: at the time of coating, the mixed concrete shall be at a temperature of not less than 5°C and not more than 35°C.

1. Should the ambient temperature be less than 5°C: The mixed concrete in the mixer shall be obtained at a temperature of not less than 5°C. The wrapped pipe and the concrete coating area must be maintained at a temperature greater than 5°C by the use of a heater system that will not contaminate the coating in any way.
2. Should the ambient temperature be more than 35°C: Temperature of various ingredients for concrete shall be calculated so as to obtain a mixture with a temperature less than 35°C, addition of ice may be found necessary but quantity added shall not be more than 50 kg/m³. If ice is used it shall be taken into account in the water to cement ratio (refer to paragraph 4.3.6).

Measures shall be taken to compensate for water evaporation such as adding a calculated amount of water or wrapping immediately the applied concrete with a polyethylene film.



Other remedial measures shall be proposed in the case or local conditions may imply concrete activity coating with external temperature steadily above 35°C.

In any case the compressive strength condition of the paragraph 4.4.2 shall be met.

5.3 Preparation before concrete application

Prior to concrete application the CONTRACTOR shall check the good condition of the anti corrosion coating by means of a holiday detection with a holiday detector. The voltage setting of the holiday detector shall be 20,000 volts. If a defect is detected, it shall be repaired and retested with the holiday detector before concrete application.

5.4 Concrete application

5.4.1 Installation

A plant which contains at least equipment and facilities shall be supplied for the following:

- The proper storing of the various concrete coating materials
- The preparation of the wire cage reinforcement (if used).

For mixing of the concrete, equipment which shall produce a homogeneous and consistent mix. Such type of mechanical equipment shall be approved by the COMPANY and shall be approved by the COMPANY and shall be capable of determining the percentages of aggregates, cement and water within 3% by weight.

Supplying the coating machine with concrete shall be achieved by means of conveyor belts or equivalent systems. Continuous conveying shall be ensured in order to avoid the segregation of the constituent parts of the mix as well as to prevent the hardening of the concrete before its application.

The application of the concrete weight coating and the weighing of the coated joints.

All other equipment that is needed for production in conformity with this Specification.

5.4.2 Installation of reinforcing steel

5.4.2.1 Welded cage

The wire cage reinforcing shall be made of circumferential and longitudinal bars covering the entire pipe length less the cut-back minus 30-50 mm on each end and the longitudinal rods shall be of a continuous piece.

The reinforcement shall be placed around the pipe and positioned in the centre of the concrete coating thickness. In no case shall the reinforcing steel be less than 15 mm from the corrosion protective coating.

Clearance of the reinforcement from the pipe wrapping shall be ensured by means of spacers, the height of which shall vary according to the concrete thickness. Such spacers shall consist of plastic contact pieces or of steel pieces welded on rings.

Clearance between the various reinforcement arrangements may be achieved by steel pieces welded on rings.

The spacers must:

- Keep the wire cage reinforcement in place when the pipe is rotating around its axis.
- Not damage the protective coating. For this purpose they shall be placed in such a manner that the corrosion wrap is not damaged.

These spacers must be submitted to the COMPANY for approval before commencement of the works.

5.4.2.2 Wire mesh

The wire mesh reinforcement shall be regularly shaped and carefully placed around the pipe without damaging the existing wrap.

A single wrap of reinforcement can be applied if the concrete coating thickness is 5 cm or less. This wrap shall be a minimum of 15 mm from the outside surface of the enamel coating except at the start of the winding operation. A double or a triple wrap of reinforcement shall be applied if the concrete coating exceeds 5 cm.

The external wire mesh wrap shall have a minimum of 10 mm of concrete cover. The wrapping shall be spirally wound onto the pipe with a minimum overlap of 2.5 cm.

At the centre of the first pipe of each day's production a water jet shall be used to clear away the freshly placed concrete down to the corrosion coating for an area approximately 75 mm wide and 200 mm long in the longitudinal direction. Inspection of this exposed area shall be used to confirm that the mesh is positioned and overlapped within the concrete as specified. If the wire is not positioned correctly, the pipe shall be rejected and recoated. Each pipe in succession shall be inspected in this manner until the position of the mesh is accepted. Repair to the inspection slot shall be as specified in Section 7.

When requested by COMPANY, concrete coated pipes shall be tested with an ohm-meter to ensure that there is no contact between the wire reinforcement and the pipe or the anodes.

5.4.3 Placing of the concrete coating

The concrete coating shall be either placed by impingement or formed by means of injection moulds. No concrete shall be applied until it is thoroughly mixed.

The coating procedure submitted to the COMPANY for approval shall ensure a satisfactory coating with respect to thickness, density and strength. The outer surface of the coating shall be uniform.

In all cases, the concrete shall be placed within 30 minutes after the water has been added to the mix. Each joint shall be coated in a continuous operation. If more than one application is required, the total time allowed for the completion of the operation shall not exceed 30 minutes.

Each pipe joint shall be coated on its whole length, except for both ends which shall be completely free of concrete for a distance specified in the particular specification (for instance 350 mm $\pm$ 25 mm). After this operation and before curing, the CONTRACTOR shall measure the outside circumference of each pipe in five, approximately equidistant locations, in order to calculate the average diameter. This information shall be given to the Inspector.

Immediately after concrete application and measurement, the negative buoyancy of the pipe shall be calculated. If the negative buoyancy is out of tolerance, either concrete will be added, not more than 3.0 minutes after coating completion, or scrapped, depending whether the particular pipe length is under or over weight.

5.4.4 Curing of the concrete

When concrete coated, the pipes with the necessary precautions will be stored in a dedicated area for the curing operation.

Concrete coating (14 days period mini) is cured so as to ensure the moisture content necessary for a satisfactory hardening. Curing may begin after impingement of the concrete or, in the case of injection moulded coating, immediately after removal of the moulds. Concrete shall be protected during curing from the sun and wind. Curing shall not begin before the complete surface hardening of the cement, so that a spray of water cannot damage the surface.

Concrete coated pipes shall not be stacked until the coating has achieved a minimum compressive strength of 15 MPa, unless compressed concrete coating has been applied and wrapped in a polyethylene film to protect it from rain and water vaporisation ensuring a good curing and a good resistance to deformation (see § 8.1.2 above).

5.4.4.1 Wet curing

Curing may consist of keeping the concrete continuously moist for at least 14 days by means of intermittent watering (minimum ambient temperature is 5°C). Spraying programme must be submitted to COMPANY for approval.

During this treatment, pipe joints shall be stored on bearers, bolsters or liners and kept.

5.4.4.2 Steam saturated atmosphere

Curing under steam atmosphere shall continue until the concrete has achieved a compressive strength of minimum 15 MPa.

Minimum curing period is 14 days.

Steam saturation shall start at ambient temperature and increase at a maximum rate of 10°C per hour, till it reaches a maximum temperature of 50°C. Coated pipes shall be held under steam curing for at least six hours and then cooled at a similar rate.

Plastic or similar cover will be placed over the concrete coated pipe to allow the steam curing.

5.4.4.3 Membrane curing

Membrane curing (see [ASTM C 171](#)) may be used but in the following conditions:

- Membrane forming compounds used shall conform to [ASTM C 309](#). The ingredients of any such compound shall be non toxic and non inflammable, and shall not react with any ingredient of the concrete, the corrosion coating or the steel of the pipe
- Membrane coating shall be continuous over the concrete and shall remain so for a minimum of seven (14) days. Edges of sheets shall overlap with a minimum of 50 mm
- Membrane coating must be agitated to uniformity prior to and during application in strict conformity with the print instructions supplied by the MANUFACTURERS of the materials
- Membrane must be removed before loading on supply vessel of the lay barge.

5.4.4.4 Curing compounds

Curing compounds may be added in the concrete mixture. These additions have to be submitted to the prior approval of the COMPANY.

5.5 Concrete weight coating of pipe with anodes

Concrete weight coating shall be applied in the same manner as for the pipes without anode bracelets.

It must be ensured that:

- There is no contact between the reinforcing bars and the anodes
- The outer surfaces of the anodes are clean and are protected by means of the prescribed wooden slat protectors.

6. Inspection and testing

6.1 General

COMPANY personnel and Inspectors shall have full and free access to the offices and/or the plant of the concrete yard or other parts (adjacent or not) implied in the whole concrete coating process, and every part of the coating yard, and on/off loading facilities.

They must assist at every stage of production.

They may request:

- A copy of all of the certificates of conformity, tests, calculation sheets, schedules, etc., written by the CONTRACTOR
- All necessary tests or procedures.

6.2 Receipt of the pipes

When the ships (or trucks or wagons) arrive with the pipe joints aboard, the reception of the pipe joints shall be organized with the Inspector.

All defects, damages and/or incidents will be carefully recorded.

Unless specify otherwise in the particular specification the length, the straightness and the ovality for each pipe must be measured. The CONTRACTOR shall check that these measurements do not exceed specified tolerances imposed to the pipe SUPPLIER(S).

6.3 Corrosion protective coatings and thermal insulation coating (if any)

Internal and external anti corrosion coatings and thermal insulation coatings will be inspected and repaired according the indication of the GS COR selected and/or the particular specification for the thermal insulation.

6.4 Cathodic protection

This inspection shall be primarily concerned with the electrical connections.

However:

- Each weld joint executed on the two halves of the anode bracelet shall be submitted to a visual examination only
- All coal tar base enamel shall be checked according to the same method used for all other corrosion protective coating.

6.5 Shear test

Concrete application can start only when it has been demonstrated to the satisfactory of COMPANY that holding of the concrete onto the external anti corrosion coating is suitable for the future pipe laying tensioning barge system. This is to avoid possible slippage of the concrete on the external anti corrosion coating pipeline during extreme weather conditions. Results shall be based on shear strength at 28 days.

Test method shall be submitted to COMPANY for approval. Minimum shear stress value is 0.5 MPa as specified in **GS COR 220** or (if different) as indicated in the PPS.

6.6 Concrete weight coating

6.6.1 Inspection of concrete weight coating materials and mix

6.6.1.1 Cement

Certificates from the cement MANUFACTURER shall be supplied to the Inspector for every cement delivery to the coating yard site.

6.6.1.2 Sand, aggregate and water

The grading and purity of sand and aggregate shall be checked at least once every three days. The purity of the mixing water shall be checked at least every week.

6.6.1.3 Tolerances on proportion of concrete material

The tolerances allowed for the mixing proportions shall be checked at least once per shift.

Tolerances are as follows:

- 3% for each type of aggregate
- 2% for the aggregate as a whole
- 1% for the total quantity of water
- 1% for the cement.

The weight of the mix shall be controlled for each operation. The accuracy of the measurement shall be checked at least once per week, taking into account the tolerances allowed for the scales and for the proportions of the various materials.

6.6.1.4 Tolerances on coating cover

The permitted dimensional tolerances shall be:

- -0 /+ 5 mm for concrete cover (thickness)
- +/- 5 mm for distance between end of reinforcement and anode or end of concrete weight coating
- +/- 50 mm for end cut-back.

6.6.2 Strength tests

Six core samples shall be taken from one joint out of every 25 produced pipes or at least once per shift, whichever is more frequent to check the compressive strength of the concrete weight coating.

Samples may be either cube samples (ISO 4012) or standardised cylinder samples (ASTM C 39) or core samples (ASTM C 39).

The cores shall be taken at two different locations of the pipe, not later than three days after coatings if steam curing is applied, otherwise when it is feasible to obtain sound cores.

The cores shall be marked with the pipe number plus LE-1, LE-2, LE-3 and TE-1, TE-2, TE-3 where LE stands for Lead End of the pipe (side of the pipe where the hard stamp appears on the bevel, and TE stands for Tail End (side of the pipe with no hard stamp on the bevel).

Two cores shall be tested after 7 days and two others after 28 days in accordance with BS 1881. The two extra cores shall be kept by the CONTRACTOR, at least until the 28 days test is completed satisfactorily, these cores will serve as spares in case of a core failure at 28 days.

The minimum core compressive strength shall be 25 N/mm² (255 kg/cm²) for the average strength of the two core samples tested after 7 days and 40 N/mm² (408 kg/cm²) for the average strength of the two core samples tested after 28 days. No single core strength shall be less than 80 percent (80%) of the specified minimum i.e.:

- No single strength below 20 N/mm² (204 kg/cm²) after 7 days
- No single strength below 32 N/mm² (326 kg/cm²) after 28 days.

Core age	Minimum average strength for two core samples	Minimum single strength for any one core sample
7 days	25 N/mm ² (255 kg/cm ²)	20 N/mm ² (204 kg/cm ²)
28 days	40 N/mm ² (408 kg/cm ²)	40 N/mm ² (408 kg/cm ²)

For every core that resulted to a strength below the minimum single strength specified above, three additional cores shall be extracted from approximately the same locations. If all the three cores meet the minimum requirement and the average strength of the three is within the minimum average specified, then the coating represented by the test will be accepted.

If any of the retest cores fails, the coating will not be accepted and pipes on either side of the rejected pipe, according to the coating sequence, shall be cored and tested on the same basis as above.

This procedure will continue until acceptable coated pipes are found. Defective pipes shall be re-concrete coated.

Core holes shall be refilled with a trowel after suitable wetting of the concrete in the area, and the replacement shall be subject to the approval of the Inspector.

Core holes shall not be filled without prior inspection by and permission from the Inspector.

6.6.3 Negative buoyancy calculation

The "as applied" negative buoyancy, corresponding to the values given, must be calculated for each pipe. Therefore, the following information for each pipe must be provided:

- Steel pipe diameter
- Pipe length
- Weight of pipe and corrosion coating before impingement

- Weight in the air after impingement
- Average of five girth measurements on the coated pipe, approximately equidistantly spaced along the pipe
- Date of concrete coating application
- Calculated "as-applied" negative buoyancy.

The formula of calculation of the "as-applied" negative buoyancy must be passed to the COMPANY in writing during initial project consultations to get its validation.

Accurate weight control is considered more important than coating thickness.

The weighing procedure shall be subject to the COMPANY approval. Pipe shall be weighed on a Weight Bridge or by any equivalent weighing method, using calibrated load cells. Calibration certificates for the proposed weighing equipment must be provided prior to any measurement. At least once every 24 hours, all weighing equipment used during the coating operation shall be re-calibrated.

At the beginning of the works, the calculated negative buoyancy must be proved to be equal to the negative buoyancy measured (tolerance $\pm 5\%$). The minimum number of pipes to be checked for each negative buoyancy is 10. This proof will be repeated during production once each 150 pipes.

A systematic weight control is required.

The anti corrosion coated pipe (W_1 in kg) must be measured before concrete application. The pipe must be weighed after concrete application (W_2 in kg).

The perimeter of the concrete in five different locations along the pipe length must be measured.

Then the apparent concrete density (D_{ac} in kg/m^3) using the following formula must be calculated as:

$$D_{ac} = ((W_2 - W_1) / (L - 2Cb)) / C_s$$

Where:

- D_{ac} Apparent concrete density
- L Pipe length in m
- Cb Concrete coating cut back in m
- C_s Concrete sectional area (average) in m^2 .

Provided the initial tests are successful, additional test will be required every months in lieu of one every 150 pipes.

The negative buoyancy (Nb) shall be calculated in kg/m according to the following formula:

$$Nb = (W_1 / L) + W_c - ((3.14 \times D_c^2 \times d_w) / 4) + A_c$$

Where:

- Nb Negative buoyancy (in kg/m)
- L Pipe length (in m)
- W_1 Weight of the anti corrosion coated pipe (in kg)
- W_c Concrete weight (in kg/m of pipe)

D_c Outside diameter of the concrete coated pipe (in m)

d_w Water or mud density (in kg/m³)

A_c Water absorption by concrete (in kg/m).

Tolerances:

The tolerance allowed for the negative buoyancy shall be -0; +4% for an average of each 100 joints taken as one pipe.

For each plain joint, the tolerance allowed in negative buoyancy is -5; +10%.

6.6.4 Water absorption test

This test must be done at least once in the production of every 50 pipes for the first 150 pipes then on one out of every 150 pipes coated.

The test on an entire concrete coated pipe joint shall be performed according to the following procedure:

1. The pipe is weighed in air and weights are recorded before and after concrete coating (the weights being W_1 and W_2 respectively).
2. The concrete coated pipe is submerged in water of known specific gravity for not less than 2 hours.
3. The concrete coated pipe is removed from the water and weighed again within 15 minutes from removal from the water. This weight is the saturated weight, W_{sat} .
4. The water absorption is calculated as follows:

$$\text{Water absorption} = \frac{W_{sat} - W_2}{W_2 - W_1} \times 100\%$$

The water absorption shall be limited to 4% maximum.

6.6.5 Electrical insulation

An insulation test every 25 concrete coated pipes shall be carried out by measuring the resistance between the reinforcement and the pipe. It shall not be less than 100 ohms.

6.6.6 Impact tests

When required by COMPANY in the PPS, full scale impact tests must be conducted.

COMPANY will provide when necessary details on tests results acceptance criteria depending on impact angles and number of blows.

Details of tests procedure and details of tests arrangement must be provided to COMPANY.

7. Repairs - Causes for rejection

7.1 Spalling

7.1.1 Depth of spall < or = to 25% With nominal concrete coating

If spalling, due to impact or erosion or resulting from improper application of the concrete is found to be not more than 25% of the depth of the coating surface, the following steps shall be taken:

1. If the damaged zone is less than 500 cm², no repairs shall be undertaken.
2. If the damaged surface is between 500 and 3000 cm², the concrete coating shall be repaired as follows:
 - The coating shall be removed until the reinforcement is visible and shall be undercut so that a key lock is formed
 - The edges of the damaged zone shall be trimmed
 - Fresh concrete shall be trowelled into the hole until the surface is level with the coating around the repair.

The pipe shall then be allowed to moist cure for a minimum of 48 hours.

3. Should the damaged surface exceed 3,000 cm², the coating shall be removed on the entire periphery of the pipe in the damaged area. The reinforcing shall be restored if Inspector deems necessary, then the cavity shall be refilled with fresh concrete having the same characteristics as the concrete around the repair. Once the pipe joint is repaired, it shall be kept in a thoroughly moist place for 48 hours.

7.1.2 Depth of spall > 25% With nominal concrete coating

If the depth of the spalled area exceeds 25% of the coating depth, then:

1. For damaged zones of 500 cm², or less the procedure specified above (2) shall be followed.
2. For damaged zones of greater than 500 cm², the procedure specified in (3) above shall be followed.

No pipes shall be accepted if spalling extends to the enamel layer.

Note: Any size of concrete repair should be repaired using a gummite machine but in any case any repair equal to or larger than 2,000 cm² shall be made using a gummite machine.

7.2 Cracking

All necessary measures to avoid concrete cracking during handling or stockpiling operations must be taken.

Must be repaired:

- Circumferential deep cracks exceeding 1.5 mm in width and extending for 180° or more circumferentially around the pipe
- Cracks over 10 cm in length longitudinally along the pipe, exceeding 0.5 mm in width.

Repairs shall be made by chiselling the crack out to a width of at least 2.5 cm throughout the length of the crack. The crack shall then be refilled with fresh concrete having a satisfactory density, preferably using a gummite machine.

After being repaired, the pipe shall be stored and kept moist for at least 48 hours.

7.3 Repairs materials and procedures

Repairs of concrete coating when applicable can be done either by fresh concrete (by a period not exceeding 30 minutes after the initial concrete application) or by gunnited concrete (on hardened concrete). Detailed repair procedures must be submitted to COMPANY for approval.

Alternative methods may be proposed.

7.4 Causes for rejection

Causes for rejection of the concrete coating shall include, but not be limited to, the following:

- Damaged surface equal or larger than 10,000 cm² or if more than two damaged surfaces equal or larger than 30,000 cm² are affecting the same pipe
- Negative buoyancy less than or greater than the tolerances allowed
- Concrete which does not meet the specified characteristics
- Improper placement of the reinforcing steel and protruding or visible reinforcement
- Pipe coating seriously damaged during handling operations
- Unfinished coating which remains so for a period exceeding 30 minutes in case of a breakdown or otherwise
- Water absorption exceeding 4%.

8. Handling and marking

At least one month before the commencement of the works, a complete description and drawings of docks, harbour, rail facilities, truck unloading facilities, and all other facilities and equipment necessary for unloading and out loading of the pipes must be provided.

These items must get COMPANY's approval.

Every stockpiling here under described shall be achieved according adequate category (diameter, wall thickness, negative buoyancy, external anti corrosion coating type, etc.).

8.1 Handling

8.1.1 Unloading and stockpiling of coated (external anticorrosion and thermal insulation) pipes

Unloading, delivery to the concrete coating yard and stockpiling of the pipes are covered within the present concrete coating activity and are relevant to this specification.

All types of cables, chains hooks or other handling methods used for the handling of the pipes must be approved by COMPANY, as must be the stockpiling procedure.

Coated pipes shall be stacked to give six point contacts (or less if specified in the PPS).

The recommended stacking height will be given in the particular specification. In any case it shall be limited to the maximum weight that the bottom layer of pipe can withstand before deformation or damage to the existing external coating.

Pipes must be stock piled only in properly built foundations. Such foundations shall in general comprise a concrete slab with wooden sleepers on top of the slab and pipes then placed on these wooden sleepers. However sand foundations may be used with the COMPANY's approval.

Coated pipe sections shall be handled and stockpiled by means of wide and non abrasive belts made of a flexible material or other approved means in order to prevent damage to the coating.

The anti-corrosion coated pipes must be stockpiled in approved storage conditions. These procedures must be approved by the COMPANY.

Conditions which should produce damage or deterioration must be avoided.

The use of unlined cables shall be strictly forbidden.

During all handling operations, particular attention must be paid to the bevel ends.

To avoid deterioration or alteration of the anti corrosion coating, the maximum weather conditions as indicated by their particular specifications permitted for the anticorrosion coated pipes stored temporarily prior to be concrete coated must not be exceeded.

8.1.2 Final stockpiling of concrete coated pipes

Concrete coated pipes with OD smaller or equal to 114 mm or pipes with heavy and large concrete wall thickness (as required) will impose special handling procedures to avoid unacceptable deflection and subsequent damages to the concrete coating.

Concrete coated pipe sections shall be handled and stockpiled by means of wide and non abrasive belts made of a flexible material or other approved means in order to prevent damage to the concrete coating.

Completed concrete coated pipes shall be stacked according the maximum height value given in the particular specification.

In the open, the pipes shall be stacked in such a way that they are clear of the ground, in order that mud and water can not enter and can not accumulate inside the pipes. In case of long storage (more than three months), closing of pipe ends with caps shall be considered.

Pipes with anode shall always be stacked on the top of the stockpile without exception.

8.1.3 Loading out

Pipes must be supplied (from supply boats or trucks, wagons, etc.) according to the instructions of the COMPANY. The COMPANY will pass instructions on:

- The number of plain joints to be loaded with indication of the average negative buoyancy
- The number of joints with anodes to be loaded.

8.2 Marking

8.2.1 Original pipe marking

All the coated pipes provided to the concrete coating yard shall arrived in the concrete yard with their original pipe marking traceable to original certification fully readable on both ends of each pipe joint in a position according to Section 11.2 of **API 5L** Specification.

8.2.2 Colour coding of concrete coated pipes

To identify pipes of different diameters or if of the same diameter, different wall thickness, grade and/or concrete coating thickness, and/or concrete coating density, a colour coding system has already been achieved in the anti corrosion coating yard.

Any additional colour coding system (including colours and system of application) proposed during the concrete coating application for identification shall be approved by COMPANY.

8.2.3 Traceability

Concrete coating process shall comply with the COMPANY existing pipe identification and traceability system all through the production.

8.3 Storage

The concrete coated pipes shall not be stored in the open before curing started and a compressive strength of 15 MPa is achieved, unless the concrete coating being wrapped in a polyethylene film, its curing is not affected by a storage in the open.

Facilities to store the concrete coated pipes in different piles according to required negative buoyancy must be supplied in due time.

9. Records

All such records and reports as and when required by COMPANY and representative must be prepared. Such records will include, but shall not be limited to, schedules giving details against each pipe serial number of weights, type of corrosion coating, concrete densities, negative buoyancy details, date concrete placed, and whether anode fitted, unloading schedules including records of all damaged pipes, monthly progress reports as well as weekly production figures and the results of tests and procedures performed under section 4 of this specification.

Filing of these records will have to match with the whole computerised organisation of pipe history system of the COMPANY.

Particular specification will detail:

- The required documents
- The schedule of submission to the approval of the COMPANY of these documents.

10. Quality Plan and Quality Assurance and Quality Control

The Quality Plan covering the entire procedure of applying concrete coating onto pipes for pipelines shall be provided by the concrete coater.

This Quality Plan must be fully adhered to.



This Quality plan must give full details on the Quality Assurance policy and on the Quality Control methods applied by the concrete coater at each single steps of the concrete coating process starting from reception of pipes at the entrance of the coating plant till the exit of the concrete coated pipes towards their next destination.

The QA/QC dossier must include all the necessary actions to guaranty the quality of every components used for the concrete coating.

It must also detail all the actions required for the coating operation to insure a smooth, efficient and safe process.

The quality plan must give full details on the final dossier which will include all the documentation and certificates.

Traceability of every component must therefore be insured.

Appendix 1 Particular Project Specification (Typical)

The additional requirements for each type of pipe for each project must be gathered in a particular project specification prepared during the basic engineering.

It shall contain as a minimum the following information (when applicable):

- One data sheet with:
the name of project, name of the line, type of effluent, pipe OD, grade, nominal wall thickness, standard length of pipe, type of pipe, type of anticorrosion coating, thermal insulation, No. of pipes, total length, name of pipe MANUFACTURER, type, characteristics of external coatings, name of external coatings SUPPLIER, names of thermal insulation SUPPLIER, number of pipes with anodes.
- Concrete coating characteristics with:
the required nominal concrete thickness, concrete density, required submerged weight, required type of cement, length of cut back.
- Applicable standard for concrete reinforcement calculation
- Applicable standard for materials
- Requirements for external caps and bevel protectors
- Requirements for impact tests and tests programme
- Maximum height of stack and maximum number of ties for bare pipes, external coated pipes and concrete coated pipes
- Minimum value for shear tests of coated pipes (for future sea laying purpose)
- Negative buoyancy optimisation study
- Storing conditions of non concrete coated pipes
- Number of contacts between stacked pipes
- And others items.

Appendix 2 Work Control Sheets

As a reminder but not to replace the concrete coater Quality Plan, the following sheets may be used to remind the usual coating steps and the respective responsibilities.

	COMPANY	Concrete Coater	Inspector
1. Unloading			
Pipe Supply	X		
Co-ordination of the Ships	X		
Delivery planning	X		
Procedure (see 1.2)		X	
Unloading		X	
Handlings		X	
Conveying of the pipes to the storage yard before coating		X	
Supply of handling Equipment, slings and bearers		X	
Visual inspection report (localization of defects)			X
Unloading cycle			X
Supervision of all unloading operations			X
Straightens, ovality, length		X	
Inspection of these tests			X
2. Corrosion protective coating			
Handlings during the coating operations		X	
Weather survey			X
3. Concrete weight coating			
Handling		X	
Supplies:			
Wire cage reinforcement		X	
Mesh		X	
Spacers		X	
Concrete materials (water, sand, cement, aggregates)		X	
Application of the unit		X	



	COMPANY	Concrete Coater	Inspector
Concrete inspection:			
Supply of the cement data sheets		X	
Measurement of ES values		X	
Tests on sand grading		X	
Tests on aggregate grading		X	
Tests on mixing water purity		X	
Control of the preparations		X	
Preparation of the control sheets			X
Design of negative buoyancy		X	
Design of theoretical concrete composition		X	
Design of daily composition		X	
Weighing of pipes before and after impingement		X	
Concrete coring		X	
Measurement of negative buoyancy		X	
Measurement of the compressive strength		X	
Preparation of the results sheets			X
Repairs on concrete coating		X	
Curing:			
Handling		X	
Curing operations		X	
Supervision	X		
4. Loading out			
Handling prior to shipping		X	
Co-ordination of the ships	X		
Delivery and shipment planning	X		
Shipping		X	
Handling		X	
Visual inspection report (defects localization)			X
Taking into account of the shipping cycle			X
Supervision	X		



	COMPANY	Concrete Coater	Inspector
5. Miscellaneous			
Provision and maintenance of the inspection offices			X
Provision and maintenance of the COMPANY's representative(s)		X	
Drawing up of:			X
The work control sheets according to each works		X	
The materials control test sheets (enamel and concrete)			
Weekly progress report			X
Monthly progress report		X	