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# A Study on use of Reclaimed Asphalt Pavements with admixtures

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**Abstract**

Reusing of materials optimizes the usage of natural resources. Reclaimed asphalt pavement (RAP) reduces the usage of virgin aggregate. In the current study only the Marshall method was used to evaluate the mixture of asphalt with varying proportions of RAP. The properties of aggregates and bitumen were estimated through laboratory tests and the results shows that the bituminous mix with RAP 30% has the maximum stability value followed by virgin mix at the bitumen content of 5.4%.

***Keywords***: *Marshall Method, RAP, Short term aged, VG-30, Virgin aggregates.*

## Introduction

Infrastructure of a country can be evaluated through efficient roads and good infrastructure transportation results in boosting the movement of people, trade and commerce with great flexibility. Pavement materials results in reutilization of existing pavement materials which results in saving money, energy and solution for waste materials. The properties of mixtures are evaluated with the partial replacement of mineral filler by varying proportions of RAP and hydrated lime.

## Literature Review

Olumide Moses Ogunpide has investigated on asphalt concrete mixtures with hydrated lime as mineral filler. The hydrated lime improves the stability of asphalt concrete. The optimum bitumen content for virgin and hydrated lime is 6.5%. Virgin asphalt concrete has Marshall Stability ranges from 5.89 – 7.9 KN with mineral filler and with hydrated lime ranges from 5.9 – 8.2 KN [1].

Serkan Tapkın[1], Abdulkadir Cevik[2], Un Usar[3] has studied on bituminous mixes using neural networks to study the mechanical properties have shown good results with admixture polypropylene whose stability $R^2$ =0.97, flow $R^2$=0.81[2].

Sunil Khuntia[1], Aditya Kumar Das[2], Monika Mohanty[3] and Mahabir Panda[4] used two techniques NN and LS-SVM model to know the Marshall Stability, Flow and Air Voids using polyethylene as admixture. NN based model is giving best results when compared to LS-SVM model [3].

Ahmed Ebrahim[1] Abu El-Maaty and Abdulla Ibrahim Elmohr[2] has studied the mechanical properties through laboratory tests which includes marshall test, indirect tensile test, granule adhesion test with the partial and total replacement of aggregates by rap. When compared to HMA mixes the asphalt mixes with replacement of RAP 50% to 100% giving better performance [4].

Hainian Wang[1], Ran Zhang[2], Yu Chen[3], Zhanping You[4] and Jun Fang[5] has evaluated on asphalt dosages from 4.5 to 5.4 with 3 different particle sizes with a rap of 25% in the laboratory with rubber as admixture which is reliable through X-Ray CT technology[5].

## Objectives

The objective of this study is to assess parameters of reclaimed asphalt pavement as follows:

- Under controlled RAP, Marshall mix design.
- The mechanical properties of viscosity grade VG-30 binder and aggregates.
- Evaluation of optimum binder content by varying bitumen content (5%, 5.2%, 5.3%, and 5.4%).
- ANOVA analysis with single factor and without replication.

## Methodology

- ➢ Basic tests on the bitumen and extracted aggregates from rap as well as virgin materials.
- ➢ Marshall mix design by varying proportion of RAP and binder.

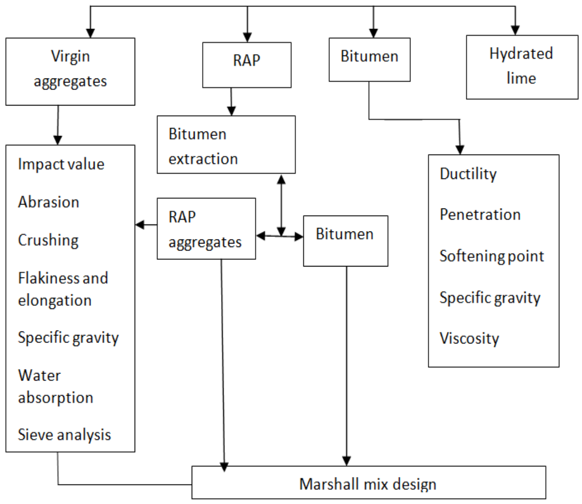


**Figure: 4.1: Preliminary laboratory tests on materials**

- Bitumen is a hydro carbon compound which is soluble in tri chloro ethylene and is substantially non volatile and softens gradually when heated. It acts as a water proofing agent. There are four grades VG-10, VG-20, VG-30 and VG-40. In this study we are using VG-30, the higher the grade the stiffer the bitumen.
- Admixtures are added to the mixture of mix of bitumen and aggregate to improve the workability. In this study we are using hydrated lime composing of calcium hydroxide ca $(OH)_2$ whose density is 2.2mg/$m^3$, apparent density 0.3 to 0.8mg/$m^3$.It acts as anti stripping agent, mineral filler to stiffen the asphalt binder, reduces air voids present in the bituminous mix. In the present study three different sizes of aggregates 20mm down size -15%, 12.5mm.
- In the present study three different sizes of aggregates 20mm down size -15%, 12.5mm down size -30%, 4.75mm size -55% were considered as aggregate proportions for blending purpose.

**Table: 4.1:** Physical properties of extracted and virgin aggregates

| S. No | Test on aggregates | Indian standard Code | Permissible values | Experimental values | | Conclusion |
|---|---|---|---|---|---|---|
| | | | | Extracted aggregates | Virgin aggregates | |
| 1 | Water absorption | IS:2386(P-3) | Max 2% | 0.20% | 0.19% | Satisfactory |
| 2 | Aggregate Impact Value | IS:2386(P-4) | Max 27% | 23.59% | 22.92% | Satisfactory |
| 3 | Aggregate Crushing Test | IS:2386(P-4) | Max 30% | 26.90% | 22.46% | Satisfactory |
| 4 | Flakiness Index and Elongation Index | IS:2386(P-1) | Max 30% | 17.65% and 13.41% | 13.73 %and 11.52% | Satisfactory |
| 5 | Los Angeles Abrasion Value | IS:2386(P-4) | Max 40% | 36.8% | 32% | Satisfactory |

**Table 4.2:** Physical properties of extracted and virgin aggregates

| Sl. No | Tests | Obtained Value | Specified Value | Remark |
|---|---|---|---|---|
| 1 | Penetration Value, cm | 83.5 | 80-100 | SATISFIED |
| 2 | Viscosity, cm | 12.27 | 15 | SATISFIED |
| 3 | Flash Point and Fire Point $^0$C | 260 and 280 | >220 | SATISFIED |
| 4 | Ductility Value, cm | 82 | >75 | SATISFIED |

## Marshall Test

In this method, the resistance to plastic deformation of cylindrical specimen of bituminous mixture is measured when the same is loaded at the periphery at 5 cm per minute. This test procedure is used in designing and evaluating bituminous paving mixes. There are two major features of the Marshall method of designing mixes (i) density-void analysis (ii) stability-flow test. The Marshall stability of the mix is defined as a maximum load carried by a compacted specimen at a standard test temperature at 60ºC. The flow value is the deformation at which the Marshall Stability test specimen undergoes during the loading up to the maximum load, in 0.25 mm unit. In this test an attempt is made to obtain optimum binder content for the type of aggregate mix and traffic intensity. For this test the samples are prepared by using different RAP proportions and varying binder content by keeping the admixture (Hydrated lime) content constant i.e. 1.5% by weight. Along with this the virgin aggregate blend is also used for the comparison of test results. The RAP percentages used are 10%, 20%, 30% and 40%. Various parameters like Marshall Stability, flow value and density were studied by using different percentages of bitumen 5%, 5.2%, 5.4% and 5.6%. The bitumen content found in RAP is 5%, It was determined using centrifugal method.

**Table 5.1:** Test results of Blending of Aggregates for virgin aggregates and different percentage of RAP

| IS Sieve Size (mm) | % passing required as per MORTH 2001 | Cumulative percent passing for virgin mixes | Grading of the mix with different percentage of RAP | | | | Conclusion |
|---|---|---|---|---|---|---|---|
| | | | 10 | 20 | 30 | 40 | |
| **19** | 100 | 100 | 99.12 | 98.78 | 97.52 | 96.52 | SATISFIED |
| **13.2** | 79-100 | 89.5 | 86.75 | 83.25 | 82.05 | 81.05 | SATISFIED |
| **9.5** | 70-88 | 79 | 80.12 | 78.60 | 75.08 | 73.08 | SATISFIED |
| **4.75** | 53-71 | 62 | 58.67 | 62.30 | 55.96 | 57.96 | SATISFIED |
| **2.36** | 42-58 | 50 | 49.45 | 48.79 | 49.12 | 46.12 | SATISFIED |
| **1.18** | 34-48 | 41 | 37.32 | 38.34 | 36.27 | 37.27 | SATISFIED |
| **0.6** | 26-38 | 32 | 29.13 | 27.98 | 28.98 | 29.98 | SATISFIED |
| **0.3** | 18-28 | 23 | 21.65 | 23.78 | 21.43 | 22.43 | SATISFIED |
| **0.15** | 12-20 | 16 | 12.02 | 14.98 | 12.98 | 12.98 | SATISFIED |
| **0.075** | 4-10 | 7 | 7.03 | 9.04 | 8.59 | 9.59 | SATISFIED |

## Analysis of test results

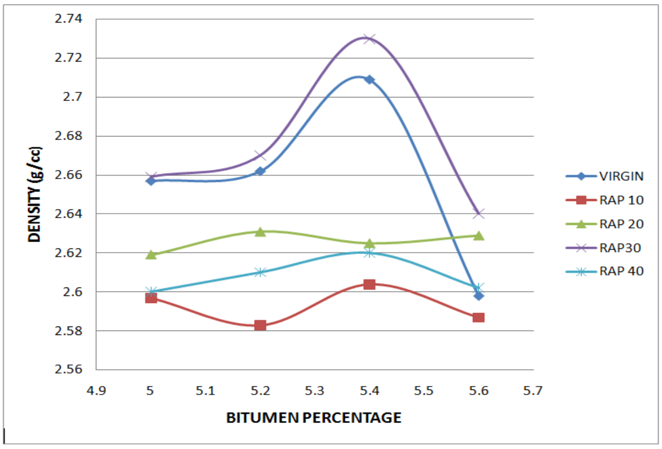


**Figure: 6.1:** Density with different bitumen percentages

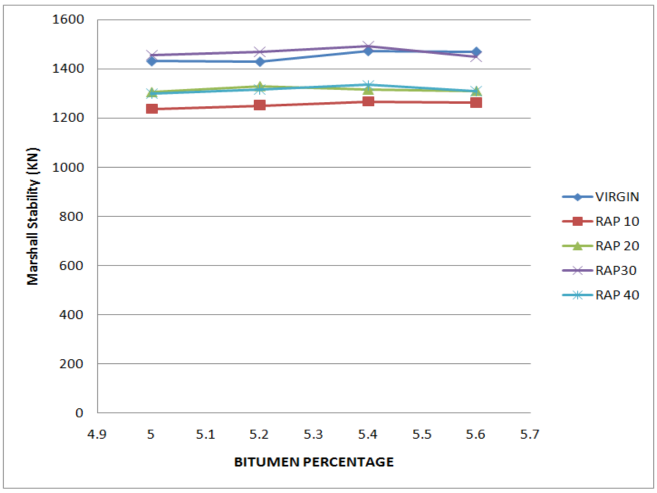


**Figure: 6.2:** Marshall Stability with different bitumen percentages

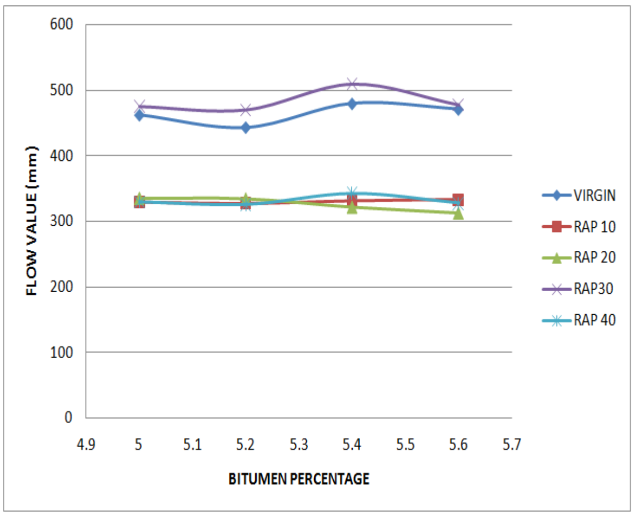


**Figure: 6.3:** Flow value with different bitumen percentages

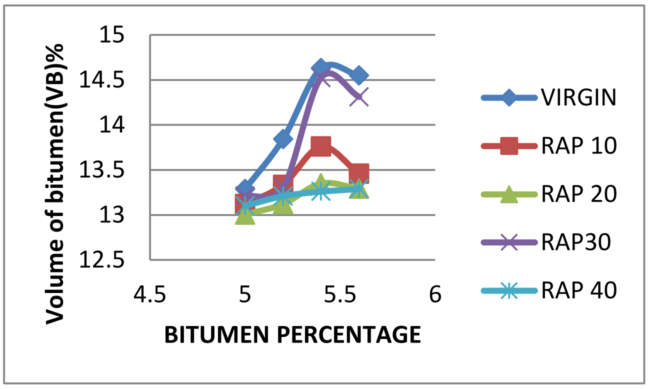


**Figure: 6.4:** Volume of bitumen with different bitumen percentages

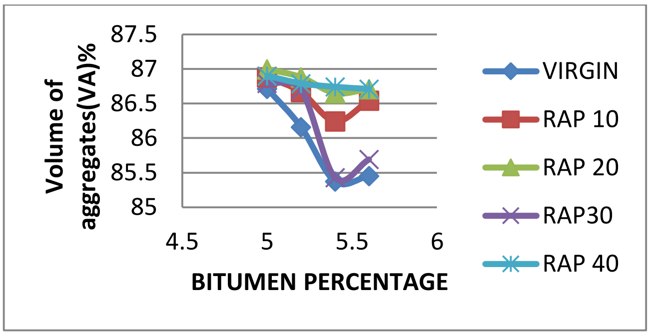


**Figure: 6.5:** Volume of aggregates with different bitumen percentages

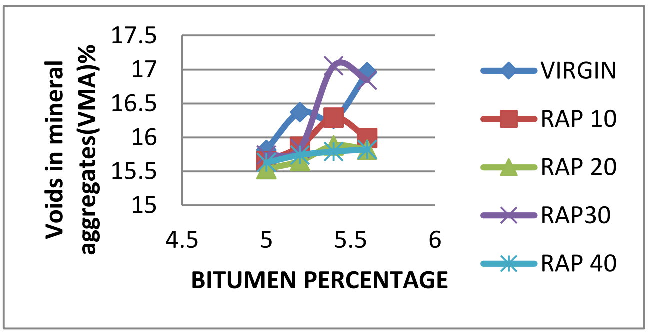


**Figure: 6.6:** Voids in mineral aggregates with different bitumen percentages

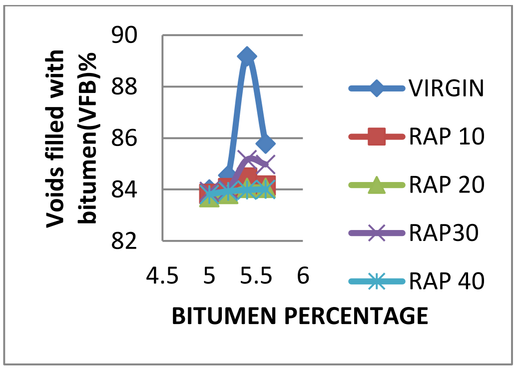


**Figure: 6.5:** Voids filled with different bitumen

Percentages

**Table 6.1:** Properties with linear equations

| Property | Virgin | RAP10 | Rap20 | Rap30 | Rap40 |
|---|---|---|---|---|---|
| Density | Y=-2.289X+98.05 | Y=-0.72X+90.39 | Y=-0.545X+89.69 | Y=-2.286X+98.27 | Y=-0.31X+88.42 |
| Marshall Stability | Y=76.5X+1045 | Y=45X+1016 | Y=0.5X+1312 | Y=1.5X+1459 | Y=24X+1188 |
| Flow Value | Y=-2.289X+98.05 | Y=-0.72X+90.39 | Y=-2.286X+98.27 | Y=-0.545X+89.69 | Y=-0.31X+88.42 |
| VB | Y=2.289X+1.941 | Y=0.72X+96.01 | Y=0.545X+10.30 | Y=2.261X+1.850 | Y=0.31X+11.57 |
| VA | Y=-1.479X+93.63 | Y=-0.72X+90.39 | Y=-0.545X+89.69 | Y=-2.286X+98.27 | Y=-0.31X+8842 |
| VMA | Y=1.666X+7.521 | Y=0.721X+12.12 | Y=0.849X+11.16 | Y=2.261X+4.380 | Y=0.31X+14.10 |
| VFB | Y=4.987X+59.44 | Y=0.7X+80.41 | Y=0.51X+81.21 | Y=2.15X+73.12 | Y=0.325X+82.21 |

The experimental results were analyzed using ANOVA with single factor and without replication factor in the statistical data analysis with admixture and without admixture with different percentages of RAP to evaluate the significance of research variables at certain levels. It is showing the optimum values.

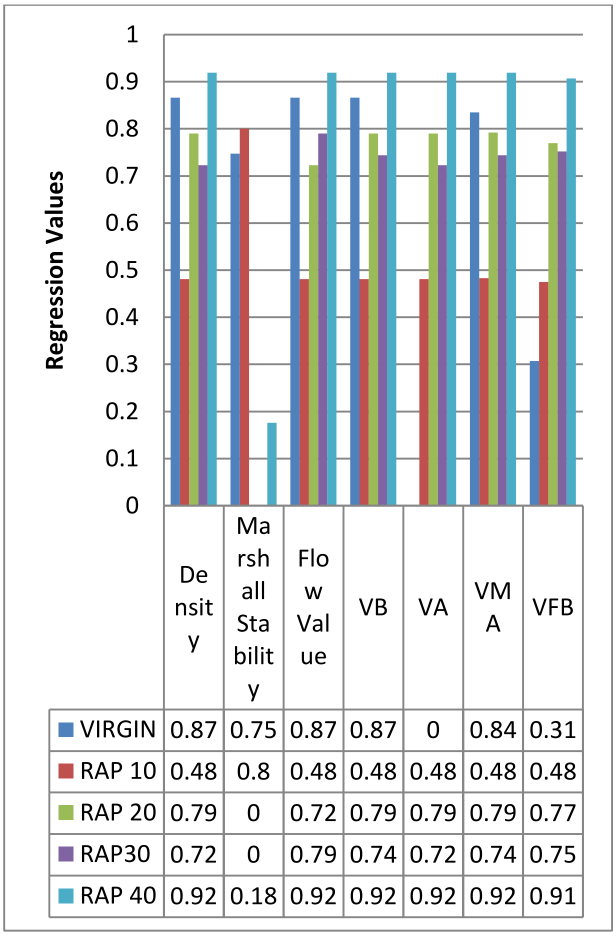


**Figure: 6.6:** Regression values with varying bitumen

**Table 6.2**: ANOVA without replication

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| **Anova: Without replication for Density** | | | | | | |
| Rows | 0.0055968 | 3 | 0.0018656 | 3.894984081 | 0.037254804 | 3.490294821 |
| Columns | 0.0183183 | 4 | 0.004579575 | 9.561198392 | 0.00103315 | 3.259166727 |
| Error | 0.0057477 | 12 | 0.000478975 | | | |
| Total | 0.0296628 | 19 | | | | |
| **Anova: Without replication for Marshall Stability** | | | | | | |
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Rows | 2263.75 | 3 | 754.5833333 | 4.89062922 | 0.019046176 | 3.490294821 |
| Columns | 139155.3 | 4 | 34788.825 | 225.4744261 | 3.54719E-11 | 3.259166727 |
| Error | 1851.5 | 12 | 154.2916667 | | | |
| Total | 143270.55 | 19 | | | | |
| **Anova: Without replication for Volume of Bitumen** | | | | | | |
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Rows | 1.8946544 | 3 | 0.631551467 | 7.573376066 | 0.004191521 | 3.490294821 |
| Columns | 2.4719495 | 4 | 0.617987375 | 7.410719541 | 0.003018124 | 3.259166727 |
| Error | 1.0006921 | 12 | 0.083391008 | | | |
| Total | 5.367296 | 19 | | | | |
| **Anova: Without replication for Volume of Aggregates** | | | | | | |
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Rows | 1.9307494 | 3 | 0.643583133 | 7.460773063 | 0.004435506 | 3.490294821 |
| Columns | 2.5013745 | 4 | 0.625343625 | 7.249330554 | 0.003297613 | 3.259166727 |
| Error | 1.0351471 | 12 | 0.086262258 | | | |
| Total | 5.467271 | 19 | | | | |
| **Anova: Without replication for Voids in Mineral Aggregate** | | | | | | |
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Rows | 1.31494735 | 3 | 0.438315783 | 5.078782113 | 0.016907178 | 3.490294821 |
| Columns | 1.6080353 | 4 | 0.402008825 | 4.658091968 | 0.016804072 | 3.259166727 |
| Error | 1.0356399 | 12 | 0.086303325 | | | |
| Total | 3.95862255 | 19 | | | | |
| **Anova: Without replication for Voids filled with bitumen** | | | | | | |
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Rows | 6.79209255 | 3 | 2.26403085 | 2.481253149 | 0.110879383 | 3.490294821 |
| Columns | 10.8616208 | 4 | 2.7154052 | 2.975934583 | 0.063832056 | 3.259166727 |
| Error | 10.9494552 | 12 | 0.9124546 | | | |
| Total | 28.60316855 | 19 | | | | |
| **Anova: Without replication for Flow Value** | | | | | | |
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Rows | 0.0294 | 3 | 0.0098 | 1.683607731 | 0.223229942 | 3.490294821 |
| Columns | 3.62767 | 4 | 0.9069175 | 155.8054402 | 3.12999E-10 | 3.259166727 |
| Error | 0.06985 | 12 | 0.005820833 | | | |
| Total | 3.72692 | 19 | | | | |

**Table 6.2:** ANOVA with single factor

| Anova: Single Factor for Density | | | | | | |
|---|---|---|---|---|---|---|
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 23.75284683 | 5 | 4.750569367 | 404.6012487 | 7.87E-18 | 2.772853153 |
| Within Groups | 0.2113445 | 18 | 0.011741361 | | | |
| Total | 23.96419133 | 23 | | | | |

| Anova: Single Factor for Marshall Stability | | | | | | |
|---|---|---|---|---|---|---|
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 6262400.708 | 5 | 1252480.142 | 5478.050408 | 5.6E-28 | 2.772853153 |
| Within Groups | 4115.45 | 18 | 228.6361111 | | | |
| Total | 6266516.158 | 23 | | | | |

| Anova: Single Factor for Volume of Bitumen | | | | | | |
|---|---|---|---|---|---|---|
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 229.1819795 | 5 | 45.8363959 | 266.5469362 | 3.21E-16 | 2.772853153 |
| Within Groups | 3.0953465 | 18 | 0.171963694 | | | |
| Total | 232.277326 | 23 | | | | |

| Anova: Single Factor for Volume of Aggregates | | | | | | |
|---|---|---|---|---|---|---|
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 21953.84688 | 5 | 4390.769375 | 24964.12904 | 6.64E-34 | 2.772853153 |
| Within Groups | 3.1658965 | 18 | 0.175883139 | | | |
| Total | 21957.01277 | 23 | | | | |

| Anova: Single Factor for Voids in Mineral Aggregate | | | | | | |
|---|---|---|---|---|---|---|
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 385.1447694 | 5 | 77.02895388 | 543.6086022 | 5.64E-19 | 2.772853153 |
| Within Groups | 2.55058725 | 18 | 0.141699292 | | | |
| Total | 387.6953566 | 23 | | | | |

| Anova: Single Factor for Voids filled with bitumen | | | | | | |
|---|---|---|---|---|---|---|
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 20904.4316 | 5 | 4180.886319 | 4194.507341 | 6.18E-27 | 2.772853153 |
| Within Groups | 17.94154775 | 18 | 0.996752653 | | | |
| Total | 20922.37314 | 23 | | | | |

| Anova: Single Factor for Flow Value | | | | | | |
|---|---|---|---|---|---|---|
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 13.28368333 | 5 | 2.656736667 | 159.8037093 | 2.93E-14 | 2.772853153 |
| Within Groups | 0.29925 | 18 | 0.016625 | | | |
| Total | 13.58293333 | 23 | | | | |

## Conclusions

- From the experimental observation we can conclude that the optimum binder content for all the mixes was at 5.4% bitumen content. It is also observed that the optimum binder content for RAP mixes and Virgin mix is same.
- Density of the RAP 30% is the maximum (2.730 g/cc) and higher than all other RAP mixes including the Virgin mix which has the maximum density of 2.709 g/cc.
- Marshall stability value of the RAP 30% is found to be maximum at the binder content 5.4% having 1493 KN which is more than the maximum Marshall stability value of Virgin mix, which has maximum value of 1472 KN at the same binder content.
- The flow value is minimum for RAP 30% at the binder content of 5.4% which is 2.93mm.
- The addition of Hydrated Lime (1.5%) also proved to be beneficial in increasing the Marshall stability and Flow values by reducing the air voids, another benefit of using Hydrated Lime was in reducing the stripping value.
- From all the tests and observation we can conclude that RAP 30% with bitumen content 5.4%, performs better than other RAP mixes and even the Virgin mix.

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