Use of Reclaimed Aggregates in Flexible Pavement

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Abstract: A strong road system is essential for a nation's economy to develop quickly since it connects outlying locations to the rest of the country for use in many types of transportation. Reclaimed asphalt pavement (RAP) is a suitable substitute for virgin material since it lessens the requirement for virgin material. In this investigation, sample of recovered asphalt pavement was gathered and examined to determine whether it would work well as flexible pavement. In this experimental study, bituminous concrete mixtures containing 10%, 20%, 30%, 40%, 50%, and 60% RAP material were the focus. These mixtures were made by scarifying bitumen like VG-30, fresh surface aggregate, and damaged existing asphalt paving without the addition of any additives. In this research, the RAP to new aggregate rates were 10:90, 20:80, 30:70, 40:60, 50:50, and 60:40. RAP mix was the subject of several laboratory tests, including the Marshall Mix design and many other Physical Properties tests, this paper presents a comprehensive investigation into the behavior of asphalt mixtures with varying proportions of RAP. Ultimately, guidelines derived from reference samples are proposed to facilitate the use of higher RAP proportions and determine the optimum value for modified samples.

Keywords**:** *RAP, Asphalt, Strength properties, Marshall Test, Aggregates characteristics*

1. Introduction

The term "recycled asphalt pavement" (RAP) refers to pavement made of aggregates and asphalt. In order to get it, asphalt pavements are usually removed in order to access subsurface utilities, rebuild, or resurface. [1] In order to produce fresh asphalt, recycled asphalt pavement is now widely used and the leading approach. As technology has advanced, so too has the use of Recycled Asphalt Pavement (RAP), providing a range of ways to integrate RAP into already-existing pavements. Studies that compare the properties of hot mix asphalt with and without RAP show that when it comes to rutting, weathering, fatigue, and cracking, the two types of asphalt are comparable. These materials are also used in the base and granular sub-base layers of flexible pavements. [2] The mixing of aggregates and the use of chemical stabilizers can improve the qualities of RAP materials. Due to a lack of accessible landfill space, the amount of garbage from reclaimed asphalt pavement has increased recently, creating difficulties for waste disposal. Reusing and recycling these materials can offer a workable alternative, with the potential to save expenses by 20% to 30% when the recycled material is utilized again at the same location. [3] Before using such materials, it is crucial to examine their mechanical properties and make sure they are blended properly. Different percentages of recycled asphalt have been studied by a variety of researchers. To ascertain the ideal proportion for road building, this work particularly examines a range of recycled asphalt, from 10% to 60%.

Producing Natural Aggregates, which also significantly consume and deplete natural resources, is one of the factors contributing to a rise in hazardous emissions. RAP (Recycled Asphalt Pavement) refers to the detached materials from asphalt pavements that contain bitumen and Aggregates. These materials are obtained when existing asphalt pavements are removed for various purposes such as resurfacing, reconstruction, or accessing buried utilities. [5] The use of RAP has become a common practice in producing new asphalt, leading to reduced construction costs and environmental impacts by reusing existing pavement. With advancements in technology, various methods have been developed for using RAP. [6]India's rapid urbanization is already having an impact on the enormous need for aggregates. In addition, the difficulty of opening new quarries is increasing because of concerns about pollution. Transporting aggregate across long distances increases fuel expenditures and pollutants. As a result, the decrease in the availability of natural aggregates has a significant impact on both the environment and prices. [5] Focusing on material preservation, reuse, and recycling has led certain governments to employ recycled materials while maintaining strength, resulting in considerable material, monetary, and energy savings. Its importance expands given the rise in bitumen costs, the scarcity of premium aggregate, and the emphasis on environmental

Preservation. Aggregates made from recycled resources are today's materials. It has been found that hot mix asphalt without RAP exhibits similar qualities to hot mix asphalt with RAP in terms of rutting, raveling,

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weathering, fatigue, and cracking. In recent years, the amount of waste has gradually increased, resulting in waste disposal problems due to limited landfill space. Reusing these materials through proper recycling can be a viable solution. Reusing recycled materials generated on-site can lead to cost reductions of about 25% to 30%. However, before utilizing such materials, their mechanical properties must be tested, and appropriate blending should be performed if necessary. [8]Researchers have chosen different percentages of recycled asphalt in their studies. In this work, a range of 10% to 60% recycled asphalt is considered to determine the best percentage for road construction. If necessary, admixtures are used to further enhance the optimal percentage, which is then finalized for use in a National Highway. Admixtures play a crucial role in construction projects as they can significantly alter the properties of bitumen at higher levels. By utilizing these materials, the issues of waste disposal can be addressed while also improving environmental conditions. RAP also helps the environment by lowering the demand for natural resources and cutting back on trash production. The burden on landfills is lessened by recycling and reusing asphalt materials, resulting in a sustainable method of waste management. Reducing the Utilization of virgin resources is one of the main advantages of RAP. [7]The need for fresh aggregates and bitumen is greatly decreased by recycling the materials now used in asphalt pavement construction. Additionally, recycling asphalt eases the load on landfills by reusing old asphalt that would have otherwise been dumped in the building sector. Reclaimed asphalt pavement has several limits, despite the advantages it offers. Depending on how well-maintained and old the original asphalt was, the recycled material's quality may change. For the recycled pavement to operate and last as long as possible, proper testing and quality control are crucial. Furthermore, the utilization of RAP aligns with the principles of the circular economy, which emphasizes the reuse and recycling of materials. By reintroducing recycled materials like RAP into the production cycle, the construction industry reduces the reliance on extracting and processing new materials. RAP has important environmental advantages as well. Reusing materials lowers the demand for new materials and conserves natural resources, which lowers the greenhouse gas emissions related to the extraction and transportation of new materials. [10] Additionally, the use of RAP lessens trash production and the need for landfill space, reducing the environmental effect of disposing of asphalt pavement. The global regulatory support for RAP is a reflection of the increasing awareness of its advantages. Policies, rules, and specifications promoting or requiring the use of RAP in road building projects have been put in place by governments and regulatory agencies. In the modern era, it is becoming increasingly crucial to eliminate waste materials like recycled asphalt pavement. Thus, reducing material and energy costs as well as overall job costs is the primary goal of this study. As part of RAP, materials are reused, resulting in a reduction in the total cost. The RAP material contents can be reused to make the best use possible of the available natural resources. Their disposal in landfills could potentially be prohibited in the future. Sustainable development can be achieved by recycling asphalt. [11] Various environmental impacts are also lessened as a result of it. Disposing of recyclable items is subject to more limitations nowadays.

The main objective of the study is to compare the physical properties of recycled aggregate with the virgin aggregate by performing various test including Impact value test, Crushing test, LOS Angeles Abrasion, Water Absorption and Aggregate Specific Gravity and also to To determine the optimum percentage for the reclaimed aggregate and virgin aggregate mix which can give the maximum values of stability, flow value so that we can use that proportion of reclaimed aggregate mixed with virgin aggregate in the construction of flexible pavement

2. Material and Methodology

2.1 Material

Aggregates

The gradation of Aggregates employed in the study was selected to comply with the IRC 90:2010 and MORTH norm. The aggregates was supplied by a local contractor from Chandigarh. Bitumen mix uses a coarse aggregate that is 12.5 mm in size, 10 mm in size, and 6.3 mm in size for crushed stones that are held on 4.75 mm sieves. Small particles, typically between 75 micrometers (0.075 mm) and

4.75 millimetres in size, make up fine aggregates. They are coarser than silt or clay but finer than coarse particles.


Figure 1: Test results of Virgin Aggregate

Table 1: Test Result of Virgin Aggregates

Test on Aggregates	Test Values	As per MORTH
Impact Value	23.39%	27% Max
Crushing Value	22.90%	24% Max
LOS Angeles Abrasion	27.08%	30% Max
Water Absorption	0.92%	2% Max
Aggregate Specific Gravity	2.76	2.5 Min

Bitumen

Bitumen can be produced artificially or as a byproduct of the petroleum distillation process the market offers a variety of grades, including VG 10, VG 20, VG 30, and VG in its diverse properties. But since the experiment is being conducted on a national highway with a large traffic volume, VG 30 grade bitumen is used as a binder content for the study, the VG 30 Bitumen procured from Jai Bitumen, Industrial Area Phase 2, Chandigarh, the physical properties of bitumen were analysed as per IS:73 2006.

(a) (b) (c)

Figure 2: Physical test of bitumen:

(a) Penetration Test, (b) Softening Test,

(c) Ductility Test

Table 2: Physical Properties of Virgin Bitumen

Test on Bitumen	Test Result	As per IS:73 2006
Penetration test	54	50-70(mm)
Softening Point	48.7	47 Min
Ductility Test	80.60	75mm Min
Specific Gravity	1.03	1.01-1.06

RA (Reclaimed Aggregates)

To substitute natural aggregates, enormous amounts of refuse generated partly or entirely by the building industry must be collected and transformed into recycled aggregates (RAs). Recycling reduces waste and energy use, which improves the environmental friendliness of the construction industry. The significance of recycling and the current condition of the world is emphasized in it. The sample is collected from NH-5 Chandigarh-Ludhiana highway. Physical property tests were conducted on the aggregates reclaimed after bitumen extraction, extracted with the help of a Bitumen Extractor Apparatus from waste remaining from repaired roads

Figure 3: Sample of Reclaimed Aggregate using Bitumen Extractor Machine

Table 3: Test Results of Reclaimed Aggregates

Test on RA	Test Result	As Per MORTH
Impact Value	19.90%	27% Max
Crushing Value	19.46%	24% Max
LOS Angeles Abrasion	24.95%	30% Max
Specific Gravity	2.68	2.5 Min
Water Absorption	1.26%	2% Max

Benzene

Benzene is a hydrocarbon compound with the chemical formula C6H6. It is a colorless, flammable liquid with a characteristic sweet odor. What distinguishes benzene is its hexagonal ring structure, which gives it the status of the simplest aromatic hydrocarbon. This ring is highly stable due to resonance, making benzene a fundamental organic compound. its primary role lies in the chemical industry, where it acts as a vital feed stock for the production of various chemicals, including plastics, synthetic rubber, dyes, and pharmaceuticals. Despite its importance in chemical synthesis, stringent safety measures are in place to minimize exposure to this hazardous substance. Here, the recycled aggregates are separated from the RAP using benzene.

Figure 4: Benzene

2.1 Methodology

The stage that is being discussed is a critical stage in any project, when the completion of tasks is essential to following the guidelines and guaranteeing the effectiveness and quality of the finished output. The first step in the process is to put the virgin aggregate through a series of physical tests, such as the aggregate specific gravity test, water absorption test, impact test, crushing test, and LOS (L.A. Abrasion) test. These tests are essential for determining the aggregate's basic characteristics, including its strength, durability, and appropriateness for use in road building. After the virgin aggregate is evaluated, focus shifts to the bitumen physical tests (VG 30). These tests, which include the Penetration, Softening Point, Ductility, and Specific Gravity tests, offer crucial information on the properties and functionality of the bituminous binder. The aggregates are next graded using the Rothfuchs Balance Area Method, which is a careful procedure that is necessary to obtain the appropriate particle size distribution in the finished mix. By ensuring that the aggregate particles are packed and interlock optimally, this approach improves the mechanical qualities of the asphalt mixture. Reclaimed aggregate is taken out of Recycled Asphalt Pavement (RAP) using a bitumen

extractor and a hydrocarbon chemical like benzene as the project explores sustainability. This procedure minimises waste and lessens the impact on the environment by enabling the effective use of recycled resources. The Marshall Stability Test, a thorough assessment technique used to ascertain the optimum binder content (OBC) required to guarantee the endurance and longevity of road materials, is the next vital stage. This test is crucial for determining the asphalt mixture's strength and stability under simulated traffic and environmental scenarios. To investigate sustainability even further, combinations are mixed with varying amounts of recycled asphalt (10% to 60%). This wide variety of ratios—10:90, 20:80, 30:70, 40:60, 50:50, and 60:40 makes it possible to conduct a thorough investigation of how recycled elements affect the asphalt mix's performance. Using the Marshall test, the flow characteristics and stability of these mixes are carefully assessed, yielding vital information needed for well-informed decision-making in road building. The project intends to advance the use of ecologically friendly road building techniques by determining the ideal mix ratio that strikes a balance between sustainability, performance, and cost-effectiveness through this thorough assessment procedure.

2.1.1 Roth Fuchs Balance Area Method

Then Roth Fuchs method is well-liked method and is regarded as one of the best graphical techniques in many other countries. It is reasonably quick and simple, and it can be used for mixtures of any number of aggregates. This technique is utilized when a lot of materials need to be combined to obtain the proper gradation.

Table 4: ***Aggregate Percentage used for Marshall Sample.***

Aggregate Size Used	Percentage retained	Percentage passing	As per MORTH (tableno .500-17)
19	0	100	100
13.2	2.15	97.85	90-100
9.5	22.04	77.96	70-88
4.75	34.72	65.28	53-71
2.36	47.06	52.94	42-58
300 mic.	79.29	20.71	18-28
75 mic.	94.21	5.79	4-10

2.1.2 Bitumen Extractor

To ascertain the bitumen binder utilization in the asphalt pavement by cold dissolver technique, the ASTM D 2172 bitumen extraction test is used. To calculate the percentage of bitumen content in the asphalt pavement, a bitumen extraction test is used.

After the paving project is finished, a particular bitumen sample needs to be collected.

Figure 5: Bitumen Extractor

2.1.3 Marshall Stability

A common test method for bitumen mix design is the Marshall Test, which was developed in 1940 by Bruce Marshall of the Mississippi State Highway Department. This automated tool evaluates the bitumen blends' flow and stability properties. It has a load cell built in that applies force to the bitumen sample, and the resulting results for flow and stability are presented right away on a digital readout.

Procedure of Marshall Stability Test

To prepare the Marshall Sample, the specified amounts of coarse aggregate, fine aggregate, and filler were placed in a designated pan and subjected to preheating in an oven at temperatures ranging from 154 to 160°C. This preheating step ensures that the aggregate and

Bitumen can be thoroughly mixed while in a heated state. And concurrently, a mixture of virgin bitumen and

recycled bitumen, blended at various proportions (10%, 20%, 30%, 40%, 50% and 60%), was heated to its melting point prior to the mixing process.

The heating range for this mixture was set between 175°C and 190°C.

The mould assembly is thoroughly cleaned before compaction, and the mould itself goes through a preheating procedure. The required bitumen content is methodically incorporated into the aggregates while they are precisely combined on a hot plate. Until the mixture reaches a temperature of 160°C, it is continually stirred.

Figure 6: Mixing of Bituminous Material

Figure 7: Compaction of the Mix

The complete mixture is then transferred into the casting mould, which has been positioned on the Marshall Compaction pedestal the mixture is subjected to compaction using 75 blows of the hammer on one face, after which the sample is inverted and subjected to an equal number of blows on the opposite face. After compaction, the sample and mould are left to cool for a number of hours. After that, the sample is taken out of the mold and left at ambient temperature for 24 hours. The sample is maintained in a water bath with a temperature of about 600C for 30 minutes prior to testing.

Figure 8: Marshall Sample

The sample is loaded vertically at a rate of 50 mm per minute, and the maximum load is applied up until the sample fails, at which point the Marshall Stability Value is recorded. Three specimens are made from the samples of recycled asphalt created at various proportions so that the average value for one percentage may be determined.

3. Result and Discussion

Aggregate are utilised in the production of asphalt concrete, conventional cement concrete, and other composite construction materials. They are also known as building aggregates in technical parlance. All these aggregates are, in essence, are groups of distinct materials with different proportions, forms, and other necessary characteristics. Aggregates can make up between 60% and 75% of the volume of composite building materials, such as concrete. As a result, their individual characteristics greatly influence the composite materials' overall characteristics. Tests of the physical characteristics including impact test, crushing test, Los Angeles test, water absorption and the aggregate specific gravity test of both virgin and recycled aggregates have been completed, and the comparative results are shown.

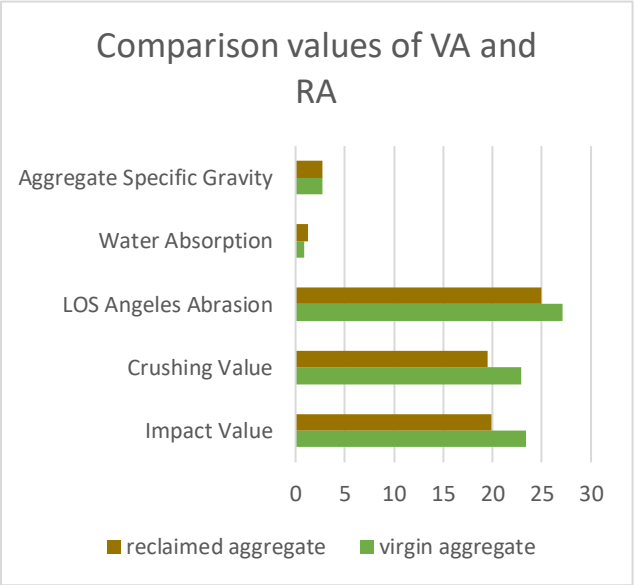

Fig 9: Comparison Values of VA and RA

Reclaimed aggregates go through a transformation process that modifies their physical characteristics. They are obtained from recycled materials from RAP that has been destroyed. In general, these qualities are reduced by around 3% to 6% in comparison to virgin aggregates. Particle size distribution, shape, consistency, and overall structural integrity are all considered in this decrease. The water absorption capacity of recycled aggregates shows a substantial variation despite this decrease in physical properties. The water absorption of recycled aggregates is around 1.26% greater than that of virgin aggregates

The ASTM Test technique for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus will be followed to prepare and compress samples with bitumen content that is adjusted by 0.5% increments for the Marshall technique. It is decided to use the grade 2 bituminous concrete that MORT&H has requested. We will use the VG-30 bitumen additive. Prepare a 1200 g bituminous combine sample. A pan is used to gather the necessary amount of aggregates, which is then stored in an oven set to 175°c. The asphalt was heated to its melting point and maintained in the oven during preheating at between 100 and 150 °C., now The specimens will be compressed on each side using 75 blow, sample is now allowed to cool down for 30 minutes at 60°C at room temperature.

Table 5: Marshall Stability of BC grade 2 for Virgin Aggregates.

BITUMEN%	5%	5.5 %	6%	6.5 %	MORTH SPECIFICATION Table no.(500-11)
Air voids	4.24	4.13	4.07	4.02	3-5
VMA	15.76	15.72	15.70	15.73	Min 15
VFB	73.09	73.72	74.07	74.44	65-75
Marshall Stability	1372	1395	1420	1406	Min 900
Flow value	3.15	3.45	3.62	3.84	2-4%

From the above calculation of the Marshall sample, the stability value is max. at 6% bitumen and after that it started decreasing, also the value of the optimum bitumen content is found to be 5.8 % and on the basis of optimum bitumen content, we have done mix proportion of virgin material with reclaimed aggregates at different RA percentage, moreover at 0% RA we perform the test of Marshall on virgin aggregates at optimum bitumen content of 5.8%.

TABLE 6: Mixing characteristics of virgin material with varied percentage of recycled aggregate

PROPERTIES	0% RA	10% RA	20% RA	30% RA	40% RA	50% RA	60% RA	MORTH
Air void	4.38	4.25	4.22	4.21	4.18	4.16	4.15	3-5
VMA	16.65	16.39	16.46	16.54	16.6	16.43	16.20	MIN 15

VFB	72.97	72.54	72.47	72.43	72.53	72.18	71.79	65-75
Marshall Stability	1408	1302	1294	1272	**1315**	1292	1280	MIN 900
Flow Value	3.49	3.46	3.26	3.34	**3.44**	3.12	2.91	2-4 (mm)

From the above results it is very clear that the from the 10 % to 60% RA, the 40% of Recycled Aggregates mixed with 60% virgin aggregate percentage is the best to be used in mixtures as it gives better stability value and the flow value

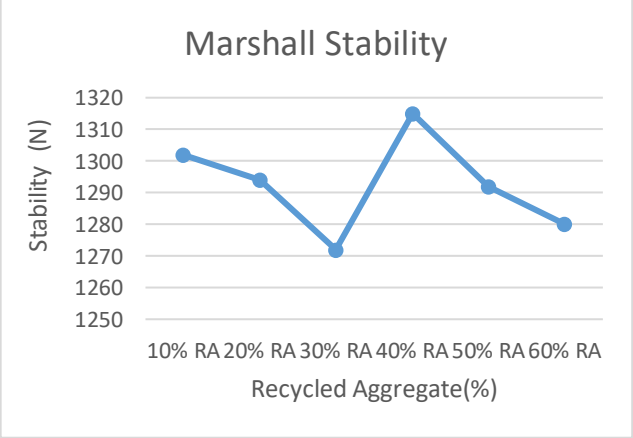

Fig 10: Marshall Stability for Reclaimed Aggregates

As some smooth, rounded aggregates are present in the mix, the shear resistance of the mixture diminishes, which eventually leads to a decrease in stability. [10] Additionally, it is reported that the value of Marshall Stability increases by 0.98% up to 40% RA from

1302 (RA 10%) to 1315 (RA 40%), and subsequently decreases from 1315 to 1280 (RA 60%) as the RAP increases from 10% to 60%.The stability value reaches its maximum stability value when the recycled percentage approaches 40%.

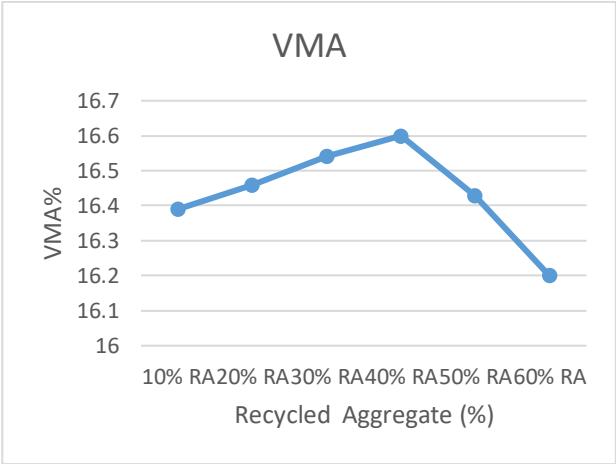

Fig 11: Volume of Mineral Aggregates (VMA) for Reclaimed Aggregates

It is shown that when the RAP percent increases, the voids in mineral aggregate also increasing. This occurs because the old, ineffective bitumen in the aggregate pores keeps the virgin bitumen from penetrating the aggregate pores deeply. [11] The value of VMA increases from 16.39 (RA 10%) to 16.60 (RA 40%) and then decreases from 16.60 to 16.20 (RA 60%) by 1.25% up to 40% RA.

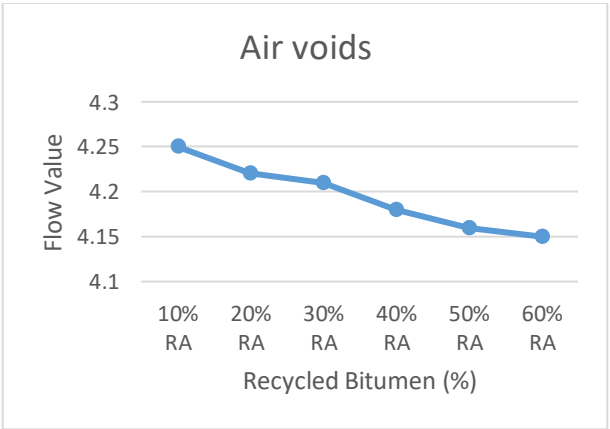

Fig 12: Air Voids for Reclaimed Aggregates

Total air voids in a mix are thought to be a crucial feature in bituminous mix design. About 3% to 5% of the total mix volume is the maximum amount of air voids that can be present in a mixture. [11] In the event that the air spaces are less than 3%, bitumen will bleed.

Furthermore, the pavement will be brittle and unstable if the percentage of air voids in the mix is higher than 5%. The bituminous binder is therefore a highly delicate component. The air void value is decreasing in sequence, falling from 4.25 (RA 10%) to 4.15 (RA 60%) by 2.35%. The old bitumen that has filled the aggregate pores and reduced the percentage of voids is the cause of this issue.

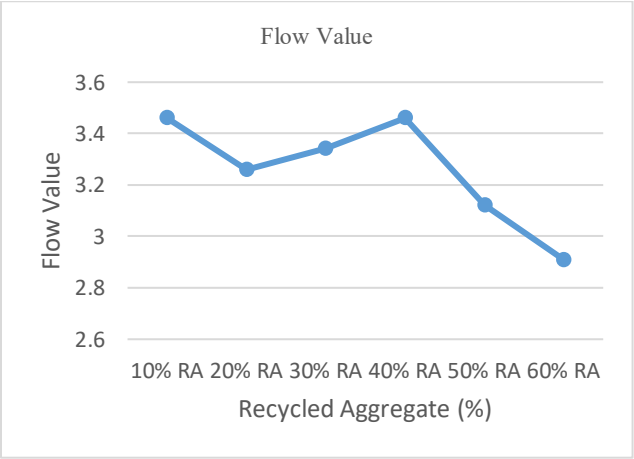

Fig 13: Flow Value for Reclaimed Aggregates

Due to the hot asphalt mixtures' lower stiffness, flow values first decrease and then started to increase From 3.46 (RA

10%) to 2.91 (RA 60%), the flow value has dropped by 18.9%.

5. Conclusion

About 40 billion tonnes of natural aggregates are physically mined annually to supply the demand and sustain the growth of the built environment worldwide. [3] According to the outcome of this study, Reclaimed aggregates that are extracted from the Reclaimed Asphalt Pavement can be used in the construction of the Flexible Pavement as the Physical properties Test results limits of reclaimed aggregate is under the MORTH specifications and it has been shown that using recycled aggregates in the construction of flexible pavement can decrease the amount of huge extraction.. The following are the study findings:

- The physical properties of reclaimed aggregates reduce to 3-6 % as compared with virgin aggregates, but the value of water absorption of reclaimed aggregates is more than virgin aggregates by 1.26%. The presence of asphalt binder on the surface of the recycled aggregates is one of the causes of this increase in water absorption. These residues help the aggregate particles retain more water due to their improved porosity and the results obtained for the reclaimed aggregates for physical properties is under the MORTH specification.
- As compared to varying percentages from 10% to 60% RA, the results show that using 40% recycled aggregates (RA) in mixes offers best stability and flow characteristics. By maintaining a balance, this proportion most likely decreases the adverse effects that may arise depending on a greater or lower RA concentration. The mixture's resistance to deformation
is shown by the stability value, and its workability is indicated by the flow value. It is clear that the 40% RA composition provides a balance, optimising the advantages of using recycled materials while retaining the mixtures desired quality requirements.

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