Before beginning the discussion of the Indiana State Highway Commission’s specifications and practices for dense-graded base construction, let’s first consider the type and characteristics of the material to be used.

The Indiana State Highway Commission’s 1960 specifications designate dense-graded materials as size numbers 53 and 73. As described in “HERPIC Report 2-61” these materials are “dense-graded.” The definition of “dense-graded” as given in that report is as follows: “An aggregate material uniformly graded from coarse to fine, with a distribution of sizes and sufficient mineral dust (passing No. 200 sieve) to yield a compacted aggregate having a minimum void space.”

The purpose of the dense-graded mixture is to obtain the maximum stability or load-carrying capacity that can be obtained from the materials without the addition of cements, such as bitumens, tars, portland cement, lime and fly ash, chemicals, such as calcium chloride and sodium chloride, or other agents. The aggregate gradation then must be carefully controlled to obtain maximum values of internal friction and cohesion which are the two properties of the mixture that determine the load-carrying capacities. Friction may be defined as the resistance of particles to movements as a result of area and the coefficient of friction developed between the contacting surfaces of the particles. Friction is usually thought of as applying primarily to coarse aggregate and the coarse sand particles. True cohesion is the resistance of particles to being pulled apart or sheared, and is due to molecular attraction at the point of contact. This value is usually low and adds little to the stability of the material.

Moisture film cohesion, which is important, especially in the fine sand fraction and the material passing the No. 200 sieve, is the resistance of particles to being pulled apart, and is due to the surface tension of the moisture film surrounding each particle. The thinner the moisture film the greater the cohesion, the greater the stability, and the
greater the density. It is the variation of the thickness of the moisture films that causes the material to change volume. If the nature of the fines were such that the contacting moisture film could be held or locked in a thin cohesive film after the material is tightly compacted, the mixture would probably be stable because it would not expand and take on more water, thus softening or reducing the load-carrying capacity of the mixture.

The dense-graded mixture utilizes the most desirable characteristics of each size material in the finished product. The aggregates have high internal friction, where properly keyed and confined, to prevent their displacement under heavy loads. Because of their large voids and the nature of the area of contact, water has little effect on their stability if the base on which they are placed remains firm. As the particle sizes become smaller there is less internal friction in the material and less load support unless certain other mechanical forces are developed. As the voids become smaller and the areas of contact become greater, cohesion begins to play a very important part in the material's stability. The small voids and moisture-locked films prevent the mixture from taking on large amounts of water which would result in loss of load-carrying capacity.

The resulting mixture or gradation of the dense-graded material may be thought of as somewhat analogous to a concrete mixture, with the fines, sands, and materials passing the No. 200 sieves serving as a mortar and the minus 200 material serving as a natural or weak binding agent. It must be remembered, however, that the fines act as a binding agent only so long as their moisture film remains thin. Excessive amounts of fines or the wrong kind of fines may take on large moisture films, reducing or destroying the cohesion and actually lubricating the coarse aggregate mixture by destroying the internal friction. To insure the quality of the mortar or fines of the mixture the specifications, in addition to the gradation requirements, require the following:

"The fraction passing the No. 200 sieve shall not exceed two-thirds the fraction passing the No. 40 sieve. The fraction passing the No. 40 sieve shall have a plasticity index between zero and five, as directed by the engineer. The liquid limit shall not exceed 25, except if slag is used the liquid limit shall not exceed 35."

The requirements are added merely as a safeguard. If the proportions of fines passing the No. 200 sieve to the fraction passing the No. 40 sieve comply with specification requirements, failures to comply with the liquid limit and plasticity index will be confined to mixtures where plastic clays are used for the fraction passing the No. 200
sieve. This is not a difficult requirement but does rule out the use of plastic clays as a binding agent.

Dense-graded materials were first introduced as mechanical stabilized mixtures in the middle 1930s.

INTENDED USE OF AGGREGATE SIZES 53, 53B, 63 AND 73

Aggregate size No. 53, as specified in the Indiana State Highway Commission's 1960 standard specifications, was developed for use as dense-graded base mixtures. When properly compacted this material in place should weigh between 145 to 152 pounds per cubic foot for normal specific gravities.

Aggregate size No. 53B was developed for use as a bituminous stabilized base mixture. The gradation of 53Bs is the same as for 53s, except the amount passing the No. 200 sieve for 53Bs is limited to zero to five per cent. It is intended that bituminous material in the amounts of three to four per cent (generally) be used as a binder or stabilizing agent instead of the five to ten per cent of minus 200 material required for 53s.

Aggregate size No. 63 does not have the close gradation requirement as specified for 53s. Although a dense-graded material can be produced under this specification, the gradation limits with no requirements specified for the No. 200 sieve, do not insure a good dense, well graded mixture. This material is intended for general maintenance use where close gradation and control is not a necessary requirement.

Aggregate size No. 73, is a dense-graded surface mixture for drag or blade maintenance. This size is the same as size 53 except the top size is reduced to a maximum of one inch.

SPECIFICATIONS AND PRACTICES

It would seem then that we should have one section and one method specified for the placing and handling of these dense-graded mixtures whether used in base or surface construction. Actually our specifications list three general methods for the preparation and handling of the same materials. The methods of placing and compacting the materials are, however, in general agreement.

The three general methods referred to are detailed in Sections C10, C12, and F40 of the Standard Specifications of the State Highway Department of Indiana, 1960. The following are brief comments on each of these sections.

SECTION C10. COMPACTED AGGREGATE BASE

This specification requires size 53 materials but does not rigidly control the moisture and placement of the material. Apparently this
method should be slightly less expensive but the quality of the end product could be variable.

SECTION C12. PLANT-MIX AGGREGATE BASE

This is an ideal method of handling and insures best results. Although it is possibly slightly more expensive, it will guarantee results. There is certainly no use specifying a properly produced material and then not insuring its proper placing or incorporation in the pavement structure. If the material segregates in handling or does not contain sufficient water for compaction, the rigid material specification for production is lost and the incorporated material is an inferior product that will not perform as designed.

SECTION F40. COMPACTED AGGREGATE BASE, WIDENING AND SHOULDERS

Although this method does not require a plant mix product it offers an alternate which will insure uniformity, no segregation, and adequate moisture for compaction.

SUMMARY

Our highway engineers, aggregate producers, contractors, and others have shown a great deal of interest in these dense-graded, moisture controlled, aggregate mixtures. They should be thought of as an upgrading of aggregate construction but should not be interpreted as an equal for bituminous, portland cement, or other paving or stabilized aggregate mixtures. When properly handled and used the dense-graded aggregates will produce the best results obtainable from available deposits or quarries without the addition of cements, bitumens, tars, chemicals, or other additives.

It should always be remembered that the final product will depend on a good, uniform material, well placed without segregation, and properly compacted. The dense-graded aggregate specification will produce a good material. Optimum moisture contents will permit proper handling of the material to avoid segregation and will furnish the necessary moisture for compaction.

The successful use of these materials in special projects for both bases and shoulders was the basis for their inclusion in the 1960 specifications. Several shoulder projects included the successful use of both calcium chloride and sodium chloride as additives. In my opinion you will be well pleased with the performance of these dense-graded aggregates.