ELLOMAY
Pumped Storage (2014) Ltd.

PSPP MANARA
156 MW

ISRAEL

PARTICULAR

CIVIL SPECIFICATIONS

TS-12 – Sealing (Membrane Face and Asphalt Face)

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REVISION NUMBER:

1.0 First edition
~~1.1 220MW in header replaced with 156MW and comments incorporated~~
2.0 Second edition: April 2019
2.1 Third edition: May 2019

Note:

Owner means Owner/Employer and/or Owners Engineer (OE)

It is further hereby clarified that any approval/non-objection made by the Owner shall not, in any way, release the Contractor from any of its responsibilities and liabilities, nor shall it impose any obligation or responsibility on the Owner which fully relies on the Contractor's expertise. It is further clarified that in any event of Owner's reservations and/or comments, it shall be the sole responsibility of the Contractor to recheck and confirm any such comment.

The Owner disclaims any and all liability for any errors, inaccuracies or incompleteness contained in this document. To the extent that the terms and conditions set forth herein conflict with the terms and conditions of the EPC Contract Agreement and/or O&M Contract Agreement, as applicable, the terms and conditions of the EPC Contract Agreement and/or O&M Contract Agreement, as applicable, will prevail.

Notwithstanding anything to the contrary in this document or any other Project Document, the Design and Works and Services (as applicable) shall be done and executed in compliance and shall adhere to the Israeli applicable standards. Compliance with an applicable recognized international standard shall not in no way derogate from the above requirement to comply at all times with the Israeli applicable standards. In the event that no Israeli standard is applicable the Design and Works and Services (as applicable) shall be done and executed in compliance and shall adhere to the relevant standard specified in the list included in the general specifications (Volume 2 Section IV, Section VI of the RFP Documents).

1 MEMBRANE FACE

1.1 General

1.1.1 Scope

For the purpose of this Specification, the term "Membrane Face" includes all activities related to membrane facing works by placing and fixation of suitable material to lines and grades shown on the drawings, or as directed by the Owner.

The works covered herein shall be carried out by a contractor specialized in this field of work and having sufficient experienced personnel and the specialized equipment required. Company and key-personnel references shall be submitted to the Owner proving that similar works have been carried out in the last five years. The engagement of a specialized sub-contractor might be necessary.

In case the Contractor cannot sufficiently demonstrate that the Contractor himself or his sub-contractor has the required experience, the Owner has the right to nominate another sub-contractor for this work.

1.1.2 Layering

Layering of the plastic membrane system proposed for the slopes of the reservoir is the following, from bottom (ground surface) to top:

a) Ground surface

Purpose of the ground surface is to form a regular and stable base for the plastic membrane system without sharp edges and protrusions. A smooth surface beneath the plastic membrane is to be preferred in order to prevent stress concentrations that may cause premature aging of the plastic membrane. A smooth surface also contributes to increase the contact area between the plastic membrane and the ground surface, providing more friction resistance against sliding and reducing stresses on the anchorage system.

b) Drainage layer

According to the ICOLD Bulletin 135, "Geo-membrane Sealing Systems for Dams-Design Principles and Review of Experience", purpose of the drainage system is:

- To collect and drain any water which may infiltrate through the geo-membrane, thus preventing hydrostatic pressure acting against the dam face and allowing pressure balance of the geo-membrane in the event of a rapid draw down of the reservoir.
- To relieve vapor pressure behind the sealing layer caused by the humidity of the dam body, which due to differential pressure created by differences in the temperature, tends to migrate towards the surface with lower pressure.
- To balance air pressure behind the sealing layer in the events of sudden changes in the atmospheric pressure, for instance when wind blows.

- To allow the monitoring of the water tightness of the geo-membrane sealing layer.

c) Waterproofing layer

The waterproofing layer consists of a flexible geo-composite, consisting of a geo-membrane, heat-bonded during extrusion to a non-woven needle-punched geotextile, with the function of anti-puncturing layer or equivalent. The backing geo-textile also improves the thermal dimensional stability of the geo-membrane, further reducing possibility and height of wrinkles, and works as drainage layer having some transmissivity.

The geo-membrane is formulated in order to be UV resistant. Thickness of the geo-membrane (mm) and weight of the geo-membrane (g/m^2) shall be selected in order to achieve a functional life of the geo-membrane system exceeding 50 years.

Geo-membranes to be used for Manara PSPP shall have been successfully applied for waterproofing dams, reservoirs and other hydraulic structures.

1.1.3 Definitions

a) Standard terminology for geo-synthetics shall be defined as per ASTM D 4439 unless otherwise indicated herein.

b) Fabricator

The person or organization responsible for fabricating and seaming sheets of flexible membrane into panels that will be shipped to the site for installation.

c) Flexible Membrane Lining (FML)

A manufactured hydraulic barrier consisting of one or more functionally continuous sheets of synthetic, or partially synthetic, flexible material, used to provide an essentially impermeable hydraulic barrier.

d) Geo-composite Drain

A geo-synthetic product consisting of a geonet core with geotextile bonded to one or both sides, intended for planar drainage of fluids or gases.

e) Geonet

A geo-synthetic consisting of integrally connected parallel sets of ribs overlying similar sets at various angles for planar drainage of liquids or gases.

f) Geo-synthetic

Synthetic fabrics (woven or non-woven), membranes or composite materials typically used in earthworks and structures for the purposes of barrier formation, containment, drainage, filtration, protection, reinforcement, separation, and erosion control.

g) Geotextile

A permeable geo-synthetic comprised solely of textiles. Geotextiles are used with foundation, soil, rock, earth, or any other geotechnical engineering-related material as an integral part of projects, structures, or systems. Interchangeable with “fabric”

h) Installer

The person or organization responsible for field handling, deploying, installing, seaming, anchoring, and field quality control testing of the Flexible Membrane Lining system.

i) Manufacturer

A person or organization responsible for producing flexible membrane and geo-synthetic materials.

j) Minimum Average Roll Value (MARV)

The value of a property of a geo-synthetic material established by the manufacturer such that the user/purchaser will have a 97.7% confidence that the property in question will meet that value. For normally distributed data, MARV is the typical value minus two standard deviations, calculated from documented quality control test results.

k) Quality Control Inspector

An independent or third-party person or organization, retained by the Provider, who is responsible for monitoring, documenting and executing activities related to the Quality Control of the Flexible Membrane Lining system from manufacturing through installation.

l) Quality Control Laboratory

An independent or third-party person or organization, retained by the Provider, who is responsible for the sampling, testing and reporting related to the Quality Control of the Flexible Membrane Lining system from manufacturing through installation.

m) Provider (may also be referred to as Vendor)

The person or organization responsible for detailed design, manufacture, fabrication, installation, and Quality Control of the Flexible Membrane Lining system, including linings, geo-synthetics, anchorages, fixtures and appurtenant works necessary to install the functional Flexible Membrane Lining system.

n) Service Life

The length of time during which the Flexible Membrane Lining system can be operated or used economically while achieving the design performance and leakage criteria:

- Flexible membrane and geo-synthetic components

  Service Life is considered to be the greater of the time until the tensile strength of the material decreases to 50% of its value at manufacture;

or the time until the properties of the material no longer conform to the minimum requirements specified in paragraph 1.3.3~~1.3.3~~. For particular lining materials, an alternative index property (e.g., elongation, molecular weight, melt index) and limiting value may be used to establish the functional Service Life. In this case, the lining Provider/Vendor shall justify and demonstrate that the lining will maintain water tightness and that its function and performance will not be impaired throughout the range of Performance Requirements and Design Requirements at the limiting value of the index property.

- Anchoring and tensioning systems, metallic components, seals, seams and appurtenant fixtures

  All elements shall maintain the design strength capacity throughout the Service Life after allowing for wear, fatigue, corrosion due to environmental exposure and operational conditions.

1.1.4 Submissions

a) Initial Submittals

- Qualifications of:
  - Provider of the Flexible Membrane Lining system.
  - Manufacturer(s) of flexible membrane and geo-synthetic materials.
  - Organization providing details and design of the Flexible Membrane Lining system.
  - Fabricator(s) of the Flexible Membrane Lining system.
  - Organization installing the Flexible Membrane Lining system.
  - Quality-control organization and laboratory.
- Evidence that the Flexible Membrane Lining system is capable of achieving the required Service Life and Performance Requirements specified in paragraph 1.3.3~~1.3.3~~ (Components).
- Preliminary data and calculations demonstrating compliance with design and performance criteria.
- Conceptual set of drawings illustrating the Flexible Membrane Lining system, layout and typical details, including but not limited to: flexible membrane and associated geo-synthetic layers as may be necessary for protection, cushioning or other purposes, anchorage, ballasting, and connection systems and fixtures; seams, seals and overlap details; and other elements of the Flexible Membrane Lining system.
- Catalog data and cut sheets for all proposed materials (lining, other geo-synthetics, anchorages, fixtures and appurtenant parts) and field installation and seaming equipment.
- Requirements for subgrade and surface preparation for the Flexible Membrane Lining, including criteria and tolerances for surface flatness and curvature.

- Schedule for installation.

b) Final Design Submittal

- Drawings, details and supporting design documentation demonstrating compliance with design and performance criteria, including the following:
  - Drawings and details of the Flexible Membrane Lining system showing the layouts and typical details, including but not limited to: liner membrane and associated geo-synthetic layers as may be necessary for protection, cushioning or other purposes; seams, seals, overlaps and connections; protective layers, coatings, linings or ballast; and other pertinent elements of the Flexible Membrane Lining system.
  - Drawings illustrating the locations and details of the lining anchoring systems (e.g., peripheral anchorages, face anchorages, floor anchorages, etc.) that will be used for various anchoring situations and conditions (e.g., concrete, rock, fill, overburden, etc.).
  - Drawings and details of the typical lining connections and fixtures to divider walls, retaining walls, inlets, manholes, clean-outs and other penetrations.
  - All necessary design data and calculations to demonstrate the lining system, anchorages, connections and appurtenant fixtures will meet the design criteria and performance requirements.
- Requirements for subgrade and surface preparation for the Flexible Membrane Lining, including criteria and tolerances for surface flatness and curvature.
- Manufacturer's material specifications.
- General description of proposed methods of installation, sequence, equipment, temporary or appurtenant installation structures, and supports

c) Other Submittals

- Prior to Fabrication
  - Shop drawings showing sheet layout, location of seams, seam connection details, anchorage details, profile and batten details, and direction and amount of overlap.
  - Manufacturer's Quality Assurance Manual for flexible membrane and geo-synthetic materials.
  - Fabricator's Quality Assurance Manual for flexible membrane materials.
  - Source quality-control test results and manufacturer's certificates for materials.
- Prior to Installation

- Installation Work Plan, including at a minimum the following information:
  - Manufacturer's material specifications, including quality-control certificates, product literature, and installation instructions.
  - Detailed description of proposed methods of installation, sequence, equipment, temporary or appurtenant installation structures, and supports.
  - Qualifications of field installation and seam welding personnel.
  - Requirements and procedures for material delivery, storage, and handling.
- Product Data
  - Adhesives, sealants and other products and materials to be used in the Flexible Membrane Lining system
  - Securing pins, batten strips, profiles, washers, anchors, nuts, bolts, gaskets and other appurtenances.
- Samples
  - Material samples for each type and class of material to be used in the Flexible Membrane Lining system. Affix product information to each sample.
  - Samples of adhesives, sealants and other products and materials to be used in the Flexible Membrane Lining system.
  - Samples of securing pins, batten strips, profiles, washers, anchors, nuts, bolts, gaskets and other appurtenances.
  - Samples of welded, sewn, or other affixed sheet-to-sheet seams.
- Construction Quality Control Plan.
- Written certifications of surface acceptability for lining placement.

- During Installation
  - Test Results
    - Test results on all field seams, certified by the Quality Control Inspector.
    - Test results on all destructively tested field seams, certified by the installer and Quality Control Laboratory.
    - Test results on all repaired seams, certified by the Quality Control Inspector.
    - Other certified quality control test results.
  - Daily reports by the installer and the Quality Control Inspector.

d) Prior to Final Acceptance of Work

- As-built Drawings that clearly and accurately show, at a minimum:
  - Final elevations, grades and geometry.
  - Locations of seams, panel corners, anchor trenches, structural anchorages, and other terminations.
  - Field quality-control test and sample locations.
  - Locations of rework and repairs.
  - Any other information needed to accurately document the as-installed condition of all elements of the Flexible Membrane Lining system.
- Final Construction Report including Acceptance Testing data and results at completion.

e) Maintenance and Inspection Plans: Prepare and submit a Maintenance Documentation Package.

1.2 Applicable Standards

a) American Concrete Institute

- ACI 350.1M Specification for Tightness Testing of Environmental Engineering Concrete Containment Structures

b) ASTM International:

- ASTM D1004 Standard Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheeting
- ASTM D 1593 Standard Specification for Non-rigid Vinyl Chloride Plastic Film and Sheeting
- ASTM D 4355 Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus
- ASTM D 4439 Terminology for Geo-synthetics
- ASTM D 4833 Standard Test Method for Index Puncture Resistance of Geo-membranes and Related Products
- ASTM D 6497 Guide for Mechanical Attachment of Geo-membrane to Penetrations or Structures
- ASTM D 7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geo-membrane Using Fluorescent UV Condensation Apparatus

c) International Standards Association:

- ISO 34 Rubber, Vulcanized or Thermoplastic. Determination of Tear Strength
- ISO 527 Plastics. Determination of Tensile Properties

d) European Committee for Standardization

- EN 12310-1 Flexible Sheets for Waterproofing. Determination of Resistance to Tearing (Nail Shank). Bitumen Sheets for Roof Waterproofing
- EN 12311-1 Flexible Sheets for Waterproofing. Determination of Tensile Properties. Bitumen Sheets for Roof Waterproofing
- EN ISO 12236 Geo-synthetics. Static Puncture Test (CBR Test)
- EN 13361 Geo-synthetic Barriers – Characteristics required for use in the construction of reservoirs and dams

e) Other

- PSPP Manara, Basic Design, Poyry Energy GmbH, 2015
- ICOLD Bulletin 135, "Geo-membrane Sealing Systems for Dams-Design Principles and Review of Experience"
- Geo-synthetic Institute. GRI Specifications, Guides and Practices / Test Methods and Standards, www.geosynthetic-institute.org.
- International Association of Geo-synthetic Installers. 2007. HDPE and LLDPE Geo-membrane Installation Specification, IAGI, St. Paul, MN.
- Koerner, R. 2005. Designing with Geo-synthetics. 5th ed. Prentice Hall. NJ.

f) Local Standards

The works shall comply with local Standards where available but shall be in no case of lower quality than the above mentioned standards indicate.

1.3 Materials

For membrane facing PVC geo-membrane has to be used. In further chapter the requirements are described in detail.

1.3.1 System Performance Requirements

a) Service Life – Flexible Membrane Lining System

- The Flexible Membrane Lining system shall have a functional Service Life of at least 50 years.
- The Flexible Membrane Lining system shall be durable without loss of functionality throughout its Service Life and shall reduce maintenance requirements to the lowest practical level in terms of required outages and maintenance and repair costs.
- The full life-cycle costs of the Flexible Membrane Lining system shall be minimized, including spare materials, inspection, servicing, maintenance, manpower, and replacement costs over its required functional Service Life.

- The Service Life and durability of the Flexible Membrane Lining system shall be applicable to all elements of the system based on an assessment of potential deterioration due to exposure, particularly in the marine environment, throughout the Service Life including, but not limited to:
  - Durability and long-term performance of the membrane lining, seals, gaskets, seams and all other components and waterproofing elements of the Flexible Membrane Lining system.
  - Corrosion of metals.
  - Long-term performance of sealants, coatings, and other forms of protection.
  - Serviceability of embedded items.

b) Service Life – Flexible Membrane and Geosynthetic Materials

- The Service Life of Flexible Membrane and geosynthetic materials shall be demonstrated using evidence of the following types:
  - Historic performance of the same or similar systems and materials.
  - Long-term environmental exposure tests and case histories.
  - Accelerated aging tests that include ASTM D 4355 or ASTM D 7238, or equivalent EN and internationally accepted standards, modified for test durations appropriate to the required functional Service Life.
  - Published research results.
  - Other evidence considered relevant by the Provider.
- Demonstration of Service Life shall consider the individual and combined effects of at least the following:
  - Ultraviolet light exposure.
  - Oxidation.
  - Ozone exposure.
  - Hydrolysis.
  - Chemical attack.
  - Biological attack.
  - Temperature.
  - Stress states due to cyclic loading, differential settlement, temperature differences and wind loads.
- Service Life shall be demonstrated with regard to the environmental conditions at the Manara reservoir.

1.3.2 Design Requirements

a) Basic Design Requirements

The materials used for the Flexible Membrane Lining system shall be chosen to be durable and to require low maintenance, taking into account high flow velocities occurring during operation.

b) Imperviousness

The geo-membrane shall have a permeability in the order of $k \geq 1 \cdot 10^{-14}$ m/s

c) Hydrostatic Uplift

The design may include provisions to accommodate hydrostatic uplift or measurement of water levels in the underdrainage system beneath the lining.

d) Settlement

Geo-membranes shall have sufficient performance with respect to differential displacements at locations where the subgrade is discontinuous and differential movements can occur (e.g. connection with stiffer structures).

e) Wind Forces

The Flexible Membrane Lining system shall withstand sustained wind speeds of 33 m/s, acting on that part of the Flexible Membrane Lining system above the minimum operating level, without damage or impairment of function.

f) Seismic

Geo-membrane for use at PSPP Manara shall have already been applied to structures in zones of high seismicity and corresponding references shall be provided.

- OBE (PGA = 0.387 g)
  - The Flexible Membrane Lining system shall sustain no permanent damage from the earthquake.
  - The Flexible Membrane Lining system may sustain damage that can be repaired without interruption of lock operations.
- MCE (PGA = 0.251 g)

  The Flexible Membrane Lining system may experience damage that requires limited replacement or localized repair.

g) Extreme temperatures behavior

The climate at the site of Manara PSPP is dominated by Mediterranean climate. The proposed geo-composite shall preserves its mechanical properties even when subject to extreme temperatures. If exposed to low temperatures, geo-membranes can experience stiffening and brittleness. It shall be provided proofing that geo-membranes to be used for PSPP Manara are resistant to low temperatures, extremely high temperatures and repeated freeze/thaw cycles (with temperatures at PSPP Manara site ranging from -4°C to +42°C). Following are some climate extremes in Israel:

- the highest temperature ever recorded: 54.7°C at Turat Tzvi, 1942
- the lowest temperature ever recorded: -13.7°C at Tel Hatanim, 1950

h) Aging

Accelerated ageing tests shall be provided proofing that geo-membranes intended for use at PSPP Manara have a functional life of 100 years or more when left exposed in a demanding environment as the Mediterranean climate in Manara.

i) Workability

Geo-composites shall be flexible enough in order to be laid free of folds and stress concentrations that could cause premature ageing. The need to minimize the height of wrinkles is due to the fact that, if high wrinkles form during installation, in the long-term such wrinkles may collapse under the external loads, forming relatively sharp folds with stress concentration, and risk of pinching the geo-membrane, if there is a cover layer. Additionally, presence of folds will make the seaming process difficult and less reliable.

j) Other Requirements

- Lining materials shall not degrade the quality of the water in the reservoir.
- The Flexible Membrane Lining system shall not employ materials that encourage growth of aquatic life within the basins.
- The Flexible Membrane Lining system shall blend in with the setting and shall have neat and clean lines.
- The design of the Flexible Membrane Lining system and the materials used shall minimize opportunities for, and susceptibility to, vandalism and accidental damage.

1.3.3 Components

a) Flexible Membrane Lining

- Flexible Membrane Lining shall be manufactured for the purpose of retaining water in open impoundments. Polymeric lining materials shall consist of one or more layers of thermoplastic polymer material including, but not limited to, polyolefins and polyvinyl chloride. Reinforced composites of polymeric material and geotextile or a geosynthetic scrim shall be permitted.
- Flexible Membrane Lining may have smooth surfaces or may be textured on one or both sides.
- Required Strength Properties of Material
    - Unless stated otherwise, all required strength properties shall be MARV.
    - Tensile Strength at Yield: At least 20 kN/m, as measured by ISO 527 (polymeric materials).

- Static Puncture Resistance: At least 2500 N, as measured by ISO 12236.
- Tear Resistance: At least 50 kN/m, as measured by ISO 34 (polymeric materials).

- The material shall not exhibit environmental stress cracking under the environmental and operating conditions at the reservoir, including rapidly cycling loads from rising and falling water levels in the reservoir.
- The thermal properties of the Flexible Membrane Lining material shall be such that exposure to daily temperature fluctuations does not cause the development of wrinkles or waves in the lining with heights exceeding 38 mm.

b) Seams

- Seams shall be made using only methods and equipment recommended by the manufacturer of the Flexible Membrane Lining material.
- Fabricated and field seams in polymeric Flexible Membrane Lining shall develop at least 90 percent of the tensile strength of the parent material, as measured in the weakest direction.
- Fabricated and field seams in bituminous Flexible Membrane Lining shall develop at least 75 percent of the tensile strength of the parent material, as measured in the weakest direction.

c) Anchorages and Connections

- The design of mechanical connections to structures and penetrations shall be consistent with ASTM D 6497.
- Connections to concrete structures, similar surfaces and rock surfaces shall be made using methods, materials, and equipment recommended by the manufacturer of the Flexible Membrane Lining material.
- Unless otherwise indicated, connections shall provide positive, durable, testable, and maintainable seals against the leakage of water from the WSBs. Redundant seals (i.e., mechanical, adhered, capping) shall be used wherever practical.
- Anchoring and tensioning systems, metallic components, seals, seams and appurtenant fixtures shall be provided as necessary for the type of lining system used.
  - Metallic components shall be stainless steel unless the Provider demonstrates that the system requirements regarding service life, leakage, and maintenance can be achieved by other materials or means (i.e., galvanizing, protective coatings, sacrificial allowances).
  - Synthetic materials such as washers, gaskets and fillers shall be durable, capable of inspection and testing, and maintainable or replaceable as necessary for the required service life.

1.4 Sampling and Testing

1.4.1 Inspection

By Provider: Inspect the completed Flexible Membrane Lining system in each basin for pinholes, punctures, tears and other defects. Inspect seams and sealed connection for unbonded and defective areas. Repair and document all defects found.

By Contractor: The completed Flexible Membrane Lining system in each basin shall be visually inspected by the Contractor, accompanied by the Quality Control Inspector and Provider's representative, for defects, holes, or damage. At the discretion of the Contractor or the Quality Control Inspector, the surface of the Flexible Membrane Lining system shall be brushed, blown, or washed by the installer to expose it for inspection. Repair and document all defects found.

1.4.2 Water Tightness Testing

To demonstrate that the Flexible Membrane Lining system meets the leakage criteria established in paragraph 1.3.3~~1.3.3~~, the lining Provider/Vendor shall perform water tightness tests for the reservoir.

The leakage shall not exceed 4% of the reservoir volume per year. This results in a maximum average loss of 4930 m^3/day for upper as well as for lower reservoir. This can be related to a measurable loss of approximately 67 mm in 24 hours in the upper reservoir and 23 mm in 24 hours in the lower reservoir.

Water tightness testing shall be performed in accordance with ACI 350.1M-10, Sections 2 and 2R; Hydrostatic Tightness Test for Open Containment Structures, or an accepted equivalent testing standard. Leakage through conduit valves shall be collected, measured, and accounted for.

The reservoir will be accepted when the leakage criteria described in paragraph 1.3.3~~1.3.3~~ is met. In the event of tightness test failure, immediate re-testing is allowed.

1.5 Execution

1.5.1 Examination

Prior to beginning installation of the Flexible Membrane Lining system in each Basin, the installer and the Quality Control Inspector shall inspect the surface for its acceptability for installation of the system. Installation shall not begin until the Basin surface has been inspected, all deficiencies have been corrected and documented, and the installer and Quality Control Inspector have both given written acceptance of the surface to the Contractor.

The installer and Quality Control Inspector shall inspect the subgrade condition each day prior to the day's deployment of flexible membrane and geo-synthetic materials. Any defects shall be corrected before deployment proceeds. The inspections and corrective measures shall be documented.

1.5.2 Preparation

Acceptance of Materials: The Quality Control Inspector shall be present during delivery and unloading of the flexible membrane and geo-synthetic materials, and shall verify the labeling and condition of the materials as received.

1.5.3 Installation procedure

It is assumed to install the geo-membrane system after all civil engineering works have been completed by the Contractor for Civil Engineering works, including excavation works, excavation support, construction of the fill dam and the construction of the upper intake structure.

Installation of the geo-membrane system shall be performed by crews of skilled workers standing on movable platforms fastened to the crest of the slopes. The geo-composite shall be supplied in rolls of width ≥ 2 m and length sufficient to cover the whole height of the slopes, from crest down to bottom. Adjacent sheets of geo-composite shall be heat seamed.

To the extent practical, flexible membrane sheets shall be factory seamed into maximum sized panels to minimize field seaming. Factory seaming shall be by methods approved by the flexible membrane manufacturer. Factory seams shall extend to the end of the sheet so that unbonded edges are minimized.

The procedures and equipment used to deploy sheet materials shall not elongate, wrinkle, scratch, or otherwise damage the flexible membrane, other geo-synthetic layers, or the underlying subgrade. Only flexible membrane panels that can be anchored and seamed together the same day shall be deployed at one time.

1.5.4 Heat seaming

Heat seams shall be performed manually by single-track seaming and with automatic two-tracks seaming machines, if possible. All heat seams shall be performed by specialized welders and shall be checked. Single-track seams shall be checked with manual point stressing, following ASTM D-4437 ("Standard Practice for Non-Destructive Testing for Determining the Integrity of Seams Used in Joining Flexible Polymeric Sheet Geo-membranes"). Double-track seams shall be checked with pressurized air channel testing, following ASTM D-7177 ("Standard Specification for Air Channel Evaluation of Polyvinyl Chloride (PVC) Dual Track Seamed Geo-membranes").

Trial seams shall be made each day prior to production seaming and whenever there is a change in seaming personnel or seaming equipment. Trial seams shall be made by each seamer and each piece of seaming equipment used that day. Trial seams shall be made under field conditions on strips of excess flexible membrane.

In sumps, corners and odd-shaped geometric locations, the number of field seams shall be minimized. Seaming shall extend to the outside edge of panels. Fish mouths in seams shall be repaired.

1.5.5 Anchorage of Plastic Membrane

Anchorages at the top of the lining (peripheral anchorage) shall be designed to pull out or fail before the tensile strength of the Flexible Membrane Lining is exceeded.

1.5.5.1 Face, bottom anchorage

The geo-composite is anchored to the slopes and the bottom of the reservoir with a system of anchor trenches.

The anchorage system so conceived shall pretension the geo-composite between two anchorage lines and, in this manner, the geo-membrane system shall be free of wrinkles, thus more durable.

1.5.5.2 Anchorage at concrete appurtenances

When concrete appurtenances are present, the geo-membrane system shall be anchored to these structures with an anchorage of the clamping compression type, which avoids water infiltrating behind the liner, such as (or equivalent):

- The geo-composite shall be compressed together with a rubber gasket between the subgrade and stainless steel batten strip.
- The stainless steel batten strips shall be anchored to the concrete by stainless steel anchor rods embedded in chemical phials, and a regularization resin shall be placed over the concrete surface. Stainless steel splice plates shall be placed at abutting batten strips.

1.5.6 Drainage system

Components of the drainage system are:

- The gap between the geo-membrane and the subgrade. If backpressures arise, then this gap increases and the water flows by gravity towards the bottom.
- The drainage geo-net placed between the geo-membrane and the subgrade.
- A drainage system placed at the bottom of the reservoir, in correspondence of the slope foot, which conveys the drained water towards the collection point (drainage shaft). The drainage system consists of a slotted PVC pipe embedded in porous concrete. See drawing MAN/TD/CD/02/004.

1.6 Quality Control Tests

1.6.1 Source Quality Control

a) The Contractor may, at his discretion, may visit the manufacturer’s or fabricator’s facilities to observe and inspect the manufacturing or fabrication processes and the quality-control monitoring, sampling, and testing.

b) Raw materials for flexible membrane and geosynthetic materials shall be tested in accordance with the approved Manufacturer’s Quality Assurance Manual. Any raw material which fails to meet the manufacturer's specified physical properties shall not be used in manufacturing the sheet. Seaming rods and pellets, if used, shall be manufactured of materials which are essentially identical to that used in the flexible membrane. Seaming rods and pellets which fail to meet the property values required for the sheet material shall not be used for seaming.

c) Flexible membrane and geo-synthetic sheets shall be tested in accordance with the approved Manufacturer's Quality Assurance Manual. Sheets not meeting the minimum requirements specified shall not be sent to the site.

1.6.2 Field Quality Control

a) A comprehensive program of inspection and testing shall be developed and carried out. The program shall be documented in the Construction Quality Control Plan. The program shall address, but not be limited to, the following:

- The organization and responsibilities of the Quality Control Inspector, the Quality Control Laboratory, the Provider's installation team, and the Contractor.
- Communication and documentation procedures.
- The types of, and technical data for, the instruments and equipment to be used for inspection and testing.
- The standards that govern how quality control testing will be performed.
- Technical procedures and methods for performing quality-control inspections for all features of the work.
- The testing criteria, procedures, methods, and other information upon which the control tests shall be made for each phase of the work.
- Distribution and review of inspection and test results.
- Handling of non-conformances, failed tests, retesting, rework, and repairs.

b) Field Seams and Connections

- All field seams and sealed connections of flexible membrane shall be 100-percent tested for leakage. Seams and sealed connections that do not pass the leakage test shall be repaired or reworked until they pass. All failed seams and sealed connections and the repair or rework performed on them shall be documented.
- Acceptable methods for testing seams and connections shall be identified by the Provider and approved by the Contractor prior to the start of installation.

c) As-Built Drawings

- The Provider shall prepare and maintain As-Built drawings that show revisions to the design and shop drawings, along with the justifications for them.
- As-Built drawings shall use copies of the design and shop drawings for the Flexible Membrane Lining system as a base.
- As-Built drawings shall be regularly updated and be available for review by the Contractor upon request. A completed set shall be provided to the Contractor at the completion of the Flexible Membrane Lining system.

d) Final Construction Report

- The Quality Control Inspector shall prepare a final construction report that documents construction conditions and procedures and summarizes the inspections and field and laboratory test results.
- At a minimum, the final certification report shall include:
  - a summary of all construction activities.
  - a description of significant construction problems and the solutions to these problems.
  - copies of daily reports by the installer and the Quality Control Inspector.
  - laboratory and field test results.
  - observation and test data sheets.
  - sampling and testing location plans.
  - copies of the As-Built Drawings.
  - a statement certifying to the report's correctness and completeness, signed by the Quality Control Inspector.

1.7 Maintenance

The Provider/Vendor shall submit a detailed Inspection, Maintenance and Repair Plan for the Flexible Membrane Lining system. The Plan shall describe the type, scope and frequency of routine maintenance and inspections, and detailed instructions for performing routine maintenance, cleaning and typical repair procedures.

Provide sufficient flexible membrane and geo-synthetic materials to fill expected maintenance and repair requirements for a period of 3 years after acceptance of the completed Flexible Membrane Lining system.

1.8 Records

Records, the number and type of batch and actual quantity of each material in each batch, shall be kept by the Contractor.

2 ASPHALT FACE

2.1 General

2.1.1 Scope

a) For the purpose of this Specification, the term "Bituminous Concrete Lining" includes all activities related to asphalt facing works by placing and compacting of suitable material to lines and grades shown on the drawings, or as directed by the Owner.

b) The works covered herein shall be carried out by a contractor specialized in this field of work and having sufficient experienced personnel and the specialized equipment required. Company and key-personnel references shall be submitted to the Owner proving that similar works have been carried out in the last five years. The engagement of a specialized sub-contractor might be necessary.

c) In case the Contractor cannot sufficiently demonstrate that the Contractor himself or his sub-contractor has the required experience, the Owner has the right to nominate another sub-contractor for this work.

2.1.2 Definitions

a) Bitumen: Bitumen is a mixture of hydrocarbon dissolved in carbon disulfide.

b) Coarse Aggregate: Coarse Aggregate is natural and dense stone which remains #8-sieve (2.38 mm).

c) Fine Aggregate: Fine Aggregate is sand which passes #8-sieve (2.38 mm).

d) Filler: Filler is limestone dust, cement, or other inert granular material which passes #200-sieve (0.074 mm).

e) Asphalt: Asphalt or Bituminous Concrete is a mixture of bitumen, coarse and fine aggregates, and filler.

f) Bituminous Concrete Lining is a composite system featuring layered construction. Double lining facing (Type A) consist of one binder layer (BN) of bituminous concrete, two Impervious bituminous concrete layers (I) and one drainage layer (DR). Single lining facing (Type B) consist of one binder layer (BN), and one impervious bituminous concrete layer (I). The finished surface of both types of facing is sealed, usually with bituminous emulsion or bituminous mastic (S), for protection against weathering and ageing.

g) Drainage Layer (DR): Porous layer consisting of a bituminous, graded, crushed material with a small amount of super-fines and functioning as a drain placed between the impervious layers.

h) Bituminous Emulsion: Bituminous Emulsion is a liquid (mixture of stabilizer, emulsifier and water) in which fine-grained bitumen is dispersed; it is sprayed on the drainage layer to stabilize the surface and to provide a better bond with the next binder layer. The emulsion also avoids erosion in the time between completion of the drainage layer and placing of the binder layer.

i) Cold Mastic (Emulsion Type): Cold Mastic (Emulsion Type) is a material used for protective course.

j) Cut-Back Asphalt: Cut-Back Asphalt is a liquid mixture of bitumen and light volatile distilled petroleum.

k) Bituminous Mastic: Bituminous Mastic is a mixture of bitumen and filler.

l) Primary Compaction: Primary Compaction is executed, as soon as bituminous concrete is placed, so that the bituminous concrete does not change in quality.

m) Secondary Compaction: Secondary Compaction follows Primary Compaction, so that bituminous concrete achieves as high density as possible.

n) Finishing Compaction: Finishing Compaction follows Secondary Compaction, so that surface is smoothly finished.

2.1.3 Submissions

a) Prior to commencing bituminous concrete lining works, the Contractor shall submit to the Owner for his approval a detailed program describing the work schedule, plant and equipment to be used for the works. The plant and equipment shall not waive or modify any provisions or requirement contained in this Specification.

b) 60 days prior to materials use the Contractor shall submit to the Owner for his approval the results of the specified tests.

c) If it is necessary to change the source of any material or to make use of any material which does not conform to the specified requirements and whenever deemed necessary by the Owner, the Contractor shall in advance submit the results of the adequate tests to the Owner for his approval.

d) The Contractor shall submit to the Owner for his approval any mix design throughout the trial test stipulated in this Specification.

e) The Contractor shall submit to the Owner daily and monthly reports in duplicate indicating executed amounts and locations of asphalt lining for each course. The report of each month shall be accompanied by a drawing indicating the monthly progress.

2.2 Applicable Standards

a) In this Specification all or part of the standards are applicable. These references include, but are not limited to:

American Society for Testing and Materials (ASTM):

D 5	Standard Test Method for Penetration of Bituminous Materials
D 36	Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)
D 70	Standard Test Method for Specific Gravity and Density of Semi-Solid Bituminous Materials
C 88	Standard Test Method for Soundness of Aggregates by use of Sodium Sulphate or Magnesium Sulphate

D 92	Standard Test Method for Flash Point
D 113	Standard Test Method for Ductility of Bituminous Materials
C 117	Standard Test Method for Materials finer than 75 gm (No.200) Sieve in Mineral Aggregates by Washing
C 127	Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate
C 128	Standard Test Method for Specific Gravity and Absorption of Fine Aggregate
D 128	Standard Test Method for Analysis of Lubricating Grease
C 136	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
C 188	Standard Test Method for Density of Hydraulic Cement
D 244	Standard Test Methods for Emulsified Asphalts
C 311	Standard Test Method for Sampling and Testing Fly Ash or Natural Pozzolans for Use as a Mineral Admixture in Portland-Cement Concrete
D 546	Standard Test Method for Sieve Analysis of Mineral Filler for Road and Paving Materials
D 1559	Standard Test Methods for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus
D 1754	Standard Test Method for Effect of Heat and Air on Asphalt Materials (Thin-Film Oven Test)
D 2042	Standard Test Method for Solubility of Asphalt Materials in Trichloroethylene
D 2397	Standard Specification for Cationic Emulsified Asphalt
D 4791	Standard Test Method for Flat or Elongated Particles in Coarse Aggregate

2.3 Materials

2.3.1 General

a) All materials used to form the bituminous concrete lining shall meet the requirements of the pertinent tests stipulated in this Specification or as directed by the Owner.

b) Except where otherwise specified herein, or directed by the Owner, the materials shall conform to the requirements contained in ASTM, latest edition.

2.3.2 Bitumen

Bitumen shall be the undiluted, plain bitumen of .classified 60 to 70 in penetration and shall have uniform composition conforming to the following requirements.

Test Item	Test Method	Standard Value
Flash Point	ASTM D 92	Not less than 232°C
Penetration	ASTM D 5	60 - 70
Softening Point	ASTM D 36	47°C - 52°C
Ductility	ASTM D 113	Min. 100 cm
Solubility in Trichloroethylene	ASTM D 2042	Not less than 99%
Retained Penetration after Thin-Film Oven Test	ASTM D 1754	Not less than 52%
Ductility after Thin-Film Oven Test	ASTM D 113	Min. 50 cm
Paraffin Content		Not more than 3%
Specific Gravity	ASTM D 70	Not less than 1.00

2.3.3 Aggregates

2.3.3.1 General

a) Aggregates used to form the bituminous concrete lining are normally crushed stones, of the type suitable for use in cement-mixed concrete.

b) Aggregates shall be limestone, granite, quartzite, porphyry, diorite, gneiss or basalt. However, the Contractor shall use sound rock of the region, providing that it meets the requirements of ASTM C 33, and other applicable standards approved by the Owner.

2.3.3.2 Coarse Aggregate

a) Quality:

Coarse aggregate shall be either natural gravel or crushed coarse limestone aggregate. Coarse aggregate shall consist of well-shaped, clean, hard, dense, durable rock fragments and shall not contain wood chips and other impurities. Coarse aggregate shall meet the following requirements.

Test Item	Test Method	Standard Value
Water Absorption Rate	ASTM C 127	Not more than 3%
Soundness by Sodium Sulphate	ASTM C 88	Not more than 10% [1)]
Density	ASTM C 127	Not more than2600 kg/m^3 [2)]
Flat or Elongated Parties	ASTM D 4791	Not more than 10%

1) After 5 cycles
2) In saturated surface dry conditions

b) Grading

Coarse aggregate shall be as follows:

Designation Size	Nominal Size Range	Sieve Opening Range
19 mm	19 to 13 mm	3/4" to 1/2'" (19.1 mm to 12.7 mm)
13 mm	13 to 5 mm	1/2" to #4 (12.7 mm to 4.76 mm)
5 mm	5 to 2.5 mm	#4 to #8 (4.76 mm to 2.38 mm)

Coarse aggregate shall be graded for each maximum size within the standard limits specified as follows:

Sieve Size	Percentage Passing by Weight		
	Fraction 19 to 13 mm	Fraction 13 to 5 mm	Fraction 5 to 2.5 mm
1 inch (25.4 mm)	100%		
3/4 inch (19.1 mm)	85 -100%	100%	
1/2 inch (12·.7 mm)	0 - 15%	85 - 100%	100%
#4 (4.76 mm)	0%	0 - 15%	85 - 100%
#8 (2.38 mm)	0%	0%	0 - 15%
#18 (1.19 mm)	0%	0%	0%

c) Storage

Coarse aggregates storage pile shall be built in such a manner as to avoid mixture with any other or foreign material, and to prevent segregation and excessive breakage.

2.3.3.3 Fine Aggregate

a) Quality

Fine aggregate shall be either natural sand or manufactured sand. It shall consist of clean, hard, dense and durable rock particles, free from injurious amounts of dust, silt, stone powder, pieces of thin stone, alkali, organic matter and other impurities. Fine aggregate shall meet the following requirements.

Test Item	Test Method	Standard Value
Water Absorption Rate	ASTM C 128	Not more than 3%
Soundness by Sodium Sulphate	ASTM C 88	Not more than 10% [1)]
Density	ASTM C 128	Not more than 2600 kg/m^3 [2)]
Water Loss	ASTM C 117	Not more than 7%

1) After 5 cycles

2) In saturated surface dry conditions

b) Grading

Fine aggregate shall conform to the following limits:

Sieve Size	Percentage Passing by Weight
#8 (2.38 mm)	90 - 100%
#200 (0.074 mm)	0 - 7%

c) Storage

Fine aggregates shall be stored in such a manner as to avoid mixture with any other or foreign materials. AII fine aggregate as delivered to the plant specified in 16.5.4 "Mixing" shall have reasonably uniform. For this purpose the Contractor shall stock pile the fine aggregate so as to drain excessive water.

2.3.4 Filler

d) Quality

Filler shall be derived from dust of crushed stone aggregate, supplemented by added fines, as needed. The added fines should be non-plastic. Filler shall meet the following requirements.

Test Item	Test Method	Standard Value
Density	ASTM C 188	Not more than 2600 kg/m^3
Moisture Content	ASTM C 311	Not more the 1%

e) Grading

Filler shall conform to the following limits:

Sieve Size	Percentage Passing by Weight
#30 (0.59 mm)	100%
#50 (0.297 mm)	95 - 100%
#200 (0.074 mm)	70 -100%

f) Storage

Filler shall be stored inside the warehouse with flooring 30 cm above the ground surface in such alignment as to be convenient for the sampling.

2.3.5 Bituminous Emulsion

Bituminous emulsion of cation type or equivalent approved by the Owner shall be used on the transition, which shall conform to ASTM D 2397 (Type: Slow-Setting, Grade: CSS-1).

2.3.6 Bituminous Concrete (Asphalt)

2.3.6.1 General

a) Each layer of bituminous concrete shall consist of a mixture of bitumen, aggregate and filler with the grading and dosage specified below, designed to provide the intended function of the specific layer.

b) The bituminous concrete shall be mixed, placed and compacted in the manner specified in 2.5.4~~2.5.4~~ "Mixing" and 2.5.6~~2.5.6~~ "Placing and Compacting".

2.3.6.2 Mix Design

a) The impervious layer (I) features a well graded aggregate and filler mix, and generally an amount of 6 to 8% of bitumen. The density of the aggregate mix in the impervious layer, ranging from 2100 to 2500 kg/m^3, together with a high degree of compaction, shall results in a bituminous mix with a void content of less than 3%.

b) The aggregate mix for the binder layer (BN) can vary from semi-open graded to open graded. The bitumen content varies accordingly (usually 4 to 6%), but must be sufficient to fully coat the aggregate and filler.

c) The binder layer (BN) shall be uniformly graded: The porosity of the mix shall be sufficient to prevent blisters formation between its layer and the overlying dense bituminous concrete course. The porosity shall be within the range of 7 to 12%, depending on the functional design of the binder layer. The void content shall preferably lie in the range of 7 to 12% vol. or even 15% vol.

d) The drainage layer (DR) shall consist of an open graded aggregate, with very small filler content, and sufficient bitumen (usually 2 to 5%).

e) The coefficient of permeability for the drainage layer (DR) should be not less than 10-4 m/s. The porosity should vary from 10 to 30%.

f) The percentages stipulated above refer to the total weight of the mix. If others mixes as stated in this Specification are employed, the Contractor requires the approval of the Owner.

2.3.7 Cold Mastic (Emulsion Type)

Cold Mastic shall conform to the following requirements.

Test Item	Test Method	Standard Value
Appearance	Visual Check	brown, smooth and creamy
Specific Gravity	ASTM D 70	0.97 ± 0.05
Solid Content	ASTM D 244	52.5 ± 5.0%
Ash Content	ASTM D 128	2.6 ± 0.5%

2.4 Sampling and Testing

2.4.1 General

a) Before commencement of works on site, the Contractor shall be responsible for selecting possible bitumen, aggregate, filler, etc. which he shall test at his own laboratory to determine the suitability of the various materials and satisfactory mixes of the asphalt facing to meet the requirements of this Specification.

b) The approval of the design mix and the method of placement and compaction, as to compliance with the requirements of the specifications, shall be based on field tests. The Contractor shall use its batch plant, placing and compacting equipment to carry out the respective tests. The work needs to be accomplished on the design slope.

2.4.2 Bitumen

The Contractor shall certify that each shipment of bitumen to the jobsite conforms to the grade and properties specified in the GTS or directed by the Owner.

2.4.3 Aggregates

a) The aggregate shall be inspected at the source, where it is quarried, crushed, screened, and washed.

b) The source can be offsite or onsite either as part of required project excavation or a designated project quarry. Inspection and testing of the material must be carried out continuously so that non-conforming material is excluded from the jobsite. Satisfactory inspection shall be documented by the results of the rock quality testing at the project laboratory, or nearby reliable commercial laboratory.

c) At the batching plant the Contractor shall ensure that segregation of the various aggregate stockpiles is not occurring, and that the aggregates are protected from contamination.

2.5 Execution

2.5.1 General

2.5.1.1 Preparatory Work

All surfaces, on which, each course of the asphalt facing shall be placed, shall be cleaned of all foreign and harmful material and be free of water.

2.5.1.2 Tolerances

a) All layers of the bituminous concrete shall be laid to the lines and levels shown on the Drawings or as directed by the Owner, with a tolerance on the compacted surfaces of the bituminous concrete of ±25 mm in surface irregularity measured over any 10 m length. Abrupt irregularities shall not exceed 5 mm in any course. Thickness of impervious layer (I), drainage layer (DR) and binder layer (BN), measured normal to the slope, shall be as specified with a tolerance of plus 10 mm and minus 0 mm.

b) The Contractor shall demonstrate to the Owners satisfaction that the bituminous concrete has been compacted to the correct thicknesses. Any damage resulting from such demonstration shall be made good at the Contractors expense.

2.5.2 Site Trial

a) During the site trials, the following shall be confirmed.

Location	Object	Item
Site Plant	Bituminous Concrete	Bitumen Content
		Aggregate Density
		Density (void ratio) by Marshall Test (ASTM D 1559)
		Slope Stability (Temperature: 60°C, Time: 48 h, Slope: 1 on 2)
Site	Joint	Permeability
	Bituminous Concrete	Placing and Compacting Temperature and Compacted Times

b) The Owner may require further items to be confirmed either in the site laboratory or in an independent laboratory. The tools and equipment used for the site trial test shall be those to be used for the effective execution of work.

c) The Contractor shall perform, on a part of embankment or elsewhere as approved by the Owner, the site trial tests which shall comprise the laying of a complete section of bituminous concrete over a width of about 10 meters. The site trial tests shall include examples of joints made both during one day's work and to material laid one or more days previously.

d) The site trial tests shall demonstrate to the Owner that the completed bituminous concrete complies with all the requirements of this specification and that the plant is suitable. Should the Owner consider that any aspect of the site trial does not comply with this specification, the Contractor shall immediately take the necessary measures to rectify the work. The Contractor shall not proceed with the execution of bituminous concrete lining until the Owner has given his consent approval.

e) Mix design, placing and compacting methods approved by the Owner, following the completion of successful site trial tests, shall be adhered to throughout asphalt facing works except for changes approved by the Owner. Before approval of any change (e.g. change of material, change of equipment etc.) the Owner may request for further site trial tests at a location selected by him.

f) Bituminous concrete work executed during the site trial which, in the opinion of the Owner, does not meet the requirements of this Specification shall be removed to a location outside the site as directed by the Owner. The Contractor shall repair any section damaged by this removal and shall execute the bituminous concrete again with the approved mix design.

2.5.3 Spraying of Weeds Killer and Bituminous Emulsion

a) Before starting the placement of the bituminous concrete layers, a 5%-solution of sodium chloric acid shall be sprayed as weeds killer on the sub-base. About 2 liter/m^2 shall be sprayed on the days without rain.

b) Spraying of bituminous emulsion shall be permitted on the sub-base where the surface has been substantially dry and the surface temperature has continuously been higher than 2°C for 4 hour, and when the air temperature is more than 5°C and no rain is falling.

c) About 2 liter/m^2 of bituminous emulsion shall be applied, and the emulsion shall be heated to 30 – 50°C before application unless the air temperature is higher than 30°C.

d) Engine-sprayer shall be used for spraying wherever possible. Spraying shall be applied from lower section to upper sections. Areas with insufficient emulsion application shall be additionally sprayed after first layer of the emulsion has percolated. Excessive sprayed emulsion shall be absorbed by placing a sufficient quantity of sand as directed by the Owner.

2.5.4 Mixing

a) The aggregates must be dried to at least 0.5% moisture content and heated prior to mixing.

b) For the mixing the following material temperatures shall be observed:

Bitumen	160 ± 10°C
Filler	more than 100°C
Impervious Course (I)	180 ± 15°C
Drainage Course (DR)	160 ± 15°C
Binder Course (BN)	180 ± 15°C

c) Mixing time, which depends on the type of mixing plant used, shall be determined during the site trial tests.

d) Only mixing and batching plant specifically designed by an expert for the design and manufacture of plant equipment for bituminous lining works shall be used. The plant shall have all equipment considered necessary for the production of bituminous concrete complying this specification including measuring and temperature control devices as considered necessary by the Owner.

e) The plant shall include a drying plant for the coarse aggregate giving a uniform production. The drying plant shall include a number of screens of sufficient size to provide the required proportion of aggregate in quantities corresponding to the maximum output of the mixer. Further, the plant shall also include a storage with at least three times the hourly capacity of the mixer, divided into compartments for storing each required fraction of aggregates. Each compartment shall have an overflow to remove excess material. Further, the plant shall have facilities for the dry storage and proportioning of the filler.

f) The mixing plant shall have appropriate devices for the accurate portioning of each fraction of aggregates and shall include a heated or insulated bucket for weighing accurately and applying the required quantity of bitumen. There shall be a self-registering clock which controls the time between adding the bitumen to the aggregates in the mixer and the mixed batch is leaving tile mixer.

2.5.5 Conveying

a) After being batched and mixed at the batch plant, the mix shall be conveyed to an insulated silo and gravity loaded into trucks. Preferably, the truck bed should be insulated and the load should be covered by tarpaulin.

b) In cold climate, only special insulated containers are allowed for the transport of the mixed batches.

2.5.6 Placing and Compacting

a) Prior to placing the bituminous concrete, the subgrade must be prepared. The subgrade shall be compacted and graded to the tolerances given in the corresponding Specification or as directed by the Owner.

b) Only equipment which has proven to be appropriate for this work shall be used for placing. Such equipment requires the approval of the Owner.

c) The surface shall be absolutely dry when receiving the bituminous concrete.

d) The temperature of the bituminous concrete, when placed and compacted and the compacting methods shall be documented as agreed with or directed by the Owner.

e) The surface of the finished bituminous concrete, on which roller marks are removed, shall be true to lines as shown on the drawings or as directed by the Owner.

f) Defective places shall be removed and be replaced as directed by the Owner at the Contractor's expense.

g) All free edges of the bituminous concrete except those of reinforcing course shall be properly filled with suitable material to form a good support and neat appearance. Feathered edges must be trimmed to vertical faces before placing adjacent suitable material.

h) Bituminous concrete shall not be placed or compacted when (i) the underlying bituminous concrete is damp, (ii) the ambient temperature is below 5°C or at another level which the Owner shall fix in relation to the mixing temperatures established, and (iii) the humidity, visibility, or wind chill reach levels at which the execution cannot be satisfactorily performed.

i) If rain starts to fall while a strip of bituminous concrete is being executed, the Contractor shall cease its operation and complete compaction of the bituminous concrete he has done thus far.

2.5.7 Joint / Seam Treatment

a) All joints in bituminous concrete shall be water tight and shall comply with all requirements stipulated herein.

b) There shall be no horizontal joints in bituminous concrete except where shown on the drawings or agreed with the Owner.

c) Joints in bituminous concrete shall not be closer than one meter to joints in the underlying bituminous concrete.

d) The edge of the first strip at a joint shall be feathered at an angle of approximately 45° to the under surface of the strip. At 'warm' joints the edge of the first strip shall be covered to conserve heat and then reheated by the joint-heater equipped in the finisher as the second strip is placed. At 'cold' joints,

as at a “day joint”, the cold edge of the-first strip shall be reheated up to the placing temperature, unless otherwise directed by the Owner, before the second strip is placed against it.

e) Where tests by vacuum permeameter indicate, that a joint has been inadequately compacted, the Contractor shall re-heat and re-compact the joint until tests indicate that an acceptable density or impermeability has been achieved.

f) All joints between bituminous concrete and concrete structure shall be water tight.

g) All concrete structure’s surfaces against which bituminous concrete are to be placed shall be primed with cut-back asphalt and asphalt mastic approved for the work and applied according to the manufacturer’s instructions.

h) The details of the joint between bituminous concrete and concrete structure shall be proposed by the Contractor to the Owner for approval. However, a system with glued-in concrete blocks, copper, foil with unfilled loop, bituminous sealing compound shall be used.

2.5.8 Reinforcing Course

i) The reinforcing courses (thickening of the bituminous layers) and its breadth shall be executed at locations agreed with or directed by the Owner.

j) Thickness of reinforcing course shall be at least 5 cm and shall conform to the specification for impervious layer (I).

k) Free edges of the reinforcing course shall be feathered at an angle of approximately 45° to the under surface.

2.5.9 Protective Course

The protective course is made of cold mastic specified in 2.3.7~~2.3.7~~ "Cold Mastic (Emulsion Type)". The cold mastic shall be sprayed uniformly three times on the surface of impervious course, which is absolutely dry and clean, at each rate (1st: 0.75 kg/m^2, 2nd: 0.75 kg/m^2, 3rd: 0.50 kg/m^2) by adequate equipment. The Contractor shall cease its operation when the ambient temperature is below 5°C or rain starts to fall.

2.6 Quality Control Tests

a) The Contractor shall propose for the Owner’s approval the types and extent of the pertinent tests.

b) All quality control tests shall be carried out according to the standards stated herein and prevailing international standards and codes.

c) Quality Control Tests are carried out with the following purposes, but not limited to:

- the quality of the component materials
- the processing of those materials into a hot bituminous concrete mix
- the hauling, placing and compaction of that mix on the facing of the dam

d) Prior to the works on site, suitability tests shall be carried out for all materials. These laboratory tests shall include:

- testing of all aggregates for suitability in hydraulic asphalt
- elaboration of adequate mix compositions and its behaviour under all aspects

e) At the batching plant, tests should be carried out to document and control:

- the grade and quality of the bitumen
- the grain-size distribution of the aggregates and filler
- the soundness and durability of the aggregates
- the moisture content of the aggregates at the time of mixing
- the temperature of the aggregates and of the bitumen entering the mixture
- the bitumen content
- the time of mixing

f) Quality control testing during construction is conducted to ensure that the as-mixed and as-placed product conforms to the requirements of the specification, reflecting the original design intent. The concerns are with:

- the laying and compaction temperatures
- the layer thickness and grade
- compaction procedures
- in-place densities
- percent air-voids after compaction
- in-place permeability and adhesion between layers and courses

g) During the period of the construction of bituminous concrete lining, quality control tests shall be carried out according to the following table. The following abbreviations apply:

QT Qualification Test

CSC Contractor’s Site Control

ECT Owner’s Control Test

1 evaluation necessary

2 for information only

3 only in special cases

Item	Specification	Bituminous Sand Mastic			Impervious Bituminous			Pervious Bituminous		
	ASTM	QT	CSC	ECT	QT	CSC	ECT	QT	CSC	ECT
AGGREGATES										
Quality Control		1			1			1		
Kind and Source		1			1			1		
Visual Check of Appearance		1	1		1	1		1	1	
Grading as delivered		1	2		1	2		1	2	
Single Properties		3	3	3	3	3		3	3	
BITUMEN										
Grade		1	2		1	2		1	2	
Properties	D2042, D70, D6	3	2		3	3	3	3	3	3
BITUMINOUS MIXES										
Grading of Aggregate Fraction		1			1			1		
Grading of Aggregate Mix		1	1	1	1	1	1	1	1	1
Bitumen Content		1	1	1	1	1	1	1	1	1
Extraction of Bitumen			3	3		2	1		2	1
Specific Gravity Mix		2		2	1	1	1			
Mass Density of Compacted Mix		2			1	1	1	1		2
Water Absorption under Vacuum					1	1	1			
Theoretical void content					1	1	1	1		2
Stripping Test										
Swelling Test					3	3		3	3	
Thickness of Specimen						1	1		1	1
Stability on Slopes		3			1			3		
Permeability of Impervious Layer						3	3			
Permeability of Pervious Layer								1		3
Compactability					1	2	2			
Flexibility					3					
Vlscosity of Grouting Mixes		3		3						

2.7 Records

Records, the number and type (e.g. impervious course, drainage course and leveling course) of batch and actual quantity of each material in each batch, shall be kept by the Contractor.

3 TUNNEL SEALING

3.1 General

Additional requirements, specifications and explanations for the tunnel sealing system in addition to the membrane sealing system specified in Chapter 1 of these Technical Specifications.

The power waterway lined with concrete lining cannot be characterized as tight lining system and required tightness will be achieved by the waterproof membrane. The membrane has to be installed between the primary support (shotcrete lining or rock mass) and the final concrete lining. The tightness will be achieved by installation of the tightening system around the whole tunnel – full-perimeter membranes including crown, walls and invert.

The tunnel sealing system with plastic membrane consists of the supporting layer, waterproofing layer and the protection layer. Spray-on membranes are not allowed.

The supporting layer has a function to separate the membrane from the installed shotcrete lining and/or the surrounding rock mass, allow free flow of grouting material during the high-pressure consolidation grouting and achieve stable and safe support for the waterproofing layer during operation and loading by the high internal water pressure.

The main waterproofing layer has the main function to tighten the tunnel in operation and must fulfill all structural and design requirements.

The protection layer is installed over the waterproofing membrane and has a function to protect the waterproofing foil from any mechanical damages during the construction time, especially by transport and reinforcement assembling.

3.2 Surface Preparation

Before the installation of the tunnel sealing system, the rock surface and also the shotcrete surfaces has to be prepared to form a stable and regular base (substrate) for the sealing system.

The following requirements must be met on the substrate before installation of the sealing system:

- Adequate dimensional stability and resistance
- Sprayed concrete quality min. C20/25 or adequate rock mass strength
- Maximal particle size of 8 mm
- Minimal thickness of 3 cm should be allowed in the design.

The geometric requirements to be met for the sprayed concrete or rock mass surface for use as the waterproofing system substrate:

- The ratio or the lowest unevenness length (l) to the greatest local unevenness depth (a) in the waterproofing substrate must be 10:1 minimum
- The angle between the joint of the apexes and the surface of the waterproofing substrate must be 30° maximum
- Radius of the curvature of the surface not less than 20 cm

These criteria apply to every scale. The most stringent criterion is to be met.

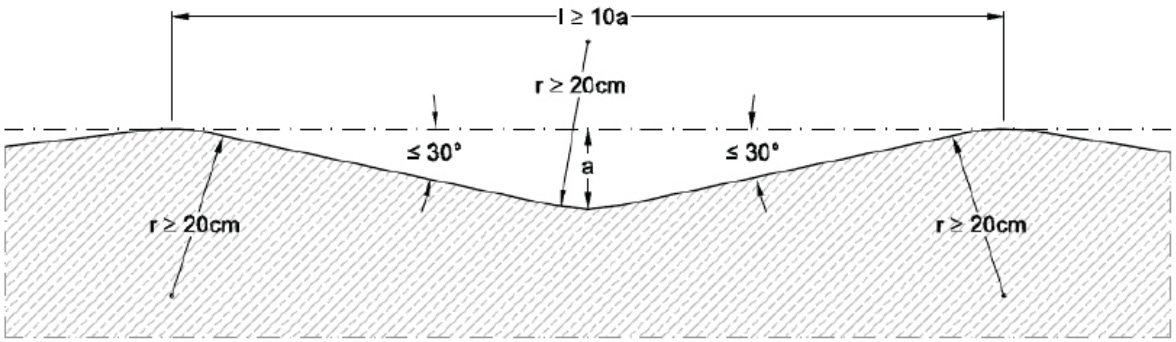


Figure: Permissible unevenness of the waterproofing substrate (Guideline Tunnel Waterproofing, Österreichische Bautechnik Vereinigung, Austria, 2015)

3.3 Membrane Material and Thickness

3.3.1 Supporting Layer

The supporting layer has two main functions: distribute grout around the perimeter and protects the waterproofing layer from puncture and damages during installation but especially during operation and loading by internal water pressure.

Two type of the supporting layers are available: geotextile or plastic geogrids. If geotextile is used it must be thin plastic foil-clad on the both sides. Only such prepared geotextile is able to distribute grout behind the geotextile during the high-pressure grouting process. Similar is with the plastic grids that also must have possibilities for free grout distribution.

Minimal geotextile weight ~~is 900g/m²~~will be defined in the detail design phase and has to be approved by the Owner.

3.3.2 Waterproofing Layer

The membranes that include materials as PVC (polyvinylchloride) and PO (polyolefin) are suggested. Use of any other material for the waterproofing layer has to be approved by the Owner.

The waterproofing layer is the main sealing element and must be able to take all loading acting on the membrane during the installation, construction and operation.

The mechanical properties of the membrane must guarantee adequate flexibility (low stiffness) to compensate without damage for any unevenness in the substrate. However, the membrane must be resistant and robust enough to absorb the anticipated level of mechanical stress and exposure without damage.

Mechanical effects, such as tensile stress in one or more axis, crushing and creasing, plus local and full area compressive and impact stress, all generate a risk of high material stress which in the worst case could cause damages and leaks in the sealing system. Therefore it is necessary to have materials with suitable robust-

ness and thickness. The minimal thickness of the sealing membrane is in the range of 2.0 – 3.0 mm and will exactly specified ~~with 3.0 mm~~in the detail design.

The minimal structural thickness of the foil is defined as a double value of the thickness of the maximal tensile crack occurring in the shotcrete and surrounding rock mass caused by on the membrane applied internal water pressure. This criterion suppresses penetration of the membrane in the crack and damage by the bending.

To facilitate the detection of any defects in the membrane, it must have a bright colored signal layer on the cavity side, which contrasts with the base material color.

The selected foil must be able to over-bridge the gap of 3 mm under the pressure perpendicular to the membrane of 15 bar.

The individual sheets are joined together by welding to form a two-dimensional tunnel seal. Weldability and the strength of the welds are therefore critical for the efficiency of the waterproofing system.

The waterproofing membrane installed on correctly designed, built and maintained tunnel should be capable of meeting all the essential requirements for the impermeability of the structure for an economical appropriate period of 100 years.

3.3.3 Protection Layer

~~Protection layer must be installed between the waterproofing membrane and reinforcement in the reinforced concrete sections. The protective layer must be able to absorb possible damages caused by reinforcement assembling and/or traffic direct on the waterproofing membrane. The protective layer is essential in the invert area of the tunnel.~~Protection layer for the invert~~,~~ may be installed between the waterproofing mem-brane and reinforcement in the reinforced concrete sections. The protective layer must be able to absorb possible damages caused by reinforcement assembling and/or traffic direct on the waterproofing membrane. The protection of the water-proofing layer is essential in the invert area of the tunnel. This could be achieved by a protective layer or by forbidding heavy equipment and sharp objects in those areas. In general the contractor has to insure that during the construction works no damages occur. In case of any damages the Contractor must repair them properly on his own costs.

The protective layer with a bright signal layer on one side in contrasting color to the base material must be made of the same material as a waterproofing layer. Minimal thickness inclusive the signal layer is 2.0 mm.

3.4 Installation and Fixation

The waterproofing system is not accessible for direct repairs after construction is completed and must be installed with a great care according to the specifications and design requirements. Follow-on operations such as reinforcement and concrete works must be coordinated with the requirements of the waterproofing system.

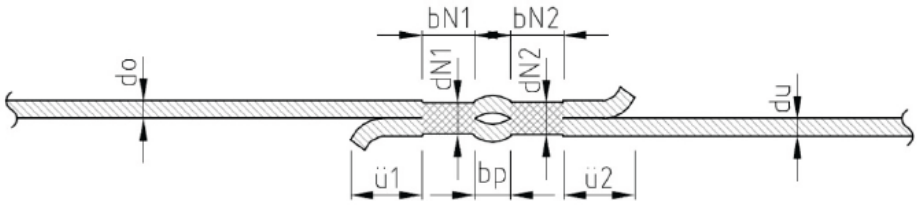
A project based installation plan must be presented by the installation contractor before construction begins and approved by the Owner.

The waterproofing membrane system is initially loose-laid and generally then joined by lap welds with a testing channel (double seams) to form a continuous watertight membrane area. If the weld cannot be lap seamed with the testing channel at some points (e.g. transitions, corners, patches and connections), a minimum 30 mm wide, manually hot air welded lap seam, without testing channel is permitted. The connection to the profiled water stop must be made by a minimum 30 mm wide lap seam without the testing channel.

Waterproofing sheets are heat welded by hot air or with a heating element. They are installed so that T-joints are located at minimum 20 cm centers. Cross joints are not permitted.

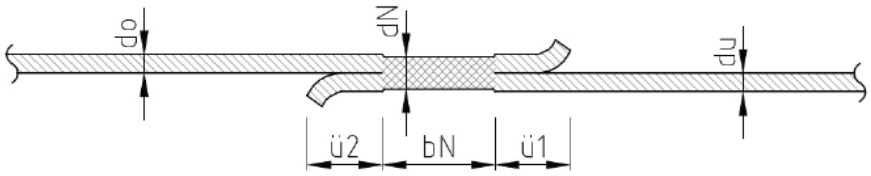
Installation aids – such as fixing elements or grouting connections – must not reduce the waterproof efficiency.

The membrane must be checked for imperfections before the inner shell concreting operation. All imperfections and folds must be eliminated before the inner shell is concreted.



do = Thickness of top sheet
du = Thickness of bottom sheet
ü1 = Lap at front
ü2 = Lap at back
bN1 = Width of part weld at front ≥: 15 mm
bN2 = Width of part weld at back ≥ 15 mm
bp = Width of testing channel ≥ 10 mm
dN1 = Thickness of part weld at front
dN2 = Thickness of part weld at back

Figure: Lap welded with testing channel ((Guideline Tunnel Waterproofing, Österreichische Bautechnik Vereinigung, Austria, 2015)



do = Thickness of top sheet
du = Thickness of bottom sheet
ü1 = Lap at front
ü2 = Lap at back
bN = Width of weld ≥: 30 mm
dN = Thickness of weld

Figure: Lap welded without testing channel ((Guideline Tunnel Waterproofing, Österreichische Bautechnik Vereinigung, Austria, 2015)

3.4.1 Leak Testing

The following methods should be used for continuous testing of the welds for the leak:

- Lap welds with testing channel — Compressed air test
- Lap welds without testing channel — Visual and scribing iron inspection

- Deposition welds — Visual and scribing iron inspection

The visual inspection covers the following characteristics in detail:

- Shape and evenness of the weld
- Central position and smooth edges
- Notches and groves in the weld
- Central position and smooth edges as beat-free as possible, for disposition welds
- Smooth non-streaky surface, for disposition welds.

Local irregularities, notches and grooves up to 0.2 mm deep with flat transition do not reduce the performance of the weld. Larger and more frequent irregularities and imperfections require appropriate remedial work.

Visual inspection of imperfections with a scribing iron or flat headed screwdriver could be carried out for spot checking on the weld from the edges for bond defects. The tool penetrates by defects.

3.4.2 Installation Procedure

Before installation begins the substrate must be accepted and approved under the requirements specified in Chapter 3.2~~3.2~~.

The supporting layer must fit tightly on the substrate with a minimal overlap of 10 cm. Lap joints must be hot air tack welded. If nails with washers are used for separate fixing their heads must be countersunk or covered to prevent damage to the watertight layer. The fixings are attached to the shotcrete layer with nail-guns, an alternative option is to fix them by drilling holes and using impact anchor fixings or screws. The positioning washers afterward act as mounting add for perforation-free welding of the waterproofing membrane.

The waterproofing membrane should be installed under as little tension as possible to fit tightly to the subbase surface and with little surplus material to avoid any creasing during concreting works. Therefore, if there are uneven areas in the substrate, the sheets should be fixed at its low points whenever possible. Following minimal requirements apply to the number of fixing points

- 3 Pcs/m² in the roof area (120° opening angle)
- 2 Pcs/m² in the abutments and side walls
- 1 Pcs/m² in the invert

The waterproofing membrane is manually hot air welded on the fixing washers. Material compatibility between washers and the membrane is essential. Washers usually consist of a plastic disk, with general outside diameter of 80 mm and thickness of 8 mm.

The protective layer in invert should be installed immediately after membrane installation and protects the membrane from mechanical damages by pedestrians, vehicles and reinforcement assembling. To prevent concrete infiltration the laps of the protection layer should be heat welded (tack welds are generally sufficient) to the waterproofing membrane.

3.5 High-pressure Consolidation Grouting through the Foil

The reinforcement could not bear the internal water load without cracking of the lining. The technically tight system is needed because of the water scarce and requirements of the tight water convey system. The design philosophy and reduction of the tensile cracks in the lining require high-pressure grouting behind the final lining and the tightening system. High-pressure grouting with pressures above 10 bar has to be foreseen.

The high-pressure consolidation grouting should be performed through the radially arranged boreholes in the rock mass. The borehole length will be defined in design and should be in length range of a radius to a diameter of the tunnel, dependent on the rock mass quality and the extent of karstification. The packer is situated in the concrete final lining allowing consolidation of the rock mass and filling of the gap between the shotcrete lining and the tightening membrane.

High-pressure grouting has to be performed through the prepared steel pipes. The pipes are fixed on the surrounding rock mass and tight connected with the foil. The pipes are used as guiding for the radial borehole drillings, and the grouting packers are set in this area. Because of the variable lining thickness, the pipes must be prepared as telescopic pipes allowing length adjustments.

The grouting procedure is described in the grouting chapter “TS-14 – Grouting” of these Technical Specifications.