GUIDE NO. AERB/NF/SG/CSE-4

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GOVERNMENT OF INDIA

AERB SAFETY GUIDE

MATERIALS OF CONSTRUCTION FOR CIVIL ENGINEERING STRUCTURES IMPORTANT TO SAFETY OF NUCLEAR FACILITIES

ATOMIC ENERGY REGULATORY BOARD

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MATERIALS OF CONSTRUCTION FOR CIVIL ENGINEERING STRUCTURES IMPORTANT TO SAFETY OF NUCLEAR FACILITIES

Atomic Energy Regulatory Board
Mumbai-400 094
India

November 2011

Price

Order for this guide should be addressed to:

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Atomic Energy Regulatory Board
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FOREWORD

Activities concerning establishment and utilisation of nuclear facilities and use of radioactive sources are to be carried out in India in accordance with the provisions of the Atomic Energy Act, 1962. In pursuance of the objective of ensuring safety of members of the public and occupational workers as well as protection of environment, the Atomic Energy Regulatory Board (AERB) has been entrusted with the responsibility of laying down safety standards and enforcing rules and regulations for such activities. The Board, therefore, has undertaken a programme of developing safety standards, safety codes and related guides and manuals for the purpose. While some of the documents cover aspects such as siting, design, construction, operation, quality assurance and decommissioning of nuclear and radiation facilities, other documents cover regulatory aspects of these facilities.

Safety codes and safety standards are formulated on the basis of nationally and internationally accepted safety criteria for design, construction and operation of specific equipment, structures, systems and components of nuclear and radiation facilities. Safety codes establish the objectives and set requirements that shall be fulfilled to provide adequate assurance for safety. Safety guides and guidelines elaborate various requirements and furnish approaches for their implementation. Safety manuals deal with specific topics and contain detailed scientific and technical information on the subject. These documents are prepared by experts in the relevant fields and are extensively reviewed by advisory committees of the Board before they are published. The documents are revised when necessary, in the light of experience and feedback from users as well as new developments in the field.

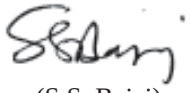
Civil engineering structures form an important feature having implications to safe performance of nuclear installations. This safety guide is developed to specify the materials to be used in construction of civil engineering structures/buildings to provide adequate assurance for safety of nuclear installations in India.

Consistent with the accepted practice, 'shall' and 'should' are generally used to distinguish between a firm requirement and a desirable option respectively. Appendix is an integral part of the document, whereas references and bibliography are included to provide further information on the subject that might be helpful to the user. Approaches for implementation, different to those set out in the guide may be acceptable, if they provide comparable assurance against undue risk to the health and safety of the occupational workers and the general public, and protection of the environment.

For aspects not covered in this guide, applicable national and international standards, codes and guides acceptable to AERB should be followed. Non-radiological aspects, such as industrial safety and environmental protection are not explicitly considered. Industrial safety is to be ensured through compliance with the applicable provisions of the Factories Act, 1948 and the Atomic Energy (Factories) Rules, 1996.

Specialists in the field drawn from the Atomic Energy Regulatory Board, the Bhabha Atomic Research Centre, Heavy Water Board and the Nuclear Power Corporation of India Limited, and other consultants have prepared this guide. It has been reviewed by experts and relevant AERB Advisory Committee on Codes and Guides and the Advisory Committee on Nuclear Safety.

AERB wishes to thank all individuals and organisations who have prepared and reviewed the document and helped in its finalisation. The list of persons, who have participated in this task, along with their affiliations, is included for information.



(S.S. Bajaj)
Chairman, AERB

DEFINITIONS

Anchor

A structural member embedded in the concrete or attachment to other structures to which a liner, embedment, or surface mounted item is attached

Anchorage (Pre-stressing)

A device by which force is transferred to concrete. In post-tensioning, the device used is to anchor tendon to the concrete member, whereas in pre-tensioning, the device is used to anchor tendon during the hardening of concrete.

Atomic Energy Regulatory Board (AERB)

A national authority designated by the Government of India having the legal authority for issuing regulatory consent for various activities related to the nuclear and radiation facility and to perform safety and regulatory functions, including their enforcement for the protection of site personnel, the public and the environment against undue radiation hazards.

Construction

The process of manufacturing, testing and assembling the components of a nuclear or radiation facility, the erection of civil works and structures, the installation of components and equipment and the performance of associated tests.

Documentation

Recorded or pictorial information describing, defining, specifying, reporting or certifying activities, requirements, procedures or results.

Embedded Parts

Any structural member, plate, angle, channel, pipe sleeve or other section anchored to a concrete structure through direct bond or other anchors.

Items Important to Safety (IIS)

The items which comprise:

- those structures, systems, equipment and components whose malfunction or failure could lead to undue radiological consequences at plant site or off-site,
- those structures, systems, equipment and components which prevent anticipated operational occurrences from leading to accident conditions, and
- those features which are provided to mitigate the consequences of malfunction or failure of structures, systems, equipment or components.

Liner

Any metallic or non-metallic material applied to the surface of a base material for the purpose of protection against corrosion, abrasion or for leak tightness for the intended service conditions.

Nuclear Power Plant (NPP)

A nuclear reactor or a group of reactors together with all the associated structures, systems, equipment and components necessary for safe generation of electricity.

Post-Tensioning

A method of pre stressing in which the tendons are tensioned after the concrete hardens.

Quality Assurance (QA)

Planned and systematic actions necessary to provide the confidence that an item or service will satisfy given requirements for quality.

Shrinkage (Concrete)

Time-temperature-humidity dependent volume reduction of concrete as a result of hydration, moisture migration and drying process.

Specification

A written statement of requirements to be satisfied by a product, a service, a material or process, indicating the procedure by means of which it may be determined whether the specified requirements are satisfied.

Stress Relaxation

A phenomenon in which loss of stress occurs when a constant strain is maintained at a constant temperature.

Surface Water (Concrete)

Water held by an aggregate on the surface except that held by absorption within the aggregate particles themselves.

Tendon

Steel element such as wire, cable, bar, rod or a bundle of such elements used to impart pre-stress to concrete.

SPECIAL DEFINITIONS
(Specific for the Present Guide)

High Performance Concrete (HPC)

Concrete which meets special performance and uniformity requirements that cannot always be achieved routinely by using only conventional materials and normal mixing, placing and curing practices. The requirements may involve enhancement of characteristics such as placement and compaction without segregation, long term mechanical properties, early age strength, toughness, volume stability or service life in severe environment.

CONTENTS

1. INTRODUCTION

1.1 General

This guide is prepared as a general guidance for use of major construction materials for civil engineering construction work for structures important to safety of nuclear facilities.

1.2 Objective

The objective of this document is to provide guidance on specification of major materials to be used in construction work of civil engineering structures important to safety of nuclear facilities and to furnish approaches for their implementation.

1.3 Scope

Provisions of this guide are applicable for materials of construction of those structures, which are engineered using codes and standards published by Atomic Energy Regulatory Board (AERB) or Bureau of Indian Standards. Material specification for structures designed using codes/specification of other country should be drawn up in line with the relevant accepted specification of that country with the approval of AERB.

Specialised items such as shielding doors, door seals and items related to liquid active waste handling systems etc. are not covered in this guide. Specification of materials for these components should be outlined with the concurrence of AERB.

1.4 Structure

This guide comprises of two sections and one appendix:

Section - 1 - Introduction.

Section - 2 - Materials of Construction.

Appendix - A - List of Applicable Standards.

Each section is divided into a number of sub-sections, which are further divided into a number of clauses or paragraphs.

2. MATERIALS OF CONSTRUCTION

2.1 General

Major materials considered to be important in civil engineering construction work of nuclear facilities are:

(i) Concrete

- (a) Normal density
- (b) Heavy density
- (c) High performance
- (d) Self compacting

(ii) Concrete ingredients

- (a) Cement
- (b) Mineral admixtures
- (c) Chemical admixtures
- (d) Fine aggregate
- (e) Coarse aggregate
- (f) Water and ice

(iii) Reinforcement steel

- (a) Passive
- (b) Prestressing

(iv) Prestressing system

- (a) High tensile strand
- (b) Bearing plates
- (c) Guide cones
- (d) Sheathing materials
- (e) Wedges

(v) Formworks

- (a) Plywood
- (b) Steel
- (c) Formwork release oils

(vi) Structural steel

(vii) Water stops and vapour barriers

- (a) Polyvinyl compound
- (b) Mild steel/Galvanised iron/Stainless steel/Copper strip

(viii) Expansion joint filler materials

(ix) Paints and coating

- (a) Normal paint
- (b) Epoxy paint
- (c) Anti-corrosive coating and grease

(x) Polysulphide sealant

(xi) Adhesives and resins

(xii) Other building materials

- (a) Cladding materials
  - (i) Concrete hollow and solid blocks
  - (ii) Bricks
- (b) Water proofing materials
  - (i) Membrane water proofing
  - (ii) Cement based treatment
  - (iii) Injection grouting

(xiii) Materials for road construction

- (a) Soil, moorum, sand, crushed stone
- (b) Aggregate
- (c) Bitumen

(xiv) Backfilling and site grading materials

(xv) Material for protective bunds

- (a) Geo-membrane
- (b) Geo-textile

(xvi) New materials

Specification of materials not listed above should be finalised with the approval of Regulatory Board.

Adequacy of material in terms of constructability should be confirmed by way of mock up simulation or by way of laboratory experiments whenever construction difficulty is foreseen or new equipment and methods are used.

2.2 Materials Specifications

List of applicable standards for material specification is given in Appendix-A. Detailed specifications of all materials should be drawn taking the following guidance into account.

2.3 Concrete

2.3.1 Normal Density Concrete

Unless specified otherwise, density of concrete of grades varying from M25 to M60 should be in the nominal range of 2.2 to 2.6 T/m^3. Normal density concrete as defined above is generally used for construction of structures. However, for non-structural use, concrete of lower density and grade may be used. Temperature of concrete at the time of mixing/placement should not exceed specified values. Production, transportation, placement, compaction and curing of concrete should be controlled in a professional manner by using mechanical equipment so as to achieve specified performance. Adequate number of trials of mixing and placement should be made to achieve the performance goals.

Various properties of fresh concrete such as workability, slump retention, pumpability, initial and final setting time etc. should be established to suit site condition and design requirement. All measures should be taken to achieve design requirements of concrete at hardened state as specified.

Total sulphate and chloride content as well as void ratio of concrete (inclusive of all ingredients) should not exceed values specified in the IS specification.

Proportioning of mix, its qualification and control, acceptance and other sensitivity tests are to be carried out as per adopted code.

At all stages, from characterisation for selection of ingredients to the final product, quality assurance programme and construction methodology, approved by competent authority, should be strictly adhered to.

2.3.2 Heavy Density Concrete

Heavy density concrete is produced using heavy density aggregates obtained by crushing of ores such as haematite, barytes, ilmenite etc. Steel/lead shots, steel punching etc. may also be used for making heavy density concrete. The heavy density concrete should have density (normally from 3.6 to 5.6 T/m^3)

as per shielding requirement and compressive strength as per design requirements. Special equipment and methods may be needed for production and placement of heavy density concrete. Density of hardened concrete should be established, depending on the aggregates used. Properties of fresh concrete should be established to suit site conditions and design requirements. Other requirement of production and use such as temperature, workability, slump retention, air entrainment, initial and final setting time etc. should be same as given for normal density concrete.

2.3.3 High Performance Concrete

Specification of high performance concrete or concrete incorporating acceptable mineral admixtures, and characterisation of its ingredients should be developed satisfying design and special performance requirements. Proportioning of this class of concrete should be such that it satisfies the performance requirements both at fresh and hardened states taking into account of the impact of admixtures on the behaviour of resulting concrete.

2.3.4 Self Compacting Concrete

Unlike traditionally placed concrete, which requires the help of vibration or external energy for compaction, self compacting concrete gets compacted after placement by its self weight. Workability of self compacting concrete is important and sensitive to mix proportion and characteristics of ingredients. In addition to relevant Indian standards, codes/specification, other documents and good practices which are useful for characterisation of ingredients, proportioning and qualification of mix for self compacting concrete mix may be taken into account. One such document is, 'Self-compacting Concrete', State of the art report of RILEM Technical Committee 174-SCC [1].

To ensure appropriate workability and other properties of self compacting concrete the following tests are to be conducted:

Characteristic	**Preferred Test Method(s)**
Flowability	Slump-flow test
Viscosity (assessed by rate of flow)	T_{500} Slump-flow test or V-funnel test
Passing ability	L-box test
Segregation	Segregation resistance (sieve) test

Specifications for the above tests would be found in references [1] and [2].

2.3.5 Acceptance Criteria of Concrete

Unless specified otherwise, acceptance criteria of concrete, other than self compacting class, at fresh state deem to satisfy if the slump is within a specified value subject to a minimum of 100 mm for pumping and 75 mm for hand placing. The self compacting concrete should satisfy the value of slump flow test as specified in 2.3.4 above.

From the consideration of strength, the acceptance criteria of concrete used for construction of structures should be as per IS: 456 and other related codes.

The permeability requirements of concrete deem to satisfy if the rapid chloride penetration test (RCPT) value is less than 3000 coulombs. The requirement is to be satisfied for 56 days test results on 28 days water cured sample. For containment and water retaining structure, RCPT value of concrete should be lower than 2000 coulombs. Effort should be made to achieve concrete mix with RCPT value lower than the above values.

If specified by designs, special tests for assessment of properties such as heat of hydration, shrinkage, creep, carbonation etc. should be carried out and concrete mix should satisfy the limiting value.

2.4 Concrete Ingredients

2.4.1 Cement

Cement should be procured only from approved sources. Type of cement should be determined as per the design requirement and should conform to IS specifications. Cement older than three months from the date of manufacture should be re-qualified and should be used within one month.

The cement should be supplied either in bags or in bulk. The cement should be stored as per the IS 4082.

Cement manufacturer's test certificate and other quality control documents should accompany each batch of supply.

2.4.2 Mineral Admixtures

Silica fumes, if used as mineral admixture, should be procured from approved sources. Use of silica fumes in concrete should be as per the recommendation of the manufacturer. Acceptance of silica fumes should be based on testing as per the codal requirement (ASTM) for SiO_2 content, loss on ignition and specific surface.

Fly ash may be used as a mineral admixture with adequate testing and quality control as per ASTM/IS specifications. All batches of fly ash should be tested to ascertain loss of ignition and fineness. Other tests should be carried out for every 2000 tonne quantity procured.

Ground granulated blast furnace slag (GGBS) may also be used as mineral admixture with adequate testing and quality control as per ASTM/IS specifications. All batches of GGBS should be tested to ascertain their quality and uniformity.

2.4.3 Chemical Admixtures

Chemical admixtures generally to be used in concrete can be of following types:

(i) Plasticisers/super plasticisers

(ii) Retarding agents

(iii) Combination of the above

(iv) Viscosity modifying agent.

Chemical admixtures should be procured from approved sources. Previous experience and data on admixture should be considered while selecting the brand in relation to the dosage, workability requirements, slump loss etc. If two or more admixtures are used simultaneously in the same concrete mix, proper investigations should be carried out to assess the interaction and compatibility. Admixture - cement compatibility is also an important consideration as regards the use of cement of different brands and/or different factories.

Trials on concrete mixes should be conducted to get adequate data before the use of admixture in concrete.

Admixtures should not impair strength and durability of concrete. It should not combine with the cement/concrete constituents to form harmful compounds and increase the risk of corrosion of reinforcement.

Right from the selection of sources to the final use of admixture in the concrete, approved quality assurance plan should be adhered to.

Adequate precaution should be taken while using admixtures having high sodium and sulphate content in situation where possibility of use of reactive aggregate is unavoidable.

2.4.4 Fine Aggregate

Fine aggregate to be used in manufacture of concrete should be either from natural source or manufactured one. Fine aggregate should be of siliceous materials, sharp, hard, strong and durable. It should be free from adherent coating such as clay and dust. Deleterious impurities in fine aggregate should be within the permissible limit as per IS 2386. In case of heavy density concrete, fine aggregate may be manufactured from the same ore as used for coarse aggregate.

2.4.5 Coarse Aggregate

Coarse aggregate to be used in the manufacture of concrete should be from natural source except for steel/lead shots, punchings etc. used in heavy density concrete. The aggregate should be sourced from the approved quarry. The aggregate should have crushing strength, abrasion resistance, impact resistance as per IS 2386 and should be free from harmful impurities. Reactive aggregate should not be used in substructure. In case it is required to be used in super structure, appropriate investigations and suitable precautionary measures should be taken. Size, shape and grading of the aggregate should also conform to the design requirements and IS 2386.

2.4.6 Water and Ice

Water used for mixing and curing should be clean, potable and free from other substances that may be deleterious to concrete or steel and should conform to IS 3025.

Ice, if used as replacement for a portion of or all the mixing water, should be produced from the water acceptable for mixing.

2.5 Reinforcement Steel

Steel reinforcement should be clean, free from grease and oils, paints, pinhole blowholes, loose mill scale, rust and bituminous materials or any other substance that will destroy or reduce bond unless such reduction in bond is quantified and accounted for in design with confirmatory sampling and testing program during construction phase. Pitted and defective steel should not be used. Reinforcement steel should have tensile strength, bond strength, ductility, bendability, weldability, etc. as per specifications given in standards in Appendix-A: A.9.

Steel reinforcement of proof stress (corresponding to 0.2% strain) more than 415 MPa may be used subject to approval of regulatory authority.

2.6 Prestressing System

Prestressing system should be procured from approved manufacturer. The material for accessories should satisfy the requirement of technical specification and IS specifications or manufacturer's specifications. Accessories should be qualified by performance test.

2.6.1 High Tensile Strands

Strand should be procured only from approved sources. Strands for prestressing work should be of carbon steel material. Strand should be of stress relieved and low relaxation quality conforming to ASTM/IS specifications.

2.6.2 Bearing Plates, Guide Cones and Wedges

Bearing plates, guide cones and wedges should be as per the specifications of the specialised agency responsible for supply of prestressing system. These should be tested for performance as per the system requirements.

2.6.3 Sheathing Materials

Sheathing may be metallic or high density polyethylene (HDPE).

Metallic sheathing should be manufactured from cold rolled close annealed (CRCA) strips conforming to IS 513. Sheathing may be flexible or rigid depending upon the design or site requirements. MS/GI pipes may also be used for rigid sheathing. Sheathing may be galvanised or lead coated. The entire qualification test is to be carried out as per IS/IRC specifications for sheathing fabricated at site from metallic strips prior to its use in the works. The bought out sheet should be qualified at the time of purchase. Thickness/ diameter of the sheathing should be as per design/site requirements.

HDPE sheathing should be manufactured from new granulated material. Recycled material should not be used. The raw material should be tested for density, melt flow rate (MFR), hardness, tensile strength and elongation at yield, carbon content, environmental stress crack resistance etc. as per the FIB guidelines, and the results should be in conformity with the applicable specifications. The sheathing should be circular in shape and of extruded type, having either helical or circular corrugation (continuous or intermittent) as per the design/ site requirements. The ducts should be joined together by heat shrinking couplers of compatible material. The individual components and as a system the HDPE sheathing should be tested for dimensional tolerance, flexural behavior of duct, flexibility of duct, lateral load resistance, longitudinal load resistance, leak tightness, wear resistance, bond behaviour and friction parameter as per FIB guidelines and the test results should meet the requirement of the design specifications. The sheath should be qualified prior to purchase.

2.7 Formworks

Materials such as plywood, steel members, pipes, battens, nails, screws etc. should conform to IS specifications and approved quality. For use of patented formwork system, prior approval should be obtained from the designer.

2.7.1 Plywood

Plywood for concrete shuttering work should be preservative treated and well bonded with adhesive. It may be either plastic coated or suitably overlaid. It should be smooth, free from pleats, overlaps and loose knots. It should have moisture content, glue adhesion in dry state and other properties as per IS specifications.

2.7.2 Steel

Steel formwork for concrete should be made from structural steel members such as channels, angles, I-beams, plates, pipes etc. It should be free from cracks, seams, irregularities. It should have adequate strength, weldability and other properties as per the IS specifications.

2.7.3 Formwork Release Oils

Formwork surface may be coated if permitted, with suitable mould oil, which acts as parting agent and also gives surface protection. Typical mould oil should be of heavy mineral or purified cylinder oil containing 5% pentachlorophenol well mixed to a viscosity of 70 to 80 centipoise. Formwork release oil should not react and adhere to the concrete surface and should be removable by water wash.

2.8 Structural Steel

All structural steel materials should be procured from approved source/ manufacturer. Type of steel viz. mild steel, carbon steel, alloy steel, stainless steel etc. should be as per design requirements. Structural steel section of various types/ sizes such as angles, channels, beams, flats, plates etc. may be used depending upon design requirements. All structural steel should conform to relevant technical and IS specifications. Supply of each lot should accompany manufacturer's test certificate. Additional tests as per QA plan may also be carried out as per requirement. Use of cold formed hollow sections should be as per requirement of design and should conform to IS specifications. All structural steel should be free from scales, blisters, laminations, cracked edges and any other defects. All joining and fastening materials to be used in the erection of structural steel work such as welding electrodes, bolts and nuts should be as per design requirements and conform to relevant ASTM/IS specification. All structural steel should also meet the requirements of AERB safety standard 'Design, Fabrication and Erection of Steel Structures Important to Safety of Nuclear Facilities' (AERB/SS/CSE-2).

Structural steel should be stored as per IS 4082.

2.9 Waterstops

Water stops made out of following materials may be used:

(i) Polyvinyl compound (PVC).

(ii) Mild steel/Galvanised iron/Stainless steel.

Water stops and gas-barriers should be procured from approved sources. PVC water stops should be moulded or extruded in such a manner that any cross section is dense, homogeneous and free from porosity and other

imperfections. PVC water stops should have tensile strength, elongation, tear resistance, stiffness in flexure and resistance to alkalis as per the relevant technical specifications and IS specifications. Metallic water stops and joining material should be as per design requirement and conform to IS specifications.

2.10 Expansion Joint Materials

Expansion joint materials should be procured from approved sources. The material for expansion joint should be selected from bitumen impregnated compressible material, high density polystyrene boards, elastomers, aluminium intrusions, expansive materials. Resilient material of specified quality can also be used. The material should conform to technical specifications and IS or other relevant specifications.

2.11 Paints and Coatings

2.11.1 Normal Paint

Normal paints like lime for white washing, dry distemper, acrylic emulsion paint, synthetic enamel paint, acid alkali resistant paint, epoxy paint, polyurethane paint, water proof cement paint etc. should be procured from approved agencies meeting the requirement of technical/manufacturer specifications. Wherever specified, required thickness of the painting should be achieved by number of coats of paints. .

2.11.2 Radiation Resistant Paint

As per the functional requirement in the areas requiring decontamination, only radiation resistant prequalified epoxy/ polyurethane paint should be used. The paints should be procured from approved agencies. The material used in the coating should not form radioactive isotope on absorbing neutrons. The paints system should form a thick, radiation resistant, abrasion resistant, impact resistant film on drying. It should also be de-contaminable easily. It should have other properties such as adhesion and cohesion, tensile strength etc. as per technical specifications.

2.11.3 Anti Corrosive Paints

Materials for anti-corrosive coating and grease should be procured from approved sources only. Material should have adequate corrosion resistance and oxidation stability. The chlorine content, nitrate content, sulphate content etc. should not exceed the limit specified in the relevant IS and technical specifications.

2.12 Polysulphide Sealant

Polysulphide sealant should be procured from approved sources. The compound should be made of two-part system. The primer used for

polysulphide should not stain the concrete and should be compatible with the base material. The compound should be stable and form a rubber like material when properly mixed. Mixing and curing time should be as per manufacturer's specifications. The polysulphide should exhibit properties of the base polymer and have low molecular weight. The consistency of the compound should be plastic during mixing and application period. The sealant material used in active area should not form radioactive isotope on absorbing neutrons. The sealant system used in active area should have properties such as radiation resistance, abrasion resistance, adhesion and cohesion and feasibility of decontamination as per the technical specifications.

2.13 Adhesives and Resins

These can be used as bonding agents and making materials such as epoxy mortar for repair works. Adhesives and resins should be procured from approved sources. Properties of adhesive and resins should suit intended use and should be as per the manufacturer's specifications. The adhesive and resins should not contain any such materials, which when exposed to radiation will form radioactive isotopes.

2.14 Other Building Materials

Materials listed below should conform to relevant IS specifications and they should be procured from approved sources:

(i) Cladding materials

(ii) Water proofing materials.

2.14.1 Cladding Materials

The material such as hollow and solid concrete blocks, burnt clay bricks, fly ash bricks to be used as cladding material should have compressive strength, water absorption and other properties as per IS specifications.

2.14.2 Water Proofing Materials

The following type of water proofing should be used wherever required:

(i) Membrane water proofing

(ii) Cement based treatment (acrylic resin, butadiene rubber)

(iii) Injection grouting (cement, polymer, epoxy).

Water proofing materials should be procured from approved sources. These should conform to relevant IS specifications. Manufacturer's test certificate should be obtained at the time of purchase. Protective layers of tiles, screeding, cement sand plaster etc. should be provided for protecting water proofing treatment from ultra violet radiation damage. Any other patented water proofing system can also be used after approval.

2.15 Materials for Road Construction

2.15.1 Soil, Moorum, Sand, Crushed Stone

Material used for the construction of formation/sub-grade/granular sub-base should be soil, moorum, sand, gravel and crushed stone or a mixture of these materials depending upon the grading required as per design and specifications. The material should be tested as per IS specifications for sand content, deleterious constituents, plasticity index, density etc. and should satisfy technical specifications and IS specifications. Source of the material should be approved prior to the start of the work.

2.15.2 Aggregate

Aggregate used for road construction should be procured from approved sources. Aggregate should be tested for gradation, impact value, abrasion resistance and crushing value etc. as per IS specifications and should satisfy technical and IS specifications requirements.

2.15.3 Bitumen

Bitumen should be procured from approved sources. Manufacturer's test certificate should be obtained at the time of purchase. Grade of bitumen should be as per design and technical specifications.

2.16 Backfilling and Site Grading Materials

All materials used for backfilling such as moorum, soil, sand, crushed stone etc. should be obtained from approved sources. Materials should have properties as mentioned in clause 2.15 above. When fillcrete (lean mix of sand and cement) is used as backfill material its mix should be properly proportioned and qualified.

2.17 Materials for Protective Bunds

Materials used for protective bunds should be from approved sources. All the materials such as stone, moorum etc. should be as per technical specifications and tested as per IS specifications. Size of stones used in core, armour layer etc. should be as per design requirements. Geo-membrane, geo-textile and other materials to be used should be obtained from the approved sources and tested to establish its acceptability.

2.17.1 Geo-membrane

Geo-membrane should be procured from approved sources only. It should be of textiles - woven sacks of high density polyethylene (HDPE)/ polypropylene (HDPP) as per IS specifications. Geo-membrane should be of monolayer blended polyethylene of appropriate thickness with carbon black content of 2 to 3 percent. It should be water proof under water pressure of

0.3 kg/cm^2. It should be flexible enough to adjust itself for all irregularities in earth and rock material. It should be durable, strong enough to withstand handling and impact during laying of stones as well as stresses in the body of the bund. It should be resistant to ultra-violet radiation, temperature, saline water and chemicals; sufficient resistance to puncture and tear. It should not contain any plasticisers, which can migrate to surface causing premature ageing.

2.17.2 Geo-textile

Geo-textile should be procured from approved sources only. Geo-textile should be polypropylene material. It should be durable, strong enough to withstand handling and impact during laying of stones as well as stresses in the body of the bund. It should be resistant to ultra-violet radiation, temperature, saline water and chemicals. It should have high water flow rate and excellent filtration characteristics.

2.18 New Materials

Materials other than mentioned above or any newly developed material can also be used after detailed studies, testing and acceptance.

APPENDIX-A

LIST OF APPLICABLE STANDARDS

A.1 Common Standards and Specifications

IS 383	-	Specification for coarse and fine aggregates from natural sources for concrete
IS 456	-	Code of practice for plain and reinforced concrete
IS 800	-	Code of practice for general construction in steel
IS 1343	-	Code of practice for prestressed concrete
IS 4082	-	Recommendations on stacking and storage of construction materials and components at site

A.2 Standards and Specifications for Concrete

A.2.1 Indian Standards

IS 516	-	Method of test for strength of concrete
IS 1199	-	Methods of sampling and analysis of concrete
IS 2386 (Part-1 to 8)	-	Methods of test for aggregates for concrete
IS 2505	-	Concrete vibrators - immersion type - general requirements
IS 2770 (Part-1)	-	Methods of testing bond in reinforced concrete - Pull-out test
IS 3085	-	Method of test for permeability of cement mortar and concrete
IS 3370 (Part-1 to 4)	-	Code of practice for concrete structures for the storage of liquids
IS 4925	-	Concrete batching and mixing plant - Specification
IS 5816	-	Method of test for splitting tensile strength of concrete
IS 7861 (Part-1)	-	Code of practice for extreme weather concreting Recommended practice for hot weather concreting
IS 8142	-	Method of test for determining setting time of concrete by penetration resistance
IS 10262	-	Guidelines for concrete mix proportioning
IS 13311 (Part-1 and 2)	-	Methods of non-destructive testing of concrete

SP 23 (S & T) - Handbook on concrete mixes (Based on Indian Standards)

SP 24 (S & T) - Explanatory handbook on Indian Standard Code of practice for plain and reinforced concrete (IS 456)

A.2.2 International Standards

ACI 211.1-91 - Standard practice for selecting proportions for normal, heavyweight, and mass concrete (Reapproved 2009)

ACI 304.2R-96 - Placing concrete by pumping method (Reapproved 2008)

ACI 318-08 - Building code requirements for structural concrete

ACI 349-06 - Code requirements for nuclear safety related concrete structures

RCC-G - Design and construction rules for civil works of PWR nuclear islands - Volume II - Part 2 - construction criteria

DIN 1048 (Part-1) - Testing concrete; testing of fresh concrete

A.3 Standards and Specifications for Cement

A.3.1 Indian Standards

IS 269 - Specification for ordinary portland cement, 33 grade

IS 455 - Specification for portland slag cement

IS 1344 - Specification for calcined clay pozzolana

IS 1489 (Part-1 and 2) - Specification for portland pozzolana cement

IS 4031 (Part-1 to 15) - Methods of physical tests for hydraulic cement

IS 6452 - Specification for high alumina cement for structural use

IS 8041 - Specification for rapid hardening portland cement

IS 8042 - Specification for white portland cement

IS 8043 - Specification for hydrophobic portland cement

IS 8112 - Specification for 43 grade ordinary portland cement

IS 12269 - Specification for 53 grade ordinary portland cement

IS 12330 - Specification for sulphate resisting portland cement

IS 12600 - Specification for low heat portland cement

A.4 Standards and Specifications for Silica Fumes

ASTM C 1240 - Standard specification for silica fume used in cementitious mixtures

A.5 Standards and Specifications for Fly Ash

A.5.1 Indian Standard

IS 3812 (Part-1 and 2) - Specification for pulverised fuel ash

A.5.2 International Standard

ASTM C 311 - Standard test methods for sampling and testing fly ash or natural pozzolans for use in portland-cement concrete

A.6 Standards and Specifications for Chemical Admixtures

A.6.1 Indian Standard

IS 9103 - Specification for admixtures for concrete

A.6.2 International Standard

ASTM C 494 - Standard specification for chemical admixtures for concrete

A.7 Standards and Specifications for Coarse and Fine Aggregate

A.7.1 Indian Standards

IS 460 (Part-1 to 3) - Specification for test sieves

IS 1607 - Methods for test sieving

IS 2386 (Parts-1 to 8) - Methods of test for aggregates for concrete

A.7.2 International Standards

ASTM E 11 - Standard specification for wire cloth and woven wire test sieve

ASTM C 33 - Standard specification for concrete aggregates

ASTM C 295 - Standard guide for petrographic examination of aggregates for concrete

A.8 Standards and Specifications for Water and Ice

A.8.1 Indian Standards

IS 3025 (Parts-1 to 59)	-	Methods of sampling and test (physical and chemical) for water and wastewater
IS 3550	-	Methods of test for routine control for water used in industry

A.8.2 International Standard

ASTM Volume	-	11.01 & 11.02 Water (I)

A.9 Standards and Specifications for Reinforcement Steel

A.9.1 Indian Standards

IS 228 (Parts-1 to 24)	-	Methods of chemical analysis of steels
IS 432 (Parts-1 and 2)	-	Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement
IS 1566	-	Specification for hard-drawn steel wire fabric for concrete reinforcement
IS 1608	-	Mechanical testing of metals - tensile testing
IS 1786	-	High strength deformed steel bars and wires for concrete reinforcement - specification
IS 2502	-	Code of practice for bending and fixing of bars for concrete reinforcement
IS 2751	-	Code of practice for welding of mild steel plain and deformed bars for reinforced concrete construction
IS 10790 (Parts-1 and 2)	-	Methods of sampling of steel for prestressed and reinforced concrete
SP-34	-	Handbook on concrete reinforcement and detailing

A.10 Standards and Specifications for High Tensile Strands

A.10.1 Indian Standards

IS 1785 (Parts-1 and 2)	-	Specification for plain harddrawn steel wire for pre-stressed concrete
IS 2090	-	Specification for high tensile steel bars used in prestressed concrete
IS 6006	-	Specification for uncoated stress relieved strand for prestressed concrete

IS 10790 (Parts-1 and 2) - Methods of sampling of steel for prestressed and reinforced concrete

IS 14268 - Uncoated stress relieved low relaxation seven ply strand for prestressed concrete - Specification

A.10.2 International Standards

ASTM A 416/A 416 M- Standard specification for steel strand, uncoated seven wire for prestressed concrete

ASTM A 421/A 421 M- Standard specification for uncoated stress relieved steel wire for prestressed concrete

A.11 Standards and Specifications for Prestressing Accessories

A.11.1 Indian Standard

IS 1608 - Mechanical testing of metals - tensile testing

A.11.2 International Standards

BS EN 13391 - Mechanical tests for post-tensioning systems

FIB Bulletin No. 30 - Acceptance of stay cable systems using prestressing steels

A.12 Standards and Specifications for Formwork

A.12.1 Indian Standards

IS 303 - Specification of plywood for general purposes

IS 1331 - Specification for cut sizes of timber

IS 4990 - Specification for plywood for concrete shuttering work

A.12.2 International Standards

ACI SP4 - Formwork for concrete

A.13 Standards and Specifications for Structural Steel

A.13.1 Indian Standards

IS 513 - Cold-reduced low carbon steel sheets and strips

IS 808 - Dimensions for hot rolled steel beam, column, channel and angle sections

IS 811 - Specification for cold formed light gauge structural steel sections

IS 814 - Covered electrodes for manual metal arc welding of carbon and carbon manganese steel - Specification

IS 1161 - Steel tubes for structural purposes - Specification

IS 1239 (Parts-1 and 2)	-	Steel tubes, tubulars and other wrought steel fittings - Specification
IS 1363 (Parts-1 to 3)	-	Hexagon head bolts, screws and nuts of product grade 'C'
IS 1364 (Parts-1 to 6)	-	Hexagon head bolts, screws and nuts of product grades A and B
IS 1367 (Parts-1 to 20)	-	Technical supply conditions for threaded steel fasteners
IS 1500	-	Method for Brinell hardness test for metallic materials
IS 1608	-	Metallic materials - tensile testing at ambient temperature
IS 1852	-	Rolling and cutting tolerances for hot rolled steel products
IS 2016	-	Plain washers
IS 2062	-	Hot rolled low, medium and high tensile structural steel
IS 3613	-	Acceptance tests for wire flux combination for submerged arc welding
IS 3757	-	High strength structural bolts
IS 3896 (Parts-1 and 2)	-	Comparison of Indian and overseas standards for iron castings
IS 4000	-	Code of practice for high strength bolts in steel structures
IS 5372	-	Taper washers for channels (ISMC)

A.13.2 International Standards

AWS A 5.1	-	Specification for carbon steel electrodes for shielded metal arc welding
AWS A 5.17	-	Specification for carbon steel electrodes and fluxes for submerged arc welding
BS EN 10088-3-		Stainless steels. Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes
BS 970-3	-	Specifications for wrought steel for mechanical and allied engineering purposes
BS 4395 (Part-1 and 2)	-	High strength friction grip bolts and associated nuts and washers for structural engineering

A.14 Standards and Specifications for Water Stops and Expansion Joint Filler Materials

A.14.1 Indian Standards

IS 277	-	Galvanized steel sheets (plain and corrugated) - specification
IS 1834	-	Specification for hot applied sealing compound for joints in concrete
IS 1838 (Parts-1 and 2)	-	Specification for preformed fillers for expansion joint in concrete pavement and structures (non extruding and resilient type)
IS 2508	-	Low density polyethylene films
IS 3414	-	Code of practice for design and installation of joints in buildings
IS 4671	-	Expanded polystyrene for thermal insulation purposes

A.14.2 International Standards

ASTM D 412	-	Standard test methods for vulcanized rubber and thermoplastic elastomers-tension
ASTM D 624	-	Standard test method for tear strength of conventional vulcanized rubber and thermoplastic elastomers
ASTM D 2240	-	Standard test method for rubber property - durometer hardness

A.15 Standards and Specifications for Epoxy Paints

A.15.1 Indian Standards

IS 101 (Parts-1 to 9)	-	Methods of sampling and test for paints, varnishes and related products
IS 158	-	Ready mixed paint, brushing, bituminous, black, lead-free, acid, alkali and heat resisting
IS 2932	-	Enamel, synthetic, exterior: (a) undercoating (b) finishing - specification

A.15.2 International Standards

ISO 4624	-	Paints and varnishes - Pull-off test for adhesion
ASTM D 154	-	Standard guide for testing varnishes
ASTM D 523	-	Standard test method of specular gloss
ASTM D 7091	-	Standard practice for nondestructive measurement of dry film thickness of nonmagnetic coatings applied to ferrous metals and nonmagnetic, nonconductive coatings applied to nonferrous metals

ASTM D 1210	-	Standard test method for fineness of dispersion of pigment vehicle systems by hegman type gage
ASTM D 1308	-	Standard test method for effect of household chemicals on clear and pigmented organic finishes
ASTM D 1474	-	Standard test methods for indentation hardness of organic coatings
ASTM D 1653	-	Standard test methods for water vapor transmission of organic coating films
ASTM D 522 -93a	-	Standard test methods for mandrel bend test of attached organic coatings
ASTM D 2697	-	Standard test method for volume nonvolatile matter in clear or pigmented coatings
BS 476 (Part-7)	-	Fire tests on building materials and structures. Method of test to determine the classification of the surface spread of flame of products

A.16 Standards and Specifications for Polysulphide Sealant

A.16.1 Indian Standards

IS 1834	-	Specification for hot applied sealing compound for joints in concrete
IS 12118 (Parts-1 and 2)	-	Specification for two parts polysulphide based sealants

A.16.2 International Standards

BS EN ISO 11600	-	Building construction. Jointing products. Classification and requirements for sealants

A.17 Adhesives and Resins

IS 354 (Part- 4)	-	Methods of sampling and test for resins for paints - special test methods for epoxy resins
IS 4631	-	Code of practice for laying of epoxy resin floor toppings
IS 9162	-	Methods of tests for epoxy resins, hardeners and epoxy resin composition for floor topping
IS 12830	-	Rubber based adhesives for fixing PVC tiles to cement
IS 14925	-	Epoxy resin for paints - Specification

A.18 Standards and Specifications for Anti-Corrosive Fluids and Grease

A.18.1 International Standards

ASTM B 117	-	Standard practice for operating salt spray (fog) apparatus
ASTM D 512	-	Standard test methods for chloride ion in water
ASTM D 566	-	Standard test method for dropping point of lubricating grease
ASTM D 937	-	Standard test method for cone penetration of petrolatum
ASTM D 942	-	Standard test method for oxidation stability of lubricating greases by the oxygen pressure vessel method
ASTM D1743	-	Standard test method for determining corrosion preventive properties of lubricating greases

A.19 Standards and Specifications for Other Construction Materials

A.19.1 Cladding Material

A.19.1.1 Indian Standards

IS 1077	-	Common burnt clay building bricks - Specification
IS 2185 (Parts-1 to 3)	-	Specification for concrete masonry units
IS 6042	-	Code of practice for construction of lightweight concrete block masonry

A.19.2 Water proofing Materials

A.19.2.1 Indian Standards

IS 216	-	Specification for coal tar pitch
IS 702	-	Specification for industrial bitumen
IS 1322	-	Specification of bitumen felts water proofing and damp-proofing
IS 1346	-	Code of practice of water proofing of roofs with bitumen felts
IS 1609	-	Code of practice for laying damp proof treatment using bitumen felts
IS 2645	-	Integral waterproofing compounds for cement mortar and concrete - Specification

A.19.3 Geo-membrane and Geo-textile

A.19.3.1 Indian Standard

IS 11652 - Textiles - woven sacks for packing cement - high density polyethylene (HDPE)/polypropylene (PP) - Specification

A.19.3.2 International Standards

ASTM D-751 - Standard test methods for coated fabrics

ASTM D-882 - Standard test method for tensile properties of thin plastic sheeting

A.20 Standards/Specifications for Road Construction

A.20.1 Indian Standards

IS 73 - Paving bitumen - Specification

IS 702 - Industrial bitumen

IS 2720 (Parts-1 to 41) - Methods of test for soils

IS 6241 - Method of test for determination of stripping value of road aggregates

A.20.2 International Standard

ASTM D 2172 - Standard test methods for quantitative extraction of bitumen from bituminous paving mixtures

A.20.3 Indian Road Congress Standards

IRC 5 - Standard specifications and code of practice for road bridges, section I - general features of design

IRC 6 - Standard specifications and code of practice for road bridges, section II - loads and stresses

IRC 15 - Standard specifications and code for practice for construction of concrete roads

IRC 19 - Standard specification and code of practice for water bound macadam

IRC 27 - Specifications for bituminous macadam

A.21 Standards and Specifications for Protective Bunds

IS 7317 - Code of practice for uniaxial jacking test for deformation modulus of rock

IS 9143	-	Method for the determination of unconfined compressive strength of rock material
IS 9221	-	Method for the determination of modulus of elasticity and Poisson's ratio of rock materials in uniaxial compression
IS 10082	-	Method of test for the determination of tensile strength by indirect tests on rock specimens

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3. ATOMIC ENERGY REGULATORY BOARD, Safety Guide, Geotechnical Aspects and Safety of Foundation for Buildings and Structures Important to Safety of Nuclear Power Plants, AERB/NPP/SG/CSE-2, Mumbai, India, 2002.

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Published by **:** Atomic Energy Regulatory Board
Niyamak Bhavan, Anushaktinagar
Mumbai - 400 094
INDIA.

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