ALDOT-307-83

DESIGN METHOD FOR SELECTING OPTIMUM ASPHALT CEMENT CONTENT OF HOT-MIX ASPHALT BY MEANS OF THE MARSHALL APPARATUS

1. Scope

1.1. This procedure covers the Department's method of designing hot-mix asphalt using the Marshall Stability Apparatus for the measurement of the resistance to plastic flow of cylindrical specimens of hot-mix asphalt loaded on the lateral surface. This method is for use with mixtures containing aggregate up to 1 in. (25 mm) maximum particle size.

2. Applicable Documents

2.1. AASHTO T 84, Standard Method of Test for Specific Gravity and Absorption of Fine Aggregate

2.2. AASHTO T 85, Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregate

2.3. AASHTO T 166, Standard Method of Test for Bulk Specific Gravity of Compacted Hot-mix Asphalt Mixtures Using Saturated Surface-Dry Specimens

2.4. AASHTO T 209, Standard Method of Test for Maximum Specific Gravity of Hot-Mix Asphalt Paving Mixtures

2.5. AASHTO T 245, Standard Method of Test for Resistance to Plastic Flow of Bituminous Mixtures using the Marshall Apparatus

2.6. AASHTO T 269, Standard Method of Test for Percent Air Voids in Compacted Dense and Open Asphalt Mixtures

2.7. The Asphalt Institute Manual, Series No. 2 (MS-2), Current Edition

3. Test Procedures

3.1. Stability and Flow

3.1.1. AASHTO T 245 shall apply except where amended as follows:

The first sentence of Paragraph 3.4.2 (AASHTO T 245) shall be amended to include the following formula for adjusting the amount of aggregate to obtain the required 63.5 mm specimen thickness:

International System of Units (SI)

$$\text{Adjusted aggregate weight} = \frac{(63.5)\ (\text{Mass of aggregate used in grams})}{\text{Measured Specimen Height in mm}}$$

3.1.2. Age the specimens (samples for compaction, samples for maximum specific gravity) in a forced draft oven at compaction temperature for 45 minutes.

3.2. Bulk Specific Gravity of Compacted Hot-mix Asphalt.

3.2.1. AASHTO T 166, Method A, shall apply.

3.2.2. Prior to testing for stability and flow, the bulk specific gravity shall be determined on the compacted hot-mix specimen prepared in accordance with AAHSTO T 245 as amended.

3.2.3. Average the bulk specific gravities for all compacted specimens of given asphalt content. Values obviously in error shall not be included in average. Values shall be carried out to three decimal places.

3.3. Maximum Specific Gravity of Bituminous Paving Mixtures

3.3.1. AASHTO T 209 shall apply.

3.3.2. Determine the maximum specific gravity of the hot-mix asphalt for at least two asphalt contents, preferably on mixes at or near the optimum asphalt content and compute the average. The maximum specific gravity of mixes with other asphalt contents can be computed as described in paragraph 4.4.

4. Density and Voids Analysis

4.1. Nomenclature

4.1.1. The following nomenclature will be used in the section:

Gb = specific gravity of asphalt
Gmb = bulk specific gravity of the compacted mixture
Gmm = maximum specific gravity of hot mix asphalt at a particular asphalt content
Gsa = apparent specific gravity of the combined coarse and fine aggregates
Gsb = bulk specific gravity of the combined coarse and fine aggregates
Gse = effective specific gravity of aggregate
Va = percent air voids by total volume in compacted mixture
Pb = percent binder by total mass of mixture
Pba = percent absorbed binder by mass of aggregate
Pbe = percent effective binder content by total mass of mixture
Ps = percent aggregate by total mass of mixture
VFA = percent of total voids filled
VMA = percent voids, by volume of compacted mix, in the mineral aggregate

4.2. Bulk and Apparent Specific Gravity of Coarse and Fine Aggregates

4.2.1. Calculate the bulk and apparent specific gravities of the coarse aggregate in accordance with AASHTO T 85. (See Note 1.)

4.2.2. Calculate the bulk and apparent specific gravities of the fine aggregate in accordance with AASHTO T 84 on the material retained on the No. 200 (75 µm) sieve after the materials passing the No. 200 (75 µm) sieve has been removed by washing. (Assume that the No. 200 (75 µm) material washed from the sample has the same specific gravity as the material retained on the No. 200 (75 µm). (See Notes 1and 2.)

4.2.3. Calculate the bulk specific gravity (Gsb) of the total combined mineral aggregate as follows: (See Note 1.)

$$G_{sb} = \frac{P1 + P2 + ---- + Pn}{\frac{P1}{G1} + \frac{P2}{G2} + -- + \frac{Pn}{Gn}}$$

Where

P1, P2, Pn = percentages by weight of aggregates 1, 2, … n

G1, G2, Gn= bulk specific gravities of aggregates 1, 2, … n

4.2.4. Calculate the apparent specific gravity (Gsa) of the total combined mineral aggregate as shown in paragraph 4.2.3 by substituting the apparent specific gravity of the aggregate in the formula for the bulk specific gravity (Gsb). (See Note 1.)

Note 1: Test results shall be carried out to three decimal places.

Note 2: The bulk specific gravity of mineral filler is difficult to determine. However, if the apparent specific gravity of mineral filler is used instead, the error is usually negligible.

4.3. Effective Specific Gravity of Aggregate (Gse)

4.3.1. Calculate the effective specific gravity (Gse) of aggregate using average Gmm as determined in paragraph 3.3.2.

$$G_{se} = \frac{(100 - Pb)}{\frac{100}{Gmm} - \frac{Pb}{Gb}}$$

Note: The asphalt content (Pb) should be the asphalt content at which Gmm was determined in paragraph 3.3.2.

4.4. Maximum Specific Gravity of Asphalt Mixtures with other Asphalt Contents. (Gmm)

4.4.1. Compute the maximum specific gravity of asphalt mixtures at other asphalt contents as follows:

$$Gmm = \left(\frac{100}{\frac{Ps}{Gse} - \frac{Pb}{Gb}} \right)$$

4.5 Percent Voids in the Mineral Aggregate (VMA), Percent Air Voids in the Compacted Mixture (Pa), and Percent Voids Filled with Asphalt in the compacted mixture (VFA)

4.5.1 Compute the percent voids in mineral aggregate of the compacted asphalt mixture for each asphalt content as follows:

$$VMA = (100) - \frac{GmbPs}{Gsb}$$

4.5.2 Compute the percent air voids of the compacted asphalt mixture for each asphalt content as follows:

$$Va = (100)\frac{Gmm - Gmb}{Gmm}$$

4.5.3 Compute voids filled with asphalt in the compacted asphalt mixture for each asphalt content as follows:

$$VFA = (100)\frac{VMA - Pa}{VMA}$$

4.6 Other Parameters

4.6.1 Asphalt Absorption (Pba) - Compute the percent of asphalt absorption as follows:

$$P_{ba} = (100)\ \frac{(Gse - Gsb)}{(Gse)(Gsb)}\ (Gb)$$

4.6.2 Effective Asphalt Content (Pbe) - Compute the effective asphalt content for bituminous mix as follows:

$$P_{be} = (Pb) - \frac{((Pba)(Ps))}{100}$$

5. Selecting Optimum Asphalt Content

5.1. Measure the stability values for a given asphalt content and average the results. Values that are obviously in error should not be included in average.

5.2. Compute the average density for each asphalt content by multiplying the average bulk specific gravity value as determined in paragraph 3.2.3 by 62.4 lb/ft^3 (1000 kg/m^3) and correct for the density of water at which the measurements were made to 77°F (25°C).

5.3. Plot a separate graph for the following values:

Stability vs. Asphalt Content
Density vs. Asphalt Content
Percent Air Voids vs. Asphalt Content
Percent Voids Filled with Asphalt vs. Asphalt Content
Percent VMA vs. Asphalt Content

Note: In each graph connect the plotted values with a smooth curve that is the "best fit" for all values.

5.4. Optimum Asphalt Content

5.4.1. The optimum asphalt content of the mix is the percent asphalt cement that yields the required percent air voids as specified for a particular mix.

5.4.2. Adjustments should be made in the hot asphalt mix if all the design criteria are not met by the optimum asphalt content.

5.4.3. Determine from the density curve the laboratory density of the mix at the optimum asphalt content. This density will be reported for use in adjustment of material thickness of each roadway layer along with in-place density determinations.

Note: Refer to BMT-153 for the typical Work Sheet and Report Form.