# USE OF PAVEMENT WASTES (RECLAIMED ASPHALT PAVEMENT) IN BASE AND SUB-BASE LAYERS OF ROAD CONSTRUCTION

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**ABSTRACT**

*Recycled asphalt pavement (RAP) has increasingly been used as a base material for highway construction as a sustainable solution. Due to the existence of asphalt, 100 % RAP typically has low strength and high potential of creep and permanent deformations. RAP can be blended with virgin aggregate, stabilized by cement and fly ash, or confined by geocell to increase its strength and reduce its creep and permanent deformations. A good road network is a key for rapid growth of economy of a country. It provides connectivity to remote areas for various transport activities. There is about 4.2 millions kilometre road network in India, which ranks second in the world only after United States. Most of the roads are bituminous surfaced pavements. These roads are periodically resurfaced as maintenance action. It is due to this periodic maintenance the roads have attained a higher raised level as compared to adjoining properties in urban locality. These roads can be lowered down up to required and feasible depth by milling process and can be resurfaced with suitable layer of bituminous mixes replacing all or part of the bituminous pavement. Reclaimed asphalt pavement (RAP) materials are resulted from milling process. In this study samples of Reclaimed asphalt pavement (RAP) materials were collected and analysed for suitability of their usage in flexible pavements. Their characteristics including gradation, California Bearing Ratio(C.B.R).Aggregate Impact value, Aggregate Crushing value, Specific gravity, Flakiness & Elongation Index, Loss Angles Abrasion value, Water absorption and soundness were determined and compared to the MORTH specifications. Form the study it was found that the RAP materials can be effectively used in the soil sub-grade, sub-base and base of the flexible pavements resulting in reduction of the construction cost.*

## I.INTRODUCTION

In current pavement engineering practice, the shortage of natural aggregate supplies along with the increase in processing cost has encouraged the use of various reclaimed materials from old structures as a source of construction material. This technology reduces both the cost of highway construction and protects the environment by reducing construction waste. Reclaimed Asphalt Concrete Pavement (RAP) had been used as aggregate for pavement construction for some time. In EI Cajon-California, considerable saving was made using RAP as a base course for the construction of a thoroughfare(Munzenmaier, 1994).

RAP is also widely used in many highway construction projects in Ontario.In most engineering applications, when used as unbound granular material(UGM), RAP is usually milled or crushed down to 37.5 mm or less, with a maximum allowable top size of approximately 50 mm. RAP has performed satisfactorily in many cases when it is blended with conventional aggregates as granular base/sub base. Some of the benefits of RAP aggregates that have been properly incorporated into granular base/sub base applications include: dequate bearing capacity, acceptable resilient modulus, good drainage characteristics and durability.

### Research objectives

The objective of this research is to carry out performance-related tests on selected RAP and natural aggregates to explore the feasibility of producing high-performance granular base/sub base layers that contain up to 100% RAP. The main objective of the study is to find out suitability of Reclaimed asphalt pavement (RAP) materials to be used in construction of flexible pavements. To perform experimental investigations to assess the values of related parameters
and their technical viability.

- To use untreated RAP materials as a stabilizing material to treat weak soil sub-grade to enhance CBR value and thereby reduction in the crust thickness and construction cost as well.
- To use RAP materials after blending in sub-base and base courses of flexible pavements.

## II.EXPERIMENTAL PROGRAM

### Physical Properties

The properties of RAP are largely dependent on the properties of the constituent materials and the type of asphalt concrete mix (wearing surface, binder course, etc.). There can be substantial differences between asphalt concrete mixes in aggregate quality, size, and consistency. Since the aggregates in surface course (wearing course) asphalt concrete must have high resistance to wear/abrasion (polishing) to contribute to acceptable friction resistance properties, these aggregates may be of higher quality than the aggregates in binder course applications, where polishing resistance is not of concern.

Both milling and crushing can cause some aggregate degradation. The gradation of milled RAP is generally finer and more dense than that of the virgin aggregates. Crushing does not cause as much degradation as milling; consequently, the gradation of crushed RAP is generally not as fine as milled RAP, but finer than virgin aggregates crushed with the same type of equipment.

The particle size distribution of milled or crushed RAP may vary to some extent, depending on the type of equipment used to produce the RAP, the type of aggregate in the pavement, and whether any underlying base or sub base aggregate has been mixed in with the reclaimed asphalt pavement material during the pavement removal.

**Table1. Typical range of particle size distribution for reclaimed asphalt pavement (RAP)**

| IS Sieve(mm) | Percentage passing by weight | Requirement for GSB grading II (table 400-2) of MORTH revision 4 |
|---|---|---|
| 53 | 100 | 100 |
| 26.5 | 92 | 50-80 |
| 19 | 80 | - |
| 10 | 66 | - |
| 4.75 | 38 | 15-35 |
| 2.36 | 22 | - |
| 0.6 | 11 | - |
| 0.075 | 2 | <10 |

**Table 2 . Physical and mechanical properties of reclaimed asphalt pavement (RAP).**

| Type of Property | RAP Property | Typical Range of Values |
|---|---|---|
| Physical Properties | Unit Weight | 1940 - 2300 kg/m$^3$ (120-140 lb/ft$^3$) |
| | Moisture Content | Normal: up to 5%<br>Maximum: 7-8% |
| | Asphalt Penetration | Normal: 10-80 at 25°C (77°F) |
| | Asphalt Content | Normal: 4.5-6% Maximum Range: 3-7% |
| | Absolute Viscosity or Recovered Asphalt Cement | Normal: 4,000 - 25,000 poises at 60°C (140°F) |
| Mechanical Properties | Compacted Unit Weight | 1600 - 2000 kg/m$^3$ (100-125 lb/ft$^3$) |
| | California Bearing Ratio (CBR) | 100% RAP: 20-25% 40% RAP and 60% Natural Aggregate: 150% or higher |

**Table 3 . Tests for Aggregates with IS codes**

| Property of Aggregate | Type of Test | Test Method |
|---|---|---|
| Crushing strength | Crushing test | IS : 2386 (part 4) |
| Hardness | Los Angeles abrasion test | IS : 2386 (Part 5) |
| Toughness | Aggregate impact test | IS : 2386 (Part 4) |
| Shape factors | Shape test | IS : 2386 (Part 1) |
| Specific gravity and porosity | Specific gravity test and water absorption test | IS : 2386 (Part 3) |

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## III.TEST RESULTS AND ANALYSIS

### MORTH Gradation

This chapter summarizes the laboratory test results of all tests and materials (both natural aggregates and blends with different RAP contents). 3.1. Collection of Samples:

The particle size distribution (PSD) of collected sample of RAP material and corresponding requirement of code to use it as granular sub-base (GSB) is shown in table no 1.

From table 1 it is clear that certain sieve size material was missing in RAP to use as GSB material. To match the required grading the following modifications were done.

- 60% of 40mm down and 10% of stone dust as filler to satisfy the requirement as per MORTH 4th revision.
- The RAP material was used up to 30% to get the desired grading of GSB (coarse grade) as per MORTH 2013.

**Table: Details of composite GSB with use of RAP**

| IS Sieve size (mm) | Material | | | Percent | | | | Requirement for GSB grading II (table 400-2) of MORTH revision 4 |
|---|---|---|---|---|---|---|---|---|
| | 40 mm down | RAP | Stone dust | 60% 40 mm down | 30% RAP | 10% Stone dust | Total | |
| 53 | 100 | 100 | 100 | 60 | 30 | 10 | 100 | 100 |
| 26.5 | 60 | 90 | 100 | 36 | 27.6 | 10 | 73.6 | 50-80 |
| 4.75 | 11 | 36 | 97 | 6.6 | 11.4 | 9.7 | 27.7 | 15-35 |
| 0.075 | 0 | 2 | 8 | 0 | 0.6 | 0.8 | 1.4 | <10 |

The table below shows the composition of mixed materials to get the desired grading of GSB material.

**Table: Details of composite WMM with use of RAP**

| IS Sieve size (mm) | Material | | | | Percent | | | | | Requirement for WMM grading (table 400-II) of MORTH revision 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| | 45 mm down | RAP | 11.2 mm down | Stone dust | 32% 45mm down | 35% RAP | 13% 11.2 mm down | 20% Stone dust | Total | |
| 53 | 100 | 100 | 100 | 100 | 32 | 35 | 13 | 20 | 100 | 100 |
| 45 | 100 | 100 | 100 | 100 | 32 | 35 | 13 | 20 | 100 | 95-100 |
| 20 | 28 | 92 | 100 | 100 | 8.96 | 32.2 | 13 | 20 | 74.6 | 60-80 |
| 12.5 | 0 | 70 | 98 | 100 | 0 | 24.5 | 12.74 | 20 | 57.2 | 40-60 |
| 4.75 | 0 | 38 | 8 | 97 | 0 | 13.3 | 1.04 | 19.4 | 33.7 | 25-40 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.36 | 0 | 22 | 0 | 75 | 0 | 7.7 | 0 | 15 | 22.7 | 15-30 |
| 0.6 | 0 | 11 | 0 | 40 | 0 | 3.85 | 0 | 18 | 11.8 | 8-22 |
| 0.75 | 0 | 2 | 0 | 8 | 0 | 0.7 | 0 | 1.6 | 2.3 | <10 |

**Sample Composition:**

Both natural and RAP samples were brought to required size and suitable grading required for sub-base, base and surface course as per MORTH specifications. Samples of different compositions were prepared by adding different percentage of RAP materials (0% RAP, 10%RAP,20%RAP, 30%RAP, 40%RAP and 100% RAP) as shown below

**Table: Samples of different compositions**

| Sample no | Details of Composition |
|---|---|
| $R_1$ | RAP 0% + 100% Natural Aggregate |
| $R_2$ | RAP 10% + 90% Natural Aggregate |
| $R_3$ | RAP 20% + 80% Natural Aggregate |
| $R_4$ | RAP 30% + 70% Natural Aggregate |
| $R_5$ | RAP 40% + 60% Natural Aggregate |
| $R_6$ | RAP 100% + 0% Natural Aggregate |

Table: Results on Samples of 100% RAP and 100% Natural Aggregates

| Characteristics | 100% RAP Aggregates | 100% Natural Aggregates | MORTH Limits (Max.) | Remarks |
|---|---|---|---|---|
| Aggregate Crushing Value | 21.5% | 19.7% | 30% | Satisfactory |
| Aggregate Impact Value | 20.6% | 18.3% | 30% | Satisfactory |
| Flakiness & Elongation Index | 22.7% | 17.6% | 35% | Satisfactory |
| Loss Angeles Abrasion Test Value | 18.3% | 16.7% | 30% | Satisfactory |
| Specific Gravity | 2.7 | 2.8 | 2.6-3.0 | Satisfactory |
| Water Absorption | 1.8% | 1.4% | 2% | Satisfactory |
| Soundness Test (with $Na_2SO_4$) | 7.5 | 5.3 | 12 | Satisfactory |

From the test results as shown in table no above, it was observed that the RAP material can be easily used in granular sub base as it satisfies the norms as prescribed by MORTH. All the parameters are with in the prescribed specifications by MORTH

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**Test Results**

**Table: Results on Samples of different compositions of RAP and Natural Aggregates combinations**

| Sample Composition | Aggregate Crushing Value | Aggregate Impact Value | Flakiness & Elongation Index (Combined) | Loss Angeles Abrasion Test Value | Specific Gravity | Water Absorption | Soundness Test |
|---|---|---|---|---|---|---|---|
| RAP 10% + 90% Natural Aggregate | 22.8% | 21.7% | 20.8% | 21.1% | 2.65 | 1.32% | 7.2% |
| RAP 20%+ 80% Natural Aggregate | 22.7% | 20.9% | 20.5% | 20.1% | 2.66 | 1.10% | 7.1% |
| RAP30% + 70% Natural Aggregate | 20.3% | 19.4% | 20.4% | 19.8% | 2.72 | 0.98% | 6.5% |
| RAP40% + 60% Natural Aggregate | 20.2% | 19.6% | 20.3% | 19.8% | 2.73 | 1.12% | 5.2% |

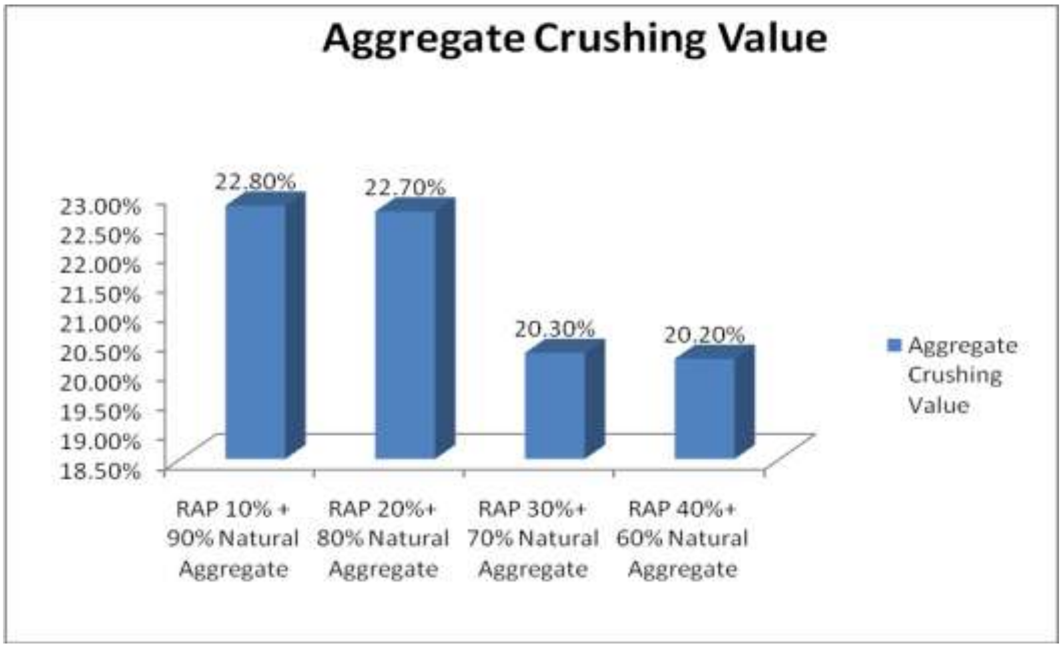



Figure.Variation of Aggregate Crushing Value for different Samples

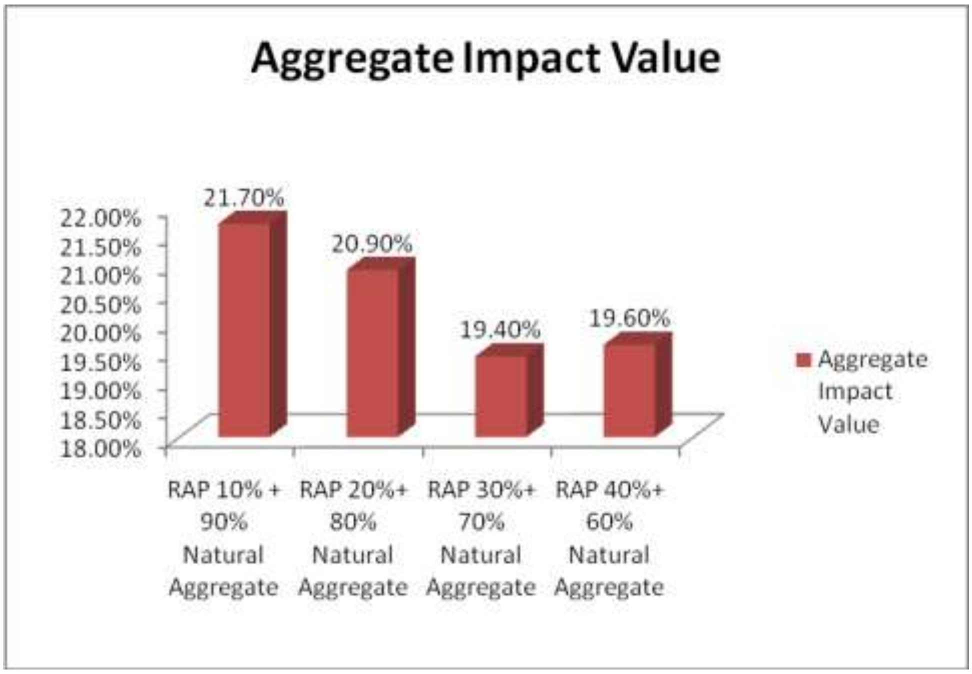



Figure.Variation of Aggregate Impact Value for different Samples

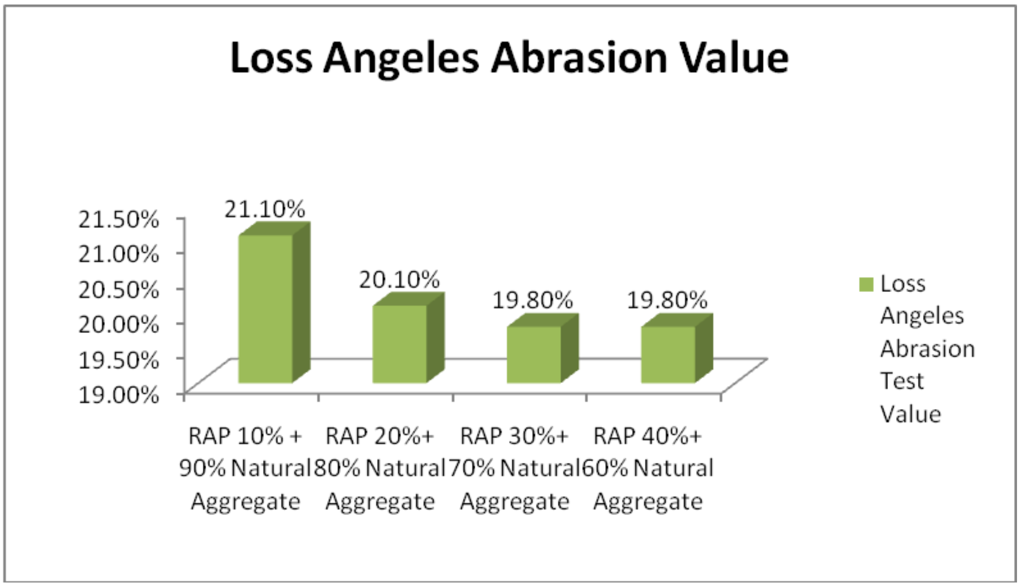



Figure.Variation of Los angeles abrasion Value for different Samples

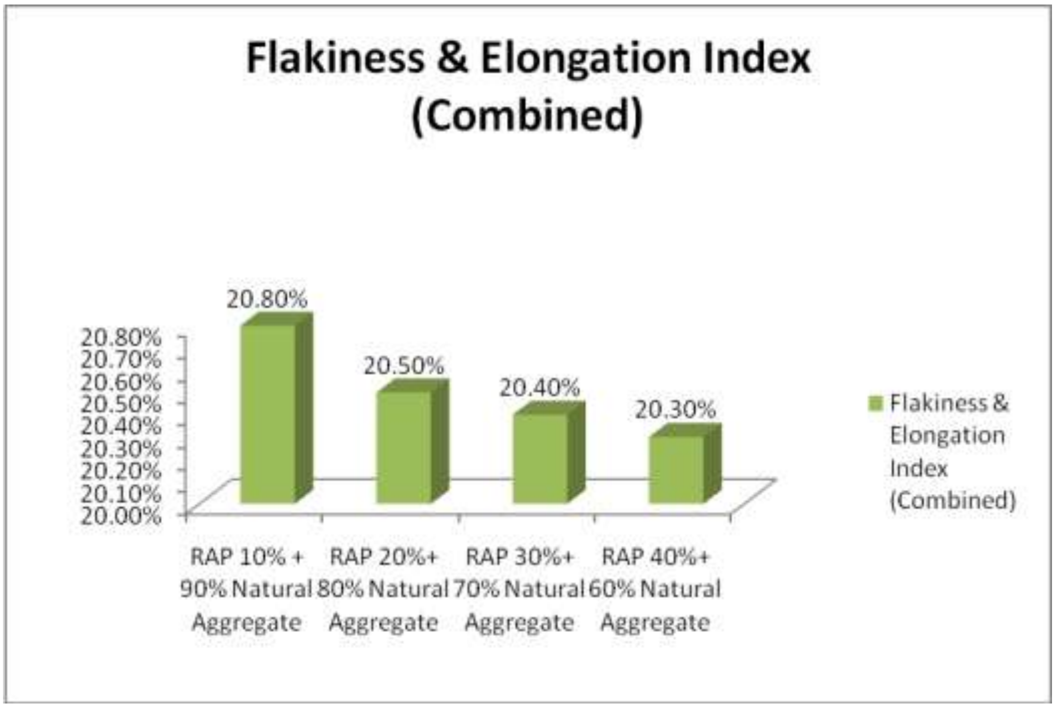



Figure.Variation of Flakiness & Elongation Index for different Samples

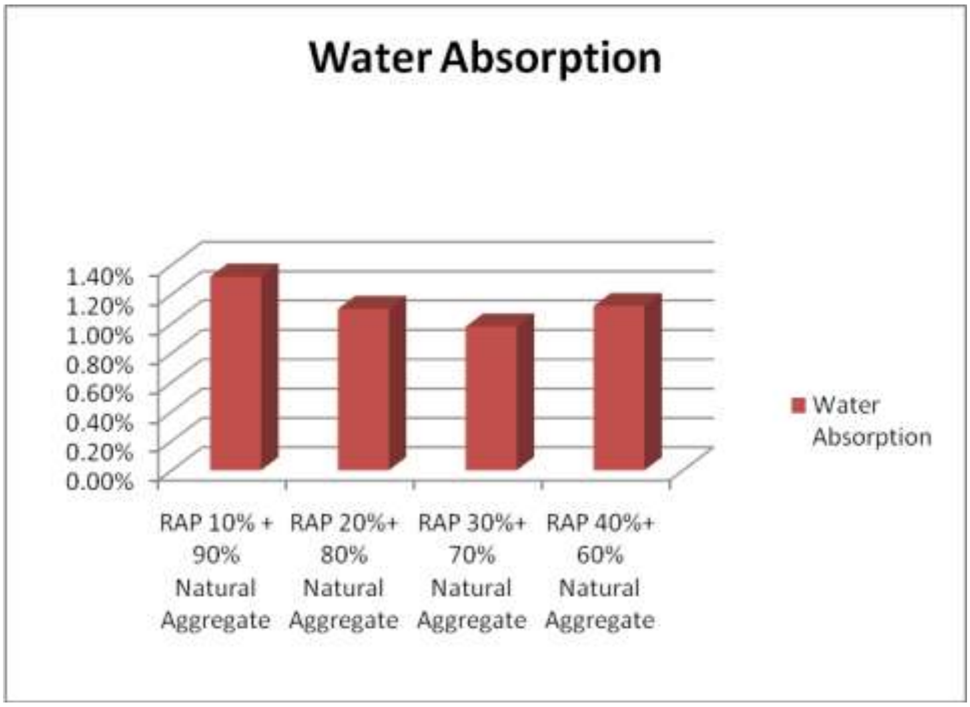



Figure. Variation of Water Absorption for different Samples

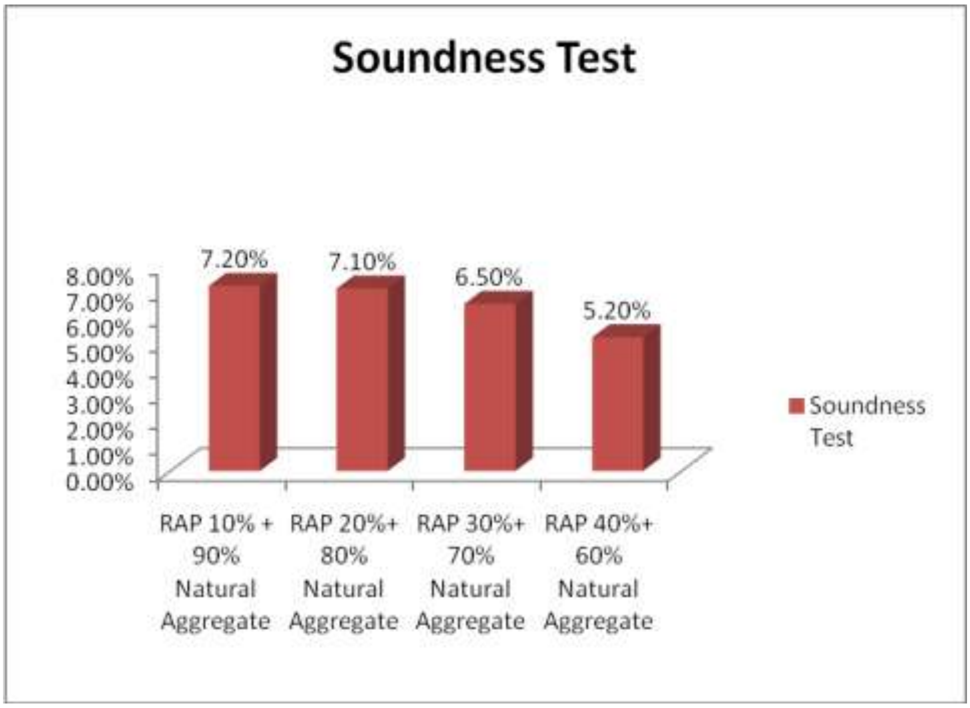
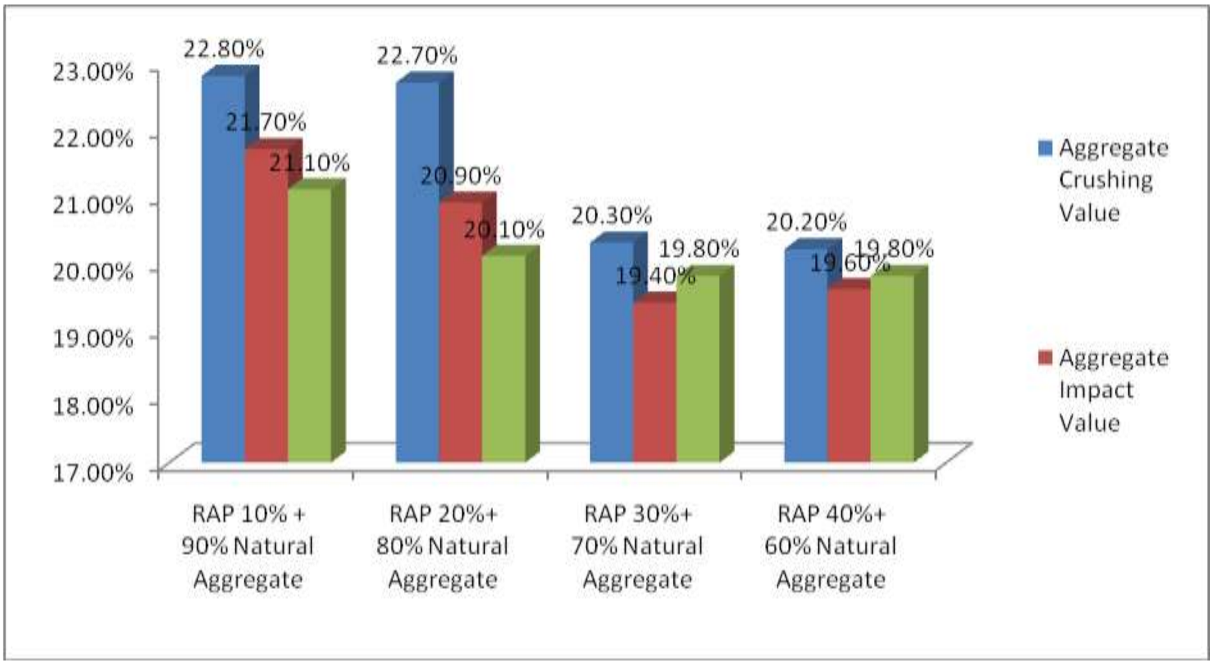



Figure.Variation of Soundness for different Samples



## IV.RESULT ANALYSIS

The test results of various combinations of proportions of RAP and natural aggregates are shown in table above. The various parameters like Aggregate Crushing Value, Aggregate Impact Value, Flakiness & Elongation Index (Combined), Loss Angeles Abrasion Test Value, Specific Gravity, Water Absorption, Soundness Test value and

California Bearing Ratio (CBR) values are within the norms prescribed by MORTH and it can also be used in base of in flexible pavements. The best result was obtained on combination of30% RAP along with 70% Natural Aggregates.

The aggregate crushing, Los Angeles abrasion and Impact values are represented in figure above. The low values shows that the fraction of aggregate crushed is low and hence stronger and more tougher the aggregate is and it can capable of withstanding on higher wheel loads. The best result was observed on combination of 30% RAP along with 70% Natural Aggregates.

Water Absorption & Soundness Values of different compositions of RAP & Natural Aggregates The Water Absorption & Soundness Values of different compositions are Plotted in figure above. The water absorption value and soundness value for 30% RAP along with 70% Natural Aggregates combination was found to be 0.98% and 6.56% respectively.

## V.CONCLUSIONS

On the basis of study and experimental investigations following conclusions were drawn

1. It was observed that the RAP materials can be successfully used in granular sub base layer of flexible pavements after blending to match the required grading as per MORTH specifications for sub base material.
2. It was also observed that the RAP materials in combination to natural aggregate in various proportions can be easily used after blending to match the required grading as per MORTH specifications in the base courses of flexible pavements
3. It is clear from the above investigation results that 30% replacement of natural aggregate can be successfully done in base course of flexible pavements, resulting in a savings of around 25-30% in construction cost.
4. It was observed that RAP has a higher content of fines as a result of degradation of material during milling and crushing operations it can be easily used for soil stabilization purpose to increase the CBR value of sub-grade and hence the crust thickness of road will be reduced resulting in reduction of cost of construction.
5. Above all the problem of disposal of RAP wastes can be easily solved and adverse effect on environment may be avoided by using the RAP materials in flexible pavement construction

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