Evaluation of Strength and Performance Characteristics of Cold Mix Bitumen using Reclaimed Asphalt

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Abstract*- An attempted has been made to evaluate the strength and performance characteristics of cold mix bitumen using reclaimed asphalt. An experimental result obtained from laboratory testing of the physical and mechanical parameters of the recycled material, in which the material from the existing pavement layers were analyses. The air void content, Marshall stability and flow of the recycled mixtures were investigated. The tests were performed on the road base mixtures incorporating reclaimed asphalt pavement (RAP) with bituminous emulsion. It was observed that the reclaimed asphalt was having impact strength of 10%, crushing strength of 8.2%. It is significant to note that the reclaimed aggregate which was subjected to loading condition already was still showing very good strength properties. The maximum stability obtained from optimum binder content was 384 kg which is a very good value for a cold mix made up of reclaimed asphalt aggregate. The flow value obtained was also 5.06 mm as observed. The aim of the tests was to evaluate the properties of the mixes in terms of the recycled aggregates. Satisfactory results were obtained.

***Keywords*: Bitumen Emulsion, Reclaimed Asphalt pavement (RAP), Cold mix bitumen.**

I. INTRODUCTION

Development of potholes on roads and streets of India after the onset of monsoons is a common phenomenon. Quit often, potholes are repaired with crude techniques such as placing soil or bare aggregate in the potholes because no hot mix asphalt is available during monsoons. The advantages of using HMA are higher stability, ease to compact and good in workability than the cold mix. One of the major disadvantage of using HMA is the emissions from hot plant mixes create pollution and thus degrade the environment. The different layers of road construction require a higher temperature range for production and laying the mix and rolling etc. Therefore, bituminous road construction with conventional paving grades bitumen is sometimes not feasible or even not desirable in high rainfall areas as intermittent rain throughout the year affect production and laying of mixes for pot holes. The cold mix can be stockpiled and remains workable for at least 6 months and therefore, it can be used throughout the year including the rainy season.

A. Cold-Mixed Patching Mixtures

These mixtures are composed of liquid bituminous binders and aggregates that have not been heated. Mixing is done either in a plant, where the materials are proportioned, or on a paved surface with few controls. The mixtures are stockpiled until needed and used cold in any season. They have the lowest quality of all the patching mixtures. Hot-mix materials are usually expected to perform better than the cold-mixed and they are considered to be permanent. Therefore, many agencies use hot-mix during summer for permanent patching. Cold-mix materials can be used in winter for temporary repairs.

B. Bitumen Emulsion

Eighteen hundred years ago, Galien, prepared the first ever man made emulsion mainly for cosmetic application. Seventeen Centuries later, Europe became the birthplace of Bitumen Emulsion. Bitumen is known to mankind for over 5000 years though the first road binders were Tars and very often 1854 are mentioned as being the year when the first paving was laid on a village square in France using a fluid Tar produced in the local gas plant. In 1922 an English chemist, Hugh Alan Mackay, filed a patent on “Bitumen Emulsion”. Generally speaking, this event is considered to be the starting point of a new generation of road binders which was to revolutionize road construction techniques in the years to come.

Since Bitumen is difficult to work with at ambient temperatures. Chemists have over the years developed techniques to convert it into stable emulsions. By definition, an emulsion is dispersion in the form of very fine particles of one liquid in another liquid in which it is not soluble. In keeping with the definition, natural forces tend to separate the different liquids forming an emulsion, but on time scales varying sufficiently to allow an emulsion to exist for a period lasting a few seconds to several years depending on the particular case concerned. This leads us to the premise that we can enable two liquids to be maintained at least for sometime in the form of an emulsion by using certain external action. This is where the technology developed by Colas S.A., the world leaders in Bitumen Emulsions comes into play. Using the specialized technology and equipment, Colas creates Bitumen Emulsions of various types for different applications.

Though Bitumen Emulsions were introduced into India much later than the western countries, they are fast gaining popularity with rapid advancements in road construction techniques. Today, Bitumen Emulsions are specified in the requirements of most road construction authorities and detailed classification has been done by the Bureau of Indian Standard under IS 8887:2004.The Indian Roads Congress & Ministry of Road Transport & Highways have recommended the use of Cationic Bitumen Emulsion in several applications of Road Work like Tack Coat, Prime Coat, Surface Dressing work, 20 mm Premix Carpet, Sealing of cracks with fog seal etc.

C. Asphalt Emulsion Chemistry[1]

Standard bitumen (asphalt) emulsions are normally considered to be contain from 50% to 75% bitumen, 0.1% to 2.5% emulsifier, 25% to 60% water plus some minor components which are described below. The bitumen droplets range from 0.1–20 micron in diameter. Emulsions with particle sizes in this range are sometimes referred to as macro emulsions. They are brown liquids with consistencies from that of milk to double cream, which depend mostly on the bitumen content and the particle size. Some bitumen droplets may contain smaller water droplets within them.

The viscosity of the emulsion and especially changes in the viscosity of the emulsion during storage are strongly influenced by this internal water phase. There is a distribution of particle sizes in the emulsion, and this distribution is influenced by the emulsion recipe and the mechanics and operating conditions of the emulsion manufacturing plant. The particle size and the particle size distribution of the emulsion droplets strongly influence the physical properties of the emulsion, such as viscosity and storage stability; larger average particle size leads to lower emulsion viscosity, as does a broad or bimodal particle size distribution. Particle size also influences the performance of emulsion. In general, smaller particle size leads to improved performance in both mix and spray applications. Some recent developments in asphalt emulsion technology have focused on the ability to control the particle size and size distribution of the emulsion during the emulsification process, and consequently to influence the emulsion properties.

D. Reclaimed Asphalt[2]

Asphalt pavements are America's most recycled product. According to the U.S. Environmental Protection Agency and the Federal Highway Administration, about 90 million tons of asphalt pavements are reclaimed each year and over 80 percent of that total is recycled. But in India, due to lack of awareness and research on this field, still we are not using this technique extensively.

Reclaimed asphalt pavement (RAP) can be recycled into pavement that is as high, or even higher, in quality as pavements made of all-virgin materials. And, the same material can be recycled again and again; it never loses its value. The asphalt cement, the glue that holds the pavement together, retains its ability to function as glue or cement, so that it is reused for its original purpose. The aggregates (rocks, sand, and gravel) in the original pavement are also conserved. Many pavements that are more than 20 years old are actually worth more than they were when originally constructed. Recycling asphalt pavement makes both environmental and economic sense. Reclaimed asphalt pavement constitutes a "treasure trove" of pre-processed road-building materials. The use of recycled asphalt pavement has grown widely, reducing the use of virgin materials and helping to preserve landfill space. Highway agencies and taxpayers benefit because recycling stretches tax dollars, allowing more roads to be kept in better condition.

Reclaimed asphalt pavement (RAP) is the term given to removed and/or processed materials containing asphalt and aggregates. These materials are generated when asphalt pavements are removed for construction, resurfacing, or to obtain access to buried utilities. Asphalt recycling is the re-use, usually after some processing of a material that has already served its first intended purpose. Asphalt binder can be re-melted and reused several times, regardless of the original method of construction.

II. METHODOLOGY

A. Aggregates Tests

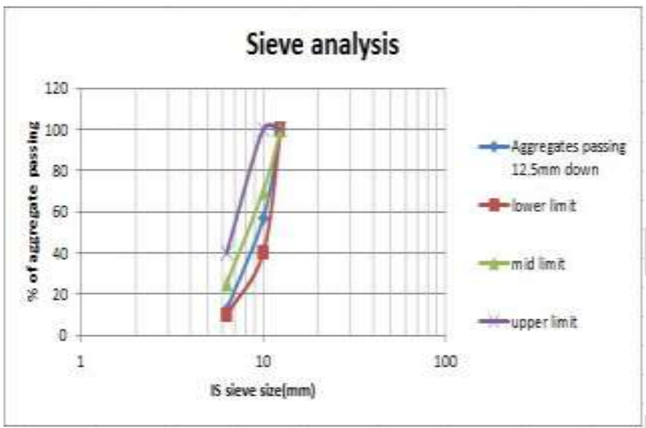
The reclaimed asphalt will be obtained in the form of large irregular size boulders. This must be brought down in size as per requirement. The size can be reduced either manually or by mechanical equipments. The former can be done with the help of a hammer while the latter requires the use of any mechanically operated crushers such as jaw crusher, cone crusher etc. once crushing process is done the reclaimed aggregates is sieved and separated as per their sizes.

Fig. 1 Reclaimed asphalt

1) Sieve Analysis:

Table no. I Gradation of Stockpile Patching Mix

IS Sieve Size (mm)	Aggregates passing 12.5mm down	Specified Gradation	Specified Lower limit	Specified mid limit	Specified upper limit
12.5	100	100	100	100	100
10	56.7	40-100	40	70	100
6.3	12.5	10-40	10	25	40



Graph 1: Sieve Analysis Results Of Reclaimed Asphalt Material

2) Test results on Aggregates:

Table no. II Aggregate test results

Serial no.	Test name	Result
1	Flakiness Index	11.5%
2	Elongation Index	12.83%
3	Angularity	4.42
4	Crushing strength	8.2%
5	Impact strength	10%

B. Tests on bitumen[3]

1) Residue by Sieving through 600-Micron IS Sieve:

Wash the sieve with xylene and then with acetone. Place it in the dish, dry in the oven at 100 to 11O°C for 1 hour, cool and weigh, to the nearest 0.01 g (W1). Remove uniformly the 4-litre sample by gentle agitation and strain immediately through the sieve into the clean, dry container. Sieve the low and high viscosity emulsion at room temperature. When whole of the emulsion has been passed through the sieve, remove the sieve and weigh the container to the nearest 1g (W2). The difference between W1 and W2 will give you the measure of residue content present in the bituminous emulsion.

2) Coagulation by miscibility with Water:

Gradually add 150 ml distilled water, with constant stirring to 50 ml of emulsion in a 400-ml beaker at a temperature of 20- 30°C. Allow the mixture to stand for 2hr. and examine it for any appreciable coagulation of the bitumen content of the emulsion.

3) Coating Test:

Using the IEC (Initial Emulsion Content) value Coating Test shall be carried out by mixing all of the batches dry aggregates and filler, and pre-wetted with varied amount of water. The asphalt emulsion is added afterwards and then mixed for about 2-3 minutes until even coating obtained. The optimum pre-wetting water content (OPW) that gave the best asphalt coating on the mineral aggregates then can be determined.

Table no. III Properties of emulsions

Properties	Values Obtained	IS: 8887-2004 Requirements
Residue on 600 micron IS Sieve, percent by mass	0.04	0.05
Viscosity at 25°C by Saybolt Furol viscometer, seconds:	26	20-100
Miscibility with water	No Coagulation	No Coagulation

C. Determination of Optimum Bitumen Content[4]

For the determination of OBC, graphs are plotted with bitumen content on the X-axis and following values on the Y-axis

- Marshall Stability values
- Flow values
- Unit weight or Bulk Density (G_b)
- Percent air voids in total mix (V_v)
- Percent voids filled with bitumen (VFB)

1) Volumetric analysis:

The specimens are compacted at 75 blows; compactive effort on both sides is used for volumetric analysis. Using the following set of equations, the maximum theoretical specific gravity and bulk specific gravity of the mixes, the volumetric properties of the bituminous mixes are evaluated.

i) Consider,

Gt = theoretical specific gravity,
Gm = measured/bulk specific gravity,
Gb = bitumen specific gravity,
Va = percentage air voids,
Vb = bitumen void,
Wb= percentage by weight of bitumen in total mix

ii) Now,

Va = (Gt-Gm)*100/Gm
Vb = (Gm*Wb)/Gb
VMA = Va+Vb (Graph 7)
VFB = Vb*100/VMA (Graph 8)

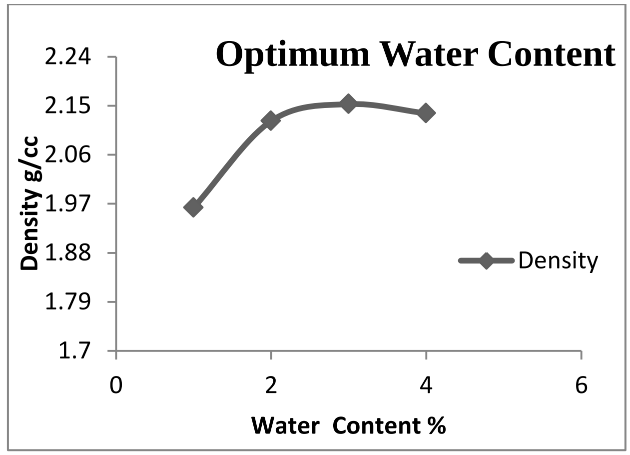
Where,

VMA is Voids in Mineral Aggregate
VFB is Voids filled with Bitumen

2) Procedure to determine OPW[4]:

The aggregates to be used for the study are proportioned according to the specified gradation as given in the Table 3.1 and were batched into a mass of 1200g. A predetermined percentage of water by dry weight of aggregates was added and mixed thoroughly and the approximate amount of bitumen emulsion as obtained by coating test is added and mixed ensuring proper coating. This process is continued by varying the amount of water added until the mix becomes soupy or segregate on standing and the mixes were examined visually for maximum coating. After obtaining the water content for maximum coating, the aggregate batches were mixed by varying water content, but with bitumen emulsion being same and were compacted using Marshall Rammer. These compacted specimens were cured for 24 hours in room temperature and later their density values were found out.

A plot was made of density versus water content at compaction. The water content resulting in the highest density is optimum for compaction and this water content was used in the further studies regardless of the residual bitumen content as shown in graph 2.



Graph 2: Optimum Water Content

D. Marshall Test Procedure[5]

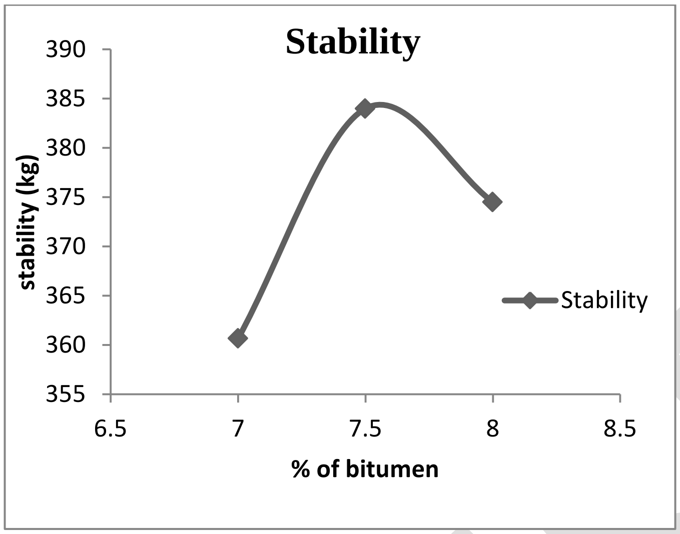
Select aggregate grading to be used. Determine the proportion of each aggregate size required to produce the design grading. Prepare the trial specimens with varying asphalt contents.

The aggregates to be used for the study are proportioned according to the specified gradation and were batched into a mass of 1200g. A predetermined percentage of water by dry weight of aggregates was added and mixed thoroughly and the approximate amount of bitumen emulsion as obtained by coating test is added and mixed ensuring proper coating. This process is continued by varying the amount of water added until the mix becomes soupy or segregate on standing and the mixes were examined visually for maximum coating. After obtaining the water content for maximum coating, the aggregate batches were mixed by varying water content, but with bitumen emulsion being same and were compacted using Marshall Rammer by giving 75 blows each side. Keep the specimen at 40°C for 72 hrs. Determine the specific gravity of each compacted specimen. Perform stability tests on the specimens. Calculate the percentage of voids, and percent voids filled with Bitumen in each specimen. Select the optimum binder content from the data obtained.

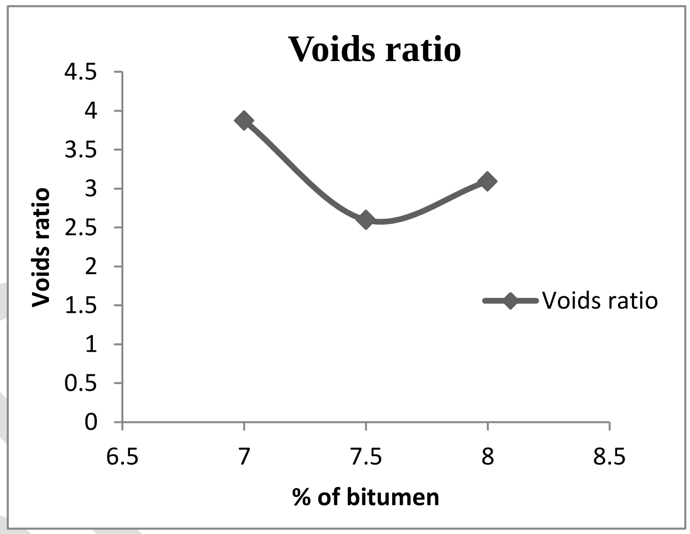
E. Marshall properties

Sl. No.	Percentage of bitumen	Average Height (mm)	Wt of specimen (gm)	Gb	Gt	Vv (%)	Vb (%)	VMA (%)	VFB (%)	Stability (KN)	Flow value (mm)
1	7	60.23	1002	2.23	2.324	3.793	8.44	12.23	68.98	362	4.72
2		60.15	1007	2.232		3.956	8.42	12.38	68.04	354	6.2
3		61.5	999	2.2		3.86	8.43	12.3	68.56	366	5.44
Average				2.234	2.324	3.872	8.43	12.3	68.53	360.66	5.45
1	7.5	64	1001	2.243	2.99	2.45	9.5	11.97	79.53	388	6.5
2		63.5	1007	2.23		2.64	9.5	12.15	78.22	384	4.4

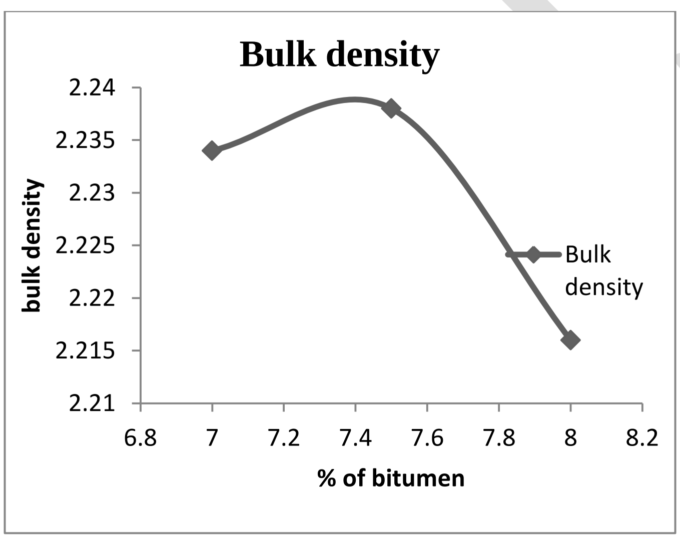
3		63	1008	2.237		2.692	9,49	12.19	77.91	380	4.3
Average				2.238	2.99	2.596	9.508	12.10	78.55	384	5.06
1	8	64.75	996	2.225	2.287	1.429	10.103	11.532	87.609	376.4	5.34
2		64.25	994	2.208		3.448	9.896	13.343	74.163	367.33	5.13
3		64.75	998	2.187		4.4	9.798	14.198	69.011	380	5.9
Average				2.216	2.287	3.092	9.932	13.024	76.928	374.5	5.45



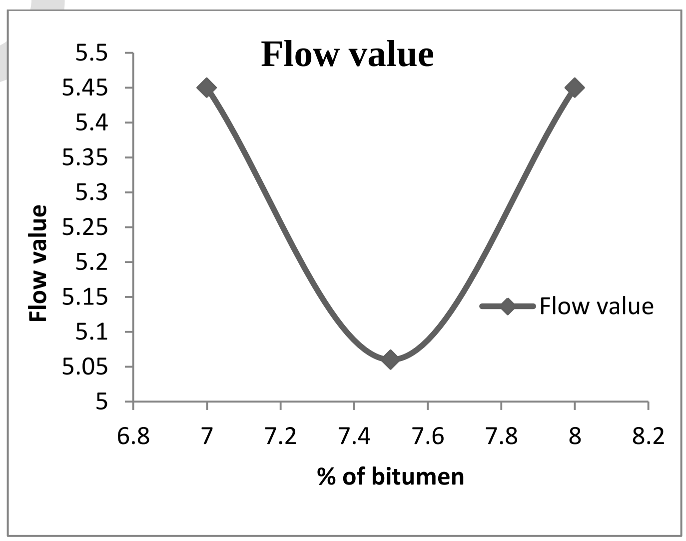
Graph 3 Stability Vs % bitumen



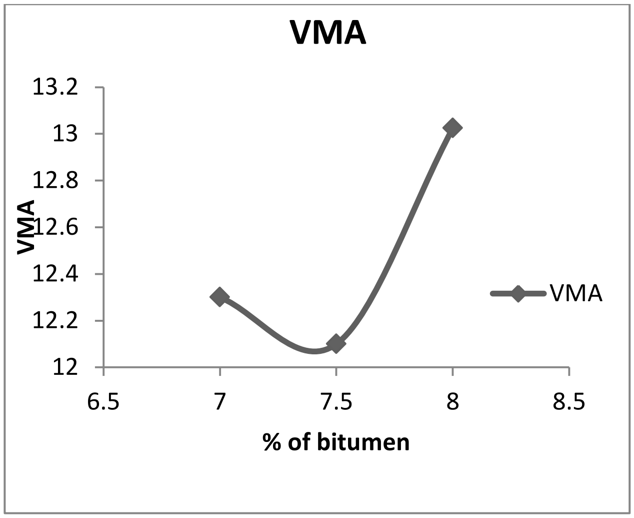
Graph 5 Voids ratio Vs % bitumen



Graph 4 Bulk density Vs % bitumen



Graph 6 Flow Vs % bitumen



Graph 7 VMAVs % bitumen

1) Abstract Sheet of Marshall Properties:

Sl No	Marshall Properties	EMULSION MIX
1	Optimum Bitumen Content, (%)	7.5
2	Stability, (KN)	384
3	Flow, (mm)	5.06
4	Bulk Density, (KN/m^3)	2.238
5	Air Voids (Vv), (%)	2.596
6	VMA, (%)	12.1
7	VFB, (%)	78.55

Table IV Abstract sheet

III. PERFORMANCE STUDY

A pothole is a type of failure in an asphalt pavement caused by the presence of water in the underlying soil structure and the presence of traffic passing over the affected area. Introduction of water to the underlying soil structure first weakens the supporting soil. Traffic then fatigues and breaks the poorly supported asphalt surface in the affected area. Continued traffic action ejects both asphalt and the underlying soil material to create a hole in the pavement. In areas subject to freezing and thawing, Frost heaving can damage a pavement and create openings for water to enter. Spring thaw of pavements accelerates this process when thawing of upper portions of the soil structure in a pavement cannot drain past still-frozen lower layers, thus saturating the supporting soil and weakening it.

Pothole patching methods fall into two distinct categories: temporary and semi-permanent. Temporary patching is reserved for weather conditions that are not favorable to a more permanent solution and usually uses a cold mix asphalt patching compound placed in an expedient manner to temporarily restore pavement smoothness.

A. Field procedure[5]

The pothole is clearly marked out using a chalk piece in square/ round shape. The marked pothole is cut and chipped out as per the marking using chisel and hammer. The surface of the pothole should be even and leveled. Remove the loose particles using broom or an air compressor. Calculate the volume of pothole and determine the amount of mix required to fill and weigh the required amount of aggregates and the calculated bituminous emulsion content to it. Mix the aggregates properly with the emulsion so that aggregates are coated evenly and a uniform black color is obtained. Apply a tack coat over the pothole for binding. Fill the pothole with 3 layers of bituminous mix and compact it evenly. It should be slightly higher than the existing road level.

B. Selected stretches for the field performance studies

The selected stretch is having total length of 500m.Which is located near Dayananda Sagar College of Engineering K. S. Layout Bangalore-78; consist of number of potholes among which five of them were selected. The details of pothole regarding its dimensions (length, breadth and depth) and nearby landmark is mentioned in the below given table.

Table V pothole details

Sl. no	Length (along wheel path) m	Breadth (Perpendicular to wheel path) m	Depth (cm)
1	0.29	0.32	5
2	0.4	0.4	3
3	0.2	0.3	6
4	0.4	0.2	5
5	0.25	0.25	6

IV. CONCLUSIONS

Development of potholes on Indian roads and streets after the onset of monsoons is a common phenomenon. Unfortunately, there is no standard readymade cold patching material available in India, which can be used during the rainy season when hot mix plants are usually shutdown. It is difficult to design stock pile patching mixtures because the properties required in stockpiling, handling and after the material is placed in the pothole or contradictory. Some of these contradictory requirements pertain to aggregate gradation, aggregate shape and binder viscosity. New concept has been postulated to meet the challenges of designing a stock pile cold mix. This cold mix patching is manufactured in a batch type hot mix plant using local aggregates. This mix can be placed without preparing the pothole such as drying, squaring the edges, cleaning and tack coat. The mix can be stock piled and remains workable for at least six months and therefore, it can be used throughout the year including the rainy season.

1) Results:

The physical properties of the emulsion used for this study were tested and are presented in table 3.3. The test results are satisfying the requirements as per IS: 8887-2010 specification. It was observed from table 3.3 which is test on emulsion, Residue on 600 micron Sieve Percent by mass obtained is 0.04% which is greater than specified 0.05% as per IS:8887-2004 and Residue by evaporation is 66% which is greater than specified 50%, as per IS:8887-2004.

2) Marshall test observations:

It was observed from the table 4.2 the Optimum Binder Content of emulsion is 7.5%. The maximum stability obtained from optimum binder content was 384 kg which is a very good value for a cold mix made up of reclaimed asphalt aggregate. The flow value obtained was also 5.06 mm as observed.

3) Reclaimed asphalt properties:

It was observed that the reclaimed asphalt was having impact strength of 10%, crushing strength of 8.2%. It is significant to note that the reclaimed aggregate which was subjected to loading condition already was still showing very good strength properties. Budget constraints reduce preventative road maintenance, with the prevalence of potholes likely to increase significantly. Potholes are typically 'repaired' by mostly unskilled or badly-trained teams on an hoc basis, quite some time after formation, thus leading to additional deterioration.

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REFERENCES

[1]. A Basic Asphalt Emulsion, Asphalt Institute Manual (MS-19).
[2]. Flynn, L. (1992) Three states OK more RAP in recycling specs: asphalt recycling and reclaiming. Roads and Bridges (October issue).Scranton Gillette Communications, Inc Arlington Heights,
[3]. IS: 8887-2004, "Bitumen Emulsion for Roads (Cationic Type)-Specification", Indian Standards Institution.
[4]. Kandhal, P. S. and D. B. Mellott. Rational Approach to Design of Bituminous Stockpile Patching Mixtures. TRB, Transportation Research Record 821, 1981.
[5]. Specifications of Road and Bridge works Ministry of Road Transport and Highways (MoRT&H), Govt. of India, Fourth Edition, 2001