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Explore the Possibilities of Utilization Geopolymer Activated Reclaimed Asphalt Pavement in Flexible Pavement Design

Mahendrasinh Sodha

Master of Transportation Engineering, Civil Engineering Department.
Marwadi University Rajkot, Gujarat, India

Abstract - *Reclaimed asphalt pavement (RAP) materials have been considered as one of the most sustainable option in the pavement industry. Reclaimed asphalt pavement is a milled material obtain from the dump pavement sites, containing a thin coating of aged bitumen on the aggregate surface. In spite of their inferior properties, RAP has been promoted to use in new pavement surface layer after blending with virgin aggregate (VA) and chemical stabilizers such as fly ash and silica fume. Hence, the non- reactive type silica fume can be activated in an alkali environment such as combination of sodium hydroxide and sodium silicate to further improve the reactivity to participant in the pozzolanic reactions. The strength and stiffness property RAP can be enhanced by stabilizing them with fly ash and silica fume. To accomplish this task, specimen was prepared at various proportions of RAP and VA materials; the mix design of silica fume at 20% and 30% by dry weight with alkali activation at 2% and 4% sodium hydroxide (NaOH) solution. The use of reclaimed asphalt pavement results in saving of around 25% to 30% in construction cost. With the silica fume and reclaimed asphalt reduce use of virgin aggregate up to 60%.*

Key Words: Reclaimed asphalt pavement, Marshall mix design, flexible pavement, virgin aggregate, geopolymer.

1. INTRODUCTION

The development of any country is depends upon a transportation system. Road transportation system makes crucial contribution to economic & social development and growth for the nation. Also brings important social benefits for a nation. For a vast country like India having an area of 3.3 million sq. km, with a population density of over 300 person/sq. km, the importance of an adequate road transportation system is quite obvious. Road transport is vital to India's economy. It enables the country transportation sector to contribute 4.7 percent towards India's gross domestic product. This is in comparison to railways, which contributed 1 percent from 2009 to 2010. Road transport has gained its important over the years despite significant barriers and inefficient in inter-state freight and passenger movement compared to railway and air. India's road network carries over 65% of its freight and about 85% of passenger traffic.

Recycling is one of the key components for sustainable development of infrastructure. However, recycled material such as construction and demolition waste from pavement and by-product from thermal power plants are highly produced, which are either stockpiled or landfilled across the world if not utilized in large quantities. Reuse of these secondary material in civil engineering application in large quantities is always a challenge due to their inferior properties. Safe disposal of recycled construction materials and industrial by product such as RAP, fly ash, waste tires, quarry waste, construction and demolition waste has become a real environment challenge. RAP is a reclaimed material obtained when a portion of distressed asphalt pavement is milled. RAP has been a resource material, when a properly stabilized, for a new surface or a base course layer of flexible pavements.

Modern pavement design is concerned with developing the most economical combination of pavement layer that will ensure that the stresses and strain transmitted from the carriageway do not exceed the supportive capacity of each layer, or of the subgrade, during the design life of the road. Major variables affecting the design of given pavement are therefore the volume and composition of traffic, the subgrade environment and strength, the materials economically available for use within the pavements layers, and the thickness of each layer.

1.1 Pavements

A structure consisting of superimposed layers of processed materials above the natural soil subgrade, whose primary function is to distribute the applied vehicle loads to the subgrade. A raised asphalt/concrete path for pedestrian at the side of a road or for the vehicles. In order to provide a stable and even surface for the traffic, the roadway is provided with a suitably designed and constructed surface. The surface of the roadway should be stable and non-yielding, to allow the heavy wheel load of road traffic to move with least possible rolling resistance. The road surface should also be even long the longitudinal profile to enable the fast vehicle to move safely and comfortably at the design speed. The earth road may not be able to fulfill any of the above requirements, especially during the varying conditions of traffic loads and the weather. Apart from this uneven pavement surface causes discomfort and fatigue to

the passengers of fast moving vehicles and cyclists. The roadway is provided with a suitably designed and constructed pavement structure.

Thus a pavement consisting of a few layers of pavements materials is constructed over a prepared soil subgrade to serve as a carriageway. The objective of laying a pavement is to support the wheel loads and to transfer the load stresses through a wider area on the soil subgrade below. Thus the magnitude of stresses transferred to the subgrade soil through the pavement layers are considerably lower than the contact pressure or compressive stresses directly under the wheel load applied on the pavement surface. The reduction in the wheel load stress due to the pavement depends both in its thickness and the charteristics of the materials used in the different pavement layers placed over the soil subgrade.

A pavement layer material is considered more effective, if it is able to distribute the wheel load stress through a larger area per unit thickness of layer. Depending on the vertical alignment and environmental condition of the site, the pavement may be constructed over an embankment, cut or almost at the ground level itself. It is always desirable to construct the pavement well above the maximum level of the ground water or the highest water table, to keep the subgrade soil relatively dry even during monsoon season. The highway pavements are designed and constructed such that road vehicles are able to travel at the design speed without undue discomfort to the occupants and also the pavement structure remain stable.

1.2 Flexible pavement

Flexible pavements are those, which on the whole have low or negligible flexural strength and are rather flexible in their structural action under the loads. The flexible pavement layers reflect the deformation of the lower layers on the surface of the layer. This if the two layer of the pavement or soil sub grade is undulated, the flexible pavement surface also get undulated. A typical flexible pavement consists of four components: soil sub grade, sub base course, base course and surface course. The flexible pavement layers transmit the vertical or compressive stresses to the lower layers by grain to grain transfer through the points of contact in the granular structure. A well compacted granular structure consisting of strong graded aggregates (interlocked aggregates structure with or without binder materials) can transfer the compressive stress through a wider area thus forms a good flexible pavement layer.

1.3 Rigid pavement

Rigid pavements are those which possess not worthy flexural strength or flexural rigidity. The stresses are not transferred from grain to grain to the lower layers as in the case of flexural pavement layers. The rigid pavements are made pf Portland cement concrete either plain, reinforced or pre stressed concrete. The rigid pavement has the concrete slab action and is capable of transmitting the wheel load stresses through a wider area below. The rigid pavement does not get deformed to the shape of the lower surface as it can bridge the minor variation of the lower layer. The stresses in rigid pavements are analysed using the elastic theory, assuming the pavement as an elastic plate resting over an elastic or a viscous foundation. The cement concrete pavement slab is not laid directly over the soil subgrade, considering the desirable long life of cement concrete pavements

2. RECLAIMED ASPHALT PAVEMENT

Removal and reuse of asphalt layer of existing pavement is termed as RAP. However full depth reclamation is defined as removal and reuse of hot mix asphalt layer and entire base course. RAP can be reused immediately at site however it may be stockpiled as the case may be. The required gradation of RAP is achieved by pulverizing the material in crusher. Large quantities of Reclaimed asphalt pavement materials are produced during highway maintenance and construction. A part of this can be used in new hot mix asphalt concrete and rest is available for other uses. If this material could be re used in base and sub-base of the roads, resulting in minimization of environmental impact, reduce the waste stream and also transported cost connected with road maintenance and construction activities. The properties of RAP material can be improved by blending of aggregates and by adding chemical stabilizers. Reuse of this material after proper recycling can be the right solution for the same. There will be reduction in cost about 25 to 30% by reusing the recycled road aggregate generated at same site. A condition of demolished flexible pavement which can be reused after proper processing, and crushed to require size and grading as per requirements of site condition.

3. OBJECTIVES

- To explore the possibilities of using RAP in construction of roads.
- To enhance the properties of RAP using Geopolymer.
- To reduce the cost and amount (quantity) of virgin material by using RAP.
- Utilization of road pavement wastes results in reduction in cost & reduced environmental effect.
- The use of reclaimed asphalt pavement in flexible pavement design also save land which would have been used for dumping of waste RAP.
- The use of RAP for road surfacing can result in reduction of cost by about 25 to 30% (Sireesh & Deepti, 2019).

4. LITERATURE REVIEW

4.1 Sireesh Saride and Deepti Avirneni (2019)

In this study, to enhance the strength and stiffness properties of fly ash stabilized RAP bases, alkali activator is adopted. The RAP was collected from ongoing cold milling operation at the national highway No.5 at Nellore, Andhra Pradesh. In the current study, to develop a sustainable fly ash stabilized recycle base material, initially the alkali-activated fly ash stabilization development of the RAP:VA mixes is evaluated in terms of unconfined compressive strength. The interaction of activated fly ash with RAP:VA mixes in strength gain is presented through Fourier transform infrared spectroscopic and X-ray diffraction. The strength increased was observed with NaOH activation, 4% NaOH showed 15% higher improvement compare to mix with 2% NaOH activation.

4.2 Dongdong Ge, Zhanping You, Siyu Chen, Chaochao Liu and Junfeng Gao (2019)

The determination of asphalt binder performance extracted from RAP, which can be beneficial to the design of asphalt mixture with RAP. The main objective of this research is to investigate the effect of solvent in binder and to determine the actual performance of asphalt binder extracted from asphalt mixture thus improving the efficiency of using RAP. The test carried out are DSE and Fourier transformed Infrared spectroscopy. This method is use to analyze the functional group, the molecular chemical bonds can be detected based on the interaction between the infra-red light beam and the functional group of asphalt binder. Adverse effect on environment may be avoided by using RAP materials in flexible pavement construction. Also observed from the above research paper that the RAP materials in combination to natural aggregate and alkali activator in various proportion increase the strength and durability.

4.3 Dongdong Ge, Zhanping You, Siyu Chen, Chaochao Liu and Junfeng Gao (2019)

In this study, the performance of recycled and rejuvenated asphalt mixture from several field project, across the United State was evaluated considering various recycling agent dosages determined by the contractors. Studies showed that recycling agent addition can reduce the viscosity, stiffness and embrittlement RAP/RAS aged asphalt binders and their ductility. Evaluate the performance of rejuvenated asphalt mixture, field core from each test section was procured and tested and visual distress, materials (raw materials, VA, base binder, recycled aggregate and recycling agent).

4.4 Mustafa Poursoltani and Said Hesami (2018)

In this study, the feasibility of using almost 100% RAP instead of virgin aggregate (VA) was studied according to the microsurfacing mix design tests. Then, 69% and 43% RAP content were also evaluated to determine better result. Sustainability, economic, advantage, reducing environment pollution and preserving natural resource are among the factors encouraging the re-use of RAP. The tests are mix time test, cohesion test, wet stripping test, wet track abrasion test, loaded wheel test to determine bitumen mix content. Among the mixtures containing 95%, 69% and 43% RAP, the one with 69% RAP showed better performance.

4.5 Zhen Leng and Anand Sreeram and Rabindra Padhan (2018)

The reclaimed asphalt pavement was obtained from the highway department, Hong Kong. The RAP binder was extracted using the solvent extraction method as per AASHTO T164. The waste PET water bottles were collected after proper identification, then bottles were cut into small pieces about 5mm by 5mm and dried at 80 C temperature for 4 hours. The main purpose of this study is to investigate the feasibility of using additives derive from waste PET through aminolysis process to improve the performance of bitumen mixture containing RAP. The various laboratory tests are DSR, bending beam rheometer, moisture susceptibility, infrared spectroscopy and fluorescence test. The result indicates that sample containing RAP and PET derived additives increased the rutting resistance by 15% and fatigue cracking resistance by up to 60%.

5. METHODOLOGY

The literature review paper is study on the different areas of transportation engineering. After selecting the area to carry out the research work, the research study was carried out on the highway pavement. The research work was to carry out, which should be beneficial to the society and economic. The main purpose to recycle the waste into existing roads by adding alkali activators to gain high strength. The objective to explore the possibilities of use RAP in flexible pavement. Which result into enhance the strength and reduce the cost of use of virgin aggregate up to 60% and to construct pavement more durable and economic.

The material to increase the strength and durability the flyash and silica fume is used with formation of geopolymer by adding the sodium hydroxide as an alkali activator in reclaimed asphalt pavement to design bitumen concrete surface layer. The RAP was collected from the dumpsite in Morbi. The extraction of RAP was performed manually to breakdown into smaller size stockpiles. And the extraction of binder content is performed at laboratory by centrifuge extractor machine. The laboratory test on the virgin aggregate and bitumen is carried out as per the specification

to check the limits lies properly as per India standard and MORTH classification.

Marshall mix design is carried out on the virgin aggregates, reclaimed asphalt with virgin aggregate and RAP with geopolymer to check the strength and durability and cracking resistance. The comparison of the two different geopolymer mix design, to evaluate the performance which show the good result. By adding geopolymer in RAP will reduced the use of virgin aggregate up to 60%, which reduce the cost and save the land for dumping waste RAP causing environmental pollution.

6. LABORATORY TEST

6.1 Test for virgin aggregates

Table -1: Test result for virgin aggregates

Test	Result	Specification	Method of test
Combined Flakiness and elongation index	22.75 %	Max 30%	IS:2386 Part I
Impact value	11.33 %	Max 30%	IS:2386 Part IV
LOS Angeles abrasion value	24.7 %	Max 30%	IS:2386 Part IV
Crushing value	20.9 %	Max 30%	IS:2386 Part IV
Water absorption	0.25 %	Max 2%	IS:2386 Part III

6.2 Aggregate gradation for Marshall stability test

Ratio for grade II bitumen concrete layer.

10 mm = 27 %

6 mm = 36 %

Stone dust = 37 %

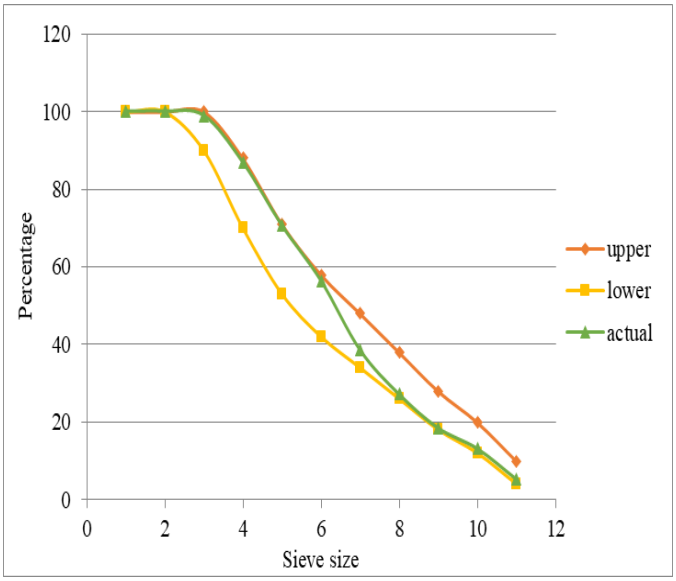
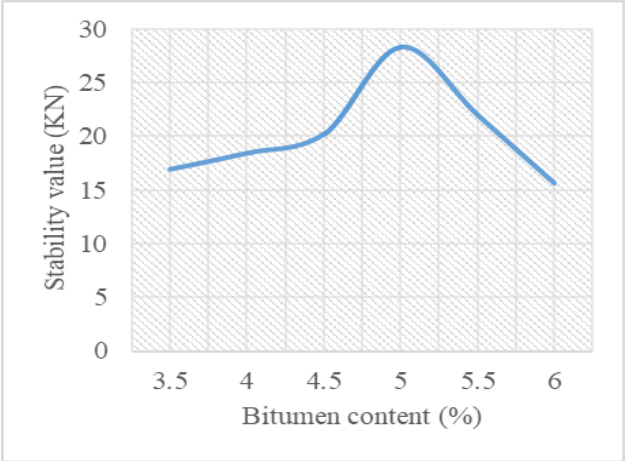
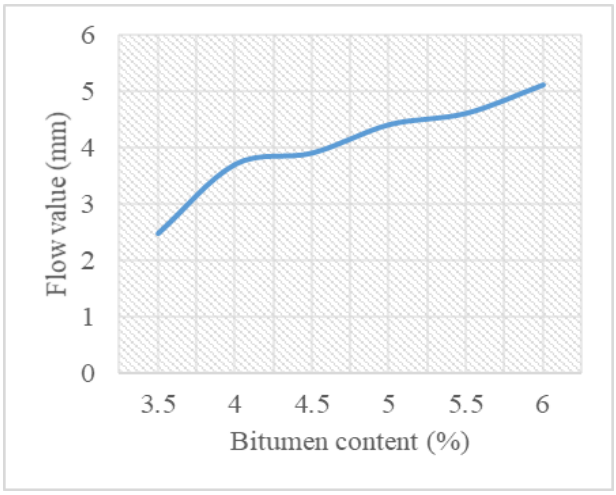


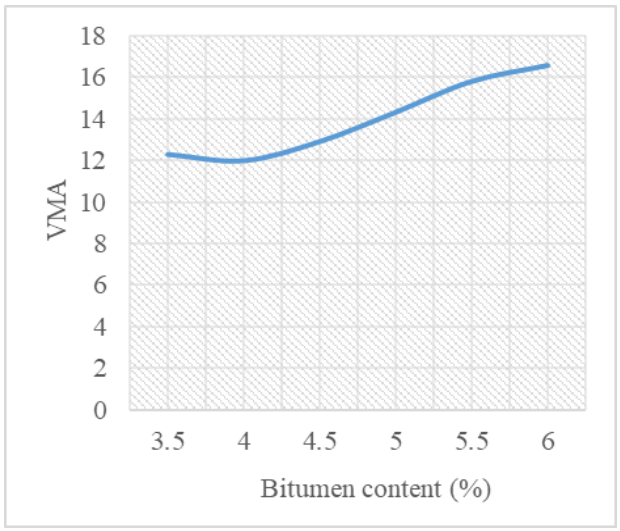
Chart -1: Graph percentage Vs Sieve size

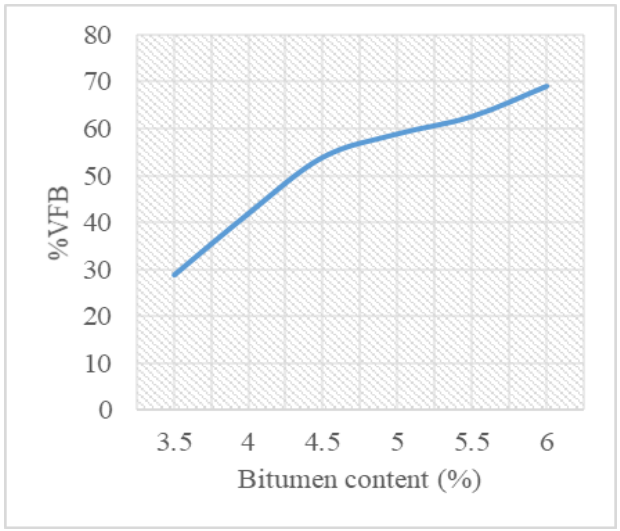
6.3 Marshall stability test for Virgin aggregate

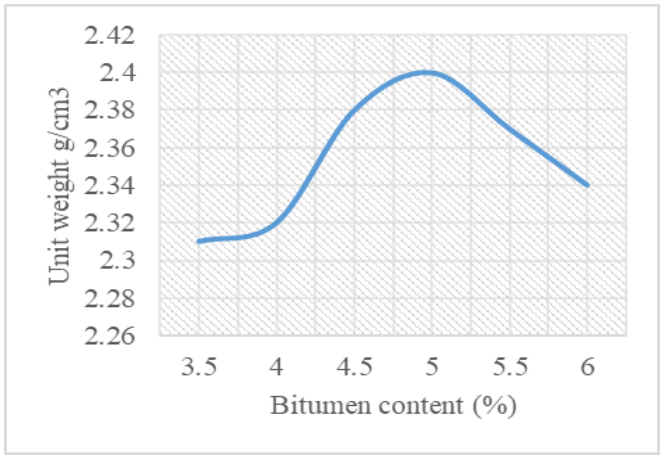
The Marshall stability test was performed on the virgin material and the optimum bitumen content value was obtaining from the test. The optimum bitumen content later used for the Marshall mix design with RAP and geopolymer.











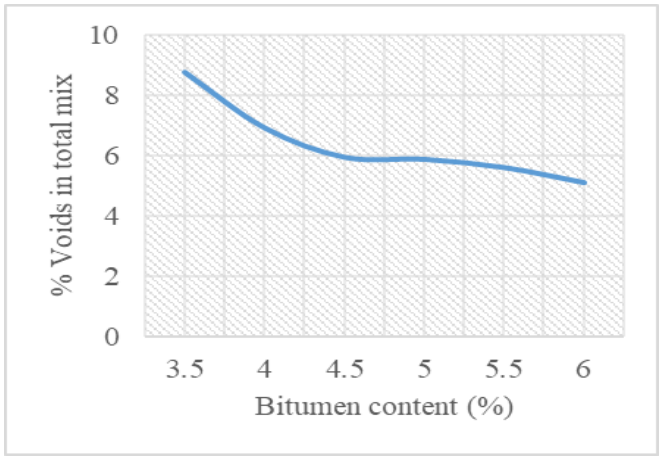
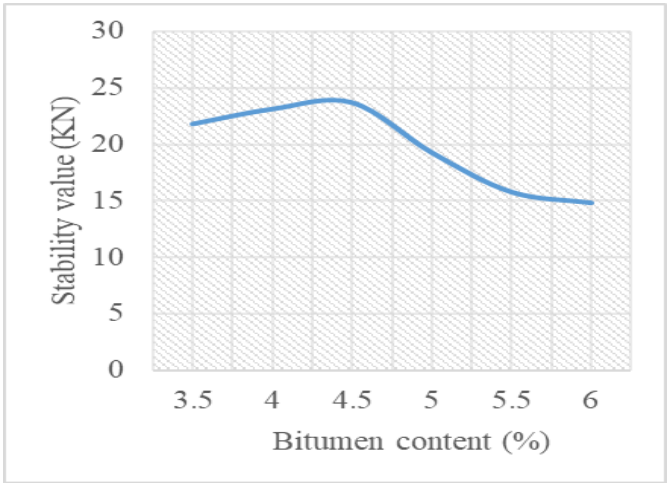
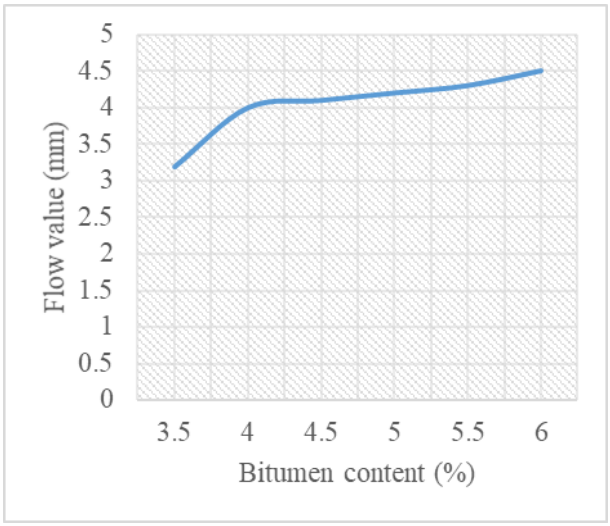


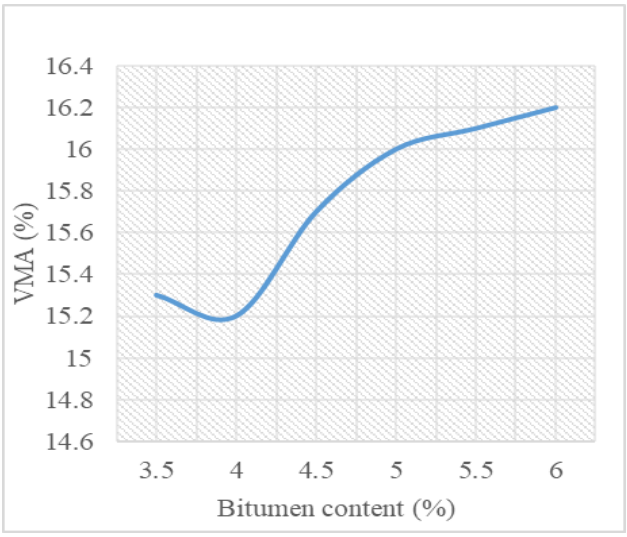
Chart- 2: Marshall curves test for Virgin aggregate

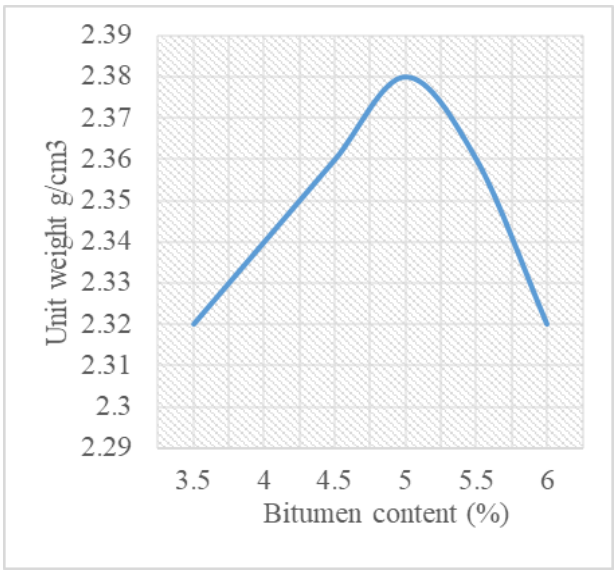
From the above Marshall stability test for virgin material the Stability and flow value is maximum at the Optimum binder content 5%.

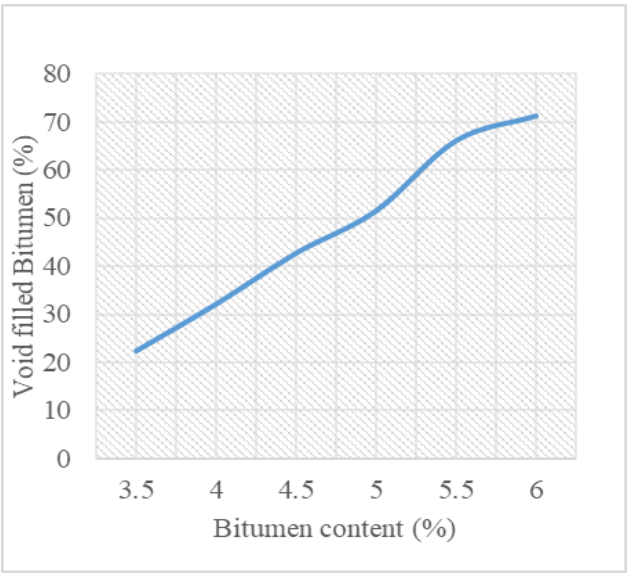
6.4 Marshall stability test for Virgin aggregate with Reclaimed asphalt pavement











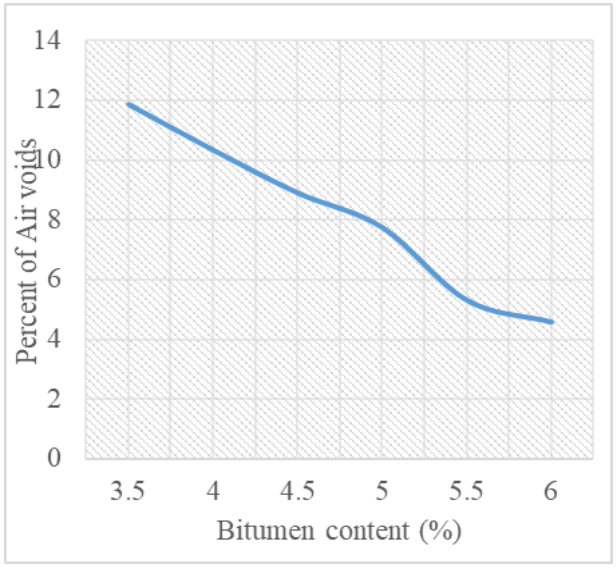


Chart-3: Marshall curves for Virgin aggregate with RAP

From the above Marshall stability test for virgin material the Stability and flow value is maximum at the Optimum Binder Content 4.5%.

6.5 Requirements for the mix as MORTH

Apart from conformity with the grading and quality requirements for individual ingredients, the mixture shall meet the requirements set out in below table.

Table-2: Requirements for the mix of BC layer as per MORTH

Properties	VG paving bitumen	Modified bitumen	
		Hot climate	Cold climate
Compaction level	75 blows on the each face of specimen		
Minimum stability (KN)	9	12	10
Marshall flow (mm)	2-4	2.5-4	3.5-5
Marshall quotient (stability/flow)	2-5	2.5-5	
% air voids	3 - 5		
% VFB	65 – 75		
% VMA	11 - 13		

7. CONCLUSION

RAP is a valuable, high-quality material that can replace more expensive virgin aggregates and binders. The most economical use of RAP is in asphalt mixtures. Studies demonstrated that untreated RAP is inefficient to be used as a pavement material unless blended with virgin aggregates (VA) and stabilized with additives, because of their inferior gradation and bonding characteristics. The outcome from this research confirms the viability of using RAP: SF blend and RAP with geopolymer as alternative sustainable pavement materials. Strength and stiffness properties of RAP:VA are enhanced by stabilizing them with silica fume and alkali activator. By using nomenclature of 60VA:40RAP can save 25% cost of materials. The quantity of virgin materials is saved by 40%.

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