Attachment No. 4 to Addendum No. 9

Attachment No. 6 to Addendum No. 3 (Revised)

6.3.2. Waterproofing

The waterproofing shall be provided at all inner surfaces of the sump, below base slab, on vertical rock surface of temporary shafts, construction joints and junction of tunnel with the shaft.

6.3.2.1. Waterproofing Scheme

1) On all inner surfaces of sump
   a) Synthetic resin emulsion-based adhesive
   b) Ultra-fast curing urethane resin spray waterproof, minimum thickness 2.0 mm
2) Below base slab
   a) Minimum 2 mm thick, "T" ribs pre-formed bonded PVC membrane.
3) On vertical rock surface of temporary shafts
   a) Minimum 2 mm thick, "T" ribs pre-formed bonded PVC membrane.
4) Junction of tunnel with shafts
   a) The Contractor shall submit the method statement for waterproofing of junction of tunnel with shafts to the Engineer for approval. It shall be ensured by the Contractor that there is no water leakage at the junction.
5) Construction joints of shafts
   a) The Contractor shall submit the method statement for waterproofing of construction joints of shafts to the Engineer for approval. It shall be ensured by the Contractor that there is no water leakage at the joints.
   b) Before placing new concrete against concrete already hardened concrete, the face of the old concrete shall be treated in accordance with Sub-Clause 7.3 of the Technical Specifications.
   c) Should such concrete be found to leak, the affected concrete shall be rectified by injection of resin material, breaking out and recasting, or other methods of sealing within the concrete, as approved by the Engineer.
   d) Inside rendering shall not be accepted as a method of making shafts watertight.
   e) Water stops used in the works shall be either elastomeric material or hydrophilic material or both. The water stops shall be installed so that they are securely held

in their correct positions whilst the concrete is being placed. No holes shall be made through any water stop except where provided for by the manufacturer.

6.3.2.2. Mechanical/Physical Properties of Material

1) Synesthetic resin emulsion based adhesive

This shall be two component solvent based epoxy primer for concrete surfaces. The technical specifications shall be as per manufacturer's literature. The Contractor shall propose the material to be used for Engineer's approval before use.

2) Ultra-fast curing polyurethane spray applied water proofing membrane.

Properties	**Minimum Values**	**Reference Code**
Tensile Strength	15 N/mm^2	JIS K6251 or equivalent
Shore A Hardness	80	JIS K6253 or equivalent
Elongations at Break	350%	JIS K6251 or equivalent
Tear Strength	40 N/mm^2	JIS K6252 or equivalent
Water Permeability	0.49 MPa	JIS K1404 or equivalent
Resistance to Alkali	No bulges, cracks or peels	JIS K5400 or equivalent
Resistance to Impact	No cracks or peels	JIS A6916 or equivalent
Gel Time	12-14 sec	-
Tack free Time	30-60 sec	-
Curing Time	120-180 sec	-
Solid Content	>99%	-

3) "T" ribs pre-formed bonded PVC membrane

a) Physical Properties

(i) Minimum 2.00 mm thick "T" ribs pre-formed bonded PVC membrane

(ii) Rolls of min 1.2m wide × 17 m long, with hot air welded, overlaps of minimum 100mm with a weld size of min 60mm comprising of a double weld with 2 weld lines of 20mm each with an air channel of 20mm in between so as to make up the total weld size of 60mm. Alternately, a hot air welding can be done using a single weld of 30 mm width.

(iii) spacing of the "T" ribs at 70-80mm c/c

(iv) Minimum height of the “T” ribs (including base layer membrane) 7 mm

(v) web thickness 1.3 mm

(vi) flange width 7mm

(vii) conforming to basement waterproofing protection to Grade 1 as per IS:16471-2017.

b) Functional Properties

The above specified waterproofing membrane shall meet following minimum requirements:

(i) Resist hydrostatic pressure of 70m head of water as per ASTM D5385.

(ii) Puncture Resistance of 1800 N (+ 5% to 10%) as per ASTM E154.

(iii) Peel Adhesion to concrete 880 N/m as per ASTM D 903.

(iv) Tensile strength 25 MPa (longitudinal direction), 18 MPa (transverse direction) as per ASTM D412.

(v) Percentage of Elongation 275% (longitudinal direction), 250% (transverse direction) as per ASTM D 412.

(vi) Shore A Hardness 85 as per ASTM D 2240

(vii) Tear resistance 150N(longitudinal), 120N(transverse) as per ASTM D1004.

(viii) Joint strength 1200N per 70 mm. as per ASTM D6392.

(ix) Resistance to fire-Class E as per EN-13501-1.

(x) Passes the test for behaviour after storage in aqueous solution as per DIN 16726.

4) Water Stop

Water stops shall be made of elastomeric strip or hydrophilic strip or both.

a) Elastomeric Strip

Water stop shall be made up of elastomeric strips having dumb bells at the ends and at the centre. Both the end dumb bells shall have holes along the length of the strip for proper fixing the strip with the reinforcement. Outside diameter of the dumb bell shall be 40±2mm. Diameter of the holes shall be 20±2mm. Width of the dumb bell strip shall be 350±2mm. Thickness of the strip at the center shall be 15±2mm.

Properties of material of water stop shall be as follows:

(i) Tensile strength: ≥ 12 MPa (as per DIN 53455)
(ii) Elongation at break (%) ≥ 300% (as per DIN 53455)
(iii) Shore A hardness = 100±2
(iv) Density = 1.4g/cc (±0.1g/cc) (as per ASTMD 792)
(v) Tear strength ≥ 12 MPa (as per DIN 53507A)

b) Hydrophilic Strip

Properties of material of hydrophilic strip of water stop shall be as follows:

Property	Value
Hardness	A45±5 (According to JIS K6253/ISO:48-4 or equivalent)
Tensile Strength	≥ 4.9 MPa (According to JIS K6251/ISO:527 or equivalent)
Elongation at Break	≥ 400% (According to JIS K6251/ISO:527 or equivalent)
Increasing rate of volume swelling	≥50%

Width and thickness of the strip shall be as per manufacturer's recommendation and approved by the Engineer.

6.3.2.3. Surface preparation

(a) Inner surfaces of sump

No waterproofing work shall commence until after obtaining approval from the Engineer. Application of waterproofing system shall only commence upon the completion of curing of concrete. All cracks on the exposed concrete surfaces of external structural members shall be effectively sealed before applying any waterproofing system. The Contractor shall ensure that surfaces to which waterproofing is to be applied, shall be clean, dust-free and dry and shall be

prepared fully in accordance with the manufacturer's recommendation. The waterproofing shall be carried out by the manufacturer's applicators strictly in accordance with the recommendations of the manufacturer and with accepted best practice in the trade.

(b) Vertical rock surface of temporary shafts

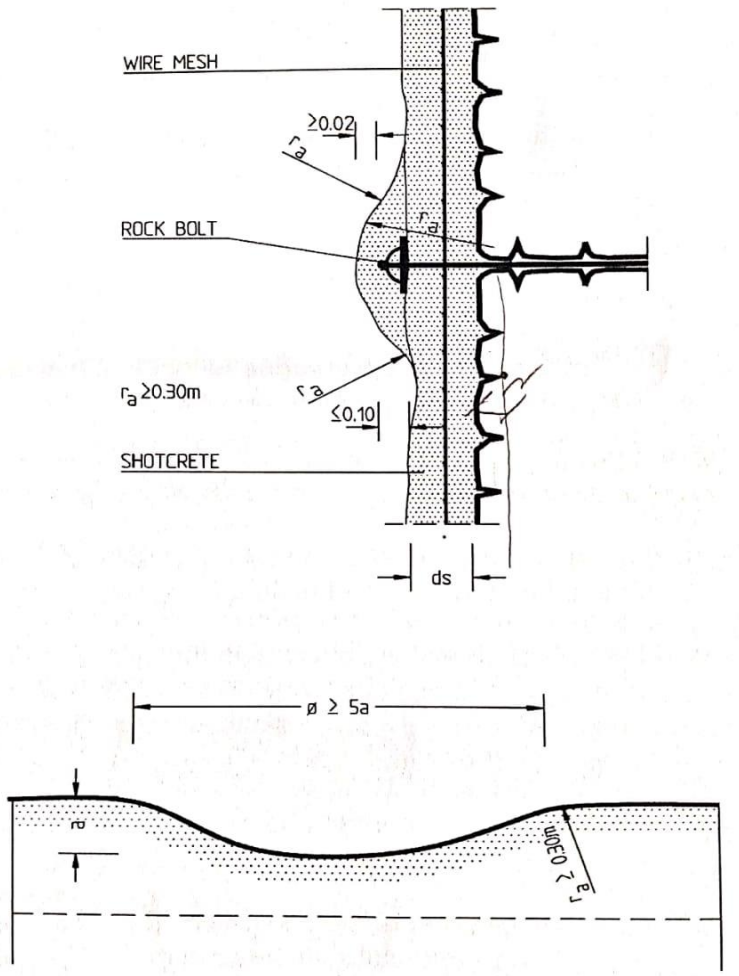
i) For the fixing of the waterproofing sheet, a minimum shotcrete cover of 50 mm to rock is required.

ii) Irregularities of the shotcrete lining surface shall be eliminated by means of additional shotcrete. The ratio of the diameter to depth of irregularities shall be not less than 5:1 (as shown in the figure below). Rounding at rock bolts (where applicable), etc. shall have a min. radius of 0.3 m.

iii) Protruding steel bars, wires, spacers, pipes etc. shall be cut off unless treated with additional shotcrete cover.

iv) Exposed steel parts such as rocks bolts shall be covered with shotcrete.

v) All shotcrete surface shall finally be smoothened with fine-graded shotcrete (round aggregates, grain size 0-8 mm), applied in a layer of 50 mm minimum thickness.



Requirements on surface irregularities of shotcrete

6.3.2.4. Fixing of waterproofing sheet

Waterproofing sheet shall be fixed on the rock surface as per recommendation of the manufacturer. The waterproofing sheet shall be laid with sufficient slack to prevent overstressing during concreting. However, excessive slack causing gap at the interface of rock and concrete shall be avoided. Adjacent sheets of waterproofing shall be joined by a double weld.

6.3.2.5. Field Trials

The Contractor shall carry out field trials to demonstrate the capabilities of the equipment, workmanship, materials and application methods under field conditions and submit the trial report containing the details and method statement to obtain approval from the Engineer.

6.3.2.6. Inspection

a) Ultra-fast curing urethane resin spray

The thickness of waterproofing membrane shall be checked for every 20 m^2 area of waterproofing. The thickness at the point of checking shall not be less than 2 mm.

b) T-ribs preformed bonded PVC membrane

All welded joints shall be tested in accordance with the table given below. Any joint that fails the test and require repair shall be marked with a permanent marker, at the time of the test.

Repairs and hand-welded joints shall be tested by hand-held vacuum chamber in accordance with the table below.

Parameter	**Test Method**	**Frequency**	**Pass Criteria**
Coverage	Visual	A visual inspection to be carried out continuously while the membrane is applied	100% coverage
Double welded seam joints	DIN 16726	Every Joint	Pressure drop not to be greater than 10% when a 2 bar pressure is applied for 10 minutes
Hand welding and repairs	ASTM D5641-94 (2006)	Every hand-weld and repair	Pressure drop not to be greater than 20% when a 0.3 bar pressure is applied for 10 minutes

Where tears, rips or defective joints in the sheet waterproof membrane are noted, these shall be repaired in accordance with manufacturer's recommendations. These shall be tested by hand-held vacuum chamber in accordance with the table above.

6.3.2.7. Water leakage criteria.

The daily water leakage in Shaft 2 and 3 after construction shall be within the values

given below:

Permissible daily leakage water quantity (l/m2) for a reference depth of	
10 m	Complete depth
0.2	0.1