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MATES

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ABC'S OF HOT-MIX ASPHALT - PART II
MARSHALL MIX DESIGN

Introduction

Our initial asphalt article (MATES Issue No. 2) noted that MDOT uses the Marshall Mix Design method for designing bituminous mixtures. The method was conceived by Bruce Marshall, a bituminous engineer with the Mississippi State Highway Department, and was further developed in the 1940's by the U. S. Army Corps of Engineers. The Corps established criteria that relate certain mix properties to field behavior of bituminous pavements under repeated loadings. The method is based on extensive testing of many different mixtures on a large-scale test track. The original criteria were later modified by the Corps based upon field experience and additional testing, and they have been modified further for use in Michigan where they have been called 'stability' or 'performance' mixes.

Mix design, from the contractor's viewpoint, involves finding or producing an aggregate or combination of aggregates that can be incorporated into the lowest cost bituminous mixture that meets MDOT specifications. Mix design, from the MDOT laboratory standpoint, involves testing of mixtures made from the contractor-supplied aggregates to determine whether or not our specifications are met and to establish the optimum asphalt cement content for the particular aggregates that the contractor proposes to use.

Definitions

Before we discuss the procedures and problems involved in the Marshall Mix Design method, the following definitions should be noted:

Voids in mineral aggregate (VMA) - the volume of a compacted bituminous mixture minus the volume occupied by aggregate. In a compacted mix, VMA would be the volume occupied by asphalt cement plus air.

Air voids - the volume of a compacted bituminous mixture not occupied by either aggregate or asphalt cement.

Theoretical maximum specific gravity - the specific gravity of a particular bituminous mixture that would exist if it were compacted to a point where it had no air voids (in fact, not possible to attain).

Bulk specific gravity - the specific gravity of a compacted bituminous mixture including the volume of the air voids.

Mix Design in our Bituminous Lab

Experimental bituminous mixtures are made and compacted in the laboratory using a method intended to approximate mix and compaction conditions that occur in the field. Each experimental mixture is an aggregate/asphalt cement combination weighing about 12 lb, combined and mixed under tightly controlled conditions of time and temperature. Several sample mixtures are prepared with asphalt content ranging from very low to very high (5 to 7 percent). Marshall test specimens are prepared (2-1/2 in. high by 4-in. diameter cylinders), with a specified compactive effort designed to duplicate compaction that occurs from field paving operations plus later compaction by traffic. At least three Marshall specimens are made from each mixture and the following determinations are made on each—with strict control of temperature, time, and equipment—and their results averaged.

1) Bulk specific gravity is determined for each Marshall specimen.

2) The specimens are then compressed to failure under load applied at a specific rate. The peak load before failure, in lb, is defined as Marshall stability. The deformation at failure, in units of 1/100 of an in. is defined as flow.

3) Theoretical maximum specific gravity is determined by immersing a portion of the bituminous mixture in hot asphalt cement; the hot asphalt cement fills voids and drives out all air. After all air is driven from the mixture, specific gravity can be calculated.

4) Using the Marshall specimen bulk specific gravities and the mixture's theoretical maximum specific gravities, calculations are made to determine the air voids and VMA of the compacted specimens.

5) Optimum asphalt content is then selected on the basis of determined air voids; thus, asphalt content is selected on the basis of volume. The volume is then converted to a weight for use in the mixing plant.

As discussed in our previous article, a mix should be designed to have sufficient air voids to prevent 'flushing,' (a rising of the asphalt cement to the pavement surface under traffic), but not so many as to allow entrance of harmful air and water. If (at optimum asphalt content) the mixture fails to meet the stability, flow, or VMA requirements, the mix design is rejected and a new mix design, with a different contractor-supplied aggregate or aggregate combination must be developed.

For example, the figures show two graphs developed from a MDOT mix design (graphs of other characteristics are developed as well). If we design the pavement to have a minimum 1,800-lb stability and 3 percent air voids after construction and compaction by traffic, Figure 1 would be entered at 3 percent air voids and it would be seen that 6.8 percent asphalt cement by weight would be required. (For the mix, the asphalt cement would be about 16 percent of the material by volume.) Entering Figure 2 with the 6.8 percent asphalt cement requirement, we see that a Marshall stability of more than 2,100 lb would be achieved. This exceeds the 1,800-lb design requirement. If the VMA and flow requirements (not shown here) were met, the mix design with 6.8 percent asphalt cement would be recommended.

Testing Laboratory U of M 1913 — Research Laboratory MSU 1939

Investigation and Research Division 1924 * Testing and Research Division 1933 * Materials and Technology Division 1985

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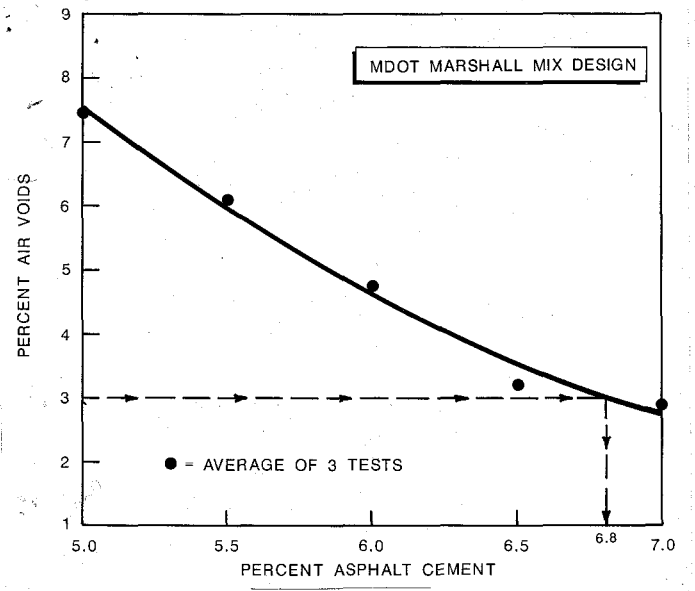

Figure 1.

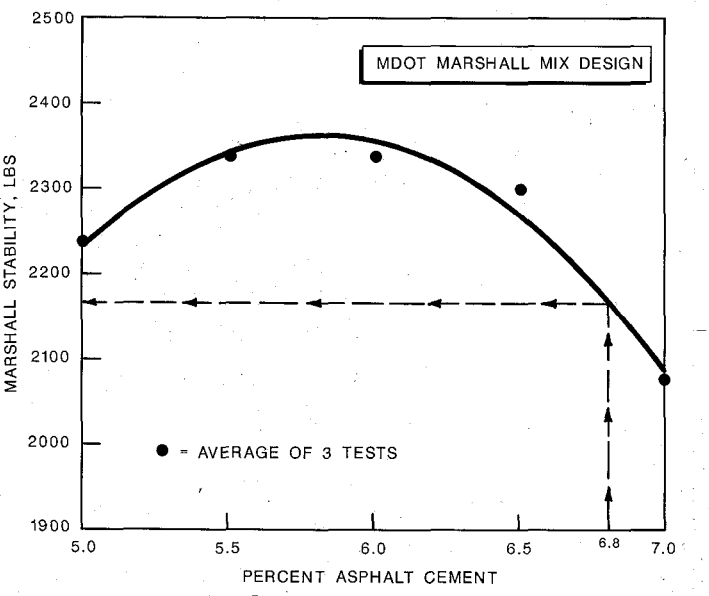

Figure 2.

Expediting Mix Design Requests

The Department performs many mix designs each year (200 in 1986). A mix design can be completed within a couple of days of receiving the aggregate sample. However, because of the number we do (especially during the peak of the construction season) it often is necessary, after receiving the aggregate sample, to use the whole two weeks allowed by specification to complete a design. The laboratory is under pressure from contractors and project personnel to get designs out faster. We do our best to accomodate MDOT requests to rush a design, but all designs cannot be top priority.

Besides the press of time, other problems are encountered; such as receiving undersized samples, improperly identified samples, unrepresentative samples, and laboratory equipment breakdowns. Those responsible for submitting samples for mix design, can assist in obtaining a rapid turnaround at the laboratory by making sure that the samples of aggregate submitted are of the required quantity and properly identified, and that they are submitted ASAP. If you have any questions about submitting samples or about mix design, contact the Traveling Mix Inspector, the District Materials office, or the Bituminous Technology Services Unit in the Testing Laboratory at (517) 322-1184.

-Bob Manninen

TECHADVISORIES

The brief information items that follow here are intended to aid MDOT technologists by advising or clarifying, for them, current technical developments, changes or other activities that may affect their technical duties or responsibilities.

NEW MATERIALS ACTION

The New Materials Committee recently:

Approved the following products:

- Sate-Lite Model 35D-40 Center Mount Delineators (without metal backs)
- FAS Splice for H-Beam Piling
- Soil Guard S-75, S-150, and SC-150 Mulch Blankets
- ARMCO ERO-MAT Mulch Blanket

For details contact Don Malott at 517-322-5687

KAYE MACDONALD

Kaye MacDonald is retiring from the Department at the end of February after 28 years of service. Kaye's entire career has been spent with the Materials and Technology Division, starting as an Aggregate Inspector A1 in 1958. Kaye was assigned to the Central Office, from the field, in 1960 where he was put in charge of highway sign inspection Statewide. In addition to handling the supervision of sign inspection, he acted as a troubleshooter whenever unusual materials problems arose. Kaye is one of those fellas who brought his sense of humor and fun to the office, and his presence will be missed. Our best wishes go with him for the future.

MATERIALS OR PROCEDURES ADVISORIES

The third draft of Independent Assurance Test Procedures for aggregates, portland cement concrete, soil and bituminous density, and bituminous mixtures has been sent to the Districts for review and comment.

OTHER PERSONNEL CHANGES

First, we'd like to welcome **Dr. Sudhakar Kulkarni** to the Division. Formerly Supervisor of Structural Engineering Unit, Engineering Systems Section, Engineering and Scientific Data Center, Dr. Kulkarni has joined us as head of our Structures Unit. He is in his 20th year with the Department. **Fred Copple** has been named Engineer of Testing, and will supervise the activities of our Testing Laboratory, a position that he has been filling on an Acting basis. Fred joined the Research Laboratory in 1955, and went on active military duty soon after. He rejoined the Division in 1959, where he has held a number of supervisory positions. Finally, **Jack DeFoe** has been named Assistant Supervising Engineer of the Soils, Bituminous, and Pavement Performance Unit. Jack started working at the old Research Laboratory on the MSU campus in 1954 as a student, and became a full-time soils engineer in 1959. Congratulations to all three!

This document is disseminated as an element of MDOT's technical transfer program. It is intended primarily as a means for timely transfer of technical information to those MDOT technologists engaged in transportation design, construction, maintenance, operation, and program development. Suggestions or questions from district or central office technologists concerning MATES subjects are invited and should be directed to M&T's Technology Transfer Unit.

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