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# Mix Design of Emulsion Treated Reclaimed Asphalt Pavement and Its Implementation at Field

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

***Keywords: RAP1-Reclaimed Asphalt Pavement, DBM2-Dense Bitumenous Macadam,ITS3- Indirect Tensile Strength,MDD4-Maximum Dry Density,OMC5-Optimum Moisture Content, HMA6-Hot Mix Asphalt, UCS7-Unconfined Compressive Strength, CIPR8-Cold In Place Recycling.***

## I. INTRODUCTION

In India more than 80% roads are bituminous paved which are continuously strengthening, widening & developing with each passing day. Most of the road construction done by the conventional method in which huge quantity of fresh material like as aggregates, bitumen binder is required and waste material removed from existing roads were not utilized properly and dumped anywhere along the road sides. Due to this type of dumping land fertility get deteriorated and it is also enhance the environmental pollution. Second thing is that lack of good quality aggregate, we are depleted the natural resources. Nowadays many construction technologies introduced over the world to preserve the environment and better utilization of existing road material. Emulsion Treated Reclaimed Asphalt Pavement as a base course in flexible pavement is one of those methods. In India these type of methods is very less implemented at ground level but in this project we are trying to use Reclaimed Asphalt Pavement it is a positive step to preserve the environment and better utilization of recycled material from existing pavement. It is also to be noted that thicknesses of existing pavements are increasing due to addition of periodic overlays. The rise of road levels causes serious drainage problems in the urban areas. In such cases, the existing bituminous pavement usually consisting of Dense Bituminous Macadam (DBM) and Bituminous Concrete (BC) can be milled and the Reclaimed Asphalt Pavement (RAP) transported to cold mix plant for recycling on service roads and/or main line. Bituminous pavements are 100% recyclable. Milling of existing pavements and recycling the same after suitable modification will address problems of drainage and conservation of materials.

We are plan to treat the recycled existing bituminous material by emulsion. WMM batching plant will be used for production of these mix after some modify a very effective technique to utilize recycled material in better way. Cold Asphalt Emulsion Mixtures (CAEMs) are economical, environmentally friendly and sustainable alternatives to hot mix asphalts. One advantage of using bitumen emulsions is that it is liquid at ambient temperatures and can be mixed with aggregates without the need to heat the stone and the bitumen as is the case with hot mix asphalts.



Outcome from Milling Machine

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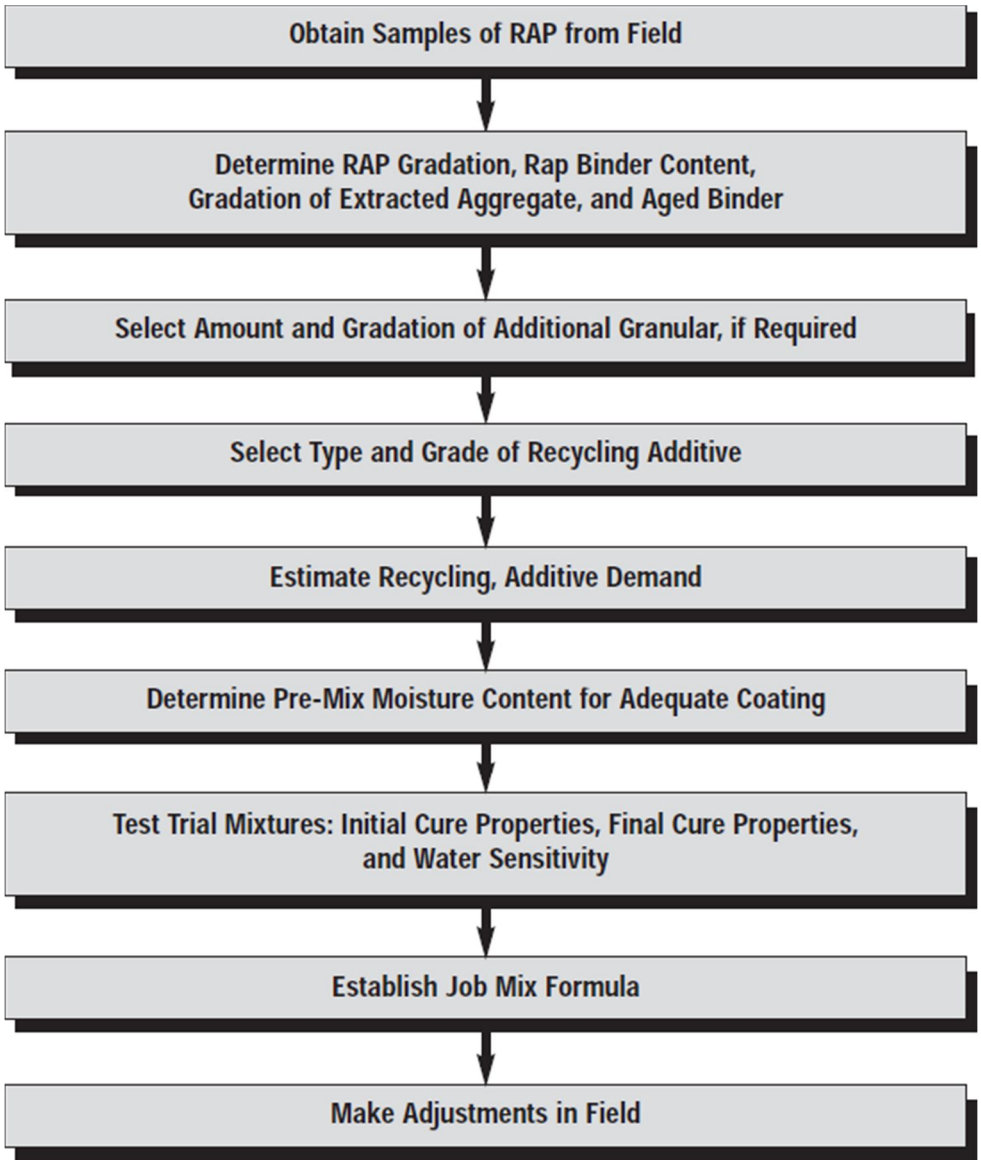
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## II. OBJECTIVE

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

*1)* Essential for future construction methodology
*2)* Saving of natural resources
*3)* Cost effective
*4)* Environmental friendly
*5)* Solve disposal problem of bituminous waste
*6)* Multi-purpose utilization of recycle bituminous material
*7)* Saving of fuel consumption in cold mix process

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




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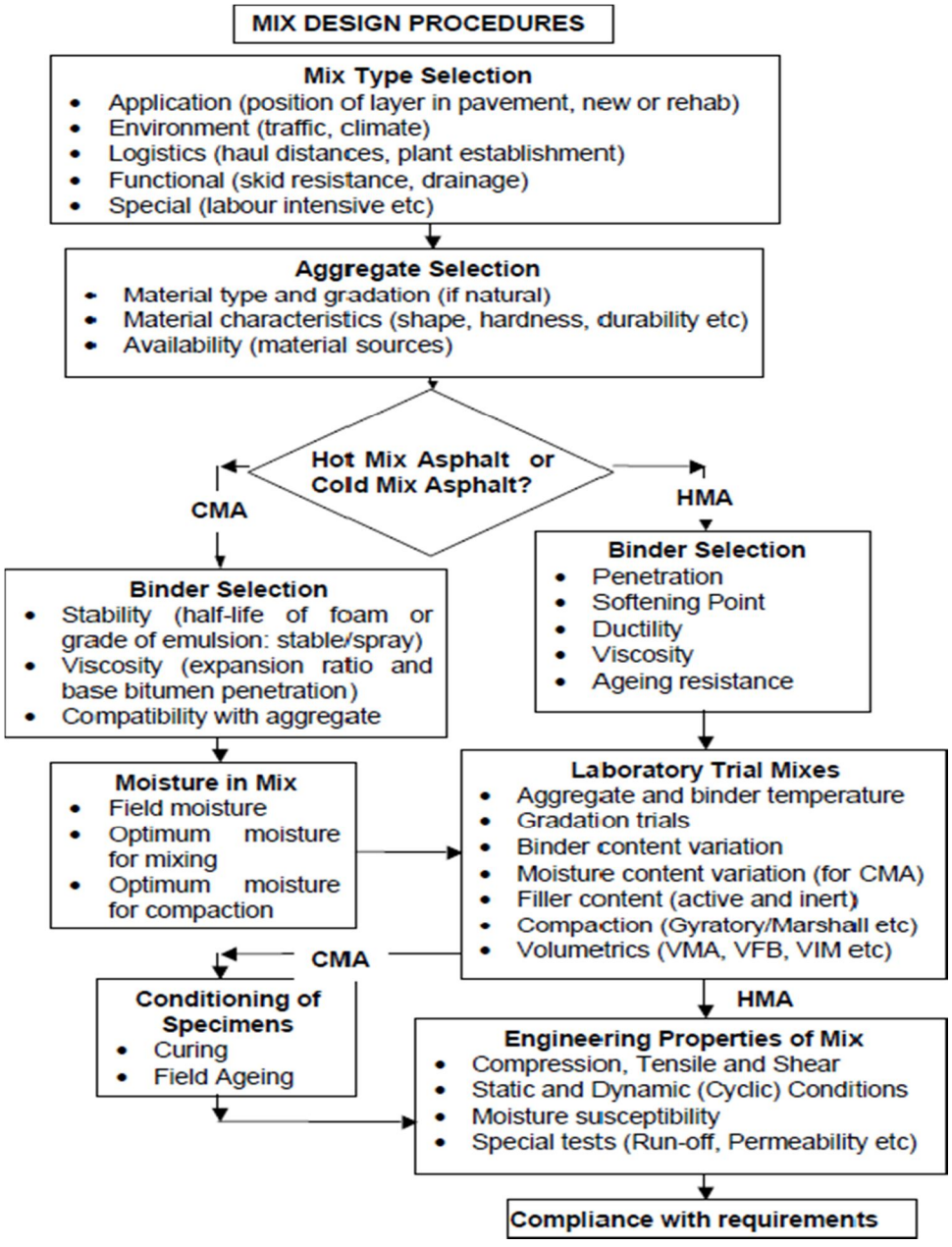
## III. MATERIAL & METHODOLOGY

The main purpose of present research is to utilize the recycled existing bituminous layer after treating with Emulsion in optimum proportioning with desirable properties, which satisfies the following characteristics, Environmental friendly, saving of natural resources, cost effective, solve disposal problem of bituminous waste, Saving of fuel consumption. Also assure the serviceability of mix design to check the quality of laid course at site.

In order to achieve the above mentioned, objective study work has been divided into three main parts:

*1)* Accumulation of material
*2)* Experimental procedure
*3)* Results and discussions

### *A. Job Mix Formula*




General Mix Design Procedure

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1) *Accumulation of Material:* Material collection is the basic and important step in any project. Also, the material which issued in a project should not cause any damage to the environment. In this research, recycled material obtained from existing pavement of Biaora Dewas project. Virgin aggregates taken from Sunera crusher situated at ch.267.800 for right proportioning of aggregates.

| Sr. No. | Type of Aggregate | Source |
|---|---|---|
| 1 | 20mm Aggregate | OSEPL Crusher, Sunera |
| 2 | Stone Dust | |
| 3 | SS2 Emulsion | A.R. Thermosets Pvt Ltd. Kanpur |
| 4 | RAP Material | Existing road Pavement (NH-3) Biaora to Dewas |
| 5 | Cement | Ultratech |

Table-1: List of Ingredients

2) *Cement:* Cement were used as a filler material in this mix design. Cement is the important binding material in today's construction world, Ordinary Portland Cement (OPC) 43 grade confirming to IS: 8112-2013 cement used. Table 2 gives the properties of cement used. Cement sample were collected from cement store of batching plant at Sunera camp and tests were performed in site laboratory. Results obtained are as follows.

| S. No. | Description of test | Test procedure followed by | Results obtained | Requirement of IS: 8112-2013 |
|---|---|---|---|---|
| 1 | Consistency Test | IS 4031 PART 4$^{th}$ & 5$^{th}$ | 28 % | |
| 2 | Initial setting time | IS 4031 PART 4$^{th}$ & 5$^{th}$ | 120 minutes | Min. 30 minutes |
| 3 | Final setting time | IS 4031 PART 4$^{th}$ & 5$^{th}$ | 230 minutes | Max. 600 minutes |
| 4 | Fineness | IS 4031 PART 1$^{st}$ | 96.99 % | Min 90 % |
| 5 | Compressive Strength Test | IS 4031 PART 6$^{th}$ | 29.44 MPA | Min 23MPAAt 3 Days |
| | | | 40.49 MPA | Min 33MPA At 7 Days |
| | | | 52.87 MPA | Min 43 MPA At 28 Days |

Table-2: Properties of cement



Cement (filler) Testing at Laboratory

3) *Stone/Crusher Dust:* In this analysis we are using crushed stone dust as a fine aggregate which is taken from Sunera village quarry and crushed at Sunera crusher. Crusher dust for mix design taken from Camp-2 stock yard and some test were conducted on collected sample such as gradation, specific gravity, water absorption etc. The properties were analyzed as per BIS standard. As per IRC 37-2012, 15 to 30% fine aggregate can be introduced in emulsion treated reclaimed asphalt design. 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.



Stone Dust sampling from Sunera Camp Stock Yard

| SPECIFIC GRAVITY AND WATER ABSORPTION TEST | | | | | | |
|---|---|---|---|---|---|---|
| S. No. | Determination | | Trial I | Trial II | Trial III | Average |
| 1 | Wt. Of Dry Sample [SSD] [gms] | A | 509.0 | 514.0 | 511.0 | |
| 2 | Wt. Of Pycnometer+Water [gms] | B | 1631.0 | 1631.0 | 1631.0 | |
| 3 | Wt. Of Pycnometer+Water+Sample [gms] | C | 1969.0 | 1968.0 | 1970.0 | |
| 4 | Wt. of Oven Dry Sample [gms] | D | 500.0 | 505.0 | 503.0 | |
| 5 | Water Absorption [%] | [(A-D)/D]*100 | 1.80 | 1.78 | 1.59 | 1.72 |
| 6 | Specific Gravity | D/(A-[C-B]) | 2.924 | 2.853 | 2.924 | 2.901 |
| 7 | Aparant Specific Gravity | D/(D-[C-B]) | 3.086 | 3.006 | 3.067 | 3.053 |

Table-3: Specific gravity and water absorption test




Water absorption and specific gravity test at site laboratory

4) *Recycle Material (RAP):* Recycle material accumulated from Biaora to Dewas (section of NH3) highway existing bituminous pavement. Existing bituminous layer milled by cold recycling process up to 200 mm and milled material transported to the Sunera camp 2. Here recycled material stored in stockpile. Sample taken from stock pile for mix design trial and various test were performed in the site laboratory like as gradation of recycle material, aggregate impact value test, bitumen extraction from recycle material. Milling material shared maximum percentile of mix design hence it is necessary to assure the quality of recycle material before use as a main ingredient of mix design. If milling material contaminated with clay, then we are used 2 % lime as per IRC 37-2012 but there is no situation arise for doing so**.** RAP is the pulverized excavated material that has been recovered usually by milling that is used as an aggregate material for the rehabilitation and maintenance of roads. The use of RAP as an alternative to new virgin aggregate materials is gaining worldwide attention as a sustainable, economic, widely available and environmentally friendly option. The RAP to be used should be properly tested and characterised to ascertain its properties that include the gradation, moisture content, density, elongation and flakiness index, the residual binder content, compatibility, penetration and softening point of the residual binder in the RAP. RAP aggregate materials can be obtained from pulverised/crushed field samples, extracted pavement cores or samples produced and crushed in the laboratory. Ideally, it is advised that pulverised/crushed samples should be obtained from field where possible. All materials used should be representative for both grading and shape with their properties properly characterised and evaluated. In characterising and evaluating the properties of RAP aggregate materials, these properties are particularly important which include aggregate gradation, particle density and water absorption, moisture content, RAP binder composition (binder content, gradation after extraction, softening point, penetration index) and the physical properties of the aggregates (shape, elongation and flakiness index). This information is valuable as it is the first step in characterising the aggregates and understanding the material properties.



Figure-: Milling of existing bituminous layer at site & Sampling of material from stockpile

| AGGREGATE IMPACT VALUE | | | | | |
|---|---|---|---|---|---|
| As per IS 2386 - Part IV | | | | | |
| S. No | Determination | Trial I | Trial II | Trial III | Average |
| 1 | Total Wt. Of Oven-dried Sample(passing 12.5mm - Retained 10mm Sieve )- W1 [gms] | 360.5 | 362.5 | 367.5 | 12.15 % |
| 2 | Wt. Of Material Retained on 2.36mm after testing - W2 [gms] | 315 | 320 | 323 | |
| 3 | Wt. Of Material Passing on 2.36mm after testing - W3 [gms] | 46 | 43 | 45 | |
| 4 | Difference in weight after testing (W1-W2-W3) | 0.0 | 0.0 | 0.0 | |
| 5 | Aggregate Impact Value (%) = (W3/W1)x100 | 12.62 | 11.72 | 12.11 | |

Table-4: Aggregate Impact Value

| Bitumen Extraction Test | | | | |
|---|---|---|---|---|
| As per IRC SP-21 | | | | |
| Sr. No. | DESCRIPTION | OBSERVATION | | |
| | | 1 | 2 | 3 |
| 1 | Wt. of Sample Before Extraction (gms) | 1560 | 1264 | 1204 |
| 2 | Wt. of Filter Paper Before Extraction (gms) | 8.66 | 9.83 | 6.91 |
| 3 | Wt. of Filter Paper After Extraction (gms) | 9.29 | 10.3 | 7.16 |
| 4 | Wt. of Aggregate in Filter Paper (gms) = (3-2) | 0.63 | 0.47 | 0.25 |
| 5 | Wt. of Sample After Extraction (gms) | 1509 | 1236 | 1151 |
| 6 | Wt. of Bitumen in gms = 1-(4+5) | 50.37 | 27.53 | 52.75 |
| 7 | % of Bitumen = (6/1)*100 | 3.23 | 2.18 | 4.38 |
| 8 | Average % of Bitumen | 3.26 | | |

Table-5 Bitumen Extraction Test



AIV test of milling material

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5) *Emulsion (SS2):* Bitumen emulsion is a dispersion of fine minute droplets of bitumen into water manufactured by using emulsifying agents to emulsify bitumen in water. A major objective of using bitumen emulsions is to obtain a product that can be used without heating. Emulsion performed as a binder which is very important ingredient. So we performed some quality assurance test on the emulsion SS2. Sample were taken from stock container for testing in site laboratory**.**




Fig-: Bitumen Extraction test of milling material



Fig-: Sampling of Bitumen emulsion from stock yard



Fig-:: Residue content test of emulsion

| RESIDUE CONTENT BY EVAPORATION | | | | | | |
|---|---|---|---|---|---|---|
| As per IS 8887-ANNEX J | | | | | | |
| S. No | Determination | Trial I | Trial II | Trial III | Remarks | Requirements |
| 1 | Weight of Sample+Beaker+Glass Rod [gms], | 402.72 | 402.72 | 402.72 | Place the Sample for 3 hrs At Temp 163 ±2.8°C | Minimum 60% as per IRC 37-2012/ IS 8887-2004 |
| 2 | Weight of Sample+beaker+residue After Removing from Ovem +[gms], A | 382.90 | 382.75 | 383.20 | | |
| 3 | Tare weight of Beaker+Weight of Glass Rod [gms],B | 352.72 | 352.72 | 352.72 | | |
| 4 | Residue Percent=2(A-B) | 60.36 | 60.06 | 60.96 | | |
| 5 | Average Residue Content(%) | 60.46 | | | | |

Table-7: Residue content by evaporation



Figure-: Penetration test in site laboratory

| PENETRATION TEST ON RESIDUE OF EMULSION SS2 (As Per IS: 1203) | | | | |
|---|---|---|---|---|
| Description | Reading - 1 | Reading - 2 | Reading - 3 | Remarks |
| Initial Dial Gauge Reading | 0 | 0 | 0 | 60 to 120 (As per IS 8887-2004) |
| Final Dial Gauge Reading | 88 | 90 | 89 | |
| Penetration (0.1 mm) | 88 | 90 | 89 | |
| Average | 89.00 | | | |

Table-8: Penetration test on residue of emulsion SS2

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Job No : 1907-1-185-2690
Booking No : RG1920/1/4591
Booking Date : 18-07-2019
Customer Ref No. : EI/TL/MP/BD/2019/1426
Customer Ref Dt. : 06-07-2019
ULR NO. : TC544419000013336F

**Sample Description:**

ONE SAMPLE DESCRIBED AS EMULSION (SS-2) MS/THERMOSET PVT.LTD,KANPUR,UP,DT OF SAMPLING 14.06.2019,LOCATION OF SAMPLING-SUNERA CAMP -02,BATCH No.70,SUB-FOUR LANING OF BIAORA-DEWAS SECTION FROM KM.426.100 TO KM.566.450 OF NH-3 IN THE STATE OF MADHYA PRADESH UNDER NHDP PHASE IV ON BOT (TOLL) BASIS ON DBFOT PATTERN),SOURCE OF MATERIAL:ART PVT LTD,MATERIAL USED FOR:EMULSION TREATED RAP,SAMPLED BY:JOINTLY; WAS RECEIVED.

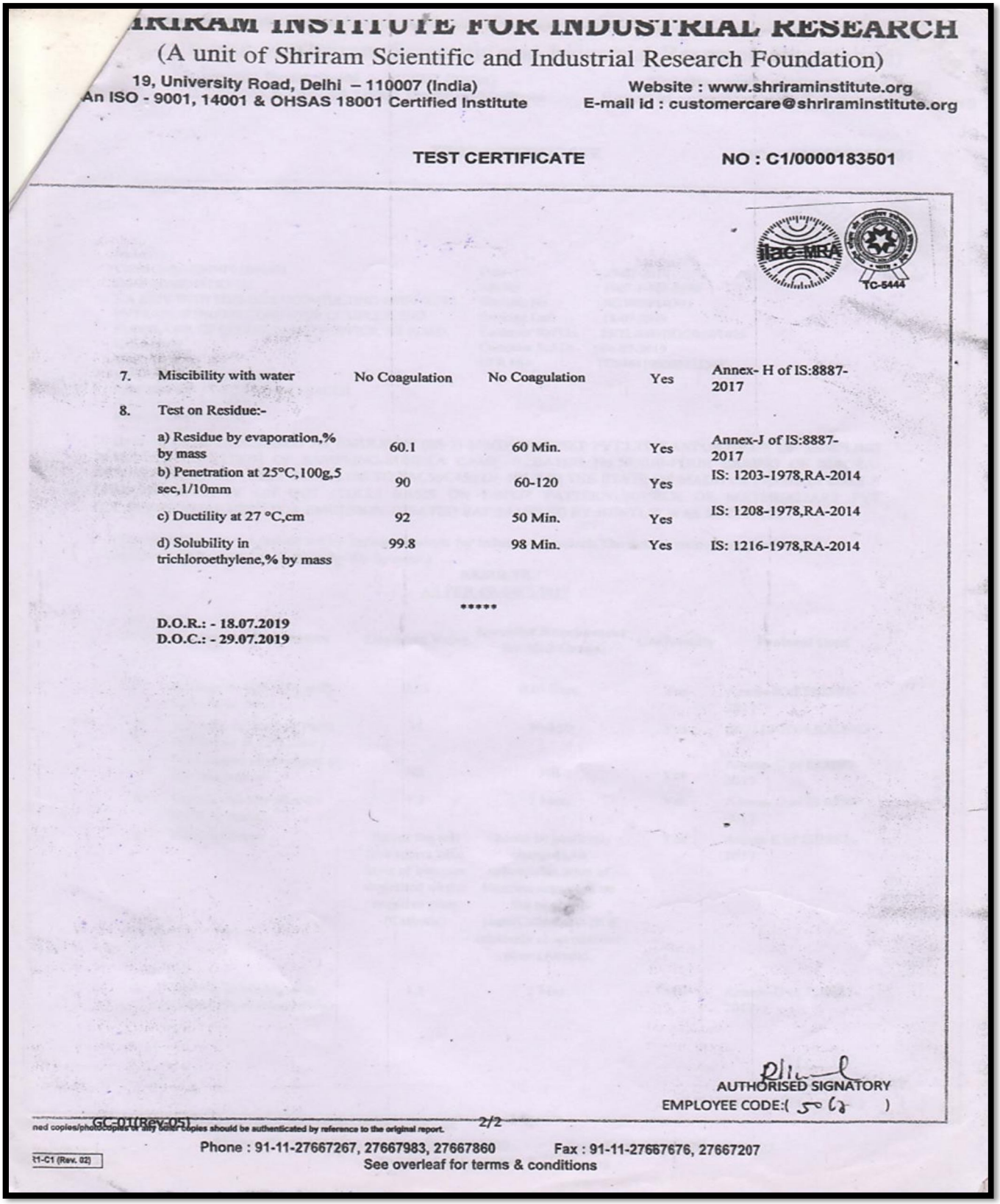
(The Sampling was not carried out by Shriram Institute for Industrial Research.The sample particulars provided in certificate are based on declaration by the Sponsor.)

**RESULTS**
**AS PER IS: 8887-2017**

| S.No | Name of Parmeters | Observed Value | Specified Requirement for SS-2 Grade | Conformity | Protocol Used |
|---|---|---|---|---|---|
| 1 | Residue on 600 micron IS Sieve,% by mass | 0.03 | 0.05 Max. | Yes | Annex-B of IS:8887-2017 |
| 2 | Viscosity by Saybolt Furol viscometer at 25°C,Sec | 31 | 30-150 | Yes | IS:3117-2004,RA-2014 |
| 3 | Coagulation of emulsion at low temperature | Nil | Nil | Yes | Annex- C of IS:8887-2017 |
| 4 | Storage stability after 24 hrs,% by mass | 1.3 | 2 Max. | Yes | Annex- D of IS:8887-2017 |
| 5. | Particle Charge | Passes the test (An appreciable layer of bitumen deposited on the negative plate (Cathode) | Should be positively charged.(An appreciable layer of bitumen deposited on the negative plate(Cathode) with a relatively clean positive plate (Anode). | Yes | Annex-E of IS:8887-2017 |
| 6. | Stability to mixing with cement (% of coagulation) | 1.2 | 2 Max. | Yes | Annex- G of IS:8887-2017 |

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| | | | | | |
|---|---|---|---|---|---|
| 7. | Miscibility with water | No Coagulation | No Coagulation | Yes | Annex- H of IS:8887-2017 |
| 8. | Test on Residue:- | | | | |
| | a) Residue by evaporation,% by mass | 60.1 | 60 Min. | Yes | Annex-J of IS:8887-2017 |
| | b) Penetration at 25°C,100g,5 sec,1/10mm | 90 | 60-120 | Yes | IS: 1203-1978,RA-2014 |
| | c) Ductility at 27 °C,cm | 92 | 50 Min. | Yes | IS: 1208-1978,RA-2014 |
| | d) Solubility in trichloroethylene,% by mass | 99.8 | 98 Min. | Yes | IS: 1216-1978,RA-2014 |

*****

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Test Report Of Emulsion Ss2 From Nabl Approved Lab

6) *Fresh Aggregate (20mm down):* Milling (recycled) material does not have any proper gradation as per our mix design requirements so here we used 20 mm size virgin aggregate for maintaining gradation as per IRC: 37-2012 Table No. IX-1. Aggregate production were done on our Sunera crusher and for testing in laboratory Sample were taken from Sunera camp stock pile. Some quality assurance test were performed on 20 mm down aggregate in site laboratory before using as a ingredients of mix design. Tests were conducted on coarse aggregate like as aggregate impact value test, flakiness indices and elongation indices test, specific gravity and water absorption test and individual gradation (Shown in next chapter).



Figure-: Sampling of 20 mm aggregate at Sunera Camp



Figure-: Specific gravity and water absorption test on 20 mm down aggregate

**SPECIFIC GRAVITY AND WATER ABSORPTION TEST OF FINE AGGREGATE**
(As per IS :2386 Part III)

| Sl. No. | Determination | | Trial I | Trial II | Trial III | Average |
|---|---|---|---|---|---|---|
| 1 | Wt. Of Dry Sample [SSD] [gms] | W1 | 1361 | 1370 | 1357 | |
| 2 | Wt of Basket in Water [ gms ] | W2 | 0 | 0 | 0 | |
| 3 | Wt of Sample and Basket in Water [gms] | W3 | 903 | 911 | 899 | |
| 4 | Wt of Oven dried Sample in air [gms] | W4 | 1354 | 1364 | 1349 | |
| 5 | Water Absorption [%] | [ (W1-W4)/W4] * 100 | 0.52 | 0.44 | 0.59 | **0.52** |
| 6 | Specific Gravity | W4/ [W1-( W3-W2 )] | 2.956 | 2.972 | 2.945 | **2.958** |
| 7 | Aparant Specific Gravity | W4/(W4-[W3-W2]) | 3.002 | 3.011 | 2.998 | **3.004** |

Table-9: Specific gravity and water absorption test of fine aggregate



Figure-: Flakiness and Elongation indices test

**FLAKINESS AND ELONGATION INDEX**
As per IS:2386 (Part-1)

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

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

**Flakiness Index(%)** : (B/A)X 100 = **15.96**
**Elongation Index(%)** :( D/C)X100 = **14.02**
**Combined (EI+FI) (%)** = ..... **29.98**

Table-10: Flakiness and elongation index

*7)* *Water:* Water is an important ingredient to achieve desirable compaction during laying of emulsion treated rap mix at site. It is fulfill the role of partial fluid content with bitumen emulsion (SS2). Desirable compaction achieved on optimum moisture content (emulsion + water). Water sample taken for mix design from Sunera camp borewell which is drinkable water and to assure quality of water, sometest were carried out in third party laboratory. It should be free from organic matter and the pH value should be between 6 and7.

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**TEST REPORT**

Page No 1/1

| | |
|---|---|
| Name and Address of Customer<br>M/s. ORIENTAL STRUCTURAL ENGINEERS PVT LTD.<br>Camp-2, Package II, Biaora To Dewas Highway Pvt Ltd.<br>Biaora-Dewas Road Project, Tehsil-Sunera<br>Dist. Shajapur M P<br>Contact Person Name : | Laboratory Reference Number (LRN) : KTRC/1907003713<br>Date of Receipt : 13/07/2019<br>Condition, When Received : Satisfactory<br>Packing, When Received : Sealed<br>Quantity Received (Approx.) : 1 Ltr. |
| Sample Identification : Water<br>Source: Sunera Bore Well<br>Sample ID : 2/T-W/15 | Date of Start of Test : 01/08/2019<br>Date of Completion of Test : 03/08/2019<br>Date of Reporting : 05/08/2019 |
| Customer Reference : BDHPL/Testing/NH-3/2K 19/446 dtd. 12.07.2019, Agreement dtd. 27.08.15, | |
| Sample Particulars : Sub.- Four Laning of Biaora to Dewas Section from KM 426.100 to Km. 566.450 of NH-3 in the State of MP under NHDP Phase-IV in BOT (Toll) basis on DBFOT pattern. (Pkg.-02) | |

**TEST RESULTS:**

| S.No. | PARAMETER | UNIT | RESULTS | SPECIFCATION AS PER IS 456 : 2000 | TEST METHOD | CONFORMITY |
|---|---|---|---|---|---|---|
| 1 | pH | - | 6.5 | Not less than 6 | IS 3025(Part 11):1983 | Yes |
| 2 | Chloride as Cl | mg/l | 16 | Max. 2000 | IS 3025(Part 32):1988 | Yes |
| 3 | Sulphate as $SO_4$ | mg/l | 5.26 | Max. 400 | IS 3025(Part 24):1986 | Yes |
| 4 | Inorganic Matter | mg/l | 76 | Max. 3000 | IS 3025(Part 16):1984 | Yes |
| 5 | Organic Matter | mg/l | 46 | Max. 200 | IS 3025(Part 18):1984 | Yes |
| 6 | Suspended Matter | mg/l | 8 | Max. 2000 | IS 3025(Part 17):1984 | Yes |
| 7 | To neutralize 100 ml sample of water by 0.02 N NaOH | ml | 1.8 | Max. 5.0 | IS 3025(Part 22):1986 | Yes |
| 8 | To neutralize 100ml sample of water by 0.02N $H_2SO_4$ | ml | 2 | Max. 25.0 | IS 3025(Part 23):1986 | Yes |

**End of Report**

Er. Ruby S. Malhotra
Quality Manager & Authorized Signatory

An ISO 9001: 2015 Certified Laboratory

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Table-11: Third party laboratory test report of water

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## IV. EXPERIMENTAL PROCEDURE

### *A. General*

According to research, up to now, there is no hard and fast rule for formal mix design of Emulsion TreatedRAP, and in that respect no hard procedure and quality control test on laying of Emulsion Treated RAP. Thus, in this research, some laboratory tests were performed to obtain some mechanical properties of this mix. Test performed on mix as per IRC-37 2012 and test performed on individual ingredients by their relevant IS code and specifications.

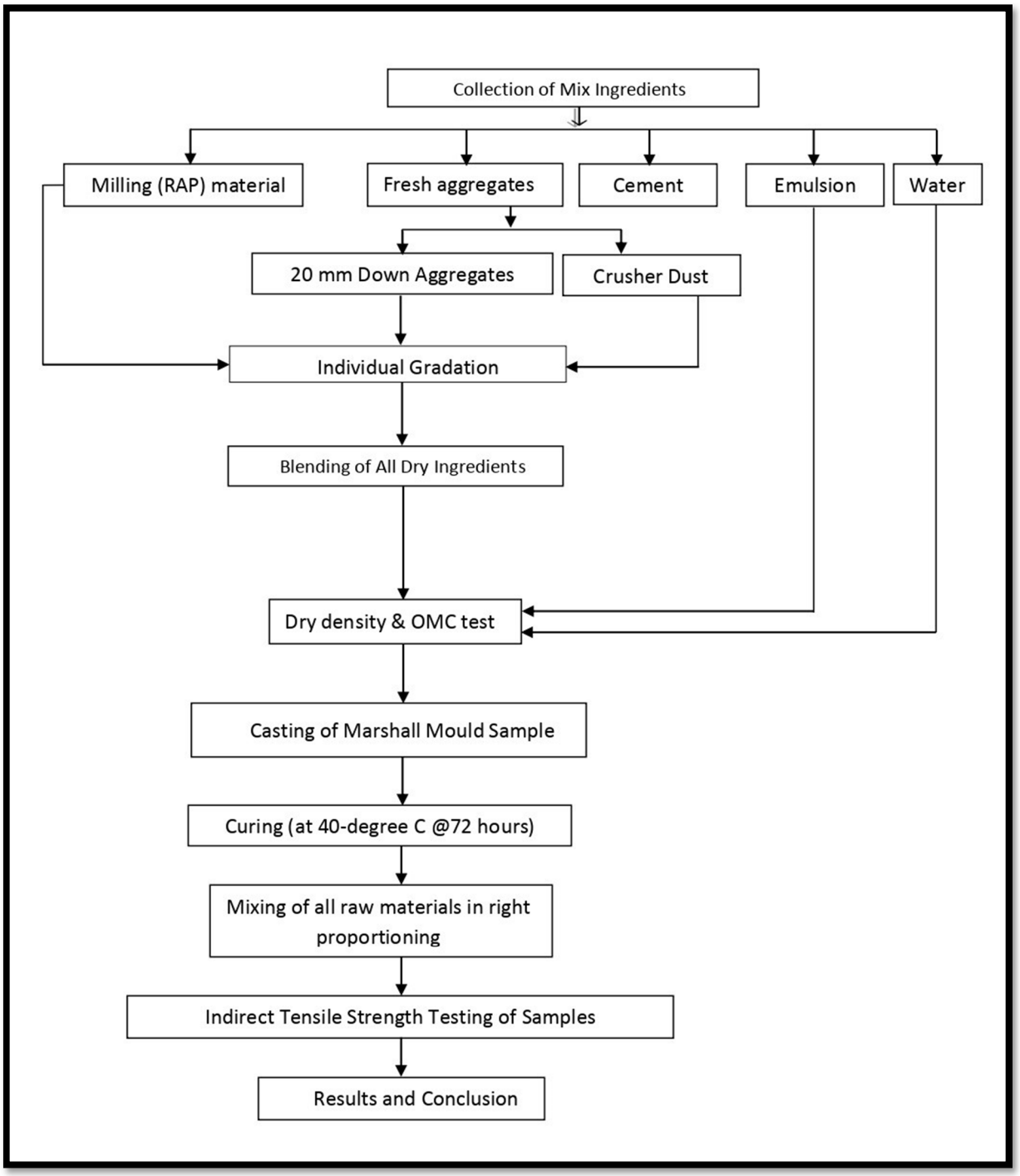



Figure-: Flow chart of Mix design

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*1) Mix Design Procedure*

Mix gradation: All accumulated samples from the stockpile & site have been dried first 24-hours then individual sample taken and gradation test were performed as per sieve designated in IRC- 37 2012 Table IX-1. Results were obtained from individual gradation are showing in given below tables

- 40mm
- 20 mm
- RAP (Milling Material)
- Crusher dust
- Filler (cement)

Various trial has been made for getting optimize gradation like as blending were made in trial-1 is 40 mm+ RAP+ crusher dust + Cement but this trial not gives a satisfactory result due to larger size aggregates fluctuated the result in huge frequency. Hence second trial were made with RAP+20 mm +Stone dust + Filler.

Blending of all ingredients by through average individual gradation as follows:

*a) 40 MM Aggregate*



| IS Sieve Size (mm) | Trial- 1 | Trial- 2 | Trial- 3 | Average passing (%) |
|---|---|---|---|---|
| 45 | 100.00 | 100.00 | 100.00 | 100.00 |
| 37.50 | 86.64 | 83.43 | 86.86 | 85.64 |
| 26.50 | 19.30 | 20.39 | 18.65 | 19.45 |
| 19.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 13.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4.75 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2.36 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.600 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.300 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.075 | 0.00 | 0.00 | 0.00 | 0.00 |

Table-12: Average of 40 MM Down Aggregate

*b) 20 MM Aggregate*

| AVERAGE % OF 20 MM DOWN AGGREGATE | | | | |
|---|---|---|---|---|
| IS Sieve Size (mm) | Trial- 1 | Trial- 2 | Trial- 3 | Average passing (%) |
| 45 | 100.00 | 100.00 | 100.00 | 100.00 |
| 37.50 | 100.00 | 100.00 | 100.00 | 100.00 |
| 26.50 | 100.00 | 100.00 | 100.00 | 100.00 |
| 19.00 | 76.25 | 79.59 | 76.88 | 77.57 |
| 13.20 | 29.07 | 30.21 | 32.02 | 30.43 |
| 4.75 | 1.35 | 1.12 | 1.57 | 1.35 |
| 2.36 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.600 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.300 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.075 | 0.00 | 0.00 | 0.00 | 0.00 |

Table-13: Average of 20 MM down aggregate




Figure-: GRADATION TEST AT SITE LABORATORY

*c) Existing Recycled Material/Milling material*

| AVERAGE % OF RAP MATERIAL | | | | |
|---|---|---|---|---|
| IS Sieve Size (mm) | Trial- 1 | Trial- 2 | Trial- 3 | Average passing (%) |
| 45 | 100.00 | 100.00 | 100.00 | 100.00 |
| 37.50 | 97.00 | 95.80 | 95.80 | 96.20 |
| 26.50 | 92.50 | 93.71 | 93.10 | 93.10 |
| 19.00 | 88.30 | 89.40 | 87.20 | 88.30 |
| 13.20 | 79.82 | 83.55 | 83.26 | 82.21 |
| 4.75 | 35.13 | 36.86 | 35.62 | 35.87 |
| 2.36 | 19.12 | 18.15 | 17.27 | 18.18 |
| 0.600 | 7.79 | 6.85 | 6.96 | 7.20 |
| 0.300 | 5.56 | 6.50 | 5.71 | 5.92 |
| 0.075 | 0.42 | 0.49 | 0.48 | 0.47 |

Table-14: Average of RAP Material

*d) Crusher/Stone Dust*

| AVERAGE % OF CRUSHER DUST | | | | |
|---|---|---|---|---|
| IS Sieve Size (mm) | Trial- 1 | Trial- 2 | Trial- 3 | Average passing (%) |
| 45 | 100.00 | 100.00 | 100.00 | 100.00 |
| 37.50 | 100.00 | 100.00 | 100.00 | 100.00 |
| 26.50 | 100.00 | 100.00 | 100.00 | 100.00 |
| 19.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 13.20 | 100.00 | 100.00 | 100.00 | 100.00 |
| 4.75 | 100.00 | 99.66 | 98.25 | 99.30 |
| 2.36 | 82.57 | 81.52 | 91.20 | 85.10 |
| 0.600 | 30.37 | 28.48 | 29.26 | 29.37 |
| 0.300 | 19.88 | 18.15 | 18.98 | 19.00 |
| 0.075 | 10.38 | 8.54 | 9.25 | 9.39 |

Table-15: Average of Crusher Dust



Figure-: Gradation test of stone dust at site laboratory

*e) Filler (Cement)*

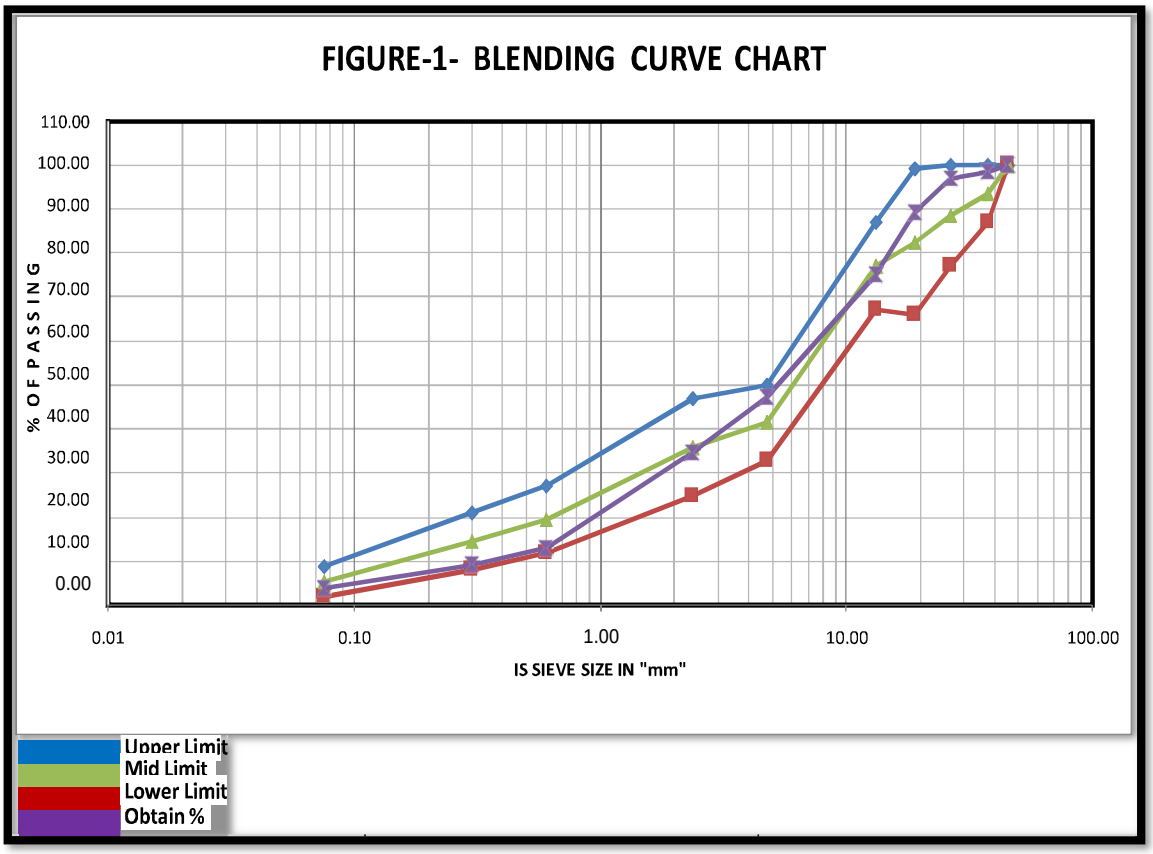
| AVERAGE % OF FILLER (CEMENT) | | | | |
|---|---|---|---|---|
| IS Sieve Size (mm) | Trial- 1 | Trial- 2 | Trial- 3 | Average passing (%) |
| 45 | 100.00 | 100.00 | 100.00 | 100.00 |
| 37.50 | 100.00 | 100.00 | 100.00 | 100.00 |
| 26.50 | 100.00 | 100.00 | 100.00 | 100.00 |
| 19.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 13.20 | 100.00 | 100.00 | 100.00 | 100.00 |
| 4.75 | 100.00 | 100.00 | 100.00 | 100.00 |
| 2.36 | 100.00 | 100.00 | 100.00 | 100.00 |
| 0.600 | 100.00 | 100.00 | 100.00 | 100.00 |
| 0.300 | 98.50 | 99.00 | 98.50 | 98.67 |
| 0.075 | 89.50 | 89.00 | 88.50 | 89.00 |

Table 16: Average of Filler

The final blending percentage was obtained for dry ingredients.

| Blending | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IS SIEVE (mm) | % of Passing | | | | Percentage for Blending | | | | | IRC:37-2012 Table No. IX-1 | | |
| | | | | | 20 mm | RAP | Dust | Cement | Total % of Passing | Lower Limit | MID LIMIT | Upper Limit |
| | 20 mm | RAP | Dust | Cement | 24% | 45% | 30% | 1% | 100% | | | |
| 45.00 | 100.00 | 100.00 | 100.00 | 100.00 | 24.00 | 45.00 | 30.00 | 1.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 37.50 | 100.00 | 96.20 | 100.00 | 100.00 | 24.00 | 43.29 | 30.00 | 1.00 | 98.29 | 87.00 | 93.50 | 100.00 |
| 26.50 | 100.00 | 93.10 | 100.00 | 100.00 | 24.00 | 41.90 | 30.00 | 1.00 | 96.90 | 77.00 | 88.50 | 100.00 |
| 19.00 | 77.57 | 88.30 | 100.00 | 100.00 | 18.62 | 39.74 | 30.00 | 1.00 | 89.35 | 66.00 | 82.50 | 99.00 |
| 13.20 | 30.43 | 82.21 | 100.00 | 100.00 | 7.30 | 36.99 | 30.00 | 1.00 | 75.30 | 67.00 | 77.00 | 87.00 |
| 4.75 | 1.35 | 35.87 | 99.30 | 100.00 | 0.32 | 16.14 | 29.79 | 1.00 | 47.26 | 33.00 | 41.50 | 50.00 |
| 2.36 | 0.00 | 18.18 | 85.10 | 100.00 | 0.00 | 8.18 | 25.53 | 1.00 | 34.71 | 25.00 | 36.00 | 47.00 |
| 0.600 | 0.00 | 7.20 | 29.37 | 100.00 | 0.00 | 3.24 | 8.81 | 1.00 | 13.05 | 12.00 | 19.50 | 27.00 |
| 0.300 | 0.00 | 5.92 | 19.00 | 98.67 | 0.00 | 2.66 | 5.70 | 0.99 | 9.35 | 8.00 | 14.50 | 21.00 |
| 0.075 | 0.00 | 0.47 | 9.39 | 89.00 | 0.00 | 0.21 | 2.82 | 0.89 | 3.92 | 2.00 | 5.50 | 9.00 |

Table-17: Blending of all aggregates




Graph-1: Blending curve chart

2) *Determination of MDD & OFC:* These step gives an optimum fluid content on which mix can 100% compacted and density obtained on OFC is utilize at field compaction test as a maximum dry density of laboratory. Fluid content of the mix is the sum of aggregate, moisture content, residual, bitumen content, water in the emulsion & additional water added to the mix. The MDD & OFC were determined as per guidelines provided in IRC-37 2012 annexure-IX (in step 1,2,3) detailed description of the procedure is given below

Equipment Required- marshal mould of 100 dia, compactor, filter paper.




Figure-: 100 dia marshall mould & Compactor

*a)* Actual moisture content of the blend of RAP, filler and virgin aggregate was determined as per ASTM 2216 guidelines. This is designated as a blend moisture content.




Figure-: NMC 0f blend material

*b)* A 50:50 blend of emulsion & water mix by volume was prepared. Water is added to the bitumen emulsion because if we add the emulsion into the water, premature breaking takes place. So preventpremature breaking, water added into the emulsion



Figure-: 50:50 blend of emulsion & water mix

*c)* A batch of cold mix was prepared as per blended percentage obtained in table no. I7 and add the blend of emulsion & water prepared in step 2, with 5%.




Figure-:

a) Dry ingredients taken as per obtained blending percentage
b) Water taken as per blending percentage
c) Emulsion SS2 as per blending percentage

*d)* Take 1200 grams' batch weight of dry ingredients. The mixing was done for 1 minute to ensureuniform & thorough coating of RAP & fresh virgin aggregate.



Figure-: Mixing of all ingredients

*e)* Clean a Marshall mould of 100 mm dia and oiling done on inner surface.

*f)* Mix put into mould and compacted with 75 blows on one face by manual compaction, reverse themould & base plate compaction process with 75 blows are performed on other face.




Figure-: a) Mix put into the marshall mould
b) Mould place in the compactor machine
c) Manaul compaction by compactor 75 blows on each face

*g)* Remove the marshal mould from the compactor. And similar 3 mould were casted on each fluid content.

*h)* Same mould were casted at every fluid content increment of 1%. The increment in fluid content wasby additional of extra water to the blend of Rap & virgin aggregate. Three marshall specimens on each individual fluid content of 5%, 6%,7%, 8% & 9% were casted.




Figure-: Three marshall specimens on each individual fluid content

*i)* Marshall specimens were left in the mould for 24 hours at room temperature.

*j)* After 24 hours the specimens were ejected from the mould by Marshall machine and evaluated for their bulk density as ASTM D 272 6.




Figure-: Extrusion of specimen from the mould by using marshall machine

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*k)* The fluid content of specimens were determined by drying them in a hot air oven maintained at 100°Cfor 24 hours.




Figure-: Drying process in hot air oven

*l)* The dry density of the specimens were calculated by equation :-Dry Density = $\frac{\text{Bulk Density}}{\text{+ Fluid content in \%}}$

*m)* A graph was plotted between the calculated dry densities and corresponding total fluid contents. The MDD & OFC was determined from the graph. OFC obtained from the drawing the vertical line corresponding from Maximum density. The calculated mean dry density at different fluid contents are given in table and the graph were plotted between the dry density & corresponding fluid contentsis shown in figure.




Figure-: Measurement taken for Dry density

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| EMULSION TREATED RECLAIMED ASPHALT PAVEMENT<br>Dry Density Test | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Specimen Identity No. | % of Emulsion Content By Wt of Total Mix | % of Moisture Content By Wt of Total Mix (Blend Material) | % of Water Content added to Blend Material | Total % of Fluid Content | Wt of Specimen in Air (gms) | Wt of Specimen in Water (gms) | SSD Wt of Specimen (gms) | Volume of replaced water (cc) | Bulk Density (g/cc) | Average Bulk Density (g/cc) | Dry Wt of Specimen (gms) | Moisture Content % | % of Fluid Content after 24 hrs (Oven Dry) | Dry Density= 10/(1+13) |
| A-1 | 3.0 | 0.50 | 1.5 | 5.00 | 1220.0 | 690.0 | 1224.0 | 534.0 | 2.285 | 2.277 | 1198.5 | 1.79 | 1.77 | 2.237 |
| A-2 | | | | | 1212.0 | 685.5 | 1219.0 | 533.5 | 2.272 | | 1191.0 | 1.76 | | |
| A-3 | | | | | 1218.0 | 687.5 | 1223.0 | 535.5 | 2.275 | | 1197.0 | 1.75 | | |
| B-1 | 3.0 | 0.50 | 2.5 | 6.00 | 1221.0 | 706.5 | 1234.5 | 528.0 | 2.313 | 2.320 | 1198.0 | 1.92 | 1.92 | 2.276 |
| B-2 | | | | | 1214.0 | 705.5 | 1223.0 | 517.5 | 2.346 | | 1192.0 | 1.85 | | |
| B-3 | | | | | 1225.0 | 710.0 | 1242.5 | 532.5 | 2.300 | | 1201.0 | 2.00 | | |
| C-1 | 3.0 | 0.50 | 3.5 | 7.00 | 1208.5 | 710.5 | 1213.0 | 502.5 | 2.405 | 2.359 | 1195.0 | 1.13 | 2.02 | 2.313 |
| C-2 | | | | | 1216.5 | 709.0 | 1223.0 | 514.0 | 2.367 | | 1192.0 | 2.06 | | |
| C-3 | | | | | 1219.0 | 699.0 | 1227.5 | 528.5 | 2.307 | | 1185.0 | 2.87 | | |
| D-1 | 3.0 | 0.50 | 4.5 | 8.00 | 1225.0 | 706.0 | 1235.0 | 529.0 | 2.316 | 2.339 | 1195.0 | 2.51 | 2.23 | 2.288 |
| D-2 | | | | | 1219.0 | 711.0 | 1235.0 | 524.0 | 2.326 | | 1193.0 | 2.18 | | |
| D-3 | | | | | 1204.0 | 714.0 | 1221.0 | 507.0 | 2.375 | | 1180.5 | 1.99 | | |
| E-1 | 3.0 | 0.50 | 5.5 | 9.00 | 1203.0 | 702.0 | 1212.0 | 510.0 | 2.359 | 2.310 | 1190.0 | 1.09 | 2.76 | 2.248 |
| E-2 | | | | | 1220.0 | 701.0 | 1232.0 | 531.0 | 2.298 | | 1186.0 | 2.87 | | |
| E-3 | | | | | 1223.0 | 702.5 | 1240.5 | 538.0 | 2.273 | | 1172.5 | 4.31 | | |

Table-18: Emulsion treated reclaimed asphalt pavement dry density test

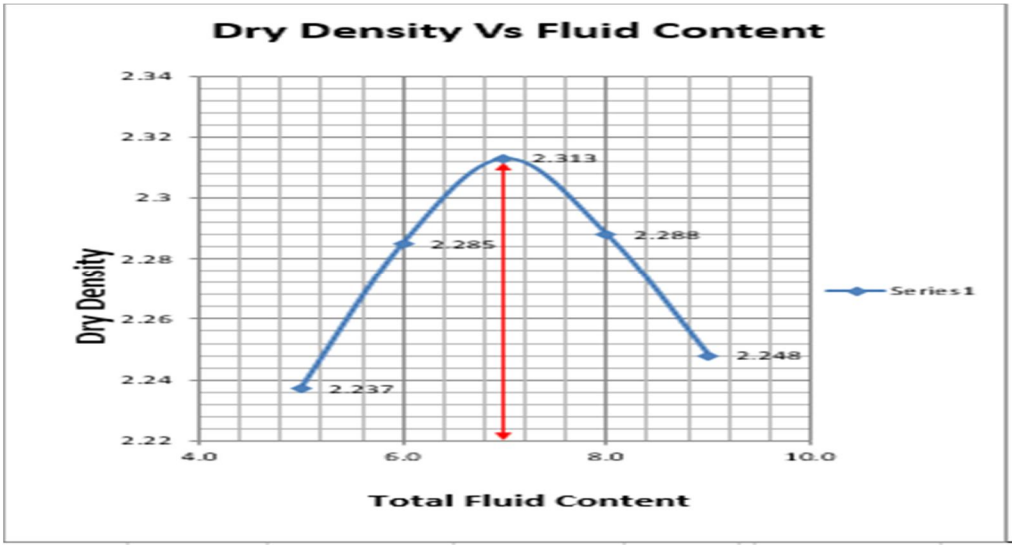



Figure-: Graph between Dry density & Fluid content

| MAXIMUM DRY DENSITY DATA FOR RECLAIMED ASPHALT PAVEMENT | | |
|---|---|---|
| OBSERVATION TABLE | | |
| Sl. No. | DESCRIPTION | OBSERVATION |
| 1 | Emulsion Content % | 3.00 |
| 2 | Water Content % | 3.5 |
| 3 | Moisture Content in Blend Material % | 0.5 |
| 4 | Total Fluid Content % | 7.00 |
| 5 | Bulk density | 2.359 |
| 6 | Dry Density (gm/cc) | 2.313 |
| Result:- Maximum Dry Density is 2.313 gm/cc found at 7.0 % Fluid Content. | | |

Table-19: Maximum dry density data for reclaimed asphalt pavement

*n)* The MDD were found to be 2.313 gm/cc & OFC 7.0 % by weight of dry aggregate respectively. Optimum fluid content is necessary for the compaction of the RAP mixes to the maximum density.

*3) Determination of ITS:* Indirect tensile strength criteria on which trial mixes depend. If any mix satisfied the minimum required in directed tensile strength which is mentioned in IRC-37-2012 table no. IX-2 in both condition (dry & wet) then mix called design mix.

For indirect tensile strength some equipment are as follows: -

*a)* Modified version of marshall test apparatus



Figure-: Modified version of marshall test apparatus

*b)* Marshall test machine




Figure-: Marshall test machine



Figure-: Calibrated proving ring & dial gauge

- Marshall mould of 100 dia
- Calibrated proving ring & dial gauge.
- Air controlled oven
- A mixing pan
- Filter paper

*B. Mould preparation Test procedure are as follows*

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



Figure-: Blended dry sample were taken for the batch of 1200 gm.

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




Figure-: Blended dry sample were taken for the batch of 1200 gm.

Emulsion may varies from 3 to 4 % by weight of total mix in increment of 0.5 %. Additional water is added to the first and mixed then the bitumen emulsion is added and mixed again approx. 1 minute takenin mixing process, so mix become uniform and coating done on each fragment of aggregates.

3) *Step-3:* After mixing, mix poured into the Marshall mould on which filter paper already placed on base plate. By using trovel or straight edge top of specimen leveled and another filter paper placed on top. So mix particle not stuck off by the hammer bottom.



Figure- Mix poured into the Marshall mould

4) *Step-4:* Prepared mix mould placed in the compactor and gives 75 blows on one face & reverse the mould& placed again, then again compacted by 75 blows on other face. Prepared six specimens of each emulsionpercentage.
5) *Step-5:* Take the casted specimen with mould and were cured in the mould at room temperature for 24 hours.



Figure-: Curing of specimen in the mould for 24 hours at room tempreture

6) *Step-6:* After 24 hours the specimens were extruded from the mould. Here we are using marshall machine to removing the specimen from the mould.




Figure-: Extrusion of mould

7) *Step-7:* All specimen evaluated for their bulk density as per ASTM D2726. Then the specimen were cured in hot air oven maintained at 40°C for 72 hours.



Figure-: Casted Mould put in hot air oven maintained at 40°C for 72 hours

*8)* *Step-8:* After completion of curing period, three cured specimens were tested for their dry ITS as per ASTM D6931 @ 25°C temperature.

Following procedure adopted for ITS testing:

*a)* Place cured specimen in the center of modified breaking apparatus.



Figure-: Mould placing in the machine for ITS testing

*b)* Check the apparatus placed in the center.



Figure-: ITS Testing

*c)* Proving ring & dial gauge set on apparatus, at zero reading or initial reading was note down.



Figure-: Take the dial gauge and proving ring initial reading

*d)* Start the marshall machine, which is operated at the speed of 55 mm/min.




Figure-: Machine operated at the speed of 55 mm/min

*e)* Take the highest reading of proving ring and also corresponding dial gauge reading were taken.




Figure-: ITS Testing in dry condition

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




Figure-: ITS Testing in wet condition

10) *Step-10:* Similarly follow all step on different emulsion content and average ITS value of each emulsion percent note down. All ITS test parameter shown in given table.

*a)* Noted highest proving reading in division it is converted into load by calibrating chart.

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

$$ITS\ (KPa) = \frac{2000 \times Pmax}{\Pi DH}$$

Here: -

**ITS** = Indirect Tensile Strength in Kpa**Pmax** = Maximum Load in Newton **H**= Thickness of the specimen
**D** = Dia of specimen

The design emulsion content is the optimum mix emulsion content which is satisfying the minimum ITS strength required given in table IX-II of IRC-37-2012, Annexure-IX. By observing the ITS results presented in table no.20

Indirect Tensile Strength Test

Data Sheet of Test Results

| | |
|---|---|
| Proving Ring capacity (KN) | 50 |
| Proving Ring per division value (Kg ) | 7.03 |

| | % of Emulsion Content By Wt of Total Mix | % of Moisture Content By Wt of Total Mix (Blend Material) | % of Water Content added to Blend Material | Total % of Fluid Content | Average Height of Specimen in mm | Dia. Of Specimen in mm | ITS Condition | Proving Ring Reading | Stability in (Kg) | Stability in Newton | Stability in Kpa | Average Stability (KPa) | Minimum Strength as per IRC 37-2012 Table no. IX-2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-1 | 3.00 | 0.5 | 3.50 | 7.0 | 64.0 | 100.0 | ITS dry | 49 | 344 | 3379 | 336 | 304.43 | >225 KPa |
| A-2 | | | | | 65.0 | | | 45 | 316 | 3103 | 304 | | |
| A-3 | | | | | 66.0 | | | 41 | 288 | 2828 | 273 | | |
| B-1 | 3.50 | 0.5 | 3.00 | 7.0 | 68.0 | 100.0 | | 56 | 394 | 3862 | 362 | 366.84 | |
| B-2 | | | | | 66.0 | | | 57 | 401 | 3931 | 379 | | |
| B-3 | | | | | 66.0 | | | 54 | 380 | 3724 | 359 | | |
| C-1 | 4.00 | 0.5 | 2.50 | 7.0 | 67.0 | 100.0 | | 48 | 337 | 3310 | 315 | 321.80 | |
| C-2 | | | | | 65.0 | | | 50 | 352 | 3448 | 338 | | |
| C-3 | | | | | 66.0 | | | 47 | 330 | 3241 | 313 | | |
| D-1 | 3.00 | 0.5 | 3.50 | 7.0 | 65.0 | 100.0 | ITS wet | 22 | 155 | 1517 | 149 | 161.49 | >100 KPa |
| D-2 | | | | | 64.0 | | | 26 | 183 | 1793 | 178 | | |
| D-3 | | | | | 67.0 | | | 24 | 169 | 1655 | 157 | | |
| E-1 | 3.50 | 0.5 | 3.00 | 7.0 | 67.0 | 100.0 | | 31 | 218 | 2138 | 203 | 191.41 | |
| E-2 | | | | | 67.0 | | | 29 | 204 | 2000 | 190 | | |
| E-3 | | | | | 68.0 | | | 28 | 197 | 1931 | 181 | | |
| F-1 | 4.00 | 0.5 | 2.50 | 7.0 | 65.0 | 100.0 | | 23 | 162 | 1586 | 155 | 153.72 | |
| F-2 | | | | | 68.0 | | | 25 | 176 | 1724 | 161 | | |
| F-3 | | | | | 67.0 | | | 22 | 155 | 1517 | 144 | | |

Table-20: Indirect tensile strength

From observed data it is found that emulsion content of 3.5% gives the better result of ITS strength andalso satisfies the mix criteria of table IX-II.

Final Confirmity

Data Sheet of Test Results

| | |
|---|---|
| Proving Ring capacity (KN) | 50 |
| Proving Ring per division value (Kg ) | 7.03 |

| Specimen Identity No. | 1<br>% of Emulsion Content By Wt of Total Mix | 2<br>% of Moisture Content By Wt of Total Mix (Blend Material) | 3<br>% of Water Content added to Blend Material | 4<br>Total % of Fluid Content | 5<br>Average Height of Specimen in mm | 6<br>Dia. Of Specimen in mm | 7<br>Stability | 8<br>Proving Ring Reading | 9<br>Stability in (Kg) | 11<br>Stability in Newton | <br>Stability in Kpa | 12<br>Average Stability (KPa) | 14<br>Minimum Strength as per IRC 37-2012 Table no.IX-2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B-1 | 3.50 | 0.5 | 3.00 | 7.0 | 68.0 | 100.0 | ITSdry | 56 | 394 | 3862 | 362 | 366.84 | >225 KPa |
| B-2 | | | | | 66.0 | | | 57 | 401 | 3931 | 379 | | |
| B-3 | | | | | 66.0 | | | 54 | 380 | 3724 | 359 | | |
| E-1 | 3.50 | 0.5 | 3.00 | 7.0 | 67.0 | 100.0 | ITSwet | 31 | 218 | 2138 | 203 | 191.41 | >100 KPa |
| E-2 | | | | | 67.0 | | | 29 | 204 | 2000 | 190 | | |
| E-3 | | | | | 68.0 | | | 28 | 197 | 1931 | 181 | | |

Table-21 : Final Conformity

As per Codal provision if ITSdry is greater than 400 Kpa & similarly ITSwet is less than 50% of the ITSdry. It is indicative of contamination with clay & 1 to 2% lime may be necessary for modifying theplasticity property of the clay.

Clay Contamination Criteria

| S. NO. | ITS Condition | Obtained Strengthin Kpa | Codal Requirementif contaminated with clay | Obtained resultfrom this mix design |
|---|---|---|---|---|
| 1 | ITSdry | 366.84 | >400 Kpa | 366.84<400 Kpa |
| 2 | ITSwet | 191.41 | <50% of ITSdry | 52.18>50% |

Table-22 : Clay contamination criteria

Hence in our trial mix ITSdry found less then 400 Kpa & the ITSwet value is greater than 50% of ITSdry. Hence these indicates there is no contamination of clay in emulsion treated RAP mix and no need of addition of lime in the mix.

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Mix design check as per TG-2/MS-14/MORTH specification (Table 500-45)

*c) Stability Check:* Marshall stability test performed on specimen prepared (casted) with followingdesign parameter:
Emulsion SS2-3.5%,Water-3.5%

20 mm – 24%

Filler – 1%

Stove dw1- 30% Recycled material-45%

Six specimens casted on above blended percentage for Marshall stability test. Test Performed at 22.2°C with Marshall machine operated at the speed of 55 mm/minute. The test done after 24 hours, three sample directly tested for dry stability & remaining three sample soaked in water and obtained result aretabulated as below:

| Check For Marshall Test | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| EMULSION TREATED RECLAIMED ASPHALT PAVEMENT | | | | | | | | |
| Data Sheet of Test Results | | | | | | | | |
| Proving Ring capacity (KN) | | 50 | | | | | | |
| Proving Ring per divisionvalue (Kg ) | | 7.03 | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Specimen Identity No. | % of Emulsion Content By Wt of Mix | % of Water Content By Wt of Mix | Proving Ring Reading (KN) | Corrected Stability for Proving Ring (Kg) | Average Stability (Kg) | Average Stability (KN) | Marshall Flow (mm) | Average Marshall Flow (mm) |
| In dry condition | | | | | | | | |
| A-1 | 3.0 | 4.0 | 55 | 387 | 384 | 3.770 | 3.00 | 3.25 |
| A-2 | | | 57 | 401 | | | 3.25 | |
| A-3 | | | 52 | 366 | | | 3.15 | |
| B-1 | 3.5 | 3.5 | 66 | 464 | 450 | 4.414 | 3.35 | 4.25 |
| B-2 | | | 64 | 450 | | | 3.75 | |
| B-3 | | | 62 | 436 | | | 3.60 | |
| C-1 | 4.0 | 3.0 | 54 | 380 | 394 | 3.862 | 3.85 | 3.75 |
| C-2 | | | 56 | 394 | | | 3.90 | |
| C-3 | | | 58 | 408 | | | 3.40 | |
| In soaked condition | | | | | | | | |
| A-1 | 3.0 | 4.0 | 30 | 211 | 211 | 2.069 | 3.00 | 1.75 |
| A-2 | | | 28 | 197 | | | 3.25 | |
| A-3 | | | 32 | 225 | | | 3.15 | |
| B-1 | 3.5 | 3.5 | 33 | 232 | 248 | 2.437 | 3.35 | 2.50 |
| B-2 | | | 38 | 267 | | | 3.75 | |
| B-3 | | | 35 | 246 | | | 3.60 | |
| C-1 | 4.0 | 3.0 | 28 | 197 | 185 | 1.816 | 3.85 | 2.00 |
| C-2 | | | 25 | 176 | | | 3.90 | |
| C-3 | | | 26 | 183 | | | 3.40 | |

Table-23 : Marshall test for reclaimed asphalt pavement

| CONFIRMITY CHECK | | |
|---|---|---|
| PARAMETER | RESULT | As per MORT&H Table No. 500-45 and MS -14 appendix-F |
| MAXIMUM STABILITY OBTAINED @ 3.5% EMULSION & 3.5% water content | 4.414 KN | Min 2.2 KN at 22.2 ºC |
| FLOW IN mm | 4.25 mm | Min 2 mm |

Table-24 : Conformity check

It is observed from the above table maximum stability found on 3.5 % emulsion content that is optimumvalue of emulsion content which is satisfied all criteria's mentioned in MORT&H Table No. 500-45 abdMS-14 appendix Flow also satisfied minimum criteria mentioned in MORTH Table-45 i.e.-2

Average dry stability & average soaked stability value observed from the test put in the following equation for checking the stability loss of trial mix at the same time dial gauge reading were note downwhich indicates the flow value.

$$\% \text{ Stability loss} = \frac{\text{A-B X 100}}{\text{A}}$$

Result obtained at optimum emulsion content that is 3.5 %, fulfill the maximum stability loss criteria.

## V. EXECUTION OF MIX AT SITE WITH QUALITY ASSURANCE TEST

*A.* Production from modified WMM plant
*B.* Prime Coat/Tack coat laying
*C.* Design RAP mix course laying by sensor paver.
*D.* Quality Test

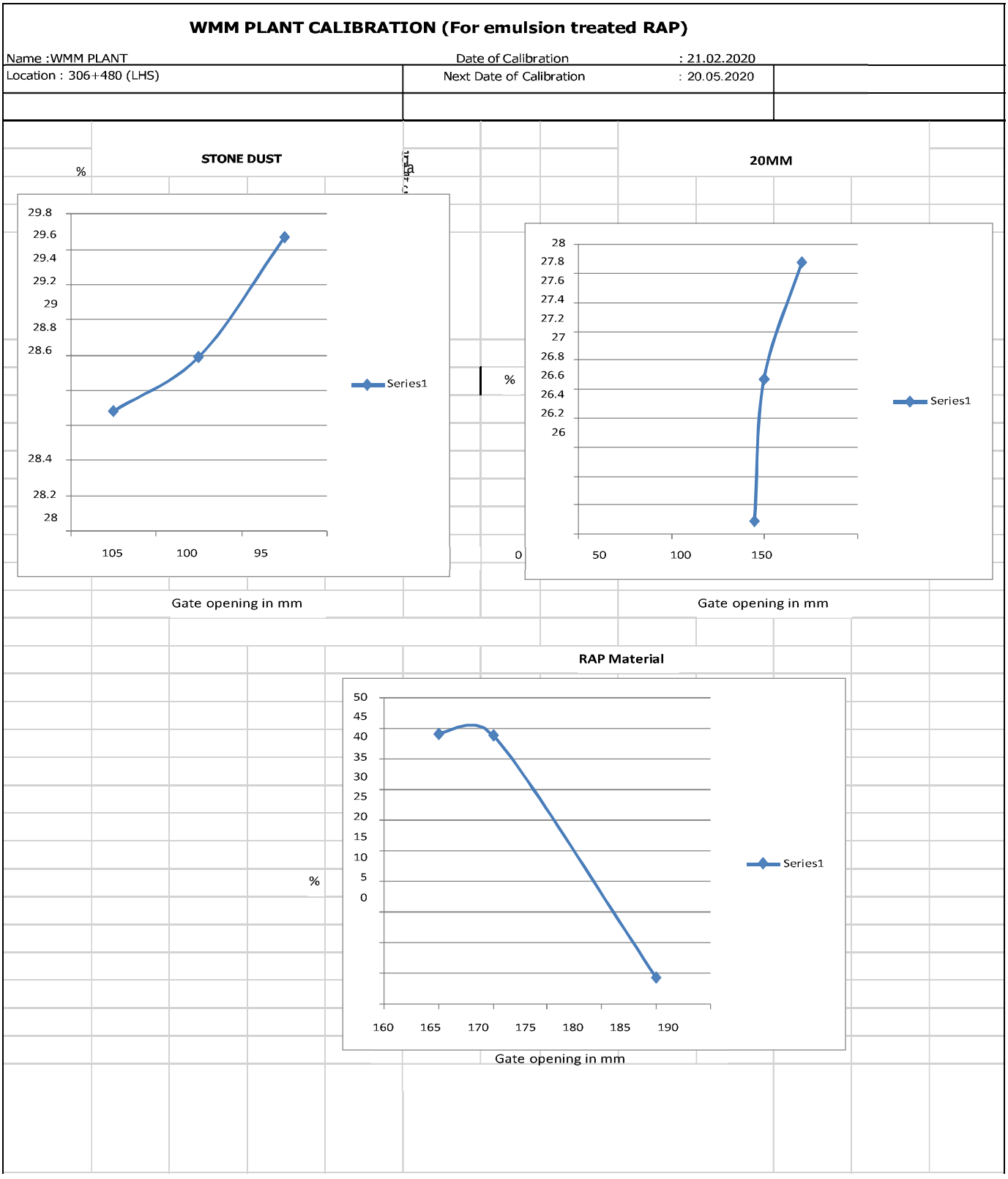
1) *Production:* Successfully finalization of design mix of emulsion treated Reclaimed Asphalt Pavement, all design parameter set in the production unit i.e. modified WMM plant. At our project production was done by modified WMM plant which became a very cost effective production unit. Because WMM plant is a common machinery equipment which is situated almost every highway construction project. Some minor modification in WMM plant like as introducing of an emulsion tank, a cement hopper (for filler mixing).

Before any production modified WMM plant set as per design parameter after calibration of WMM plant as per mix design parameter, production standard for 100-meter trial.

Calibration of WMM plant

| WMM PLANT CALIBRATION (For emulsion treated RAP) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Name : | WMM PLANT | Date of Calibration | 21.02.2020 | | | | |
| Location : | : Camp3 @ CH-306+480 (LHS) | Next Date of Calibration | 20.05.2020 | | | | |
| PLANT CAPACITY =135 TPH | | | | | | | |
| Design Percentage(%) | | | | | | | |
| Stone Dust: | | 30 | | | | | |
| 20mm Aggregate : | | 24 | | | | | |
| RAP Material : | | 45 | | | | | |
| Cement | | 1 | | | | | |
| 1 Metre Belt sample wt | | | | | | | |
| 1st Trial | | | | | | | |
| Sr.No | Gate opening as scale (mm) | Sample | sample No-1 | sample No-2 | Average | Percentage | Remark |
| 1 | 120 | 20mm | 5725 | 5695 | 5710 | 27.88 | |
| 2 | 185 | RAP material | 8920 | 8875 | 8897.5 | 43.44 | |
| 3 | 105 | Stone Dust | 5910 | 5840 | 5875 | 28.68 | |
| | | | | | 20482.5 | | |
| 2nd Trial | | | | | | | |
| 1 | 100 | 20mm | 5310 | 5320 | 5315 | 27.02 | |
| 2 | 170 | RAP material | 8610 | 8645 | 8627.5 | 43.87 | |
| 3 | 100 | Stone Dust | 5730 | 5720 | 5725 | 29.11 | |
| | | | | | 19667.5 | | |
| 3rd Trial | | | | | | | |
| 1 | 95 | 20mm | 5005 | 5025 | 5015 | 26.09 | |
| 2 | 165 | RAP material | 8495 | 8515 | 8505 | 44.25 | |
| 3 | 95 | Stone Dust | 5710 | 5695 | 5702.5 | 29.67 | |
| | | | | | 19222.5 | | |

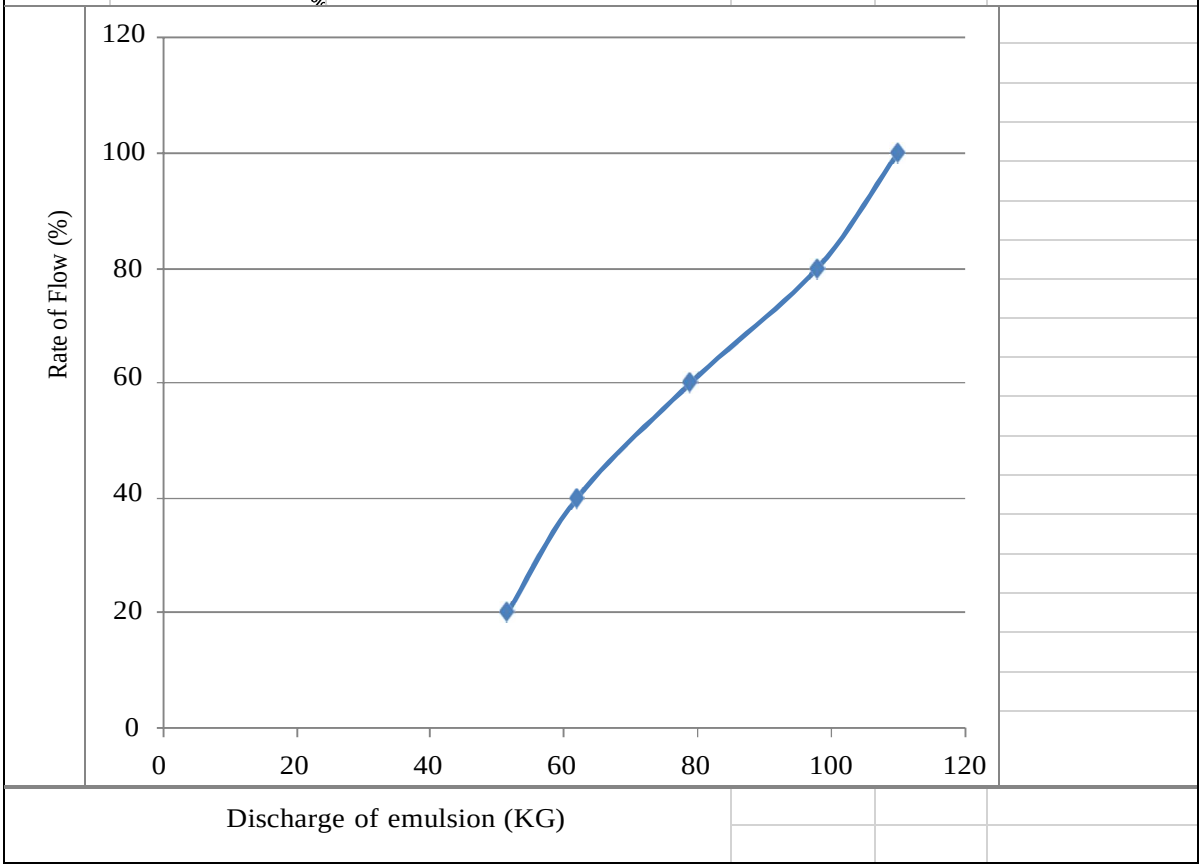
Table-25: Calibration Report of WMM Plant




Graph-: Calibration of 20 mm Stone dust and RAP material in WMM plant

| WMM PLANT CALIBRATION (For emulsion treated RAP) | | | |
|---|---|---|---|
| Name : | WMM PLANT | Date of Calibration | : 21.02.2020 |
| Location : | CH-306+480(LHS) | Next Date of Calibration | : 20.05.2020 |

| Calibration of Emulsion (SS2) | | | |
|---|---|---|---|
| EMULSION: 3.5% (As per Design) | | | |
| Sl No | Rate of flow (%) | Discharge of Emulsion in 1 minute (kg) | Required as per Design |
| 1 | 100 | 110 | Discharge of Emulsion in 1 minute is 78.75Kg |
| 2 | 80 | 98 | |
| 3 | 60 | 79 | |
| 4 | 40 | 62 | |
| 5 | 20 | 51.5 | |



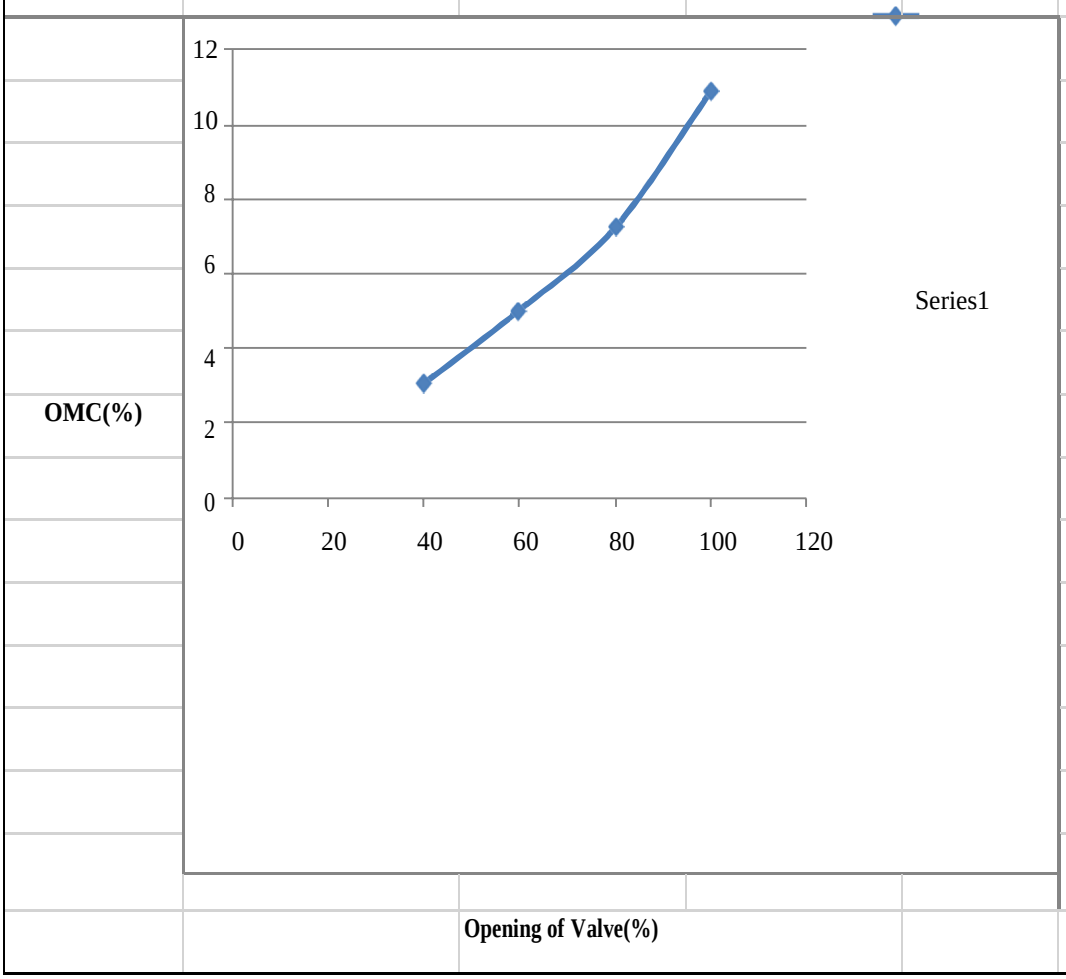

Graph-: Calibration of cement in modified WMM plant

**WMM PLANT CALIBRATION (For emulsion treated RAP)**

| | | | |
|---|---|---|---|
| Name : | WMM PLANT | Date of Calibration | : 21.02.2020 |
| Location : | CH-306+480 (LHS) | Next Date of Calibration | : 20.05.2020 |

**Calibration of Water**

| Sl No | Opening of valve( %) | Wet material Wt (gm) | Dry material Wt(gm) | Difference in Wt (gm) | % of MC |
|---|---|---|---|---|---|
| 1 | 100 | 1020 | 920 | 100 | 10.87 |
| 2 | 80 | 1040 | 970 | 70 | 7.22 |
| 3 | 60 | 1050 | 995 | 55 | 5.53 |
| 4 | 40 | 1020 | 985 | 35 | 3.55 |



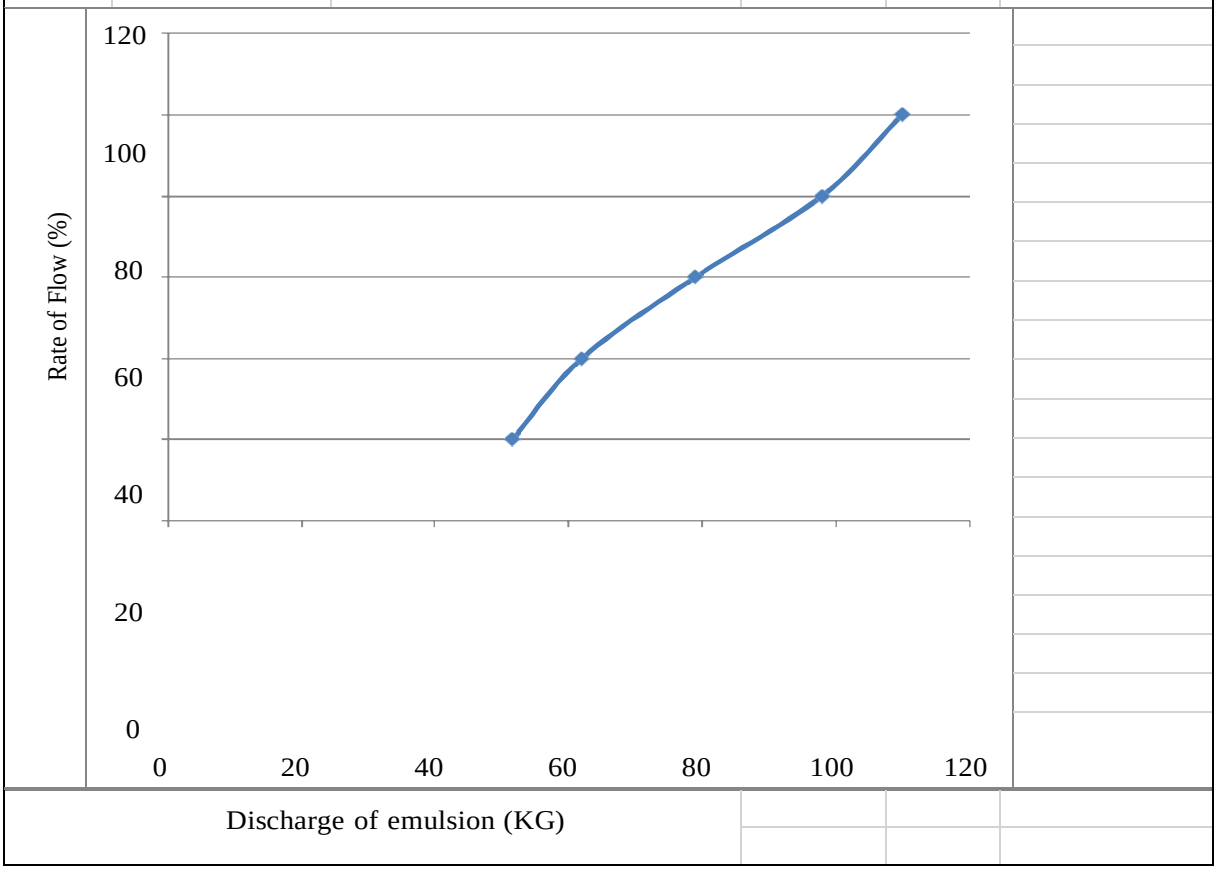

Graph-: Calibration of water

| WMM PLANT CALIBRATION (For emulsion treated RAP) | | | |
|---|---|---|---|
| Name : | WMM PLANT | Date of Calibration | : 21.02.2020 |
| Location : | CH-306+480(LHS) | Next Date of Calibration | : 20.05.2020 |

**Calibration of Emulsion (SS2)**

EMULSION: 3.5% (As per Design)

| Sl No | Rate of flow (%) | Discharge of Emulsion in 1 minute (kg) | Required as per Design |
|---|---|---|---|
| 1 | 100 | 110 | Discharge of Emulsion in 1 minute is 78.75Kg |
| 2 | 80 | 98 | |
| 3 | 60 | 79 | |
| 4 | 40 | 62 | |
| 5 | 20 | 51.5 | |




Graph-: Calibration of Emulsion SS2

Additional 1.5 to 2.5 % water from the Optimum Fluid Content may be added to the emulsion treatedRAP mixes during construction due to rapid evaporation of water from the RAP mixes in hot weather.Since the OFC is necessary for achieving maximum compaction & gaining strength. Produce mix transported by tipper, with a covering membrane on mix.




Figure-:

a) At Biaora Dewas 4-lanning project NH-3 :-Modified wmm plant for producing RAP mix
b) Production of emulsion treated RAP mix from modified WMM plant

2) *Prime Coat and Tack Coat Laying:* As per designed cross section of service road from section of highway from 326+750 to 332+569, 40 mm BC as a wearing/surface course, 80 mm thick emulsiontreated RAP, 200 mm cement treated subbase 500 mm prepared subgrade. Hence, after laying of CTSB to process and completion of its curing period. Prime coat with cationicbitumen emulsion SS-1, manufactured by A.R. Thermosets. For uniform spraying of prime coat on cement treated subbase, mechanical self-propelled bitumen pressure sprayer were used. The rate of spray of prime coat 9 to12 kg per 10 sqm as per MORT&H Section table-500-3 NO heating and dilution allowed at site in SS-1 emulsion for prime coat spraying. After sprayed at site, 24 hours curing period required before spraying of tack coat. After completionof curing period, Tack coat is sprayed similarly as a prime coat. The sprayer is used for spraying tackcoat, the rate of spray 2.5 to 3.0 kg/10 sqm as per MoRT&H table 500-3. For tack coat cationic bitumen emulsion RS-1 were used. NO any traffic allowed on primed or tack coat layer other than essential construction equipments. The tac coat shall be left to cure until all the violations have evaporated before any subsequent construction is started.

3) *Laying of Emulsion Treated RAP at Site:* After completion of curing period of tack coat, sensor paver used to laid of mix design course, before laying, leveling peg & string wire set out by surveyorteam as per design plan & profile. The compacted thickness of course is 80 mm. sensor rod attached on sting wire, transported mix shifted into the paver hopper. Then sensible paver operated accordingto set level. Assure the mix were laid unfirmly. Hence sample were taken in each 400 tonne mix laidand also thickness checked at site time to time. As per design cross section, service road have 7 m wide carriageway so, paver laid the course in 3.5 m lane width in single time, after laying of mix course, Tandem roller of 80 to 100 Kn were used for achieving compaction as much as high. The compaction operation completed within 2 hours of laying of course.




Figure-A) Laying of mix in service road as a base course by sensible paver
B) Compaction of emulsion treated RAP course by tandem roller

*4)* *Quality Test:* Some tests were performed on laid mix RAP ad mix ingredients used in the productionunit such as:

*a)* Gradation of mix ingredient

*b)* Sample of produce mix for Marshall testing or ITS testing.

*c)* Sand pouring cylinder test for compaction.

*d)* Regular test on bitumen emulsion

All mix ingredients which is involve in the mix design are graded individually and blended as per designed blending mix percentage and every day before starting the mix production, all ingredients (like as cement 20 mm, Recycled material, dust) were taken and as per mix design grading test done in site laboratory. Blending percentage lies within job mix formula limit mentioned in Morth table for DBM/BC.

When production started as per site requirement, the sample taken from production unitto test indirect tensile strength test or Marshall test which is previously described in the mix designChapter. For example, Complete Test report which is performed on emulsion treated RAP mix hasbeen given below with their RFI.




Figure-: Serviceability of various weather condition

## VI. RESULTS AND DISCUSSION

Sieve Analysis were carried out for each individual crushed aggregate and material obtained from recycling of existing highway. The Average Grading were adopted for blending together the combinedgrading.

A series of blending were made to get different combined grading and Marshall properties Test were carried out on different grading to find out the best suited properties.

The Proportion of aggregate is used as given below: -

| Sr. No. | Description Of Test | Sample Description | Test Result Observed | MORT & H Specification (Clause-507.2.2 &Table 500-16) |
|---|---|---|---|---|
| 1 | Combined Flakiness & Elongation Indices | 20 mm Aggregate | 31.00 | Max 35 |
| 2 | Aggregate Impact value | RAP Material | 12.15 | Max 24 |
| | | 20 mm Aggregate | 8.56 | |
| 3 | Water Absorption | 20 mm Aggregate | 0.52 | Maximum 2.0 |

Table-26 : The Proportion of aggregate

This all above listed test indicates the aggregate used in our trial mix have very good mechanical properties and suitable to use as a virgin aggregate.

| Sr. No | Material | % Used by the weight of Dry Aggregate | % Used by the weight of Dry Aggregate and Fluid |
|---|---|---|---|
| 1 | 20 mm Aggregate | 24.00 | 22.32 |
| 2 | Stone Dust | 30.00 | 27.90 |
| 3 | RAP Material | 45.00 | 41.85 |
| 4 | Cement (Filler) | 1.00 | 0.93 |
| 5 | Emulsion SS2 | | 3.50 |
| 6 | Water | | 3.50 |
| 7 | Moisture Correction | | - |
| | Total % | 100.00 | 100.00 |

Table-27 : Final design mix percentage

| Sr. No | Description of Property | Observed Result | Remarks |
|---|---|---|---|
| 1 | Emulsion Content (% ) | 3.50 | |
| 2 | Fluid Content % | 3.50 | |
| 3 | Bulk Density (gm/cc) | 2.359 | |
| 4 | Dry Density (gm/cc) | 2.313 | |
| 6 | Indirect Tensile Strength (KPa) | 366.84 ITS dry<br>191.41 ITS wet | |

Table-28 : Result of Density & ITS on final mix

Submission of Mix design by concessionaire

ORIENTAL

**BIAORA TO DEWAS HIGHWAY PRIVATE LIMITED**

CIN No : U45203DL2015PTC283060

18th Oct, 2019

**Ref: -** BDHPL/IE/NH-3/2K 19/2042

To,

**The Team Leader**
Egis International SA in JV with Egis India Consulting Engineers Pvt. Ltd.
Supreme Computer 2nd Flour Opposite of Collected Office AB Road,
Email- EGIS.BiaoraDewas@egis-india.com

**Sub:** Four Laning of Biaora to Dewas Section from Km 426.100 to Km 566.450 of NH-3 in the State of Madhya Pradesh under NHDP Phase – IV in BOT (Toll) basis on DBFOT pattern.
**- Reg. Submission of Mix Design of Emulsion Treated Reclaimed Asphalt Pavement .**

**Ref:** The Concession Agreement dated 27.08.2015

**Dear Sir,**

With reference to above cited subject, we are submitting herewith test Report of mix design of Emulsion Treated Reclaimed Asphalt Pavement for service road, conducted in presence of IE representative at our Sunera Laboratory and result found satisfactory.
This is for your kind information and Record please

Thanking you and assuring you of our best services at all times.

Yours Truly,
For **Biaora To Dewas Highway Pvt. Ltd.,**

(J. P. Tiwari)
**Project Director (Execution)**
**Oriental Structural Engineers Pvt. Ltd.**
**Encl:** As stated above
**C.C.:-** For favor of information please-

1. The Project Director, NHAI, PIU, Indore.
2. Sh. Raman Kumar, Director (Tech), OSEPL, HO: Delhi.
3. Sh. Ashok Bhasin, President (Tech), OSEPL, HO:Delhi.
4. Sh. Ullas Bhattacharya, AVP (Tech.), OSEPL, HO: Delhi.

Received
M/s EGIS SHAJAPUR
No. 3632
Date 19/10/19, Time:- 04:26PM
Name Sign

Registered Office. 21/48, Commercial Complex, Malcha Marg, Diplomatic Enclave, New Delhi-110 021 India
Phone: 91-11-46044604, Telefax: 91-11-26114421
E-mail: spv.ose@gmail.com,otpl@orientalindia.com
CIN No : U45203DL2015PTC283060

BIAORA-DEWAS ROAD PROJECT
Office: C/o SHRI UDAY BHAVSAR
9, Station Road, SHAJAPUR (M.P.), Pin-465001
E-mail: biaora-dewas@orientalindia.com

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Approval from the NHAI Consultant

egis International

Independent Engineer services for 4-laning of Biaora–Dewas section from Km. 426.100 to Km. 566.450 of NH-3 (Package-III) in the State of Madhya Pradesh to be executed on BOT (Toll) on DBFOT pattern under NHDP Phase - IV

Our ref: EI/TL/MP/BD/2019/1585 26/10/2019

**To,**

**The Project Director, (Execution)**
M/s Biaora to Dewas Highway Private Ltd.
Km. 500+350 of NH-3 (A.B. Road)
Village & Post - Sunera
Tehsil & District – Shajapur (M.P.) 465-001

Sub: - Four laning of Biaora-Dewas Section from Km 426.100 to Km 566.450 of NH-3 in the State of Madhya Pradesh under NHDP Phase IV on BOT (Toll) basis on DBFOT Pattern. – **Submission of Mix Design of Emulsion Treated Reclaimed Asphalt Pavement.**

**Ref:** Your Letter no. BDHPL/IE/NH-3/2K-19/2042, Dated 18/10/2019

**Sir,**

With reference to the above subject and your letter vide which the Mix Design report of Emulsion Treated Reclaimed Asphalt Pavement has been submitted to us for review and found in order.

This has been verified and result found in order as per MORT&H Specification Clause No. 507.2.2 & Table-500-16. Trial shall be done according to Clause 501.6 of MORTH Specification.

**The Details/Results are as below:** -

| Sr.No. | Description | Source | Results | Remark |
|---|---|---|---|---|
| 1 | --- | OSE Quarry Sunera | --- | |
| 2 | Aggregate impact value | --- | 12.15% | |
| 3 | Combined Flakiness & Elongation indices | --- | 29.98% | |
| 4 | 20 mm% | --- | 22.32% | |
| 5 | Stone dust | --- | 27.92% | |
| 6 | RAP Material | --- | 41.85% | |
| 7 | Cement Filler | --- | 0.93% | |
| 8 | Emulsion SS-2 | --- | 3.50% | |
| 9 | Water | --- | 3.50% | |

The Mix Design has been confirmed through a trial stretch at Ch. 317+980 of 100mt. length found in order. Fresh Mix design will have to be conducted and submitted to IE for review if any change in source of materials and etc.

Thanking you.

Yours faithfully
For Egis International SA in JV with Egis India Consulting Engineers Pvt. Ltd.

Egis International S.A.

**(J.L. Roy)**
Team Leader

**Encl:** As above

**CC:** 1. The Project Director, NHAI, PIU – Indore.
2. Authorized Representative, Egis India Gurgaon.

**Egis International S.A. in JV with Egis India Consulting Engineers Pvt. Ltd.**

**Project Office:** Supreme Computer Complex 2nd Floor, Opposite of Collectorate Office, AB Road, Laighati, Shajapur (MP) Pin: 465001, Email: EGIS.BiaoraDewas@egis-indi
**Regd. Office:** T-305, TF, Tirupati Plaza, Sector-XI, (MLU) PKT-4, Plot No. 11, Dwarka, New Delhi-110075, India Tel.: +91 11 4570 4300.
**Corporate Office:** Plot No.68, Sector-32, Gurgaon – 122 001, Ph: 0124-4249200, 300, Fax No. 0124-4249299, Email: egis-india@egis-india.com

Caisse des Dépôts GROUP

## VII. COST ANALYSIS

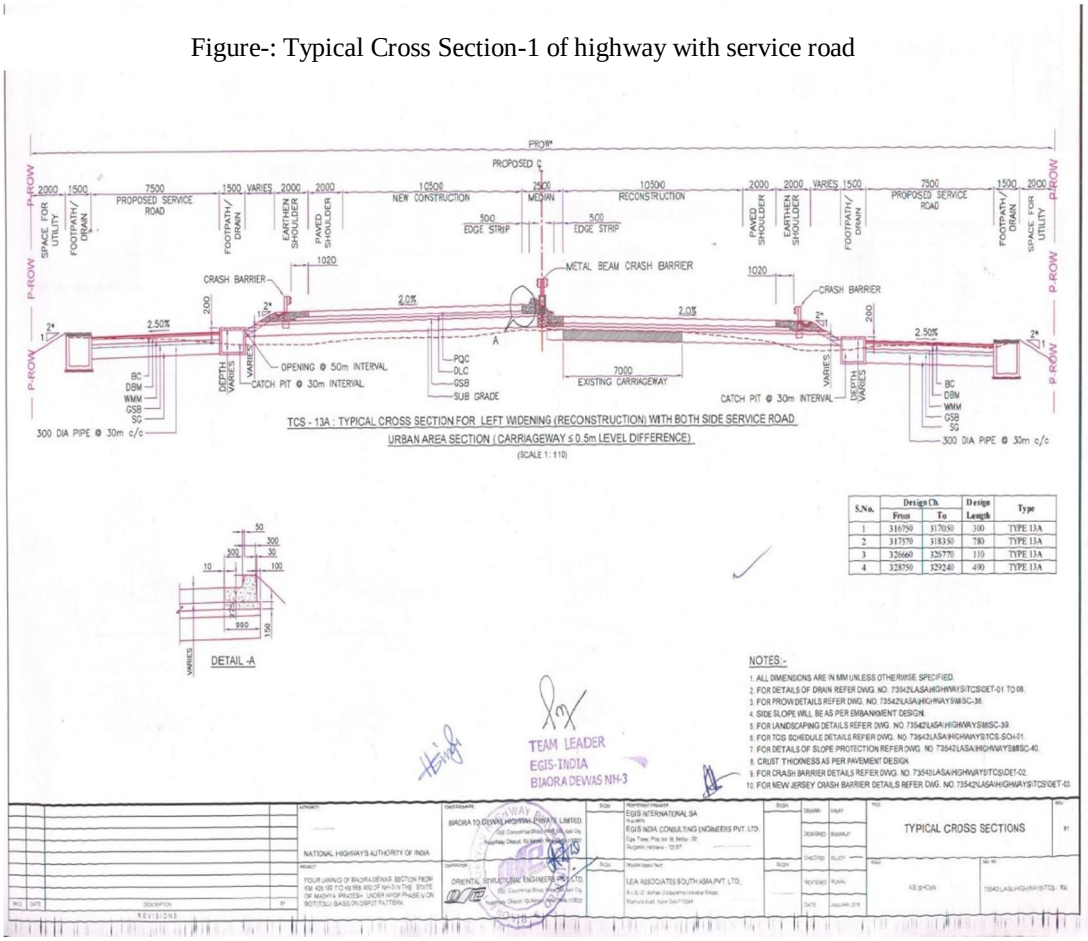
Cost analysis for emulsion treated RAP mix is based on "Schedule of Rates for Road & Bridge Works Government of Madhya Pradesh Public Works Department in force from 06-06-2016 issued by - Engineer-In-Chief public works department M.P. Bhopal". In this SOR all expenses on material & labor for Madhya Pradesh zone is considered and machinery charges, overhead charges, production charges were also included.

In our project stretch 2 type of cross sections for service road finalized from designer
In adherence to clause 5.5.5 of IRC: SP: 84-2014 flexible pavement of service road /slip road/exit ramp/entry ramp has been designed for 10 MSA. Further to utilize the reclaimed asphalt pavement layers due to insertion of new VUP/PUP, reconstruction stretches, two pavement options with different pavement layers material type have been designed (Structural Analysis Input and Output are given in Appendix 6-4) and presented next:

Design traffic: 10 msa Binder: VG 30 grade BitumenSubgrade CBR: 8.5%
Embankment CBR: 4.0% Effective Design CBR: 7.0%
Pavement Alternative 1: Bituminous Pavement with Granular Base and Sub-base

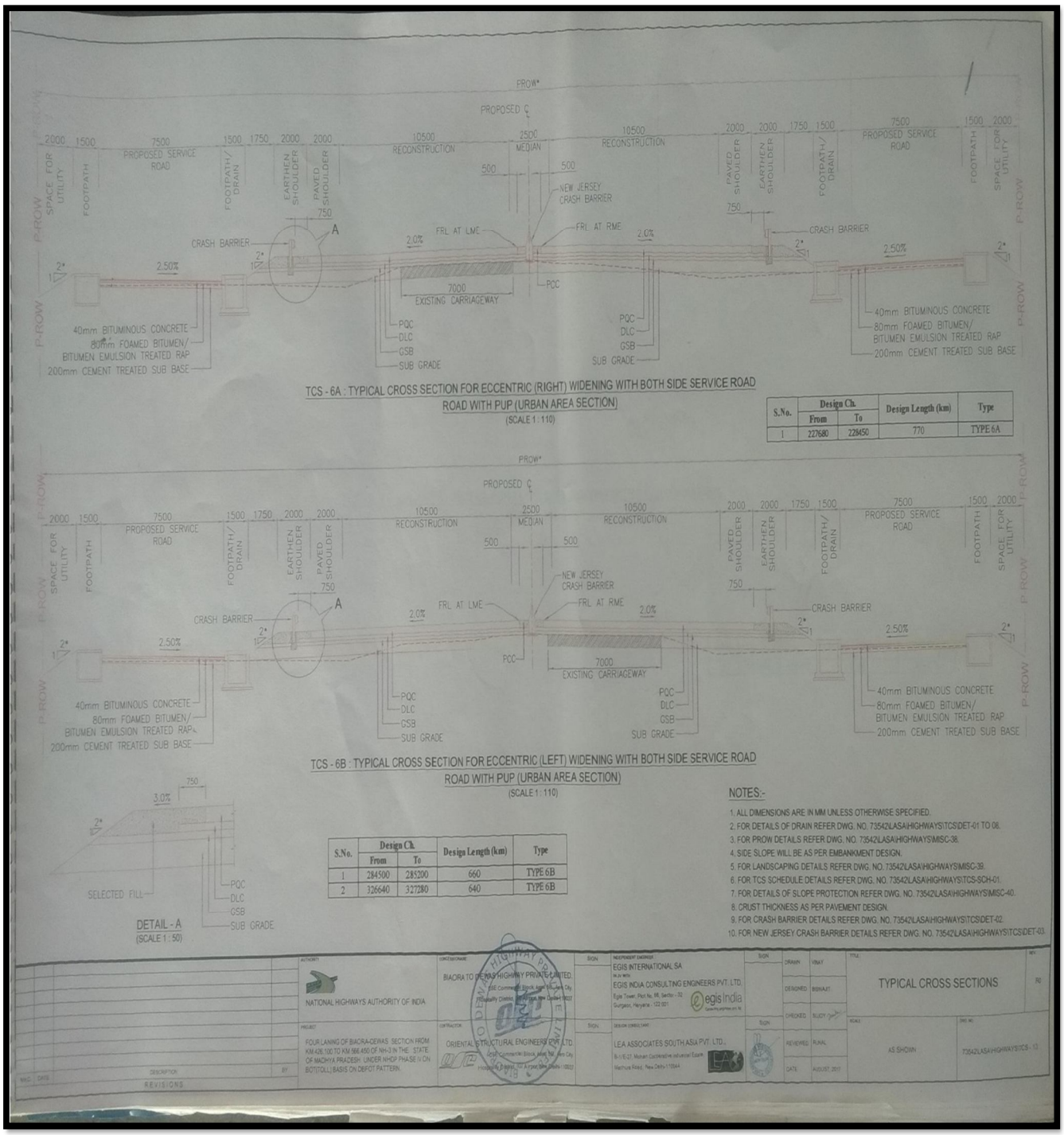
| Description | Thickn ess (mm) |
|---|---|
| Bituminous Concrete | 40 |
| Dense Bituminous Macadam | 60 |
| Granular Base (WMM) | 200 |
| Granular Sub base, Grading-V | 220 |
| Total Thickness | 520 |

Figure-: Typical Cross Section-1 of highway with service road



Pavement Alternative 2: Bituminous Pavement with Foamed Bitumen/Bit u men Emulsion Treated RAP

| Description | Thickn ess (mm) |
|---|---|
| Bituminous Concrete | 40 |
| Foamed Bitumen/Bitumen Emulsion treated RAP | 80 |
| Cement Treated Sub-base,CTSB | 200 |
| Total Thickness | 320 |



| Sr. No. | Item description | Cost per cum | Remarks |
|---|---|---|---|
| 1 | Dense Graded Bituminous Macadam grading-1 | 6663 INR | Rate of mix derived from GOVERNMENT OF MADHYA PRADESH PUBLIC WORKS DEPARTMENT SCHEDULE OF RATES For ROAD& BRIDGE WORKS SOR 2017 |
| 2 | Dense Graded Bituminous Macadam grading-2 | 6630 INR | |
| 3 | Emulsion treated reclaimed asphaltpavement | 4617 INR | |

### *A. Cost Effectiveness*

After studying both the cross section for service road showing in the above ,it is observed that DBM has been replaced by emulsion treated RAP. As per above derived tabulated cost per cubic meter including contractors profit and overhead charges it isclear that cost of Dense graded bituminous macadam grading-1 & 2 are approx. 7000 per cum and emulsiontreated RAP cost is 4617 INR per cum which is 2/3 of cost of DBM. So this course not only eco-friendly as well as cost effective.

## VIII. CONCLUSION

From the results obtained, the following conclusions were made:

*1)* Considering the desirable indirect tensile strength shown by the tested specimen, it is clear that emulsion treated mix design is suitable for laying at site whenever road is constructed for low volume traffic like as service road to facilitated local vehicular user.

*2)* In our research we are not only finalized the mix design for recycling the existing bituminous road material (RAP) but also execute the same at site as a base course (80 mm thick) of service road in our highway project.

*3)* Cost effectiveness that is also an objective of this research has been fulfilled after using of modifiedWMM plant for successfully production of emulsion treated reclaimed asphalt pavement mix because WMM plant generally situated at all highway construction projects that's why no need ofseparate production unit for this mix. Hence we save machinery cost that's why our overall cost also reduces at much higher level.

*4)* Depletion of natural resources day by day is become a very noticeable problem and in every construction project huge amount of aggregates used which is directly obtained from querry minesbut in this research, we are successfully replaced upto 45% virgin aggregate by recycled material (after milling) and also, implementation of this mix design were done in service road of Biaora Dewas project.

*5)* If we are using hot mix process, then huge amount of fuel was consumed in heating of aggregates,filler & bitumen, to produce the mix but this study based on cold mix process hence we saved the cost of additional fuel which is required in heating process that's why cold mix process is becomecost effective process due to low fuel consumption.

*6)* A Case Study on Pollutants Emission and Environmental Management Plan for Hot Mix Asphalt Plant by Krishnareddygari shows that the drier and bitumen heating tank emit very dangerous & toxic air pollutants such as Emission from drier (Suspected particulate matter, SO2 concentration, gas emission, dust emission, SO2 emission) and emission from bitumen heating tank (Nitrogen dioxide, Sulfur dioxide, Hydrogen sulfate, Phenol, Ozone, Hydrocarbons (C1 -C14), Hydrocarbons(C2 -C6), Particulate matter, Poly nuclear aromatic compunds (total), Vanedium, V2U5 fumes, Nickle and soluble nickle compunds (as Ni), Cadmium fume Lead and inorganic compunds). Thisproblem has been resolved in our study by using modified WMM plant and cold mix process in which no need of any heating so it become ecofriendly production unit.

### *A. Scope For Further Work*

In India various studies and research is going on for recycled existing material but further need of a standard codal specification and guideline. In our study we follow the guidelines of IRC 37-2012, MoRTH, TG-2 to finalization of trial mix but after finalization when this mix executed on site there is need to provide guideline for quality assurance tests on field.

There is a lot of scope for further research and meaningful work in this endeavor. Some of these includethe study of:

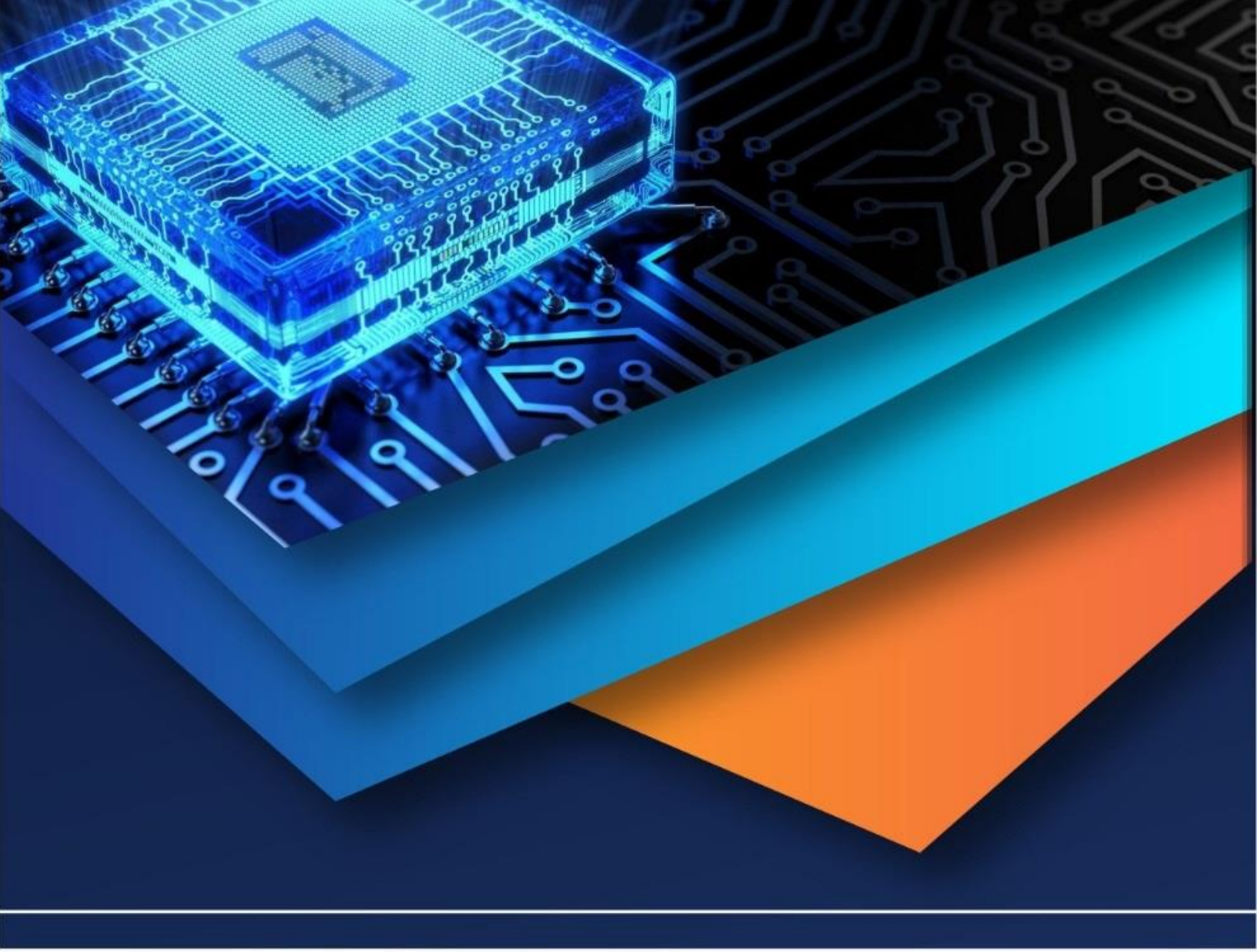
*1)* Research on quality assure test of executed emulsion treated reclaimed asphalt pavement course.

*2)* Research on serviceability of road which is constructed by recycled material.

*3)* Research on contribution of bitumen content which is exist in recycled material.

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