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Indian Standard

CORROSION PROTECTION OF STEEL BY FIBREGLASS REINFORCED POLYESTER LINING — CODE OF PRACTICE

भारतीय मानक

तंतुकाँच प्रबलित पोलिएस्टर के अस्तर से इस्पात जंग संरक्षण — रीति संहिता

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards on 23 February 1989, after the draft finalized by the Corrosion Protection Sectional Committee had been approved by the Structural and Metals Division Council.

The use of linings of polymeric materials as a protection against corrosion has been the normal industrial practice for nearly half a century but the use of monolithic reinforced plastic lining has several distinct advantages over any other coating. The primary advantage is that the monolithic liner is structurally sound for providing reasonable insurance against leakage through holidays developing due to external corrosion.

A standard specification for fibreglass used for reinforcement is under preparation.

In the preparation of this standard, assistance has been derived from the following:

a) BS : CP 3003 : Part 5 : 1966 Code of practice for epoxy phenolic linings. British Standards Institution, United Kingdom; and

b) ASTM D-4097-82 Specification for contact moulded glass fibre reinforced thermoset resin chemical resistant tanks. American Society for Testing and Materials, USA.

Indian Standard

CORROSION PROTECTION OF STEEL BY FIBREGLASS REINFORCED POLYESTER LINING — CODE OF PRACTICE

1 SCOPE

1.1 This standard covers the code of practice for corrosion protection of steel by the use of fibreglass reinforced unsaturated polyester lining.

1.2 The selection, application, inspection and testing of the lining are also covered by this standard.

2 REFERENCES

2.1 The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
IS 1323 : 1982	Code of practice for oxy-acetylene welding for structural work in mild steel (*second revision*)
IS 2825 : 1969	Code for unfired pressure vessels
IS 3531 : 1983	Glossary of terms relating to corrosion of metals (*first revision*)
IS 5746 (Part 1):1987	Specification for woven glass fibre fabrics for plastic laminates for aerospace purposes: Part 1 Loom-state fabrics (*second revision*)
IS 6746 : 1972	Specification for unsaturated polyester resin systems for low pressure fibre reinforced plastics
IS 9595 : 1980	Recommendations for metal arc welding of carbon and carbon manganese steels
IS 11273 : 1985	Specification for woven roving fabrics of 'E' Class fibre
IS 11551 : 1986	Specification for glass fibre chopped strand mat for the reinforcement of polyester resin systems

3. TERMINOLOGY

3.1 For the purpose of this standard, apart from definitions given in IS 3531 : 1983 the following definition shall apply.

3.2 Glassfibre Reinforced Unsaturated Polyester Linings

Linings based on unsaturated polyester resins which are generally a mixture of condensation products of an unsaturated dibasic acid and a glycol dissolved in a cross-linking monomer, suitably reinforced with glassfibre in the form of non-woven mat or woven fabric.

4 MATERIALS

4.0 The selection of suitable materials, for the lining and thickness of lining required including its method of application, has to be based on the information supplied by the user. Therefore, it is necessary that full details and applications are submitted to the contractor to enable him to choose the suitable lining. Annex A gives the information to be supplied by the user to the manufacturer.

4.1 Purpose

4.1.1 FRP linings are used for protecting equipment and steel structure against chemical attack. They are also used for the prevention of contamination of various products that may arise due to reaction of chemical with metallic equipment/vessel.

4.1.2 Unless the lining is known from previous experience to be suitable, test panels should be exposed to conditions similar to those of service for not less than three months or preferably longer. These panels should be examined carefully for any signs of failure before instructions for application of the lining are given.

4.2 Grades and Properties

Any FRP material is essentially composed of:

a) Glassfibre reinforcement, and

b) Resin system.

4.2.1 *Glassfibre Reinforcement*

The most common glassfibre reinforcement used in FRP linings is in the form of a chopped strand mat (CSM) (*see* IS 11551 : 1986) commonly available with a mass of 300, 450 and 600 g/m^2. CSM forms the main body of the lining and progressive layers are used to build up to the required thickness.

4.2.1.1 Alternatively, this part of the lining could also be built up using woven glassfibre fabric [*see* IS 5746 (Part 1):1987] available in various masses, namely, 200, 360 and 610 g/m^2 or by combining both CSM and woven rovings (*see* IS 11273 : 1985). The composition of glassfibre used for the reinforcement will be a low alkali 'E' type glass.

4.2.1.2 The surface of the lining is reinforced with a chemical resistant glass in the form of a 'surfacing veil' (also called surfacing mat) and is capable of absorbing between 7 and 10 times its own weight of resin.

4.2.2 *Unsaturated Polyester Resin*

The resin used shall be of Type 2 of IS 6746 : 1972. The resin shall meet the chemical resistance requirements as agreed to between the manufacturer and the purchaser when tested in accordance with the provisions of **4.3** of IS 6746 : 1972.

4.2.3 The resin, containing no fillers except a thixotropic agent that does not interfere with visual inspection of laminate quality, or with required corrosion resistance of the laminate, may be added for viscosity control.

NOTE — The addition of thixotropic agent will reduce the resistance of many resin systems to certain corrosive chemical environments.

4.2.4 Resin shall contain no pigments, dyes, or colorants except as agreed upon between the manufacturer and the purchaser.

NOTE — The addition of pigments, dyes or colorants may interfere with visual inspection of the laminate quality.

4.2.5 Ultraviolet absorbers may be added for improved weather resistance if agreed upon between the manufacturer and the purchaser.

4.2.6 Resin capable or withstanding corrosive environments can be divided into two types:

a) Rigid, and

b) Flexible.

4.2.6.1 Flexible resins give improved reverse impact resistance on equipment where jarring or vibration is likely to take place. These resins also offer good resistance to thermal shock which is extremely important when extremes of temperatures are encountered.

4.2.7 The following basic grades of unsaturated polyester resin family are recommended:

a) Based on isophthalic, and

b) Based on bisphenol-A.

4.2.7.1 Between the two, isopolyesters have a lower resistance to chemical attack and temperature. However, they are entirely suitable for a wide range of acids, mild alkalies, salts and other commercially used chemicals. For mild, relatively inert applications. isophthalic polyesters are adequate. However, the chemical resistant properties of these resins decline rapidly at elevated temperatures.

4.2.7.2 For aggressive chemical environments such as, strong acids and alkalies, at elevated temperatures, a rigid bisphenol polyester offers the broadest corrosion resistance and temperature limits.

4.2.8 The resin system used must be tested for viscosity, gel time and hardness prior to actual use.

4.2.9 The user or specifier shall obtain full information on chemical resistance of the resin prior to specifying its use for a particular condition. When requesting resin recommendation for corrosion resistant FRP equipment, users or specifiers shall supply the data given in Annex A. The resin manufacturer shall also furnish the data listed in Annex B for the benefit of the user.

4.3 Effect of Temperature

4.3.1 The effect of temperature on these linings varies with each resin. It also depends on the chemical in use and on its concentration. It must be noted that due to the differential in the coefficient of thermal expansion between FRP and the base material, higher temperature becomes a limiting factor. Therefore, FRP linings may be used at temperatures up to 80°C, quite often this may be lowered due to the chemicals in use or other conditions prevalent.

4.3.2 In all cases, it is assumed that a sufficiently thick and pin hole free lining has been applied.

5 DESIGN

5.1 General

5.1.1 *Interior Surface and Fittings*

The surfaces which are to be covered with FRP lining shall be easily accessible and free from pitting or other physical imperfections. Interior fittings shall be designed to allow safe and easy movement of the operator. In case of FRP linings of vessels, manhole shall be provided in each section of the vessel being lined.

5.1.2 *Access to Vessel and Ventilation*

The design of all vessels shall allow for adequate access and venting of fumes during the preparation of the surface and the application of the lining.

5.1.3 *Flanges and Outlets*

The lining shall be taken over all flanged faces/outlets to prevent the ingress of liquids/fluids behind the linings.

5.1.4 *Surface Contents*

Sharp changes of contour in the surfaces to be covered shall be avoided. Corners in the surface to be covered should be finished to a suitable radius which should be as large as possible but not less than 8 mm.

5.2 Fabricated Mild Steel Vessels

5.2.1 *Fabrication and Testing*

Mild steel vessels shall be fabricated and tested in accordance with recognized standards of good design and practice. Only welded or seamless construction shall be used. Rivetted constructions shall not be used.

5.2.2 Welding shall be in accordance with the requirements of either IS 9595 : 1980, IS 1323 : 1982 or IS 2825 : 1969. Lap joints shall be avoided. The weld shall be ground smooth and flush on the side to be covered.

6 DESIGN OF LININGS

6.1 Selection of Material

The selection of the resin and the FRP lining shall be based on the information supplied by the user. Full details of the applications of the vessel involved must be provided, as given in Annex A.

6.2 Quality of Lining

When the lining is to be applied by a contractor, the lining materials to be used shall be agreed between him and the purchaser. The contractor shall guarantee that the lining will satisfy the chemical and physical conditions met with the required services. The contractor shall supply samples with the lining materials or panels to which this has been applied for future reference in case of disputes. He shall not change the composition in any way except by agreement with the purchaser.

6.3 Thickness of Lining

For all conditions, the minimum thickness of FRP lining shall be 2 mm. Higher thickness shall be used where necessitated by the conditions of temperature, chemical attack or vessel size require this.

7 METHOD OF LINING

7.1 Steel Vessels/Structures

7.1.1 Remove deposits of oil, grease and other foreign matter by washing with solvent or other suitable cleaner.

7.1.2 Sandblast the cleaned surface until it is uniformly gray-white in colour and slighly roughened (white metal blast). The surface shall be free of visible mill scale, rust, corrosion oxides, paint or other contamination. After blasting, clean the tank thoroughly to remove all traces of abrasive and blast products. Vacuum cleaning is particularly suitable.

7.1.3 A primer coat of resin shall be applied within eight hours of sand blasting or sooner if humid conditions prevail. The primer coat shall be applied to a thickness of approximately 0·125 mm. A typical primer formulation is 25 parts styrene in 100 parts of resin.

7.1.4 *Putty Application*

After the primer coat is applied, all rivets, welded lap seams and the angles where the tank bottom and the walls meet shall be filled with putty to provide smooth rounded contour. Any obvious holes and pits shall be also filled with putty. Typical putty is a mix of 100 parts of gelcoat resin and 50 to 100 parts of the silica flour.

7.2 Preparation of Concrete Surface

7.2.1 The concrete substrate must be clean and dry, rough and at least 30 days old. The concrete surface shall be sandblasted until it is cleaned of oily spots and 'flaky' concrete, and is uniformly roughened. Residue and by-product from sandblasting shall be removed, preferably by vacuum cleaning. In small tanks or other places where sandblasting is not practicable, the surface shall be etched with dilute hydrochloric acid. Application of the acid shall be done with a stiff broom, scrubbing the surface to remove flaky material. When the acid is applied, bubbling should take place indicating a reaction; if not, the surface shall be sandblasted again. After etching with acid, the concrete shall be washed with a dilute ammonia solution and flushed with clean water. The concrete surface shall be thoroughly dried before application of the primer coat of resin. It is very necessary that the concrete surface is completely dry to obtain proper adhesion of lining.

7.2.2 *Priming*

After etching or sandblasting, the concrete becomes porous and shall be sealed with a primer coat approxmiately 0·125 mm thick. The primer coat, shall be applied the same day preferably within eight hours after sandblasting is completed.

7.2.3 *Putty Application*

The procedure outlined in **7.1.4** for steel surfaces shall be followed.

8 APPLICATION OF LAMINATE

8.1 The time required for the primer coat to harden depends on the ambient temperature of the working area and the quantity of accelerator, catalyst and the promoter used, and is normally 40 minutes or less at 30°C.

8.2 After the resin is cured, the area can be laminated with FRP by the hand lay up technique outlined in **8.3**.

8.3 Procedure

The glass mat is cut to convenient sizes for handling, making allowance for overlaps of 50 mm at seams. Resin mixture is applied to the area of the substrate to be covered first. The cut mat is positioned on the resin and worked with a roller with simultaneous strippling with a paint brush until the mat is completely wetted out and no resin starved areas or air bubbles are present. Additional resin is applied to the lay-up where needed and between the layers as they are built up. When the entire tank surface has been covered with one complete layer of glass, further layers are applied using the same technique until the lamination is complete.

NOTES

1 All reinforcing media should be lapped and not butted.

2 Mat should be lapped minimum of 25 mm and woven roving on cloth a minimum of 50 mm.

3 The overlaps should be staggered throughout the FRP lining not superimposed.

8.3.1 For maximum corrosion resistance, the glass concentration in the laminate shall be in the range of 25 to 30 percent.

8.3.2 *Top Coating*

The lining shall be finished with a fibreglass surfacing mat for a resin rich surface, minimum of 0·3 mm thick for maximum corrosion resistance. The resin used for this top coat shall contain 0·6 percent paraffin wax to provide for a tack free surface.

8.3.3 *Post Curing*

After the lining job is completed, it shall be allowed to post cure at room temperature (30°C, *Min*) for a minimum period of three weeks. This would ensure that the lining attains the maximum chemical resistance and is relieved of all internal stresses that might have developed during the lamination. Accelerated curing may be possible at higher temperature as recommended by the manufacturer.

9 ACCEPTANCE TESTS

9.1 Test for Completeness of Cure

9.1.1 Whether a resin has properly cured or not can be easily determined using a Barcol hardness tester. For most polyester cured resin system, the Barcol hardness value lies between 35 to 50. However, Barcol hardness reading may vary with different resin system, for example, more resilient resins normally produce lower Barcol readings. In practice readings of 90 percent of a manufacturer's recommendation for the particular cast resin may be obtained.

9.1.2 Laminates containing thixotropic agents may have higher hardness readings by about 3 to 5 units. The use of parraffin, synthetic fibre overlays, may lower the hardness reading by 3 to 10 units.

9.1.3 *Acetone Sensitivity*

Barcol hardness tests cannot be expected to detect air-inhibited surfaces in all cases. Therefore, it is recommended that the acetone sensitivity test may also be employed where appropriate. This test involves application of a small amount of acetone on the resin surface. The wetted surface is lightly rubbed with a finger until the acetone has evaporated. If the surface softens or becomes tacky, the resin has not properly cured.

9.2 Visual Inspection

Linings shall be inspected visually to ensure freedom from poorly set out glass entrapped air and exposed fibres.

9.2.1 *Tests for Continuity of Lining*

The inspection for visual defects shall be carried out over the entire surface in sufficient light. The entire surface shall be free of cracks, traces of bubbles, lack of adhesion, hollow spaces, etc.

9.3 Holiday Test or Spark Test

A high voltage, high frequency spark tester shall be used for testing voids and pinholes. Where a defect occurs in the lining, the discharge is earthed producing a strong white continuous spark. The surface of the lining shall be clean and dry when the test is carried out. Excessive voltage or long residence time or both may puncture the lining, and care should, therefore, be taken to select the correct voltage and to ensure that the probe does not remain in one position for too long. The voltage depends on the thickness of the lining to be tested and shall be determined by trial on sample test pieces.

9.4 Repairs

Defects are repaired by sanding a generous area around the defect and applying a layer of glass mat saturated with activated resin and then top coating with surfacing mat and parafin filled resin.

9.5 Vacuum Test

Lined vessels subjected to vacuum during operation shall undergo a vacuum test at specified vacuum. The vacuum shall be maintained for a period of minimum one hour and the lining shall show no defects on reinspection.

10 PRECAUTIONS

10.0 During lamination, the following precautions shall be strictly observed.

10.1 Cobalt napthenate and methyl ethyl ketone peroxide (MEKP) shall not be mixed together as they form a highly reactive mixture and a

fire or explosion may result. These components shall be added and mixed in the batch, separately.

10.2 Enforce 'NO SMOKING' rules and avoid ignition sources in the working area since MEKP and styrene are flammable.

10.3 Concentration of vapours may cause complaints of disagreeable odour or eye irritation. Working areas shall be well ventilated so that concentration in the atmosphere does not rise to intolerable limits.

ANNEX A

(*Clauses* 4.0, 4.2.9 *and* 6.1)

INFORMATION TO BE FURNISHED BY PURCHASER TO THE MANUFACTURER/SUPPLIER

A-1 The purchaser shall furnish the following information:

a) Site conditions which may affect the work, availability of services for site lining, access and lifting facilities.

b) Safety measures to be taken; the details of medical and technological precautions to be taken during storing and handling should be given by the resin supplier.

c) Construction of equipment to be lined, location of welds, branches, joints and supports and finish of the surface to be lined.

d) Nature and concentration of the contents of the vessel or equipment with their maximum and minimum concentrations possible.

e) Presence of abrasives in contents.

f) Range of normal operating temperature and pressures with the maximum and minimum temperature and pressures and their duration.

g) Methods of heating and cooling the contents of the vessels.

h) Fire retardancy and thermal insulation requirement.

j) Service life required.

k) Cycle of operation whether batch or continuous.

m) Possibilities of any vibration and any mechanical damage during operation.

ANNEX B

(*Clause* 4.2.9)

DATA TO BE FURNISHED BY RESIN MANUFACTURER

B-1 The resin manufacturer shall furnish the following data to the supplier/purchaser:

a) Resin grade and type recommended for the specific application indicated by the user,

b) Viscosity,

c) Gel time,

d) Hardness,

e) Curing cycle,

f) Shelf life,

g) Storage recommendations,

h) Handling precautions, and

j) Any other information that may be necessary.

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