# CHAPTER-I

# INTRODUCTION

## 1.0 General:

Of the different factors that influence the characteristics of an asphalt paving mixture, aggregate gradation is an important one. It affects its stability, density and durability and also the asphalt requirement thereby influencing the economy of pavement construction. It has received the attention of several investigators who have given their recommendations based on their observations. Fuller and Thompson (17)*, Talbot and Richart (65), Andreasen and Anderson (2), Nijboer (52) and Goode and Lufsey (21) have proposed densest gradation curves leading to the adoption of continuous gradings. On the other hand preference has been expressed by Feret (14), Furnas (18), Kapolyi (35) and some others for gap gradations wherein the densest mixes are achieved by skipping certain component fractions within the largest and the smallest component sizes. The proponents of each type of grading have conflicting claims that have resulted in a certain amount of confusion in the minds of the engineers as to what kind of grading is satisfactory.

An important contribution to aggregate gradation has been the modification of the theoretical gradation curves to fit

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* Numbers in parentheses refer to the literature cited at the end.

the actual aggregate characteristics given by Campen (8) and Worthington (77) based on their laboratory experiments and by Hveem (30) based on the survey of gradings giving satisfactory field performance. But the solutions offered by them could not be used as general ones to cover all types of aggregates and their different characteristics. There is a need for some laboratory procedure by which the gradings can be developed using suitable parameters which represent comprehensively the characteristics of the aggregate.

Aggregate gradation specifications for asphalt mixtures have been developed by different countries and agencies based on their field experience. The aim of these specifications was to control construction in the field in order to get a desired end product, to obtain the best possible utilization of the available aggregate and to affect reduction in cost through the standardization of sizes. But a survey of the current standard specifications laid down by various agencies shows that they are many in number and differ widely in their requirements. While some specifications are so tight as to disallow any variation in their range, others are so broad as to permit variations that result in mixtures ranging from very close to open textured. The tight specifications suffer from the drawback of not being easily adoptable while the broad specifications are too general in nature and they require use of judgement and intuition by the engineer to make the selection according to his needs.

This inconsistency in the requirements of gradings can be attributed to the fact that their evaluation is not attempted on the basis of any intrinsic characteristics. They are based mostly on trial and error procedures. This justifies the need for an investigation to identify some inherent characteristics which can resolve this inconsistency.

The voids ratio of a grading was identified as a factor which might represent the combined influence of various changing factors of aggregate like its shape, size and surface texture. For a particular geometry of an aggregate of a given surface texture, the voids ratio of an aggregate blend depends on the various size fractions, their size ratios and their volumetric proportions. This factor (voids ratio) has been explored in the past by Furnas (18) and Powers (59,60) and recently by Lees (39) to explain the packing properties of aggregate particles to develop rational gradation design procedures. The idealized concepts associated with aggregate sizes, their size ratios and voids ratios have helped these investigators to understand the packing properties of aggregates but the gradation designs proposed by them require the use of generalized graphical charts and/or formulae which could not always suit the variations in the aggregate types. It is felt that instead of these so-called general solutions which do not accommodate the variations of the aggregate characteristics there should be a general procedure which can make use of the inherent characteristics of the aggregates in developing the gradings. Such a procedure would aim at achieving a desired or minimum possible voids ratio through a judicious selection of aggregate components; and the grading so achieved might be continuous or gap grading depending on the availability of aggregate materials and the desired characteristics of paving mixes formed with them.

Further, there is a need to understand the type of aggregate-structure that results from combining various size groups of aggregate particles, a factor, hitherto not considered. This would help in selecting sizes of aggregates that give the best composition so that only stable, durable and economical mixes would result.

As for the economy in construction, a judicious selection and proportioning of the locally available aggregate materials would reduce the cost of construction by effecting saving in asphalt and avoiding long haulages and crushing of aggregates. It is hoped that a rational design procedure for aggregate gradations would help in achieving economy as well as quality of paving mixes; hence the need for an investigation aiming at the development of such a method.

## 1.1 Scope and Objectives of the Investigation:

The main aim of this investigation is to develop a laboratory procedure for the design of aggregate gradings based on their intrinsic characteristics, namely, the voids ratio and the aggregate mix-structure.

To determine the voids ratios of the aggregate components and their various combinations a simple laboratory test designated as 'the dry compaction test' was used. Briefly, the procedure involves filling a cylindrical mould in three equal layers of aggregates and vibrating them to maximum packing. With the knowledge of volume, weight and specific gravity of the aggregate, the voids ratio of the packed bed could be determined.

Mix Structure Identified:

To study the effect of combining two aggregate components with changing size-ratios and volumetric proportions on the resulting voids ratio, various such combinations were taken. A relationship was established (Fig.4.7) connecting size ratios, volumetric-proportions and the minimum voids ratios. This relationship clearly indicated two broad categories of mixes based on the size-ratios of their constituent components. Binary mixes possessing size ratios less than 0.10 could be covered under a mix structure wherein the smaller particles fill the void spaces available within the outer structure of the larger particles. Such mix structure was designated as the 'filler mix structure'. Mixes possessing higher size ratios were of a different structure designated as 'the composite mix structure'. The basic difference between the two is that while in the filler structure the finer component only fills the void space of the coarse aggregate structure, in the composite structure it also dilates it. It could be easily visualized that in a composite structure both the coarse and fine aggregate particles share the strength development of the mix simultaneously while in the filler one the fine particles lie dormant and become active only when the coarse aggregate structure yields under the loads. Further, the voids ratio diagrams of these binary mixtures (Figs. 4.3 through 4.6) have shown that three stages of proportions exist under each type of aggregate structure. These are -

i. the stage abundant in fine aggregate;

ii. the balanced stage; and

iii. the stage abundant in coarse aggregate.

It was readily understood that the balanced stage represents the maximum packing of particles due to its minimum achievable voids ratio.

Blending Methods Compared:

Next, it was decided to develop gradings to possess the desired or minimum voids ratios by maintaining the composite nature of the mixes. It was found that this could be achieved by various blending procedures wherein the aggregate components are proportioned at their balanced stages considering two at a time. Two simplest methods, namely, (i) blending from coarse to fine and (ii) blending from fine to coarse were compared by developing composite continuous balanced gradings of eight and six components. A continuous grading developed from Nijboer (52) gradation chart also was included for comparison with the eight component gradings. The Marshall characteristics of paving mixes of the gradings developed from fine to coarse blending method were found to be superior to the ones from coarse to fine blending method. The eight component grading developed from fine to coarse blending method also gave slightly superior properties over the corresponding grading developed from Nijboer's curve. This part of the study helped in choosing the fine to coarse blending method as the method for designing the balanced gradings.

Equi-Voids-Ratio Grading Developed:

Three standard continuous gradings with 20 mm, 12.50 mm and 10 mm top-sizes were selected conforming to the American Society of Testing Materials (ASTM) (3) and Indian Roads Congress (IRC) (31) specifications. The gradings were designated ST1, ST2 and ST3. The voids ratios of these gradings were determined by the dry compaction test. Six gradings including skipped gradings with the same voids ratio as ST1, five as ST2 and three as ST3 were designed by the balanced design procedure and called the equi-voids-ratio (EVR) gradings. Had all the components of these gradings been proportioned at the balanced stages the voids ratio thus achieved would have been lower than the voids ratio corresponding to the standard gradings. Therefore, the proportions of the components were adjusted at the penultimate stage of blending by taking more of coarse aggregate thus raising the achieved voids ratios to the level of the standard gradings. The three groups of equi-voids-ratio gradings were compared for their Marshall properties.

Marshall Test Adopted for Comparison:

The Marshall test was selected for comparing the