"ASPHALT MIX DESIGNS"

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1. The U.S. Coast and Geodetic Survey on triangulation surveys;
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6. The Flexible Pavement Branch, Waterways Experiment Station, Corps of Engineers in research in air field pavement design for military aircraft.

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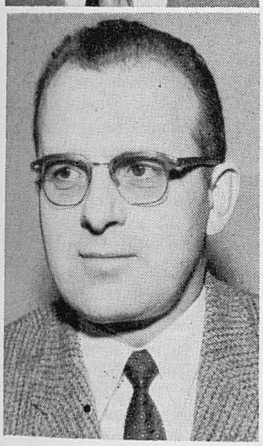

Graduate of the Johns Hopkins University, Bachelor's degree in Civil Engineering. Employed by the South Dakota State Highway Commission from 1950 to 1955. Working in the Materials Division, was in charge of asphalt paving mix design and control. Conducted soil surveys for base improvement and asphalt resurfacing projects.

Since joining The Asphalt Institute in 1955 as Assistant Engineer of Research, has been engaged in research studies on asphalt paving mix design, stabilization of base materials with asphalt, and hydraulic applications of asphalt.

Introduction

The design of hot-mix asphalt paving involves the selection and proportioning of two materials: mineral aggregates and asphalt cement. The selection and proportioning of these materials must meet several design objectives. The objectives of asphalt paving mix design are discussed in detail in publications such as the Asphalt Institute Mix Design Manual.[1] In broad terms, asphalt paving mixes

[1] Paper prepared for presentation at the Twelfth Annual Kentucky Highway Conference, University of Kentucky, Lexington, Kentucky, March 1-2, 1960.

must be designed to be adequate structurally for the loads imposed on them and they must be durable. Moreover, design must accomplish structural adequacy and durability economically.

Mineral aggregates will normally comprise about 85% or more of the volume of an asphalt pavement. Aggregates may vary considerably in their physical properties. Because they make up the largest part of the pavement it is reasonable that considerable importance be attached to them in paving mix design.

Asphalt cement, a thermoplastic material, makes up about 10 to 12 percent of the volume of a normal asphalt pavement. The asphalt completely coats and cements together all aggregate particles. It serves to make the pavement waterproof, abrasion resistant and durable. The combination of asphalt and aggregates in a pavement produces a resilient structure. The asphalt pavement is probably best described by the term visco-elastic.

The remaining 3 to 5 percent of the volume of a pavement is air. Though not contributing directly to the structural strength some air voids are necessary in most asphalt pavements, primarily in order that adequate stability be maintained.

Many paving technologists long have felt that the mechanical behavior or strength properties of asphalt paving mixtures can, and eventually will, be measured by triaxial test methods.[2] Considerable research has been done and is continuing toward this end. Utilization of triaxial test methods and data however has not gained widespread use largely because of uncertainties resulting from the application of the various theories involved.

Thus, in the development of the widespread use of asphalt concrete a number of simpler tests and methods for designing and predicting the mechanical behavior of paving mixes have been developed. These are the well known Hveem, Marshall and Hubbard-Field methods which are all strictly empirical in nature. These methods when properly used, and when limited to the correlations that exist between their test values and pavement performance, are extremely useful for designing paving mixes. Some of the methods may be used effectively for controlling the manufacture of the paving mix.

Of these test methods, the Marshall has gained the most widespread use. The balance of this discussion will be related largely to the use of the Marshall method and particularly to the effect that certain aggregate variables have on Marshall test properties.

Consider four aggregates, two fine and two coarse. One fine aggregate, a natural sand from Louisiana, is very well rounded and smooth surface textured. The other fine aggregate is a crushed New York trap rock, very angular and rough surface textured. Similarly one of the coarse aggregates, Washington gravel, is well rounded and smooth surface textured; and the other coarse aggregate, California granite is extremely angular and rough surface textured. Four combinations of these materials were made. All of the combinations were made to produce a dense surface course mix of constant gradation, with maximum size ¾ inches and 55% passing the No. 8 sieve. Aggregates passing the ¾ inch sieve and retained on the No. 8 sieve are referred to as coarse aggregates, and aggregates passing the No. 8 sieve and retained on the No. 200 sieve are called fine aggregates in this paper. All combinations of aggregates contained 9.4 percent of the total aggregate passing the No. 200 sieve. The total minus No. 200 fraction was a commercial limestone dust mineral filler. An 85-100 penetration grade asphalt cement was used. These combinations permit relative comparisons to be made for a single, dense gradation and probably represent the near extreme changes in test properties that could be expected for a typical dense graded surface mix.

Aggregate Characteristics and Stability

Aggregate characteristics, namely, particle angularity and surface texture, have pronounced effects on Marshall stability test values. Figure 1 shows a family of stability curves for the combinations of aggregates previously described.

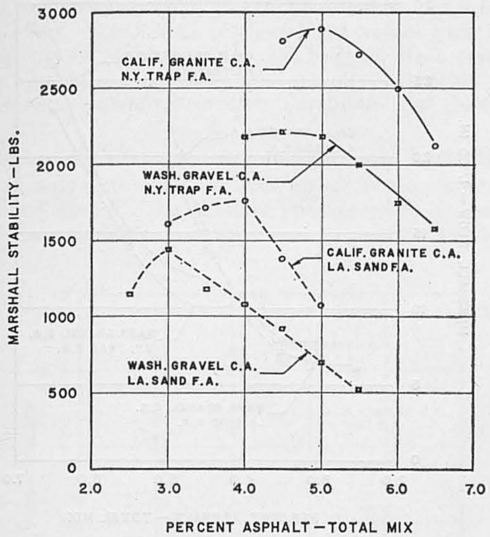

Fig. 1—Effect of Aggregate Characteristics on Marshall Stability.

The combination of the highly angular and rough surfaces textured California granite coarse aggregate with the New York trap rock fine aggregate resulted in the highest stability. The stability of this combination is approximately twice that resulting from the combination of the well rounded and smooth surface textured Washington gravel coarse aggregate with Louisiana sand fine aggregate. It will also be noted that increasing angularity and roughness of surface texture shifts the peak of the Marshall stability curve to the right, in the direction of higher asphalt contents.

When the angular and rough surface textured California granite coarse aggregate was combined with the rounded and smooth surface textured Louisiana sand fine aggregate, the stability level increased 200 to 300 pounds compared to the same fine aggregate combined with the rounded Washington gravel coarse aggregate.

When the highly angular and rough surface textured New York fine aggregate was combined with the rounded and smooth surface textured Washington gravel, it resulted in a 500 to 700 lbs. stability increase compared with a blend of the same coarse aggregate and rounded and smooth surface textured sand fine aggregate.

Thus, this family of curves for a constant dense aggregate gradation using four different aggregates varying widely in angularity and surface texture clearly shows the effect of aggregate characteristics on Marshall stability values. The curves also give an indication of the magnitude of Marshall stability change that can be expected as angularity and surface texture of aggregates are varied either in the production of aggregates or in the selection of aggregate sources.

Aggregate Characteristics and Flow

The effect of aggregate characteristics on Marshall flow values for these same combinations of aggregates is shown in Figure 2.

For this dense graded mix Marshall flow values are influenced mainly by the changes in angularity and surface texture of the fine aggregate fraction. Increasing angularity and roughness of surface texture of the fine aggregate fraction can

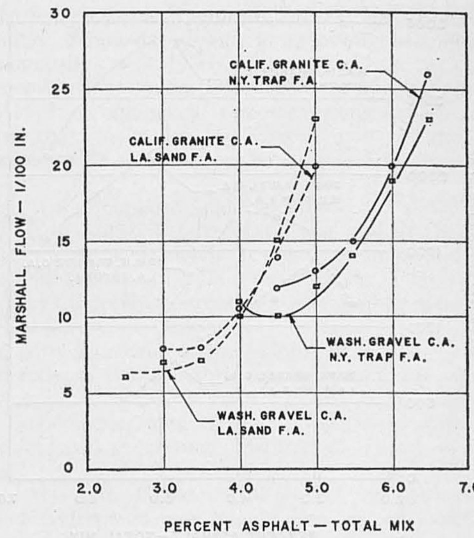

Fig. 2—Effect of Aggregate Characteristics on Marshall Flow Values.

result in an increase or decrease of flow values depending upon the asphalt content at which comparisons are made. Varying angularity and surface texture characteristics of the coarse aggregate fractions have little effect on Marshall flow values.

Aggregate Characteristics and VMA

The effect of aggregate angularity and surface texture characteristics on voids in the mineral aggregates for the same aggregates and combinations are shown in Figure 3. It is readily seen that fine aggregate characteristics are the dominant influence on aggregate voids values. Coarse aggregate angularity and surface

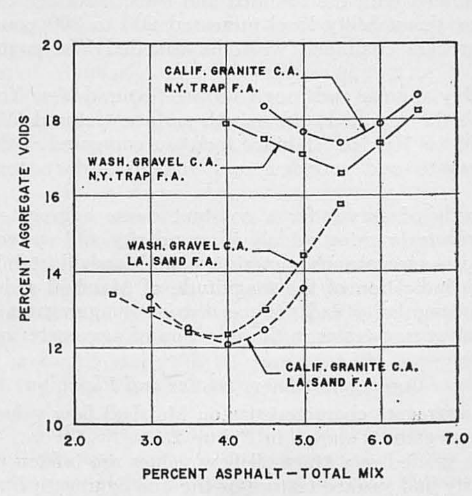

Fig. 3—Effect of Aggregate Characteristics on Percent Aggregate Voids.

texture may have a slight effect on aggregate voids values but it is small compared to fine aggregate effect. Significance of these VMA values from the standpoint of mix design is that use of highly angular and rough surface textured aggregates, particularly fine aggregates, increases the amount of asphalt that a mix will accommodate, thereby providing greater durability and better resistance to fatigue.

Aggregate Characteristics and Air Void Contents

The effects of aggregate characteristics on air void contents for these same mixes are shown in Figure 4. The effect of fine aggregate characteristics are very pronounced and the angularity and roughness of surface texture of the coarse

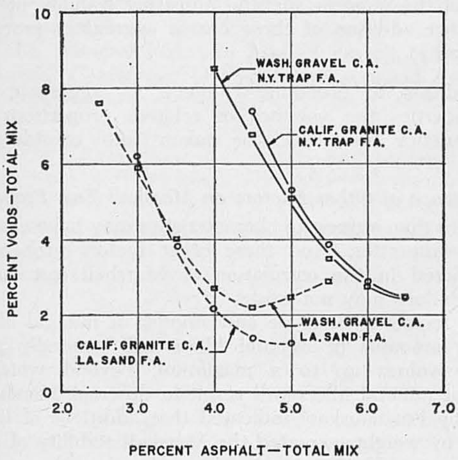

Fig. 4—Effect of Aggregate Characteristics on Percent Voids in Total Mix.

aggregate fractions have little effect. The asphalt content corresponding to 4% air voids in the mixes containing the well rounded and smooth surface textured Louisiana sand fine aggregate is about 3.5%. The asphalt content corresponding to 4% air voids in mixes containing the angular and rough surface textured New York trap rock fine aggregate is about 5.5%.

Changes in Proportions of Coarse and Fine Fractions and Marshall Test Properties

The previous data and discussion was confined to a constant gradation. It would be expected that the influence of aggregate characteristics of coarse and fine fractions on Marshall test properties would also be dependent upon the relative volumes or proportions of each of the fractions in the mix. This is the case: These effects of changes in relative proportions of coarse and fine aggregate fractions and these effects on Marshall test properties were examined in considerable detail by the authors and the results of these studies have been reported previously.[3]

In general some of the findings reported primarily with respect to Marshall stability were:

1. Very little increase in Marshall stability can be expected when increasing amounts of rounded and smooth textured coarse aggregates are added to well rounded and smooth textured fine aggregate. Stability decreases would probably result when the coarse aggregate fraction exceeded about 50% by weight.

2. Moderate increases in Marshall stability will result from increasing additions of highly angular and rough surface textured coarse aggregates to a rounded and smooth natural sand fine aggregate up until the coarse fraction reached 50% by weight. Further increases in the coarse fraction probably will result in a stability decrease.

3. The addition of rounded and smooth coarse aggregates in amounts up to about 25% by weight to a highly angular and rough surfaced textured fine aggregate mix will not effect stability. Addition of amounts greater than 25% will result in Marshall stability decreases.

4. The addition of increasing amounts of highly angular and rough textured coarse aggregates to an equally angular and rough textured fine aggregate will result in about the same or slightly increasing stability up to about 60% by weight. Further addition of these coarse aggregates probably will decrease Marshall stability.

Thus, in addition to pronounced effects of aggregate characteristics on Marshall test properties the volumes or relative proportions of aggregates of differing characteristics must also be taken into consideration in practical application.

Influence of Other Factors on Marshall Test Properties

Other variables than aggregate characteristics may have considerable influence on Marshall test properties. And these other factors probably have not been adequately considered in the correlation of Marshall test values to field performance or correlations may not exist.

One of these factors is the type and amount of mineral filler used in paving mixes. Increasing amounts of mineral fillers will generally produce increasing Marshall stability values up to a maximum, beyond which stability values decrease. Different mineral fillers will result in different Marshall stability values. Studies reported by Puzinauskas[4] indicated that additions of limestone dust filler up to about 25% by weight increased the Marshall stability of a sand asphalt mix from about 600 lbs. to 1800 lbs. Amounts greater than this reduced the stability. It is not likely that such large stability changes would result in a typical dense graded high stability surface coarse mix due to increasing mineral filler contents. It is generally thought that other design factors than stability should be considered such as durability, flexural and fatigue characteristics in the determination of the optimum amount or type of mineral fillers.

The effect of the consistency of asphalt cements used also has an appreciable effect on Marshall stability levels. A series of laboratory tests made with a sand aggregate containing no mineral filler indicated that as the penetration of the asphalt was decreased from 90 to 45, the maximum Marshall stability of the mixes increased from about 300 to 600 pounds. The same sand aggregate with a 25 penetration asphalt cement had a maximum Marshall stability value of 1700 lbs. As is the case with mineral fillers, it is generally felt that other and perhaps more important factors must be considered along with stability in selection of asphalt consistency in mix design.

Summary and Conclusion

Asphalt paving mix design has been discussed in broad terms. One of the most widely used empirical methods of mix design, the Marshall method, has been considered in some detail. Test data has been presented that has shown the considerable effects of aggregate characteristics on Marshall test properties. It is thought that more attention to aggregate characteristics, particle angularity and surface texture, and particularly those characteristics in the fine aggregate fraction in dense graded surface course mixes, will lead to higher stability and more durable asphalt pavements. The authors feel that, if it is recognized that these methods such as the Marshall and Hveem are empirical, good use can be made of these methods in mix design. It is our feeling that these methods probably have not reached the limits of their usefulness and that more careful and wider correlations with field pavement performance may increase their usefulness. These test methods certainly can serve as well until improved and perhaps more rational methods are developed.

References

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