



REPUBLIC OF LIBERIA
MINISTRY OF PUBLIC WORKS



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TECHNICAL SPECIFICATION

FOR

CONSTRUCTION OF COMMUNITY GRAVEL ROADS INCLUDING
EARTHWORKS, GRAVEL WEARING COURSE, ROAD DRAINAGE AND CROSS-
DRAINAGE (CIRCULAR REINFORCED CONCRETE CULVERTS)

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INTRODUCTION

This Technical Specification governs the construction of Community Gravel Roads and shall be read in conjunction with the Conditions of Contract, Bill of Quantities, Drawings, Scope of Works, and all other documents forming the Contract. It sets out the complete technical requirements for site clearance and preparation; earthworks and subgrade preparation and improvement; construction of the gravel wearing course; road drainage works; cross-drainage structures using circular reinforced concrete pipe culverts of 600 mm, 900 mm and 1200 mm diameter, including their concrete encasement, headwalls, wing walls and aprons; structural concrete and reinforcement; quality control and quality assurance; environmental, health, safety and traffic management; and measurement and payment for the Works, so that a single specification governs the complete carriageway and drainage system.

The materials, dimensions, tolerances, construction methods, testing frequencies, and measurement and payment provisions set out in this Specification are binding requirements of the Contract and shall govern the execution of the Works. Where a Drawing shows a dimension, level, alignment, or detail for a specific location that differs from a general provision of this Specification, the Drawing shall govern for that location, in accordance with the order of precedence set out in Section 1.4.

1 GENERAL

1.1 Scope and Purpose

This Specification covers the materials, workmanship, construction methods, quality control, and measurement and payment requirements for the construction of unsealed (gravel) community roads, comprising:

- Site clearance, preparation and setting out;
- Earthworks: excavation, embankment construction and subgrade preparation;
- Subgrade improvement and treatment where subgrade conditions are inadequate;
- Construction of the gravel wearing course (materials, placement, compaction and finishing);
- Road drainage works, including side drains, mitre drains, outlets and erosion protection;
- Cross-drainage works using circular reinforced concrete (RC) pipe culverts of 600 mm, 900 mm and 1200 mm diameter, including full concrete encasement of the culvert pipe lines, associated headwalls, wing walls, aprons and erosion protection;
- Structural concrete and steel reinforcement for drainage structures;
- Quality control and quality assurance testing;
- Environmental, health, safety and traffic management during construction; and
- Measurement, payment, inspection, testing, completion and acceptance of the Works.

The rate and amount given in the Contract for each Item shall represent the full cost of executing the whole of that Item as described in the Bill of Quantities and the rest of the Contract documents, including all work of whatsoever nature necessary or ancillary to its execution, unless a separate payment item is expressly provided.

1.2 Definitions and Abbreviations

Term	Definition
PE	Project Engineer (or Engineer's Representative) administering the Contract
MPW	Ministry of Public Works, Republic of Liberia
HDU / DSD	Highway Design Unit / Design and Supervision Division of MPW
C-GRIP	Community Gravel Roads Improvement Program
BOQ	Bill of Quantities
OMC / MDD	Optimum Moisture Content / Maximum Dry Density

Term	Definition
CBR	California Bearing Ratio
PI	Plasticity Index
FM	Fineness Modulus
RCP	Reinforced Concrete Pipe (culvert)
ROW	Right-of-Way
QA/QC	Quality Assurance / Quality Control
AASHTO	American Association of State Highway and Transportation Officials
ASTM	ASTM International (American Society for Testing and Materials)
BS / BS EN	British Standard / British Standard, European Norm
ORN 31	TRL Overseas Road Note 31 – Guide to the Structural Design of Bitumen-Surfaced Roads (used here for its low-volume/gravel-road material guidance, widely applied in West Africa)
HEC-14 / HEC-22	FHWA Hydraulic Engineering Circulars for culvert energy dissipation / storm drainage design

1.3 Reference Standards and Codes

The following standards, or their current editions, apply except where varied by this Specification or the Drawings. Where a Liberian or ECOWAS national standard exists and conflicts with an international standard cited below, the national standard shall govern unless the PE directs otherwise.

- AASHTO M145 – Classification of Soils and Soil-Aggregate Mixtures for Highway Purposes
- AASHTO T87/T88/T89/T90 – Particle-size analysis and Atterberg limits (liquid limit, plastic limit, PI) of soils
- AASHTO T99 (Standard Proctor) and T180 (Modified Proctor) – Moisture-density relations of soils
- AASHTO T191 / T310 – Field density by sand-cone method / nuclear method
- AASHTO T193 – California Bearing Ratio (CBR) of laboratory-compacted soils
- AASHTO T27 – Sieve analysis of fine and coarse aggregates
- AASHTO T96 – Resistance to degradation of coarse aggregate (Los Angeles Abrasion)

- AASHTO T176 – Sand equivalent of soils and fine aggregate
- AASHTO M170 / ASTM C76 – Reinforced concrete culvert, storm drain and sewer pipe
- ASTM C150 – Standard Specification for Portland Cement
- ASTM C33 – Standard Specification for Concrete Aggregates
- ASTM C39 – Compressive strength of cylindrical concrete specimens
- ASTM C143 – Slump of hydraulic-cement concrete
- ASTM A615 / BS 4449 – Deformed and plain carbon-steel bars for concrete reinforcement
- BS 8110 / BS EN 1992 (Eurocode 2) – Structural use of reinforced concrete (design reference)
- BS EN 1916 / BS 5911 – Concrete pipes and fittings (alternative reference where BS-based pipes are supplied)
- TRL Overseas Road Note 31 (ORN 31) – Guide to structural design and material selection for low-volume/gravel roads in tropical and sub-tropical countries
- TRL Overseas Road Note 20 – Maintenance management for district engineers (gravel road maintenance reference)
- FHWA Hydraulic Engineering Circular No. 14 (HEC-14) – Hydraulic design of energy dissipators for culverts and channels
- FHWA Hydraulic Design Series No. 5 (HDS-5) / HEC-22 – Hydraulic design of highway culverts / storm drainage
- ILO Code of Practice on Safety and Health in Construction; national OSH and environmental regulations of Liberia (EPA Liberia environmental guidelines)

1.4 Order of Precedence of Documents

In the event of ambiguity or conflict between this Specification and other Contract documents, the order of precedence shall be as stated in the Conditions of Contract; where not stated, the order shall be:

- (i) Contract Agreement and Addenda,
- (ii) Conditions of Contract,
- (iii) Drawings,
- (iv) This Specification,
- (v) Bill of Quantities,

- (vi) Other documents forming the Contract. The Contractor shall notify the PE in writing of any discrepancy before proceeding with the affected work.

1.5 Program of Works

The program of work required under the General Conditions of Contract shall be submitted to the PE not later than 7 days after the Contractor is issued the Notice to Proceed. Approval of any program by the PE carries no contractual significance beyond confirming that the PE would be satisfied were the work executed accordingly; it does not limit the PE's right to instruct variation of the program, or the Contractor's right to claim delay or disruption in terms of the Conditions of Contract. Should the Employer request and the Contractor undertake, acceleration of the Works, payment for acceleration shall only be made where agreed beforehand in writing.

2 WORKMANSHIP, QUALITY CONTROL AND CONTRACTOR'S OBLIGATIONS

The Contractor shall produce work conforming in quality and accuracy of detail to the Specification and Drawings, and shall, at its own expense, institute a quality control system with experienced engineers, foremen, surveyors and materials technicians, together with the transport, instruments and equipment needed to ensure adequate supervision and positive control of the Works. The cost of all Contractor supervision and process control, including routine testing, shall be deemed included in the rates tendered for the related items of work, except where separate payment for specific tests or testing equipment is expressly provided elsewhere in this Specification.

Unless otherwise instructed, the Contractor shall obtain the PE's approval for each layer of the Works — embankment, subgrade, or gravel wearing course — before proceeding with the subsequent layer, and shall give the PE reasonable notice to allow inspection. Where a test is required to verify compliance, the Contractor shall program the Works to allow the PE sufficient time to carry it out; unless instructed otherwise, the Contractor may proceed before test results are available but shall re-execute any work subsequently shown non-compliant. Approval by the PE at any stage does not relieve the Contractor of its obligations under the Contract.

The Bill of Quantities sets out estimated quantities used for comparing Tenders and awarding the Contract; only the actual quantities of work done, measure in accordance with this Specification, will be paid for, and billed quantities may be increased or decreased in accordance with the General Conditions of Contract.

3 SITE CLEARANCE, PREPARATION AND SETTING OUT

3.1 Site Clearance and Grubbing

This work consists of clearing, grubbing and disposing of all trees, stumps, roots, brushwood, vegetation, structures, fencing and other obstructions within the road reserve and at borrow pits, drainage lines and construction camp areas, to the limits shown on the Drawings or as instructed by the PE.

- Trees and stumps within the roadbed, side-drain lines, and within 1.0 m of the top edge of cut or toe of fill (unless retained for slope stabilization on the PE's instruction) shall be removed complete with roots to at least 500 mm below finished formation or natural ground level, whichever is lower.
- Topsoil within the earthworks footprint shall be stripped to its full depth (typically 150–300 mm, or as found) and stockpiled separately for later use in erosion control, slope dressing or reinstatement, unless otherwise directed.
- Cleared organic material and debris shall be removed from the Site and disposed of at locations approved by the PE and, where applicable, by the Environmental Protection Agency (EPA) of Liberia; burning shall only be undertaken with the PE's written permission and in compliance with local fire and environmental regulations.
- Existing culverts, headwalls, pavement, or other structures to be removed shall be dismantled, removed and disposed of or salvaged as directed, in accordance with Section 8.2.

3.2 Setting Out

The Contractor shall set out the Works from control points, benchmarks and reference pegs established or verified jointly with the PE prior to commencement, and shall protect and maintain all survey monuments, reference pegs, and benchmarks for the duration of the Contract, replacing any disturbed or destroyed at its own cost. Centerline pegs shall be placed at maximum 25 m intervals on straights and 10–20 m intervals on curves; with offset reference pegs placed clear of construction traffic. Cross-sections shall be taken at each chainage point and at all changes of grade, culvert locations, and structure sites, and agreed with the PE before earthworks commence. As-built survey records of all setting-out and level data shall be maintained and submitted to the PE.

4 EARTHWORKS

4.1 General

Earthworks comprise excavation of unsuitable material, roadway and borrow-pit excavation, formation of embankments, and preparation of the subgrade to the lines, levels, grades, cross-sections and dimensions shown on the Drawings or as directed by the PE. All earthworks shall be executed in the dry season or during periods of favorable weather to the greatest extent practicable, given Liberia's high seasonal rainfall (typically exceeding 2,500 mm/year in coastal counties); the Contractor shall program earthmoving activities accordingly and shall provide temporary drainage, dewatering, and erosion-control measures at cuttings, embankments and stockpiles at all times, including during the rainy season if the program requires works to continue.

4.2 Excavation

- Roadway excavation: excavation of material of any classification (soil, weathered rock, laterite, or rock requiring mechanical breaking) within the road prism to the lines and levels shown, including disposal, stockpiling of suitable material for reuse, and trimming of cut slopes to the design batter (typically 1:1 to 1:1.5 in residual/lateritic soils, or as directed based on geotechnical conditions).
- Borrow excavation: excavation of approved fill or gravel-wearing-course material from designated or Contractor-sourced borrow areas, subject to PE approval of the source, haul route, and rehabilitation plan for the borrow pit on completion.
- Unsuitable material: material classified by the PE as unsuitable for fill (organic soil, highly plastic clay with PI greater than 50, material with excessive moisture content that cannot be economically dried, or material containing deleterious matter) shall be excavated to the depth directed and removed to spoil, and replaced with approved material compacted in accordance with Section 4.3.
- Excavated material suitable for fill shall be classified, stockpiled separately by type where necessary, and reused in embankment or gravel-wearing-course construction insofar as practicable; waste material and surplus suitable material shall be disposed of at locations approved by the PE, in a manner that does not obstruct natural drainage or create erosion risk.

4.3 Embankment Construction

- The foundation for embankments shall be cleared, grubbed and, where the natural ground slope exceeds 1:4, benched in steps not exceeding 300 mm high before fill placement, to key the embankment into the existing ground and prevent slippage.
- Fill material shall be free of vegetation, roots, organic matter, and stones larger than two-thirds of the compacted layer thickness (and in any case not exceeding 150 mm), and shall have a soaked CBR of not less than 5% at 95% AASHTO T99 (Standard Proctor) density unless a lower embankment zone is specifically permitted by the Drawings.
- Fill shall be placed and compacted in horizontal layers not exceeding 200 mm loose thickness (150 mm within 300 mm of finished subgrade level), moisture-conditioned to within -2% to $+2\%$ of optimum moisture content (OMC), and compacted to a minimum of 95% of maximum dry density (MDD) per AASHTO T99 for embankment body, and 100% MDD for the top 300 mm (upper subgrade zone) beneath the gravel wearing course.
- Each layer shall be tested and approved by the PE before the next layer is placed, in accordance with the testing frequencies in Section 10.
- Embankment side slopes shall be constructed to the batters shown on the Drawings (typically 1:1.5 to 1:2 in fill, flatter in erodible soils), trimmed to a uniform surface, and protected against erosion in accordance with Section 7.

4.4 Subgrade Preparation

- Where the road is constructed on natural ground (no embankment fill required), the top 300 mm of the existing subgrade shall be scarified, moisture-conditioned and re-compacted to not less than 100% AASHTO T99 MDD.
- The finished subgrade surface shall be trimmed to line, level and cross-fall (minimum 3% cross-fall, or as shown on the Drawings) to shed water to the side drains and prevent ponding prior to placement of the gravel wearing course.
- Surface tolerance of the finished subgrade shall be within ± 20 mm of design level under a 3 m straightedge, and cross-fall shall be within $\pm 0.5\%$ of design.
- No gravel wearing course material shall be placed on a subgrade that has not been inspected, tested, and approved in writing by the PE.

4.5 Compaction and Tolerance Summary

Layer	Compacted Layer Thickness (max)	Compaction (% AASHTO T99 MDD)	Moisture Range	Level Tolerance
Embankment (body)	200 mm	$\geq 95\%$	OMC – 2% to +2%	± 30 mm
Embankment (upper 300 mm) / Subgrade	150 mm	$\geq 100\%$	OMC – 2% to +2%	± 20 mm
Gravel wearing course	150 mm compacted	$\geq 95\%$ AASHTO T180 (Modified)	OMC – 1% to +2%	± 15 mm

5 SUBGRADE IMPROVEMENT AND TREATMENT

Where the in-situ or constructed subgrade fails to achieve a minimum soaked CBR of 5% at 100% AASHTO T99 MDD (or the design CBR stated on the Drawings), or exhibits a Plasticity Index greater than 20, expansive behavior, or a California Bearing Ratio swell exceeding 2%, the PE may direct one or more of the following treatments, the extent and method of which shall be agreed with the PE and paid for as a separate BOQ item unless included in the Contract as a provisional sum:

- Undercutting and replacement: removal of unsuitable subgrade material to a depth of 300–600 mm (as directed) and replacement with approved granular material compacted per Section 4.3, with a geotextile separation layer (non-woven, minimum 150 g/m², or as specified) placed at the interface where the underlying material is soft, saturated, or fine-grained, to prevent contamination and pumping of fines into the improved layer.
- Mechanical stabilization: blending of the subgrade with imported granular material to improve grading and reduce plasticity, compacted to the requirements of Section 4.3.
- Capping layer: provision of an additional granular capping layer (150–300 mm compacted thickness, minimum soaked CBR 15% at 95% AASHTO T180) between a weak subgrade and the gravel wearing course, in lieu of full undercutting, where directed by the PE based on the pavement design.
- Drainage improvement: installation of subsoil drains, or lowering of the water table locally by open ditches, where a high water table is the cause of subgrade weakness (see also Section 7).

6 GRAVEL WEARING COURSE

6.1 Material Sources and Approval

Gravel wearing-course material shall be obtained from sources (borrow pits/quarries) approved in writing by the PE prior to use. The Contractor shall submit representative samples of each proposed source, together with full test results (grading, Atterberg limits, CBR, compaction), not less than 21 days before the material is required, for the PE's approval. Where the source or quality of material changes during the Contract, new samples and test results shall be submitted and approved before the changed material is used. Approval of a source does not relieve the Contractor of responsibility for the quality of material actually supplied.

6.2 Material Requirements

Gravel wearing-course material shall consist of natural gravel, lateritic gravel, crushed stone, or an approved blend, free of organic matter, roots, and deleterious substances, and shall conform to the following requirements unless varied on the Drawings to suit an approved local material with a demonstrated satisfactory performance record:

Property	Test Method	Requirement
Maximum particle size	AASHTO T27	37.5 mm (or two-thirds of compacted layer thickness, whichever is less)
Grading — % passing 50 mm	AASHTO T27	100
Grading — % passing 20 mm	AASHTO T27	60 – 90
Grading — % passing 5 mm	AASHTO T27	30 – 65
Grading — % passing 2.0 mm	AASHTO T27	20 – 50
Grading — % passing 0.425 mm	AASHTO T27	10 – 30
Grading — % passing 0.075 mm (fines)	AASHTO T27	5 – 20
Liquid Limit (LL)	AASHTO T89	≤ 35% (≤ 45% in areas of low rainfall, PE discretion)
Plasticity Index (PI)	AASHTO T90	6 – 20 (minimum 6 to bind material; maximum 20 to limit)

Property	Test Method	Requirement
		swell/slipperiness)
Shrinkage Product (LS × % passing 0.425 mm)	AASHTO T92 / local method	≤ 240
Soaked CBR at 95% AASHTO T180 MDD	AASHTO T193	≥ 30% (4-day soak)
Los Angeles Abrasion (coarse fraction)	AASHTO T96	≤ 50%

Where naturally occurring lateritic gravel does not meet the grading or plasticity requirements above but has a demonstrated satisfactory in-service performance on comparable roads in the area, the PE may approve its use, provided the material meets the minimum soaked CBR and is free of organic matter and oversize material.

6.3 Placement and Spreading

- Gravel wearing-course material shall not be placed until the underlying subgrade (or capping layer) has been inspected and approved by the PE.
- Material shall be transported, tipped, and spread by grader (or approved equivalent) in uniform layers, avoiding segregation of coarse and fine particles; segregated material (visible concentrations of oversize stone or fines) shall be removed and replaced or reworked to achieve uniform grading before compaction.
- Where the total compacted thickness exceeds 150 mm, the material shall be placed and compacted in two or more layers not exceeding 150 mm compacted thickness each.
- Material shall not be placed in rain, or on a wet or muddy subgrade, without the PE's written permission.

6.4 Moisture Conditioning

Gravel material shall be conditioned, by watering or aeration/drying as necessary, to a moisture content within -1% to +2% of the OMC determined by AASHTO T180 (Modified Proctor) immediately prior to compaction. Water shall be applied uniformly by an approved water cart or bowser fitted with a spray bar; ponding, rutting, or washing of fines from the surface shall be avoided. Where the natural moisture content is excessive due to rain, compaction shall be deferred, and the material harrowed/aerated, until the moisture content is within the specified range.

6.5 Compaction

Each layer shall be compacted using an approved vibratory or smooth-wheeled roller (or pneumatic-tired roller for the final finishing pass) to achieve not less than 95% of the maximum dry density determined by AASHTO T180 (Modified Proctor), tested at the frequency set out in Section 10. Compaction shall proceed from the edges towards the center on straight sections and from the low side to the high side on super elevated curves, with sufficient roller passes to achieve a tight, closed surface free of loose material, raveling, or roller marks. Compaction shall not be carried out when the layer is too wet to achieve the specified density without displacement (“checking”/ shoving), nor when it has dried below the acceptable moisture range.

6.6 Thickness, Tolerances, Camber/Cross fall and Longitudinal Profile

- Minimum compacted thickness of the gravel wearing course shall be 150 mm, or as shown on the Drawings based on the design traffic and subgrade CBR, and shall not be less than 125 mm at any point (local tolerance).
- Camber/cross fall on straight sections shall be 4–6% (recommended 5%) from the crown to each edge to promote rapid shedding of surface water, given Liberia's high rainfall intensities; on super elevated curves, cross fall shall follow the design super elevation shown on the Drawings, subject to a maximum of 7%.
- Surface level tolerance shall be within ± 15 mm of design level under a 3 m straightedge, both longitudinally and transversely, with no isolated deviation exceeding 20 mm.
- Longitudinal profile shall be free of humps, depressions, or corrugations exceeding 15 mm under a 3 m straightedge; ruts or depressions capable of retaining water (birdbaths) shall not be permitted at Practical Completion.
- Edge of gravel wearing course shall be constructed neatly to line, with a positive edge to prevent uncontrolled edge-break, and shall tie into the shoulder/verge at the level shown on the Drawings.

6.7 Surface Finishing

On completion of compaction, the surface shall be given a final light rolling with a pneumatic-tyre roller (where available) to seal the surface and close any residual cracks, and shall be free of loose material, ridges, and roller-wheel marks. Any areas of segregation, insufficient compaction, or non-conforming level identified by the PE shall be scarified to the full layer depth, reworked, re-moisture-conditioned and re-compacted at the Contractor's expense before acceptance. The finished wearing course shall be kept free of standing water and shall be protected from damage by construction traffic until Practical Completion, in accordance with Section 14.

7 ROAD DRAINAGE WORKS

7.1 Side Drains

- Open side (table) drains shall be excavated along both sides of the road, or on the upslope side where the road runs along a hillside, to the line, level, shape, and dimensions shown on the Drawings, generally trapezoidal or V-shaped with a minimum invert width of 300 mm, side slopes not steeper than 1:1.5 (flatter in erodible soils), and a minimum depth of 300 mm below finished subgrade/shoulder level, increased where required by the hydraulic design.
- Side-drain longitudinal gradient shall follow the road profile subject to a minimum self-cleansing gradient of 0.5%; where the natural ground is flatter than 0.5%, the drain invert shall be graded independently to achieve the minimum gradient, discharging to the nearest natural watercourse or approved outfall.
- Side drains shall be kept clear of spoil, vegetation, and construction debris at all times during construction and shall be functional (free-draining) at Practical Completion.

7.2 Mitre (Turnout) Drains and Cross-Fall Relief

- Mitre drains shall be provided to lead water out of the side drains and away from the road at intervals not exceeding 50 m on grades up to 5%, reducing to 25 m on grades exceeding 5%, and at all low points, or as shown on the Drawings.
- Mitre drains shall be excavated at an angle of approximately 30–45° to the side drain, sized to convey the design discharge without erosion, and discharge to natural ground, vegetated buffer strips, or approved watercourses at a level below the road formation, avoiding discharge directly onto adjoining cultivated land or property without the landowner's and PE's agreement.

7.3 Outlets and Erosion Protection

- All drain and culvert outlets shall be provided with erosion protection appropriate to the discharge velocity and outlet soil conditions: grassing/turfing for low-velocity outlets, stone pitching or rip-rap (150–300 mm nominal stone size, minimum 300 mm thick) for medium-velocity outlets, and stilling basins or energy dissipators designed in accordance with FHWA HEC-14 for high-velocity/high-discharge outlets as shown on the Drawings.
- Scour checks (stone-pitched or gabion check dams) shall be provided in side drains and mitre drains on gradients exceeding 4%, spaced to limit the drop in invert level between checks to approximately 300–500 mm, to control erosive velocities.

- Cut and fill slopes shall be protected against erosion by turfing, grassing, or approved slope-protection measures immediately following completion of earthworks in that section, and before the onset of heavy rainfall where practicable.

7.4 General Requirements for Drainage Structures

All drainage structures (culverts, causeways, and associated works) shall be located, sized, and constructed as shown on the Drawings or as directed by the PE, based on the catchment hydrology of each crossing. Cross-drainage requirements for circular RC pipe culverts are set out in Section 8.

8 CROSS-DRAINAGE STRUCTURES — CIRCULAR REINFORCED CONCRETE PIPE CULVERTS (600 mm, 900 mm AND 1200 mm DIAMETER)

This Section sets out the complete requirements for the supply and installation of circular reinforced concrete (RC) pipe culverts of 600 mm, 900 mm and 1200 mm internal diameter, together with the associated excavation, bedding, backfilling, concrete encasement, headwalls, wing walls, aprons, and erosion protection.

The work under this Section comprises:

- Removal of existing drainage structures where indicated;
- Excavation for structure foundations;
- Backfilling of structures;
- Supply and installation of reinforced concrete pipe culverts of 600 mm, 900 mm and 1200 mm diameter;
- Full concrete encasement of all culvert pipe lines in Class 25 (C25) concrete, 203 mm (8 inch) minimum thickness;
- Supply, placing and compacting of stone-mix-with-sand (or crushed-stone) bedding for culvert foundations;
- Supply, bending and fixing of steel reinforcement for headwalls, wingwalls, and aprons;
- Supply of materials, casting/construction and curing of concrete for headwalls, wingwalls, and aprons;
- Construction of inlet and outlet protection (aprons, rip-rap, cut-off walls) and erosion control;
- Provision of dewatering, cofferdams, and construction of detours/water diversions where required.

8.1 Removal of Existing Structures

This work consists of dismantling, removing and disposing of, or salvaging (wholly or in part), existing drainage structures (culverts and bridges) which are to be replaced, as indicated on the Drawings or as instructed by the PE. Serviceable salvaged material identified by the PE shall be stockpiled at a location directed for reuse or return to the Employer; all other material shall be disposed of at an approved location.

8.2 Excavation for Structures

This work consists of excavation in any material for the foundations of structures, disposal of excavated material, temporary works to protect the stability and safety of excavated foundations, and pumping and bailing of water from foundations. Excavation for structures may involve the use of cofferdams; the cost of cofferdams and other temporary works is not paid separately and shall be deemed included in the Tender Sum. Work shall be carried out at the locations and to the lines, levels, grades and dimensions shown on the Drawings, or as directed by the PE.

8.2.1 Excavation Methods

- The Contractor shall notify the PE before commencing excavation of foundations so that cross-sections, elevations and measurements of undisturbed ground may be taken.
- Foundations shall be excavated to the lines, grades and elevations shown on the Drawings or as directed; the PE may order changes as deemed necessary to provide a secure foundation, the elevations shown being approximate only.
- Excavation beyond the required level shall be backfilled by the Contractor, at its own expense, with sand or other approved material placed in layers and thoroughly compacted, back to foundation bottom level.
- Excavations shall be sufficiently large to provide the necessary working space, shuttering, and other temporary works.
- Boulders, roots and other objectionable material encountered shall be removed; the excavated foundation shall be cleared of loose material and cut to a firm surface.
- The final 100 mm of excavation under footings or abutments shall be deferred so the foundation bottom is not exposed until immediately before concrete or masonry work begins.
- The Contractor is solely responsible for the safety and stability of the excavation and shall provide all protective supports, bracing and shoring required.
- Excavated material classified as suitable for fill shall be stockpiled; waste material and surplus suitable fill shall be disposed of outside the Site limits.
- No footing, bedding material, or structure shall be placed in any foundation until the PE has inspected and approved the depth of excavation and the foundation material.

8.2.2 Poor Foundation Material

Where, in the PE's opinion, the bottom of an excavated foundation is soft or otherwise unsuitable, the Contractor shall remove the unsuitable material and fill with sand or blinding concrete as directed by the PE, placed as specified for backfilling in Section 8.3.

8.2.3 Pumping and Bailing

Foundations shall be kept free of water at all times during construction. Pumping and bailing from any foundation shall be carried out to preclude the movement of water through or alongside any concrete being placed.

8.2.4 Cofferdams

“Cofferdam” or “artificial island” denotes any temporary or removable structure constructed to hold surrounding earth, water, or both, out of the excavation, including earth dikes, timber cribs, sheet piling, removable steel sheets and all bracing. The Contractor shall, upon request, submit drawings of its proposed cofferdam construction, but remains fully responsible for the adequacy of design for strength, stability, and the safety of persons working therein.

- Cofferdams shall be constructed to protect newly cast concrete from sudden rising water and to prevent foundation erosion.
- The natural stream bed adjacent to a cofferdam shall not be disturbed without the PE's permission; any adjacent excavation shall be backfilled to original ground/stream-bed level to the PE's satisfaction, and no material shall be disposed of within the stream area.
- Cofferdams shall be removed after completion of the structure without disturbing or marring the finished work, unless the PE orders that part or all be left in place, which shall not entitle the Contractor to additional payment.
- Where dewatering before placing concrete is judged impossible, the PE may require a concrete foundation seal to be placed as directed; the foundation shall then be de-watered and the footing placed.
- Where piles are driven inside a cofferdam that cannot be de-watered before concreting, excavation may be extended below design level to allow for swell during driving; material rising above design level shall be removed.

8.2.5 Measurement and Payment — Excavation for Structures

Item No.	Description	Unit
8.2-A	Excavation of Foundations for Structures — measured and paid per m ³ , at the Contract unit rate, full compensation for all excavation for structures including supply of materials, labour, equipment, tools and incidentals, protective supports, construction/removal of cofferdams, de-watering and disposal of materials.	m ³

8.3 Backfilling of Structures

Backfilling of constructed concrete culverts (600 mm, 900 mm and 1200 mm), and of foundation walls/beddings where applicable, shall be carried out in accordance with the Drawings and BoQ, and includes backfilling and shaping the approaches of constructed structures to the required length as directed by the PE. Backfilling over an encased culvert line shall not commence until the concrete encasement described in Section 8.4.3 has cured in accordance with Section 9.3.6.

- Backfill material shall consist of approved granular material, compacted to a minimum dry density of 95% AASHTO T99 (or as otherwise stated for the relevant zone), placed in layers not exceeding 150 mm loose thickness, each layer compacted with an appropriate compactor in a manner that does not damage the structure; once sufficient cover is achieved, compaction of backfill and approaches shall proceed with a pedestrian roller or as directed. Material shall be watered to optimum moisture content where necessary.
- Where backfilling follows masonry or concrete work, it shall not commence until 14 days after the cement-bound masonry or concrete walls were constructed/cast, to allow proper curing.
- Stone filters behind walls shall be placed as specified on the Drawings and as directed by the PE.
- All excavated foundations shall be backfilled around the permanent structure to original ground level; no backfilling shall be placed against any structure without the PE's prior permission. Protective supports, bracing or shoring shall be removed progressively as backfilling proceeds, to prevent caving-in.
- Sand backfill shall be placed and thoroughly compacted in layers not exceeding 150 mm.
- The back of abutments, wing walls and return walls with weep holes shall be provided with a vertical layer of granular filter material approximately 450 mm thick.
- Backfill shall be placed to approximately equal height on each side of the structure; where conditions require appreciably higher backfilling on one side, additional material shall not be placed until the PE, satisfied the structure can withstand the resulting pressure, gives permission. Backfill/embankment fill shall not be placed behind bridge or box-culvert walls until the superstructure or top slab has been cast and cured; backfill behind abutments held at the top by the superstructure shall be carried up simultaneously behind opposite abutments and side walls, always maintaining a horizontal berm of compacted material at least equal in width to the height of the abutment/wall being backfilled.

Measurement and Payment — Backfilling

Item No.	Description	Unit
8.3-A	Backfill of Structure — measured and paid per m ³ of net compacted volume (after adjustment for the space occupied by the structure), on completion of compaction to smooth finish/shape, cleaning of Site, and removal of surplus material, and PE approval.	m ³

8.4 Supply and Installation of Circular Reinforced Concrete Culvert Pipes: 600 mm, 900 mm and 1200 mm

This Item consists of supplying the concrete pipe rings and laying and jointing the rings; excavation, backfilling, culvert headwalls and wing walls, and aprons are not included in this Item and are measured separately under Sections 8.2, 8.3, and 8.6/8.7 respectively.

- Pipe rings shall be reinforced concrete with ogee (HE and SHE) joints, of concrete Class 30 (minimum 28-day compressive strength 30 MPa), cured at least 28 days, manufactured on Site where possible; where not manufactured on Site, the supplier shall be approved by the PE and shall supply pipes conforming to AASHTO M170 / ASTM C76 (or BS EN 1916/BS 5911 where a BS-based product is proposed).
- Rings shall be in standard lengths of 1 m. Damaged pipes shall not be accepted and, where already installed, shall be removed from the line.
- The culvert gradient, including the outlet, shall be a minimum of 2%, or as required by the hydraulic design shown on the Drawings, whichever is steeper.
- Culvert joints shall be sealed with mortar of mix ratio 1:2 (cement: sand).
- Surplus material shall be disposed of at locations approved by the PE.
- Where the culvert crosses a trafficked road, excavation of trenches and laying of pipe rings shall be carried out in stages to allow vehicles to pass, with adequate traffic signs, flagmen and temporary crossing provided in accordance with Section 11.3. Installation shall start, wherever possible, from the outlet side.

8.4.1 Minimum Cover, Alignment, Grade and Structural Requirements

Parameter	Requirement
Minimum cover over crown (under carriageway)	450 mm for 600 mm diameter RCP; 600 mm for 900 mm and 1200 mm diameter RCP; or as designed for heavier construction traffic loading. Not less than 300 mm under

Parameter	Requirement
	shoulders/verges outside the wheel path, subject to PE approval
Pipe class	Class 30 concrete minimum (30 MPa, 28-day cylinder strength); higher class where cover is less than the minimum above, as designed
Concrete encasement	All culvert lines (600 mm, 900 mm and 1200 mm) shall be fully encased in Class 25 (C25) concrete, 203 mm (8 inch) minimum thickness around the full pipe circumference — see Section 8.4.3
Minimum longitudinal gradient	2% (self-cleansing minimum); increased where required by the hydraulic design for the specific catchment shown on the Drawings
Alignment	Straight between headwalls unless otherwise shown; skew angle to match natural watercourse alignment where practicable to minimize scour
Jointing	Ogee (HE/SHE) spigot-and-socket joints sealed with 1:2 cement:sand mortar, full circumference
Bedding	150 mm minimum compacted stone-mix-with-sand or crushed stone bedding, shaped to the pipe invert (see Section 8.5)
Number of barrels / diameter selection	As shown on the Drawings, based on catchment area, design storm return period, and headwater/tailwater constraints (see Section 8.8)

8.4.2 Construction Methods

Supply or manufacture reinforced concrete culvert pipe rings; cure concrete pipes not less than 28 days; transport culvert pipes to the work location; excavate and shape the trench; place pipes and join them; lay to a minimum 2% gradient (or as designed) and to the levels shown on the Drawings or as established by the PE.

8.4.3 Concrete Encasement of Culvert Pipe Lines

All culvert pipe lines installed under this Contract — 600 mm, 900 mm and 1200 mm diameter alike — shall be fully encased in concrete along their entire length, from headwall to headwall, in addition to the bedding specified in Section 8.5. This requirement applies regardless of the cover achieved above the pipe crown, unless the Drawings expressly exempt a specific run.

- Encasement concrete shall be Class 25 (C25), with a minimum 28-day compressive strength of 25 MPa, conforming to the materials, mixing, placing, compaction and testing requirements of Section 9.2 and 9.3.
- Minimum encasement thickness shall be 203 mm (8 inches), measured radially from the outer face of the pipe barrel to the outer face of the encasement, uniformly around the full circumference of the pipe (invert, sides and crown) and along the full length of the culvert line, including through the headwall/wingwall zone.
- Encasement shall be placed only after the pipe rings have been laid, jointed, sealed, and inspected and approved by the PE; joints and any weep provisions shall be complete and approved before encasement concrete is placed, as the encasement renders the pipe joints inaccessible thereafter.
- Formwork shall be used to maintain a uniform encasement thickness and true pipe alignment, and shall incorporate cradles, spacers, or an equivalent approved method to hold the pipe centred to line and grade and prevent flotation or displacement of the pipe during concrete placement and compaction.
- Concrete shall be placed in a manner that avoids segregation and ensures complete, void-free encasement under the pipe haunches, in accordance with Section 9.3.4; internal vibration shall be used with care to avoid pipe displacement.
- Curing of the encasement shall be carried out in accordance with Section 9.3.6 (minimum 21 days) before backfilling or embankment loading is placed over the encased culvert line.
- Where encasement is constructed in sections (e.g., per standard pipe length), construction joints between successive encasement pours shall be treated in accordance with Section 9.3.2.

Measurement and Payment — Concrete Encasement

Item No.	Description	Unit
8.4-D	Concrete encasement of culvert pipe line, Class 25 (C25) concrete, 203 mm (8 inch) minimum thickness, complete, including formwork,	m (linear) of culvert

Item No.	Description	Unit
	placing, compaction and curing	line encased

Payment shall be full compensation for all materials (cement, aggregate, water), formwork, placing, compaction, curing, and labor, equipment and incidentals necessary to complete the concrete encasement in accordance with this Specification and the Drawings, measured per linear meter of culvert line actually encased and approved, unless the Bill of Quantities directs measurement by cubic meter of concrete placed.

8.4.4 Measurement and Payment — Culvert Pipes

Item No.	Description	Unit
8.4-A	Provide and install reinforced concrete culvert, 600 mm diameter x 1.0 m length	m (linear)
8.4-B	Provide and install reinforced concrete culvert, 900 mm diameter x 1.0 m length	m (linear)
8.4-C	Provide and install reinforced concrete culvert, 1200 mm diameter x 1.0 m length	m (linear)

Payment shall be effected upon completion of the culvert line to sealing stage and PE approval, based on the length measured and computed after construction. The rate shall cover all costs relating to the work as described — methods, performance standards, and operation of all labour, equipment and resources needed for the Item. Concrete encasement is measured and paid separately under Item 8.4-D above.

8.5 Stone Mix with Sand for Culvert Foundation

Stone-mix sand beds required for structure works shall be constructed as specified on the Drawings and directed by the PE, including supply of approved material, placing and compacting. Stone dimensions shall be 40 mm x 60 mm, mixed with sand at 50% by volume; maximum stone size 150 mm, and sand minimum Fineness Modulus (FM) 1.2.

Test	Method	Frequency	Tolerance
Dimensions and levels	Tape, line level and straight edge	All bedding runs	± 20 mm
Compaction	Visual / trial density where directed	All bedding runs	Uniform, no visible

Test	Method	Frequency	Tolerance
			movement under compaction plant

Measurement and Payment — Bedding

Item No.	Description	Unit
8.5-A	Stone mix with sand bedding	m ³
8.5-B	Sand filling / sand cushioning	m ³

Stone mix with sand bedding shall be measured for payment in cubic metres as the normal volume of completed and accepted work. Material placed in excess of the approved theoretical volume shall not be measured or paid for, unless otherwise indicated in the Bill of Quantities.

8.6 Headwalls, Wing walls and Aprons

- Headwalls and wing walls shall be constructed in reinforced concrete or cement-bound stone masonry, as shown on the Drawings, at both the inlet and outlet of each culvert, to retain the embankment fill, guide flow into and out of the barrel(s), and reduce the risk of scour and embankment erosion.
- Wing walls shall be splayed at an angle of 30–45° to the culvert axis (or as shown on the Drawings) and shall extend to a length sufficient to retain the fill batter at the design side-slope.
- A cut-off wall (toe wall) shall be provided at the downstream end of the outlet apron, founded at a depth not less than 600 mm below the anticipated scour level, to prevent undermining.
- Weep holes (typically 75–100 mm diameter at approximately 1 m centers, both directions) shall be provided in wing walls and headwalls above normal water level, backed by a granular filter layer, to relieve hydrostatic pressure.
- Concrete aprons (minimum 150 mm thick, reinforced with welded mesh or as shown on the Drawings) shall be provided at the inlet and outlet, extending a minimum of 1.5 times the culvert diameter (or as designed) beyond the end of the barrel, to protect against local scour.
- All headwall, wing wall and apron concrete and reinforcement shall conform to Section 9 of this Specification.

Measurement and Payment — Headwalls, Wing walls and Aprons

Item No.	Description	Unit
8.6-A	Construct reinforced concrete/masonry headwall, complete	No.
8.6-B	Construct reinforced concrete/masonry windgall, complete	No. / m ³
8.6-C	Construct reinforced concrete apron (inlet/outlet), complete	m ² / m ³

Payment for headwalls, wing walls and aprons shall be by the unit or volume basis set out in the Bill of Quantities, at the Contract rate, which shall be full compensation for all materials, formwork, reinforcement, concrete, labor, equipment, curing, and finishing necessary to complete the item in accordance with the Drawings and this Specification.

8.7 Inlet and Outlet Protection and Erosion Control

- Inlet and outlet aprons shall be provided as described in Section 8.6, supplemented by rip-rap or stone pitching (150–300 mm nominal size, minimum 300 mm thick, on a granular or geotextile filter layer) extending beyond the apron where the PE determines that discharge velocities or catchment characteristics warrant additional protection.
- Where outlet velocities are calculated to exceed the permissible non-erosive velocity for the receiving channel material (typically 1.0–1.5 m/s for erodible soils, higher for rock or well-vegetated channels), an energy dissipator (stilling basin, riprap apron, or check structure) shall be designed in accordance with FHWA HEC-14 and shown on the Drawings.
- Channel realignment or protection works immediately upstream and downstream of the structure shall be undertaken as shown on the Drawings to ensure smooth entry and exit conditions and to minimize afflux (upstream backwater).

8.8 Hydraulic Design Considerations

Although this Specification governs construction rather than design, the following hydraulic parameters shall be verified by the PE (or the project's hydraulic design report) before culvert size and invert levels shown on the Drawings are constructed, and the Contractor shall notify the PE of any site condition (catchment change, evidence of higher flood marks, debris accumulation) that appears inconsistent with the design assumptions:

- Design discharge shall be estimated using an appropriate method for the catchment size (e.g., Rational Method for catchments under approximately 15 km², or a regional flood-frequency method for larger catchments), for a minimum design return period of 10–25 years for community gravel road cross-drainage (higher where the culvert also serves as the only access to a community, subject to PE/HDU direction).

- Headwater depth at the design discharge shall not overtop the road formation, and shall provide a minimum freeboard of 150–300 mm below the formation level, or as shown on the Drawings.
- Outlet velocity and scour potential shall be assessed and mitigated in accordance with Section 8.7.
- Where flow exceeds the capacity of a single barrel, multiple barrels (as shown on the Drawings) or a larger single diameter shall be used in preference to allowing overtopping, unless the road is specifically designed as a low-water crossing/causeway.

8.9 Construction Tolerances — Culverts

Parameter	Tolerance
Invert level at each joint	± 15 mm from design
Horizontal alignment	± 50 mm from design centerline
Longitudinal gradient	Not less than the design/minimum 2% gradient at any point
Joint gap / mortar seal	Full circumference sealed, no visible gap
Cover over crown	Not less than the minimum specified in Section 8.4.1
Concrete encasement thickness	203 mm (8 in) minimum, all round; $- 0$ mm / $+ 25$ mm
Headwall/wing wall verticality	± 10 mm per meter height

9 REINFORCED CONCRETE WORKS FOR DRAINAGE STRUCTURES

This Section applies to all reinforced concrete work associated with drainage structures under this Specification, including headwalls, wing walls, aprons, foundations, and any cast-in-place elements shown on the Drawings, and sets out the complete reinforcement, concrete materials, mixing, placing, curing and finishing requirements for such work

9.1 Steel Reinforcement: Bars and Mesh

This work consists of the supply and placing of steel reinforcement in concrete structures, in accordance with this Specification and the types, sizes and positions shown on the Drawings.

9.1.1 Material

- Mild Steel Plain Round Bar of structural or intermediate grade conforming to ASTM A51 or A615, with yield strength not less than 275 MPa (Grade 40).
- High Strength Deformed Bar (HSD) conforming to ASTM A615 or BS 4461, with yield strength not less than 413 MPa (Grade 60).
- Reinforcing steel shall be free from flaws or defects, and free from rust, grease, pitting, mud, loose scale, mortar or other foreign material that may impair quality. Bars shall be in one length as far as practicable, without welding.
- Binding wire shall be 24 BWG galvanized iron wire.
- The PE may order laboratory testing of reinforcing bar, with samples cut by the Contractor as directed.

9.1.2 Construction Methods

- Storage: reinforcing bar shall be handled and stored to prevent undue bending and accumulation of oil, grease, dirt or mud, and shall be cleaned and brushed immediately before use to remove any oil, grease, dirt, mud, paint, loose scale, rust or other foreign substance.
- Cutting and bending: all bars shall be cut and bent cold to the dimensions shown on the Drawings, using equipment and methods approved by the PE.
- Splicing: the lap length for mild-steel plain bar shall be 40 bar diameters with hooks and 56 bar diameters without hooks; for mild-steel or HSD bar, 30 bar diameters up to 16 mm diameter and 40 bar diameters for larger sizes. Splices shall generally be located at points of minimum tensile stress; where more than half the bars are spliced within a length of 40 bar diameters, or splices occur at points of maximum stress, the lap length shall be increased and

spirals or closely spaced stirrups used around the splice. Use or splicing of bars shorter than shown on the Drawings requires the PE's permission. Reinforcing bars in structures shall not be welded unless specified on the Drawings or approved by the PE.

- **Placing:** reinforcement shall be placed, supported and maintained in the position shown on the Drawings; all intersecting bars shall be tied with binding wire, with wire ends turned into the body of the concrete. Reinforcement shall be supported on pre-cast mortar blocks (mix 1:2 cement: sand) or metal chairs of adequate strength and minimum size, cast with wire ties, approved by the PE. Bar substitution requires the PE's permission and shall use bars of the same type with equal or larger cross-sectional area. All placed reinforcement shall be approved by the PE before concrete is poured.

9.1.3 Measurement and Payment — Reinforcement

Item No.	Description	Unit
9.1-A	Supply and place reinforcement, 275 MPa (Grade 40)	kg
9.1-B	Supply and place reinforcement, 413 MPa (Grade 60)	kg

Measurement shall be the computed weight (kg) of reinforcing bar shown on the Drawings, placed and accepted, using theoretical weights for the type and cross-section shown. Computed weight shall include hooks, stirrups, tie anchorages and laps; extra material from using bars larger in diameter or shorter in length than specified shall not be measured. Payment shall be full compensation for supply and placing of reinforcement, including all materials, supports, binding wire, cutting and bending, labor, equipment, tools and incidentals.

9.2 Supply of Material, Casting/Construction and Curing of Concrete

This work consists of the construction of all Portland cement concrete in structures, with or without reinforcement, to the strengths, lines, levels, grades and dimensions shown on the Drawings or as required by the PE. Concrete shall consist of a mixture of Portland cement, coarse and fine aggregates, and water.

9.2.1 Materials

- **Cement:** shall conform to ASTM C150 Type I, or a similar approved standard for normal Portland cement, free from hardened lumps and foreign matter, with a minimum of 90% by weight passing the 75-micron sieve, an initial setting time exceeding 30 minutes, and a final setting time under 7 hours.
- **Coarse aggregate:** hard, durable, angular fragments of crushed stone and/or crushed natural gravel, with a Flakiness Index below 30, clean and free of dust and deleterious substances,

conforming to the grading: 25.0 mm – 100% passing; 19.5 mm – 90–100%; 12.5 mm – 20–55%; 9.5 mm – 0–15%; 4.75 mm – 0–5%.

- Fine aggregate: natural sand with FM not less than 1.8, all passing the 4.75 mm sieve, not more than 3% by weight passing the 75-micron sieve, clean and free of deleterious substances.
- Water: subject to PE approval, reasonably clear, free from oil, alkali, salts, acid, organic substances, and objectionable quantities of suspended material.
- Storage: cement shall be stored in a waterproof, shaded area, stacked a minimum 300 mm from walls, on a damp-proof floor raised at least 300 mm above ground. Damaged/lumpy cement shall be removed from Site within 24 hours of the PE's instruction. The Contractor shall maintain records of cement deliveries and use.

9.2.2 Testing of Materials

- Cement: each batch delivered shall be sampled and tested before approval for use; factory test certificates may be requested prior to concreting. Cement shall be sampled on Site (most conveniently upon delivery) and tested for fineness and setting time; a heat-generation field test shall be carried out; lumpy/caked cement shall be rejected and disposed of by the Contractor at its own cost. The PE may order additional testing.
- Aggregate: the Contractor shall supply samples for testing of Flakiness Index and Aggregate Impact Value (coarse aggregate) and Fineness Modulus (fine aggregate), grading, and other tests as required. Samples from any new aggregate source shall likewise be tested. Grading of mixed coarse aggregate shall be checked on Site.

9.2.3 Composition and Strength of Concrete

- Concrete in reinforced structures shall have a minimum 28-day compressive strength (cylinder test) of 30 MPa unless otherwise stated on the Drawings, with a maximum aggregate size of 20 mm and minimum cement content of 360 kg/m³.
- Concrete in reinforced pre-cast or bored piles shall have a minimum 28-day compressive strength (cylinder test) of 35 MPa unless otherwise stated, maximum aggregate size 20 mm, minimum cement content 400 kg/m³.
- Cube strength (150 x 150 x 150 mm) shall be 17.5% higher than cylinder strength; 7-day strength shall be a minimum of 70% of 28-day strength.
- Water-cement ratio shall be as low as possible, generally 0.45–0.50 by weight.
- Trial mixes of the designed proportions shall be prepared and tested for slump and strength, made and compacted in the PE's presence using the equipment to be used for the Works.

Once approved, no variation in mix proportions or in type, size, grading zone or source of constituents shall be made without the PE's consent, and no concrete of that specification shall be placed until the trial mix is approved.

9.2.4 Testing of Concrete

- Compressive strength: cylinder or cube testing shall be carried out as required by the PE, with a minimum of three test specimens taken for each day's casting or for every 15 m³ of concrete cast in larger pours; two sets of three test moulds shall be made available on Site. Specimens shall be sampled in the PE's presence and dated, and tested at 7 and 28 days. The average 28-day strength shall exceed the specified strength; one of three specimens may be below specified strength provided it is not less than 85% of specified strength, and not more than one test result per element may be below specified strength.
- Slump test: carried out as required by the PE, minimum one test at the start of each casting, one per hour of casting, and one each time a strength-test specimen is taken. A slump cone shall be available on Site.

9.3 Construction Methods

9.3.1 Formwork

Formwork shall be of timber or steel, built mortar-tight and sufficiently rigid to maintain the concrete in position during placing, compacting, setting and hardening; rigidly constructed, supported on a firm bearing base, braced to retain shape and position, and set to specified lines and levels. Formwork shall permit removal of loose material from inside without disturbance. Metal ties/anchorages shall permit removal to a depth of 50 mm from the face without disturbing the concrete, minimizing the size of the resulting cavity. Timber formwork shall be dressed timber, smoothed on the concrete face (or fitted with an approved form liner) to give a fair-faced finish; steel formwork shall be rigid, free of surface blemish that would impair the finish. Forms shall be sufficiently tight to prevent loss of mortar. All formwork shall be approved by the PE before concrete placing commences.

9.3.2 Construction Joints

Construction joints shall be made only where shown on the Drawings or as directed by the PE. Before laying new concrete against an already-hardened face: (a) if new concrete is laid within 48 hours, the old face shall be cleaned with a wire brush and water, and coated with cement mortar grout before placing new concrete; (b) if laid after 48 hours, the old face shall be roughened by chiseling, cleaned of loose aggregate and foreign matter, watered, and coated with cement mortar grout before placing new concrete.

9.3.3 Mixing of Concrete

All concrete shall be machine-mixed on Site in an approved batch mixer of a size and type ensuring uniform distribution of materials; no mixer of less than one-bag capacity shall be used, nor charged beyond its rated capacity. The first batch shall contain sufficient excess cement, sand and water to coat the drum without reducing the required mortar content. The mixer shall be thoroughly cleaned after any considerable pause in mixing. Measuring containers for aggregate, sand, water and cement shall be PE-approved. Coarse aggregate shall be fed first, then sand, then cement, mixed dry before water is added; mixing shall continue not less than 2 minutes after all materials, including water, are in the mixer, until a uniform consistency is obtained. The mixer drum shall be fully emptied before the next batch commences. Concrete shall be placed and compacted within 30 minutes of batching; concrete that has undergone initial set shall not be used, and re-mixing is not permitted.

9.3.4 Handling and Placing of Concrete

Concrete shall not be placed until reinforcement and formwork have been inspected and approved by the PE. Before placing, all sawdust, wood chips, construction debris and extraneous matter shall be removed from inside the forms, the reinforcement thoroughly cleaned, and the forms and reinforcement thoroughly wetted. Concrete shall be placed to avoid segregation and displacement of reinforcement; the use of long troughs and chutes requires the PE's permission and they shall be kept clean and free of hardened concrete. Concrete placed from a height exceeding 1.5 m shall be poured through troughs/tremie pipes, or as directed. Struts, stays and braces temporarily holding forms shall be removed once no longer necessary and shall not be buried in the concrete. Concrete shall be laid in layers 150–300 mm thick, each properly vibrated before the next layer is laid.

9.3.5 Compaction of Concrete

Concrete shall be thoroughly compacted by mechanical vibration during and immediately after placing, using equipment of a type and design approved by the PE, generally internal vibration unless otherwise authorized, capable of not less than 4,500 impulses per minute, of sufficient intensity to visibly affect a mass of concrete over a radius of at least 450 mm. Vibration shall be applied at the point of deposit and in the area of freshly deposited concrete, and shall not be applied directly, or through reinforcement, to concrete that has hardened beyond the point of remaining plastic under vibration, nor used to make concrete flow over distances so great as to cause segregation.

9.3.6 Curing of Concrete

Curing shall continue for not less than 21 days after placing, by one of the following methods: (a) covering the exposed surface with moist sand or gunny bags, kept moist by flushing or sprinkling water; or (b) ponding, with an enclosed square over the area and a minimum water depth of 50 mm.

9.3.7 Removal of Formwork

Formwork shall be removed only with the PE's approval. Forms on exposed vertical faces shall remain in place at least 3 days after placing concrete; forms under slabs, beams and girders shall remain at least 21 days. Formwork shall be removed in a manner ensuring the safety of the structure, with all bracing removed at the same time as the forms. Cavities left by metal ties and anchorages shall be filled with cement mortar and left smooth and even.

9.3.8 Finishing Concrete Surfaces

All concrete shall be given a fair-faced finish unless otherwise specified on the Drawings or directed by the PE. Where requested by the PE, exposed faces of wingwalls and headwalls shall be given a rubbed finish.

10 QUALITY CONTROL AND QUALITY ASSURANCE

10.1 General

The Contractor shall establish and maintain a Site laboratory (or approved arrangement with an accredited external laboratory) capable of performing the routine tests listed below, and shall submit test results to the PE within 48 hours of testing (or as otherwise agreed) for each test performed. All testing equipment shall be calibrated and maintained in good working order, with calibration certificates available for the PE's inspection. The PE reserves the right to order independent check-testing at any stage, at the Contractor's expense where non-compliance is confirmed.

10.2 Earthworks and Gravel Wearing Course — Testing Frequency

Test	Method	Minimum Frequency	Acceptance Criterion
Field density / compaction	AASHTO T191 (sand cone) or T310 (nuclear)	1 per 500 m ² per layer (embankment/subgrade); 1 per 250 m ² per layer (gravel wearing course)	As per Section 4.5 / 6.5
Moisture content	Oven-dry / speedy moisture	Concurrent with each density test	Within specified OMC range
Moisture-density relationship (Proctor)	AASHTO T99 / T180	1 per material source, and on any change of source or material type	Establishes MDD/OMC reference
Grading (sieve analysis)	AASHTO T27	1 per 1,000 m ³ of gravel placed, and on change of source	Within grading envelope, Section 6.2
Atterberg limits (LL, PI)	AASHTO T89 / T90	1 per 1,000 m ³ of gravel placed, and on change of source	Within limits, Section 6.2
CBR (soaked)	AASHTO T193	1 per material source, and every 5,000 m ³ thereafter	≥ 30% (wearing course) / per Section 4/5 for subgrade
Level and surface	Survey /	Every 50 m and at all	Per Sections 4.4 / 6.6

Test	Method	Minimum Frequency	Acceptance Criterion
tolerance survey	straightedge	changes of grade	

10.3 Concrete and Reinforcement — Testing Frequency

Test	Method	Minimum Frequency	Acceptance Criterion
Slump	ASTM C143	Start of each casting; every hour of casting; each time a strength specimen is taken	As approved trial-mix slump ± 25 mm
Compressive strength	ASTM C39 (cylinder) or cube equivalent	3 specimens per day's casting, or per 15 m ³ in larger pours	Per Section 9.2.4 acceptance rule
Cement fineness / setting time	Field test on delivery	Each batch/delivery to Site	Per Section 9.2.1
Aggregate grading, Flakiness Index, LA Abrasion	AASHTO T27 / T96 / local method	Each source, and monthly thereafter	Per Section 9.2.1
Reinforcement — mill certificates / sample test	ASTM A615 / BS 4449	Each delivery; laboratory test if ordered by PE	Yield strength per Section 9.1.1

10.4 Culvert Pipe Quality

Each delivery (or production batch, where cast on Site) of RC pipe culvert rings shall be inspected for cracks, honeycombing, dimensional accuracy (internal diameter, wall thickness, joint profile) and curing age (minimum 28 days before installation) prior to acceptance for laying. Manufacturer's certificates of compliance with AASHTO M170/ASTM C76 (or the equivalent BS standard) shall be provided where pipes are not manufactured on Site; where certificates are unavailable, the PE may order sample crushing/load tests in accordance with the referenced standard.

10.5 Non-Conformance and Rejection

Any material or completed work failing to meet the criteria in this Section shall be rejected, reworked, or removed and replaced at the Contractor's expense, and shall be retested at the same frequency until compliance is demonstrated. Payment shall not be made for rejected work or material. Repeated non-conformance from a given material source shall be grounds for the PE to withdraw approval of that source.

11 ENVIRONMENTAL, HEALTH, SAFETY AND TRAFFIC MANAGEMENT

11.1 Environmental Management

- The Contractor shall implement the project Environmental and Social Management Plan (ESMP), where one exists, and shall otherwise avoid unnecessary disturbance to vegetation, watercourses, and adjoining land beyond the approved Right-of-Way and designated borrow/spoil areas.
- Borrow pits and quarries shall be operated and, on completion, rehabilitated (reshaped, drained, and re-vegetated) in accordance with the approved borrow-pit management plan and Liberian EPA requirements.
- Construction camps, fuel storage and equipment wash-down/maintenance areas shall be located and bonded to prevent contamination of watercourses and groundwater; spill-response materials shall be kept on Site.
- Dust from haul roads and exposed earthworks shall be controlled by watering or other approved means, particularly near settlements and schools.
- Waste (including cleared vegetation, packaging, and construction debris) shall be disposed of at approved sites; open burning shall require the PE's written permission and compliance with local regulations.
- Watercourses shall not be used for washing equipment, mixing concrete, or disposing of waste; sediment and turbidity controls (silt fences, sediment traps) shall be provided at drainage outlets and stream crossings during construction.

11.2 Health and Safety

- The Contractor shall comply with the ILO Code of Practice on Safety and Health in Construction (or equivalent national OSH regulations) and shall appoint a Site Safety Officer responsible for implementing a Site-specific Health and Safety Plan.
- Personal protective equipment (helmets, high-visibility vests, safety boots, and task-specific PPE) shall be provided to and worn by all workers and visitors on Site.
- The PE shall be notified immediately of any accident on or off Site involving the Contractor's operations, resulting in injury to any person, whether directly involved with the Site or a third party; verbal notification shall be followed by a written comprehensive report within 24 hours.

- Excavations, cofferdams, and open trenches shall be barricaded, signed, and, where left overnight or unattended, lit or otherwise made safe against inadvertent entry by the public, particularly children.
- Transportation of materials shall be in suitable vehicles that, when loaded, do not cause spillage, with all loads suitably secured; vehicles failing to comply with this requirement or local traffic regulations shall be removed from Site.
- First-aid facilities and emergency-response arrangements (including transport to the nearest medical facility) shall be maintained on Site at all times.

11.3 Accommodation of Public Traffic and Traffic Management

- The Contractor shall plan operations to maintain the flow of traffic through the Works without disruption or delay; road closures may only be permitted by the PE in exceptional circumstances, with at least 7 days' notice of any proposed closure.
- At the end of each day's work, or whenever the Works are left unattended, the Contractor shall leave the Works in a condition allowing safe passage of traffic, and shall comply with all local regulations on temporary road closures, including local radio announcements where required.
- Where road width is restricted, or an obstruction or danger to traffic exists, the Contractor shall provide adequate flagmen, signs, barriers, lights, communications, and staff to ensure traffic is safely conducted through the Works.
- The Contractor shall take all reasonable precautions to prevent roads and thoroughfares used for construction or haulage from becoming dirtied as a result of the Works, and shall clean them immediately if this occurs, in the PE's opinion.
- At culvert and drainage crossings, temporary detours, pipes, or approved crossing structures shall be provided to maintain community and vehicular access during construction, in accordance with Section 8 and as shown on the Drawings.

12 MEASUREMENT AND PAYMENT — SUMMARY OF BILL ITEMS

Measurement and payment for each work section shall be as detailed in the corresponding Section of this Specification, and summarized below for convenience. Quantities in the Bill of Quantities are estimated only; only actual quantities of work done, measured as described, will be paid for, in accordance with Section 2 and the General Conditions of Contract.

Item No.	Description	Unit
3.1	Site clearance and grubbing	m ² / km
4.2	Roadway / borrow excavation	m ³
4.3	Embankment construction (fill placement and compaction)	m ³
4.4	Subgrade preparation (scarify, condition, compact)	m ² / km
5	Subgrade improvement (undercut/replace, capping, geotextile) — where directed	m ³ / m ²
6	Gravel wearing course — supply, place and compact	m ³ (compacted) or per km per specified thickness
7.1–7.3	Side drains, mitre drains, outlet/erosion protection	m (linear) / m ³ / m ²
8.2-A	Excavation of foundations for structures	m ³
8.3-A	Backfill of structures	m ³
8.4-A / 8.4-B / 8.4-C	Supply and install RC culvert, 600 mm / 900 mm / 1200 mm diameter	m (linear)
8.4-D	Concrete encasement of culvert pipe line, C25, 203 mm (8") thick	m (linear)
8.5-A / 8.5-B	Stone mix with sand bedding / sand filling	m ³
8.6-A/B/C	Headwalls, wingwalls, aprons	No. / m ³ /

Item No.	Description	Unit
		m ²
9.1-A / 9.1-B	Reinforcement, Grade 40 / Grade 60	kg
9.2	Structural concrete (by class/strength as scheduled)	m ³

Where a work activity described in this Specification is not listed as a separate Bill Item, its cost shall be deemed included in the rates for the related Items, in accordance with Section 1.1.

13 INSPECTION, TESTING, COMPLETION AND ACCEPTANCE

13.1 Inspection and Hold Points

The following stages constitute mandatory hold points, beyond which the Contractor shall not proceed without the PE's written approval: completion of clearing/grubbing and setting out; completion of each embankment/subgrade layer; completion of subgrade prior to gravel placement; completion of each gravel-wearing-course layer; completion of excavation for structures, prior to placing bedding or blinding concrete; placement of reinforcement and formwork, prior to concrete pour; and completion of backfilling, prior to reinstatement of the running surface over a structure.

13.2 Practical Completion

The PE reserves the right not to certify the Works as “practically completed,” as required by the Conditions of Contract, unless the following portions are completed in accordance with this Specification: (a) the gravel wearing course; and (b) all drains and drainage structures for which timely instructions were given by the PE. Opening of individual sections or lots to traffic shall not entitle the Contractor to a Completion Certificate unless those sections are separately identified in the Contract or otherwise qualify under the Conditions of Contract.

13.3 Protection of Completed Work

The Contractor shall provide temporary drainage works (drains, channels, banks) and operate temporary pumps and equipment as necessary to protect, drain and de-water the Works and temporary works, in addition to any permanent drainage separately paid for. Completed layers shall be kept properly drained; material shall not be dumped on a completed layer in a way that inhibits surface drainage or causes wet spots; and all parts of the Works shall be protected against erosion by floods and rain. Material shall not be spread on a layer so wet as to damage underlying layers or prevent adequate compaction of overlying layers; such wet layers shall be dried and re-compacted, or removed. Excavations for culverts and similar structures shall be adequately protected against the ingress of water during rainstorms. All completed layer work shall be protected and maintained, with immediate repair of any damage or defect, until the following layer is applied or the Works reach Practical Completion.

13.4 Payments and Tolerances — General

Work shall comply with the dimensional and other tolerances specified for each activity; where no tolerance is specified, the standard of workmanship shall be in accordance with normal good practice. Where work is not constructed within the authorized dimensions plus or minus any allowed tolerance, the PE may nevertheless accept the work for payment at its sole discretion; in

such cases, no payment shall be made for quantities in excess of those calculated from the authorized dimensions, and where actual dimensions are less than authorized (minus tolerance), quantities for payment shall be based on the actual as-built dimensions.

13.5 Defects Liability

The Contractor is responsible for maintaining the Works until the end of the Defects Liability Period specified in the Contract, and shall make good, at its own cost, any defect (including erosion damage, settlement, cracking, or drainage failure attributable to defective materials or workmanship) notified by the PE during that period.