Mix Design of DBM with RAP Aggregates

(Construction Materials)

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***Abstract*— Recycling of asphalt pavements (RAP) is an economical, reasonable and environmentally friendly method material. In the face of rising asphalt prices, low availability of similar products, and extrusion to protect the environment, using RAP is superior to raw materials. So with this project, we can reduce the use of natural resources without compromising the specifications. Recycling the used aggregates with its properties can last for long years of life span of pavement. The main factor driving renewal in recent years is the product, including the price of asphalt and the absence of similar products. Therefore, recycling helps reduce costs, conserve scarce materials and lower labor costs. Thus recycling has an advantage of reducing the budget, protect limited material and decrease the amount of energy requisite.**

By the time goes, new recycling innovations has been acquiring the word of Technology of different levels of construction. With the recycled materials with minimum content of binder contents can elaborate the usage of materials

Keywords- Asphalt, RAP, DBM, Mix Design, Binder Content, Marshall Stability

I. INTRODUCTION

Reclaimed Asphalt Pavement (RAP) has been used as a valuable factor of new asphalt mix for many ages. Most RAP is produced from milling. RAP is milled from surviving pavement by producing to an appropriate size for using which used as a component for new asphalt mixture. Economically, there is an advantage for using RAP till these modules can be reused, thus can decrease the expenditure of purchasing and use less new virgin materials. In spite to economic benefits, the RAP usage has environmental positive. Recycling resource can lessens the reduction of consumption of non-renewable natural resources such as aggregates and asphalt binder. A RAP obtained from different purposes can have different asphalt binder content and properties, aggregate physical and gradation. Some of designers fractionate the RAP through one or more screens to have coarse and fine stockpiles, which will can increase the higher percentage RAP use.

According to Federal Highway Administration, the graph shows the pavement condition, recycling and sustainability relationship.

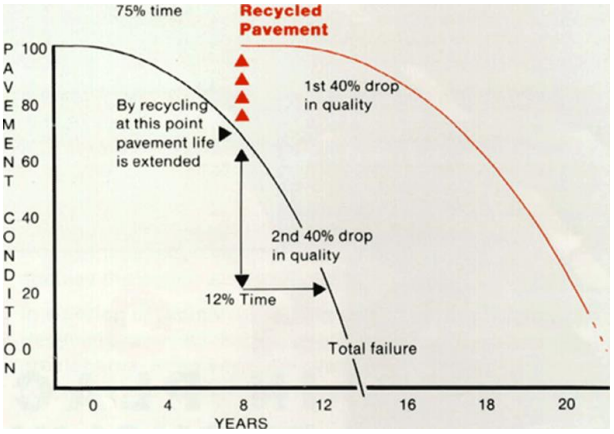


Fig No: 1 Graph showing Pavement condition, recycling and sustainability relationship

Recovered or reclaimed Asphalt Pavement (RAP) refers to asphalt and aggregate and paving contents of coarse aggregates and asphalt binder. These materials are formed from asphalt pavements which are removed for repair, resurfacing, or service. RAP consists of fine, fine grade aggregate and asphalt cement when properly crushed and analyzed.

Asphalt pavements are usually separated by milling or full depth exclusion. Milling takes place in removing the coating using a milling machine that can capture up to 50 mm of thickness in one go. The whole decision involves crushing and breaking the pavement using a truck horn and/or pneumatic pavement breakers. In the best example, crushed material is picked up by a front loader and loaded onto a truck and then transported to the main production area for processing. In this area, RAP is processed by processes such as crushing, screening, transport and stacking. Although most of the old asphalt pavement is reused.

At large construction sites, asphalt pavements will be pulverized on site and mixed into a granular or stabilized base using self-propelled grinders. The process of heating-in-place and cooling-in-place provides continuous progress towards the rail, including cutting deep into the pavement to increase adhesive strength, mixing new recycled materials with aggregates, binders and/or useful products such as softeners or regenerators and place and compact the resulting mixture in one pass.

Yuetan Ma, S.M.ASCE, 2023 studied the mobility of mobile and immobilized RAP binders, showing that fixed RAP binders can enhance asphalt-aggregate interaction and increase the overall asphalt content, together with increasing the strength of 100% recycled asphalt. Shenghua Wu, M. ASCE, 2022 scholarly analyzed the utilization of RAP at low temperatures with 100% coldmix and rejuvenator. The results provides that rutting resistance and dampness resistance were good. Mansour Solaimanian and Xuan Chen, 2021 investigated the degree of blending. The research was unique and innovative volumetric mix design estimated that relatively 75% lingering RAP binder cooperated with the virgin binder and contributed to the final mix. Amal Abdelazia; Eyad Masad, 2021 inquested the procedure of extraordinary volumes of RAP in asphalt pavements and exhibited the effect of the efficiency of recycling agents in enlightening blending and sinking stiffness and aging susceptibility. Ramya Sri Mullapudi, 2020 studied the healing properties of bituminous mixes by means of RAP and emanated with the result that with increasing the proportion of RAP in the mix can increase the fatigue life of mix.

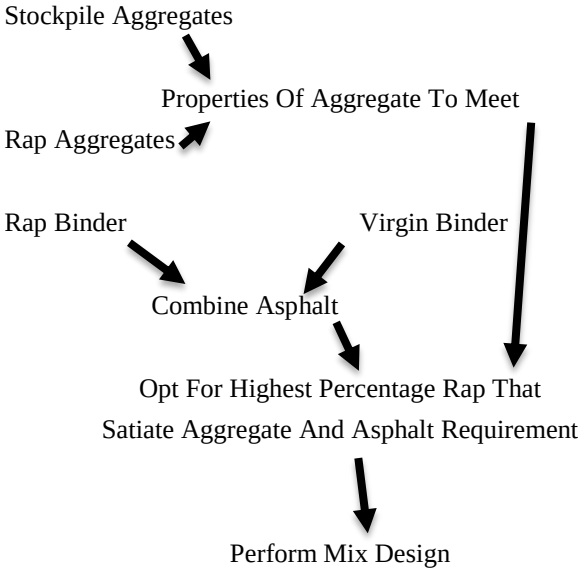
Common RAP Enactment In Pavements

The special effects of RAP have been appraised by many researchers, research societies and engineering establishments, some of the discoveries are offered here in this division. The valuation of missions based on binder properties, structural analysis, serviceability and mix by the Louisiana Department of Transportation and Development in the United States. The research specifies an assuasive presentation as compared to the use of ceremonious materials, about 20 to 50% of RAP was used on these projects. Innumerable of projects are accomplished by means of RAP with proportions ranging between 8% to 79% were appraised by the Washington State Department of Transportation and established that out of 16 projects, the principal two preliminary projects performed well at the time of assessment. The remaining were completed at about 2.5 years before the study, the results indicated a promising result. However, the results indicated that pavement with RAP showed more longitudinal cracking distresses. A study by Jorisa et al (2019), using 30% RAP and measured indicated that pavement roughness was low-slung, no rutting noticed and viscosity was upper than that of control asphalt mix.

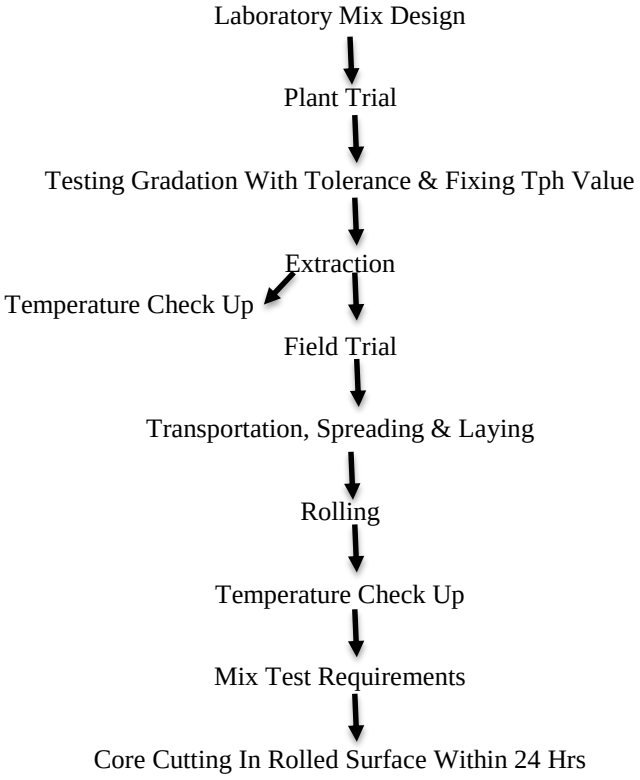
II. OBJECTIVES

To evaluate the final Mix design of DBM with RAP percentage and minimum binder content which is lesser than least content.

III. METHODOLOGY



Flow Chart of First Stage



Flow Chart of Second stage

JOB MIX FORMULA

The job mix formula has to approved before the work heretofore to start. So, below mentioning reports have to be submit with the job mix formula.

Source and location of all materials.

Asphalt content, type and percentage by weight of total mix.

Aggregate (coarse and fine), filler proportions by weight of total aggregate mix.

Design mix definite percentage for aggregates.

Gradation of aggregates and filler.

Test reports of weight of each fraction of aggregates and binder.

Reports of tests taken for physical properties of the aggregates heretofore in the work.

Test results for measurement of mixture such as maximum gravity (Gmm) of loose mixture, density of compacted sample for various binders, voids in mineral aggregates (VMA), air voids in compressed mixtures (Va), Void filled in bitumen (VFB).

Marshall Stability, stability and flow reports.

Mixing and compacted temperature.

Marshall Design curves plotted for different binder standards showing stability, flow, velocity, volume, VMA, and VFB.

MATERIAL PROPERTIES

3.2.1 RAP properties

For any mix designing, one should know the asphalt binder content and gradation as well as physical properties for blending charts used to choice the applicable grade of virgin or freshly added asphalt binder.

RAP binder content and aggregate gradation

There are two main methods for determining the RAP binder content: the electrical extraction method (following the procedure in AASHTO T 308) and heavy extraction (AASHTO T 164). The extract was then put to the test. The RAP binder content is determined by solvent extraction using a solvent such as petroleum (AASHTO T 164 or ASTM D-2172).

Average Binder Content is 2.80%.

RAP Gradation

This facilitates the determination of aggregate grain size, which is the most important characteristic of coarse or fine aggregates that dominate the maintenance of hot asphalt mixes. A study by Roberts et al. (1996) discussed that stability, durability, rigidity, workability, fatigue and permeability are exaggerated by gradation in hot mix asphalt mixture. ASTM C136 and AASHTO T27 are standard gradation references and sieve analysis for coarse and fine aggregates. RAP mix performs better than other products in cleaning and RAP processes due to poor performance in hot asphalt products. The types of materials and aggregates used in RAP production determine the size of the aggregates obtained by grinding.

Fig No: 2 RAP Gradation

Physical Properties of Virgin aggregates

The Aggregates from crusher located at Theodical, Ranni were tested for physical properties in the laboratory located at Perumthuruthy. The test Results are summarized as detailed below:

Table No: 1 Physical properties of Virgin aggregates

NAME OF TEST	TEST METHOD	TEST RESULTS	REQUIREMENT AS PER MORT&H
Aggregate Impact Value	IS:2386 Part-4	21.97	Max:27 %
Flakiness & Elongation Index	IS:2386 Part-1	22.94	Max:35 %
Coating and stripping of Bitumen aggregate mixture	IS:6241	98%	Max:95 %
Cleanliness for 3mm Down Aggregate	IS:2386 Part-1	0.54	Max:5% Passing 0.075 mm Sieve
Loss Angeles	IS 2386 Part-4	22.2	Max 35 %
Water Sensitivity	AASHTO 283	93.6	Min:80 %
Plasticity Index	IS:2720 Part-5	NP	Max:4%

Table No: 2 Average Individual Hot Bin Gradation For DBM (Rap)

IS Sieve (mm)	32-19 mm	19-10 mm	10-4 mm	4mm down	Filler	RAP material
37.5	100	100	100	100	100	100
26.5	100	100	100	100	100	100
19.00	35.81	100	100	100	100	100
13.20	2.31	55.68	100	98	100	98.1
4.75	0	15.22	42.2	54	100	54.3
2.36	0	1.06	32.3	82.2	100	29.9
0.300	0	0	1.2	35.3	100	9.3
0.075	0	0	0	9.8	100	2.7

Properties of Bitumen

The Bitumen Grade of VG-30 brought from BPCL used for carrying out the laboratory design mix. The specific gravity of Bitumen is 1.05 and the other properties like penetration, softening point, specific gravity are also accordance with the under quality requirement as per is 73-2013 indicated below:

Table No: 3 Bitumen Test Results

NAME OF TEST	TEST METHOD	TEST RESULTS	REQUIREMENT AS PER IS:73
Specific Gravity at 25 ºC	IS:1202-1978	1.05	Minimum 0.99
Penetration at 25º C ,mm	IS:1203-1978	49	Minimum 35
Softening point, ºC	IS:1205-1978	51	Minimum 50
Ductility in CM	IS:1208-1978	90	Minimum 25
Viscosity(Absolute), Poise	IS:1208-1978	3490	2400-3600

MIX DESIGN

Mix design starts with individual gradation of virgin materials available at stockpiles. Desired mix design is Dense Graded Bituminous Macadam (DGBM) which is well compacted, densely graded ready mix asphalt mix to create a good pavement substrate. The Dense Bituminous Macadam consists of proportioned mixture of Coarse aggregate, Fine aggregates, Bitumen VG-30 and Recycled Asphalt Pavement (RAP) material to meet the requirements of mix gradation, Stability, Flow, Density and Voids analysis. The Laboratory determination of "Job Mix Formula" for Dense Graded Bituminous Macadam course was carried out for the source of bitumen from BPCL, Aggregates obtained from the Amity Crusher and Rap material of Existing Road from RKI Package IV-Road 7- Rehabilitation and Up-gradation of Thattararmbalam - Michel junction - Kochalummood - Mangankuzhy - Pandalam Road (Length 18.657 Km) in Alappuzha District.

Proposed Aggregates for Mix Design

Source of Aggregates: Amity Crusher Plant Located at Ranni Theodical. The Selected Aggregates for Dense Graded Bituminous Macadam Design are Crushed Stone Aggregate and Size as Follows.

Hot Bin No B1 32 - 19 mm

Hot Bin No B2 19 - 10 mm

Hot Bin No B3 10 - 4 m

Hot Bin No B4 4 mm DOWN

Filler (Cement) B5

RAP R1

Fig No: 3 Trial & Error method for fixing blending proportions

Size of aggregates	Mix proportion (%)
32-19 mm	**24**
19-10 mm	**13**
10-4 mm	**15**
4 mm DOWN	**26**
CEMENT	**2**
RAP	**20**

Job Mix Formula on Asphalt Mixtures with 20% Reclaimed Asphalt Pavement (RAP) Dense Graded Bituminous Macadam

For recycled materials, defined as the percentage of the total weight, the amount of raw bitumen should be added to the test mix. Using an aggregate blend of 20% RAP aggregate and 80% of new aggregate, trial mixes of different asphalt content (varying in 0.5% increment) are prepared according to standard Marshall method. The binder content of normal DBM is 4.5% but in this project, content is reduced to 4.25% as part of cost friendly as well as comsumption.

Average % of Bitumen content in Rap Material from Extraction, Rib = 2.8%

Table No: 4 Percentage proportion of Bitumen and Aggregates

Asphalt Content, BP	4.25
Total Aggregate Pa (%)	95.75
Virgin Aggregate%=(Pa*80/100)	76.60
Rap Aggregate Ra %=(Pa*20/100)	19.15
Rap Material after adjusting for bitumen, % = (Ra+((20*Rib)/100))	19.71
New Bitumen Content (%) = (BP-((20*Rib)/100))	3.69
DBM Grade-2 with Rap Mix (%)	100

PREPARATION OF MIX

The Dense Graded Bituminous Macadam (DGBM) mix shall be produced from the hot mix plant, which is located at Perumthuruthy. The plant was calibrated for weight batches of aggregates, Bitumen was found satisfactory.

Fig No: 4 HM Plant

According to the Australian document: Draft Engineering Road Note 13 B-Asphalt Mix Design with RAP, the percentage of RAP in HMA is divided into three levels:
Level - 1: ≤ 10% RAP
Level - 2: 11% - 25% RAP
Level - 3 : 26% - 40% RAP
Max. 15% RAP for heavy vehicles and polymer surfaces. For mid-range traffic max. 20% RAP. Max 25% Discount on RAP Light Vehicle Crash Route, 40-55% for middle and primary school grades.

Fig No: 5 Laying

Fig No:6 Spreading

Table No: 5 Mix requirements of DBM

Properties	Viscosity grade paving bitumen	Modified bitumen		Code
		Hot climate	Cold climate	
Compaction level	75 blows on each face of the specimen			
Minimum stability (KN at 60 ^{0}C)	9.0	12.0	10.0	AASHTO T245
Marshall flow (mm)	2 - 4	2.5 - 4	3.5 - 5	AASHTO T245
Marshall quotient (stability / flow)	2 - 5	2.5 - 5		MS-2 and ASTM D 2041
Air voids %	3 - 5			
Voids filled with bitumen (VFB)%	65 - 75			
Coating of aggregate particle	95 % (Min)			IS: 6241
Tensile strength ratio	80 % (Min)			AASHTO T 283
Voids in mineral aggregate (VMA) %	Minimum percent voids in mineral aggregate (VMA) are set out in table 500-12 of MoRTH			

Fig No: 7 Extraction Test

Fig No: 8 Density Checking

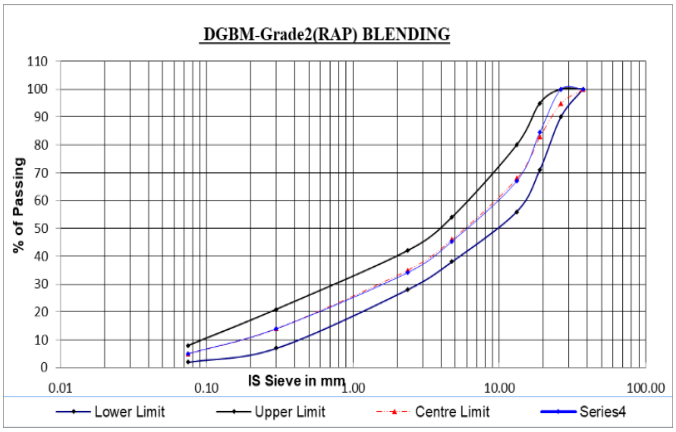
Fig No: 9 Core Cutting

Fig No: 10 Marshall Stability Testing

IV. RESULT AND DISCUSSION

Table No:6 Combined Gradation after Mix Preparation

				Sample weight gm	15000
IS Sieve (mm)	**Weight Retained (gm)**	**Cumulative Weight Retained (gm)**	**Cumulative Weight Retained (%)**	**Achieved Gradation**	**Specification Limits**
37.50				**100.00**	100
26.50				**100.00**	90-100
19.00	2312	2312	15.41	**84.59**	71-95
13.20	2633	4945	32.97	**67.03**	56-80
4.75	3261	8206	54.71	**45.29**	38-54
2.36	1685	9891	65.94	**34.06**	28-42
0.30	3021	12912	86.08	**13.92**	7.-21
0.075	1334	14246	94.97	**5.03**	2.-8



This gradation graph represents the range of material sizes involved in the mixes and upper and lower limits in the graph compares the specifications as per Mo&RTH. As per the result obtained, the percentage of aggregates blended in the design are in correct proportion and good parameter for well graded asphalt mix.

Table No: 4.2 Results of DBM Mix with RAP @ OBC

Sl no:	Description	Specification limits	Marshall Parameters @ Optimum binder Content 4.25%
1	Bitumen Content(OBC) %	4.5	4.25
2	Bulk Density of mix(g/cc)	-	2.456
3	Max. Specific Gravity of Mix(GMM)	-	2.548
4	Marshall Stability in KN	9	13.65
5	Marshall Flow in mm	2-4	2.95
6	Marshall quotient(stability/flow Ratio)	2-5	4.6
7	% Air Voids(VIM)	3-5	3.62
8	Voids in Mineral Aggregates(VMA)	Min 12 %	12.77
9	Voids Filled With Bitumen(VFB)	65-75 %	71.67
10	Water Sensitivity	Min 80 %	94.5

This is result obtained after the field trial mix laid with paver at site for compaction study as well as blending nature of mix. With good texture of mix, without any segregation and bleeding the mix is laid at high temperature specified in Mo&RTH. The quality tests results are given above. The results showing that with 20% RAP with DBM mix design gives a good mixture of Asphalt mix at minimum binder content which is economical as well as environmental friendly.

The procedure of higher proportion of RAP in mixtures can ultimately increases the virgin binder content because the finer materials will consume more binders than other coarse materials. With comparative amount of RAP with asphalt mixes and minimum binder content can results required to meet the parameters needed for the pavement design. Hence, it will increase the durability and compaction of pavement. Bleeding phenomena in pavements occurs during high temperatures due to the overuse of binder content. The RAP binder content and virgin binder in required minimum amounts can eliminate this phenomena.

Research on the distribution of recycled material, showing that the perfect mix of old and virgin is wrong in every case. There are some combinations of these adhesives depending on the involvement temperature and some other factors like age and viscosity of the original bonding agent, percentage of RAP modified, type of mix, selection of plant, timing of mixing engines. Older and unused binders may be found in recycled materials in separate stages. The degree of mixing of the two mixtures will depend on the temperature, the viscosity of the adhesive, and the biochemical composition of the material. More budgeting and cost-effective installation with minimal details.

The air voids in aggregates is the air void in between the body skeletons twisted by coarse aggregates, the asphalt binder, fine aggregates and air voids. The air void remunerations a role in determining the aggregate interconnecting between them, and directly reflects on aggregate compaction. To some extent, compaction of pavement decreases the volume of air voids in mixture thereby packing of pavement mix. Therefore, the representative of apprehension is the volume of air within the compacted package of pavement, which is characteristically enumerated as a percentage of air voids in relation to total volume and expressed as “percent air voids”. With effect of RAP mix in asphalt mixes, have high fine contents can eliminate the air voids to some extent. This phenomena can increase the strength of pavement.

V. CONCLUSIONS

As an upshot, the subsequent conclusions and recommendations are,

With increased percentage of RAP in Asphalt mixes can increase the environmental pollution and impact the durability of pavement. So, always considered to be precise with our requirements and limitations for the mix design and specifications. The balanced mix design procedure is mostly based on determining OBC, specified density, rutting and fatigue criteria.

Usage of rejuvenators initiated to proliferatiing the moisture resistance, cracking resistance nevertheless can impact the rutting resistance of recycled mixture, and hence here the mix design is free from rejuvenators. In many places, availability of these rejuvenators is also not convenient and compactable.

Entry into the RAP area indicates continued use of the product of the mix while avoiding the use of virgin natural aggregates and therefore requiring less energy and handling. This method reduces transportation costs, affects less traffic, takes less time, but requires the use of bulky machinery. The Eco friendly resources consumption can increase green technology use of materials, increases the life of ecosystem. According to the results obtained, RAP can be used as a non-binding material in all areas except acidic areas (eg pH $\leq$ 4). These acidic areas include, but are not limited to, mines containing sulfur-containing minerals and landfills where organic matter decomposes to create an acidic environment.

Reuse of a resource such as aggregates of RAP lessens the depletion of non-renewable natural resources and low consumption of natural resources. Limited RAP usage can increase life of pavement and reduce land fill consumption. The use of RAP reduces the need for new fuel in the asphalt process. Recycled asphalt is 100% recyclable and renewable so it has a very long life. It reduces other waste in the landfill. Sidewalks and other RAP are made from a combination of recycled materials, including glass, rubber, metal and cement.

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