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# "Use Of Reclaimed Asphalt Pavement (RAP) Materials In WMM And DBM Layers Of Flexible Pavements"

Harish Kumar Rai
*Master Of Technology In Highway Engineering*
*School Of Engineering And Technology,*
*Shri Venkateshwara University, U.P.*
*Gajraula -244236*
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***Abstract***
*Reclaimed Asphalt Pavement (RAP) is the term to removal and processed materials containing asphalt and aggregate. These materials are generated when asphalt pavement is removed for construction, resurfacing or to obtain excess to buried utilities. RAP material makes both environmental and economic sense. The use of recycle asphalt pavement has grown widely reducing the use of virgin material. When properly crushed and screened, RAP consists of high quality, well-graded aggregate coated by asphalt cement.*
*A good road network is key for economic and social development of a country. There is about 4.2-million-kilometer road network in India which rank second in the world only after United States. It is necessary to maintain previously constructed roads along with new road construction. Both construction and maintenance of roads leading to over exploitation of resources of aggregates. Most of Indian roads are bituminous surfaced pavements. A good road network is key for economic and social. Apart from depleting resources and Environmental issues, these roads are periodically resurfaced as maintenance action which intend to roads to attain a higher raised level as compared to initial level of road and joining properties and structures level. Recycled or Reclaimed Asphalt Pavement (RAP) has increasingly been used to replace fresh or virgin materials for highway construction and maintenance as an Ecofriendly-Sustainable solution to overcome these problems. RAP can be used in different layers of Flexible and Rigid pavements. In this research paper, an effort has been made to characterize the RAP based on gradation characteristics of RAP aggregate sand sources of RAP.*
*The use of recycled materials as a sustainable alternative is gaining significant worldwide attention. To achieve the objectives of the research, six proportions of RAP aggregate materials in addition to Virgin Aggregates (VA) were used as categorized below:*
*Category1: 00% RAP (95%VA+05%Stone dust)*
*Category2: 10% RAP (75%VA+15%Stone dust)*
*Category3: 25% RAP (58%VA+17%Stone dust)*
*Category4: 35% RAP (40%VA+25%Stone dust)*
*Category5: 45%RAP (25%VA+ 30%Stone dust)*
*Category6: 60% RAP (05%VA+35%Stone dust)*
*Use of RAP aggregates along with the new/fresh aggregates will reduce the use of new material for construction offlexible pavement. Also, it will cut down the cost of construction.*

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## I. Introduction

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, economic, and environmental reasons.

Large quantities of Reclaimed asphalt pavement (RAP) materials are produced during highway maintenance and construction. A part of this can be used in new hot mix asphalt concrete and rest is available for other uses. If these materials could be re-used in base and sub-base of the roads or also in surface course (for low volume traffic, or in service road), resulting in minimization of environmental impact, reduce the waste stream and transportation costs connected with road maintenance and construction activities.

The properties of RAP materials can be improved by blending of aggregates and by addition of chemical stabilizers. In recent years there was a gradual increase in construction and demolition wastes. It has resulted in waste disposal problem due to shortage of available land fills. Reuse of these material safter proper recycling can be the right solution for the same. There will be a reduction in cost about 25 to 30% by reusing the recycled road aggregate generated at same site. Before using such materials, the mechanical properties must be tested, and suitable blending is done if required.

The most used recycled materials are Reclaimed asphalt pavement (RAP) materials and recycled concrete aggregate (RCA). The generation of RAP and RCA result in an aggregate of high quality and grading. Due to coating of asphalt on the aggregate of RAP it reduces the water absorption in aggregates. Production of Reclaimed asphalt pavement (RAP) materials:

Removal and reuse of asphalt layer of existing pavement is termed as RAP. However full depth reclamation (FDR) is defined as removal and reuse of hot mix asphalt layer and entire base course. RAP can be reused immediately at sites; however, it may be stockpiled. The required gradation of RAP is achieved by pulverizing the material in a crusher.

A condition of demolished flexible pavement is shown in Fig-1 which can be reused after proper processing and crushed to required size and grading as per requirements of site condition.

Fig.1.1 Dismantling of DBM Layer of Road Surface

Pavements are designed to provide durable all-weather travelling surfaces for safe, smooth and speedy movement of vehicles carrying people and goods with areas on able level of comfort to its users. Road pavements are valuable assets as they constitute primary means of communication and transportation of people, goods and services on a daily basis. The design and construction of pavements requires a fundamental understanding of materials as once they are open to traffic loads, the pavements gradually deteriorate with time, traffic load applications and change in climatic conditions. Lack of maintenance on the pavement could result in rutting, fatigue cracking and other distress types that eventually result in an unacceptable ride quality for users.

**Properties of RAP:**

A Comparison can be made between RAP and crushed natural aggregates. RAP has a higher content of fines because of degradation of material during milling and crushing operations. Typical physical properties of RAP are tabled below:

**Table-1.1. Typical properties of RAP**

| S. No. | Parameters | Values |
|---|---|---|
| 1 | Unit Weight(Kg/m³) | 1900-2250 |
| 2 | Moisture Content | Max 3% |
| 3 | Asphalt Content | Max 4% |
| 4 | Asphalt Penetration(%)at25°C | 10-80 |
| 5 | Compacted Unit Weight(Kg/m³) | 1500-1950 |
| 6 | California Bearing Ratio(CBR) | 100%RAP:20-25% |

Consumption of natural aggregate can be reduced by using Reclaimed asphalt pavement(RAP) materials. Amount of binder can also be reduced in asphalt paving mixes by using Reclaimed asphalt pavement (RAP) materials. Studies have revealed that performance of pavement by using up to 30% RAP material is like that of pavement constructed with natural aggregates without RAP materials. Increase demand of aggregates and binder supply can be meet out up to certain extent by using Reclaimed asphalt pavement (RAP) materials in hot mix asphalt (HMA) and other courses of the flexible pavements like sub-base and base. Finally recycling asphalt creates a cycle of reuse that optimizes the use of natural resources and sustains the asphalt industry.

Economy, ecology, and energy conservation are all achieved when the two main components i.e., asphalt and aggregate are reused as construction materials to provide a strengthened and improved pavement.

The use of RAP has become relatively common practice in most countries, as it is both an environmentally and economically attractive proposition. RAP material is generated when old, damaged pavement materials are milled and crushed for addition as a component to new mixtures placed in the pavement structure. Historically, old pavement material was removed and disposed of in landfills.

**Methods of Reclaimed Asphalt Pavements**

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

- Hot mix plant recycling
- Hot in place recycling
- Cold mix plant recycling
- Cold in place recycling

The addition of Reclaimed asphalt pavement to an asphalt mixture changes the mechanistic property (i.e., strength durability of the mixture and affects its performance).

*Hot Mix Plant Recycling*

Hot mix recycling is defined as a process that combines RAP with virg in aggregates, bitumen and sometimes recycling agents to produce hot mix asphalt. The RAP may be obtained by pavement milling with a rotary drum, cold milling machine or from a ripping/crushing operation stated that hot mix recycling is the most common method of recycling asphalt pavements and can perform as well as mixtures with entirely new materials.

Fig.-1.2 Hot Mix Plant in Patna-Dobhi Road Project

*Hot in Place Recycling*

Initially the pavement intended to be recycled is heated to a higher temperature using suitable heating arrangement. This facilitates easier removal of materials. After heating, the pavement surface is scarified to there quired depth. Further, depending on there requirement fresh aggregate and binder are added. The material is mixed well and compacted to there quired thickness. As this process consumes less time, least disruption to traffic is caused. Also, the transportation cost is less, as materials need not be taken away. Machinery required for this purpose being bulky in nature, sufficient right-of-way is required. This becomes an important consideration for in-place recycling within the city areas.

*Cold Mix Plant Recycling*

Cold mix recycling is a process of recycling without the use of heat where existing asphalt pavements are pulverized, mixed with new virg in aggregates and stabilizing agents to produce a new material that is expected to meet the standards. Cold recycling is an economical technique since the material does not need to be heated contributing to a reduction in energy, fuel, and material consumption.

*Cold in Place Recycling*

Cold in-place recycling is are habilitation technique where existing asphalt pavement materials are reused and mixed in-place without the application of heat. The RAP is obtained by milling or crushing the existing pavement. Virg in aggregate, recycling agents or both are usually added to the RAP which is then laid and compacted. The use of cold in-place recycling can restore old pavement to the desired profile, eliminate existing wheel ruts, potholes, irregularities, and rough areas. It can also eliminate transverse, reflective, and longitudinal cracks. This method for the maintenance and rehabilitation of pavements promotes sustainability and helps in limiting the use of scarce materials that include gravel and crushed rock. Cold in-place recycling promotes a high production rate of asphalt mixtures resulting in cost savings, minimum traffic disruption, ability to retain original profile and environmental benefits all without the use of heat.

**Need of Study**

Reclaimed asphalt pavement (RAP) is the term given to removed and/or reprocessed pavement materials containing aggregates asphalt and. These materials are generated when asphalt pavements are removed for reconstruction, resurfacing or to obtain access to buried utilities. When properly crushed and screened, RAP consists of high-quality, well-graded aggregates coated by asphalt cement. Asphalt pavement is generally removed either by milling or full- depth removal. Milling entails removal of the pavement surface using a milling machine, which can remove up to 150 mm thickness in a single pass and transported to a central facility for processing. At this facility, the RAP is processed using a series of operations, including crushing, screening, conveying, and stacking. RAP can be used to a larger extent as a base course; however, a limitation of using RAP as fill material is the unknown risk of leaching of pollutants from the aggregate to the environment.

RAP can be used as an aggregate substitute material, but in this application, it also provides additional asphalt cement binder, thereby reducing the demand for asphalt cement in new or recycled asphalt mixes containing RAP. As far as life cycle assessment of RAP is concerned, the life of the recycled pavement materials starts at breaking up the existing old pavement, followed by transportation to depositor asphalt/concrete plant, and then followed by crushing, mixing of new pavement material and transportation to the location of the new pavement. In summary, the benefits of RAP include Reduction in CO2emissions due to lower demand of construction materials, Reduction in the asphalt (bitumen) content, Reduction in the overall cost, almost same if not more of the performance and durability characteristics of a conventional dense graded asphalt concrete materials Cost is an important factor in terms of recyclability and reuse of material and can be an incentive to use such material.

The construction industry will certainly recognize the economic benefits of using recycled materials, such as crushed RAP aggregates for base courses of the pavements. The cost- effectiveness of substituting conventional aggregate with recycled materials is highly dependent on the location, the quality, and cost of local aggregates. Recycling versus tipping fee sand distances to land fillsare other important aspects for the feasibility of recycling. In some urban areas recycling can be more profitable than in rural areas. In rural areas recycling can be expensive and impractical due to high transportation cost and the lack of nearby materials. On the other hand, if materials are available, reuse of materials that otherwise have to be transported can be very cost effective. Overall, there is a critical need to understand the use of recycling of existing damaged asphalt pavement materials to produce new pavements with considerable savings in materials, energy, and cost in the Indian context. In addition, aggregate sand binders from old asphalt pavement sare still valuable even though the damaged pavements have reached the end of their service lives.

- The demand of aggregate to construct pavement ismore & more soto recover it and for the optimization of natural resources.
- To overcome the problem related to dumped materials and recycle of dumped material and conserve the natural resources.
- To minimize the adverse effect son environment.
- To use the Recycled material as filling material without doing any analyzed and test in low lying areas.
- Touse the Recycled material as WMM after investigating and then adding them is sing sieve size material.

**Aim**

Proposing use of Reclaimed Asphalt Pavement (RAP) in WMM layer and DBM layer of flexible pavement.

**Objective**

The main objective of the study is to develop specifications and practices for recycled asphalt pavement (RAP) mixes and to understand the performance characteristics of the asphalt mixes, mainly from the perspectives of materials, energy, and costs. The proposed work envisages the following scope of the effort:

- Review of the RAP mix design methods practiced worldwide.
- Select appropriate percentage of RAP to be used with new materials which will result inadequate density (and porosity) of the conventional mixes.
- Investigate the use of modifiers(crumb rubber and polymer additives) in the RAP mix designs.
- Conduct material characterization (binder sand mixtures) laboratory test stop evaluate for their rutting, cracking, and moisture resistance characteristics.

- Compare the test results with the performance of the traditional control conventional asphalt mixes in the laboratory with the RAP (conventional and modified) mixes.
- Develop rutting, cracking and moisture performance criteria and models.
- To reduce the use of fresh aggregates up to the possible extent.

**Scope & Limitation**

The scope of my study is as follow: -

- To carry out detailed study of literature and pavement construction practices.
- Use of RAP material in flexible pavement.
- Review on foam and emulsion based cold recycle asphalt mixes
- To carry out various laboratory teston material sand RAP

The limitation of my study is as follow:

- Hot mix plant recycling method is used for laboratory tests to calculate the various engineering property of reclaimed asphalt pavement.
- All the results of various laboratory test on material and RAP are compared with IS codes and MoRTH guidelines of pavement design

**Methodology**

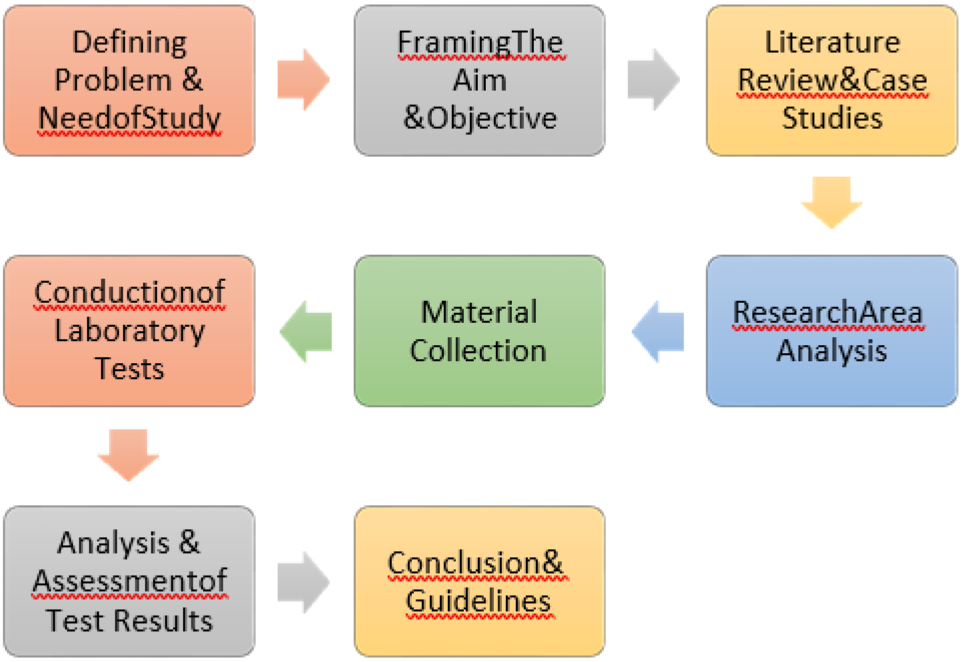



Fig 1.3-methodology

**Report Structure**

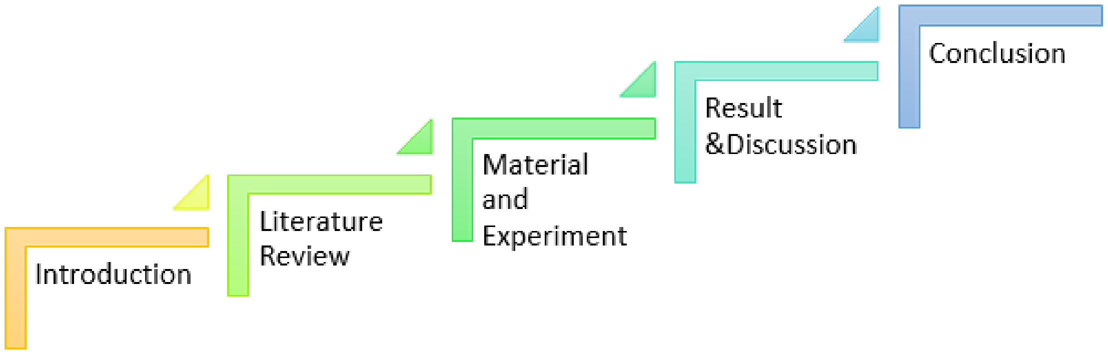



Fig-1.4

## II.Literature Review

The present investigation deals with studies & ground implementation on the mix design of emulsion treated reclaimed asphalt pavement and so an attempt has been made to briefly review the available literature on the following topics:

Evaluate the amount of blending that occurs between RAP and virgin asphalt binders in plant produced HMA in which RAP is incorporated.

- Review On Foam and Emulsion Based Cold Recycled Asphalt Mixes.
- Case Study on Cement Treated Rap Containing Asphalt Emulsion and Acryl Polymer: Many research and investigations were conducted on cold and hot mixes of RAP all over the world. Some reviews on recycled material mix are as follows.

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

***Evaluation of Blending that Occurs between RAP and Virgin Asphalt Binders by 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.R A P 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 with in 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, there cycling of HMA pavement scan provide economic 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, most of the asphalt binder within the mix was not significantlyaffectedbytheagedRAPasphaltbinder.TheRAPasphaltbindersignificantly affected 5 to 13 percent of the total asphalt binder extracted. Another 18 percent was affected; however, the failure temperature was like 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.

***Review on Foam and Emulsion Based Cold Recycled Asphalt Mixes by Siksha Swaroopa Kar, Arvind Krishna Swamy, Devesh Tiwari, Dr. P. K. Jain***

Due to the increase of road infrastructure around the world, its impact on the environment and scarcity of aggregates requiresseriousattentiontoconstructionofsustainablepavementwhich 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 number 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 must 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 has 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.

Case Study on Cement Treated Rap Containing Asphalt Emulsion and Acryl Polymer By Masoud Faramarzi

A Korean contractor developed and used a cement treated Reclaimed AsphaltPavement(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,maingoalswereevaluationofsomemechanicalpropertiesaswellasunderstandingthe material category of this mixture. To achieve these goals, a series of literature reviews and laboratorytestswerecarriedoutincludingMarshallstabilityandflow,indirecttensilestrength, water sensitivity, rutting resistance and compressive strength of both "Contractor mix" and RhodeIsland(RI)pavementmaterialsi.e.,typicalhotmixasphalt(HMA)andPortlandCement Concrete (PCC). According to the Asphalt Pavement Analyzer (APA) test results, it was observed that "Contractor mix" behaved like an elastic material at low temperatures while it tendstobehavelikeaviscos-elasticmaterial athightemperaturestosomeextent.Also,itwas 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 transverseandreflective cracking. Finally,becauseofhighcementcontent andrigidbehavior it was decided to model this material as concrete and/or cement treated RAP material in the second phase of this study.

Formorethanacentury,HotMixedAsphalt(HMA)hasbeenusedforpavingroadsandstreets. Sincethemidtwentiethcentury,transportationorganizationshaverecycledoldbrokenasphalt mixtures for reuse, instead of disposing the asphalt mixture in landfills. In the 1970′s, these organizationsrecycledmoreHMAthaneverbeforebecauseoilpricesincreasedandaccessto 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 morebrittlethananewerone.Therefore, addingsomerejuvenatorsoradditives,e.g.,emulsions cancompensateforthesedeficiencies.Secondly,becauseofmillingandcrushingoperations 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 atlowertemperaturesattheplantorinplace,andtheseprocessesarecalledColdCentralPlant RecyclingandColdIn-PlaceRecycling,respectively.Thecoldrecyclingmethodsleadtomore economic, environmental and construction benefits in comparison with hotrecycling 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:

- Portlandcementacceleratescuringprocessof emulsionsincoldrecycledasphalt mixture.
- Portlandcementincreasesviscosityofbinder.
- Portlandcementbinderprobablyincreasesresistanceofmixtureagainstcompressive 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 controversialforthismixtureis,understandingitsbehavioratdifferenttemperatures.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 mechanicalpropertiesarealmostindependenttothechangesoftemperature,whileasphaltisa viscos-elasticmaterialthatitsphysicalandmechanicalpropertiesarehighlydependentonthe temperature.

Muchresearchhasbeenconductedonasphaltemulsioncoldrecycledmixturesveryfewstudies havebeenperformedoncoldrecycledmixturescontaininghighPortlandcement.Mixture

evaluatedinthisstudywasdesignabout20yearsagoinKoreaasacoldcentralplantrecycled 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 like cement treated RAP mixture.

Unfortunately, it was observed that the pavement with this mixture ("Contractor mix") had cracksandotherdistressesonthesurfaceBecauseoflackofresearchandspecificationsabout 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.

Whileinitiallythismaterialwasnamedcementtreatedcoldrecycledasphaltmixture,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.

BecausethestudiedmaterialincludesbothasphaltemulsionandPortlandcementitwasakind 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.

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 specimensrepresenting"Contractormix"inthefield.Also,itwasfoundthat"Contractormix" specimenshadhigherMarshallStability,lessflow,andlessdensityincomparisonwithHMA.

CasestudyonEffectofWaterSubmergenceontheCharacteristicsofBituminousMixes Using Reclaimed Asphalt Pavement by Md. Akhtar Hossain

The main purpose of this study is to investigate the effect of water on the use of reclaimed asphalt pavement materials in bituminous mix and to determine the optimum percentage of reclaimed asphalt pavement materials with virgin pavement materials and optimum days of water submergence according to the Marshall Mix design criteria based on medium traffic condition.Toachievetheobjectivesofthisstudythebasicpropertiestestswereperformedon thestudiedmaterialsandthenMarshallTestwasconductedonasphaltmixtureswithdifferent percentagesofreclaimedasphaltpavementmaterialswithoptimumbitumencontent

determinedfor100%freshaggregate.Thedifferentpercentagesofreclaimedasphaltpavement materialinasphaltmixturesare0%,10%,20%,30%and40%.MarshallCriteriawassatisfied up to 20%. Then the specimen prepared with 20% reclaimed asphalt pavement material was submergedinwaterat0, 5,10,15and20days.Optimumdaysofwatersubmergencewere15 days on the basis of Marshall Mix design criteria.

Case study on Use of Reclaimed Asphalt Pavement (RAP) Materials in Flexible Pavements by Brajesh Mishra

In this study sample of Reclaimed asphalt pavement (RAP) materials were collected and analyzed for suitability of their usage in flexible pavements. Their characteristics including gradation, California Bearing Ratio (C.B. R). Aggregate Impact value, Aggregate Crushing value, Specific gravity, Flakiness & Elongation Index, Loss Angles Abrasion value, Water absorptionandsoundnessweredeterminedandcomparedtotheMORTHspecifications.Form thestudyitwasfoundthattheRAPmaterialscanbeeffectivelyusedinthesoilsubgrade,sub- base and base of the flexible pavements resulting in reduction of the construction cost. The main objective of the study is to find out suitability of Reclaimed asphalt pavement (RAP) materials to be used in construction of flexible pavements. To perform experimental investigations to assess the values of related parameters and their technical viability.

Stated the Performance Evaluation of Warm Mix Asphalt Mixtures with Recycled Asphalt Pavement by BurakSengoz

Thispapershowsthefeasibilityofutilizingfourdifferent WMAadditives(organic,chemical, syntheticzeolite,andnaturalzeolite)withdifferentratesofRAP.Followingthedetermination of optimum RAP content corresponding to each WMA additive, Marshall Analysis, indirect tensile stiffness modulus and fatigue behavior of HMA and WMA involving RAP were analyzed and compared with control specimens. Hamburg wheel tracking device was also utilizedtoevaluatethepermanentdeformationcharacteristicsofmixturescontainingoptimum RAP content. In this research, RAP has been used (at contents of 10–50%) within both HMA and WMA mixtures. Each type of WMA mixture has been prepared with an optimum rate of WMA additive that is based on the recommendation of manufacturers (organic additive at a rate of 3%, chemical additive at a rate of 2% and two types of water containing additives at a rate of 5% by weight of the bitumen). The mechanical performances of the samples were evaluated by Marshall Stability test. Following the determination of optimum RAP content regardingeachmixtureinvolvingfourdifferenttypesofWMAadditive,indirecttensile stiffnessmodulus(ITSM)andfatiguebehaviorof WMAandHMA containingoptimumRAP contentwereanalyzedandcomparedwithcontrolspecimens.Hamburgwheeltrackingdevice wasalsousedtodeterminetheruttingpropertiesofmixturesinvolvingoptimumRAPcontent.

Case Study on the utilization of recycled asphalt pavement in the Urban Area at Surat, Gujarat, India by Maulik Rao

Themain / primary objective was to justify the cost of milling and to makeit viable option so thatthesamecanbeusedeffectively.SomepracticaloptionstousetheRAPmaterialinurban areas are discussed in this study and thereby achieving economy in the construction besides solving the raised level of roads, effective disposal of RAP and above all using the principles of environment friendly green technology that is: Reduce, Reuse and Recycle. The practical study shows the definite impact on replacement of virgin material for various road constructions. The CBR values increasing to 2%, 3.8% and 6.8% respectively by 20%, 40% and 60% RAP mixing in black cotton soil surely work for improved sub-grade.

CasestudyonLaboratoryinvestigationofPortlandcementconcretecontainingrecycled asphalt pavements by Baoshan Huang, Xiang Shu, Guoqiang Li

In this paper, they used the RAP as aggregate in both fine and coarse, and conducted experimental study on its behavior, how it effects on the properties of the concrete like compression, toughness, etc.in this study they are prepared four concrete mixes with and withoutRAPtheRAPusingpercentagesformixesare0%&0%,100%&100%,100%&0%, 0%&100% both coarse RAP and fine RAP respectively in each case. They conducted compressionstudyonRAPconcretewithconcretemadewithrubberaggregates.Therubberis replaced as aggregates with various percentage of volume of aggregates they are 0%, 10%, 15%, 25%, 50%. As the percentage of rubber is increasing in the concrete, in same manner strengthofconcretealso decreasing.The authors concludethat frominvestigationresult RAP concrete is better than the rubber concrete. The concrete made with one coarse RAP is giving good strength than other. RAP concrete had more toughness than nominal concrete.

Case study on the Performance-Related Tests of Recycled Aggregates for Use in Unbound Pavement Layers by Athar Saeed

This study is performing test on RAP and RCP (reclaimed concrete pavement) these to materials are used as aggregates in the unbounded base and subbase pavement layers. He conducted different laboratory test for selection material and to find properties of material on theRAPandRCP,testislikesieveanalysisforscreening,toughnesstest,moistureand

absorption test, stiffness test and frost susceptibility. Theproperties theserecycled aggregates adversely affecting the performance of the unbound base and subbase pavements like shear strength,durability,stiffnessoflayeretc.WhatevertheusageofrecycledaggregatelikeRAP, RCP etc, in unbounded base and subbase pavement layer make project more economical.

2.10 Case study on Concrete Containing RAP for Use in Concrete Pavement by Michael J. Bergin, Mang Tia, and Nabil Hossiney (2010)

In this experiment they had replaced the natural aggregate with the RAP in concrete. The concreteit'scontainingRapinpercentages0,10,20,40werecastedinlaboratoryandevaluate performance of replaced concrete. The investigation results show that, the RAP is adversely affecting on concrete properties they are compressive & flexural strength, elastic modulus. ThesepropertiesaredecreasingwithincreasingthepercentageofRAP,butitdidn't affectthe thermal expansion, dry shrinkage of the concrete. The evaluation is carried with software analysis,theanalysiswasperformedonbothRAPconcreteandnormalconcrete.Thesoftware was used for analysis is finite element analysis of concrete slab, of version four (FEACONS IV). This software has developed by university of Florida for transportation department to analyzeperformanceofPCCpavementsunderloadandthermaleffectconditions.Theanalysis says that maximum stress to flexural ratio is decreasing with increasing RAP content.

LearningsfromLiteratureReview

- The main carriage way section of Tumkur–Honnavar Highway, NH-206 near Tumkur strength end by Full Depth Reclamation (FDR) Technology with a Commercial CementitiousStabilizer.Thepavementsectionisabletowithstandheavytraffic.FWDtests was doneto verify design modulus and GPR test was donetocheckthe uniformity&crack formation in cementitious layer.
- TheonesidecarriagewayofBangaloreUniversityinfrontofCivilEngineeringDepartment was strengthened by Cold Recycling Technology with a Commercial Cementitious Stabilizer. The pavement section is able to withstand heavy traffic in the night-time as the road is connecting two major roads approaching Bangalore city. The stretch was evaluated for roughness & stiffness by MERLIN & Geo-gauge respectively.
- ChennaiTadaNH 5 Section total of12 km with width of8.75m.
- BarodaHalolphase1total lengthof 11kmrecycled toa depthof 20cm.
- Baroda-Halol(Phase2)thetotalsectionof6kmwasexecutedtoadepthof16cmwithfoam bitumen as binder.
- Ahmedabad Mehsana 6 km of cold recycling to a depth of 160mm under rehabilitation by cold recycling using foam bitumen as binder.
- Hotin-siturecyclingofMehraulitoBadarpurunderDelhiPWD.
- RecyclingofroadsinDelhiunderDelhi PWD.
- NH-6 in West Bengal: Cold in-situ recycling of Reclaimed Asphalt Pavement was done in 2004 andpavement evaluation before and after the recycling showed marked improvement in the strength of the pavement. Pavement performance is evaluated by FWD and modulus of the RAP improved considerably.
- PlantrecyclingwasdoneinKolkataonaheavilytraffickedmain road (Prince Anwershah Road) using foamed bitumen. Pavements were evaluated both before milling the bituminous surface and after the construction of the foamed bituminous baseand SemiDenseCarpetwearingcourse.The roadwasfoundtobesoundevenafterthe two heavy monsoons along with occasional waterlogging.

Thereviewsofliteratureonearlierworksrevealthefollowing:

- Industrial wastes can be consumed as by-products and can specially be used as fine- aggregate and / or micro filler in concrete mixtures, inducing benefits on its mechanical properties.
- Natural wastes like rice husk-ash, coconut fiber, durain fiber, wood sawdust and limestone dust composition produce a comparatively lighter than conventional concrete brick. It does not exhibit a sudden brittle fracture even beyond the failure loads and indicates high energy absorption capacity byallowinglaboringcost.Also, itscompressiveandflexuralstrengthvaluessatisfytherequirementsofBS 6073for a building material to be used in the structural application.
- Also,mostoftheinvestigationswerecarriedoutonalotofindustrialwasteslikefly- ash,boronwasteand blast furnace slag as replacement of fine aggregates in concrete blocks. Only very few literaturesurveys were available in regard to papercrete.
- Intheearlierworks,attemptshavebeenmadebyafewauthorstoinvestigatethepaper millresidualsandwastepapersludgeashonthestrengthandotherengineeringpropertiesof concreteorbuildingblocks.
- Thereisalotofscopeforstudyingthepapercretebricksanditsimpactonthevarious engineering properties.

CurrentManagementOptions

Recycling

ThemajorityoftheRAPthatisproducedisrecycledandused,althoughnotalwaysinthesame year that it is produced. Recycled RAP is almost always returned back into the roadway structure in some form, usually incorporated into asphalt paving by means of hot or cold recycling, but it is also sometimes used as an aggregate in base or subbase construction.

It has been estimated that as much as approximately 33 million metric tons (36 million tons), or80to85percentoftheexcessasphaltconcretepresentlygenerated,isreportedlybeingused either as a portion of recycled hot mix asphalt, in cold mixes, or as aggregate in granular or stabilized base materials.(2)Some of the RAP that is not recycled or used during the same construction season that it is generated is stockpiled and is eventually reused.

Disposal

Excess asphalt concrete is disposed of in landfills or sometimes in the right of way. In most situations,thisoccurswheresmallquantitiesareinvolved,orwherethematerialiscommingled with other materials, or facilities are not readily available for collecting and processing the RAP. It is estimated that the amount of excess asphalt concrete that must be disposed is less than 20 percent of the annual amount of RAP that is generated.

Market Sources

Inmostcases,recycledhotmixasphaltcanbeobtainedfromcentralRAPprocessingfacilities where asphalt pavements are crushed, screened, and stockpiled for use in asphalt concrete production, cold mix, or as a granular or stabilized base material. Most of these processing facilities are located at hot mix asphalt plant sites, where the RAP is either sold or used as feedstock for the production of recycled hot mix asphalt pavement or recycled cold mix.

ThepropertiesofRAParelargelydependentonthepropertiesoftheconstituentmaterialsand asphaltconcretetypeusedintheoldpavement.SinceRAPmaybeobtainedfromanynumber of old pavement sources, quality can vary. Excess granular material or soils, or even debris, cansometimesbeintroducedintooldpavementstockpiles.Thenumberoftimesthepavement hasbeenresurfaced,theamountofpatchingand/orcracksealing,andthepossiblepresenceofprior seal coat applications will all have an influence on RAP composition. Quality control is needed to ensurethat the processedRAP will besuitablefor theprospectiveapplication. This is particularly the case with in-place pavement recycling.

Applications

TheRAPmaterialreplacesthenaturalaggregateinbaselayerofflexiblepavements,resulting in a saving of construction cost.

Reclaimedasphaltpavementmaterialhasthehighercontentoffinesbecauseofdegradationof material during milling and crushing operations it can be easily used for soil stabilization purposetoincreasetheCBRvalueofsubgradeduetowhichthecrustthicknessofroadwillbe reduced, resulting in reduction of cost of construction

TheRAPmaterialcanbesuccessfullyusedingranularsubbaselayerofflexiblepavementafter blending to match the requirement grading as per MORTH & IRC specifications for base & subbase 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).

Advantages of Reclaimed Asphalt Pavement Materials:

- 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 ecofriendly 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 becauserecycledmaterialalsoacervulinesomebitumenbinderwhichisformedstrongbond 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.

- Reductioninconsumption anduseofnatural resources.
- Reductionindamages tootherroadsduetotransportation ofmaterials fromquarry sites.
- Conservationof energy
- Preservationofenvironment
- Reducedcostofconstruction.
- Conservationofaggregateandbinder
- Preservationofexistingpavementgeometricsetc.

Studieshaveshownthatupto50%ofRAPhasbeenusedaspartreplacementofgranularsub- base and wet mix macadam (WMM) in various projects of National Highway Development Plan(NHDP)inIndia.Recyclingofmilledbituminousmaterialhasbeengainingpopularityin Indiainrecenttimes duetoseveralsuccessfultrialsinselectedprojects.Adetailedlaboratory investigation is required to use RAP in Hot mix asphalt (HMA)and Cold asphalt mix (CAM) to ensurethat mixes have necessaryminimum strength and durability. For betterperformance the following points should also be considered which are listed below:

- Qualitycontrol andadditional processing
- Classifying RAP
- Changingthevirginbinder grade

## III. Material & Methodology

Thematerialstobeusedincludesrecycledbituminousmaterial Rapmaterials,freshaggregate, cement (filler), Stone Dust, emulsion (binder) and water.

**Table3.1-Source of Materials**

| SrNo | Typesof Materials | Source |
|---|---|---|
| 1 | 20 mm | Hunturganj |
| 2 | StoneDust | Rafiganj |
| 3 | SS2 Emulsion | Howarh |
| 4 | RAP Material | ExitingRoad Pavements |
| 5 | Cement | OPC 43 Ultratech |

Aggregates (20mm)

Milling (recycled) material does not have any proper gradation as per my mix design requirements so here we used 20 mm size virgin aggregate for maintaining gradation as per IRC:37-2012 Table no IX-1. Aggregate productions weredone on my hunterganj crusher and for testing in laboratory Sample were taken from Dobhi camp stockpile.

Some quality assurance tests were performed on 20 mm down aggregate in site laboratory before using as a ingredients of mix design. Tests were conducted on coarse aggregate like as aggregate impact value test, flakiness indices and elongation indices test, specific gravity and water absorption test and individual gradation.

Theaggregates fromRAP maynot havethe required gradation for agood mix and used fresh aggregates in RAP materials.

Sometestsareperformed onaggregatesare:
Aggregateimpactvalue (IS:236,PART4),1963
Flakinessand elongationindices testasper Part1&MORTH
SpecificgravitytestandWaterabsorptionas per IS2386Part3 &MORTH

AggregateImpact Value Test

Toughnessisthepropertyofamaterialtoresistimpact.Duetotrafficloads,theroadstonesare subjectedtothepoundingactionorimpactandthereispossibilityofstonesbreakingintosmaller pieces.Theroad stonesshouldthereforebetough enoughtoresistfractureunderimpact.A test designed to evaluate the toughness of stones i.e., the resistance of the fracture under repeated impacts may be called an impact test for road stones. Objective:Todetermine thetoughnessofroadstonematerialsbyImpacttest.

Apparatus:

Impact Testing Machine: The machine consists of a metal base with a plane lower surface supported well on a firm floor, without rocking. A detachable cylindrical steel cup of internal diameter102mmanddepth50mmisrigidlyfastenedcentrallytothebaseplate.Ametalhammer of weight between 13.5 and 14.0 kg having the lower end cylindrical in shape, 100mm in diameterand50mmlong,with2mmchamferattheloweredgecanslidefreelybetweenvertical guides and fall concentric over the cup. There is an arrangement for raising the hammer and allowing it to fall freely between vertical guides from a height of 380mm on the test sample in the cup, the height of fall being adjustable up to 5mm. A key is provided for supporting the hammer while fastening or removing the cup.

Measure: A cylindrical metal measure having internal diameter 75mm and depth 50mm for measuring aggregates.

TampingRod:Astraightmetalstampingrodofcircularcrosssection,10mm in diameter and 230mm long, rounded at one end.

Sieve:IS sieveof sizes12.5mm, 10mm, and2.36mm forsieving theaggregates.

Balance:Abalanceofcapacity notless than500gm toweigh accurateup to0.1gm.

Oven: A thermostatically controlled drying oven capable of maintaining constant temperature between 100 C to110 C.

**Fig3.1-AIV Machine**

Procedure:

Thetestsampleconsistsofaggregatespassing12.5mmsieveandretainedon10mmsieveand driedinanovenforfourhoursatatemperature1000Cto1100Candcooled.Testaggregates arefilleduptoaboutone-thirdfullinthecylindricalmeasureandtamped25timeswithrounded endofthetampingrod. Furtherquantityofaggregatesisthenaddeduptotwo-thirdfullinthe cylinder and 25 stocks of the tamping rod are given. The measure is now filled with the aggregates to overflow, tamped 25 times. The surplus aggregates are struck off using the tampingrodasstraightedge.Thenetweightoftheaggregatesinthemeasureisdeterminedto thenearestgramandthisweightoftheaggregatesisusedforcarryingoutduplicatetestonthe same material. The impact machine is placed with its bottom plate flat on the floor so that the hammer guide columns are vertical. The cup is fixed firmly in position on the base of the machineandthewholeofthetestsamplefromthecylindricalmeasureistransferredtothecup and compacted by tamping with 25 strokes.

Thehammeris raiseduntil its lowerfaceis 380mm abovetheuppersurfaceofthe aggregates in the cup and allowed to fall freely on the aggregates. The test sample is subjected to a total 15 such blows, each being delivered at an interval of not less than one second.

Thecrushedaggregateisthenremovedfromthecupandthewholeofitsievedonthe2.36mm sieve until no further significant amount passes.

**Fig3.2-Passing12.5mmSieve** **Fig3.3-TampingonAggregates**

**Table 3.2- AIV Test Report**

| AGGREGATEIMPACTVALUE | | | | | |
|---|---|---|---|---|---|
| **AsperIS2386-Part IV** | | | | | |
| **S. No** | **Determination** | **Trial I** | **Trial II** | **Trial III** | **Average** |
| 1 | TotalWt.OfOven-driedSample(passing12.5mm-Retained 10mmSieve)-W1[gms] | **355** | **357** | **350** | **26.66%** |
| 2 | Wt.OfMaterialRetainedon2.36mmaftertesting-W2[gms] | **280** | **277** | **275** | |
| 3 | Wt.OfMaterialPassingon2.36mmaftertesting-W3[gms] | **75** | **80** | **75** | |
| 4 | Differenceinweightaftertesting(W1-W2-W3) | **0.0** | **0.0** | **0.0** | |
| 5 | AggregateImpactValue(%)=(W3/W1)x100 | **21.13** | **22.41** | **21.43** | |

Thefractionretainedonthesieveisalsoweighedandifthetotalweightofthefractionspassing and retained on the sieve is added it should not beless the original weightof the specimen by more than one gram, if the total weight is less than the original by over one gram the results should be discarded, and a fresh test made.

**Fig3.4- Sieve with 2.36mm Sieve**

**Fig3.5-Giving 15 blows by using AIV**

The aggregate impact value is expressed as the percentage of the fines formed in terms of the total weight of the sample.
Where, W1= Originalweightofthe sample.
W2=Weight offractionpassing 2.36mmIS sieve.

Results:
ThemeanofthethreeresultsisreportedastheAIV(AggregateImpactValue)ofthespecimen to the nearest whole number.

Limits:
<10%Exceptionallystrong.
10 – 20% Strong
20 – 30% Satisfactoryforroad surfacing.
>35%Weakfor road surfacing.

Flakinessandelongationindicestest.Introduction:
The particle shape of aggregates is determined by the percentages of flaky and elongated particles contained in it. For base course and construction of bituminous and cement concrete types,thepresenceofflakyandelongatedparticlesisconsideredundesirableastheymaycause inherent weakness with possibilities of breaking down under heavy loads. The angularity number i.e., flaky and elongation has considerable importance in the graduation requirements of various types of mixes such as bituminous concrete,

cement concrete and soil aggregate mixes.


**Fig3.6- Sieve Used in Flakiness and Elongation Indices**

Objective:
To determine the flakiness and elongation of the aggregates by standard flakiness gauge and elongation gauges.

Apparatus:

a) Flakiness Gauge (Thickness Gauge): The Flakiness index of aggregates is the percentages by weight of particles whose least dimension is less than three-fifths (0.6) of their mean dimension.Thetestisnotapplicabletosizessmallerthan6.3mm.Theapparatusconsistsof astandardthicknessgaugeofISsievesizes63,50,40,31.5,25,20,16,12.5,10and6.3mm and a balance to weigh the samples.


**Fig3.7-Aggregates passing through F. G    Fig3.8-Flakiness Gauge**

b) ElongationGauge(LengthGauge):Theelongationindexofaggregateisthepercentageby weightofparticleswhosegreatestdimension(length)isgreaterthanoneandfourfifthtimes (1.8)theirmeandimension.Theelongationtestisnotapplicabletosizessmallerthan6.3mm.Theapparatusconsistsofa standard-lengthgaugeofISsievesizes50,40,31.5,25, 20, 16, 12.5, 10 and 6.3mm.


**Fig3.9-Passing aggregates by Elongation gauge    Fig3.10-Elongation Gauge**

Procedure:

FlakinessIndex:Thesampleissievedwiththesievesmentionedinabove.Aminimumof200 pieces of each fraction to be tested is taken and weighed. To separate flaky materials, each fractionisthengaugedforthicknessonathicknessgauge.Theamountofflakymaterialpassing the gauge is weighed to an accuracy of at least 0.1 percent of the test sample.

Calculation:

To calculate the flakiness index of the entire sample of aggregates first the weight of each fractionofaggregatepassingandretainedonthespecifiedsetofsievesisnoted(X1,X2,X3… etc.). Each of the particle from this fraction of aggregate is tried to be passed through the slot of the specified thickness of the thickness gauge are found and weighed (x1, x2, x3…etc.). Thentheflakinessindex isthetotalweight oftheflakymaterialpassingthevariousthickness gauges expressed as a percentage of the total weight of the sample gauged.

Elongation Index:

The sample is sieved through the IS sieves specified as above. A minimum of 200 pieces of eachfractionistakenandweighed.Toseparateelongatedmaterial,eachfractionisthengauged individually for length in a length gauge. The pieces of aggregates from each fraction tested which could not pass through the specified gauge length with its long side are elongated particles and are collected separately to find the total weight of aggregates retained on the lengthgaugefromeachfraction.Thetotalamountofelongatedmaterialretainedbythelength gauge is weighed to an accuracy of at least 0.1 percent of the weight of the sample.

Calculation:

To calculate the Elongation index of the entire sample of aggregates first the weight of each fractionofaggregatepassingandretainedonthespecifiedsetofsievesisnoted(Y1,Y2,Y3… etc.).Eachpieceofthese istriedtobepassedthroughthespecifiedlengthofthegaugelength withitslongestsideandthoseelongatedpieceswhichdonotpassthegaugeareseparatedand weighed (y1, y2, y3…). Then the Elongation index is thetotal weight of the material retained on the various length gauges, expressed as a percentage of the total weight of the sample gauged.

Combined Flakiness & Elongation Index: To determine this combined proportion, the flaky stone from a representative sample should first be separated out. Flakiness index is weight of flaky stone metal divided by weight of stone sample. Only the elongated particle is separated outfromtheremaining(non-flaky)stonemetal.Elongationindexisweightofelongatedparticlesdividedbytotalnon-flakyparticles.Thevalueofflakinessindexandelongationindex so found are added up.

Limits:

Flakiness Index for Bituminous and Non-bituminous Mixes = Max. 15% ElongationIndexforBituminousandNon-bituminousmixes=Max.15%

CombinedFlakiness,ElongationIndexforBituminous&Non-bituminousmixes=Max.30% Flakiness Index for Concrete mixes = Max.35%

**Table3.3-Flakiness and elongation indices test report**

**FLAKINESS AND ELONGATION INDEX**

As per IS:2386 (Part-1)

| Sieve Size (mm) | | FLAKINESS INDEX | | ELONGATION INDEX | |
|---|---|---|---|---|---|
| Passing | Retained | Wt. Of the Fraction Gauged(gm) | Wt. Of material passing through Flakiness Gauge (gm) | Wt. Of the Fraction Gauged (gm) | Wt. Of the material returned through Elongation Gauge (gm) |
| 63.0 | 50.0 | | | | |
| 50.0 | 40.0 | | | | |
| 40.0 | 31.5 | | | | |
| 31.5 | 25.0 | | | | |
| 25.0 | 20.0 | | | | |
| 20.0 | 16.0 | 1225 | 255 | 970 | 139 |
| 16.0 | 12.5 | 832 | 82 | 750 | 87 |
| 12.5 | 10.0 | 658 | 78 | 580 | 85 |
| 10.0 | 6.3 | 230 | 55 | 175 | 36 |
| | **Total** | 2945 | 470 | 2475 | 347 |

Note: Minimum 200 pcs. Should be taken on each fraction for test.

**Flakiness Index(%)** : (B/A)X 100 = **15.96**

**Elongation Index(%** :( D/C)X100 = **14.02**

**Combined (EI+FI) (%)** = ….. **29.98**

SpecificgravityandWaterabsorptiontestIntroduction:

The specific gravity of an aggregate is a measure of strength or quality of the material. The specific gravity test helps in the identification of stone.

Water absorption gives an idea of strength of aggregate. Aggregates having more water absorption are more porous in nature and are generally considered unsuitable unless they are found to be acceptable based on strength, impact, and hardness tests.

Object:Tofindthespecificgravity & waterabsorptionofaggregatesbyperforated basket.

Apparatus:

- A wire basket of not more than 6.3mm mesh or a perforated container of convenient size with thin wire hangers for suspending it from the balance.
- Athermostaticallycontrolledoventomaintaintemperature of 100to110C.
- Acontainerforfillingwaterandsuspendingthebasket.d)Anairtightcontainerofcapacity like that of the basket.
- A balance of capacity about 5 kg, to weigh accurate to 0.5 g, and of such a type and shape as to permit weighing of the sample container when suspended in water.
- Ashallowtray andtwo dryabsorbent clothes, each notless than750 X450 mm.

**Fig3.11-Specific Gravity Machine**

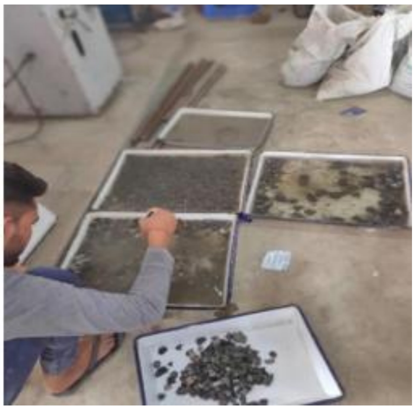


**Fig3.12-Different Size of Aggregates**

Procedure:

About 2 kg of the aggregate sample is washed thoroughly to remove fines, drained, and then placedinthewirebasketandimmersedindistilledwateratatemperaturebetween 100to120 C with a cover of at least 50mm of water above the top of the basket. Immediately after immersion the entrapped air is removed from the sample by lifting the basket containing it 25mmabovethebaseofthetankandallowingittodrop25timesattherateofaboutonedrop per second. The basket and the aggregate should remain completely immersed in water for a period of 24 +/- 0.5 hours afterwards.

Thebasket andthesamplearethenweighedwhilesuspendedinwateratatemperatureof220 to 320 C. In case it is necessary to transfer the basket and the sample to a different tank for weighing, they should be jolted 25 times as described above in the new tank to remove air before weighing. This weight is noted while suspended in water W1 g. The basket and the aggregatearethenremovedfromwaterandallowedtodrainforafewminutes,afterwhichthe aggregatesaretransferredtooneofthedryabsorbentclothes.Theemptybasketisthenreturned to the tank of water, jolted 25 times and weight in water W2 gm.

Theaggregatesplacedontheabsorbentclothesaresurfacedriedtillnofurthermoisturecould beremovedbythiscloth.Thentheaggregatesaretransferredtothesecond dryclothspreadin a single layer, covered, and allowed to dry for at least 10 minutes until the aggregates are completelysurfacedry.10to60minutesdryingmaybeneeded.Theaggregatesshouldnotbe exposed to theatmosphere, direct sunlight oranyothersourceofheat whilesurfacedrying.A gentlecurrentofunheatedairmaybeusedduringthefirsttenminutestoacceleratethedrying of aggregate surface. The surface dried aggregate is then weighed W3 g. The aggregate is placedinashallowtrayandkeptinanovenmaintainedatatemperatureof110Cfor24hours. It is then removed from the oven, cooled in an airtight container, and weighed W4 g. At least two tests should be carried out, but not concurrently.


**Fig3.13- Oven Machine**

**Table3.4-Test Report of Specific Gravity and Water Absorption**

| SPECIFICGRAVITY ANDWATERABSORPTIONTEST | | | | | | |
|---|---|---|---|---|---|---|
| S.No. | Determination | | TrialI | Trial II | TrialIII | Average |
| 1 | Wt.OfDrySample[SSD] [gms] | A | 509.0 | 514.0 | 511.0 | |
| 2 | Wt.OfPycnometer+Water[gms] | B | 1631.0 | 1631.0 | 1631.0 | |
| 3 | Wt.OfPycnometer+Water+Sample[gms] | C | 1969.0 | 1968.0 | 1970.0 | |
| 4 | Wt.ofOvenDrySample [gms] | D | 500.0 | 505.0 | 503.0 | |
| 5 | WaterAbsorption[%] | [(A-D)/D]*100 | 1.80 | 1.78 | 1.59 | 1.72 |
| 6 | SpecificGravity | D/(A-[C-B]) | 2.924 | 2.853 | 2.924 | 2.901 |
| 7 | Average3.SpecificGravity | D/(D-[C-B]) | 3.086 | 3.006 | 3.067 | 3.053 |

Limits:

The specific gravity of aggregates ranges from 2.5 to 3.0 The water absorption of aggregates ranges from 1 to 4.0%

**Table3.5- Test Result and Limits**

| DescriptionofTest | TestMethod | TestResults | MORTHStandards |
|---|---|---|---|
| Aggregateimpact value | IS2386Part4&MORTH | 26.66_ | Maximum30% |
| Combinedflakinessand elongationindices | IS2386Part1&MORTH | 29.98_ | Maximum35% |
| Waterabsorption | IS2386Part3&MORTH | 1.72_ | 2.5%to 3% |
| Specificgravitytest | IS2386Part3&MORTH | 3.053_ | 0.1%to 4% |

EMULSION

Bitumen emulsion is one of the binding materials that can be used in the construction, maintenanceofroad,pavement,andhighways.AsperIRC37-2012wewilluseemulsionasa binder in my mix proportion.

Bitumen emulsion is a dispersion of fine minute droplets of bitumen into water manufactured byusingemulsifyingagentstoemulsifybitumeninwater.Amajorobjectiveofusingbitumen emulsions is to obtain a product that can be used without heating.

Benefitsand Issueswith BitumenEmulsionAdvantagesofusingbitumenemulsionsinclude:

- Theycanbe usedwithdampaggregates.
- Elevatedtemperaturesarenotrequiredforproperuseandapplication.
- Theyprovideeconomic, environmental, andsustainablebenefits.

**Fig3.14- Sampling of Bitumen Emulsion from Stock Yard**

Tests can be conducted as per IS8887-2004
1. Residuecontentof emulsionbyevaporation (%by mass)
2. Penetrationvalueofresiduecontentofemulsion

Table3.6-Test Resultand Limits

| DescriptionofTest | Test Method | Test Result Obtained | Requirements ofIS:73-2013 |
|---|---|---|---|
| Residuecontentofemulsionbyevaporation (% by mass) | Asper IS 8887-2004 | 60.46 | 60 minimum |
| Penetrationvalueofresiduecontentofemulsion | | 89.00 | 60 to 120 |

**3.3 Cement**

Cement orlimewould useas a fillerin cold mix design, it is performed very important roleif recycled material contaminated with clay.

Cement was used as a filler material in this mix design. Cement is the important binding materialintoday'sconstructionworld,OrdinaryPortlandCement(OPC)43gradeconfirming toIS:8112-2013cement used.Cementsamples werecollected from cementstoreof batching plant at Dobhi camp and tests were performed in site laboratory.

**TestperformedonCement:-**

1. Consistencyofcement [AsperIS:4031Part-4]
2. InitialSettingTime [Asper IS:4031(Part-5) –1988]
3. FinalSettingTime [Asper IS:4031(Part-5) –1988]
4. Finenessofcement [Asper IS:4031 (Part-1) –1996]

***3.3.1 ConsistencyofCement[Asper IS: 4031 Part-4]***

***Object:*** Determinationofthequantityofwaterrequiredtoproduceacementpasteofstandard consistency.

***Apparatus:*** Vicatapparatus(confirmingtoIS:5513–1968)with plunger(10mmin dia).

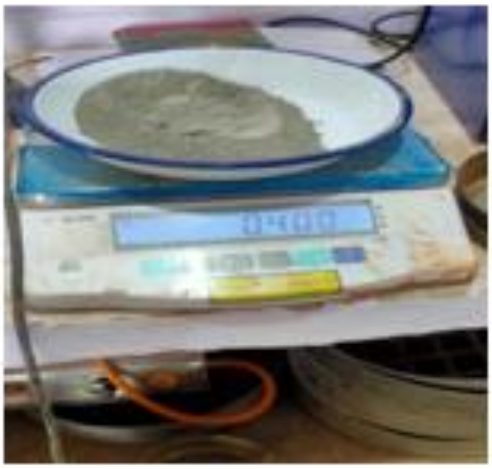
Fig3.15-Vicat Apparatus

***Theory:***

Thestandardconsistencyofacementpasteisdefinedasthatconsistencywhichwillpermitthe vicat plunger to penetrate to a point 5 to 7 mm from the bottom of the vicatmould, when the cement paste is tested as described in the following procedure.

***Procedure:***

- Prepareapasteofweightedquantityofcement(400gms)withaweightedquantityofwater, start with 30% water of 400 gms of cement taking care that the time of gauging is not less than3minutesandnotmorethan5minutesandthegaugingshallbecompletedbeforeany sign of setting occurs.
- Thegaugingtimeshallbecountedfromthetimeofaddingthewatertothedrycementuntil commencing to fill the mould. Fill the vicatmould with this paste, the mould resting upon a non-porous plate. After completely filling the mould, trim off the surface of the paste, makingitinlevelwiththetopofthemould.Themouldmayslightlybeshakentoexpelthe air.
- Place the test block with the mould, together with the non-porous resting plate, under the rodbearingtheplunger(10mmdia)lowertheplungergentlytotouchthesurfaceofthetest blockand quickly release, allowing it to penetrate into thepaste.This operation shall carry out immediately after filling the mould.



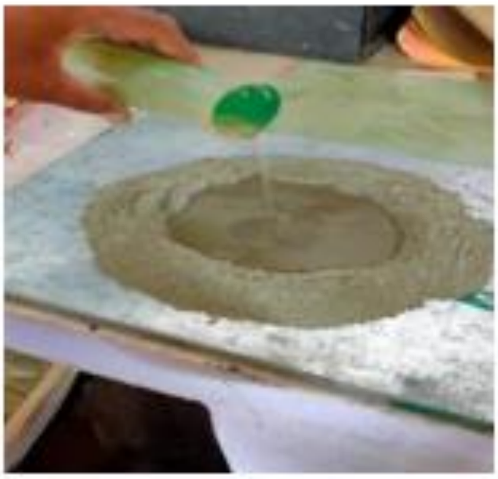


Fig3.16-Sampleof Cement

- Prepare trial pastes with varying percentages of water and test as described above until the amountofwaternecessaryformakingthestandardconsistencyasdefinedaboveisobtained. Express the amount of water as a percentage by weight of the dry cement.

Fig 3.17-PreparingaPaste ofCement with Water

***Precautions:***

Use clean appliances for gauging.Thetemperatureofcementandwater andthatoftestroom, at thetimewhen theabove operations arebeing performed, shall be270 C +/-20 C. theroom temperature shall be maintained at 270 C +/- 20 C.

This test helps to determine the water content for other tests like initial setting time and final setting time.

*3.3.2* ***InitialSettingTimeandFinalSettingTime***

***Object:***DeterminationoftheInitialandFinalsettingtimesofcement.

***Apparatus:*** The vicat apparatus (conforming to IS: 5513 – 1968)

***Sample:*** 350 gms of cement is taken.

***Procedure:***

*PreparationofTestBlock*

Prepareaneatcementpastebygauging350gmsofcementwith0.85timesthewaterrequired togiveapasteofstandardconsistency.Thepasteshallbegaugedinthemannerandunderthe conditions prescribed in determination of consistency of standard cement paste. Start a stopwatch at the instant when water is added to the cement. Fill the mould with the cement pastegaugedasabove,themouldrestingonanon-porousplate,fillthemouldcompletelyand smoothoffthesurfaceofthepastemakingitlevelwiththetopofthemould.Thecementblock thus prepared in the mould is the test block.

Inconsistencytestofcement,weadd120mlofwatersointhistestweadd85%of120mlthat is 102 ml water is add to cement to became a paste.

Use clean appliances for gauging. The temperature of water and that of the test room, and the time gauging, shall be 270 C +/- 20 C.

During the test, the block shall be kept at a temperatureof 270 C +/- 20 C and at not less than 90% relative humidity.

*DeterminationofInitialSetting Time:*

Place the test block confined in the mould and resting on the non-porous plate, under the rod bearing initial setting needle, lower the needle gently in contact with the surface of the test block and quickly release, allowing it to penetrate the test block. In the beginning the needle will completely pierce the test block. Repeat this procedure until the needle, when brought in contactwiththetestblockandreleasedasdescribedabove,failstopiercetheblockfor5+/-0.5mmmeasuredfromthebottomofthemould.Theperiodlapsingbetweenthetimewateris added to the cement and the time at which the needle fails to pierce the test block by 5 +/- 0.5 mm shall be the initial setting time.

*DeterminationofFinalSettingTime:*

Replacetheneedleofthevicatapparatusbytheneedlewithanannularring.Thecementshall be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression thereon, while the outer ring fails to do so. The period elapsingbetweenthetimewhenwaterisaddedtothecementandthetimeatwhichtheneedle makes an impression on the surface of the test block while the attachment fails to do so, shall be the final setting time.

***Limits:***

- InitialSettingTime,minimum-030 minutes.
- FinalSettingTime, maximum-600 minutes.

*3.3.3 **FinenessofCement[AsperIS:4031(Part-1)–1996]***

***Object:*** To determine the fineness of cement by dry sieving.

***Apparatus:***

a) Standardbalancewith 100gm.weighing capacity.

b) IS:90-micronsieveconfirmingto IS: 460–1962andaBrush.

***Procedure:***

- Breakdownanyair-setlumpsin thecementsamplewith fingers.
- Weighaccurately 100 gms of thecement andplaceit on astandard 90micronIS.sieve.

- Continuouslysievethesamplefor15 minutes.
- Weighttheresidueleftafter 15minutesof sieving. This completesthe test.

***Result:***

Thepercentageweight of residue overthetotal sampleis reported.

%Weightof Residue =(Wt.OfSampleRetainedonthe Sieve/TotalWeight ofthe Sample)

Fig3.18-Cement Test

***Limits:*** Thepercentageresidueshould notexceed10%.

***Precautions:*** Sieving shall be done holding the sieve in both hands and gentle wrist motion, this will involve no danger of spilling the cement, which shall be kept well spread out on the screen. Continuous rotation of the sieve shall be carried out throughout sieving.

Washers, shots and slugs shall not be used on the sieve. The underside of the sieve shall be lightly brushed with a 25- or 40-mm bristle brush after every five minutes of sieving.

Mechanical sieving devices may be used, but the cement shall not be rejected if it meets the fineness requirement when tested by the hand method.

Table3.7-CementTestResultandlimit

| **Description of Test** | **TestResult Obtained** | **Requirements of IS: 8112-1989** |
|---|---|---|
| InitialSetting Time | 120 min | Min.30 Minutes |
| FinalSetting Time | 245 | Max.600 Minutes |
| Fineness | 3.25% | Notmorethe 10% |

**3.4 RecycleMaterial (RAP):**

RecyclematerialaccumulatedfromPATNAtoDOBHI(NH-83)highwayexistingbituminous pavement.Existingbituminouslayermilledbycoldrecyclingprocessupto150mmandmilled material transported to the Dobhi camp 3. Here recycled material stored in stockpile. Sample takenfromstockpileformixdesigntrialandvarioustestwereperformedinthesitelaboratory like as gradation of recycle material, aggregate impact value test, bitumen extraction from recycle material. Milling material shared maximum percentile of mix design hence it is necessary to assure the quality of recycle material before use as a main ingredient of mix design. If milling material contaminated with clay, then we are used 2 % lime as per IRC 37- 2012 but there is no situation arise for doing so.

RAP is the pulverized excavated material that has been recovered usually by milling that is usedasanaggregatematerialfortherehabilitationandmaintenanceofroads.TheuseofRAP as an alternative to new virgin aggregate materials is gaining worldwide attention as a sustainable, economic, widely available, and environmentally friendly option. The RAP to be used should be properly tested and characterized to ascertain its properties that include the gradation, moisture content, density, elongation and flakiness index, the residual binder content, compatibility, penetration, and softening point of the residual binder in the RAP.

Fig3.19-StockyardsofRAP materials

**TestperformanceonRAP materials**

1. AggregatesImpactValueTest(AIV)
2. BitumenExtractionTest

Table3.8-AIVTestReport

| AGGREGATEIMPACT VALUE | | | | | |
|---|---|---|---|---|---|
| AsperIS 2386-PartIV | | | | | |
| **S. No** | **Determination** | **Trial I** | **Trial II** | **Trial III** | **Average** |
| 1 | Total Wt. Of Oven-dried Sample (passing 12.5mm–Retained10mmSieve)-W1[gms] | 360.5 | 362.5 | 367.5 | **12.15%** |
| 2 | Wt.OfMaterialRetainedon2.36mmafter testing -W2[gms] | 315 | 320 | 323 | |
| 3 | Wt.OfMaterial Passingon2.36mmaftertesting -W3[gms] | 46 | 43 | 45 | |
| 4 | Differenceinweightaftertesting(W1-W2-W3) | 0.0 | 0.0 | 0.0 | |
| **5** | **AggregateImpactValue(%)=(W3/W1) x100** | **12.62** | **11.72** | **12.11** | |

Table3.9-BitumenExtractionTest Report

| BitumenExtractionTest | | | | |
|---|---|---|---|---|
| **AsperIRCSP-21** | | | | |
| **Sr. No.** | **DESCRIPTION** | **OBSERVATION** | | |
| | | **1** | **2** | **3** |
| 1 | Wt.ofSampleBeforeExtraction(gms) | 1560 | 1264 | 1204 |
| 2 | Wt.ofFilterPaperBeforeExtraction(gms) | 8.66 | 9.83 | 6.91 |
| 3 | Wt.ofFilterPaperAfter Extraction(gms) | 9.29 | 10.3 | 7.16 |
| 4 | Wt.ofAggregate inFilterPaper(gms)=(3-2) | 0.63 | 0.47 | 0.25 |
| 5 | Wt.ofSampleAfterExtraction(gms) | 1509 | 1236 | 1151 |
| 6 | Wt.of Bitumen in gms=1-(4+5) | 50.37 | 27.53 | 52.75 |
| 7 | %ofBitumen=(6/1)*100 | 3.23 | 2.18 | 4.38 |
| 8 | **Average%ofBitumen** | **3.26** | | |

Fig3.20-BitumenExtractionTest

### 3.5 ExperimentalProcedure

According to research, up to now, there is no hard and fast rule for formal mix design of EmulsionTreatedRAP,andinthatrespectnohardprocedureandqualitycontroltestonlaying of Emulsion Treated RAP. Thus, in this research, some laboratory tests were performed to obtainsomemechanicalpropertiesofthismix.TestperformedonmixasperIRC-372012and test performed on individual ingredients by their relevant IS code and specifications.

#### *3.5.1.MixDesignProcedure*

*1. MixGradation:* Allaccumulatedsamplesfromthestockpile&sitehavebeendriedfirst24- hours then individual sample taken and gradation test wereperformed as per sieve designated in IRC37 2012 Table IX-1.

Resultswereobtainedfrom individualgradationareshowingingiven below.

- 40 mm
- 20 mm
- Crusherdust
- RAP (Milling Material)
- Filler(cement)

Varioustrialhasbeenmadeforgettingoptimizegradationlikeasblendingweremadeintrial- 1 is 40 mm+RAP+crusherdust +Cement but this trial does not give asatisfactoryresult due tolargersizeaggregatesfluctuatedtheresultinhugefrequency.Hencesecondtrialweremade with RAP + 20 mm + Stone dust + Filler.

BothnaturalandRAPsampleswerebroughttorequiredsizeandsuitablegradingrequiredfor subbase, base, and surface course as per MORTH specifications.

#### *3.5.2 SamplesofDifferentCompositionsandResults*

Samples of different compositions were prepared by adding different percentage of RAP materials (0% RAP, 10% RAP, 25% RAP, 35% RAP, 45% RAP and 60% RAP).

Table-3.10-CompositionofDifferent Materials

| SampleNo. | DetailsofComposition |
|---|---|
| R1 | RAP0%+95%Natural Aggregate +5%Stone dust |
| R2 | RAP10%+75%Natural Aggregate +15%Stonedust |
| R3 | RAP25%+58%Natural Aggregate +17%Stonedust |

| | |
|---|---|
| R4 | RAP35%+40%Natural Aggregate +25%Stonedust |
| R4 | RAP45% +25%NaturalAggregate+30%Stonedust |
| R6 | RAP60%+5%NaturalAggregate+35%Stone dust |

Table3.11-TestResults Table

| Sample Composition | Aggregate Impact Value | Flakiness & ElongationIndex (Combined) | LossAngeles Abrasion Test Value | Water Absorption |
|---|---|---|---|---|
| RAP 0% + 95% Natural Aggregate+5%Stonedust | 26.5% | 25.8% | 31% | 1.9% |
| RAP 10% + 75% Natural Aggregate+15%Stonedust | 25% | 23.2% | 28.9% | 1.82% |
| RAP 25% + 58% Natural Aggregate+17%Stonedust | 22.2% | 28.4% | 26.2% | 1.92% |
| RAP 35% + 40% Natural Aggregate+25%Stonedust | 20.5% | 24.6 | 25.4% | 1.72% |
| RAP 45% + 25% Natural Aggregate+30%Stonedust | 17.8% | 20.5% | 19.8% | 1.10% |
| RAP 60% + 5% Natural Aggregate+35%Stonedust | 18.9% | 22.5 | 18.5% | 1.63% |

Table3.12-STANDARDWMMMIXEDDesign

| | AggregatesImpact Value | Flakiness And ElongationTest | Loss Angeles AbrasionTest Value | Water Absorption |
|---|---|---|---|---|
| **StandardWMM Mixed Design** | 21.70% | 24.04% | 23.8% | 0.74% |

*3.5.2.1 Outcoming:*

- From the test result as shown in table, it was observed that sample having composition of **RAP 45%, 20mm fine aggregate, Stone dust 30%** give the best result and follow the MORTH limit.
- Samplehavingcompositionof **RAP45%,20mmfine aggregate,Stonedust30%** canbe used in WMM layers for flexible pavements.
- From the test result as shown in table, it was observed that sample compositions of RAP 45%, 20mm fine aggregates, Stone dust 30% give best result and also follow the MORTH limit.

- **3.6 Blending**

Blendingofallingredientsbythroughaverageindividualgradationasfollows:

Table3.13-GradingAnalysisof20mmDownAggregates(Sample-1)

| 20 mm | | | | | |
|---|---|---|---|---|---|
| SAMPLE-1 | | | | | |
| GRADINGANALYSIS | | | | | |
| (Asper:2386,Part-1&MORTH) | | | | | |
| ISSieveSize (mm) | Material Retained(gms) | CumulativeMaterial Retained (gms) | %Retained cumulative | %Passing | Remarks |
| 45 | 0 | 0 | 0.00 | 100.00 | |
| 37.50 | 0 | 0 | 0.00 | 100.00 | |
| 26.50 | 0 | 0 | 0.00 | 100.00 | |
| 19.00 | 2197 | 2197 | 23.75 | 76.25 | |
| 13.20 | 4364 | 6561 | 70.93 | 29.07 | |
| 4.75 | 2564 | 9125 | 98.65 | 1.35 | |
| 2.36 | 125 | 9250 | 100.00 | 0.00 | |
| 0.600 | 0 | 9250 | 100.00 | 0.00 | |
| 0.300 | 0 | 9250 | 100.00 | 0.00 | |
| 0.075 | 0 | 9250 | 100.00 | 0.00 | |

Table3.14-GradingAnalysisof20mmDownAggregates(Sample-2)

| 20 mm | | | | | |
|---|---|---|---|---|---|
| SAMPLE-2 | | | | | |
| GRADINGANALYSIS | | | | | |
| (Asper:2386,Part-1&MORTH) | | | | | |
| ISSieveSize in mm | Material Retained(gms) | CumulativeMaterial Retained (gms) | %Retained cumulative | %Passing | Remarks |
| 45 | 0 | 0 | 0.00 | 100.00 | |
| 37.50 | 0 | 0 | 0.00 | 100.00 | |
| 26.50 | 0 | 0 | 0.00 | 100.00 | |
| 19.00 | 2872 | 2872 | 20.41 | 79.59 | |
| 13.20 | 6948 | 9820 | 69.79 | 30.21 | |
| 4.75 | 4093 | 13913 | 98.88 | 1.12 | |
| 2.36 | 157 | 14070 | 100.00 | 0.00 | |
| 0.600 | 0 | 14070 | 100.00 | 0.00 | |

Table3.15-GradingAnalysisof20mmDownAggregates(Sample-3)

| 20 mm | | | | | |
|---|---|---|---|---|---|
| SAMPLE-3 | | | | | |
| GRADINGANALYSIS | | | | | |
| (Asper:2386,part-1&MORTH) | | | | | |
| ISSieveSize in mm | Material Retained(gms) | Cumulative Material Retained (gms) | %Retained cumulative | %Passing | Remarks |
| 45 | 0 | 0 | 0.00 | 100 | |
| 37.50 | 0 | 0 | 0.00 | 100.00 | |
| 26.50 | 0 | 0 | 0.00 | 100.00 | |
| 19.00 | 3517 | 3517 | 23.12 | 76.88 | |
| 13.20 | 6823 | 10340 | 67.98 | 32.02 | |
| 4.75 | 4631 | 14971 | 98.43 | 1.57 | |
| 2.36 | 239 | 15210 | 100.00 | 0.00 | |
| 0.600 | 0 | 15210 | 100.00 | 0.00 | |
| 0.300 | 0 | 15210 | 100.00 | 0.00 | |
| 0.075 | 0 | 15210 | 100.00 | 0.00 | |

Table3.16-GradingAnalysisof20mmDownAggregates(Average)

| AVERAGE%0F20MMFRESHT AGGREGATES | | | | |
|---|---|---|---|---|
| ISSieveSize (mm) | Trial-1 | Trial-2 | Trial-3 | %Passing |
| 45 | 100.00 | 100.00 | 100.00 | 100,00 |
| 37.50 | 100.00 | 100.00 | 100.00 | 100.00 |
| 26.50 | 100.00 | 100.00 | 100.00 | 100.00 |
| 19.00 | 76.25 | 79.59 | 76.88 | 77.57 |
| 13.20 | 29.07 | 30.21 | 32.02 | 30.43 |
| 4.75 | 1.35 | 1.12 | 1.57 | 1.35 |
| 2.36 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.600 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.300 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.075 | 0.00 | 0.00 | 0.00 | 0.00 |

*3.6.2:RAP Material*

Table3.17-GradingAnalysisofRAPMaterials(Sample-1)

| SAMPLE-1 | | | | | |
|---|---|---|---|---|---|
| RAPMATERIALS | | | | | |
| GRADINGANALYSIS | | | | | |
| (Asper2386, part-1&MORTH) | | | | | |
| ISSieveSize(mm) | Material Retained(gms) | Cumulative Retained(gms) | %Retained cumulative | %Passing | Remarks |
| 45 | 0 | 0 | 0 | 100.00 | |
| 37.50 | 318 | 318 | 3.00 | 97.03 | |
| 26.50 | 476 | 794 | 7.50 | 92.50 | |
| 19.00 | 445 | 1239 | 11.70 | 88.30 | |
| 13.20 | 898 | 2137 | 20.18 | 79.82 | |
| 4.75 | 4733 | 6870 | 64.87 | 35.13 | |
| 2.36 | 1695 | 8565 | 80.88 | 19.12 | |
| 0.600 | 1200 | 9765 | 92.21 | 7.79 | |
| 0.300 | 236 | 10001 | 94.44 | 5.56 | |
| 0.075 | 544 | 10545 | 99.58 | 0.42 | |

Table3.18-GradingAnalysisofRAPMaterials(Sample-2)

| SAMPLE-2 | | | | | |
|---|---|---|---|---|---|
| GRADINGANALYSIS | | | | | |
| (Asper2386,part-1&MORTH) | | | | | |
| ISSieveSize in mm | Material Retained (gms) | Cumulative Material Retained(gms) | %Retained cumul0ative | %Passing | Remarks |
| 45 | 0 | 0 | 0 | 100.00 | |
| 37.50 | 401 | 401 | 4.20 | 95.80 | |
| 26.50 | 258 | 659 | 6.90 | 93.10 | |
| 19.00 | 563 | 1222 | 12.80 | 87.20 | |
| 13.20 | 377 | 1599 | 16.74 | 83.26 | |
| 4.75 | 4549 | 6148 | 64.38 | 35.62 | |
| 2.36 | 1753 | 7901 | 82.73 | 17.27 | |
| 0.600 | 984 | 8885 | 93.04 | 6.96 | |
| 0.300 | 120 | 9005 | 94.29 | 5.71 | |
| 0.075 | 499 | 9504 | 99.52 | 0.48 | |

Table3.19-GradingAnalysisofRAPMaterials(Sample-3)

| SAMPLE-3 | | | | | |
|---|---|---|---|---|---|
| GRADINGANALYSIS | | | | | |
| (Asper2386,part-1&MORTH) | | | | | |
| ISSieveSize in mm | Material Retained (gms) | Cumulative Material Retained(gms) | %Retained cumulative | %Passing | Remarks |
| 45 | 0 | 0 | 0 | 100.00 | |
| 37.50 | 424 | 424 | 4.20 | 95.80 | |
| 26.50 | 212 | 636 | 6.29 | 93.71 | |
| 19.00 | 435 | 1071 | 10.60 | 89.40 | |
| 13.20 | 591 | 1662 | 16.45 | 83.55 | |
| 4.75 | 4718 | 6380 | 63.14 | 36.86 | |
| 2.36 | 1891 | 8271 | 81.85 | 18.15 | |
| 0.600 | 1142 | 9413 | 93.15 | 6.85 | |
| 0.300 | 35 | 9448 | 93.50 | 6.50 | |
| 0.075 | 607 | 10055 | 99.51 | 0.49 | |

Table3.20-GradingAnalysisofRAPMaterials(Average)

| AVERAGE%0FRAP MATERIALS | | | | |
|---|---|---|---|---|
| ISSieveSize in mm | Trial-1 | Trial-2 | Trial-3 | %Passing |
| 45 | 100.00 | 100.00 | 100.00 | 100.00 |
| 37.50 | 97.00 | 95.80 | 95.80 | 96.20 |
| 26.50 | 92.50 | 93.71 | 93.10 | 93.10 |
| 19.00 | 88.30 | 89.40 | 87.20 | 88.30 |
| 13.20 | 79.82 | 83.55 | 83.26 | 82.21 |
| 4.75 | 35.13 | 36.86 | 35.62 | 35.87 |
| 2.36 | 19.12 | 18.15 | 17.27 | 18.18 |
| 0.600 | 7.79 | 6.85 | 6.96 | 7.20 |
| 0.300 | 5.56 | 6.50 | 5.71 | 5.92 |
| 0.075 | 0.42 | 0.49 | 0.48 | 0.47 |

### 3.6.3Crusher Dust

Table3.21-GradingAnalysisofCrusherDust(Sample-1)

| CRUSHERDUST | | | | | |
|---|---|---|---|---|---|
| SAMPLE-1 | | | | | |
| GRADINGANALYSIS | | | | | |
| (Asper2386,part-1&MORTH) | | | | | |
| ISSieve Size in mm | Material Retained (gms) | Cumulative Material Retained(gms) | %Retained cumul0ative | %Passing | Remarks |
| 45 | 0 | 0 | 0.00 | 100 | |
| 37.50 | 0 | 0 | 0.00 | 100.00 | |
| 26.50 | 0 | 0 | 0.00 | 100.00 | |
| 19.00 | 0 | 0 | 0.00 | 100.00 | |
| 13.20 | 0 | 0 | 0.00 | 100.00 | |
| 4.75 | 0 | 0 | 0.00 | 100.00 | |
| 2.36 | 959 | 959 | 17.43 | 82.57 | |
| 0.600 | 2872 | 3831 | 69.63 | 30.37 | |
| 0.300 | 577 | 4408 | 80.12 | 19.88 | |
| 0.075 | 523 | 4931 | 89.62 | 10.38 | |

Table3.22-GradingAnalysisofCrusherDust(Sample-2)

| CRUSHERDUST | | | | | |
|---|---|---|---|---|---|
| SAMPLE-2 | | | | | |
| GRADINGANALYSIS | | | | | |
| (Asper2386,part-1&MORTH) | | | | | |
| ISSieveSize in mm | Material Retained (gms) | Cumulative Material Retained(gms) | %Retained cumul0ative | %Passing | Remarks |
| 45 | 0 | 0 | 0.00 | 100 | |
| 37.50 | 0 | 0 | 0.00 | 100.00 | |
| 26.50 | 0 | 0 | 0.00 | 100.00 | |
| 19.00 | 0 | 0 | 0.00 | 100.00 | |
| 13.20 | 0 | 0 | 0.00 | 100.00 | |
| 4.75 | 6 | 6 | 0.34 | 99.66 | |
| 2.36 | 323 | 329 | 18.48 | 81.52 | |
| 0.600 | 944 | 1273 | 71.52 | 28.48 | |
| 0.300 | 184 | 1457 | 81.85 | 18.15 | |
| 0.075 | 171 | 1628 | 91.46 | 8.54 | |

Table3.23-GradingAnalysisofCrusherDust(Sample-3)

| CRUSHERDUST | | | | | |
|---|---|---|---|---|---|
| SAMPLE-3 | | | | | |
| GRADINGANALYSIS | | | | | |
| (Asper2386, part-1&MORTH) | | | | | |
| ISSieve Size in mm | Material Retained (gms) | Cumulative Material Retained(gms) | %Retained cumul0ative | %Passing | Remarks |
| 45 | 0 | 0 | 0.00 | 100 | |
| 37.50 | 0 | 0 | 0.00 | 100.00 | |
| 26.50 | 0 | 0 | 0.00 | 100.00 | |
| 19.00 | 0 | 0 | 0.00 | 100.00 | |
| 13.20 | 0 | 0 | 0.00 | 100.00 | |
| 4.75 | 29 | 29 | 1.75 | 98.25 | |
| 2.36 | 282 | 311 | 18.80 | 81.20 | |
| 0.600 | 859 | 1170 | 70.74 | 29.26 | |
| 0.300 | 170 | 1340 | 81.02 | 18.98 | |
| 0.075 | 161 | 1501 | 90.75 | 9.25 | |

Table3.24-GradingAnalysisofCrusherDust (Average)

| AVERAGE%OFCRUSHER DUST | | | | |
|---|---|---|---|---|
| ISSieveSize in mm | Trial-1 | Trial-2 | Trial-3 | %Passing |
| 45 | 100.00 | 100.00 | 100.00 | 100,00 |
| 37.50 | 100.00 | 100.00 | 100.00 | 100.00 |
| 26.50 | 100.00 | 100.00 | 100.00 | 100.00 |
| 19.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 13.20 | 100.00 | 100.00 | 100.00 | 100.00 |
| 4.75 | 100.00 | 99.66 | 98.25 | 99.30 |
| 2.36 | 82.57 | 81.52 | 91.20 | 85.10 |
| 0.600 | 30.37 | 28.48 | 29.26 | 29.37 |
| 0.300 | 19.88 | 18.15 | 18.98 | 19.00 |
| 0.075 | 10.38 | 8.54 | 9.25 | 9.39 |

Thefinal blendingpercentagewasobtained fordry ingredients.

Table3.25-AnalysisofFinal Blending

| Final Blending | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IS SIEVE (mm) | % of Passing | | | | Percentage for Blending | | | | | IRC:37-2012 Table No. IX-1 | | |
| | | | | | 20mm | RAP | Dust | Cement | Total % of Passing | Lower limit | MID LIMIT | Upper Limit |
| | 20 mm | RAP | Dust | Cement | 24% | 45% | 30% | 1% | 100% | | | |
| 45.00 | 100.00 | 100.00 | 100.00 | 100.00 | 24.00 | 45.00 | 30.00 | 1.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 37.50 | 100.00 | 96.20 | 100.00 | 100.00 | 24.00 | 43.29 | 30.00 | 1.00 | 98.29 | 87.00 | 93.50 | 100.00 |
| 26.50 | 100.00 | 93.10 | 100.00 | 100.00 | 24.00 | 41.90 | 30.00 | 1.00 | 96.90 | 77.00 | 88.50 | 100.00 |
| 19.00 | 77.57 | 88.30 | 100.00 | 100.00 | 18.62 | 39.74 | 30.00 | 1.00 | 89.35 | 66.00 | 82.50 | 99.00 |
| 13.20 | 30.43 | 82.21 | 100.00 | 100.00 | 7.30 | 36.99 | 30.00 | 1.00 | 75.30 | 67.00 | 77.00 | 87.00 |
| 4.75 | 1.35 | 35.87 | 99.0 | 100.00 | 0.32 | 16.14 | 29.79 | 1.00 | 47.26 | 33.00 | 41.50 | 50.00 |
| 2.36 | 0.00 | 18.18 | 85.10 | 100.00 | 0.00 | 8.18 | 25.53 | 1.00 | 34.71 | 25.00 | 36.00 | 47.00 |
| 0.600 | 0.00 | 7.20 | 29.37 | 100.00 | 0.00 | 3.24 | 8.81 | 1.00 | 13.05 | 12.00 | 19.50 | 27.00 |
| 0.300 | 0.00 | 5.92 | 19.00 | 98.67 | 0.00 | 2.66 | 5.70 | 0.99 | 9.35 | 8.00 | 14.50 | 21.00 |
| 0.075 | 0.00 | 0.47 | 9.39 | 89.00 | 0.00 | 0.21 | 2.82 | 0.89 | 3.92 | 2.00 | 5.50 | 9.00 |

Fromthetestresultasshownintable,itwasobservedthatsamplecompositionsofRAP45%, 24% 20mm fine aggregates, Stone dust 30% and 1% give best result and also follow the MORTH limit.

Andalso,thefinalblendingpercentageofblendingmaterialscomeunderthelimitinbetween lower limit and upper limit as per IRC:37-2012 Table No. IX-1 And also follow all limits of test results of materials under MORTH and IRC.

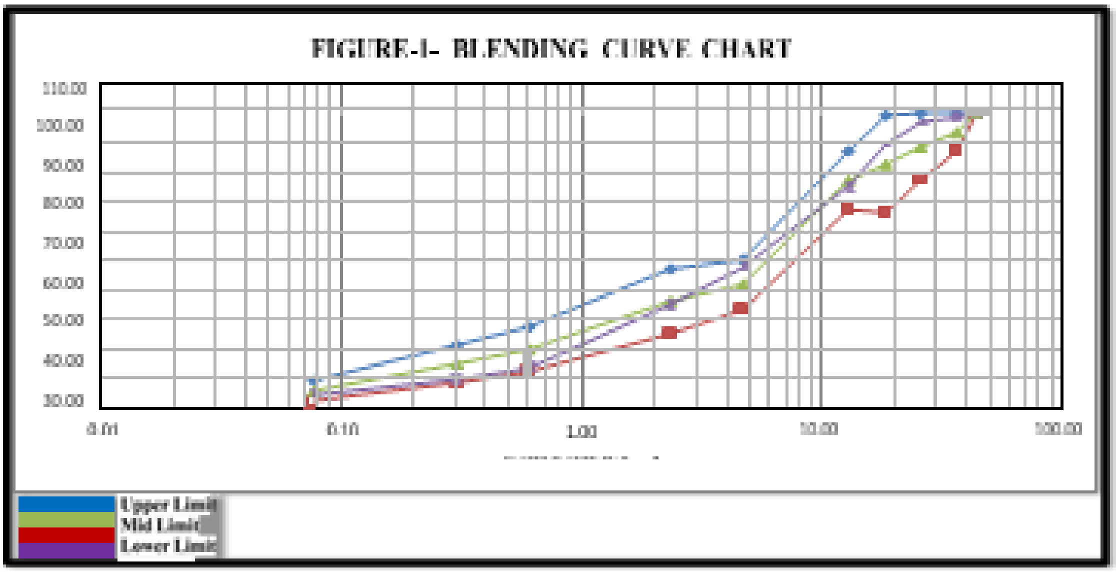



Fig.3.21-BlendingCurveChart

*3.7.***Determination ofMDD&OFC**

These step gives an optimum fluid content on which mix can 100% compacted and density obtained onOFC is utilize at field compaction test as a maximum dry density of laboratory.

Fluidcontent of the mix is the sum of aggregate, moisture content, residual, bitumen content, water in the emulsion & additional water added to the mix.

The MDD & OFC were determined as per guidelines provided in IRC-37 2012 annexure-IX (in step 1,2,3) detailed description of the procedure is given below.

In this test we done 5 trial and each trail have 3 no. of 100mm diameter Mould cast. Take 1200gmbatchweightofdryingredients.Themixingwasdonefor1minutetoensureuniform & thorough coating of RAP & fresh virgin aggregate.

- Emulsion– 3%
- Water–2%
- 20mmaggregate -24%
- Stone dust – 30%
- Cement–1%(Use as afiller material)
- RAPmaterial–45%

Bythe helpofthesepercentage, wefound theweight ofthesematerials.


Fig3.22-100mm dia.Mould

- ActualmoisturecontentoftheblendofRAP,fillerandvirginaggregatewas determinedasperASTM 2216 guidelines. This is designated as a blend moisture content.
- 50:50blendofemulsion&watermixbyvolumewasprepared.Waterisaddedtothe

bitumenemulsionbecauseifweaddtheemulsionintothewater,premature breakingtakes place. So, prevent premature breaking, water added into the emulsion.

- Take 1200 grams' batch weight of dry ingredients. The mixing was done for 1 minute to ensure uniform & thorough coating of RAP & fresh virgin aggregate.

Fig3.23-MixingofmaterialsforcastingofMould

- CleanaMarshallMouldof 100mm dia.and oilingdone oninner surface.
- Mix put into Mould and compacted with 75 blows on one face by manual compaction, reverse the Mould& base plate compaction process with 75 blows are performed on other face.
- RemovethemarshalMouldfromthecompactor.Andsimilar3Mouldwerecastedoneach fluid content.
- Same Mould were casted at every fluid content increment of 1%. The increment in fluid content was by additional of extra water to the blend of Rap & virgin aggregate. Three Marshall specimens on each individual fluid content of 5%, 6%,7%, 8% & 9% were casted.
- After 24 hours the specimens were ejected from the Mould by Marshall machine and evaluated for their bulk density as ASTM D 272 6.

Fig3.24-PedestalHammer

- A graph was plotted between the calculated dry densities and corresponding total fluid contents.TheMDD&OFCwasdeterminedfromthegraph.OFCobtainedfromthedrawing theverticallinecorrespondingfromMaximumdensity.Thecalculatedmeandrydensityat differentfluidcontentsisgivenintableandthegraphwereplottedbetweenthedrydensity & corresponding fluid contents is shown in figure.

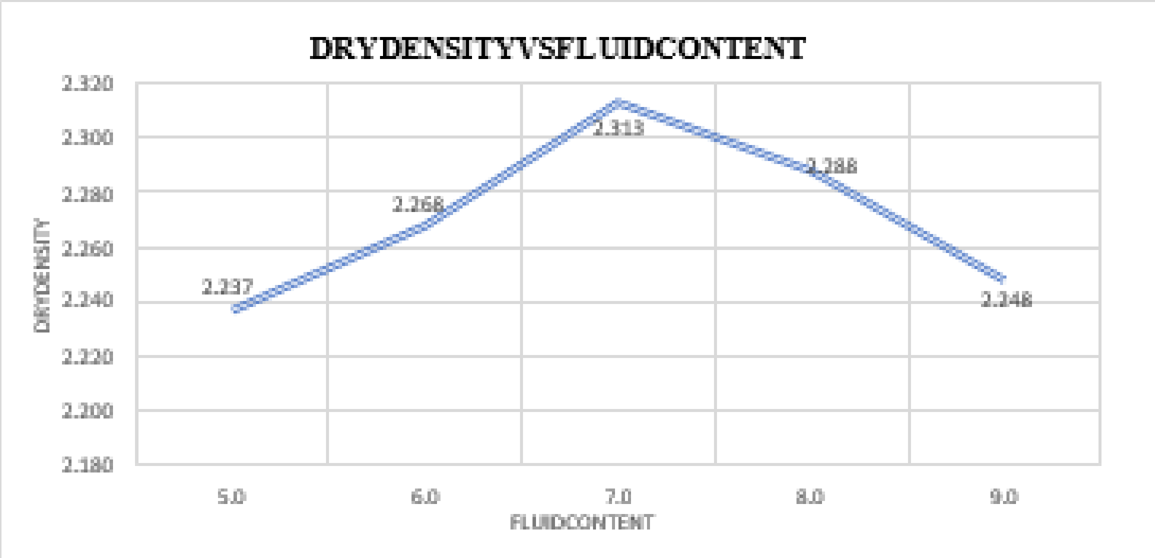



Fig3.25-DryDensityandFluidContent

Table3.25-EmulsiontreatedReclaimedAsphaltPavementDensity Test

| EMULSIONTREATEDRECLAIMEDASPHALTPAVEMENT DryDensityTest | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Specimen Identity No. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| A-1 | | | | | 1220.0 | 690.0 | 1224.0 | 534.0 | 2.285 | | 1198.5 | 1.79 | | |
| A-2 | 3.0 | 0.50 | 1.5 | 5.00 | 1212.0 | 685.5 | 1219.0 | 533.5 | 2.272 | 2.277 | 1191.0 | 1.76 | 1.77 | 2.237 |
| A-3 | | | | | 1218.0 | 687.5 | 1223.0 | 535.5 | 2.275 | | 1197.0 | 1.75 | | |
| B-1 | | | | | 1221.0 | 706.5 | 1234.5 | 528.0 | 2.313 | | 1198.0 | 1.92 | | |
| B-2 | 3.0 | 0.50 | 2.5 | 6.00 | 1214.0 | 705.5 | 1223.0 | 507.5 | 2.346 | 2.320 | 1192.0 | 1.85 | 1.92 | 2.276 |
| B-3 | | | | | 1225.0 | 710.0 | 1242.5 | 532.5 | 2.300 | | 1201.0 | 2.00 | | |
| C-1 | | | | | 1208.5 | 710.5 | 1213.0 | 502.5 | 2.405 | | 1195.0 | 1.13 | | |
| C-2 | 3.0 | 0.50 | 3.5 | 7.00 | 1216.5 | 709.0 | 1223.0 | 514.0 | 2.367 | 2.359 | 1192.0 | 2.06 | 2.02 | 2.313 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C-3 | | | | | 1219.0 | 699.0 | 1227.5 | 528.5 | 2.307 | | 1185.0 | 2.87 | | |
| D-1 | 3.0 | 0.50 | 4.5 | 8.00 | 1225.0 | 706.0 | 1235.0 | 529.0 | 2.316 | 2.339 | 1195.0 | 2.51 | 2.23 | 2.288 |
| D-2 | | | | | 1219.0 | 701.0 | 1235.0 | 534.0 | 2.326 | | 1193.0 | 2.18 | | |
| D-3 | | | | | 1204.0 | 714.0 | 1221.0 | 507.0 | 2.375 | | 1180.5 | 1.99 | | |
| E-1 | 3.0 | 0.50 | 5.5 | 9.00 | 1203.0 | 702.0 | 1212.0 | 510.0 | 2.359 | 2.310 | 1190.0 | 1.09 | 2.76 | 2.248 |
| E-2 | | | | | 1220.0 | 701.0 | 1232.0 | 531.0 | 2.298 | | 1186.0 | 2.87 | | |
| E-3 | | | | | 1223.0 | 702.5 | 1240.5 | 538.0 | 2.273 | | 1172.5 | 4.31 | | |

Table3.26-ObservationTable

| OBSERVATIONTABLE | | |
|---|---|---|
| **S.No.** | **DESCRIPTION** | **OBSERVATION** |
| 1 | EmulsionContent% | **3.00** |
| 2 | WaterContent% | **3.5** |
| 3 | MoistureContentinBlendMaterial % | **0.5** |
| 4 | TotalFluidContent% | **7.00** |
| 5 | Bulkdensity | **2.359** |
| 6 | DryDensity(gm/cc) | **2.313** |

**Outcome**:MaximumDryDensityis2.**313gm/cc**foundat**7.0%FluidContent**.

### 3.8 IndirectTensileStrength (ITS)

Indirecttensilestrengthcriteriaonwhichtrialmixesdepend.Ifanymixsatisfiedtheminimum requiredindirectedtensilestrengthwhichismentionedinIRC-37-2012tableno.IX-2inboth condition (dry & wet) then mix called design mix.

ForindirecttensilestrengthsomeMould preparationTest procedureareasfollows–

**Step-1** First of all, collect all required Marshall mould and other related equipment then thoroughly cleaned and inner surface greasing were done on mould.

**Step-2** Take a 1200 gm batch of blended dry sample and according to the batch weight first take the emulsion & water mix which is equal to the OFC obtained in previously performed MDD & OFC test.

Emulsion may vary from 3 to 4 % by weight of total mix in increment of 0.5 %. Additional water is added to the first and mixed then the bitumen emulsion is added and mixed again approx.1minutetakeninmixingprocess,somixbecomeuniformandcoatingdoneoneach

**Step-3**Aftermixing,mixpouredintotheMarshallMouldonwhichfilterpaperalreadyplaced onbaseplate.Byusingtrovelorstraightedgetopofspecimenleveled,andanotherfilterpaper placed on top. So mix particle not stuck off by the hammer bottom.

Fig3.26-MixpouredintotheMarshallMould

**Step-4**PreparedmixMouldplacedinthecompactorandgives75blowsononeface&reverse the Mould& placed again, then again compacted by 75 blows on other face. Prepared six specimens of each emulsion percentage.

**Step-5**TakethecastedspecimenwithMouldandwerecuredintheMouldatroomtemperature for 24 hours.

**Step-6**After24hoursthespecimenswereextrudedfromtheMould.Hereweareusingmarshal machine to remove the specimen from the Mould.

**Step-7**AllspecimenevaluatedfortheirbulkdensityasperASTMD2726.Thenthespecimen was cured in hot air oven maintained at 40°C for 72 hours.

**Step-8**Aftercompletionofcuringperiod,threecuredspecimensweretestedfortheirdryITS as per ASTM D6931 @ 25°C temperature.

FollowingprocedureadoptedforITStesting:

- Placecuredspecimen inthecenterofmodifiedbreaking apparatus.
- Checktheapparatusplacedinthecenter.
- Provingring&dialgaugesetonapparatus,atzeroreadingorinitialreadingwasnotedown.
- Startthemarshalmachine,whichisoperatedatthespeedof55 mm/min.
- Takethehighest readingofproving ring & correspondingdialgaugereadingwere taken.

**Step-9** Another 3 cured specimen placed in water for 24 hours to perform ITS test in wet condition. Take the specimen after 24 hours, and performed the test similarly mentioned in step-8 and note down both ITS value in dry & wet condition.

**Step-10**Similarlyfollowallstepondifferentemulsioncontentandaverage ITSvalueofeach emulsion percent note down. All ITS test parameter shown in given table.

- Notedhighestprovingreadingindivisionitisconvertedintoloadbycalibrating chart.
- Take the load reading in Newton and placed in the following formula which is mentioned in IRC-37- 2012-Equation IX-2 i.e.

$$ITS(KPa) = \frac{200 \times Pmax}{\pi DH}$$

**ITS**=IndirectTensileStrengthinKpa

**Pmax** = Maximum Load in Newton

**H**= Thickness of the specimen

**D**=Diaof specimen

Thedesignemulsioncontentistheoptimummixemulsioncontentwhichissatisfyingthe minimum ITS strength required given in table IX-II of IRC-37-2012, Annexure-IX.

ByobservingtheITSresultspresented intableno.28.

Table3.27-IndirectTensile Strength

Indirect Tensile Strength Test

Data Sheet of Test Results

Proving Ring capacity (KN): 50

Proving Ring per division value (Kg.): 7.83

| | % of Emulsion Content By Wt of Total Mix | % of Moisture Content By Wt of Total Mix | % of Water Content added in Blend Material | Total % of Fluid Content | Average Height Specimen mm | Dia. of Specimen in mm | ITS in Condition | Proving Ring Reading | Stability in (Kg) | Stability in Newton | Stability in Kpa | Average Stability (KPa) | Minimum Strength as per IRC 37-2012 Table no.IX-2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-1 | 3.00 | 0.5 | 3.50 | 7.0 | 64.0 | 100.0 | ITSdry | 44 | 344 | 3379 | 336 | 304.43 | >225 KPa |
| A-2 | | | | | 65.0 | | | 45 | 316 | 3103 | 304 | | |
| A-3 | | | | | 66.0 | | | 41 | 288 | 2828 | 273 | | |
| B-1 | 3.50 | 0.5 | 3.00 | 7.0 | 68.0 | 100.0 | | 56 | 394 | 3862 | 362 | 366.84 | |
| B-2 | | | | | 66.0 | | | 57 | 401 | 3931 | 379 | | |
| B-3 | | | | | 66.0 | | | 54 | 380 | 3724 | 359 | | |
| C-1 | 4.00 | 0.5 | 2.50 | 7.0 | 67.0 | 100.0 | | 48 | 337 | 3310 | 315 | 321.80 | |
| C-2 | | | | | 65.0 | | | 50 | 352 | 3448 | 338 | | |
| C-3 | | | | | 66.0 | | | 47 | 330 | 3241 | 313 | | |
| D-1 | 3.00 | 0.5 | 3.50 | 7.0 | 65.0 | 100.0 | ITSwet | 22 | 155 | 1517 | 149 | 161.49 | >100 KPa |
| D-2 | | | | | 66.0 | | | 26 | 183 | 1793 | 176 | | |
| D-3 | | | | | 67.0 | | | 24 | 169 | 1655 | 157 | | |
| E-1 | 3.50 | 0.5 | 3.00 | 7.0 | 67.0 | 100.0 | | 31 | 218 | 2138 | 203 | 191.43 | |
| E-2 | | | | | 67.0 | | | 29 | 204 | 2000 | 190 | | |
| E-3 | | | | | 68.0 | | | 28 | 197 | 1931 | 181 | | |
| F-1 | 4.00 | 0.5 | 2.50 | 7.0 | 65.0 | 100.0 | | 23 | 162 | 1586 | 155 | 153.72 | |
| F-2 | | | | | 68.0 | | | 25 | 176 | 1724 | 161 | | |

Fromobserveddataitisfoundthatemulsioncontentof3.5%givesthebetterresultofITSstrength and also satisfies the mix criteria of table IX-II.

Table3.28-FinalconformityasperMORTH

| FinalConfirmity | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DataSheetofTestResults | | | | | | | | | | | | |
| | ProvingRingcapacity(KN) | | | | | | 50 | | | | | | |
| | ProvingRingpordivisionvalue(Kg) | | | | | | 7.00 | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 11 | | 12 | 14 |
| SpecimenIdentityNo. | % of EmulsionContentBy Wt of TotalMix | % of Moisture Content ByWtof TotalMix(BlendMaterial) | % of WaterContentaddedtoBlendMaterial | Total% ofFluidContent | Average HeightofSpecimenmm | Dia.Of Specimenmm | Stability | ProvingRingReading | Stability in (Kg) | Stability in Newton | Stability in Kpa | Average Stability(KPa) | Minimum Strength as per IRC37-2012 Table no.IX-2 |
| I-1 | 3.50 | 0.5 | 3.00 | 7.0 | 68.0 | 100.0 | ITSdry | 56 | 394 | 3862 | 362 | 366.84 | >225KPa |
| I-2 | | | | | 66.0 | | | 57 | 401 | 3931 | 379 | | |
| I-3 | | | | | 66.0 | | | 54 | 380 | 3724 | 359 | | |
| I-1 | 3.50 | 0.5 | 3.00 | 7.0 | 67.0 | 100.0 | ITSwet | 31 | 218 | 2138 | 203 | 191.41 | >100KPa |
| I-2 | | | | | 67.0 | | | 29 | 204 | 2000 | 190 | | |
| I-3 | | | | | 68.0 | | | 28 | 197 | 1931 | 181 | | |

AsperCodalprovisionif ITSdryisgreaterthan400KPa&similarlyITS wetislessthan50% of the ITS dry.

### 3.9 MarshallStability Test

Marshallstabilitytestperformedonspecimenprepared(casted)withfollowingdesign parameter:

- Emulsion SS2-3.5%
- Water-3.5%
- 20 mm– 24%
- Filler–1%
- Stovedw1-30%
- Recycledmaterial-45%

Sixspecimenscastedonaboveblendedpercentageformarshallstabilitytest.TestPerformedat 22.2°CwithMarshallmachineoperatedatthespeedof55mm/minute.Thetestdoneafter24hours, three sampledirectlytestedfordrystability&remainingthreesamplesoakedinwaterandobtained result aretabulated as below:

Table3.29-EmulsionTreatedReclaimedAsphaltPavement

| CheckForMarshallTest | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| EMULSIONTREATEDRECLAIMEDASPHALTPAVEMENT | | | | | | | | |
| DataSheetofTestResults | | | | | | | | |
| ProvingRing capacity(KN) | | 50 | | | | | | |
| Proving Ring per divisionvalue(Kg) | | 7.03 | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Specimen Identity No. | % of Emulsion ContentBy Wt ofMix | % of Water Content ByWtofMix | Proving Ring Reading (KN) | Corrected Stability for Proving Ring(Kg) | Average Stability (Kg) | Average Stability (KN) | Marshall Flow (mm) | Average Marshall Flow (mm) |
| In drycondition | | | | | | | | |
| A-1 | 3.0 | 4.0 | 55 | 387 | 384 | 3.770 | 3.00 | 3.25 |
| A-2 | | | 57 | 401 | | | 3.25 | |
| A-3 | | | 52 | 366 | | | 3.15 | |
| B-1 | 3.5 | 3.5 | 66 | 464 | 450 | 4.414 | 3.35 | 3.56 |
| B-2 | | | 64 | 450 | | | 3.75 | |
| B-3 | | | 62 | 436 | | | 3.60 | |
| C-1 | 4.0 | 3.0 | 54 | 380 | 394 | 3.862 | 3.85 | 3.75 |
| C-2 | | | 56 | 394 | | | 3.90 | |
| C-3 | | | 58 | 408 | | | 3.40 | |
| Insoakedcondition | | | | | | | | |
| A-1 | 3.0 | 4.0 | 30 | 211 | 211 | 2.069 | 3.00 | 1.75 |
| A-2 | | | 28 | 197 | | | 3.25 | |
| A-3 | | | 32 | 225 | | | 3.15 | |
| B-1 | 3.5 | 3.5 | 33 | 232 | 248 | 2.437 | 3.35 | 2.50 |
| B-2 | | | 38 | 267 | | | 3.75 | |
| B-3 | | | 35 | 246 | | | 3.60 | |
| C-1 | 4.0 | 3.0 | 28 | 197 | 185 | 1.816 | 3.85 | 2.00 |
| C-2 | | | 25 | 176 | | | 3.90 | |
| C-3J | | | 26 | 183 | | | 3.40 | |

Table3.30-ConformityCheck

| CONFIRMITYCHECK | | |
|---|---|---|
| **PARAMETER** | **RESULT** | **AsperMORT&HTableNo.500-45 and MS -14 appendix-F** |
| Maximumstabilityobtained@3.5%Emulsion& 3.5% Water content | 4.414KN | Min2.2KN**at22.2°C** |
| Flow(mm) | 4.25mm | Min2mm |

It is observed from the above table maximum stability found on 3.5 % emulsion content that is optimumvalueofemulsioncontentwhichissatisfiedallcriteria's mentionedinMORT&HTable No. 500-45 abdMS-14 appendixFlow also satisfied minimum criteria mentioned in MORTH Table-45.

On comparing the results of emulsion treated Reclaimed Asphalt Pavement and DBM mixed designanditisobservedthatemulsiontreatedreclaimedasphaltpavementisnotusedonnational highway wheretrafficloadis veryhigh. But it isusedon serviceroad as a DBM layerand where also traffic load is low.

Table3.31-TestResultAnd Comparison

| TestResultsComparisonwithMoRTHGuidelines& StandardDBM(Grade)-I | | | | |
|---|---|---|---|---|
| PARAMETER | | RESULT | Standard DBM Grade–I | AsperMORTH Standard |
| IndirectTensile Strength(KPa) | Dry | [illegible] | | >225 KPa |
| | Soaked | [illegible] | | >100 KPa |
| StabilityNumber(KN) | | 4.414KN | 4.22KN | Min2.2KN@22.2°C |
| FLOWvalue(mm) | | 4.25mm | 5.2MM | Min2mm |

*Outcomings*

- FromthetestresultasshownintabIe,itwasobservedthatEmulsiontreatedRAP(**RAP45%, 20mmfineaggregate,Stonedust30%,3%Emulsion&4%Water**)givethebestresultand follow the MORTH guidelines & result of Standard DBM Grade-I.
- ProposedEmulsiontreatedRAPmixdesigncanbeusedinDBMLayersforServiceroadsand low traffic load roads.

# CHAPTER:-4

## 4. RESULTAND DISCUSSION

### 4.1 Useof ReclaimedAsphalt Pavement designmix in WMMLayer

The samples having different compositions were prepared by adding different percentage of RAP materials (0% RAP, 10% RAP, 25% RAP, 35% RAP, 45% RAP and 60% RAP).

Table4.1-CompositionofDifferentMaterials

| SampleNo. | DetailsofComposition |
|---|---|
| R1 | RAP0%+95%Natural Aggregate +5%Stone dust |
| R2 | RAP10%+75%Natural Aggregate +15%Stonedust |
| R3 | RAP25%+58%Natural Aggregate +17%Stonedust |
| R4 | RAP35%+40%Natural Aggregate +25%Stonedust |
| R4 | RAP45% +25%NaturalAggregate+30%Stonedust |
| R6 | RAP60%+5%NaturalAggregate+35%Stone dust |

Then,variousstandardtestsareperformedonsamplesandcomparedwithMORTHspecifiedWMM design mix

Table4.2-TestResults Table

| Sample Composition | Aggregate Impact Value | Flakiness & ElongationIndex (Combined) | LossAngeles Abrasion Test Value | Water Absorption |
|---|---|---|---|---|
| RAP 0% + 95% Natural Aggregate+5%Stonedust | 26.5% | 25.8% | 31% | 1.9% |
| RAP 10% + 75% Natural Aggregate+15%Stonedust | 25% | 23.2% | 28.9% | 1.82% |
| RAP 25% + 58% Natural Aggregate+17%Stonedust | 22.2% | 28.4% | 26.2% | 1.92% |
| RAP 35% + 40% Natural Aggregate+25%Stonedust | 20.5% | 24.6 | 25.4% | 1.72% |
| RAP 45% + 25% Natural Aggregate+30%Stonedust | 17.8% | 20.5% | 19.8% | 1.10% |
| RAP 60% + 5% Natural Aggregate+35%Stonedust | 18.9% | 22.5 | 18.5% | 1.63% |

Table4.3-STANDARDWMMMIXEDDesign

| | AggregatesImpact Value | Flakiness And ElongationTest | Loss Angeles AbrasionTest Value | Water Absorption |
|---|---|---|---|---|
| StandardWMM Mixed Design | 21.70% | 24.04% | 23.8% | 0.74% |

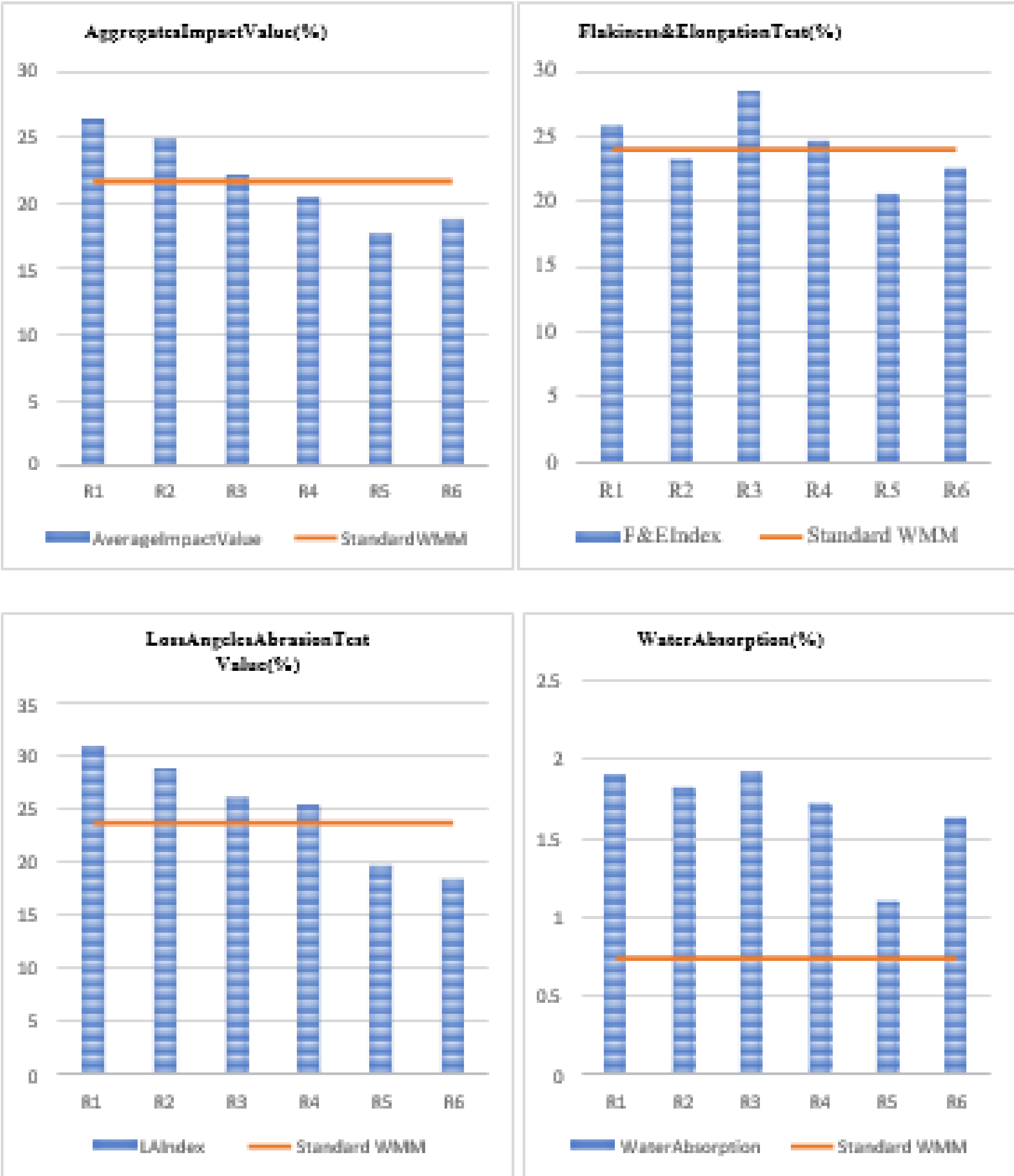



Fig4.1-ResultandcomparisonwithstandardWMMmixedDesign.

*Outcoming:*

- Fromthetestresultasshownintable4.3andfigure4.1,itwasobservedthatsamplehaving compositionofRAP45%,20mmfineaggregate24%,Stonedust30%andCement1%give the best result and follow the MORTH limit.

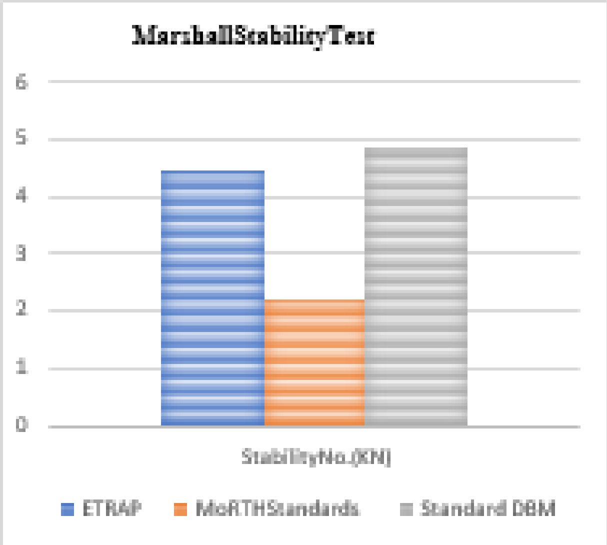
- Sample having composition of RAP 45%, 20mm fine aggregate 24%, Stone dust 30% and Cement 1% can be used in WMM layers for flexible pavements.

**4.2 Use of Emulsion Treated Reclaimed Asphalt Pavement design mix in DBM Layer**3.5%Emulsionand3.5%water(Gross7%FluidContent)addedinRAP45%,20mmfine aggregate,Stonedust30%toget"EmulsionTreatedReclaimedAsphaltPavementdesignmix" andthen,variousstandardtestsareperformedonsamplesandcomparedwithMORTH specified DBM design mix (Grade-I).

Table4.4-TestResults Comparison

| TestResultsComparisonwithMoRTHGuidelines&StandardDBM (Grade-I) | | | | |
|---|---|---|---|---|
| PARAMETER | | RESULT | StandardDBMGrade-I | AsperMORTH Standard |
| IndirectTensile Strength (KPa) | Dry | 366.84 | N/A | >225KPa |
| | Soaked | 191.41 | N/A | >100KPa |
| StabilityNumber(KN) | | 4.414 KN | 4.81KN | Min 2.2 KN@ 22.2 ℃ |
| FLOWvalue(mm) | | 3.56 mm | 5.1MM | Min 2 mm |


Fig4.2-ResultandcomparisonwithstandardsMORTH specification



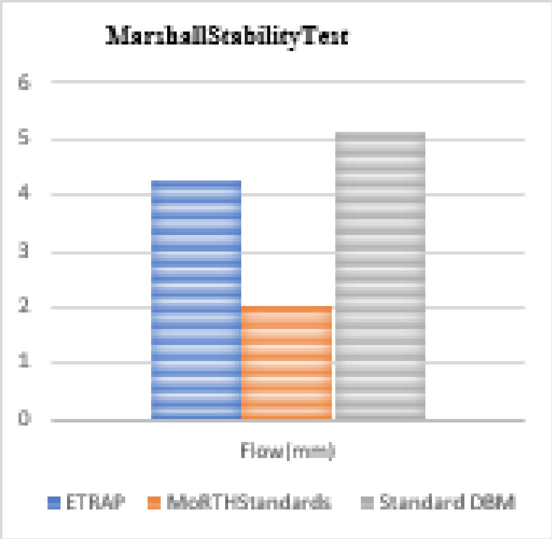




Fig4.3-ResultOfEmulsionTreatedRapAndComparisonWithMORTHStandards

From the test result as shown in table 4.4 and Fig-4.3, it was observed that Emulsion treated RAP(**RAP45%,20mmfineaggregate,Stonedust30%,3%Emulsion&4%Water)give the** best result and follow the MORTH guidelines & result of Standard DBM Grade-I. Therefore, Emulsion treated RAP mix design can be used in DBM Layers for Service roads and low traffic load roads.

**CHAPTER:-5**

## 5.1 RECOMMENDATIONSANDCONCLUSION

Basedonstudyandexperimentalinvestigationsfollowingconclusionsweredrawn

- ItwasobservedthattheRAPmaterialscanbesuccessfullyusedinwetmixmecadamlayer andDensebitumenmecadamo**fflexiblepavementsafterblendingtomatchtherequired grading as per MORTH** specifications for subbase material.

- It was also observed that the RAP materials in combination to natural aggregate in various proportionscanbeeasilyusedafterblendingtomatchtherequiredgradingasperMORTH specifications in the base courses of flexible pavements.

- Itisclearfromtheaboveinvestigationresultsthat20-30%replacementofnaturalaggregate can be successfully done in base course of flexible pavements, resulting in a savings of around 25- 30% in construction cost.

- ItwasobservedthatRAPhasahighercontentoffinesasaresultofdegradationofmaterial duringmillingandcrushingoperationsitcanbeeasilyusedforsoilstabilizationpurposeto increase the CBR value of sub-grade and hence the crust thickness of road will be reduced resulting in reduction of cost of construction.

- AboveallTheproblemofdisposalofRAPwastescanbeeasilysolvedandadverseeffect on environment may be avoided by using the RAP materials in flexible pavement construction.

# 10.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] IRCSP37-2012, "GuidelinesforTheDesignofFlexiblePavements(ThirdRevision)"

[4] IRC120-2015,"RecommendedPracticeforRecyclingOfbituminousPavements"

[5] MORTH(5threvisionsection500)[7]TG-2/MS-14(Thedesignanduseofgranularemulsion mixes)

[6] SP 20-2002: IRCRuralRoadManual.

[7] Specification of Road & Bridge Work, Ministry of Shipping, Road Transport & Highway, Revision 4.

[8] ISCodes: 2386, 2720.

[9] IRC-37:2012, Tentative Guidelines for The Design of Flexible Pavement, Indian Road Congress, New Delhi.

[10] Sunil S, K M Mallesh and T ChnadraSekharaiah, Experimental Investigations on the performance of Bituminous Mixes with Reclaimed Asphalt Pavement Material, International Journal of Research in Engineering and Technology, Volume 3, 2004.

[11] Dr. B. B. Pandey, Cold Mix Recycling and Mix Design, Workshop on Recycling and other Pavements Rehabilitation Methods, 2005, 7-11, IIT Kanpur

[12] S.K.KhannaandC.E.G.Justo,highwaymaterialtestingmanual.

[13] Brajesh Mishra, "A Study on Use of Reclaimed Asphalt Pavement (RAP) Materials in Flexible Pavements, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4, Issue 12, December 2015.

[14] SunilS,KMMalleshand T Chnadra Sekharaiah, Experimental Investigations on the

performanceofBituminousMixeswithReclaimedAsphaltPavementMaterial,International Journal of Research in Engineering and Technology, Volume 3, 2004.

[15] ByV.K.L.RaoV.K.L.RaoM.Tech(GTE),MIE.,MIRC.,MIIBE.,MICI.,MIGS.,CE
Senior QualitycumMaterialExpert-HIGHWAYMATERIALTESTINGMANUAL

[16] Masoud Faramarzi Case Study on Cement Treated Rap Containing Asphalt Emulsion and Acryl Polymer

[17] Md. Akhtar Hossain studied the Effect of Water Submergence on the Characteristics of Bituminous Mixes Using Reclaimed Asphalt Pavement.

[18] BurakSengoz Stated the Performance Evaluation of Warm Mix Asphalt Mixtures with Recycled Asphalt Pavement.

[19] MaulikRao Studiedthe utilizationofrecycledasphaltpavementinthe UrbanAreaatSurat, Gujarat,India

[20] Baoshan Huang, Xiang Shu, Guoqiang Li (2005) are had done "Laboratory investigation of Portland cement concrete containing recycled asphalt pavements" this paper is theyare used the RAP as aggregate in both fine and coarse, and conducted experimental study on its behavior.

[21] Athar Saeed (2008) had conducted study on the "Performance-Related Tests of Recycled Aggregates for Use in Unbound Pavement Layers", this study is performing test on RAP

[22] MichaelJ.Bergin,MangTia,andNabilHossiney(2010)

[23] AASHTO, 1986. Guide for Design of Pavement Structures. American Association of State Highway and Transportation Officials, Washington.

[24] Asphalt Emulsion Manufacturers Association (AEMA), 2009. Basic Asphalt Emulsion Manual, Manual Series No. 19, Third Edition, USA.

[25] Ahmad M. Abdo, Utilizing Reclaimed Asphalt Pavement (RAP) Materials in New Pavements. International Journal of Thermal & Environmental Engineering, Volume 12, No.1 (2016), pp. 61-66.