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GUIDELINES FOR WET MIX MACADAM

(First Revision)

INDIAN ROADS CONGRESS
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GUIDELINES FOR WET MIX MACADAM

1 INTRODUCTION

The Indian Roads Congress published the Guidelines for Wet Mix Macadam in 1997. This document served the profession well for about two decade. Taking note of the technological development and performance experience, the Flexible Pavement Committee (H-2) felt the necessity for the revision of the document. The initial revised draft guidelines were prepared by Shri Bidur Kant Jha and thereafter brought into shape by the Sub-Group comprising Shri A.V. Sinha, Dr. Sunil Bose, Shri S.K. Nirmal, Shri R.K. Pandey and Shri Kaushik Basu. The draft of the said Guidelines was discussed in various meetings. The H-2 Committee finalized the draft in its meeting held on 07.06.2014.

The Composition of H-2 Committee is as given below:

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The finalized revised guidelines were approved by the Highways Specifications and Standards Committee (HSS) in its meeting held on 9th August, 2014. The document was approved by the Executive Committee in its meeting held on 18th August, 2014. The IRC Council in its meeting held at New Delhi on 19th and 20th August, 2014 approved the draft IRC:109 “Guidelines for Wet Mix Macadam” (*First Revision*) for publishing.

2 DESCRIPTION

Wet Mix Macadam (WMM) construction is an improvement upon the conventional WBM and is intended to be as an alternative and more durable pavement layer.

Wet Mix Macadam is a sub-base/base course of the pavement wherein clean, crushed graded aggregates and granular material, like, graded coarse sand are mixed with water and rolled to a dense mass on a prepared surface. The work may be done in layers. The thickness of an individual layer shall not be less than 75 mm and can be upto 250 mm.

3 MATERIALS

3.1 Aggregate

3.1.1 *Physical Requirements*

Coarse aggregates shall be crushed stone/crushed gravel/shingle, not less than 90 percent by weight of gravel/shingle retained on 4.75 mm sieve shall have at least two fractured faces. The aggregates shall conform to the physical requirements set forth in **Table 1**.

If the water absorption value of the coarse aggregates is greater than 2 percent, soundness test shall be carried out on the material as per IS:2386 (Part V) with sodium sulphate which should not exceed 12 percent.

Table 1 Physical Requirement of Coarse Aggregates for Wet-Mix Macadam

Sl. No.	Test	Test Method	Requirements
1.	*Los Angeles Abrasion Value or	IS:2386 (Part IV)	40 percent (Maximum)
	*Aggregate impact Value	IS:2386(Part IV) or IS:5640)	30 percent (Maximum)
2.	**Combined Flakiness and Elongation indices (Total)	IS:2386 (Part I)	35 percent (Maximum)

* Aggregates may satisfy requirements of either of the two tests.

** To determine the combined proportion of flaky and elongated particles, the flaky stone from a representative sample should first be separated out. Flakiness index is weight of flaky stone divided by weight of stone sample. Only the elongated particles be separated out from the remaining (non-flaky) stone metal. Elongation index is weight of elongated particles divided by total non-flaky particles. The value of flakiness index and elongation index so found are added up.

3.1.2 *Grading Requirements*

Materials shall have particle size distribution and particle shape which provide high mechanical stability and should contain sufficient fines to produce a dense material when compacted. If the amount of fine aggregate produced during the crushing operation is insufficient, non-plastic angular sand may be used to make up the deficiency. In constructing a crushed stone road base, the aim should be to achieve maximum impermeability compatible with good compaction and high stability under traffic.

The aggregates shall conform to the grading given in **Table 2**.

Table 2 Grading Requirements of Aggregates for Wet-Mix Macadam

IS Sieve Designation	53.00 mm	45.00 mm	22.40 mm	11.20 mm	4.75 mm	2.36 mm	600* micron	75* micron
Percent by Weight Passing Sieve	100	95-100	60-80	40-60	25-40	15-30	6-18	4-8

* The fraction passing the 75 micron sieve shall not be greater than two-thirds of the fraction passing the 600 micron sieve.

The grading of the WMM shall be within and approximately parallel to the grading envelope. The grading within the limit set forth in **Table 2** shall be graded from coarse to fine and shall not vary from the low limit on one sieve to the high limit on the adjacent sieve or the vice versa. The grading can be produced by crushing rock and may be an all-in product, usually termed a 'crusher-run'. If it is unable to achieve the required grading directly and continuously from crushing, screen the material into at least four fractions and reconstitute the material to conform to the Specifications by mixing it together in a pug mill.

Material finer than 425 micron shall have Plasticity Index (PI) not exceeding 6. For determination of laboratory MDD/OMC, for sample having aggregate passing through 37.5 mm sieve, bigger size mould of volume 2250 cc as specified in IS:2720, (Part VIII) shall be used.

4 CONSTRUCTION OPERATIONS

4.1 Weather and Seasonal Limitations

The work of laying of wet mix macadam shall not be done during rain.

4.2 Preparation of the Sub-base/base

The surface of the sub-base/base to receive the WMM course shall be prepared to the specified lines and cross-fall (camber) and made free of dust and other extraneous matter.

Any ruts or soft yielding places shall be corrected in an approved manner and rolled until firm surface is obtained, if necessary by sprinkling water. Laying of WMM over an existing bituminous surface is not permitted.

4.3 Provision of Lateral Confinement of Wet Mix Layer

While constructing WMM, arrangement shall be made for the lateral confinement of wet mix. This shall be done by laying materials of adjoining shoulders along with that of wet mix layer. The sequence of operations shall be such that the construction of the shoulder is done in layers each matching the thickness of the adjoining pavement layer. Only after a layer of pavement and corresponding layers in shoulder have been laid and compacted, the construction of the next layer of pavement and shoulder shall be taken up.

4.4 Preparation of Mix

When the WMM mix is the crusher run material, it shall be stockpiled with the front end loader. Before sending the mix for laying, the stockpile shall be watered and homogeneously mixed and loaded to the tipper/dumper. In other case WMM shall be prepared in an approved mixing plant of suitable capacity conforming to requirements detailed in **Annexure**. In exceptional cases, for small quantity of wet mix work, mixing may be done in ordinary concrete mixer.

Optimum moisture for mixing shall be the laboratory OMC. While adding water, due allowance should be made for evaporation losses. However, at the time of compaction, water in the wet mix should not vary by more than ± 2 percent.

4.5 Spreading of Mix

Immediately after mixing, the mixed material shall be transported to site and spread uniformly and evenly upon the prepared sub-base/base in required quantities. Hauling of the mix over a freshly completed stretch is not permitted. Transportation of mix is usually done by tipping trucks. In order to avoid moisture loss in transit due to evaporation, mix should be covered with tarpaulin. The material is usually kept wet during transport and laying to reduce the likelihood of particle segregation.

The mix may be spread by a paver finisher. However in case of multilayer construction the bottom layer/layers may be allowed to be laid by motor grader. In exceptional cases, for portions where mechanical means cannot be used, manual method of spreading can be adopted. The equipment used for spreading shall be capable of spreading the material uniformly all over the surface. Single full width paver or two pavers of lesser width working in tandem within the short distances should be used for obtaining good results.

The paver finisher shall be self-propelled, having features given in **Annexure**.

The surface of the layer as spread shall be carefully checked with templates and all high or low spots remedied by removing or adding wet mix material as may be required. The layer thickness may be checked by depth blocks during construction. No segregation of coarse or fine particles shall be allowed. The layer as spread shall be of uniform gradation and shall not have pockets of fine materials.

4.6 Compaction

After the mix has been laid to the required thickness, grade and cross-fall/camber, the same shall be uniformly compacted to the full depth with a suitable roller. The speed of roller shall not exceed 5 km/hr. Formulation of compaction methodology to meet the compaction requirements of the Specifications shall be based on trial section. Guidelines in this regard are available in **Annexure**.

In portions having uni-directional crossfall/superelevation, rolling shall commence from the lower edge and progress gradually towards the upper edge. Thereafter roller should progress parallel to the center line of the road, uniformly overlapping each preceding track by at least one third width until the entire surface has been rolled.

In portions in camber, rolling should begin at the edge with the roller running forward and backward until the edge has been compacted firmly. The roller then progress gradually towards the center parallel to center line of the road uniformly overlapping each of the proceeding track by at least one third width. The process of compaction is then to be repeated from the other edge of the pavement upto the center line until the entire pavement is compacted.

Any displacement occurring as a result of reversing of the direction of a roller or from any other cause shall be corrected. Alternate trips of the roller shall be terminated in stop atleast 1 m away from the preceding stop.

Along forms, kerbs, walls or other places not accessible to the roller, the mix shall be thoroughly compacted with mechanical tampers or a plate compactor. Skin patching of an area without scarifying the surface to permit proper bonding of the added material shall not be permitted.

Rolling should not be done when the subgrade is soft or yielding or when it causes a wave-like motion in the sub-base/base coarse or sub-grade. If irregularities develop during rolling which exceed 12 mm when tested with a 3 metre straight edge, the surface should be loosened and premixed material added or removed as required before rolling again so as to achieve a uniform surface conforming to the desired grade and cross-fall. In no case should the use of unmixed material be permitted to make up the depressions.

Rolling shall be continued till the density achieved is atleast 100 percent of the maximum dry density for the material as determined by the method outlined in IS:2720 (Part VIII).

After completing, the finished surface shall present a well-closed appearance, free from movement under compaction equipment or any compaction marks, ridges, cracks and loose material. All loose, segregated or otherwise defective areas shall be made good to the full thickness of the layers and recompacted until the specified density is achieved through out the entire layer. The finally compacted layer shall be free from surface laminations, portions exhibiting segregation of the fine and coarse aggregate, corrugations, or other defects that may adversely affect the performance of the layer.

Longitudinal joints and edges shall be constructed true to the delineating line parallel to the center line of the road. All longitudinal and transverse joints shall be cut vertical to the full thickness of the previously laid mix before laying the fresh mix.

4.7 Setting and Drying

The laid wet mix macadam course shall be allowed to dry for 24 hours before priming.

5 OPENING TO TRAFFIC

No vehicular traffic except construction vehicles with speed less than 5 km/hr shall be allowed on the finished WMM surface.

6 SURFACE FINISH, CONSTRUCTION TOLERANCES, QUALITY CONTROL OF WORK AND TESTING

6.1 The surface level of a WMM as a base course shall have the tolerance of + 10 mm and - 10 mm. For checking compliance with this, surface levels shall be taken on a grid of points placed 6.25 m longitudinally and 3.5 m transversely. For 10 consecutive measurements taken longitudinally or transversely, not more than one measurement shall be permitted to exceed the above tolerances, thus one measurement being not in excess of 5 mm above the permitted tolerance.

6.2 The longitudinal profile shall also be checked by a 3 metre straight edge at the middle of each traffic lane along a line parallel to the center line of the road. The maximum allowable difference between the road surface and underside of a 3 metre straight edge shall be 8 mm.

The frequency of the quality control tests shall be as under:

Table 3 Frequency of Quality Control Tests of WMM

Sl. No.	Description of Quality Control Test	Frequency of Quality Control Test
1.	Gradation	One test per 500 m^3 subjected to minimum 2 tests per day
2.	Plasticity Index	One test per 500 m^3 subjected to minimum 2 tests per day
3.	Moisture Content prior to compaction	One test per 250 m^3
4.	Density of compacted layer	One test per 2000 m^2 subjected to minimum 4 test per day
5.	Aggregate Impact Value/Los Angeles Abrasion Value	One test per 1000 m^3 subjected to minimum 1 test per day
6.	Flakiness and Elongation Index	One test per 500 m^3 subjected to minimum 1 test per day

6.3 The in-place dry density shall be measured according to sand replacement method. If a nuclear method is used for determining density and moisture content, tests will be done at least at the same frequency required when using the sand replacement method but at each nuclear densometer test location, the average of two readings taken at positions rotated by 180 degree shall be used. A check/comparison test using the sand replacement method shall be carried out as required by the Engineer.

Initial calibration of the nuclear testing equipment shall be done by carrying out at least fifty tests in parallel with the sand replacement method for each different material encountered. Whenever there is a change of source of material calibration shall be carried out in accordance with the manufacturer's guidelines or as required by the Engineer to establish a moisture correction and any correction of density required. Check tests will be used to update the initial calibration of the nuclear density testing equipment. The calibration shall be repeated at regular intervals i.e. for every change of material source or 3 months, whichever is earlier.

For testing the compaction requirements, test locations shall be chosen only through random sampling techniques. Control shall not be based on the result of any one test but on the mean value of 5-10 density determinations. The number of tests in one set of measurements shall be 6 (if non-destructive tests are carried out, the number of tests shall be doubled) as long as it is felt that sufficient control over the constituent materials forming the mix is being exercised. If considerable variations i.e. 15 percent and above are observed between individual density results, the minimum number of tests in one set of measurement shall be increased to 10. The acceptance criteria shall be subject to condition that the mean density of a set of measurement shall not be less than the specified density plus:

$$1.65 - \frac{1.65}{\sqrt{(No.of\ samples\ )}}\, x \text{ standard deviation}$$

For ready reference & using the afore-mentioned equation, the acceptance criteria shall be subjected to the compliance of the following requirements:

No. of Tests	6	7	8	9 or more
Minimum average value (% relative field compaction)	100.5	100.6	100.7	100.8
Minimum value of any single test (% relative field compaction)	96.8	96.7	96.6	96.5

6.4 Rectification of Surface Irregularity

Where the surface irregularity of the layer as laid exceeds the permissible tolerances or where the course is otherwise defective due to underside layer soil/GSB getting mixed with the aggregates, the full thickness of the layer shall be scarified over the affected area reshaped with added premix material removed and replaced with fresh premix material and recompacted. The area treated in this manner shall not be less than 5 m long and 2 m wide. In no case shall depressions be filled up with unmixed and ungraded material or fines.

ANNEXURE

(Refer Para 4.4)

EQUIPMENT FOR WET MIX MACADAM

1 Production of Aggregates

Multi-stage stone crushing plant with vibratory screening arrangement and conveyor based stockpiling arrangement is suitable for obtaining required shape and size of aggregates and storing them in different stockpiles. The stone crushing plant should have necessary process controls for consistent production of required size and quantity of aggregate.

2 Wet Mix Plant

This plant consists of following: considering the relatively larger sized aggregates only power mixer (forced mixing) should be used, which could be Vertical Shaft Mixers (Pan Mixers) or Horizontal Shaft Mixers (Trough Mixers or Pugmill). Pan Mixers are generally suitable for aggregate sizes up to 40 mm, whereas Trough Mixers or Pugmill can handle even larger sized aggregates. Plant should be calibrated for accuracy before commencing work and thereafter at regular intervals.

i) **Bin Feeder Unit:** This is the unit for aggregate gradation control and feeding. It should have minimum 4 storage bins with adjustable quadrant side gates for smooth flow of aggregate onto auxiliary conveyor underneath. It is advisable to have grizzly screens for oversize particle rejection on top of bins, in the absence of which a scalping screen should be used after the bin feeder. The auxiliary conveyors should preferably be driven by variable speed motors. These auxiliary conveyors should discharge aggregate onto a single gathering conveyor underneath which should then transfers material onto the Secondary Conveyor (if grizzly screens are present) or onto the Scalping Screen (if grizzly screens are absent). In those plants with fixed speed motors, gradation is controlled by adjusting the gate openings. A surface vibration should be provided on the outside of the sand/fines bin to maintain uniform flow.

ii) **Grizzly Screen/Scalping Screen:** Both are used for screening of oversized particles which might cause damage to the mixing elements, if allowed to pass into it. grizzly screens are a grid of parallel metal bars set on a static inclined frame on top of the bin at an angle of 30 degree to 45 degree in the direction of the slope and movement of aggregates. A single deck vibratory scalping screen placed at the discharge end of the gathering conveyor will also screen out oversized particles.

iii) **Water Supply Unit:** Water Supply Unit consists of a water storage tank, a water pump, pump drive motor and water pipelines. The tank has to be of adequate capacity with provision for replenishing the water. The water pump feeding water to the mix is usually a centrifugal pump driven by an electric motor. The pump capacity should be adequate to provide the design moisture content at maximum plant production rate. Water pipeline draws water from the storage tank and discharges it into the pugmill through a set of nozzles which are formed by making perforations in the pipe. The nozzle pipe should be installed transverse to the direction of aggregate flow for uniform mixing with water.

iv) **Pugmill:** This is basically a trough mixer with paddle arms and paddle tips mounted on shaft(s). Usually a twin shaft pugmill is used. The rotating paddle tips churn the mix within the stationery pugmill chamber. This forced mixing causes thorough and uniform mixing of aggregate and water to produce a homogenous mix. The pugmill should have replaceable inner liner plates. The clearance between the tips of the paddles and liners should be less than maximum aggregate size so that the aggregates are pushed forward while mixing. The paddles should be adjustable so that clearance can be set according to maximum size of aggregate. The size of the mixing chamber and the size and number of paddles determine the maximum output capacity of the pugmill. The pugmill should be fully covered. There should be safety mechanism to prevent accidental powering-on of the pugmill while being accessed during inspection or maintenance or cleaning.

v) **Gob Hopper:** This hopper is available at the discharge end of the load out conveyor and is used for temporary storage of mix and for enmass drop of the mix onto dumper/tipper to minimise segregation. The hopper gates are hydraulically or pneumatically controlled and may be operated manually or automatically (preferable).

vi) **Conveyor System:** Belt conveyors are used at various stages for aggregate and mix handling. Usually, there is a secondary conveyor which takes aggregate from the Bin Feeder and loads them into the pugmill. There is also a loadout conveyor which takes the mix from the pugmill and loads it into the gob hopper. The inclination of belt conveyors should be less than 19 degree to prevent aggregate rollback. For steep angles ribbed belts or cleated belts may be used. High level conveyors should have belts with cleats on sides and/or safety sheets below belts, to restrain or retain aggregates falling over the sides. Conveyors having load cells installed underneath should have a self tensioning arrangement to maintain constant tension in the belt.

vii) **Aggregate Metering System:** Generally a load cell based conveyor weighing arrangement is used to measure the aggregate mass flow rate. If a scalping screen is used, the load cell should be placed under the secondary conveyor, otherwise it may be placed under the gathering conveyor too. High end plants may have individual bins of the bin feeder unit mounted on load cells so as to have precise control on aggregate gradation. In such cases the sum of individual aggregate mass flow rates from individual bins yield the total aggregate mass flow rate. The aggregate metering system should be calibrated before commencement of work and thereafter at regular intervals which should not be more than 7 days for conveyor weighing arrangement and 1 month for bin weighing arrangement. The tolerance shall be ± 2 percent.

viii) **Water Metering System:** Metering of water flow rate can be achieved with the help of electronic flow meter measuring the water flow rate and (i) variable speed centrifugal pump or (ii) Electronically operated hydraulic Valve. In the former case the pump discharge itself is controlled by varying the speed of centrifugal pump with the help of a variable speed motor. In the latter case, the effective flow into the water pipeline discharging into the pugmill is controlled with the valve which diverts a portion of the flow back into the water storage tank through a bypass line. The metering system should be calibrated before commencement of work and thereafter at regular intervals which should not be more than 7 days for variable speed motor driven centrifugal pump, not more than 3 months for electronically operated hydraulic valve. A mechanically operated totalizer should be installed in the water pipeline after the delivery valve to record the cumulative flow and use it to calibrate the electronic flow meter. The tolerance shall be ±1 percent.

ix) **Control Cabin:** There shall be a central control cabin housing the control system for centralized plant operations. The control cabin shall be designed and erected to enable full view of the plant from inside. Alternatively, CCTV system may be used to provide real-time view of the full plant. The control cabin shall have air conditioning, proper illumination, and furnishing. It should have a public address system for addressing/warning people outside. The operation and maintenance manual of the plant, calibration charts, plant logbook, and such other documents related to plant operation, maintenance and performance shall be kept in the control cabin at all times.

x) **General Requirements:** The plant shall be functionally adequate, operationally efficient, ergonomically designed and environmentally compliant. It should have necessary safety features, some of which are mentioned below, with the express understanding that these are not exclusive and there may be others.

a) The pugmill should have fail-safe power cut-off mechanism during access.

b) All motors, couplings and high speed drives or components shall be fully covered.

c) All electrical components and wirings shall be properly insulated and earthed.

d) All high level conveyors will have aggregate fall protection system.

Concrete batching plants having forced mixing arrangement and all the above process control features can also be used for production of WMM.

3 Paver Finishers

Paver finisher shall have following features:

i) It shall have loading hoppers of adequate capacity with hydraulically actuated wings.

ii) It shall have a suitable distributing mechanism for transfer of mix from the hopper unit to the screed unit with provision for varying the feed rate as per requirement.

iii) The distribution mechanism shall be such that both bidirectional (for normal paving) and unidirectional (for one side paving) spreading is possible in front of the screed and transverse to the direction of paving.

iv) The screed shall have side plates on both sides for lateral confinement of the mix.

v) The screed shall have tamping and vibrating arrangement having proper stroke/amplitude and frequency for imparting initial compaction to the layer as it is spreads without rutting or otherwise disturbing the surface profile.

vi) The screed shall be easily extensible to the required width with the help of a hydraulically operated telescopic mechanism. For mechanical pavers, bolt-on extension may be used.

vii) The spreading augers shall have provision for add-on extension so that gap between auger and side plate is always less than 150 mm to avoid the requirement of manual filling.

viii) The paver shall be equipped with necessary control mechanism so as to ensure that the laid mat is true to the specified thickness and profile and is free from surface blemishes.

ix) Hydrostatic Pavers shall be capable of working with installed or retrofitted electronic sensors and controllers for automatic precision control of paving operation.

4 Compaction Equipment

Compaction shall be done with the help of smooth-wheeled roller (or vibratory roller without vibration), vibratory roller, pneumatic-tyred roller, etc. having minimum static weight of 100 kN with or without ballast. In confined spaces, where standard road roller cannot be used, mini compaction equipment like rammers, vibratory plate compactor, vibro tamper, plate rammer, etc. may be used.

The exact configuration of the compaction equipment fleet, the operational equipment settings like ballast, amplitude/vibration, number of passes, direction of proceed, overlap between passes, sequence of compaction (in case fleet with different compactors are used) is decided on the basis of compaction trials. For selection of initial parameters, guidelines given in **Table 4** may be used.

Table 4 Guidelines for Initial Setting of Parameters for Compaction Trial

Type of Compaction Equipment	Category	Minimum Number of Passes for Layers Not Exceeding the Following Compacted Thickness		
		100 mm	150 mm	250 mm
Smooth-wheeled roller (or vibratory roller operating without vibration)	Mass per metre width of roll: over 2700 kg up to 5400 kg over 5400 kg	 16 8	 Unsuitable 16	 Unsuitable Unsuitable
Vibrating Roller	Mass per metre width of vibrating roll: Over 700 kg upto 1300 kg Over 1300 kg upto 1800 kg Over 1800 kg upto 2300 kg Over 2300 kg upto 2900 kg Over 2900 kg upto 3600 kg Over 3600 kg upto 4300 kg Over 4300 kg upto 5000 kg Over 5000 kg	16 6 4 3 3 2 2 2	Unsuitable 16 6 5 5 4 4 3	Unsuitable Unsuitable 10 9 8 7 6 5

For the purposes of above **Table 4**, the following shall apply:

i) The number of passes is the number of times that each point on the surface of the layer being compacted shall be traversed by the item of compaction plant in its operating mode.

ii) The compaction plant in the **Table 4** is categorised in terms of static mass. The mass per metre width of roll is the total mass on the roll divided by the total roll width. Where a smooth-wheeled roller has more than one axle, the category of the machine shall be determined on the basis of the axle giving the highest value of mass per metre width.

iii) Where the mechanical vibration is applied to two rolls in tandem, the minimum number of passes shall be half the number given in the above **Table 4** for the appropriate mass per metre width of one vibrating roll but if one roll differs in mass per metre width from the other, the number of passes shall be calculated as for the roll with the smaller value. Alternatively the minimum number of passes may be determined by treating the machine as having a single vibrating roll with a mass per metre width equal to that of the roll with the higher value.