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SPECIFICATIONS FOR OPEN-GRADED FRICTION COURSE

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SPECIFICATIONS FOR OPEN-GRADED FRICTION COURSE (OGFC)

1. INTRODUCTION

Open-Graded Friction Course (OGFC) is a thin open-graded bituminous wearing course which was developed back in the 1950s. It has been successfully used in many of the developed countries. It primarily consists of interconnected air voids, which enhances surface drainage during the rainfall, thus reducing the hydroplaning potential. In addition to being a drainage and friction course layer, the OGFC has the following advantages:

i. Reduction in vehicle splash (macrotexture)
ii. Reduced pavement-tire noise (macrotexture)
iii. Improved night time visibility. All of these advantages add up to improve road safety ultimately.
iv. Improves the frictional properties of the pavement surface
v. It also helps in rain harvesting when used as shoulders, a parking lot and a walkway. The details are given in **Annex A**.

Although, OGFC was widely used, there was no Indian Specification for the benefit and adoption by the Engineers. Therefore, IRC decided to prepare document on this subject and entrusted this task to Flexible Pavement, Airfield & Runways Committee (H-2) of IRC during tenure 2018-20. The initial draft was prepared by Dr. Sunil Bose and Dr. Sridhar Raju and the same was further deliberated in various meetings of (H-2). The H-2 Committee in its meeting held on 08.06.2019 approved the document subject to incorporation of comments of members for placing before HSS Committee.

The composition of the H-2 Committee is given below:

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The HSS Committee in its meeting held on 20.07.2019 authorized the Co-Convenor to finalize the document based on comments offered during the meeting and submit final document to IRC for placing before the Mid-Term Council meeting. The Mid-Term Council in its meeting held on 9th and 10th August, 2019 at Goa approved the document for publishing.

2. SCOPE

The work shall consist of laying of OGFC on an impervious bituminous surface. OGFC depends on stone-to-stone contact to transfer load, while also acting as a skid-resistant-cum-drainage layer by reducing the potential of hydroplaning.

3. MATERIALS

3.1 Bitumen

The bitumen for fibre-stabilized OGFC shall be viscosity grade VG-40 complying with Indian Standard Specification for Paving Bitumen IS:73 or Polymer Modified Bitumen (PMB) IS:15462-2019/Crumb Rubber Modified Bitumen (CRMB) IS:17079-2019, complying with the Indian Roads Congress Specification IRC:SP:53.

3.2 Coarse Aggregates

The coarse aggregate shall consist of crushed rock retained on 4.75 mm sieve. It shall be of cubical shape, clean, hard, durable and free from dust, soft organic and other deleterious substances. The aggregate shall satisfy the physical requirements given in **Table 1**.

Table 1 Physical Requirements for Coarse Aggregates

Properties	Test	Method	Specification
Cleanliness	Grain Size Analysis	IS:2386 (Part-1)	<2% passing 0.075 mm sieve
Particle Shape	Combined Flakiness and Elongation Index	IS:2386 (Part-1)	<30%
Strength	Los Angeles Abrasion Value	IS:2386 (Part-4)	<30%
	Aggregate Impact Value	IS:2386 (Part-4)	<15%
Polishing	Polished Stone Value	IS:2386 (Part-4)	>55
Durability	Soundness (either Sodium or Magnesium) – 5 cycles		
	Sodium Sulphate	IS:2386 (P-5)	<12%
	Magnesium Sulphate	IS:2386 (P-5)	<18%
Water Absorption	Water Absorption	IS:2386 (P-3)	<2%

3.3 Fine Aggregates

Fine aggregate (passing 4.75 mm sieve and retained on 0.075 mm sieve) shall consist of 100% crushed, manufactured sand resulting from crushing operations. The fine aggregate shall be clean, hard, durable, of fairly cubical shape and free from soft pieces, organic or other deleterious substances. The Sand Equivalent Test (IS:2720, Part 37) value for the fine aggregate shall not be less than 50. The fine aggregate shall be non-plastic.

3.4 Stabilizer Length

Only pelletized cellulose fibres shall be utilized. The dosage rate for cellulose fibres is 0.3% minimum by weight (on a loose fibre basis) of the total mix. The dosage rate shall be confirmed so that the bitumen drain-down does not exceed 0.3% when the designed mix is tested in accordance with ASTM D 6390 and AASHTO T305, "Determination of Drain down Characteristics in Un-Compacted Asphalt Mixtures" (see **Annex B** for the outline of the test) or the Schellenberg Binder Drainage Test given in **Annex C**.

3.4.1 The cellulose fibres used in the form of pellets shall meet the following requirements:

Maximum fibre length - 8 mm

Ash content - maximum of 20% nonvolatile

Oil absorption - more than 4 times of the fibre weight

Moisture content - less than 5% by weight

3.4.2 When the Contractor submits the proposed job-mix formula for OGFC for approval, it shall include the fibre manufacturer's most recently dated actual test data showing that the fibres meet the above requirements. The Contractor shall protect the cellulose from moisture and contamination prior to incorporating it into the OGFC.

4. OGFC MIX DESIGN

4.1 The combined grading of the coarse aggregate and fine aggregate shall be within the limits shown in **Table 2**.

4.2 The OGFC mix will be designed using ASTM D 7064M-08(2013) - Standard Practice for Open-Graded Friction Course (OGFC) Mix Design. The outline of the OGFC mix design is given in Sections 4.3 through 4.10. The OGFC mix shall be compacted with 25 blows on each side using the Marshall procedure given in the Asphalt Institute MS-2 (Sixth edition). The designed mix shall meet the requirements given in **Table 3**.

4.3 Determination of Voids in Coarse Aggregates (VCA)

The coarse aggregate in OGFC of nominal sizes 9.5 mm (for OGFC mix design purposes only) as all material retained on the 4.75 mm sieve. This sieve is also referred to as the breakpoint sieve. Wash the coarse aggregate and determine its Dry Rodded Unit Weight in accordance with ASTM C 29 (see **Annex D** for the outline of the test). Calculate the dry-rodded VCA of the coarse aggregate fraction by the following equation:

$$VCA_{DRC} = \frac{G_{ca}\gamma_w - \gamma_s}{G_{ca}\gamma_w} \times 100$$

Where,

VCA_{DRC} = voids in the coarse aggregate in the dry-rodded condition,
G_{ca} = bulk specific gravity of the coarse aggregate,
γ_w = unit weight of water (998 kg/m^3), and
γ_s = unit weight of coarse aggregate fraction in dry-rodded condition (kg/m^2).

Table 2 Aggregate Gradation for OGFC

Layer	**Surface Layer**
NMAS	9.5 mm
Nominal Layer thickness (mm)	25 mm
IS Sieve Size (mm)	Cumulative % by weight of total aggregate passing
13.2	100
9.5	85-100
4.75	20-40
2.36	5-10
0.075	2-4

Table 3 OGFC Mix Requirements

Mix Design Parameters	Requirements
Air void content, per cent	18-22 (range)
Bitumen content, per cent	Minimum of 5.5%
Cellulose fibres	0.3 per cent by weight of total mix (minimum)
Voids in Mineral Aggregates (VMA), per cent	25 min.
VCA_{mix}, per cent	Less than VCA_{DRC}
Asphalt drain-down, per cent AASHTO T 305	0.3 max.
Tensile Strength Ratio (TSR), per cent AASHTO T 283	80 min.

4.4 Selection of Trial Bitumen Content

The initial bitumen content of the mix for the gradation selection phase of the design should be a minimum of 4.5%. It is suggested that a good starting point be 5.0% for mixes with aggregate specific gravities equal to or less than 2.75. If the bulk specific gravity of the aggregate exceeds 2.75 the bitumen content can be reduced slightly. The VMA of the mix must still meet the specified minimum value.

4.5 Specimen Preparation and Testing

Twelve specimens' needs are required; four specimens at each of the three trial gradations at the bitumen content selected above. The aggregates and fibres should be dry mixed before adding the bitumen. The mixing and compaction temperatures shall be arrived based on the viscosity temperature relationship. Three specimens from each trial gradation shall be compacted with 25 blows on each face and used to determine the volumetric properties of Marshall specimens. The fourth specimen shall be used to determine the theoretical maximum specific gravity (G_{mm}) according to ASTM D 2041 (see **Annex E** for the outline of the test).

The bulk specific gravity of compacted OGFC specimens can also be measured by coating with paraffin wax in accordance with AASHTO T 275" after "Compact the specimens, allow it for overnight cooling and extrude from the mounds. Determine the bulk specific gravity, Gmb, of the specimens (ASTM D6752).

4.6 Selection of the Job Mix Gradation

Compact the specimens, allow it for overnight cooling and extrude from the mould. Determine the bulk specific gravity, G_{mb}, of the specimens (ASTM D 6752 or AASHTO T 275). The uncompacted mix samples are used to determine the theoretical maximum specific gravity, G_{mm} (ASTM D 2041). See **Annex E** for the outline of ASTM D 2041. Using G_{mb} and G_{mm}, the per cent air voids (V_a, VMA and VCA_{mix}) are calculated by the following formulae:

Voids in Mineral Aggregates (VMA)

$$VMA = 100 - \left(\frac{G_{mb}}{G_{sb}} \times P_s\right)$$

Percent Air Voids, (V_a)

$$V_a = 100 \times \left(1 - \frac{G_{mb}}{G_{mm}}\right)$$

Voids in Coarse Aggregate Mix (VCA_{mix})

$$VCA_{mix} = 100 \times \left(\frac{G_{mb}}{G_{ca}} \times P_{ca}\right)$$

Where,

P_s = Percent of aggregate in the mix

P_{ca} = Percent of coarse aggregate in the total mix

G_{mb} = Bulk specific gravity of the compacted mix

G_{mm}= Theoretical maximum density of the mix

G_{sb} = Bulk specific gravity of total aggregate, and

G_{ca} = Bulk specific gravity of the coarse aggregate fraction.

The blend that exceeds the minimum VMA requirement and has a VCA_{mix} that is less than the VCA_{DRC} should be selected as the desired mix design aggregate blend. To ensure stone-on-stone contact within the coarse aggregate it is very essential that VCA_{mix} is less than VCA_{DRC}.

4.7 Determination of the Optimum Bitumen Content

The optimum bitumen content shall be determined corresponding to the design air void content, V_a of 20.0%. The remaining mix properties should meet those specified in **Table 4**. A good starting point for the mix design is 5.0% bitumen content by weight of the mix.

4.8 Drain-down Test

Drain-down of the loose OGFC mix shall be determined according to ASTM D 6390 (see **Annex B** for the outline of the test) or by the Schellenberg Binder Drainage Test given in **Annex C**. The drainage test should be performed at the anticipated plant production temperature and should satisfy the specified maximum drain-down of 0.30%. If the mix fails to meet this requirement then the per cent fibres should be increased to a level that reduces drain down to the acceptable limit.

4.9 Tensile Strength Ratio

Determine the Tensile Strength Ratio (TSR) in accordance with AASHTO T 283, "Resistance of Compacted Bituminous Mixtures to Moisture-Induced Damage" following the freeze and thaw option. See **Annex F** for the outline of the test.

4.10 Cantabro Abrasion Test

Determine the Cantabro Abrasion loss for the aged & un-aged OGFC Marshall specimens, which is to be carried out in the Los Angeles abrasion machine (IS:2386 (Part-IV)). The recommended maximum permitted abrasion loss is 20%. (See **Annex G** for the outline of the test.)

4.11 Laboratory Permeability Test

The laboratory permeability testing of the compacted OGFC specimens using an approved method is optional. Laboratory permeability values greater than 100 m/day are recommended.

5. OGFC PRODUCTION

Mixing: For batch plant, the fibre will be added directly into the weigh hopper above the pugmill. Adequate dry mixing time is required to disperse the fibre uniformly throughout the hot aggregate. Dry mixing time will be increased by 5 to 10 seconds. Wet mixing time shall be increased by at least 5 seconds. For drum mix plant, a separate fibre feeding system shall be utilized that can accurately and uniformly introduce fibre into the drum at such a rate as not to limit the normal production of the mix through the drum. At no time shall there be any evidence of fibre in the baghouse/wasted baghouse fines.

6. OGFC PLACEMENT AND COMPACTION

6.1 Preparation of Existing Bituminous Surface

The existing impermeable bituminous surface shall be cleaned of all loose extraneous matter by means of mechanical broom and high-pressure air jet from the compressor or any other approved equipment/method. Any potholes and/or cracks shall be repaired and sealed.

6.2 Tack Coat

A bitumen emulsion complying with IS:8887-2004 of a type SS-2 shall be applied on the existing impermeable bituminous layer. Quantity of liquid bituminous material shall vary from 0.23 to 0.45 kg/m^2 in case of emulsion. In this regard IRC:16 may be referred. The tack coat shall be applied by a self-propelled or towed bitumen pressure sprayer equipped for spraying the bitumen binder uniformly at a specified rate. The emulsion tack coat shall be allowed to set (turn black from brown) before laying the hot mix.

6.3 Transportation

The OGFC shall be transported in clean, insulated covered vehicles. An asphalt release agent, which does not adversely affect the bituminous mix may be applied to the interior of the vehicle to prevent sticking and to facilitate discharge of the material. The haul distance should be limited to 56 km or the haul time should be limited to 1 hour.

6.4 Lift Thickness

The OGFC shall be placed in thin lift of 20 to 40 mm with a tolerance of ± 5 mm. The OGFC shall be compacted quickly after placement using an 8-Ton Static Steel-wheeled roller. The speed of roller shall not exceed 5 kmph. Pneumatic roller tyres shall be avoided with OGFC mixes.

6.5 Laying

6.5.1 *Weather and seasonal limitations*

The OGFC mix shall not be laid:

- In the presence of standing water on the surface.
- When rain is imminent and during rains, fog, or dust storm.
- When the base/binder course is damp.
- When the air temperature on the surface on which it is to be laid is less than 10°C for a mix with conventional bitumen as a binder and is less than 15°C for a mix with polymer modified bitumen as a binder.
- When the wind speed at any temperature exceeds 40 km/h at 2 m height.

6.5.2 *Spreading*

Except in areas where paver cannot access bituminous material shall be spread, levelled and tamped by self-propelled hydrostatic paver finisher preferably with the sensor. As soon as possible after arrival at the site, the material shall be supplied continuously to the paver and laid without delay. The rate of delivery of material to the paver shall be regulated to enable the paver to operate continuously. The travel rate of paver and the method of operation shall be adjusted to ensure even and uniform flow of bituminous material across the screen, free from dragging, tearing and segregation.

Restricted areas (such as confined space, footways, irregular shape and varying thickness, approaches to expansion joints etc.) where paver cannot be used, the material shall be spread, raked and levelled with suitable hand tool by trained staff.

6.6 Compaction

6.6.1 Compaction shall commence immediately after laying and shall be completed before the temperature falls below 100°C (higher temperature when PMB/CRMB is used). Rolling of the longitudinal joints shall be done immediately behind the paving operation. After this, the rolling shall commence at the edge and progress towards the centre longitudinally except at sections with unidirectional camber, where it shall progress from lower edge to upper edge parallel to centerline of the pavement.

6.6.2 All deficiencies in the surface after laying shall be made good by the attendant behind the paver before initial rolling is commenced. The initial or breakdown rolling shall be done with the 8 to 10 tons static steel wheel roller. A vibratory breakdown roller may have to be operated at transverse joints and longitudinal joints at few occasions, to help knock down a high joint. Generally, the use of vibratory compaction should be discouraged. The intermediate rolling shall also be done with 8 to 10 tons deadweight or vibratory roller. Pneumatic rolling shall not be used on OGFC because of potential pickup problems. The finished rolling shall be done with 6 to 8 tons smooth wheel roller. Rolling shall continue till all the roller marks are removed from the surface and the minimum specified field density is achieved.

6.6.3 The OGFC mix shall be rolled in the longitudinal direction, with the roller as close as possible to the paver (within 15 m). The overlap on successive passes should be at least one-third of the width of the rear wheel. The roller should move at a speed of not more than 5 km/h. The roller shall not be permitted to stand on the pavement, which has not been fully compacted. All precautions shall be taken to prevent dropping of oil, grease, petrol or other foreign material on the pavement. The wheel of the rollers shall be kept moist with the water or spray system provided with the machine to prevent the mix from adhering to the wheels. The minimum moisture to prevent adhesion between wheels and mix shall be used and surplus water shall not be allowed to stand on the partially completed pavement.

6.6.4 The density of the finished paving layers shall be determined by taking 150 mm diameter cores. The density of finished paving layer shall not be less than 98% of the average (sample size N=2) laboratory bulk density (G_{mb}) obtained on that day in accordance with AASHTO T 275 or ASTM D 6752. However, the air voids shall not be greater than 22% in the field core when compared with the G_{mm} obtained on that day (ASTM D 2041).

6.7 Joints

6.7.1 Where joints are made, the material shall be fully compacted and the joint made flush in one of the following ways:

6.7.2 All joints shall be cut vertical to the full thickness of the previously laid mix. All loosened material shall be discarded and the vertical face is coated with any viscosity grade bitumen or cold applied emulsified bitumen or rubberized bitumen tack coat (minimum thickness 3 mm), prior to laying the adjacent lane. While spreading the material along with the joint the material spread shall overlap 25 mm to 30 mm on the previously laid mix beyond the vertical face of the joint.

6.7.3 By using two or more pavers in echelon, where this is practicable and in sufficient proximity for adjacent width to be fully compacted by continuous rolling.

6.7.4 By heating the joints with an approved infrared joint heater when the adjacent lane is being laid, but without cutting back or coating with the binder. The heater shall raise the temperature of the full depth of material, to minimum rolling temperature for a width of 75 mm. The temperature shall not exceed 175°C.

6.7.5 For transverse joints, the method suggested in Section 6.6.2 can be adopted. In multi-layer construction, the joint in one layer shall offset the joint in the underlying layer by about 150 mm. However the joint in the top layer shall be along the centre line of the pavement.

6.8 Arrangement for Traffic

It shall be ensured that traffic is not allowed on the OGFC surface until the paved mat has cooled to ambient temperature in its entire depth.

7. CONTROLS

7.1 Surface Finish

7.1.1 The levels of the OGFC mix shall not vary from those calculated with reference to longitudinal and cross profile of the roads as per the contract beyond + 6 mm provided that the negative tolerance shall not be permitted in conjunction with the positive tolerance for the base course if the thickness of the former is thereby reduced by more than 6 mm.

7.1.2 For checking the compliance with the above requirement, measurements of the surface level shall be taken on a grid of points spaced 6.25 m along the length and 0.5 m from the edges and at the centre of the pavement. The compliance shall be deemed to be met for the final road surface only if the tolerance given above is satisfied for any point on the surface.

7.1.3 In case, where surface levels fall outside the specified tolerance, the Contractor shall be liable to rectify these by replacing the full depth of the layer. In all cases of replacement, the area treated shall not be less than 5 m in length and not less than 3.5 m in width.

7.2 Surface Evenness

7.2.1 The measurement and checking of surface evenness shall be done by a 3 m straight edge in accordance with the procedures in IRC:SP:16.

7.2.2 The maximum permissible surface unevenness using longitudinal profile 3 m straight edge shall be 5 mm for OGFC mixes. The maximum permissible unevenness using transverse profile camber shall be 4 mm.

7.2.3 The maximum permissible frequency of surface unevenness (3-5 mm) in 300 m length in longitudinal profile shall be 15, similar to Stone Matrix Asphalt.

7.2.4 Where the surface unevenness falls outside the tolerance, in either case, i.e. the surface is low or high, the full depth of the layer shall be removed and replaced with fresh material and compacted to the Specification.

7.2.5 In all cases of removal and replacement, the area treated shall not be less than 5 m in length and 3.5 m in width.

7.3 Surface Roughness

7.3.1 Surface roughness shall be checked in accordance with procedures in IRC:SP:16.

7.3.2 The maximum permissible value of surface roughness measured with a bump integrator shall be less than 2000 mm/km.

7.4 Quality Control during Construction

7.4.1 The material supplied and the work shall conform to the Specifications prescribed in the preceding Clauses. To ensure the quality of the material and the work, control tests shall be conducted during the execution of the paving project. The tests and minimum frequency for each test is indicated in **Table 4**.

7.5 Acceptance Criteria

7.5.1 The acceptance criteria for test on density (N = 3 minimum) and laboratory air voids and VMA (N = 2 minimum) shall be subjected to the condition that the mean value of N samples is not less than the specified value plus

$$\left[1.65-\left(\frac{1.65}{\sqrt{No.of\ Samples}}\right)\right]\times S.D.$$

Where,

S.D. = Standard Deviation

8. TRIAL/EXPERIMENTAL SECTION

Trial section(s), a minimum of 150 m each, shall be constructed off-site to examine the mixing plant process control to meet the job mix formula within tolerances, placement procedures, OGFC surface appearance, and compaction patterns. Work on the main project will be allowed after satisfactory test results (especially mix composition, graduation, and volumetric) have been obtained on the test section.

Table 4 Quality Control Tests for OGFC Mix

Sr. No.	Test	Frequency
1.	Quality of binder	Number of samples per lot and tests as per IS:73 or IRC:SP:53
2.	Aggregate impact value/Los Angeles Abrasion value	One test per 50 m^3 of aggregate
3.	Flakiness index	One test per 50 m^3 of aggregate
4.	Soundness test (Sodium and Magnesium Sulphate test)	One test for each method for each source and whenever there is a change in the quality of aggregate
5.	Water absorption of aggregate	One test for each source and whenever there is change in the quality of aggregate
6.	Sand equivalent test	One test for each source
7.	Plasticity Index	One test for each source
8.	Polished stone value	One test for each source
9.	Per cent of fractured faces	One test per 50 m^2 of aggregate when crushed gravel is used.

Sr. No.	Test	Frequency
10.	Mix grading	One set for individual constituent and mixed aggregate from the dryer for every 400 tons of mix subject to a minimum of two tests per day per plant
11.	Air voids and VMA analysis of mix including theoretical maximum specific gravity of loose mix	Three tests for density and void contents for every 400 tons of mix subject to a minimum of two tests per day per plant
12.	Moisture Susceptibility of the mix (AASHTO T283)	One test for each mix type whenever there is a change in the quality or source of coarse or fine aggregate
13.	The temperature of binder in the boiler, aggregate in dryer and mix at the time of laying and compaction	At regular intervals
14.	Binder content	One set for every 400 tons of mix subject to a minimum of two tests per day per plant
15.	Rate of spread of mix material	After every 5th truckload
16.	The density of the compacted layer	One test per 250 m^2 area.

ANNEX A

THE FOLLOWING SCHEMATIC SKETCHES ARE ILLUSTRATIVE EXAMPLES FOR PLACEMENT OF OGFC FOR QUICK DRAINAGE OF WATER

CHARACTERISTICS OF OGFC

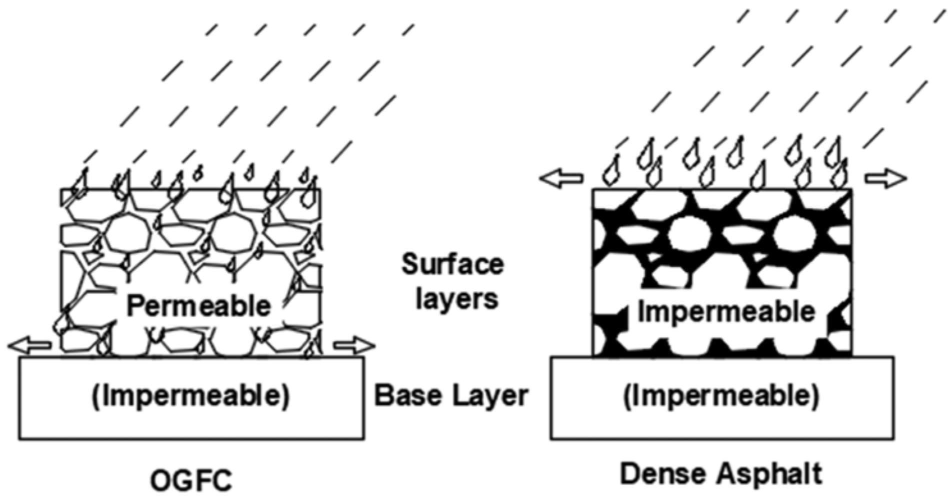

Fig. 1 Comparative illustration of OGFC and Dense Asphalt

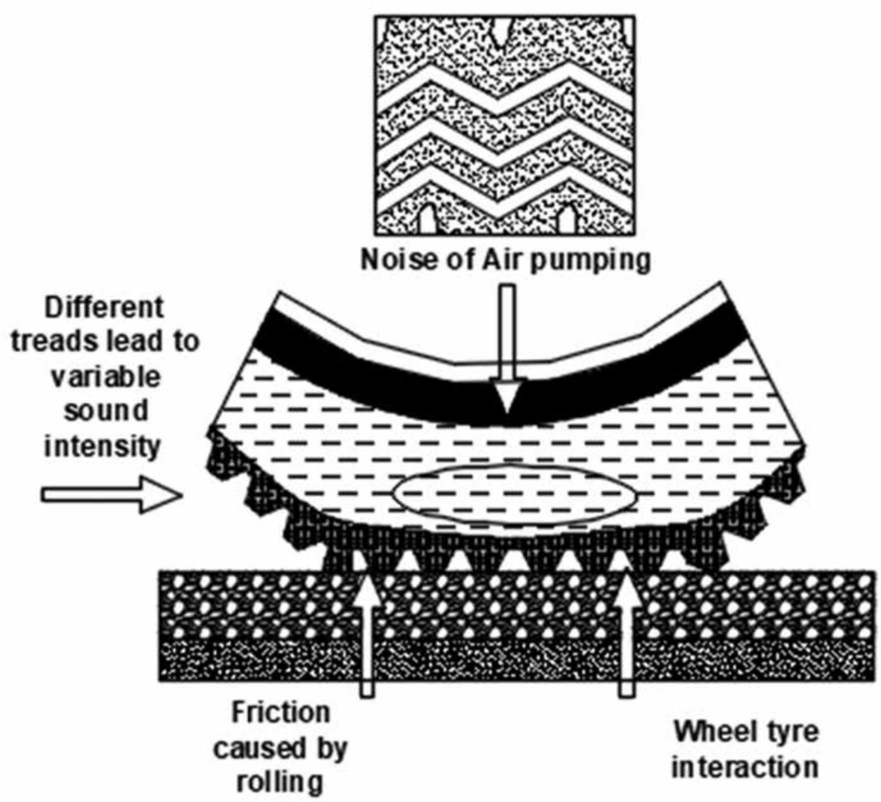

Fig. 2 Illustration of OGFC and Wheel Tyre Interaction

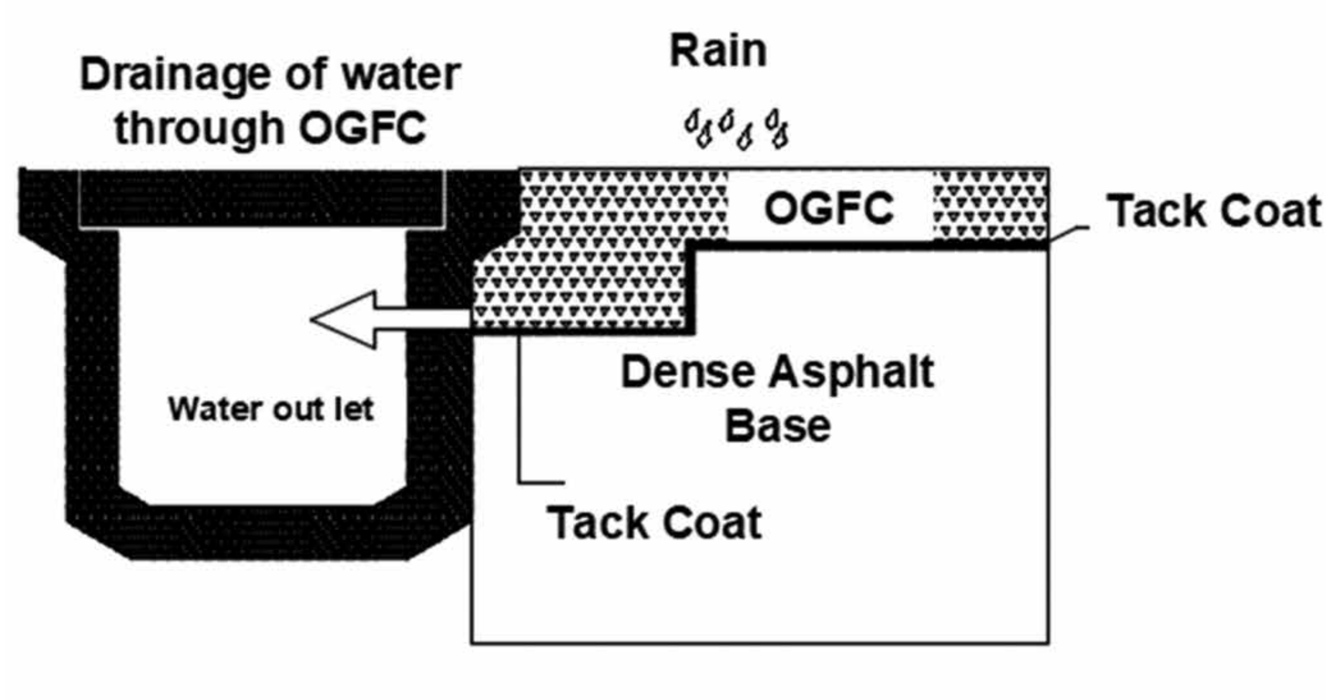

Fig. 3 Drainage through OGFC

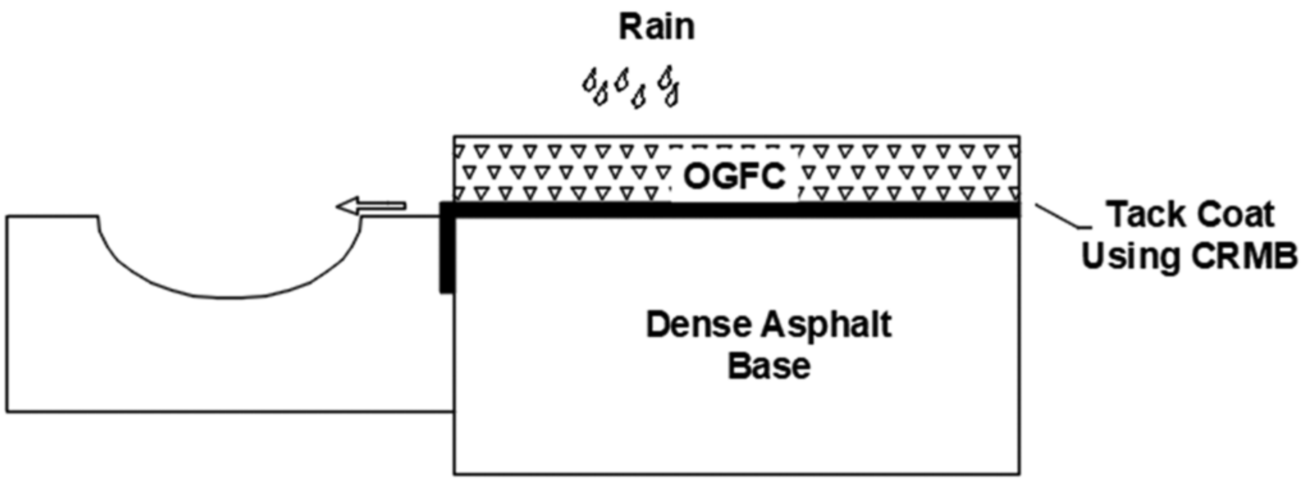

Fig. 4 Drainage through Central Verge

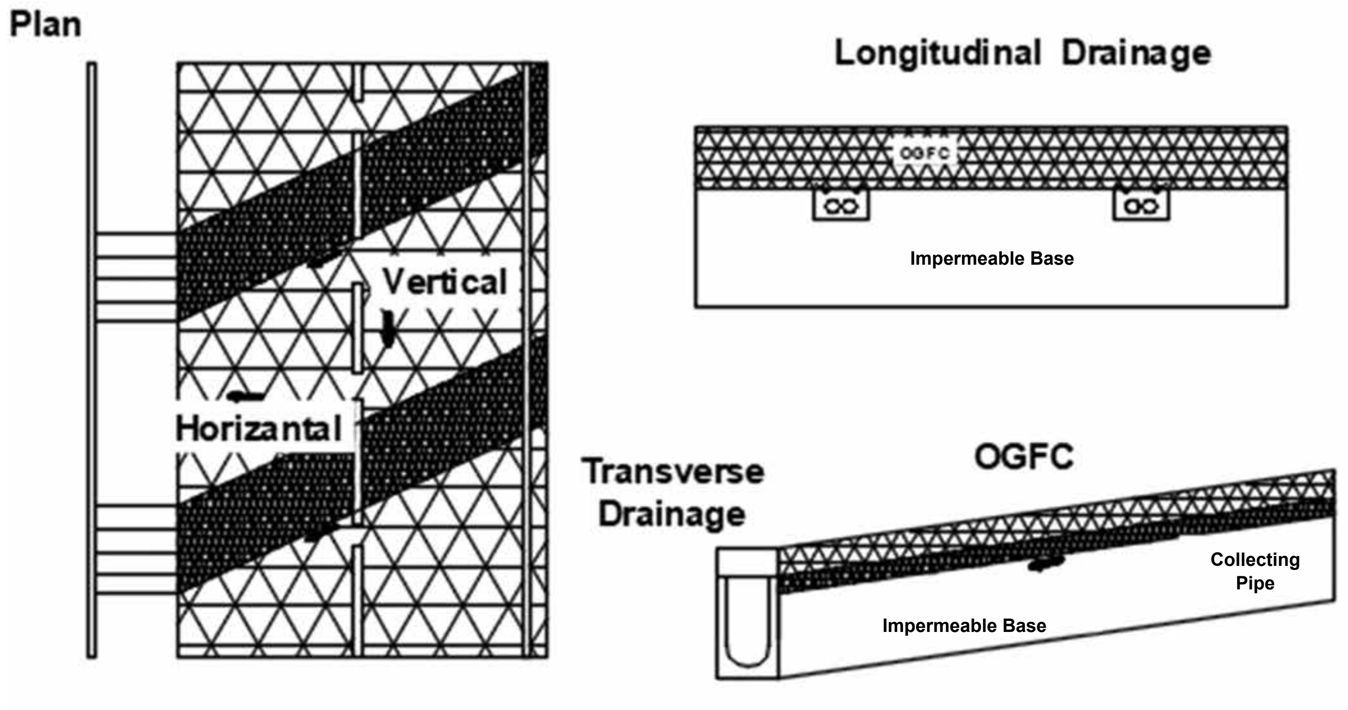

Fig. 5 Drainage System for OGFC

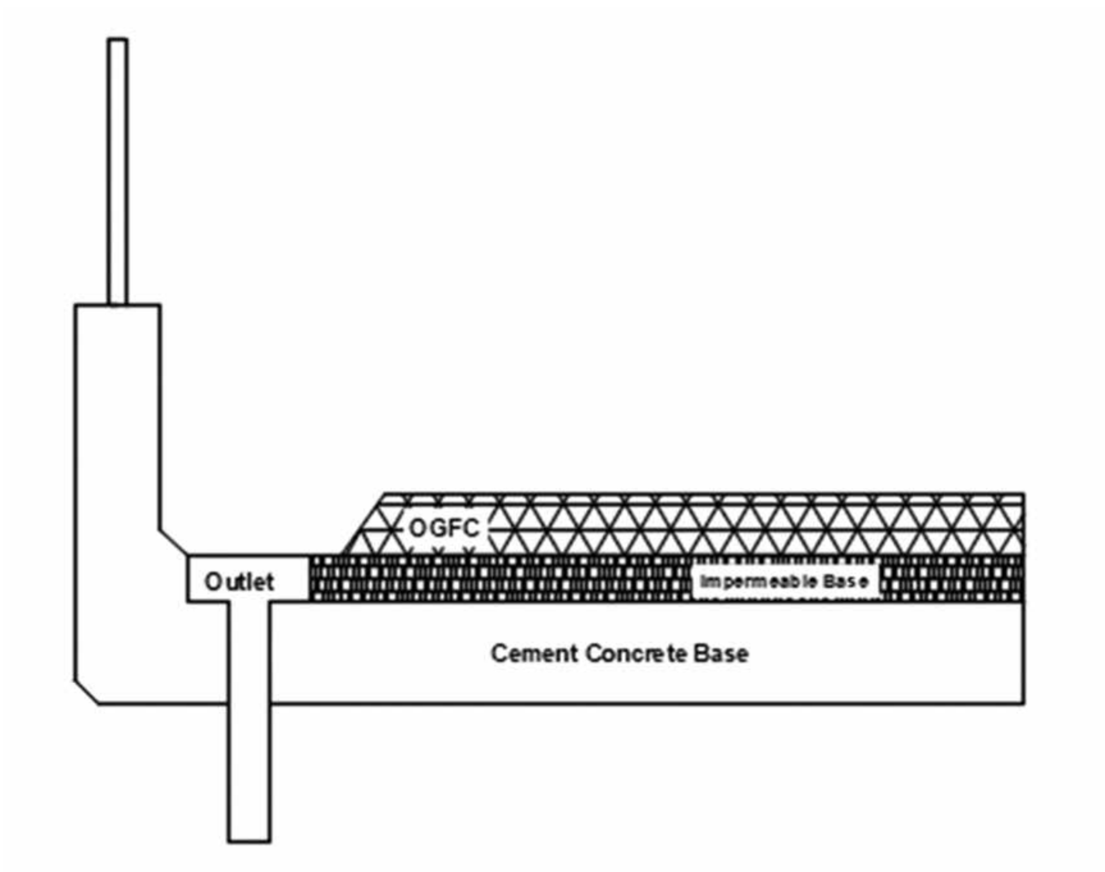

Fig. 6 Drainage Structure on a Bridge Deck

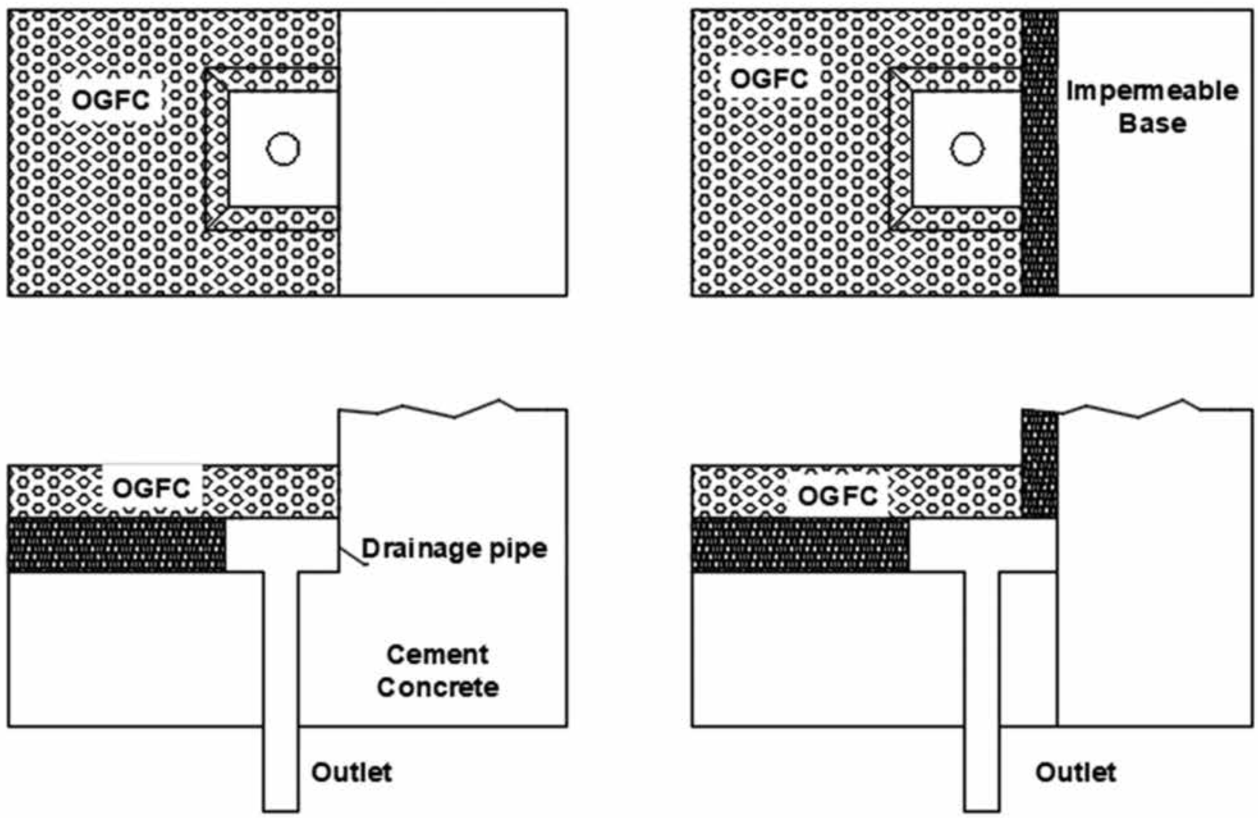

Fig. 7 Use of OGFC on a Bridge Deck

Annex B

OUTLINE OF ASTM D 6390, "DETERMINATION OF DRAIN-DOWN CHARACTERISTICS IN UNCOMPACTED ASPHALT MIXES"

A. Scope and Summary of Test

This method determines the amount of drain-down in an uncompacted asphalt mix sample when the sample is held at elevated temperatures, which are encountered during the production, transportation, and placement of the mix. This test is especially applicable to open-graded asphalt mixes.

A fresh sample of the bituminous mix (either made in the laboratory or from an asphalt plant) is placed in a wire basket. The wire basket is hung in a forced draft oven for one hour at a pre-selected temperature. A catch plate of known mass is placed below the basket to collect material drained from the sample. The mass of the drained material is determined to calculate the amount of drain down as a percentage of the mass of the total asphalt mix sample.

B. Testing Equipment

1. Forced draft oven, capable of maintaining temperatures in a range of 120 to 175°C with ± 2°C of the set temperature.
2. Plates to collect the drained material.
3. Standard wire basket meeting the dimensions shown in **Fig. 8**. A standard 6.3 mm sieve cloth shall be used to make the basket. The dimensions shown in the figure can vary by ±10 per cent.
4. Balance readable to 0.1 gram

C. Testing Procedure

1. For each mix to be tested, the drain down characteristics shall be determined at two temperatures: at the anticipated plant production temperature and at a temperature 10°C higher than the anticipated production temperature. Duplicate samples shall be tested at each temperature. Therefore, a minimum of 4 samples shall be tested.
2. Weigh the empty wire basket (W_1).
3. Place in the wire basket 1200 ± 200 grams of fresh, hot asphalt mix (either prepared in the laboratory or from an asphalt plant) as soon as possible without losing its temperature. Place the mix loosely in the basket without consolidating it. Determine the mass of the wire basket plus sample to the nearest 0.1 gram (W_2).
4. Determine the mass of the empty plate to be placed under the basket to nearest 0.1 gram (W_3).
5. Hang the basket with the mix in the oven preheated to a selected temperature. Place the catch plate beneath the wire basket. Keep the basket in the oven for 1-hour ± 5 minutes.

6. Remove the basket and catch plate from the oven. Let it cool to ambient temperature. Determine the mass of the catch plate plus the drained material to the nearest 0.1 gram (W_4).
7. Calculate the percentage of the mix which drained to the nearest 0.1 % as follows:

$$Draindown\ (\%) = \frac{W_4 - W_3}{W_2 - W_1} \times 100$$

Where,

W_1 = Mass of empty Wire Basket (g)
W_2 = Mass of basket and sample (g)
W_3 = Mass of empty catch plate (g)
W_4 = Mass of catch plate and drained material (g)

8. Average the two drain down results at each temperature and report the average to nearest 0.1 per cent.

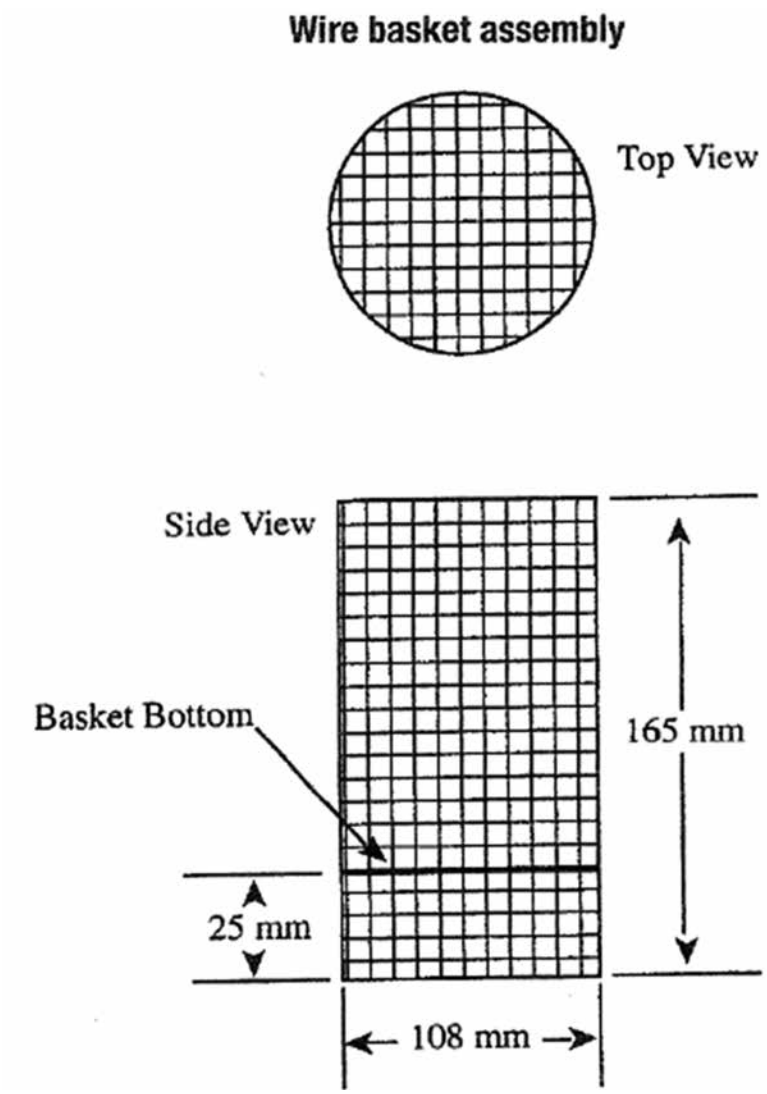

Fig. 8 Wire Basket Assembly for Drain-down Test

Annex C

OUTLINE OF "THE SCHELLENBERG BINDER DRAINAGE TEST"

1. Determine the weight of an empty 850 ml glass beaker, approximately 98 mm diameter by 136 mm high, to the nearest 0.1 gram (W_1).
2. Pour approximately 1 kg of the mix immediately into the glass beaker after mixing at the anticipated field mixing temperature. Re-weigh the beaker together with the mix (B) to the nearest 0.1 gram (W_2).
3. Place the glass beaker with a glass or tin cover in an oven maintained at 170°C ± 1°C for 1 hour ± 1 minute.
4. At the end of the 1 hour period, immediately remove the glass beaker from the oven and empty the beaker without the use of any shaking or vibration. Reweigh the beaker (C) to the nearest 0.1 gram (W_3).
5. Calculate the percentage of binder drain down (defined as the percentage of the mass of the mix deposited in the beaker) as follows:

$$Draindown(\%) = \frac{W_3 - W_1}{W_2 - W_1} \times 100$$

Annex D

OUTLINE OF ASTM C 29, "BULK DENSITY (UNIT WEIGHT) AND VOIDS IN AGGREGATE"

A. Scope and Summary of Test

This method covers the determination of bulk density (unit weight) of a coarse aggregate in a specified compacted condition and calculated voids between aggregate particles based on this determination. The amount of calculated voids are used in the mix design of OGFC. Only the dry-rodded compaction is covered in this outline of the test method.

B. Testing Equipment

1. Balance or scale accurate up to 0.1 percent of the test load.
2. Tamping rod: a round, straight steel rod, 16 mm (5/8 inch) in diameter and approximately 600 mm in length. Tamping end shall be rounded to a hemispherical tip with a diameter of 16 mm.
3. A sturdy, cylindrical metal measure with a capacity of 10 litres. The height and diameter of the measure should be approximately equal.
4. A Shovel or scoop for filling the measure with aggregate.
5. Piece of plate glass at least 6 mm thick and at least 25 mm larger than the diameter of the measure.

C. Testing Procedure

1. Calibrate the measure and determine its capacity in mm^3 by filling it with water and covering with plate glass to eliminate air bubbles and excess water. Determine the mass of water in the measure. Calculate the volume of the measure, V, by dividing the mass of the water by its density.
2. Use the dry rodding procedure to place and compact the oven-dry coarse aggregate in the measure. Fill the measure 1/3 full with aggregate and level the surface with fingers. Rod the layer of the aggregate with 25 strokes of the tamping rod evenly distributed over the surface. Fill the measure 2/3 full, level with fingers and rod as above again. Finally, fill the measure slightly overflowing the measure and rod again as before. Level the surface of aggregate with fingers in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

3. Determine the mass of the measure plus its contents and the mass of the measure alone and record the values to the nearest 0.05 kg.
4. Calculate the unit weight of the coarse aggregate by the dry rodding procedure as follows:

$$\gamma_s = \frac{G - T}{V}$$

Where,

γ_S = unit weight of the coarse aggregate in dry-rodded condition, (kg/m^3)

G = mass of the measure plus aggregate, (kg)

T = mass of the measure, (kg)

V = volume of the measure, (m^3)

Annex E

OUTLINE OF ASTM D 2041, "THEORETICAL MAXIMUM SPECIFIC GRAVITY AND DENSITY OF BITUMINOUS PAVING MIX"

A. Scope and Summary of the Test

Method

This test method covers the determination of the theoretical maximum specific gravity and density of uncompacted bituminous paving mixes at 25°C. The theoretical maximum specific gravity (G_{mm}) is used: (a) to calculate air voids in compacted bituminous mixes, (b) to calculate the amount of bitumen absorbed by the aggregate, and (c) to provide target value for the compaction of paving mixes in the field.

A sample of loose paving mix is placed in a tared vacuum vessel. Water is added to completely submerge the sample. A specified amount of vacuum is gradually applied to remove the air bubbles entrapped between bituminous mix particles. After the vacuum is released, the volume of the sample of the voidless paving mix is obtained by either immersing the vacuum container with the sample in a water bath or weighing or by filling the calibrated vacuum container level full of water and weighing in air.

B. Testing Equipment

1. Container (either a or b below)
   (a) **Vacuum bowls:** Either a metal or plastic bowl with a diameter ranging from 180 to 260 mm and a bowl height of at least 160 mm. The bowl shall be equipped with a stiff, transparent cover fitted with a rubber gasket and a connection for the vacuum line. The hose connection shall be covered with a small piece of fine wire mesh to minimize loss of any fine material from the mix.
   (b) Vacuum flask for weighing in air only. A thick-walled volumetric glass flask with a capacity of approx. 4000 ml, fitted with a rubber stopper with a connection for the vacuum line. The hose connection shall be covered with a small piece of fine wire mesh to minimize loss of any fine material from the mix.
2. Balance capable of being read to the nearest 0.1 g. If weighing is to be done under water, a suitable suspension arrangement shall be provided for weighing the sample while suspended from the center of the balance.
3. Vacuum pump, capable of evacuating air from the vacuum container to a residual pressure of 4.0 kPa (30 mm of Hg) or less. Provide a suitable trap between the pump and container to minimize water vapour entering the vacuum pump.
4. Residual pressure manometer or calibrated absolute pressure gauge with a bleed valve to adjust the vacuum level.
5. Water bath capable of maintaining a constant temperature of 25±1^{0}C and suitable for immersion of the suspended container.

C. Calibration of Containers

1. **Bowls:** Determine the mass (B) of the container immersed in water at 25±1°C. If the bowl is used for weighing in air, place the volumetric lid on the bowl while under water. Remove the water-filled bowl with the lid in place and dry prior to determining the combined mass of the bowl, lid and water. Repeat 3 times and average the 3 masses. Designate the average mass as D.
2. **Flasks:** Calibrate the volumetric flask by accurately determining the mass of the flask filled with water at 25±1°C. Use a glass cover plate to ensure the flask is completely full.

D. Testing Procedure

1. Separate the particles of the loose paving mix (while it is warm) by hand so that the particles are not larger than about 6 mm don't fracture the aggregate. Place the mix sample directly into the tarred bowl or flask. Weigh the container with the sample and designate the net mass of the sample only as A.

   [Note: The minimum sample size shall be 1500 g for mixes with nominal maximum aggregate sizes of 12.5 mm or smaller; and shall be 2500 g for mixes with nominal maximum aggregate sizes from 19 to 25 mm.]

2. Add sufficient water at 25^0C to cover the sample completely. Place the cover (bowls) or stopper (flasks) on the containers.
3. Place the container with the sample and water on a mechanical agitation device or agitate manually at frequent intervals (2 to 3 minutes). Begin removing entrapped air by gradually applying vacuum and increasing the vacuum pressure until the residual manometer reads 3.7+0.3 kPa (27.5+2.5 mm of Hg). After achieving this level within 2 minutes, continue the vacuum and agitation for 15+2 minutes. Gradually release the vacuum with the bleed valve.
4. Weighing in water: Suspend the bowl (without lid) and contents in water for 10 + 1 minute and then determine mass. Designate the mass under water of the bowl and sample as C.
5. Weighing in air
   (a) **Bowl:** Submerge the bowl and sample slowly in the 25±1°C water bath. Keep it there for 10±1 minutes. Immerse the lid in water and slide it onto the bowl without removing water from the bowl so that no air is trapped inside the bowl. Remove the bowl with the lid in place from the water bath. Dry the bowl and lid with a dry cloth. Determine the mass of the bowl, sample, and lid and designate it as E.
   (b) **Flask:** Fill the flask slowly with water ensuring not to introduce any air into the sample. Place the flask in water bath for 10±1 minutes to stabilize the temperature at 250°C without submerging the top of the flask. Completely fill the flask with water using a cover plate without entrapping air beneath the cover plate. Wipe the exterior of the flask and cover plate. Determine the mass of the flask, plate and its contents completely filled with water. Designate this mass as E.

6. Calculations: Calculate the maximum specific gravity of the sample of loose paving mix as follows:

(a) Bowls used under Water Determination:

$$G_{mm} = \frac{A}{A-(C-B)}$$

Where,

G_{mm} = maximum specific gravity of the mix
A = mass of the dry sample in air, (g)
B = mass of bowl under water, (g)
C = mass of bowl and sample under water, (g)

(b) Bowl in Air Determination

$$G_{mm} = \frac{A}{A+D-E}$$

Where,

G_{mm} = maximum specific gravity of the mix gravity
A = mass of dry sample in air, (g)
D = mass of lid and bowl with water at 25°C, (g)
E = mass of lid, bowl, sample water at 25°C, (g)

(c) Flask Determination

$$G_{mm} = \frac{A}{A+D-E}$$

Where,

G_{mm} = maximum specific gravity of the mix gravity
A = mass of dry sample in air, (g)
D = mass of cover plate and flask filled with water at 25°C, (g)
E = mass of flask, cover, sample and water at 25°C, (g)

Annex F

OUTLINE OF AASHTO T 283 "RESISTANCE OF COMPACTED ASPHALT MIXES TO MOISTURE-INDUCED DAMAGE"

A. Scope and Summary of Test Method

This method covers preparation of compacted bituminous mixes and the measurement of the change of diametral tensile strength resulting from the effects of water saturation and laboratory accelerated stripping phenomenon with a freeze-thaw cycle. The result may be used to predict long-term stripping susceptibility of bituminous mixes and evaluate liquid anti-stripping additives that are added to the bitumen or pulverized mineral materials such as hydrated lime, which are added to the mineral aggregate.

Each set of 6 compacted specimens is divided into two equal subsets. One subset is tested in a dry condition for indirect tensile strength. The other subset is subjected to vacuum saturation and a freeze-thaw cycle (thawing in a hot water bath) before testing for indirect tensile strength. Numerical indices of retained indirect tensile strength properties are calculated from the test data to obtain by testing the two subsets viz. dry and conditioned.

B. Test Equipment

1. Vacuum container, vacuum pump, manometer, and other accessories as specified in ASTM D 2041, "Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures".
2. Balance or scale accurate to 0.1% of the test load
3. Two water baths capable of maintaining temperatures of 60°C±1°C and 25°C±0.5°C
4. Freezer maintained at 18°C + 3°C
5. 10 ml graduated cylinder
6. Loading jack and ring dynamometer (Marshall stability testing machine can be used) to provide a vertical rate of deformation of 50 mm (2 inches) per minute and capable of reading the maximum failure load.
7. Steel loading strips with a concave surface having a radius equal to the normal radius of the test specimen. The loading strips shall be 12.7 mm (0.5 inches) wide for specimens 100 mm (4 inches) in diameter. The loading strips for 150 mm (6 inches) diameter specimens shall be 19.05 mm (0.75 inches) wide. The length of the loading strips shall exceed the thickness of the specimens. Steel strips are provided at the top and bottom of specimens during indirect tensile testing.

C. Testing Procedure

1. Make at least 6 compacted specimens for each mix, 3 to be tested dry and 3 to be tested after partial saturation and moisture conditioning with a freeze-thaw cycle. Some extra specimens will need to be made to establish compaction procedures in order to obtain specified air void contents in the test specimens by trial and error.

2. Compact the 6 specimens with 25 Marshall blows on each face of the OGFC specimen so that the compacted specimens will have air voids of 20.0±0.5%. Air void content must be calculated from the bulk specific gravity of the compacted specimen (determined by the paraffin wax coating method [AASHTO T 275]).
3. Separate the 6 specimens into 2 subsets so that the average air voids of the two subsets are approximately equal.
4. One set will be tested dry. Keep it at room temperature and then place in a 25°C±0.5°C water bath for 2 hours prior to determining their indirect tensile strength.
5. The other subset will be conditioned as follows:
   a. Place and submerge the 3 specimens in the vacuum container filled with water at room temperature. Apply a vacuum of 87.8 kPa absolute pressure (660 mm of mercury partial pressure) for 10 minutes to saturate the compacted specimens to the required saturation level (ASTM D 7064/D 7064M-08[2013]). Submerge the specimens in water during freeze cycles to maintain saturation. If the mixture fails to meet the moisture susceptibility requirements, hydrated lime, or liquid anti-strip, or both, additives can be used. If these measures prove ineffective, the aggregate source, or bitumen, or both, source can be changed to obtain better aggregate/bitumen compatibility.
   b. Wrap a plastic film around each saturated specimen and place the wrapped specimen in a plastic bag containing 10 ml of water and seal the plastic bag. Place the plastic bag in a freezer at a temperature of 18^0C ± 3^0C for a minimum of 16 hours. Remove the specimens from the freezer.
   c. Place the specimens in a water bath maintained at 60^0C±1^0C for 24 hours. Remove the plastic bag and the plastic film from each specimen after placing the specimens under water.
   d. Remove the specimens from hot water bath and place in a water bath maintained at 25^0C+0.5^0C for 2 hours.
   e. Remove the conditioned specimens and test for indirect tensile strength.
6. Determine the indirect tensile strength of the 3 dry and 3 conditioned specimens at 25^0C ± 0.5^0C after removing from the water bath. First, measure their mean thicknesses (t). Then place the two steel loading strips on the bottom and top of the specimens across diameter and place in the Marshall testing machine or a compression-testing machine. Apply load to the specimens diametrically at a vertical rate of 50 mm per minute.
7. Record the maximum compressive strength noted on the testing machine and continue loading until a vertical crack appears in the specimen. Remove the cracked specimen from the machine and visually estimate the approximate degree of moisture damage (extent of stripped or bare aggregate) on the fractured faces of the specimen on a scale of 0 to 5 (5 being the most stripping).

8. Calculate the tensile strength of each specimen as follows in SI units:

$$S_t = \frac{2000P}{\pi t d}$$

Where,

S_t = tensile strength (kPa)

P = maximum loads (N)

t = specimen thickness (mm)

d = specimen diameter (mm)

9. Express the numerical index of resistance of bituminous mix to the detrimental effects of water as the ratio of the original strength that is retained after accelerated moisture and freeze-thaw conditioning.

Calculate the tensile strength ratio (TSR) as follows:

$$TSR = \frac{S_2}{S_1} \times 100$$

Where,

S_1 = average tensile strength of the dry subset (kPa)

S_2 = average tensile strength of the conditioned subset (kPa)

Annex G

OUTLINE OF "DETERMINATION OF CANTABRO ABRASION LOSS FOR OPEN-GRADED FRICTION HMA COURSE (FOR AGED AND UNAGED SPECIMENS)"

A. Scope and Summary of the Test

This method is used to determine the abrasion loss of compacted hot-mix OGFC specimen for aged and unaged specimens. This method is carried out in the Los Angeles abrasion machine, to measure the breakdown of compacted OGFC specimens. The per cent (%) of weight loss acts as an indicator for the durability of OGFC. This procedure is designed to determine the abrasion resistance of open-graded courses.

A compacted specimen is placed in the rotating drum of a Los Angeles abrasion machine, and the drum is rotated for 300 revolutions (without the charge of steel balls), with a speed of 30-33 rpm. After completion of Loss in the weight is calculated (in terms of percentage) for the compacted specimen.

A minimum of 5 aged and 5 unaged specimens are required.

B. Ageing

A minimum of 5 OGFC Marshall Specimens compacted with 25 blows on each face are placed in a heating oven maintained at 60°C for 168 hours (7 days). The specimens are then cooled to 25°C and stored for 5 hours prior to testing for Cantabro Abrasion test.

C. Testing Equipment

1. A Los Angeles Abrasion Machine, capable of rotating at 30-33 rpm.
2. Balance or scale accurate up to 0.1 per cent of the test load.
3. Plates to collect the material

D. Testing procedure

1. A compacted OGFC specimen (conforming to the gradation) is prepared with 25 Marshall blows on each face of the OGFC specimen.
2. The mass of the specimen is weighed to the nearest of 0.1 gram and is termed as P_1.
3. The compacted specimen is placed in the rattler of the Los Angeles Abrasion Machine and operated for 300 revolutions at a rate of 300 rpm.
4. After the operation is done, the specimen is removed and weighed to nearest 0.1 gram and is termed as P_2.

5. The percentage Cantabro Abrasion Loss (P) is calculating by using the following formula:

$$P = \left(\frac{P_1 - P_2}{P_1}\right) \times 100$$

E. Test Summary

1. The average of Cantabro Abrasion losses (%) for unaged specimen shall not exceed 20%.
2. The average of Cantabro Abrasion losses (%) for aged specimen shall not exceed 30% and individual result shall not exceed 50% (for aged and unaged specimens).

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(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/Manual, etc. from the date specified therein)