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ARAB ENGINEERING BUREAU

14 PROTECTIVE TREATMENTS FOR CONCRETE

14.1 GENERAL

14.1.1 Scope

- 1 This Part covers the materials and application requirements for coatings for concrete surfaces including epoxy coatings, waterproof membranes, penetrative primers, protective coatings, and coatings and treatments for specialist applications where there is a harsh environment.
- 2 Related Section and Parts are as follows:

This Section

Part 1, General

14.1.2 References

- 1 The following standards are referred to in this Part:
 - ASTM C981 Standard Guide for Design of Built-Up Bituminous Membrane Waterproofing Systems for Building Decks
 - ASTM D412..... Test Methods for Vulcanized Rubbers and Thermoplastic Elastomers Tension
 - ASTM D543..... Test Method for Resistance of Plastics to Chemical Reagents
 - ASTM D570..... Test Method for Water Absorption of Plastics
 - ASTM D638..... Test Method for Tensile Properties of Plastics (Metric)
 - ASTM D746..... Test Method for Brittleness Temperature of Plastics and Elastomers by Impact
 - ASTM D882..... Test Methods for Tensile Properties of Thin Plastic Sheeting
 - ASTM D1000..... Test Method for Pressure Sensitive Adhesive Coated Tapes Used for Electrical and Electronic Applications
 - ASTM D1004..... Test Method for Initial Tear Resistance of Plastic Film and Sheeting
 - ASTM D2178/D2178M Standard Specification for Asphalt Glass Felt Used in Roofing and Waterproofing
 - ASTM D2240..... Standard Test Method for Rubber Property—Durometer Hardness
 - ASTM D4541..... Test Method for Pull Off Strength of Coatings Using Portable Adhesion Testers
 - ASTM D4637/D4637M Standard Specification for EPDM Sheet Used In Single-Ply Roof Membrane (reinforced sheets only)
 - ASTM D6221/D6221M Standard Specification for Reinforced Bituminous Flashing Sheets for Roofing and Waterproofing
 - ASTM D6222/D6222M Standard Specification for Atactic Polypropylene (APP) Modified Bituminous Sheet Materials Using Polyester Reinforcements

- ASTM D6769/D6769M Standard Guide for Application of Fully Adhered, Cold-Applied, Prefabricated Reinforced Modified Bituminous Membrane Waterproofing Systems
- ASTM D7465/D7465M Standard Specification for Ethylene Propylene Diene Terpolymer (EPDM) Sheet Used In Geomembrane Applications (reinforced sheets only)
- ASTM D7693/D7693M Standard Guide for Application of Heat Weldable Modified Bituminous Waterproofing Membranes Systems for New Concrete Decks
- ASTM E96/E96M.... Standard Test Methods for Gravimetric Determination of Water Vapor Transmission Rate of Materials
- ASTM E154..... Test Methods for Water Vapor Retarders Used in Contact with Earth Under Concrete Slabs, on Walls, or as Ground Cover
- ASTM F2873 Standard Practice for the Installation of Self-Leveling Underlayment and the Preparation of Surface to Receive Resilient Flooring.
- BS 1521 Waterproof building papers
- BS 1881 Testing Concrete
- BS 3416 Bitumen based coatings for cold application, suitable for use in contact with potable water
- BS 6319 Testing of resin and polymer/cement compositions for use in construction.
- BS 6319-11 Testing of resin and polymer/cement compositions for use in construction. Methods for determination of creep in compression and in tension
- BS 6920 Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of the water
- EN1062-6..... Paints and varnishes - Coating materials and coating systems for exterior masonry and concrete - Part 6: Determination of carbon dioxide permeability
- EN 1928 Flexible sheets for waterproofing - Bitumen, plastic and rubber sheets for roof waterproofing - Determination of watertightness
- EN 12039 Flexible sheets for waterproofing. Bitumen sheets for roof waterproofing. Determination of adhesion of granules.
- EN 12350 Testing fresh concrete
- EN 12597..... Bitumen and bituminous binders. Terminology
- EN 12615..... Products and systems for the protection and repair of concrete structures. Test methods. Determination of slant shear strength
- EN 12620 Aggregates for concrete

- EN 13304 Bitumen and bituminous binders. Framework for specification of oxidised bitumen
- EN 13305 Bitumen and bituminous binders. Framework for specification of hard industrial bitumens.
- EN 13707 Flexible sheets for waterproofing. Reinforced bitumen sheets for roof waterproofing. Definitions and characteristics
- EN 14023 Bitumen and bituminous binders. Specification framework for polymer modified bitumens.
- EN 14691 Flexible sheets for waterproofing. Waterproofing of concrete bridge decks and other concrete surfaces trafficable by vehicles. Compatibility by heat conditioning
- EN 14692 Flexible sheets for waterproofing. Waterproofing of concrete bridge decks and other concrete surfaces trafficable by vehicles. Determination of the resistance to compaction of an asphalt
- EN 14693 Flexible sheets for waterproofing. Waterproofing of concrete bridge decks and other concrete surfaces trafficable by vehicles. Determination of the behaviour of bitumen sheets during application of mastic asphalt
- EN 15836-2 Plastics. Plasticized poly(vinyl chloride) (PVC-P) membranes for inground swimming pools. Reinforced membranes of nominal thickness equal to or greater than 1,5 mm

CIRIA Technical Note 130, Protection of Reinforced Concrete by Surface Treatments.

- ISO 34 Rubber, vulcanized or thermoplastic — Determination of tear strength
- ISO 527-3 Plastics — Determination of tensile properties — Part 3: Test conditions for films and sheets
- ISO 9001 Quality systems - Model for quality assurance in design, development, production, installation and servicing
- ISO 12236 Geosynthetics — Static puncture test (CBR test)
- PD 6682-1 Aggregates. Aggregates for concrete. Guidance on the use of BS EN 12620

14.1.3 Submittals

- 1 The Contractor shall submit manufacturers' specifications, installation instructions and other data to show compliance with the requirements of this part of the specification and the Contract Documents.
- 2 The Contractor shall submit samples of all materials to be used in the works before delivery of material to Site. Samples of membrane waterproofing shall be 300 mm square. Samples of liquid components shall be a minimum of one litre.

- 3 The Contractor shall submit comprehensive test results for the protective coating system as per the tests in the specification which shall clearly indicate whether the values are mean values measured in current production or minimum values which the property does not fall below.
- 4 The Contractor shall clearly state the chemical composition of the material and the process by which protection is given to the concrete.
- 5 In addition to the test methods identified in this clause of this specification, the Engineer may require the Contractor to carry out further tests to different standards.
- 6 If the Contractor wishes to propose a material which has been tested to alternative standards, the Contractor shall submit correlation tests showing the comparable values of the two test methods. These test results shall be comprehensive giving full details of the sample conditioning, preparation, method of test, criteria for assessment etc.
- 7 The Contractor shall submit comprehensive information of previous applications of the material in similar conditions and environments. This information shall include: project name, type/grade of material used, quantity of material used, name of client, name of consultant, name of Contractor. If requested by the Engineer, the Contractor shall supply the contact details of the client, consultant or Contractor where the material was previously installed.
- 8 The Contractor shall submit a guaranty for the protective coating system and the workmanship. The guaranty shall be worded to reflect the required performance of the material and shall be approved by the Engineer. The guaranty shall be worded to include the phrase 'the Contractor shall, at the convenience of the Employer, effect all repairs and replacements necessary to remedy defects all to the complete satisfaction of the Engineer'. Unless stated otherwise in the contract specific documentation, the performance guaranty shall be for a period of ten years except for the penetrative primer which shall be for a period of five years.
- 9 The use of alternatives may be considered by the Engineer. If the Contractor wishes to propose such systems, a technical submission shall be made which shall include a comprehensive justification giving an explanation of why the proposed system is equivalent or superior to the one designated.

14.1.4 Quality Assurance

- 1 The protective coating system shall be supplied by a manufacturer who is certified to the ISO 9000 series of quality standards. The Contractor shall submit to the Engineer a copy of the ISO 9000 series certificate that clearly states the scope of the certification.
- 2 The protective coating system shall be supplied by a manufacturer who provides technical assistance on the suitability for the application and installation for the material. For the initial use of the material on Site, the Contractor shall arrange for the technical representative of the manufacturer to be present to demonstrate the correct use of the material.

- 3 The protective coating system shall be applied by a contractor or subcontractor who is certified to the ISO 9000 series of quality standards. The Contractor shall submit to the Engineer a copy of the ISO 9000 certificate that clearly states the scope of the certification. the Engineer may permit the use of an applicator who is not certified to ISO 9000 if the applicator works to a quality system that is approved by the Engineer.
- 4 The works shall be executed by an approved specialist subcontractor having a minimum of 5 years successful experience in the installation of the specified material. Only tradesmen experienced with the installation of the materials specified shall be used.

14.1.5 Preinstallation and Co-ordination

- 1 After approval of all materials and before installation, a prework conference with the Engineer shall be held at the Site. The meeting shall be attended by representatives of the Engineer, Contractor, subcontractor, and manufacturer.
- 2 The parties shall:
 - (a) review drawings, specifications and approved materials
 - (b) correct conflicts, if any, between approvals and specification requirements
 - (c) examine Site conditions, including inspection of substrate, material labels and methods of storing materials
 - (d) review installation procedures and scheduling
 - (e) review protection methods for finished work from other trades.
- 3 Before applying the coating system to the permanent works the Contractor shall carry out a small trial of the coating system for the review and approval of the Engineer.

14.1.6 Delivery, Storage and Handling

- 1 Materials shall be delivered in their original, tightly sealed containers or unopened packages, all clearly labelled with the manufacturer's name, brand name, and number and batch number of the material where appropriate. Materials and equipment shall be stored as directed in a neat and safe manner.
- 2 Storage areas shall comply with the manufacturers requirements with regard to shade, ventilation and temperature limits and shall be located away from all sources of excess heat, sparks or open flame. Containers of liquid material shall not be left open at any time in the storage area.
- 3 Materials not conforming to these requirements will be rejected by the Engineer and shall be removed from the Site and replaced with approved materials.
- 4 The Contractor shall deliver materials to Site in ample time to avoid delay in job progress and at such times as to permit proper co-ordination of the various parts.

14.1.7 Protection

- 1 The Contractor shall protect the protection system installation from damage during the construction period so that it will be without any indication of abuse, defects or damage at the time of completion.

- 2 The Contractor shall protect the building/structure from damage resulting from spillage, dripping and dropping of materials.
- 3 The Contractor shall prevent any materials from running into and clogging drains.
- 4 Materials and plant shall not be stored on any newly constructed floor without the permission of the Engineer.
- 5 Impervious membranes shall be laid as protection to all concrete surfaces in contact with the soil and shall consist of tanking or similar accepted material, based on soil investigation report.
- 6 All foundations shall be provided with protection such as epoxy coatings or similar other accepted equivalents so that concrete is not exposed to harmful effects of soil, chlorides etc.

14.1.8 General Requirements for all Treatments

- 1 Protective treatments shall be applied where designated in the contract specific documentation.
- 2 All protective coating systems to be used shall be applied strictly in accordance with the manufacturers recommendations.
- 3 The Contractor shall take all necessary precautions against fire and other hazards during delivery, storage and installation of flammable materials specified herein and comply any regulations imposed by the Civil Defence Department of the Ministry of the Interior in respect of the storage and use of hazardous materials required under this section.
- 4 The Engineer shall specify the required final colour of the coating and the Contractor shall submit samples showing the colour before ordering the materials.

14.1.9 Final Inspection

- 1 Upon completion of the installation, an inspection shall be made by a representative of the material manufacturer in order to ascertain that the system has been properly installed.

14.2 EPOXY COATING

14.2.1 General

- 1 The coating shall be a decorative flexible high solids, epoxy polyurethane, epoxy Polysulphide coating applied in two coats to a minimum dry film thickness of 200 µm.

14.2.2 Surface Preparation

- 1 The surface of the concrete shall be free from oil, grease, loose particles, decayed matter, moss or algae growth and general curing compounds. All surface contamination and surface laitance shall be removed by high pressure water jetting or sweep blasting.
- 2 Blow holes and areas of substantial pitting shall then be filled with a solvent free thixotropic epoxy resin fairing coat. The mixing and application of this coat shall be in accordance with the product manufacturer's recommendations.

- 3 Where surface cracking is apparent these cracks shall be chased, by an approved mechanical means, to the depth of the crack. A thixotropic epoxy resin shall be applied using a trowel, scraper or filling knife ensuring that full compaction is achieved into the chased section and providing a flush finish with the concrete surface. A minimum period of 24 h shall be allowed before applying any subsequent protective coating systems.

14.2.3 Materials

- 1 External above ground coating materials shall provide protection against chlorides and carbonation, and be UV and abrasion resistant.
- 2 The above ground coating shall be applied over the below ground coating and shall continue for a minimum of 150 mm above the ground level.
- 3 The epoxy coating shall be UV stable.
- 4 The finished coating shall be pinhole free and have a total minimum dry film thickness of 200 µm.
- 5 The materials used in the coating system shall comply with the following requirements:

Solids content	-----	> 85 %
Service temperature	-----	20 C° to 70 C°
Tensile strength (ASTM D638), min	-----	20 MPa
Elongation @ 7 days (ASTM D638, ASTM D882), min	-----	4%
Resistance against crack; Tear strength (DIN 53515; ISO 34-1)	min 6 kN/m (6N/mm)	
Adhesion to concrete (ASTM D4541; ASTM D7234)	-----	greater than 3.5 MPa
Compressive strength (ASTM D695)	-----	min. 90 MPa (neat resin)
Water absorption (MIL D24613)	-----	Nil
Abrasion resistance (ASTM C501)	-----	max 50 mg
Thermal coefficient of expansion (ASTM C531)	-- 46.8 x 10 ⁻⁶	mm/mm/degree C

14.2.4 Application

- 1 Where required by the Engineer, trial areas not exposed in the finished work shall first be treated using the selected materials.
- 2 The exposed concrete surfaces as defined in the documents or as agreed with the Engineer shall be treated with the material.
- 3 The coating shall be applied by spray, roller or brush to achieve a finish acceptable to the Engineer.
- 4 In all operations of storage, mixing and application, the Contractor is to comply with the health and safety recommendations of the manufacturer and governing authorities.

14.3 WATERPROOF MEMBRANE

14.3.1 General

- 1 This Subpart covers the use of waterproof membrane for general protection to buried concrete.
- 2 Where indicated on the Drawings or directed by the Engineer, concrete in contact with the ground shall be protected by a preformed flexible self-adhesive bituminous type membrane.
- 3 The laying, lapping and sealing of the membrane shall be in accordance with the manufacturer's instructions.

14.3.2 Materials

- 1 The material shall be an externally applied waterproof membrane shall be an impervious, cold applied flexible laminated sheet, consisting of multilayer high density cross-laminated polyethylene film with a backing of self-adhesive rubber bitumen compound, protected with silicone coated release paper.
- 2 Primer for Sheet Membrane: As recommended by the manufacture of the sheet membrane.
- 3 Protection Board: Provide a minimum 6 mm thick asphalt protection board manufactured from selected aggregates, bound in modified bitumen encased between two layers of strengthened asphalt paper. The bituminous material shall be a minimum of 1.0 mm thick and the membrane shall be capable of bridging crack widths in the substrate up to 0.6 mm wide.

14.3.3 Waterproof Membrane

- 1 The material shall be suitable for use in the Gulf region the compound shall be specially formulated for hot climates and shall have proven experience in the Middle East.
- 2 The waterproofing material shall conform to the standards detailed in Table 14.1

Table 14.1
Waterproof Membrane Property Requirements

Property	Standard	Value
Elongation Film	ASTM D638; ASTM D882	Longitudinal min 210 % Transverse min 160 %
Tear film resistance	ASTM D1004	Longitudinal min 340 N/mm Transverse min 310 N/mm
Adhesion to primed concrete	ASTM D1000	min 1.8 N/mm
Elongation compound	ASTM D1000	1600%
Puncture resistance	ASTM E154	220 N over 45 mm
Water resistance	ASTM D570	After 24 h. max 0.14 % After 35 d max 0.95 %
Environmental resistance	ASTM D543	
Moisture vapour transmission rate	ASTM E96	max 0.3g/m ² 24 h
Minimum thickness	ASTM D5147	1.0 mm.

14.3.4 Application

- 1 Waterproofing membranes placed on vertical concrete faces shall be protected by preformed asphalt board.
- 2 Boards shall be bonded onto position with high quality solvent borne contact adhesive based on polychloroprene rubber.
- 3 The Contractor shall co-ordinate the installation of waterproofing membrane with floor drains, equipment bases and other adjacent work and mask adjacent work to prevent soil marks.
- 4 Areas where waterproofing is applied shall be protected from all traffic and where necessary backfilling. All damage to finished portions of the waterproofing membrane shall be either repaired or replaced, or both, in a manner acceptable to the Engineer.

14.4 PENETRATIVE PRIMER

14.4.1 General

- 1 The system shall be a penetrating hydrophobic treatment that protects concrete from both water and chloride intrusion, while permitting water vapour transmission.
- 2 The treatment shall significantly reduce the absorption of water and water borne salts but allow the transmission of water vapour from the substrate.
- 3 The treatment shall not produce any discolouration of the substrate and shall have excellent resistance to weathering.

14.4.2 Material

- 1 The material shall be a low viscosity migrating corrosion inhibitor, based upon silane-siloxane, which penetrates deeply into a porous substrate and reacts to produce a bonded hydrophobic lining to the pores.
- 2 It shall demonstrate at least 90% reduction in active corrosion in cracked concrete and shall prevent the ingress of chlorides in accordance with ASTM 1152.
- 3 The material shall be resistant to petrol, oil, and atmospheric contaminants such as car exhaust fumes and industrial exhausts.

14.4.3 Surface Preparation

- 1 The surface shall be dry, free from oil and grease, loose particles, decayed matter, algae growth and curing compounds.
- 2 If the concrete surface is newly cast and has a very smooth finish, the surface shall be roughened by sand or grit blasting, water blasting or some mechanical means. The Engineer shall decide if this means of preparation is required.
- 3 Moss or algae growth on the surface shall be removed using a proprietary fungicidal wash in accordance with the manufacturer's recommendations.
- 4 Concrete finishing required shall be completed before the application of the treatment.
- 5 Cracks of width greater than 0.2 mm shall be filled in accordance with the manufacturer's recommendations.

14.4.4 Application

- 1 Unless directed otherwise by the Engineer the treatment shall be applied a minimum period of 24 h after the wet curing period, and shall be surface dry.
- 2 The Contractor shall carry out tests to verify the depth of penetration of the material. These tests shall be carried out on specimens of the actual mix design and shall use coloured dyes to trace the penetration of the material.
- 3 Where fine cracking has occurred in the concrete (at a width not greater than 0.3 mm for reinforced concrete and 0.2 mm for water retaining structures) an additional four 'stripe coats' of the treatment shall be applied before the main treatment.
- 4 The application of the material on surfaces shall be by a low pressure spray direct from the can. Under no circumstances should thinning of the material be carried out.
- 5 The rate of application shall ensure that the surface is completely saturated. The impregnated coating shall be applied to two or more flood coats each flood coat shall be a minimum of 0.4 l/m².
- 6 The material shall be applied strictly in accordance with the manufacturers instructions and as follows:
 - (a) the material shall be applied by a fine nozzle spray

- (b) application will not be permitted when the ambient air temperature is above 35 °C or in windy conditions
- (c) the surface shall be cleaned by a stiff brush or compressed air to remove all loose deposits
- (d) concrete to be treated shall be surface dry for a minimum period of 24 h before impregnation
- (e) membranes, joint sealers and cast in concrete ancillaries shall be masked off before treatment
- (f) application shall be made by saturation flooding
- (g) the interval between application shall be at least 6 h
- (h) treated areas shall be protected from sea water and rain for 6 h after treatment.

14.5 PROTECTIVE COATING

14.5.1 General

- 1 The coating system shall be used for the protection of new or existing reinforced concrete structures against carbonation or chloride induced corrosion.
- 2 The system shall comprise of a penetrating, reactive primer and an acrylic polymer top coat system to minimise ingress of acidic gases, chlorides and water.

14.5.2 Surface Preparation

- 1 Before application, all surfaces must be dry and free from oil, grease, loose particles, decayed matter, moss or algae growth and general curing compounds.
- 2 All such contamination and laitance must be removed by the use of grit blasting, high pressure water jetting or equivalent mechanical means.
- 3 Before proceeding to apply the protective coatings, all surfaces which are not to be coated but which may be affected by the application of the coating shall be fully masked and, in particular, flora and fauna shall be protected.
- 4 Blow holes and areas of pitting shall be made good with a one part modified cementitious material and allowed to cure in accordance with the manufacturer's recommendations. In particular, the application shall be in accordance with the manufacturer's recommendations, with respect to the maximum application thickness.

14.5.3 Material– Anti Carbonation Coating

- 1 The materials are required to provide in-depth protection against carbonation and chloride penetration and permitting water vapour transmission from the concrete.
- 2 The primer shall be a low viscosity silane-siloxane system which penetrates deeply into a porous substrate and reacts to produce a bonded hydrophobic lining to the pores.

3 The material employed for the coating shall comply with the following requirements:

Carbon Dioxide diffusion resistance (EN1062-6; Taywood Engineering Laboratories)	R Value at 325 microns > 161 metres.
Water vapour transmission (ASTM E96/E96M; Taywood Engineering Laboratories)	max 13 g/m ² .d
Reduction in chloride ion penetration (BS 1881 : Part 124)	94 % minimum at 28 d
Tear Resistance (ASTM D624)	min 7.3 kN/mm
Crack bridging (BRE Method) (min)	1.0 mm
Chloride Ion Diffusion (ASTM C1556; Taywood Engineering Laboratories)	max 3.63×10^{-10} cm ² /sec.

- 4 Where test methods are not specified, the procedure for establishing compliance with the above criteria shall be agreed with the Engineer.
- 5 The Contractor is required to adhere strictly to the manufacturer's recommendations regarding the use, storage, application and safety rules in respect of the approved materials.

14.5.4 Material - Aggressive Environment Resistant

- 1 The coating shall be a solvent and pitch free two component epoxy resin coating which meets ANSI / ASTM C881 Type III, Grade 2, Class B or Tar free epoxy as requested by the Engineer.
- 2 The material shall comply with the following requirements or equivalent testing standards:

Volume Solids ASTM D2697	100%
Tensile Strength ASTM D638 (min)	18 MPa at 7 days
Elongation at break ASTM D638 (min)	2 % at 7 days
Bond strength ASTM D4541 (min)	3.00MPa at 300 microns Dry Film Thickness of 500 microns
Abrasion resistance ASTM D4060 :max	17 milligram at (Dry Film Thickness of 500 microns)
Permeability - EN 12390	NIL. at 300 microns Dry Film Thickness at 5 bars of pressure

14.5.5 Material - Potable water tanks

1 The protection system shall be two components high build, non-toxic, solvent free, epoxy Coating or single layer unreinforced synthetic PVC membrane and should be non toxic, rot proof with a long life expectancy and comply with the local and international food and hygiene standard

2 If the Epoxy coating is used; the material shall comply with the following requirements or equivalent testing standards:

Solid content	100 %
Dry Film Thickness (min)	400 microns
Bond Strength ,ASTM D4541,(min)	2 MPa
Compressive Strength BS 6319 , (min)	80 MPa
Tensile Strength ASTM D638 (min)	25 MPa

3- If the PVC membrane is used; the material shall comply with the following requirements or equivalent testing standards:

Thickness	1.5 mm
Tensile Strength – ISO 527 – 3 (min)	17 N/mm ²
Elongation @ Break - ISO 527- 3 (min)	300 %
Puncture Resistant- DIN 16726; ASTM E154/E154M (min)	800 mm
Tear Resistance ISO 34 (specimen fig. 2): (min)	45 N/mm
Resistance to static punching ISO 12236 (min)	1800 N
Hydrostatic Pressure Resistant (6h@ 5 Bars) EN 1928 (B)	WaterProof (watertight)

4 Where test methods are not specified, the procedure for establishing compliance with the above criteria shall be agreed with the Engineer.

5 The Contractor shall require to adhere to the manufacturer's recommendations regarding the use, storage, application and safety rules in respect of the approved materials.

14.5.6 Application

1 The exposed concrete surfaces as defined in the documents or as agreed with the Engineer shall be conditioned by the application of a penetrating hydrophobic treatment. The primer shall be allowed to dry in accordance with the manufacturer's requirements.

2 The Contractor shall then apply two coats of pigmented topcoat in accordance with the manufacturer's instructions. The finished coating shall be pinhole free and have a total minimum dry film thickness of 150 µm. The colour and finish is to be as agreed with the Engineer.

3 The coating shall be applied by spray, roller or brush to achieve a finish acceptable to the Engineer.

- 4 In all operations of storage, mixing and application the Contractor shall comply with the health and safety recommendations of the manufacturer and governing authorities.

14.6 PLASTIC SHEET LINER FOR CONCRETE STRUCTURES

14.6.1 General

- 1 This Subpart covers the supply and installation of sheet liners in reinforced concrete structures.
- 2 The liner must be continuous and free of pinholes both across the joints and in the liner itself.
- 3 All work for and in connection with the installation of the lining in concrete pipe and structure, and the field sealing and welding of joints, will be done in strict conformity with all applicable specifications, instructions, and recommendations of the lining manufacturer.

14.6.2 Shop Drawings and Submittals

- 1 The Contractor shall submit to the Engineer for approval the following:
 - (a) liner schedule
 - (b) material certifications
 - (c) test results
 - (d) material samples
 - (e) the manufacturer of the lining will submit an affidavit attesting to the successful use of its material as a lining for sewer pipes and structures for a minimum period of five years in service conditions recognised as corrosive or otherwise detrimental to concrete.

14.6.3 Liner Material Requirements

- 1 The sheet liner shall be manufactured from, high molecular weight PVC or PE resin and other components necessary to make a material of permanent flexibility suitable for a liner in concrete pipes and structures in sewerage service. The weld strips and the joint strips shall be made from like material. For PVC and PE sheet liners, the actual resin used in manufacture must constitute not less than 99 % of the resin used in the formulation.
- 2 Copolymer resins will not be permitted.
- 3 All plastic sheets including locking extensions, all joints and welding strips shall be free of cracks, asperities and other defects that may affect the protective properties of the material.

- 4 The properties of PVC and PE sheet are shown in Table 14.2

Table 14.2
Properties of PVC and PE Sheet Liners

Property	Test Method	Requirement
PVC		
Elongation at break	ASTM D638/ ASTM D882	min 300 %
Tensile Strength	ASTM D638/ ASTM D412	min 15 MPa
PE	ASTM D746	0°C
Elongation at break	ASTM D638/ D882	Exceeds 600 %
Tensile Strength	ASTM D638/ D412	10-20 MPa
Low Temp. Brittleness	ASTM D746	-75 °C

14.6.4 Plastic Sheet Liner Strip Properties

- 1 Except at shop welds, all plastic sheet liners and strips shall have the properties shown in Table 14.3 when tested at 25°C.

Table 14.3
Properties of Plastic Sheet Liner Strips

Property	Requirement
Tensile strength	min 15 MPa (ASTM D638/ ASTM D412)
Elongation at break	min 200 % ASTM D638/ ASTM D882
Shore Durometer	1 s 50 - 60 ± 5 (with respect to 10 s 35 - 50 ± 5) ASTM D2240 Type D
Weight change	± 1.5 %

14.6.5 Basic Sheet Dimensions

- 1 The minimum thickness of the material shall be as shown in Table 14.4

Table 14.4
Plastic Sheet Liner Minimum Dimensions

Material Thickness	Structures
Sheet with locking extensions	4.0 mm
Sheet, plain	2.3 mm
Joint strip	1.9 mm
Weld strip	2.4 mm

14.6.6 Liner Details

- 1 Locking extensions (T-shaped) shall be of the same materials as that of the liner and shall be integrally extruded with the sheet.
- 2 Locking extensions shall be approximately 65 mm apart and shall be at least 10 mm high.
- 3 Sheets not used for shop fabrication into larger sheets shall be shop tested for pinholes using an electrical spark tester set at 9000 V per 1.0 mm thickness of lining minimum. Holes shall be repaired and retested.

14.6.7 Installation

- 1 Installation of the lining, including preheating of sheets in cold weather and the welding of all joints, shall be performed in accordance with the recommendations of the manufacturer.
- 2 The lining to be held snugly in place against inner forms by means of steel banding straps or other means recommended by the manufacturer.
- 3 Concrete that is to be poured against the lining shall be vibrated, spaded, or compacted in a careful manner to protect the lining and produce a dense, homogenous concrete, securely anchoring the locking extensions into the concrete.
- 4 In removing forms care shall be taken to protect the lining from damage. In particular:
 - (a) sharp instruments not to be used to pry forms from lined surfaces.
 - (b) when forms are removed, any nails that remain in the lining to be pulled, without tearing the lining, and the resulting holes clearly marked.
 - (c) form tie holes to be marked before ties are broken off and all areas of serious abrasion or damage shall be marked.
- 5 All nail and tie holes and all cut, torn, and seriously abraded areas in the lining shall be patched as follows:
 - (a) patches made entirely with welding strip to be fused to the liner over the entire patch area
 - (b) larger patches may consist of smooth liner sheet applied over the damaged area with adhesive
 - (c) all edges must be covered with welding strip fused to the patch and the sound lining adjoining the damaged area.
- 6 Hot joint compounds, such as coal tar, shall not be poured or applied to the lining.
- 7 The Contractor shall take all necessary measures to prevent damage to the installed lining from equipment and materials used in or taken through the work.

14.6.8 Testing Requirements

- 1 Samples taken from sheets, joints or weld strips shall be tested to determine material properties. Determination of tensile strength and elongation shall be in accordance with ASTM D 412 using Die B. Determination of indentation hardness shall be in accordance with ASTM D 2240 using a Type D Durometer, except that a single thickness of material and indentation hardness shall be made on 25 mm by 75 mm specimens. Thickness of specimens shall be the thickness of the sheet or strip.
- 2 The measurement of initial physical properties for tensile strength, weight, elongation and indentation hardness shall be determined before chemical resistance tests.
- 3 Chemical resistance tests shall be carried out to determine the physical properties of the specimens after exposure to chemical solutions. Test specimens shall be conditioned to constant weight at 43 °C before and after submersion in the solutions detailed in Table 14.5 for a period of 112 d at 25 ± 3 °C.
- 4 Volumetric percentages of concentrated reagents of CP grade: At 28 day intervals, specimens shall be removed from each chemical solution and tested. If any specimen fails to meet the 112 day exposure, the material will be subject to rejection.
- 5 Pull test for locking extensions: Liner locking extensions embedded in concrete shall withstand a test pull of at least 18 kN/m, applied perpendicularly to the concrete surface for a period of 1 min, without rupture of the locking extensions or withdrawal from embedment. This test shall be made at a temperature between 21 °C to 27 °C inclusive.
- 6 Shop-welded joints: Shop-welded joints, used to fuse individual sections of liner together, shall be at least equal to the minimum requirements of the liner for thickness, corrosion resistance and impermeability. Welds shall show no cracks or separations and shall be tested for tensile strength. Tensile strength measured across the welded joint in accordance with ASTM D 412 using Die B shall be at least 15 MPa. Test temperature shall be 25 ± 3 °C and the measured minimum width and thickness of the reduced section shall be used.
- 7 Spark test: All liner shall be shop tested for holes with a spark tester set to provide from 15 000 to 20 000 V. Sheets having holes shall be satisfactorily repaired in the shop before shipment from the manufacturer's plant.
- 8 The Contractor shall provide the Engineer with certified copies of test reports before the shipment of the product to the Site.

Table 14.5
Chemical Resistance Tests

Chemical Solutions	Concentration
Sulphuric Acid	20 %
Sodium Hydroxide	5 %
Ammonium Hydroxide	5 %
Nitric Acid	1 %
Ferric Chloride	1 %
Soap	0.1 %
Detergent (Linear alkyl benzyl sulphonate or LAS)	0.1 %
Bacteriological	BOD not less than 700 mg/l
Phosphoric Acid	50 %

14.6.9 Special Requirements

- 1 Liner sheets to be closely fitted and properly secured to the inner forms.
 - (a) sheets that are to be cut to fit curved and warped surfaces shall use a minimum number of separate pieces
 - (b) a 50 mm wide water resistant tape or welding strip shall be welded on the back of butt joints to prevent wet concrete from flowing around the edges.
- 2 Unless otherwise shown on the Drawings, the lining will be returned at least 75 mm at the surfaces of contact between the concrete structure and items not of concrete and
 - (a) the same procedure will be followed at joints where the type of protective lining is changed or the new work is built to join existing unlined concrete
 - (b) at each return, the returned liner will be sealed to the item in contact with the plastic lined concrete with an adhesive system
 - (c) if the liner cannot be sealed with this adhesive because of the joint at the return being too wide or rough or because of safety regulations, the joint space shall be densely caulked with lead wool or other approved caulking material to a depth of 50 mm and finish with a minimum of 25 mm of an approved corrosion resistant material.

14.6.10 Joints in Lining for In-Situ Concrete Structures

- 1 Field joints and Lining at joints shall be free of all mortar and other foreign material and shall be clean and dry before joints are made.
- 2 All welding is to be in strict conformance with the specifications of the lining manufacturer.

14.6.11 Testing and repairing damaged surfaces

- 1 All surfaces covered with lining, including welds, will be tested with an approved electrical holiday detector with the instrument set at 9000 V per 1.0 mm of lining minimum:
 - (a) all welds shall be physically tested by a non-destructive probing method
 - (b) all patches over holes, or repairs to the liner wherever damage has occurred.

- 2 Each transverse welding strip which extends to a lower edge of the liner will be tested by an approved testing agency at the cost of the Contractor.
- (a) the welding strips will extend 50 mm below the liner to provide a tab.
 - (b) a 5 kg pull will be applied to each tab. The force will be applied normal to the face of the structure by means of a spring balance
 - (c) liner adjoining the welding strip will be held against the concrete during application of the force
 - (d) the 5 kg pull will be maintained if a weld failure develops until no further separation occurs.
 - (e) defective welds will be retested after repairs have been made
 - (f) tabs shall be trimmed away neatly by the installer of the liner after the welding strip has passed inspection.
 - (g) inspection will be made within two days after joints has been completed in order to prevent tearing the projecting weld strip and consequent damage to the liner from equipment and materials used in or taken through the work.

END OF PART