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Sand Silt Ratio as Design Criteria in Design of Bituminous Paving Mixtures

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Abstract: ***Highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the subgrade. Flexible pavements will transmit wheel load stresses to the lower layers by grain-to-grain transfer through the points of contact in the granular structure. The wheel load acting on the pavement will be distributed to a wider area, and the stress decreases with the depth. Taking advantage of these stress distribution characteristic, flexible pavements normally has many layers. Hence, the design of flexible pavement uses the concept of layered system. Pavements are a conglomeration of materials. These materials, their associated properties, and their interactions determine the properties of the resultant pavement. Thus, a good understanding of these materials, how they are characterized, and how they perform is fundamental to understanding pavement. The materials which are used in the construction of highway are of intense interest to the highway engineer. Mineral aggregates are used in combination with bitumen to prepare mixtures for a wide variety of purposes. As the aggregates normally constitute 90% or more by weight of such mixers, their properties and grading have a very significant effect on the characteristics of bituminous mixture such as stability, workability and density.Sand-Silt ratio may be considered as a simple factor to guide the field Engineer in his interpretation of the significance of his daily extraction results.***

Keywords: Dense Bituminous Concrete Pavement, Coarse Aggregate, Fine Aggregate, Sand-Silt Ratio, Filler-Bitumen Ratio, Stability-Flow Ratio

1. Introduction

Bitumen is used in bituminous paving mixture principally as a binding and water proofing ingredient. When an excessive amount of bitumen is present, it may enhance the water proofing function but it then ceases to act as a binder and tends to lubricate the aggregate mass in such a manner that stability is seriously lowered. In acting as a binder, bitumen tends to keep the aggregate particles in position as these were distributed during construction. This in one form of offering resistance to the displacement under the action of traffic. Bitumen present in the mixture allows the deformed paving layer to rebound upon removal of the load and to once again offer resistance to deformation from additional loads.

2. Aggregate Frame Work

a. Under normal conditions, bitumen is quite plastic in character and will offer flow under small load. Therefore the major share of the resistance to deformation must be borne by the aggregate frame work present in the bituminous paving mixture. The aggregate frame work has a great effect on the flexibility bituminous paving mixture. A weak aggregate frame work will deform easily under load, while rigid frame work may result in brittleness and weakness under impact loads. The aggregate frame work can be varied considerably by altering the gradation.
b. Three size ranges of materials are very commonly used and are identified as follows:
   i. Coarse Aggregate … Material retained on 240 ISS (ASTM No.8)
   ii. Fine Aggregate …Material passing on 240 ISS (ASTM No.8) and retained on ISS 8 (ASTM No. 200))
c. In most specifications, each of the separate aggregate, coarse, fine and filler is required to be well graded from coarse to fine as in the combination of these materials. The concept simply is that in a well graded aggregate each smaller size or fraction of aggregate serves to fill the voids in the next larger one with the result that a very dense aggregate combination may be secured.

3. Functions of Aggregate

The function of coarse aggregate in a bituminous concrete mixture is to give stability through the interlocking and frictional resistance of the aggregate particles. The fine aggregate component of the mixture adds to the stability through interlocking of the particles at the same time reducing the voids in the coarse aggregate. The principal function of filler in bituminous concrete mixtures to assist in rendering the surface denser so that it will be less acted upon by water and less liable to interior displacement or movement. Not only the material, classified into three ranges, but also their proportion has an important effect on the characteristics of the finished bituminous product.

4. Mix Design

The major properties to be incorporated in a bituminous paving mixture are stability, durability, flexibility and skid resistance. Generally mix design methods were established to determine which combination of aggregate and bitumen would perform satisfactorily, particularly with respect to stability and durability.

a. When a bituminous paving mixture is designed by a standard method like Marshall to satisfy the design criteria and especially when it has a continuous grading in both

coarse and fine aggregate sizes, there is generally no need of any additional criterion to be satisfied like the sand-silt ratio, filler-bitumen ratio (maximum 1.2), stability-flow ratio (minimum 120) etc., as the design criteria are well correlated with the performance of the mixture. Even an immersion compression test is specified only in cases where aggregate of low stripping resistance is used.

b. In any Mix design, the procedure followed are:
   1) Selection of aggregate to be employed in the mix.
   2) Selection of grading to be used.
   3) Determination of the proportion of each aggregate to get at a satisfactory grading.
   4) Stability and other tests on the bituminous paving mixture.
   5) Selection of aggregate combination and optimum bitumen content from the test results.
c. Before taking up, stability and other tests on the bituminous paving mixture, sand-silt ration can be used as check. If this is not satisfied, the aggregate gradation can be suitably altered, to follow the medium grading as well as the sand-silt ration made to fall within the stipulated value. So in this paper it is proposed to deal with sand-silt ratio as a design criteria in arriving at the proper aggregate blend for any dense mixture.

5. Sand-Silt Ratio

Sand is defined as an aggregate passing ISS 240 (ASTM No.8). Silt (as filler) is defined as an aggregate material passing ISS 8 (ASTM No. 200). The sand-silt ratio is the ratio by weight of sand to silt in any aggregate.

a. Too low a ratio such as three of sand to one of silt may indicate harmful qualities of clay. It also indicated that the surface area is excessive and that the amount of bitumen necessary to coat the aggregates may overfill the voids in the compacted mixture. If the ratio is controllable, it can be used to regulate flexibility, stability, impermeability, mix density and other characteristics. Many Engineers in charge of bituminous mix construction have had the mistaken idea that an increase in dust content in the mix requires a comparative increase in bitumen content. A careful explanation of the sand-silt ratio as it affects stability of the mix at various bitumen content has been exceedingly helpful in combating this idea.
b. In the reference cited[1] in the references a detailed study of the service behavior of pavements both in field and laboratory, with varying sand silt ratios had been taken up. When examining a core of a pavement in service for a period, it is observed that the density is higher in the top one third than at the bottom. Kneading compactor produces also similar specimens and hence it is considered more suitable. In the mix design, Hveem's method had been used and correlation of field and laboratory test results pertaining to density, stabilometer values, cohesiometer values had been established. It is shown that for a mix with sand-silt ratio of 5.5 to 10.1 (Table-1) performances will be adequate. This is assuming of course, that bitumen content near the recommended amount has been used and that good construction method has been used in placing the mix.
c. A comparison of Sand-Silt ratios for the various standard mixtures of American Society of testing materials, Asphalt Institute, British Standard specification, Indian Roads Congress and Shell International show that the above specified limits are generally satisfied in almost all cases.

Scientifically Designed and Laid Pavements in India

a. Recently before one Year, Two roads at Cresent Circle & Bhagvati Circle in Bhavnagar City were widened to two lane width with dense graded bituminous concrete wearing course. The design & control over laying was undertaken by the Bhavnagar Municipal Corporation, Mix design method employed were Marshall and Hubbard field. To measure the loss of cohesion resulting from the action of water on compacted bituminous mixture, Immersion-Comparison Test was employed.
b. At a binder content of 6.25 percent by weight of Aggregate, the mixture satisfied all criteria and hence this was used on the job. The pavement had been laid a year back and its performance under service condition is satisfactory.
c. Sand-Silt ratio works out to 6.5 (Table-2).
d. A dense bituminous concrete pavement 15 cm thick was laid in a stretch of about 5 Km as test purpose in road i.e. Bhavangar to Kobdi in between Bhavnagar to Somnath National highway NH8E(Six lane). This road is classified as National Highways with a carriage way width 30.00 meter (7.5 meter for each lane). This road is subjected to heavy traffic due to Alang Ship Breaking Yard, Pipavav Port & Somnath as a religious place & Mix design was based on Marshall method. The gradation of total aggregate is given in Table.2

Table 1: Relationship of Sand-Silt ratio to various characteristics of bituminous mixes assuming optimum bitumen content in each case. (Adopted from Asphalt Institute Manual on design)

Passing ASTM 8 Sieve	Passing ASTM 200 Sieve	Sand-Silt Ratio	Resistance to Distortion(Stabilometer)	Cohesion	Impermeability	Resistance to Dry heat (Flushing)	Resistance to Revelling
40	8	5:1	Fair	Excellent	Excellent	Fair	Excellent
40	7	5.7:1	Good	Excellent	Excellent	Good	Excellent
40	6	6.7:1	Excellent	Excellent	Excellent	Good	Excellent
40	5	8:1	Excellent	V. Good	V. Good	Excellent	Good
40	4	10:1	Excellent	Good	Good	Excellent	Good
40	3	13.3:1	Excellent	Poor	Fair	Excellent	Fair
40	2	20:1	Excellent	V. Poor	Poor	Excellent	Poor

Table 2: Gradation of Total Aggregates (Amounts finer than each laboratory Sieve-Weight percentage)

Sr. No	Name of Project	ISS	25 mm	20 mm	12 mm	9 mm	6 mm	480	240	120	60	40	30	15	10	Sand/silt Ratio
		ASTM	1	3/4	1/2	3/8	-	4	8	16	30	40	50	100	200	
1	B.M.C internal Roads(Cresent & Bhagwati Circle		100	94.60	80.18	67.63	53.96	49.13	45.00	41.07	32.18	25.87	19.69	12.99	6.86	6.5
2	Road Between Bhavangar to Kobdi		-	100	84.5	-	60	52.7	45.3	-	29.2	-	22.9	13.9	6.3	7.1

Sand-Silt Ratio of the aggregate blend works out to 7.1 percent.

6. Conclusion

1. Sand-Silt ratio may be considered as and additional design criterion in arriving at the proper aggregate blend. To suit Indian conditions, the limit specified between 5.5:1 to 10:1 may be suitably altered, after detailed study both in laboratory and field.
2. Further Sand-Silt ratio may be considered as a simple factor to guide the field Engineer in his interpretation of the significance of his daily extraction results. The field Engineer may not fully understand voids of some of the other more complex terminology used by asphalt technologists; but the sand-silt ratio is something he can measure himself. Hence a detailed probe into the sand-silt ratio may prove fruitful in both arriving at good mixture and also laying under easy controlled condition.

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