RECYCLED ASPHALT PAVEMENT USING WASTE VEGETABLE OIL AS REJUVENATOR

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ABSTRACT

As the cost of asphalt binder is rising and the budgets in hand are limited thus maximum use of recycled asphalt is the need of the hour. While Industries all over the world are moving towards sustainable practices, we should also aim for the same. Many industries are looking only to develop hot asphalt mixes as recycle with only 40% RAP content; this research aims to take it to 100%. The main drawback of using 100% recycling is the unknowing of properties of 100% RAP pavements and lack of knowledge for selection of materials and mix design. The aim of this research is to critically examine the idea of 100% recycling of asphalt, determine whether such mixtures can perform at par with regular asphalt mixes. A mix design approach is presented based on performance which reduces the emission also cuts down cost of material and have a positive environmental impact. We have used Marshall Stability and flow test for asphaltic mix. Validation of this method is based on laboratory performance of 100% old asphalt modified by waste vegetable oil as rejuvenator, which restores the chemical and physical properties of 100% RAP to perform as equal to conventional asphalt mixes. After analysis, we have found that 12% additions of rejuvenator with the addition of just 0.25% of bitumen (VG-30) in old asphalt have satisfied the required Marshall Stability and flow value. Recycled asphalt pavement using waste vegetable oil as rejuvenator production has enabled material related cost savings of 76.52 % compared to conventional asphalt pavement mix.

Keywords: - *Mixture design, Recycled asphalt pavement (RAP), Rejuvenators, Bitumen, Marshall Stability test.*

1. INTRODUCTION

India has a very huge road network roughly around 5.89 million kms, it is second in world ranking and it is responsible for 64.5% of goods traffic and 90% of travelling traffic in the country. Over the years the country has witnessed increase in road connectivity throughout its length and breadth, this in turn has boosted the sale of automobiles both in LMV and HMV categories. So, there is a huge stress on our roads and naturally available aggregates. Even the environment and our economy are under huge stress for constructing and maintaining the roads. There has been rapid increase in the prices of bituminous pavement materials, so there is a need to find out alternative use of materials. Stone quarries have reduced in numbers because of already continuing extensive mining, this is one day lead us to shortage of material due to depletion of natural resources and thus there is a need to successfully carry out "Recycling". Recycling helps in reducing the usage of virgin natural aggregates, which in retrospect cuts down the cost of material and also is environment friendly. Removed pavement material comprising of bitumen and aggregates, such materials can be found when we remove asphalt pavement while reconstruction or resurfacing work, upon the process of crushing and screening we find that RAP has very high quality and well graded aggregates which are asphalt coated. If we compare the base virgin mix to RAP they tend to show poor performance since they are detoriated version of asphalt and aged aggregate with bitumen, therefore we need to

enhance the performance of RAP which can be done by adding "rejuvenators " which could be in the form of waste vegetable oil in appropriate proportions. Rejuvenators act as aid in recycling; they are suitable for oxidizing RAP mixtures in large quantities. By using rejuvenators we put back the oils of bitumen binders which are lost during aging of asphalt mix; it also balances back the composition of bitumen to make it non brittle. The entire idea behind RAP is to restore the properties of aged bitumen to its original strength while enhancing the properties of aged bitumen. Use of RAP would significantly reduce the cost of material and in turn the cost of the entire project. It will help us in maintaining the pre existent pavements and also support in preserving the environment. Since we can reuse old pavements it paves room for efficient rehabilitation thereby making RAP a more apt technique.

2. LITERATURE REVIEW

2.1 Related Reserach Work

1) Martins Zaumanis, Rajib B. Mallick, Robert Frank described a mix design based for binder and mixture on performance related test methods. Six rejuvenators were tested for rutting and low temperature cracking for 100% recycled asphalt mixtures, modified with the same and the results indicated that optimal design can provide equivalent performance to virgin mixture. All the samples pass the specification requirement but rejuvenator shows an increment in rutting depth. The sample of virgin mix has failed the specific limits. The only samples i.e., Aromatic Extract and waste vegetable oil mix has performed as per limits required. It has shown good results in low temperature cracking test.

2) Dr. Lily Poulikakos , Dr. Martins Zaumanis, Dr. Maria Chiara Cavalli, Dr. Maria Munoz Fernandez , Dr. Norbert Heeb explained working of AMMANN RAH100 Plant, the project is considered to make 100% recycled asphalt pavement according to the current Swiss standards. Adding of rejuvenator has no emission increase, adding of 3% to 5% rejuvenator compared to 0% rejuvenator. Smoke is used to heat the aggregates with high temperatures. The emission of 100% recycled asphalt is low compared to conventional mixture, it was seen that by changes in asphaltic mixture, it is possible to make the asphalt mixture work as 100% provides similar performance as equal to traditional asphalt.

3) Rajib B. Mallick, Mingjiang Tao, Karen A. O'Sullivan described that a sample was prepared with milled RAP. Dynamic modulus and creep compliance test was done in laboratory. Samples are observed for specific temperatures over for five week. After adding rejuvenator the sample gets soften which improved the age of sample at -10˚C. Studies say that rejuvenators are an important material for large recycled asphalt mixes which is presently produced at traditional asphalt plants. They concluded that rejuvenator plays key roles and has shown low-temperature cracking which has a major concern for RAP mixes used; RAP can be produced using existing suitable plant with good quality performance.

4) Russell Edgar Carlson IV described that asphalt mixtures are produced at 135°C in a regular asphalt plant. However all binder from RAP materials may not be effective enough for coating aggregates at the said temperature of 135°C. The aim of the study is to evaluate the amount of binder available from RAP in the asphalt mix. Aged binders are a part of RAP which can significantly affect mix designs and virgin binder. In detailed analysis by low temperature cracking resistance and fatigue performance, various samples were prepared both by using virgin binders and also without using virgin binders in order to evaluate best ratio of binders. Compaction tests were conducted by heating RAP materials under various temperatures, in conclusion it was discovered that 100% RAP mixes are not feasible for field use. Thus beam fatigue testing results were acceptable. But increased heating is needed to elevate the effectiveness of asphalt.

5) Ahanthem Korea, Amit Goel describes the ideal RAP mix proportions for this did tests like impact test, crushing test, Marshall stability and flow test on the pavement containing RAP in various proportions 20% to 50% excluding the RAP of size 20mm , they added Zycotherm an anti-stripping agent, after the screening process 1% of virgin binder contain are replaced by binder attached on RAP aggregates. For modified and conventional pavement sample Marshall Stability and flow value tests performed. Impact test, crushing test, shape test, specific gravity and bitumen extraction test are performed for RAP aggregates and virgin aggregates. For virgin bitumen and modified bitumen softening and penetration test are performed. It was found that when zycotherm is added the Penetration value of bitumen decreases. When 3.8% of RAP bitumen is added to the virgin bitumen then we get best results.

3. METHODOLOGY

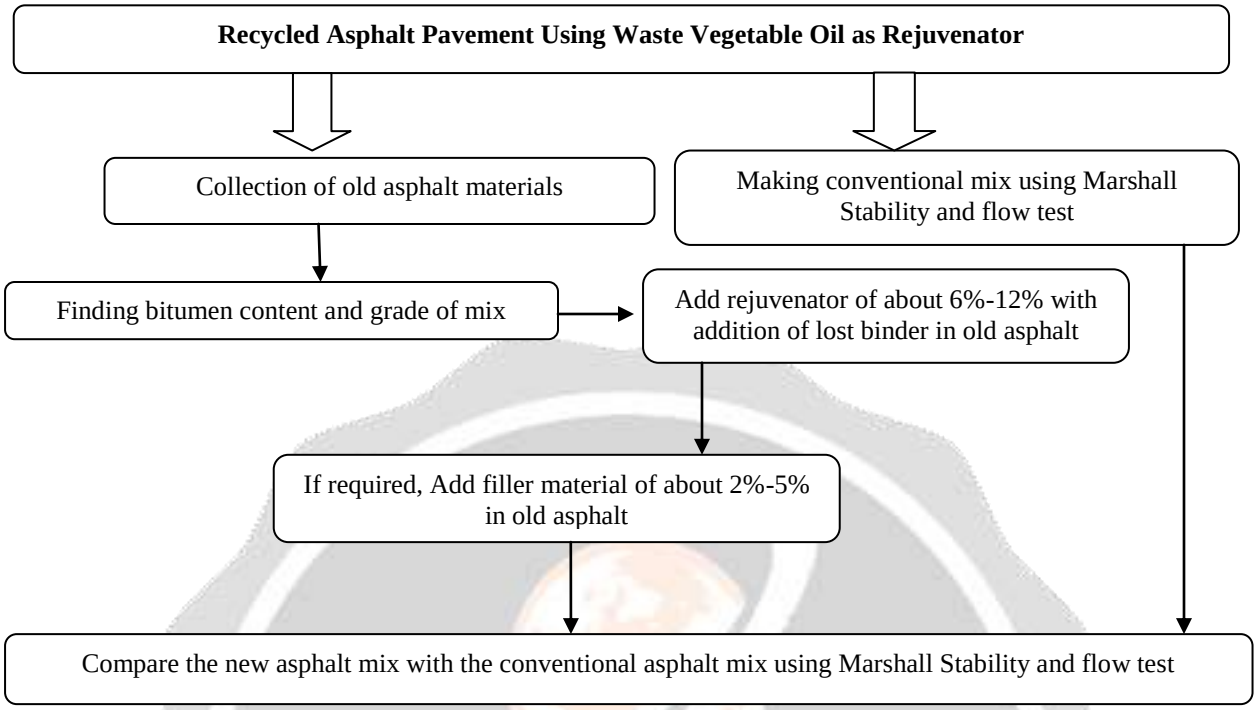

Fig -3: Flow Chart of the Methodology

3.1 Collection of Materials

- Collection of old asphalt
- Rejuvenator – Waste vegetable oil
- Bitumen binder – VG 30
- Filler material – Cement OPC 43 grade
- Fresh Aggregates

Fig -3.1: Old Asphalt Sample

3.2 Extraction of Bitumen (VG-30) from Old Asphalt

Extraction of bitumen is done using the bitumen extractor machine by cold solvent extraction. Bitumen obtained is **4.36 %**.

3.3 Gradation of Old Asphalt

According to MoRTH 4th Revision, **Semi-Dense Bituminous Concrete** has satisfied the required specified limits of gradation. As SDBC has satisfied more numbers of gradation limits, the mix design for fresh aggregates and old asphalt will be done using SDBC Grade-I graded aggregates.

Fig -3.3: Gradation of Old Asphalt

4. ANALYSIS OF MIX DESIGN USING FRESH AGGREGATES

4.1 Preliminary Tests

The testing of materials helps us to know the knowledge of strength and properties of the materials. Below mentioned following are the tests done on aggregates and bitumen with their results:

Los Angeles Abrasion Value Test – 22.63 %
Impact Value Test – 20.66 %
Specific Gravity of aggregate mix – 2.60
Water Absorption of aggregate mix – 1.63 %
Flakiness and Elongation index – 13.74 %
Specific Gravity of Bitumen – 1.08
Flash point – 290°C
Fire point – 315°C
Softening point of bitumen – 50°C
Penetration value of bitumen – 44
Specific gravity of old asphalt aggregate mix - 2.64

4.2 Mix Design for Conventional Asphalt Mix

Mixes are made with blend aggregates with increasing percentage of binder content, say from 4.0% to 5.5% by weight of aggregates with an increasing percentage of 0.5%., three test samples is made for every binder content.

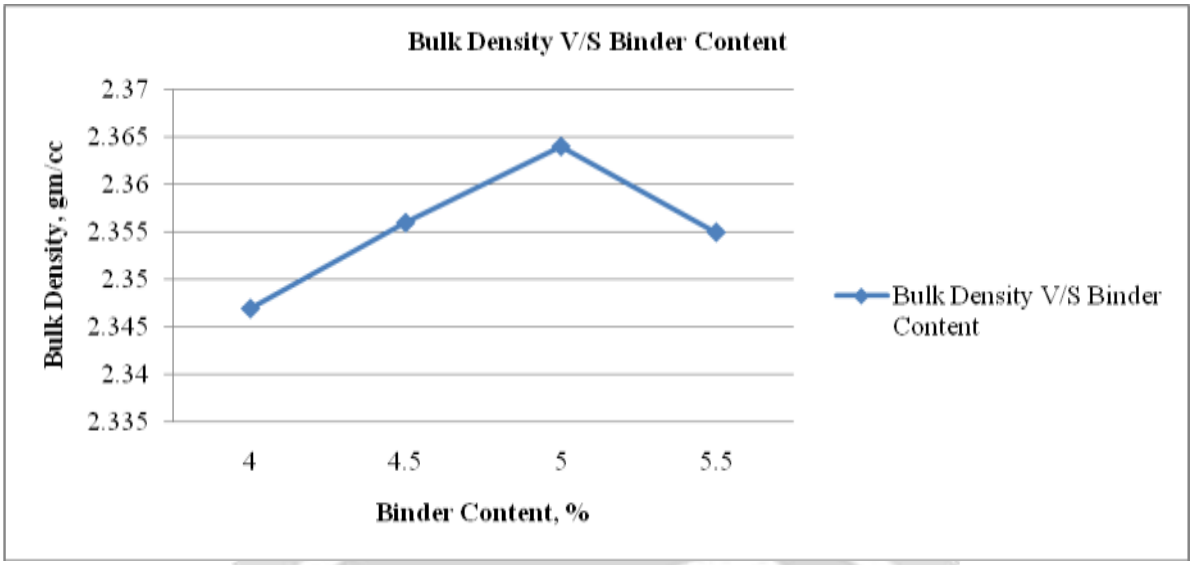

Chart -4.2.1: Bulk Density V/S Binder Content

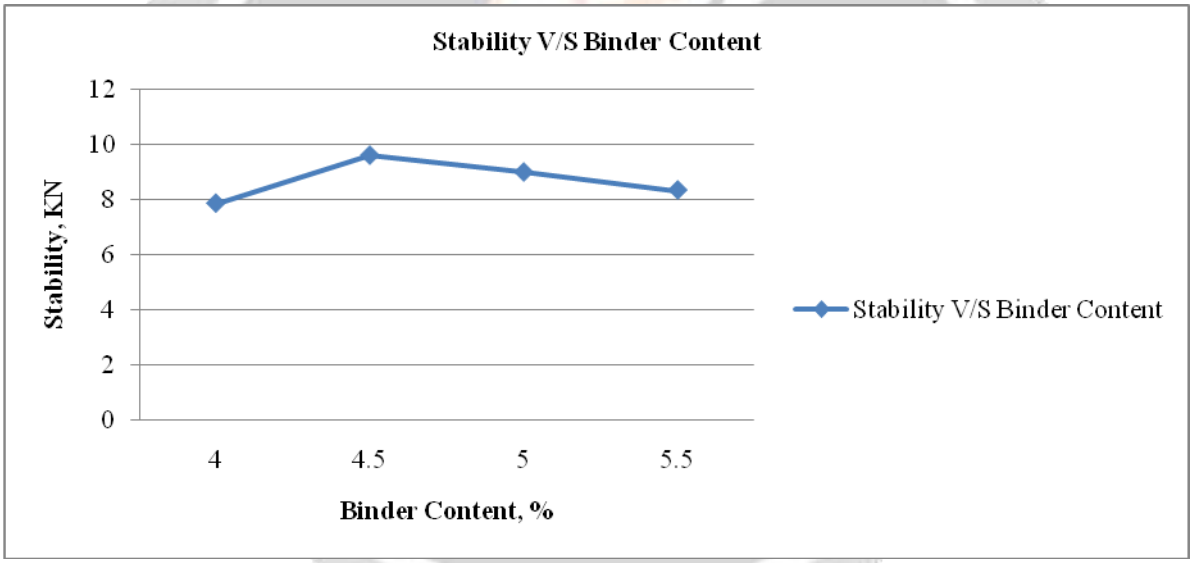

Chart -4.2.2: Stability V/S Binder Content

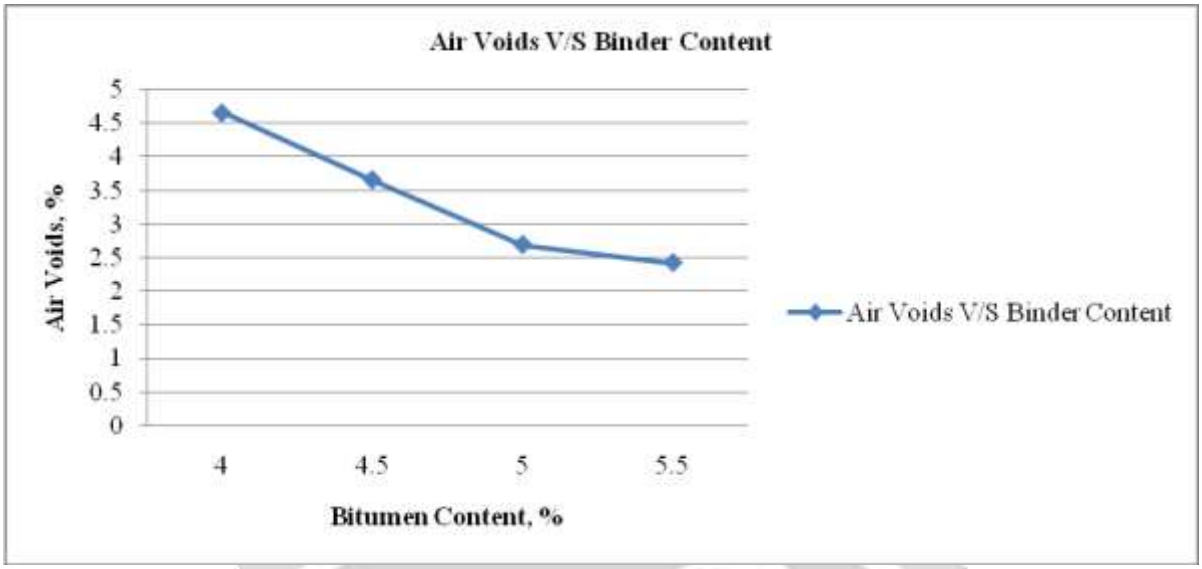

Chart -4.2.3: Air Voids V/S Binder Content

4.3 Optimum Binder Content

1) Binder Content for Maximum Bulk Density = 5.0%

2) Binder Content for Maximum Stability = 4.5%

3) Binder Content for 4% Air Voids = 4.3 %

Average Binder Content = 4.6%

4.4 Final Testing of Conventional Asphalt Pavement Mix

Table -4.4: Conventional Asphalt Pavement Mix

Sl. No.	Particulars	For Bitumen @ 4.6%		
	Trail	Trail 1	Trail 2	Trail 3
1	Weight of core in air (grams)	1215	1240	1225
2	Weight of core in water (grams)	715	730	720
3	Saturated surfacedry core weight (grams)	1230	1255	1240
4	Volume of core (cc), (3-2)	515	525	520
5	Density of core (grams/cc), (1/4)	2.359	2.361	2.355
	Density Average	2.358		
6	Marshall stability(KN)	11.23	11.33	10.94
	Marshall stability Average	11.16		
7	Flow value (mm)	3.64	3.86	3.52
	Flow value Average	3.67		

Fig -4.4: Mould for Conventional Asphalt Pavement Mix

4.5 Cost Analysis of Conventional Asphalt Pavement Mix

Cost for conventional asphalt pavement mix is done as per Port Blair (Andaman Islands) material price, May 2021.

Table -4.5: Cost for 1 m^3 of Conventional Asphalt Pavement Mix

Sl.No.	Particulars	Units	Rate	Percentage/Quantity	Amount
1	16 mm	m^3	Rs 1600	10%	Rs 160
2	12.5 mm	m^3	Rs 1600	50%	Rs 800
3	Less than 4.75 mm	m^3	Rs 1800	38%	Rs 684
4	Transportation	m^3	Rs 250	1	Rs 250
5	Bitumen VG-30	kg	Rs 65	110.4 (4.6%)	Rs 7176
6	Cement OPC 43 grade	kg	Rs 10.8	28.8 (2%)	Rs 311.04
7	Fuel (Diesel)	Liters	Rs 75.69	2	Rs 151.38
8	Labours	Persons	Rs 25	7	Rs 175
	Total Amount for 1 m^3				Rs 9707.42

5. ANALYSIS OF MIX DESIGN USING OLD AGGREGATES

Rejuvenators are the key agents which bring back the chemical, mechanical and physical properties of aged bitumen to work as almost equal to its original form. Rejuvenator is added around the mass of weight of 4.36% of bitumen in every mix. Adding the appropriate percentage of rejuvenator will make the old asphalt to be worked as 100%. Below mentioned following are the percentage of rejuvenator with the addition of bitumen binder of about +0%, +0.1, +0.2%, +0.3%, +0.4%, +0.5%:

Adding bitumen (VG-30) from 0% - 0.5% in rejuvenated asphalt mix of 6%, 8%, 10%, 12%.

Table -5.1: For 6 % Rejuvenator in Old Asphalt Mix

Sl. No.	Particulars	0% Binder	0.1% Binder	0.2% Binder	0.3% Binder	0.4% Binder	0.5% Binder
1	Marshall stability(KN)	9.95	11.80	11.88	13.82	14.37	14.93
2	Flow value (mm)	4.88	4.98	5.16	5.66	6.02	6.24
3	Bitumen content	4.36 %	4.46 %	4.56 %	4.66 %	4.76 %	4.86 %

Table -5.2: For 8 % Rejuvenator in Old Asphalt Mix

Sl. No.	Particulars	0% Binder	0.1% Binder	0.2% Binder	0.3% Binder	0.4% Binder	0.5% Binder
1	Marshall stability (KN)	9.12	10.17	10.78	12.96	14.11	14.65
2	Flow value (mm)	4.74	4.88	5.12	5.56	5.98	6.10
3	Bitumen content	4.36 %	4.46 %	4.56 %	4.66 %	4.76 %	4.86 %

Table -5.3: For 10 % Rejuvenator in Old Asphalt Mix

Sl. No.	Particulars	0% Binder	0.1% Binder	0.2% Binder	0.3% Binder	0.4% Binder	0.5% Binder
1	Marshall stability (KN)	8.64	9.79	10.65	11.80	13.53	14.10
2	Flow value (mm)	4.44	4.66	4.94	5.18	5.58	5.74
3	Bitumen content	4.36 %	4.46 %	4.56 %	4.66 %	4.76 %	4.86 %

Table -5.4: For 12 % Rejuvenator in Old Asphalt Mix

Sl. No.	Particulars	0% Binder	0.1% Binder	0.2% Binder	0.3% Binder	0.4% Binder	0.5% Binder
1	Marshall stability (KN)	7.46	8.01	**9.40**	**11.23**	12.16	13.82
2	Flow value (mm)	3.58	3.72	**3.88**	**3.98**	4.84	5.28
3	Bitumen content	4.36 %	4.46 %	4.56 %	4.66 %	4.76 %	4.86 %

It was found that at 12% rejuvenator dose the mix was able to achieve the required strength and flow value.

Above table result shows that with 12% rejuvenator and addition of only +0.2% and +0.3% of bitumen binder has satisfied Marshall Stability strength and also satisfied the flow value. Hence, 12% rejuvenator is recommended for 100% recycled asphalt pavement mix.

5.1 Optimum Binder Content

1) Binder Content attained for Minimum Stability = 4.56%

2) Binder Content attained for Maximum Stability = 4.66%

Average Binder Content = 4.61%

5.2 Final Testing of Recycled Asphalt Pavement Mix

Table -5.2: Recycled Asphalt Pavement Mix

Sl. No.	Particulars	For Bitumen @ 4.61%		
	Trail	Trail 1	Trail 2	Trail 3
1	Weight of core in air (grams)	1225	1215	1250
2	Weight of core in water (grams)	720	715	735
3	Saturated surfacedry core weight (grams)	1240	1230	1265
4	Volume of core (cc), (3-2)	520	515	530
5	Density of core (grams/cc), (1/4)	2.355	2.359	2.358
	Density Average	2.357		
6	Marshall stability(KN)	10.08	10.36	10.50
	Marshall stability Average	10.31		
7	Flow value (mm)	3.88	3.92	3.90
8	Flow value Average	3.90		

Fig -5.2: Mould for Recycled Asphalt Pavement Mix

5.3 Cost Analysis of Recycled Asphalt Pavement Mix

Cost for recycled asphalt pavement mix is done as per Port Blair (Andaman Islands) material price, May 2021.

Table -5.3: Cost for 1 m^3 of Recycled Asphalt Pavement Mix

Sl.No.	Particulars	Units	Rate	Percentage/Quantity	Amount
1	Aggregate milling	m^3	Rs 1000	1	Rs 1000
2	Transportation	m^3	Rs 250	1	Rs 250
3	Bitumen VG-30	kg	Rs 65	6 (0.25%)	Rs 390
4	Rejuvenator (Waste vegetable oil)	Liters	Rs 25	12.55 (12%)	Rs 313.75
5	Fuel (Diesel)	Liters	Rs 75.69	2	Rs 151.38
6	Labours	Persons	Rs 25	7	Rs 175
	Total Amount for 1 m^3				Rs 2280.13

6. RESULTS

The result shows that conventional asphalt pavement mix has more strength stability compare to recycled asphalt pavement mix, but recycled asphalt pavement mix has managed to satisfy the minimum specific limits. Therefore, recycled asphalt pavement mix can be used in road construction works. Recycled asphalt pavement mix shows huge cost of saving for construction of around 76.52 % compare to conventional asphalt pavement mix. Below mentioned table will show the result comparisons:

Table -6: Result Comparisons

Requirements	Specific Limits	Conventional asphalt pavement mix	Recycled asphalt pavement mix
Minimum Stablity (KN at 60°C)	8.2	11.16	10.31
Flow Value (mm)	2 - 4	3.67	3.90
Percent air void (%)	3 – 5	3.44	4.78
Void filled with bitumen, VFB (%)	65 - 78	74.48	67.78
Cost		Rs 9707.42	Rs 2280.13

Recycled asphalt pavement using waste vegetable oil as rejuvenator has enabled material related cost savings of 76.52 % compared to conventional asphalt pavement mix.

7. CONCLUSIONS

1) 100 % recycled asphalt pavement mix of par performance can be achieved in a hot mix plant.
2) After detailed study and experiment it is found that a dose of 12% rejuvenator needs to be added to make the 100% RAP workable.
3) After adding only 12% dose of rejuvenator, the required strength as per MORTH specification is achieved.
4) Use of 100% RAP will result in cost saving upto 76.52 % as compared to current conventional asphalt pavement mix.
5) During laboratory experiment it was found that recycled asphalt mix with using waste vegetable oil as rejuvenator if designed using Marshall Stability and flow value method performs almost similar to conventional asphalt pavement mix.
From all these inferences it can be said that 100% RAP is a successful approach towards future sustainable practices, it is environmental friendly due to recycling, it is cost efficient and help in conserving non-renewable resources. It is very helpfully particularly in those locations which are either remotely located or with longer haul distances and also in places where bitumen or aggregate are in low supply.

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