EFFECTS OF MODIFYING COLD MIX BITUMEN BY MAKING USE OF VARIOUS METAL SHAVINGS AS REINFORCEMENT

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Abstract: This exploration program aims to inspect the effect of utilizing metal shavings which is a waste item as reinforcing materials on mechanical properties of cold mix bitumen. Two unique sorts of metal shavings were utilized, steel and aluminum. Different samples of cold mix bitumen in with different percentages of steel and aluminum were arranged and tried. The emulsion content was varied from 8-10% by weight of aggregate. 1% cement was utilized as added substance. SS-2 grade emulsion was utilized as binder. The optimum emulsion content was seen as 8.83%. At first an appropriate experimental methodology was framed and afterward the impacts of metal shavings on the performance of compacted mix were examined. Four distinct dosages of metal shavings were taken (0.2%, 0.35%, 0.50%, and 0.65% by the aggregate weight). Laboratory tests (Marshall Test, Indirect Tensile Strength test, Abrasion Resistance Test) normally utilized for hot mixes were considered, adjusting the testing techniques considering the particular characteristics of cold mixes. The outcomes demonstrated huge improvement in mechanical properties of mixes. Marshall and Flow values of the mixes were seen to be improved, the Indirect Tensile Strength increased, that demonstrates a considerable commitment towards slowing crack propagation. Also finally, abrasion resistance that was represented in terms of particle loss also improved.

***Index Terms* – Cold mix, Additives, Metal shavings, Optimum emulsion content, Marshall stability, Tensile strength, Flow value, Abrasion resistance.**

I. INTRODUCTION

Certain aspiring road development strategies and exercises principally include bituminous asphalts with the hot mix innovations. The technology based on hot mixes that has been traditionally used for the construction of roads has fundamentally fulfilled the performance requirements over numerous years. Though in terms of performance, this technology is regarded as the most viable for the asphalt structures, however its common usage has a few downsides like the hazards they pose to environment, high utilization of energy, increment in the amount of greenhouse gases released into atmosphere, less yield for the production of mix, etc. Also, because of the geological and climate imperatives in some places like Jammu & Kashmir, Arunachal Pradesh, Meghalaya, it is hard to work with hot mix in such bumpy locales. So it is imperative to discover an appropriate alternative option for the hot mix technology.

Cold mix technology, which is usually emulsion based, the processes which include adding pre-wetting water to the aggregates, incorporation of the emulsions in it, production of the mix, laying and the compaction, all are performed at the room temperatures (23°C to 25°C). Moreover, various trials carried on field on mixes have also revealed that the cold mixtures can simply be manufactured by utilizing hot mix plants and can be placed by using same procedures. This technology has also successfully proved to be labor friendly.

Despite the fact that the emulsion based cold mixes overcome hot mix issues, they have pulled in little consideration yet are viewed as substandard as compared to hot blend in their utilization as structural layers mainly because of their less acceptable performance. Thanaya et al. (2009) announced some issues with cold mixes, which could not be overlooked, for example, high content of air-voids in the compacted mixes, frail early life strength because of pre-wetting water, greater time is required by the samples until fully cured for better performance. With a view to improve the properties of cold mixtures, various researches have been performed till now, still they are not many in number as compared to hot mixtures.

In order to broaden cold mix applications, their methods of testing and specifications, this study needs advanced research studies and proper field examinations. Hot blend innovation has witnessed noteworthy advances through numerous researches. Cold mix innovation is lagging behind in research as well as application phases, something that is very noticeable in developing countries like India. Cold mix asphalt pavement can provide energy savings up to 50% in contrast to traditional hot mixes. So it tends to be considered as green bituminous mix for rural road construction and development. It very well may be effortlessly arranged utilizing little set up nearby. It very well may be delivered physically for little scope work.

The principal target of our study is the laboratory examination of the exhibition of metal shaving reinforced Cold Mix Asphalt (CMA) mixtures. These mixtures are additionally contrasted with traditional hot mix asphalt mixtures. Broadly, the aim of this research work is detailed below.

- To stipulate suitable design mix parameters and to assess their consequent effects on the properties of the cold mix asphalt mixtures (CMA).
- To analyse and evaluate the effects of the metal shavings on the properties of the cold asphalt mixtures.
- To suggest the most viable design mix parameters so as to enhance the performance of cold asphalt mixtures.

- To determine the optimum dosages of the metal shavings and additives used and their effect on gain in the early strength of cold mix asphaltic mixtures.

II. METHODOLOGY

In this investigation, BM graded cold mixes were readied. Determination of materials and aggregate gradations was according to particulars indicated later. The step by step preparation and testing of samples and aggregates was carried out. The impacts of additives on the mix and determination of their ideal dosages was likewise inspected. Various properties of mixes were figured and design parameters, for example, voids content, voids filled with binder and so on were calculated and ideal emulsion content was computed. The metal shavings were included in different percentages and their impact on individual design parameters of mix, such as, Marshall stability, density, air voids, voids filled with bitumen, flow value was estimated. For compaction of cold mixes, Marshall Compaction was followed. 1% cement by weight of aggregate was utilized as a filler material. At this filler content, the most consistent mix was acquired. Finally, cold bituminous mix was strengthened in with two kinds of shavings (steel and aluminum) dosed at 0%, 0.2%, 0.35%, 0.50% and 0.65% by weight of aggregates. The overall methodology of the experimental program is described as follows:

- Selection of material and BM gradation.
- Selection of cold mix design procedure.
- Adding 1% cement as filler material.
- Determining optimum composition.
- Adding steel and aluminium shavings as reinforcement.
- Developing samples with different % of reinforcement.
- Result analysis and conclusion.

III. MATERIALS

A) Aggregates

For the preparation of cold mixes, the gradations of bituminous macadam (BM) were taken in accordance with the IRC:SP:100 (2014) specifications that are given in the Table 1, as follows.

Table 1 Adopted Gradation (BM) for Aggregate

Nominal Maximum Aggregate Size 19 mm		
Sieve size (mm)	Specified Limit (%)	Percentage passing
26.5	100	100
19.0	90-100	100
13.2	56-88	61.15
9.5	20-55	41.36
4.75	16-36	19.75
2.36	4-19	13.17
0.30	2-10	9.93
0.075	1-4	2.09

i) Coarse Aggregates

The raw materials comprised of stone chips, were gathered from a nearby local source. Aggregates having dimensions upto 4.75mm IS sieve sizes were utilized as the coarse aggregates. The specific gravity was seen as 2.75 according to the IS: 2386 (Part-III) procedures. The standard testing methods were employed to evaluate the other dominant physical properties and are summed up in Table 2.

Table 2 Physical Properties of Coarse aggregate

Property	Test Method	Test Result
Aggregates Impact Value (%)	IS:2386 (Part-IV)	18.18
Aggregates Crushing Value (%)	IS:2386 (Part-IV)	13.01
Los Angeles Abrasion Value (%)	IS:2386 (Part-IV)	18.08
Flakiness Index (%)	IS:2386 (Part-I)	18.84
Elongation Index (%)	IS:2386 (Part-I)	21.4
Water Absorption (%)	IS:2386 (Part-III)	1.2

ii) Fine Aggregates

The raw materials comprised of the stone crusher dusts, were gathered from a nearby crushing plant. The aggregate with the fragments passing through the 4.75mm IS sieve and held on the 0.075mm IS sieve were utilized as fine aggregates. Their specific gravity was observed as 2.620 according to the IS: 2386 (Part-III) procedures.

B) Filler

The raw materials for the stone crusher dusts were gathered from a local crusher while the cement (Grade 43) was collected from the nearby store. Material passing through the 0.075mm IS sieve was used as the filler material. For cement, the specific gravity was seen as 3.15.

C) Binder

Slow Setting (SS-2) bitumen emulsion gathered from the reliable source was used in this investigation to prepare the samples. Slow-Setting-2 bituminous emulsion is a specially designed water based bitumen emulsion with low viscosity and the extended setting time. Slow-Setting-2 bitumen emulsion is manufactured strictly as per the provisions of IS-8887:2004. The residual asphalt percentage was seen as 64%. Various important physical properties of this binder are given in Table 3.

Table 3 Physical properties of bitumen emulsion (SS-2)

Property	Test Method	Test Result
Viscosity by Say Bolt Furol Viscometer at 50°C in seconds	IS:8887-2004	120
Residue by Evaporation in (%)	IS:8887-2004	64
Residue Penetration at 25°C, 100gm, 5 sec in 0.1 mm	IS:8887-2004	84
Residue Ductility at 27° C in cm	IS:8887-2004	95
Residue Specific Gravity	IS:1202-1978	1.01

D) Metal Shavings

Metal shavings that are unwanted materials from the metal manufacturing plants, are generally acquired from metal industries or machining stores. Two different types of metal shavings were used i.e. steel (Fig 1) and aluminum (Fig 2). Shavings of size passing through 4.75mm sieve were used as reinforcement material.

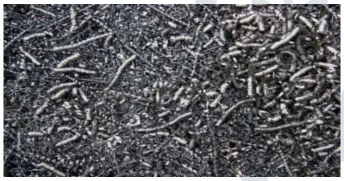

Figure 1 Steel Shavings

Figure 2 Aluminium Shavings

IV. EXPERIMENTAL INVESTIGATIONS

A) Preparation and testing of samples

At present, there is no universally acknowledged design procedure for a cold mix. In this examination, the mixes were produced utilizing a simplified cold-mix design procedure which was previously employed by the researchers. This design method beats the impractical necessity to determine the optimum water content at the compaction on location. It guarantees that the air void prerequisite is met; that the retained stability is computed at optimum residual bitumen content only, which lowers the quantity of samples required, and it likewise gives information about the ultimate strength of the cold mix under the full curing conditions. The mix design procedure involves a number of sequential steps which are enumerated as follows.

(a) Estimation of aggregate gradation.
(b) Determination of the IEC.
(c) Binder coating tests with variations in pre-wetting water content to obtain the best aggregate coating.
(d) Estimation of the adequate compaction level to serve necessities of final air void content.
(e) Emulsion contents are varied.
(f) Curing of the compacted samples.
(g) Estimation of optimum residual bitumen content.
(h) Retained stability at the optimum residual bitumen content is computed.
(i) The ultimate strength at full curing conditions is computed.

The mixes were prepared in accordance with the cold mix design procedure as illustrated follows.

- The validation of design procedure was accomplished by taking five sets of IEC for Marshall Compaction Method, one IEC value was taken as per given formula and other were taken as per given formula and the other were taken by increasing emulsion content 0.5%.

- In next step 1% cement was substituted separately for stone crusher dusts in the mix composition. In this study, the stone crusher dust was used as the primary filler material while cement; the secondary filler material was used as an addititive.
- Medium level of compaction i.e., 50 blows on each end using a Marshall hammer was done.
- The mix properties were analyzed by determining Marshall properties of the compacted mixes. The optimum emulsion content (OEC) was determined.
- Cold bituminous mix reinforced with two types of shavings (steel and aluminum) dosed at 0%, 0.2%, 0.35%, 0.50% and 0.65% by weight aggregate were prepared with OEC and analyzed by determining Marshall properties.

B) Laboratory testing

i) Marshall Test

The Marshall test is utilized to choose and proportion aggregates and asphalt material for the preparation of mix design. The primary reason for conducting this test is the evaluation of optimum binder content that will ensure maximum strength to the mix. In this test procedure, the resistance to the plastic deformation of a compacted cylindrical measure of bituminous mixture is estimated when the sample is loaded diametrically at a deformation rate of 50 mm per minute.

ii) Indirect Tensile Strength Test

Indirect Tensile Strength test is utilized to assess the Indirect Tensile Strength (ITS) of bituminous mixes. In this test, a compressive load is applied on a cylindrical measure (Marshall Sample) along a vertical diammetrical plane through two curved strips whose radius of the curvature is the same as that of the sample. A uniform tensile stress is created perpendicular to the direction of the applied load and along a similar vertical plane making the sample to fail by splitting. This test is also called as splitting test.

iii) Abrasion Resistance Test

Asphalt mixes are exposed to wearing impacts persistently because of traffic loads. Hence, leads to degradation of pavements. This test gives the measure of Abrasion Resistance of the mix. This test is also called as Cantabro Test. In this test, Marshall samples of various types of mixes were tested by utilizing the Los Angeles rattler machine. It comprises of exposing a compacted sample to 300 revolutions (30 cycles per min) inside Los Angeles rattler machine with no metal balls.

V. RESULTS AND DISCUSSION

A) Design justifications and OEC determination

The samples so prepared were compacted by Marshall Method after mixing the aggregate, crusher dust and 1% cement as filler material according to the adopted aggregate gradation as specified earlier. The Marshall Specimen were subjected to different tests viz bulk density, stability and flow values. Marshall Stability and Flow values were determined in dry state at 25 degree Celsius. Different properties of mixes were determined and design parameters like voids content, voids filled with binder etc were calculated. Finally optimum emulsion content (OEC) was determined.

The mix was designed, keeping a number of factors in mind, to ensure high quality standards such as aggregate shape, specific gravity of the aggregate, aggregate type and residual asphalt content. As per the criteria of adopted design procedure illustrated earlier, samples were produced by Marshall Compaction. The test results have been summarized in Table 4 and are illustrated in Fig. 3 to Fig 7.

Table 4 Marshall test and Density-Void Analysis

Emulsion content (%)	Stability (Kg)	Flow (mm)	Bulk density	V_v	V_b	VMA (%)	VFB (%)
8	533.5	7	2.339	12.87	18.33	31.20	58.74
8.5	570.06	7.1	2.348	12.13	19.55	31.68	61.70
9	610.24	7.25	2.389	11.33	21.06	32.39	65.02
9.5	580.59	7.75	2.360	9.95	21.96	31.91	68.82
10	550.50	8.4	2.342	9.45	22.94	32.39	70.83

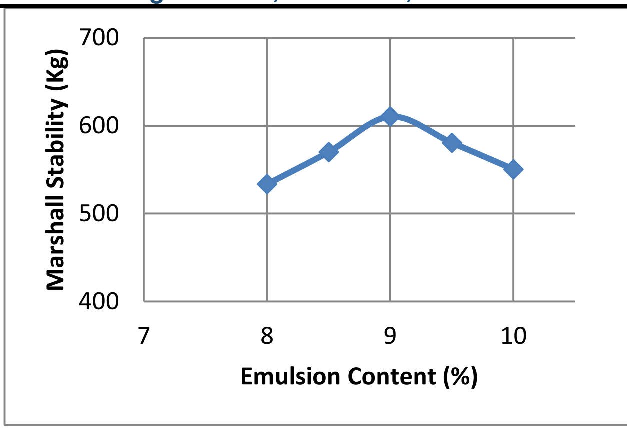

Figure 3 Marshall Stability Vs Emulsion Content

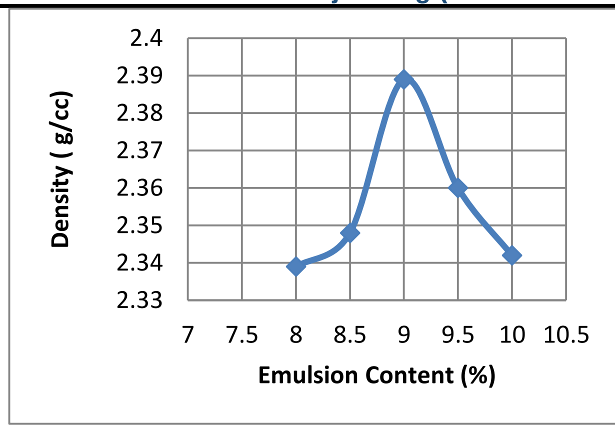

Figure 4 Bulk Density Vs Emulsion Content

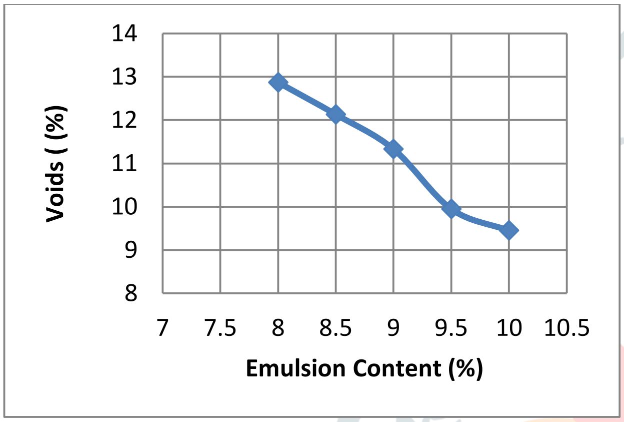

Figure 5 Air Voids Vs Emulsion Content

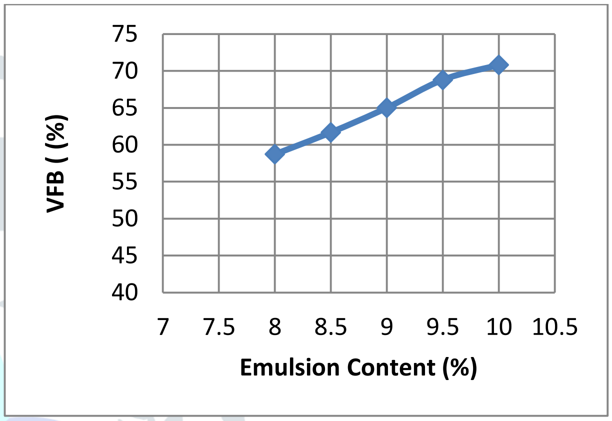

Figure 6 VFB Vs Emulsion Content

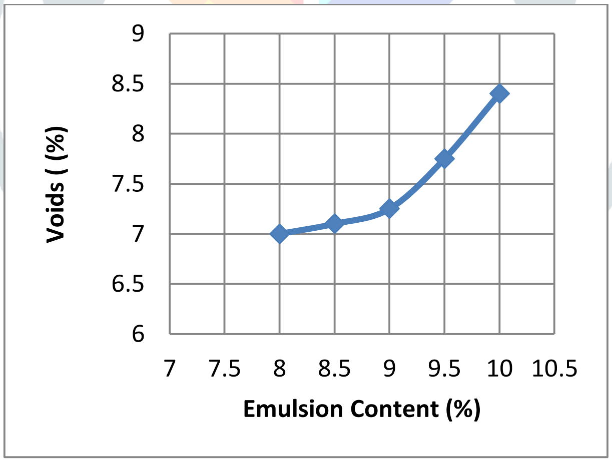

Figure 7 Flow Value Vs Emulsion Content

Considering the results obtained as shown in Fig. 3 to Fig. 7, it was observed that the maximum stability was achieved at 9% emulsion content also bulk specific gravity is maximum at 9% emulsion content. Emulsion content corresponding to 12% air voids was found to be 8.5%. The OEC was taken as the mean of these three values.

B) Effect of Metal Shavings

i) Steel shaving reinforced cold mixes

0.2, 0.35, 0.50, and 0.65% steel shavings were added to the cold mix. The obtained test results are shown in Fig.8 to 11. It was observed that with the increase in % of steel shavings, Marshall stability increased and flow value decreased. Also the indirect tensile strength of cold mixes increased with increase in % of steel shavings. Abrasion resistance calculated in terms of particle loss also increased with increase in % of steel shavings.

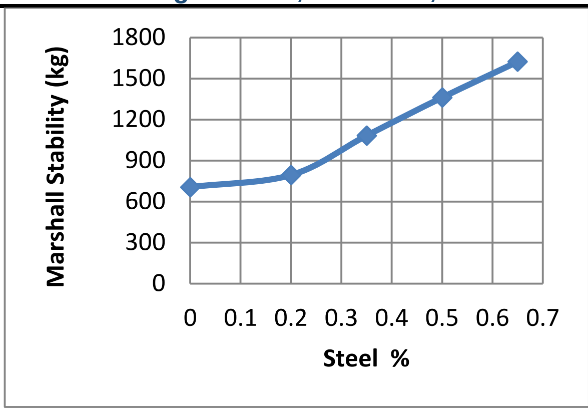

Figure 8 Marshall Stability Vs Steel %

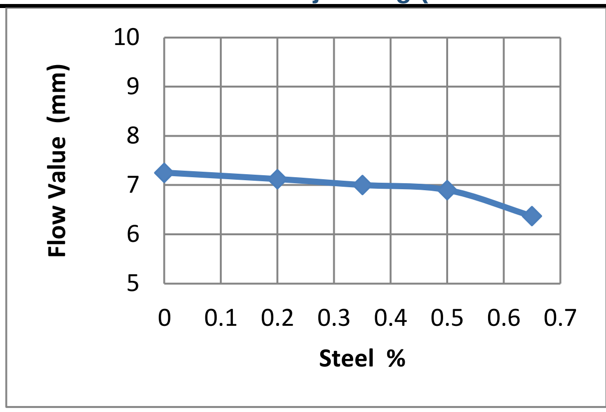

Figure 9 Flow value Vs Steel %

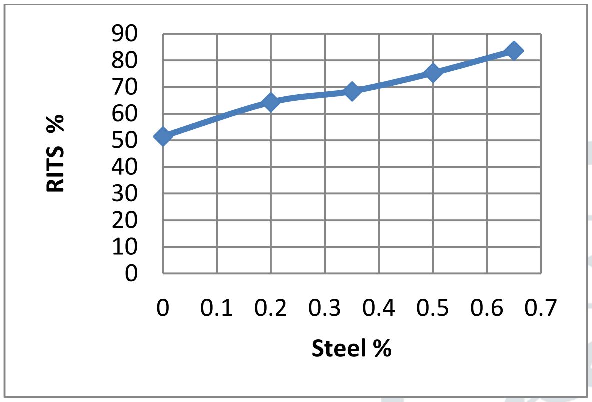

Figure 10 Retained Tensile Strength Vs Steel %

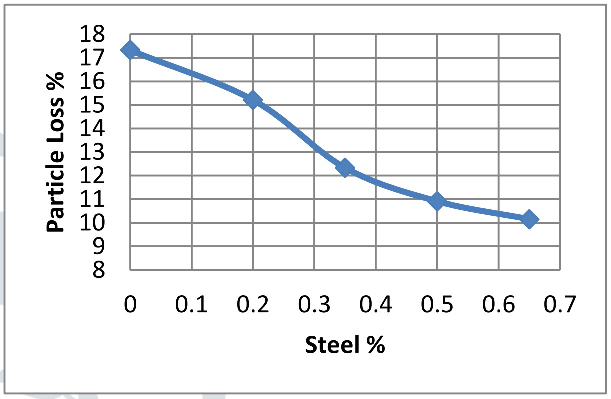

Figure 11 Particle loss Vs Steel %

ii) Aluminium shaving reinforced cold mixes

0.2, 0.35, 0.50 and 0.65% Aluminum shavings were added to the cold mix. The obtained test results are shown in Fig. 12 to Fig. 15. It was observed that with the increase in % of Aluminum shavings, Marshall Stability increased and flow value decreased. Also, the Indirect Tensile Strength of cold mixes increased with increase in % of aluminum shavings. The increase in Marshall Stability was more as compared to steel reinforced samples. The decrease in flow value was also more.

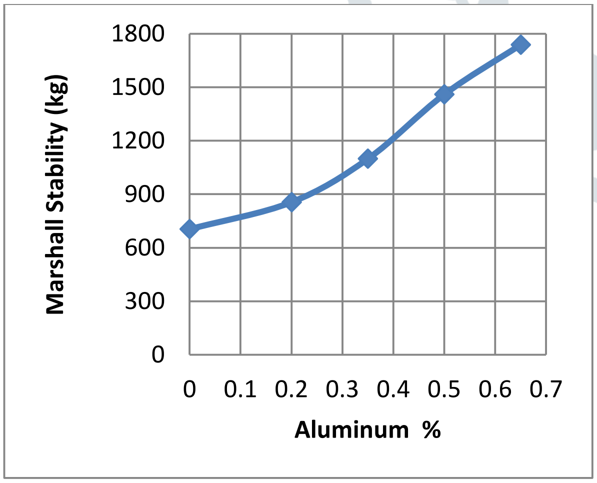

Figure 12 Marshall Stability Vs Aluminum %

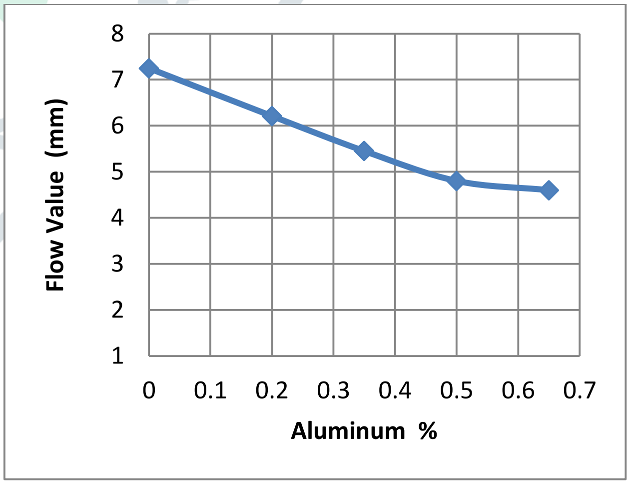

Figure 13 Flow value Vs Aluminum %

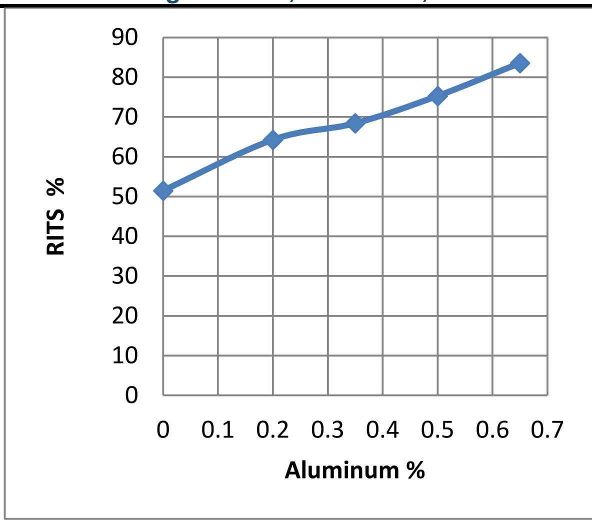

Figure 14 Retained Tensile Strength Vs Aluminum %

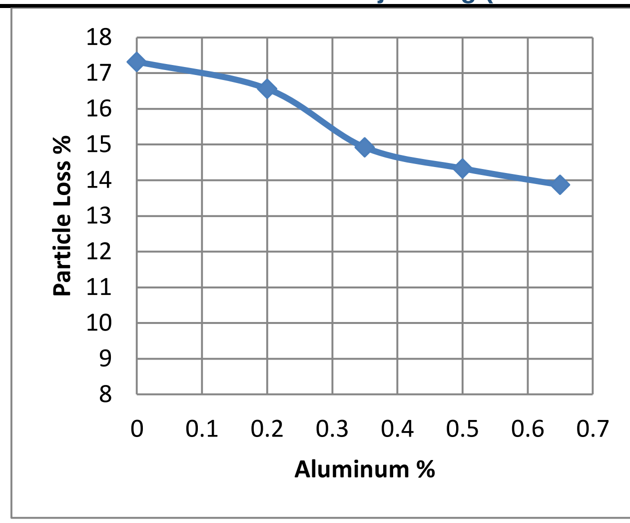

Figure 15 Particle loss Vs Aluminum %

iii) Comparative study between Steel and Aluminum reinforced cold mix

It was observed that the performance of Aluminum reinforced CMBM was better in terms of Marshall Stability, but in terms of flow and tensile strength, Steel reinforced CMBM showed better results. The combined results are given in Table 5.

Table 5 Combined test results of Steel & Aluminum shaving reinforced CMBM

Metal Shavings %	Marshall stability (kg)		Flow Value (mm)		Retained Indirect Tensile Strength (%)		Particle Loss (%)	
	Steel	Aluminium	Steel	Aluminium	Steel	Aluminium	Steel	Aluminium
0.00	705.00	705.00	7.25	7.25	51.44	51.44	17.32	17.32
0.20	793.00	856.00	7.12	6.21	64.24	60.54	15.21	16.56
0.35	1082.00	1099.00	7.00	5.45	68.38	65.28	12.33	14.92
0.50	1361.00	1460.00	6.90	4.80	75.26	69.31	10.91	14.33
0.65	1623.00	1738.40	6.37	4.60	83.54	73.54	10.15	13.87

IV. CONCLUSIONS

From the study conducted, following conclusions were drawn based on the performance of the cold mix.

- The Marshall stability of the CMA mixtures reinforced with metal shavings increased with the increase in percentage of metal shavings for both steel and aluminum. The increase in stability was seen more in mixes reinforced with aluminum shavings.
- The flow values of CMA mixtures reinforced with metal shavings decreased with the increase in the % of metal shavings for both steel and aluminum. The decrease in flow value was seen more in aluminum reinforced mixes.
- The retained indirect tensile strength of CMA mixtures reinforced with metal shavings showed substantial increase in % of metal shavings. The steel reinforced mixes showed better results than aluminum reinforced mixes.
- Particle loss of CMA mixtures decreased with increase in the percentage of metal shavings for both steel and aluminum. Thus it can be said that abrasion resistance increased with the increase in the % of metal shavings.
- The examination demonstrated that metal shavings are uniformly scattered in the mixture. The shavings have various diameters, width, and spatial orientation, affirming the heterogeneity of this sort of metal.
- The increase in 1–2% cement by mass into cold mixes essentially improved the general performance of the cold mix; specifically the tensile strength (ITSM), resistance to creep and also accelerated strength gain process. It didn't, in any case, improved the fatigue performance of the cold mixes beyond that of the hot mixes.
- The edge defects and complex geometry of the metal shavings surface didn’t support the bitumen flow during compaction, despite the fact that these assist in increasing the adhesion of the metal shavings to the bituminous mix, decreasing the pull-out failures by external mechanical effect.

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