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APPROVAL PAGE

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PULCHOWK CAMPUS

DEPARTMENT OF CIVIL ENGINEERING

The undersigned certify that they have read and recommended to the Institute of Engineering for acceptance, a final report of thesis entitle "**A Study on Marshall Properties of Hot Mix Reclaimed Asphalt Pavement"** submitted by Reeta Khadka in partial fulfillment of the requirements for the degree of Master of Science in Transportation Engineering, Nepal is a record of works carried out by her under my supervision and guidance.

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ABSTRACT

In this research work, we mainly focused on the use of waste construction materials (Reclaimed Asphalt Pavement-RAP) for the construction of new surface course of flexible pavement. Here we adopt Marshall Mix design method for the analysis of waste construction material (Reclaimed Asphalt Pavement-RAP). Reclaimed Asphalt Pavement (RAP) is any removed or reprocessed pavement material that contains aggregates and bitumen. Recycling pavement provides an even greater economy by eliminating the cost associated with the removal and hauling of waste materials.

Altogether 18 samples for fresh mix design and 33 samples containing different percentage of RAP mix design with or without Rejuvenating Agent (RA) were prepared for the calculation of OBC at fresh mix and Marshall Properties of mix containing different percentage of RAP. Here we used OBC of fresh mix design for the analysis of Marshall Properties of mix containing different percentage of RAP.

Seven different percentage of RAP (15%, 20%, 25%, 30%, 50%, 75% and 100%) were mixed with the new graded aggregate for job mix. Rejuvenating Agent is added at job mix design containing higher percentage of RAP (30%, 50%, 75% and 100%).

Higher stability is found in the mix design containing 50% of RAP (13.724 KN) without addition of RA. With the addition of RA, stability of varying RAP contain mix design seems to be slightly decreased and increase in flow value. Mix design containing up to 30% RAP with or without RA satisfies Marshall Properties as per SSRBW, 2073. So we can recommend the use of up to 30% RAP for the construction of new surface course of flexible pavement.

Keywords: Reclaimed Asphalt pavement, Marshall Mix Design, Bitumen, Aggregate, Rejuvenating Agent and Marshall Properties.

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LIST OF ABBREVIATIONS

RAP	Reclaimed Asphalt Pavement
RA	Rejuvenating Agent
USACE	U.S. Army Corps of Engineers
FHWA	Federal Highway Administration
VFB	Voids Filled with Bitumen
VMA	Voids in Mineral Aggregate
HMA	Hot Mix Asphalt
WMA	Warm Mix Asphalt
SSRBW	Standard Specification for Road and Bridge Works
OBC	Optimum bitumen content
PCC	Plain Cement Concrete
DoR	Department of Road
VG	Viscosity Grade
FDR	Full depth reclamation
SSS	Sodium Sulphate Soundness
AIV	Aggregate Impact Value
G	Specific gravity/Unit weight
LAA	Los Angeles Abrasion

CHAPTER 1 INTRODUCTION

1.1 Marshall Stability and Asphalt Concrete

1.1.1 Background

The basic concepts of the Marshall Mix design method were originally developed by Bruce Marshall of the Mississippi Highway Department around 1939 and then refined by the U.S. Army Corps of Engineers (USACE) during Second World War and eventually by state highway departments. The mix method primarily depends upon the aggregate and asphalt selection, followed by preparation of cylindrical specimens with different proportions; complying with air void concept, voids in mineral aggregate (VAM), voids filled with bitumen (VFB), minimum stability and flow requirement. The strength and flow value correspond with strength and flexibility property of asphalt concrete mix.

Asphalt Concrete is the dense graded premixed bituminous mixture consisting of carefully proportioned mixture of dry coarse aggregate, fine aggregate, mineral filler and bitumen. When properly designed with appropriate proportion of ingredients, it will provide a surfacing of exceptional durable and capable in carrying the heaviest traffic. It is the highest quality of construction among the group of black top pavements.

Suitably designed bituminous mix will withstand heavy traffic loads under adverse climatic conditions and also fulfill the requirement of structural and pavement surface characteristics. The objective of the design of bituminous mix is to determine an economical blend through several trial mixes. The gradation of aggregate and the corresponding binder content should be such that the resultant mix should satisfy the following conditions.

i. Sufficient binder to ensure a durable pavement by providing a water proofing coating on the aggregate particles and binding them together under suitable compaction.

ii. Sufficient stability for providing resistance to deformation under sustained or repeated loads. This resistance in the mixture is obtained from aggregate interlocking and cohesion which generally develops due to binder in the mix.

iii. Sufficient flexibility to withstand deflection and bending without cracking.
iv. To obtain desired flexibility, it is necessary to have proper amount and grade of bitumen.
v. Sufficient voids in the total compacted mix to provide space for additional compaction under traffic loading.
vi. Sufficient workability for an efficient construction operation in laying the paving mixture.

Bituminous Binder: A dark brown to black cementations material in which the predominating constituents are bitumen which occur in nature or are obtained in petroleum processing.

Aggregate: Construction aggregate, or simply "aggregate", is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geo-synthetic aggregates. Aggregates are the most mined materials in the world.

1.2 Reclaimed Asphalt Pavement

1.2.1 Introduction

Reclaimed Asphalt Pavement (RAP) is any removed or reprocessed pavement material that contains aggregates and bitumen. RAP is obtained during rehabilitation or reconstruction of existing asphalt pavements, or from utility cuts across the roadways which were necessary to gain access to underground utilities. When RAP is properly crushed and screened, it will consist of high-quality aggregates coated with a bituminous binder which can be used in a number of highway construction applications. Use of RAP in asphalt mixes helps reduce costs, conserves bitumen and aggregate resources, and limits the amount of waste material going into landfills (FHWA, 2016).

It has long been accepted that RAP can be a feasible constituent in HMA pavements and if properly designed and constructed, HMA pavements incorporating mixtures with RAP can perform as well as conventional mixtures(Hossain, M., Maag, R.G., and Fager, 2010).

1.2.2 History of RAP

Asphalt pavement has been American's most recycled material for a long time. First sustained effort to recover and reuse old asphalt, paving materials was conducted during 1947 in Nevada and Taxes. Using RAP material has well-recognized financial and environmental benefits(FHWA, 2016).

1.2.3 RAP in Context of Nepal

Asphalt pavement has recent history in the context of our country Nepal. After few years, reconstruction, resurfacing of asphalt pavement will be essential in our country too. For these purpose, reclaimed asphalt/recycled pavement may be the best solution. Recycling pavement conserves not only materials, but also energy. Recycling pavement provides an even greater economy by eliminating the cost associated with the removal and hauling of waste materials. Based on cost effectiveness, environmental impact, energy savings, and shortage of quality materials, reclaimed asphalt pavement (RAP) used for pavement construction does not only reduce aggregate need, but it also solves the problem of RAP disposal. Thus, RAP is the best solution for pavement rehabilitation and reconstruction in the developing country like ours.

1.2.4 Guidelines for RAP

Standard Specification for Road and Bridge Works, 2073 describe only the general introduction for application of recycle material. No coder provision is built for the use of RAP in our country.

1.3 Scope of Research

The outcomes of this research help in the following context of the flexible pavement design.

i. Hot mix design
ii. Recycled waste use
iii. Derive a recommended mix of RAP for general use pavement

1.4 Objective of Research

The major objective of this research work is the use of Recycled Asphalt Concrete and recommended desirable quantity of Recycle Asphalt Concrete in mix design of new asphalt pavement. This will finally results reduce in aggregate need and haulage problems of recycle materials.

Specific Objective

i. To determine OBC of virgin mix (without RAP)

ii. To determine optimum mix among the different RAP percentage at OBC.

iii. To determine the most economic RAP mix design sample.

iv. To recommend the effectiveness of the recommended mix in use as asphalt pavement as per the specification given.

1.5 Assumptions and Limitations

The assumptions of research works are listed below:

i. Addition of different percentage of RAP satisfied the gradation of virgin job mix as per SSRBW, 2073, table 13.26

ii. Mix design of Virgin aggregate of one quarry and RAP sample of another quarry satisfy the Marshall Mix Design.

The limitations of research works are:

i. The properties of mix were defined based on only Marshall test

ii. RAP wastes from a single site was selected of a particular age for the study

iii. Study of only Hot Recycled Mix was performed

iv. Tests for recovered bitumen were not conducted.

v. Weight of RA i.e. Kerosene was not taken in the job mix design of varying RAP percentage.

CHAPTER 2 LITERATURE REVIEW

2.1 RAP Properties on Hot Mix

RAP mixes were observed to have higher values of strength. Minimum strength requirement of 43 MPa was achieved by mortar mixes with 25% RAP aggregate content showing the potential of the same as a replacement aggregate (Abraham & Ransinchung, 2018b).

Hot Mix Recycling techniques have higher advantages and are well suited for Indian conditions (Mittal, Bose, & Nagabhushaha, 2010).

RAP mix has good resistance to moisture damage at low RAP percentage whereas there is no significant increase in resistance to moisture damage with increase in RAP percentage in mix (Hunag, 2006).

The layer thickness of granular sub-base and base can be reduced by using RAP(Du & Hung, 2012).

Based on mechanical properties, volumetric and performance criteria, 20 percent RAP performs better than conventional mixes under similar conditions (Pradyumna, Mittal, & Jain, 2013).

Resilient modulus values for RAP containing mixes are higher than mixes without RAP at 25°C, 35°C and 45°C temperatures, which indicate mixes with RAP has better load spreading properties than mixes without RAP (Pradyumna & Jain, 2016).

Replacing virgin coarse aggregate by RAP in a typical PCC pavement mix has caused reductions in compressive strength, modulus of elasticity, flexural strength and splitting tensile strength (Schroeder, 1994).

The 40%RA mix has the best fatigue performance followed by the 0%RA and 20%RA mixes (Fallon, McNally, & Gibney, 2016).

RAP concrete mixtures exhibited satisfactory strength properties allowing them for use in low-strength and high ductility applications (Hassan, Brooks, & Erdman, 2000).

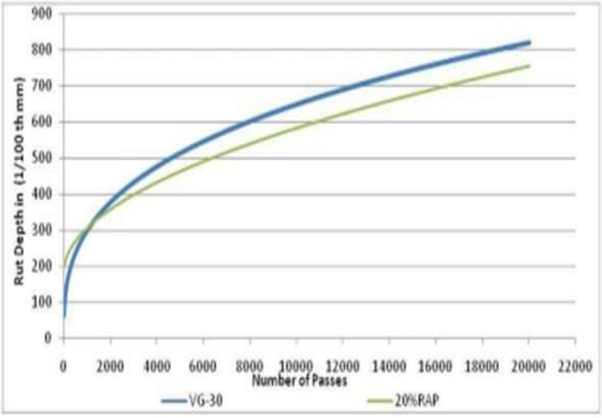


Figure 2-1 Rut Depth per Number of Passes (Pradyumna et al., 2013)

2.2 Enhancing the Property of RAP by the Addition of Other Compounds

Use of a small amount of sodium chloride was shown to be effective in increasing strength of RAP-fly ash-Carbide lime blends as well as improving durability (after 12 wetting-drying cycles) (Consoli et al., 2018).

Chilena natural zeolite (clinoptilolite-modernite type) can be used to design WMA mixtures with RAP, allowing a decrease of 20°C in manufacturing temperature in relation to HMA conventional mixture (Vidal, Floody, & Alonso, 2018).

The flexural strength of cement-treated recycled pavement materials depends mainly on cement content, while their strain at break is highly influenced by RAP percentage; increasing RAP percentage leads to a more ductile behavior (strain at break increased about three times when RAP varied from 20% to 70% (Lopez, 2018).

2.3 Rejuvenating Agent

Rejuvenating Agent are organic compounds derived from petroleum extracts during petroleum hydrocarbon processing used to regain the properties of aged bitumen used in RAP. RA can be divided into three main types: super-soft asphalt cement, naphthenic (aromatic) oils and paraffin oils (FHWA, 2016).

The recommended quantity of Rejuvenating item is 10 percent (Pradyumna et al., 2013).

Table 2-1 Viscosity test on recovered bitumen (Pradyumna et al., 2013)

Property	Viscosity
VG-30Bitumen	2400Poise
Recovered Bitumen	2820Poise
10%RejuvenatingAgent	2420Poise
15%RejuvenatingAgent	2070Poise
20%RejuvenatingAgent	1740Poise

The RAP can decrease the moisture resistance of the asphalt mixture, but the rejuvenating agent can improve the moisture resistance, although the Marshall stability decreasing slightly when rejuvenating agent was added (Cong, Zhang, & Liu, 2016).

2.4 Extraction of Reclaimed Asphalt Pavement

Asphalt pavement is generally removed either by milling or by full-depth removal. Milling is typically done in rehabilitation projects where the existing wearing course is removed and then replaced to increase the pavement's service life. RAP produced from milling is ready to be recycled with little or no processing, depending on the amount being used in the mixture. Full-depth removal involves milling the existing HMA pavement structure in several passes, depending on existing depth of the structure, or by ripping and breaking the pavement into large pieces using rippers on a bull dozer. Broken RAP pieces are collected, loaded onto trucks, and usually transported to processing facilities. RAP is processed by crushing and screening, and then is conveyed and stockpiled (FHWA, 2016).

Extraction of Reclaimed Asphalt Pavement (RAP)

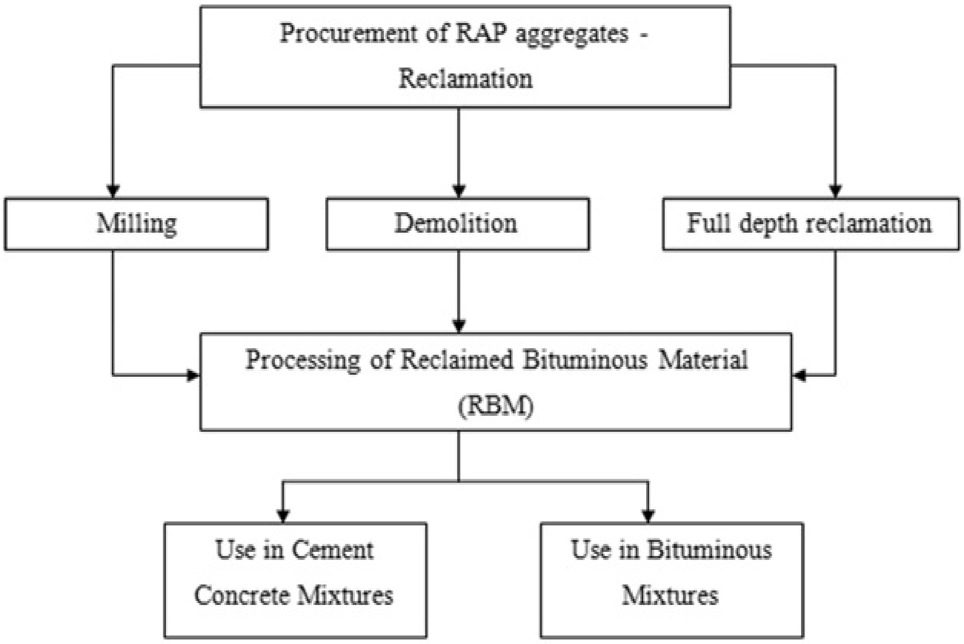


Figure 2-2 Flowchart of Production of RAP Aggregates(Abraham &Ransinchung, 2018a)

2.4.1 Recycling of Reclaimed Asphalt Pavement (RAP)

According to their working mechanisms, RAP recycling technologies can be divided into the following categories (FHWA, 2016):

i. Hot in-plant recycling
ii. Hot in-place recycling
iii. Full depth reclamation
iv. Cold in-plant recycling
v. Cold in-place recycling

Hot Mix Recycling

Reclaimed asphalt pavement (RAP) can be used as aggregate in the hot recycling of asphalt paving mixtures in one of two ways:

a. RAP is combined with virgin aggregate and new asphalt cement in a central mixing plant to produce new hot mixed paving mixtures.

b. Asphalt pavement surface distress is corrected by softening the existing surface with heat, mechanically removing the pavement surface, mixing it with a recycling or rejuvenating agent, possibly adding virgin asphalt and/or aggregate, and replacing it on the pavement without removing the recycled material from the pavement site (FHWA, 2016).

Cold Mix Recycling:

Reclaimed asphalt pavement (RAP) can be used as aggregate in the cold recycling of asphalt paving mixtures in one of two ways:

a. RAP is combined with new emulsified or foamed asphalt and a recycling or rejuvenating agent, possibly also with virgin aggregate, and mixed at a central plant or a mobile plant to produce cold mix base mixtures.

b. Asphalt pavement is recycle in-place, where the RAP is combined without heat and with new emulsified or foamed asphalt and/or a recycling or rejuvenating agent, possibly also with virgin aggregate, and mixed at the pavement site, at either partial depth or full depth, to produce a new cold mix end product(FHWA, 2016).

Full Depth Reclamation:

Full depth recycling or full depth reclamation(FDR) is a process that rebuilds worn out asphalt pavement by recycling the existing roadway(FHWA, 2016).

2.5 Marshall Mix Design

Standard specification for road and bridge works (DoR, 2015) of Nepal also suggested mix design with a standard Marshall test procedure conforming to Asphalt Institute Manual MS-2.

Strength is measured in terms of the 'Marshall's Stability' of the mix following the specification ASTM D 1559 (2004), which is defined as the maximum load carried by a compacted specimen at a standard test temperature of 60˚C. In this test compressive loading was applied on the specimen at the rate of 50.8 mm/min till it was broken. The temperature 60˚C represents the weakest condition for a bituminous pavement.

The flexibility is measured in terms of the 'flow value' which is measured by the change in diameter of the sample in the direction of load application between the start of loading and at the time of maximum load. During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) due to the loading. The associated plastic flow of specimen at material failure is called flow value.

The density- voids analysis is done using the volumetric properties of the mix.

2.5.1 Volumetric Properties

Fundamentally, mix design is meant to determine the volume of bitumen binder and aggregates necessary to produce a mixture with the desired properties.

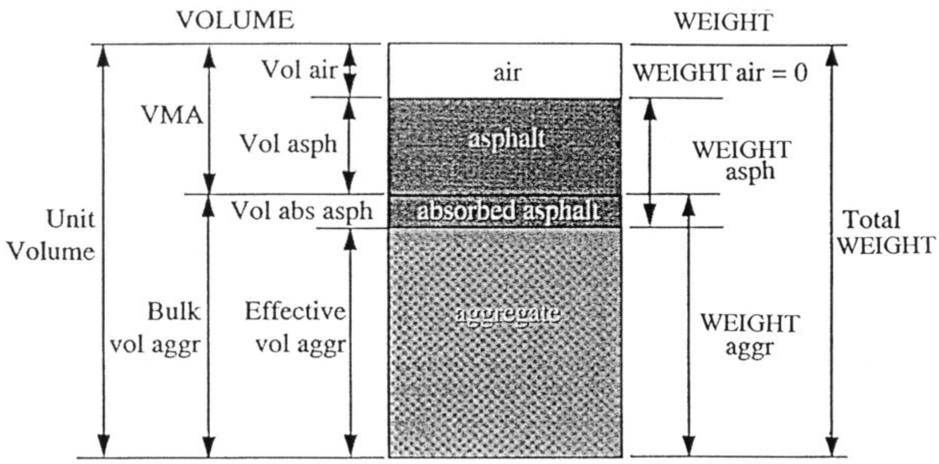


Figure 2-3 Component Diagram of Compacted Sample of HMA (ASTM, 2000)

Specific Gravity – Specific gravity of HMA is defined as ratio of mass of given volume of substance to the equal volume of water, temperature of both being 27°C.

Air Voids – The total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as percent of the total volume of the sample.

Voids in Mineral Aggregate (VMA) – The volume of inter-granular void space between the aggregate particles of a compacted paving mixture that includes the air voids and the effective asphalt content, expressed as a percent of the total volume of the sample.

Voids Filled with Asphalt (VFA) – The portion of the volume of inter-granular void space between the aggregate particles (VMA) that is occupied by the effective asphalt.

CHAPTER 3 MEOTHODOLOGY

The research methodology follows a basic shape as shown in the figure 4.

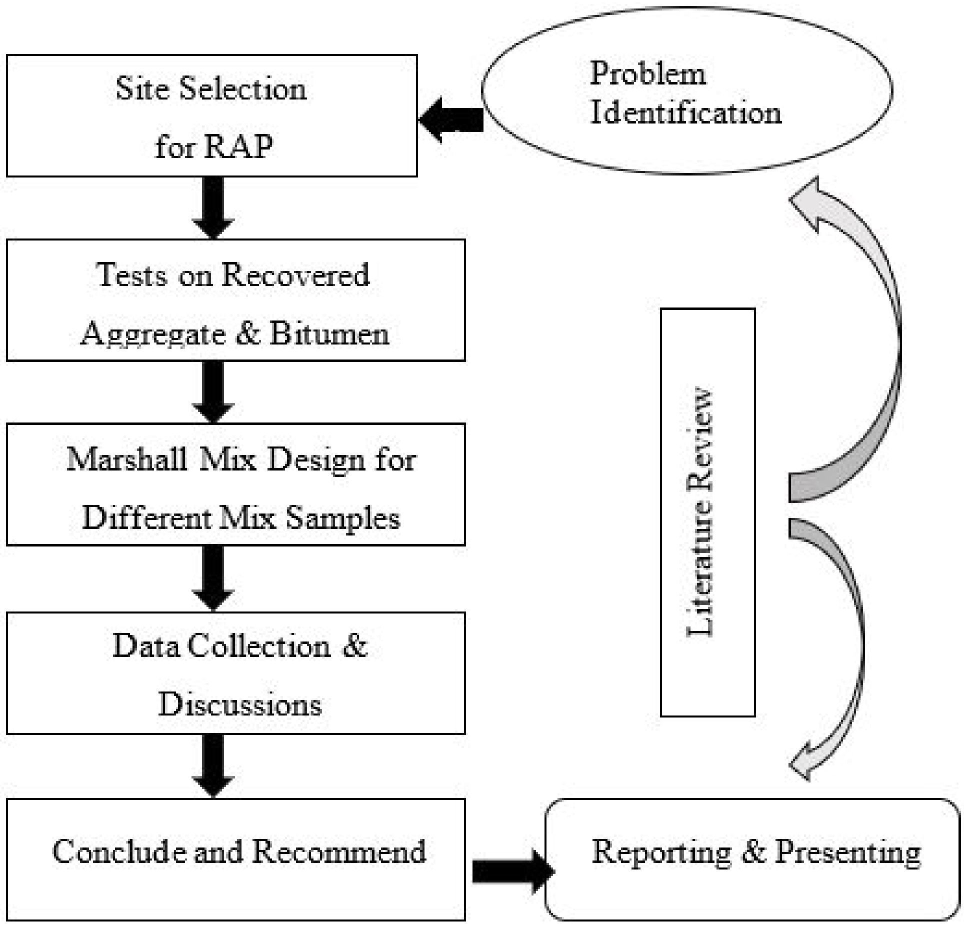


Figure 3-1 Flow diagram of study procedure

3.1 Problem Identification

Asphalt pavement has recent history in the context of our country Nepal. After few years, reconstruction, resurfacing of asphalt pavement will be essential in our country too. Based on cost effectiveness, environmental impact, energy savings, and shortage of quality materials, reclaimed asphalt pavement (RAP) used for pavement construction does not only reduce aggregate need, but it also solves the problem of RAP disposal. Thus, RAP is the best solution for pavement rehabilitation and reconstruction in the developing country like ours.

3.2 Sample Collection, Preparation, Testing and Result Analysis

The sample of RAP was taken from Satdobato- Lagankhel road section which in widening phase.

According to the DOR of Lalitpur District, the age of asphalt concrete of this section is only about 5 years and the aggregate used for that mix design was taken from Tikabhairav of Lalitpur district and the binder used was 60/70 penetration grade bitumen.

The specific gravity and bitumen content of RAP sample was found as 2.431 and 5.21% respectively.

3.2.1 Test Result of Recovered Aggregate

Recovered aggregates are obtained by extraction of bitumen by adding benzene on old asphalt concrete by Centrifuge Method. Aggregate Impact Value of RAP aggregate is found as 15.02% and Specific gravity of RAP aggregate was found as 2.691. Gradation of recovered aggregate is as shown in table.

Table 3-1 Gradation of Recovered Aggregate

IS Sieve Designation, mm	Wt. retained individual (g)	Cum. Wt. passing (g)	Cumulative Percentage of Wt. retained (%)	Cum. Percentage of Wt. Passing (%)
13.20	97.1	831.2	10.46%	89.54%
10.00	142.3	688.9	25.79%	74.00%
4.75	332.1	356.8	61.56%	38.44%
2.36	71.1	285.7	69.22%	31.00%
1.18	115.9	169.8	81.71%	18.29%
0.60	32.7	137.1	85.23%	15.00%
0.30	41.7	95.4	89.72%	10.28%
0.15	24.7	70.7	92.38%	8.00%
0.075	28.3	42.4	95.43%	4.57%
Pan	42.4	0.0	100.00%	0.00%
Total	928.3			

3.2.2 Extraction of Binder of RAP

The binder of RAP was extracted by washing the oven dry crushed RAP with benzene. 10 liter of benzene was required for extracting about 600 ml of bitumen of old asphalt pavement. The extracted bitumen was so soft that we cannot able to conduct any of the tests of recovered bitumen in our laboratory.

3.2.3 Selection and Test Result of New Aggregate

The new aggregate for this thesis work is taken from Chalal Ganesh Quarry of Kavre District. The major source of material for construction work in and around the Kathmandu valley is Tikabhairav, due to massive use there will be chance of shortage of materials. So, in this research work I have selected the Quarry of Kavre district which is near to valley and substitute the need of material requirement in near future. Three types of Aggregate namely 20 mm down, 10 mm down and 4.75 mm down were taken from that quarry. The properties of new aggregate are listed in table.

Sp. Gravity 20 down= 2.688

Sp. Gravity 10 down = 2.689

Sp. Gravity 4.75 down = 2.697

Table 3-2 Test Result on New Aggregate

Test	Limiting Value	Result	Standard
Los Angeles Abrasion Test	Maximum 30%	26%	IS: 2386 Part IV
Aggregate Impact Test	Maximum 24%	19%	IS: 2386 Part IV
FI 20mm Down	35% max	28%	IS: 2386 Part I
EI 20mm Down			
FI 10mm Down	35% max	26%	IS: 2386 Part I
EI 10mm Down			
Sodium Sulphat Soundness Test (SSS)	Max 12%	3.72%	IS: 2386 Part V
Stripping value	Min 95%	>95%	IS:6241
Water Absorption			IS: 2386 Part III
20mm down	Max 2%	0.49%	
10mm down	Max 2%	0.49%	

Gradation of New Aggregate

Three type of aggregated taken from Chalal Ganesh of Kavre District are arranged to meet the gradation specified by Standard specification for Road and Bridge Work, 2073. The combined gradation (job mix design) of the three aggregate chosen is given in the table and figure as follows.

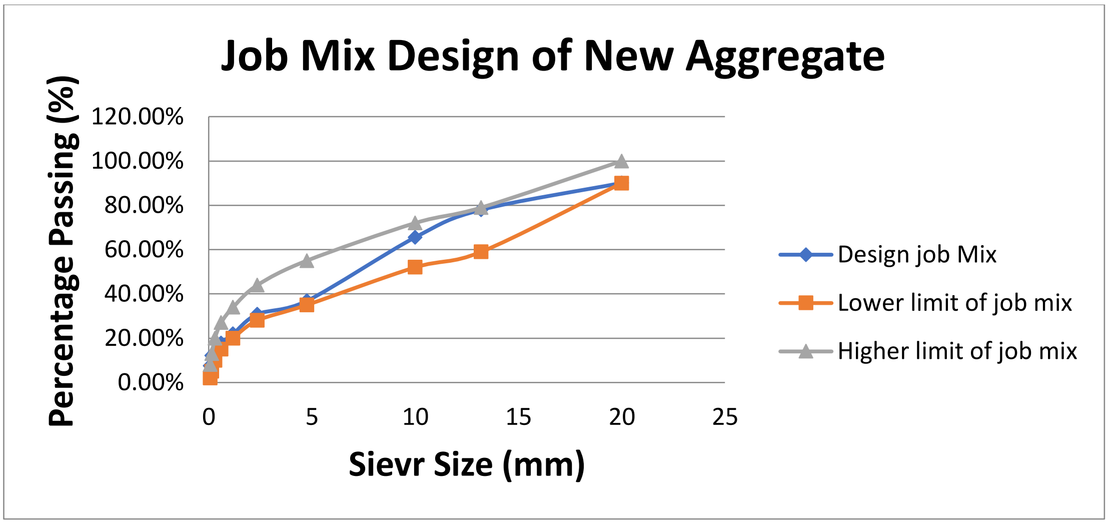


Figure 3-2 Job Mix Design of New Aggregate

Table 3-3 Gradation for Job Mix Design

Gradation for job mix design					SSRW, 2073	
Sieve size(mm)	**20mm (30%)**	**10mm (27%)**	**Dust (43%)**	**Total (100%)**	**Range for 50mm thickness**	
20.00	20.11%	27.00%	43.00%	90.11%	90.00%	100.00%
13.20	8.11%	26.88%	43.00%	77.98%	59.00%	79.00%
10.00	2.54%	20.03%	43.00%	65.57%	52.00%	72.00%
4.75	0.48%	0.37%	35.96%	36.82%	35.00%	55.00%
2.36	0.33%	0.27%	30.25%	30.85%	28.00%	44.00%
1.18			21.91%	21.91%	20.00%	34.00%
0.60	0.20%	0.12%	17.47%	17.79%	15.00%	27.00%
0.30			13.57%	13.57%	10.00%	20.00%
0.15			12.16%	12.16%	5.00%	13.00%
0.075	0.00%	0.00%	7.48%	7.48%	2.00%	8.00%

3.2.4 Selection of Bitumen

The bitumen used in this thesis work is viscosity grade 30 bitumen. Selection criteria for viscosity grade bitumen based on highest and lowest daily mean temperatures at a particular site, as per SSRBW, 2073-Table 13-1.

Table 3-4 Selection Criteria for Viscosity Grade Bitumen

Lowest Daily Mean Air Temperature, °C	**Highest Daily Mean Air Temperature, °C**		
	Less than20°C	**20 to 30°C**	**More than30°C**
More than -10°C	VG-10	VG-20	VG-30
-10°C or lower	VG-10	VG-10	VG-20

(DoR, 2015)

The test results of selected VG-30 bitumen are listed in the table.

Table 3-5 Test on Fresh Binder

S.N	**Characteristics**	**Method of Test**	**Value**
I	Penetration at 25°C, 100 g, 5 s, 0.1 mm, Min	IS 1203	58.3
Ii	Absolute viscosity at 60 °C, Poises	IS 1206 part 2	2927.7
iii	Softening point (R & B) °C,	IS 1205	51.8
Iv	Ductility at 25 °C, cm	IS 1208	>100
V	Specific gravity	IS 1202	1.03

Dosage of Rejuvenating Agent

The dosage of rejuvenating agent (RA) was fixed as 10% by weight of recovered bitumen, since at this dosage the properties of the rejuvenated bitumen are similar to that of the VG-30 bitumen.

3.2.5 Marshall Hot-Mix proportion

Marshall Specimens of mixture RAP, selected three types of natural aggregate and selected bitumen were prepared as per the standard specified by ASTM-D6926, 2010.

Marshall Specimens of fresh mix were prepared for the test. Bitumen content is started from 4% and increased at the rate of 0.5% to reach 6.5%. Three specimen of each bitumen content were prepared for fresh mix design.

Marshall Specimen of varying RAP and new graded aggregate were prepared at Optimum Binder Content (OBC) of fresh mix. Percentage of RAP is taken as 15%, 20%, 25%, 30%, 50%, 75% and 100%; three Marshall specimens of each RAP contain were prepared.

10% Rejuvenating Agent (RA) of bitumen contained of RAP is added at 30%, 50%, 75% and 100% of RAP mix design for sampling 3 specimen of each by Marshall mix design at OBC of fresh virgin mix. Rejuvenating Agent (RA) used in this process is normal kerosene which is one of the aromatic oils.

Table 3-6 Marshall Hot-Mix proportion

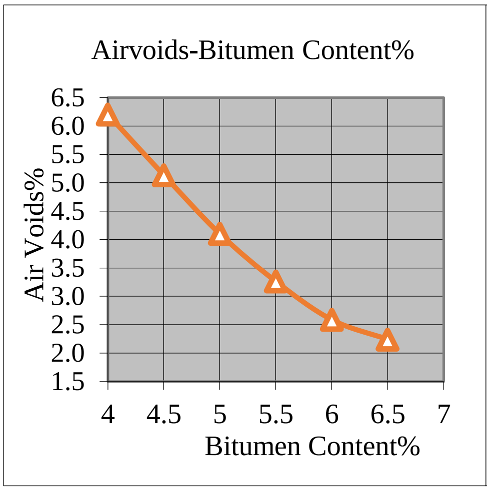
RAP Content	Mix Design	Remarks
15%	Marshall mix design method without RA	Marshall Properties (Stability, Flow value, Air voids, VMA, VFB) are determined under OBC of Fresh Mix.
20%		
25%		
30%		
50%		
75%		
100%		
30%	Marshall mix design method with Rejuvenating Agent (10% of binder content of RAP)	
50%		
75%		
100%		
No RAP	Marshall mix design	Optimum Binder Contain (OBC) is found

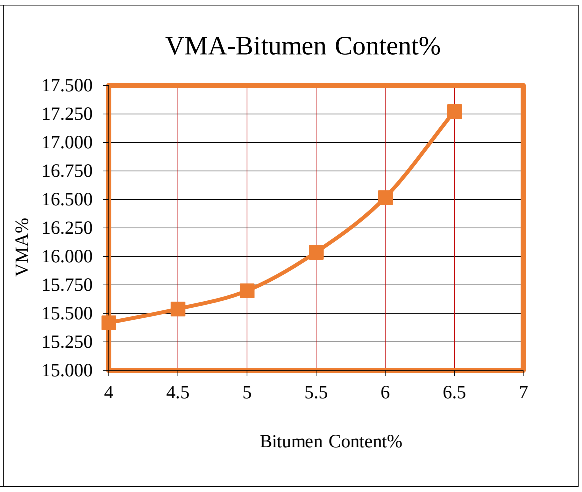
Marshall Test had been performed with respect to the ASTM-D6927, D6926 and SSRBW 2073, standard test method for Marshall Stability and of bituminous mixtures.

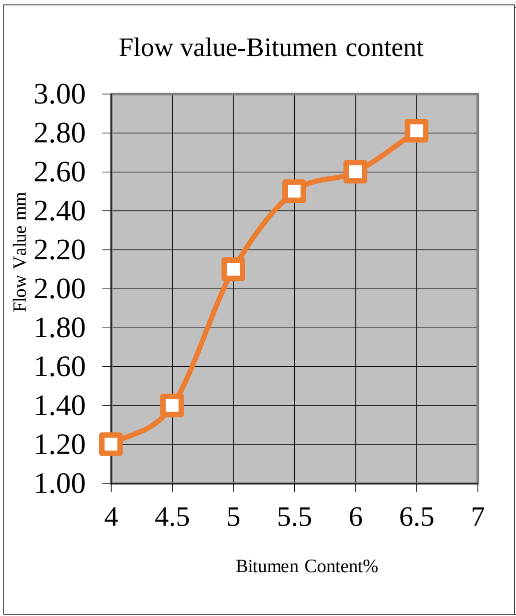
3.2.6 Presentation of Data and Table

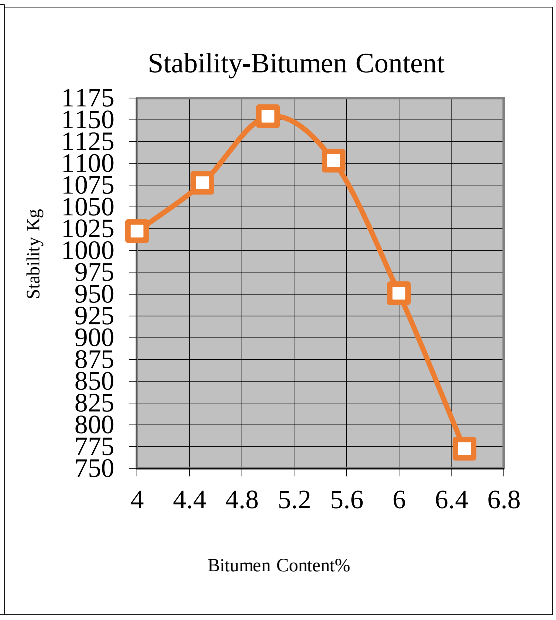
Result on Marshall Mix Design of Fresh Mix of Aggregate

Optimum binder content of fresh mix design was found with respect to Marshall Stability, Air Voids and Specific Gravity of fresh mix. The results of test of fresh aggregate are shown in figure below:









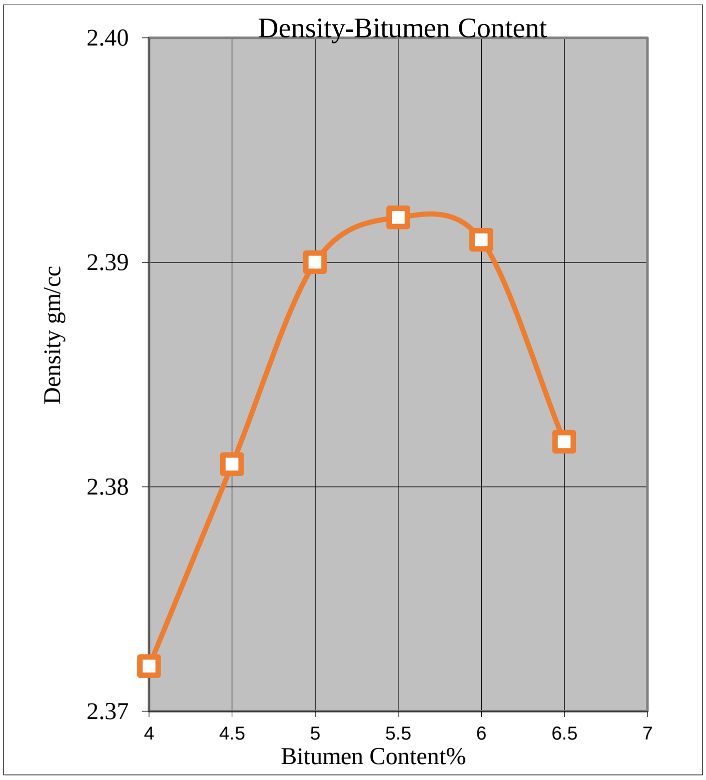


Figure 3-3 Results on Marshall Mix Design of Fresh Aggregate

From the above graphs we have found the following outcomes for the Marshall Mix design of fresh aggregate.

Table 3-7 Marshall Test Results of New Aggregate

Bitumen content at maximum stability= 5.0%
Bitumen content at maximum density= 5.5%
Bitumen content at 4% air voids= 5.02%
Optimum bitumen content of the proposed asphalt concrete grading= 5.17%
Stability at 5.17% bitumen content=11.49KN
Density at 5.17% bitumen content=2.391
Air voids at 5.17 % bitumen content=3.9%
Flow value at 5.17% bitumen content=2.2 mm
VMA at 5.17 % bitumen content=15.75 %

The Optimum Binder content of new Marshall Mix specimen is found to be 5.17% with respect to maximum Marshall Stability, 4% Air voids and maximum Specific gravity. At OBC, the Stability was found as 11.49 KN, Flow Value as 2.2 mm and Air Void as 3.9 %. We have adopted OBC as 5.17% for further analysis of Marshall Mix Design containing different RAP percent.

3.2.7 Results of Fresh and RAP Mix Marshall Mix Design

The test results of fresh and varying percentage (15%, 20%, 25%, 30%, 50%, 75% and 100%) of RAP Marshall Mix design with the addition of 10% Rejuvenating Agent (Kerosene) to the mix design of 30%, 50%, 75% and 100% RAP with fresh aggregate are discussed in following table and graphs.

Table 3-8 Results of Fresh and RAP (with 10% RA at (30%, 50%, 75% and 100%) RAP) Mix Marshall Mix design

S.N	**RAP %**	**OBC (%)**	**Marshall Stability (KN)**	**Flow Value (mm)**	**Density (g/cc)**	**Air voids (%)**	**VMA (%)**	**VFB (%)**	**Marshall Quotient (Stability /flow)**
1	15	5.17	**11.18**	**2.22**	**2.379**	**3.9**	16.20	75.64	**4.956**
2	20	5.17	**10.15**	**2.21**	**2.376**	**4.0**	16.31	75.70	**4.593**
3	25	5.17	**10.19**	**2.15**	**2.374**	**3.9**	16.38	75.95	**4.741**
4	30	5.17	**10.51**	**2.12**	**2.376**	**3.8**	16.31	76.99	**4.957**
5	50	5.17	**13.72**	**2.09**	**2.383**	**3.0**	16.06	81.04	6.566
6	75	5.17	**13.38**	1.94	**2.371**	**3.0**	16.48	81.80	6.896
7	100	5.17	**13.09**	1.59	**2.363**	**3.1**	16.76	83.36	8.236
8	30+K	5.17	**10.23**	**2.24**	**2.383**	**3.8**	16.06	78.40	**4.568**
9	50+K	5.17	**13.16**	**2.41**	**2.394**	2.6	15.67	83.42	5.460
10	75+k	5.17	**13.12**	**2.55**	**2.379**	2.8	16.20	83.50	5.289
11	100+K	5.17	**12.93**	**2.6**	**2.383**	2.0	16.06	87.75	5.112

*K = Kerosene (Rejuvenating Agent)

Analysis of Test Result of Marshall Stability at Varying RAP%

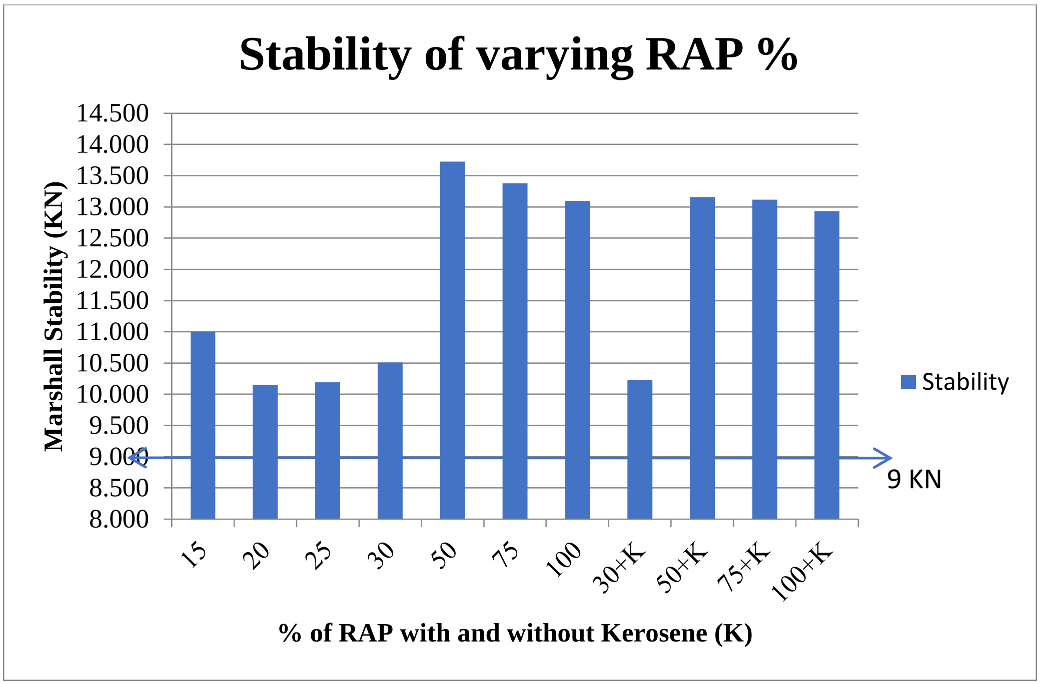


Figure 3-4 Marshall Stability at Varying RAP%

For the Marshall Mix Design to be acceptable with respect to Stability value as per SSRBW, 2073 it shall be greater than 9 KN. On Analyzing the values obtained from the test of Marshall Mix Design Specimen containing different percent of RAP with or without Rejuvenating Agent (kerosene) every sample seems to have the stability value greater than 9 KN. On the basis of Stability Value we can accept all of the samples i.e. RAP of 15% to 100% with and without rejuvenating agent on the construction of new surface course of the flexible pavement.

The maximum stability was found on the sample containing 50% RAP (13.72 KN).

The Marshall Mix Design Specimen containing 50%, 75% and 100% RAP without adding 10% Rejuvenating Agent (RA) have stability value higher than the stability of fresh mix at OBC. This indicates that the aggregates used in RAP have higher strength than the aggregate we have chosen for Marshall Mix Design in fresh mix.

With the addition of RA in higher percentage of RAP i.e. 30%, 50%, 75% and 100%, the Marshall Stability value seems to be slightly decreased with the respect of same mix design without RA. Using the higher percentage of RAP is restricted without addition of RA (Pradyumna & Jain, 2016). This result indicates that addition of 10%

RA on the mix design containing higher percentage of RAP slightly increases the flow of binder and hence slightly decreases the stability of the specimen.

Analysis of Test Result of Marshall Flow Value at Varying RAP%

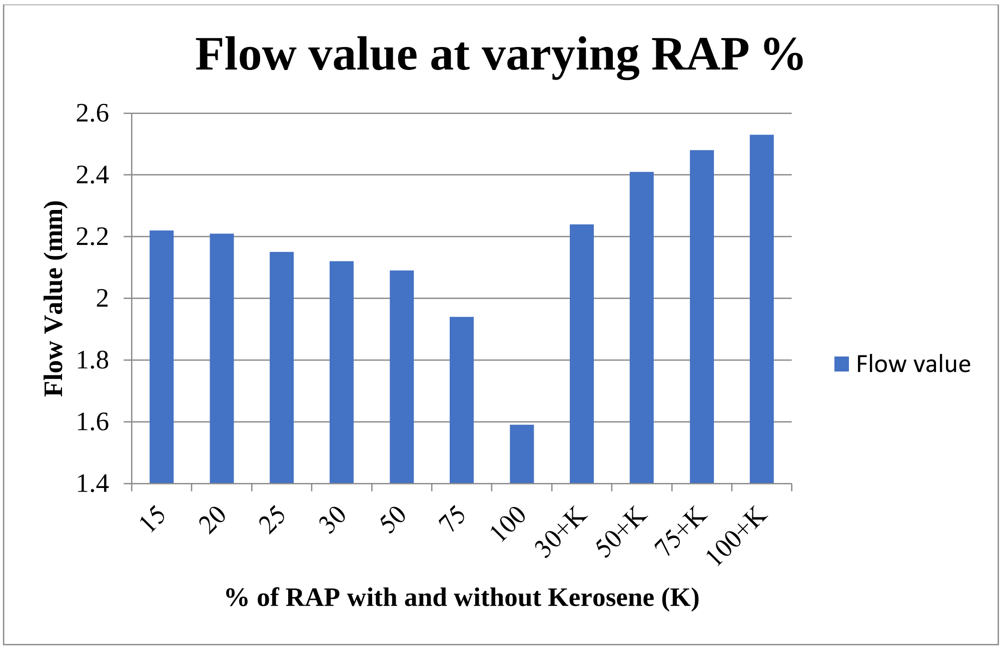


Figure 3-5 Flow Value at Varying RAP%

The acceptable range of Marshall Mix Design Specimen Flow Value should be 2-4 mm as per SSRBW, 2073. Marshall Mix Design Specimen with RAP percentage (without addition of RA) 15%, 20%, 25%, 30% and 50% has satisfies the flow value as per required standard whereas Marshall Mix Design Specimen with RAP Value of 75% and 100% has not satisfied the standard. This indicated that every sample satisfying Stability condition may not satisfied the flow value condition and hence cannot be used for the construction of surface course of Flexible Pavement (i.e. only Sample containing RAP % of 15 to 50 can be used without rejuvenating agent).

When rejuvenating agent is used for higher value of RAP (30, 50, 75 and 100 %), the entire specimen has satisfied the flow value requirement. This shows that the addition of RA on Marshall Specimen containing RAP enhance flexibility on flexible pavement design. So we can recommend that the higher percentage of RAP can be used for the construction of new surface course of flexible pavement with the addition of 10% rejuvenating agent.

Analysis of Test Result of Marshall Quotient at Varying RAP%

For the sample to be acceptable Marshall Quotient should be in between 2 to 5 KN/mm as per SSRBW, 2073. On analyzing the result of various samples Marshall Mix Design, specimen having RAP % of 15, 20, 25, and 30 had satisfied the requirement without adding the rejuvenating agent whereas with rejuvenating agent on higher RAP% (30%, 50%, 75% and 100%) only 30% RAP has satisfied the requirement. This result shows the sample satisfying the stability and flow value may fail on Marshall Quotient. On the basis of this test result, we can recommended that the mix design containing up to 30% RAP with or without RA can be used for the construction of surface course of flexible pavement.

Analysis of Test Result of Air Voids at Varying RAP%

Air Voids of 3 to 5 % is acceptable for the adaptation of Marshall Mix Design Samples as per SSRBW, 2073. Entire Sample without rejuvenating agent has satisfied the requirement for air voids contain whereas sample with rejuvenating agent only samples having RAP% less than 50 has satisfied the condition. So with the addition of RA at the higher percentage of RAP mix design (30%, 50%, 75% and 100%) air void limit was not meet, the indicate there will not sufficient space for future expansion of bitumen due to heavy traffic load and temperature effect.

On the basis of air void analysis, we can recommended the use of up to 30% RAP with or without RA for the construction of new surface course of flexible pavement.

Analysis of Test Result

The test results show that, at OBC the mix design containing different percentage of RAP (15%, 20%, 25%, 30%, 50%, 75% and 100%) the Marshall properties like Stability, Flow Value, Air Voids, VMA, Marshall Quotient are in usable range for the mix design containing RAP percentage of 15, 20 25 and 30 as per SSRBW, 2073.

The Marshall Stability of all the RAP mix satisfies the specification i.e. Stability value for all percentage of RAP mix design is above 9KN. With the addition of 10% Rejuvenating Agent (Kerosene) on the higher percentage RAP mix design (30%, 50%, 75% and 100) there seems a slight decrease in stability in comparison of mix without Rejuvenating Agent (RA). In the case of Flow Value, only the mix design containing 15%, 20%, 25%, 30% and 50% satisfies the standard as per SSRBW, 2073 i.e. flow value in between 2-4 mm. With the addition of 10% RA on the higher percentage RAP mix design (30%, 50%, 75% and 100), flow value increases and all the mix design containing different percentage of RAP satisfies the specification.

All the mix design of varying RAP percentage satisfied the Air Voids as per SSRBW, 2073 i.e. air void in between 3%-5 %. With the addition of 10% RA on the higher percentage RAP mix design (30%, 50%, 75% and 100), only the mix design containing 30% RAP meets the specification. Mix design specimen containing 15%, 20%, 25% and 30% RAP satisfies the Marshall Quotient as per SSRBW, 2073 i.e. Marshall Quotient in between 2-5. With the addition of 10% RA on the higher percentage RAP mix design (30%, 50%, 75% and 100), only the mix design containing 30% RAP meets the specification.

On analyzing the various parameters of Marshall Mix Design and quantifying with the requirement of SSRBW, 2073 only samples having RAP % of 15, 20, 25 and 30 seems to be acceptable without rejuvenating agent and when rejuvenating agent is added to the sample only one 30% RAP is acceptable range.

Thus, for the construction of new surface course of Flexible Pavement we can recommend the use of RAP % having vale of 15 to 30 without rejuvenating agent whereas only one sample with RAP % of 30 can be recommended with rejuvenating agent.

Marshall Mix design containing 15% RAP has found higher stability i.e. 11.18KN among 15%, 20%, 25% and 30% RAP containing mix design. Thus, 15% RAP containing mix design have higher stability and others Marshall Parameters are also in acceptable range, we can recommend that 15% RAP containing mix design is the optimum mix among the different RAP percentage at OBC.

3.2.8 Cost Estimation

Table 3-9 Cost Estimation for mix containing different percentage of RAP per cubic meter

SN	Fresh Asphalt	RAP	Quantity per cum		Rate		Amount		Total amount for 1 cum	Difference in rate wrt fresh asphalt
			Fresh asphalt	RAP	Fresh asphalt	RAP	Fresh asphalt	RAP		
1	85%	15%	0.85	0.15	18300	2127.9	15555.4	319.2	15874.6	2425.9
2	80%	20%	0.8	0.2	18300	2127.9	14640.4	425.6	15065.9	3234.5
3	75%	25%	0.75	0.25	18300	2127.9	13725.3	532	14257.3	4043.1
4	70%	30%	0.7	0.3	18300	2127.9	12810.3	638.4	13448.7	4851.8

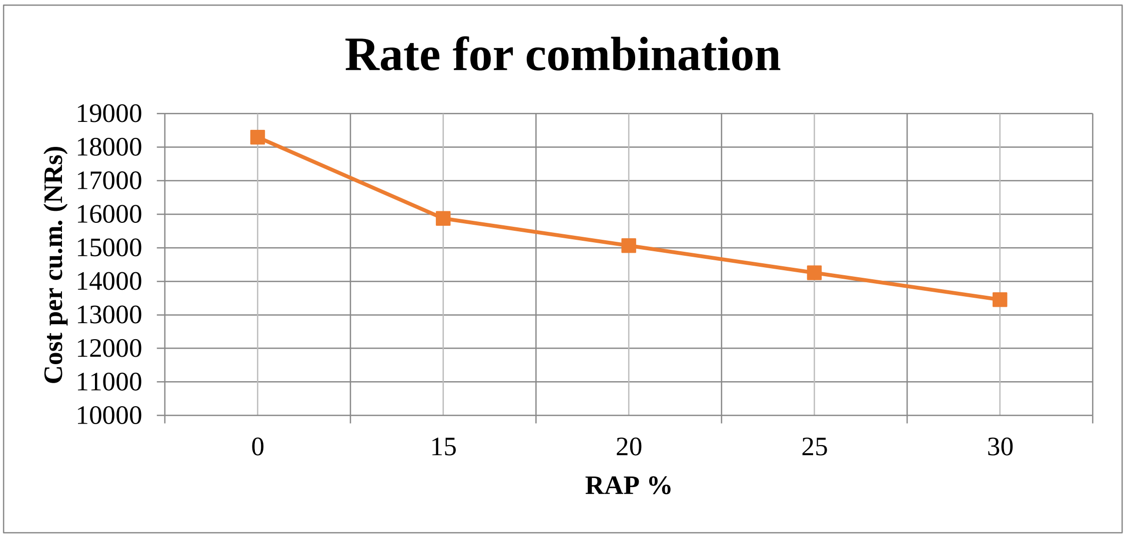


Figure 3-6 Graph for Different Percentage of RAP versus Cost per Cubic Meter

Cost estimation of different RAP mix is done on the basis of rate analysis of Lalitpur district 2075/76. In this analysis, milling and transport of RAP is considered as free of cost because the RAP is assumed to be used for the same place and processing cost of RAP is considered equal to heating cost of fresh aggregates because there is no Norms for RAP processing. Fresh aggregate use for this cost analysis is chosen as Tikabhairab quarry which is the nearest source for quality materials. Cost estimation of fresh aggregate is done on the basis of DoR norms for rate analysis of Lalitpur district 2075/76. As per rate analysis, the cost of fresh asphalt is NRs. 18300/cum & that of RAP is NRs. 2128/cum. About NRs. 16172 per cu. m can be saved by using RAP.

From the analysis of above table and graphs on Marshall Properties, we have taken the percentage of RAP in mix design as 15%, 20%, 25% and 30% for the construction of new asphalt pavement and cost estimation is done for these four RAP % (15%, 20%, 25% and 30%). Above graph of cost estimate shows that at 0% RAP cost for laying asphalt pavement is Rs.18300 per cubic meter and the cost decreases about linearly with the addition of 15, 20, 25 and 30 percent of RAP in mix design.

This reflects that addition of higher percentage of RAP i.e. 30% in constructing new asphalt pavement reduces about 22% cost per cubic meter of the project. This result shows that using higher percentage of RAP provides greater economy by eliminating the cost associated with the removal and hauling of waste materials and also aid for energy saving and shortage of quality materials. Hence, using higher percentage of RAP economizes the overall cost of project with least environmental impact.

CHAPTER 4 CONCLUSION

In this research work we studied about the use of different percentage of Reclaimed Asphalt Pavement (RAP) with or without using 10% Rejuvenating Agent in Marshall Mix Design.

We have observed the following outcomes in our experiment.

i. Strength (AIV) of the recovered aggregate is found higher than the Fresh Aggregate.

ii. Optimum Binder Content (OBC) of convectional mix design is found as 5.17%. OBC of fresh mix is used for the analysis of different percentage of RAP mix.

iii. Marshall Stability for varying RAP (15%, 20%, 25%, 30%, 50%, 75% and 100%) content is in usable range as per SSRBW, 2073. Addition of 10% Rejuvenating Agent (Kerosene) on the higher percentage RAP mix design (30%, 50%, 75% and 100) stability slight decrease in comparison of mix without Rejuvenating Agent (RA).

iv. Mix design containing 15%, 20%, 25%, 30% and 50% satisfies the specification as per SSRBW, 2073. Addition of 10% Rejuvenating Agent (RA) on the higher percentage RAP mix design (30%, 50%, 75% and 100) all the mix design containing varying RAP meets the specification.

v. Air Voids of all of the mix containing varying RAP percent satisfies the specification as per SSRBW, 2073. Addition of 10% Rejuvenating Agent (RA) on the higher percentage RAP mix design (30%, 50%, 75% and 100) only mix design consisting 30% RAP meets the standard.

vi. RAP % of 15, 20, 25, and 30 has satisfied the requirement for Marshall Quotient as per SSRBW, 2073 without adding the rejuvenating agent whereas with rejuvenating agent on higher RAP% (30%, 50%, 75% and 100%) only 30% RAP has satisfied the requirement.

vii. Based on the laboratory test on Marshall Properties for different percentage of RAP mix with fresh aggregate, we can recommend only 15%, 20%, 25% and 30% of RAP mix for construction of new surface course of the flexible pavement.

viii. 15% RAP containing mix design have higher stability and others Marshall Parameters are also in acceptable range, we can recommend that 15% RAP containing mix design is the optimum mix among the different RAP percentage at OBC

ix. Only considering the stability, flow value and percentage of air voids the higher percentage of RAP mix i.e. 50%, 75% and 100% with the addition of 10% RA can be recommended for the construction of new asphalt pavement but further research will be needed for the effective functioning of these RAP mix.

x. Cost estimation of RAP is done on the basis of rate analysis of Lalitpur district 2075/76. For the cost estimation, 15%, 20% 25% and 30% RAP mix design are considered.

xi. Using of higher percentage of RAP i.e. 30% in constructing new asphalt pavement reduces about 22% cost per cubic meter of the project. This shows that, using higher percentage of RAP provides greater economy by eliminating the cost associated with the removal and hauling of waste materials and also aid for energy saving and shortage of quality materials. Hence, using higher percentage of RAP economizes the overall cost of project with least environmental impact.

xii. The mix design containing 30% RAP is the optimum mix on the basis of cost estimation.

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APPENDIX 1 SEIVE ANALYSIS OF NEW AGGREGATE

10 mm Down				
IS Sieve Designation	Wt. retained individual	Cum. Wt. passing	Cumulative Percentage of Wt. retained	Cum .Percentage of Wt. Passing
(mm)	(g)	(g)	(%)	(%)
13.20	42	9046	0.46%	99.54%
10.00	2304	6742	25.81%	74.19%
4.75	6616	126	98.61%	1.39%
2.36	34	92	98.99%	1.01%
0.60	50	42	99.54%	0.46%
Pan	42	0	100.00%	0.00%
Total	9088			

20 mm Down				
IS Sieve Designation	Wt. retained individual	Cum. Wt. passing	Cumulative Percentage of Wt. retained	Cum .Percentage of Wt. Passing
(mm)	(g)	(g)	(%)	(%)
26.50	686	11408	5.67%	94.33%
20.00	3510	7898	34.69%	65.31%
16.00	2028	5870	51.46%	48.54%
13.20	2772	3098	74.38%	25.62%
10.00	2226	872	92.79%	7.21%
4.75	798	74	99.39%	0.61%
2.36	42	32	99.74%	0.26%
0.60	20	12	99.90%	0.10%
Pan	12	0	100.00%	
Total	12094			

4.75 mm Down (Dust)				
IS Sieve Designation	Wt. retained individual	Cum. Wt. passing	Cumulative Percentage of Wt. retained	Cum .Percentage of Wt. Passing
(mm)	(g)	(g)	(%)	(%)
4.75	103.6	529.3	16.37%	83.63%
2.36	84.0	445.3	29.64%	70.36%
1.18	122.8	322.5	49.04%	50.96%
0.60	65.3	257.2	59.36%	40.64%
0.30	57.4	199.8	68.43%	31.57%
0.15	20.8	179.0	71.72%	28.28%
0.075	68.9	110.1	82.60%	17.40%
Total	632.9			

APPENDIX 2 LAA AND AIV OF NEW AGGREGATE

LAA for 20 Down

Grading B		
No. of spheres used		11
S.N	**Sieve Size (mm)**	**Weight (g)**
1	20-12.5	2500
2	12.5-9.5	2500
Total		5000
LAA Sheet		
S.N	**Description**	**Test Result**
1	Wt. of specimen W1 (g)	5000
2	Wt. of specimen after abrasion test, coarser than 1.70mm IS sieve, W2 (g)	3698
3	Percentage Wear = (W1-W2)/W1*100 %	26.04%

AIV			
Sample Preparation			
S.N	**Notation**	**Description**	**Weight (g)**
1	A1	Wt. of Measure + Compacted Sample	1252.2
2	A2	Wt. of Measure	915.4
3	A	Wt. of Compacted Sample = (A1-A2)	336.8
Test Procedure			
S.N	**Notation**	**Description**	**Weight (g)**
1	B	Wt. passing 2.83mm sieve	62.8
2	C	Wt. of Retained on 2.83mm sieve	274
3	D	Total = B+C	336.8
Aggregate Impact Value= (B/A)*100%			**18.65%**

APPENDIX 3 FLAKINESS INDEX OF NEW AGGREGATE

Flakiness Index of 20 mm down aggregate			
Flakiness plate Slot size Identification	**Wt. Retained on flakiness plate**	**Wt. Passing slot on flakiness plate**	**Total weight tested**
C	D	E	F=D+E
(mm)	(g)	(g)	(g)
40 to 25	460	228	688
25 to 19	1440	258	1698
19 to 16	764	134	898
16 to 12.5	674	136	810
12.5 to 9.5	492	190	682
9.5 to 6.3	192	86	278
Total		1032	5054
Flakiness Index (%)= (E/F)*100%			
Flakiness Index (%)= 20%			

Flakiness Index of 10 mm down aggregate			
Flakiness plate Slot size Identification	**Wt. Retained on flakiness plate**	**Wt. Passing slot on flakiness plate**	**Total weight tested**
C	**D**	**E**	**F=D+E**
(mm)	**(g)**	**(g)**	**(g)**
40 to 25			0
25 to 19			0
19 to 16			0
16 to 12.5			0
12.5 to 9.5	576	178	754
9.5 to 6.3	178	38	216
Total		216	970
Flakiness Index (%)= (E/F)*100%			
Flakiness Index (%)= 22%			

APPENDIX 4 ELONGATION INDEX OF NEW AGGREGATE

Elongation Index of 20mm down Aggregate			
Flakiness plate Slot size Identification	**Wt. passing slot on flakiness plate**	**Wt. retained on flakiness plate**	**Total weight tested**
C	**D**	**E**	**F=D+E**
(mm)	**(g)**	**(g)**	**(g)**
50 to 40			
40 to 25	628	60	688
25 to 19	1208	490	1698
19 to 16	725	166	891
16 to 12.5	450	350	800
12.5 to 9.5	448	232	680
9.5 to 6.3	187	94	281
Total	3646	1392	5038
Elongation Index (%)= (E/F)*100%			
Elongation Index (%)= 28%			

Elongation Index of 10mm down Aggregate			
Flakiness plate Slot size Identification	**Wt. passing slot on flakiness plate**	**Wt. retained on flakiness plate**	**Total weight tested**
C	**D**	**E**	**F=D+E**
(mm)	**(g)**	**(g)**	**(g)**
50 to 40			0
40 to 25			0
25 to 19			0
19 to 16			0
16 to 12.5			0
12.5 to 9.5	650	100	750
9.5 to 6.3	174	187	361
Total		287	1111
Elongation Index (%)= (E/F)*100%			
Elongation Index (%)= 26%			

APPENDIX 5 SPECIFIC GRAVITY OF NEW AGGREGATE

SPECIFIC GRAVITY AND WATER ABSORPTION			
Location:	**Chalal Ganesh Quary (Panauti)**		
20 mm down			
S.N	**Determination Number**	**Notation**	**Weight (g)**
1	Wt. Pan+ Saturated, Surface Dry Sample	B1	2266.30
2	Wt. Pan	B2	424.80
3	Wt. Saturated, Surface Dry Sample(B1-B2)	B	1841.50
4	Wt. Basket + Sample in Water	C1	1707.40
5	Wt. Basket in Water	C2	547.70
6	Wt. Sample in water (C1-C2)	C	1159.70
7	Wt. of Oven Dry Sample	A	1832.60
Bulk G (Oven Dry) = A/(B-C)			**2.688**
Bulk G (SSD) = B/(B-C)			**2.701**
Apparent G = A/(A-C)			**2.723**
Absorption=[(B-A)/A]*100%			**0.49%**

10 mm down aggregate			
S.N	**Determination Number**	**Notation**	**Weight**
1	Wt. Pan+ Saturated, Surface Dry Sample	B1	2246.70
2	Wt. Pan	B2	439.80
3	Wt. Saturated, Surface Dry Sample(B1-B2)	B	1806.90
4	Wt. Basket + Sample in Water	C1	1685.90
5	Wt. Basket in Water	C2	547.70
6	Wt. Sample in water (C1-C2)	C	1138.20
7	Wt. of Oven Dry Sample	A	1798.00
Bulk G (Oven Dry) = A/(B-C)			**2.689**
Bulk G (SSD) = B/(B-C)			**2.702**
Apparent G = A/(A-C)			**2.725**
Absorption=[(B-A)/A]*100%			**0.49%**

Dust 4.75mm down			
S.N	**Determination Number**	**Notation**	**Weight (g)**
1	Wt. PYC + Water (full)	A	742.50
2	Wt. PYC Empty and Dry	B	219.90
3	Temp of Water	T1	25°C
4	Wt. PYC + Oven Dry Sample	C	1753.00
5	Wt. of Oven Dry Sample= C-B	D	524.00
6	Wt. PYC+ Sample + Water (Full)	E	1072.80
7	Temp of Water	T2	25°C
8	Relative Density of Water at temp T2	GW	0.997077
9	**Specific Gravity= GW*(D/D+A-E)**		**2.697**

APPENDIX 6 JOB MIX DESIGN OF NEW AGGREGATE

Sieve size (mm)	20 mm (40%)	10 mm (10%)	Dust (50%)	Total (100%)
26.5	37.73%	10.00%	50.00%	97.73%
20.00	26.12%	10.00%	50.00%	86.12%
16.00	19.41%	10.00%	50.00%	79.41%
13.20	10.25%	9.95%	50.00%	70.20%
10.00	2.88%	7.42%	50.00%	60.30%
4.75	0.24%	0.14%	39.01%	39.40%
2.36	0.11%	0.10%	30.11%	30.31%
1.18			13.90%	13.90%
0.60	0.04%	0.05%	8.57%	8.66%
0.30			4.07%	4.07%
0.15			1.87%	1.87%
0.075	0.00%	0.00%	0.00%	0.00%

Sieve Size (mm)	20 mm (30%)	10 mm (20%)	Dust (50%)	Total (100%)
26.50	28.30%	20.00%	50.00%	98.30%
20.00	19.59%	20.00%	50.00%	89.59%
16.00	14.56%	20.00%	50.00%	84.56%
13.20	7.68%	19.91%	50.00%	77.59%
10.00	2.16%	14.84%	50.00%	67.00%
4.75	0.18%	0.28%	41.82%	42.28%
2.36	0.08%	0.20%	35.18%	35.46%
1.18			23.11%	23.11%
0.60	0.03%	0.09%	19.12%	19.24%
0.30			15.77%	15.77%
0.15			14.13%	14.13%
0.075	0.00%	0.00%	12.74%	12.74%

Sieve Size (mm)	20 mm (30%)	10 mm (25%)	Dust (45%)	Total (100%)
26.50	28.30%	25.00%	45.00%	98.30%
20.00	19.59%	25.00%	45.00%	89.59%
16.00	14.56%	25.00%	45.00%	84.56%
13.20	7.68%	24.88%	45.00%	77.57%
10.00	2.16%	18.55%	45.00%	65.71%
4.75	0.18%	0.35%	37.63%	38.16%
2.36	0.08%	0.25%	31.66%	31.99%
1.18			20.80%	20.80%
0.60	0.03%	0.12%	17.21%	17.36%
0.30			14.19%	14.19%
0.15			12.71%	12.71%
0.075	0.00%	0.00%	11.46%	11.46%

Sieve Size (mm)	20 mm (33%)	10 mm (22%)	Dust (45%)	Total (100%)
26.50	31.13%	22.00%	45.00%	98.13%
20.00	21.55%	22.00%	45.00%	88.55%
16.00	16.02%	22.00%	45.00%	83.02%
13.20	8.45%	21.90%	45.00%	75.35%
10.00	2.38%	16.32%	45.00%	63.70%
4.75	0.20%	0.31%	37.63%	38.14%
2.36	0.09%	0.22%	31.66%	31.97%
1.18			20.80%	20.80%
0.60	0.03%	0.10%	17.22%	17.35%
0.30			14.21%	14.21%
0.15			12.73%	12.73%
0.075	0.00%	0.00%	7.83%	7.83%

Sieve Size (mm)	20 mm (31%)	10 mm (25%)	Dust (44%)	Total (100%)
26.50	29.24%	25.00%	44.00%	98.24%
20.00	20.24%	25.00%	44.00%	89.24%
16.00	15.05%	25.00%	44.00%	84.05%
13.20	7.94%	24.88%	44.00%	76.83%
10.00	2.24%	18.55%	44.00%	64.78%
4.75	0.19%	0.35%	36.80%	37.33%
2.36	0.08%	0.25%	30.96%	31.29%
1.18			20.33%	20.33%
0.60	0.03%	0.12%	16.84%	16.99%
0.30			13.89%	13.89%
0.15			12.44%	12.44%
0.075	0.00%	0.00%	7.65%	7.65%

Sieve size(mm)	20 mm (30%)	10 mm (27%)	Dust (43%)	Total (100%)	Range for 50mm thickness (SSRBW, 2073)
26.50	28.30%	27.00%	43.00%	98.30%	**100%**
20.00	20.11%	27.00%	43.00%	90.11%	**90-100**
16.00	15.03%	27.00%	43.00%	85.03%	
13.20	8.11%	26.88%	43.00%	77.98%	**59.79**
10.00	2.54%	20.03%	43.00%	65.57%	**52-72**
4.75	0.48%	0.37%	35.96%	36.82%	**35-55**
2.36	0.33%	0.27%	30.25%	30.85%	**28-44**
1.18			21.91%	21.91%	**20-34**
0.60	0.20%	0.12%	17.47%	17.79%	**15-27**
0.30			13.57%	13.57%	**10-20**
0.15			12.16%	12.16%	**5-13**
0.075	0.00%	0.00%	7.48%	7.48%	**2-8**

APPENDIX 7 MARSHALL MIX DESIGN

Total weight of aggregate	**1200 g**	**G**
4% bitumen content		
Wt. of bitumen	**48 g**	**g**
Wt. of aggregate	**1152**	**g**
20 mm down	30% of 1152	345.60
10 mm down	27% of 1152	311.04
Dust (4.75mm down)	43% of 1152	495.36

4.5% bitumen content		
Wt. of bitumen	**54**	**g**
Wt. of aggregate	**1146**	**g**
20 mm down	30% of 1152	343.80
10 mm down	27% of 1152	309.42
Dust (4.75mm down)	43% of 1152	492.78

5% bitumen content		
Wt. of bitumen	**60**	**g**
Wt. of aggregate	**1140**	**g**
20 mm down	30% of 1152	342.00
10 mm down	27% of 1152	307.80
Dust (4.75mm down)	43% of 1152	490.20

5.5% bitumen content		
Wt. of bitumen	**66**	**g**
Wt. of aggregate	**1134**	**g**
20 mm down	30% of 1152	340.20
10 mm down	27% of 1152	306.18
Dust (4.75mm down)	43% of 1152	487.62

6% bitumen content		
Wt. of bitumen	**72**	**g**
Wt. of aggregate	**1128**	**g**
20 mm down	30% of 1152	338.40
10 mm down	27% of 1152	304.56
Dust (4.75mm down)	43% of 1152	485.04

6.5% bitumen content		
Wt. of bitumen	**78**	**g**
Wt. of aggregate	**1122**	**g**
20 mm down	30% of 1152	336.60
10 mm down	27% of 1152	302.94
Dust (4.75mm down)	43% of 1152	482.46

APPENDIX 8 MARSHALL TEST RESULT OF NEW AGGREGATE

S. N	% Bitumen	Avg. thicknes s (mm)	Wt. in air (g)	Wt. in water (g)	Wt. of SSD sample (g)	Flow (mm)	Stability (KN)	G1	G2	G3	G	Stability (KN)	Correction Factor	Actual Stability (KN)	Avg. Actual Stability (KN)	Flow (mm)
1	4	66.83	1197.7	694.9	1201.6	1.21	10.5	2.363	2.371	2.380		10.5	0.927	9.734		
2	4	63.51	1194.2	696.1	1198.0	1.27	10.5	2.379	2.386	2.397	2.372	10.5	0.999	10.490	10.218	1.267
3	4	64.13	1198.3	697.4	1202.3	1.32	10.6	2.373	2.381	2.392		10.6	0.984	10.430		
4	4.5	64.63	1197.5	695.4	1198.9	1.27	10.8	2.378	2.381	2.385		10.8	0.972	10.498		
5	4.5	63.53	1195.4	697.3	1198.3	1.30	11.1	2.386	2.392	2.399	2.381	11.1	0.999	11.089	10.774	1.290
6	4.5	63.75	1196.6	696.5	1199.8	1.30	10.8	2.377	2.384	2.393		10.8	0.994	10.735		
7	5	62.83	1197.3	700.3	1202.7	1.77	11.0	2.383	2.394	2.409		11.0	1.017	11.187		
8	5	61.63	1200.0	701.8	1203.9	1.77	11.3	2.389	2.398	2.409	2.390	11.3	1.048	11.842	11.537	1.720
9	5	61.47	1198.4	702.0	1201.9	1.62	11.0	2.397	2.404	2.414		11.0	1.053	11.583		
10	5.5	63.43	1198.9	701.6	1202.3	2.10	10.8	2.394	2.401	2.411		10.8	1.002	10.822		
11	5.5	63.43	1199.8	701.9	1203.5	2.17	11.1	2.392	2.399	2.409	2.392	11.1	1.002	11.122	11.029	2.140
12	5.5	62.97	1199.0	701.6	1203.1	2.15	11.0	2.391	2.399	2.411		11.0	1.013	11.143		
13	6	61.77	1196.3	696.5	1199.2	2.55	9.0	2.380	2.386	2.394		9.0	1.044	9.396		
14	6	61.43	1199.6	704.2	1203.0	2.48	9.1	2.405	2.412	2.421	2.391	9.1	1.055	9.601	9.508	2.560
15	6	61.67	1195.6	698.0	1198.3	2.65	9.1	2.390	2.395	2.403		9.1	1.047	9.528		
16	6.5	62.05	1196.5	699.3	1202.1	2.34	7.3	2.380	2.391	2.406		7.3	1.03	7.519		
17	6.5	61.55	1196.2	696.1	1199.0	2.27	7.4	2.379	2.384	2.392	2.382	7.4	1.051	7.777	7.723	2.277
18	6.5	61.13	1199.9	701.5	1203.8	2.22	7.4	2.389	2.397	2.408		7.4	1.064	7.874		

APPENDIX 9 VOLUMETRIC PARAMETER OF FRESH AGGREGATE

S.N.	% Bitumen	Sp. Gr. of 20 mm down aggregate	Sp. Gr. of 10 mm down aggregate	Sp. Gr. of Coarse dust(4.75mm down)	Sp. Gr. of agg. mix	% agg. Mix	Density .of comp. Mix g/cc	Max Sp. Gr.	Theoretical Sp. Gravity	% Air voids	% VMA	% VFB	Sp. Gr. of bitumen	Remarks
1	4	2.688	2.689	2.697	2.692	96.0	2.372	2.529	2.529	6.21	15.42	59.70	1.03	
2	4.5	2.688	2.689	2.697	2.692	95.5	2.381	2.510	2.510	5.14	15.52	66.90	1.03	
3	5.0	2.688	2.689	2.697	2.692	95.0	2.389	2.491	2.491	4.10	15.70	73.90	1.03	
4	5.5	2.688	2.689	2.697	2.692	94.5	2.392	2.473	2.473	3.26	16.04	79.60	1.03	
5	6	2.688	2.689	2.697	2.692	94.0	2.391	2.454	2.454	2.59	16.52	84.30	1.03	
6	6.5	2.688	2.689	2.697	2.692	93.5	2.382	2.437	2.437	2.24	17.27	87.00	1.03	

APPENDIX 10 TESTS ON FRESH BITUMEN

Tests on Bitumen

Penetration Test

Temperature of Water Bath = 25 °C

Weight of Piston = 100 g

A	Description	1	2	3
B	Penetration (1/10mm)	58	58	59
C	**Average Penetration**	**58.33**		

Softening Point			
Bath Liquid			
Start Temperature : Water= 4°C to 6°C			
A	Description	1	2
B	Softening Temp. (°C)	51.5	52
C	**Average Softening Temp.(°C)**	**51.75**	

Flash and Fire point		
1	Flash Point (°C)	292
2	Fire Point (°C)	322
Ductility		
Ductility >100cm		
Water content = Nil		
Sp. Gravity		
1	32.934	**1.03**
2	81.714	
3	68.487	
4	82.818	

Viscosity Test					
		Constant	Time	Sec	Poise
Bulb	B	33.5224		46	1542.03
Bulb	C	15.2412		283	4313.27
Viscosity of the Bitumen at 60°C			**2927.651**	**Poise**	
			292.7651	**PaS**	

APPENDIX 11 EXTERACTION OF BINDER CONTENT OF RAP

Bitumen Content Of RAP				
EXTRACTION OF AGGREGATE				
S. N	**Notation**	**Description**	**Weight**	**Unit**
1	A1	Weight of pan+ Sample	2519.6	g
2	A2	Weight of pan	1502.1	g
3	A	Weight of sample= A1-A2	1017.5	g
4	B1	Weight of pan + Dry sample from Bowl after Extraction	2442.5	g
5	B2	Weight of pan	1502.1	g
6	B	Weight of dry sample from bowl after Extraction = B1-B2	940.4	g
7	C	Weight of Dry filter ring after extraction	12.6	g
8	D	Weight of Dry filter ring before extraction	11.9	g
9	E	Weight of Aggregate in filter ring = C-D	0.7	g
10	F	Total Weight of extracted Aggregate = B+E	941.1	g
MINERAL MATTER IN EXTRACT				
1	G	Weight of dry Centrifuge Cup after centrifuging	234.1	g
2	H	Weight of dry Centrifuge Cup before centrifuging	210.7	g
3	I	Weight of mineral matter in extract = G-H	23.4	g
WATER CONTENT				
1	J	Moisture contain of sample from test D1416	0	%
2	K	Weight of water in sample= (L*A)/100	0	g
BITUMEN CONTENT				
1	L	Weight of aggregates + minerals in sample = F+I	964.5	g
2	M	Weight of bitumen in sample = A-L-K	53.0	g
3	N	**Bitumen content = (M/A)*100%**	**5.21**	**%**

APPENDIX 12 SPECIFIC GRAVITY OF RAP AND RAP AGGREGATE

Specific Gravity of RAP aggregate			
S.N	**Determination Number**	**Notation**	**Weight (g)**
1	Wt. Pan + Saturated, Surface Dry Sample	B1	2289.5
2	Wt. Pan	B2	432.6
3	Wt. Saturated, Surface Dry Sample(B1-B2)	B	1856.9
4	Wt. Basket + Sample in Water	C1	1728.5
5	Wt. Basket in Water	C2	547.7
6	Wt. Sample in water (C1-C2)	C	1180.8
7	Wt. of Oven Dry Sample	A	1824.8
Bulk G (Oven Dry) = A/(B-C)			**2.699**
Bulk G (SSD) = B/(B-C)			**2.746**
Apparent G = A/(A-C)			**2.833**
Absorption=[(B-A)/A]*100%			**1.76%**

Sp. Gravity of RAP			
S.N	**Determination Number**	**Notation**	**Weight (g)**
1	Wt. PYC + Water (full)	A	1595.7
2	Wt. PYC Empty and Dry	B	471.3
3	Temp of Water	T1	25°C
4	Wt. PYC + Oven Dry Sample	C	1333.6
5	Wt. of Oven Dry Sample= C-B	D	862.3
6	Wt. PYC+ Sample + Water (Full)	E	2104.3
7	Temp of Water	T2	25°C
8	Rel. Density of Water at temp T2	GW	0.997077
9	**Specific Gravity= GW*(D/D+A-E)**		**2.431**

APPENDIX 13 AIV OF RAP AGGREGATE

AIV of RAP aggregate			
Sample Preparation			
S.N	**Notation**	**Description**	**Weight (g)**
1	A1	Wt. of Measure + Compacted Sample	1305.6
2	A2	Wt. of Measure	928.0
3	A	Wt. of Compacted Sample = (A1-A2)	377.6
Test Procedure			
S.N	**Notation**	**Description**	**Weight (g)**
1	B	Wt. passing 2.83mm sieve	56.7
2	C	Wt. of Retained on 2.83mm sieve	320.9
3	D	Total = B+C	377.6
Aggregate Impact Value= (B/A)*100%			**15.02%**

APPENDIX 14 JOB MIX DESIGN CONTAINING DIFFERENT PERCENTAGE OF RAP

Total	RAP		New Aggregate + Bitumen		New Aggregate + Bitumen									
	%	Wt. (g)			New Aggregate		20mm		10mm		4.75mm		Bitumen	
			%	Wt. (g)	%	Wt. (g)	%	Wt. (g)	%	Wt. (g)	%	Wt. (g)	%	Wt. (g)
1200	15%	180	85%	1020	94.83%	967.266	30%	290.18	27%	261.16	43%	415.92	5.17%	52.73
1200	20%	240	80%	960	94.83%	910.368	30%	273.11	27%	245.80	43%	391.46	5.17%	49.63
1200	25%	300	75%	900	94.83%	853.47	30%	256.04	27%	230.44	43%	366.99	5.17%	46.53
1200	30%	360	70%	840	94.83%	796.572	30%	238.97	27%	215.07	43%	342.53	5.17%	43.43
1200	50%	600	50%	600	94.83%	568.98	30%	170.69	27%	153.62	43%	244.66	5.17%	31.02
1200	75%	900	25%	300	94.83%	284.49	30%	85.35	27%	76.81	43%	122.33	5.17%	15.51
1200	100%	1200	0%	0	94.83%	0.00	30%	0.00	27%	0.00	43%	0.00	5.17%	0.00

APPENDIX 15 MARSHALL TEST RESULT CONTAINING VARYING RAP PERCENTAGE

S.N	Bitumen %	% RAP	Avg. thickness (mm)	Wt. in air (g)	Wt. in water (g)	Wt. of SSD sample (g)	Flow (mm)	Stability (KN)	G1	G2	G3	G	Stability (KN)	Correction Factor	Actual Stability (KN)	Avg. Actual Stability (KN)	Flow (mm)
1	5.17	15	63.45	1197.2	701.2	1201.5	2.25	10.6	2.392	2.401	2.414		10.6	1.001	10.611		
2	5.17	15	61.70	1196.4	698.4	1200.7	2.20	10.5	2.382	2.390	2.402	2.379	10.5	1.046	10.983	11.003	2.22
3	5.17	15	61.35	1197.1	694.6	1201.5	2.22	10.8	2.362	2.370	2.382		10.8	1.057	11.416		
4	5.17	20	62.10	1200.0	701.9	1202.9	2.20	9.6	2.395	2.410	2.409		9.6	1.035	9.936		
5	5.17	20	62.50	1198.4	687.7	1200.9	2.19	9.8	2.335	2.340	2.346	2.376	9.8	1.025	10.045	10.15	2.21
6	5.17	20	62.00	1197.4	699.7	1199.0	2.23	10.1	2.398	2.401	2.405		10.1	1.037	10.474		
7	5.17	25	62.36	1196.2	696.3	1197.9	2.15	9.8	2.385	2.388	2.392		9.8	1.028	10.074		
8	5.17	25	62.73	1200.0	700.2	1204.8	2.16	10.0	2.378	2.387	2.400	2.374	10.0	1.019	10.190	10.1934	2.15
9	5.17	25	61.83	1197.5	692.9	1200.8	2.15	9.9	2.358	2.364	2.373		9.9	1.042	10.316		
10	5.17	30	62.23	1200.0	700.3	1204.4	2.10	10.0	2.380	2.389	2.401		10.0	1.032	10.320		
11	5.17	30	62.30	1199.0	695.4	1201.7	2.10	10.3	2.368	2.373	2.380	2.376	10.3	1.030	10.609	10.508	2.12
12	5.17	30	61.60	1197.8	696.4	1199.8	2.15	10.1	2.379	2.383	2.388		10.1	1.049	10.595		
13	5.17	50	61.70	1197.7	699.5	1200.0	2.10	13.5	2.393	2.398	2.404		13.5	1.046	14.121		
14	5.17	50	64.63	1193.0	695.8	1199.8	2.08	13.6	2.367	2.380	2.399	2.383	13.6	0.985	13.396	13.724	2.09
15	5.17	50	63.33	1198.7	699.7	1201.5	2.08	13.6	2.389	2.394	2.402		13.6	1.004	13.654		
16	5.17	75	64.10	1192.0	690.3	1200.3	1.95	13.3	2.337	2.353	2.376		13.3	0.981	13.047		
17	5.17	75	63.73	1200.0	702.2	1203.4	1.91	13.3	2.394	2.401	2.410	2.371	13.3	0.994	13.220	13.379	1.94
18	5.17	75	62.10	1196.0	695.2	1197.3	1.96	13.4	2.382	2.384	2.388		13.4	1.035	13.869		
19	5.17	100	63.07	1199.6	696.0	1202.9	1.50	13.2	2.366	2.373	2.382		13.2	1.007	13.292		
20	5.17	100	62.40	1199.2	702.9	1200.1	1.67	13.2	2.412	2.414	2.416	2.363	13.2	1.027	13.556	13.095	1.59
21	5.17	100	66.90	1195.5	680.7	1198.4	1.61	13.3	2.309	2.315	2.322		13.3	0.935	12.435		
22	5.17	30+K	62.87	1201.9	699.8	1204.1	2.24	10.1	2.383	2.388	2.393		10.1	1.080	10.908		
23	5.17	30+K	63.27	1200.7	697.1	1202.5	2.24	9.9	2.376	2.379	2.384	2.383	9.9	1.005	9.9495	10.232	2.24
24	5.17	30+K	63.33	1199.0	699.7	1201.5	2.25	9.8	2.389	2.394	2.401		9.8	1.004	9.839		
25	5.17	50+K	63.93	1200.0	704.1	1205.4	2.34	12.9	2.394	2.404	2.419		12.9	0.998	12.874		
26	5.17	50+K	62.87	1199.4	700.5	1203.3	2.44	13.0	2.385	2.393	2.404	2.394	13.0	1.038	13.494	13.157	2.41
27	5.17	50+K	63.03	1192.0	698.7	1194.9	2.45	13.0	2.402	2.408	2.416		13.0	1.008	13.104		
28	5.17	75+K	62.90	1186.8	691.7	1188.7	2.41	12.6	2.388	2.392	2.397		12.6	1.080	13.608		
29	5.17	75+K	63.00	1183.4	685.5	1186.2	2.51	12.3	2.363	2.369	2.376	2.379	12.3	1.009	12.411	13.116	2.48
30	5.17	75+K	62.10	1196.0	695.8	1197.3	2.52	12.4	2.385	2.387	2.391		12.4	1.075	13.330		
31	5.17	100+K	62.10	1196.0	695.2	1197.3	2.45	12.6	2.382	2.384	2.388		12.6	1.035	13.041		
32	5.17	100+K	63.57	1183.4	685.5	1186.2	2.59	12.5	2.363	2.369	2.376	2.383	12.5	0.999	12.499	12.933	2.53
33	5.17	100+K	62.17	1200.0	703.0	1202.5	2.56	12.8	2.402	2.407	2.414		12.8	1.036	13.261		

APPENDIX 16 VOLUMETRIC PROPERTIES OF RAP MIX WITH FRESH AGGREGATES

S. N.	RAP%	% Bitumen	Wt. of RAP	Wt. of RAP aggregate without bitumen	% of RAP without bitumen	Sp. Gravity of agg. Of RAP	Sp. Gr. Of RAP	Sp.Gr. of 20 mm down aggregate	Sp.Gr. of 10 mm down aggregate	Sp.Gr. of dust 4.75mm down aggregate	Sp. Gr.of agg. mix	% agg. Mix	% new agg. in total mix	Density .of comp. Mix g/cc	Max Sp. Gr	Effective Sp Gravtiy	Theoritical Sp Gravtiy	% Air voids	% VMA	% VFB	Sp.Gr .of bitumen	Remarks
1	15	5.17	180	170.62	14.22	2.69	2.43	2.69	2.69	2.70	2.69	94.83	80.61	2.38	2.48	2.48	2.48	3.95	16.20	75.64	1.03	
2	20	5.17	240	227.50	18.96	2.69	2.43	2.69	2.69	2.70	2.69	94.83	75.86	2.38	2.48	2.47	2.47	3.96	16.31	75.70	1.03	
3	25	5.17	300	284.37	23.70	2.69	2.43	2.69	2.69	2.70	2.69	94.83	71.12	2.37	2.48	2.47	2.47	3.94	16.38	75.95	1.03	
4	30	5.17	360	341.24	28.44	2.69	2.43	2.69	2.69	2.70	2.69	94.83	66.38	2.38	2.48	2.47	2.47	3.75	16.31	76.99	1.03	
5	50	5.17	600	568.74	47.40	2.69	2.43	2.69	2.69	2.70	2.69	94.83	47.42	2.38	2.48	2.46	2.46	3.05	16.06	81.04	1.03	
6	75	5.17	900	853.11	71.09	2.69	2.43	2.69	2.69	2.70	2.69	94.83	23.71	2.37	2.48	2.44	2.44	3.00	16.48	81.80	1.03	
7	100	0.00	1200	1137.48	94.79	2.69	2.43	0.00	0.00	0.00	0.00	0.00	0.00	2.36	0.00	2.43	2.43	2.79	16.76	83.36	1.03	
8	30+ K	5.17	360	341.24	28.44	2.69	2.43	2.69	2.69	2.70	2.69	94.83	66.38	2.38	2.48	2.47	2.47	3.47	16.06	78.40	1.03	
9	50+ K	5.17	600	568.74	47.40	2.69	2.43	2.69	2.69	2.70	2.69	94.83	47.42	2.39	2.48	2.46	2.46	2.60	15.67	83.42	1.03	
10	75+ K	5.17	900	853.11	71.09	2.69	2.43	2.69	2.69	2.70	2.69	94.83	23.71	2.38	2.48	2.44	2.44	2.67	16.20	83.50	1.03	
11	100+ K	0.00	1200	1137.48	94.79	2.69	2.43	0.00	0.00	0.00	0.00	0.00	0.00	2.38	0.00	2.43	2.43	1.97	16.06	87.75	1.03	

*K= Kerosene (10% of Binder Contain of RAP)

APPENDIX 17 COST ESTIMATION

Rate Analysis of New Asphalt Concrete

Description of Work: **Spec. cl. No: 1309**	**Bituminous Concrete / Asphalt Concrete, Providing and laying Bituminous concrete/ Asphalt concrete using crushed aggregates of specified grading, premixed with bituminous binder and filler as per Drawing and Technical Specifications, Grading - I-19 mm (Nominal Size)**	**95.5 cum**

Norms No.	**Labour (A)**					**Material (B)**					**Equipment (C)**					**Formworks (D)**				
	Type	Unit	Quantity	Rate	Amount	Type	Unit	Quantity	Rate	Amount	Type	Unit	Quantity	Rate	Amount	Type	Unit	Quantity	Rate	Amount
13.6	Unskilled	day	15	750	11250.0	Bitumen	tonne	12.94	78032.6925	1009743	Batch mix HMP	hour	6.00	14122.0	84732.0					
	Skilled	day	5	1030	5150.0	Aggregate					Paver Finisher	hour	6.00	4775.0	28650.0					
						Grading - I-19 mm (Nominal Size)					Generator	hour	6.00	1288.0	7728.0					
						Aggregate 20 - 10 mm	cum	49.48	2405.499344	119024.11	Smooth Wheeled Roller	hour	12.00	1607.0	19284.0					
						Aggregate 10 - 5 mm	cum	32.52	2405.499344	78226.839	Pneumatic Roller	hour	6.00	3319.0	19914.0					
						Aggregate 5 mm and below	cum	56.55	2405.499344	136030.99										
						Filler [stone_dust]	tonne													
				Sub total of A =	16400.0				**Sub total of B =**	1343025.0				**Sub total of C =**	160308.0				**Sub total of D =**	0.0
				Sub total of A +B + C =	1519733.0				**Sub total of A + B + C + D=**	1519733.0				**Contractor's overhead expenses 15% =**	227959.9				**Norms Rate =**	1747692.9
																			Unit Rate =	**18300.45**

Rate Analysis of RAP

Description of Work:	**Rate Anatyis of RAP**	**95.5 cum**
Spec. cl. No: 1309		

Norms No.	**Labour (A)**					**Material (B)**					**Equipment (C)**					**Formworks (D)**				
	Type	Unit	Quantity	Rate	Amount	Type	Unit	Quantity	Rate	Amount	Type	Unit	Quantity	Rate	Amount	Type	Unit	Quantity	Rate	Amount
13.6	Unskilled	day	15	750	11250.0	Bitumen	tonne	0	78032.6925	0	Batch mix HMP	hour	6.00	14122.0	84732.0					
	Skilled	day	5	1030	5150.0	Aggregate					Paver Finisher	hour	6.00	4775.0	28650.0					
						Grading - I-19 mm (Nominal Size)					Generator	hour	6.00	1288.0	7728.0					
						Aggregate 20 - 10 mm	cum	0	2405.499344	0	Smooth Wheeled Roller	hour	12.00	1607.0	19284.0					
						Aggregate 10 - 5 mm	cum	0	2405.499344	0	Pneumatic Roller	hour	6.00	3319.0	19914.0					
						Aggregate 5 mm and below	cum	0	2405.499344	0										
						Filler [stone_dust]	tonne													
Sub total of A =					16400.0	**Subtotal of B =**				0.00	**Sub total of C =**				160308.0	**Subtotal of D =**				0.0
Sub total of A +B + C =					176708.0	**Sub total of A + B + C + D=**				176708.0	**Contractor's overhead expenses 15% =**				26506.2	**Norms Rate =**				203214.2
																Unit Rate =				**2127.9**

APPENDIX18 APPROVAL LETTER FROM CENTRAL LABORATORY OF DOR

त्रिभुवन विश्वविद्यालय
इन्जिनियरिङ्ग अध्ययन संस्थान
पुल्चोक क्याम्पस

सिभिल इन्जिनियरिङ्ग विभाग

पत्र संख्या ३६/०७६/७७ | मिति २०७६/०४/१७

०७६/०७७

च.नं.

श्री सडक विभाग
गुणस्तर, अनुसन्धान तथा विकास केन्द्र
चाकुपाट, ललितपुर ।

बिषय:थेसिस प्रयोजनका लागि सहयोग गरिदिने बारे ।

उपरोक्त सम्बन्धमा यस क्याम्पसमा Msc in Transportation Engineering मा अध्ययनरत विद्यार्थीहरुका थेसिस प्रयोजनका लागि निर्माण सामग्रीहरुको तपशिल बमोजिमका टेष्टहरु गर्नुपर्ने भएकोले तहाँको ल्याव उपलब्ध गरा आवश्यक सहयोग गरिदिनु हुन अनुरोध गर्दछु ।

विद्यार्थीहरुको नाम	रोल नं.
१. अविरल आशिष	073/MSTR/251
२. पदम बहादुर मडै	073/MSTR/257
३.रिता खड्का	073/MSTR/259
४. समिर वैद्य	072/MSTR/263

गर्नु पर्ने परिक्षण

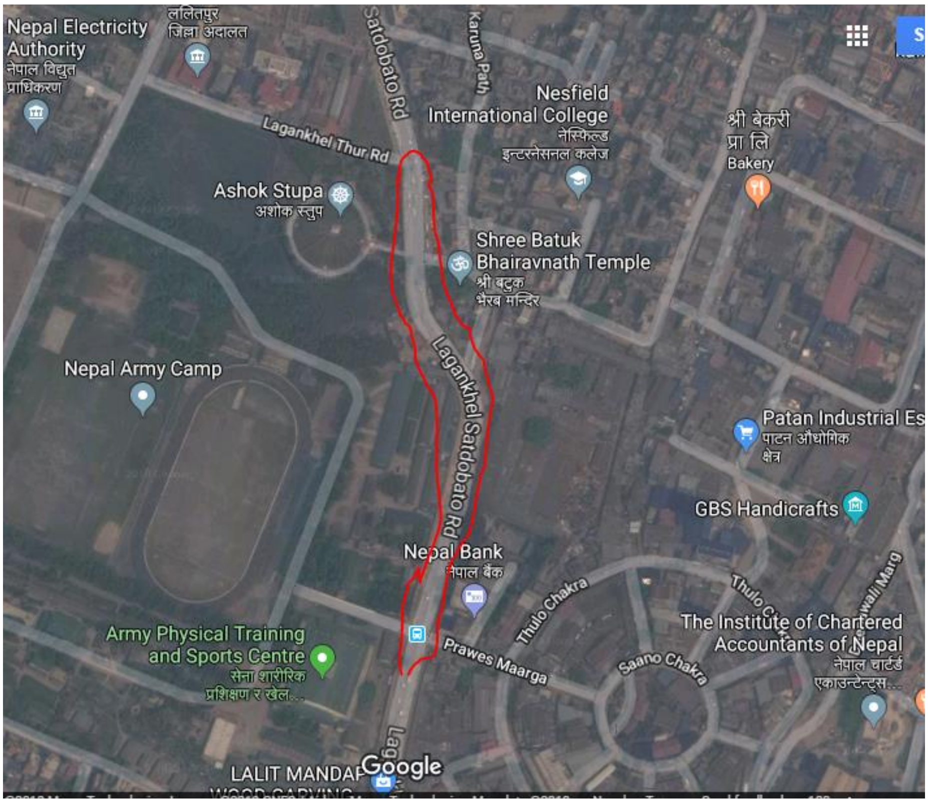
1. All aggregates test
2. All bitumen tests
3. Marshall Stability Test

Institute of Engineering
Dept. of Civil Engineering
Pulchowk Campus

डा. प्रदिप श्रेष्ठ
विभागीय उप प्रमुख

आनन्द निकेतन, पुल्चोक, ललितपुर, नेपाल । पो.ब.नं. ११७५, काठमाडौं
फोन नं. ५५२५४७७, ५५४३०७० फयाक्स : ९७७-१-५५२५४७७

APPENDIX19 PHOTOGRAPHS



Photograph 0-2 Location Map of Satdobato Lagankhel Road Section

Photograph 0-1 RAP Sample of Satdobato- Lagankhel Road Section

Photograph 0-3 Extraction of Bitumen from RAP

Photograph 0-4 Extraction of Aggregate from RAP Sample

Photograph 0-6 Location Map of Chalal Ganesh Quarry, Kavre

Photograph 0-5 Sodium Sulphate Soundness and Striping Test of New Aggregate

Photograph 0-7 Marshall Sample Preparation and Testing of Virgin Mix

Photograph 0-8 Marshall Sample of New Graded Aggregate with Varying RAP