PQ CORPORATION

Advera® WMA
Warm Mix Asphalt

Production, Testing and Compaction Details

4/17/2017
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Chapter 1 General Product Information

Product

Advera® WMA

Manufacturing Company

PQ Corporation  
www.pqcorp.com  
www.adverawma.com

Contact

Questions on the content of this report

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Clayton, MO 63105  
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Advera® WMA is a mineral foaming additive for the manufacture of warm mix asphalt (WMA).

Advera® WMA is a synthetic mineral. Since it is synthetic it has standard size and moisture content. Advera® WMA is an inorganic chemical in powder form containing 18-20% moisture which is chemically and structurally bound. The material is at equilibrium at this moisture content. Therefore it takes significant energy, temperatures above 100°C, to release this water. The release of moisture out of the sub-micron pore causes micro bubbles which enhance the workability of the asphalt mix. The foam is released over time which gives long lasting workability and minimizes the amount of water which is lost to the bag house at the asphalt plant.

Time release of water over time with neat zeolite can be observed in Figure 1.1.
Figure 1.1: Differential Scanning Calorimeter/Thermographic Analyzer (DSA/TGA)

Advera® WMA is generally recognized as safe by the EPA and has a very favorable rating from the National Fire Protection Association, NFPA. See Appendix A – Material Safety Data Sheet
Chapter 2 Mix Design, QC/QA Considerations

1. Mix Design Procedures

If the state allows, Advera® WMA may be added to the HMA mix design with no mix design change. HMA mix design will be done as usual, and Advera® WMA added after design is completed – no change in mix design is required.

If a WMA mix design is required, utilize AASHTO R35 for Superpave mixes and the Draft Appendix to AASHTO R 35: Special Mixture Design Considerations and Methods for Warm Mix Asphalt (WMA) (See Appendix B). Note the recommended change below.

An alternate method of incorporation of the Advera® WMA into the asphalt mix versus section 7.4.6 and 7.4.7 in the Draft Appendix to AASHTO R35, is to pre-blend the Advera® WMA with the bitumen using the following procedures.

1. Mix the Advera® WMA with the bitumen using a mechanical stirrer prior to incorporation with the aggregate. It is important that the Advera® WMA be well blended with the oil so the material is evenly dispersed.
2. Add the mixture to the aggregate and mix follow procedure in the draft appendix from 7.4.8.

Potential concerns with other binder modifiers

None, except as noted below

Note: Silicone additives are historically used as both an antifoam and defoamer to inhibit foaming in asphalt binder applications. Although no issues have been noted with Advera® WMA, it is best to ensure silicone additive compatibility.

Anti-Strip Requirements

If needed to pass moisture sensitivity testing.

Advera® WMA has no known compatibility problems with anti-strip additives.
Anticipated Differences between mix design values and production values

**Plant Produced Mixtures**

Sampling and testing of Plant produced mixtures should be the same as hot mix asphalt procedures.

No changes in volumetrics are expected between field and laboratory mix designs when mix design is done in the laboratory.

If Advera® WMA is added to the HMA mix design then the following may be observed:

- Reduced Absorption of Asphalt into the Aggregate.

Advera® WMA has been shown to reduce the absorption of asphalt into the aggregate, causing an increase in the amount of effective asphalt. In some highly absorptive aggregates this will equate to an increase in the effective binder of approximately 0.1 – 0.2%.
Chapter 3 Plant Operations

1. Storage and Handling

Advera® WMA is currently available in the following packaging options.

Bulk: Available in both bulk truck and rail car volumes for storage in a silo. This is the preferred method for commercial mix operations. Either permanent or portable feeder equipment may be used. If stored in a silo, dry compressed air should be utilized.

Bulk Sacks: 1,000 lb. sacks which are packaged 2 to a pallet, 2,000 lbs. /pallet. This option is used for small to medium projects utilizing portable feeder equipment.

Advera® WMA should be stored under cover away from precipitation. Material may clump if it gets wet.

Shelf Life: If stored properly - indefinite.

2. Addition Rate

Typical Rate: 0.20 - 0.25% on the weight of the asphalt mix.

Min/Max Rates: 0.05% - 0.30% on the weight of the asphalt mix.

Criteria for Adjusting Rate

- Hot Mix Compaction aid – When utilized as hot mix asphalt compaction aide the Advera® WMA dosage rate may be reduced.

- No changes in dosage rate are required for varying RAP and/or RAS content. Usage is based on mix not total binder content. See chart below.

<table>
<thead>
<tr>
<th>Material Use</th>
<th>Typical Starting Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virgin Mix</td>
<td>0.20% on weight of asphalt mix</td>
</tr>
<tr>
<td>PMA</td>
<td>0.20% on weight of asphalt mix</td>
</tr>
<tr>
<td>RAP 10 % or less</td>
<td>0.20% on weight of asphalt mix</td>
</tr>
<tr>
<td>RAP more than 10%</td>
<td>0.20% on weight of asphalt mix</td>
</tr>
<tr>
<td>RAP 10 % or less / PMA</td>
<td>0.20% on weight of asphalt mix</td>
</tr>
<tr>
<td>RAP more than 10% /PMA</td>
<td>0.20% on weight of asphalt mix</td>
</tr>
<tr>
<td>RAP/RAS</td>
<td>0.20% on weight of asphalt mix</td>
</tr>
<tr>
<td>RAP/RAS/PMA</td>
<td>0.20% on weight of asphalt mix</td>
</tr>
</tbody>
</table>

In addition, Advera® WMA may be used as a stockpile flow aid for RAS and RAP, or in combination with water injection systems to improve longevity of the workability of mechanical foamed mixes. Please contact your account manager for dosage and use information.
3. **Production Temperatures**

Depending on the specification requirements of the agency/owner, “warm mix asphalt” may be produced from existing hot mix asphalt temperatures down to 250°F.

Due to the wide definition of “warm mix asphalt” we recommend that you contact an Advera® WMA representative for production temperature and dosage of a specific mix design.

4. **Operations**

1. Plant Equipment should be thoroughly heated prior to making warm mix asphalt at reduced warm mix asphalt temperatures. This includes drum, slate conveyors and silos. Once the equipment is heated to hot mix asphalt temperatures, it may be brought down slowly to warm mix asphalt target.
2. Check Bag house to make sure temperatures remain above dew point.
3. Material should be sampled from truck for all testing.
4. Silo Storage—As with any mix, the storage time in a silo should be minimized. Storage overnight is fine if temperature is maintained near production temperature. Storage over the weekend is discouraged, although has been done successfully.

5. **Equipment**

Advera® WMA is added at the asphalt mix production facility. It can be successfully utilized at both batch and drum plants. Feed Equipment for Drum and Batch plants are listed below.

In addition, Advera® WMA may be premixed with Recycled asphalt shingles (RAS) or Reclaimed Asphalt Pavement (RAP) as a stockpile aid and method of introduction into the asphalt plant through existing recycle feed systems. RAP and RAS treatment methods include auguring into the grinding, screening, or plant processes.

Contact your Advera® WMA account manager for additional information, or visit [www.adverawma.com](http://www.adverawma.com).
Both Drum and Batch Plants

An auger system may be setup to administer product onto existing belts and is re-filled via super sack using a properly rated forklift.

Plant Requirements for the auger system

Electrical: 480V 3 phase, 35 amp service.

Air: 80 PSI minimum.

Typical Plant Set-Up

The auger sits on load cells to allow for easier understanding of product availability and assist in calculating feed rate. Advera® WMA can be administered onto a recycle belt in either a drum or batch plant using this volumetric hopper and auger. In order to achieve this setup, the approximate rate of the belt must be supplied by the asphalt plant. Once known, the auger system will be dialed in to match the rate of the belt in the quantity or ratio desired. A simple VFD chart that outlines the output of the auger will be developed for the asphalt plant to accommodate rate changes. The hopper and auger system is versatile for easy placement in various plant conditions. Should the Asphalt producer wish to achieve greater interlock of the auger system into the plants, Plant I.T. personnel would need to outline the requirements and degree of automation requested, prior to equipment delivery.
Drum Plant

Advera® WMA is pneumatically conveyed through a port placed near the asphalt binder line, and directed into the binder stream, before it makes contact with the aggregate.

The requirement for a portable feeder is noted below. Methods to utilize Advera® WMA in a drum plant, which may utilize existing equipment at a mix plant operator’s facility, are available by contacting the Advera® WMA representative.

Plant Requirements for the Portable Drum Feeder

**Electrical:** 480V 3 phase, 60 amp service.

**Air:** 80 PSI minimum.

**Fiber Port on the drum:** 4 inch threaded pipe male threads is preferred, as the blower line will clamp on to a standard Dixon fitting.

**Connections to plant:** Should the plant wish to set up simple automation, all that is required is an analog signal that could be scaled to the plant rate, a start and stop circuit that would initiate ON/OFF of machine and correspond with oil flow. Additionally, the portable plant can send back a dry contact that would open in the event machine malfunction, and is typically used by the plant alarm system.

The feeder controller, a Melfi System controller, uses a Control Logix processor and is easily slaved to a plant using Ethernet, but will require set up by plant I.T. to obtain the above functions digitally.

Data recording is done on the supplied laptop and will monitor the machine’s output; all files are easily transferrable for review electronically. Depending on setup of plant it may be possible to allow host plant data recording to monitor output though daily reports generated by plant.

**Leveling:** Machine should be setup in a dry, compact and level location. Asphalt or Concrete is best, but not mandatory.

**Location:** The feeder should be placed as close to the fiber port as possible. Access to the unit is necessary in order to refill the unit if bulk bags are used; this should also be taken into account during location selection. Distances from machine to plant should be less than 75 feet.
Batch Plant

Material is added via dense phase conveying into the pug mill through a 2” port which is placed in the middle of the pug mill. Advera® WMA is introduced after the asphalt binder drops. There are multiple methods for feeding into a batch plant.

The requirement for a portable feeder is noted below. Methods to utilize Advera® WMA in a batch plant, which may utilize existing equipment at a mix plant operator’s facility, are available by contacting the Advera® WMA representative.

**Plant Requirements for a Portable Batch Feeder**

**Electrical:** 480V 3 phase 60 amp service.

**Air:** An air compressor is included with the portable unit, and will generate all process air need to operate equipment.

**Leveling:** site should be dry compacted and level, asphalt or concrete is best but not mandatory.

**Location:** Locate the feeder as close to the pug mill as possible. The shorter the run of pipe the easier it is to install the system to the plant. Machine should be no further than 40 feet from plant.

**Plumbing:** A 2 inch nipple is supplied and will require welding into the pug mill so that during injection of the Advera® WMA it is directed to the center of the batch. Prior to running, a test batch will be fired into pug mill to confirm port is properly placed.

The batch plant system is controlled by an Allen Bradley SLC 5/05 controller, or a Compaq Logix It has an available slot on the rack so any PLC communication protocol accepted by a SLC 500 can be used. For additional information on the SLC 500 PLC, please refer to the Allen Bradley website (http://www.ab.com/en/epub/catalogs/12762/2181376/2416247/1239758/1734542/)

**Control of feeding system:**
Control of sending batches of additive to the plant is accomplished using the 110 v supplied from the Asphalt dump valve. Upon entering the wet mix cycle, the dump valve solenoid fires, the Advera® WMA batch machine will inject Advera® WMA into the mix, using a dense phase process. Subsequent relays can be used as a limit factors if the plant desires. Control of batch size is typically done by the operator manually changing the batch size from the panel view in the asphalt plant’s control room. However depending on Plant IT capabilities Advera® WMA Batch plant can be configured so that this process is automatic. This information is obtained from the asphalt plant’s plc; however programming changes will need to be identified and tested prior to start up.

**Data Recording:**
The systems data is recorded to the panel view, or laptop, supplied with the unit. Communication with the plant data recording software can be done but needs to be set up ahead of time with the appropriate communications protocols.
6. Laydown/Compaction

Paving crews should use best practices for paving, just as with hot mix asphalt. The paving crew should see a reduction in temperature and odor versus hot mix asphalt. No special handling requirements are needed. There is no change needed in the loose mix thickness to achieve specified compacted thickness.

A test strip is recommended in order to establish a roller pattern. Typically density is reached faster and is more consistent than hot mix asphalt. Densities should be taken in the field, and density gauges correlated with cores. Placement of additional lifts and final opening of traffic are similar to that of hot mix asphalt.
Appendix A – Material Safety Data Sheet

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product name: ADVERA® WMA Aluminosilicate
Product description: Hydrated zeolite sodium A powder
Manufacturer: PQ Corporation
P. O. Box 940
Valley Forge, PA 19482 USA
Telephone: 610-651-4200
In case of emergency call: 610-651-4200
For transportation emergency: Not applicable
Call CHEMTREC: 800-424-9300

2. COMPOSITION/INFORMATION ON INGREDIENTS

<table>
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<tr>
<th>Chemical and Common Name</th>
<th>CAS Registry Number</th>
<th>Wt. %</th>
<th>OSHA PEL</th>
<th>ACGIH TLV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zeolite</td>
<td>1318-02-1</td>
<td>78-82%</td>
<td>15 mg/m³ total dust 5 mg/m³ respirable (Permissible: Not Otherwise Regulated)</td>
<td>10 mg/m³ 3 mg/m³ respirable</td>
</tr>
<tr>
<td>Water</td>
<td>7732-18-5</td>
<td>18-22%</td>
<td>Not established</td>
<td>Not established</td>
</tr>
</tbody>
</table>

3. HAZARDS IDENTIFICATION

Emergency Overview: White, odorless, powder. May cause respiratory irritation. May cause irritation to the eyes and skin. Noncombustible.
Eye contact: Causes mild irritation to the eyes.
Skin contact: May cause irritation to the skin.
Inhalation: May cause respiratory irritation.
Ingestion: No known hazards. Inedible.
Chronic hazards: No known hazards.
Physical hazards: No known hazards.

Eye: In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Get medical attention if irritation persists.
Skin: In case of contact, immediately flush skin with plenty of water. Remove contaminated clothing and shoes. Get medical attention if irritation develops and persists. Wash clothing before reuse. Thoroughly clean shoes before reuse.
Inhalation: Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.
Ingestion: Not applicable.
5. FIRE FIGHTING MEASURES

Flammable limit: This material is noncombustible.
Extinguishing Media: This material is compatible with all extinguishing media.
Hazard to fire-fighters: See Section 3 for information on hazards when this material is present in the area of a fire.
Fire-fighting equipment: The following protective equipment for fire fighters is recommended when this material is present in the area of a fire: chemical goggles, body-covering protective clothing, chemical resistant gloves, and rubber boots.

6. ACCIDENTAL RELEASE MEASURES

Personal protection: Wear safety goggles, body-covering protective clothing, chemical resistant gloves, and rubber boot, NIOSH-approved dust respirator where dust occurs. See section 8.
Environmental Hazards: Sinks in water. No known environmental hazards.
Small spill cleanup: Carefully shovel or sweep up spilled material and place in suitable container. Avoid generating dust. Use appropriate Personal Protective Equipment (PPE). See section 8.
Large spill cleanup: Keep unnecessary people away, isolate hazard area and deny entry. Do not touch or walk through spilled material. Carefully shovel or sweep up spilled material and place in suitable container. Avoid generating dust. Use appropriate Personal Protective Equipment (PPE). See section 8.
CERCLA RQ: There is no CERCLA Reportable Quantity for this material. If a spill goes off site, notification of state and local authorities is recommended.

7. HANDLING AND STORAGE

Handling: Avoid contact with eyes, skin and clothing. Avoid breathing dust. Keep container closed. Promptly clean up spills. Wash thoroughly after handling.
Storage: Keep containers closed. Store in original containers or clean metal, plastic, or fiber containers.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Engineering controls: Use with adequate ventilation. Safety shower and eyewash fountain should be within direct access.
Respiratory protection: Use a NIOSH-approved dust respirator where dust occurs. Observe OSHA regulations for respirator use (29 C.F.R. §1910.134)
Skin protection: Wear body-covering protective clothing and gloves.
Eye protection: Wear safety goggles.
9. PHYSICAL AND CHEMICAL PROPERTIES

- **Appearance:** Powder.
- **Color:** White.
- **Odor:** Odorless.
- **pH:** (Water dispersion) 10.1-11.4
- **Bulk density:** Approximately 25-30 lbs./ft³.
- **Solubility in water:** Insoluble.

10. STABILITY AND REACTIVITY

- **Stability:** Stable.
- **Conditions to avoid:** None.
- **Materials to avoid:** Hydrides and other water-reactive compounds, strong acids, strong alkalis.
- **Hazardous decomposition products:** None.

11. TOXICOLOGICAL INFORMATION

- **Acute Data:** When tested for primary eye irritation potential, hydrated sodium zeolite A was nonirritating or caused mild or slight irritation which subsided within 48 hours. When tested for primary skin irritation potential, hydrated sodium zeolite A was nonirritating or caused mild irritation. This material is acutely non-toxic by ingestion. When tested for respiratory irritation potential, hydrated sodium zeolite A caused no effect or irritation similar to calcium carbonate and less than silica.

- **Subchronic Data:** In a study of rats fed hydrated zeolite A for 168 or 200 days at 0.125% and 2% of the diet adverse effects were reported in the urinary bladder and kidney similar to those reported for other silicates ingested at high levels.

- **Special Studies:** In a study of rats fed hydrated zeolite A for 104 weeks at dosages as high as 0.1% of the diet caused adverse effects to the kidneys, but no treatment associated carcinogenic effect. No carcinogenic or fibrogenic effects were observed in rats exposed by inhalation to approximately 20 mg/m³ hydrated zeolite A for 5 hrs/day, 5 days/week for 22 months. Hydrated sodium zeolite A is not listed by IARC, NTP or OSHA as a carcinogen.

12. ECOLOGICAL INFORMATION

- **Ecotoxicity:** Both acute and long term studies of sodium zeolite A on freshwater microcrustacean, Daphnia magna, and the freshwater fish, Ictalurus melas, showed no significant effects on survival or reproduction. 96 hour lethality tests with Sodium Zeolite A on the freshwater species, Oligostomus sizeirostris, Ictalurus punctatus, and Pimephales promelas, also did not reveal any effects with concentrations of Sodium Zeolite A of up to 650 mg/L. Similar results were obtained for the marine species, Ctenodactylus virginiensis, Penaeus duorarum, and Lagodon rhomboides at concentrations of Sodium Zeolite A of up to 750 mg/L. A 30-day test with
Trade Name: ADVERA® WMA Aluminosilicate
Date Prepared: 07/10/07

Fathead minnows showed no significant effects of suspended Sodium Zeolite A on hatchability, survival, or growth at the highest concentration tested, 57 mg/L. Long term pond studies also failed to show any deleterious effects of sodium zeolite A on zooplankton, macroinvertebrates, or fish populations, when ponds were treated either with 80-200 mg/L sodium zeolite A under static conditions, or with a continuous input of 15 mg/L.

Environmental Fate:
Sodium zeolite A is thermodynamically unstable. In aqueous suspensions, Sodium zeolite A will transform to smarphous sodium aluminosilicate in minutes to hours, at natural environmental pH. Because sodium zeolite A rapidly hydrolyzes under environmental conditions, it cannot bioaccumulate.

Physical/Chemical:
Sinks in water. Only water will evaporate from this material.

13. DISPOSAL CONSIDERATIONS

Classification:
This material is not RCRA Hazardous waste.

Disposal Method:
Dispose in accordance with federal, state and local regulations.

14. TRANSPORT INFORMATION

DOT UN Status:
This material is not regulated hazardous material for transportation.

15. REGULATORY INFORMATION

CERCLA:
No CERCLA Reportable Quantity has been established for this material.

SARA TITLE III:
Not an Extremely Hazardous Substance under §302. Not a Toxic Chemical under §313. Hazard Categories under §§311/312: Acute

TSCA:
All ingredients of this material are listed on the TSCA inventory.

FIFRA:
Sodium zeolite A and exempt from the requirement of a tolerance when used in accordance with good agricultural practice as an inert (or occasionally active) ingredient in pesticide formulations applied to growing crops or to raw agricultural commodities after harvest when used as a solid diluent, carrier pursuant to 40 C.F.R. §180.1401.

FDA:
The use of ADVERA sodium zeolite A is authorized by FDA as a stabilizer for polyvinyl chloride plastics intended for single and repeated use in contact with food, at levels not to exceed 5% by weight of the finished food contact article pursuant to FCN 000134; and as a for use as a pigment extender at levels not to exceed 5.4 percent by weight of the finished paper and paperboard pursuant to 21 CFR §176.170.
16. OTHER INFORMATION

Prepared by: John G. Blumberg
Supersedes revision of: New issue.

THE INFORMATION ON THIS SAFETY DATA SHEET IS BELIEVED TO BE ACCURATE AND IT IS THE BEST INFORMATION AVAILABLE TO PQ CORPORATION. THIS DOCUMENT IS INTENDED ONLY AS A GUIDE TO THE APPROPRIATE PRECAUTIONS FOR HANDLING A CHEMICAL BY A PERSON TRAINED IN CHEMICAL HANDLING. PQ CORPORATION MAKES NO WARRANTY OF MERCHANTABILITY OR ANY OTHER WARRANTY, EXPRESS OR IMPLIED WITH RESPECT TO SUCH INFORMATION OR THE PRODUCT TO WHICH IT RELATES, AND WE ASSUME NO LIABILITY RESULTING FROM THE USE OR HANDLING OF THE PRODUCT TO WHICH THIS SAFETY DATA SHEET RELATES. USERS AND HANDLERS OF THIS PRODUCT SHOULD MAKE THEIR OWN INVESTIGATIONS TO DETERMINE THE SUITABILITY OF THE INFORMATION PROVIDED HEREIN FOR THEIR OWN PURPOSES.

Draft Appendix to AASHTO R 35

Appendix: Special Mixture Design Considerations and Methods for Warm Mix Asphalt (WMA)

1. PURPOSE

1.1. This appendix presents special mixture design considerations and methods for designing warm mix asphalt (WMA) using AASHTO R 35. WMA refers to asphalt concrete mixtures that are produced at temperatures approximately 50 °F (28 °C) or more cooler than typically used in the production of HMA. The goal with WMA is to produce mixtures with similar strength, durability, and performance characteristics as HMA using substantially reduced production temperatures.

1.2. The methods in this appendix are applicable to a wide range of WMA processes including:

- WMA additives that are added to the asphalt binder,
- WMA additives that are added to the mixture during production,
- Wet aggregate mixtures, and
- Plant foaming processes.

1.3. The information in this appendix supplements the standard procedures contained in AASHTO R 35. This appendix assumes the user is proficient with the standard procedures contained in AASHTO R 35.

2. SUMMARY

2.1. This appendix includes separate sections addressing the following aspects of WMA mixture design:

- Equipment for Designing WMA,
- WMA Process Selection,
- Binder Grade Selection,
- RAP in WMA,
- Process Specific Specimen Fabrication Procedures,
- Evaluation of Coating
- Evaluation of Compactability,
- Evaluation of Moisture Sensitivity,
- Evaluation of Rutting Resistance, and
- Adjusting the Mixture to Meet Specification Requirements.
2.2. In each section, reference is made to the applicable section of AASHTO R 35.

3. ADDITIONAL LABORATORY EQUIPMENT

3.1. All WMA Processes:

3.1.1. Mechanical mixer. A planetary mixer with wire whip having a capacity of 20 qt. or a 5 gal. bucket mixer.

Note 1 – The mixing times in this appendix were developed using a planetary mixer with wire whip, Blakeslee Model B-20 or equivalent. Appropriate mixing times for bucket mixers should be established by evaluating coating of HMA mixtures prepared at the viscosity based mixing temperatures specified in Section 8.2.1 of AASHTO T 312.

3.2. Binder Additive WMA Processes:

3.2.1. Low shear mechanical stirrer. A low shear mechanical stirrer with appropriate impeller to homogeneously blend the additive in the binder.

3.3. Plant Foaming Processes:

3.3.1. Laboratory foamed asphalt plant. A laboratory scale foamed asphalt plant capable of producing consistent foamed asphalt at the water content used in field production. The device should be capable of producing foamed asphalt for laboratory batches ranging from approximately 10 to 20 kg.

4. WMA PROCESS SELECTION

4.1. There are over 20 WMA processes being marketed in the United States. Select the WMA process that will be used in consultation with the specifying agency and technical assistance personnel from the WMA technology providers. Consideration should be given to a number of factors including: (1) available performance data, (2) the cost of the warm mix additives, (3) planned production and compaction temperatures, (4) planned production rates, (5) plant capabilities, and (6) modifications required to successfully use the WMA process with available field and laboratory equipment.

4.2. Determine the planned production and planned field compaction temperatures.

5. BINDER GRADE SELECTION

5.1. Use the same grade of binder normally used with HMA. Select the performance grade of the binder in accordance with Section 5 of AASHTO M 323 considering the environment and traffic at the project site.
**Note 2** – For WMA processes having production temperatures that are 100 °F (56 °C) or more lower than HMA production temperatures, it may be necessary to increase the high temperature performance grade of the binder one grade level to meet the rutting resistance requirements included in this appendix.

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6. **RAP IN WMA**

6.1. For WMA mixtures incorporating RAP, the planned field compaction temperature shall be greater than the as-recovered high temperature grade of the RAP binder.

**Note 3** – This requirement is included to ensure that there is mixing of the new and recycled binders. Laboratory studies showed that new and recycled binders do mix at WMA process temperatures provided this requirement is met and the mixture remains at or above the planned compaction temperature for at least 2 hours. Plant mixing should be verified through an evaluation of volumetric or stiffness properties of plant produced mixtures.

6.2. Select RAP materials in accordance with Section 6 of AASHTO M 323.

6.3. For blending chart analyses, the intermediate and low temperature properties of the virgin binder may be improved using Table 1.

**Note 4** – The intermediate and low temperature grade improvements given in Table 1 will allow additional RAP to be used in WMA mixtures when blending chart analyses are used. An approximately 0.6 °C improvement in the low temperature properties will allow approximately 10 percent additional RAP binder to be added to the mixture based on blended binder grade requirements.
Table 1. Recommended Improvement in Virgin Binder Low Temperature Continuous Grade for RAP Blending Chart Analysis for WMA Production Temperatures.

<table>
<thead>
<tr>
<th>Virgin Binder PG Grade</th>
<th>58-28</th>
<th>58-22</th>
<th>64-22</th>
<th>64-16</th>
<th>67-22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average HMA Production Temperature, °F</td>
<td>285</td>
<td>285</td>
<td>292</td>
<td>292</td>
<td>300</td>
</tr>
<tr>
<td>Rate of Improvement of Virgin Binder Low Temperature Grade per °C Reduction in Plant Temperature</td>
<td>0.035</td>
<td>0.025</td>
<td>0.025</td>
<td>0.012</td>
<td>0.025</td>
</tr>
<tr>
<td>WMA Production Temperature, °F</td>
<td>300</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td></td>
<td>295</td>
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7. PROCESS SPECIFIC SPECIMEN FABRICATION PROCEDURES

7.1. Batching

7.1.1. Determine the number and size of specimens that are required. Table 2 summarizes approximate specimen sizes for WMA mixture design.

Note 5 – The mass of mixture required for the various specimens depends on the specific gravity of the aggregate and the air void content of the specimen. Trial specimens may be required to determine appropriate batch weights for the AASHTO T 283 and flow number testing.
### Table 2. Specimen Requirements.

<table>
<thead>
<tr>
<th>Specimen Type</th>
<th>Gyratory Specimen Size</th>
<th>Approximate Specimen Mass</th>
<th>Number Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Specific Gravity</td>
<td>NA</td>
<td>500 to 6,000 g depending on maximum aggregate size</td>
<td>2 per trial blend plus 8 to determine design binder content plus 1 at design binder content for compactability evaluation</td>
</tr>
<tr>
<td>Volumetric Design</td>
<td>150 mm diameter by 115 mm high</td>
<td>4,700 g</td>
<td>2 per trial blend plus 8 to determine design binder content</td>
</tr>
<tr>
<td>Coating</td>
<td>NA</td>
<td>500 to 6,000 g depending on maximum aggregate size</td>
<td>1 at the design binder content</td>
</tr>
<tr>
<td>Compactability</td>
<td>150 mm diameter by 115 mm high</td>
<td>4,700 g</td>
<td>4 at the design binder content</td>
</tr>
<tr>
<td>AASHTO T 283</td>
<td>150 mm diameter by 95 mm high</td>
<td>3,800 g</td>
<td>6 at the design binder content</td>
</tr>
<tr>
<td>Flow Number</td>
<td>150 mm diameter by 175 mm high</td>
<td>7,000 g</td>
<td>4 at the design binder content</td>
</tr>
</tbody>
</table>

7.1.2. Prepare a batch sheet showing the batch weight of each aggregate fraction, RAP, and the asphalt binder.

7.1.3. Weigh into a pan the weight of each aggregate fraction.

**Note 6** – For WMA processes that use wet aggregate, weigh the portion of the aggregate that will be heated into one pan and weigh the portion of the aggregate that will be wetted into a second pan.

7.1.4. Weigh into a separate pan, the weight of RAP.

7.2. **Heating**

7.2.1. Place the aggregate in an oven set at approximately 15 °C higher than the planned production temperature.

**Note 7** – The aggregate will require 2 to 4 hours to reach the temperature of the oven. Aggregates may be placed in the oven overnight.
7.2.2. Heat the RAP in the oven with the aggregates, but limit the heating time for the RAP to 2 hours.

7.2.3. Heat the binder to the planned production temperature.

7.2.4. Heat mixing bowls and other tools to the planned production temperature.

7.2.5. Preheat a forced draft oven and necessary pans to the planned field compaction temperature for use in short-term conditioning the mixture.

3. Preparation of WMA Mixtures With WMA Additives Added to the Binder

Note 8 – If specific mixing and storage instructions are provided by the WMA additive supplier, follow the supplier’s instructions.

7.3.1. Adding WMA Additive to Binder

7.3.1.1. Weigh the required amount of the additive into a small container.

Note 9 – The additive is typically specified as a percent by weight of binder. For mixtures containing RAP, determine the weight of additive based on the total binder content of the mixture.

7.3.1.2. Heat the asphalt binder in a covered container in an oven set at 135 °C until the binder is sufficiently fluid to pour. During heating occasionally stir the binder manually to ensure homogeneity.

7.3.1.3. Add the required amount of additive to the binder and stir with a mechanical stirrer until the additive is totally dispersed in the binder.

7.3.1.4. Store the binder with WMA additive at room temperature in a covered container until needed for use in the mixture design.

7.3.2. Preparing WMA Specimens

7.3.2.1. Heat the mixing tools, aggregate, RAP, and binder in accordance with Section 7.2.

7.3.2.2. If a liquid anti-strip is required, add it to the binder per the manufacturer’s instructions.

7.3.2.3. Place the hot mixing bowl on a scale and zero the scale.

7.3.2.4. Charge the mixing bowl with the heated aggregates and RAP and dry mix thoroughly.
7.3.2.5. Form a crater in the blended aggregate and weigh the required amount of asphalt binder into the mixture to achieve the desired batch weight.

**Note 10** – If the aggregates and RAP have been stored for an extended period of time in a humid environment, then it may be necessary to adjust the weight of binder based on the oven dry weight of the aggregates and RAP as follows:

1. Record the oven dry weight of the aggregates and RAP, \( w_1 \)
2. Determine the target total weight of the mixture

\[
 w_t = \frac{w_i}{1 - \frac{P_{b_{new}}}{100}}
\]

where:

- \( w_t \) = target total weight
- \( w_i \) = oven dry weight from step 1
- \( P_{b_{new}} \) = percent by weight of total mix of new binder in the mixture
3. Add new binder to the bowl to reach \( w_t \)

7.3.2.6. Remove the mixing bowl from the scale and mix with a mechanical mixer for 90 sec.

7.3.2.7. Place the mixture in a flat shallow pan at an even thickness of 25 to 50 mm and place the pan in the forced draft oven at the planned field compaction temperature for 2 hours. Stir the mixture once after the first hour.

**4. Preparation of WMA Mixtures With WMA Additive Added to the Mixture**

**Note 11** – If specific mixing and storage instructions are provided by the WMA additive supplier follow the supplier’s instructions.

7.4.1. Weigh the required amount of the additive into a small container.

**Note 12** – The quantity of additive may be specified as a percent by weight of binder or a percent by weight of total mixture.

7.4.2. If a liquid anti-strip is required, add it to the binder per the manufacturer’s instructions.

7.4.3. Heat the mixing tools, aggregate, RAP, and binder in accordance with Section 7.2.

7.4.4. Place the hot mixing bowl on a scale and zero the scale.

7.4.5. Charge the mixing bowl with the heated aggregates and RAP and dry mix thoroughly.
7.4.6. Form a crater in the blended aggregate and weigh the required amount of asphalt binder into the mixture to achieve the desired batch weight.

**Note 13** – If the aggregates and RAP have been stored for an extended period of time in a humid environment, then it may be necessary to adjust the weight of binder based on the oven dry weight of the aggregates and RAP as follows:

1. Record the oven dry weight of the aggregates and RAP, \( w_1 \)
2. Determine the target total weight of the mixture
   \[
   w_t = \frac{w_j}{1 - \frac{P_{b_{new}}}{100}}
   \]
   where:
   - \( w_t \) = target total weight
   - \( w_j \) = oven dry weight from step 1
   - \( P_{b_{new}} \) = percent by weight of total mix of new binder in the mixture
3. Add new binder to the bowl to reach \( w_t \)

7.4.7. Pour the WMA additive into the pool of new asphalt binder.

7.4.8. Remove the mixing bowl from the scale and mix with a mechanical mixer for 90 sec.

7.4.9. Place the mixture in a flat shallow pan at an even thickness of 25 to 50 mm and place the pan in the forced draft oven at the planned field compaction temperature for 2 hours. Stir the mixture once after the first hour.

5. **Preparation of WMA Mixtures With A Wet Fraction of Aggregate**

**Note 14** – Consult the WMA process supplier for appropriate additive dosage rates, mixing temperatures, percentage of wet aggregate and wet aggregate moisture content.

7.5.1. Adding WMA Additive to Binder

7.5.1.1. Weigh the required amount of the additive into a small container.

**Note 15** – The additive is typically specified as a percent by weight of binder. For mixtures containing RAP, determine the weight of additive based on the total binder content of the mixture.

7.5.1.2. Heat the asphalt binder in a covered container in an oven set at 135 °C until the binder is sufficiently fluid to pour. During heating occasionally stir the binder manually to ensure homogeneity.
7.5.1.3. Add the required amount of additive to the binder and stir with a mechanical stirrer until the additive is totally dispersed in the binder.

7.5.2. Preparing WMA Specimens

7.5.2.1. Add the required moisture to the wet fraction of the aggregate, mix thoroughly, then cover and let stand for at least 2 hours before mixing with the heated fraction.

7.5.2.2. Heat the mixing tools, dry aggregate portion, and dry RAP portion to the initial mixing temperature in accordance with Section 7.2.

7.5.2.3. Place the hot mixing bowl on a scale and zero the scale.

7.5.2.4. Charge the mixing bowl with the heated aggregates and RAP and dry mix thoroughly.

7.5.2.5. Form a crater in the blended aggregate and weigh the required amount of asphalt binder into the mixture to achieve the desired batch weight.

**Note 16** – If the aggregates and RAP have been stored for an extended period of time in a humid environment, then it may be necessary to adjust the weight of binder based on the oven dry weight of the aggregates and RAP as follows:

1. Record the oven dry weight of the heated aggregates and RAP, \( w_i \)
2. Determine the target total weight of the mixture:

\[
W_t = \left(\frac{w_i + w_{\text{def}}}{1 - \frac{P_{b_{\text{new}}}}{100}}\right)
\]

where:
- \( w_t \) = target total weight
- \( w_i \) = oven dry weight from step 1
- \( w_{\text{def}} \) = oven dry weight of the wet fraction from the batch sheet
- \( P_{b_{\text{new}}} \) = percent by weight of total mix of new binder in the mixture

3. Determine the target weight of the heated mixture:

\[ w_{\text{shm}} = w_t - w_{\text{def}} \]

where:
- \( w_{\text{shm}} \) = target weight of the heated mixture
- \( w_t \) = target total weight
- \( w_{\text{def}} \) = oven dry weight of the wet fraction from the batch sheet
4. Add new binder to the bowl to reach $w_{\text{dry}}$

7.5.2.6. Add the additive to the binder immediately before mixing with the heated fraction of the aggregate per Section 7.5.1.

7.5.2.7. Remove the mixing bowl from the scale and mix with a mechanical mixer for 30 sec.

7.5.2.8. Stop the mixer and immediately add the wet fraction.

7.5.2.9. Restart the mixer and continue to mix for 60 sec.

7.5.2.10. Place the mixture in a flat shallow pan at an even thickness of 25 to 50 mm.

7.5.2.11. Check the temperature of the mixture in the pan. It shall be between 90 and 100 °C.

7.5.2.12. Place the pan in the forced draft oven at the planned field compaction temperature for 2 hours. Stir the mixture once after the first hour.

5. Preparation of Foamed Asphalt Mixtures

7.6.1. The preparation of foamed asphalt mixtures requires special asphalt binder foaming equipment that can produce foamed asphalt using the amount of moisture that will be used in field production.

7.6.2. Prepare the asphalt binder foaming equipment and load it with binder per the manufacturer’s instructions.

7.6.3. If a liquid anti-strip is required, add it to the binder in the foaming equipment per the manufacturer’s instructions.

7.6.4. Heat the mixing tools, aggregate, and RAP in accordance with Section 7.2.

7.6.5. Prepare the foamed asphalt binder per the instructions for the foaming equipment.

7.6.6. Place the hot mixing bowl on a scale and zero the scale.

7.6.7. Charge the mixing bowl with the heated aggregates and RAP and dry mix thoroughly.

7.6.8. Form a crater in the blended aggregate and add the required amount of foamed asphalt into the mixture to achieve the desired batch weight.
Note 17 – The laboratory foaming equipment uses a timer to control the amount of foamed asphalt provided. Make sure the batch size is large enough that the required amount of foamed asphalt is within the calibrated range of the foaming device. This may require producing one batch for the two gyratory specimens and the two maximum specific gravity specimens at each asphalt content then splitting the larger batch into individual samples.

Note 18 – If the aggregates and RAP have been stored for an extended period of time in a humid environment, then it may be necessary to adjust the weight of binder based on the oven dry weight of the aggregates and RAP as follows:

1. Record the oven dry weight of the aggregates and RAP, $w_i$
2. Determine the target total weight of the mixture
   \[
   w_r = \frac{w_i}{1 - \frac{P_{b_{new}}}{100}}
   \]
   where:
   - $w_r$ = target total weight
   - $w_i$ = oven dry weight from step 1
   - $P_{b_{new}}$ = percent by weight of total mix of new binder in the mixture
3. Add foamed binder to the bowl to reach $w_r$

7.6.9. Remove the mixing bowl from the scale and mix with a mechanical mixer for 90 sec.

7.6.10. Place the mixture in a flat shallow pan at an even thickness of 25 to 50 mm and place the pan in the forced draft oven at the planned field compaction temperature for 2 hours. Stir the mixture once after the first hour.

8. WMA MIXTURE EVALUATIONS

8.1. At the optimum binder content determined in accordance with Section 10 of AASHTO R 35, prepare WMA mixtures in accordance with the appropriate procedure from Section 7 of this appendix for the following evaluations:
   - Coating
   - Compactability
   - Moisture sensitivity
   - Rutting resistance
8.2. Coating

8.2.1. Prepare sufficient mixture at the design binder content to perform AASHTO T 195 using the appropriate WMA fabrication procedure from Section 7 of this appendix. Do not short-term condition the mixture.

8.2.2. Evaluate the coating in accordance with AASHTO T 195.

8.2.3. The recommended coating criterion is at least 95 percent of the coarse aggregate particles fully coated.

8.3. Compactability

8.3.1. Prepare sufficient mixture at the design binder content for 4 gyratory specimens and one maximum specific gravity measurement using the appropriate WMA fabrication procedure from Section 7 of this Appendix including short-term conditioning for 2 hours at the planned compaction temperature.

8.3.2. Determine the theoretical maximum specific gravity ($G_{mm}$) according to AASHTO T 209.

8.3.3. Compact duplicate specimens at the planned field compaction temperature to $N_{design}$ gyrations in accordance with AASHTO T 312. Record the specimen height for each gyration.

8.3.4. Determine the bulk specific gravity of each specimen in accordance with AASHTO T 166.

8.3.5. Allow the mixture to cool to 30 °C below the planned field compaction temperature. Compact duplicate specimens to $N_{design}$ gyrations in accordance with AASHTO T 312. Record the specimen height for each gyration.

8.3.6. Determine the bulk specific gravity of each specimen in accordance with AASHTO T 166.

8.3.7. For each specimen determine the corrected specimen relative densities for each gyration using Equation 1.

\[ \%G_{mm_x} = 100 \times \left( \frac{G_{mb} \times h_g}{G_{mm} \times h_N} \right) \]  

where:

$\%G_{mm_x}$ = relative density at $N$ gyrations;

$G_{mb}$ = bulk specific gravity of specimen compacted to $N_{design}$ gyrations;
\[ h_d = \text{height of the specimen after } N_{\text{design}} \text{ gyrations, from the Superpave gyratory compactor, mm; and} \]
\[ h_N = \text{height of the specimen after } N \text{ gyrations, from the Superpave gyratory compactor, mm} \]

8.3.8. For each specimen, determine the number of gyrations to reach 92 percent relative density.

8.3.9. Determine the average number of gyrations to reach 92 percent relative density at the planned field compaction temperature.

8.3.10. Determine the average number of gyrations to reach 92 percent relative density at 30 °C below the planned field compaction temperature.

8.3.11. Determine the gyration ratio using Equation 2.

\[
\text{Ratio} = \frac{(N_{92})_{T=30}}{(N_{92})_T} \tag{2}
\]

where:
\[
\text{Ratio} = \text{gyration ratio} \\
(N_{92})_{T=30} = \text{gyrations to 92 percent relative density at 30 °C below the planned field compaction temperature} \\
(N_{92})_T = \text{gyrations to 92 percent relative density at the planned field compaction temperature}
\]

8.3.12. The recommended compactability criterion is the gyration ratio should be less than or equal to 1.25.

\textbf{Note 18 –} The compactability criterion limits the temperature sensitivity of WMA to that for a typical HMA mixture. The criterion is based on limited research conducted in NCHRP 9-43. The criterion should be considered tentative and subject to change as additional data on WMA mixtures are collected.

8.4. Evaluating Moisture Sensitivity

8.4.1. Prepare sufficient mixture at the design binder content for 6 gyratory specimens using the appropriate WMA fabrication procedure from Section 7 of this appendix including short-term conditioning.

8.4.2. Compact test specimens to 7.0 ± 0.5 percent air voids in accordance with AASHTO T 312.

8.4.3. Group, condition and test the specimens in accordance with AASHTO T 283.

8.4.4. The recommended moisture sensitivity criteria are the tensile strength ratio should be greater than 0.80 and there should not be any visual evidence of stripping.
8.5. Evaluating Rutting Resistance

8.5.1. Evaluate rutting using the flow number test in AASHTO TP 79.

8.5.2. Prepare sufficient mixture at the design binder content for four flow number test specimens using the appropriate WMA fabrication procedure from Section 7 of this appendix including short-term conditioning.

8.5.3. The test is conducted on 100 mm diameter by 150 mm high test specimens that are sawed and cored from larger gyratory specimens that are 150 mm diameter by at least 175 mm high. Refer to AASHTO PP 60 for detailed procedures for test specimen fabrication procedures. The short-term conditioning for WMA specimens is 2 hours at the compaction temperature.

8.5.4. Prepare the flow number test specimens to 7.0 ± 1.0 percent air voids.

8.5.5. Perform the flow number test at the design temperature at 50% reliability as determined using LTPP Bind Version 3.1. The temperature is computed at 20 mm for surface courses, and the top of the pavement layer for intermediate and base courses.

8.5.6. Perform the flow number test unconfined using repeated deviatoric stress of 600 kPa with a contact deviatoric stress of 30 kPa.

8.5.7. Determine the flow number for each specimen, then average the results. Compare the average flow number with the criteria given in Table 3.

Table 3. Minimum Flow Number Requirements

<table>
<thead>
<tr>
<th>Traffic Level, Million ESALs</th>
<th>Minimum Flow Number</th>
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<td>&lt;3</td>
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</tr>
<tr>
<td>3 to &lt; 10</td>
<td>30</td>
</tr>
<tr>
<td>10 to &lt; 30</td>
<td>105</td>
</tr>
<tr>
<td>≥ 30</td>
<td>415</td>
</tr>
</tbody>
</table>

9. ADJUSTING THE MIXTURE TO MEET SPECIFICATION PROPERTIES

9.1. This section provides guidance for adjusting the mixture to meet the evaluation criteria contained in Section 8 of this appendix. For WMA mixtures, this section augments Section 12 in AASHTO R 35.
9.2. **Improving Coating**- Most WMA processes involve complex chemical reactions and/or thermodynamic processes. Consult the WMA additive supplier for methods to improve coating.

9.3. **Improving Compactability**- Most WMA processes involve complex chemical reactions and/or thermodynamic processes. Consult the WMA additive supplier for methods to improve compactability.

9.4. **Improving the Tensile Strength Ratio** – Some WMA processes include adhesion promoters to improve resistance to moisture damage. Consult the WMA additive supplier for methods to improve the tensile strength ratio.

9.5. **Improving Rutting Resistance** - The rutting resistance of WMA can be improved through changes in binder grade and volumetric properties. The following rules of thumb can be used to identify mixture adjustments to improve rutting resistance.

- Increasing the high temperature performance grade one grade level improves rutting resistance by a factor of 2.
- Adding 25 to 30 percent RAP will increase the high temperature performance grade approximately one grade level.
- Increasing the fineness modulus (sum of the percent passing the .075, 0.150, and 0.300 mm sieves) by 50 improves rutting resistance by a factor of 2.
- Decreasing the design VMA by 1 percent will improve rutting resistance by a factor of 1.2.
- Increasing $N_{\text{design}}$ by one level will improve rutting resistance by factor of 1.2.

10. **ADDITIONAL REPORTING REQUIREMENTS FOR WMA**

10.1. For WMA mixtures, report the following information in addition to that required in Section 13 of AASHTO R 35.

10.1.1. WMA process description.

10.1.2. Planned production temperature.

10.1.3. Planned field compaction temperature.

10.1.4. High temperature grade of the binder in the RAP for mixtures incorporating RAP.

10.1.5. Coating at the design binder content.

10.1.6. Gyrations to 92 percent relative density for the design binder content at the planned field compaction temperature and 30 °C below the planned field compaction temperature

10.1.7. Gyration ratio.
10.1.8. Dry tensile strength, tensile strength ratio, and observed stripping at the design binder content.

10.1.9. Flow number test temperature and the flow number at the design binder content.