International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 9 Issue 2 ǁ 2021 ǁ PP. 59-67

Effect of Fillers on Bituminous Paving Mixes

AUTHOR

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 bituminous 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. Brick dust and Steel slag as fillers with 2%, 3.5%, 5%, and 6.5% was used to improve the physical characteristics of bitumen mixes.

KEY WORDS: *Steel slag, Brick dust, Marshall Stability test.*

Date of Submission: 10-02-2021 Date of acceptance: 24-02-2021

I. INTRODUCTION:

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. 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. A precise engineering design of a flexible pavement may save considerable investment; as well as reliable performance of the in-service pavement can be achieved.

Pavements can be divided into 3 major types:

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

The following types of construction have been used in flexible pavement:

- Conventional layered flexible pavement,
- Full depth asphalt pavement, and
- Contained Rock Asphalt Mat (CRAM).

Conventional flexible pavement are layered systems with high quality expensive materials are placed in the top where stresses are high, and low quality cheap materials are placed in lower layers. Full depth asphalt pavements are constructed by placing bituminous layers directly on the soil sub grade. This is more suitable when there is high traffic and local materials are not available. Contained Rock Asphalt Mat (CRAM) is constructed by placing dense/open graded aggregate layers in between two asphalt layers. Modified dense grade asphalt concrete is placed above the sub grade will significantly reduce the vertical compressive strain on soil sub grade and grade and protect from surface water. **1.**Presented a modified marshal mix design methodology which listed a minimum VMA requirement of 15%. He provided design charts that covered the range of aggregate specific gravity from 2.00 up to 3.00 and asphalt specific gravity from 0.95 to 1.1 **Mc Loed (1956) 2.** Investigated the application of fly ash as an additive in amounts of 5%, 6%,7% and 8% by the total aggregate weight to the asphalt concrete mixture. Marshall Tests were applied and the optimum bitumen content was determined .the highest stability was obtained from 5% fly ash added mix and at 8% of fly ash the stability value decreased. **Henning N.E [4] (1974) 3.** did a comparative study between soma fly ash (F class) and calcareous as fillers in his experiment .he took 60/70 penetration bitumen with 7% of fillers by weight of aggregates. **Tapkin [14] (2007) 4.** investigated the effects of using granular volcanic ash as a partial replacement of conventional aggregate on properties of hot mix asphalt. **Jamil A Nagi, Ibrahim M Asi**

Objectives:
The objectives of the mix design is to determine an economical blend of stone aggregates, sand and fillers such as brick dust and steel slag proportionate various components so as to have:
1. Sufficient bitumen to ensure a **durable** pavement.
2. Sufficient **strength** to resist shear deformation under traffic at higher temperature.
3. Sufficient **air voids** in the compacted bitumen to allow for additional compaction by traffic.
4. `Sufficient **workability** to permit easy placement without segregation.
5. Sufficient **flexibility** to avoid premature cracking due to repeated bending by traffic.
6. Sufficient flexibility at low temperature to prevent shrinkage cracks.

MATERIALS USED:
- Aggregates
  - Coarse Aggregates
  - Fine Aggregates
- Bitumen
- Fillers
  - Steel Slag
  - Brick Dust

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.
Bitumen: 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. Bituminous materials are very commonly used in highway construction because of their binding and water proofing properties. The different grades of bitumen used for pavement construction work of roads and airfields are called paving grade bitumen and those used for water proofing of structures and industrial floors etc. are called industrial grade bitumen. 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".
Mineral filler: Mineral filler is largely visualized as a void filling agent and is used in the mix for better binding of materials. Crushed aggregates and sharp sands produce higher stability of the mix when compared with gravel and rounded sands. Rock dust, slag dust, hydrated lime, hydraulic cement, fly ash, mineral filler and cement are used as filler in Bituminous mix, also Fraction passing 0.075mm or 75 microns IS sieve was used as a filler. The filler material used in the study is stone dust. In this project, brick dust and steel slag are used as fillers.

Brick Dust: Brick dust is obtained from light red collared bricks consisting alumina, lime, oxide of iron, magnesia. The brick dust is collected from bricks manufacturing plant. The Chemical compositions of Brick Dust are mentioned in Table 1.

Table1: Properties of Brick Dust

Chemical Composition	Percentage
Alumina	20 To 30%
Lime	5%
Oxide Of Iron	5-6%
Silica	50-60%

Steel slag: Steel slag, a by –product steel making, is produced during the separation of the molten steel from impurities in steel making- furnaces. The slag occurs as a molten liquid molten and is a complex solution of silicates and oxides that solidifies upon cooling. The steel slag consisting CaO, SiO_2, MgO, Al_2O_3, and MnO.

The steel slag is collected from **Concast Ferro inc (P)Ltd, Dusi (v).** The Chemical compositions of Steel Slag are mentioned in Table 2.

Table2: Chemical Composition of Steel Slag

Constituent	Composition (%)
CaO	40-52
SiO_2	10-19
FeO	10-40
MnO	5-8
MgO	5-10
Al_2O_3	1-3

Tests On Aggregate And Bitumen:

(A) SIEVE ANALYSIS
Sieve analysis is the test used to determine the grain size distribution of the different sizes of aggregates such as coarse aggregates, fine aggregates and for filler material.
(1)
In this test, the sieves are set in such a way that the large aperture of the sieve is placed on the top and the smaller aperture sieve is placed at the bottom. Specific amount of the material is taken on the sieves and thorough sieving is done by shaking the sieves clockwise, anticlockwise, up and down directions. By using formulas, percentage retained, cumulative percentage and percentage finer is calculated.

(B) AGGREGATE IMPACT TEST
Aggregate passing 12.5mm sieve and retained on 10mm sieve is filled in the cylindrical measure in three layers by tamping each layer by 25 blows by each layer by the tamping rod. The sample is weighed and transferred by measure to the cup of aggregate impact testing machine and compacted by tamping 25 times. The hammer is raised to height of 380mm above the upper surface of the aggregate in the cup and allowed to fall freely on the specimen. After subjecting the test specimen to 15 blows, the crushed aggregate is sieved on 2.36mm sieve formed in terms of the total weight of the sample. The above test repeated using another specimen of the same aggregate sample, by taking the same weight in the first test. The mean of the two results is reported as the aggregate impact value of the specimen, to the nearest whole number.

(C) LOS ANGLES ABRASION TEST:
The 5000g of aggregates are taken for the grade d consisting 20mm to 12.5 mm sieve, and placed in the machine along with the specified abrasive charge. The machine is rotated at a speed of 30 to 33 rpm for the specified 500 number of revolutions. The abraded aggregates is then sieved on 1.7mm IS sieve, and weight of powdered aggregate passing this sieve is found. The result of abrasion test as the percentage wear or the percentage passing 1.7mm sieve expressed in terms of the original weight of the sample. The los angles abrasion value of good aggregates accepectable for bitumen concrete and other quality pavement materials should be less than 30%.

(D) AGGREGATE CRUSHING VALUE TEST:
Dry aggregates passing 12.5mm IS sieve and retained on 10mm sieve is filled in the cylindrical measure in three equal layers each layer being ramped 25 times by the tamper. The test sample is weighed (equal to W1g) and placed in the test cylinder in to three equal layers, tamping each layer 25 times. The plunger is placed on the top of specimen and load of 40 tonnes is applied at rate of 4 tons per minute by the compression machine. The crushed aggregates are removed and sieved on 2.36mm IS sieve. The crushed material which passes this sieve is weighed equal to W2g. The aggregate crushing value is the percentage of the crushed material passing 2.36mm sieve in terms of original weight of the specimen.

(E) FLAKINESS INDEX:
The sample of aggregates to be tested is first sieved through a set of sieves and separated into specified size ranges. Now to separate the flaky material, the aggregates which pass through the appropriate elongated slot of the thickness gauge are found. The width of the slot would be 0.6 of average of the size range. If the selected size range of aggregate in a group is 20 – 16mm (i.e., passing 20mm and retained 16mm sieve), the width of the slot to be selected in thickness gauge would be 18*0.6= 10.8mm. The flaky material passing the appropriate slot from each size range of aggregates are added up and let this total weight of flaky particles be

W1g. If the total weight of sample taken from the different size ranges is Wg, the flakiness index is given by $\left[\frac{W_1}{W} \times 100\right]\%$ in other words F.I is the percentage of flaky materials, the width of which are less than 0.6 of the mean dimensions.

(F) 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. Test results of aggregates are shown in table 3.

Table 3. Tests results of Aggregates

S.NO	DESCRIPTION OF TEST	PROPERTY	TEST METHOD	TEST RESULT	MORTH SPECIFICATION LIMIT
1	ABRASION VALUE	HARDNESS	IS:2386 PART4 1963	24.4%	40%(Maximum)
2	IMPACT VALUE	TOUGHNESS	IS:2386 PART4 1963	13.21%	24%(Maximum)
3	CRUSHING VALUE	STRENGTH	IS:2386 PART3 1963	16.31%	30%(Maximum)
4	SPECIFIC GRAVITY OF COARSE AGGREGATE	–	IS:2386 PART4 1963	2.65	2.5-3.5
5	SPECIFIC GRAVITY OF FINE AGGREGATE	–	IS:2386 PART4 1963	2.50	2.5-3.0
6	WATER ABSORPTION	–	IS:2386 PART3 1963	0.6%	2%(Maximum)
7	FLAKINESS INDEX	SHAPE	IS: 2386 PART1 1963	19.5%	30%(Maximum)
8	ELONGATION INDEX	SHAPE	IS: 2386 PART1 1963	13.2%	Max15%

(G) PENETRATION:

The consistency of bitumen cement is measured by the penetration test. A weighted needle (100 g) is allowed to bear on the surface of a dish of bitumen of standard test temperature (770 F) for a given length of time (5 sec). The depth of penetration of needle into the bitumen is termed as the penetration of the bitumen and is measured in units of 0.1mm. The needle penetrates farther into soft bitumen than into the harder grades, and thus the lower the penetration, the harder the bitumen. This test is the basis upon which most bitumen cements are classified into standard penetration ranges.

(H) SOFTENING POINT:

Objective of this test is to know the softening temperature of the bitumen. Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test. The test is conducted by using Ring and Ball apparatus. A brass ring containing test sample of bitumen is suspended in liquid like water or glycerine at a given temperature. A steel ball is placed upon 5-the bitumen sample and the liquid medium is heated at a rate of 5^oC per minute. Temperature is noted when the softened bitumen touches the metal plate which is at a specified distance below. Generally, higher softening point indicates lower temperature susceptibility and is preferred in hot climates. Figure 3.14 shows Softening Point test setup.

(I) DUCTILITY:

The bitumen sample is heated and poured in the mould assembly placed on a plate .the ductility test specimen and moulds are shown in the figure. The samples along with the moulds are cooled in air and then in water bath maintained at 27c .the excess bitumen material is trimmed and surface is levelled using a hot knife. The mould assembly containing sample is replaced in water bath of the ductility testing machine for 85 to 95min. the sides of the mould are removed, the clips hooked on to the machine and the pointer is adjusted to zero. The distance up to the point of breaking of thread is reported as ductility value, in cm. the ductility value gets seriously affected by factors such as pouring temperature, dimensions of briquette, level of briquette in the water bath, presence of air pockets in the specimen briquettes, test temperature and rate of pulling. The ductility values of bitumen generally vary from 5 to over 100 for different bitumen grades. A minimum ductility value of 50 to 75 cm is generally specified for bitumen used in pavement construction.

(J) FLASH AND FIRE POINT TEST:

Flash point test gives an indication of the critical temperature at and above which suitable precautions should be taken while heating the binder .in order to eliminate fire hazards during heating, mixing or application ,the paving engineer should restrict the mixing and application temperatures well below this temperature. All parts of the cup are cleaned and dried thoroughly before the test is started. The material is filled in the cup up to a mark and the lid is placed to close the cup in a closed system. All accessories including thermometer of the specified range are suitably fixed. The sample is then heated. The test flame is lit and adjusted in such a way that the size of a bed is of 4mm diameter. The heating of sample is done at a rate of 50 to 60c per minute during heating the sample the stirring is done at a rate of approximately 60 revolutions per minute. The test flame is applied at intervals depending upon the expected flash and fire points and corresponding temperatures at which the material shows the sign of flash and fire are noted. The results are mentioned in Table 4.

Table 4: Results of Bitumen

S.No	Description Of Test	Test Result	Specified Limit	Test Method
1	Penetration value	65mm	65-70	IS:1203
2	Ductility	78cm	Not less than 75	IS:1208
3	Specific gravity	1.03	0.99 (Minimum)	IS:1202
4	Flash point	240^0C	220(Minimum)	IS:1209
5	Fire point	255^0C	220(Minimum)	IS:1209
6	Softening point	48.65^0C	40^0C-55^0C	IS:1205

Tests On Fillers

Specific Gravity test and Water Absorption Test are done for the fillers and their results are mentioned in Table 5.

Table 5: 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

Marshall Mix Design:

- 1200gm aggregate are weighted and heated to a temperature of 160^0C-170^0C. Compaction mould assembly and rammer are cleaned and preheated to a temperature of 100^0C-145^0C.
- Bitumen is heated to a temperature of 160^0C.
- Aggregates & Bitumen are mixed thoroughly until a uniform grey color is obtained.
- The mix is placed in Marshall Mould of diameter 100mm & 64mm height compacted with 75 blows on each face.
- Mould is taken out and kept under normal laboratory temperature for 12 hours.
- It is then immersed in water bath kept at a constant temperature 60^0C for 30 minutes. Load is applied vertically at the rate of 51mm per minute.

The maximum load at sample fails is recorded as the Marshall Stability value. Corresponding vertical strain is termed as the flow value

The above procedure is repeated on specimens prepared with other values of bitumen content; in suitable increments say 0.53

II. RESULTS AND DISCUSSIONS:

Graphical Representation of Marshall Properties

1.Bitumen Vs Density graph is shown in Fig.1

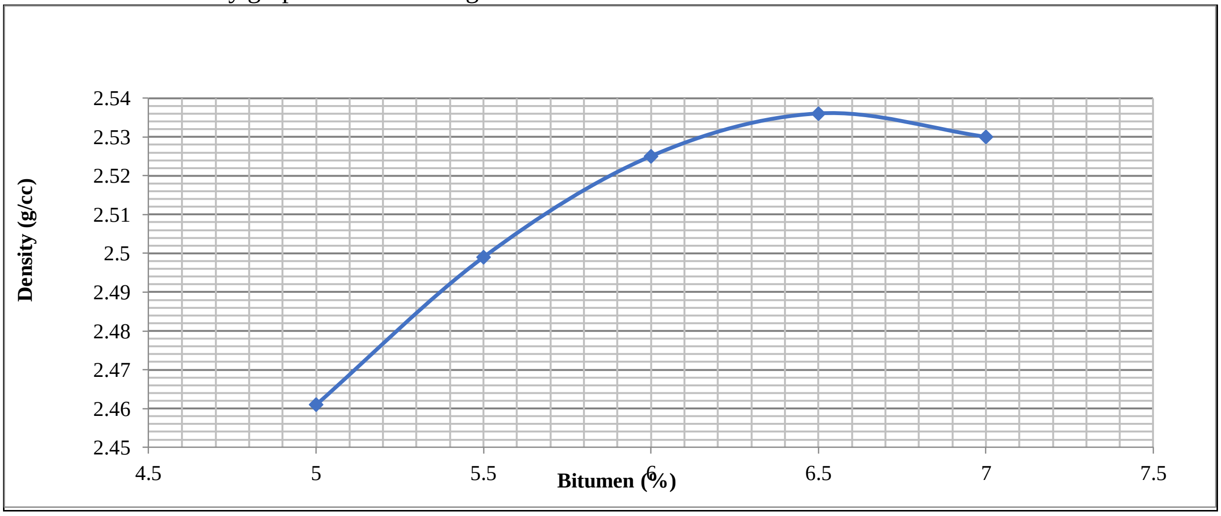

Fig 1: Bitumen vs. Density of Nominal mix

2.Bitumen Vs Air Voids graph is shown in Fig.2

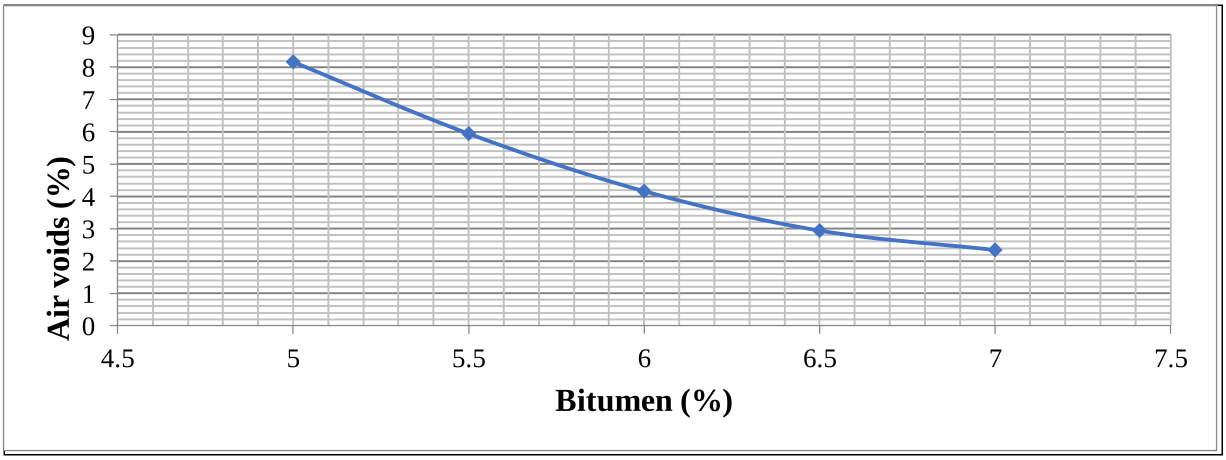

Fig 2: Bitumen vs. Air voids of Nominal mix

3.Bitumen Vs VMA graph is shown in Fig.3

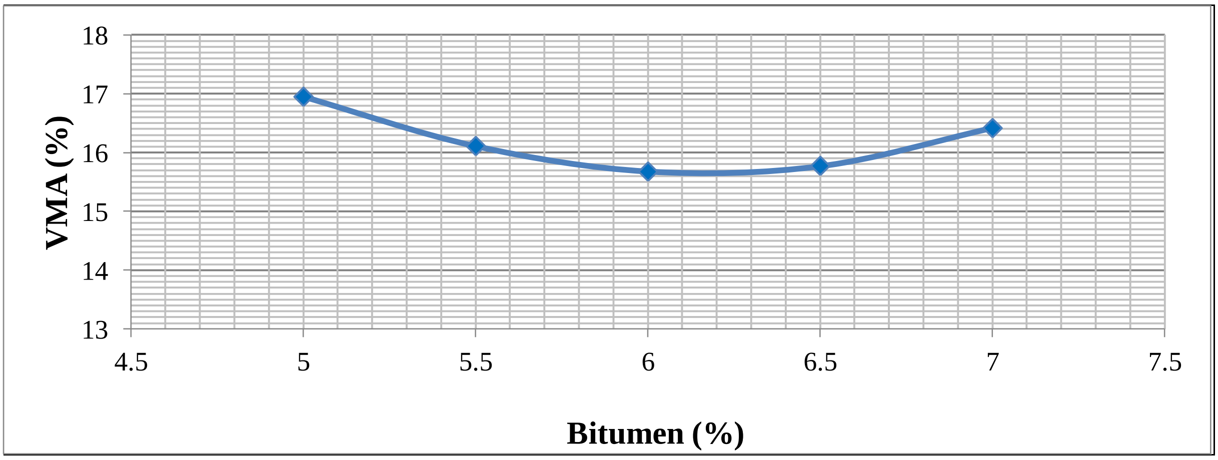

Fig 3: Bitumen vs. VMA of Nominal mix

4.Bitumen Vs VFB graph is shown in Fig.4

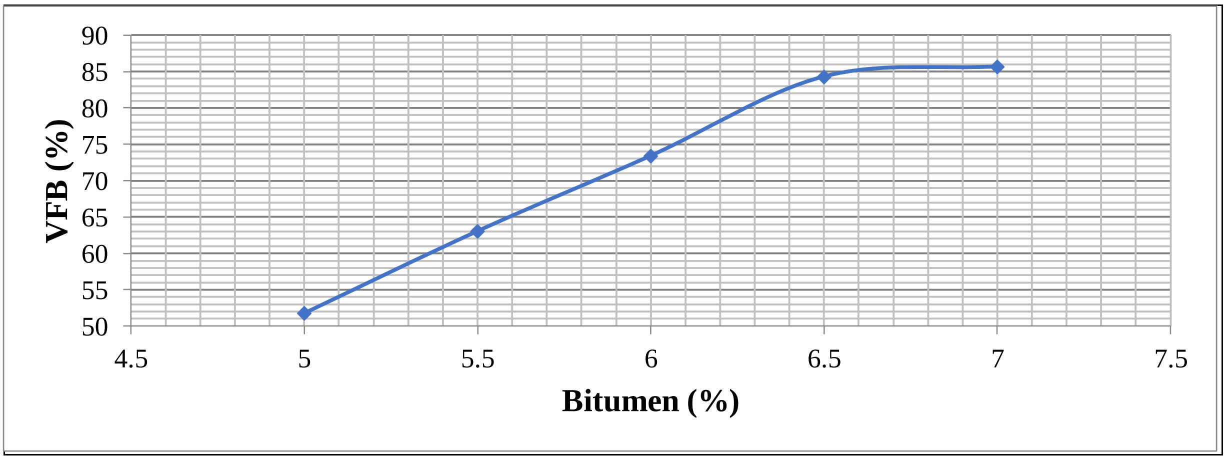

Fig 4: Bitumen vs. VFB of Nominal mix

5.Bitumen Vs Stability graph is shown in Fig.5

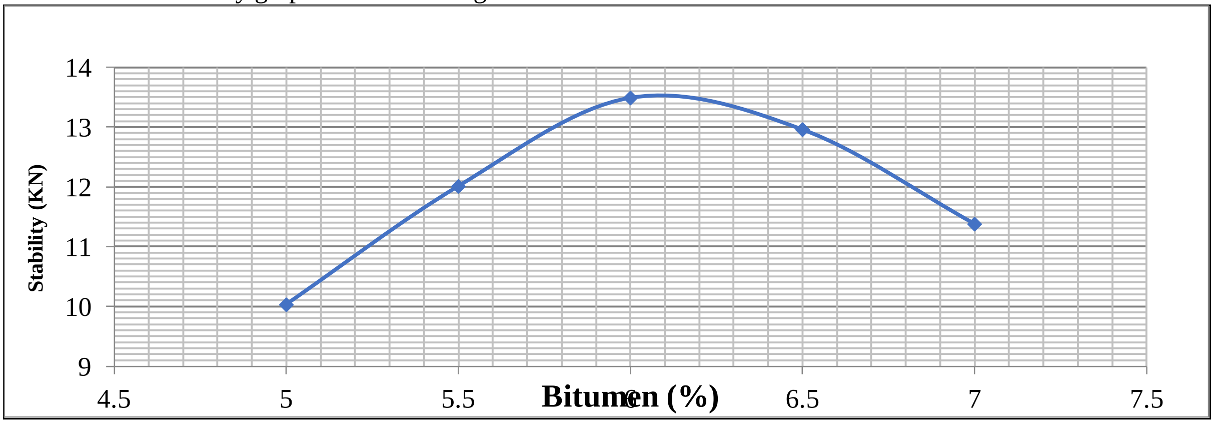

Fig 5: Bitumen vs. Stability of Nominal mix

6.Bitumen Vs Flow graph is shown in Fig.6

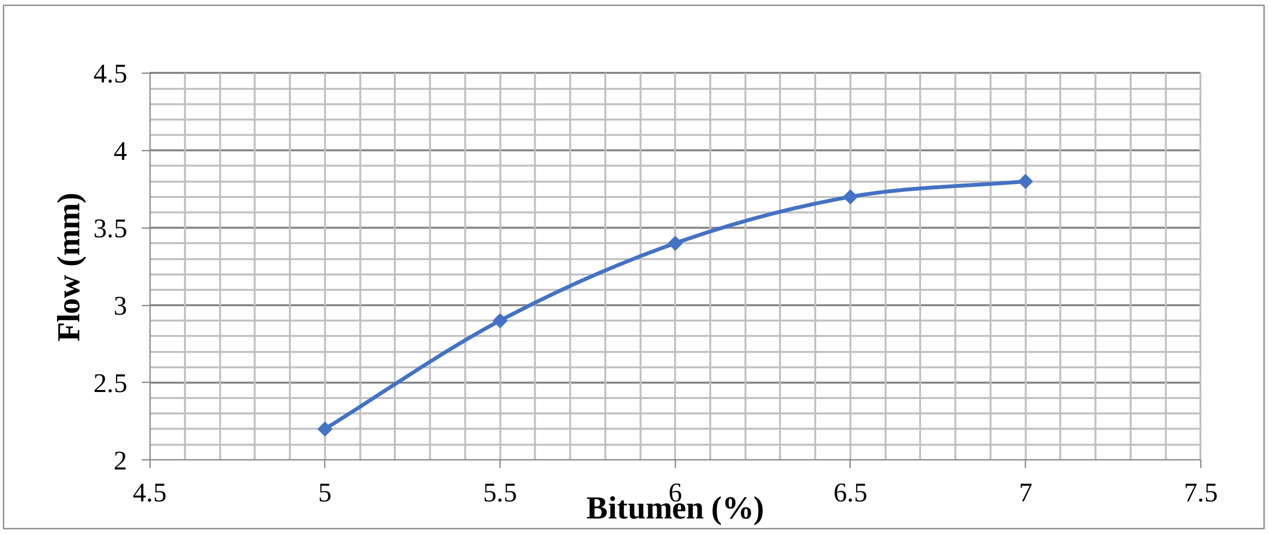

Fig 6: Bitumen vs. Flow of Nominal mix

Table 6: Summary of Test Result (Nominal mix)

Summary of Test Result
BITUMINOUS CONCRETE

S.No	Name of Test	Unit	Test Result	Specified Limit	
				Min.	Max.
1	Stability	KN	12.51	9	-
2	Flow	Mm	3.20	2	4
3	Air Void	%	2.13	3	5
4	G_m	gm/cc	3.645	-	-
5	VMA	%	14.70	12.00	-
6	VFB	%	72.03	65	75
7	Unit Weight	gm/cc	3.625	-	-
8	Optimum Binder	%	5.10	_	-

Table 7: Marshall Properties (Specimen With Steel Slag)

% Bitumen	Density g/cc	Air Voids %	VMA %	VFB %	Stability KN	Flow mm
5	2.47	6.74	15.25	51.03	12.45	2.2
5.5	2.507	5.45	16.44	62.44	14.17	2.7
6	2.524	3.11	15.19	70.59	13.47	3.2
6.5	2.52	4.46	14.23	75.65	11.45	3.4
7	2.506	2.38	16.91	79.51	10.37	3.6

Table 8: Summary of Test Result (Specimen with Steel Slag)

Summary of Test Result (Steel Slag) BITUMINOUS CONCRETE					
S.No	Name of Test	Unit	Test Result	Specified Limit	
				Min.	Max.
1	Stability	KN	13.85	9	-
2	Flow	mm	4.11	2	4
3	Air Void	%	3.21	3	5
4	G_m	gm/cc	2.646	-	-
5	VMA	%	13.92	12.00	-
6	VFB	%	71.41	65	75
7	Unit Weight	gm/cc	3.423	-	-
8	Optimum Binder	%	6.00	4.0	-

Table 9: Summary of Test Result (Specimen with Brick dust)

Summary of Test Result BITUMINOUS CONCRETE					
S.No	Name of Test	Unit	Test Result	Specified Limit	
				Min.	Max.
1	Stability	KN	13.85	9	-
2	Flow	mm	4.11	2	4
3	Air Void	%	3.21	3	5
4	G_m	gm/cc	2.646	-	-
5	VMA	%	13.92	12.00	-
6	VFB	%	71.41	65	75
7	Unit Weight	gm/cc	3.423	-	-

Table 10: Marshall Properties (Specimen with Brick dust)

% Bitumen	Density g/cc	Air Voids %	VMA %	VFB %	Stability KN	Flow mm
5	2.443	8.9	15.13	51.90	11.34	2.5
5.5	2.562	6.89	15.49	60.84	10.02	3.1
6	2.43	4.23	13.93	72.14	11.08	3.3
6.5	2.523	3.73	15.09	74.75	12.31	3.6
7	2.325	4.67	17.02	76.91	13.06	3.8

Table 11: Comparison of Marshall Properties between Steel Slag and Brick Dust

S.NO	PARAMETERS	STEEL SLAG	BRICK DUST
1	Optimum bitumen content (%)	**6**	**6**
2	Optimum filler content (%)	**3.5**	**5**
3	Stability (KN)	**13.85**	**12.86**
4	Flow (mm)	**4.11**	**3.40**
5	% of air voids	**3.21**	**4.00**
6	VMA (%)	**13.92**	**15.00**
7	VFB (%)	**71.41**	**73.00**

III. CONCLUSIONS

- Bituminous mixes containing stone dust as fillers have found an optimum bitumen content at 6%.
- Bituminous mixes containing steel slag as filler displayed maximum stability at 3.5% 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.
- Bituminous mix's containing steel slag as filler showed higher stability values when compared with brick dust and stone dust fillers.
- 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.

REFERENCES

[1]. Ali , Chan, Simn and Bushman, "mechanistic evaluation of fly ash asphalt concrete mixtures" Journal of materials in civil engineering (1996).

[2]. Anderson and Goetz, "Mechanical behaviour and reinforcement of mineral filler – asphalt mixtures," proc, Association of Asphalt Paving Technologies, vol. 42, 37-66(1973)

[3]. Bureau of Indian Standards (BIS), Methods of testing tar and bituminous material: determination of softening point, IS: 1205, New Delhi, India, 1978, pp. 33-38.

[4]. Bureau of Indian Standards (BIS), Methods of testing tar and bituminous material: determination of penetration, IS: 1203, New Delhi, India, 1978, pp. 25-26.

[5]. Bureau of Indian Standards (BIS), Methods of test for aggregates for concrete, part-III specific gravity, density, voids, absorption and bulking, IS: 2386 (Part – III), New Delhi, India, 1963, pp. 4 – 11.

[6]. Bureau of Indian Standards (BIS), Methods of test for aggregates for concrete, Part IV, mechanical properties, IS: 2386 (Part-IV), New Delhi, India, 1963, pp. 10-13, 16-19.

[7]. Bureau of Indian Standards (BIS), Methods of test for aggregates for concrete, Part I particle shape and size, IS: 2386 (Part I), New Delhi, India, 1963, pp. 11-14.

[8]. Bureau of Indian Standards (BIS), Methods of testing tar and bituminous materials: Determination of specific gravity, IS: 1202, New Delhi, India, 1978, pp. 19-22.

[9]. Dongue,.Bahia "rhelogical properties of mineral filler-asphalt mastics and its importance to pavements.

[10]. Henning. "Evaluation of lignite fly ash as mineral filler in asphaltic concrete". Report No. item 20, Twin City Testing and Engineering Laboratory, St.paul, minn.(1974).

[11]. Hossam Hassam Recycling Of Municipal Solid Waste incinerator ash in Hot Mix Asphalt concrete, Department of civil engineering and architecture engineering, Sultan Qaboos University, 2003.