Effect of Fillers on Bituminous Paving Mixes

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***Abstract*: One of the costliest and highest types of flexible pavement layer used is bituminous concrete or asphalt concrete. Construction of highways involves huge outlay of investment. To satisfy the design requirements of stability and durability the bituminous mixes should be designed effectively. The ingredients of the mixture include dense grading of coarse aggregates, fine aggregates, fillers and bitumen binder. In this study an attempt was made to find the effect of filler on the behaviour of bituminous mixes. Filler plays an important role in the filling of voids and hence change the physical and chemical properties. An important role is played by the fillers that pass through 0.075mm sieve. Conventionally stone dust is used as filler. An attempt has been made in this investigation to assess the influence of non-conventional and cheap fillers such as brick dust and steel slag in bitumen paving mixes. The properties of bituminous mixes containing these fillers were studied and compared with each other. Various tests were also conducted on aggregates and bitumen and the results were compared with the specifications. The study revealed that use of brick dust and slag as fillers with 2%, 3.5%, 5%, and6.5% was used to improve the physical characteristics of bitumen mixes. Marshall Stability and flow value of bitumen mix also improved.**

***Keywords*: Steel Salg, Brick Dust, Marshall Stability Test.**

I. INTRODUCTION

A. General

Highway construction activities have taken a big leap in the developing countries since last decade. As well as the traffic demand is growing at a rapid rate along with the increase in the axle loads, it is necessary to improve the highway paving materials.

The main objective of highway authorities is to provide safe, smooth, imperishable and economical pavements that are capable of carrying the anticipated loads. To achieve this objective, many specialists, engineers and researches are anxious and dedicated to select the paving material that can curtail pavement distress and upgrade the performance of asphalt pavements. Fillers has one of the constituent in an asphalt mixture, especially its binding and interlocking effects.

Basically, highway pavements can be categorized into two groups, flexible and rigid. Flexible pavements are those which are surfaced with bituminous (or asphalt) materials. These can be either in the form of pavement surface treatments (such as bituminous surface treatment (BST) generally found on lower volume roads) or, HMA surface courses (generally used on higher volume roads such as the Interstate highway networks). These types of pavements are called “flexible” since the total pavement structure “bends” or “deflects” due to traffic loads. A flexible pavement structure is generally composed of several layers of materials which can accommodate this “flexing”. On the other hand, rigid pavements are composed of a PCC surface course. Such pavements are substantially “stiffer” than flexible pavements due to the high modulus of elasticity of the PCC material. Flexible pavements being economical are extensively used as far as possible.

In recent years, many countries have experienced an increase in truck tire pressures, axle loads and traffic volumes. Tire pressure and axle load increases mean that the bituminous layer near the pavement surface is exposed to higher stress. High density of traffic in terms of commercial vehicles, overloading of trucks and significant variations in daily and seasonal temperature of pavements have been responsible for development of distress symptoms like ravelling, undulations, rutting, cracking, bleeding, shoving and potholing of bituminous surfaces. Sustainable material combinations and modified bituminous binders have been found to result longer life for wearing courses depending upon the percentage of fillers used.

B. Introduction on Base layer:

Base course is a layer of material of specified thickness constructed on the sub-base of a pavement to serve the functions, such as distributing loads, providing drainage, or minimizing frost action. This is main pavement which receives and resists the load from the vehicles as well as impact. Pavement “base” shall be granular material specified in terms of “traffic category”. Base material shall be manufactured from hard, durable stone or recycled building materials free of clay lumps, organic matters and other deleterious substances.

C. Types of Pavements:

Pavements can be divided into 3 major types:

- Flexible pavements (upper layers of asphalt).
- Rigid pavements (upper layers of concrete).
- Composite pavements.

The following types of construction have been used inflexible pavement:

- Conventional layered flexible pavement,
- Full depth asphalt pavement, and
- Contained rock asphalt mat (CRAM).

D. Typical layers of flexible pavement:

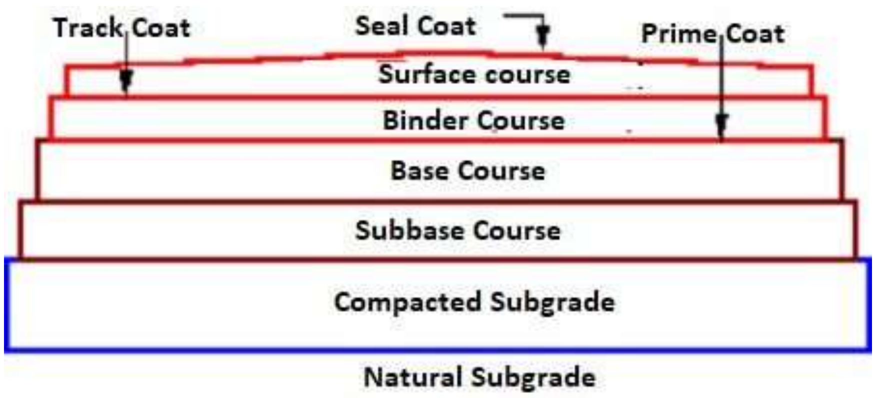


Fig 0.1: Typical layers of flexible pavement

Typical layers of flexible pavement of conventional flexible pavement includes seal coat, surface course, tack coat, binder course , prime coat, base course, sub base course , compacted sub grade and natural sub grade

E. Types of mix: i. Hot mix asphalt concrete, ii. Warm mix asphalt concrete, iii. Cold mix asphalt concrete, iv Cut-back asphalt concrete, and v. Mastic asphalt concrete or sheet asphalt

F. Flexible Pavement Layers: i. Sub grade, ii. Sub base course, iii. Base course and iv. Surface course

If any one of the above mentioned layers becomes unstable or weak then it will result in failure of flexible pavement. Therefore it is very important to design and construct each layer with outmost care.

II. LITERATURE REVIEW

A. Evolution of mix design concepts

During 1900's, the bituminous paving technique was first used on rural roads – so as to handle rapid removal of fine particles in the form of dust, from Water Bound Macadam, which was caused due to rapid growth of automobiles [Roberts et al. 2002]. At initial stage, heavy oils were used as dust palliative. An eye estimation process, called pat test, was used to estimate the requisite quantity of the heavy oil in the mix. By this process, the mixture was patted like a pancake shape, and pressed against a brown paper. Depending on the extent of stain it made on the paper, the appropriateness of the quantity was adjudged [Roberts et al. 2002]. The first formal mix design method was Hubbard field method, which was originally developed on sand-bitumen mixture. Mixes with large aggregates could not be handled in Hubbard field method. This was one of the limitations of this procedure. Fransis Hveem, a project engineer of California Department of Highways, developed the Hveem stabilometer (1927). Hveem did not have any prior experience on judging the just right mix from its colour, and therefore decided to measure various mix parameters to find out the optimum quantity of bitumen .Hveem used the surface area calculation concept (which already existed at that time for cement concrete mix design), to estimate the quantity of bitumen required [Hveem 1942]. Moisture susceptibility and sand equivalent tests were added to the Hveem test in 1946 and 1954 respectively [Roberts et al. 2002]. Bruce Marshall developed the Marshall testing machine just before the World War-II. It was adopted in the US Army Corpus of Engineers in 1930's and subsequently modified in 1940's and 50's.

B. Role of mix volumetric parameters

Bitumen holds the aggregates in position, and the load is taken by the aggregate mass through the contact points. If all the voids are filled by bitumen, then the load is rather transmitted by hydrostatic pressure through bitumen, and strength of the mix therefore reduces. That is why stability of the mix starts reducing when bitumen content is increased further beyond certain value During summer season, bitumen melts and occupies the void space between the aggregates and if void is unavailable, bleeding is caused. Thus, some amount of void is necessary to provide by design in a bituminous mix, even after the final stage of compaction. However excess void will make the mix weak from its elastic modulus and fatigue life considerations. The chances of oxidative hardening of bitumen are more, where, the mix has more voids. Evaluation and selection of aggregate gradation to achieve minimum VMA is the most difficult and time-consuming step in the mix design process .VMA specification has always been a big issue in mix design specifications. The recommendation of minimum VMA is sometimes questioned by the researchers, and is said not to be equitable across different gradations. It is seen that the bitumen film thickness, rather than the VMA, may be related to durability of the mix.

C. Various mix design approaches

There is no unified approach towards bituminous mix design, rather there are a number of approaches, and each has some merits are demerits. Table-1 summarizes [RILEM 17 1998] some of the important bituminous mix design approaches. **Clifford Richardson** was probably the first to describe the importance of filler. He believed that particles smaller than 0.05 mm were the most valuable particles, and suggested that good filler should contain at least **60** percent by weight particles smaller than this size. He also proposed the dual function of filler as: **(a.)** Rendering the mixes higher density, and **(b.)** stiffen the asphalt cement. His view was shared by Spaulding and others. Satisfactory fillers recommended by Richardson included Portland cement, ground limestone, ground shale and ground clay.

Tillson (1990):

In his book, "Street Pavements and Paving Materials" in brought up the object of the powdered mineral matter as to fill the voids in the sand so as to make the total voids as small as possible and thus the exact quantity to be used in an bitumen wearing surface mixture should be determined by the gradation of the sand.

Richardson (1913) :

Extended the function of filler to include making the bitumen cement less susceptible to changes in consistency caused by heat. Filler was defined as a part of the mineral filler with at least 75 percent passing # 200 sieve and at least 66 percent remaining suspended in water for 15 seconds. Acceptable fillers were extended to include ground trap rock, marl and volcanic ash.

Richardson(1915)

He is presented "The Theory of the Perfect Sheet Bitumen Surface", in which he stressed the importance of fine particle size and surface area of the filler saying, We now understand the fact that an extended surface area in addition to providing for the use of a. larger amount of bitumen exercises a still more important function, due to the greater surface energy developed by the larger surface area of a fine mixture over that of a coarse one and that, aside from the greater surface presented by a fine sand as compared to a -coarse one,

The presence of highly dispersed colloids with their extensive surface is necessary for the production of the most satisfactory surface.

This concept was shared later by many others with regard to the function of the filler.

Spielmann And Hughes agreed with Richardson's conception that the filler forms a colloidal suspension in bitumen and together fills the voids in the aggregate. In addition, they specified that the immediate effect of the admixture of filler to bitumen was to increase its adhesive powers, and raise its softening point and its general stability.

Warden et al. (1952): Fly ash was a suitable filler material in terms of mixing, placing and composition, stability, resistance to water damage, and flexibility.

III. EXPERIMENTAL STUDY

A. Materials Used :

- Aggregates
- Coarse aggregates
- Fine aggregates
- Bitumen
- Fillers
- Steel slag
- Brick dust

1. Aggregates:

Stone aggregates are the major portion of the pavement structure and they from the prime materials used in the construction of the different pavement layers. Aggregates used in the different pavement layers have to bear different magnitudes of stresses due to the wheel loads. The aggregates of the pavement surface course have to resist the wear due to the abrasion action of traffic and deterioration due to weathering and highest magnitude of wheel load stresses.

The stone aggregates are used in the construction of various pavement layers such as bituminous pavement layer of flexible pavements and cement concrete mixes used for cement concrete pavement and also other drainage works most of the road aggregates are prepared by crushing the natural rock. Gravel aggregates are small rounded stones of different sizes which are generally obtained as such from some river beds. The aggregates are specified based on their grain size, shape, texture and its gradation. The crushed aggregates of different size are separated by sieving through square sieves of successively decreasing sizes.

The aggregates are classified in to two types:

- Coarse aggregates
- Fine aggregates
- Coarse aggregate: Aggregates passing through 13mm sieve and retained from 2.36mm sieve is used in this entire project.
- Fine aggregate: Aggregates passing through 2.36mm sieve and retained from 0.075 mm sieve is used in this entire project.

Fig 0.1: Aggregates

2. Desirable properties of aggregates:

- Resistance to impact or toughness.
- Resistance to abrasion or hardness.
- Resistance to crushing strength.
- Good shape factors to avoid too flaky and elongated particle of coarse aggregate.

3. Bitumen:

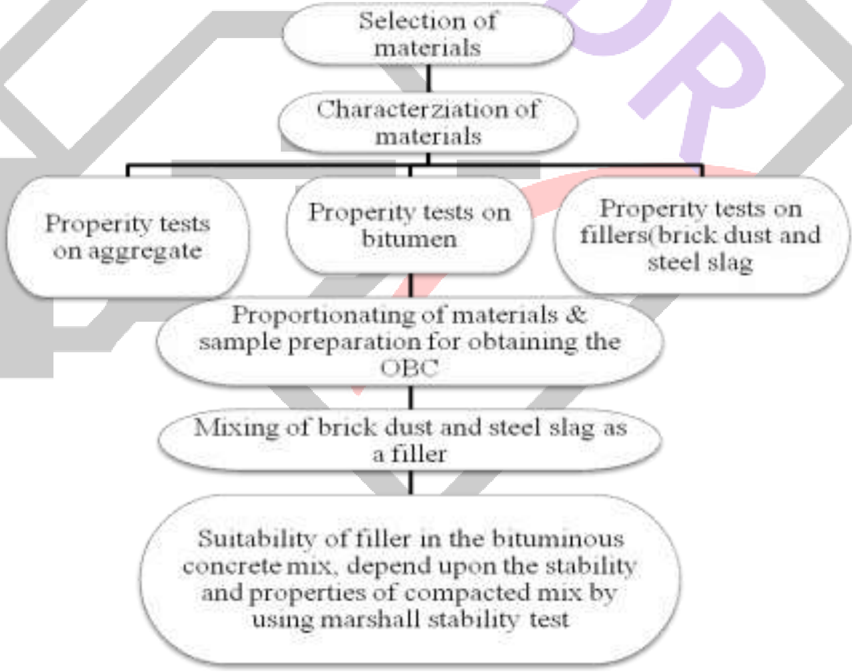
Bituminous binders used in pavement construction works are bitumen and tar. Bitumen is a petroleum product obtained by the distillation of petroleum crude. Coal tar is produced from coal as a by product of coke; both bitumen and tar have similar appearance as both are black in colour. Though both these binders were used for pavement works, they have widely different characteristics. Tar is no longer used for paving applications because of its undesirable characteristics including high temperature susceptibility ad harmful effects of its fumes during heating.

Bitumen is hydrocarbon material of either natural or pyrogeneous origin found in gaseous, liquid, semisolid form and is completely soluble in carbon disulphide and in carbon tetra chloride, bitumen is a complex organic material and occurs either naturally or maybe obtained artificially during the distillation of petroleum. Bituminous materials are very commonly used in highway construction because of their binding and water proofing properties. For the construction of bituminous pavement, the paving grade bitumen is heated to temperatures in the range 0f 130 to 175c or even higher, depending upon the type and grade of bitumen selected and the type of the construction work. Mixing of the bitumen with the aggregates is done in a hot mix plant to obtain “hot bituminous mix”.

Fig 0.2 Bitumen binder

B. Detailed Methodology :

The following methodology is under taken and various tests were conducted for both steel slag and brick dust.



Tests on Aggregate:

Tests which are generally carried out for judging the desirable properties and stability of stone aggregate are listed below:

- Sieve Analysis
- Aggregate impact test
- Los angles abrasion test
- Aggregate crushing test
- Flakiness and elongation index
- Specific gravity and water absorption test

C. Elongation index:

The sample of aggregate to be tested is sieved through a set of sieves and separated into specified size ranges. The longest side of aggregate particles from each of the size range is then individually passed through the appropriate gauge of the length gauge; the gauge length would be 1.8 times the mean size of the aggregate. The portion of the elongated aggregate having length greater than the specified gauge from each size range is weighed. The total weight of the elongated stones is expressed as a percentage of the total weight of the sample taken to obtain the elongation index.

Fig 0.3 : Elognation Index Set Up

Test results of aggregates:

Table 0.1: Test results of aggregate:

S.NO	DESCRIPTION OF TEST	TEST METHOD	TEST RESULT	MORTH SPECIFICATION LIMIT
1	ABRASION VALUE	IS:2386 PART4	24.4%	MAX40%
2	IMPACT VALUE	IS:2386 PART4	13.21%	MAX24%
3	CRUSHING VALUE	IS:2386 PART3	16.31%	MAX30%
4	SPECIFIC GRAVITY OF COARSE AGGREGATE	IS:2386 PART4	2.65	2.5-3.5
5	SPECIFIC GRAVITY OF FINE AGGREGATE	IS:2386 PART4	2.50	2.5-3.0
6	WATER ABSORPTION	IS:2386 PART3	0.6%	MAX2%
7	FLAKINESS INDEX	IS: 2386 PART1	19.5%	Max30%
8	ELONGATION INDEX	IS: 2386 PART1	13.2%	Max15%

1. Tests on Bitumen:

- Penetration test
- Flash and fire point
- Ductility test
- Flash and fire point
- Specific gravity

2. Grading of bitumen:

In India until recently bitumen binder for use in pavement construction was classified in to various penetration grade such as 80/100, 60/70, 30/40 etc. based on the penetration of test values determined at 25^0 c, now more rational method of grading paving bitumen known as "viscosity grading" has been adopted by the bureau of Indian standards for grading of bitumen in India, based on absolute viscosity values determined at 135^0C. Generally pavement service temperature is considered to be around 6^0C and the laying temperature of hot bituminous mixes to be about 135^0C.

Table 0.2 : Viscosity grading of bitumen and consistency properties (as per section 500):

S.NO	VISCOCITY GRADE	RANGE OF PENETRATION VALUE AT 25^0C
1	VG 10	80-100
2	VG 20	60-80
3	VG 30	50-70
4	VG 40	40-60

Table 0.3 : Results of bitumen:

S.NO	DESCRIPTION OF TEST	TEST RESULT	SPECIFIED LIMIT	TEST METHOD
1	Penetration value	65	65-70	IS:1203
2	Ductility	78	Not less than 75	IS:1208
3	Specific gravity	1.03	0.99 min	IS:1202
4	Flash point	240	Min 220	IS:1209
5	Fire point	255	Min 220	IS:1209
6	Softening point	48.65	40^0c-55^0c	IS:1205
7	Viscosity	500	Min 300CST	IS:1206

D. Tests on Fillers:

1. Specific gravity and water absorption:

Rinse the inside of neck of pycnometer with water and add sufficient water to bring the water level in the pycnometer to its calibrated capacity. Adjust its temperature to 73.4 + 3.1 F, if necessary by immersion in circulating water. With a rolled up paper towel, dry the inside neck of pycnometer just above calibration level. Determine and record this mass of the pycnometer, sample, and water to the nearest 0.1 gram. Remove the fine aggregate from the pycnometer and dry to constant mass at a temperature of 230 + F. (Constant mass shall be determined as follows: Dry the sample for a minimum of 1 weighing unit the weight does not change more than 0.1 gm at drying intervals of a minimum of 30 minutes.) Cool in a room at a temperature for 1.0 + 0.5 hours. Determine and record the mass to the nearest 0.1 gm.

Table 0.4 : Test results of fillers:

S.NO	FILLER	SPECIFIC GRAVITY	WATER ABSORPTION
1	Stone dust	2.6	1.43
2	Brick dust	2.15	1.23
3	Steel slag	2.7	1.52

IV. MARSHALL MIX DESIGN FOR BITUMINOUS CONCRETE

A. General:

The bituminous mixes laid in the lower layers of flexible pavements such as the base course are subjected to lower levels of stresses due to the traffic loads then those laid in the surfacing course. Further the lower pavements layers are subjected to lesser variations in temperature and moisture due to climatic factors and no wear and tear due to traffic movements .Therefore the bituminous mixes used in these layers may be designed considering lower requirements of stability and durability.

On important highways carrying heavy traffic loads, the flexible pavements are provided with thick bituminous layers using dense graded bituminous mixes : in such cases a dense bituminous macadam(DBM) "binder course" and bituminous concrete (BC) surface coarse may be laid over a well prepared base course and drainage layer , the stability and other requirements of both the DBM and BC layers may be almost the same. For Further details, refer chapter, "highway construction".

B. Constituents of Bitumen Mix and Their characteristics:

The constituents of a dense graded bituminous mix to be used as a surface course o a flexible pavement are:

- Coarse aggregates
- Fine aggregates
- Filler
- Bituminous binder

The gradation of the selected coarse aggregates should be such that the combined aggregates can fulfil the specified or desired gradation of the mixed aggregates. Selection of maximum size of coarse aggregate in the mix should be based on the compacted thickness the layer in which mix to be laid. Fine aggregates may be either manufactured or nature sand or mix of both .The filler material consists of finely powered mineral material (85 to 100 percent passing 0.075mm sieve) such as hydrated lime, Portland cement or rock dust or mix of these, based on requirements. Appropriate type and grade of bituminous binder is selected depending on the climatic conditions, with particular reference to the actual temperature range at the site.

Fig 0.3: Fine aggregate sieve & Coarse aggregate sieves

Aggregate mix used; the type, grade and percentage of bituminous binder in the mix also contributes towards the stability of the mix. The flexibility of the compacted bituminous mix depends mainly on the binder content and the filler-binder system in the mix.

C. Desirable properties of bituminous mix for pavement surface course:

The important requirements of the well designed bituminous mixes fort use in flexible pavements layers are given below:

(a) Adequate stability of the mix to withstand fatigue effects and deformation due to the repeated application of wheel loads; this may be achieved by selecting suitable type and gradation of aggregates, appropriate binder and its proportion.

(b) Adequate flexibility of the mix to withstand fatigue effects and developments of cracks during service life of the pavements; to be achieved by selection of proper mix if aggregate and binder.

(c) Adequate resistance to permanent deformation such as rutting due to the movement of heavy wheel loads during hot weather; this may be achieved by selection of good quality of aggregate, ensuring its appropriate gradation and densification of the mix during compaction.

(d) Posses adequate resistance to lower temperature cracking under traffic movements; this may be achieved by selection of suitable type and grade of bituminous binder.

D. Requirements of design mix:
The bituminous mix is designed in the laboratory considering the following requirements:
(a) The stability of the mix corresponding to the design binder content to be more than minimum specified value.
(b) Flexibility or deformation at failure to be within the specified range.
(c) Durability of the mix under stagnant water to be assessed by water sensitivity t

Table 0.1 : Requirements of bituminous concrete
(AS PER MORTH: CLAUSE 507.3.1):

Minimum stability (KN at 60c)	9.0
Flow(mm)	2-4
Percent of air voids	3-6
Volume of mineral aggregate(%)	12-15
Voids filled with bitumen (%)	65-75

E. Bitumen concrete mix design:
Marshall Method of mix design has been adopted in this project. Accordingly aggregates /with the grading 2 of **MORTH** and bitumen 60/70 having properties as described in the preceding Paragraphs have been used.
The objective of bituminous paving mix design is to develop an economical blend of aggregates and Bitumen. In the developing of this blend the designer needs to consider both the first cost and the life cycle cost of the project. Considering only the first cost may result in a higher life cycle cost.
F. The following steps may be followed for design of a bituminous mix:
1. Selection of aggregate:
Aggregates which posses sufficient strength ,hardness ,toughness soundness and polishes stone Value as chosen ,keeping in view the availability .crushed aggregate and sands produce higher stability of the mix when compared with gravel and rounded sands.

Fig 0.4: Selection of aggregate

2. Selection of aggregate grading:
The properties of a bituminous mix including the density and stability are very much dependent on the aggregates and their grain size distribution .most of the engineering organization have specified the use of dense grade mixes and not open graded mixes . as higher maximum size of aggregates gives higher stability usually larger size that can be adopted depends on the compacted thickness of pavement layer provide all over other factors are fulfilled .maximum aggregate size of 25 to 50 mm are used in bituminous mixes for base course and 12.5 to 18.7 mm size are used for surfaces course .generally the maximum size of aggregate varies from one third to two third of layers thickness. The gradation of final mix after blending of aggregates and filler should be within the specified range as per the specifications of either the Indian roads congress (IRC) or the ministry of road transportation and highways (MORTH), government of India**.**

Table 0.2: Aggregate grading (AS PER SECTION 500, TABLE 500-9):

Grading	2
Nominal aggregate size	13.2mm
Layer thickness	30-40mm
I.S sieve	Cumulative percent by weight of total aggregate passing
19	100
13.2	90-100
9.5	70-88
4.75	53-71
2.36	42-58
1.18	34-48
0.6	26-38
0.3	18-28
0.15	12-20
0.075	4-10
Bitumen content by mass of total mix	5.0-7.0
Bitumen Grade (penetration)	60/70
Percentage of filler in total mix	2.0-8.0

3. Proportioning of aggregate:

The layer and the availability of aggregates then the available aggregates are proportioned by one of the method such as:

1. Trial and error Method
2. Graphical method
3. Analytical Method

Generally it is attempted to obtain midpoint of the difference ranges are specified for the respective sizes vide MORTH specification. Two of the graphical methods of proportioning, viz: triangular chart method has been explained in chapter 9 soil stabilized roads the triangular chart method is suitable for proportioning three different aggregates. However rotch futch graphical method of proportioning is found to be suitable when any number of coarse and fine aggregates to be mixed to obtain the desired gradation for design of bituminous mixes.

Tabl 0.3: Calculation of quantity of aggregates for nominal mix:

Sieve size	**% Passing**		**% Retained adopted**	**Material**	**Amount of aggregate taken in the binder content in grams**				
	Range	**Mid-range**			1200	1200	1200	1200	1200
19	100	100	0	**Coarse aggregate**	0	0	0	0	0
13.2	90-100	89.5	10.5		120	119	119	118	117
9.5	70-88	79	10.5		120	119	119	118	117
4.75	53-71	62	17		194	193	193	192	191
2.36	42-58	50	12		137	136	136	135	133
1.18	34-48	41	9	**Fine aggregate**	103	102	101	100	100
600	26-38	32	9		102	101	100	100	100
300	18-28	23	9		102	102	100	100	100
150	12-20	16	7		80	80	80	79	78
75	4-10	7	9		102	102	100	100	100
Pan			7	**Filler**	80	80	80	80	80
Bitumen	5-7				5%	5.5%	6%	6.5%	7%
Bitumen in grams					60	66	72	78	84

Total Ingredients		1 126 0	1266	1272	127 8	128 4

V.RESULTS and DISCUSSIONS

Table 0.1 Marshall Properties (Nominal mix)

% Bitumen	Density	Air Voids	VMA	VFB	Stability	Flow
5	2.461	8.17	16.95	51.79	10.03	2.2
5.5	2.499	5.95	16.11	63.06	12.01	2.9
6	2.525	4.17	15.68	73.41	13.49	3.4
6.5	2.536	2.95	15.77	84.29	12.96	3.7
7	2.53	2.35	16.42	85.68	11.38	3.8

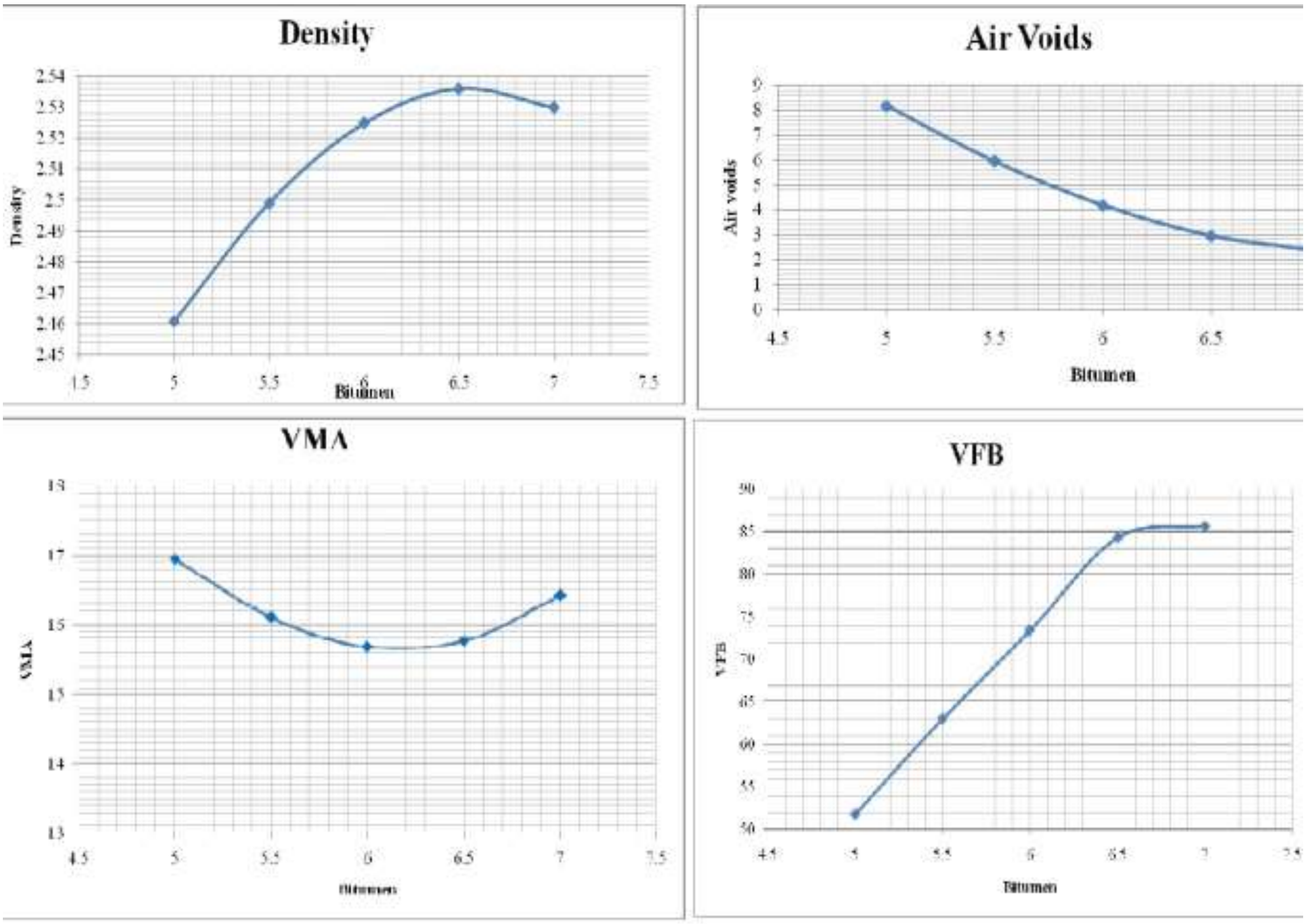


Fig 0.1 Nominal mix [(bitumen vs Density), (bitumen vs Air voids), (bitumen vs VMA) & (bitumen vs VFB)

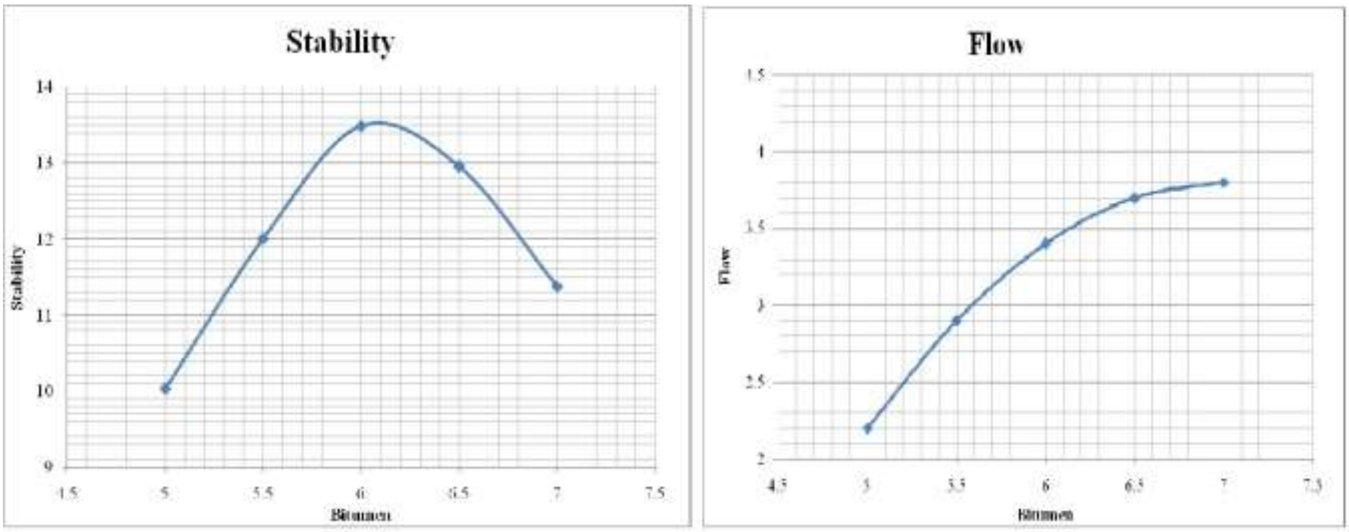


Fig 5.2 Nominal mix [(bitumen vs Stability) &(bitumen vs Flow)]

Table 0.2 Marshall Properties (Specimen With Steel Slag)

% Bitumen	Density	Air Voids	VMA	VFB	Stability	Flow
5	2.47	7.84	16.35	52.04	11.55	2.3
5.5	2.507	5.65	15.54	63.64	13.07	2.9
6	2.524	4.21	14.9	72.69	14.97	3.1
6.5	2.52	3.56	16	77.75	12.65	3.2
7	2.506	3.28	16.91	80.61	11.27	3.3

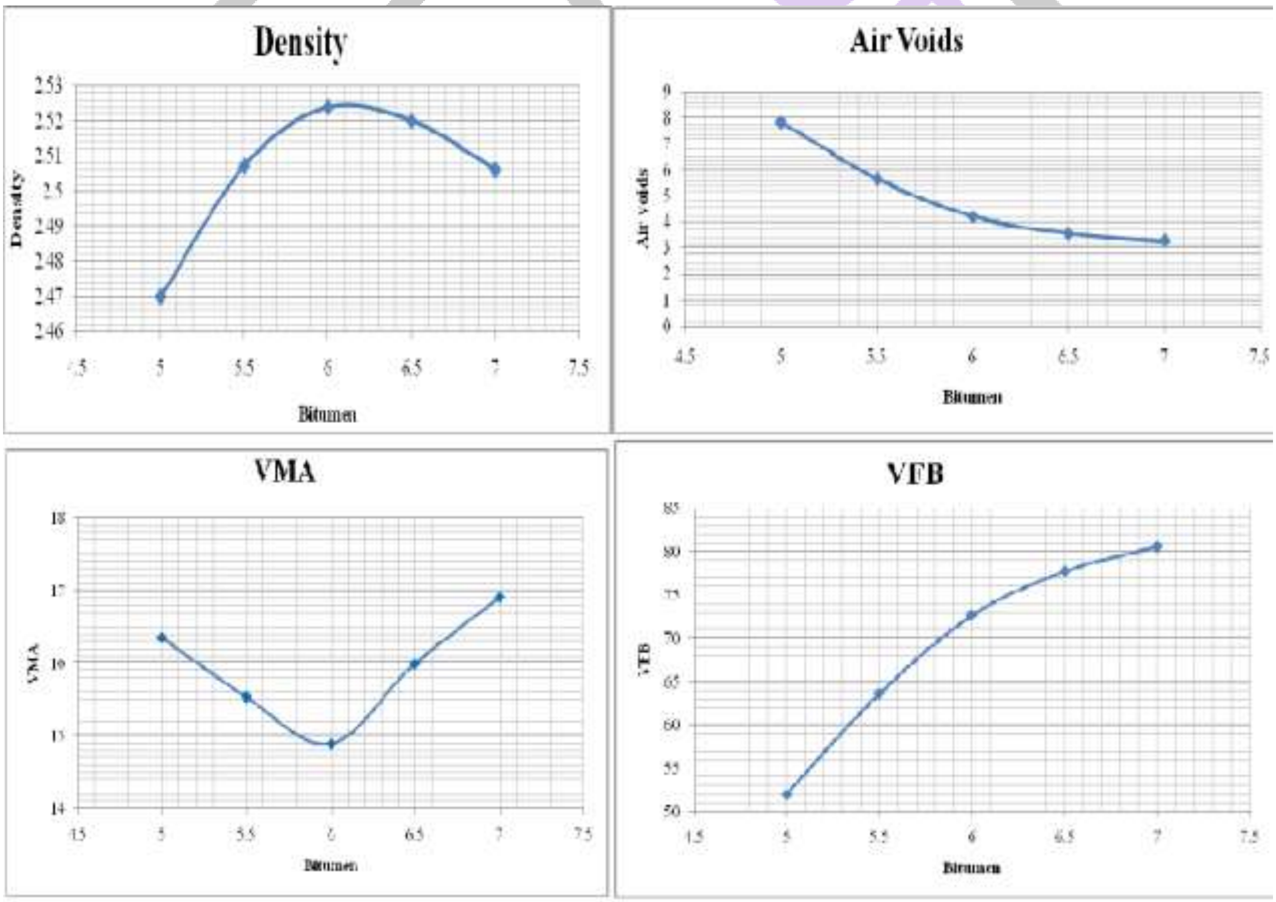


Fig 0.3 Specimen With Steel Slag (bitumen vs Density), (bitumen vs Airvoids), (bitumen vs VMA) & (bitumen vs VFB)

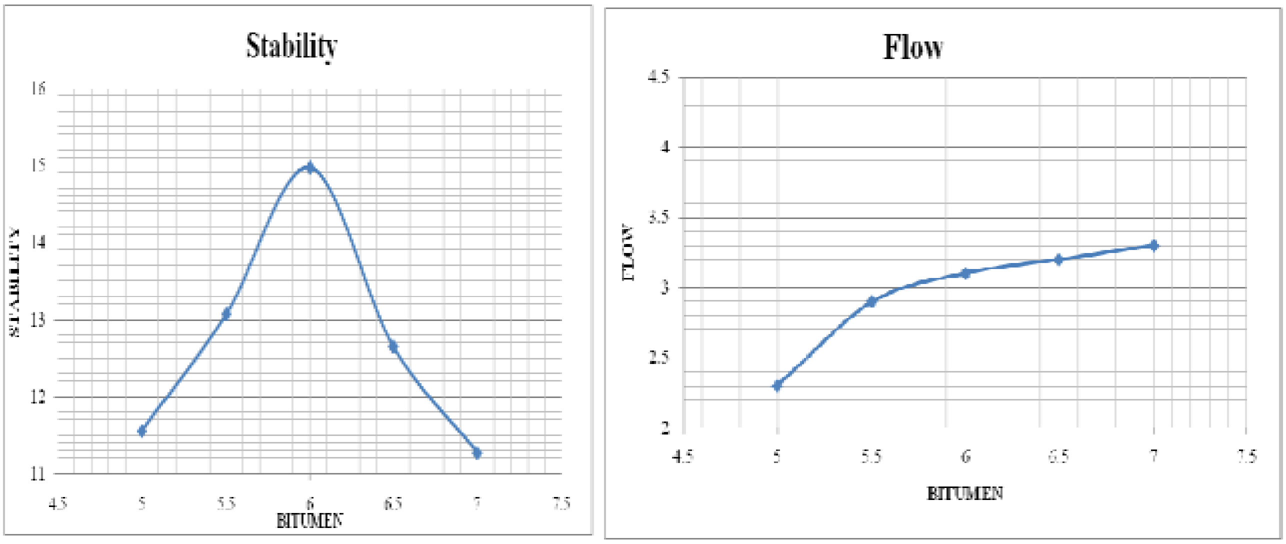


Fig 0.4 Specimen With Steel Slag (bitumen vs Stability) & (bitumen vs Flow)

Table 0.3 Marshall Properties (Specimen With Brick dust)

% Bitumen	Density	Air Voids	VMA	VFB	Stability	Flow
5	2.459	7.9	16.12	50.99	10.54	2.5
5.5	2.491	5.89	15.48	61.94	12.02	3.1
6	2.52	4	14.94	73.24	12.8	3.3
6.5	2.502	3.88	16	75.75	12.1	3.6
7	2.485	3.76	17.02	77.91	11.07	3.8

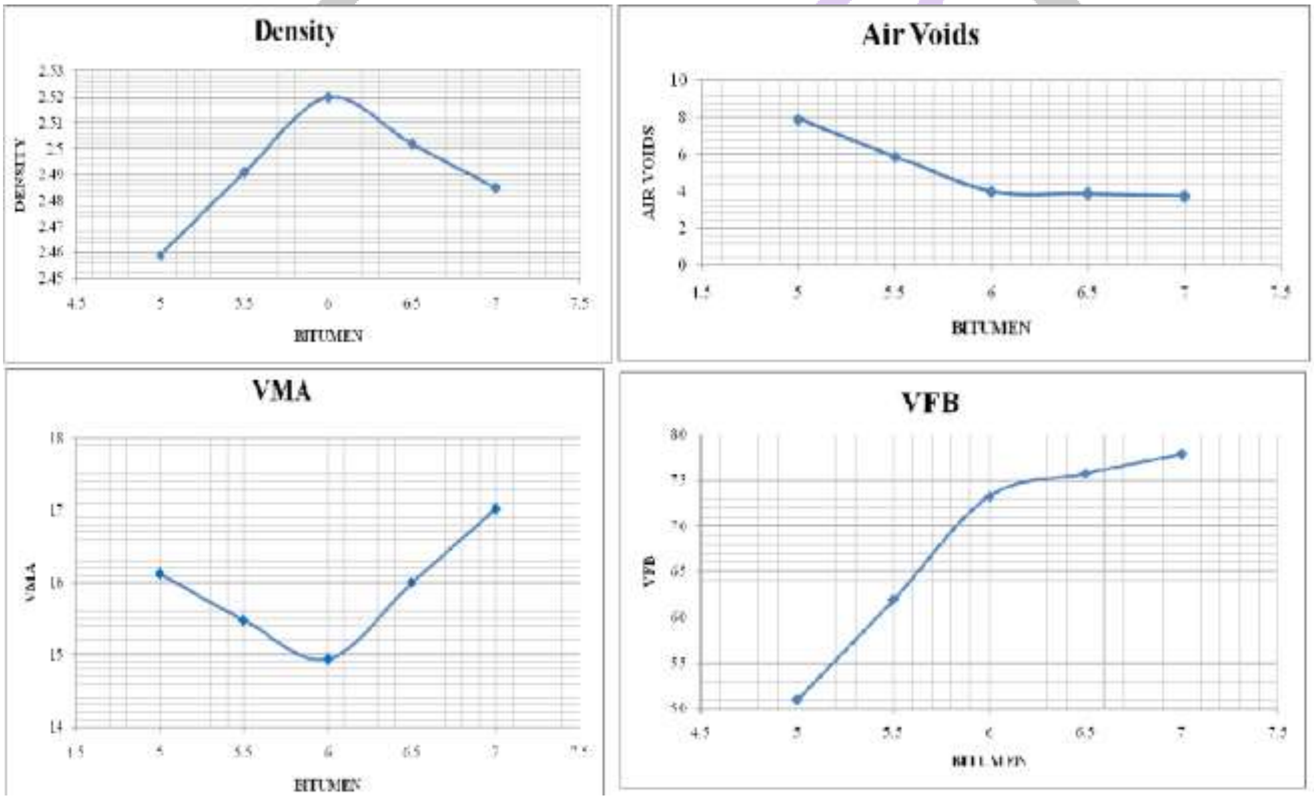


Fig 0.5 Specimen With Brick dust (bitumen vs Density) (bitumen vs Air voids) , (bitumen vs Air voids) & (bitumen vs Air voids)

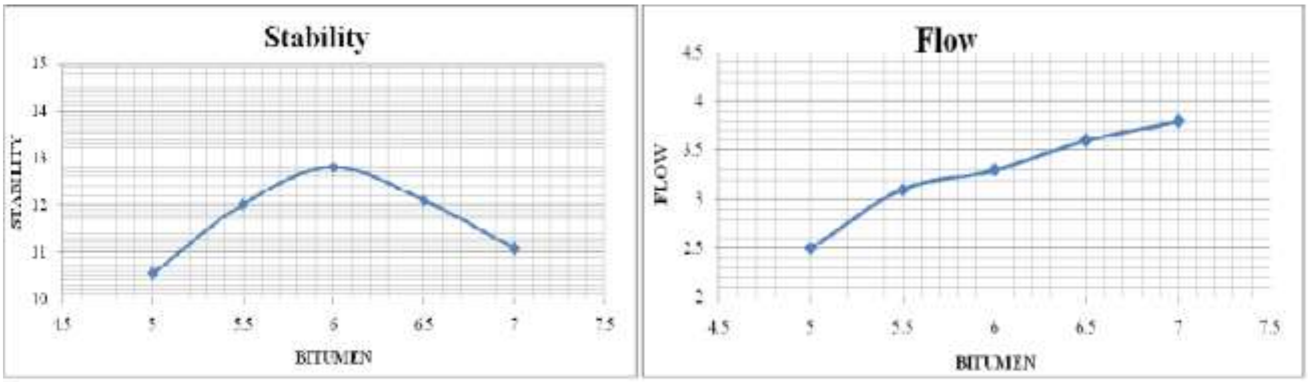


Fig 0.6 Specimen With Brick dust (bitumen vs Stability) and (bitumen vs Stability)

Comparison of Marshall Properties of various fillers:

Table 0.4 Marshall PROPERTIES

S.NO	PARAMETERS	STEEL SLAG	BRICK DUST
1	Optimum bitumen content(%)	6	6
2	Optimum filler content(%)	3.5	5
3	Stability(kn)	14.95	12.86
4	Flow(mm)	3.10	3.40
5	% of air voids	4.20	4.00
6	VMA(%)	14.90	15.00
7	VFB(%)	72.50	73.00

VI. CONCLUSIONS AND FUTURE SCOPE

CONCLUSIONS:

- Bituminous mixes containing stone dust as fillers are found an optimum bituminous mix at 6% of the bitumen content.
- Bituminous mixes containing steel slag as filler displayed maximum stability at 3.5% of c of filler content having an increasing trend up to 3.5% and then gradually decreasing, the unit weight/ bulk density also displayed a similar trend with flow value being satisfactory at 3.5% of filler content at optimum bitumen content (6%).
- Bituminous mixes containing brick dust as filler showed maximum stability at 5% of filler content displaying an ascending trend up till 5% of filler content and then decreasing, the flow value showed an increasing trend and similar was the trend shown by unit weight/bulk density, the percentage of air voids obtained were seen to be decreasing with increase in filler content thus from here we can see that at 5% of filler content we are obtaining satisfactory results at optimum bitumen content(6%).
- These mixes were seen to display higher air voids than required for normal mixes.
- Higher bitumen content is required in order to satisfy the design criteria and to get usual trends.
- From the above discussion it is evident that with further tests steel slag and brick dust generated as waste materials can be utilized effectively in the making of bitumen concrete mixes for paving purposes.
- Further modification in design mixes can result in utilization of steel slag and brick dust as fillers in bituminous pavement thus partially solving the disposal of industrial and construction wastes respectively.
- Though stone dust being conventional filler however steel slag and brick dust can be utilized in their place effectively thus solving the waste material disposal substantially resulting in utilization of industrial space being consumed in disposal of industrial wastes.
- The cost effectiveness of these non-conventional filler specimens can be realized after performing a cost analysis of these non-conventional materials against the conventional specimen resulting in reduction of the construction costs considerably.
- It is evident that with further tests steel slag and brick dust generated as waste materials can be utilized effectively in the making of bitumen concrete mixes for pavements.

FUTURE SCOPE:

- Pavement mixes with brick dust and steel slag as fillers using modified binders such as CRMB (60).
- Indirect tensile test of bituminous mixes can give us an idea about the tensile strength of the bituminous mixes.
- Repeated load testing can give us an overview about the fatigue failure resistance of the specimen.

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