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EVALUATION OF RECLAIMED ASPHALT PAVEMENT (RAP) IN FLEXIBLE PAVEMENT LAYERS

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ABSTRACT

The tremendous usage of natural or virgin aggregates is leading to their exploitation as a resource. There is a high priority for the partial replacement of virgin aggregates with alternate construction material which shall be environmentally responsible and it should perform equally well as the conventional one. Reclaimed Asphalt Pavement (RAP) can be an excellent choice for the base and sub-base layers of Highway Pavements. This RAP can be used with stabilizer like Cement, which gives the pavement better load dispersion and greater load resistance. So, the current study consists of various laboratory tests with 0%, 3% and 5% of cement which is used as a stablizer and conclusions based on that.

KEYWORDS: RAP, Optimum Moisture Content (OMC), Maximum Dry Density (MDD), California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS).

INTRODUCTION

Natural aggregates have been carried out from a variety of rock sources and have been used as a road material. But the extraction of these virgin aggregate resources is increasingly being restrained by urbanization, increased costs and environmental concerns. The use of reclaimed asphalt pavement (RAP) materials in road construction could serve the purpose of reducing the amount of construction, land disposa, reducing environmental disturbance and the rate of natural resource depletion. Most reclaimed asphalt pavement materials, when used as a total substitute for natural aggregates in base applications, does not meet the minimum requirements of standards. In such cases, stabilization with stabilizers like cement allows the use of these low quality reclaimed asphalt pavement materials with the minimum required strength characteristics. Ultimately, recycling asphalt creates a cycle that Control the use of natural Resources and sustains the asphalt pavement industry. In order for it to be successful, recycled asphalt pavement must be cost-effective, perform well, and be environmentally sound, easily available. The use of RAP may grow by increasing the number of highway construction and rehabilitation projects that use RAP, as well as by increasing the amount of RAP used in specific projects. To meet these goals, establish a public or industry working group and Create funded or coordinated research and demonstrations projects.

LITERATURE REVIEW

In the early 1990s, FHWA and the U.S. Environmental Protection Agency calculated that more than 90 million tons of asphalt pavement were reclaimed every year, and over 80 percent of RAP was recycled, making asphalt the most frequently recycled material. RAP is most commonly used as an aggregate and virgin asphalt binder, but it is also used as a granular base or subbase, stabilized base aggregate, and embankment or fill material. RAP is a high-quality material that can replace more expensive virgin aggregates and binders.

Taha et al (1999)[4] studied laboratory evaluation of RAP and RAP-virgin aggregate mixtures as road base and sub-base materials at Oman and found. From the literature survey it was observed that the RAP material can be recycled and utilized in the base course with new or virgin aggregates to an extent of 10 to 100% RAP (Taha et al 1999, 2002, Thammavong et al 2006)[4, 8, 9] in presence of stabilizing materials like fly ash, lime, cement, foamed bitumen and RBI Grade-81 etc. which improves the strength and durability of the RAP mix. To check the suitability of RBI Grade-81 stabilization in base layer Kumar et al (2010)[5] studied the soil and aggregate stabilization using RBI Grade-81 stabilizers for subgrade and base layer and found that RBI Grade-81 stabilized aggregate layer is suitable as a base layer.

With increased demand and limited aggregate and binder supply, Hot Mix Asphalt (HMA) producers have begun using reclaimed asphalt pavement (RAP) as a valuable component in HMA. As a result, there has been renewed interest in increasing the amount of RAP used in HMA. Materials are the most expensive production cost category, comprising about 70 percent of the cost to produce HMA. The most expensive and economically variable material in an asphalt mixture is the asphalt binder. It is most commonly used in the layers of flexible pavement to provide tensile strength to resist distortion, protect the asphalt pavement structure and subgrade from moisture, and provide a smooth, skid-resistant riding surface. As a result, the most economical use of RAP is in the intermediate and surface layers of flexible pavements where the less expensive binder from RAP can replace a portion of the more expensive virgin binder.

Cement as stabiliser act as a binder material. While sufficient amounts of cement should be specified to provide adequate structural support for the pavement surface layer, the addition of excessive amounts of cement can cause cracking of the affected layer.

MATERIALS

First of all, it is required to determine sources for the materials to be used which includes the RAP, crushed aggregates, cement and fine sand.

This section discusses the different mix ingredients that were evaluated as part of this research, as well as the properties of the materials that were chosen for use in this study.

Reclaimed Asphalt Pavement

An appropriate RAP source proved to be the most difficult item to secure. RAP from road near Civil Engineering Dept. Labs were collected. Based on the literature review and conventional practice, RAP physical characteristics include its bitumen content, particle gradation and Moisture condition. These various characteristics vary with the RAP source, based on among other things, the characteristics of the asphalt pavement from which the RAP was produced.

Source

The reclaimed bitumen was obtained from the broken pavement near the Civil Engg. Dept. Lab of JUET, Guna. The source shows suitable bitumen content and shows considerable crushing strength and toughness, as measured by various experiments performed in the lab. It fulfills various requirements for testing it further for CBR and UCS with cement as stabilizer.

Crushing of RAP

RAP was crushed with hammer and chisel to separate the bitumen from the aggregates. The stockpile was loose, but it did appear moist.

RAP aggregates have shown still better hardness and toughness than the normal aggregates. This may be due to some bitumen stuck to them, which may have increased the impact value and abrasion value as described in forward sections.

Natural Aggregate

The addition of RAP has seen causing significant adverse effects on the end product; therefore, in an attempt to produce a better material, RAP was mixed with virgin aggregate for each of the mixtures produced in this study.

Coarse Aggregates

Coarse Aggregates used in this study were obtained from Civil Labs, JUET Guna. The aggregates used are basically crushed rocks.

Fine Sand

The fine aggregate was ordinary concrete sand; the coarse aggregate consisted of a standard crushed rock. These aggregates were reportedly in conformance with Indian Standards.

LABORATORY INVESTIGATIONS

The experimental research was basically designed to test and determine the maximum dry density, California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) of RAP material specimens at the suitable gradation and different dosages of cement, acting as a stabilizer For finding out the materials suitability for experimental research, it is high priority that the same shall convincingly meet the criteria for their physical characteristics like Impact Test, Abrasion Test, moisture content and Bitumen Content. The minimum criteria have been specified in MORT and H Section 400.

Abrasion test and impact test results of RAP show lower values as compared to virgin aggregates. This can be attributed to the protective layer of bitumen over RAP aggregates, which ensures the RAP show better toughness and hardness Moisture content in RAP was higher than virgin aggregate, owing to the material left dumped in the open. Bitumen content is adequate in the RAP material. This was tested using centrifuge extractor test.

Table 1: Comparison of Physical Characteristics of RAP and Virgin Aggregates.

Test	Rap	Virgin aggregate
Abrasion Test	18.44 %	21.33 %
Impact Test	14.69 %	20.43%
Moisture Content	1.73	1.205
Bitumen Content	4.166 %	-

Material Gradation by Job Mix Formula

Because of pulverization caused due to removal of asphalt pavement, the gradation is disturbed. To get desired gradation and percentage of additional material required to be mixed with RAP material; job mix formula is adopted. The test results are shown in Table 2.

Table 2: Grading distribution of materials and their limits as per MORTH Section 400.

Sieve Size, mm	% Passing				MORT and H Limits (Section-400-Bases(Non-bituminous), Table 4)	
	RAP	12.5 mm virgin aggregates	Fine Sand	Desired Grading	Lower Limit	Upper Limit
40	100	100	100	100	95	100
20	99.5	99.34	100	99.71545	45	100
9.5	44.8038	18	100	66.56162	35	100
4.75	21.6438	0.32	100	56.23787	25	100
0.60	3.62	0.06	52	27.10845	8	65
0.30	2.1638	0	41	27.17252	5	40
0.075	0.83	0	12	6.251238	0	10

By job mix formula, the suitable proportions of RAP material, 12.5 mm passing coarse aggregates and fine sand are estimated by Solver in Excel, which shows approximate proportions of 28%, 22% and 50 % respectively. For the sake of ease and optimum utilization of RAP material, we take the ratios in the proportions of 30%, 25% and 45% respectively.

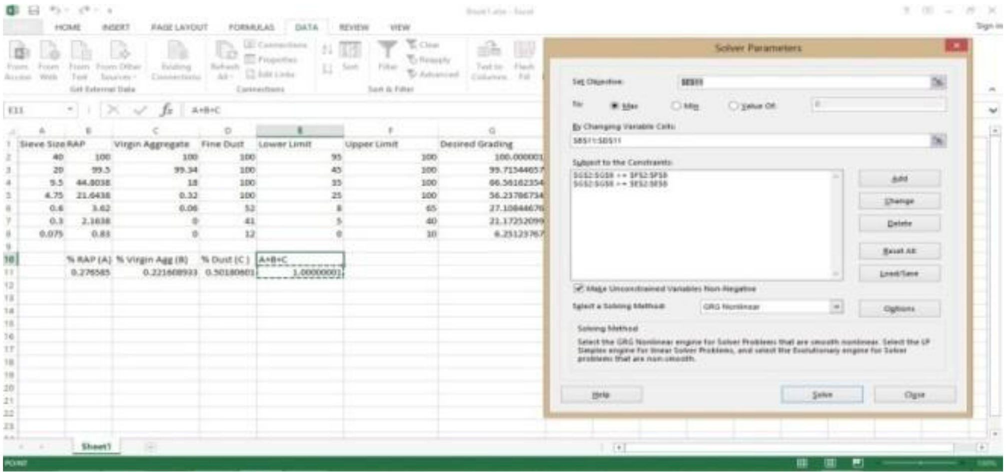


Figure 1: Calculating mix proportions of constituents using Solver in excel.

DISCUSSIONS

The grain size distribution curve was plotted on a logarithmic scale. The gradation of RAP can be compared to that of virgin aggregate, although with a higher content of fines. The gradation of RAP is better as compared to the virgin aggregates, as depicted by the Grain Size Distribution curve.

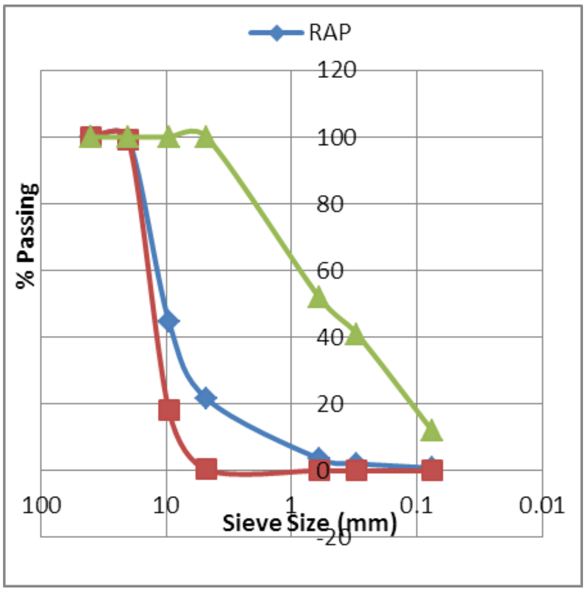


Figure 2: Particle Size distribution curve.

OMC (Optimum Moisture Content) and MDD (Maximum dry density)

RAP material, new aggregate and sandare mixed in the obtained proportions as per Job Mix Formula. Mix (RAP + virgin aggregates + fine dust), 12 kg overall, passing the 20 mm IS sieve were taken. This mix was distributed in four samples, weighing 2.5 kg overall. The samples were mixed thoroughly with different amounts of water to give a suitable range of moisture contents. Then, the method for testing was followed as per IS: 2720 Part-8 for materials susceptible to crushing. . Modified proctor compaction test is carried out as per IS: 2720 part-8 for 0, 3 and 5% stabilizer dosages (using for materials susceptible to crushing as specified in the code). Each procedure was done thrice with cement varying as 0%, 3% and 5%.Water content was varied with 4, 5, 6 and 7% and corresponding maximum dry density is calculated after plotting graphs of MDD vs OMC.

The test was conducted and moisture density curves were plotted for different cement dosages. The test results are shown in Table.3

Table 3: Moisture Density Relations with Different dosages of cement.

Dosage of stabilizer(cement) %	Optimum Moisture Content(OMC)%	Maximum Dry Density(MDD) gm/cc
0	6.2	2.104
3	6.5	2.09
5	6.6	2.075

Figure 3: a.) (RAP+virgin aggregate+Fine sand) mix and b.) Proctor mould for the mix.

CBR (California Bearing Ratio) Test

CBR test is done to ensure cement’s contribution in the strength gaining. For evaluating the strength of RAP mix, CBR test is performed as per IS: 2720 part-16 for 0, 3 and 5% cement dosages immediately after preparing the sample. However, soaked CBR test is to be conducted on untreated RAP mix (0% cement). The strength of the RAP mix increases with increase in curing period. To study this increase, CBR tests are to be carried out on RAP mix cured for 4 days. The test results have been tabulated in Table 4.

Table 4: CBR values (soaked and unsoaked) for different cement dosages.

Cement Dosage in %	CBR (%)	
	Unsoaked	4days soaked
0	51	44
3	42	61
5	38	71

The curves obtained basically were the normal curves with convexity upwards, and no sign of upward concavity was seen up till now. So, there was no need felt for any correction. One curve depicting 0% dosage has been drawn here in Fig.6. Also, sample calculation for this dosage has been shown, for which the CBR values comes out to be 51%.

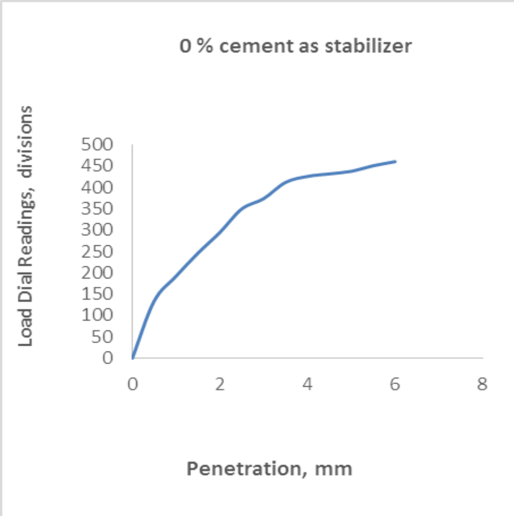


Figure 4: CBR curve for 0% cement dosage.

DISCUSSIONS

Cement acts as a stabilizer by contributing to the binding of the material, which can be seen by the increasing values of the 4 days soaked CBR samples.

UCS (Unconfined Compressive Strength) Test

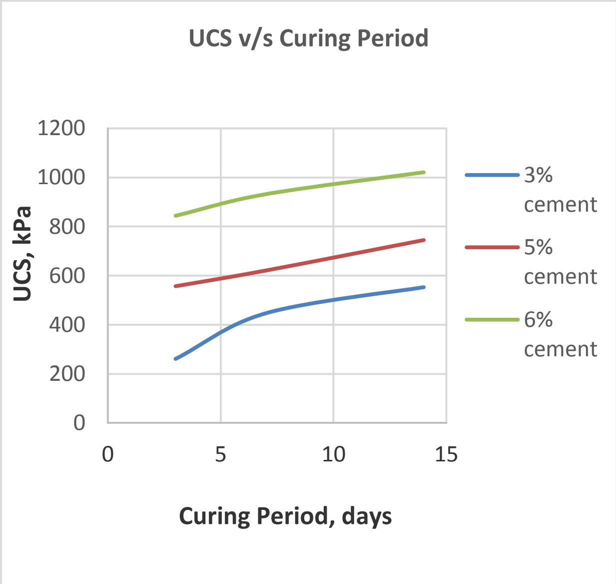
Test aims to determine the appropriate cement dosage and curing period for getting sufficient strength for the RAP mix.

Specimen is prepared using a mould of circular cross-section of 100 mm diameter and 200 mm height. Specimen is prepared at the earlier determined optimum water content and maximum dry density.

The test is performed as per IS:2720 Part 10 for 3,5 and 6% cement dosages cured for 3, 7 and 14 days.

Table 5: UCS values for different cement dosages and curing periods.

Cement dose (%)	3	3	3	5	5	5	6	6	6
UCS(kPa)	261	447	553	557	621	745	844	932	1021
Curing Period (days)	3	7	14	3	7	14	3	7	14



DISCUSSIONS

The strength of the RAP mixed stabilized with cement increases with the increase in cement dosage and curing period. This is because higher cement content along with higher curing period increases bondage between the inter-particles and helps in achieving higher strength.

Marshall Stability Value

1. Marshal stability

This is defined as the maximum load carried by a compacted specimen at a standard test temperature of 60˚C.

2. Flow

This is a measure of flexibility, measured by the change in diameter of the test sample in the direction of load application between the start of loading and the time of maximum load.

3. Compacted density of the mix (CDM)

4. Voids in the mix (VIM), meaning the percentage of air voids by volume in the specimen.

5. Percentage voids in mixed aggregates (VMA)

It is the volume of inter-granular void space between the aggregate particles of a compacted paving mixture, including the air voids and the volume of bitumen not absorbed into the aggregate. VMA-value is expressed as a percentage of the total volume of the mix.

For each of the five mixes, samples were prepared for nine different bitumen contents of 5.5%, 6.0%, 6.5%, 7.0%, 7.5% and 8.0%.

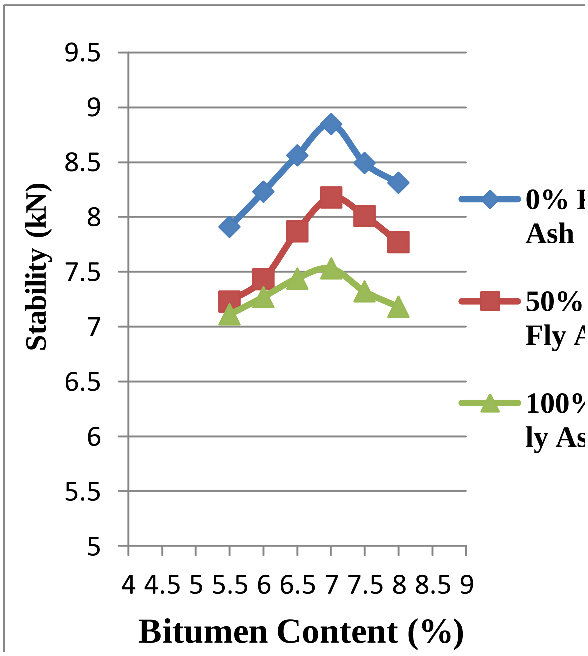


Figure 6: Plot showing Marshall Stability v/s Bitumen Content.

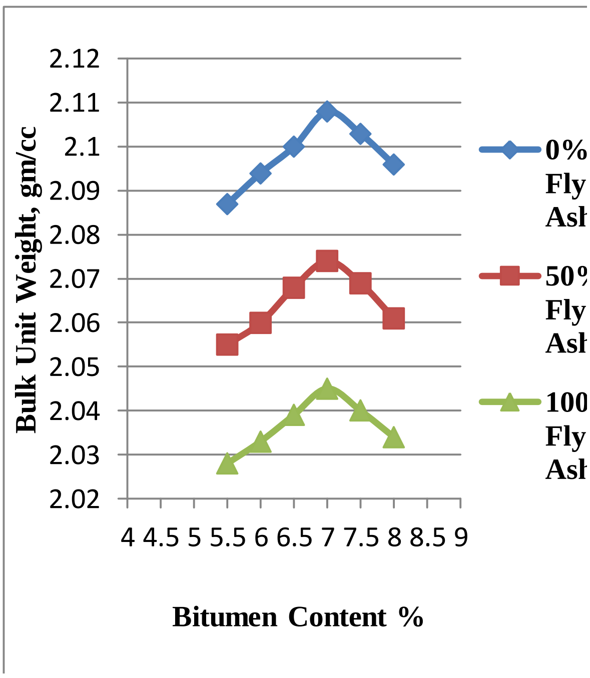


Figure 7: Plot showing Bulk Unit Weight v/s Bitumen Content.

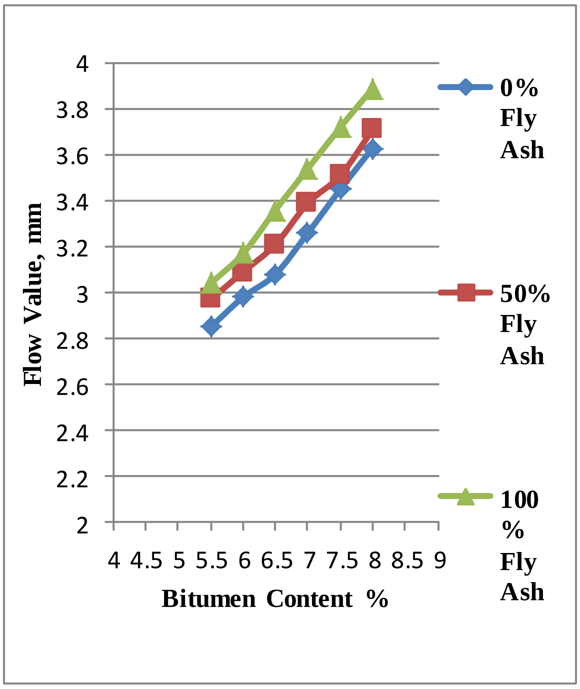


Figure 8: Plot showing Flow Value v/s Bitumen Content.

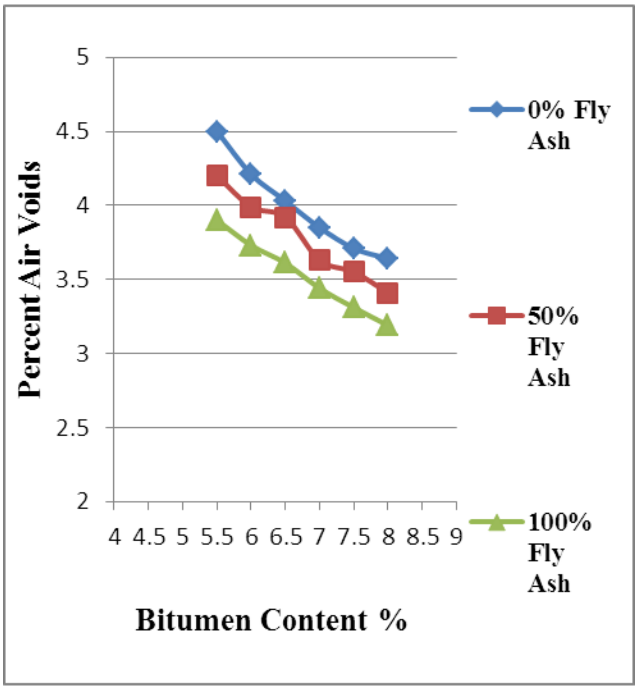


Figure 9: Plot showing Percent Air Voids v/s Bitumen Content.

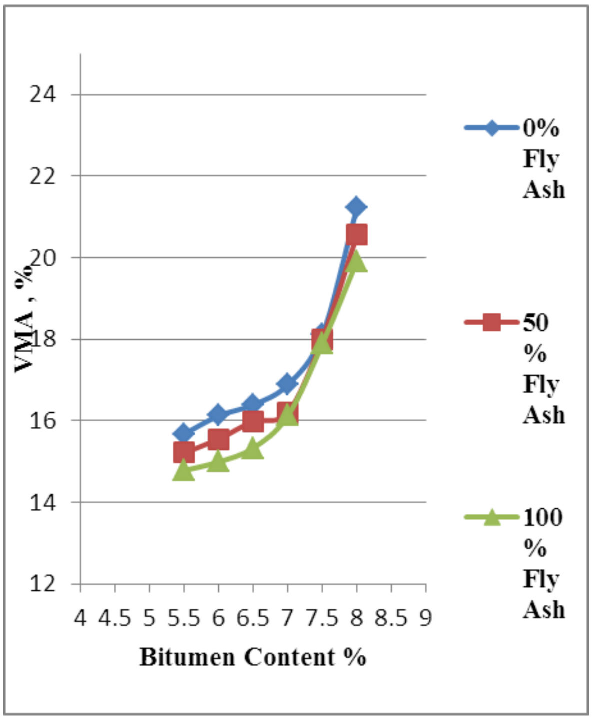


Figure 10: Plot showing Voids in Mineral Aggregates v/s Bitumen Content.

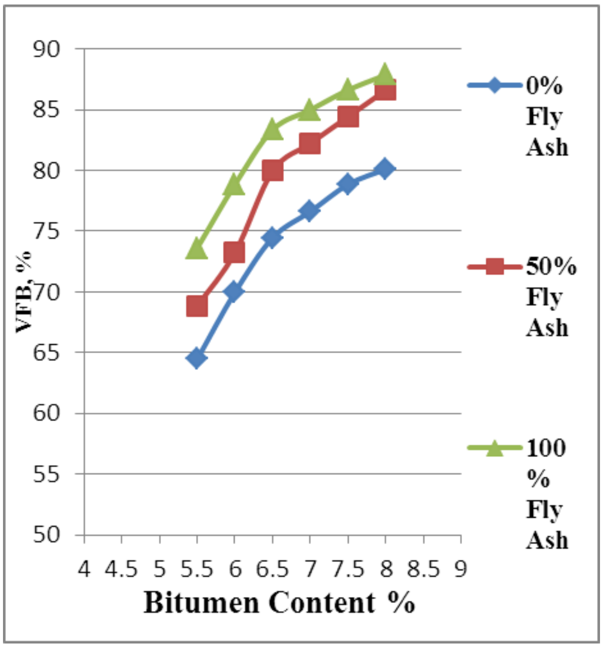


Figure 11: Plot showing Voids Filled with Bitumen v/s Bitumen Content.

DISCUSSIONS

The mix design was performed for Bituminous Concrete. Here, the suitable proportions of the mix were decided by the Job Mix Formula. These proportions came out to be 61%, 35% and 4% for RAP, virgin aggregates and filler respectively. The 50% Fly Ash mix was found out to give satisfactory results, and limits within the standards. Also, Fly Ash being a waste material is utilized here effectively, which will contribute significantly in reducing the environmental disturbance. Although, Control mix (0% Fly Ash+100% OPC) was found to give more stability and lesser flow value, but still this mix cannot be preferred. This is because the pavement surface layer needs to be a little bit flexible and not too much stable. So, 50% Fly Ash mix was found to be the optimum mix. The optimum binder content for the mix came out to be 6.7%.

CONCLUSIONS

a) The optimum dosage of the blend, as per job mix formula, comes out to be 28, 22 and 50% for RAP, virgin aggregate and fine sand respectively.

b) Maximum dry density is achieved in the range of 6-7% water content for 0, 3 and 5% cement dosages.

c) CBR value increases with increase in dosage and curing period of 4 days.4 days soaked CBR value comes as 71% for 5% cement, which is attributed to the bondage of cement with adequate water.

d) UCS values come out in increasing order with dosage as well curing period. It's value is 1021 kPa for 5 % cement and 14 days curing

e) The RAP material can be further tested for finding out the Resilient. Modulus, and suitably the base/sub-base layer can be designed with the help of various software using IRC: 37-2012

f) The mix design of surface course was performed for Bituminous Concrete. Here, the suitable proportions of the mix were decided by the Job Mix Formula. These proportions came out to be 61%, 35% and 4% for RAP, virgin aggregates and filler respectively. The 50% Fly Ash mix was found out to give satisfactory results, and limits within the standards.

g) Control mix (0% Fly Ash+100% OPC) was found to give more stability and lesser flow value, but still this mix cannot be preferred. This is because the pavement surface layer needs to be a little bit flexible and not too much stable.

h) The optimum binder content for the mix came out to be 6.7%

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