IMPROVEMENT IN RECYCLING OF RECLAIMED ASPHALT PAVEMENTS USING DIFFERENT MATERIALS IN FLEXIBLE PAVEMENT

A Thesis Submitted

In partial fulfillment of the requirement

For the Degree of

Master of Technology

In

Transportation Engineering

By

SARTHAK GOEL

ROLL NO. - 1170465003

Under the guidance of

Prof D.S. RAY

PROFESSOR

In

Department Of Civil Engineering

BABU BANARSI DAS UNIVERSITY, LUCKNOW

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LUCKNOW

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CERTIFICATE

This is to certify thesis entitled **"IMPROVEMENT IN RECYCLING OF RECLAIMED ASPHALT PAVEMENTS USING DIFFERENT MATERIALS IN FLEXIBLE PAVEMENT"** which has been carried out by Mr. Sarthak Goel (Roll No. 1170465003) for partial fulfillment of requirement for the award of Master of Technology degree in Transportation Civil Engineering of Babu Banarasi Das University, Lucknow, is a record of his work carried out by him under the guidance and supervision. The result embodied in this thesis has not been submitted elsewhere for award of any other degree or diploma.

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DECLARATION

I , hereby declare that the work which is being presented in the **M.Tech** Thesis Report entitled **"IMPROVEMENT IN RECYCLING OF RECLAIMED ASPHALT PAVEMENTS USING DIFFERENT MATERIALS IN FLEXIBLE PAVEMENT",** in fulfillment of the requirements for the award of the Master Of Technology in **Transportation Engineering (Civil Engineering)** and submitted to the Department of Civil Engineering of Babu Banarasi Das University, Lucknow (U.P.) is an authentic record of our own work carried out during the period from August 2017 to June 2019 under the guidelines of **Prof. D.S. Ray, Department Of Civil Engineering**. The matter presented in this thesis has not been submitted by me for the award of any other degree elsewhere.

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Thank You

Mr. SARTHAK GOEL

(Roll No. 1170465003)

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CHAPTER : 1

INTRODUCTION

1.1 GENERAL

Recycling of Reclaimed Asphalt Pavements abbreviated as (RAP) is required to be used for technical, economical, and environmental reasons. Use of RAP has been favoured all over the world over the use of virgin materials because of the increasing cost of bitumen, the scarcity of quality aggregates, and the persistent need to preserve the environment. The use of RAP also decreases the amount of waste produced and helps to resolve the disposal problems of highway construction materials.

When asphalt pavements which have reached the end of their service life are frequently rehabilitated by milling the existing pavement surfaces and replacing the milled portion with new hot mix asphalt (HMA). A large amount of recycled asphalt pavement (RAP) is generated every year because of this practice. So now the use of RAP should be in practice as this reduces the cost of construction materials, reduces the use of petroleum-based products and helps conserving the natural resources by requiring less virgin aggregate and asphalt in road construction projects.

There are several recycling techniques, such as hot mix plant recycling, hot in-place recycling, cold mix plant recycling, cold in-place recycling, and full depth reclamation which have evolved over the past 35 years. In-place recycling not only reduces the use of new materials but also reduces emissions, traffic, and energy associated with the transport and production of these materials.

Hot Mix Recycling is the most common method of recycling asphalt pavements in developed countries. It involves combining RAP with new or virgin aggregate, new asphalt binder, and recycling agents in a central hot mix plant to produce a recycled mix. The amount of RAP allowed in a recycled mix and guidelines as to where the recycled mix can be used in the pavement structure varies from agencies to agencies. Agencies recommendations and international guidelines such as those given by Asphalt Institutes may be used in different trials because of lack of experience in India.

Cold Mix Recycling is a method of recycling where RAP, new aggregate (if needed) and emulsified bitumen or foamed bitumen without the need for heat are mixed in a centrally located cold mix plant. Many old road having thick bituminous layers can be converted in four and six lane projects and the entire RAP and aggregates can be reclaimed by milling machine and reused in new construction work. Since the components of a cold mix plant are fairly portable, it can be assembled in satellite locations close to a project site. Cold recycled mix is hauled to the job site with conventional dump trucks or belly dump trucks. Placement and compaction of cold recycled mixes are done with the same conventional pavers and rollers used for hot mix asphalt construction. Cold recycled mixes are normally coated with hot mix asphalt or surface dressing (chip seal) depending on the expected traffic level for the finished pavement.

1.2 COLD MIX RECYCLING :

Cold recycling is process which involves rehabilitation of the existing asphalt or granular road surface. The existing surface is milled and the material is mixed on the site with foamed bitumen or Bitumen emulsion. The process of in-situ recycling of distressed pavement using cold mix technology is referred to as cold in-place recycling (C.I.P.R.).

C.I.P.R. thus is a pavement rehabilitation measure that tyFigureally consists of the following operations :

1. Milling the existing pavement layers upto a depth of 300 mm;

2. Treatment with bitumen emulsion or foamed bitumen, often in combination with addition of crusher dust, fresh aggregates (if required) and a small percentage of active filler such as cement;

3. Adding compaction water; and

4. Repaving the mix.

5. Compaction

In a CIPR process as described above, the top bituminous layer (Reclaimed asphalt pavement) as well as a part or whole of the granular or stabilised base layer are recycled. The residual binder content added to the mineral aggregates in the process of CIPR is generally lower (<4 per cent) in comparison to hot bituminous mixtures. The recycled product is not used as final surfacing layer but used as base or sub-base layer.

1.3 ADVANTAGES

1. CIPR is an attractive alternative for highway rehabilitation operations because of its economic and environmental advantages. Major economic advantages involve the recycling of existing road surface aggregates and reduced haul requirements for incorporating new aggregates.

2. In India, there are many regions where aggregate resources are limited or will be depleted in the near future. Aggregate haul in these regions is quite expensive.

3. By recycling existing in-place road materials and providing additional strength with mixing of different emulsions or strengthening agents, new aggregates and bitumen requirements are reduced.

4. In addition, impacts on adjacent haul roads are minimized or eliminated because of reduced new aggregate requirements.

5. A major environmental advantage involved in the use of cold in-place recycling is that there is no requirement for heat during construction work.

6. CIPR is an energy efficient process that does not produce harmful emissions and does not require the bituminous mixtures to be transported to an off-site plant.

7. In addition, transportation of large amounts of aggregate are reduced and hence it is fuel efficient also.

1.4 OBJECTIVE :

The objective of this study was to examine the strength of non - bituminous R.A.P. of W.M.M. (Wet Mix Macadam) layer of pavement by combining it with different emulsions and chemical additives. Tests were conducted for each combination. The Indirect tensile strength test and Marshall test observations are used for comparison. The emulsion used were SS_2 and old engine oil while the chemical additive used for stabilizing the R.A.P. were cement , fly-ash , hydrated lime , fibre respectively.

1.5 SCOPE OF WORK :

Strengths of each combinations is determined by the tests , so it will be easy to compare that which material and emulsion combination can be used practically apart from the conventional cement – bitumen combination. It will also determine the cost effectiveness of each material combination , as in , whether it is feasible to use the materials practically . The R.A.P. used is also non-bituminous which is the uniqueness in this project as it will help in defining that how the cost and the raw material used in a road project can be reduced by using different materials used in this study.

1.6 THESIS ORGANISATION

This report consists of seven chapters which are described below :

1. The first chapter introduces an overview for this research area and describes the objectives and scope of this study.
2. The second chapter gives a thorough discussion on various literatures on the to Figures related to Recycling of reclaimed asphalt pavement.
3. In the third chapter discusses the various materials , chemical stabilizers and waste materials used in the project.
4. In fourth chapter methodology of experimental investigations for this project work is highlighted.
5. Information and experimental data regarding the materials used , adopted mix design and laboratory test procedure are provided in detail in chapter five.
6. The results and analysis are illustrated in detail in chapter six.
7. The conclusion of the study is given in this chapter.
8. References are given at the end of this report.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

In this study the R.A.P. will be combined with different combination of emulsions and chemical additives. These chemical additives are used for stabilizing the R.A.P. The emulsions used in the combination will be SS_2 and old engine oil while the chemical additives will be cement , lime , fly-ash , fibre. According to IRC 37 the emulsion added in the mix should be between 3% - 4% , in this study the emulsion added in each combination is around 3.5 % of the weight of the mix. Indirect Tensile Strength test and Marshall test are conducted for checking the strength of each combination. Various test are conducted for testing the materials as well.

Dulal Chandra Saha, J. N. Mandal in (2017) [4] conducted a study on Laboratory investigations on Reclaimed Asphalt Pavement (RAP) for using it as base course of flexible pavement. According to this study, during Capacity augmentation of existing National Highway (NH) Projects, grade separated structures in terms of Flyovers, Vehicular underpass (VUP), Pedestrian underpass (PUP), Cattle underpasses (CUP) are proposed at regular intervals. Accordingly, existing road levels at approaches of these structures are required to be raised making the existing pavement materials redundant. Existing pavement materials are also obtained due to milling of existing pavement surface before laying overlay for strengthening.

So this study assesses the suitability of using these redundant pavement materials also called Reclaimed Asphalt Pavement (RAP) as potential subbase / base course materials for flexible pavement. It was observed from literature survey of various past studies that California bearing ratio (CBR) of 100% RAP is not suitable for its use as base of flexible pavement as per Indian Standards (IRC). Accordingly, attempts were made to improve strength of RAP in terms of CBR by mixing it with crushed stone aggregates, stabilizing it with cement and combination of both.

In this study, laboratory CBR tests have been conducted on RAP, mixture of RAP and crushed stone aggregates and also on mixture of RAP and crushed stone aggregates stabilized with various percentages of cement. And it was observed that though unsoaked CBR values of RAP were not influenced much due to its mixing with crushed stone aggregates and/or stabilization with cement, soaked CBR values increased substantially due to both mixing with crushed stone aggregates and stabilizing with cement. The soaked CBR value of RAP increases from 20% to in excess of 100% when it is mixed with crushed stone aggregates in various proportions and stabilized with small percentages of cement and thereby making it suitable for using it as subbase/base of flexible pavement. Modified proctor compaction tests were conducted on both RAP and mixture of RAP and crushed stone aggregates to established optimum moisture content for the preparation of CBR moulds for tests. It was observed that there was a slight increase in Unsoaked CBR value but substantial increase in 4 days soaked CBR value when RAP was blended with crushed stone aggregates. There was a slight increase in Unsoaked CBR value but substantial increase in 4 days soaked CBR value when RAP was stabilized with cement. There was a slight increase in Unsoaked CBR value but substantial increase in 4 days soaked CBR value when RAP was blended with crushed stone aggregates and stabilized with cement.

Also Soaked CBR values observed to be substantially higher than Unsoaked CBR in all cases due to curing effect. 4 days soaked CBR values of RAP-Crushed stone aggregates in various proportions varied from 10% to 80%. 4 days soaked CBR values of 75% RAP + 25% Crushed stone aggregates exceeds 100% CBR when stabilized with 3.0% cement. 4 days soaked CBR values of 50% RAP + 50% Crushed stone aggregates exceeds 100% CBR when stabilized with 2.0% cement. And 4 days soaked CBR values of 25% RAP + 75% Crushed stone aggregates exceeds 100% CBR when stabilized with 1.0% cement.

Md Mehedi Hasan, Md Rashadul Islam, Rafiqul A. Tarefder in (2014) [9] conducted a study on Characterization of subgrade soil mixed with recycled asphalt pavement. In this study investigates the effect of RAP on the resilient modulus (M) of subgrade soils mixed with RAP materials. Note that M_R is the principal material input parameter for designing asphalt pavement using the recent mechanistic-empirical pavement design software. As a first step of this study, different percentages of RAP and moisture were thoroughly mixed with subgrade soils. Then, the M_R of these RAP mixed soils were determined using the

AASHTO -T 307 (1999) at different stress levels in the laboratory. Results show that the M_R of RAP mixed soil increases with the applied deviatory and bulk stresses, however, it is less sensitive to applied confining pressure. Use of RAP materials has made the soils stiff value reaches a maximum at the optimum moisture content and increases linearly with RAP content. The enough not to respond to the confining pressure. As expected, the MR value reaches a maximum at the optimum moisture content and increases linearly with RAP content. The MR values and characteristics of the RAP mixed subgrade soils , as determined by this study, can be used for subgrade design and stabilization using RAP for better pavement design.

The above mentioned conclusions are based on a single soil and single RAP materials. For further generalization, wide varieties of soils and RAP sources and grades can be selected and tested in a study that can be pursued in a future research.

ARSHAD Hussain, QIU Yanjun in (2014) [3] conducted a study on Evaluation of Asphalt Mixes Containing Reclaimed Asphalt Pavement. In this paper presented an experimental study to evaluate the effect of various types and percentages of RAP on the properties of asphalt mixtures. Four mixtures, which were the combination of two different virgin aggregates and two different RAP sources were studied in this research. The mixtures were designed by Marshall method at a wide range of 0 to 100% RAP blends. RAP material was blended with virgin aggregate such that all specimens tested had approximately the same gradation. Mixtures containing RAP showed significant variability and the variability increased with the increase in RAP content.

In laboratory the RAP mixtures designed using Marshall method performed same as virgin mixtures. Generally the Marshall stability increases with increase in RAP content with good linearity. The stability of the 100% RAP mixtures was about two times the stability of the virgin mixtures. The crushed limestone gave better performance with both the RAP sources as compared to the quartzite. When mostly riverbed and rounded particles were used the stability did not change significantly and the flow exceeded the maximum limit.

It was observed that using RAP in design even up to 30% will help in conserving the natural resources, reducing the HMA price and improve the performance. It was suggested to

construct a trial section using virgin and RAP blends to verify the suitability of RAP mixtures to the country climate condition and traffic loadings which was recommended for future study to use modified binder and different NMAS to see the RAP mixture performance.

Salim Al-Oraimi, Hossam F. Hassan and Abdulwahid Hago in (2009) [10] conducted a study on Recycling of Reclaimed Asphalt Pavement in Portland Cement Concrete. In this research investigates the properties of concrete utilizing recycled reclaimed asphalt pavement (RAP). Two control mixes with normal aggregate were designed with water cement ratios of 0.45 and 0.5. Reclaimed asphalt pavement was used as a coarse aggregate substitute in two different normal concrete mixes having 28 days cube compressive strengths of 33 and 50 MPa. RAP was used with 25, 50, 75, 100% replacement of coarse aggregate. In addition to the control mix (0%), the mixes containing RAP were evaluated for slump, compressive strength, flexural strength, and modulus of elasticity. Durability was evaluated using surface absorption test. The slump decreased with the increase in RAP content. The compressive and flexural strength decreased as well with the increase in RAP content. The general trend of strength development, as well as the relations between flexural strength, elastic modulus and compressive strength for the RAP mixes agreed well with that for normal concrete. The surface absorption was not significantly affected by the addition of RAP. The results indicated the viability of RAP as an aggregate in non-structural concrete applications. The percentage of RAP should be limited according to the application. Low slump should also be considered when utilizing RAP in the mixes.

CHAPTER 3

MATERIAL USED

3.1 INTRODUCTION

In the study investigation is done on recycling of reclaimed asphalt pavement using cold mix procedure by using different material combinations. Apart from RAP various materials used which are binders , chemical stabilizers and also waste materials.

Materials used as binders are SS_2 and old or used Engine oil , which is also a waste product. While the materials used as chemical stabilizers are Cement, Hydrated lime , Recron 3s fibre and Fly-ash. Fly-ash is also a waste material. The objective of using these materials is improve the quality of RAP and decreasing the thickness of layer where RAP is used. This will reduce the cost of construction as well as the problem of dumping the waste material may reduce.

3.2 RECLAIMED ASPHALT PAVEMENT (R.A.P.)

Reclaimed asphalt pavement (RAP) is defined as removed pavement materials containing asphalt and aggregates. 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 has been the most recycled material for a long time in America. Using RAP material has well-recognized financial and environmental benefits. Although most of the produced RAP is recycled, a large portion of it is wasted or down-graded when used in landfills, embankment or base layers.

The asphalt pavements which have reached the end of their service life are frequently rehabilitated by milling the existing pavement surfaces and replacing the milled portion with new hot mix asphalt (HMA). A large amount of recycled asphalt pavement (RAP) is generated every year because of this practice. The use of RAP has been in practice since 1930s and is necessary to reduce the cost of construction materials, to reduce the use of

petroleum-based products, and to conserve natural resources by requiring less virgin aggregate and asphalt in road construction projects.

But this concept is new to India and it has great potential for research and practical use. Currently, great emphasis is placed on sustainable construction and infrastructure because the demand for sustainable and environmental friendly roads is increasing. More green technologies for sustainable roadway construction are needed. One way to construct environmentally sound roads is through the use of RAP materials. RAP has been used with new bituminous materials by either a hot-mix or cold-mix recycling process. However, a large quantity of RAP materials remains unused. Recent investigations have shown that the waste problems can be reduced by using RAP as base and subbase aggregate materials. Using RAP as a base course material would preserve non-renewable aggregate as well as reduce the amount of space needed to store millions of tons of RAP created each year.

Figure - 3.1 The non – bituminous R.A.P used in the study

Generally the previous research were conducted on the R.A.P. of bituminous layer of pavement but in this study we will be using the non-bituminous R.A.P. The R.A.P used is of the W.M.M. layer of pavement.

3.3 BITUMEN

Asphalt, also known as bitumen is a sticky, black, and highly viscous liquid or semi-solid form of petroleum. It may be found in natural deposits or may be a refined product, and is classed as a pitch. Before the 20th century, the term asphaltum was also used. The word is derived from the Ancient Greek - ásphaltos. The primary use of asphalt is in road construction, which is around 70% , where it is used as a binder mixed with aggregate particles to create asphalt concrete. It is also used as an bituminous waterproofing product , including production of roofing felt and for sealing flat roofs.

The terms "asphalt" and "bitumen" are often used interchangeably to mean both natural and manufactured forms of the substance. In American English, "asphalt" (or "asphalt cement") is commonly used for a refined residue from the distillation process of selected crude oils. Outside the United States, the product is often called "bitumen", and geologists worldwide often prefer the term for the naturally occurring variety. Common colloquial usage often refers to various forms of asphalt as "tar", as in the name of the La Brea Tar Pits.

Naturally occurring asphalt is sometimes specified by the term "crude bitumen". Its viscosity is similar to that of cold molasses while the material obtained from the fractional distillation of crude oil boiling at 525 °C (977 °F) is sometimes referred to as "refined bitumen". The Canadian province of Alberta has most of the world's reserves of natural asphalt in the Athabasca oil sands, which cover 142,000 square kilometres (55,000 sq. mi), an area larger than England.

3.4 EMULSION

An emulsion is a mixture of two or more liquids that are normally immiscible (unmixable or unblendable). Emulsions are part of a more general class of two-phase systems of matter called colloids. Although the terms colloid and emulsion are sometimes used interchangeably, emulsion should be used when both phases, dispersed and continuous, are liquids. In an emulsion, one liquid (the dispersed phase) is dispersed in the other (the continuous phase). Examples of emulsions include vinaigrettes, homogenized milk, and some cutting fluids for metal working. The word "emulsion" comes from the Latin mulgeo,

mulgere "to milk",[specify] as milk is an emulsion of fat and water, along with other components.

Two liquids can form different types of emulsions. As an example, oil and water can form, first, an oil-in-water emulsion, wherein the oil is the dispersed phase, and water is the dispersion medium. (Lipoproteins, used by all complex living organisms, are one example of this.) Second, they can form a water-in-oil emulsion, wherein water is the dispersed phase and oil is the external phase. Multiple emulsions are also possible, including a "water-in-oil-in-water" emulsion and an "oil-in-water-in-oil" emulsion.

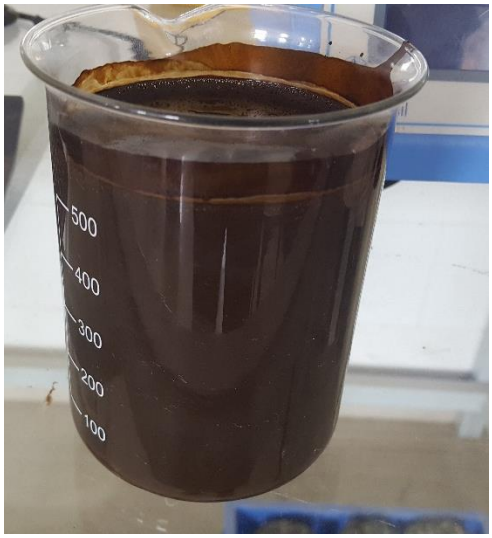


Figure – 3.2 Bitumen emulsion used in the study (SS_2)

3.4.1 Types of Bitumen Emulsion

The bitumen emulsion is classified into two types:

1. Based on Setting Time

When the bitumen emulsion is applied on the aggregate for the road works the water evaporates leaving behind the bitumen droplets. These droplets spread on the aggregate and bind with each other and gains strength eventually.

Based upon the time taken by the vitamin emulsion to evaporate the water and between particles to separate from water, bitumen emulsion is further classified into 3 types based on setting time:

a) Slow setting emulsion

In this type of emulsion, a special type of emulsifier is used to slow the process of water evaporation. This type of emulsifier are relatively stable.

b) Medium setting emulsion

This type of bitumen emulsion doesn't break as when applied on aggregate. The process of evaporation starts when the fine dust of mineral are mixed with the aggregate emulsion mix.

c) Rapid setting emulsion

This type of bitumen emulsion breaks down rapidly as it comes with contact with aggregate helping in fast setting and rapid curing.

2. Based on Surface Charge

Based upon the type of surface charge, they are divided into 2 types:

- Anionic Bitumen Emulsion
- Cationic Bitumen Emulsion

In anionic bitumen emulsion, the tiny droplets of bitumen are electronegative recharged. In Cationic bitumen emulsion the tiny droplets of bitumen are electro positively charged.

The average and commonly used between emulsions is cationic between emulsions.

Selection of positive or negative recharge between emulsions depends upon the mineral composition of aggregate on which it is used

3.4.2 Advantages and Uses of Bitumen Emulsions are

- Bitumen emulsion are used extensively in bituminous road construction. Other than this they are used for maintenance and repair work.
- Emulsions can be used in wet weather even if it is raining.
- Is eco-friendly as it is water based.
- Bitumen emulation is also used in soil stabilization in desert areas.
- It doesn't need extra heat while placing.
- There is no wastage in placing and laying of bitumen.
- They possess anti-stripping properties.
- Rapid setting type of emulsion are used in surface of roads.
- Medium setting type of emulsion are used in premixing of bitumen emulsion and coarse aggregate.
- Slow setting type of emulsion are used with fine aggregates as the surface area is large and requires time for uniform mixing.

3.4.3 Limitations of Bitumen Emulsion

- Storage time of bitumen emulsion ranges from few days to 6 months depending upon the percentage of Bitumen added while production.
- Setting time may vary due to temperature, wind and type of emulsion.
- Not a single type of bitumen emulsion can be used for all works it depends upon the aggregate type setting time nature of work etc.

In this study SS_2 emulsion is used. The SS_2 used is of HINCOL brand (Jhansi unit).

3.5 OLD ENGINE OIL

Used engine oil or old engine is used as an emulsion in this study . The idea was to use this waste material for road construction as it may show some binding properties with any of the chemical additives like cement , hydrated lime , Fly ash or fibre.

The used engine may be derived from any mechanical machine like generators etc.

3.6 CEMENT

A cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Cement is the most widely used material in existence and is only behind water as the planet's most-consumed resource.

Cements used in construction are usually inorganic, often lime or calcium silicate based, and can be characterized as either hydraulic or non-hydraulic, depending on the ability of the cement to set in the presence of water.

Non-hydraulic cement does not set in wet conditions or under water. Rather, it sets as it dries and reacts with carbon dioxide in the air. It is resistant to attack by chemicals after setting.

Hydraulic cements (e.g., Portland cement) set and become adhesive due to a chemical reaction between the dry ingredients and water. The chemical reaction results in mineral hydrates that are not very water-soluble and so are quite durable in water and safe from chemical attack. This allows setting in wet conditions or under water and further protects the hardened material from chemical attack. The chemical process for hydraulic cement found by ancient Romans used volcanic ash (puzzolana) with added lime (calcium oxide).

3.6.1 Modern cements

Modern hydraulic development began with the start of the Industrial Revolution (around 1800), driven by three main needs:

- Hydraulic cement render (stucco) for finishing brick buildings in wet climates.
- Hydraulic mortars for masonry construction of harbour works, etc. , in contact with sea water.
- Development of strong concretes.

Modern cements are often Portland cement or Portland cement blends, but industry also uses other cements.

Figure - 3.3 Cement used in the study (OPC 43)

3.6.2 Portland cement

Portland cement is by far the most common type of cement in general use around the world. This cement is made by heating limestone (calcium carbonate) with other materials (such as clay) to 1450 °C in a kiln, in a process known as calcination that liberates a molecule of carbon dioxide from the calcium carbonate to form calcium oxide, or quicklime which then chemically combines with the other materials in the mix to form calcium silicates and other cementitious compounds. The resulting hard substance, called 'clinker', is then ground with a small amount of gypsum into a powder to make ordinary Portland cement, the most commonly used type of cement (often referred to as OPC).

Portland cement is a basic ingredient of concrete, mortar, and most non-specialty grout. The most common use for Portland cement is to make concrete. Concrete is a composite material made of aggregate (gravel and sand), cement, and water. As a construction material, concrete can be cast in almost any shape, and once it hardens, can be a structural (load bearing) element. Portland cement may be grey or white.

In this study Ordinary Portland Cement is used. The grade of cement is 43 i.e. OPC 43.Ordinary Portland Cement of Grade 43 (OPC 43) shall conform to IS:8112-1989 and the designed strength of 28 days shall be minimum 43 MPa or 430 kg/sq.cm**.**

3.7 FLYASH

Fly ash is a fine powder that is a by-product of burning pulverized coal in electric generation power plants. Fly ash is a puzzolan, a substance containing aluminous and siliceous material that forms cement in the presence of water. When mixed with lime and water, fly ash forms a compound similar to Portland cement. This makes fly ash suitable as a prime material in blended cement, mosaic tiles, and hollow blocks, among other building materials. When used in concrete mixes, fly ash improves the strength and segregation of the concrete and makes it easier to pump.

Fly ash can be used as prime material in many cement-based products, such as poured concrete, concrete block, and brick. One of the most common uses of fly ash is in Portland cement concrete pavement or PCC pavement. Road construction projects using PCC can use a great deal of concrete, and substituting fly ash provides significant economic benefits.

3.7.1 Advantages of using Fly ash

Fly ash can be a cost-effective substitute for Portland cement in many markets. Fly ash is also recognized as an environmentally friendly material because it is a by-product and has low embodied energy, the measure of how much energy is consumed in producing and shipping a building material. By contrast, Portland cement has a very high embodied energy because its production requires a great deal of heat. Fly ash requires less water than Portland cement and is easier to use in cold weather.

Other benefits include:

- Produces various set times
- Cold weather resistance
- High strength gains, depending on use
- Can be used as an admixture
- Considered a non-shrink material
- Produces dense concrete with a smooth surface and sharp detail
- Great workability
- Reduces crack problems, permeability, and bleeding
- Reduces heat of hydration
- Allows for a lower water-cement ratio for similar slumps when compared to no-fly-ash mixes
- Reduces CO2 emissions

3.7.2 Disadvantages of using Fly ash

Smaller builders and housing contractors may not be familiar with fly ash products, which can have different properties depending on where and how it was obtained. Additionally, fly ash applications may face resistance from traditional builders due to its tendency to effloresce along with concerns about freeze/thaw performance. Other concerns about using fly ash in concrete include:

- Slower strength gain
- Seasonal limitation
- Increased need for air-entraining admixtures
- Increase of salt scaling produced by higher proportions of fly ash

3.8 HYDRATED LIME

Lime is a calcium-containing inorganic mineral composed primarily of oxides, and hydroxide, usually calcium oxide and or calcium hydroxide. The word lime originates with its earliest use as building mortar and has the sense of sticking or adhering. These materials are still used in large quantities as building and engineering materials (including limestone products, cement, concrete, and mortar), as chemical feedstock, and for sugar refining, among other uses. Lime industries and the use of many of the resulting products date from prehistoric times in both the Old World and the New World. Lime is used extensively for wastewater treatment with ferrous sulphate.

The rocks and minerals from which these materials are derived, figure ally limestone or chalk, are composed primarily of calcium carbonate. They may be cut, crushed, or pulverized and chemically altered. Burning (calcination) of these minerals in a lime kiln converts them into the highly caustic material burnt lime, unslaked lime or quicklime (calcium oxide) and, through subsequent addition of water, into the less caustic (but still strongly alkaline) slaked lime or hydrated lime (calcium hydroxide, $Ca(OH)_2$), the process of which is called slaking of lime.

When the term is encountered in an agricultural context, it usually refers to agricultural lime, which is crushed limestone, not a product of a lime kiln. Otherwise it most commonly means slaked lime, as the more dangerous form is usually described more specifically as quicklime or burnt lime.

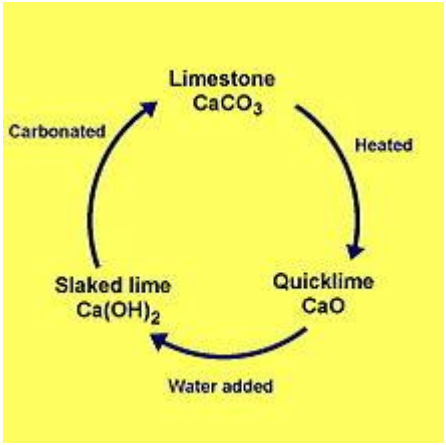


Figure – 3.4 The lime cycle for high-calcium lime

The process by which limestone (calcium carbonate) is converted to quicklime by heating, then to slaked lime by hydration, and naturally reverts to calcium carbonate by carbonation is called the lime cycle. The conditions and compounds present during each step of the lime cycle have a strong influence of the end product, thus the complex and varied physical nature of lime products.

Uses include lime-mortar, lime-plaster, lime-render, lime-ash-floors, tabby concrete, whitewash, silicate mineral paint, and limestone blocks which may be of many types. The qualities of the many types of processed lime affect how they are used. The Romans used two types of lime mortar to make Roman concrete, which allowed them to revolutionize architecture, sometimes called the Concrete revolution.

Figure – 3.5 Hydrated Lime used in the study

3.8.1 Advantages of using Lime

Lime has many complex qualities as a building product including workability which includes cohesion, adhesion, air content, water content, crystal shape, board-life, spread ability, and flow ability; bond strength; comprehensive strength; setting time; sand-carrying capacity; hydrolocity; free lime content; vapour permeability; flexibility; and resistance to sulphates.

The Hydrated Lime used in this study is bought from Ankur chemicals.

3.9 FIBRE

Research and development work in Fiber Reinforced Concrete (FRC) composites began in India in the early 1970s. Fiber reinforced concrete was developed to overcome the problems associated with cement based materials such as low tensile strength, poor fracture toughness and brittleness of cementations composites. In the beginning, FRC was primarily used for pavements and industrial floors but now a day FRC composite is being used for a wide variety of applications including bridges, tunnel and canal linings, hydraulic structures, pipes, safety vaults and structural members.

Recron-3s fiber is also used in concrete element such as RC and PC lintel, Beam, column, flooring and wall plastering, foundation, tanks, manhole cover and tiles plastering, Road and pavement, hollow block and precast, Railway slippers, swimming pools.

There are so many type of polymer fiber available as secondary construction materials. The Recron-3S fiber is one of them, and The Reliance Industry Limited (RIL) has launched Recron-3S. Recron-3s polymer fiber for mixing concrete and mortar for improving certain properties of the concrete and mortar. Fibers have special triangular shape for better anchoring with other ingredient of the mix. Recron-3S fiber is available in 6mm and 12mm length.

Figure – 3.6 Fibre – Recron 3s used in the study

3.9.1 Advantages and disadvantages of Recron 3s Fiber :

Advantages :

- Control cracking : It helps in controlling micro shrinking cracks in plastic stage.
- Reduces water permeability : Test results have confirmed that the use of recron-3s reduces water permeability of the Pavement concrete.
- Reduces rebound loss : Use of Recron 3s reduce the rebound loss of mortar and concretes as confirmed by user feedback.
- Increases flexibility : Due to its high modulus of elasticity, recron-3s has found to be helping in increasing the flexural strength of Pavement concrete.
- Alkali resistance : Results have shown that Recron 3s has acceptable range of alkali resistance.
- Maintenance : There is no special maintenance required with the use of Recron-3s fiber.
- Environmental : Recron-3s is environmental friendly.

Disadvantages :

- With the use of this product some extra weight is added in concrete and this will increase specific gravity of concrete and self-weight of structure.
- Adding of this product in Pavement concrete will increase the cost, so it is more costly than ordinary concrete.
- Using of FRC required highly skilled worker to finish the task in proper way.

CHAPTER 4

METHODOLOGY

4.1 INTRODUCTION

The main method used in this study is recycling of reclaimed asphalt pavement using Cold Mix procedure. To obtain the strength parameters of various combinations used in the study , Indirect Tensile Strength and Marshall Test were conducted. Various other test were conducted for different materials used in the test like Cement , Emulsion SS_2 , Water , Coarse Aggregate and R.A.P.

The list of tests conducted for each material is as follows :

4.1.1 Coarse Aggregate :

- Specific Gravity & Water Absorption of coarse Aggregate {As per IS 2386 : Part 3 – 1963 R.A. 2007 method}.
- Soundness of coarse aggregate with Sodium Sulphate (Na_2SO_4) { As per IS : 2386 (Part 5) – 1963 reaffirmed 2011}.
- Soundness of coarse aggregate with Magnesium Sulphate ($MgSO_4$) {As per IS : 2386 (Part 5) – 1963 reaffirmed 2011}.
- Determination of aggregate Abrasion value - Los Angeles method {As per IS : 2386 (Part – 4) – 1963 , reaffirmed 2007 }.
- Determination of aggregate Impact value of coarse aggregate {As per IS : 2386 (Part – 4) – 1963 , reaffirmed 2007 }.
- Combined Flakiness & Elongation Index {As per IS : 2386 Part -1 & Table 500-8 of MORTH Specs. 2001 }.
- Atterberg Limit {As per IS : 2720 (P 5) – 1985 , RA 2010 }.

4.1.2 Emulsion (SS_2) :

- Residue by sieving through 600 –micron Sieve of bitumen emulsion (cationic) {As per IS : 8887 – 2004 , reaffirmed in 2009 – Annex B }.
- Viscosity by Furol Viscometer of Bitumen Emulsion (cationic) {As per IS : 8887 – 2004 , & IS : 3117 – 2004 reaffirmed in 2009 }.
- Coagulation of bitumen emulsion (cationic) at low temperature {As per IS : 8887 – 2004 , reaffirmed in 2009 Annex – C }.
- Determination of Storage stability of bitumen emulsion (cationic) { As per IS : 8887 – 2004 , reaffirmed in 2009 Annex – D }.
- Determination of Particle charge on bitumen emulsion (cationic) { As per IS : 8887 – 2004 , reaffirmed in 2009 Annex – E }.
- Stability to mixing with cement of bitumen emulsion (cationic) { As per IS : 8887 – 2004 , reaffirmed in 2009 Annex – G }.
- Miscibility with water of bitumen emulsion (cationic) { As per IS : 8887 – 2004 , Annex – H }.
- Determination of residue by evaporation of bitumen emulsion (cationic) { As per IS : 8887 – 2004 , reaffirmed in 2009 Annex – J }.
- Determination of Penetration of residue of bitumen emulsion (cationic) {As per IS : 8887 – 2004 , reaffirmed in 2009 Annex – J & IS : 1203 – 1978 }.
- Ductility Test on Residue of Bitumen Emulsion (cationic){As per IS : 8887 – 2004 , Annex – J & IS : 1208 – 1978 }.
- Solubility in Trichloroethylene – TCE of residue of Bitumen emulsion (cationic) {As per IS : 8887 – 2004 , reaffirmed in 2009 Annex – J & IS : 1216 -1978 }.

4.1.3 Water :

- pH value of water for construction purpose - Electrometric method {As per IS : 3025 part 11 – 1983 RA 2014 }.
- Limit of acidity in water for construction purpose {As per IS : 456 and IS : 3025 (Part 22) – 1986 RA 2009 }.
- Limit of alkalinity in water for construction purpose {As per IS : 456 and IS : 3025 (Part 23) – 1986 RA 2009 }.

- Inorganic & organic Solids {As per IS : 3025 (Part 18) – 1984 RA 2006 }.
- Sulphates (SO_4) in Ground water & water for construction purpose {As per IS : 3025 (Part 24) – 1986 RA 2009 }.
- Chloride (Cl) in Ground water & water for construction purpose {As per IS : 3025 (Part 32) – 1988 RA 2009 }.
- Total suspended matter in water for construction purpose {As per IS : 3025 (Part 17) – 1984 RA 2006 }.

4.1.4 Cement :

- Determination of consistency of standard cement paste {As per IS : 4031 (Part – 4) : 1988 , RA 2009 }.
- Determination of Initial and Final setting time of cement {As per IS : 4031 (Part – 5) : 1988 , RA 2009 }.
- Determination of Soundness of cement by Le – Chaterlier Method {As per Clause : 5 , IS : 4031 (Part – 3) : 1988 , RA 2009 }.
- Determination of Soundness of cement by Autoclave Method {As per Clause : 6 , IS : 4031 (Part – 3) : 1988 , RA 2009 }.
- Determination of Fineness by Blaine Air Permeability method {As per IS : 4031 (Part – 2) : 1999 , RA 2013 }.
- Determination of Compressive strength of cement mortar cubes {As per IS : 4031 (Part – 6) : 1988 , RA 2009 }.
- Wet gradation of Cement {As per IS : 2386 Part 1 – 1963 , Reaffirmed in 2016 & Table IX – 1 , IRC : 37 – 2012 }.

4.1.5 R.A.P. :

Wet Gradation of RAP {As per IS : 2386 Part 1 – 1963 , Reaffirmed in 2016 & Table IX – 1 , IRC : 37 – 2012 }.

Gradation of lime and Fly-ash is also conducted.

4.2 Cold mix Recycling

4.2.1 Design for Bitumen Emulsion RAP Mixes :

The first step is Gradations of Aggregates : The aggregates from RAP may not have the required gradation for a good mix. RAP alone has poor internal friction and its CBR may be as low as 30 though a fresh close graded aggregates may have CBR as high as 200. Addition of crusher dust containing particle size from 6 mm to 0.075 mm and fines passing 0.075 mm adds to angle of internal friction as well as some cohesion to the RAP mixes. The crusher dust requirement can be 15 to 30 per cent and 1 per cent cement or lime or both by weight of dry aggregates helps in dispersion of the bitumen emulsion in the mix. Lime modifies the clay that may have contaminated the RAP. RAP may need re-crushing if they have lumped up during storage. If milled aggregates are from those of Bituminous Macadam, it may be open graded and some additional fresh aggregates may be necessary for the adjustment of gradation. The grading of the blend of RAP/fresh aggregates and crusher dust should meet the requirement shown in Table following table 4.1 adopted from the South African Standard 'TG2 (64) CSIR Built Environment, Pretoria. The grading has been slightly adjusted to correspond to the sieve size designation in MORTH.

Table 4.1 - Gradation of RAP Mixes

Sieve size,mm	per cent passing
45	100
37.5	87-100
26.6	77-100
19	66-99
13.2	67-87
4.74	33-50
2.36	25-47
0.60	12-27
0.3	8-21
0.075	2-9

Some RAP may be contaminated with clay which might have risen from the subgrade during the wet weather. Addition of 2 per cent lime would modify the clay and the mix becomes suitable for use.

The second step is to determine the Bitumen Emulsion Type : Since the blend of RAP and crusher dust consists of plenty of fine particles, only slow setting emulsion (SS2) with minimum residual bitumen content of 60 per cent is recommended to prevent the emulsion from breaking during the mixing and construction.

The third step is to Determination of Optimum Fluid Content **:** A RAP bitumen emulsion mix can be compacted to maximum density only at optimum fluid content. Compaction tests are to be done at different fluid content to arrive at the optimum fluid content. Procedures given in Manual 14 'The design and Use of Granular Emulsion Mixes' Published by South African Bitumen and Tar association (SABITA) (7) and TG-2 of South Africa (64) have been suggested for mix design. Users may adopt other methods of mix design given in 'Cold Mix Recycling' and 'Asphalt cold Mix Manual (MS-14)'Published by Asphalt Institute, USA.

4.2.2 Procedure followed is :

1. Prepare a 50:50 blend of bitumen emulsion and water by volume. Water is added to bitumen emulsion and not the emulsion to water for dilution to prevent premature breaking. Compatibility for dilution may be checked.

2. Actual water content of the blend of RAP, crusher dust and filler may be determined by oven drying and fluid increment of 1 per cent by weight of the blend may be added and thoroughly mixed .The mix is transferred to a a standard 100mm diameter Marshall mould and compacted by 75 blows on each face at ambient temperature. A minimum of three samples are cast at each fluid content.

3. Dry density should be computed at each fluid content as per the following :

$$D_{dd} = \frac{D_{bulk}}{1 + FC}$$

Where D_{dd} = Dry density in kg/m^3, D_{bulk} = Bulk density in kg/m^2, FC = Fluid content by dry weight of aggregates in decimal.

A plot is made for dry density vs. fluid content as shown below and maximum dry density and the corresponding optimum fluid content is determined. Optimum fluid content is necessary for the compaction of the RAP mixes to the maximum density.

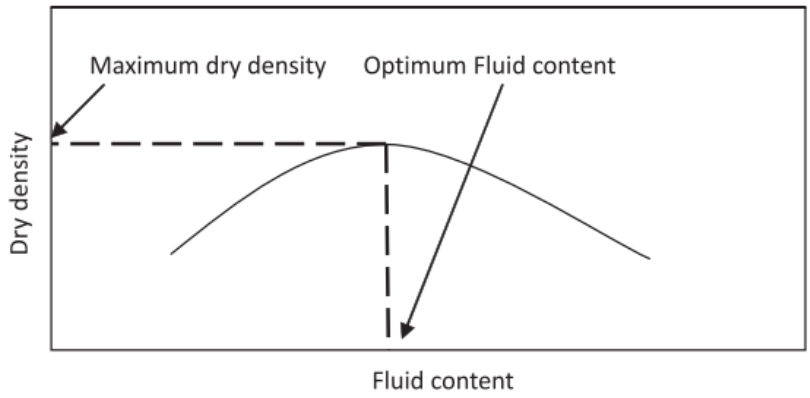


Figure - 4.1 Dry Density-Fluid Content Relation for Blended Rap Mix

4. Marshall samples are prepared at different emulsion content starting from 3 per cent to 4 per cent by weight of the total mix in increment of 0.5 per cent. Additional water is added first and mixed then the bitumen emulsion is added and mixed again. The total fluid is close to the optimum. The sample is compacted in a Marshall mould by applying 75 blows on each face. Six samples are prepared at each fluid content.

5. The samples should be left in the mould for 24 hours and then placed in an oven for 72 hours at 40°C for curing after the extraction. The sample should be kept on a tray. Most of the moisture will be lost through evaporation.

6. Laboratory tests : Indirect tensile strength tests are to be carried out on dry samples in a standard Marshall loading frame which applies load at rate of nearly 50 mm per minute (50.8 mm per minute) and the maximum load is determined at 25°C. Three samples are also tested at 25°C after 24 hours of soaking in water.

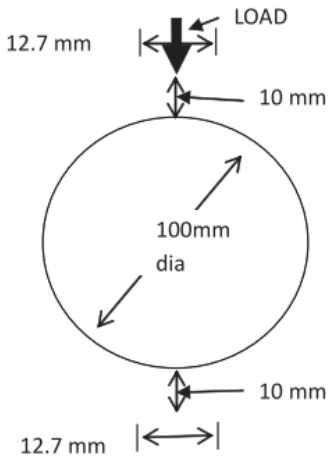
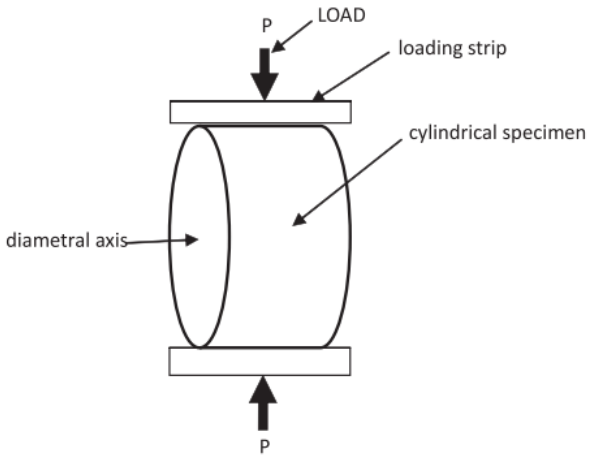


Figure – 4.2 , 4.3 - Marshall Samples of RAP 100 mm Diameter and 63 mm Long Under Indirect Tensile Test



The loading strip is 12.7 mm wide and about 70 mm long to test samples of height up to 70 mm. A modified version of Marshall Test apparatus as per Figure 4.2 & 4.3 can be fabricated in a workshop. It is available commercially also.

$$\text{Indirect tensile strength, ITS (kPa)} = \frac{2000P}{\pi dh}$$

Where P = the maximum load in Newton, d = diameter of the sample, mm (may be close to 100 mmm), h = height (thickness) of the sample, mm .

Table 4.2 - Minimum Strength Requirement of RAP Mixes

Strength Test	Specimen diameter	Minimum strength, KPa
ITS_{dry}, 25°C	100 mm	> 225 kPa
ITS_{wet} 25°C	100 mm	> 100 kPa

If ITS dry is greater than 400 kPa and ITS is less than 50 per cent of the dry value, it is indicative of contamination with clay and 1 to 2 per cent lime may be necessary for modifying the plasticity of the clay. For 100 mm diameter samples, aggregates passing 26.5 mm sieve should be used for mix design. Effect of higher aggregate size is to increase the strength of the mixes.

The bitumen emulsion content satisfying the minimum strength requirement given in Table 4.2 can be used for the mixing. Additional 1.5 to 2.5 per cent water may be added to the RAP mixes during the construction due to rapid evaporation of water from the RAP mixes in the hot weather since optimum fluid content is necessary for maximum compaction and strength gain. Within a few hours of laying of RAP mix, the top layer is able to stand the construction traffic due to loss of water on hot sunny days.

Figure – 4.4 Pouring R.A.P. for making the mix

Figure - 4.5 Adding cement in the mix

Figure - 4. 6 Adding Emulsion in the mix

Figure – 4.7 Compaction machine for moulds

Figure – 4.8 Sample moulds kept for conditioning

Figure – 4.9 Moulds used in lab work

4.3 Marshall Test

4.3.1 Introduction

Marshall stability and flow values along with density; air voids in the total mix, voids in the mineral aggregate, or voids filled with asphalt, or both, filled with asphalt are used for laboratory mix design and evaluation of bituminous mixtures. In addition, Marshall stability and flow can be used to monitor the plant process of producing bituminous mixture. Marshall stability and flow may also be used to relatively evaluate different mixes and the effects of conditioning such as with water.

Figure - 4.10 Marshall and I.T.S. test apparatus

4.3.2 Procedure

1. A minimum of three specimens of a given mixture shall be tested. The specimens should have the same aggregate type, quality, and grading; the same mineral filler type and quantity; and the same binder source, grade and amount. In addition, the specimens should have the same preparation, that is, temperatures, cooling, and compaction.

2. Specimens should be cooled to room temperature after compaction. During cooling they should be placed on a smooth, flat surface. Bulk specific gravity of each specimen shall be determined by Test Methods D2726, D1188,orD6752. The bulk specific gravities of replicate specimens for each binder content shall agree within 60.020 of the mean as noted in Practice D6926.

3. Measure specimen thickness according to Test Method D3549.

4. Specimens can be conditioned for testing as soon as they reach ambient room temperature. Testing shall be completed within 24 h after compaction. Bring specimens prepared with asphalt cement, tar, or tar-rubber to the specified temperature by immersion in the water bath 30 to 40 min, or placement in the oven for 120 to 130 min. Maintain the bath or oven temperature at 60 ± 1°C (140 ± 2°F) for asphalt cement , 49 ± 1°C (120 ± 2°F) for tar-rubber

specimens, and 38 ±1°C (100 ± 2°F) for tar specimens. Bring specimens prepared with cutback asphalt to temperature by placing them in the air bath for 120 to 130 min. Maintain the air bath temperature at 25 ± 1°C (77 ± 2°F).

5. Thoroughly clean the guide rods and inside surfaces of the test head segments prior to conducting the test. Lubricate guide rods so that the upper test head segment slides freely over them. The testing head shall be at a temperature of 20 to 40°C (70 to 100°F). If a water bath is used, wipe excess water from the inside of the testing head segments.

6. Remove a specimen from the water, oven, or air conditioning bath (in the case of a water bath remove excess water with a towel) and place in the lower segment of the testing head. Place the upper segment of the testing head on the specimen, and place the complete assembly in position in the loading machine. If used, place the flowmeter in position over one of the guide rods and adjust the flowmeter to zero while holding the sleeve firmly against the upper segment of the testing head. Hold the flowmeter sleeve firmly against the upper segment of the testing head while the test load is being applied.

7. The elapsed time from removal of the test specimens from the water bath to the final load determination shall not exceed 30 s. Apply load to the specimen by means of the constant rate of movement of the loading jack or loading machine head of 50 ± 5 mm/min (2.00 ± 0.15 in./min) until the dial gage releases or the load begins to decrease.

8. In Method A, release the flowmeter sleeve or note the micro-meter dial reading, where used, the instant when the load decreases, or in Method B, stop the test when the load cell indicates that the incremental rate of loading, which is driving the constant rate of deformation, has begun to decrease. The Marshall flow is the total sample deformation from the point where the projected tangent of the linear part of the curve intersects the *x*-axis (deformation) to the point where the curve starts to become horizontal. The termination of flow usually corresponds to the peak stability; however, as an alternative when the failure condition is not clearly defined, it can be selected as the point on the curve which is six (0.01in.) flow points (or 1.5 mm) to the right of the tangent line. The flow value is usually recorded in units of 0.25 mm (0.01 in.); for example, 0.12 in. is recorded as a flow of 12. The Marshall Stability is defined as the load corresponding to the flow.

This procedure may require two people to conduct the test and record the data, depending on the type of equipment and the arrangement of dial indicators. Depending on chart speed, Marshall flow may be read directly from the load-deformation chart or be determined after converting the chart reading with an appropriate factor.

Figure – 4.11 Conducting Marshall Test

4.3.3 Calculations

Laboratory moulded specimens shall satisfy the thickness requirement of 63.5 ± 2.5 mm (2.50 ± 0.10 in.). Specimens within the thickness tolerance may be corrected based on specimen volume or thickness. Stabilities determined on field cores with large variation in volume or thickness shall also be corrected. However, results with larger corrections should be used with caution. Correction factors (correlation ratios) are given in ASTM : D6927 - 06. The correlation ratio is used in the following manner.

$$A = B \times C$$

where:

A = corrected stability,

B = measure of stability (load), and

C = correlation ratio from Table given in ASTM : D6927 - 06

4.4 Indirect Tensile Strength test (I.T.S.) :

4.4.1 Introduction

The IDT strength of bituminous mixtures is conducted by loading a cylindrical specimen across its vertical diametric plane at a specified rate of deformation and test temperature. The peak load at failure is recorded and used to calculate the IDT strength of the specimen.

The values of IDT strength may be used to evaluate the relative quality of bituminous mixtures in conjunction with laboratory mix design testing and for estimating the potential for rutting or cracking. The results can also be used to determine the potential for field pavement moisture damage when results are obtained on both moisture-conditioned and unconditioned specimens.

4.4.2 Procedure

1. Determine the specimen height in accordance with Test Method D 3549, to the nearest 1 mm (0.05 in.).

2. For core specimens, measure the diameter, at the mid height along axes that are 90º apart, and record the average to the nearest 1 mm (0.05 in.).

3. Bring the specimen to test temperature ±1°C (±1.8°F) by any of the following three alternative procedures. The recommended test temperature is 25ºC (77ºF).

Procedure A—Place the specimen in an air bath for a minimum of 4 hours.

Procedure B—Place the specimen in a heavy duty leak-proof plastic bag and then place the specimen in a water bath for a minimum of 2 hours.

Procedure C—Place the specimen in a water bath for a minimum of 30 minutes but not longer than 120 minutes.

4. Remove the specimen from the air or water bath, remove the specimen from the plastic bag (if necessary), and place onto the lower loading strip. Slowly lower the top loading strip to bring it into light contact with the specimen. Ensure that the loading strips are parallel and centred on the vertical diametric plane. The elapsed time between removal of test specimens from the bath and the final load determination shall not exceed 2 minutes.

5. Apply a vertical compressive ramp load until the maximum load is reached. The recommended deformation rate is 50 ± 5 mm/min (2.00 ± 0.15 in./min). Record the maximum load. Also recommended in Test Method D 5581 when testing larger specimens for Marshall Stability with a nominal diameter of 150 mm (5.91 in.).

Research has not yet indicated if this deformation rate should be adjusted for IDT strength specimens with a nominal diameter of 150 mm (5.91 in.). Some researchers have also used a rate of 3.75 mm/min (0.15 in./min) at higher temperatures (30-40°C (86-104°F)) on specimens with a nominal diameter of 150 mm (5.91 in.) to evaluate rutting potential.

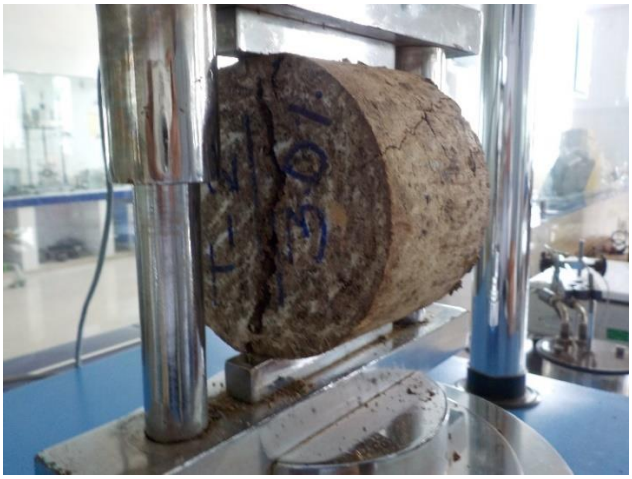


Figure – 4.12 Conducting I.T.S. test

4.4.3 Calculation

Calculate the IDT strength as follows:

$$S_t = \frac{2000 \times P}{\Pi \times t \times D}$$

In (kPa)

Or

$$S_t = \frac{2 \times P}{\Pi \times t \times D}$$

In (psi)

where:

St= IDT strength, kPa (psi)

P = maximum load, N

t = specimen height immediately before test, mm (in.)

D = specimen diameter, mm (in.)

4.5 R.A.P. - VARIATIONS USED IN THE STUDY

Table - 4.3 : Variations with SS2 as binder

Variations with SS_2 as binder			
R.A.P.	Fresh aggregate	Emulsion – SS_2	Cement – OPC 43
R.A.P.	Fresh aggregate	Emulsion – SS_2	Fibre – Recron 3s
R.A.P.	Fresh aggregate	Emulsion – SS_2	Hydrated Lime
R.A.P.	Fresh aggregate	Emulsion – SS_2	Fly Ash

Table - 4.4 : Variations with Old Engine Oil as binder

Variations with Old Engine Oil as binder			
R.A.P.	Fresh aggregate	Old Engine oil	Cement – OPC 43
R.A.P.	Fresh aggregate	Old Engine oil	Fibre – Recron 3s
R.A.P.	Fresh aggregate	Old Engine oil	Hydrated Lime
R.A.P.	Fresh aggregate	Old Engine oil	Fly Ash

CHAPTER 5

RESULTS AND ANALYSIS

SUMMARY RESULTS OF INDIRECT TENSILE STRENGTH

Combination: RAP + Aggregate + Fibre + SS_2

Table – 5.1

Sample ID	Emulsion Content (%)	Moisture Content in blend (%)	Additional water (%)	Fluid Content (%)	Mass in Air (g)	Mass in Water (g)	Mass SSD (g)	Volume of sample (cm^3)	Bulk Density (g/cm^3)	Mass of dry sample (g)	Moisture Content (%)	Fluid Content (%)	Dry Density (g/cm^3)	Diameter (mm)	Height (mm)	Load (KN)	Dry ITS (kPa)	Wet ITS (kPa)
T7/D1	3.5	0.65	3.5	7.65	1246.7	719.0	1272.1	553.1	2.247	1212.7	3.09	5.49	2.130	101.50	71.23	2.93	258.01	
T8/D2					1246.9	719.0	1272.7	553.7	2.245	1212.9	3.06	5.35	2.131	101.52	69.90	2.98	267.5	
T9/D3					1245.8	718.0	1271.0	553.0	2.246	1211.3	3.09	5.50	2.129	101.64	70.95	3.04	268.5	
T10/W1	3.5	0.65	3.5	7.65	1243.3	715.0	1266.4	551.4	2.248	1208.3	3.06	5.54	2.130	101.30	70.24	2.22		198.7
T11/W2					1244.6	717.0	1270.2	553.2	2.430	1210.2	3.08	5.35	2.129	101.64	68.92	2..24		203.7
T12/W3					1244.5	717.0	1270.6	553.6	2.241	1210.0	3.07	5.11	2.132	101.28	68.75	2.21		202.2

SUMMARY RESULTS OF INDIRECT TENSILE STRENGTH

Combination: RAP + Aggregate + Cement + SS_2

Table – 5.2

Sample ID	Emulsion Content (%)	Moisture Content in blend (%)	Additional water (%)	Fluid Content (%)	Mass in Air (g)	Mass in Water (g)	Mass SSD (g)	Volume of sample (cm^3)	Bulk Density (g/cm^3)	Mass of dry sample (g)	Moisture Content (%)	Fluid Content (%)	Dry Density (g/cm^3)	Diameter (mm)	Height (mm)	Load (KN)	Dry ITS (kPa)	Wet ITS (kPa)
T7/D1	3.5	0.65	3.5	7.65	1224.2	681.0	1234.7	553.7	2.204	1209.3	1.22	1.38	2.174	101.35	71.86	2.93	256.88	
T8/D2					1223.9	676.5	1235.9	559.4	2.181	1213.0	0.89	1.07	2.158	103.65	68.66	2.80	250.20	
T9/D3					1222.3	676.5	1230.9	554.4	2.198	1212.4	0.81	0.64	2.184	102.10	70.16	2.84	252.23	
T10/W1	3.5	0.65	3.5	7.65	1224.6	682.0	1233.9	551.9	2.212	1213.4	0.91	1.00	2.197	101.42	69.42	2.02		182.63
T11/W2					1226.5	684.5	1233.6	549.1	2.227	1213.2	1.08	1.41	2.203	101.29	69.53	2.10		190.22
T12/W3					1221.2	677.5	1228.2	550.7	2.211	1210.5	0.88	1.28	2.190	101.39	70.01	2.09		188.24

SUMMARY RESULTS OF INDIRECT TENSILE STRENGTH

Combination: RAP + Aggregate + Lime + SS_2

Table - 5.3

Sample ID	Emulsion Content (%)	Moisture Content in blend (%)	Additional water (%)	Fluid Content (%)	Mass in Air (g)	Mass in Water (g)	Mass SSD (g)	Volume of sample (cm^3)	Bulk Density (g/cm^3)	Mass of dry sample (g)	Moisture Content (%)	Fluid Content (%)	Dry Density (g/cm^3)	Diameter (mm)	Height (mm)	Load (KN)	Dry ITS (kPa)	Wet ITS (kPa)
T7/D1	3.5	0.65	3.5	7.65	1222.6	680.0	1226.3	546.3	2.231	1214.7	0.65	0.95	2.216	101.57	68.95	2.67	242.47	
T8/D2					1223.6	682.0	1230.0	548.0	2.226	1214.0	0.78	0.63	2.212	101.03	70.60	2.78	248.52	
T9/D3					1224.7	683.0	1228.0	545.0	2.240	1214.9	0.80	0.67	2.225	101.45	69.71	2.72	245.17	
T10/W1	3.5	0.65	3.5	7.65	1226.6	686.0	1230.6	544.6	2.246	1216.1	0.81	0.81	2.228	101.63	68.73	1.89		172.31
T11/W2					1224.5	684.0	1229.1	545..7	2.237	1215.2	0.76	0.40	2.228	101.64	68.53	1.81		165.69
T12/W3					1221.9	685.0	1225.5	540.5	2.254	1212.6	0.76	0.67	2.239	101.23	69.10	1.84		167.87

SUMMARY RESULTS OF INDIRECT TENSILE STRENGTH

Combination: RAP + Aggregate + Fly Ash + SS_2

Table – 5.4

Sample ID	Emulsion Content (%)	Moisture Content in blend (%)	Additional water (%)	Fluid Content (%)	Mass in Air (g)	Mass in Water (g)	Mass SSD (g)	Volume of sample (cm^3)	Bulk Density (g/cm^3)	Mass of dry sample (g)	Moisture Content (%)	Fluid Content (%)	Dry Density (g/cm^3)	Diameter (mm)	Height (mm)	Load (KN)	Dry ITS (kPa)	Wet ITS (kPa)
T7/D1	3.5	0.65	3.5	7.65	1221.3	687.0	1226.7	539.7	2.256	1211.2	0.83	0.80	2.238	101.40	68.3	2.60	239.64	
T8/D2					1222.7	686.5	1222.6	539.7	2.259	1213.0	0.79	0.62	2.245	101.97	68.10	2.61	240.33	
T9/D3					1222.9	685.0	1228.5	543.5	2.243	1213.1	0.80	0.71	2.227	101.61	68.67	2.59	236.78	
T10/W1	3.5	0.65	3.5	7.65	1219.4	686.5	1225.4	538.9	2.256	1208.0	0.93	1.03	2.233	101.93	68.36	1.63		148.80
T11/W2					1218.0	684.0	1222.7	538..7	2.254	1208.7	0.76	0.40	2.245	101.50	68.38	1.60		146.54
T12/W3					1220.3	683.0	1225.4	542.4	2.243	1211.4	0.73	0.18	2.239	101.07	70.45	1.70		150.99

SUMMARY RESULTS OF INDIRECT TENSILE STRENGTH

Combination: RAP + Aggregate + Fibre + Old Engine Oil

Table – 5.5

Sample ID	Emulsion Content (%)	Moisture Content in blend (%)	Additional water (%)	Fluid Content (%)	Mass in Air (g)	Mass in Water (g)	Mass SSD (g)	Volume of sample (cm^3)	Bulk Density (g/cm^3)	Mass of dry sample (g)	Moisture Content (%)	Fluid Content (%)	Dry Density (g/cm^3)	Diameter (mm)	Height (mm)	Load (KN)	Dry ITS (kPa)	Wet ITS (kPa)
T7/D1	3.5	0.65	3.5	7.65	1220.5	675.2	1230.7	555.5	2.191	1210.49	0.82	1.01	2.171	101.25	70.88	1.93	235.85	
T8/D2					1211.5	672.5	1225.9	553.4	2.183	1201.2	0.85	0.83	2.165	102.65	68.98	1.95	232.98	
T9/D3					1226.7	676.5	1232.5	556.0	2.200	1217.3	0.78	0.82	2.182	102.22	70.18	2.04	237.28	
T10/W1	3.5	0.65	3.5	7.65	1233.1	681.3	1240.8	559.5	2.197	1222.37	0.87	0.92	2.177	101.78	69.55	1.44		129.52
T11/W2					1227.5	678.0	1233.8	555.8	2.202	1216.21	0.92	0.69	2.187	101.65	68.84	1.49		122.88
T12/W3					1210.8	672.0	1219.4	547.4	2.205	1201.48	0.77	0.96	2.178	101.77	69.69	1.48		125.69

SUMMARY RESULTS OF INDIRECT TENSILE STRENGTH

Combination: RAP + Aggregate + Cement + Old Engine Oil

Table – 5.6

Sample ID	Emulsion Content (%)	Moisture Content in blend (%)	Additional water (%)	Fluid Content (%)	Mass in Air (g)	Mass in Water (g)	Mass SSD (g)	Volume of sample (cm^3)	Bulk Density (g/cm^3)	Mass of dry sample (g)	Moisture Content (%)	Fluid Content (%)	Dry Density (g/cm^3)	Diameter (mm)	Height (mm)	Load (KN)	Dry ITS (kPa)	Wet ITS (kPa)
T7/D1	3.5	0.65	3.5	7.65	1243.5	718.5	1270.5	552.0	2.246	1206.8	2.95	5.64	2.126	101.45	70.28	2.01	226.84	
T8/D2					1245.8	715.2	1271.3	556.1	2.234	1208.5	2.99	5.27	2.122	101.49	69.30	2.05	229.34	
T9/D3					1244.5	718.9	1270.9	552.0	2.248	1208.4	2.90	6.13	2.118	101.61	69.78	2.00	225.58	
T10/W1	3.5	0.65	3.5	7.65	1244.3	715.5	1268.9	553.4	2.242	1207.72	2.94	5.36	2.128	101.77	69.55	1.58		105.36
T11/W2					1241.8	716.4	1271.2	554.8	2.232	1205.42	2.93	5.08	2.124	101.69	68.71	1.60		101.88
T12/W3					1245.3	716.0	1270.5	554.5	2.239	1208.69	2.94	5.86	2.115	101.35	68.89	1.60		107.65

SUMMARY RESULTS OF INDIRECT TENSILE STRENGTH

Combination: RAP + Aggregate + Lime + Old Engine Oil

Table – 5.7

Sample ID	Emulsion Content (%)	Moisture Content in blend (%)	Additional water (%)	Fluid Content (%)	Mass in Air (g)	Mass in Water (g)	Mass SSD (g)	Volume of sample (cm^3)	Bulk Density (g/cm^3)	Mass of dry sample (g)	Moisture Content (%)	Fluid Content (%)	Dry Density (g/cm^3)	Diameter (mm)	Height (mm)	Load (KN)	Dry ITS (kPa)	Wet ITS (kPa)
T7/D1	3.5	0.65	3.5	7.65	1224.7	683.5	1229.2	545.7	2.238	1216.13	0..70	0.67	2.223	101.47	68.88	1.77	181.50	
T8/D2					1224.2	682.2	1232.8	550.8	2.216	1216.61	0.62	0.50	2.205	101.09	70.01	1.88	188.82	
T9/D3					1222.6	681.9	1230.5	548.6	2.222	1214.29	0.68	0.54	2.210	101.44	69.88	1.72	185.24	
T10/W1	3.5	0.65	3.5	7.65	1236.5	686.1	1241.8	555.7	2.218	1227.1	0.76	0.41	2.209	101.57	68.45	1.31		82.93
T11/W2					1222.8	682.0	1228.1	546.1	2.232	1214.0	0.72	0.68	2.217	101.63	68.99	1.28		79.88
T12/W3					1229.6	685.1	1235.6	550.5	2.227	1221.12	0.69	0..54	2.215	101.70	69.12	1.30		84.54

SUMMARY RESULTS OF INDIRECT TENSILE STRENGTH

Combination: RAP + Aggregate + Fly Ash + Old Engine Oil

Table – 5.8

Sample ID	Emulsion Content (%)	Moisture Content in blend (%)	Additional water (%)	Fluid Content (%)	Mass in Air (g)	Mass in Water (g)	Mass SSD (g)	Volume of sample (cm^3)	Bulk Density (g/cm^3)	Mass of dry sample (g)	Moisture Content (%)	Fluid Content (%)	Dry Density (g/cm^3)	Diameter (mm)	Height (mm)	Load (KN)	Dry ITS (kPa)	Wet ITS (kPa)
T7/D1	3.5	0.65	3.5	7.65	1228.1	687.5	1232.4	544.9	2.247	1218.7	0.76	0.58	2.234	101.43	68.92	1.50	154.87	
T8/D2					1230.5	686.0	1233.5	547.5	2.240	1220.9	0.78	0.40	2.231	101.90	68.45	1.44	151.54	
T9/D3					1224.0	686.8	1228.8	542.0	2.252	1215.3	0.73	0.41	2.243	101.65	67.95	1.40	157.28	
T10/W1	3.5	0.65	3.5	7.65	1228.9	686.5	1232.2	545.7	2.245	1219.2	0.79	0.58	2.232	101.88	67.54	1.18		68.34
T11/W2					1234.2	688.0	1238.8	550.8	2.234	1225.4	0.71	0.27	2.228	101.45	68.45	1.22		72.24
T12/W3					1231.7	687.4	1235.0	547.6	2.242	1222.4	0.76	0.22	2.237	101.12	69.65	1.21		70.49

Summary of Test Result - Marshall Stability Test at 25ºc

Combination: RAP + Aggregate + Fibre + SS_2

No. of Blows: 75 on each side

Duration of specimen kept in mould: 24 hours

Pavement Layer: Stabilized WMM - RAP

Duration of Conditioning at 40ºC: 72 hours

Table – 5.9

Trial No.		Emulsion Content by weigh of mix. (%)	Wt. of dry spec. in Air (A) – (gm)	SSD Wt. spec. in (B) – (gm)	Wt. of spec.in water (C) – (gm)	Bulk Volume – (cm^3)	Bulk Specific Gravity –(G_{mb})	Density – (g/cm^3) {G_{mb} X 0.997}	Water Content - % by mass	Test Temp. in - ºC	Moisture in Blend - %	Fluid Content - %	Marshall Stability				Flow in – (mm)
													Age of Specimen - Hours	Load – (KN)	Correction Factor – (KN)	Corrected Load – (KN)	
T1	WET SUBSET	3.5	1246.3	1299.7	716.0	583.7	2.135	2.129	3.5	25	0.65	7.65	96	12.70	0.83	10.29	3.08
T2			1245.8	1300.0	717.0	583.0	2.137	2.131					96	11.95	0.83	9.92	2.84
T3			1247.1	1301.3	718.0	583.3	2.138	2.132					96	12.51	0.83	10.38	2.86
T4	DRY SUBSET	3.5	1249.8	1304.8	720.0	584.8	2.137	2.131	3.5	25	0.65	7.65	96	20.67	0.83	17.16	2.92
T5			1250.4	1307.1	722.0	585.4	2.136	2.130					96	20.88	0.81	16.91	2.35
T6			1251.2	1310.0	724.0	586.0	2.135	2.129					96	20.68	0.81	16.75	2.40

Summary of Test Result - Marshall Stability Test at 25ºc

Combination: RAP + Aggregate + Cement + SS_2

No. of Blows: 75 on each side

Duration of specimen kept in mould: 24 hours

Pavement Layer: Stabilized WMM - RAP

Duration of Conditioning at 40ºC: 72 hours

Table – 5.10

Trial No.		Emulsion Content by weigh of mix. (%)	Wt. of dry spec. in Air (A) – (gm)	SSD Wt. spec. in (B) – (gm)	Wt. of spec.in water (C) – (gm)	Bulk Volume – (cm^3)	Bulk Specific Gravity –(G_{mb})	Density – (g/cm^3) {G_{mb} X 0.997}	Water Content - % by mass	Test Temp. in - ºC	Moisture in Blend - %	Fluid Content - %	Marshall Stability				Flow in – (mm)
													Age of Specimen – Hours	Load – (KN)	Correction Factor – (KN)	Corrected Load – (KN)	
T1	WET SUBSET	3.5	1213.0	1223.2	667.0	556.2	2.181	2.147	3.5	25	0.65	7.65	96	11.29	0.89	10.05	3.50
T2			1209.8	1217.8	667.0	550.8	2.196	2.190					96	11.18	0.89	9.95	3.22
T3			1208.0	1223.3	674.5	548.8	2.201	2.195					96	11.21	0.89	9.98	3.17
T4	DRY SUBSET	3.5	1214.8	1220.7	671.5	549.2	2.212	2.205	3.5	25	0.65	7.65	96	17.47	0.89	15.55	2.99
T5			1213.9	1219.5	669.5	550.0	2.207	2.200					96	16.73	0.89	14.89	2.72
T6			1211.3	1223.9	668.5	555.4	2.181	2.174					96	18.20	0.89	16.20	2.88

Summary of Test Result - Marshall Stability Test at 25ºc

Combination: RAP + Aggregate + Lime + SS_2

No. of Blows: 75 on each side

Duration of specimen kept in mould: 24 hours

Pavement Layer: Stabilized WMM - RAP

Duration of Conditioning at 40ºC: 72 hours

Table – 5.11

Trial No.		Emulsion Content by weigh of mix. (%)	Wt. of dry spec. in Air (A) – (gm)	SSD Wt. spec. in (B) – (gm)	Wt. of spec.in water (C) – (gm)	Bulk Volume – (cm^3)	Bulk Specific Gravity –(G_{mb})	Density – (g/cm^3) {G_{mb} X 0.997}	Water Content - % by mass	Test Temp. in - ºC	Moisture in Blend - %	Fluid Content - %	Marshall Stability				Flow in – (mm)
													Age of Specimen - Hours	Load – (KN)	Correction Factor – (KN)	Corrected Load – (KN)	
T1	WET SUBSET	3.5	1214.8	1222.3	678.5	543.8	2.234	2.227	3.5	25	0.65	7.65	96	9.19	0.93	8.55	3.89
T2			1212.6	1218.1	672.0	546.1	2.220	2.214					96	9.05	0.93	8.42	3.45
T3			1214.8	1218.4	672.0	546.4	2.223	2.217					96	8.73	0.93	8.12	3.95
T4	DRY SUBSET	3.5	1215.4	1222.3	674.5	546.8	2.223	2.216	3.5	25	0.65	7.65	96	16.25	0.89	14.46	2.97
T5			1214.5	1221.8	672.0	542.5	2.239	2.232					96	16.01	0.93	14.89	3.15
T6			1212.9	1217.6	673.0	539.9	2.247	2.240					96	15.01	0.93	13.96	2.85

Summary of Test Result - Marshall Stability Test at 25ºc

Combination: RAP + Aggregate + Fly Ash + SS_2

No. of Blows: 75 on each side

Duration of specimen kept in mould: 24 hours

Pavement Layer: Stabilized WMM - RAP

Duration of Conditioning at 40ºC: 72 hours

Table – 5.12

Trial No.		Emulsion Content by weigh of mix. (%)	Wt. of dry spec. in Air (A) – (gm)	SSD Wt. spec. in (B) – (gm)	Wt. of spec.in water (C) – (gm)	Bulk Volume – (cm^3)	Bulk Specific Gravity –(G_{mb})	Density – (g/cm^3) {G_{mb} X 0.997}	Water Content - % by mass	Test Temp. in - ºC	Moisture in Blend - %	Fluid Content - %	Marshall Stability				Flow in – (mm)
													Age of Specimen – Hours	Load – (KN)	Correction Factor – (KN)	Corrected Load – (KN)	
T1	WET SUBSET	3.5	1211.1	1215.7	680.0	535.7	2.261	2.254	3.5	25	0.65	7.65	96	8.20	0.93	7.63	4.53
T2			1208.0	1220.9	673.5	547.4	2.207	2.200					96	8.73	0.89	7.77	4.22
T3			1212.2	1218.6	673.5	545.1	2.224	2.217					96	8.82	0.93	8.20	4.89
T4	DRY SUBSET	3.5	1212.7	1227.5	674.5	553.0	2.193	2.186	3.5	25	0.65	7.65	96	13.62	0.89	12.12	4.02
T5			1213.0	1227.3	678.0	549.3	2.208	2.201					96	12.57	0.89	11.19	4.1
T6			1212.7	1226.2	679.5	546.7	2.218	2.212					96	13.47	0.89	11.99	3.85

Summary of Test Result - Marshall Stability Test at 25ºc

Combination: RAP + Aggregate + Fibre + Old Engine Oil

No. of Blows: 75 on each side

Duration of specimen kept in mould: 24 hours

Pavement Layer: Stabilized WMM - RAP

Duration of Conditioning at 40ºC: 72 hours

Table – 5.13

Trial No.		Emulsion Content by weigh of mix. (%)	Wt. of dry spec. in Air (A) – (gm)	SSD Wt. spec. in (B) – (gm)	Wt. of spec.in water (C) – (gm)	Bulk Volume – (cm^3)	Bulk Specific Gravity –(G_{mb})	Density – (g/cm^3) {G_{mb} X 0.997}	Water Content - % by mass	Test Temp. in - ºC	Moisture in Blend - %	Fluid Content - %	Marshall Stability				Flow in – (mm)
													Age of Specimen - Hours	Load – (KN)	Correction Factor – (KN)	Corrected Load – (KN)	
T1	WET SUBSET	3.5	1230.6	1242.6	675.0	567.0	2.170	2.164	3.5	25	0.65	7.65	96	5.92	0.86	5.09	2.95
T2			1226.9	1236.5	672.4	564.1	2.175	2.168					96	6.43	0.86	5.53	2.75
T3			1228.5	1235.2	672.1	563.1	2.181	2.174					96	6.24	0.86	5.37	2.88
T4	DRY SUBSET	3.5	1229.3	1240.5	673.8	566.7	2.169	2.162	3.5	25	0.65	7.65	96	11.40	0.86	9.80	2.28
T5			1220.2	1232.5	670.6	561.9	2.172	2.165					96	12.02	0.86	10.34	2.04
T6			1229.3	1237.5	673.5	564.0	2.180	2.173					96	11.15	0.86	9.60	2.18

Summary of Test Result - Marshall Stability Test at 25ºc

Combination: RAP + Aggregate + Cement + Old Engine Oil

No. of Blows: 75 on each side

Duration of specimen kept in mould: 24 hours

Pavement Layer: Stabilized WMM - RAP

Duration of Conditioning at 40ºC: 72 hours

Table – 5.14

Trial No.		Emulsion Content by weigh of mix. (%)	Wt. of dry spec. in Air (A) – (gm)	SSD Wt. spec. in (B) – (gm)	Wt. of spec.in water (C) – (gm)	Bulk Volume – (cm^3)	Bulk Specific Gravity –(G_{mb})	Density – (g/cm^3) {G_{mb} X 0.997}	Water Content - % by mass	Test Temp. in - ºC	Moisture in Blend - %	Fluid Content - %	Marshall Stability				Flow in – (mm)
													Age of Specimen - Hours	Load – (KN)	Correction Factor – (KN)	Corrected Load – (KN)	
T1	WET SUBSET	3.5	1245.6	1280.5	711.5	569.0	2.189	2.182	3.5	25	0.65	7.65	96	5.04	0.86	4.33	3.05
T2			1243.2	1285.3	712.4	572.9	2.170	2.163					96	5.54	0.86	4.76	2.98
T3			1244.2	1288.5	714.0	574.5	2.166	2.160					96	4.98	0.83	4.13	3.15
T4	DRY SUBSET	3.5	1238.8	1279.0	711.2	567.8	2.182	2.175	3.5	25	0.65	7.65	96	10.78	0.86	9.27	2.95
T5			1240.3	1282.8	709.5	573.3	2.163	2.157					96	9.80	0.83	8.13	2.75
T6			1242.6	1288.4	718.5	569.9	2.180	2.174					96	9.95	0.86	8.88	2.89

Summary of Test Result - Marshall Stability Test at 25ºc

Combination: RAP + Aggregate + Lime + Old Engine Oil

No. of Blows: 75 on each side

Duration of specimen kept in mould: 24 hours

Pavement Layer: Stabilized WMM - RAP

Duration of Conditioning at 40ºC: 72 hours

Table – 5.15

Trial No.		Emulsion Content by weigh of mix. (%)	Wt. of dry spec. in Air (A) – (gm)	SSD Wt. spec. in (B) – (gm)	Wt. of spec.in water (C) – (gm)	Bulk Volume – (cm^3)	Bulk Specific Gravity –(G_{mb})	Density – (g/cm^3) {G_{mb} X 0.997}	Water Content - % by mass	Test Temp. in - ºC	Moisture in Blend - %	Fluid Content - %	Marshall Stability				Flow in – (mm)
													Age of Specimen - Hours	Load – (KN)	Correction Factor – (KN)	Corrected Load – (KN)	
T1	WET SUBSET	3.5	1221.4	1227.6	680.7	546.9	2.233	2.226	3.5	25	0.65	7.65	96	3.98	0.89	3.54	3.58
T2			1233.7	1240.8	684.1	556.7	2.216	2.209					96	4.24	0.89	3.77	3.45
T3			1233.3	1238.5	681.6	556.9	2.215	2.208					96	3.62	0.89	3.22	3.77
T4	DRY SUBSET	3.5	1228.6	1235.8	681.2	554.6	2.215	2.208	3.5	25	0.65	7.65	96	9.44	0.89	8.40	3.07
T5			1227.6	1238.1	682.2	555.9	2.208	2.201					96	8.56	0.89	7.62	3.12
T6			1234.5	1240.2	683.3	556.9	2.217	2.210					96	8.29	0.89	7.38	3.15

Summary of Test Result - Marshall Stability Test at 25ºc

Combination: RAP + Aggregate + Fly Ash + Old Engine Oil

No. of Blows: 75 on each side
Pavement Layer: Stabilized WMM - RAP

Duration of specimen kept in mould: 24 hours
Duration of Conditioning at 40ºC: 72 hours

Table – 5.16

Trial No.		Emulsion Content by weigh of mix. (%)	Wt. of dry spec. in Air (A) – (gm)	SSD Wt. spec. in (B) – (gm)	Wt. of spec.in water (C) – (gm)	Bulk Volume – (cm^3)	Bulk Specific Gravity –(G_{mb})	Density – (g/cm^3) {G_{mb} X 0.997}	Water Content - % by mass	Test Temp. in - ºC	Moisture in Blend - %	Fluid Content - %	Marshall Stability				Flow in – (mm)
													Age of Specimen - Hours	Load – (KN)	Correction Factor – (KN)	Corrected Load – (KN)	
T1	WET SUBSET	3.5	1238.4	1242.3	675.5	566.8	2.185	2.178	3.5	25	0.65	7.65	96	2.44	0.86	2.10	4.75
T2			1238.1	1244.8	673.4	571.4	2.167	2.160					96	2.80	0.86	2.41	4.52
T3			1238.0	1243.5	673.9	569.6	2.173	2.167					96	2.53	0.86	2.18	4.68
T4	DRY SUBSET	3.5	1231.1	1236.7	681.3	555.4	2.217	2.210	3.5	25	0.65	7.65	96	6.89	0.89	6.13	4.23
T5			1229.3	1234.9	678.9	556.0	2.211	2.204					96	7.04	0.89	6.27	4.12
T6			1236.6	1241.2	679.9	561.3	2.203	2.196					96	6.57	0.86	5.65	4.35

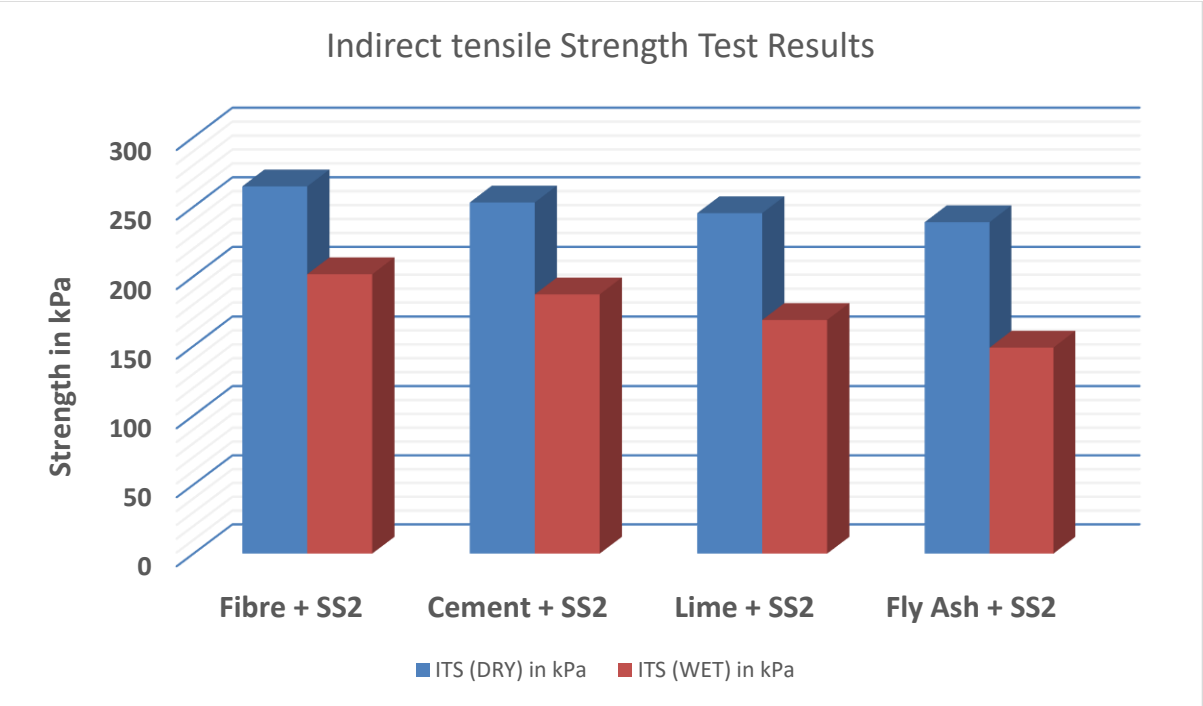
AVERAGE VALUES

Combinations	ITS (dry)	ITS (wet)	Marshall (Dry)	Marshall (Wet)	Flow values (dry)	Flow Values (wet)
Fibre + SS2	264.67	201.53	16.94	10.20	2.56	2.93
Cement + SS2	253.10	187.03	15.55	9.99	2.86	3.30
Lime + SS2	245.39	168.68	14.44	8.36	2.99	3.76
Fly Ash + SS2	238.92	148.78	11.77	7.86	3.99	4.55
Fibre + engine oil	235.37	126.03	9.91	5.33	2.17	2.86
Cement + Engine Oil	227.25	104.96	8.76	4.41	2.86	3.06
Lime + Engine Oil	185.19	82.45	7.80	3.51	3.11	3.60
Fly Ash + Engine oil	154.56	70.37	6.02	2.23	4.23	4.65

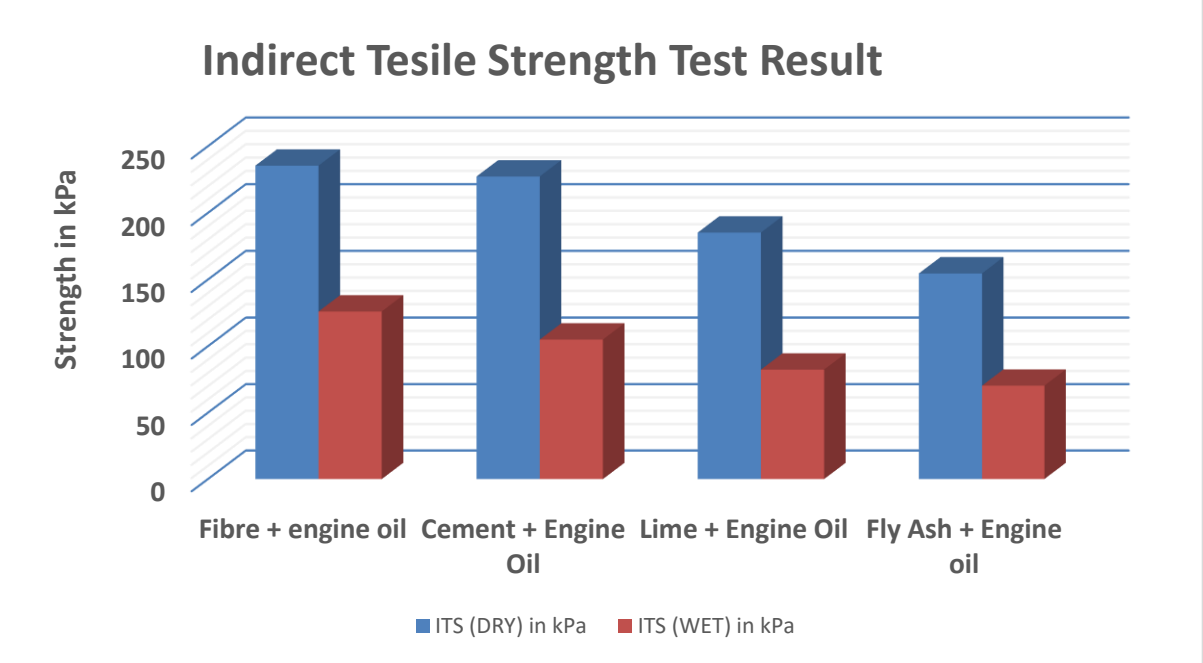
Table – 5.17

GRAPHS

Comparing I.T.S. (dry – condition) and I.T.S. (wet – condition) values for each combinations :

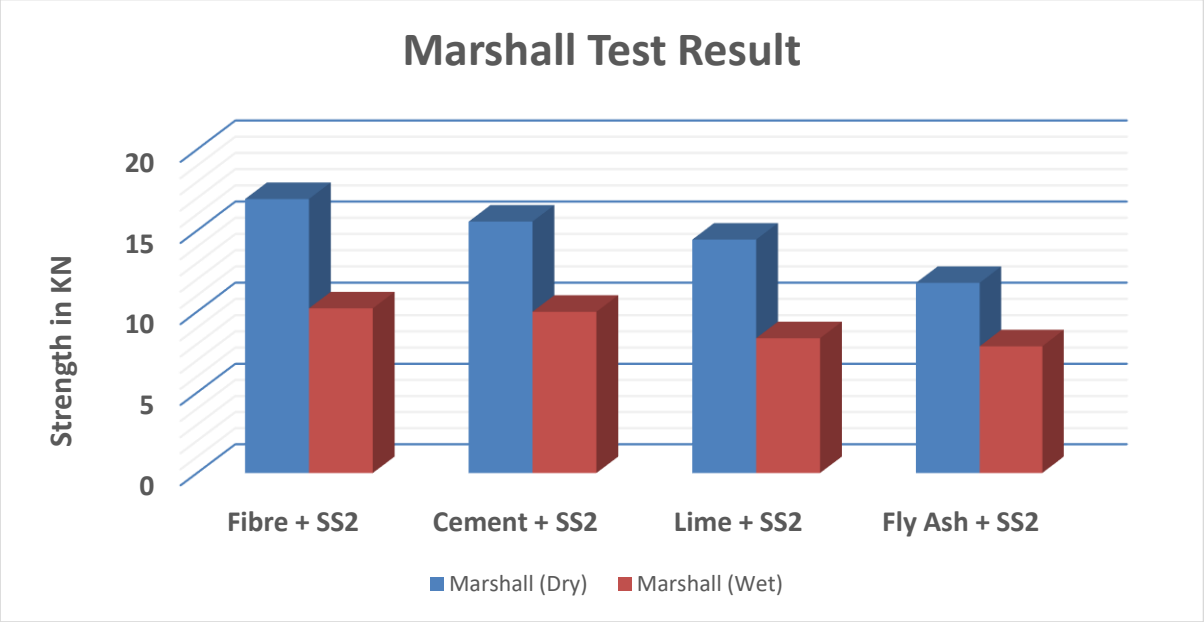


Graph-1. Variations with emulsion SS_2 (I.T.S.)

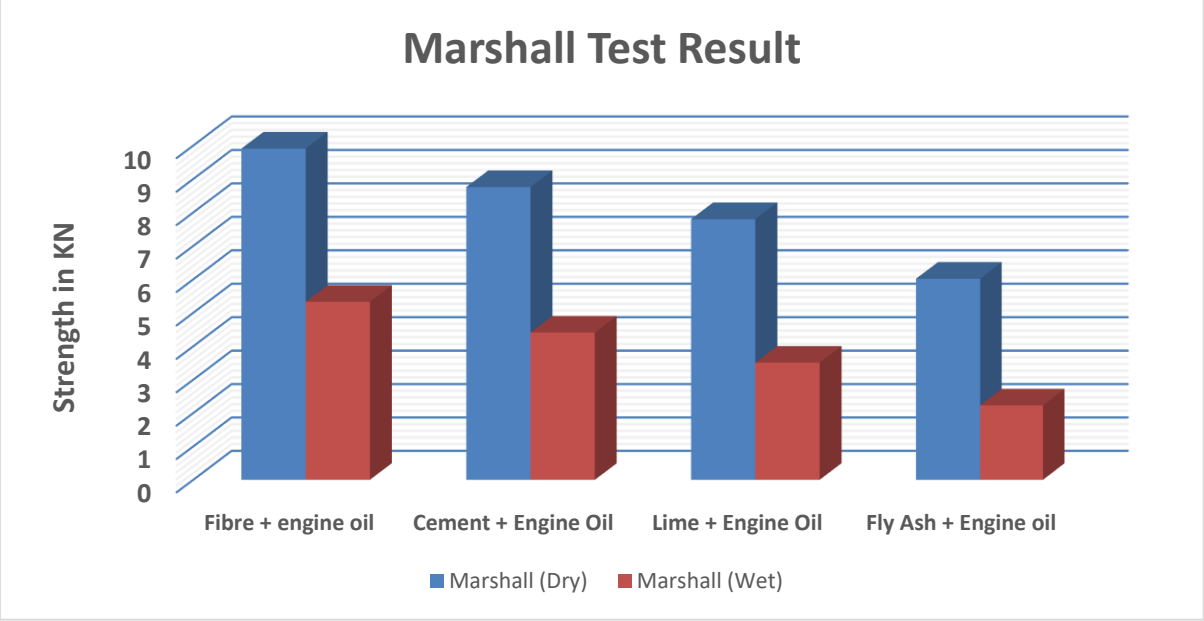


Graph-2. Variations with Old Engine Oil (I.T.S.)

Comparing Marshall (dry – condition) and Marshall (wet – condition) values for each combinations :

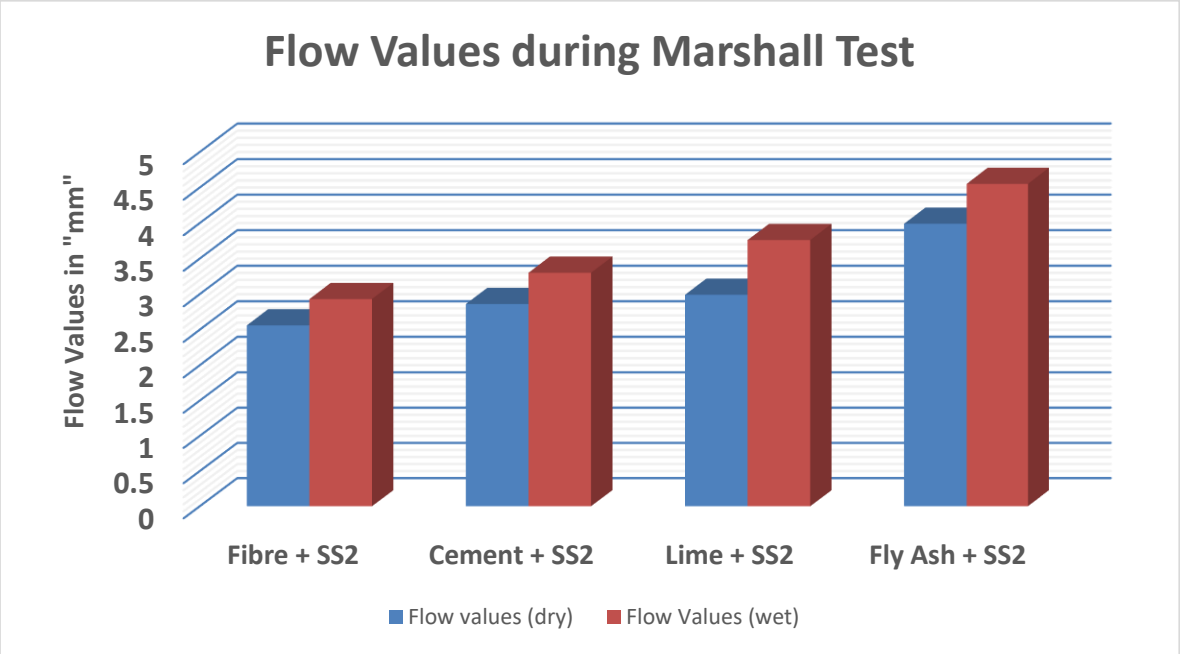


Graph-3. Variations with SS_s (Marshall)

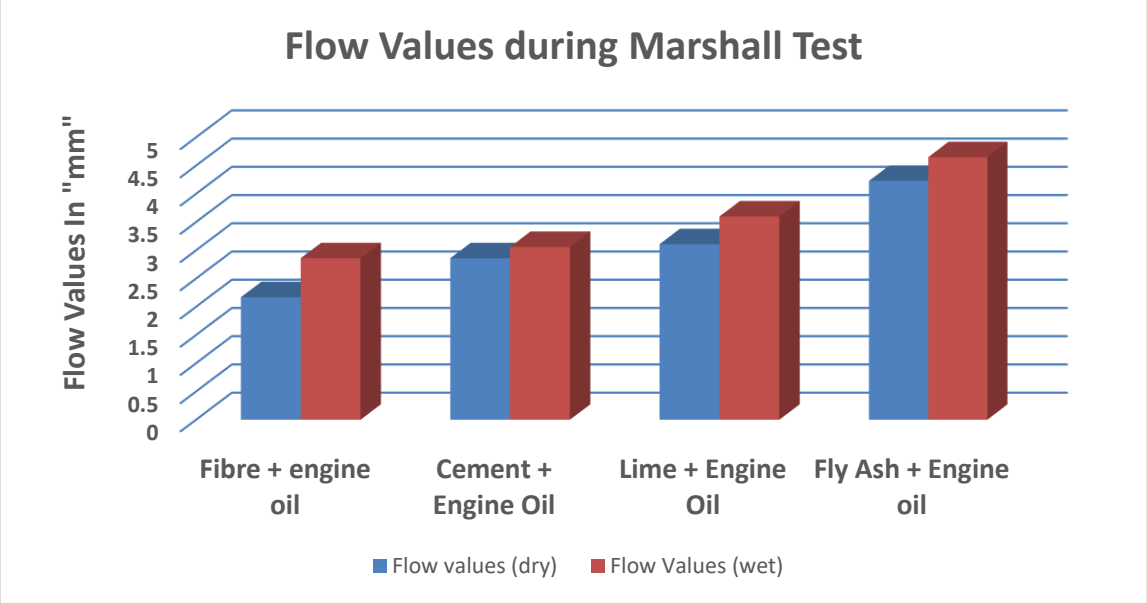


Graph-4. Variations with Old Engine Oil (Marshall)

Comparing Flow Values(dry – condition) and Flow Values (wet – condition) for each combinations :



Graph-5. Variations with SS_2 (Flow Value)



Graph-6. Variations with Old Engine Oil (Flow Value)

CHAPTER 6
SUMMARY AND CONCLUSION

Today great importance is given to sustainable construction and infrastructure as the demand for sustainable and environmental friendly roads is increasing. More green technologies for sustainable road construction are needed. So one way to construct environmental friendly roads is through the use of RAP materials as a large quantity of RAP materials remains unused. Recent researches have shown that the waste problems can be reduced by using RAP as base and subbase aggregate materials.

Historically, RAP has been used with new bituminous materials by either a hot-mix or cold-mix recycling process. But in this study we used the Cold – mix recycling process. Also using RAP as a base course material would preserve non-renewable aggregate as well as reduce the amount of space needed to store millions of tons of RAP created each year.

Literature indicates that 100 percent RAP could not produce base course of high quality pavements. As several researchers have suggested that high-quality base courses could be obtained by blending RAP with fresh (or virgin) aggregates and stabilizing RAP with chemical additives such as cement. So in this study we completely replaced cement with hydrated lime, fly-ash and recron 3s fibre respectively as chemical additives to obtain their strength. Which gave the following conclusions :

- Recron 3s Fibre showed maximum strength in combination with SS_2 as well as old engine oil.
- Variations with Cement gave lesser strength than fibre combinations but more than lime and fly ash combinations.
- Fly ash showed poor strength , i.e. , Fly ash combinations gained least strength.
- As Recron 3s fibre is a great construction material (as per previous study) , it should be used more frequently.
- Usage of Recron 3s fibre reduces cost of project as it may reduce the cost of maintenance work by reducing cracks and permeability and hence durability increases.

- Fibre can also be used for National Highway projects and expressways , though the initial project cost may be more as it's an expensive alternative but maintenance cost may be less as well it will be more durable.
- Fly – ash with SS_2 shows less strength but fairly above the minimum parameters , so it can be used for less important road projects as the cost of fly ash is minimal or no cost and only transportation cost will be applied. Therefore fly ash can be the cheapest alternative.
- Lime can also be used as alternative to cement as it shows fair amount of strength but it is an expensive alternative.
- Old or used engine oil can be used as construction material in place of regular emulsions as it shows some binding properties with recron 3s fibre. But engine oil should be used in the WMM layer only if we are using 125 µm polythene sheet beneath the WMM layer.

So as per above conclusions we can assume that the thickness of the WMM layer can be decreased by using fibre with emulsion SS_2 as it shows strength more than cement , which will reduce the construction cost of a road project. Old engine oil can also be replaced with SS_s as a binding material at least for rural roads or roads with less importance. As old or used engine oil is almost free so it will save the cost of purchasing expensive emulsions.

SCOPE OF FUTURE INVESTIGATION

Based on the present study it can be said that there is much more to explore about RAP.

- One can do a cost analysis of RAP with using the same binders and chemical stabilizers used in this study. As the there is a wide range of alternatives and the cost of these alternatives vary widely.
- One can analyse the life cycle cost of the project.
- Design of crust using RAP with these materials can be done.
- One can find out the M_R values of these combinations of RAP , which will help them to get the durability of each combination.

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APPENDIX

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate: Fibre	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#7	#8	#9
1.	Specimen Diameter	d	mm	101.50	101.52	101.64
2.	Specimen Height	h	mm	71.23	69.90	70.95
3.	Weight of Specimen in Air	A	g	1246.7	1246.9	1245.8
4.	Weight of Specimen in Water	C	g	719.0	719.0	718.0
5.	SSD Weight of Specimen	B	g	1272.1	1272.7	1271.0
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.254	2.252	2.253
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.247	2.245	2.246
8.	Volume of Specimen	B-C	cm^3	553.1	553.7	553.0
9.	Maximum Load Achieved	k	KN	2.93	2.98	3.04
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	258.01	267.50	268.50
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.253		
12.	Average Density	G_{mb} x 0.997	g/cm^3	2.246		
	Reported Indirect Tensile Strength-ITS: 264.67 kPa					

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate: Fibre	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#10	#11	#12
1.	Specimen Diameter	d	mm	101.30	101.64	100.28
2.	Specimen Height	h	mm	70.24	68.92	68.75
3.	Weight of Specimen in Air	A	g	1243.3	1244.6	1244.5
4.	Weight of Specimen in Water	C	g	715.0	717.0	717.0
5.	SSD Weight of Specimen	B	g	1266.4	1270.2	1270.6
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.255	2.437	2.248
7.	Density of Specimen	$G_{mb} \times 0.997$	g/cm^3	2.248	2.430	2.241
8.	Volume of Specimen	B-C	cm^3	551.4	553.2	553.6
9.	Maximum Load Achieved	k	KN	2.22	2.24	2.21
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	198.7	203.7	202.2
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.313		
12.	Average Density	$G_{mb} \times 0.997$	g/cm^3	2.306		
	Reported Indirect Tensile Strength-ITS: 201.53 kPa					

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Cement	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#7	#8	#9
1.	Specimen Diameter	d	mm	101.35	103.65	102.10
2.	Specimen Height	h	mm	71.86	68.66	70.16
3.	Weight of Specimen in Air	A	g	1224.2	1223.9	1222.3
4.	Weight of Specimen in Water	C	g	681.0	676.5	676.5
5.	SSD Weight of Specimen	B	g	1234.7	1235.9	1230.9
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.210	2.188	2.205
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.204	2.181	2.198
8.	Volume of Specimen	B-C	cm^3	553.7	559.4	554.4
9.	Maximum Load Achieved	k	KN	2.93	2.80	2.84
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	256.88	250.20	252.23
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.201		
12.	Average Density	G_{mb} x 0.997	g/cm^3	2.194		
	Reported Indirect Tensile Strength-ITS: 253.10 kPa					

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Cement	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#10	#11	#12
1.	Specimen Diameter	d	mm	101.42	101.39	101.39
2.	Specimen Height	h	mm	69.42	69.53	70.01
3.	Weight of Specimen in Air	A	g	1224.6	1226.5	1221.2
4.	Weight of Specimen in Water	C	g	682.0	684.5	677.5
5.	SSD Weight of Specimen	B	g	1233.9	1233.6	1228.2
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.226	2.241	2.225
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.214	2.234	2.218
8.	Volume of Specimen	B-C	cm^3	551.9	549.1	550.7
9.	Maximum Load Achieved	k	KN	2.02	2.10	2.09
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	182.63	190.22	188.24
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.231		
12.	Average Density	G_{mb} x 0.997	g/cm^3	2.224		
	Reported Indirect Tensile Strength-ITS: 187.03 kPa					

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Lime	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#7	#8	#9
1.	Specimen Diameter	d	mm	101.57	101.03	101.45
2.	Specimen Height	h	mm	68.95	70.60	69.71
3.	Weight of Specimen in Air	A	g	1222.6	1223.6	1224.7
4.	Weight of Specimen in Water	C	g	680.0	682.0	683.0
5.	SSD Weight of Specimen	B	g	1226.3	1230.0	1228.0
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.238	2.233	2.47
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.231	2.226	2.240
8.	Volume of Specimen	B-C	cm^3	546.3	548.0	545.0
9.	Maximum Load Achieved	k	KN	2.67	2.78	2.72
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	242.47	248.52	245.17
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.239		
12.	Average Density	G_{mb} x 0.997	g/cm^3	2.232		
	Reported Indirect Tensile Strength-ITS: 2.72 kPa					

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Lime	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#10	#11	#12
1.	Specimen Diameter	d	mm	101.63	101.64	101.23
2.	Specimen Height	h	mm	68.73	68.53	69.10
3.	Weight of Specimen in Air	A	g	1226.6	1224.5	1221.9
4.	Weight of Specimen in Water	C	g	686.0	684.0	685.0
5.	SSD Weight of Specimen	B	g	1230.6	1229.1	1225.5
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.252	2.244	2.261
7.	Density of Specimen	$G_{mb} \times 0.997$	g/cm^3	2.246	2.237	2.254
8.	Volume of Specimen	B-C	cm^3	544.6	545.7	540.5
9.	Maximum Load Achieved	k	KN	1.89	1.81	1.84
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	172.31	165.69	167.87
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.52		
12.	Average Density	$G_{mb} \times 0.997$	g/cm^3	2.46		
	Reported Indirect Tensile Strength-ITS: 1.85 kPa					

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Fly Ash	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#7	#8	#9
1.	Specimen Diameter	d	mm	101.40	101.97	101.61
2.	Specimen Height	h	mm	68.30	68.10	68.67
3.	Weight of Specimen in Air	A	g	1221.3	1222.7	1222.9
4.	Weight of Specimen in Water	C	g	687.0	686.5	685.0
5.	SSD Weight of Specimen	B	g	1226.7	1222.6	1228.5
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.263	2.266	2.250
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.256	2.259	2.243
8.	Volume of Specimen	B-C	cm^3	539.7	539.7	543.5
9.	Maximum Load Achieved	k	KN	2.60	2.61	2.59
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	239.64	240.33	236.78
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.260		
12.	Average Density	G_{mb} x 0.997	g/cm^3	2.253		
	Reported Indirect Tensile Strength-ITS: 2.60 kPa					

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Fly Ash	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#10	#11	#12
1.	Specimen Diameter	d	mm	101.93	101.50	101.70
2.	Specimen Height	h	mm	68.36	68.38	70.45
3.	Weight of Specimen in Air	A	g	1219.4	1218.0	1220.3
4.	Weight of Specimen in Water	C	g	686.5	684.0	683.0
5.	SSD Weight of Specimen	B	g	1225.4	1222.7	1225.4
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.263	2.261	2.250
7.	Density of Specimen	$G_{mb} \times 0.997$	g/cm^3	2.256	2.254	2.243
8.	Volume of Specimen	B-C	cm^3	538.9	538.7	542.4
9.	Maximum Load Achieved	k	KN	1.63	1.60	1.70
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	148.80	146.54	150.99
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.258		
12.	Average Density	$G_{mb} \times 0.997$	g/cm^3	2.251		
	Reported Indirect Tensile Strength-ITS: 148.78 kPa					

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Fibre	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#7	#8	#9
1.	Specimen Diameter	d	mm	101.25	102.65	102.22
2.	Specimen Height	h	mm	70.88	68.98	70.18
3.	Weight of Specimen in Air	A	g	1220.5	1211.5	1226.7
4.	Weight of Specimen in Water	C	g	675.2	672.5	676.5
5.	SSD Weight of Specimen	B	g	1230.7	1225.9	1232.5
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.200	2.189	2.206
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.193	2.183	2.200
8.	Volume of Specimen	B-C	cm^3	555.5	553.4	556.0
9.	Maximum Load Achieved	k	KN	1.93	1.95	2.04
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	235.85	232.98	237.28
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.198		
12.	Average Density	G_{mb} x 0.997	g/cm^3	2.192		
	Reported Indirect Tensile Strength-ITS: 235.37 kPa					

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min	50.8	RAP:Coarse Aggregate:Fibre	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#10	#11	#12
1.	Specimen Diameter	d	mm	101.78	101.65	101.77
2.	Specimen Height	h	mm	69.55	68.84	69.69
3.	Weight of Specimen in Air	A	g	1233.1	1227.5	1210.8
4.	Weight of Specimen in Water	C	g	681.3	678.0	672.0
5.	SSD Weight of Specimen	B	g	1240.8	1233.8	1219.4
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.204	2.209	2.212
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.197	2.202	2.205
8.	Volume of Specimen	B-C	cm^3	559.5	555.8	547.4
9.	Maximum Load Achieved	k	KN	1.44	1.49	1.48
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	129.52	122.88	125.69
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.208		
12.	Average Density	G_{mb} x 0.997	g/cm^3	2.201		
	Reported Indirect Tensile Strength-ITS: 126.03 kPa					

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Cement	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#7	#8	#9
1.	Specimen Diameter	d	mm	101.45	101.49	101.61
2.	Specimen Height	h	mm	70.28	69.30	69.78
3.	Weight of Specimen in Air	A	g	1243.5	1245.8	1244.5
4.	Weight of Specimen in Water	C	g	718.5	715.2	718.9
5.	SSD Weight of Specimen	B	g	1270.5	1271.3	1270.9
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.253	2.240	2.255
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.246	2.234	2.248
8.	Volume of Specimen	B-C	cm^3	552.0	556.1	552.0
9.	Maximum Load Achieved	k	KN	2.01	2.05	2.00
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	226.84	229.34	225.58
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.250		
12.	Average Density	G_{mb} x 0.997	g/cm^3	2.243		
	Reported Indirect Tensile Strength-ITS: 227.25 kPa					

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min	50.8	RAP:Coarse Aggregate:Cement	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#10	#11	#12
1.	Specimen Diameter	d	mm	101.77	101.69	101.35
2.	Specimen Height	h	mm	69.55	68.71	68.89
3.	Weight of Specimen in Air	A	g	1244.3	1241.8	1245.3
4.	Weight of Specimen in Water	C	g	715.5	716.4	716.0
5.	SSD Weight of Specimen	B	g	1268.9	1271.2	1270.5
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.248	2.238	2.246
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.242	2.232	2.239
8.	Volume of Specimen	B-C	cm^3	553.4	554.8	554.5
9.	Maximum Load Achieved	k	KN	1.58	1.60	1.60
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	105.36	101.88	107.65
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.244		
12.	Average Density	G_{mb} x 0.997	g/cm^3	2.238		
	Reported Indirect Tensile Strength-ITS: 104.96 kPa					

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Lime	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#7	#8	#9
1.	Specimen Diameter	d	mm	101.47	101.09	101.44
2.	Specimen Height	h	mm	68.88	70.01	69.88
3.	Weight of Specimen in Air	A	g	1224.7	1224.2	1222.6
4.	Weight of Specimen in Water	C	g	683.5	682.2	681.9
5.	SSD Weight of Specimen	B	g	1229.2	1232.8	1230.5
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.244	2.223	2.229
7.	Density of Specimen	$G_{mb} \times 0.997$	g/cm^3	2.238	2.216	2.222
8.	Volume of Specimen	B-C	cm^3	545.7	550.8	548.6
9.	Maximum Load Achieved	k	KN	1.77	1.88	1.72
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	181.50	188.82	185.24
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.232		
12.	Average Density	$G_{mb} \times 0.997$	g/cm^3	2.225		
	Reported Indirect Tensile Strength-ITS: 185.19 kPa					

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min	50.8	RAP:Coarse Aggregate:Lime	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#10	#11	#12
1.	Specimen Diameter	d	mm	101.57	101.63	101.70
2.	Specimen Height	h	mm	68.45	68.99	69.12
3.	Weight of Specimen in Air	A	g	1236.5	1222.8	1229.6
4.	Weight of Specimen in Water	C	g	686.1	682.0	685.1
5.	SSD Weight of Specimen	B	g	1241.8	1228.1	1235.6
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.225	2.239	2.234
7.	Density of Specimen	$G_{mb} \times 0.997$	g/cm^3	2.218	2.232	2.227
8.	Volume of Specimen	B-C	cm^3	555.7	546.1	550.5
9.	Maximum Load Achieved	k	KN	1.31	1.28	1.30
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	82.93	79.88	84.54
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.233		
12.	Average Density	$G_{mb} \times 0.997$	g/cm^3	2.226		
	Reported Indirect Tensile Strength-ITS: 82.45 kPa					

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Fly Ash	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#7	#8	#9
1.	Specimen Diameter	d	mm	101.43	101.90	101.65
2.	Specimen Height	h	mm	68.92	68.45	67.95
3.	Weight of Specimen in Air	A	g	1228.1	1230.5	1224.0
4.	Weight of Specimen in Water	C	g	687.5	686.0	686.8
5.	SSD Weight of Specimen	B	g	1232.4	1233.5	1228.8
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.254	2.247	2.258
7.	Density of Specimen	$G_{mb} \times 0.997$	g/cm^3	2.247	2.240	2.252
8.	Volume of Specimen	B-C	cm^3	544.9	547.5	542.0
9.	Maximum Load Achieved	k	KN	1.50	1.44	1.40
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	154.87	151.54	157.28
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.253		
12.	Average Density	$G_{mb} \times 0.997$	g/cm^3	2.246		
	Reported Indirect Tensile Strength-ITS: 154.56 kPa					

TEST DATA SHEET

Determination of Indirect Tensile Strength -ITS of RAP Mixture
IRC: 37-2012, Annex IX & ASTM D 6931-15

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	O1
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min	50.8	RAP:Coarse Aggregate:Fly Ash	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#10	#11	#12
1.	Specimen Diameter	d	mm	101.88	101.45	101.12
2.	Specimen Height	h	mm	67.54	68.45	69.65
3.	Weight of Specimen in Air	A	g	1228.9	1234.2	1231.7
4.	Weight of Specimen in Water	C	g	686.5	688.0	687.4
5.	SSD Weight of Specimen	B	g	1232.2	1238.8	1235.0
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.252	2.241	2.249
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.245	2.234	2.242
8.	Volume of Specimen	B-C	cm^3	545.7	550.8	547.6
9.	Maximum Load Achieved	k	KN	1.18	1.22	1.21
10.	Indirect Tensile Strength	$S=2000P/\pi hd$	kPa	68.34	72.24	70.49
11.	Average Bulk Sp. Gravity	G_{mb}	---	2.238		
12.	Average Density	G_{mb} x 0.997	g/cm^3	2.231		
	Reported Indirect Tensile Strength-ITS: 70.36 kPa					

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate: Fibre	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#1	#2	#3
1.	Specimen Diameter	d	mm	101.23	101.45	100.90
2.	Specimen Height	h	mm	70.10	68.90	70.29
3.	Weight of Specimen in Air	A	g	1246.3	1245.80	1247.1
4.	Weight of Specimen in Water	C	g	716.0	717.0	718.0
5.	SSD Weight of Specimen	B	g	1299.7	1300.0	1301.3
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.135	2.137	2.138
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.129	2.131	2.132
8.	Volume of Specimen	B-C	cm^3	583.7	583.0	583.3
9.	Stability Correction Factor	k	---	0.83	0.83	0.83
10.	Marshall Stability (Measured)	MS	kN	12.70	11.95	12.51
11.	Marshall Stability (Corrected)	MS.k	kN	10.29	9.92	10.38
12.	Flow Value	F	mm	3.08	2.84	2.86
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.137		
14.	Average Density	G_{mb} x 0.997	g/cm^3	2.130		
	Reported Flow Value:	**2.93**	mm			
	Reported Marshall Stability:	**10.20**	kN			

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate: Fibre	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#4	#5	#6
1.	Specimen Diameter	d	mm	101.89	100.72	10.1.54
2.	Specimen Height	h	mm	69.88	70.21	68.33
3.	Weight of Specimen in Air	A	g	1249.8	1250.4	1251.2
4.	Weight of Specimen in Water	C	g	720.0	722.0	724.0
5.	SSD Weight of Specimen	B	g	1304.8	1307.1	1310.0
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.137	2.136	2.135
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.131	2.130	2.129
8.	Volume of Specimen	B-C	cm^3	584.8	584.4	586.0
9.	Stability Correction Factor	k	---	0.83	0.81	0.81
10.	Marshall Stability (Measured)	MS	kN	20.67	20.88	20.68
11.	Marshall Stability (Corrected)	MS.k	kN	17.16	16.91	16.75
12.	Flow Value	F	mm	2.92	2.35	2.40
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.136		
14.	Average Density	G_{mb} x 0.997	g/cm^3	2.130		
	Reported Flow Value:	**2.56**	mm			
	Reported Marshall Stability:	**16.94**	kN			

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Cement	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#1	#2	#3
1.	Specimen Diameter	d	mm	102.10	101.87	101.28
2.	Specimen Height	h	mm	69.08	69.54	70.22
3.	Weight of Specimen in Air	A	g	1213.0	1209.8	1208.0
4.	Weight of Specimen in Water	C	g	667.0	667.0	674.5
5.	SSD Weight of Specimen	B	g	1223.2	1217.8	1223.3
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.181	2.196	2.201
7.	Density of Specimen	$G_{mb} \times 0.997$	g/cm^3	2.147	2.190	2.195
8.	Volume of Specimen	B-C	cm^3	556.2	550.8	548.8
9.	Stability Correction Factor	k	---	0.89	0.89	0.89
10.	Marshall Stability (Measured)	MS	kN	11.29	11.18	11.21
11.	Marshall Stability (Corrected)	MS.k	kN	10.05	9.95	9.98
12.	Flow Value	F	mm	3.50	3.22	3.17
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.193		
14.	Average Density	$G_{mb} \times 0.997$	g/cm^3	2.186		
	Reported Flow Value:	**3.30**	mm			
	Reported Marshall Stability:	**9.99**	kN			

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Cement	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#4	#5	#6
1.	Specimen Diameter	d	mm	101.84	101.29	102.20
2.	Specimen Height	h	mm	70.66	71.20	70.15
3.	Weight of Specimen in Air	A	g	1214.8	1213.9	1211.3
4.	Weight of Specimen in Water	C	g	671.5	669.5	668.5
5.	SSD Weight of Specimen	B	g	1220.7	1219.5	1223.9
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.212	2.207	2.181
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.205	2.200	2.174
8.	Volume of Specimen	B-C	cm^3	549.2	550.0	555.4
9.	Stability Correction Factor	k	---	0.89	0.89	0.89
10.	Marshall Stability (Measured)	MS	kN	17.47	16.73	18.20
11.	Marshall Stability (Corrected)	MS.k	kN	15.55	14.89	16.20
12.	Flow Value	F	mm	2.99	2.72	2.88
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.200		
14.	Average Density	G_{mb} x 0.997	g/cm^3	2.193		
	Reported Flow Value:	**2.86**	mm			
	Reported Marshall Stability:	**15.55**	kN			

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Lime	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#1	#2	#3
1.	Specimen Diameter	d	mm	101.34	101.55	101.92
2.	Specimen Height	h	mm	68.98	69.52	68.60
3.	Weight of Specimen in Air	A	g	1214.8	1212.6	1214.8
4.	Weight of Specimen in Water	C	g	678.5	672.0	672.0
5.	SSD Weight of Specimen	B	g	1222.3	1218.1	1218.4
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.234	2.220	2.223
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.227	2.214	2.217
8.	Volume of Specimen	B-C	cm^3	543.8	546.1	546.4
9.	Stability Correction Factor	k	---	0.93	0.93	0.93
10.	Marshall Stability (Measured)	MS	kN	9.19	9.05	8.73
11.	Marshall Stability (Corrected)	MS.k	kN	8.55	8.42	8.12
12.	Flow Value	F	mm	3.89	3.45	3.95
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.226		
14.	Average Density	G_{mb} x 0.997	g/cm^3	2.219		
	Reported Flow Value:	**3.76**	mm			
	Reported Marshall Stability:	**8.36**	kN			

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Lime	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#4	#5	#6
1.	Specimen Diameter	d	mm	100.98	101.15	101.57
2.	Specimen Height	h	mm	69.80	69.75	68.95
3.	Weight of Specimen in Air	A	g	1215.4	1214.5	1212.9
4.	Weight of Specimen in Water	C	g	674.5	672.0	673.0
5.	SSD Weight of Specimen	B	g	1222.3	1221.8	1217.6
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.223	2.239	2.247
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.216	2.232	2.240
8.	Volume of Specimen	B-C	cm^3	546.8	542.5	539.9
9.	Stability Correction Factor	k	---	0.89	0.93	0.93
10.	Marshall Stability (Measured)	MS	kN	16.25	16.01	15.01
11.	Marshall Stability (Corrected)	MS.k	kN	14.46	14.89	13.96
12.	Flow Value	F	mm	2.97	3.15	2.85
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.236		
14.	Average Density	G_{mb} x 0.997	g/cm^3	2.230		
	Reported Flow Value:	**2.99**	mm			
	Reported Marshall Stability:	**14.44**	kN			

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Fly Ash	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#1	#2	#3
1.	Specimen Diameter	d	mm	100.98	100.81	101.20
2.	Specimen Height	h	mm	70.98	71.28	71.14
3.	Weight of Specimen in Air	A	g	1211.1	1208.0	1212.2
4.	Weight of Specimen in Water	C	g	680.0	673.5	673.5
5.	SSD Weight of Specimen	B	g	1215.7	1220.9	1218.6
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.261	2.207	2.224
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.254	2.200	2.217
8.	Volume of Specimen	B-C	cm^3	535.7	547.4	545.1
9.	Stability Correction Factor	k	---	0.93	0.89	0.93
10.	Marshall Stability (Measured)	MS	kN	8.20	8.73	8.82
11.	Marshall Stability (Corrected)	MS.k	kN	7.63	7.77	8.20
12.	Flow Value	F	mm	4.53	4.22	4.89
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.231		
14.	Average Density	G_{mb} x 0.997	g/cm^3	2.224		
	Reported Flow Value:	**4.55**	mm			
	Reported Marshall Stability:	**7.87**	kN			

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	SS-2	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Fly Ash	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#4	#5	#6
1.	Specimen Diameter	d	mm	101.31	100.81	101.43
2.	Specimen Height	h	mm	70.69	71.83	71.19
3.	Weight of Specimen in Air	A	g	1212.7	1213.0	1212.7
4.	Weight of Specimen in Water	C	g	674.5	678.0	679.5
5.	SSD Weight of Specimen	B	g	1227.5	1227.3	1226.2
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.193	2.208	2.218
7.	Density of Specimen	$G_{mb} \times 0.997$	g/cm^3	2.186	2.201	2.212
8.	Volume of Specimen	B-C	cm^3	553.0	549.3	546.7
9.	Stability Correction Factor	k	---	0.89	0.89	0.89
10.	Marshall Stability (Measured)	MS	kN	13.62	12.57	13.47
11.	Marshall Stability (Corrected)	MS.k	kN	12.12	11.19	11.99
12.	Flow Value	F	mm	4.02	4.10	3.85
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.206		
14.	Average Density	$G_{mb} \times 0.997$	g/cm^3	2.200		
	Reported Flow Value:	**3.99**	mm			
	Reported Marshall Stability:	**11.77**	kN			

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Fibre	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#1	#2	#3
1.	Specimen Diameter	d	mm	101.45	101.73	101.28
2.	Specimen Height	h	mm	69.66	69.84	70.21
3.	Weight of Specimen in Air	A	g	1230.6	1226.9	1228.5
4.	Weight of Specimen in Water	C	g	675.0	672.4	672.1
5.	SSD Weight of Specimen	B	g	1242.6	1236.5	1235.2
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.170	2.175	2.181
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.164	2.168	2.174
8.	Volume of Specimen	B-C	cm^3	567.0	564.1	563.1
9.	Stability Correction Factor	k	---	0.86	0.86	0.86
10.	Marshall Stability (Measured)	MS	kN	5.92	6.43	6.24
11.	Marshall Stability (Corrected)	MS.k	kN	5.09	5.53	5.37
12.	Flow Value	F	mm	2.95	2.75	2.88
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.175		
14.	Average Density	G_{mb} x 0.997	g/cm^3	2.168		
	Reported Flow Value:	**2.86**	mm			
	Reported Marshall Stability:	**5.33**	kN			

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Fibre	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#4	#5	#6
1.	Specimen Diameter	d	mm	101.52	101.98	101.35
2.	Specimen Height	h	mm	69.15	69.73	69.69
3.	Weight of Specimen in Air	A	g	1229.3	1220.2	1229.3
4.	Weight of Specimen in Water	C	g	673.8	670.6	673.5
5.	SSD Weight of Specimen	B	g	1240.5	1232.5	1237.5
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.169	2.172	2.180
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.162	2.165	2.173
8.	Volume of Specimen	B-C	cm^3	566.7	561.9	564.0
9.	Stability Correction Factor	k	---	0.86	0.86	0.86
10.	Marshall Stability (Measured)	MS	kN	11.40	12.02	11.15
11.	Marshall Stability (Corrected)	MS.k	kN	5.09	5.53	5.37
12.	Flow Value	F	mm	2.28	2.04	2.18
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.175		
14.	Average Density	G_{mb} x 0.997	g/cm^3	2.167		
	Reported Flow Value:	**2.17**	mm			
	Reported Marshall Stability:	**9.91**	kN			

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Cement	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#1	#2	#3
1.	Specimen Diameter	d	mm	100.83	100.97	100.52
2.	Specimen Height	h	mm	70.62	70.87	70.50
3.	Weight of Specimen in Air	A	g	1245.6	1243.2	1244.2
4.	Weight of Specimen in Water	C	g	711.50	712.4	714.0
5.	SSD Weight of Specimen	B	g	1280.5	1285.3	1288.5
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.189	2.170	2.166
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.182	2.163	2.160
8.	Volume of Specimen	B-C	cm^3	569.0	572.9	574.5
9.	Stability Correction Factor	k	---	0.86	0.86	0.83
10.	Marshall Stability (Measured)	MS	kN	5.04	5.54	4.98
11.	Marshall Stability (Corrected)	MS.k	kN	4.33	4.76	4.13
12.	Flow Value	F	mm	3.05	2.98	3.15
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.175		
14.	Average Density	G_{mb} x 0.997	g/cm^3	2.168		
	Reported Flow Value:	**3.06**	mm			
	Reported Marshall Stability:	**4.41**	kN			

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Cement	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#4	#5	#6
1.	Specimen Diameter	d	mm	101.12	100.77	101.30
2.	Specimen Height	h	mm	70.11	70.84	70.37
3.	Weight of Specimen in Air	A	g	1238.8	1240.3	1242.6
4.	Weight of Specimen in Water	C	g	711.2	709.5	718.5
5.	SSD Weight of Specimen	B	g	1279.0	1282.8	1288.4
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.182	2.163	2.180
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.175	2.157	2.174
8.	Volume of Specimen	B-C	cm^3	567.8	573.3	569.9
9.	Stability Correction Factor	k	---	0.86	0.83	0.86
10.	Marshall Stability (Measured)	MS	kN	10.78	9.80	9.95
11.	Marshall Stability (Corrected)	MS.k	kN	9.27	8.13	8.88
12.	Flow Value	F	mm	2.95	2.74	2.89
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.175		
14.	Average Density	G_{mb} x 0.997	g/cm^3	2.168		
	Reported Flow Value:	**2.86**	mm			
	Reported Marshall Stability:	**8.76**	kN			

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Fly Ash	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#1	#2	#3
1.	Specimen Diameter	d	mm	101.29	102.12	101.88
2.	Specimen Height	h	mm	71.39	71.75	71.17
3.	Weight of Specimen in Air	A	g	1238.4	1238.1	1238.0
4.	Weight of Specimen in Water	C	g	675.5	673.4	673.9
5.	SSD Weight of Specimen	B	g	1242.3	1244.8	1243.6
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.185	2.167	2.173
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.178	2.160	2.167
8.	Volume of Specimen	B-C	cm^3	566.8	571.4	569.6
9.	Stability Correction Factor	k	---	0.86	0.86	0.86
10.	Marshall Stability (Measured)	MS	kN	2.44	2.80	2.53
11.	Marshall Stability (Corrected)	MS.k	kN	2.10	2.41	2.18
12.	Flow Value	F	mm	4.75	4.52	4.68
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.175		
14.	Average Density	G_{mb} x 0.997	g/cm^3	2.168		
	Reported Flow Value:	**4.65**	mm			
	Reported Marshall Stability:	**2.23**	kN			

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Fly Ash	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#4	#5	#6
1.	Specimen Diameter	d	mm	102.20	102.12	101.91
2.	Specimen Height	h	mm	71.66	71.35	71.08
3.	Weight of Specimen in Air	A	g	1231.1	1229.3	1236.6
4.	Weight of Specimen in Water	C	g	681.3	678.9	679.9
5.	SSD Weight of Specimen	B	g	1236.7	1234.9	1241.2
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.217	2.211	2.203
7.	Density of Specimen	$G_{mb} \times 0.997$	g/cm^3	2.210	2.204	2.196
8.	Volume of Specimen	B-C	cm^3	555.4	556.0	561.3
9.	Stability Correction Factor	k	---	0.89	0.89	0.86
10.	Marshall Stability (Measured)	MS	kN	6.89	7.04	6.57
11.	Marshall Stability (Corrected)	MS.k	kN	6.13	6.27	5.65
12.	Flow Value	F	mm	4.23	4.12	4.35
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.210		
14.	Average Density	$G_{mb} \times 0.997$	g/cm^3	2.204		
	Reported Flow Value:	**4.23**	mm			
	Reported Marshall Stability:	**6.02**	kN			

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	WET
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Lime	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#1	#2	#3
1.	Specimen Diameter	d	mm	101.51	101.20	101.95
2.	Specimen Height	h	mm	69.33	69.80	69.65
3.	Weight of Specimen in Air	A	g	1221.4	1233.7	1233.3
4.	Weight of Specimen in Water	C	g	680.7	684.1	681.6
5.	SSD Weight of Specimen	B	g	1227.6	1240.8	1238.5
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.233	2.216	2.215
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.226	2.209	2.208
8.	Volume of Specimen	B-C	cm^3	546.9	556.7	556.9
9.	Stability Correction Factor	k	---	0.89	0.89	0.89
10.	Marshall Stability (Measured)	MS	kN	3.98	4.24	3.62
11.	Marshall Stability (Corrected)	MS.k	kN	3.54	3.77	3.22
12.	Flow Value	F	mm	3.58	3.45	3.77
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.221		
14.	Average Density	G_{mb} x 0.997	g/cm^3	2.214		
	Reported Flow Value:	**3.60**	mm			
	Reported Marshall Stability:	**3.51**	kN			

TEST DATA SHEET

Resistance to Plastic Flow of RAP Mixtures Using Marshall Apparatus
IRC: 37-2012, Annex IX & ASTM D 6927-15, D-6926-16, D 2726-17 & 3549-17

Source of Aggregate	Project Site	Ambient Temperature-°C	22±2
Depth of RAP- mm	75	Relative Humidity -RH %	50±5
Grade of Cationic Emulsion	Old Engine Oil	Type of Specimen-WET/DRY	DRY
Quantity of Emulsion-%	3.5	Preconditioning Period-hours	01
Quantity of Water-%	3.5	Preconditioning Temperature-ºC	22.2±1.7
Loading Rate- mm/min.	50.8	RAP:Coarse Aggregate:Lime	89 : 10 : 01

OBSERVATION & RESULTS

Sl.	Characterstic Parameters	Symbol	Unit	Obsered Value		
				#4	#5	#6
1.	Specimen Diameter	d	mm	101.37	100.92	101.45
2.	Specimen Height	h	mm	69.73	70.50	69.89
3.	Weight of Specimen in Air	A	g	1228.6	1227.6	1234.5
4.	Weight of Specimen in Water	C	g	681.2	682.2	683.3
5.	SSD Weight of Specimen	B	g	1235.8	1238.1	1240.2
6.	Bulk Specific Gravity	$G_{mb}=\frac{A}{B-C}$	---	2.215	2.208	2.217
7.	Density of Specimen	G_{mb} x 0.997	g/cm^3	2.208	2.201	2.210
8.	Volume of Specimen	B-C	cm^3	554.6	555.9	556.9
9.	Stability Correction Factor	k	---	0.89	0.89	0.89
10.	Marshall Stability (Measured)	MS	kN	9.44	8.56	8.29
11.	Marshall Stability (Corrected)	MS.k	kN	8.40	7.62	7.38
12.	Flow Value	F	mm	3.07	3.12	3.15
13.	Average Bulk Sp. Gravity	G_{mb}	---	2.213		
14.	Average Density	G_{mb} x 0.997	g/cm^3	2.206		
	Reported Flow Value:	**3.11**	mm			
	Reported Marshall Stability:	**7.80**	kN			

TEST DATA SHEET

Combined Flakiness & Elongation Index

Ref.: IS 2386 Part 1 & Table 500-8 of MORTH Specs. 2001

Sample Source/Location	KABARI	Ambient Temperature °C	32±2
Nom. Size of Aggregate-mm	20MM	Relative Humidity -RH %	40±5
Conditioning Temperature °C	105±5	Conditioning Period-h	24

OBSERVATION & RESULTS

Size of Aggregate		Flakiness Index & Elongation Index			
Passing Through IS Sieve -mm	Retained on IS Sieve -mm	Total Sample Weight -g	Wt. of Aggregate Passing Through Thickness Gauge -g	Wt. of Aggregate Retained on Thickness Gauge (Non-Flaky) -g	Wt. of Aggregate Retained on Lenght Gauge (Elongated) -g
		A	B	C	D
50	40	-	-	-	-
40	31.5	-	-	-	-
25	20	3336.8	489.8	2847.0	278.8
20	16	1861.4	280.8	1580.6	316.3
16	12.5	1006.1	138.4	867.7	278.6
12.5	10	-	-	-	-
10	6.3	-	-	-	-
Total		ΣA = 6204.3	ΣB = 909.0	ΣC = 5295.3	ΣD = 873.7

Flakiness Index (FI) = $\left(\frac{\sum B \times 100}{\sum A}\right)$: 14.7 %

Elongation Index (EI) = $\left(\frac{\sum D \times 100}{\sum C}\right)$: 16.5 %

Reported Flakiness & Elongation Index = (FI+EI) : 31.2 %

TEST DATA SHEET

Specific Gravity & Water Absorption of Coarse Aggregate Greater than 10 mm

Ref.: IS 2386 Part 3:1963 R.A. 2007 Method

Sample Source/Location	KABARI	Ambient Temperature °C	32±2
Nom. Size of Aggregate-mm	20MM	Relative Humidity -RH %	40±5
Conditioning Temperature °C	105±5	Conditioning Period-h	24

OBSERVATION & RESULTS

Sl. No.	Characterisitics Parameters	Computation	Unit	Trial #1	Trial #2
1.	Weight of saturated aggregate suspended in water with the basket	A_1	g	3104	3115
2.	Weight of basket suspended in water	A_2	g	1878	1878
3.	Weight of saturated aggregate in water	$A=(A_1-A_2)$	g	1226	1237
4.	Weight of saturated surface dry aggregate in air	B	g	1940	1954
5.	Weight of oven dry sample	C	g	1938	1952
6.	Weight of water equal to the volume of the aggregate	(B - A)	g	714	717
7.	Weight of water absorbed	(C - A)	g	712	715
8.	Absorbed water by aggregate	B - C	g	02	02
9.	Specific Gravity	$\frac{C}{(B - A)}$	–	2.714	2.722
10.	Apparent Specific Gravity	$\frac{C}{(C - A)}$	---	2.722	2.730
11.	Water Absorption	$\frac{100\ (B - C)}{C}$	%	0.10	0.10
I.	Average Specific Gravity : 2.718				
II.	Average Water Absorption-% :0.10				

TEST DATA SHEET

Determination of Aggregate Impact Value of Coarse Aggregate

Ref.: IS 2386 (Part 4):1963, RA 2016

Sample Source/Location	KABARI	Ambient Temperature °C	32±2
Nom. Size of Aggregate-mm	20MM	Relative Humidity -RH %	40±5
Conditioning Temperature °C	105±5	Conditioning Period-h	04

Procedure:

The test sample shall consist of aggregate, the whole of which passes a 12.5 mm sieve & it retained on 10 mm sieve. The sample shall be dried in oven for a period of 4 hours at a temp. of 100 to 110°C & cooled. The measure shall be filled about one third fall with the aggregate with 25 strokes of the rounded end of the tamping rod, further similar quantity of aggreagte shall be added & a further tamping of 25 strokes given. The measure shall finally be filled to overflowing tamped 25 times & the surplus aggregate struck off, using the tamping rod as straight edge. The net weight of aggregate in the measure shall be determined to the nearest gram & this weight of aggregate shall be used for the duplicate test.

OBSERVATION & RESULTS

Sl. No.	Test Characteristics/Parameters	Symbol	Unit	Observation & Result	
				Test 1	Test 2
1.	Weight of aggregate sample for filling the cylindrical measure	A	g	328.8	328.8
2.	Weight of aggregate passing 2.36 mm sieve after the test	B	g	53.6	54.1
3.	Weight of aggregate retained on 2.36 mm sieve after the test	C	g	274.8	274.3
4.	Total loss in aggeing weigh	A - (B + C)	g	0.4	0.4
5.	Aggregate impact value - AIV	$\frac{B}{A}$ x100	%	16.3	16.5
6.	Reported aggregate impact value - AIV	---	%	16	

TEST DATA SHEET

Determination of Aggregate Abrasion Value-Los Angeles Method

Ref.: IS 2386(Part IV):1963, Reaffirmed 2007

No.

Sample Source/Location	KABARI	Ambient Temperature °C	32±2
Nom. Size of Aggregate-mm	20MM	Relative Humidity -RH %	40±5
Selected aggregate grading	B	Total Nos. of M/c revolutions	500
Nos. of steel spheres used	11	Weight of charge spheres-kg	4.584± 0.025

Procedure:

The test sample shall consist of clean aggregate which has been dried in an oven at 105 to 110°C to constant weight. The grading used shall be most nearly representing the aggregate furnished for the work. The test sample & abrasive charge shall be placed in the Los Angeles abrasion testing machine & the machine rotated at 30 to 33 rev./min. The machine is rotated at 500 revolution for A,B,C & D grading & 1000 revolutions for grading E, F & G. At the completion of the test, the material is sieved on 1.70 mm & washed dried to constant weight & percentage of wear is calculated. The test is performed in duplicate in accordance with clause 5.2 of IS:383-1970, reaffirmed 2007

OBSERVATION & RESULTS

Sl. No.	Test Characteristics/ Parameters	Symbol	Unit	Observation & Results	
				Test 1	Test 2
1.	Weight of dried specimen for the test a. 1st weighing	W_1	kg	5.000	5.000
	b. 2nd weighing			5.000	5.000
	c. 3rd weighing			5.000	5.000
2.	Washed & dried specimen wt. retained on 1.70 mm sieve a. 1st weighing	W_2	kg	3.955	3.985
	b. 2nd weighing			3.955	3.985
	c. 3rd weighing			3.955	3.985
3.	Computed percentage wear	$\frac{(W_1-W_2)}{W_1}\times 100$	%	20.9	20.3
4.	Reported aggregate abrasion value	---	%	20.6	

TEST DATA SHEET

Soundness of Coarse Aggregate with Sodium Sulphate(Na_2SO_4)

Ref.: IS: 2386(Part 5) -1963 Reaffirmed 2011

Sp. Gr. of Na_2So_4 Soln.	1.151-1.174
Time of Immersion(hrs)	16 - 18
Draining Time (min.)	15
Drying Time (hrs)	Constant weight
Cooling Time (hrs)	04 to 18
Temp. of Solution	27 ± 1^{0}C
Source	KABRAI

Lab Temp. ^{o}C 27 ±1			Humidity % 65±5		
Date of Testing	30.04.2018 to 09.04.2018				
No. of Cycles	1	2	3	4	5
Date & Time of Immersion	03.04 6:50	04.04 4:50	05.04 4:50	06.04 4:50	07.04 4:50
Date & Time of Removal	04.04 9:50	05.04 9:50	06.04 9:50	07.04 9:50	08.04 9:50

OBSERVATION & RESULTS

Sieve Size, mm		Grading of Original sample percent	Weight of test friction before test, g	Weight of sample after cooling-g	Percentage passing finer sieve after test (actual percent loss)	Weighted average (Corrected percent loss)
Passing	retained on					
1	2	3	4	5	6	7
63	40	-	-	-	-	-
40	20	-	-	-	-	-
20	10	67.6	1000.00	933.4	6.66	4.50
10	4.75	-	-	-	-	-
Total		100%				4.50

Number of particles coarser than 20 mm			Numbers of particles affected
Passing	Retained	Number of Particles	
63	40	-	-
40	20	-	-

Soundness (% by mass)=4.50

TEST DATA SHEET

Soundness of Coarse Aggregate with Magnesium Sulphate($MgSO_4$)

Ref.: IS: 2386(Part 5) -1963 Reaffirmed 2011

Sp. Gr. of $MgSo_4$ Soln.	1.295-1.305
Time of Immersion(hrs)	16 - 18
Draining Time (min.)	15
Drying Time (hrs)	Constant weight
Cooling Time (hrs)	04 to 18
Temp. of Solution	27 ± 1^{0}C
Source	KABRAI

Lab Temp. ^{o}C 27 ±1			Humidity % 65±5		
Date of Testing	03.04.2018 to 09.04.2018				
No. of Cycles	1	2	3	4	5
Date & Time of Immersion	03.04 4:50	04.04 4:50	05.04 4:50	06.04 4:50	07.04 4:50
Date & Time of Removal	04:04 9:50	05:04 9:50	06:04 9:50	07:04 9:50	08:04 9:50

OBSERVATION & RESULTS

Sieve Size, mm		Grading of Original sample percent	Weight of test friction before test, g	Weight of sample after cooling-g	Percentage passing finer sieve after test (actual percent loss)	Weighted average (Corrected percent loss)
Passing	retained on					
1	2	3	4	5	6	7
63	40	-	-	-	-	-
40	20	-	-	-	-	-
20	10	67.6	1000.0	899.4	10.06	6.80
10	4.75					
Total		100%				6.80

Number of particles coarser than 20 mm			Numbers of particles affected
Passing	Retained	Number of Particles	
63	40	-	-
40	20	-	-

Soundness (% by mass) = 6.80

TEST DATA SHEET ATTERBERG LIMIT

Ref.: IS 2720 (P 5):1985, RA 2010

Sample Source/Location	KABRAI	Ambient Temperature °C	32±2
Type of Soil	20MM	Relative Humidity -RH %	40±2
Size-Passing/Retained	425µm	Nos. of Test Specimen	10

	LIQUID LIMIT					PLASTIC LIMIT				
Determination No.	1	2	3	4	5	1	2	3	4	5
Number of drops	-	-	-	-	-	-	-	-	-	-
Container number	1	2	3	4	5	6	7	8	9	10
Wt. of container +wet soil, g m_2	-	-	-	-	-	-	-	-	-	-
Wt. of container +oven dry soil,g m_3	-	-	-	-	-	-	-	-	-	-
Wt. of water, g m_2-m_3	-	-	-	-	-	-	-	-	-	-
Wt. of container,g m_1	26.82	21.41	31.08	24.72	26.77	25.48	26.08	21.41	20.21	25.88
Wt. of oven dry soil, g m_3-m_1	-	-	-	-	-	-	-	-	-	-
Moisture percent	-	-	-	-	-	-	-	-	-	-
						Average (PL)				

TEST DATA SHEET

Residue by Sieving Through 600-Micron Sieve of Bitumen Emulsion (Cationic)
Ref. Std.: IS 8887:2018, Annex B

Source/Location/Chainage	HINCOL	Ambient Temperature-ºC	27± 2
Grade/Type of Emulsion	SS2	Relative Humidity-RH%	25 ± 5
Sample Quantity for Test-ml	4000	Size of Std. Sieve-Microns	600

Procedure:

Wash the sieve with xylene & then with acetone. Place it in the dish, dry in the oven at 105°C for one hour, cool & weigh together with dish to the nearest 0.01 (W_1).

Remove the sieve from the dish and moisten with the solution. Remove uniformly the four (04) litre sample by gentle agitation & strain immediately through the sieve into the clean, dry weighed container (W_4). Sieve the low & high viscosity emulsion at room temperature & 50°C respectively.

When whole of the emulsion has been passed through the sieve, remove the sieve and weigh the container to the nearest 1g (W_2). Wash the sieve repeatedly with distilled water until the washings run clear.

Place the sieve in the small dish to dry for 2 hour in the oven at 105°C cool & reweigh together to the nearest 0.01g (W_3).

OBSERVATION & RESULTS

Sl.	Characteristic Parameters	Unit	Symbol	Observed Value
1.	Mass of sieve and small dish	g	W_1	371.6
2.	Mass of container and emulsion	g	W_2	4106.8
3.	Mass of sieve, small dish & residue	g	W_3	372.3
4.	Mass of container alone	g	W_4	242.3
5.	Percentage retained $= \frac{W_3 - W_1}{W_2 - W_4} \times 100$	% by mass	---	0.018
	Reported Value of Residue on 600 micron - % by mass: 0.02			

TEST DATA SHEET

Viscosity by Saybolt Furol Viscometer of Bitumen Emulsion (Cationic)
Ref. Std.: IS 8887:2018 & IS 3117:2004

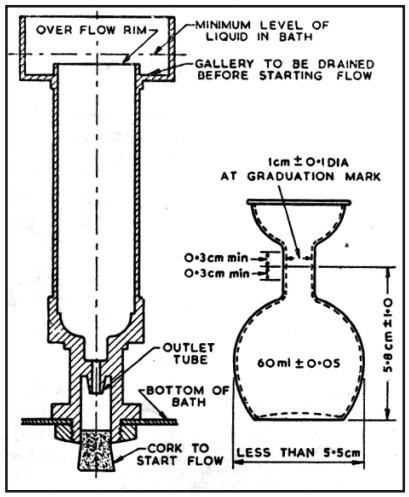
Source/Location/Chainage	HINCOL	Ambient Temperature-ºC	25± 2
Grade/Type of Emulsion	SS2	Relative Humidity-RH%	27± 5
Sample Quantity for Test-ml	60	Temperature of the Test-ºC	25

Procedure:

Pour the sample into the tube until it ceases to overflow into the gallery. Keep it well stirred with the tube thermometer, care being taken to avoid touching the outflow tube. Adjust the bath temperature until the temperature of the material remains constant & variation within ±0.03°C.

After the temperature of the material in the oil tube has remained constant within ±0.02ºC of the desired temperature for one minute with constant stirring withdraw the tube thermometer and remove the surplus liquid quickly from the gallery by means of the withdrawal tube so that the level of the material in the gallery is below the level in the tube proper. Insert the tip of the withdrawal tube at one point in he gallery.

Place the receiving flask in position so that the stream of liquid from outlet tube strikes the neck of the flask is not less than 10 cm not more than 13 cm from the bottom of the bath. Snap the cork from its position and at the same instant start the timer. Stop the timer when the bottom of the meniscus of the liquid reaches the mark on the neck of the receiving flask.



OBSERVATION & RESULTS

Sl.	Characteristic Parameters	Unit	Observed Value
1.	Constant Temperature of the tube unit	°C	25
2.	Volume of the graduated glass flask	ml	60
3.	Internal dia of the calibrated metal orifice	mm	3.15
4.	Distance between bottom tube & flask neck	mm	125
5.	Time recorded to fill the flask upto the mark	s	68
6.	Saybolt Furol viscosity of emulsion	s	68

TEST DATA SHEET

Coagulation of Bitumen Emulsion (Cationic) at Low Temperature
Ref. Std.: IS 8887:2018, Annex C

Source/Location/Chainage	HINCOL	Ambient Temperature-ºC	27± 2
Grade/Type of Emulsion	SS2	Relative Humidity-RH%	25 ± 5
Sample Quantity for Test-ml	20	Temperature of the Test-ºC	-4

Procedure:
Take 20 ml of sieved emulsion into the boiling tube and bring to 30°C by plunging tube in water & stir to maintain the constant temperature. Remove the tube from warm water & plunge into the beaker containing iced water, stir slowly. Lower the temperature of water by adding common salt to -1.0°C, so that the emulsion is at 0°C.

Transfer the tube to a beaker maintained at (-) 4°C & allow the emulsion to remain quiescent for 30 mins. Remove & allow to the temperature to rise to room temperature & sieve on 600 micron sieve. The coagulated bitumen, if any will be retained in the sieve. Report the emulsion as passed, if no coagulation takes place.

OBSERVATION & RESULTS

Sl.	Characteristic Parameters	Unit	Observed Value
1.	Volume of bitumen emulsion for test	ml	20
2.	Warming temp. of emulsion sample	°C	30
3.	Intermediate cooling temperature of sample	°C	-1
4.	Low temperature of emulsion after cooling	°C	-4
5.	Sieving temperature after cooling cycles	°C	27
6.	Presence of coagulated bitumen on sieve	---	No Coagulation
	Report on coagulation of bitumen emulsion :	NIL	

TEST DATA SHEET

Determination of Storage Stability Bitumen Emulsion (Cationic)
Ref. Std.: IS 8887 : 2018, Annex D

Source/Location/Chainage	HINCOL	Ambient Temperature-ºC	27± 2
Grade/Type of Emulsion	SS2	Relative Humidity-RH%	25 ± 5
Sample Quantity for Test-ml	1000	Temperature of the Test-ºC	163± 2.8

Procedure:

Bring the bitumen emulsion to room temperature of 20-30 °C. Place 500 ml representatative sample in each of the two glass cylinders & keep stopped for 24 h. Remove 55 ml from top of emulsion by pipette. Thoroughly mix the portion & transfer 50 ± 0.1g each to 1000 ml glass beaker & dry for 2 + 1 h at 163 ± 2.8 °C in oven. Weigh the beaker after cooling for residue from top.

After removal of the top 55 ml, now siphon off next 390 ml from each cylinder then mix the emulsion remaining in the cylinder & weigh 50 ± 0.1g in seperate weighed of 1000 ml beaker. Determine the bituminous residue of the sample.

Calculate storage stability as numerical difference between the average percentage of bitumen residue found in two top & bottom samples.

RESIDUE FROM BITUMEN EMULSION-TOP & BOTTOM PORTION

Sl.	Characteristic Parameters	Unit	Symbol	Top Emulsion		Bottom Emulsion	
				Trial 1	Trial 2	Trial 1	Trial 2
1.	Wt. of empty beaker & glass rod	g	W_1	276.9	270.8	271.8	274.6
2.	Wt. of beaker, glass rod & emulsion	g	W_2	326.9	320.8	321.8	324.8
3.	Wt. of beaker, glass rod & emulsion after 3 h heating at 163±2.8^{0}C	g	W_3	309.6	303.4	305.0	307.9
4.	Bituminous residue $= \frac{W_3 - W_1}{W_2 - W_1} \times 100$	% by mass	R	65.4	65.2	66.4	66.6
5.	Avg. Bituminous residue	% by mass	R	65.3		66.5	
6.	Storeage stability: R (bottom-top)	%	---	1.2			

TEST DATA SHEET

Determination of Particle Charge on Bitumen Emulsion (Cationic)
Ref. Std.: IS 8887:2018, Annex E

Source/Location/Chainage	HINCOL	Ambient Temperature-ºC	27± 2
Grade/Type of Emulsion	SS2	Relative Humidity-RH%	25 ± 5
Sample Quantity for Test-ml	100	Temperature of the Test-ºC	27

Procedure:

Take approx 100 ml emulsion sample in a 500 ml glass beaker & immerse the two SS plates of 75 × 25 mm, to a depth of 25 mm connected to the 12V battery circuit through a switch. Mark the plates as +ve & –ve. Close the switch & adjust the rehostat to 4mA current.

Open the circuit after 30 mins. & remove the plates. Gently wash the plates with distilled water & remove unbroken emulsion and then examine.

An appropriate layer-continuous opaque film of depointed bitumen on the –ve plate-cathode with a relatively clean bitumen free +ve plate-anode, indicates a cationic emulsion of +ve charged particles.

OBSERVATION & RESULTS

Sl No.	Characteristic Parameters	Unit	Observations
1.	Dimension of SS plate used for test	mm	75X25
2.	Volume of bitumen emulsion for test	ml	100
3.	Current Passed in the Circuit	Ohm	04
4.	Time/duration of particle charge test	min.	30
5.	Deposition on (-) Plate/Cathode	(–)	Weak Deposit
6.	Deposition on (+) Plate/Anode	(+)	Clean
	Reported particle charge of bitumen emulsion :		Weak Positive

TEST DATA SHEET

Stability to Mixing with Cement of Bitumen Emulsion (Cationic)

Ref. Std.: IS: 8887: 2018, Reaffirmed 2009-Annex G

Source/Location/Chainage	HINCOL	Ambient Temperature-ºC	27 ± 2
Grade/Type of Emulsion	SS2	Relative Humidity-RH%	25 ± 5
Sample Quantity for Test-ml	100	Temperature of the Test-ºC	100

Procedure:

Make up the water content of emulsion to 50% by adding extra water. Weigh 50g cement passing 150 micron. Weigh the 1.40m to IS sieve and shallow pan to nearest 0.1g (W_1). Add 100 ml of emulsion to the cement in the dish and stir the mixture with steel rod with a circular motion making about 60 rev/min.

At the end of one min. mixing period add 150 ml freshly boiled distilled water at room temperature and continue stirring for three min. Maintain the ingredients at a temperature of approx. 25°C during mixing.

Pour the mixture through the weighed 1.40 mm IS sieve and rinse with distilled water. Place the sieve & weighed pan in the oven at 110°C to dry and weigh to nearest 0.1g (W_2). Report the coagulation value as percentage to the nearest whole number.

OBSERVATION & RESULTS

Sl.	Characteristic Parameters	Unit	Symbol	Observation
1.	Volume of Emulsion with ~50% water content	ml	V	100
2.	Mass of cement passed through 150µ sieve	g	w_c	50
3.	Mass of weighed 1.40 mm IS sieve and pan	g	w_1	889.0
4.	Mass of sieve and pan with retained material	g	w_2	909.8
5.	Mass of binder in 100 ml diluted emulsion	g	w_3	65.2
6.	Coagulation value of emulsion = $\frac{W_2 - W_1}{W_3}$	%by mass	---	0.32
	Reported Percentage Coagulation Value : 0.32			

TEST DATA SHEET

Miscibility with Water of Bitumen Emulsion (Cationic)

Ref.Std.: IS 8887:2018, Annex H

Source/Location/Chainage	HINCOL	Ambient Temperature-ºC	27± 2
Grade/Type of Emulsion	SS2	Relative Humidity-RH%	25 ± 5
Sample Quantity for Test-ml	400ml Beaker	Temperature of the Test-ºC	

OBSERVATION & RESULTS

Sl.	Characteristic Parameters	Unit	Symbol	Observations & Results
1.	Wt. of sample taken for analysis	ml	V	50
2.	Volume of Distilled water taken for analysis.	ml	V	150
3.	After mixing at 20-30^{0}C, keep the beaker for 2 hr. and then see the any appreciable coagulation of the bitumen content of the emulsion.	---	---	No Coogulation

TEST DATA SHEET

Determination of Residue by Evaporation of Bitumen Emulsion (Cationic)

Ref. Std.: IS 8887:2018, Annex J

Source/Location/Chainage	HINCOL	Ambient Temperature-ºC	27± 2
Grade/Type of Emulsion	SS2	Relative Humidity-RH%	25 ± 5
Sample Quantity for Test-ml	150	Temperature of the Test-ºC	163± 2.8

Procedure:

Weigh the three glass beakers of 1000 ml capacity. Add 50 gm of thoroughly mixed emulsion in each of the beaker glass rod. Place the beakers in oven at 163 ± 2.8ºC for 2 hours. Now take the beakers out of the oven and stir the residue throughly. Place them again in the oven for 1 hour and then leave it to cool to room temperature. Weigh the beakers with glass rod again & calculate the residue percent. Take the average of the three values obtained for residue percent.

OBSERVATION & RESULTS

Sl. No.	Characterstic Parameters	Unit	Symbol	Observed value		
				Trial 1	Trial 2	Trial 3
1.	Weight of beaker with glass rod	g	M_1	271.3	273.2	274.0
2.	Wt. of emulsion, beaker & glass rod	g	M_2	321.3	323.2	324.0
3.	Oven temp. to heat emulsion for 2 h	0ºC	T_1	163	163	163
4.	After stirring further heating-1 h	0ºC	T_2	163	163	163
5.	Weight of residue beaker & glass rod	g	M_3	303.9	305.8	306.6
6.	Percentage residue : $Ra = \frac{M_3 - M_1}{M_2 - M_1} \times 100$	%	---	65.2	65.2	65.2
7.	Average percentage residue	% by mass	---	65.2		

Reported residue by evaporation-% by mass: 65.2

TEST DATA SHEET

Determination of Penetration of Residue of Bitumen Emulsion (Cationic)
Ref.Std.: IS 8887:2018, Annex J & IS 1203:1978

Source/Location/Chainage	HINCOL	Ambient Temperature-ºC	25± 2
Grade/Type of Emulsion	SS2	Relative Humidity-RH%	24 ± 5
Sample Quantity for Test-ml	150	Temperature of the Test-ºC	25

Procedure:

Soften the material to a pouring consistency at a temp. not more than 90°C above softening point and stir thoroughly untill it is homogenous and free from air bubbles & water. Pour the melt into the container to a depth at least 10 mm in excess of the expected penetration. Cool the material to 15-30°C for 45 min. & then place it along with the transfer dish in the water bath at 25±0.1°C and allow to remain for 45 min.

Note the reading of the dial or bring the pointer to zero. Release the needle and adjust the points, if necessary to measure the distance penetrated. Make at least three determinations at points on the surface of the sample not less than 10 mm apart & not less than 10 mm from the side of dish. Express the depth of penetration of the needle in tenth of millimeter. Report the mean of three values.

STD. TEST CONDITIONS

Period of cooling at room temp.-h	1½	Diameter of metal container-mm	55
Period of cooling in water bath-h	1½	Internal depth of container-mm	35
Constant temp. of water bath-°C	25	Diameter of penetration needle-mm	1.0
Test temperature of specimen-°C	25	Dia. of penetration needle tip-mm	0.16

OBSERVATION & RESULTS

S.No.	Characterstic Parameters	Symbol	Observed Value		
			Trial 1	Trial 2	Trial 3
1.	Superimposed weight-load on needle	g	100	100	100
2.	Time interval for std. penetration test	s	05	05	05
3.	Initial reading of penetrometer dial	A	00	00	00
4.	Final reading of penetrometer dial	B	62	61	62
5.	Computed penetration value (B-A)	---	62	61	62
6.	Average computed penetration value	---	62		

Reported penetration value of residue of bitumen emulsion: 62

TEST DATA SHEET

Ductility Test on Residue of Bitumen Emulsion (Cationic)

Ref. Std.: IS 8887 : 2018, Annex - J & IS 1208:1978

Source/Location/Chainage	HINCOL	Ambient Temperature-ºC	27 ± 2
Grade/Type of Emulsion	SS2	Relative Humidity-RH%	24 ± 5
Sample Quantity for Test-ml	150	Temperature of the Test-ºC	27

Procedure:

The ductility of the bituminous material is measured by the distance in centimeters to which it will elongate before breaking when a briquette specimen of the material of the form are pulled apart at a specified temperature.

The material between the two clips pulls out to a point or to a thread and rupture occurs where the cross-sectional area is minimu. Report the averageof three normal tests as the ductility of the sample, provided the three determinations are within ±5 percent of their mean value.

STD. TEST CONDITIONS

Pouring temperature of material-°C	135	Length of metal moulds-mm	75±0.5
Period of cooling ambient air-h	½	Thickness of metal mould -mm	10±0.1
Cooling in water bath-before trim-h	½	Width at min. cross section-mm	10±0.1
Cooling in Water bath after trim-h	1½	Rate of separation of mould-mm/min.	50±2.5

OBSERVATION & RESULTS

Sl. No.	Characterstic Parameters	Unit	Observed value		
			Trial 1	Trial 2	Trial 3
1.	Temperature of the ductility bath-water	°C	27	27	27
2.	Initial reading on distance scale	cm	00	00	00
3.	Elongated distance before rupture of thread	cm	67	68	68
4.	Computed distance-ductility of material	cm	67	68	68
5.	Average computed ductility of material	cm	67.67		
6.	Reported ductility of material at 27°C	cm	68		
	Report on ductility of bitumen emulsion : 68				

TEST DATA SHEET

Solubility in Trichloroethylene-TCE of Residue of Bitumen Emulsion (Cationic)

Ref.Std.: IS 8887:2018, Annex J & IS 1216:1978

ource/Location/Chainage	HINCOL	Ambient Temperature-ºC	27 ± 2
Grade/Type of Emulsion	SS2	Relative Humidity-RH%	24 ± 5
Sample Quantity for Test-ml	150	Temperature of the Test-ºC	27

Procedure:

If the material contains water, heat it to a temp. not exceeding 130°C until the water has been removed. Weigh about 2 g of the dry material correct to nearest 0.001g into a 250 ml conical flask and add 100 ml of TCE, stir & allow to stand for one hour. Filter the contents in a weighed filter crucible, wash the residue material with successive small amounts of TCE until the filterate obtained is clear. Allow the crucible to dry in air for 30 minutes & then heat in oven at 105°C for one hour. Allow the crucible to cool in a desiccator and then weigh. Report the result obtained to the nearest 0.05 percent as the matter soluble in TCE of the dry material.

OBSERVATION & RESULTS

Sl.No.	Characterstic Parameters	Unit	Symbol	Observed Value
1.	Weight of bituminous residue for test	g	w_1	2.0048
2.	Volume of TCE used for dissolution	ml	v	100
3.	Weight of empty & dry filter crucible	g	w_2	27.5227
4.	Weight of crucible & retained material	g	w_3	27.5307
5.	Weight of retained material on crucible	g	$w_4 = w_3 - w_2$	0.0080
6.	Solubility in TCE: $\frac{w_1 - w_4}{w_1} X\ 100$	% by mass	--	99.60
Reported solubility in Trichloroethylene-TCE-% by mass: 99.60				

TEST DATA SHEET

Limit of Acidity in Water for Construction Purpose (IS: 456)

Ref.: IS 3025 (Part-22):1986 RA-2014

Sample Source/Location	Project Site	Ambient Temperature °C	29±2
Type of Water	Construction Water	Relative Humidity -RH %	45±5
Sample Quantity-ml	100	Nos. of Test Specimen	01

Method :- Limits of Acidity is determind by using Phenolphthalein Indicator & Titrate it with 0.02N NaOH Solution.

OBSERVATION & RESULTS

Sl. No.	Characteristics Parameters	Symbol	Unit	ObservedValue	IS :456 limit	Conformity
1.	Volume of Specimen	V_1	ml	100	5.0 Max	Yes/No
2.	Initial Volume of 0.02 N NaOH Solution	V_2	ml	0.0		
3.	Final Volume of 0.02 N NaOH Solution used in Titration	V_3	ml	0.9		
Reported Value :- Limit of Acidity :- 0.9						

TEST DATA SHEET

pH Value of Water for Construction Purposes-Electrometric Method
Ref.: 3025 Part 11-1983 RA-2017

Sample Source/Location	Project Site	Ambient Temperature °C	29±2
Type of Water	Construction Water	Relative Humidity -RH %	45±5
Sample Quantity-ml	100	Instruction Used	pH Meter

Procedure : After warm-up period, standardize the instrument with a buffer solution of pH near to that of sample and check electrode with at least one additional buffer of different pH value. Measure the temperature of water pH using the digital pH meter. Report pH to the nearest 0.1 unit and temperature to the nearest °C

STANDARDIZATION OF pH METER

pH Buffer Solution-I		**pH Buffer Solution-II**		**pH Buffer Solution-III**	
Brand Name	Merck	Brand Name	Merck	Brand Name	Merch
Batch No.	HC74112806	Batch No.	HC74738968	Batch No.	HC74408591
Expiry Date	31/10/2020	Expiry Date	31/12/2020	Expiry Date	30/11/2020
pH Value@25°C	4.01	pH Value@25°C	6.86	pH Value@25°C	9.18

OBSERVATION & RESULTS

Sl.	Characteristics Parameters	Unit	Observed Value		
			# 1	# 2	# 3
1.	Volume of Water Sample	ml	100	100	100
2.	Temperature of Water Sample	°C	27	27	27
3.	Observed Reading on pH Meter	---	8.041	8.032	8.048
4.	Average pH Value of Water Sample	---	8.04		
	Reported pH Value of Water Sample : 8.0				

TEST DATA SHEET

Limit of Alkalinity in Water for Construction Purpose (IS 456)

Ref.: IS 3025 (Part-23)-1986 RA-2014

Sample Source/Location	Project Site	Ambient Temperature °C	29±2
Type of Water	Construction Water	Relative Humidity -RH %	45±5
Sample Quantity-ml	100	Nos. of Test Specimen	01

Method :- Limits of Alkanility is determind by using mixed Indicator & Titrate it with 0.02 N H_2So_4 Solution.

OBSERVATION & RESULTS

Sl. No.	Characteristics Parameters	Symbol	Unit	ObservedValue	IS :456 limit	Conformity
1.	Volume of Specimen	V_1	ml	100	25.0 Max	Yes/No
2.	Initail Volume of 0.02 N H_2So_4 Solution	V_2	ml	0.0		
3.	Final Volume of 0.02 N H_2So_4 Solution used in Titration	V_3	ml	16.7		

Reported Value :- Limit of Alkanility :- 16.7

TEST DATA SHEET

Inorganic & Organic Solids

Ref.: IS 3025 (Part-18):1984 RA-2017

Sample Source/Location	Project Site	Ambient Temperature °C	30±2
Type of Water	Construction Water	Relative Humidity -RH %	40±5
Sample Quantity-ml	100	Nos. of Test Specimen	01

Method :- First take the empty wt. of dish and add 100 ml. of specimen.Keep the dish on steam bath as well as hot air oven for completely dry the sample. cool & take the wt. of dish with ppt. Keep the dish in muffle furnace at 550 ^{0}C for 1 hrs. cool and take the wt. of dish with ppt & calculate the organic & inorganic matter.

OBSERVATION & RESULTS

Sl. No.	Characteristics Parameters	Symbol	Unit	Observed Value	IS :456 limit	Conformity
1.	Volume of Specimen	V	ml	100		
2.	Wt. of empty & dry Dish	w_1	ml	69.8654		
3.	Wt. of Dish + ppt	w_2	ml	69.9389		
4.	Wt. of Dish + ppt (After ignition in furnace)	w_3	ml	69.9237	200 Max (for Organic matter)	Yes/No
5.	Organic matter :- $\frac{(w_2 - w_3) \times 10^6}{V}$	---	mg/l	152	3000 Max (For Inorganic matter)	Yes/No
6..	Inorganic matter :- $\frac{(w_3 - w_1) \times 10^6}{V}$	---	mg/l	583		

Reported Value :- Organic matter :- 152 (mg/l)

Inorganic matter:- 583 (mg/l)

TEST DATA SHEET

Sulphates (SO_4) in Ground Water & Water for Construction Purpose

Ref.: IS 3025(Part-24):1986 RA-2014

Sample Source/Location	Project Site	Ambient Temperature °C	30±2
Type of Water	Construction Water	Relative Humidity -RH %	40±5
Sample Quantity-ml	20	Nos. of Test Specimen	01

Method :- Sulphate is determined in acidic medium by using Barium Chloride (10%) Solution.The ppt. is filtered with 42 No. filter paper and ignite in muffle furnace then take Ash wt. (as $BaSO_4$) & Calculate sulphate.

OBSERVATION & RESULTS

Sl. No.	Characteristics Parameters	Symbol	Unit	Observed Value	IS :456 limit	Conformity
1.	Volume of Specimen	V	ml	20	400 Max	Yes/No
2.	Volume of $BaCl_2$ (10%) Solution Used for Precipitation	V_1	ml	10		
3.	Initial wt. of empty Silica crucible	w_1	g	22.8503		
4.	Final wt. of Silica crucible with Ash	w_2	g	22.8623		
5.	wt. of Ash (w_2 - w_1)	w_3	g	0.0120		
6.	Sulphate Content:SO_4 $\frac{w_3 \text{ X } 411.5 \text{ X } 1000}{V}$	SO_4	mg/l	246.9		

Reported Value :- 246.9 mg/l

TEST DATA SHEET

Chloride (Cl) in Ground Water & Water for Construction Purpose

Ref.: IS 3025 (Part-32):1988 RA-2014

Sample Source/Location	Project Site	Ambient Temperature °C	30±2
Type of Water	Construction Water	Relative Humidity -RH %	40±5
Sample Quantity-ml	100	Nos. of Test Specimen	01

Method :- Chloride is determined by potassium chromate (5%) Indicator & Titrate it with Std. $AgNO_3$ Solution.

OBSERVATION & RESULTS

Sl. No.	Characteristics Parameters	Symbol	Unit	Observed Value	IS :456 limit	Conformity
1.	Volume of Specimen	V	ml	100	500 Max	Yes/No
2.	Intial Volume of Std. $AgNO_3$ Solution	V_1	ml	0.0		
3.	Final Volume of Std. $AgNO_3$ Solution Used in Titration	V_2	ml	6.8		
4.	Normality of Std $AgNO_3$ Solution	N	--	0.0141		
5.	Chloride Content: $\frac{(V_2 - V_1) \times N \times 35450}{V}$	Cl	mg/l	33.99		
	Reported Value :- Chloride as Cl :-			34.0 (mg/l)		

TEST DATA SHEET

Total Suspended Matter in Water for Construction Purpose

Ref.: IS 3025 (Part-17):1984 RA-2017

Sample Source/Location	Project Site	Ambient Temperature °C	29±2
Type of Water	Construction Water	Relative Humidity -RH %	45±5
Sample Quantity-ml	100	Nos. of Test Specimen	01

Method : Total suspended solids is determined by filtering the sample through a weighed sintered glass crucible No.4 & drying it in oven at 103 to 105 ^{O}C till constant weight or less than 0.5 mg loss variation in subsequent weighings. Cool, weigh & calculate the non-filterable residue as suspended solids.

Precaution: Take sufficient volume to obtain at least 2.5 mg residue When the turbidity of water is less than 50 filter atleast 1000 ml of sample is to be taken for filtration.

OBSERVATION & RESULTS

Sl. No.	Characteristics Parameters	Symbol	Unit	Observed Value			
1.	Volume of Water Sample	V	ml	100			
2.	Weight of sintered Crucible	w_1	g	I	II	III	Final
				32.3177	32.3177	32.3177	32.3177
3.	Weight of Crucible + Non Filterable Residue	w_2	g	32.3189	32.3189	32.3189	32.3189
4.	Weight of Residue (w_2 - w_1)	w_3	g	0.0012			
5.	Non Filterable	$\frac{w_3 \times 10^6}{V}$	mg/l	12			

Reported Value :- Non - Filterable Residue (Total Suspended Solids-TSS): 12 mg/l

TEST DATA SHEET

Determination of Consistency of Standard Cement Paste

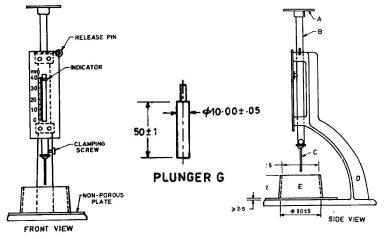
Ref.: IS: 4031 Part 04:1988, RA 2009

Sample Source/Location	Project Site			Ambient Temperature -°C	27±2
Type/Grade of Cement	OPC/43			Relative Humidity -RH %	70±5
Batch Number	W	M	Y	Cement Brand	Birla Gold

Procedure: Prepare a paste of 500g dry cement with a weighed quantity of distilled water, taking care that the time of gauging is not less than 3 minutes, nor more than 5 min, and the gauging shall be completed before any sign of setting occurs. The gauging time shall be counted from the time of adding water to the dry cement until commencing to fill the mould.

Place the test block in the mould, together with the non-porous resting plate, under the rod bearing the plunger; lower the plunger gently to touch the surface of the test block, and quickly release, allowing it to sink into the paste.

The standard consistency of a cement paste is defined as that consistency which will permit the vicat plunger G to penetrate to a point 5 to 7 mm from the bottom of the vicat mould



VICAT APPARATUS & PLUNGER G

OBSERVATION & RESULTS

Sl.	Characteristic Parameters	Unit	Symbol	Observed Value
1.	Weight of dry cement sample	g	m_1	500
2.	Weight of distilled water added	g	m_2	152.5
3.	Time of gauging	minute	---	03-05
4.	Penetration of plunger G	mm	---	05
5.	Consistency of cement	% by mass	$P = \frac{m_2}{m_1} \times 100$	30.5

Water required to produce a cement paste of Standard Consistency (P):30.5% by mass

(Reported to first place of decimal)

TEST DATA SHEET

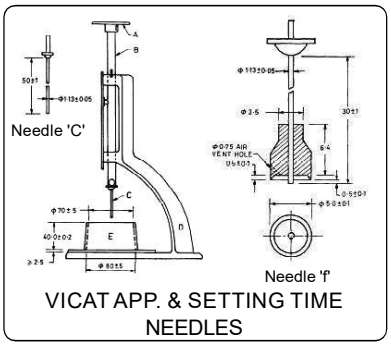
Determination of Initial and Final Setting Times of Cement

Ref.: IS 4031 Part 5:1988, RA 2009

Sample Source/Location	Project Site			Ambient Temperature -°C	27±2
Type/Grade of Cement	OPC/43			Relative Humidity -RH %	70±5
Batch Number	W	M	Y	Closet Temperature-°C	27
Cement Brand	Birla Gold			Closet Humidity-RH %	790

Procedure: Initial Setting Time - Place the test block confined in the vicat mould and resting on the non-porous plate, under the rod bearing the needle C, lower the needle C gently until it comes in contact with the surface of the test block and quickly release, allowing it to penetrate into the test block. In the beginning, the needle will completely pierce the test block. Repeat this procedure until the needle, when brought in contact with the test block and released as described above, fails to pierce the block beyond 5.0 ± 0.5 mm measured from the bottom of the mould.

Final Setting Time - The cement shall be considered as finally set when, upon applying the needle F gently to the surface of the test block, the needle makes an impression thereon, while the attachment fails to do so. Note: In the event of a scum forming on the surface of the test block, use the underside of the block for the determination.



VICAT APP. & SETTING TIME NEEDLES

OBSERVATION & RESULTS

Sl.	Characteristic Parameters	Unit	Symbol	Observed Value
1.	Weight of dry cement sample	g	m_1	500
2.	Weight of distilled water added to cement	g	$\frac{0.85\ P \times m_1}{100}$	129.6
3.	Time when water added to dry cement	minute	t_1	00:00
4.	Time of gauging	HH:MM	- - -	00:05
5.	Time when needle C stops at 5 ± 0.5 mm	HH:MM	t_2	2:40
6.	Time when needle F makes an impression	HH:MM	t_3	2:50
7.	Reported initial setting time (to nearest 5 min)	minute	t_2-t_1	160
8.	Reported final setting time (to nearest 5 min)	minute	t_3-t_1	172

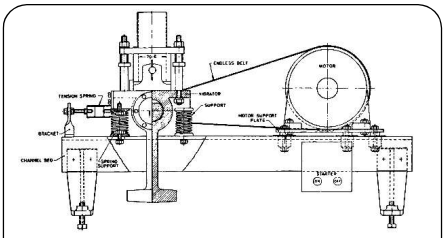
TEST DATA SHEET

Determination of Compressive Strength of Cement Mortar Cubes

Ref.: IS 4031 Part 06: 1988, RA 2009

Sample Source/Location	Project Site			Ambient Temperature -°C	27±2
Type/Grade of Cement	OPC/43			Relative Humidity -RH %	70±5
Batch Number	W	M	Y	Closet Temperature-°C	27
Cement Brand	Birla Gold			Rate of Loading kN/s	2.9

Procedure: Take 200g of cement & 600g of standard sand & mix it dry for 01 minute. Now add distilled water to it & mix on a non-porous plate immediately place the mortar in 70.6 mm cube fixed on the vibration machine in 02 layers. The mortar shall be prodded 20 times in 8 seconds by poking rod. Now compact the mortar by vibration for a period of 2 minutes. Remove the mould & base plate from the vibration machine & finish the top with trowel. Keep the moulds in moist closet at RH > 90% for 24 hours before removing of specimens from mould.



CEMENT VIBRATION MACHINE

TEST SPECIMEN PREPERATION DETAILS

Consistency of cement (P)%	30.5	Time of mixing-minute	04
Wt. of dry cement- g	200	Nos. of layers	02
Wt. of grade I sand- g	200	Nos. of prodding/layers	20
Wt. of grade II sand- g	200	Duration of prodding/layers-s	08
Wt. of grade III sand- g	200	Perod of vibration- minute	02
Wt. of water- 8[(P/4)+3]-g	85	Frequercy of vibration/minute	12000±400
Curing period- hour	72/168	Curing temperature-ºC	27

OBSERVATION & RESULTS

Sl. No.	Cube ID	Wt. of SSD Cube-g	Density -g/cm^3	Date of Testing	Age -Days/Hrs	Load -kN	Comp. Strength -N/mm^2	Avg. Compressive Strength- N/mm^2
1.	8424-28	832.5	2.37	03/10/18	07/72	134.7	27.0	27.2
2.	8424-28	831.9	2.36			136.1	27.3	
3.	8424-28	834.5	2.37			135.9	27.3	
4.	8424-28	818.9	2.33	07/10/18	07/168	184.7	37.1	37.1
5.	8424-28	828.3	2.35			183.9	36.9	
6.	8424-28	826.7	2.35			186.1	37.3	
7.				28/10/18	28/672			
8.								
9.								

** Average compressive strength to the nearest 0.5 N/mm^2

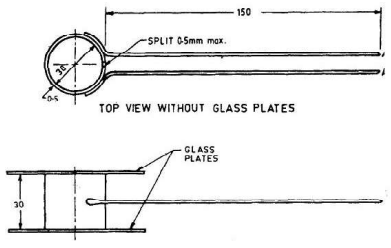
TEST DATA SHEET

Determination of Soundness of Cement by Le-Chatelier Method
Ref.: IS Clause 5, IS 4031 Part 3 : 1988, RA 2009

Sample Source/Location	Project Site			Ambient Temperature -°C	27±2
Type/Grade of Cement	OPC/43			Relative Humidity -RH %	70±5
Batch Number	W	M	Y	Curing Temperature- °C	27
Cement Brand	Birla Gold			Curing Period-hour	24
Casting Date- DD/MM/YY				Testing Date- DD/MM/YY	

Procedure: Place the lightly oiled mould on a lightly oiled glass sheet and fill it with cement paste formed by gauging cement with 0.78 times the water required to give a paste of standard consistency The paste shall be gauged in the manner Cover the mould with another piece of lightly oiled glass sheet, place a small weight on this covering glass sheet and immediately submerge the whole assembly in water at a temperature of 27 ± 2°C and keep there for 24 hours.

Measure the distance separating the indicator points to the nearest 0.5 mm (d_1). Submerge the mould again in water at the temperature prescribed above. Bring the water to boiling, with the mould kept submerged, in 25 to 30 minutes, and keep it boiling for three hours. Remove the mould from the water, allow it to cool and measure the distance between the indicator points (d_2). The difference between these two measurements indicates the expansion of the cement.



LE-CHATELIER MOULD

OBSERVATION & RESULTS

Sl.	Characteristic Parameters	Unit	Symbol	Observed Value	
				#1	#2
1.	Weight of dry cement sample	g	m_1	50	50
2.	Weight of distilled water added to cement	g	$\frac{0.78P \times m_2}{100}$	11.90	11.90
3.	Initial distance between the indicator points	mm	d_1	10.02	10.01
4.	Duration of boiling of test specimens	hour	---	03	03
5.	Final distance between the indicator points	mm	d_2	10.63	10.62
6.	Expansion of cement	mm	(d_2-d_1)	0.61	0.61
7.	Avg Expansion of cement	mm	---	0.61	

Soundness of cement by Le-Chatelier Method: 0.6 mm (Mean value reported to the nearest 0.5 mm)

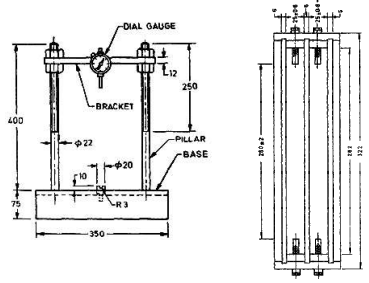
TEST DATA SHEET

Determination of Soundness of Cement by Autoclave Method
Ref.: Clause 6, IS 4031 Part 3 : 1988 RA 2009

Sample Source/Location	Project Site			Ambient Temperature -°C	27±2
Type/Grade of Cement	OPC/43			Relative Humidity -RH %	70±5
Batch Number	W	M	Y	Casting Date-DD/MM/YY	
Cement Brand	Birla Gold			Testing Date-DD/MM/YY	
Length of Ref. Bar-mm	300 : 18			Length of Knurled Studs-mm	21

Procedure: Take 500g of cement & cast 03 specimens of size 25x25x282mm of effective gauge length 250mm with 0.78 times the water of standard consistency. Fill the mould in 02 layers & compact it by thumb & forefinger covered by rubber glove. Keep the mould in moist closet at RH> 90% for 24 hours. Now demould the specimen at 24±0.5 hours & measure the length (l_i) keep the specimen in autoclave at 2.1± 0.1MPa & 215.7±1.ºC for 3 hours.

At the end of 3 hour, shuts off the heat supply & start the far, allow it to cool till pressure reaches 0.1MPa in <1 hour. Release the pressure valve & transter the specimen to a water bath set at 90 ºC & bring it to 27ºC in 15 minutes. Allow the specimen to stand for another 15 minutes at 27ºC. Remove the specimen from bath & measure the reading after autoclaving (l_f).



AUTOCLAVE MOULD

OBSERVATION & RESULTS

Sl.	Characteristic Parameters	Unit	Symbol	Observed Value		
				#1	#2	#3
1.	Weight dry of cement sample	W	g	500	500	500
2.	Weight of water added	P.W/100	g	152.5	152.5	152.5
3.	Dial reading with reference bar	mm	l_r	11.668		
4.	Dial reading before autoclaving	mm	l_i	2.798	2.810	2.816
5.	Dial reading after autoclaving	mm	l_f	2.988	2.990	3.006
6.	Effective guage length of specimen	mm	$L= [300.18 - (l_r-l_i)]-42.0$	249.310	249.322	249.323
7.	Final guage length of the specimen	mm	$L^i= [300.18- (l_r-l_f)]-42.0$	249.500	249.502	249.518
8.	% Change in effective gength	%	$100 (L^i-L)/L$	0.076	0.072	0.076
9.	Avg. % Change in effective gength	%	----	0.07		

Soundness of Cement by Autoclave Method : 0.07 % (Mean value reported to the nearest 0.01%

TEST DATA SHEET

Determination of Fineness by Blaine Air Permeability Method

Ref.: IS 4031 Part 2: 1999 RA 2013

Sample Source/Location	Project Site			Ambient Temperature -°C	27±2
Type/Grade of Cement	OPC/43			Relative Humidity -RH %	70±5
Batch Number	W	M	Y	TestTemperature-°C	27
Cement Brand	Birla Gold			Filter Paper Used	Whatman 40

OBSERVATION & RESULTS

Sl.	Characteristic Parameters	Symbol	Unit	Observed Value			
1.	Volume of the cell	V	cm^3	1.8608			
2.	Porosity of the bed	e	---	0.500			
3.	Density of cement	σ	g/cm^3	3.14			
4.	Mass of cement sample	$m_1 = e\ \sigma\ v$	g	2.9215			
5.	Viscosity of air	η_0	Pa.S	0.001357			
6.	Time taken by the manometer liquid to flow from 2nd etched mark to 3rd etched mark. (to nearest 0.2 seconds)	t	second	#1		#2	
				R1	R2	R1	R2
				41.3	41.2	41.3	41.1
7.	Test temperature	---	°C	27	27	27	27
8.	Apparatus constant	$K = 1.414\ S_0\rho_0\ \frac{\sqrt{0.1\eta_0}}{\sqrt{t_0}}$	---	2.6676			
9.	Specific surface of the cement	$S = \frac{521.08\ K\sqrt{t}}{\rho}\ (cm^2/g)$	cm^2/g	2844.9	2841.5	2844.9	2838.0
10.	Average specific surface of the cement	S	cm^2/g	2842.3			
11.	Reported specific surface of the cement	S	cm^2/g (m^2/kg)	2842.3 (284.2)			

TEST DATA SHEET

Gradation of Mineral Filler for Bituminous Mixes
Ref.: IS 2386 Part-1 1963 RA 2011 & Table 500-9 MORTH Specs 2013

Source/ Location: LIME (Ankur Chemicals) Quantity: 1000 gm

Sl.	IS Sieve	Retained Weight (g)	Passing Weight (g)	% Passing	Required % Passing
1.	600 μm	00	1000.0	100	100
2.	300 μm	0.1	999.9	100	95-100
3.	75 μm	16.9	983.0	98.3	85-100

TEST DATA SHEET

Determination of Grain Size Analysis of Soil
Ref.: IS 2720 (Part 04): 1985 RA 2015

Sample Source/Location	BARA (Jhansi)	Ambient Temperature °C	22 ± 2
Sample Identification	FLY-ASH	Relative Humidity -RH%	60 ± 5

Standard IS Sieve Size (mm)	Wet Sieve Analysis Weight of Sample: 200 g			
	Weight Retained	% Wt. Retained	Cumulative % Retained	Cumulative % Passing
100 mm	00	00	00	100
75 mm	00	00	00	100
19 mm	00	00	00	100
4.75 mm	11.2	5.60	5.60	94.4
2.00 mm	14.6	7.30	12.90	87.1
0.425 mm	28.7	14.35	27.25	72.8
0.212 mm	44.6	22.30	49.55	50.5
0.150 mm	34.7	17.35	66.90	33.1
0.075 mm	33.3	16.65	83.55	16.5
PAN	32.9	16.45	100.00	00.0

% Gravel($R_{4.75\ mm}$): **5.60** % Sand($P_{4.75\ mm}$-$R_{0.075\ mm}$): **77.95** % Silt & Clay ($P_{0.075\ mm}$): **16.45**

TEST DATA SHEET

Gradation of Reclaimend Asphalt Pavement-RAP Mixes
Ref.: IS 2386 (Part 1):1963 Reaffirmed 2016 & Table IX-1, IRC:37-2012

Source/ Location: Cement (Trial 1) Quantity: :1000.0gm

Sl.	IS Sieve	Retained Weight (g)	Passing Weight (g)	% Passing	Table IX-1 % Passing	Conformity
1.	45 mm	00	1000	100	100	Yes
2.	37.5 mm	00	1000	100	87-100	Yes
3.	26.5 mm	00	1000	100	77-100	Yes
4.	19.0 mm	00	1000	100	66-99	Yes
5.	13.2 mm	00	1000	100	67-87	Yes
6.	4.75 mm	00	1000	100	33-50	Yes
7.	2.36 mm	00	1000	100	25-47	Yes
8.	600 μm	00	1000	100	12-27	Yes
9.	300 μm	01	999	99.90	08-21	Yes
10.	75 μm	50	949	94.90	02-09	Yes
	Bitumen Emulsion Type:					

TEST DATA SHEET

Gradation of Reclaimend Asphalt Pavement-RAP Mixes
Ref.: IS 2386 (Part 1):1963 Reaffirmed 2016 & Table IX-1, IRC:37-2012

Source/ Location: Trial 1 Quantity: : 5000.0 gm

Sl.	IS Sieve	Retained Weight (g)	Passing Weight (g)	% Passing	Table IX-1 % Passing	Conformity
1.	45 mm	00	5000	100	100	Yes
2.	37.5 mm	325	4675	93.50	87-100	Yes
3.	26.5 mm	565	4110	82.20	77-100	Yes
4.	19.0 mm	280	3830	76.60	66-99	Yes
5.	13.2 mm	365	3465	69.30	57-87	Yes
6.	4.75 mm	1705	1760	35.20	33-50	Yes
7.	2.36 mm	225	1535	30.70	25-47	Yes
8.	600 μm	220	1315	26.30	12-27	Yes
9.	300 μm	195	1120	22.40	08-21	No
10.	75 μm	775	345	6.90	02-09	Yes
	Bitumen Emulsion Type:					

Source/ Location: Trial 2 Quantity: : 5000.0 gm

Sl.	IS Sieve	Retained Weight (g)	Passing Weight (g)	% Passing	Table IX-1 % Passing	Conformity
1.	45 mm	00	5000	100	100	Yes
2.	37.5 mm	260	4740	94.80	87-100	Yes
3.	26.5 mm	395	4345	86.90	77-100	Yes
4.	19.0 mm	685	3660	73.20	66-99	Yes
5.	13.2 mm	645	3015	60.30	57-87	Yes
6.	4.75 mm	1420	1595	31.90	33-50	No
7.	2.36 mm	140	1455	29.10	25-47	Yes
8.	600 μm	180	1275	25.50	12-27	Yes
9.	300 μm	440	835	16.70	08-21	Yes
10.	75 μm	565	270	5.40	02-09	Yes
	Bitumen Emulsion Type:					

TEST DATA SHEET

Gradation of Reclaimend Asphalt Pavement-RAP Mixes
Ref.: IS 2386 (Part 1):1963 Reaffirmed 2016 & Table IX-1, IRC:37-2012

Source/ Location: Trial 3 Quantity: :5000.0gm

Sl.	IS Sieve	Retained Weight (g)	Passing Weight (g)	% Passing	Table IX-1 % Passing	Conformity
1.	45 mm	00	5000	100	100	Yes
2.	37.5 mm	215	4785	95.70	87-100	Yes
3.	26.5 mm	415	4370	87.40	77-100	Yes
4.	19.0 mm	390	3980	79.60	66-99	Yes
5.	13.2 mm	465	3515	70.30	67-87	Yes
6.	4.75 mm	1545	1970	39.40	33-50	Yes
7.	2.36 mm	330	1640	32.80	25-47	Yes
8.	600 μm	415	1225	24.50	12-27	Yes
9.	300 μm	185	1040	20.80	08-21	Yes
10.	75 μm	650	390	7.80	02-09	Yes
	Bitumen Emulsion Type:					

Aggregate Blend Wet Gradation Results of Reclaimed Asphalt Pavement RAP Mix for WMM Layer

Reference Standard: IRC:37-2012, Table IX-1

	RAP (Project Site)				10 mm-Kabrai		Cement-OPC 43		Filler Lime		Extra			
Sieve Size	**% Pass**	**Trial**	**% Pass**	**Trial**	**% Pass**	**Trial**	**% Pass**	**Trial**	**% Pass**	**Trial**		**Combined Grading**	**Mid**	**Table IX-1, IRC:37-2012 Limits**
		89%		**0%**		**10%**		**1%**		**0%**	**0%**	**100%**	**100%**	
45.0	100.00	89.0	0.00	0.00	100.00	10.00	100.00	1.00	0.00	0.00	0.00	100.00	100.00	100
37.5	95.70	85.2	0.00	0.00	100.00	10.00	100.00	1.00	0.00	0.00	0.00	96.17	93.50	87-100
26.5	87.40	77.8	0.00	0.00	100.00	10.00	100.00	1.00	0.00	0.00	0.00	88.79	88.50	77-100
19	79.60	70.8	0.00	0.00	100.00	10.00	100.00	1.00	0.00	0.00	0.00	81.84	82.50	66-99
13.2	70.30	62.6	0.00	0.00	94.70	9.47	100.00	1.00	0.00	0.00	0.00	73.04	72.00	57-87
4.75	39.40	35.1	0.00	0.00	1.20	0.12	100.00	1.00	0.00	0.00	0.00	36.19	41.50	33-50
2.36	32.80	29.2	0.00	0.00	0.60	0.06	100.00	1.00	0.00	0.00	0.00	30.25	36.00	25-47
0.600	24.50	21.8	0.00	0.00	0.60	0.06	100.00	1.00	0.00	0.00	0.00	22.87	19.50	12-27
0.300	20.80	18.5	0.00	0.00	0.60	0.06	99.90	1.00	0.00	0.00	0.00	19.57	14.50	8-21
0.075	7.80	6.9	0.00	0.00	0.30	0.03	94.90	0.95	0.00	0.00	0.00	7.92	5.50	2-9

BLEND OF R.A.P. :

Wet Gradation of R.A.P. of WMM layer gave the following Ratio :

S.No.	Material	Content (in %)	Content by weight (g)
1	R.A.P. (Non - Bituminous)	89%	1068
2	Fresh Aggregate	10%	120
3	Chemical Stabilizers	1%	12

- Each sample mould is of 1200 gm.
- The amount of Emulsion added is 3.5 % of 1200 gm , i.e. , 42 gm.
- The amount of Water added is 3.5 % of 1200 gm , i.e. , 42 gm.
- The amount of Chemical stabilizers like cement , Fly – ash , H. Lime , Fibre added is 1% of the mix , i.e. , 12 gm.

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Roll No.: ……..

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Research Article Volume 9 Issue No.3

Improvement in Recycling of Reclaimed Asphalt Pavements using Different Materials in Flexible Pavement

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Abstract:
This paper aims to study properties, strength, advantages and disadvantages of RAP (Recycling of Reclaimed Asphaltic Pavement) using different materials in flexible pavement. This is a Cold-in-Place Recycling (CIPR) method for flexible pavements. This was experimented on the base course of pavement by replacing the WMM (wet mix macadam) layer of Flexible Pavement which is non bituminous. This method has various economical and environmental advantages whichinvolve the recycling of existing road surface aggregates and reduced haul requirements for incorporating new aggregates. By recycling existing in-place road materials and providing additional strength with mixing of different emulsions or strengthening agents, new aggregates and bitumen requirements are reduced. Various Laboratory tests were conducted by using different binding materials and different materials like cement , fly ash , lime , fibre (Recron 3s Fibre).

I. INTRODUCTION

Recycled asphalt pavement (RAP) has increasingly been used as a base material for highway construction as a sustainable solution. Due to the existence of asphalt, 100 % RAP typically has low strength and high potential of creep and permanent deformations. RAP can be blended with virgin aggregate, stabilized by cement fly-ash lime or fibre to increase its strength and reduce its creep and permanent deformations. Asphalt pavements which have reached the end of their service life are frequently rehabilitated by milling the existing pavement surfaces and replacing the milled portion with new hot mix asphalt (HMA). A large amount of recycled asphalt pavement (RAP) is generated every year because of this practice. The use of RAP has been in practice since 1930s and is necessary to reduce the cost of construction materials, to reduce the use of petroleum-based products, and to conserve natural resources by requiring less virgin aggregate and asphalt in road construction projects. RAP can be used as a granular base material in paved and unpaved roadways, parking areas, bicycle paths, gravel road rehabilitation, shoulders, residential driveways, trench backfill, engineered fill, and culvert backfill. Currently, great emphasis is placed on sustainable construction and infrastructure because the demand for sustainable and environmental friendly roads is increasing. More green technologies for sustainable roadway construction are needed. One way to construct environmentally sound roads is through the use of RAP materials. Historically, RAP has been used with new bituminous materials by either a hot-mix or cold-mix recycling process. However, a large quantity of RAP materials remains unused. Recent investigations have shown that the waste problems can be reduced by using RAP as base and subbase aggregate materials. Using RAP as a base course material would preserve non-renewable aggregate as well as reduce the amount of space needed to store millions of tons of RAP created each year. Literature indicates that 100 % RAP could not produce base course of high quality due to its significant rate dependency and high deformation and creep. Several researchers have suggested that high-quality base courses could be obtained by blending RAP with virgin aggregates, stabilizing RAP with chemical additives such as cement, lime, fly ash, fibre. Fly ash is a fine, glass-like powder material recovered from gases created by coal-fired electric power generation. Millions of tons of fly ash were produced by INDIAN power plants annually. Stabilizing RAP with fly ash is an attractive and sustainable solution because fly ash traditionally has been disposed in landfills. Stabilizing RAP with fibre such as Recron 3s is also a option to be considered. Recron 3S Fibre is a modified polyester fibre. It is generally used as secondary reinforcing material in concrete and soil to increase their performance. Use ofRecron-3S as a reinforcing material is to increase the strength in various applications like cement based precast products, filtration fabrics etc. It is a reinforcing fibre that improves properties such as tear, tensile, burst and bulk.

II. KEYWORDS OF THE PROPOSED EXPERIMENT

Here we will be discussing the major keywords used the paper.

A. Recycling of Reclaimed asphalt pavement (RAP)

Recycling of Reclaimed Asphalt Pavements (RAP) must be used for technical, economical, and environmental reasons. Use of RAP has been favoured all over the world over virgin materials in the light of the increasing cost of bitumen, the scarcity of quality aggregates, and the pressing need to preserve the environment. The use of RAP also decreases the amount of waste produced and help store solve the disposal problems of highway construction materials. Reclaimed Asphalt Pavements contain best quality aggregates and they can be effectively improved with foamed asphalt/bitumen emulsion along with/without fresh aggregates and crusher dust to impart necessary strength for durable pavements. If only the surface layer is weathered or damaged, hot recycling can be an attractive proposition. Several recycling techniques, such as hot mix plant recycling, hot in-place recycling, cold mix plant recycling, cold in-place recycling, and full depth reclamation, have evolved over the past 35 years. In-place recycling not only reduces the use of new materials but also reduces emissions, traffic, and energy associated with the transport and production of these materials. Hot Mix Recycling is the most

common method of recycling asphalt pavements in developed countries. It involves combining RAP with new or virgin aggregate, new asphalt binder, and recycling agents in a central hot mix plant to produce a recycled mix. The amount of RAP allowed in a recycled hot bituminous mix as per different guidelines varies from agencies to agencies. Cold Mix Plant Recycling is a method of recycling where RAP and emulsified bitumen or foamed bitumen are mixed cold in a centrally located cold mix plant. Many old road alignment having thick bituminous layers are being abandoned in four and six lane projects and the entire RAP can be salvaged by milling machine and reused in new construction. Even cement treated aggregates have been milled and reused in USA, South Africa and China. Since the components of a cold mix plant are fairly portable, it can be assembled in satellite locations close to a project site. Cold recycled mix is hauled to the job site with conventional dump trucks or belly dump trucks. Placement and compaction of cold recycled mixes are done with the same conventional pavers and rollers used for hot mix asphalt construction. Cold recycled mixes are normally overlaid with hot mix asphalt or surface dressing (chip seal) depending on the anticipated traffic level for the finished pavement.

B. Recron 3s fibre

Research and development work in Fibre Reinforced Concrete (FRC) composites began in India in the early 1970s. fibre reinforced concrete was developed to overcome the problems associated with cement based materials such as low tensile strength, poor fracture toughness and brittleness of cementations composites. In the beginning, FRC was primarily used for pavements and industrial floors but now a day FRC composite is being used for a wide variety of applications including bridges, tunnel and canal linings, hydraulic structures, pipes, safety vaults and structural members.

There are so many type of polymer fibre available as secondary construction materials, The Recron-3S fibre is one of them, and The Reliance Industry Limited (RIL) has launched Recron-3S. Recron-3s polymer fibre for mixing concrete and mortar for improving certain properties of the concrete and mortar. Fibres have special triangular shape for better anchoring with other ingredient of the mix. Recron-3S fibre is available in 6mm and 12mm length.

III. Experimental Method and its Methodology

A. Cold in place recycling (CIPR):

It involves rehabilitation of the existing asphalt or granular road surface. The existing surface is pulverized and the material is mixed on the site with foamed bitumen or bitumen emulsion. The process of in-situ recycling of distressed pavement using cold- mix technology is referred to as cold in-place recycling (CIPR). CIPR thus is a pavement rehabilitation measure that typically consists of the following operations, Often all are carried out in one-pass of a recycling machine and a badly distressed pavement is transformed into a stronger good looking pavement.

1. Milling the existing pavement layers up to a depth of 300 mm;
2. Treatment with bitumen emulsion or foamed bitumen, often in combination with addition of crusher dust, fresh aggregates if required, and a small percentage of active filler such as cement , lime , fibre etc.
3. Adding compaction water; and
4. Repaving the mix.
5. Compaction with a pad foot roller when the compacted thickness exceeds 150mm.

In a CIPR process as described above, the top bituminous layer (Reclaimed asphalt pavement) as well as a part or whole of the granular or stabilized base layer are recycled. The residual binder content added to the mineral aggregates in the process of CIPR is generally lower (<4 per cent) in comparison to hot bituminous mixtures. The recycled product is not used as final surfacing layer but used as base or sub-base layer.

B. ADVANTAGES OF C.I.P.R.

CIPR is an attractive alternative for highway rehabilitation operations because of its economic and environmental advantages. Major economic advantages involve the recycling of existing road surface aggregates and reduced haul requirements for incorporating new aggregates. In India, there are many regions where aggregates resources are limited or will be depleted in the near future. Aggregate haul in these regions is quite expensive. In addition, impacts on adjacent haul roads are minimized or eliminated because of reduced new aggregate requirements. A major environmental advantage involved in the use of cold in-place recycling is that there is no requirement for heat during construction work. CIPR is an energy efficient process that does not produce harmful emissions and does not require the bituminous mixtures to be transported to an off-site plant. In addition, transportation of large amounts of aggregate are reduced and hence it is fuel efficient also.

C. EXPERIMENTAL METHOD

In this study, the major test conducted will be Marshall test and Indirect tensile strength test (ITS). A number of combination of materials and binders will be studied.

Variations with SS_2as binder			
R.A.P.	Fresh aggregate	Emulsion – SS_2	Cement – OPC 43
R.A.P.	Fresh aggregate	Emulsion – SS_2	Fibre – Recron 3s
R.A.P.	Fresh aggregate	Emulsion – SS_2	Hydrated Lime
R.A.P.	Fresh aggregate	Emulsion – SS_2	Fly Ash

Variations with Old Engine Oil as binder			
R.A.P.	Fresh aggregate	Old Engine oil	Cement – OPC 43
R.A.P.	Fresh aggregate	Old Engine oil	Fibre – Recron 3s
R.A.P.	Fresh aggregate	Old Engine oil	Hydrated Lime
R.A.P.	Fresh aggregate	Old Engine oil	Fly Ash

IV. CONCLUSION

The results of the test conducted for the first combination i.e. the combination of RAP with cement and emulsion SS_2 are following:
ITS_{dry}: 264.67 kPa
$ITS_{wet:}$ 201.53 kPa
Marshall $_{dry}$: 16.94 KN
Marshall $_{wet:}$ 10.20 KN
The values mentioned above are the average of three values for each test. The results of the Marshall and ITS test mentioned above will be compared with all the other combinations in this study. Also this study will determine which of these combinations are passing the required parameters and whether they are economical for practical use.

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Research Article Volume 9 Issue No. 5

Improvement in Recycling of Reclaimed Asphalt Pavements using Different Materials in Flexible Pavement

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Abstract:
The objective of this paper is to study properties, strength, advantages and disadvantages of RAP (Recycling of Reclaimed Asphaltic Pavement) using different materials in flexible pavement. This is a Cold-in-Place Recycling (CIPR) method for flexible pavements. This was experimented on the base course of pavement by replacing the WMM (wet mix macadam) layer of Flexible Pavement which is non bituminous. This method has various economical and environmental advantages which involve the recycling of existing road surface aggregates and reduced haul requirements for incorporating new aggregates. By recycling existing in-place road materials and providing additional strength with mixing of different emulsions or strengthening agents, new aggregates and bitumen requirements are reduced. Various Laboratory tests were conducted by using different binding materials and different materials like cement, fly ash, lime, fibre (Recron 3s Fibre).

1. INTRODUCTION

Recycling of Reclaimed Asphalt Pavements abbreviated as (RAP) is required to be used for technical, economical, and environmental reasons. It has been favoured all over the world over the use of virgin materials because of the increasing cost of bitumen, the scarcity of quality aggregates, and the persistent need to preserve the environment. The use of RAP also decreases the amount of waste produced and helps to resolve the disposal problems of highway construction materials. When asphalt pavements which have reached the end of their service life are frequently rehabilitated by milling the existing pavement surfaces and replacing the milled portion with new hot mix asphalt (HMA). A large amount of recycled asphalt pavement (RAP) is generated every year because of this practice. So now the use of RAP should be in practice as this reduces the cost of construction materials, reduces the use of petroleum-based products and helps conserving the natural resources by requiring less virgin aggregate and asphalt in road construction projects. There are several recycling techniques, such as hot mix plant recycling, hot in-place recycling, cold mix plant recycling, cold in-place recycling, and full depth reclamation which have evolved over the past 35 years. In-place recycling not only reduces the use of new materials but also reduces emissions, traffic, and energy associated with the transport and production of these materials. Cold Mix Recycling is a method of recycling where RAP, new aggregate (if needed) and emulsified bitumen or foamed bitumen without the need for heat are mixed in a centrally located cold mix plant. Many old road having thick bituminous layers can be converted in four and six lane projects and the entire RAP and aggregates can be reclaimed by milling machine and reused in new construction work. Since the components of a cold mix plant are fairly portable, it can be assembled in satellite locations close to a project site. Cold recycled mix is hauled to the job site with conventional dump trucks or belly dump trucks. Placement and compaction of cold recycled mixes are done with the same conventional pavers and rollers used for hot mix asphalt construction. Cold recycled mixes are normally coated with hot mix asphalt or surface dressing (chip seal) depending on the expected traffic level for the finished pavement.

2. EXPERIMENTAL WORK AND MATERIALS USED

2.1 MATEIALS USED

2.1.1 RECLAIMED ASPHALT PAVEMENT (R.A.P.) - is defined as removed pavement materials containing asphalt and aggregates. 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. Using RAP material has well-recognized financial and environmental benefits. Although most of the produced RAP is recycled, a large portion of it is wasted or down-graded when used in landfills, embankment or base layers.

2.1.2 BITUMEN

Asphalt, also known as bitumen is a sticky, black, and highly viscous liquid or semi-solid form of petroleum. It may be found in natural deposits or may be a refined product, and is classed as a pitch. Before the 20th century, the term asphaltum was also used. The word is derived from the Ancient Greek - ásphaltos. The primary use of asphalt is in road construction, which is around 70% , where it is used as a binder mixed with aggregate particles to create asphalt concrete. It is also used as an bituminous waterproofing product , including production of roofing felt and for sealing flat roofs.

2.1.3 EMULSION

An emulsion is a mixture of two or more liquids that are normally immiscible (un-mixable or un-blendable). Emulsions are part of a more general class of two-phase systems of matter called colloids. Although the terms colloid and emulsion are sometimes used interchangeably, emulsion should be used when both phases, dispersed and continuous, are liquids. In an emulsion, one liquid (the dispersed phase) is dispersed in the other (the continuous phase). Examples of emulsions include vinaigrettes, homogenized milk, and some cutting fluids for metal working. The word "emulsion" comes from the Latin

mulgeo, mulgere "to milk",[specify] as milk is an emulsion of fat and water, along with other components. Two liquids can form different types of emulsions. As an example, oil and water can form, first, an oil-in-water emulsion, wherein the oil is the dispersed phase, and water is the dispersion medium. Bitumen Emulsion (SS_2) is used in this project.

2.1.4 OLD ENGINE OIL

Used engine oil or old engine is used as an emulsion in this study. The idea was to use this waste material for road construction as it shows some binding properties with fibre (Recron 3s). The used engine may be derived from any mechanical machine like generators etc.

2.1.5 CEMENT

A cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Cement is the most widely used material in existence and is only behind water as the planet's most-consumed resource. OPC_{43} is used in this project.

2.1.6 FLYASH

Fly ash is a fine powder that is a by-product of burning pulverized coal in electric generation power plants. Fly ash is a puzzolan, a substance containing aluminous and siliceous material that forms cement in the presence of water. When mixed with lime and water, fly ash forms a compound similar to Portland cement. This makes fly ash suitable as a prime material in blended cement, mosaic tiles, and hollow blocks, among other building materials. When used in concrete mixes, fly ash improves the strength and segregation of the concrete and makes it easier to pump. Fly ash can be used as prime material in many cement-based products, such as poured concrete, concrete block, and brick. One of the most common uses of fly ash is in Portland cement concrete pavement or PCC pavement. Road construction projects using PCC can use a great deal of concrete, and substituting fly ash provides significant economic benefits.

2.1.7 HYDRATED LIME

Lime is a calcium-containing inorganic mineral composed primarily of oxides, and hydroxide, usually calcium oxide and or calcium hydroxide. The word lime originates with its earliest use as building mortar and has the sense of sticking or adhering. These materials are still used in large quantities as building and engineering materials (including limestone products, cement, concrete, and mortar, as chemical feedstock, and for sugar refining, among other uses. Lime industries and the use of many of the resulting products date from prehistoric times in both the Old World and the New World. Lime is used extensively for wastewater treatment with ferrous sulphate. The rocks and minerals from which these materials are derived, figure ally limestone or chalk, are composed primarily of calcium carbonate. They may be cut, crushed, or pulverized and chemically altered. Burning (calcination) of these minerals in a lime kiln converts them into the highly caustic material burnt lime, unslaked lime or quicklime (calcium oxide) and, through subsequent addition of water, into the less caustic (but still strongly alkaline) slaked lime or hydrated lime (calcium hydroxide, $Ca(OH)_2$), the process of which is called slaking of lime.

2.1.8 FIBRE

Research and development work in Fibre Reinforced Concrete (FRC) composites began in India in the early 1970s. Fibre reinforced concrete was developed to overcome the problems associated with cement based materials such as low tensile strength, poor fracture toughness and brittleness of cementations composites. In the beginning, FRC was primarily used for pavements and industrial floors but now a day FRC composite is being used for a wide variety of applications including bridges, tunnel and canal linings, hydraulic structures, pipes, safety vaults and structural members. Recron-3s fibre is also used in concrete element such as RC and PC lintel, Beam, column, flooring and wall plastering, foundation, tanks, manhole cover and tiles plastering, Road and pavement, hollow block and precast, Railway slippers, swimming pools. There are so many type of polymer fibre available as secondary construction materials. The Recron-3S fibre is one of them, and The Reliance Industry Limited (RIL) has launched Recron-3S. Recron-3s polymer fibre for mixing concrete and mortar for improving certain properties of the concrete and mortar. Fibres have special triangular shape for better anchoring with other ingredient of the mix. Recron-3S fibre is available in 6mm and 12mm length.

2.2 METHODOLOGY

Design for Bitumen Emulsion RAP Mixes:

The first step is Gradations of Aggregates: The aggregates from RAP may not have the required gradation for a good mix. RAP alone has poor internal friction and its CBR may be as low as 30 though a fresh close graded aggregates may have CBR as high as 200. Addition of crusher dust containing particle size from 6 mm to 0.075 mm and fines passing 0.075 mm adds to angle of internal friction as well as some cohesion to the RAP mixes. The crusher dust requirement can be 15 to 30 per cent and 1 per cent cement or lime or both by weight of dry aggregates helps in dispersion of the bitumen emulsion in the mix. Lime modifies the clay that may have contaminated the RAP. RAP may need re-crushing if they have lumped up during storage. If milled aggregates are from those of Bituminous Macadam, it may be open graded and some additional fresh aggregates may be necessary for the adjustment of gradation. The grading of the blend of RAP/fresh aggregates and crusher dust should meet the requirement shown in Table following table 1 adopted from the South African Standard 'TG2 (64) CSIR Built Environment, Pretoria. The grading has been slightly adjusted to correspond to the sieve size designation in MORTH.

Table.1. Gradation of Rap Mixes

Sieve size,mm	per cent passing
45	100
37.5	87-100
26.6	77-100
19	66-99
13.2	67-87
4.74	33-50
2.36	25-47
0.60	12-27
0.3	8-21
0.075	2-9

Some RAP may be contaminated with clay which might have risen from the subgrade during the wet weather. Addition of 2 per cent lime would modify the clay and the mix becomes

suitable for use. The second step is to determine the Bitumen Emulsion Type: Since the blend of RAP and crusher dust consists of plenty of fine particles, only slow setting emulsion (SS2) with minimum residual bitumen content of 60 per cent is recommended to prevent the emulsion from breaking during the mixing and construction. The third step is to Determination of Optimum Fluid Content **:** A RAP bitumen emulsion mix can be compacted to maximum density only at optimum fluid content. Compaction tests are to be done at different fluid content to arrive at the optimum fluid content. Procedures given in Manual 14 'The design and Use of Granular Emulsion Mixes' Published by South African Bitumen and Tar association (SABITA) (7) and TG-2 of South Africa (64) have been suggested for mix design. Users may adopt other methods of mix design given in 'Cold Mix Recycling' and 'Asphalt cold Mix Manual (MS-14)'Published by Asphalt Institute, USA.

2.3 EXPERIMENTAL METHOD

In this study, the major test conducted were Marshall test and Indirect tensile strength test (ITS). A number of combination of materials and binders were used as follows:

Table.2. Variations with Ss_2 as Binder

Variations with SS_2 as binder			
R.A.P.	Fresh aggregate	Emulsion – SS_2	Cement – OPC 43
R.A.P.	Fresh aggregate	Emulsion – SS_2	Fibre – Recron 3s
R.A.P.	Fresh aggregate	Emulsion – SS_2	Hydrated Lime
R.A.P.	Fresh aggregate	Emulsion – SS_2	Fly Ash

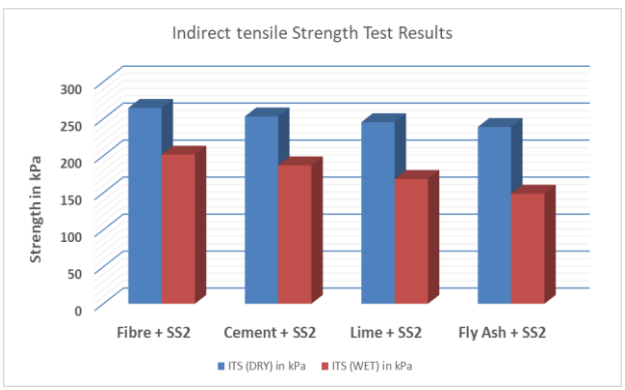
Table.3. Variations with Old Engine Oil As Binder

Variations with Old Engine Oil as binder			
R.A.P.	Fresh aggregate	Old Engine oil	Cement – OPC 43
R.A.P.	Fresh aggregate	Old Engine oil	Fibre – Recron 3s
R.A.P.	Fresh aggregate	Old Engine oil	Hydrated Lime
R.A.P.	Fresh aggregate	Old Engine oil	Fly Ash

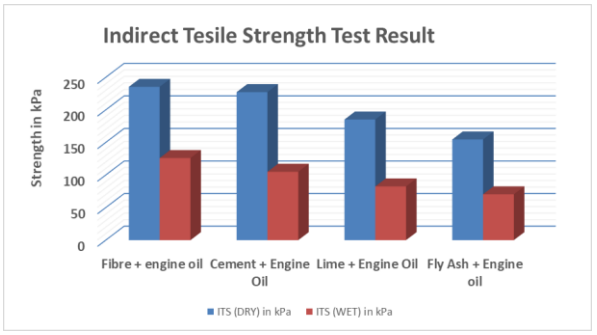
3. RESULT AND OBSEVATIONS

3.1 GRAPHS

3.1.1 Comparing I.T.S. (dry) and I.T.S. (wet) values for each combinations:

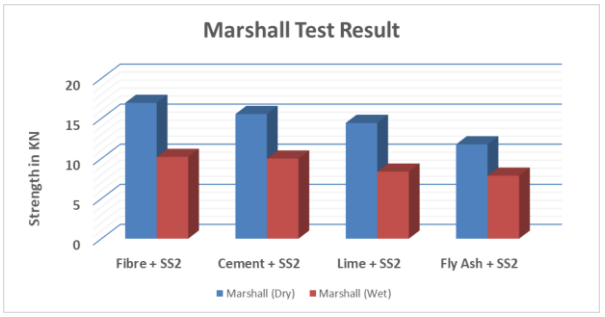


Graph.1. Variations with emulsion SS2 (I.T.S.)

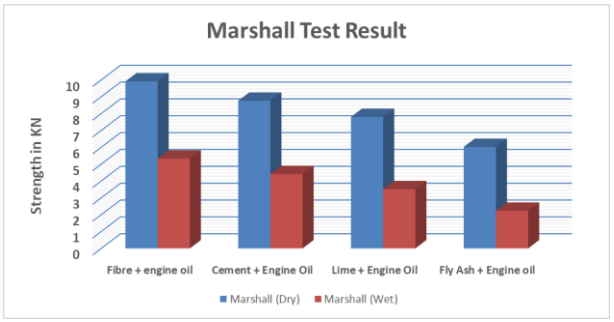


Graph.2. Variations with Old Engine Oil (I.T.S.)

3.1.2 Comparing Marshall (dry) and Marshall (wet) values for each combinations:

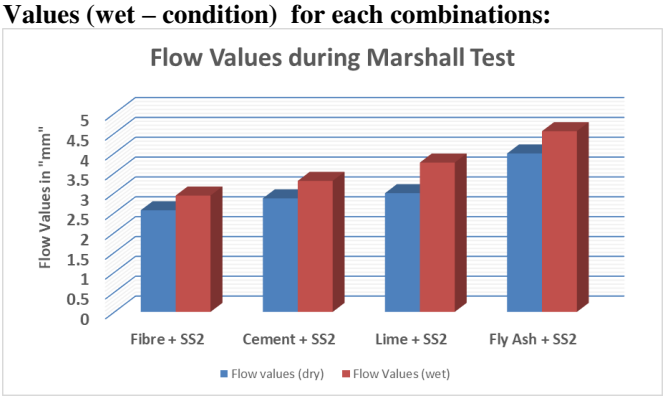


Graph.3. Variations with SSs (Marshall)

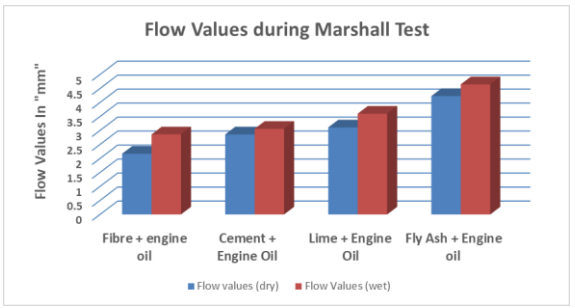


Graph.4. Variations with Old Engine Oil (Marshall)

3.1.3 Comparing Flow Values(dry – condition) and Flow Values (wet – condition) for each combinations:



Graph.5. Variations with SS2 (Flow Value)



Graph.6. Variations with Old Engine Oil (Flow Value)

3.2. AVERAGE VALUES: (TABLE - 4)

Tabl.4. Average values

Combinations	ITS (dry)	ITS (wet)	Marshall (Dry)	Marshall (Wet)	Flow values (dry)	Flow Values (wet)
Fibre + SS2	264.67	201.53	16.94	10.20	2.56	2.93
Cement + SS2	253.10	187.03	15.55	9.99	2.86	3.30
Lime + SS2	245.39	168.68	14.44	8.36	2.99	3.76
Fly Ash + SS2	238.92	148.78	11.77	7.86	3.99	4.55
Fibre + engine oil	235.37	126.03	9.91	5.33	2.17	2.86
Cement + Engine Oil	227.25	104.96	8.76	4.41	2.86	3.06
Lime + Engine Oil	185.19	82.45	7.80	3.51	3.11	3.60
Fly Ash + Engine oil	154.56	70.37	6.02	2.23	4.23	4.65

3. CONCLUSION

As several researchers have suggested that high-quality base courses could be obtained by blending RAP with fresh (or virgin) aggregates and stabilizing RAP with chemical additives such as cement. So in this study we completely replaced cement with hydrated lime, fly-ash and Recron 3s fibre respectively as chemical additives to obtain their strength. Which gave the following conclusions:

- Recron 3s Fibre showed maximum strength in combination with SS_2 as well as old engine oil.
- Variations with Cement gave lesser strength than fibre combinations but more than lime and fly ash combinations.
- Fly ash showed poor strength , i.e. , Fly ash combinations gained least strength.
- As Recron 3s fibre is a great construction material (as per previous study) , it should be used more frequently.
- Usage of Recron 3s fibre reduces cost of project as it may reduce the cost of maintenance work by reducing cracks and permeability and hence durability increases.
- Fibre can also be used for National Highway projects and expressways , though the initial project cost may be more as it's an expensive alternative but maintenance cost may be less as well it will be more durable.
- Fly – ash with SS_2 shows less strength but fairly above the minimum parameters , so it can be used for less important road projects as the cost of fly ash is minimal or no cost and only transportation cost will be applied. Therefore fly ash can be the cheapest alternative.
- Lime can also be used as alternative to cement as it shows fair amount of strength but it is an expensive alternative.
- Old or used engine oil can be used as construction material in place of regular emulsions as it shows some binding properties with recron 3s fibre. But engine oil should be used in the WMM layer only if we are using 125 µm polythene sheet beneath the WMM layer.

So as per above conclusions we can assume that the thickness of the WMM layer can be decreased by using fibre with emulsion SS_2 as it shows strength more than cement , which will reduce the construction cost of a road project. Old engine oil can also be replaced with SS_s as a binding material at least for rural roads or roads with less importance. As old or used engine oil is almost free so it will save the cost of purchasing expensive emulsions.

4. REFERENCES

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