TECHNICAL SPECIFICATION

CONCRETE COATING OF LINEPIPE

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DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

PREFACE

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NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP gives minimum requirements for the application of reinforced concrete coating to the exterior surface of steel linepipe (which has been coated previously with anti-corrosion coating) for use in marine environments, estuaries, rivers, wadis, swamps, etc.

This DEP is written on the assumption that it will be used as the technical specification incorporated into a coating contract. It could, however, be used as an attachment to a purchase order.

(P) The concrete is classified as either strength Grade A or B, as specified by the Principal in the contract Scope of Work. The choice of grade shall be made during the detailed design stage of the pipeline project, based on the external forces it will be subjected to during installation and operation, e.g. related to water depth, required tensions etc. Grade A is intended for more arduous in-service and/or installation conditions than Grade B coating, e.g. Grade B is intended for estuaries, rivers, wadis, swamp use.

This DEP includes the installation of anodes (including thermit welds) but excludes the design or purchase of anodes.

The scope of this DEP does not include:

- specific design requirements (these would be established in the pipeline design)
- the choice of anti-corrosion coating or its application
- the design, purchase and installation of buckle/crack arresters
- the use of intermediate coatings (e.g. anti-slip coatings)
- slotting of the concrete to reduce bending stiffness
- concrete coating thicknesses less than 25 mm

NOTE: Important aspects of these excluded items are briefly discussed in Appendix 1.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIPM, the distribution of this DEP is confined to companies forming part of or managed by the Royal Dutch/Shell Group, and to Contractors nominated by them (i.e. the distribution code is "C", as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use primarily in exploration and production applications but may also be applied, where appropriate, in oil refineries, chemical plants, gas plants and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this document which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this document as closely as possible.

1.3 DEFINITIONS

For the purposes of this DEP, the following definitions apply:

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, and concrete coating application for the project. The Principal may sometimes undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorised to act for the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

Scope of Work is the section of the coating contract which describes the scope of work relating to the concrete coating of linepipe.

1.4 ACTION ITEMS

Where the Principal is required to make a decision or give a particular design value of a parameter, this is shown by the use of a (P) in the margin

NOTE: A summary checklist of these and other relevant items is given in (11). Where the Principal's approval is only required under certain circumstances, this is not shown by a margin marker.

Where the Contractor is required to obtain the Principal's approval for a particular action or procedure, this is shown by the use of a (C) in the margin.

NOTE: It is intended that most, if not all, of these approvals would be part of the qualification testing which is required prior to the start of full concrete production. Details of the requirements for procedure specifications, qualification testing and a summary listing of approvals are given in (9). It is assumed that the Contractor's quality systems and procedural details will have been screened prior to contract award and that the referenced approvals merely need finalizing and formalizing.

1.5 CROSS-REFERENCES

Where cross-references are made within this DEP, the number of the cross-referenced section/sub-section is shown in brackets. All referenced standards invoked by this DEP are listed in (12).

2. MATERIALS

2.1 LINEPIPE

The Contractor shall unload, receive and store either bare or anti-corrosion coated pipe (or both).

2.1.1 Unloading/receipt of linepipe

The Contractor shall unload all pipes using slings, spreader bars and protected lifting hooks which have current test and insurance certificates. The equipment shall be proposed by the
(C) Contractor for approval by the Principal prior to use.

A pipe tally shall be made at the time of offloading and stacking; recording mill number, pipe length, pipe weight, heat number, contract number, steel grade and any further information
(P) that the Principal considers to be relevant or required.

(P) The Principal shall provide the Contractor with a copy of the pipe specification, against which the Contractor shall inspect each pipe at the time of receipt. Inspection shall consist of visual inspection of outer and inner surfaces and coating damage (if applicable), the end bevels for mechanical damage or manufacturing defects, and pipe end ovality.

Any such damage or defects noted shall be recorded by the Contractor and reported in writing to the Principal within three working days. Any damaged area noted shall be marked on the pipe surface using marking material compatible with proposed coating system(s).

Pipes which are out of specification or have an identification anomaly shall be clearly marked with the word "HOLD" on the outer surface of the pipe.

Any damage to pipes after receipt by the Contractor shall be brought to the attention of the Principal within three working days. The Principal shall instruct the Contractor on the method to be used by the Contractor to correct the damage.

2.1.2 Handling and storage of linepipe

The Contractor shall stockpile all pipes received at the Contractor's coating yard. Pipes shall be handled and stockpiled in such a manner as to prevent damage to pipe or coating. For safety reasons, the pipe shall not be stacked more than 4 m high. The Contractor shall store the pipe by laying out on prepared sand rows. Sand rows shall be kept clean and clear of vegetation, large and injurious aggregates, or any other deleterious substances. Pipe for long term storage (in excess of 2 months) shall be laid on prepared sand rows having a covering of polyethylene sheeting.

The bottom layer of pipes, as a minimum, shall be secured with wedges or clips to prevent collapse of the stockpile.

(C) The Contractor shall submit a description of the stockpiling and storing method, which shall require the approval of the Principal prior to use.

2.1.3 Handling, stockpiling and loading out of concrete coated pipe

Pipes shall be handled at all times in a suitable manner to avoid damage to pipe, attachments, coating or concrete.

The Contractor shall clean the end cutback of coated pipes, to remove all concrete spatter
(C) and any deleterious material, prior to load out. The Contractor shall propose a method of cleaning, for approval by the Principal.

The Contractor shall rebevel pipe ends only when specifically instructed to do so by the Principal. The procedure for rebevelling shall be agreed with the Principal prior to any rebevelling being carried out. The Contractor shall not carry out repairs to the Principal's pipe other than rebevelling, minor filing or grinding defined in this DEP.

(C) The Contractor's proposed methods of lifting and handling concrete coated pipe shall be submitted to the Principal for approval prior to use.

(C) Concrete coated pipe shall be stockpiled at the Contractor's yard prior to load out. The Contractor shall submit a description of the manner he proposes to use for stockpiling concrete coated pipe, together with calculations to derive the maximum stack height. These shall be approved by the Principal prior to use. Concrete coated pipe shall not be stacked more than 4 m high. Pipes fitted with anodes/arresters shall form a top tier, and shall be laid out individually on top of the pipe stacks at the frequency required for load out and laying.

(P) When specified by the Principal, the Contractor shall clean the inside of the coated pipe immediately prior to load out. The cleaning process shall remove mill scale and loose debris from the internal pipe surface, together with surface rust, to the cleanliness standard specified by the Principal in the Scope of Work. The Contractor shall propose a procedure for the Principal's approval prior to use.

2.2 CEMENT

All cement used for the preparation of the concrete coating shall be ordinary Portland, conforming to ASTM C-150, type II, or BS 12. Cement held in storage for longer than 3 months shall be tested in accordance with these standards, prior to use.

The alkali content shall be less than 0.6 percent. The Tri-calcium Aluminate (C3A) content shall be less than 8%.

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

Tests certificates from the cement manufacturer shall be supplied for every cement delivery to the coating yard site. If no alkali percentage is stated on the certificate an additional laboratory test shall be carried out.

The use of Portland blast furnace cement to ASTM-C-595 or BS 146 shall only be permitted when the ambient temperature is higher than 20°C.

2.3 SAND/AGGREGATES

Sand shall be well graded from fine to coarse and shall consist of a silica type sand. Clayey and schistose sands shall not be used.

The aggregate shall be crushed granite, or any other aggregate approved by the Principal, and shall conform to ASTM-C-33 or BS 882, with the exception of grading.

Sand/aggregate shall be washed and shall be clean and free from injurious amounts of salts, alkali, organic impurities or deleterious substances such as oxides of lead and zinc that may affect the strength of the concrete. Sampling and testing shall be carried out in accordance with ASTM-C-33 or BS 882.

(C) The aggregate grading envelope shall be proposed by the Contractor and shall have the Principal's approval.

Aggregate cleanliness and grading shall be checked at least twice per week as well as for each new consignment. Where higher density concrete is required to achieve the required submerged weight a portion or all of the aggregate shall be made up from iron ore or other heavy aggregate.

Different types of aggregate shall be stored separately in bins or well prepared areas, i.e. cobbled, paved or well compacted areas allowing adequate drainage of materials.

2.4 WATER

Water used in concrete shall comply with BS 3148 Appendix A. At the Principal's discretion the water shall be tested in accordance with BS 3148 to demonstrate compliance.

2.5 REINFORCEMENT STEEL

2.5.1 **General** (see Fig. 1)

Steel reinforcement shall be provided to limit spalling and control cracking of the concrete.

The minimum circumferential reinforcement shall be 0.5 percent of the longitudinal cross-sectional area of the concrete coating. The minimum longitudinal reinforcement shall be 0.05 percent of the transverse cross-sectional area of the concrete coating. The reinforcement provided shall be either the steel welded wire fabric type or cage type.

(P) The reinforcement provided shall be either the steel welded wire fabric type or cage type. The selection of the type of reinforcement shall be made by the Principal, as stated in the Scope of Work.

NOTE: The use of galvanized steel poultry netting, or chicken wire (e.g. to ASTM A-390) is generally not recommended. However, it may be used in certain applications, such as small river crossings on land lines, where external forces on the concrete would be minimal.

The minimum distance between the reinforcement and the anti-corrosion coating shall be 10 mm. Contacts shall not be made with anodes and/or buckle/crack arresters, and if the reinforcing passes over arresters the minimum gap shall be 10 mm.

When more than one layer of reinforcing is used there shall be a minimum spacing of 10 mm between layers.

Reinforcing shall terminate 20 mm (± 5 mm) from the end of the concrete coating and adjacent to anodes. There shall be no electrical contact between reinforcing and pipe or between reinforcing and anodes.

The reinforcement shall be free of oil, grease and dirt.

2.5.2 Steel welded wire fabric

The steel welded wire fabric shall be galvanised. The chemical and physical properties shall conform to ASTM A82, A185, A641 or BS 4483.

The minimum diameter of the reinforcing wire should be 1.6 mm.

Reinforcement steel may be applied by any method that will provide for continuity of reinforcing. The longitudinal overlap shall be at least 30 mm.

For concrete thickness up to 50 mm, one wrap of reinforcing shall be used. For thicknesses of more than 50 mm, two layers should be considered. Additional layers may be necessary for concrete thicknesses in excess of 120 mm, but this would then require further Principal's approval.

The reinforcement shall be positioned at least 10 mm below the outer concrete surface.

2.5.3 Cage type (see Fig. 2)

The reinforcement shall be in the form of specially wound cages having a continuous hoop wire or single circumferentials with a number of straight longitudinal bars evenly spaced around the spiral and welded at each wire intersection. The material used shall be hard drawn wire to BS 4482 or ASTM A615M (deformed), or to a Principal-approved equivalent standard. The welding of the materials shall result in a steel fabric in accordance with BS 4483 or ASTM A185.

The reinforcement shall be positioned within the middle third of the concrete coating with a concrete cover of at least 9 mm.

The diameter of the circumferential and longitudinal bars shall be calculated from the required percentage of reinforcing, with a minimum diameter of 3 mm.

(C) The Contractor shall propose the welding procedure in accordance with a National/ International code or standard to be approved by the Principal. The procedure shall be qualified prior to use.

The Contractor shall carry out shear testing of four welds each month in accordance with BS 4483 or ASTM A185. The welding at intersections of the cage shall result in a minimum shear strength as specified in BS 4483 or ASTM A185.

The spacing of the longitudinal bars shall be between 50 and 250 mm but not less than four longitudinal bars (at approximately equal spacing) shall be provided. The circumferential bar spacing shall be not more than 150 mm. Cages shall have two loops spaced 50 mm apart

at each pipe end and adjacent to anodes and arresters.

NOTE: 'Close fitting' arresters may be designed to have the concrete around them, in which case this requirement is not applicable.

Where a lap is required, one part cage shall have its longitudinal wires extended to ensure a minimum overlap of 200 mm with the longitudinal wires of the other cage and with the circumferential wires of each cage having not less than 25 mm between them. Lap wires shall be bent down as necessary to maintain alignment.

(C) Cages shall be rigidly held concentric to the pipe at the correct location by electrically insulating plastic or concrete spacers. The type of spacer shall be proposed by the Contractor for approval by the Principal. Spacers shall have flush bases to prevent indentation into the anti-corrosion coating.

3. EQUIPMENT

The Contractor shall use suitable equipment capable of applying concrete coating in accordance with this DEP.

The Contractor's equipment shall provide for the batching of materials by weight on scales accurate to within 1.5 percent (if other than weighed and sacked material is used). Such scales shall be calibrated weekly using weights which have an accuracy of 0.3 % or better. Each batch shall be weighed separately and mixed in a turn drum type mixer, or other batch type mixer that will ensure a thorough mixing of all materials in the batch. The concrete batching plant shall be in accordance with BS 1305 and shall be performance tested, at the discretion of the Principal, in accordance with BS 3963.

Alternative systems such as continuous concrete mixing and recycling shall be subject to the Principal's approval prior to use.

Water shall be supplied from a measuring tank so set that it discharges into the mixer only the quantity required for the concrete to meet this specifications, to an accuracy of 1.5 percent of the specified quantity.

(C) Weighing equipment for the determination of the submerged weight of each pipe shall be certified, by an independent third party proposed by the Contractor and approved by the Principal. The equipment shall be accurate to within 0.5 % or better. Calibration shall be carried out at the beginning of each working shift, using weights which have an accuracy of 0.1 % or better.

4. COATING PROCESS

4.1 PROPORTIONING OF MATERIALS

The Contractor will be permitted to select any proportioning of materials to produce the requirements of concrete strength and density/submerged weight. The Contractor shall prove the suitability of his mix design by pre-qualification testing, to be witnessed and approved by the Principal prior to the start of production coating. Approved mix designs shall not be
(C) changed without re-testing and approval by the Principal. Mix designs submitted to the Principal for approval shall at least contain following information:

- the proportions and weights of the component materials used for the mix;
- the water/cement ratio (not to exceed 0.45 by weight);
- the grading of the aggregates accompanied by appropriate curves;
- the test results of the mix for strength, density and water absorption;
- the measures taken to minimise drying shrinkage.

4.2 APPLICATION OF CONCRETE COATING

4.2.1 Prechecks

(C) The Contractor shall visually inspect each pipe and test each pipe with a holiday detector of a type proposed by the Contractor and approved by the Principal (depending upon the
(P) anti-corrosion coating specification which shall be designated by the Principal).

Any pipes containing coating defects shall be put aside or repaired in accordance with the Principal's coating repair procedure. The testing shall take place just prior to the fitting of the reinforcement steel and, additionally, prior to the attachment of anodes or buckle/crack arresters.

Special care shall be taken with pipes to which sacrificial anodes and/or buckle/crack arresters have been fitted. Anode attachment and cable-to-pipe connectors shall be inspected to ensure that they are secure and are properly coated with an anti-corrosion coating determined by the use of the holiday detector.

4.2.2 Application

The concrete shall be applied to the pipe by either the impingement or the compression method.

The concrete shall be placed on the pipe within 30 minutes of the water being first added to the mix. Each pipe shall be coated in a continuous operation in such a manner that the thickness of coating is applied uniformly, smoothly, without corrugations and concentric with the steel pipe.

If more than one application is required to produce a coating of the specified thickness, then the time allowed between the first coat and the second coat shall not exceed 30 minutes. If a period exceeding 30 minutes does occur, the previous coating layer shall be removed and the entire pipe shall be recoated.

Both ends of each pipe (i.e. the bare pipe and the anti-corrosion coating) shall be completely free of concrete or any other foreign matter. The concrete shall be terminated either square
(P) or tapered back at an angle to the pipe surface as specified in the Scope of Work.
The outer surface of each anode (with the exception of the ends) shall be kept free of concrete.

Each concrete coated pipe shall be weighed immediately after the coating operation and its submerged weight established and recorded.

4.2.3 Limitations

Concrete coating shall not be carried out when the pipe, coating or air temperature exceeds 35°C, or when there is evidence of flash setting of concrete.

In the event that the ambient temperature falls below 4°C the Contractor may request to use a 'Winter Concrete Application' procedure. Prior to use, this procedure shall be qualified by the Contractor in the manner specified by the Principal .

The use of recycled rebound material is allowed. Secondary mixing of the freshly batched concrete with the recycled material shall follow immediately and shall produce a homogeneous cohesive mixture. The amount of recycled material used shall not exceed 10% of the total mix by weight. When breaks in the operation for whatever reason exceed thirty minutes then the recycled material not previously added to a mix shall be discarded and removed from the coating area.

4.3 CURING

4.3.1 General

Immediately after completion of coating, the pipe shall be removed from the coating machine and transferred, after weighing and diameter measurements, to the storage yard for curing. The coated pipe shall be gently lifted and transported to the curing yard and placed, so as to prevent cracking or damage to the concrete, in a single layer.

Curing shall be performed either by using water curing, steam curing, curing by sealing compounds or polyethylene wrapping. The exposed surfaces of the concrete shall be protected during curing from any adverse effects of sunshine, drying winds, rain or running water.

The curing process shall continue until a minimum compressive strength of 14 N/mm^2 has been achieved (as demonstrated by the qualification tests and/or subsequent core tests), after which the pipe can be lifted, transported or stacked.

If the curing process involves steam or warm high humidity air, then it shall be demonstrated that the process will have no deleterious effects on the concrete. Under no circumstances shall the pipe wall be allowed to reach a temperature that would cause any damage to the anti-corrosion coating (60°C, or as advised otherwise by the Principal).

(C) Prior to use, the curing facilities and procedure shall be proposed by the Contractor for approval by the Principal.

4.3.2 Water curing

Water curing shall consist of wetting and moistening the concrete coating, starting not later than 6 hours after concrete placing completion.

The concrete coating shall be kept continuously moist by intermittent spraying for a period of at least 7 days. The interval between spraying shall not be more than 24 hours. At temperatures below 4°C, suitable precautions shall be taken to prevent damage due to freezing.

4.3.3 Steam curing

Curing by steam shall not start sooner than 3 hours after concrete application completion.

Concrete coated pipes shall be enclosed in plastic or a similar cover suitable to maintain steam circulation.

Steam circulation shall start at ambient temperature and shall be controlled to give a temperature gradient of approximately 10°C/hour up to a maximum steel/coating temperature of 60°C.

The pipes shall be held under steam curing for at least 6 hours and then allowed to cool for a similar period. The Contractor shall demonstrate by pre-qualification that the curing time used is sufficient to meet the required strength levels specified.

4.3.4 Curing by sealing compounds (membrane)

Sealing compounds shall meet requirements as per ASTM C309-89. The material shall be stored, prepared and applied in strict conformity with the printed instructions supplied by the compound manufacturer. The compound shall be non-toxic and non-inflammable and shall not react with any constituent of the concrete, the reinforcement, the anodes, the protective coating or the pipe steel.

Unless otherwise specified by the compound manufacturer's instructions, membrane sealing compounds shall be sprayed over the concrete surface within 6 hours after concrete placing completion and shall remain for a minimum of 7 days. The materials shall not be applied at a temperature of less than 4°C.

Sealing compound shall not be sprayed on any part of the anode surface.

4.3.5 Curing under polyethylene wrapping

Wrapping in plastic film (e.g. polyethylene film), shall take place by mechanical apparatus immediately after the coating is applied to the pipe and preferably before the pipe is removed from the concrete coating apparatus. A light spray of water shall be applied before applying the plastic film. The film shall have a minimum thickness of 0.1 mm and overlap of the sheet shall not be less than 25% of the sheet width. Polyethylene film shall be in accordance with ASTM C171.

The polyethylene wrapping shall be removed prior to load-out of pipe.

5. INSPECTION AND TESTING

5.1 GENERAL

The Principal may have a full-time or part-time representative(s) at the Contractor's plant, to monitor sampling, testing, calibrating and curing during production.

(C) The Contractor shall supply details of all sampling and testing procedures and shall receive the Principal's approval prior to use.

(C) Strength, density and water absorption tests shall be carried out by a third party proposed by the Contractor and approved by the Principal, unless the Contractor's own facilities and procedures are accepted by the Principal.

5.2 MISCELLANEOUS INSPECTIONS/TESTS

5.2.1 Steel reinforcement check

When steel wire fabric reinforcement is used, at least 2 pipes per shift shall be selected at random for checking that the distribution of the reinforcement is as specified in (2.5). The method of checking shall be to remove a small area of concrete coating (200 mm long x 100 mm wide) by means of a high pressure water jet. Any pipe inspected and found satisfactory shall be reinstated.

An electrical resistance check shall be made between the pipe and the (inner) reinforcement on at least 2 pipes per shift. This shall be carried out in the period between concrete application and curing, using an Ohm-meter. The resistance shall be at least 1000 Ohms.

Pipes with unsatisfactory distribution of reinforcement, or which fail the electrical resistance test, shall be stripped and recoated after correct installation of reinforcement. In this event, three additional pipes from the same batch shall also be checked to gain acceptance of the batch.

5.2.2 Diameter measurements

The diameter measurements immediately after concrete coating application shall satisfy the following two requirements:

(i) The radial distance between any high and low points of the coating surface shall not exceed 8 mm in any 500 mm length, nor 5 mm in the last 1 m length at each end.

(ii) The diameter of each coated pipe shall be measured using a girth tape in six positions spaced at approximately equal intervals with the two end measurements being approximately 600 mm from the ends of the concrete coating. All diameter measurements shall be recorded and the mean value per pipe shall be used to calculate
(P) the mean concrete thickness. The concrete thickness and acceptance tolerance shall be as stated in the Scope of Work.

Coated pipes outside the stated tolerances shall be repaired or stripped and re-coated, at the discretion of the Principal.

5.2.3 Visual inspection

5.2.3.1 General

All concretes coated pipes shall be visually inspected and examined for damage, cracks, voids or other defects.

All cores removed for strength testing shall be visually examined for voids and other defects.

5.2.3.2 Cracking

Circumferential surface cracking of the concrete, with a crack width less than 5 mm, shall not be considered a defect.

Longitudinal surface cracks of any width and less than 250 mm in length shall not be considered defects, but holes of 10 mm nominal diameter shall be drilled at the crack tips to prevent crack propagation. Longitudinal cracks in excess of 1000 mm in length or extending the full depth of the coating are not acceptable and coating with such a crack shall be removed from the entire length of the pipe. Longitudinal cracks with a length between 250 mm and 1000 mm shall be repaired (6.3).

Circumferential annular cracking visible at pipe ends is not acceptable. Any such cracking noted shall be reason to consider the concrete suspect and liable to rejection. An investigation shall be made, including a back check of pipe produced prior to and following the suspect pipe. Any concrete coating noted with annular cracking of the concrete shall be destructively tested by the Contractor. This testing shall take the form of saw cutting and

removal of sections of the concrete from the pipe to determine whether the concrete is a homogeneous mass throughout the length of the pipe.

5.2.3.3 Damage

Surface damage will not be considered a defect if:

(i) the total surface area of damage per pipe is less than 0.1 m^2, and
(ii) the maximum depth does not exceed 20% of the coating thickness, and
(iii) the remaining concrete is sound.

Damage at the ends of the concrete need not be repaired provided that the damaged area is less than one third of the circumference for a length less than 200 mm.

5.3 STRENGTH AND DENSITY TESTING

The compressive strength and density of the applied concrete after 7 and 28 days shall be determined by two different methods of testing:

(i) taking of test cubes from the transfer belt between the concrete batching plant and the application machine (or from the mixer outlet for continuous mixing equipment);

(ii) taking of core samples from the actual concrete coating on the pipes.

Acceptance shall be based only on 28 day core sample strength results.

5.3.1 Test cubes

The cubes shall be taken at a frequency of one sample for every 25 pipe joints coated, up to a maximum of three times per work shift. A minimum of 4 cubes (100 x 100 mm) from each sample shall be taken. Two cubes shall be tested at 7 days age and the remaining cubes at 28 days age. The test cubes shall be made, cured and tested according to BS 1881 part 108/111/116 or ASTM C 39. The test cubes shall be tested for density and compressive strength, to indicate the consistency of the concrete.

5.3.2 Core samples

The core sampling frequency shall be 3 core specimens from one pipe for every 15 pipes coated. The cores shall be sampled at equidistant points along each pipe.

Cores shall be cut within four days of concrete application and stored in a curing tank until tested.

Samples shall be obtained using a diamond cutter set to ensure that the cut is perpendicular to the pipe surface and fitted with a positive depth of cut limit stop to ensure that the core barrel cannot penetrate closer than 7 mm to the anti-corrosion coat of the pipe joint. Cores shall be taken so as not to cut through the steel bar cage if this type of reinforcement is applied.

The diameter of the core shall be between 35 and 44 mm. A single core diameter shall be used throughout the coating operation. The height to diameter ratio of the core when trimmed for testing shall be 1.00. For coatings less than approximately 45 mm thick, where a height to diameter ratio of 1.00 is not possible, strength testing shall be performed either with cubes or with alternative cores, at the Principal's discretion. In either case a correlation shall be made with previous results from identical mix designs or from qualification pipes coated with at least 45 mm thick concrete, at the Principal's discretion.

Sampling, storing and testing of the core and calculation of the test results shall be in accordance with the provisions of BS 1881 Part 120, ASTM C42 or C39.

Testing shall be carried out on 7 day and 28 day specimens.

The results from the 7 day tests shall be used to give advance warning of any variations in the concrete strength. The 28 day tests shall be the basis for acceptance, as detailed below.

5.3.3 Acceptance criteria (28 day core tests)

	Compressive Strength (N/mm^2)	
	Grade A	Grade B
Minimum value for individual core	33	23
Minimum mean value of 3 cores	35	25

In the event that an individual core has a strength less than the specified minimum, one further core shall be taken from the same pipe. This additional test result may then be used to calculate the 3 core mean. If the additional test value is below the specified individual minimum then the coating from the particular pipe shall be rejected and a further pipe shall be tested.

In the event that the mean strength value from 3 acceptable individual cores from a particular pipe is less than the specified minimum mean, the coating from that pipe shall be rejected and two further pipes shall be tested.

In the event that the mean value of the results of all the core tests over a shift falls below the 3 core mean then the Contractor shall either reject all coating or test the coating from each individual pipe from that shift.

The Contractor shall also carry out an analysis of cube and core test results on a "25 result basis", for both 7 and 28 day results. The analysis shall be carried out by using the first 25 results available for the first analysis and thereafter on a "5 on - 5 off" basis or "day-on-day" basis whichever is more appropriate. The Coefficient of Variation of the strength values within the 25 result analysis shall not exceed 15 percent of the mean compressive strength of that group of results.

NOTE: For each group of results, the Coefficient of Variation is equal to the Standard Deviation divided by the Mean.

Failure to meet the Coefficient of Variation criterion shall result in the shift's production being held suspect and subject to further testing, as decided by the Principal.

5.4 DETERMINATION OF SUBMERGED WEIGHT

The unsaturated (as applied) submerged weight per metre for each pipe shall be calculated from the pipe weight in air immediately after coating. The submerged weight shall be calculated using the following formula:

N/linear metre

$$\text{Submerged weight} = \frac{W - 2cw - B}{L - 2c}$$

where: W = total weight of concrete coated pipe in air (N)
B = buoyancy of pipe (as defined below) (N)
L = length of pipe (m)
w = unit weight of bare steel pipe (N/m), to be specified by the Principal (2.1.1)
(P) c = length of concrete cutback (m), to be specified by the Principal

The buoyancy of the pipe, B, is given by:

N

$$B = \frac{\pi}{4} * \rho * \left(\frac{D}{1000}\right)^2 * (L - 2c) * g$$

where: D = outside diameter of concrete (mm), average of 6 measurements

ρ = density of the displaced water (kg/m^3)

g = gravitational acceleration (m/s^2)

For anode and crack arrester pipes the specified submerged weight maxima may be exceeded. Variations in buoyancy shall be ignored and the submerged weight value shall be adjusted by using an increased weight in air. The allowable weight variations shall be
(P) specified by the Principal in the Scope of Work.

The results shall be recorded and tabulated against pipe number and presented to the Principal at the completion of each days' production. The submerged weight of each coated
(P) pipe shall be within the acceptance tolerances stated by the Principal in the Scope of Work. Test results shall be analysed on a "25 result basis" as described above for strength testing. However, the analysis shall commence by using results of the first 25 pipes and from then on, each pipe coated shall be added to the list and the first pipe on the list deducted, thereby retaining a 25 joint total at all times for submerged weight analysis.

If a pipe requires scraping or additional concrete to control or adjust its weight, the minimum specified cover shall remain over the reinforcement and any addition shall be applied within 30 minutes of the first concrete application.

Any pipes that are rejected for being outside the submerged weight tolerances shall have all concrete coating removed.

5.5 WATER ABSORPTION TEST

The water absorption of the concrete shall be determined at least once per production shift by taking samples of freshly applied concrete from the pipe ends.

The test method shall be as follows:

a) remove the sample (at least 500 grams) from the pipe and transfer immediately to the laboratory;

b) brush the sample with a fine bristle brush to remove all loose particles from the sample surface;

c) weigh sample (weight X);

d) transfer sample to pipe curing cells and allow to cure for the same period of time as the coated pipe;

e) immerse the sample in sea water tank at 21°C for at least 24 hours but in any event until the weight has stabilised to within 1% of the mean of 3 successive weighings (at minimum intervals of 3 hours). Record sample weight (weight Y). All weighing shall be made after towel drying the sample;

f) calculate the water absorption (%) $= \frac{Y - X}{X} * 100$

The increase in weight of concrete due to water absorption shall not be greater than 3% or 5% for Grade A and B respectively.

During the first 3 days' production at least one pipe per day shall be selected for a full-scale immersion test. The submerged weight shall be measured every 8 hours and registered until there is no significant change. The test pipes shall be taken after 4 days of curing, with a minimum period of immersion of 24 hours.

5.6 IMPACT TESTING

5.6.1 General

Impact testing may be required to demonstrate suitability for use in offshore applications where fishing activities occur.

(P) When specified by the Principal in the Scope of Work, impact testing shall be carried out in accordance with the following details.

Impact testing shall be carried out on qualification test pipes selected by the Principal and on one concrete coated pipe per week or at the Principal's discretion until the Principal is satisfied that the concrete coating procedures produce a consistent product with acceptable impact resistance.

(C) The impact testing equipment and procedure are detailed below. The exact details of the test rig shall be submitted to the Principal for approval and shall include details of safety measures to be taken to avoid injury to personnel.

Pipes subject to impact testing shall be scrapped and not repaired or incorporated in the pipeline.

5.6.2 Impact test rig

The impact test rig is designed to simulate impact by the trawl beam shoes of typical North Sea fishing trawl equipment.

It shall consist of a steel framework on which a heavy cylindrical impact 'hammer' is suspended. The hammer shall be supported in the horizontal position by two sets of wire ropes attached to the supporting framework.

The impact hammer shall be designed to simulate the mass and momentum of a 2.68 tonne trawl board travelling at 7 knots over the seabed. The 'hammer' shall be 300 mm long, have a 10 mm radius tip, and be connected to a plate perpendicular to the pipe axis as shown in Fig. 3. The mass of the hammer shall be 2.68 tonne with the capability of reducing the mass to 1.84 tonne. The vertical drop of the hammer shall be 660 mm giving a velocity on impact of 3.60 m/s (7 knots).

The concrete coated test pipe shall be rigidly supported from the rear over its full length by moist sand. The pipe shall be held rigidly at its ends by wooden cradles and wedges to prevent movement of the pipe under impact.

The point of impact on the concrete shall be at the 3 o'clock position. The pipe shall be supported so that impact of the concrete is made when the hammer is at the lowest point in its swing.

5.6.3 Test procedure

Testing shall be carried out in three ways:

1. 90° to pipe axis at one location (2.68 t)
2. 90°to pipe axis at five locations each 300 mm apart (2.68 t)
3. 60° to pipe axis at one location (1.84 t).

Test 1

The test pipe shall be supported with a minimum of 2 m concrete section either side of the section under test. Impact blows shall be directed on the same location and the condition of the concrete recorded after each blow, until the anti-corrosion coating is exposed.

Test 2

The test pipe or rig shall be moved along at least 2 m and then a single blow shall be directed on five locations, each 300 mm apart. The condition of the concrete shall be recorded after each blow.

Test 3

The test pipe or rig shall be moved along at least another 2 m and the pipe impacted in the 60° position to the line of motion of the hammer. Five impact blows shall be directed on the same location and the condition of the concrete recorded after each blow.

For all tests, recording of impact locations shall include:

a) photograph after each blow;

b) diagram(s) of crack patterns and spalled areas including dimensions of major cracks (length and width);

c) dimensional changes, if any, of the pipe; detected by visual internal inspection and subsequent external measurement.

The concrete area covering crack arresters shall be impacted during qualification tests, for information purposes.

5.6.4 Acceptance criteria for impact testing

Concrete coating will be considered acceptable when the following conditions are satisfied for 16" diameter pipe and larger with concrete coating thicknesses of at least 50 mm. For smaller diameter pipes and/or concrete coating thicknesses less than 50 mm, the Principal may modify these acceptance criteria as specified in the Scope of Work.

Test 1

a) The anti-corrosion coating shall not be visible and the steel pipe wall shall not be indented or damaged after 5 blows.

b) Spalling shall not occur over an axial distance greater than 300 mm each side of the points of impact, after 5 blows.

Test 2

Any spalling shall not extend from one impact location to another.

Test 3

The anti-corrosion coating shall not be visible after five blows.

6. REPAIRS

6.1 GENERAL

Concrete coated pipes may be rejected by the Principal when any of the previously stated acceptance criteria are not met, and in such case the coating shall be completely removed rather than partially repaired. Damage, cracks and core holes shall be repaired in accordance with this section.

Concrete used for repairs shall contain the same proportions of dry constituents as the original coating but the water/cement ratio may be higher, to improve workability.

Prior to application of repair material, the defective area shall be thoroughly cleaned by removing concrete coating sufficiently to clean under the reinforcing bars and the concrete edges shall be cut so as to form a holding key.

All repairs shall be moist cured for a minimum period of 48 hours.

(C) The Contractor shall demonstrate that the procedures for repair application and cure will result in an acceptable coating with the compressive strength of repair being at least equal to the strength of the coating. All repair methods shall be subject to the Principal's approval prior to use.

6.2 DAMAGED AREAS

Damaged areas shall be repaired when they are considered defects as defined in (5.2.3.3).

Areas of damage not in excess of 0.8 m^2 in any 3 m length of pipe (restricted to two such areas in any 12 m length of pipe) may be repaired by hand patching if repairs are carried out while the concrete is in a 'green' state (i.e. within 4 hours of coating application and prior to curing).

In the event that the Contractor wishes to repair areas on cured concrete, a guniting process shall be used and the procedure shall be approved by the Principal prior to use.

Areas where coating has been damaged during coating application in excess of 0.8 m^2 but not more than 25% of the total coating area, shall be repaired immediately prior to the pipe being removed from the coating applicator by re-application of the spalled areas using the application machine used to coat the pipe.

Where damage to concrete is in excess of 25% of the total coating area, repairs shall not be allowed. All coating shall be removed and the pipe re-coated.

(C) The Contractor shall propose a procedure for removing rejected coating and shall receive the Principal's approval prior to use.

6.3 CRACKS

Longitudinal cracks in excess of 250 mm in length shall be repaired as specified below with the addition that the ends of each crack shall be drilled with a hole of 10 mm nominal diameter to prevent crack propagation. The bottom of this hole shall be 7-10 mm from the anti-corrosion coating.

Repairs to cracks shall be made by opening the crack to 25 mm width by chiselling out. The prepared area shall be undercut to form an adequate key for the repair material. The repair material shall be trowelled or impinged into the prepared area and smoothed down to the level of the original coating. Prior to repairing, the prepared area shall be inspected by the Principal for damage to the coating or metal surface.

6.4 CORE HOLES/INSPECTION AREAS

Core holes shall not be refilled without prior inspection and approval by the Principal. The core holes shall then be hand filled with a stiff mix similar to that used in the coating process.

(C) Prior to use, the detailed procedure shall be proposed by the Contractor and approved by the Principal.

7. INSTALLATION OF ANODES

(P) The Principal shall provide design drawings which include anode dimensions and installation details.

7.1 UNLOADING, HANDLING, STORAGE AND CLEANING

Upon receipt, the Contractor shall inspect all anodes for damage and identification markings and produce an anode tally accordingly. Site storage, lifting and handling shall be performed in a manner which does not cause damage to anode material, steel core or electrical connectors.

Anodes may be specified by the Principal to have an internal surface coating. Prior to installation, the Contractor shall ensure that the internal and external surface of each anode half-shell is free from unspecified oils, grease, etc. The anode shall be protected from damage during the concrete coating process.

7.2 INSTALLATION

Anodes shall be located at pipe mid length. The Contractor shall carefully remove the anti-corrosion coating from the areas designated for the attachment of the bonding leads. These areas shall be at least 150 mm from any seam or girth weld. Anodes shall be fitted tightly over and around the anti-corrosion coating by use of a tension applicator (i.e. 3 ton pull lift chain type) or other Principal-approved method. Once the two halves are correctly aligned, their cages and straps shall be fillet welded together in accordance with a prequalified
(C) procedure to a National/International code or standard proposed by the Contractor and approved by the Principal.

All galvanising and coating shall be removed for at least 15 mm around the intended weld areas. The fillet welds shall also be continuous around all edges and shall be visually inspected by the Principal for compliance with the approved code or standard. The anti-corrosion coating shall be protected from an arc being struck on it during welding.

7.3 ELECTRICAL CONNECTIONS

The bonding leads of the anodes shall be a polyethylene (PE) or polyvinyl chloride (PVC) sheathed multicore cable with a minimum cross-sectional area of 16 mm^2 and a minimum length of 250 mm. Two bonding leads will be supplied with each anode half, either separate
(P) or pre-welded at one end, as specified by the Principal in the Scope of Work. Bent or out of round cable ends shall be removed using a proper cable cutter. The Contractor shall remove 25 mm of the PVC insulation at the cable ends. Pipe surface areas shall be clean, to ISO 8501-1, grade St-3, prior to bonding the clean cable ends to the pipe surface by a thermit weld. The weld shall be made using a maximum powder charge of 15 gram.

NOTE: Thermit welding shall not be used on stainless steel pipes.

The cable connection shall be made in an area where no concrete will be applied (in the gap between the two half-shells, if possible).

(C) The welding method and the equipment shall be proposed by the Contractor for approval by the Principal.

The Contractor shall pre-heat an area of 150 mm x 50 mm at the position of the intended thermit welds. The pre-heat temperature shall be 25 - 50°C as measured one minute after the removal of the external heat source and immediately prior to the thermit weld. The Contractor shall ensure that the mould is at a temperature of approximately 50°C immediately prior to use and of a type with a curved base to match the curvature of the pipe. Between welds, the moulds shall be carefully cleaned. Each mould shall be used a maximum of fifty times and discarded sooner if it becomes cracked or chipped.

The cable shall be inserted into the mould so that its end is under the centre of the tap hole and in the centre of the weld cavity.

As part of the qualification test, the Contractor shall prove that the welding process fulfils the following requirements in three separate consecutive tests. The pipe selected for these welding tests shall have chemical analysis and mechanical properties typical of those which will be used in production. If several pipes from different steel heats are to be welded then destructive tests shall be made from the pipe having the highest carbon equivalent. The test welds shall be sectioned diametrically (see Fig. 4) and specimens shall have polished surfaces.

a) Copper penetration requirements

The fusion line between the copper alloy nugget and the parent metal shall not be more than 1 mm below the original surface of the parent metal. Intergranular penetration of the steel grain boundaries beyond the fusion line shall not exceed 0.5 mm (determined using a magnification of 200).

b) Hardness requirements

The hardness of the weld shall be tested in accordance with ASTM E92 along 3 lines, 1, 2, and 3 mm below and parallel to the original surface of the parent metal. These lines shall run through the centre of the weld as viewed from above the weld, see Fig. 4. The hardness values shall be taken at 2 mm intervals extending to 10 mm either side of the extreme edges of the weld. The hardness shall not exceed 300HV10.

Only operators who have made acceptable thermit weld tests, in accordance with a) and b) above, will be approved to carry out welding.

On completion of all welds, the weld area and any other bare steel areas on the anode cage or straps shall be thoroughly cleaned and, if necessary, degreased. The Contractor shall clean the weld and immediately surrounding material by wire brushing to ISO 8501-1, grade St-3.

(C) The Contractor shall propose an anti-corrosion coating and application method for approval by the Principal. The Contractor shall coat the prepared surfaces in a manner to suit the type of anti-corrosion coating selected.

(C) The gap between the anode halves on both sides shall be filled with a material which has been proposed by the Contractor and approved by the Principal.The gap shall be filled level with the outer surface of the anode.

7.4 INSPECTION AND TESTING

All fillet welds shall be visually inspected for profile and dimensions for conformance with the design drawings provided by the Principal. Magnetic particle examination or liquid penetrant inspection in accordance with ASTM E709 or ASTM E165 shall be performed on the welds of anode straps on at least 2 pipes per shift. The welds shall be ground-out and rewelded if a crack or lack of fusion is detected.

The Contractor shall test the connection of all bonding leads by both electrical and mechanical means. The resistance across the weld, measured between the anode and the pipe steel, shall not exceed 0.01 Ohms. This shall be measured with a low resistance Ohm-meter employing a battery cell and providing a current of approximately 100 amperes. Mechanical integrity of each lead shall be established visually and by means of a sharp blow from a 1 kg hammer. Any weld not proving satisfactory shall be carefully removed down to the parent metal surface. The reweld shall be carried out at a new location approved by the Principal.

Each completed installation shall be inspected by the Principal prior to moving the pipe from the anode installation area.

7.5 STACKING

Pipes with anodes installed shall be stacked such that the anode is not in contact with any pipe, concrete or object that could damage the anode or its connections.

8. PIPE IDENTIFICATION

8.1 GENERAL

Each pipe shall be supplied to the Contractor with pipe identification numbers provided by the mill and corresponding with the mill certificates. These mill allocated pipe numbers shall be used on all tally sheets/ documentation, etc. needed for the coating process, and therefore the preservation of these numbers is essential. In the event that linepipe is supplied from different sources, mills, etc. then the relevant lots shall be stored and kept separated at all times.

8.2 MARKING

(P) All concrete coated pipes shall be colour coded in order to readily identify the different categories of pipe thickness, coating thickness and attachments. A colour coding scheme shall be specified by the Principal in the Scope of Work. The Contractor shall apply marine paint colour bands near both ends of the concrete coating. These bands shall be 50 mm wide starting at 150 mm from each concrete coating end. The bands shall be applied immediately after concrete curing.

8.3 PIPE TALLY

A certified permanent record/tally shall be supplied to the Principal showing the mill data and all weights, date of concrete coating, tests and inspection done with results, potential repairs and special applications using the pipe mill serial number sequence in combination with the sequence of the coating process.

9. DOCUMENTATION AND APPROVALS

9.1 DOCUMENTATION

All documentation submitted to the Principal shall be in the English language and shall reference the Principal's name and project identification.

9.2 PROCEDURE SPECIFICATIONS

(C) The Contractor shall prepare and submit to the Principal for approval, a minimum of 1 month before commencement of the work, documents containing, but not limited to, details of the following:

- the Contractor supplied materials: specifications, type, supplier, methods of control, etc.;
- concrete coating processes, procedures, incl. curing, repair procedure, coating equipment and facilities, identifying the ranges of parameters to be used;
- anode installation;
- crack/buckle arrester installation, if appropriate;
- inspection and testing (including procedures and pro-formas);
- proposed schedule for qualification testing, as defined below.

9.3 QUALIFICATION TESTING

Prior to the start of full production the Contractor shall carry out procedure qualification testing to prove to the Principal that the plant, materials, equipment and procedures result in an end product conforming to this Specification. Qualification testing shall be carried out on the following activities:

- installation of at least 1 anode (if applicable), including 3 thermit welds;
- coating of 5 pipes;
- coating of 1 pipe with an anode;
- repairs to small and large areas, including core hole repairs.

The full range of inspections and tests which are detailed in this specification shall be applied to each of the above activities or end products.

The Contractor may wish to elect to commence full production prior to completion of all testing and the Principal's approval. This may be allowed, at the Principal's discretion, but at the Contractor's risk of product failure and rejection leading to subsequent rework.

(C) The Contractor shall issue, for approval by the Principal, a detailed report of the operational parameter ranges, test results and certificates for all materials used for qualification testing.

After successful qualification, operational parameters or material specifications shall not be changed without prior Principal's approval. Such approval may require further qualification tests.

9.4 SUMMARY OF REQUIRED PRINCIPAL'S APPROVALS

Section/ Clause	Activity/Procedure requiring approval
	Materials
2.1.1	Suitability of lifting equipment
2.1.2	Stockpiling and storing method
2.1.3	Pipe end cleaning method
2.1.3	Pipe lifting and handling methods
2.1.3	Pipe stockpiling method
2.3	Aggregate grading envelope
2.5.3	Cage welding procedure
2.5.3	Spacer type
	Equipment
3.	Third party certification company
	Coating Process
4.1	Concrete mix design
4.2.1	Holiday detector type and procedure
4.3.1	Curing facilities and procedure
	Inspection and testing
5.1	Inspection and testing procedures
5.1	Third party testing company/facilities
5.6.1	Impact test rig design (including safety features)
	Defects/Repairs
6.1	Repair methods
6.2	Removal of rejected coating
6.4	Filling of core holes
	Installation of anodes
7.2	Strap welding procedure
7.3	Thermit welding equipment and procedure
7.3	Thermit weld coating material and method
7.3	Anode filling material
	Documentation and approvals
9.2	Procedure specifications
9.3	Qualification testing results

10. SUMMARY OF INSPECTIONS/TESTS

The types and frequencies of the required inspections/tests are summarised below, with references to the appropriate sections in this specification:

Section Reference	Test	Frequency
2.	**Materials**	all pipes
2.1	Pipe identification/damage inspection	
2.2	Cement certificates	per delivery
2.3	Aggregate cleanliness and grading	2/week
2.4	Water	at Principal's discretion
2.5.3	Cage weld strength	1/week
3.	**Equipment**	at Principal's discretion
3.	Batching plant performance	
3.	Batch plant weighing equip calibration	1/week
3.	Pipe weighing equipment calibration	1/shift
4.	**Coating Process**	all pipes
4.2.1	Holiday detection	
5.	**Inspection and Tests**	2 pipes/shift
5.2.1	Steel wire fabric location	
5.2.1	Resistance check	2 pipes/shift
5.2.2	Concrete diameter	all pipes
5.2.3	Visual	all pipes
5.3	Strength and density	
	- cubes	1 x 4 cubes/25 pipes
	- cores	1 x 3 cores/15 pipes
5.4	Submerged weight	all pipes
5.5	Water absorption	1/shift (using samples)
5.6	Impact testing	at Principal's discretion
6.	**Defects/repairs**	
6.1	Prepared area prior to repair	all crack repairs
6.2	Filling of core holes	all core holes
7.	**Installation of anodes**	
7.4	Electrical resistance of Thermit weld	all thermit welds
7.4	Mechanical strength of Thermit weld	all thermit welds
7.4	Visual on anode strap welds	all strap welds
7.4	MPI on anode strap welds	2 pipes/shift
9.	**Documentation and approvals**	
9.3	Qualification tests	prior to full production

11. SCOPE OF WORK CHECKLIST

The Contract Scope of Work shall provide/specify the data/activities detailed below, for **each pipe size and coating thickness type** required.

Section Reference	Description	Value
1.1	**Concrete grade**	A/B
2.1.1	**Pipe specification number**	.....
	Pipe data:	
	- Outside diameter	..... in
	- Wall thickness	..... mm
	- Steel grade	.....
	- Pipe tally details (length, weight. heat no., etc.)	.....
2.1.3	**Internal pipe cleaning prior to load out**	Yes/No
2.1.3	**Internal cleanliness grade (ISO 8501-1), if applicable**	St3/Sa1/Sa2
2.5.1	**Reinforcement type.** NOTE (1)	welded wire/ rebar cage/ chicken wire
4.2.1	**Anti-corrosion coating specification number**	.....
	- Anti-corrosion coating thickness	..... mm
	- End cut-back of anti-corrosion coating	..... mm (+/- ..... mm)
4.2.2	**Concrete end termination**	square/tapered at .....° to pipe axis
5.2.2	**Concrete thickness**	..... mm (+/- 5 mm)
5.4	**End cut back of concrete**	..... mm (+/- 15 mm)
5.4	**Submerged weight requirement** (unsaturated - as applied)	
	- nominal submerged weight	... N/m
	- individual pipe tolerance	+/- ... N/m
	- 25 pipe analysis tolerance	+/- 4%
	- shift's production average tolerance	+/- 2%
	Allowable variations per pipe joint (weight in air). NOTE (2)	
	- pipes fitted with zinc anodes	+ ..... N
	- pipes fitted with crack arresters	+ ..... N
	- pipes fitted with buckle arresters	+ ..... N
5.6.1	**Impact testing** NOTE (3)	Yes/No
7.	**Anode design drawing number** (drawing to be provided by the Principal)	.....
7.3	**Anode bonding leads supplied loose**	Yes/No
8.2	**Colour code**	.....

NOTES:
1. Chicken wire is not normally recommended, see (2.5.1).
2. These are nett variations, after allowing for reduction in concrete.
3. Acceptance criteria need to be specified for pipes with diameter less than 16 inches, or for concrete thicknesses less than 50 mm.

12. REFERENCES

In this DEP, reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

AMERICAN STANDARDS

Standard specification for steel wire, plain, for concrete reinforcement	ASTM A82
Standard specification for steel welded wire fabric, plain, for concrete reinforcement	ASTM A185
Standard specification for zinc coated (galvanized) steel poultry fence fabric (hexagonal and straight line)	ASTM A390
Standard specification for deformed and plain billet-steel bars for concrete reinforcement (metric)	ASTM A615M
Standard specification for zinc coated (galvanized) carbon steel wire	ASTM A641
Standard specification for concrete aggregates	ASTM C33
Standard test method for compressive strength of cylindrical concrete specimens	ASTM C39
Standard method for obtaining and testing drilled cores and sawed beams of concrete	ASTM C42
Standard specification for Portland cement	ASTM C150
Standard specification for sheet materials for curing concrete	ASTM C171
Liquid membrane-forming compounds for curing concrete	ASTM C309-89
Standard specification for blended hydraulic cements	ASTM C595
Standard test method for Vickers hardness testing of metallic materials	ASTM E92
Standard practice for liquid penetrant inspection method	ASTM E165
Magnetic particle examination, practice for	ASTM E709

Issued by:
American Society for Testing and Materials,
1916 Race Street,
Philadelphia, 19103,
USA.

BRITISH STANDARDS

Specification for Portland cements	BS 12
Specification for Portland-blast furnace cement	BS 146

Specification for aggregates from natural sources for concrete	BS 882
Specification for batch type concrete mixers	BS 1305
Testing concrete, method of sampling fresh concrete on site	BS 1881
Methods of test for water for making concrete (including notes on the suitability of the water)	BS 3148:1980
Method for testing the mixing performance of concrete mixers	BS 3963
Specification for cold reduced steel wire for the reinforcement of concrete	BS 4482
Specification for steel fabric for the reinforcement of concrete	BS 4483

Issued by:
British Standards Institution,
2 Park Street,
London W1A 2BS,
England.

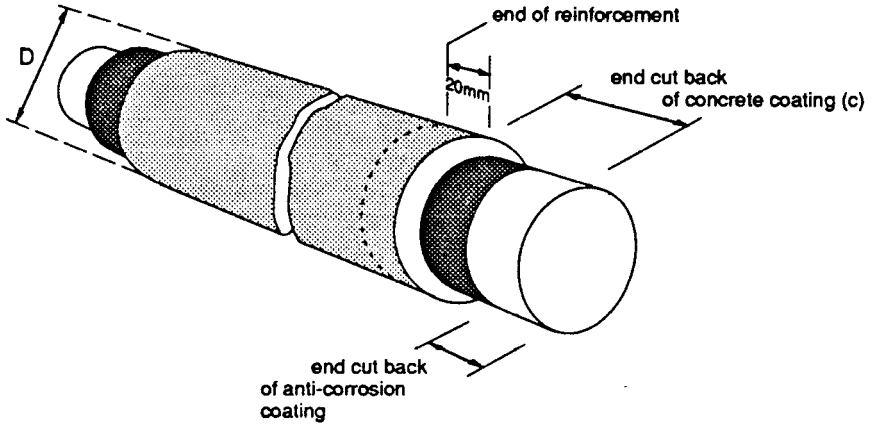
INTERNATIONAL STANDARDS

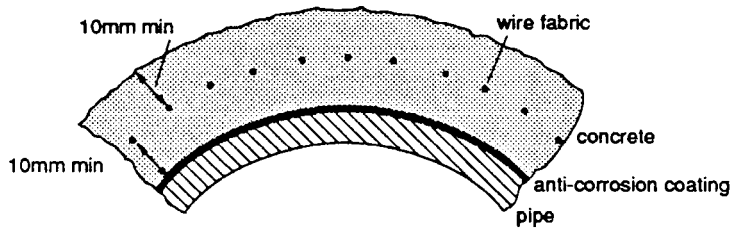
Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness - Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings.	ISO 8501-1

Issued by:
Central Secretariat of ISO
1, Rue de Varembé,
1211 Geneva 20,
Switzerland.

Copies can also be obtained through the National standards organizations

FIGURES





Section through typical wire fabric reinforcement

Fig. 1 REINFORCEMENT DETAILS

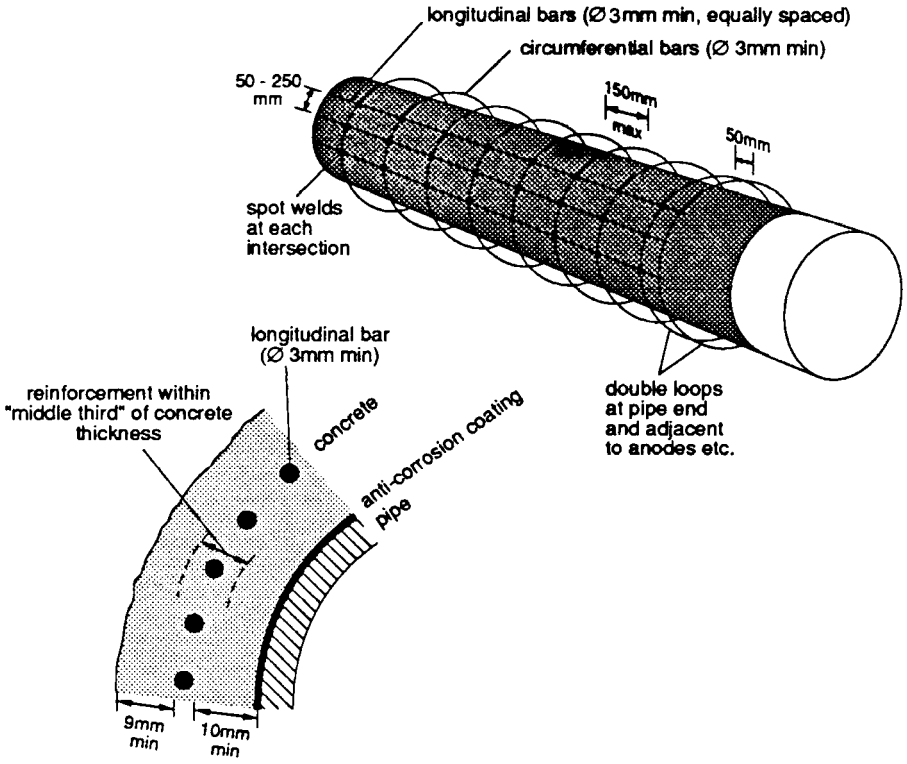


Fig. 2 CAGE REINFORCEMENT DETAILS

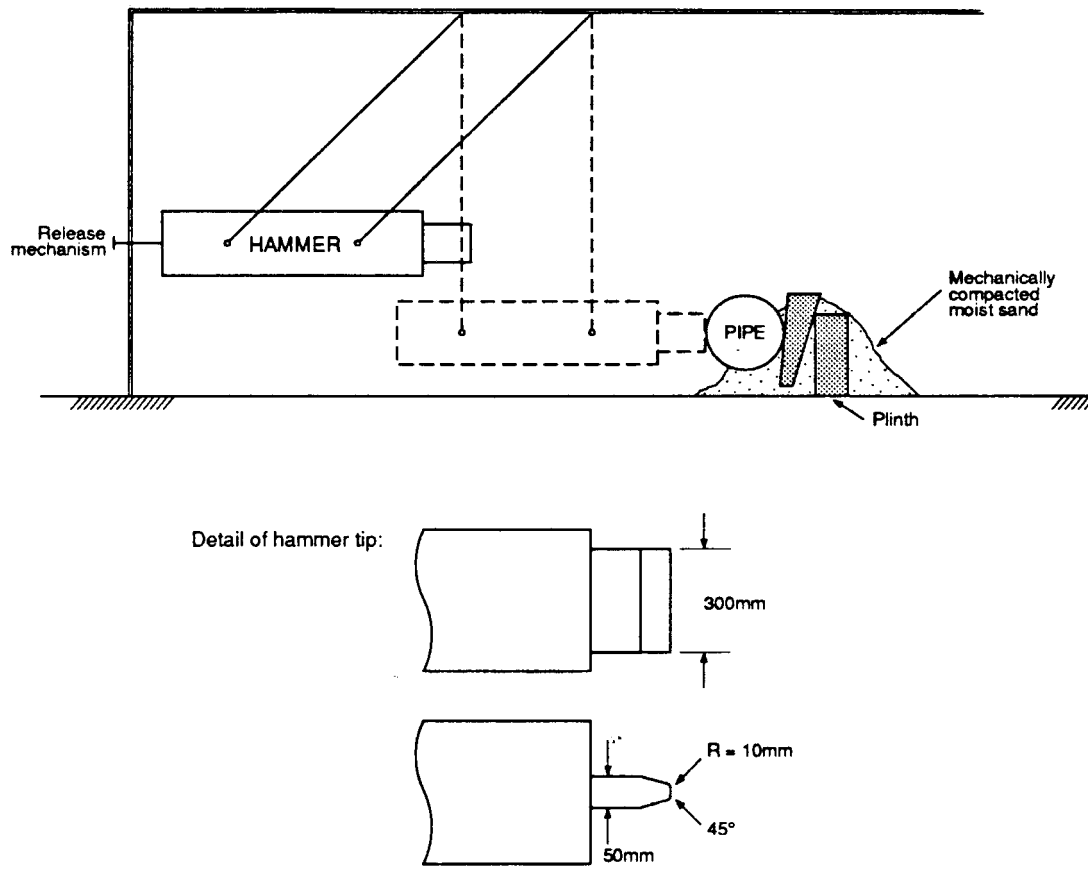


Fig. 3 IMPACT TEST RIG

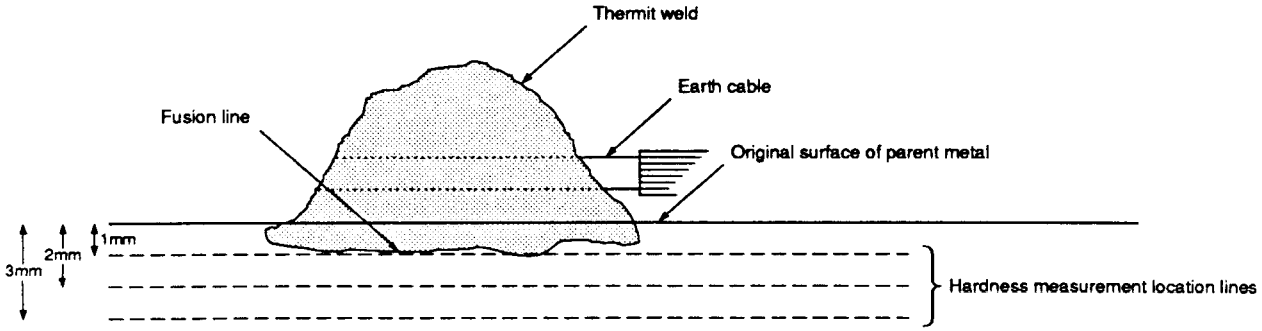


Fig. 4 CROSS SECTION THROUGH THERMIT WELD

APPENDIX 1 SOME IMPORTANT DESIGN ASPECTS

1. Concrete slippage

For submarine applications some coatings, e.g. fusion bonded epoxy, polyethylene, polypropylene, will normally need an intermediate coating to provide increased friction to avoid slippage between concrete and coating during pipelaying.

For laybarges with a single tensioner, precautions may be needed to avoid breakage and slippage of the concrete at the ends of the pipe. This might be achieved with temporary infill blocks or could involve stronger longitudinal reinforcing wire. (Any dimensional irregularities at the end of the coating, e.g. "bell ends", will exacerbate this problem.)

The exposed end portion of anti-corrosion coating may become too short or even disappear if slippage does occur.

2. Anti-corrosion coating damage

An intermediate "barrier" layer may be needed to prevent damage from the concrete impingement process.

3. Choice of anti-corrosion coating

There are normally many factors involved in the choice of coating for a particular pipeline. The above two potential problem areas may need to be taken into account in this choice.

4. Pipe dimensions and stiffness

Pipes with large diameter/wall thickness (D/t) ratios have a tendency to become oval when loaded externally and may also buckle at the field joint area when the concrete coated pipes are installed.

Large concrete thicknesses can be the cause of ovalization.