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EFFECT OF RECLAIMED ASPHALT PAVEMENT (RAP) AGGREGATE ON PERMEABILITY OF GRANULAR LAYER

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***Abstract*:** The aim of the research work is to test the feasibility of use of RAP aggregate for improving properties of GSB (granular sub-base) mixes. The main objectives of the research work are to determine the properties of materials namely fresh aggregate, Reclaimed Asphalt Pavement aggregate and stone dust used in the study, To determine the maximum dry density (MDD), optimum moisture content (OMC) and CBR value of the GSB mixes with fresh aggregate and RAP aggregate, To determine the permeability of the GSB mixes with fresh aggregate and RAP aggregate, To study the effect of replacement of fresh aggregate with RAP aggregate in varying proportion of 0% to 70% with increment of 10% on compaction and strength characteristics of the GSB mixes, To develop relationships between strength and compaction characteristics of GSB mixes with proportion of RAP.

Study on the Utilization of Reclaimed Asphalt Pavement aggregate for road construction can be an effective and cost efficient method. It reduces the disposal problem caused by construction waste and also helps to conserve natural aggregate. The study has been taken up mainly to understand the feasibility of use of RAP aggregate for construction of granular sub base. In this study, fresh aggregate was replaced with Reclaimed Asphalt Pavement aggregate in various proportions, 0%, 10%, 20%, 30%, 40%, 50%, 60% and 70%, for testing the compaction, strength and permeability characteristics of the GSB mixes. The results of the study are applicable only to the materials used and specified characteristics studied in this work. However, the methodology can be applied to other similar materials as well and the expected results may also be similar and compatible.

INTRODUCTION

Most people require some kind of mobility. People have always traveled, whether for work or play. The advancement of human civilization is greatly influenced by transportation.

Based on their structural behavior, pavements are categorized as either rigid or flexible. In most cases, the roadways are built in many levels. In contrast to rigid pavements, which include of a cement concrete slab, flexible pavements have several layers, including subgrade, subbase, base, and surface course.

Research topic and its significance

This study's overarching goal is to determine whether or not reclaimed asphalt pavement aggregate (RAP) is suitable for use in granular mixes. The granular sub base (GSB) material must have sufficient permeability to perform its primary role of drainage. In this study, we look into granular sub base Grading III and Grading VI using RAP aggregate.

Objectives of the study

It is the intention of this study to determine if granular subbase (GSB) mixtures may be improved by adding RAP aggregate.

In order to ascertain the characteristics of the materials utilized in the research, namely new aggregate, recycled asphalt pavement aggregate, and stone dust.

The goal is to find the MDD, OMC, and CBR values of the GSB mixtures made using RAP and green aggregate. This study aims to examine the impact on the compaction and strength properties of GSB mixes caused by substituting RAP aggregate for fresh aggregate in varied proportions ranging from 0% to 100% with increments of 25%.

Scope of the study

Research on the use of recycled asphalt pavement (RAP) aggregate in road building has the potential to be a practical and economical solution. The building waste disposal problem is alleviated, and natural aggregate is conserved, as a result. Primarily, we set out to learn if it would be possible to build granular sub bases using RAP aggregate.

This study examined the compaction, strength, and permeability properties of GSB mixes by substituting reclaimed asphalt pavement aggregate for new aggregate in varying quantities (0%, 10%, 20%, 30%, 40%, 50%, 60%, and 70%). Only the materials and features specifically examined here can be considered in drawing conclusions from the study. But the same approach may be used with other comparable materials, and the outcomes could be compatible too.

LITERATURE REVIEW

- With contributions from Saravanan Kothandaramana and Goutham Sarang (2023)
  This research looked at RAP-incorporated concrete from four different angles: practicability, replaceability, enrichment, and durability. The conclusions were derived from a thorough examination of several research publications, technical reports, conference papers, etc.
- João Paulo Souza Silva, Lilian Ribeiro de Rezende, and Lara Batista Ferreira de Lima (2023)
  In this study, adding of RAP to lateritic soil in certain amounts improved the material's behavior. That the base course of the pavement construction and traffic characteristics evaluated are best served by a blend of 25% RAP and 75% lateritic soil.
- Kumar Shubham, Abdhesh Kumar Sinha, Sabyasachi Biswas, and Diptikanta Rout (2023)
  The OMC content of RAP concrete mixtures ranges from three to seven percent by weight. The OMC value drops as the proportion of RAP aggregate in concrete mixes increases, as RAP is a substitute for natural aggregates.
- Gurukalyana Biswal and Sujit Kumar Pradhana (2022) at IGIT Sarang
  The MoRTH requirements allow an AIV for the granular sub base layer of up to 40%; nevertheless, Another interesting finding is that the specific gravity of RAP is lower than that of fresh aggregate, which is still excellent.
- Abdelhalim Azam, Eman Mousa, and Sherif El-Badawy (2021) in Egypt
  The present study found that VA and RAP mixes had higher Mr values. According to CBR, RAP can be used with crushed aggregates up to a maximum of 60%.

INTRODUCTION TO MATERIALS USED

Fresh aggregate, RAP aggregate, and stone dust are the materials utilized in the research. The recycled material from Mohali was mixed with new aggregate from the Ambala Chandigarh Highway building site.

Standard Specifications

Granular sub base, water bound macadam, wet mix macadam, and different bituminous and concrete layers are some of the many uses for aggregate in pavement.

Granular Sub Base (GSB)

In certain pavement layers, GSB serves as the subbase course. It separates the pavement layers and allows water to flow away from them.

Materials

For GSB, material that is properly graded, like natural sands, moorum, crushed stone, gravel, or a mix of these. For the subbase, materials such as crushed concrete, brick, metal, kankar etc.

Table: Grades of Granular Sub Base

IS Sieve (mm)	By weight passing through the sieve as a percentage					
	Grading I	Grading II	Grading III	Grading IV	Grading V	Grading VI
75	100	-	-	-	100	-
53	80-100	100	100	100	80-100	100
26.5	55-90	70-100	55-75	50-80	55-90	75-100
9.5	35-65	50-80	-	-	35-65	55-75
4.75	25-55	40-65	10-30	15-35	25-50	30-55
2.36	20-40	35-50	-	-	10-20	10-25
0.425	10-15	10-15	-	-	0-5	0-8
0.075	<5	<5	<5	<5	-	0-3

METHODOLOGY

The methodology of this study involved conducting many trials with different types of aggregate, including fresh and reclaimed asphalt pavement aggregate, in order to determine the optimal proportions of crushed asphalt pavement (RAP) and crushed natural asphalt (NA) for use in road building.

Methodology Flow Chart

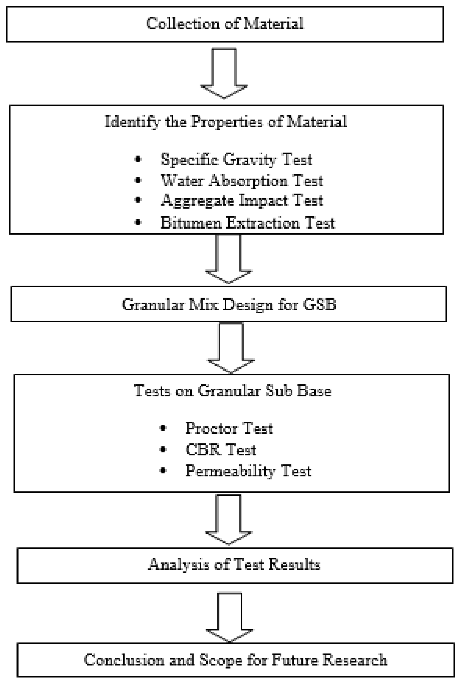

Figure: Methdology Flow Chart

Program for Testing

Raw aggregate, recycled aggregate, and GSB grades III and VI were all subjected to a battery of tests.

Evaluations **on Aggregate**

- Examining the Aggregate Impact Value
- A test for specific gravity
- Hydrophilicity Evaluation
- Asphalt Removal Evaluation

GSB Grading III & Grading VI TEST

- Workload Allocation Method
- Test Administrator
- Bearing Ratio Evaluation in California
- Test for Permeability

Stone Dust Experiments

A test for specific gravity

RESULTS AND DISCUSSION

In order to assess the material and GSB (Granular subbase) mix qualities, a series of laboratory experiments are conducted using different amounts of fresh and RAP aggregate. The leftover 80 mm layer of bituminous macadam (BM) from a road building site in Mohali is used to make the RAP that is milled. We followed all of the instructions from the IRC, the IS codes, and the MoRTH specs when we ran the testing. We have studied the data with relation to the recommendations made by MoRTH.

Result for Aggregate Impact

Table: AIV for Fresh aggregate and RAP aggregate.

Type of Aggregate	Aggregate Impact Value (AIV)
Fresh aggregate	16.75 %
RAP aggregate	14.73%

Result Specific Gravity

Tabl: Specific gravity of materials

Type of Material	Specific Gravity
Fresh Aggregate 20mm	2.69
Fresh Aggregate 10mm	2.63
RAP Aggregate	2.50
Stone Dust	2.61

Result of Water Absorption

Table: Water absorption of fresh aggregate and RAP aggregate.

Type of Aggregate	Water Absorption
Fresh Aggregate (mix of 20 and 10 mm)	0.56%
Fine aggregate (stone dust)	1.1%
RAP aggregate	1.02%

Result of Bitumen Extraction

Table: Binder content of RAP aggregate

Type of Aggregate	Binder content
RAP Aggregate	2.04 %

Designing of Job Mix

Approaches to Aggregate Proportioning

- Triangle diagram approach
- Rothfuch's approach
- Procedure for analysis
- The method of trial and error

Design of Granular Mix

GSB Grading III Mix Design

It is the result of a process of trial and error that the mix design of the granular sub base is developed. According to the most recent version of the MoRTH specifications, there are six different grades of Granular Sub-Base. The lower sub-base, or separation layer, is often composed of Grading III and IV, while the top sub-base, or drainage layer, is often composed of Grading V and VI.

Table: Blending Specifications for Grade III Materials Devoid of RAP Aggregate

Sieve Size (mm)	% by weight of Passing						
	40 mm (A)	20 mm (B)	10 mm (C)	SD (D)	Filler(cement) (E)	Required Grading	Proportion A:B:C:D:E 44:15:16:23:2
53	100	100	100	100	100	100	100
26.5	23.4	100	100	100	100	55-75	66.29
4.75	0	0	9.7	95.7	100	10-30	24.61
0.075	0	0	0	3.9	1.7	<5	0.936

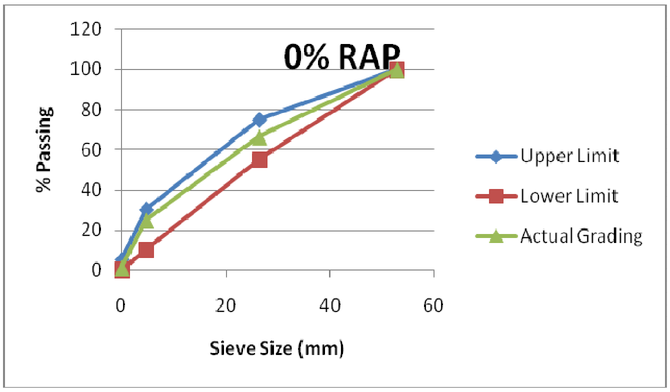

Figure: Partitioning for GSB Grading III with 0% RAP

Table: Design of GSB Mix for Grading III with 10% and 20% RAP Aggregate

Sieve Size (mm)	% by weight of Passing								
	40 mm	20 mm	10 mm	RAP	SD	Filler (cement) (F)	Required Grading	Proportion A:B:C:D:E:F	Proportion A:B:C: D:E:F
	(A)	(B)	(C)	(D)	(E)			42:12:17:10:17:2	38:12:12:20:16:2
53	100	100	100	100	100	100	100	100	100
26.5	23.4	100	100	87.8	100	100	55-75	66.6	68.45
4.75	0	0	9.7	13.6	95.7	100	Oct-30	21.19	21.11
0.075	0	0	0	0.15	3.9	2.1	<5	0.756	0.732

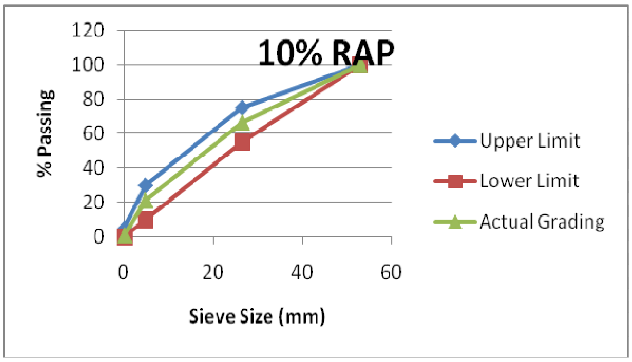

Figure: The distribution of 10% RAP for GSB Grading III

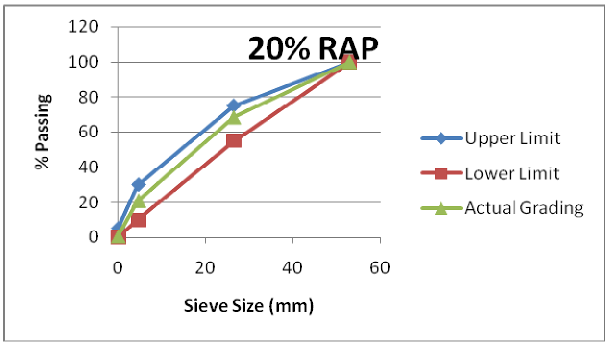

Figure: The distribution for GSB Grading III of 20% RAP

Table: The mix design of GSB for Grading III with 30% and 40% RAP aggregate

Sieve Size (mm)	% by weight of Passing								
	40 mm	20 mm	10 mm	RAP	SD	Filler (cement) (F)	Required Grading	Proportion A:B:C:D:E:F	Proportion A:B:C:D:E:F
	(A)	(B)	(C)	(D)	(E)			35:12:11:30:10:2	33:10:7:40:8:2
53	100	100	100	100	100	100	100	100	100
26.5	23.4	100	100	87.8	100	100	55-75	69.53	69.84
4.75	0	0	9.7	13.6	95.7	100	Oct-30	16.63	15.69
0.075	0	0	0	0.15	3.9	1.8	<5	0.513	0.45

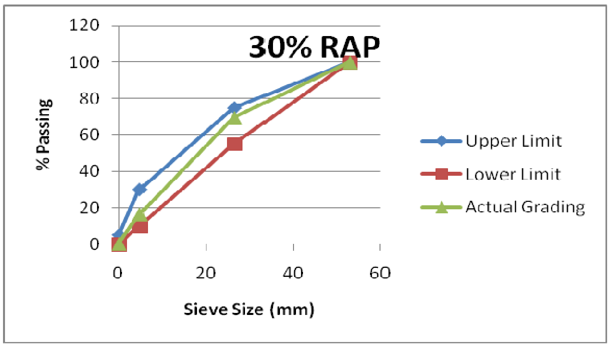

Figure: the distribution for GSB Grading III with 30% RAP

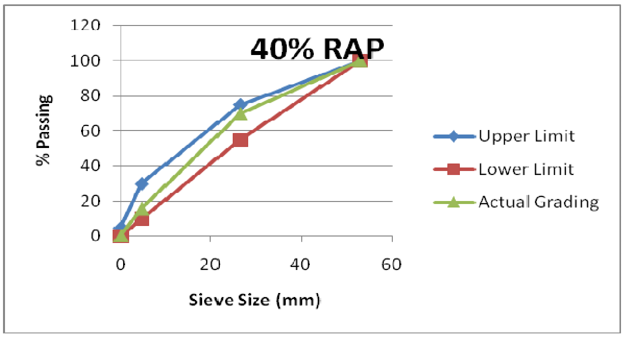

Figure: With 40% RAP proportions for GSB Grading III

Table: Mix design of GSB for Grading III with 50% and 60% RAP Aggregate

Sieve Size (mm)	% by weight of Passing								
	40 mm	20 mm	10 mm	RAP	SD	Filler (cement) (F)	Required Grading	Proportion A:B:C:D:E:F	Proportion A:B:C:D:E:F
	(A)	(B)	(C)	(D)	(E)			30:6:6:50:6:2	28:2:3:60:5:2
53	100	100	100	100	100	100	100	100	100
26.5	23.4	100	100	87.8	100	100	55-75	70.92	71.23
4.75	0	0	9.7	13.6	95.7	100	Oct-30	15.04	15.15
0.075	0	0	0	0.15	3.9	1.9	<5	0.387	0.363

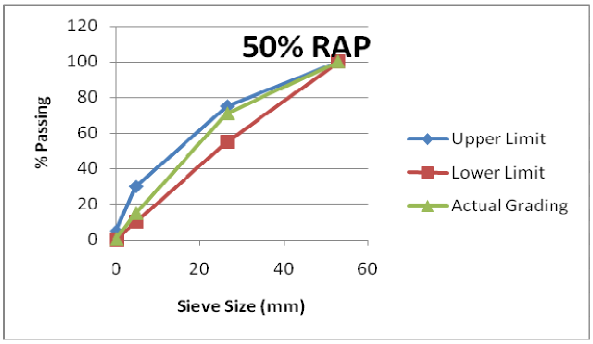

Figure: The Proportioning for GSB Grading III of 50% RAP

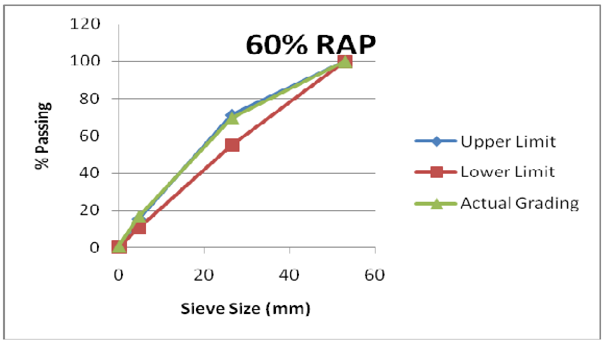

Figure: The Proportioning for GSB Grading III of 60% RAP

Table: Mix design of GSB for Grading III with RAP Aggregate 70%

Sieve Size (mm)	% by weight of Passing							
	40 mm	20 mm	10 mm	RAP	SD	Filler (cement) (F)	Required Grading	Proportion A:B:C:D:E:F
	(A)	(B)	(C)	(D)	(E)			22:3:2:70:1:2
53	100	100	100	100	100	100	100	100
26.5	23.4	100	100	87.8	100	100	55-75	74.61
4.75	0	0	9.7	13.6	95.7	100	Oct-30	12.58
0.075	0	0	0	0.15	3.9	2.4	<5	0.222

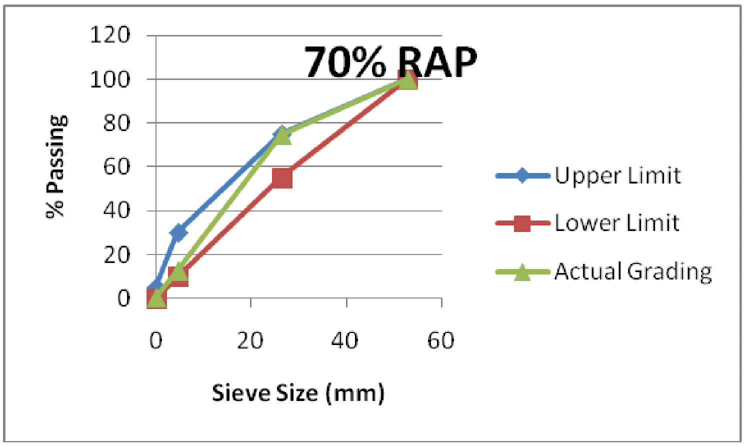

Figure: Proportioning for GSB Grading III of 70% RAP

Mix Design for GSB Grading VI

Table: Mix design of GSB for Grading VI without RAP Aggregate

Sieve Size (mm)	% by weight of Passing						
	40 mm (A)	20 mm (B)	10 mm (C)	SD (D)	Filler (cement) (E)	Required Grading	Proportion A:B:C:D:E 11:13:45:29:2
75	100	100	100	100	100	100	100
53	100	100	100	100	100	100	100
26.5	23.4	100	100	100	100	76-100	91.57
9.5	0	1.1	72.4	100	100	55-75	63.72
4.75	0	0	9.7	95.7	100	30-55	34.03
2.36	0	0	0	56.5	100	10-25	17.51
0.425	0	0	0	23.4	100	0-8	7.25
0.075	0	0	0	3.9	2.3	0-3	1.21

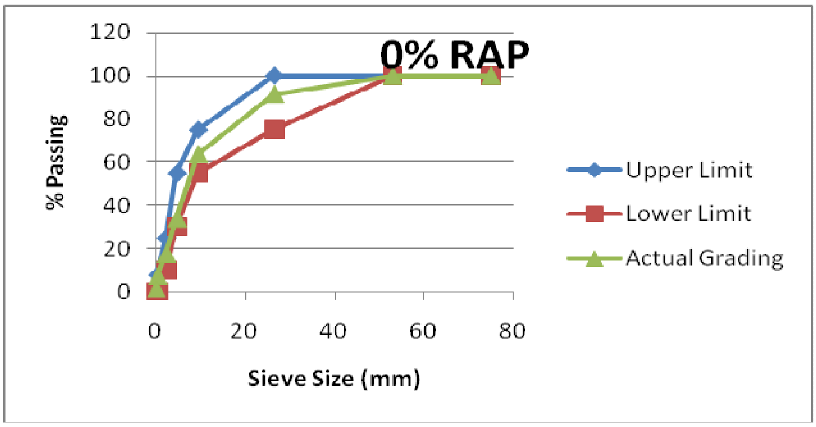

Figure: Proportioning for GSB Grading VI of 0% RAP

Table: Mix design of GSB for Grading VI with RAP Aggregate 10% & 20%

Sieve Size (mm)	% by weight of Passing								
	40 mm (A)	20 mm (B)	10 mm (C)	RAP (D)	SD (E)	Filler (cement) (F)	Required Grading	Proportion A:B:C:D:E:F 9:9:41:10:29:2	Proportion A:B:C:D:E:F 5:5:40:20:28:2
75	100	100	100	100	100	100	100	100	100
53	100	100	100	100	100	100	100	100	100
26.5	23.4	100	100	87.8	100	100	75-100	91.88	93.73
9.5	0	1.1	72.4	39.3	100	100	55-75	64.71	66.87
4.75	0	0	9.7	13.6	95.7	100	30-55	35.00	35.31
2.36	0	0	0	4.5	56.5	100	10-25	17.96	17.85
0.425	0	0	0	0.75	23.4	100	0-8	7.33	7.17
0.075	0	0	0	0.15	3.9	2.4	0-3	1.224	1.2

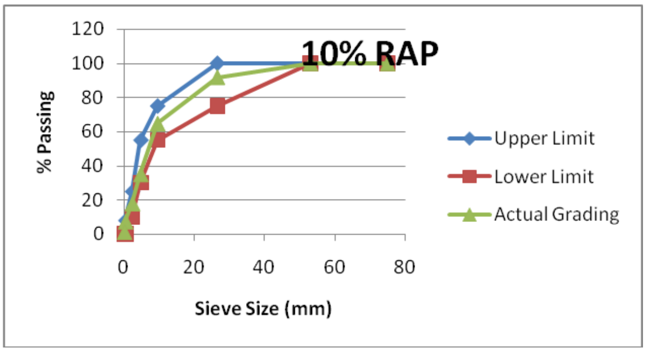

Figure: Proportioning for GSB Grading VI of 10% RAP

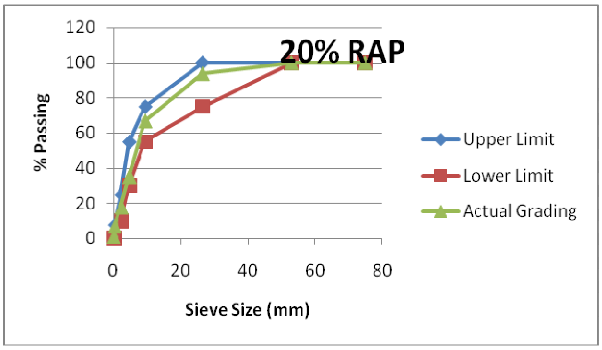

Figure: Proportioning for GSB Grading VI of 20% RAP

Table: Mix design of GSB for Grading VI with RAP Aggregate 30% & 40%

Sieve Size (mm)	% by weight of Passing								
	40 mm (A)	20 mm (B)	10 mm (C)	RAP (D)	SD (E)	Filler (cement) (F)	Required Grading	Proportion A:B:C:D:E:F 5:5:30:30:28:2	Proportion A:B:C:D:E:F 3:2:25:40:28:2
75	100	100	100	100	100	100	100	100	100
53	100	100	100	100	100	100	100	100	100
26.5	23.4	100	100	87.8	100	100	75-100	92.51	92.82
9.5	0	1.1	72.4	39.3	100	100	55-75	63.56	63.84
4.75	0	0	9.7	13.6	95.7	100	30-55	35.7	36.57
2.36	0	0	0	4.5	56.5	100	Oct-25	18.3	18.75
0.425	0	0	0	0.75	23.4	100	0-8	7.24	7.32
0.075	0	0	0	0.15	3.9	2.3	0-3	1.215	1.23

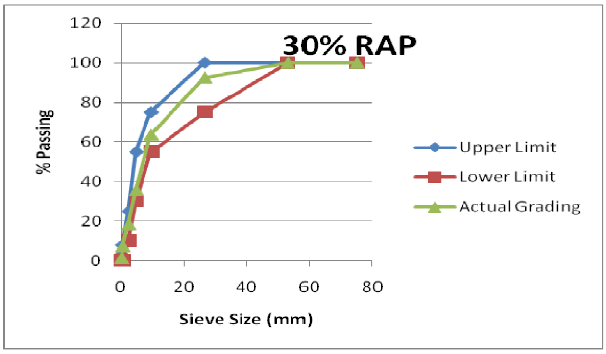

Figure: Proportioning for GSB Grading VI of 30% RAP

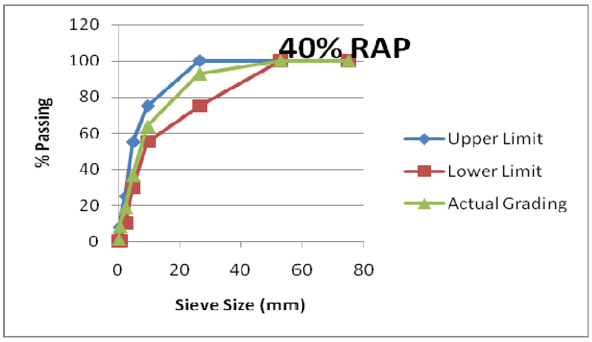

Figure: Proportioning for GSB Grading VI of 40% RAP

Table: Mix design of GSB for Grading VI with RAP Aggregate 50% & 60%

Sieve Size (mm)	% by weight of Passing								
	40 mm (A)	20 mm (B)	10 mm (C)	RAP (D)	SD (E)	Filler (cement) (F)	Required Grading	Proportion A:B:C:D:E:F 2:3:16:50:27:2	Proportion A:B:C:D:E:F 0:0:15:60:23:2
75	100	100	100	100	10	100	100	100	100
53	100	100	100	100	10	100	100	100	100
26.5	23.4	100	100	87.8	10	100	75-100	92.37	92.68
9.5	0	1.1	72.4	39.3	10	100	55-75	60.28	59.44
4.75	0	0	9.7	13.6	95.	100	30-55	36.1	33.54
2.36	0	0	0	4.5	56.	100	Oct-25	18.63	16.82
0.425	0	0	0	0.75	23.	100	0-8	7.16	6.3
0.075	0	0	0	0.15	3.9	2.5	0-3	1.206	1.065

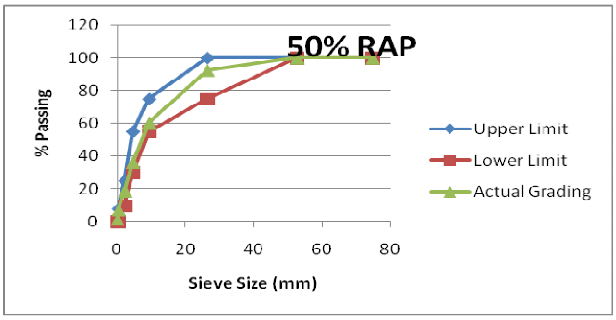

Figure: Proportioning for GSB Grading VI of 50% RAP

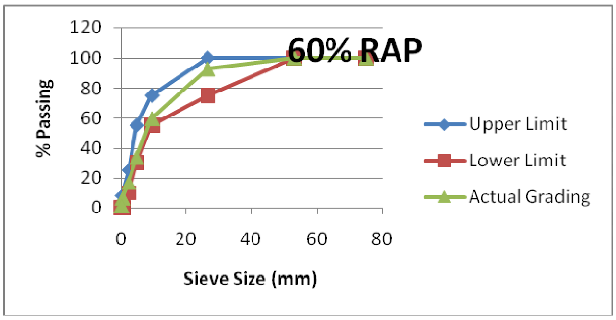

Figure: Proportioning for GSB Grading VI of 60% RAP

Table: Mix design of GSB for Grading VI with RAP Aggregate 70%

Sieve Size (mm)	% by weight of Passing							
	40 mm (A)	20 mm (B)	10 mm (C)	RAP (D)	SD (E)	Filler (cement) (F)	Required Grading	Proportion A:B:C:D:E:F 0:0:0:70:28:2
75	100	100	100	100	100	100	100	100
53	100	100	100	100	100	100	100	100
26.5	23.4	100	100	87.8	100	100	75-100	91.46
9.5	0	1.1	72.4	39.3	100	100	55-75	57.51
4.75	0	0	9.7	13.6	95.7	100	30-55	38.23
2.36	0	0	0	4.5	56.5	100	10-25	20.1
0.425	0	0	0	0.75	23.4	100	0-8	7.45
0.075	0	0	0	0.15	3.9	2.5	0-3	1.275

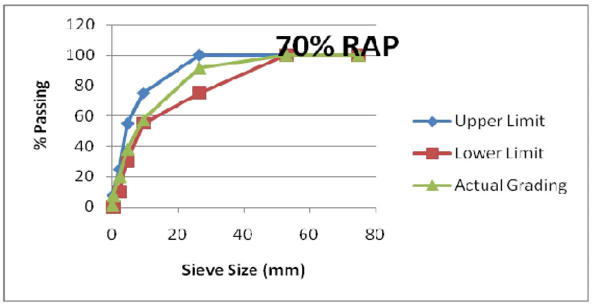

Figure: Proportioning for GSB Grading VI of 70% RAP

Result of GSB Mixes

Proctor Test Results for GSB Grading III

Table: MDD & OMC of GSB (Grading III) Mixes

Percentage of RAP	MDD (g/cc)	OMC (%)
0% RAP	2.221	5.4
10% RAP	2.227	5.7
20% RAP	2.232	5.9
30% RAP	2.241	6.1
40% RAP	2.256	6.4
50% RAP	2.239	6.7
60% RAP	2.198	6.8
70% RAP	2.114	6.9

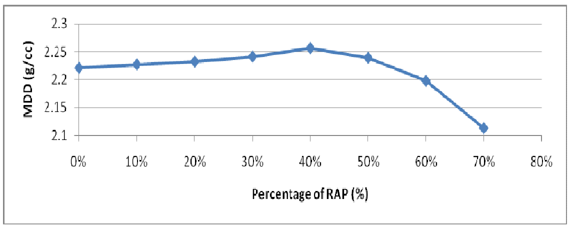

Figure: variation of MDD with % of RAP aggregate for GSB Grading III

The maximum dry density (MDD) of GSB mixes with increasing RAP aggregate percentages up to 40%, and then fell after that, conclude that GSB-III mixtures containing up to 50% RAP are effective.

Proctor Test Results for GSB Grading VI

Table: MDD & OMC of GSB (Grading VI) Mixes

Percentage of RAP	MDD (g/cc)	OMC (%)
0% RAP	2.208	8.9
10% RAP	2.231	9
20% RAP	2.26	9.2
30% RAP	2.251	9.8
40% RAP	2.233	9.9
50% RAP	2.212	10.1
60% RAP	2.206	10.3
70% RAP	2.118	10.4

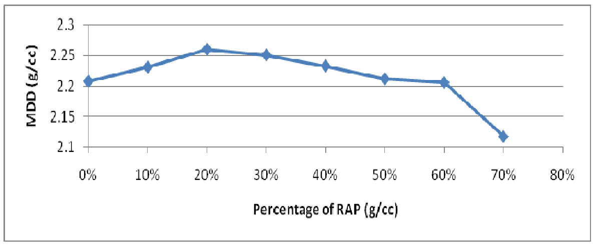

Figure: Changes in MDD as a function of RAP aggregate percentage for Grade VI GSB

The MDD value of GSB mixes with increasing RAP aggregate percentages up to 20% and then fell. that GSB-VI mixes can benefit from RAP up to 50%.

California Bearing Ratio Test

The CBR test was done on GSB mixes for the 4-days soaked samples as per IS.2720 Part-16:1987.

CBR Test Results for GSB Grading III

Table **Error! No text of specified style in document.**-1: CBR of GSB (Grading III) Mixes

Percentage of RAP	CBR Value (%)
0% RAP	32.76
10% RAP	33.12
20% RAP	33.91
30% RAP	34.67
40% RAP	35.12
50% RAP	31.78
60% RAP	29.16
70% RAP	25.67

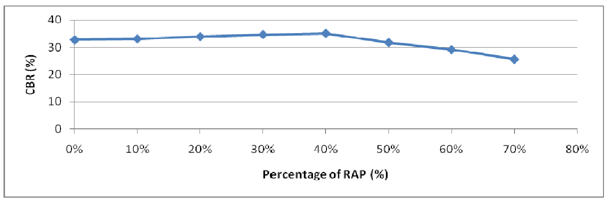

Figure: The CBR value for GSB Grading III varies with the percentage of RAP aggregate

The CBR value of GSB mixes with increasing RAP aggregate percentages up to 40%.

CBR Test Results for GSB Grading VI

Table: CBR of GSB (Grading VI) Mixes

Percentage of RAP	CBR Value (%)
0% RAP	31.94
10% RAP	32.42
20% RAP	33.19
30% RAP	32.09
40% RAP	30.71
50% RAP	28.93
60% RAP	27.61
70% RAP	26.03

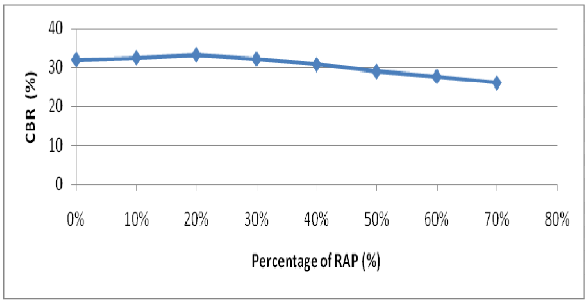

Figure: variation of CBR value with % of RAP aggregate for GSB Grading VI

The CBR value of GSB mixes with increasing RAP aggregate percentage up to 20%. On the other hand, compared to the GSB mix without RAP, the CBR value up to 30% RAP was more apparent. These results demonstrate the beneficial usage of RAP in GSB-VI blends up to 30%. An increase in the MDD value of the mixture may explain why the addition of RAP increases CBR up to a specific percentage of RAP.

Permeability Test Results for GSB Grading III

Table: Permeability of GSB (Grading III) Mixes

Percentage of RAP	Time taken	Permeability (m/day)
0% RAP	1:32:44	27.09
10% RAP	0.071169	24.43
20% RAP	1:54:11	21.86
30% RAP	2:11:54	19.02
40% RAP	2:20:38	17.8
50% RAP	2:34:56	16.18
60% RAP	2:43:41	15.29
70% RAP	0.1231366	14.16

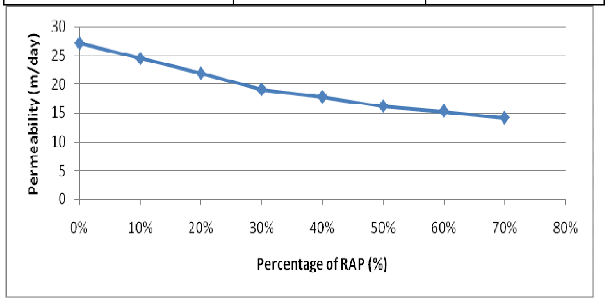

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Figure: variation of Permeability with % of RAP aggregate for GSB Grading III

Permeability Test Results for GSB Grading VI

Table: Permeability of GSB (Grading VI) Mixes

Percentage of RAP	Time taken	Permeability (m/day)
0% RAP	0.084988426	20.59
10% RAP	2:13:51	18.74
20% RAP	0.101446759	17.18
30% RAP	2:37:36	15.87
40% RAP	0.116145833	15.01
50% RAP	0.122650463	14.24
60% RAP	3:04:55	13.54
70% RAP	3:17:32	12.65

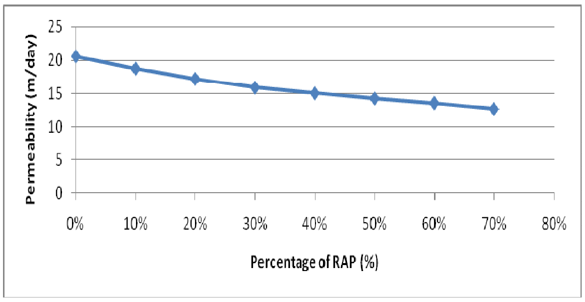

Figure: variation of Permeability with % of RAP aggregate for GSB Grading VI

Above results concludes that if we increase the RAP aggregate percentage, the permeability value decreased in the both the cases GSB of Grading III and Grading VI. This is because of binder coated with the RAP aggregate.

CONCLUSIONS

Results from the aggregate impact value test showed that the RAP aggregate's strength was comparable to that of the fresh aggregate. The impact value for RAP aggregate was found to be 16.75%, whereas the value for fresh aggregate was 14.73%.

There was a specific gravity of 2.69 for 20 mm and 10 mm fresh aggregate, 2.63 for RAP aggregate, 2.50 for stone dust, and 2.61 for all three.

The water absorption values for RAP aggregate were 1.02%, whereas fresh aggregate had a value of 0.56%.

The initial MDD value for GSB Grading III was found to be 2.221 g/cc when no RAP was added, however after 40% RAP aggregate was substituted for fresh aggregate, the value was raised to 2.256 g/cc.

It was found that the value of MDD with 0% RAP content was 2.208 g/cc for GSB Grading VI. By substituting 20% of the fresh aggregate with RAP aggregate, this value was enhanced to 2.260 g/cc.

After 40% RAP aggregate was substituted for fresh aggregate, the California bearing ratio (CBR) for GSB Grading III went from 32.76% with no RAP content to 35.12%. It follows that a replacement level of around 40% RAP aggregate was optimal.

After determining that the CBR value with 0% RAP content was 31.94% for GSB Grading VI, the value was raised to 33.19% by substituting 20% RAP aggregate for fresh aggregate. The ideal amount of RAP aggregate to replace it was, therefore, around 20%.

Scope for the Future Study

Due of the massive building sector expansion and environmental concerns, mining is already a major issue, and it might become much worse in the future.

This study utilized RAP aggregate sourced from premix carpet; however, future research might expand to include additional RAP materials, such as thick bituminous macadam or bituminous asphalt.

An alternative to RAP material is waste from inflexible pavements and previously destroyed building sites.

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