4 UNBOUND PAVEMENT MATERIALS

4.1 GENERAL

4.1.1 Scope

1 This Part includes materials, equipment and construction requirements for unbound layers (aggregate Subbase and Road Base courses).

2 Related Parts are:

Part 1..... General
Part 3..... Earthworks
Part 5..... Asphalt Works

4.1.2 References

1 The following standards are referred to in this Part:

ASTM C88.....Standard Test Method for Soundness of Aggregates by Use of Sodium Sulphate or Magnesium Sulphate

ASTM C131.....Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

ASTM C136.....Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates

ASTM C535.....Standard Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

ASTM D1556.....Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method

ASTM D1557.....Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3 (2,700 kN-m/m3))

ASTM D1883.....Standard Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils

ASTM D2216.....Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

ASTM D2419.....Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate

ASTM D4318.....Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

ASTM D4429.....Standard Test Method for CBR (California Bearing Ratio) of Soils in Place

ASTM D4791.....Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

ASTM D4944.....Standard Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester

ASTM D5821.....Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate

ASTM D6913 .....Standard Test Methods for Particle Size Distribution (Gradation) of Soils Using Sieve Analysis

ASTM D6938.....Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

ASTM E1703.....Standard Test Method for Measuring Rut-Depth of Pavement Surfaces Using a Straightedge

AASHTO T307 .....Standard Method of Test for Determining the Resilient Modulus of Soils and Aggregate Materials

BS 1377 Part 3.....Methods of test for Soils for Civil Engineering Purposes: Chemical and electro-chemical tests

4.1.3 Definitions

1 Optimum moisture content (OMC): the moisture content of soil at which a specific compaction effort will produce the maximum dry density when determined in accordance with the ASTM D1557.

2 Maximum dry density (MDD): The dry density of soil obtained using a specified compaction effort at the optimum moisture content when determined in accordance with the modified compaction test ASTM D1557. Unit weight and moisture content of materials containing more than 5% by mass of oversize fraction tested in accordance with ASTM D1557 should be corrected following ASTM D4718.

3 Subgrade: the compacted existing ground or fill for 500mm beneath formation.

4 Formation: the compacted subgrade level shaped in readiness to receive the Subbase or Road Base courses.

5 Subbase: It is the layer between the subgrade and the Road Base. It consists of compacted selected granular materials.

6 Road Base: It is the layer directly beneath the asphalt course layers and above the subbase or subgrade layer. It consists of compacted selected materials. It can be untreated or treated with suitable stabilizing admixtures.

4.1.4 Submittals

1 The Contractor shall submit recent test results for the proposed sources of materials for all quality requirements of the Contract. The Contractor shall submit a test certificate that proves that the raw materials that are purchased/used comply with specifications. The testing may be performed by an approved private laboratory or by the laboratory associated with the plant itself as approved by the engineer.

2 The contractor shall submit to the Engineer for approval method statements for the following:

(a) Materials production, handling, storage, identification, marking and traceability to source of production.

(b) Quality assurance and quality control plans for all construction activities.

(c) Materials production, handling, storage, identification and marking, traceability to source of production.

(d) Quality control testing plan.

(e) Equipment and its suitability to fulfill all construction activities to the required quality.

(f) Personnel capability.

(g) Safety and environment preservation measures.

4.1.5 Quality Assurance

1 If requested the Contractor shall arrange for the Engineer to visit the source of the materials and jointly take samples for testing. The Contractor shall carry out testing as directed by the Engineer.

4.2 MATERIALS

4.2.1 Sources of Materials

1 The Contractor shall notify the Engineer of the proposed sources of materials. The Contractor shall ensure that the sources of all aggregates have been approved by the Municipality concerned.

2 The Engineer shall approve the sources before delivery of materials to the site.

3 Where a proposed source of material is not approved, the Contractor shall propose an alternative source of material.

4.2.2 Storage and Handling of Materials

1 Materials shall be so stored and handled as to assure the preservation of their quality and fitness for use in the works. Even after source approval has been given materials may again be inspected and tested before use in the work.

2 Stored material shall be located so as to facilitate prompt inspection.

3 All storage sites shall be restored to their original condition before acceptance of the Works.

4 Handling and stockpiling of aggregates shall at all times be such as to eliminate segregation or contamination of the various sizes. Stockpiles shall be kept flat, and the formation of high cone-shaped piles shall not be permitted. When conveyor belts are used for stockpiling aggregates the Engineer may require the use of baffled chutes or perforated chimneys.

5 When trucks are used to construct stockpiles, the stockpiles shall be constructed one layer at a time with trucks depositing their loads as close to the previous load as possible. The use of tractors or loaders to push material deposited at one location to another location in the stockpile shall not be allowed during the construction of the stockpile and their use shall be limited to levelling the deposited material only.

6 The Contractor shall take all necessary protection measures in the storage, handling and stockpiling of materials to prevent contamination of materials by dust. The measures that the Contractor proposes to take shall be subject to the approval of the Engineer.

4.2.3 Inspection Testing and Control

1 Loose materials for testing and acceptance shall be sampled from the un-compacted in-place layer.

2 For verification of plant weights and measures, character of materials used in the preparation of the mixes, testing and other quality control requirements, the Engineer shall at all times be provided access to all portions of the mixing plant, aggregate plant, storage yards, crushers and other facilities used for producing and processing the materials of construction.

3 The Engineer shall have authority to take samples and perform tests on any material supplied to the site from any source whatsoever in order to establish compliance and to accept or reject as he deems necessary. Samples shall also be taken from completed work to determine compliance. The frequency of all sampling and testing shall be as designated by the Engineer.

4 The Contractor shall provide suitable facilities at the quarry or plants to carry out all necessary tests on the raw materials and mixes.

5 The Contractor shall arrange for obtaining specimens of materials and samples taken from stockpiles, including the provision of any necessary equipment and plant. This work shall be performed in the presence of the Engineer if so directed by the Engineer.

6 Materials that are not in compliance shall be rejected and removed immediately from the site of the works unless otherwise instructed by the Engineer.

7 Where defects in the materials or the completed work have been corrected, the Contractor shall not proceed with subsequent work until approval has been given by the Engineer.

4.2.4 Fine Aggregate

1 Fine aggregate (passing the 4.75 mm sieve) shall consist of crushed mineral aggregate and/or natural sand.

2 The fine aggregate shall be clean and free from clay-balls and other extraneous or detrimental materials.

3 Where the source of fine aggregate does not meet the requirements listed in Table 4.1, the Contractor may, with the Engineer's approval, add fine aggregate and filler to correct the gradation or to change the characteristics of the material passing the 0.425mm sieve so as to meet the requirements. Such additional material shall be added in a manner which ensures a completely homogeneous material.

Table 4.1

Specifications of fine aggregates for Road Base and Subbase layers

Parameter	Standard	Specification Limits		Minimum Frequency
		Road Base	Subbase	
Liquid Limit	ASTM D4318	25%max.	25% max.	- Each source - Visible change in material - 1 test every 1000m^3
Plasticity Index	ASTM D4318	6 % max.	6 % max.	
Sand equivalent	ASTM D2419	35 min.	25 min.	
Organic content	BS 1377 Part 3	0.5% max.	0.5% max.	

4.2.5 Coarse / Combined Aggregate

1 Coarse aggregate (retained on the 4.75 mm sieve) shall consist of crushed stone or crushed gravel and shall be free from organic matter, clay and other extraneous or detrimental materials.

2 The required properties of coarse aggregates for Road Base and Subbase layers are listed in Table 4.2.

Table 4.2
Specifications of coarse aggregates for Road Base and Subbase layers

Parameter	Standard	Specification Limits		Minimum Frequency
		Road Base	Subbase	
Fractured Faces	ASTM D5821	50% min.	50% min.	- Each source - Visible change in material - 1 test every 3000m^3
Flat and Elongated Particles (5:1)	ASTM D4791	10% max.	15% max.	
Loss by Abrasion	ASTM C131 ASTM C535	30% max.	40% max.	
Soundness (5 cycles by $MgSO_4$)	ASTM C88	15% max.	20% max.	

3 Loose materials for testing and acceptance shall be sampled from the un-compacted in-place layer.

4 The required properties of combined aggregate for Road Base and Subbase layers are listed in Table 4.3.

5 Unit weight and moisture content of materials containing more than 5% by mass of oversize fraction tested in accordance with ASTM D1557 should be corrected following ASTM D4718.

6 When nuclear gauge is used for field density and moisture content testing, 3 readings shall be made at each test location within a radius of 2 meters. The average of the 3 readings is considered to be the density for that test location. Individual density readings shall not be less than the target relative density by more than 0.5%.

7 When nuclear gauge is used for field density and moisture content testing, the density and moisture content for each material shall be verified by measurements in accordance with ASTM D1556 and ASTM D2216, respectively. The mean value of the replicate readings shall be used as the calibration point value for each material.

8 In case abnormally high relative density values are encountered, it will be required to re-evaluate the related field and laboratory density values.

9 Gradation requirements of combined aggregate for Road Base and Subbase layers are listed in Table 4.4.

4.2.6 Recycled Aggregate

1 Recycled aggregate produced from excavating natural ground and from demolition wastes can be used in subgrade and subbase layers provided that the specifications stated in Section 6 - Part 9 are complied.

Table 4.3

Specifications of combined aggregates for Road Base and Subbase layers[1]

Parameter	Standard	Specification Limits		Minimum Frequency
		Road Base	Subbase	
Maximum Dry Density	ASTM D1557	2.15 Mg/m^3 min.	2.05 Mg/m^3 min.	- Each source. - Visible change in material - 1 test per 1000m^3
Gradation	ASTM D6913	Table 4.4	Table 4.4	
California Bearing Ratio (CBR)	ASTM D1883 (Soaked)	80% min.	70% min.	
Swelling		0.5% max.	1.0% max.	
Field Density	ASTM D6938 ASTM D1556	100% of MDD	100% of MDD	- 1 per 200 m^2 per layer - 1 every 75m per lane per layer
In Place Moisture Content[2]	ASTM D6938 ASTM D4944	± 1.5% of OMC	± 2% of OMC	
In Place California Bearing Ratio (CBR)	ASTM D4429	80% min.	70% min.	1 per 2000 m^2
Acid soluble Chloride Content	BS 1377 Part 3	2% max.	2% max.	1 per 3000 m^3
Acid soluble sulphate content	BS 1377 Part 3	3% max.	3% max.	

[1]*Loose materials for testing and acceptance shall be sampled from the un-compacted in- place layer.*

[2]*During compaction.*

Table 4.4

Gradation limits for Road Base and Subbase layers

Sieve Size	Road Base	Subbase
50.0 mm	100	100
37.5 mm	95 – 100	90 – 100
19.0 mm	70 – 92	70 – 90
9.5 mm	50 – 70	45 - 75
4.75 mm	35 – 55	30 – 60
0.600 mm	12 – 25	10 – 30
0.075 mm	0 – 8	0 – 12

4.2.7 Water

1 Sea, brackish or saline water shall not be used in the mixing, spreading and compacting operations for Road Base / Subbase layers.

4.2.8 Performance Indicators

1 Upon the request of the Engineer, the following performance related indicators shall be determined from loose in place materials for verification of the pavement structural design following the AASHTO Mechanistic-Empirical Pavement Design Guide:

(a) Resilient Modulus (M_R) in accordance with AASHTO T307 at optimum moisture content and maximum density as per ASTM D1557.

(b) Parameters and moduli required for determining the Permanent Deformation Potential in accordance with AASTHO Mechanistic Empirical Design Guide.

(c) Parameters and moduli required for measuring the Fatigue Cracking Potential for stabilized and surface layers in accordance with AASHTO Mechanistic Empirical Design Guide.

2 For performance testing, one sample shall be tested every 10,000 m^3, and for constructions having less than 10,000 m^3 volume, one sample shall be tested every 50% of the total volume.

4.3 MAIN EQUIPMENT

4.3.1 General

1 Unless otherwise stipulated herein the provisions of Section 6, Part 3 (Earthworks), in respect of the main machinery and tools used in earthworks construction, shall be adhered to, subject to the modifications and additions in this clause.

2 The Contractor shall not be allowed to use any equipment or plant before obtaining the approval of the Engineer, and the Contractor shall undertake sound technical methods in operation and to engage skilled and trained operators, mechanics and labor to carry out the works.

3 The Engineer shall have the right to stop the use of any equipment or plant which he deems to be inferior to the quality required and to instruct the removal of such equipment and to have it replaced by suitable equipment or to alter the method of operation at any time he so desires.

4 The Contractor shall immediately comply with such instructions without being entitled to any indemnities or extensions as a result of such instructions.

5 The Engineer shall have the right to expel any operators, mechanics or labor and to instruct suitable replacement thereof at any time he deems such action is necessary.

4.3.2 Paving Machines

1 Paving machines shall be self-propelled and shall be capable of spreading the Subbase and Road Base materials in one operation so as to make it ready for compaction with minimum shaping.

2 The paving machines shall be provided with a screed that strikes off and distributes the material to the required width and level.

3 The width of each spread shall not be less than a traffic lane wide.

4 The screed shall be adjustable to the required width being laid.

5 Screed action includes any practical motion that produces a finished surface texture of uniform appearance.

4.3.3 Central Mixers

1 A central mixing plant shall be either of an approved drum or pugmill type with a moisture control system so that the material may be spread without further mixing or processing.

2 Means shall be provided for regulating the flow of material to the mixer. The various feeds shall be calibrated to allow adjustments to the mix design to be carried out.

4.4 MIX DESIGNS

1 Aggregate Subbase and Road Base courses shall consist of crushed mineral aggregates or natural mineral aggregates of the designated gradation and thickness.

2 The maximum dry density and the optimum moisture content of the material shall be ascertained as per the test procedure given in ASTM D1557 and this shall be used to assess the degree of compaction of the mix after rolling.

3 The pavement layer designated as sub-base may be substituted by any of the materials designated to be laid on it subject to the approval of the Engineer.

4.5 SCREENING AND MIXING

1 Screening shall be required for the materials used in Subbase and Road Base courses to ensure that the designated gradation is attained.

2 Screens shall be of the size and number required to remove oversize aggregate and to separate the materials into two or more fractions so that they may be combined to meet the required gradation.

3 A central mixing plant shall be used for the mixing of materials.

4 Mixing of separate materials on the roadway by motor grader will not be permitted.

4.6 SPREADING AND COMPACTION

1 Before commencing the construction of the Subbase and Road Base courses, a written approval for the Engineer must be obtained that the subgrade is in compliance.

2 The optimum moisture content of the material shall be noted from the mix design and the actual moisture content determined at the plant after mixing.

3 If the natural moisture content is less than the optimum moisture content, the necessary amount of water must be added to obtain the optimum content.

4 Allowance shall be made for the quantity of moisture which may be lost by evaporation in the process of raking, levelling and compacting, depending on atmospheric temperature.

5 The compacted layer shall have moisture content within ± 1.5% of the optimum moisture content for Road Base layers and within ± 2% for Subbase layers.

6 The moisture content shall be uniform in all parts of the section where the work is being carried out and in the various depths of the layer thickness.

7 Subbase and Road Base courses shall be laid by a paving machine with a spreader box.

8 Loose samples of materials for testing and acceptance shall be obtained from behind the paving machine upon the approval of the Engineer.

9 Compaction shall start immediately the material has been laid and as per the approved rolling pattern.

10 Work on the Subbase and Road Base courses shall not be permitted during rainy weather.

11 Material shall be spread to a thickness that would result in layers not more than 150 mm thick after compaction. Where the finished compacted thickness exceeds 150 mm placing shall be executed in composite layers each layer not exceeding 150 mm in compacted thickness as directed by the Engineer.

12 The course shall not be rolled when the underlying material is soft or yielding or when the rolling causes a wave-like motion in this course.

13 When the rolling develops irregularities, the irregular surface shall be loosened, then refilled with the same kind of material as used in constructing the course and again rolled.

14 Along places inaccessible to rollers, the Subbase and Road Base courses material shall be tamped thoroughly with suitable mechanical tampers to achieve the required density and finish.

15 Rolling must continue until a relative density of not less than 100 % of the maximum dry density has been obtained as determined by the moisture-density relationship in ASTM D1557.

16 Care shall be taken so that layers already compacted under the layer being executed are not damaged, or that the formation is not damaged.

17 This aspect must be given special attention in places where rolling equipment makes turns to change direction.

18 Any such damage resulting in mixing the various layers constituting the different subgrades, Subbase and Road Base courses shall be carefully made good by the Contractor at his own expense and to the satisfaction of the Engineer.

4.7 CORRECTIVE ACTION

1 Any material that fails to meet test requirements shall either be reworked or removed and replaced and then retested to check for compliance.

2 Any soft spots, irregularities or depressions that develop in the surface of the Subbase or Road Base courses, shall either be corrected by loosening the surface of such areas and adding further material, or by removing the material in such areas and replacing with further approved material.

3 In the event of heave occurring during compaction, caused either by excessive build-up of pore water pressure or the groundwater table being sufficiently high to affect construction techniques, either of the following procedures shall be adopted subject to the approval of the Engineer:

(a) Sufficient time shall be allowed to elapse enabling the excess pore water to dissipate before further construction or compaction is carried out

(b) The affected material shall be removed, and approved alternative construction layers substituted.

4 For correction of low density or incorrect level, the top 75 mm shall be scarified, reshaped with material added or removed as necessary and re-compacted to the designated requirement. The area treated shall not be less than 30 metres long and 2 metres wide or such area determined by the Engineer as necessary to attain compliance.

5 Where the surface of the sub-base is covered in a very thin smooth skin composed of fine particles cemented together acting as a barrier to the prime coat the top 75 mm shall be scarified, reshaped, watered if necessary, and re-compacted prior to the application of prime coat.

6 The Contractor shall carry out additional testing if required by the Engineer to ensure that the standard of compaction is satisfactory through the full depth of the layer.

4.8 PROTECTION OF SURFACE

1 The Contractor shall protect the Subbase and Road Base courses so that it shall be maintained sound during work progress, after its completion and before receiving the bituminous layers or before laying the surface overlay thereon.

2 Any damage caused to the layer if exposed to traffic or natural conditions resulting in damage to its surface shall be made good at the expense of the Contractor and to the satisfaction of the Engineer.

3 The Engineer has the right to stop all hauling over completed or partially completed Subbase and Road Base courses when in his opinion such hauling is causing damage.

4 Following the completion of the Subbase or Road Base courses the Contractor shall perform all maintenance work necessary to keep the course in a condition for priming.

4.9 TESTING

4.9.1 General

1 Loose materials for testing and acceptance shall be sampled from the un-compacted in-place layer.

2 All testing shall be conducted in accordance with ASTM, AASHTO and BS standards listed in section 4.2.

3 Testing frequency for the properties of Subbase or Road Base layers are listed in Tables 4.1, 4.2 and 4.3.

4 At any stage in the mixing, transportation, spreading or compaction process, the Engineer may instruct that these tests are carried out.

5 Before the application of any prime coat or any other paving course, the aggregate Subbase or Road Base courses shall have been tested for compliance with the requirements of this clause on testing and approved by the Engineer.

4.9.2 Thickness

1 The thickness of the material shall be derived from checking the level by dipping from string lines stretched across the roadway between pins or kerbs. Unless agreed otherwise with the Engineer dipping shall be carried out at intervals of not less than 10m.

2 The thickness of the material shall be measured at the location where the material is removed from the roadway for gradation analysis.

3 Wherever the thickness of compacted aggregate Subbase or Road Base courses is found to vary from the thickness specified in the project drawings or specification by more than 10 % the area involved shall be satisfactorily corrected to provide the required thickness constructed to the designated grade level.

4.9.3 Evenness and Level

1 The final surfaces of the Subbase or Road Base courses shall be tested by means of a 3 meter long straight edge in accordance with ASTM E1703 and no rises or depressions in excess of 10 mm shall appear in the surface. Measurements shall be carried out at maximum spacing of 30m of road length for each lane.

2 The finished surface shall also be checked by dips or spot levels and shall be constructed to the designated grade levels to within ± 10 mm.

3 Where these requirements are not met, the Contractor shall determine the full extent of the area which is out of tolerance and shall make good the surface of the course by scarifying to a minimum depth of 75 mm or 4 times the maximum particle size, whichever is greater, reshaping by adding or removing material as necessary, adding water if necessary and re-compacting.

END OF PART