Gradation 5(G5)-A New Approach for Asphalt Mix Design

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Abstract
The hot mix asphalt industry is constantly seeking new approaches to produce cost effective and high performance asphalt concrete. There have been many mixture design methods over the previous century that have furthered the understanding of asphalt mix. These mix design methods rely on the experience of seasoned mix designers and their understanding of local materials. Increased understanding of the effect of aggregate gradation in asphalt mix is necessary to advance the design, construction, and performance of these mixes. It is herein proposed to introduce a gap graded aggregate combination to obtain a dense graded mix. The present study reports about obtaining such a mix by adopting the proposed approach and performance of the same with the selected aggregates.
Keywords**— Optimization, void index, gap-graded**

INTRODUCTION

Apart from the binder related considerations, as the aggregate component represents about 90 to 95% of the weight of the mix, predicting and controlling the packing properties of the aggregates is thus of prime importance. Optimum particle packing implies minimizing porosity and thereby reducing the amount of binder content to fill the voids between aggregate particles. From the beginning of asphalt mix design it was desired to understand the interaction of aggregates and the voids created during their compaction and the guidance is lacking in understanding the interaction of aggregates in the mix.

Objective of the study

Main objective of this study is to evaluate the relevancy of the proposed approach with the selected aggregates and to achieve most dense packing possible in order to reduce binder content by introducing gap graded aggregate combinations. And also to evaluate the performance of such mixes when combined with the modified bitumen

Methodology

When studying the porosity of mixes composed of two aggregates with differing yet one dimensional individual sizes, there are two types of interparticle interaction on the void index, namely

‘Wall effect’

‘Interference effect’ also called as loosening effect

Wall effect is described as the interaction between particles and any type of wall (pipe, formwork, etc) placed in contact with the granular mass.

The interference effect can be illustrated by focusing on the effect induced by introducing a few fine particles into an infinite volume of coarse particles. As the amount of fines increases, at some point the coarse particles are forced apart by means of loosening, thus modifying their spatial configuration, interference occurs.

Due to these effects there will be loss of contact between the coarse particles and in turn creates more voids in the mix. (Fig 1)

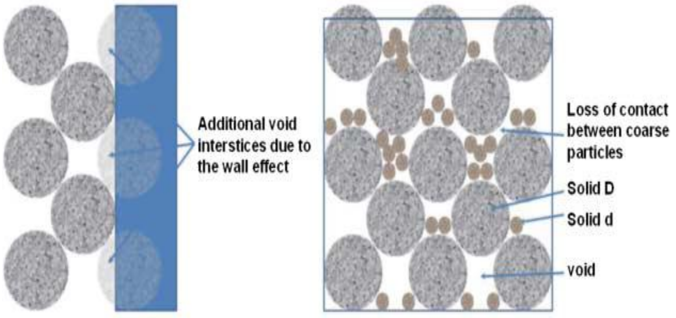

Fig: 1 schematic representation of wall and interference

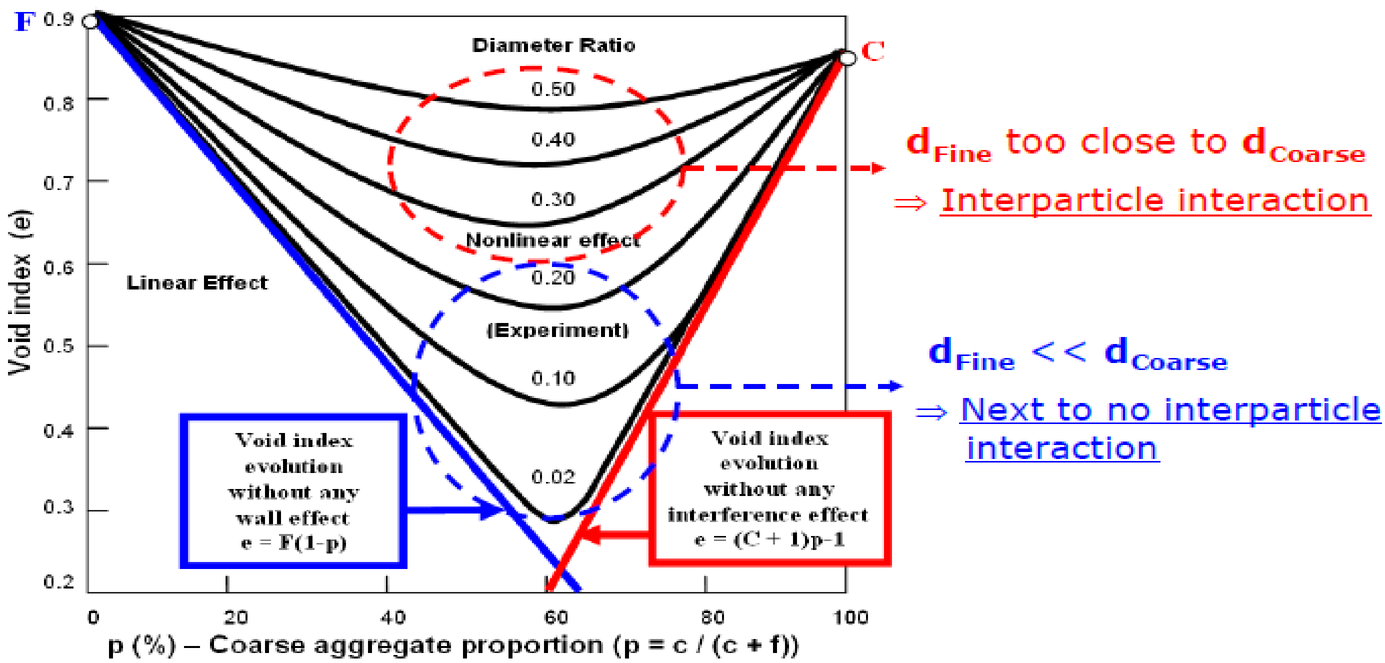

Fig: 2 effect of diameter ratio (d_{FINE}/d_{COARSE}) on void index (*e*)

Effect of diameter ratio on void index

If the average particle dimension of fines (d_{FINE}) is small enough compared with the one of coarse particles (d_{COARSE}) (e.g. when the d_{FINE} / d_{COARSE} ratio is lower than 0.2), the wall effect is linear and satisfies the superposition principle.

Furnas (1928), Powers (1968) and Oger (1987) showed the dependence of the shift in void index(*e*) versus coarse aggregate portion in a binary combination on the ratio of average particle sizes.

Figure 2 reveals that as the ratio of average fine aggregate dimension-to-average coarse aggregate dimension rises, interaction effects become more significant as well. In order to reduce interactions of intermediate particles with the coarsest ones in the mix, it is crucial to limit both their size and amount and fill air voids by a higher fraction of fines instead.

Laboratory investigation

In the present study it was desired to find void

Marshall Hammer (Impact loading) of weight 4.5 kg was used to compact the aggregate mix with 75 blows.

On the basis of effect of diameter ratio on void index, a single gap graded aggregate combination with diameter ratio less than 0.2 has been selected for the study.

To make the simplest possible selection of an optimal granular combination with a maximized coarse fraction, it is herein proposed to separate the granular skeleton into four phases: fine, intermediate, coarse and filler particles as detailed below.

Coarser fraction 9.5/19 mm

SIEVE SIZE IN mm	% PASSING
19	81.22
13.2	25.49
9.5	2.57

Average diameter found was d_{50}=15.75

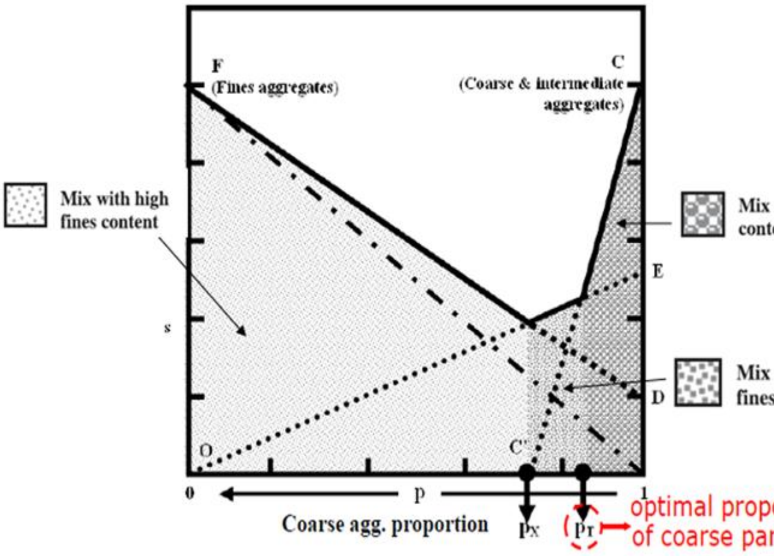

Fig: 3 Evolution of void index (*e*) according to the coarse agg. proportion (*p*) according to Baron's approach(1982)

Intermediate fraction 0/6.3 mm

SIEVE SIZE IN mm	% PASSING
6.3	98.1
4.75	85.26
2.36	48.06
1.18	34.84
0.6	28.12
0.3	19.08
0.15	13.18
0.075	10.6

Average diameter found was d_{50}=2.48

Diameter ratio

$$\frac{d_{inter}}{d_{coarse}} = 0.157 < 0.2$$

Finer fraction 0/1.18 mm

SIEVE SIZE IN mm	% PASSING
1.18	99.88
0.6	82.46
0.3	47.47
0.15	26.16
0.075	7.94

Average diameter found was d_{50}=0.3216

Diameter ratio

$$\frac{d_{fine}}{d_{inter}} = 0.129 < 0.2$$

Filler <75µ

Filler material was the stone dust from the same quarry and passing through the 75µ.Here no aggregates of size between 6.3 to 9.5 mm (i. e 6.3/9.5 mm gap)

The experimental method was performed in three steps.

Step 1

In the first step of the experiment intermediate aggregate and coarse aggregate were blended together and compaction was done at various percent's of coarse aggregate (i.e. determination of the corresponding optimal ratio according to Baron's approach illustrated in Figure 3)
In this step the obtained optimum percent of coarse and fine particles were 92.7 and 7.3 respectively.

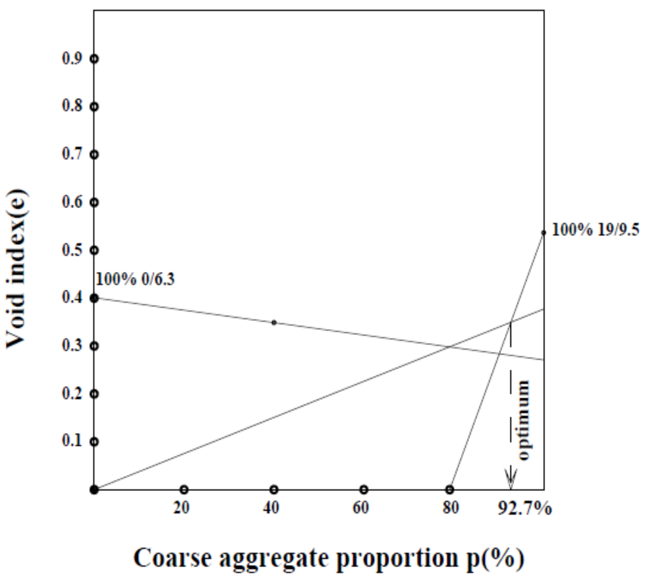

Fig 4 Optmization of coarse and intermediate fraction

Step 2

To the previously obtained concentrations of 19/9.5 & 0/6.3 in first step, 0/1.8 fraction was added and again the same procedure was repeated (same methodology, Figure 3) The obtained percent of coarse (19/9.5 & 0/6.3) and fine 0/1.8 were 90 and 10 respectively.

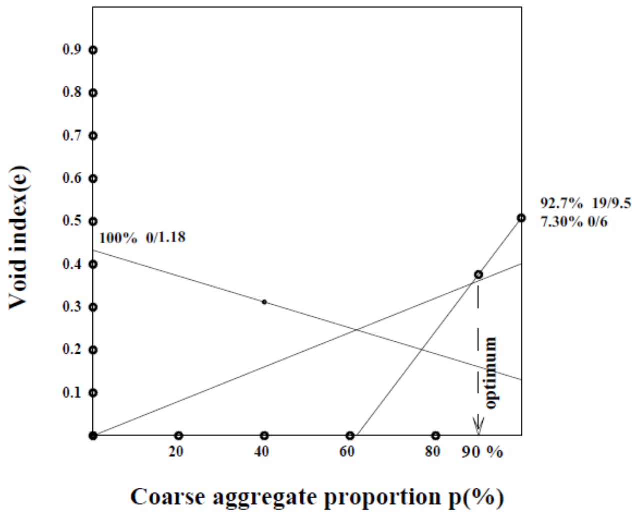

Fig 5 Optmization of coarse intermediate and fine fraction

Step 3

In the final stage the filler material is mixed with the previously optimized aggregates blend (same methodology, Figure 3).

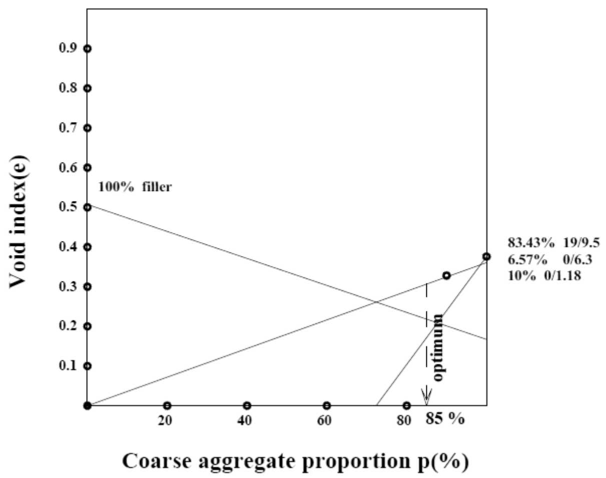

Fig 6 Optmization of coarse intermediate fine and fiiler fraction

Finally the optimum proportions obtained were as follows

1. 9.5/19 content: (85%×83.43) =70.91%
2. 0/6.3 content: (85%×6.57) =5.58%
3. 0/1.18 content: (85%×10) =8.50%
4. Filler content (100-84.99) =15.01%

Fig: 7 picture showing the mould used for compacting the aggregates

Materials

Aggregates

In the present work, crushed stone aggregates (coarse, fine and filler) from a quarry located near thavarekere, Bengaluru were used and the characteristics are mentioned in table 2.

Property	Obtained value %	Permissible Limit(as per table 500-14 of MoRT&H)
Impact value	14.15	27
Crushing value	18.32	24
Abrasion value	32.96	35
Specific Gravity	2.57	2.5-3.0
Water absorption	0.3	2.0
Combined index	19.52	30

Table 1 Test Results of Aggregates

Bitumen

In the present work, Crumb Rubber Modified Bitumen (CRMB-55) which was procured from Tinna Rubber and Infrastructure Pvt. Limited, a modified bitumen plant, refinery road, rajapur, Panipat was used throughout the study and the characteristics are mentioned in table 2.

Sl. No.	Characteristics	Required	Obtained	IS Code Ref.
i	Penetration at 25 Deg. C,0.1 mm, 100g, 5s	<60	32	1203
ii	Softening Point, (R&B),Deg. C Min.	55	58	1205
iii	Flash Point, COC, Deg. C.Min.	220	288	1209
iv	Viscosity at 150 Deg. C,Poise	2-4	3.2	1206 (Part 11)

Table 2 Test Results of bitumen

Results

The optimum binder content obtained was 3.95%.

The stability values reached up to 1200 kg with somewhat lower binder content and it shows the maximized coarse aggregate proportion would help in obtaining more stability values for the mix.

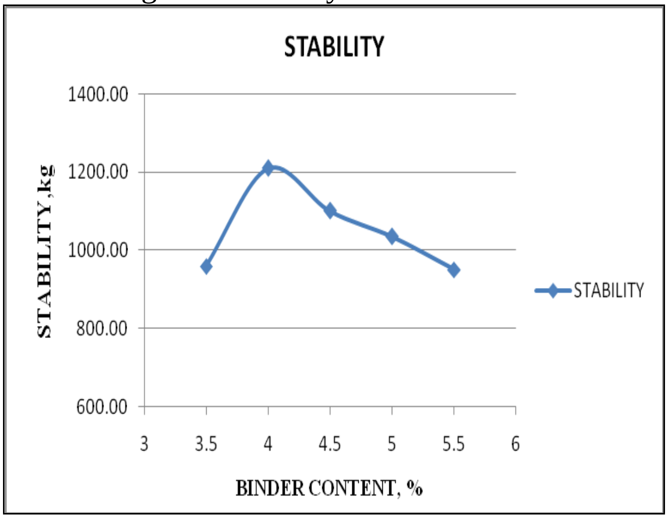

Fig: 8 Stability v/s bitumen content

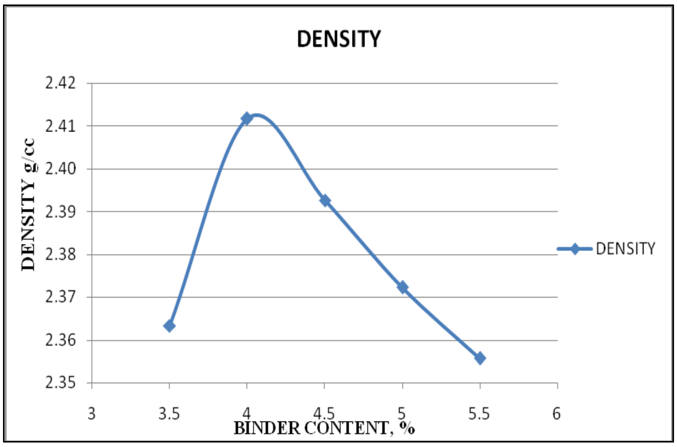

Fig: 9 Density v/s bitumen content

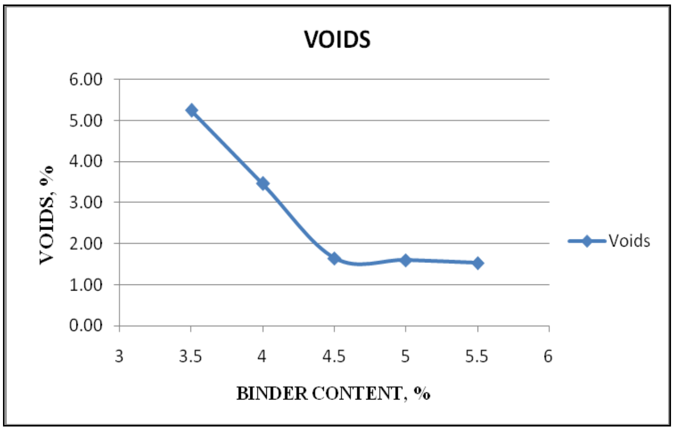

Fig: 10 Air voids v/s bitumen content

Fig: 11 picture showing the prepared specimens

Fig: 12 Specimen being tested in Marshall Apparatus

Conclusion

Effective particle packing seeks to select proper sizes and proportions of small particle shaped materials to fill larger voids. These small particles in turn contain smaller voids that are filled with smaller particles, and so on. Such well-interlocked gap-graded mixtures have greater friction angles than the continuously dense-graded mixtures.

Even with a somewhat low value of binder content the proposed approach allow one to obtain encouraging result.

The laboratory assessments of the optimal single-gap graded dense mix were found to be encouraging. This particular combination of gap graded mix first of all enables low binder content to be achieved, and thus makes it economical.

Acknowledgement

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