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Use of Iron Ore Tailings in Bituminous Concrete Mix for Road Construction

Bandagi sab[1], Chandan P [2], ChetanShidagoudaMudalgi[3], Harshavardhan M[4], Vinay A[5]
[1,2,3,4]UG Student, Dept. of Civil Engineering, DayanandSagar college of Engg., Karnataka, India
[5]Assistant Professor, Dept. of Civil Engineering, DayanandSagar college of Engg., Karnataka, India

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ABSTRACT -In present scenario disposal of various wastes generated from various industries as created a huge havoc as well as hike in the prices of available natural resources. Most of the developing countries have come off with a very innovative idea of utilizing industrial wastes for the construction of roads. The concept of reusing wastes material is seams very simple but very powerful concept. In the present study, Iron Ore Tailings (IOT) procured from Hospet are used as partial replacement of both Coarse and Fine aggregates at levels of 25, 50, 75 & 100 percent and the basic material properties, strength parameters are studied.

Author keywords: Hot Mix asphalt; Iron ore Tailings; Granite stone dust; Marshall Stability test (MST)

I. INTRODUCTION

India is one of the crucial iron ore producers and exporter in the world. Waste material management is one of the powerful concepts in recent year in a country like India. However, the speedy growths in production, mainly from large surface mines, have already caused ecological unevenness in their respective regions and appear as the source of main environmental hazards. To overcome the iron ore tailings (waste) by heaps and bond requires reuse of waste materials in road construction. The tailings which are ultra-fines or slimes, have diameter less than 150 micro meters, are not useful and are discarded. Approximately 10 – 12 million tons of such mined ore is lost as tailings in India. The safe dumping or utilization of such huge mineral in the form ultra-fines or slimes has remained a major unsolved and provoking task for the Indian iron ore industry. Most of the developing countries have come off with a very innovative idea of utilizing industrial wastes for the construction of roads. The concept of reusing wastes material is seams very simple but very powerful concept. In upcoming years in different part of the country various steel plants are being planned to setup, therefore the amount of iron ore wastes would also be generated in higher quantities. Therefore various operation and techniques need to be adopted to utilize the iron ore tailings in various construction purposes.

HOT MIX ASPHALT (HMA)

Hot mix asphalt (HMA) is used as a pavement material. It is a combination of aggregate and **asphalt** binder **mixed** together at higher temperatures of about 150^0 c forming a hard and strong construction material when the temperatures are lowered. Hot Mix Asphalt pavements are in practice for decades. It is either produced in batch mix plants or drum mix plants.

Heating the asphalt reduces the viscosity thereby making it easier to mixing and drying the aggregates removes moisture, therefore results in a rich mix. Mixing of the asphalt, paving as well as compaction of the pavement are all required to be performed while the mix is sufficiently enough. Major highways, racetracks, airfields and other roads mainly use various forms of hot mix asphalt. In this project we are considering HMA to conduct Marshall test to find Marshall properties of bituminous concrete.

Objectives

- Detailed examination on the properties of Iron Ore Tailings.
- To study the use of Iron Ore Tailings in production of hot mix asphalt for road construction by replacing aggregates in various proportions and performing laboratory tests.
- Four different percentages (25%, 50%, 75%, and 100%) of IOT are being used, and the proposed mix designs for HMA are prepared in accordance with Marshall mix design and conduct the experiment to check for various improvements on the properties of HMA.

- To know about the Stability and flow value of the bituminous concrete mix using IOT

II. LITERATURE REVIEW

In 1956, Prof. LadisCsanyi, Lowa State College, understood the capability of frothed bitumen for use as a dirt cover. From that point forward, frothed blacktop innovation, which permits lower blending temperatures, has been utilized effectively in numerous nations. The first procedure comprised of infusing steam into hot bitumen. In 1968, Mobil Oil Australia, which had obtained the patent rights for Csanyi's creation, changed the first procedure by including cold water as opposed to steam into the hot bitumen. The bitumen frothing procedure at that point turned out to be more practical. Conocowas later authorized to advertise frothed blacktop in the U.S. also, further propelled the innovation and assessed the item as a base stabilizer both in the lab and in the field.

In the mid-1970s, Chevron created blend plan and thickness structure strategies for clearing blends (base, open-reviewed, and thick evaluated) settled with Emulsified black-top. In 1977, Chevron distributed their "Bitumuls Blend Manual" as a viable rule, which contains a lot of important data for determining, structuring, and delivering emulsion-balanced out blends. Afterward, other comparative rules followed (FHWA, 1979; Blacktop Emulsion Producers Affiliation [AEMA], 1981).

Kuennen revealed that emulsified blacktop blends are famous in country settings where good ways from HMA plants and lower traffic volumes may block HMA. Further, chilly blend plants have a lower beginning expense than regular HMA plants, are all the more effectively moved, and might be arranged anyplace without Ecological Security Organization (EPA) allows because of their absence of discharges. Besides, they are agreeable to blends in with high rates of recovered blacktop asphalt.

In 1994, Maccarone and others, considered cold-blended blacktop based frothed bitumen and extremely high cover content emulsions and inferred that the utilization of cold blends for use on streets was picking up acknowledgment worldwide because of vitality productivity and lower emanations. Truth be told, they expressed that, "Chilly advanmixs speak to the future in street surfacing".

In 1995, Shell Bitumen recorded a patent to cover a warm-blend blacktop method that utilized a two-segment procedure, of Shell Worldwide Arrangements, depicted an inventive WMA process that was tried in the research center and assessed in enormous scope field preliminaries (in Norway, the Unified Realm, and the Netherlands) with specific reference to the creation and situation of thick reviewed wearing courses. Shell's work brought about the improvement of WAM-Foam.

Jenkins and others, presented another procedure including a half-warm frothed bitumen treatment. They investigated the ideas and potential advantages of warming a wide assortment of totals to temperatures above surrounding yet underneath 212°F before the utilization of frothed Bitumen. Preheating totals upgraded molecule covering, blend union, elasticity, and Compaction. This is especially valuable for blends containing recovered blacktop asphalt (RAP) or thickly reviewed squashed totals.

Abhishek S,Rachitha P (2020), Waste material (iron ore tailings) can be used as backfill material in asphalt concrete mixture for road construction. In the present study, the importance was to add the hot mix additives to Dense Bituminous Macadam (DBM) mix and to evaluate the different properties of the mix such as Marshall Stability test. Marshall Stability test was done for various field temperatures.

III. METHODOLOGY AND MATERIALS

Bitumen

The Asphalt binder to be used in present research is Straight-run (plain) bitumen of penetration grade 60/70 (equivalent to viscosity grade-VG 30) the physical properties of the procured binder are presented in Table 1

Aggregates

Coarse Aggregate: The coarse aggregates consisted of crushed granite rock retained on 2.36 mm sieve. They were free of dust, soft organic and other harmful substances, and were safe, hard, and durable. The aggregates meet the physical specifications specified in Table-2.

Fine Aggregate: Fine aggregates (passing 2.36mm sieve and retained on 0.075 mm sieve) consisted of 100 per cent crushed sand resulting from granite rock crushing operations. The fine aggregate was clear of soft fragments, organic or other harmful substances, and was clean, hard, sturdy, and of a fairly cubical form.

Mineral filler: In our project we made use of granite stone dust as filler material. As Fly ash creates difficulty in mixing of binder and aggregates, it was rejected as filler material in Hot Mix Asphalt. Only 7% of granite stone dust passing through 0.075mm IS sieve was used.

Iron Ore Tailings: Tailings are the residual materials during process of separating the valuable fraction from the useless fraction of an ore.Among all kinds of mining solid wastes in the world, IOTs are abundantly generated due to high output and low utilization ratio. The overall production of IOTs wasaround 220 million Metric tonnes as of 2019 as said by FICCI. Iron ore mainly consist of lumps, fines, aggregates. Properties of the IOTs are indicated in Table 3

Figure -2 Iron ore tailings

Table-1 physical properties of bitumen

Sl no	Tests	As per IS code Test procedure	Range	Results
1	Penetration test (1/10th of mm)	IS 1203-1978	60-70	61
2	Specific gravity	IS :1202	-	1.02
4	Ductility test (cm)	IS 1208-1978	75 minimum	77
5	Softening point (°C)	IS 1205-1978	45-55	54
6	Flash point (°C)	IS 1209-1978	175 minimum	302
7	Fire point (°C)	IS 1209-1978	175 minimum	343
8	Viscosity at 135°C, centipoise	IS 1206-1978	350 minimum	358

Sl. No.	**Tests**	**As Per IS-Codes**	**Specifications**	**Results**

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		Test Procedure	(2009)	
1	Specific gravity	IS-2386 Part III	-	2.62
2	Crushing Value	IS-2386 Part IV	-	25.4%
3	Abrasion Value	IS-2386 Part IV	Max 25%	22.0%
4	Impact Value	IS-2386 Part IV	Max 24%	20.89%
5	Water Absorption	IS-2386 Part III	2%	0.35%
6	Combined Elongation and Flakiness Indices	IS-2386 Part I	Max 30%	28.0%

Table -2 physical properties of coarse aggregates

Table -3 physical properties of Iron ore tailings

Sl. No.	Tests	As Per IS-Codes Test Procedure	Results
1	Specific gravity	IS 383-1970	3.45
2	Crushing Value	IS: 2386 part-4-1963	28.4%
3	Abrasion Value	IS:2386 part 4-1963	27.8%
4	Impact Value	IS: 2386 part 4-1963	27.89%
5	Water Absorption		0.24%
6	Combined Elongation and Flakiness Indices		25.0%

Marshall Test

The Marshall Stability test was performed on bituminous mixes containing varying amounts of bitumen, at various temperatures, and with various stabilizer rates. It was used in research to find the Optimum Binder Content (OBC), with a focus on maximum stability, unit weight, and 4 percent voids or 75% voids filled with bitumen. This test is commonly used in paving job routine testing programs. A maximum load borne by a compacted specimen at a typical test temperature of 600C is used to determine the mix's stability. The flow is measured as the deformation in units of 0.25 mm between no load and maximum load carried by the specimen during stability test (flow value may also be measured by
Deformation units of 0.1mm.The test was carried out according to the ASTM: D: 1559-65

Figure -3 Marshall apparatus

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IV.RESULTS AND DISCUSSIONS

Design of HMA mix

The Marshall Stability specimens were prepared with plain bitumen by varying the binder content from 5 per cent to 6.5 per cent by an increment of 0.5 per cent. Three specimens were prepared for each binder content. In the conventional Marshall Mix design 1.2 kg of aggregates were used to prepare the specimen.

Marshall Stability test was conducted and properties like stability, flow, bulk density, volume of voids and voids filled with bitumen are found for mid gradation. The Marshall Stability test results are shown in the table.

The graphs were plotted between bitumen content and Marshall Stability, Bulk density and Air voids. The bitumen content corresponding to maximum stability, Bulk density and 4.0% air voids was obtained from these graphs. The average of the three bitumen contents was calculated and treated as optimum bitumen content (OBC).

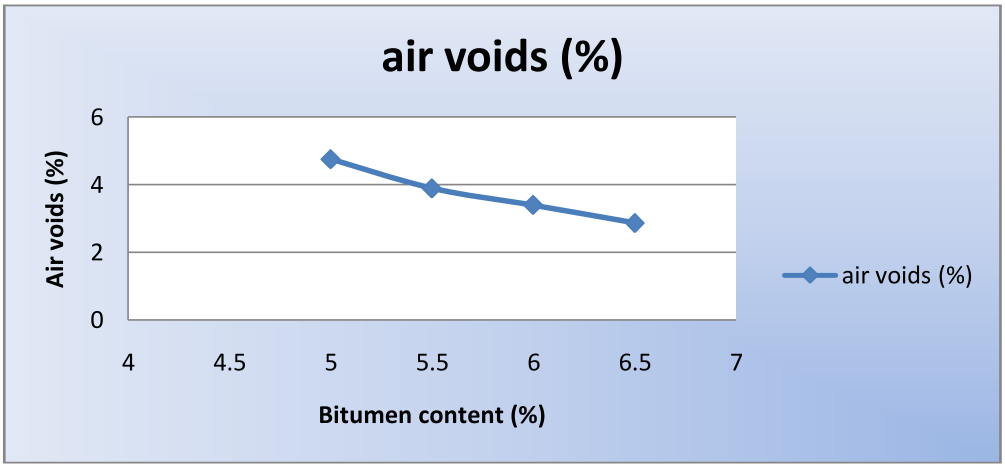
Marshall Properties

The Marshall Stability first increases with bitumen content, reaches a maximum value when the bitumen content is almost equal to the OBC value and then decreases. At OBC the Marshall Stability values for HMA samples prepared using mid gradation is 11.57kN. The flow value increases with increase in bitumen content for both HMA mixes. Flow values were between 4.5-5.3mm.

The Voids in Mineral Aggregates (VMA) for all with bitumen content. Samples were between 16%-18%. Voids Filled with Bitumen (VFB) is in the range of 70-84% and it shows a gradual increasing trend with bitumen content.

Table -4 properties of HMA sample for different gradation by Marshall Method

Properties	Bitumen content			
Mid Gradation	**5.0%**	**5.5%**	**6.0%**	**6.5%**
Marshall stability (kN)	12.09	11.57	11.5	10.79
Flow Value (mm)	4.5	4.8	5	5.3
Bulk density (kg/m^3)	2353.84	2359.45	2355.99	2353.49
Volume of voids Vv (%)	4.76	3.89	3.4	2.87
Voids in Mineral Aggregate VMA (%)	16.3	16.62	17.26	17.87



(a) Binder content (%) v/s Air voids (%)

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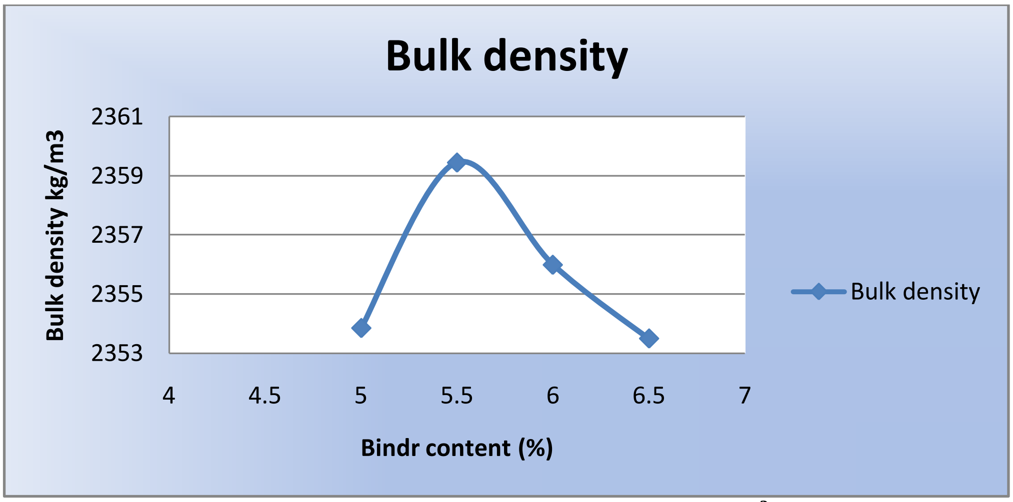
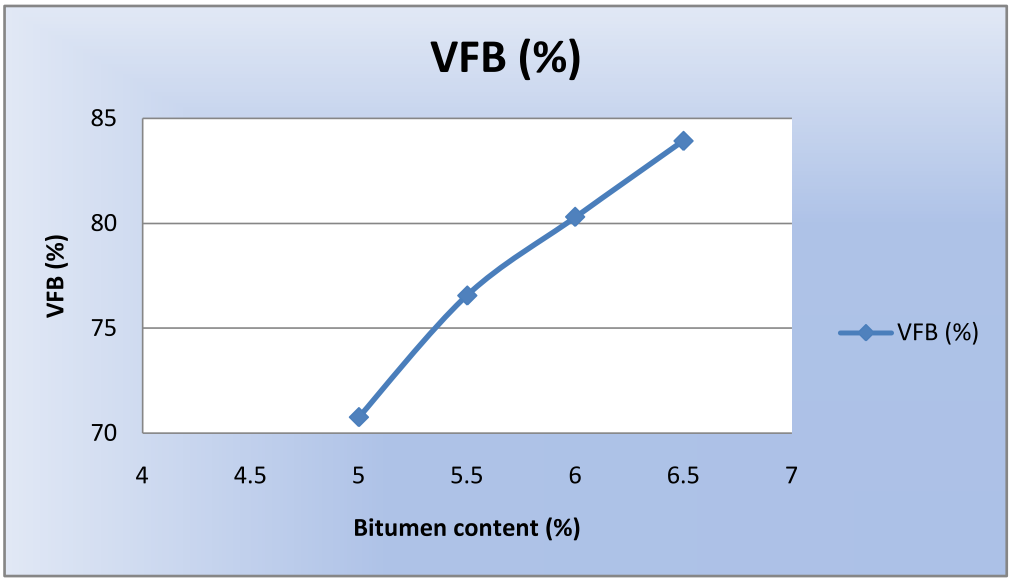
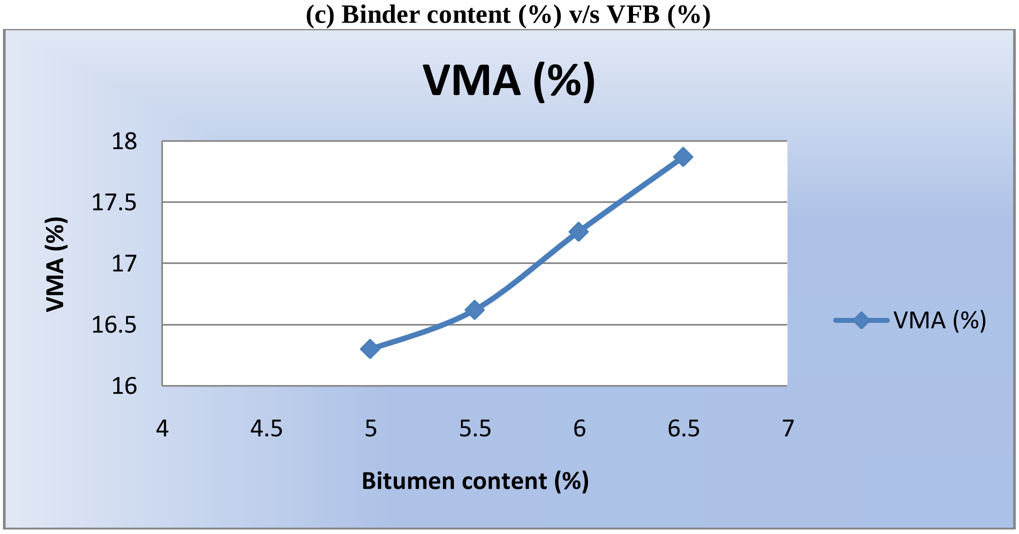


(b) Binder content (%) v/s Bulk density (kg/m^3)



(c) Binder content (%) v/s VFB (%)



(d) Binder content (%) v/s VMA (%)

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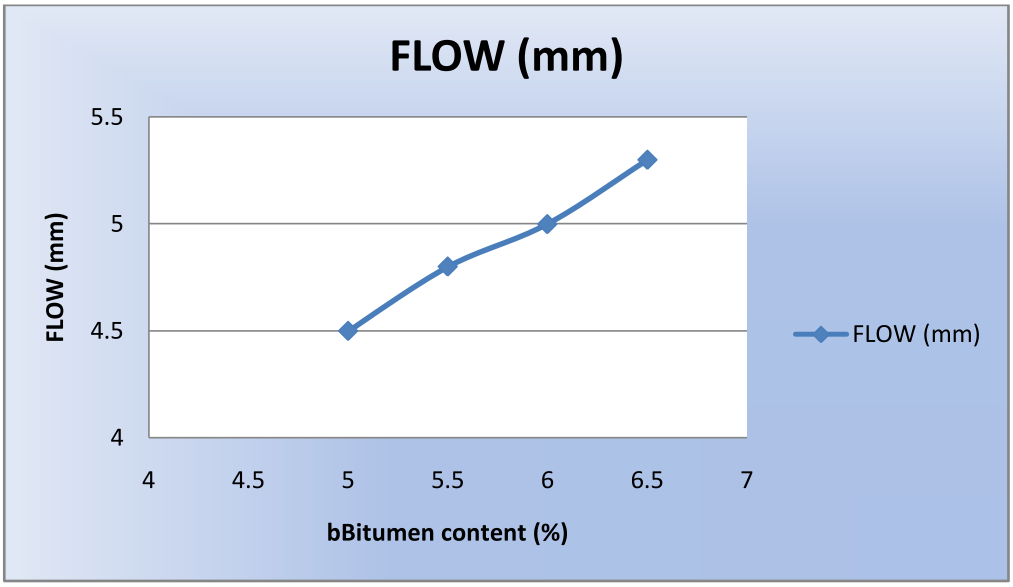
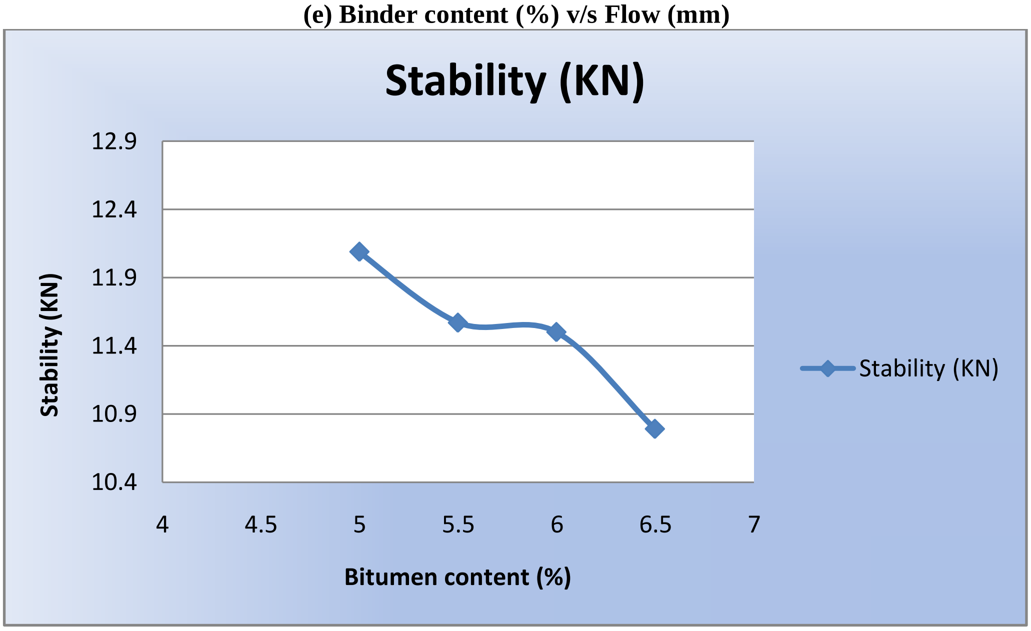


(e) Binder content (%) v/s Flow (mm)



(f)Binder content (%) v/s Stability (kn)

Figure -4 (a-f) properties of SMA sample for mid gradation by Marshall Method

Marshall Properties

The Marshall stability value for the HMA mix without iron ore tailings are found to be 9.17KN.The Marshall Stability value for the HMA mix with iron ore tailings of 25%, 50% 75%, 100% are found to be 13.60KN, 11.60KN, 10.80KN and 9.54KN respectively. The Marshall Stability values are found to be more in 25% replacement of IOT with natural aggregates. This maximum stability is may be due to better coating and bonding between the mixes. The voids in mineral aggregates for all samples were between 16-20%. Voids filled with bitumen are in the range of 70-83%.

Properties	**IOT content**				
IOT	0%	25%	50%	75%	100%

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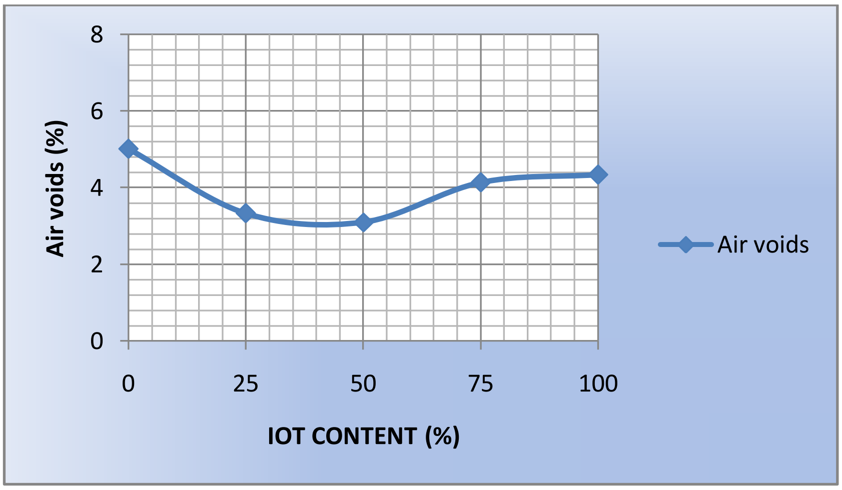
Marshall stability (kN)	9.17	13.6	11.06	10.8	9.54
Flow Value (mm)	9.07	4.47	5.32	5.13	5.8
Bulk density (kg/m^3)	2331.24	2442.06	2479.21	2524.63	2557.86
Volume of voids Vv (%)	5.01	3.33	3.1	4.14	4.34
Voids in Mineral Aggregate VMA (%)	16.82	16.34	17.28	19.35	19.81
Void filled with bitumen VFB (%)	70.2	79.64	82.03	81.47	78.09



(a)**IOT content (%) v/s Air voids (%)**

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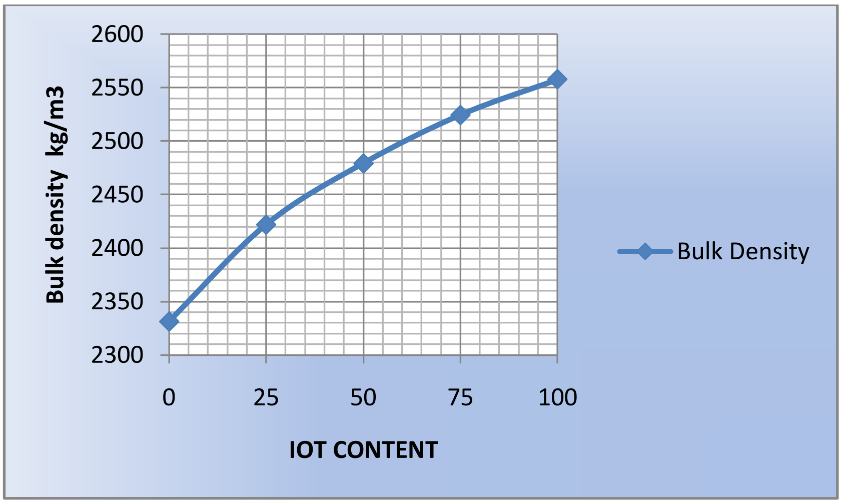
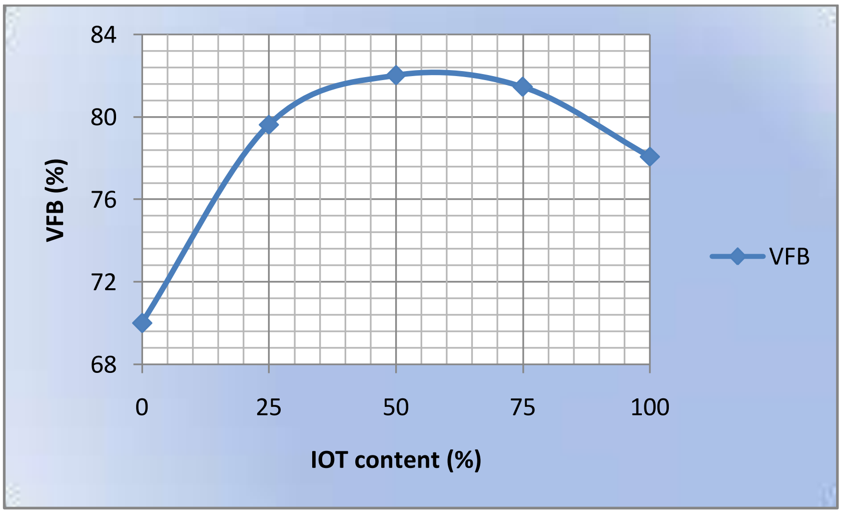
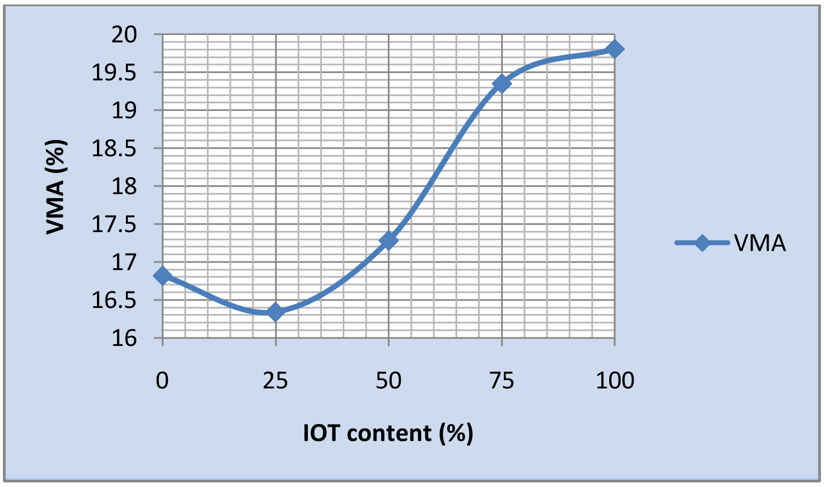


(b) IOT content (%) v/s Bulk Density (kg/m3)



(c) IOT content (%) v/s VFB (%)



(d) IOT content (%) v/s VMA (%)

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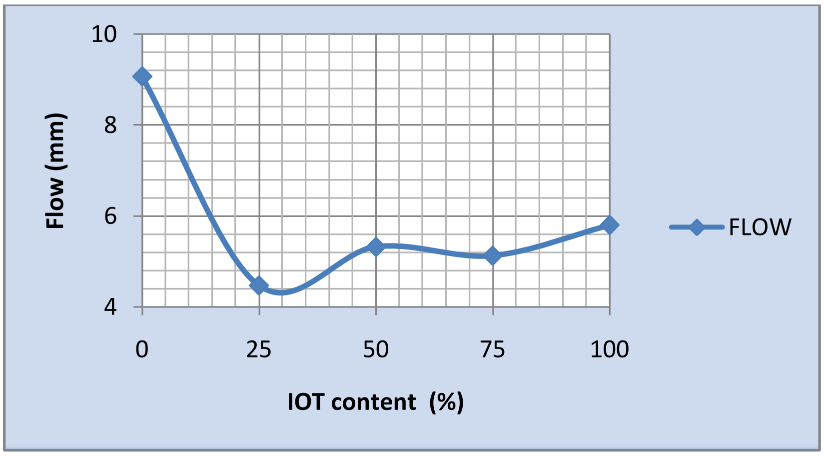
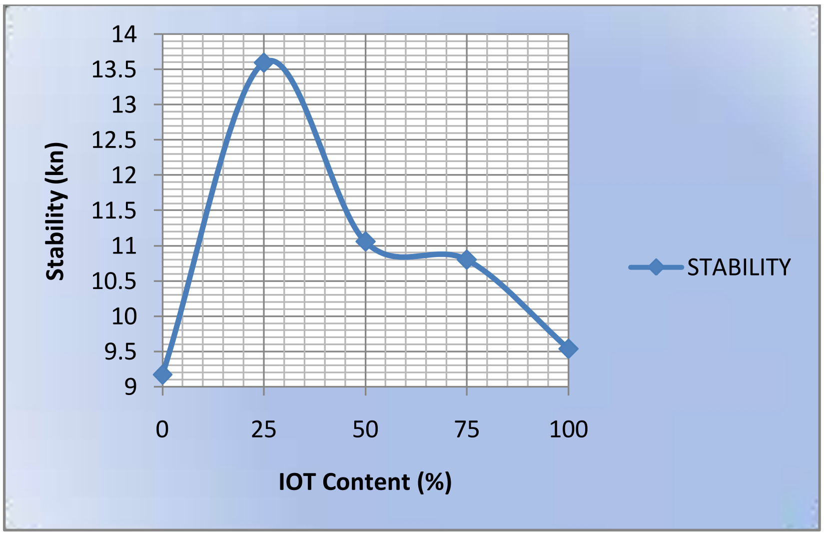


(e) IOT content (%) v/s Flow (mm)



(f) IOT content (%) v/s Stability (kn)

Fig-5(a-f) Properties HMA samples using Iron Ore Tailings to prepared by Marshall Method at OBC

CONCLUSIONS

Following conclusions are made based on the result obtained in the present investigation:

1. The physical properties were conducted on the aggregates used in the present studies satisfies the requirements as per the MORT&H specifications.
2. The physical properties were conducted on the 60/70 (VG – 30) grade bitumen and warm mix binder used for the present studies and satisfies the requirements as per MORT&H specifications
3. The Marshall property of HMA in the present studies satisfies the MORT&H specifications.
4. The optimum bitumen content was found to be 5.5% for HMA mix at 150^0 c temperature.
5. The Marshall Stability values are found to be more in 25% replacement of IOT with natural aggregates. This maximum stability is may be due to better coating and bonding between the mixes.
6. The percentage air voids in the mix were found to less in 25% replacement of IOT with natural aggregates.
7. With increase in the properties of IOTs, the bulk density of the mix increased respectively along with VMA.
8. Based on the experiments and tests conducted, 25% replacement of aggregates with IOTs was found to be more suitable road construction and it gives more strength and stability.

Scope for further research

- In the future performance of Iron ore Tailings with other grades of bitumen, modified bitumen, cutbacks and emulsion can also be tested for their performance.

- Use of IOT may also be tested not only for HMAs but also for different other WMAs and super pave.
- Bio-degradability of HMA using UV rays may be investigated in laboratory.

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