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REVIEW ON MIX DESIGN OF EMULSION TREATED RECLAIMED ASPHALT PAVEMENT

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Abstract - *Reclaimed asphalt pavement (RAP) is a valuable, high quality material that can be replace over expensive virgin aggregates and binder that can be used for technical, economical and environmental reasons. Use of RAP can be favored all over the world over virgin material on the light of increasing cost of bitumen, the scarcity of high quality aggregates and the pressing need to preserve the environment. Overlay and maintenance resolve medium distress, but reconstruction may feasible and economical while Asphalt pavement are badly deteriorated with time and traffic. This requires the removal of existing pavement surfaces. Recycling such construction waste has benefited from economic to sustainability point of view and reduce the exploitation of natural resources. The shortage of virgin aggregate supplies along with the increase in processing and hauling cost have encouraged the use of reclaimed material from the old structure as base course construction materials and involved in regular practice in various countries around the world.*

1. INTRODUCTION

There are several methods of reclaimed asphalt pavements such as: -

1. Hot mix plant recycling
2. Hot in place recycling
3. Cold mix plant recycling
4. Cold in place recycling
5. Full depth reclamation recycling

In our project (Four Lanning of Biaora to Dewas Section from Km 426.100 to Km 566.450 of NH-3 in the State of Madhya Pradesh under NHDP Phase – IV in BOT (Toll) basis on DBFOT pattern.) For low volume traffic on slip roads of flexible pavement, we are recycled the existing bituminous road up to 200 mm depth which falls under the full depth reclamation procedure for producing cost effective mix of recycled material. We are plan to treat the recycled existing bituminous material by emulsion. WMM batching plant will be used for production of these mix after some modification so it will also save cost of separate production unit. In India it will become a very effective technique to utilize recycled material in better way.

2. Objective:

The major Objective of the project is replacing the virgin aggregate due to scarcity of high quality aggregates and the pressing need to preserve the environment. We need to make right proportion of recycle material and fresh aggregate with suitable binder to achieve this object. It is also our objective to produce this mix at very low cost, which satisfies

- Essential for future construction methodology
- Saving of natural resources
- Cost effective
- Environmental friendly
- Solve disposal problem of bituminous waste
- Multi-purpose utilization of recycle bituminous material
- Saving of fuel consumption in cold mix process

The main objective of this project is optimize the Emulsion Treated Reclaimed Asphalt Pavement mix with desirable properties, which satisfies the above mentioned needs.

3. Literature Review:

Many researches and tests were conducted on cold and hot mixes of RAP all over the world. Some reviews of mix design are as follows.

3.1 L. Allen Cooley, Jr., Ph.D. Kevin Williams, P.E

The objective of this study was to evaluate the amount of blending that occurs between RAP and virgin asphalt binders in plant produced HMA in which RAP is incorporated. Recycled Asphalt Pavement (RAP) is the most recycled material in the U.S. RAP has been routinely used in the production of hot mix asphalt (HMA) since the 1970's. Historically, there have been three theories of how RAP behaves when included within HMA. The first is that the highly oxidized asphalt binder contained within the RAP essentially makes the RAP a "black rock". The second theory is that the asphalt binder within the RAP becomes fluid during the production and construction process and totally blends with the new, virgin asphalt binder. In 2011, the Federal Highway Administration (FHWA) estimated that over 90 percent of the highway and roads within the US were constructed with hot mix asphalt (Copeland, 2011). As these pavements age and fulfill their intended performance

life, there will always be a need to maintain, rehabilitate, or reconstruct these pavements. In many instances, cold planning is used to remove a layer of HMA that has become distressed. Cold planning is the removal of an existing pavement to a desired depth. After an asphalt pavement has been removed, one option is to recycle the material back into an HMA in the form of recycled asphalt pavement (RAP). As described in the FHWA quote, the recycling of HMA pavements can provide economical and environmental benefits. Copeland (2011) stated that RAP is a useful alternative to virgin aggregates during the production of HMA. The use of RAP minimizes the tonnage of virgin aggregates that must be bought. Copeland (2011) also states that the amount of virgin asphalt binder that must be purchased is reduced. Both virgin aggregates and virgin asphalt binder are non-renewable resources, so the use of RAP also provides an environmental benefit.

The objective of this study was accomplished by testing plant produced mixture from three different on-going HMA projects. Two of the three projects incorporated 15 percent RAP within the HMA while the third project incorporated 30 percent. Samples were obtained at three locations during the production and construction process. These samples were brought back to the laboratory and subjected to a staged extraction/recovery process. Based upon the research approach for this project, the following conclusions are provided.

- Asphalt binder content measurements for HMA determined using the ignition oven are generally higher than asphalt binder contents determined using solvent extraction.
- The difference in measured asphalt contents between the ignition oven and solvent extraction appear to be aggregate type dependent.
- Failure temperatures measured using the DSR were relatively consistent within each stage for mixes containing 15 percent RAP.
- Failure temperatures measured using the DSR were higher for mixes containing 30 percent RAP.
- The stiffness of the blended asphalt binder generally increased for each stage for all mixes containing RAP. The asphalt binder recovered in each stage for the 30 percent RAP mixes increased at a greater rate than mixes containing 15 percent RAP.
- For mixes containing 30 percent RAP, the majority of the asphalt binder within the mix was not significantly affected by the aged RAP asphalt binder. The RAP asphalt binder significantly affected 5 to 13 percent of the total asphalt binder extracted. Another 18 percent was affected; however, the failure temperature was similar to a PG76-XX asphalt binder.
- The theories of RAP behaving as a black rock and total blending of RAP and virgin asphalt binders were proven false. The data explicitly shows that partial blending takes place between RAP and virgin asphalt binders.

3.2 Siksha Swaroopa Kar, Arvind Krishna Swamy, Devesh Tiwari, Dr. P. K. Jain

Review On Foam and Emulsion Based Cold Recycled Asphalt Mixes

Due to the increase of road infrastructure around the world, its impact on the environment and scarcity of aggregates requires serious attention to construction of sustainable pavement which constitutes towards the use of cold mix recycled asphalt technology. Cold mix recycled asphalt with bitumen emulsion and Foamed bitumen is a technique still in development, which has proved to be very promising, both in economic and environmental terms. This technology saves energy, natural resources, reduces CO emissions as recycling is done at lower temperature and increases the amount of recycled materials. The objective of this review is to summarize the study on Foam Bitumen and Emulsion incorporating RAP in construction materials, which is a challenging task due to the heterogeneity of the materials.
Conservation of energy and materials is important practices for achieving sustainability in road construction. Major road infrastructure activities currently under taken by different agencies for the last one decade have shown greater impact on energy consumption and depletion of aggregates. The production of huge quantities of Hot Mix Asphalt (HMA) releases a significant amount of greenhouse gases. Also, there is a problem of the scarcity of aggregates and aggregate being very expensive because of large lead distances, therefore, a serious attempt has to be made to develop and adopt alternative technologies for road construction and maintenance to reduce consumption of fuel and aggregates. It is also to be noted that thicknesses of existing pavements are increasing due to addition of periodic overlays.
The rise of road levels causes serious drainage problems in the urban areas. In such cases, the existing bituminous pavement usually consisting of Dense Bituminous Macadam (DBM) and Bituminous Concrete (BC) can be milled and the Reclaimed Asphalt Pavement (RAP) transported to cold mix plant for recycling on service roads and/or main line. Bituminous pavements are 100% recyclable. Milling of existing pavements and recycling the same after suitable modification will address problems of drainage and conservation of materials. Recycling of existing pavements is a common practice in South Africa, Europe and United States. Use of either hot or cold in-place in-plant techniques to rehabilitate the distressed pavements haś been practiced for a long time. The purpose of this State-of-the-Art is to summarize the leading studies including scientific papers, technical reports and thesis that have been conducted on Foam bitumen and Emulsions over the last decade, and to draw general conclusions regarding the present state of knowledge of Cold Recycled Mixes.

3.3 Masoud Faramarzi

Case Study on Cement Tretated Rap Containing Asphalt Emulsion and Acryl Polymer

A Korean contractor developed and used a cement treated Reclaimed Asphalt Pavement (RAP) containing asphalt emulsion and acryl polymer as base layer in Korea.

Unfortunately, it was reported that the performance of the mixture was controversial by appearance of reflective and other cracking on the surface of the pavement. In the phase one study, main goals were evaluation of some mechanical properties as well as understanding the material category of this mixture. To achieve these goals, a series of literature reviews and laboratory tests were carried out including Marshall stability and flow, indirect tensile strength, water sensitivity, rutting resistance and compressive strength of both "Contractor mix" and Rhode Island (RI) pavement materials i.e. typical hot mix asphalt (HMA) and Portland Cement Concrete (PCC). According to the Asphalt Pavement Analyzer (APA) test results, it was observed that "Contractor mix" behaved similar to an elastic material at low temperatures while it tends to behave like a visco-elastic material at high temperatures to some extent. Also, it was resistance enough against the moisture damages and rutting phenomena, however, showed considerably lower compressive strength compared to PCC. Because of low compressive strength and probably high shrinkage of this mixture, it could be problematic to use it as base layer material and could affect pavement resistance against some distresses, particularly transverse and reflective cracking. Finally, because of high cement content and rigid behavior it was decided to model this material as concrete and/or cement treated RAP material in the second phase of this study.

For more than a century, Hot Mixed Asphalt (HMA) has been used for paving roads and streets. Since the mid twentieth century, transportation organizations have recycled old broken asphalt mixtures for reuse, instead of disposing the asphalt mixture in landfills. In the 1970′s, these organizations recycled more HMA than ever before because oil prices increased and access to high quality aggregates became more difficult. When old or distressed asphalt concrete is recycled, it can qualify for reused in asphalt pavement layers. Recycled Asphalt Pavement (RAP) is generated by milling partial or full depth asphalt pavement scheduled for removal.

RAP must be modified to meet the requirements for the binder and aggregate specifications. First, the asphalt content may not be sufficient for making a new asphalt mixture, and on the other hand, because of exposure to weathering and sun light, the old asphalt binder is usually more brittle than a newer one. Therefore, adding some rejuvenators or additives, e.g. emulsions can compensate for these deficiencies. Secondly, because of milling and crushing operations during the asphalt pavement removal process, RAP aggregates do not contain enough coarse aggregate. Adding some additional virgin coarse aggregate can not only meet the grading requirements, but also improves the quality of aggregates. Thirdly RAP modifications can be accomplished by the addition of some stabilizer or additives such as Portland cement and Polymeric additives etc.

These materials can change quality of RAP mixture by improving the mechanical properties and decreasing the moisture sensitivity of mixture.

Asphalt emulsion and foamed asphalt are the most common materials used in cold recycling of asphalt pavements. These emulsions which make it feasible to recycle old asphalt concrete at lower temperatures at the plant or in place, and these processes are called Cold Central Plant Recycling and Cold In-Place Recycling, respectively. The cold recycling methods lead to more economic, environmental and construction benefits in comparison with hot recycling method. One of additives, which could be added to RAP, is Portland cement. Portland cement looks promising to improve mechanical properties of cold recycled asphalt concrete because of the following reasons:

- Portland cement accelerates curing process of emulsions in cold recycled asphalt mixture.
- Portland cement increases viscosity of binder.
- Portland cement binder probably increases resistance of mixture against compressive stresses in comparison with neat asphalt binder.

However, Portland cement and asphalt emulsion have different basis, and their bond and interactions may lead to deficiencies in the produced mixture. Another issue which could be controversial for this mixture is, understanding its behavior at different temperatures. Pavement designers need to know properties of materials to be able to predict their behavior under different pressures and temperature. Mixture containing both asphalt emulsion and Portland cement could be hard to predict, because Portland cement is an elastic material and its mechanical properties are almost independent to the changes of temperature, while, asphalt is a visco-elastic material that its physical and mechanical properties are highly dependent on the temperature.

Many researches have been conducted on asphalt emulsion cold recycled mixtures very few studies have been performed on cold recycled mixtures containing high Portland cement. Mixture evaluated in this study was design about 20 years ago in Korea as a cold central plant recycled asphalt mixture, to be used in the base layer. However, because of too high ratio of cement to emulsion, it became too brittle and more similar to cement treated RAP mixture.

Unfortunately, it was observed that the pavement with this mixture ("Contractor mix") had cracks and other distresses on the surface Because of lack of researches and specifications about cold recycled asphalt mixtures at that

time, it was not designed according to any confirmed procedure.

That is why researchers in this study were suspicious about this material as a cold recycled asphalt mixture and tried to understand category and characteristics of this material via performing a literature review and experimental investigation. While initially this material was named cement treated cold recycled asphalt mixture, because of different nature of this mixture compared with cold mix asphalts, it will be called as "Contractor mix" in the rest of this manuscript.

Because the studied material includes both asphalt emulsion and Portland cement it was a kind of new nature, so, not quite the same material could be found at the conducted literature reviews, however, the following studies were found to be the closest ones.

In an investigation conducted by Guthrie et al. different combinations of RAP and cement contents were studied. It was reported that RAP contents between 50%–75%, and Portland cement content of 1.0% by the weight of RAP, can result a mixture with the best results compared with other mixtures with different combinations of RAP and cement contents. In another study performed on CIR mixtures containing RAP and cement, it was found that Portland cement could improve Marshall stability, resilient modulus, IDT strength, moisture sensitivity and rutting resistance of CIR mixtures. Yuan et al. studied cement-treated RAP as base layer material. Effects of different parameters such as IDT strength, resilient modulus, cement content and RAP content were evaluated in a mix design. According to the tests results, it was found that there are direct relationships between contents of RAP and cement on one side, and mechanical characteristics such as strength and modulus on the other side. Those relationships were discussed and suggested for mix design consideration. Khay et al. studied the formulation and mechanical characterization of cement-treated RAP material as a rehabilitated base layer material. It was concluded that higher RAP content leads to higher elastic modulus, compressive strength, IDT strength, and flexural strength. Asphalt Recycling & Reclaiming Association (ARRA) recommends a minimum 3:1 ratio of residual asphalt to cement in making cement treated cold recycled asphalt mixture. Also, according to ARRA recommendation, cements contents should be kept low, typically 0.25% to a maximum of 1.0% of RAP weight content, to prevent brittle behavior of the cement treated cold recycled mixture. The ratio of asphalt residue to cement should be a minimum of three to one, however, this ratio was one to four for the studied "Contractor mix". As a result, this ratio was 12 times lower than the minimum ratio recommended by ARRA. It showed this mixture could not be categorized as a cold recycled asphalt mixture, however, to better understand the mechanical characteristics (rutting and moisture susceptibility) as well as effects of containing asphalt emulsion and liquid polymer additives on the visco-elastic behavior of this material, this study was continued by conducting aforementioned experimental activities.

As a comprehensive investigation was conducted on "Contractor mix" modified with high cement content. In the first phase of this study, some mechanical properties and moisture susceptibility of this mixture were evaluated and compared with conventional HMA and PC concrete. Performed evaluations showed that studied "Contractor mix" behaves more like PC concrete rather than asphalt mixture. In addition:

- Performed literature review showed that ARRA recommends a minimum 3:1 ratio of residual asphalt to cement for emulsified asphalts to prevent brittle behavior of mixture, however, this ratio was 1–4 for the studied "Contractor mix" (12 times less than minimum ratio).

- It was observed that some of RAP aggregates were crushed when they were being compacted by Marshall Hammer. It can affect grading of aggregates in "Contractor mix" specimens and consequently may not represent materials in the field. On the other, SGC could better lead to specimens representing "Contractor mix" in the field. Also, it was found that "Contractor mix" specimens had higher Marshall Stability, less flow and less density in comparison with HMA.

- Comparing conditioned and unconditioned IDT strengths of "Contractor mix" and RI HMA showed "Contractor mix" had a higher tensile strength at both conditions. Also TSR values are higher for RI HMA compared with "Contractor mix", however both TSR values are higher than the minimum recommended by AASHTO T283, i.e., 80%.

- APA test showed that "Contractor mix" was more sensitive to moisture damage compared with RI HMA. This result was compatible with the one by TSR. Also HMA experienced 5–6 times more permanent deformation (rut depth) than "Contractor mix" by APA.

- Compressive strength of "Contractor mix" was observed to be 5–6 times less than PC concrete. Transverse and reflective cracking of pavements made by PC concrete or PC treated base layer are highly related to compressive and flexural strength of those materials, so, cracking happened in roads of Korea constructed with the studied "Contractor mix" material could be attributed to this factor. Another reason could be shrinkage cracking. Because of relatively high cement content of "Contractor mix", it is prone and flexural strength of this cementitious material to shrinkage, on the other hand low compressive make it more vulnerable against shrinkage.

- Generally, it seemed that "Contractor mix" behaved like a semi rigid material, or more like a rigid material than a flexible one.

- That is why, this mixture will be more evaluated as well as modeled as a rigid and cementitious material in the second phase of study, not as an asphalt mixture. On the other hand, proper mix-design to make this mixture to a cold recycled asphalt mixture will be found, too.
- All, old "Contractor mix", new designed cold recycled asphalt mixtures, HMA and PCC mixtures will be modeled by the Pavement ME software to predict and compare their performance during the design life time.
- Performed literature review showed that ARRA recommends a minimum 3:1 ratio of residual asphalt to cement for emulsified asphalts to prevent brittle behavior of mixture, however, this ratio was 1–4 for the studied "Contractor mix" (12 times less than minimum ratio).
- It was observed that some of RAP aggregates were crushed when they were being compacted by Marshall Hammer. It can affect grading of aggregates in "Contractor mix" specimens and consequently may not represent materials in the field. On the other, SGC could better lead to specimens representing "Contractor mix" in the field. Also, it was found that "Contractor mix" specimens had higher Marshall Stability, less flow and less density in comparison with HMA.
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- All, old "Contractor mix", new designed cold recycled asphalt mixtures, HMA and PCC mixtures will be modeled by the Pavement ME software to predict and compare their performance during the design life time.

RECOMMENDATIONS:

In the next phase of Masoud Faramarzi Study's cold recycled asphalt mixtures treated with Portland cement will be designed according to the ARRA standard recommendations and using the same materials as Korean "Contractor mix".

4. MATERIAL & METHODOLOGY

The materials to be used includes recycled bituminous material, fresh aggregate, cement (filler), emulsion (binder) and water.

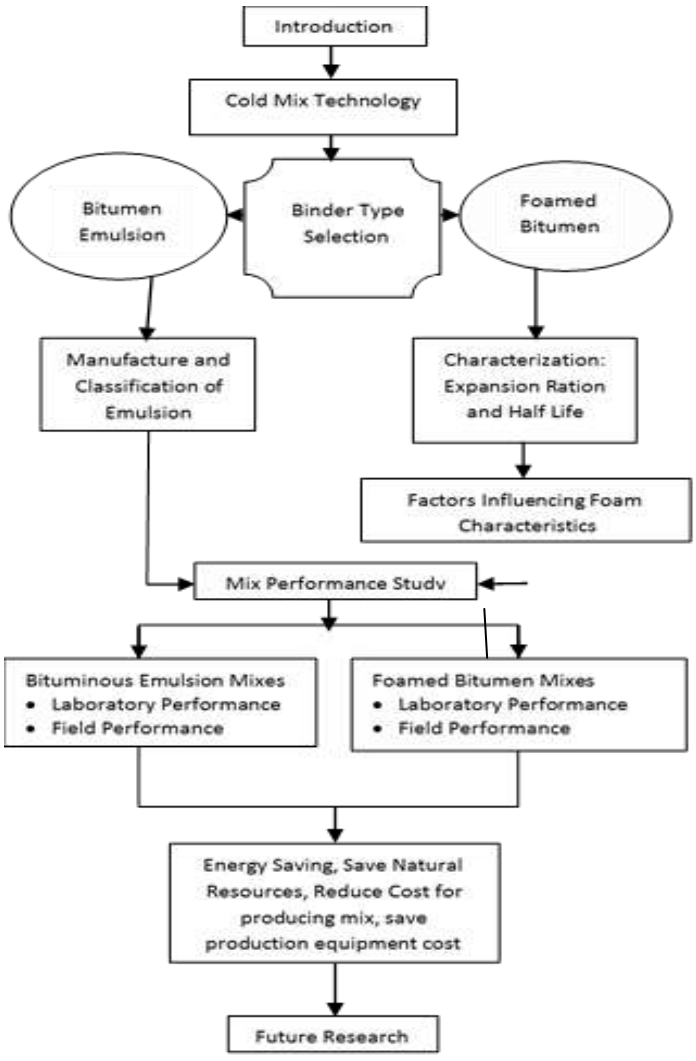

Fig: Flow Chart for Proposed Methodology

4.1 Emulsion:

Bitumen emulsion is one of the binding materials in this project. As per IRC 37-2012 we will use slow setting-2 emulsion as a binder in our mix proportion. Since the blend of RAP and crusher dust consists of plenty of fine particles, only slow setting emulsion (SS2) with minimum residual bitumen content of 60 per cent is recommended to prevent the emulsion from breaking during the mixing and construction. We will conduct some tests to assure the quality of emulsion as follows:

Description of Test	Test Method	Test Result Obtained	Requirements of IS: 73-2013
Residue content of emulsion by evaporation (% by mass)	As per IS 8887-2004	-	60 minimum
Penetration value of residue content of emulsion		-	60 to 120

4.2 Recycled material and virgin aggregate:

The aggregates from RAP may not have the required gradation for a good mix. RAP alone has poor internal friction and its CBR may be as low as 30 though a fresh close graded aggregates may have CBR as high as 200. Addition of crusher dust containing particle size from 6 mm to 0.075 mm and fines passing 0.075 mm adds to angle of internal friction as well as some cohesion to the RAP mixes. The crusher dust requirement can be 15 to 30 per cent and 1 per cent cement or lime or both by weight of dry aggregates helps in dispersion of the bitumen emulsion in the mix The grading of the blend of RAP/fresh aggregates and crusher dust should meet the requirement shown in Table adopted from the South African Standard 'TG2 (64) CSIR Built Environment, Pretoria. The grading has been slightly adjusted to correspond to the sieve size designation in MORTH. We will perform following tests to assure the quality of recycle material and fresh aggregate

Description of Test	Test Method	Test Result Obtained	Requirement as per MORTH
Gradation	IS 2386 Part 1 & MORTH	-	Combined mix gradation as per IRC 37-2012 Table no. IX-1
Aggregate impact value	IS 2386 Part 4 & MORTH	-	Maximum 24%
Combined flakiness and elongation indices	IS 2386 Part 1 & MORTH	-	60 Maximum 35%
Water absorption	IS 2386 Part 3 & MORTH	-	Maximum 2%
Specific gravity test	IS 2386 Part 3 & MORTH	-	

4.3 Cement:

Cement or lime will use as a filler in cold mix design, it is perform very important role if recycled material contaminated with clay. As per IRC 37-2012, one percent cement or lime or both by weight of dry aggregates will be used. Some RAP may be contaminated with clay which might have risen from the subgrade during the wet weather. Addition of 2 per cent lime would modify the clay and the mix becomes suitable for use.

Description of Test	Test Result Obtained	Requirements of IS: 8112-1989
Initial Setting Time	-	Min. 30 Minutes
Final Setting Time	-	Max. 600 Minutes
Fineness	-	Min. 225 m^2/kg

4.4 Water:

Water will performed as a partial fluid of the mix which will be useful for binding the recycle material and fresh aggregate on optimum moisture content. It helps to give better compaction in initial stage. It should be free from organic matter and the pH value should be between 6 to 7.

4.5 Test to be perform on Mix:

Marshall mold will be casted and tested for maximum dry density at optimum moisture content as per IRC 37-2012.

After find out the MDD and OMC of mix, sample mold casted on 3 to 4 % emulsion (SS2) for indirect tensile strength which will be obtained as follows:

Minimum Strength Requirement of RAP Mixes

Strength Test	Specimen diameter	Test Result Obtained	Minimum Strength Required
ITSdry, 25°C	100 mm	-	> 225 kPa
ITSwet 25°C	100 mm	-	> 100 kPa

Mix Design Check as Per TG-2/MS-14/MORTH

Parameter	Test Result Obtained	Mix Requirements for Designed Cold Mix
Minimum Stability	-	2.2 kN at 22.2°C for paving
Percent maximum stability loss	-	50
Minimum flow (mm)	-	2
Compaction level (number of blows)	-	50
Percent air voids	-	3-5
Minimum Percent voids in mineral aggregate (VMA)	-	13

Recycling of existing bituminous road pavement in Biaora Dewas Project

Sampling of recycled bituminous material in stockpile at Camp-2 sunera

5. Applications:

- The RAP material replace the natural aggregate in base layer of flexible pavements, resulting in a saving of construction cost.
- Reclaimed asphalt pavement material has the higher content of fines as a result of degradation of material during milling and crushing operations it can be easily used for soil stabilization purpose to increase the CBR value of subgrade due to which the crust thickness of road will be reduced, resulting in reduction of cost of construction
- The RAP material can be successfully used in granular sub base layer of flexible pavement after blending to match the requirement grading as per MORTH & IRC specifications for base & sub base material.
- In Full depth reclamation (FDR) all the reclaimed materials of the pavement, with or without fresh materials, is stabilized in-situ with suitable stabilizers to produce the base course of the pavement to be overlaid by bituminous course(s). If economically feasible.
- After treating the RAP material with emulsion/foamed bitumen in cold mix technology gives the better serviceability for low volume traffic road (slip service road).

6. Advantages of Emulsion Treated Reclaimed Asphalt Pavement:

- All the problem related to disposal of RAP wastes can be easily solved and adverse effect on environment may be avoided by the using the RAP materials in flexible pavements constructions so it is also an eco-friendly treatment.
- In cold mix plants recycling process we are done by some minor modification in WMM plant by which we can reduce the cost of separate batching plant.
- Saving of bituminous binder content as compared to other conventional bituminous mix because recycled material also acervuline some bitumen binder which is formed strong bond between RAP material and fresh aggregate in summer vacation.
- Low energy consumption in cold mix process as compared to hot mix technology because in hot mix technology High energy consume for heating the ingredients of mix.
- Hot mix technology creates noise and air pollution during entire process of production. while cold mix technology is free from noise and air pollution.
- By using the cold mix technology, we can produce a good mix at room temperature on the other hand hot

mix technology is sensitive to temperature control during entire process.

- Cold mix process is suitable for workers to work in a secure and healthy environment because in this process no heating required. While HMT is Unsafe for worker's health.

7. Future Use:

India is a developing country, nowadays development in highway sector is going on rapidly. At present more than 80% roads are bituminous which is continuously under developed or either will be developed in future. The main object of our project to reuse/recycle the existing bituminous material in a better way. Disposal of bituminous waste also create pollution, on the other hand natural resources depleting day by day and scarcity of good quality aggregate also seen at many locations. Emulsion treated Reclaimed Asphalt Pavement technique gives us better solution to resolve such type of problems.

Today pollution is a global problem & increasing day by day. Large amount of pollution is also created in road construction by hot mix process. We can reduce this pollution by using cold mix process.

It can be used for low volume traffic like as service road along main carriageway gives better option to reuse the existing bituminous recycle material after necessary treatment. In my project we are planning to construct the slip service road from village Siya to Dewas approx. 14 km where we will use emulsion treated reclaimed asphalt pavement after successful finalization of this mix design. In India we are using conventional method of flexible road construction which required higher energy. By using cold mix technology, we can reduce energy consumption.

In cold mix recycling Full Depth Reclamation, where the thickness of pavement to be recycled is greater than typically 150 mm. The pavement is ripped, the material pulverized and stabilized with lime, cement, emulsion or cementitious materials and compacted upto the required strength. So in this process we can stabilize the recycle material for base subbase or surface course of flexible pavements.

REFERENCES

[1] L. Allen Cooley, Jr., Ph.D. Kevin Williams, P.E Development of Laboratory Mix Design Procedures for RAP Mixes

[2] Siksha Swaroopa Kar, Arvind Krishna Swamy, Devesh Tiwari, Dr. P. K. Jain "Review On Foam and Emulsion Based Cold Recycled Asphalt Mixes".

[3] Masoud Faramarzi "Case Study on Cement Tretated Rap Cintaining Asphalt Emulsion and Acryl Polymer.

[4] IRC SP 37- 2012, "Guidelines For The Design Of Flexible Pavements (Third Revision)"

[5] IRC 120-2015, "Recommended Practice For Recycling Of bituminous Pavements"

[6] MORTH (5th revision section 500)

[7] TG-2/MS-14 (The design and use of granular emulsion mixes)