Material Test Framework for Warm Mix Asphalt Trials

A number of new processes have been developed to allow asphalt mixtures to be mixed and compacted at lower temperatures. These processes tend to reduce the viscosity of the mixture at mixing and compaction temperatures. Collectively, these processes are referred to as warm mix asphalt (WMA). In an effort to evaluate WMA technologies, contractors and agencies have constructed or are planning to construct trial sections. When considering a WMA trial, a minimum desired test section would be 800-1000 tons of WMA. This will allow a plant run of approximately four hours at reasonable production rates. Further, it is desirable to have a hot mix control section to be produced using the same mix design (without the WMA additives).

In order to maximize the benefit from these trial sections, it is desirable to have a framework which provides for a minimum level of uniform data collection which can be shared with other contractors and agencies. Additional testing is described, which may enhance the knowledge learned from the trial sections. The following is a working document which will be periodically updated in order to improve the knowledge gained. The primary goals of the framework are as follows:

- Document the WMA project,
- Evaluate the effect on laboratory compaction and volumetric properties to develop information for future mix design and quality control procedure,
- Evaluate potential impact on performance in terms of:
    - Rutting – reduced aging of the binder could increase rutting potential,
    - Moisture susceptibility – incomplete drying of the aggregate could increase moisture susceptibility,
    - Low temperature cracking – certain WMA additives may increase the potential for low temperature cracking based on binder tests, conversely the reduced aging of the binder could reduce the potential for low temperature cracking,
    - Mixture stiffness – reduced aging of the binder may reduce the mixture stiffness
    - Fatigue life – reduced aging of the binder may increase the mixtures fatigue capacity.
- Production, construction and in-place compaction,
- Provide a limited quantity of materials for future research.

The following describes the desirable data to be collected as part of a WMA trial:

1) Project Summary
    a) Project location
    b) Agency (if applicable)
    c) Contractor
    d) Paving date(s)
    e) Paving time(s), day, night, ect.

   f) Weather conditions – particularly ambient air and surface temperatures during laydown
   g) WMA process(es) used
   h) Tonnage produced
   i) Digital photos or video of the project during construction (production and/or laydown of HMA, photos of key operations, photos after completion, etc.)
   j) Any reports about the project produced by the agency, contractor or others
   k) Traffic: AADT, percent trucks and ESAL factor or load spectra, number of lans, and ecetera
2) Material Properties
   a) Aggregate properties
      i) Aggregate type(s)
      ii) Dry bulk specific gravity
      iii) Water absorptions
      iv) Stockpile moisture contents
      v) Superpave consensus and source properties (generally should be part of mix design, including: coarse aggregate angularity (ASTM D5821), uncompacted voids in fine aggregate (AASHTO T304 Method A), flat and elongated particles (ASTM D4791), sand equivalent (AASHTO T176), LA Abrasion (AASHTO T96), and soundness (AASHTO T104).
   b) Binder properties
      i) Binder supplier
      ii) Binder grade (attach copy of Manufacturer's certification)
      iii) Base binder grade, if WMA used to modify binder, e.g. Sasobit
      iv) Modifiers (if any)
   c) Mix Design (attach copy of mix design volumetric properties)
      i) Nominal maximum aggregate size
      ii) Target gradation
      iii) Optimum asphalt content
      iv) Laboratory compaction effort
3) Production information
   a) Plant type
   b) Plant model
   c) Describe method of introducing WMA additive(s)
   d) Production rate
   e) Aggregate discharge temperature temperature (if applicable)
   f) Mix discharge temperatures (history during production)
   g) Observations regarding motor amperages, particularly drag chain
   h) Collect fuel consumption data for both the HMA and WMA[1]
   i) Observations regarding baghouse after WMA run (moisture problem?)
   j) Use of silos and typical storage time.
4) Laydown information
   a) Temperature range of WMA at load out
   b) Truck type (tandems, live bottom etc.)
   c) Haul distance/Haul time
   d) Release agent used (if any)

- e) Observations regarding dumping material/sticking in truck beds (if any)
- f) Use of windrow or transfer vehicles
- g) Paver type and model
  - i) Vibratory screed on?
  - ii) Screed heated?
- h) Compacted thickness
- i) Temperature immediately behind screed (history)
- j) Roller Train
  - i) Type and model
  - ii) Weight
  - iii) Amplitude and frequency of vibratory rollers (if applicable)
  - iv) Tire pressure of pneumatic roller (if applicable)
- k) Roller Pattern – a separate roller pattern should be performed for the WMA and control mixes
- l) Time and mat temperature when opened to traffic

5) Testing
- a) Laboratory Mix Tests (Field Mixed/Laboratory Comapcted) – to be performed on both the WMA and control sections.
  - i) Moisture content of mix at load out (sampled from truck) – AASHTO T329
  - ii) Gyratory compaction of six pills for each sample to specified Ndesign compaction effort <u>without reheating mix other than to desired compaction temperature</u>. Record time needed to reheat samples (if any). After the volumetric properties are measured, the samples will be tested in the Asphalt Pavement Analyzer[2] (APA) for rutting potential at the recommended climatic high temperature for the site.
  - iii) Maximum specific gravity
  - iv) Prepare 6-8 samples to 7 ± 0.5 percent air voids and a height of 95 mm for Tensile Strength Ratio Testing[3] <u>without reheating mix other than to desired compaction temperature.</u> Record time needed to reheat samples (if any).

    The following equation has been used to estimate TSR sample weight in order to obtain 7 percent voids:

    $$M = (0.915)(Gmm)(\pi)(56.25)(9.5) = 1536.1(Gmm)$$

    The 150 mm diameter samples should be compacted to a constant height of 95 mm. Typically NCAT will compact two trial samples first, allow to cool, bulk, and adjust the mass as necessary to obtain 7 percent voids for an additional six samples.

  - v) Compact three samples in the gyratory compactor to a height of 170 mm at the anticipated in-place (field) density for simple performance testing (SPT)[4]. The following equation has been used to estimate the target sample weight for 150 mm diameter samples compacted to a height of 170 mm. The first factor, 0.895, is the anticipated in-place density (93 percent of Gmm) minus 4.5 percent. The adjustment to the anticipated in-place density is necessary to correct for surface texture and the fact that the center of the sample is denser than the total samples (100 mm diameter samples, 150 mm tall, will be cored from the oversize SGC samples).

$$M = (0.895)(Gmm)(\pi)(56.25)(17.0) = 2688.7(Gmm)$$

vi) Low Temperature Cracking – comparisons can be made between the low temperature cracking potential using the IDT test (AASHTO T322).

b) Field Tests (Field Mixed/Field Compacted) – to be performed on both the WMA and control sections
   i) Density Tests – in-place density should be determined based on cores. A minimum of nine cores should be taken from stratified random locations from each section. The cores should be sawed and measured for thickness. After density testing, the indirect tensile strength of three of the cores should be determined at 77 °F. Loading rate for the indirect tensile strength shall be 2 inches/minute (same rate as for TSR).
   ii) The three remaining cores should be used to determine bond strength between layers[5].
   iii) Recoveries should be performed on the cores and the recovered binder graded to assess the reduced aging during construction. Extractions and recoveries should be performed according to AASHTO T319 or AASHTO T164 Method A with Rotovap recovery. The extraction solvent should be toluene and 95% ethanol mixed at a ration of 85:15. The 95% ethanol contains 5 percent water. A maximum Rotovap temperature of 140 °C should be used, lower if reduced pressures are utilized.
   iv) An additional six cores should be taken, three in and three between the wheel paths at three months, one year and two years after construction. The cores should be tested for density and the indirect tensile strength determined at 77 °F. The additional coring with time is to serve two purposes: 1) WMA additives have indicated reduced asphalt contents during design, the cores will be used to assess the in-place densification under traffic. This data will be related back to the QC air voids; 2) indirect tensile strength will be used to assess binder aging.
   v) Recoveries should be performed on the cores taken after construction, once indirect tensile strength has been determined, and the recovered binder graded to assess the aging as a function of time. Extractions and recoveries should be performed according to AASHTO T319 or AASHTO T164 Method A with Rotovap recovery. The extraction solvent should be toluene and 95% ethanol mixed at a ration of 85:15. The 95% ethanol contains 5 percent water. A maximum Rotovap temperature of 140 °C should be used, lower if reduced pressures are utilized.

c) Sampling
   i) Obtain at least one-gallon of the binder, preferably in 4 quart cans.
   ii) Obtain approximately 30 lbs of each aggregate stockpile and RAP, if used.
   iii) Obtain three five-gallon buckets (approximately 180 lbs) of mix.
   iv) Obtain at least a one-gallon sample of any warm mix additive added directly at the plant (zeolite or Sasobit).

d) Additional Performance Testing (Field Mixed/Lab Compacted) – The following tests should be considered desirable, but not mandatory. Since WMA reduces the aging of the binder, it should improve mixture performance in terms of certain durability parameters such as fatigue life and low temperature cracking.
   i) Hamburg Tests for moisture susceptibility and rutting
   ii) Fatigue Life
      (1) Beam fatigue tests – samples for beam fatigue testing should be prepared, preferably with out reheating, to the anticipated in-place air void content. Improved densification tends to improve fatigue life. Therefore, every effort should be made to capture the effect of improved compaction obtained with WMA (AASHTO T321).
      (2) Fracture energy – an alternative method of assessing resistance to cracking is fracture energy testing, performed on SGC samples, using the IDT.
      (3) Other methods of assessing cracking potential may also be used, such as the TTI overlay tester.
   iii) TSRST Low Temperature testing
   iv) Smoothness testing, prior to opening to traffic
   v) Rut depth profiles, prior to opening to traffic (mark set locations for future testing)

6) Materials Testing Contacts:
   a) Warm Mix Asphalt Technical Working Group (WMA TWG)
      i) Dave Newcomb – National Asphalt Pavement Association – (888) 468-6499 DNewcomb@hotmix.org
      ii) Matthew Corrigan – Federal Highway Administration – (202) 366-1549 Matthew.Corrigan@FHWA.DOT.gov

Testing Notes

[1]Fuel consumption can be difficult to measure. Natural gas usage is the easiest to quantify. Tank dips can be inaccurate, particularly if recycled oil is used as fuel or another fuel which may not be completely atomized.

[2]APA testing to be conducted climatic PG high temperature, e.g. 64 °C, with a hose pressure of 100 psi and a vertical load of 100 lbs.

[3]The testing conducted by NCAT to date has been completed according to ASTM D4867. For laboratory prepared mixes, the 72-96 hour counter curing period of the compacted sample, specified in AASHTO T283, has been eliminated. Practically speaking, this curing period has been included in the field testing due to the shipping time required to get the samples back to the laboratory. One freeze-thaw cycle was applied to the conditioned samples. Freeze-thaw cycles simulate the pore pressure which develops in the mix under traffic and are valid even in areas where freezing temperatures are not likely to occur.

[4]Dynamic modulus and repeated load permanent deformation should be conducted according to the test procedures described in NCHRP Report 513. More up-to-date test procedures are available from the NCHRP 9-29 contractor. Repeated load creep testing to be performed at the base climatic PG binder grade -6°C, e.g. IF a PG 64-XX meets the climatic requirements, conduct the repeated load permanent deformation test at 58 °C. A vertical load of 600 kPa (87 psi) is generally believed to simulate mixed traffic expected on most sites. Confinement pressure is important for certain mix types such as OGFC and SMA. A confinement pressure of 20 psi is recommended. Repeated load creep testing may be conducted following dynamic modulus testing, assuming the maximum permanent strain criterion for dynamic modulus testing is not exceeded.

[5]There is some concern that the reduced mixture temperatures for WMA may fail to adequately bond to the underlying layer, particularly when PG binders are used as tack coat. A number of tests have been used to assess bond strength. Florida DOT and NCAT have both used guillotine type devices to measure bond strength. Some of NCAT’s work is described in NCAT Report No. 05-08, which is available at www.NCAT.us