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Characterization Of Soil For Road Shoulders Mixed With Reclaimed Asphalt Pavement Waste

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Abstract: The use of recovered asphalt pavement can reduce the amount of new bitumen and aggregates used in pavement construction and rehabilitation (RAP). RAP is a waste product that results from the removal of an old or damaged pavement surface. Although it has been used since the 1970s, and numerous recommendations for using RAP in the new mixture have been made, there are only a few research available. Because the materials used are recycled, it is also cost-effective and environmentally friendly. The purpose of this study is to characterize soil that has been blended with reclaimed asphalt pavement (RAP) for use on the local road shoulder. RAP is one of the rehabilitation procedures used to repair a deteriorated surface by removing the upper pavement and replacing it with new pavement. According to earlier study, mixing dirt with different materials improves the finding. The goals of this study are to establish the material qualities of soil and RAP, determine the optimum moisture content of material and degree of compaction for road shoulders, and determine the appropriate mix proportion of soil and RAP for road shoulders using the California Bearing Ratio (CBR) test. The Atterberg limit, liquid limit, and plastic limit for soil were evaluated on a sample of soil and RAP. For soil and RAP, a sieve analysis was performed. Compaction tests for soil and RAP were carried out with a mixture of 10S, 2S8RAP, 4S6RAP, 6S4RAP, 8S2RAP, and 10RAP, as well as CBR tests for soil and RAP. . According to the results of the laboratory test, 20% of RAP (8S2RAP) had a better mixed proportion for the road shoulder. As a result, repurposed materials like as RAP can be used as a road shoulder material.

Keywords: Reclaimed, Asphalt, Soil,Road.

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1. INTRODUCTION

Since the events of September 11, 2001, there has been a street framework in Afghanistan connecting Kabul with the province's essentially alternate urban regions. The efforts to improve the street system have been done appropriately and through the quick improvement arrangement, particularly the provinces Plan at regular intervals which were promoted by the Afghan government. After the US force entered Afghanistan, the world paid attention to Afghanistan reconstruction.

The US and NATO governments spend a lot of money building streets in Afghanistan in accordance with requirements, advance planning, and street solidness requirements that depend on a variety of factors. The flexible asphalt is typically recommended for use for ten to fifteen years in asphalt plans. In order to ensure quality and improve the street's usability, the recovery and support activities are absolutely essential.

Nowadays, the development sector offers maintainability a more significant attention. The methodologies used in development, the planning processes, the technology, and the materials used in development are only a few of the many factors that contribute to economic progress. As technology and the use of conventional resources grow, so do interest in bitumen and the overall cost of material development.

Asphalt pavement reuse has become a common activity in the transportation industry. The environmental, financial, and societal benefits are frequently cited as motivations for reuse. By wisely using common resources, the use of Reclaimed Asphalt Pavement (RAP) in the construction of new roads aligns with the broader goal of sensible transformation (Hoppe et al., 2015).

Bituminous pavement recycling is not a novel concept, but it is one of the options that supports sustainability while also lowering construction and material costs. The 1970s saw advances in recycling machinery and technology. It lowered the amount of waste that was routinely dumped into landfills, maintained the environment, reduced building costs, and improved the efficacy of the pavement overall (Asphalt Recycling and Reclaiming Association, 2001).

Using salvaged asphalt pavement is one of the common ways to recycle bituminous materials (RAP). RAP, or reclaimed asphalt pavement, was taken out of service via milling or full-depth removal. In view of the rising expense of asphalt and the necessity to protect the environment, using RAP has been preferred over using virgin materials. The use of recycled asphalt also lessens trash generation and aids in the solution of the issue of how to dispose of materials used in highway building.

1.1 Background of study

In order to meet the needs of road users, there is a significant need for new roads to be built as well as upgrades to existing ones. This expansion in road building and rehabilitation improves the workability of roads while accelerating socioeconomic development. Road construction has significantly aided in economic expansion and the eradication of poverty (Fan and Chan-Kang, 2005).

But one issue that frequently arises during road building and needs to be changed or repaired is pavement deterioration. As a result, road surface development, upkeep, and restoration are issues that are becoming more and more crucial both in Slovenia and around the world. In addition to the volume of traffic, additional elements that affect the longevity of roads and their durability include local weather conditions, road design, and the quality and performance of the materials used in their construction (Ossa et al., 2016).

Due to this circumstance, the road repair and reconstruction business has supported the disposal of road trash, consumed vast amounts of raw materials, and produced enormous volumes of waste while building and demolishing roads, walkways, and bridges. The main components of this waste are bitumen grinding, aggregate, and mortar.

1.2 Problem statement

Our natural resources have been plundered in recent years by the construction industry, which inevitably led to environmental damage. If there is constant demand for construction materials, which causes the depletion of natural resources and an increase in waste materials, contractors who lack environmental awareness have irreparably harmed the environment by disposing of waste materials.

In order to withstand expected loads over the course of the road's design life, pavements are specifically constructed for them. Concrete pavements come in a variety of types, from flexible to semi-stiff to hard. The pavement will erode and sustain surface damage after a number of years of use. In order to get out of this condition, restoration and maintenance can halt but not stop pavement deterioration.

It has been determined that recycling bituminous pavement materials is the best way to reduce the use of natural resources and address the problems associated with waste disposal. RAP can now be added to the combination for the first time, according to numerous research. For instance, only a few locations in the US have effectively implemented RAP in the on-site pavement mixing (Federal Highway 4 Administration, 2016).

However, researches continue to come to differing conclusions about the performance of RAP, particularly with the proper dosage of RAP to be added to the combination. For instance, Yang and Lee (2016) recommended that RAP make up less than 25% of the whole combination, although other researchers asserted that with correct handling, larger RAP content might still perform as well as the conventional mixture (Poulikakos et al., 2014).

By adding or replacing components in the current pavement structure, rehabilitation is required to address the consequences of deterioration. Resurfacing is one of the pavement rehabilitation techniques that involves adding new materials to an existing surface in order to strengthen the surface's structural integrity and enhance the way it rides.

Milling waste is the byproduct of renewing pavement or wearing course. By carrying out this resurfacing, a new issue will develop since milling debris is seen as a waste product from work done to restore the existing pavement. Because milling waste is a hazardous waste and cannot be disposed of, it poses a problem for road building and rehabilitation. The additional issues with milling are piles of waste at specific construction sites and dumping by the side of the road. According to this study, recycling milling waste for use in road shoulders will lessen roadside dumping and the stockpile of milling waste.

1.3 Aim and objectives

The following objectives of this investigation were to determine the bituminous mixture:

i. To determine the soil and RAP's material qualities.
ii. To deternine the ideal material moisture content and level of compaction for the road shoulder.
iii. To determine the optimum mix proportion under California Bearing Ratio (CBR) test for road shoulder.

1.4 Scope of the study

This study's objectives were primarily to be accomplished through experimental work. The testing processes and methodologies were established in accordance with those advised by the British Standard Institution, along with some that had been suggested by earlier studies.

1.5 Significance of the study

The importance of this study lies in its emphasis on the use of recovered asphalt pavement (RAP) as a material for the road shoulder as well as on RAP's great capacity to improve its qualities. In addition, this study offers trustworthy experimental data because there haven't been many studies on RAP for road shoulders. The information and data from this study can be used for subsequent research and may aid another researcher in defining the needs and specifications for the development of the road shoulder. Additionally, because RAP is used in road shoulders and can prevent milling waste from being dumped along the side of the road, the cost of road shoulder construction can be decreased. Additionally, employing RAP as road shoulder materials will lessen the need for using natural resources like aggregate and sand, which are extensively used in the building sector.

2. MATERIAL AND METHOD

As part of an integrated transportation system, roads will be developed as a safe and dependable mode of transportation that will benefit society, promote economic growth, and facilitate the free movement of people, products, and services, all of which will improve national competitiveness. Road transportation, more than any other method of transportation, has increased the mobility and accessibility of the vast majority of people around the world, according to Starkey (2002). The road's specific function is to link to economic hubs including production, distribution, and marketing centers (Febiansyah, 2012).

As the road shoulder is crucial to the development of the street transportation framework, the provincial road shoulder was selected as the review case and combined with the proper blended extent to serve the perfect path for overhauling the road shoulder. Without street bears, there will be certain problems for those who use the streets, especially when a vehicle needs to stop suddenly or when a car problem arises.

2.1. Road Shoulder

The purpose of the road shoulder is to provide a strip of land along the edge of the roadway for stopping cars. It also acts as an emergency lane for moving vehicles and offers lateral support for base and surface courses. Even in damp weather, it must be sturdy enough to support the weight of a transport that is completely loaded or empty. Its width must be sufficient to provide extra room around a stopped vehicle. In the case of highways and large roads, it may be wrapped, but it is often unsealed, shallower, and made of a lower-quality material than the neighboring traffic lane.

The purpose of the road shoulder is to protect the sealed pavement from excessive deterioration and to provide a safety measure for drivers who unintentionally enter or exit the area of sealed pavement (Road Shoulder, 2008). If vehicles may safely stop on the road shoulder and return to the traffic track after having accidentally driven against it, the risk of an impact is reduced. Stopping and also re-directing the vehicle onto the roadway will be simpler if the vehicle tires can grab the shoulder surface, especially when this happens quickly.

If the shoulder is sufficiently wide and the tires of the car can hold the shoulder's surface, the vehicle will be better prepared to execute both of these tasks (Shoulder Improvements, 1995). Tires are better able to grip a fixed street surface. The ability of the car tires to grip the shoulder surface will make it easier to stop and also steer the vehicle back onto the street when a vehicle leaves the road, especially when this happens quickly.

It is easier for a driver to steer the car back onto the street at a shallower edge with enough road shoulder width, which lowers the likelihood that the driver may "overcorrect" and enter an oncoming activity. Road shoulders that are excessively wide become dangerous if they are used as an additional walkway (Zegeer et al., 1980).

There are a few advantages of a good plan of the street shoulder, for example:

- Reduce street head-on and running off after accidents.
- Wider road shoulder allows vehicles to leave the road in an emergency and gives them room from traffic (however crashes can happen when vehicles endeavor to re-join the movement).
- Wrapped road shoulders provide a safe area for cycling and can be designated as designated riding path ways.
- Road shoulders that are wrapped provide crucial support for the street asphalt. Fixing can reduce "edge drop" (a distinction stature between street surface and the street bear). The edge drop may make it more difficult for vehicles to re-enter the street after leaving it (Balgowan, 2014).

There are some execution issues of street shoulder, which are:

i. Shoulder broadening and fixing can be finished in the meantime to cut down the expenses.
ii. Edge covering can be enhanced at the season of redesigning the shoulder (particularly when fixing).
iii. Road shoulders must not be too wide in light of the fact that drivers may use them as an extra street.

2.2.Pavement Recycling

According to a Federal Highway Administration report released in the United States of America in 1997, asphalt pavement is the most often reused component (as compared to others (in terms of tonnage), such as newsprint, glass bottles, aluminum, tins, and plastic bottles.

Recycled asphalt pavement is compared to other products in Figure 2.1 (Asphalt Pavement Alliance, a Coalition of Asphalt Institute, 2004). Because of the following benefits, degraded asphalt pavements are now recycled more frequently than they are overlaid with new asphaltic concrete material or completely rebuilt (depending on the nature and severity of the distress).

- A decrease in building costs.
- Aggregate, binders, and transportation fuel preservation (for new materials).
- Maintenance of the pavement's geometrical patterns.
- Environment protection.
- Lessening the need for landfills by recycling existing materials rather than throwing them away.

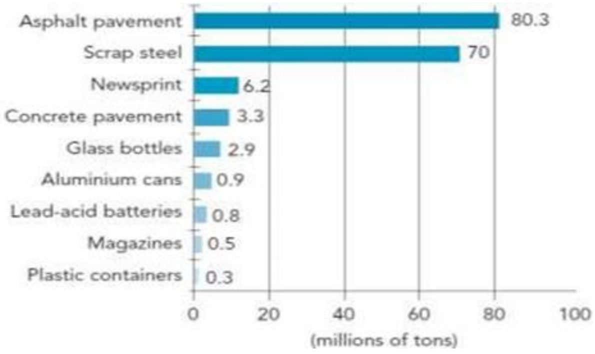

Figure 2.1: Comparison of Various Recycling Products

Poor ride quality, decreased vehicle traction due to reduced surface friction, and higher vehicle maintenance expenses are all effects of deteriorating pavement. Choosing the best recycling technique and, lastly, details on current recycling projects finished in Malaysia Recycling of old pavement can be used in conjunction with other preventive pavement management procedures to create a long-lasting, highly serviceable surface. The four basic types of recycling methods are defined by the Asphalt Recycling and Reclaiming Association (ARRA) (Kandhal et al., 1997).create a long-lasting, highly serviceable surface. The four basic types of recycling methods are defined by the Asphalt Recycling and Reclaiming Association (ARRA) (Kandhal et al., 1997).

i. Hot in-place recycling.
ii. Hot mix recycling.
iii. Cold in-place recycling.
iv. Complete depth reclamation.

One of the many solutions available for restoring pavements is recycling. The specific decision about the rehabilitation approach should be based on life cycle cost and designing considerations. The type, extent, and intensity of discomfort, an indicator of activity, and the structural state of the pavement should all be taken into consideration when designing. By determining the cost of the pavement using any of the several methods, such as present value or equal uniform yearly cost, economic considerations can be made.

The benefits of recycling pavement, different reusing strategies, and choosing a particular reusing strategy have all been looked at. The importance of pavement restoration (including the reuse technology) over new road building is becoming evidently more important as the country develops and organizes its development strategies. Pavement recycling is expected to become increasingly significant in the coming years as resources become distinctly scarcer and environmental awareness becomes more pervasive.
Table 2.1 lists the example of pavement recycling projects in Malaysia. (Malaysian Contractor Specializing in Pavement Recycling, 2004)

Table 2.1: Pavement recycling projects in Malaysia

Location	**Types of recycling pavement method**	**KM**
Jerangau - Jabor	Cold in-place recycling method mixed with cement	Federal Route 14 (km 99.5 - 105.0)
Bukit Sagu - Cerul, Kuantan	Cold in-place recycling using foamed bitumen	Route 1581 (km 21 - km 35)
Kapar - Sabak Bernam	Cold mix recycling (central plant)	Federal Route 5
Pulau Indah, Kelang	Hot in-place recycling	Route 181

Recycling techniques will likely replace the traditional overlay method or mill and pave methods for more road rehabilitation in Malaysia in the future. Pavement made on recycled asphalt (RAP).Reclaimed asphalt pavement (RAP) is commonly understood to be the fine bits of bitumen and inorganic material created by the mechanical grinding of asphaltic concrete components (often from dust to around 25 mm) (Balachanter, 2010).

RAP wastes often come from layers of the road's surface that are being removed to make room for resurfacing, according to Balachanter (2010). This material is removed from surfaces that are either too high to form an overlay, are deemed inappropriate, or cannot support the new surface layer. Bitumen typically ranges from 5% to 7% in RAP trash.

The precise composition and characteristics of the material, however, depend on a number of factors, including the age of the source asphalt mix, the type of mix, the bitumen and aggregate properties used in the mix, the design and operation of the RAP plant, and the clipping of underlying layers during the RAP process. Asphalt pavement recycling is a beneficial strategy for technical, economical, and environmental reasons (Kennedy et al., 1998).

Aging of the RAP binder is being significantly more viscous and having lower penetration values than the virgin bitumen.

Figure 2.2: Abandon Reclaimed Asphalt Pavement (RAP)

Resurfacing of flexible pavement's top layer is known as RAP. Binder and wearing courses make up the bottom and top layers of the surface layer, respectively. Using asphaltic concrete or hot mix asphalt (HMA) mixtures, this layer is cambered for drainage purposes. Aggregate, filler, and bitumen are the materials used. The majority of the mix, or 93%, is composed of aggregate.

Although reclaimed asphalt pavement materials, including mixes with moderate to high RAP proportions that are not inferior paving products, have been successfully designed and produced for many years, some people in the pavement community have a negative opinion about employing them. The performance is what counts: According to Long-Term Pavement Performance, a recent study evaluated the performance of recovered and virgin mixes (LTPP). According to the statistics, blends with at least 30% RAP perform equally well as virgin mixtures across all metrics (West, 2010).

Utilizing RAP would necessitate a connection to durability issues pertaining to the interactions between virgin and recycled materials. The degree of relationships between old and new asphalt binders is the key component that is still incoherent.
The layer that distributes course load to the road base and offers a level, even surface for the wearing of the course. The typical maximum aggregate size is 28 mm, and 3.5 to 5.5% of it is bitumen. The typical notation for this mixture is ACxx, where AC stands for asphaltic concrete and xx denotes the largest aggregate permitted in the mixture.

The pavement's top layer, which serves as a skid-resistant surface, protects the beneath layers and the drainage layers, offers smooth, safe riding, and supports traffic loading. The usual bitumen content ranges from 4.0 to 7.0%, with a maximum aggregate size of 14mm. This mixture is typically identified as ACxx, where xx represents the largest aggregate size in the mixture and AC stands for asphaltic concrete. The aggregate, bitumen, and mixture requirements must be met by all ingredients. The standard and construction layer thickness for the wearing course and binder course are shown in Table 2.2. (Hainin et al., 2016).

Table 2.2: Standard and construction layer thickness

Type of layer	**Standard Thickness (cm)**	**One layer Lift (cm)**
Wearing Course	4 - 5	4 – 5
Binder Course	5 – 10	5 – 10

The prior research on 100% RAP's stiffness and strength is shown in Table 2.3. However, collections of fine aggregate and asphalt mastic may tend to be brittle or flexible depending on the condition of the asphalt caused by aging, oxidation, and temperature exposure. Original coarse aggregate particles can be assumed to have good strength and be resistant to deform (Hoppe et al., 2015).

Table 2.3: Findings from the previous researcher for 100% RAP (strength and stiffness)

Researcher	**Finding for 100% RAP**
Bennert *et al.*, 2000	They found that 100% RAP samplings have a high stiffness and high resilient modulus amount, and lesser shear strengths than the dense-graded aggregate base course samplings. While RAP is stiffer than the thick evaluated total base course, 100% RAP material gathers the most noteworthy measure of stable strain. They also reported that the causing contrast in the middle of 100% RAP resilient modulus and its permanent deformation might be assigned to the advanced breakdown of asphalt binder under loading.
Dong and Huang, 2014	Showed that RAP materials tended to have a high resilient modulus and more permanent deformations when experimented as unbound aggregates. Triaxle creep experiment outcomes verified viscous properties and heat Dependency of unbound RAP base mixture.
Locander, 2009	Reported that the shear strength decreases as a number of RAP increases
Taha *et al.*, 1999	Indicated that the existence of RAP outcomes in the lower bearing capacity of the samplings matched to the virgin aggregates.

According to Ayan (2011), bitumen-coated aggregates slid over one another under load application, causing a drop in CBR values with increasing RAP concentration in unbound subbase. Ayan claimed that the performance with the 50/50 blend of RAP and recycled concrete aggregate was satisfactory (RCA). 15% RAP content was determined to satisfy the repeated load's triaxial criteria for application in the pavement in Australia by (Arulrajah et al., 2014) mixed RAP and RCA research. The best results were obtained between 59% and 78% of the ideal moisture level. The CBR readings for this blend, however, were just a little bit below the acceptable design value of 80.

Table 2.4 indicates the finding from previous research for RAP mixed with other materials and recommended a percentage of RAP mixed with other materials.

Table 2.4: Finding from the previous researcher for mixed RAP with other materials

Researcher	Finding for mixed RAP
(Bennert and Maher, 2005)	From this finding, it was concluded that the general trend of larger permanent deformations and lower CBR values as the RAP content increased in the granular mixture. The writers suggested that RAP is mixed with virgin aggregate to be limited to 50% by weight.
Bleakley and Cosentino, 2013	Granular RAP and lime rock mixtures without a stabilising agent can meet the strength and creep requirements for the base course if blended up to a maximum of 25% RAP and 75% lime rock. If the maximum of 50% of RAP is used but combined with a chemical stabilising agent, such as cement, the amount and type of the stabilising agent should be determined by a mix design method that results in a blend that meets the required performance specifications.

Table 2.5: Finding from the previous researcher for mixed RAP with other materials (Continue)

McGarrah, 2007	This author published her study on the properties of RAP blends and determined that 100% RAP does not construct a product of suitable base course quality and would not be allowable. This is because the more RAP content will decrease, the shear strength of the blend lower than the necessary level. She also suggested controlling the RAP quantity to 25% and mixing RAP with virgin aggregate at the mixing plant. Poor onsite mixing, resulting in base course separation.
Dong and Huang, 2014	The authors recommended that no 100% unbound RAP base be used under asphalt pavements.
Schaefer *et al*., 2008	The authors concluded that only 20% to 50% RAP contented is usually used in real construction.

Table 2.5: Finding from the previous researcher for mixed RAP with other materials (Continue)

Ooi, 2010	The author concluded that limiting RAP to 50% may be prudent as long as the material meets all other requirements in the specifications that a virgin aggregate would satisfy. In addition, he also recommended the minimum CBR values of 80 and 60 for the base and subbase aggregate blends, respectively. The intent was to provide performance specifications expressed in terms of CBR test results.

2.2.1. Recycling technique.

Since 1915, technology has been developed to recycle old pavement material for road restoration and development projects. Recycling of pavements refers to the reusing of materials from existing pavements that have been treated to provide high-quality paving materials suitable for use in new pavement construction or pavement restoration. Recycling can aid in maximizing the use of energy and material resources while lowering the expense of maintaining streets, roads, and highways. The following categories are used by TRB (Transportation Research Board, 1980) to categorize road recycling techniques:

I. Surface recycling involves employing a plane heater, heater- scraper, and hot or cold milling to recycle asphalt pavement with a thickness of less than 25 mm. This method works well to fix pavement problems such ravelling, rutting, flushing, and corrugation.
II. In place surface and base recycling refers to the practice of implementing in-place recycling on pavement with a thickness of more than 25 mm, which is subsequently followed by compaction and reshaping. This method is employed to strengthen the pavement layers structurally. Lime, cement, asphalt, and other chemicals are used to stabilize the pavement that already exists. Cold-Mix Recycling Foam Bitumen (CMFRB) and Cement Treated Recycling Base were two technologies on this technology (CTRB).
III. Central-plant recycling involves scraping the existing pavement and delivering it to the central plant as the first step in recycling. With or without the addition of fresh aggregate and modifier, the procedure is carried out in the central plant before being transported back to the site to be spread out, shaped, and compacted. CMFRB and hot mix recycling asphalt were two of the technologies used in this process (HMRA). A recycling technique called CTRB uses cement to stabilize the base layer's foundation, which consists primarily of aggregates. The stabilization of current asphalt pavement with foamed asphalt is known as CMFRB. RAP, foam bitumen, new aggregate (if necessary), and filler (cement or lime) are the components of CMFRB, which is spread out and compacted in cold weather. According to the results of the research center tests, (Saeed, 2008) the following evaluation of

the suitability of RAP in unbound applications was made:

IV. Strength test the findings demonstrate that RAP can be properly blended for application in high traffic areas in non-freezing temperatures or in low and medium traffic regions in freezing climes with low moisture surroundings.
V. Test for Frost Susceptibility, the findings demonstrate that RAP can be correctly mixed for application in high-traffic environments.
VI. According to the findings of the static triaxle test, RAP is suitable for use in locations with heavy traffic in non-freezing temperatures, medium traffic in freezing temperatures with little moisture present, and low traffic areas in freezing conditions.
VII. Repeated triaxle loading test. Results indicate that RAP can be used in low traffic and medium traffic regions in non-freezing weather.
VIII. Test for stiffness According to the results, RAP blends can be used in high traffic areas in non-freezing temperatures as well as in medium and low traffic areas in freezing temperatures.

2.2.1 Physical properties of reclaimed asphalt pavement (RAP)

RAP is the waste product that results from grinding the pavement surface. It could have both wearing and binder courses in addition to both. RAP may typically be re-used in roads as a base or surface material. The attributes and performance of the resulting recovered mixture, specifically the stiffness of its binder, have an impact on the physical characteristics of RAP. As a result of age, RAP binder coating is more viscous and has lower penetration values than virgin binders. The asphalt binder can be split into two categories: short-term and long-term, with chemical changes within the binder being the primary cause of aging (Sondag et al., 2002).

RAP has a distinct quality from virgin materials, however adding it to new combinations could often lower the cost of the materials (Asphalt Recycling and Reclaiming Association, 2001). Numerous variables, like the pavement's age, the amount of air voids, and the degree of moisture damage to the original asphalt pavement, all affect the varying quality.

RAP composition is typically described using applicable material standards. For instance, EN 13108-8: European Standard for Reclaimed Asphalt (European Committee for Standardization, 2005) permits the use of RAP in the manufacture of new HMA while incorporating the following requirements: no tar in the reclaimed asphalts; no foreign matter content; type of binder; binder properties; aggregate grading; and content of foreign matter.

2.2.2. Chemical properties

The fundamental knowledge that aids in a better understanding of controlling asphalt performance is how chemical parameters influence physical qualities. Bitumen is an organic mixture that is predominantly made up of highly condensed polycyclic aromatic hydrocarbons. It is black, sticky, highly viscous, and completely soluble in carbon disulphide.

Asphalt cement typically consists of friable, dark brown particles. Determining the entire amount of asphalt cement depends on the kind of non-polar solvent used to precipitate it. As the component of asphalt cement that increases viscosity, asphaltenes have a significant impact (Roberts et al., 1996).

In other words, there is a connection between time and temperature impacts. The behavior at high temperatures over a brief period of time is equivalent to what occurs over a longer length of time and at the same temperature. This is sometimes referred to as the cement or asphalt transition time and temperature superposition notion.

The summarization of the prior research' recommendations for RAP is provided in Table 2.6. Studies on the application of RAP were heavily emphasized as a platform for this effort. Even though the use of RAP has been discussed and put into practice, numerous observations caused by the various materials, environments, and ambient temperatures have prompted further research into evaluating the use of RAP.

Table 2.6: Recommended usage of RAP

Researcher	**Recommended RAP (%)**
Poulikakos *et al*., (2014)	40
Yang and Lee, (2016)	< 25
Valdés *et al*., (2009)	60
Widyatmoko, (2008)	40

2.3.Soil

The soil is defined as an accumulation of broken rock put in the multi-phased interface section of the earth, created by weathering development, which occurs when rock buried in the earth layer is mechanically degenerated or biologically decomposed. The soil deposit is often divided into two basic categories: transported soil and residual soil. While transported soil is made up of material that has been transferred from another area by transporting agents like water, wind, glaciers, and others, residual soil is generated via the weathering of rock or a collection of organic material that is still present at its initial position.

Due to the nature of their pore fluids and fabric's mineralogy, several types of soil may yield diverse soil properties. The soil's weak circumstances made it easy for its stiffness to be impacted, which led to the soil's decline in strength. The most important aspect of any soil qualities is its strength. A big and high load could not be supported on soil with weak strength.

2.3.1. Classification of soil

Soil can typically be divided into two categories. The first type is referred to as coarse-grained dirt, and one of its distinguishing features may be seen clearly even without magnification. Sands and gravels can be found in these soils. Any soil component larger than gravel is referred to as cobbles or boulders. The element size itself is typically used to categorize coarse-grained soils. The second is fine-grained dirt, a component of which is very minute and some of which cannot be seen without the right tools. Silts and clays are present in these types of soils. These divisions are based on the soil's plasticity. Due to the variety in water content, clay soil is more malleable than silt soil, which has little to no plasticity. The general properties of soils are explained by the classification systems for soil, which are often based on soil parameters.

Depending on the void ratio achieved from the arrangement, David (2007) claims that stacking soil particle is similar to stacking marbles, either loosely or densely. According to David (2007), the organization of deposits of coarse-grained and silt soil is greatly influenced by the force of gravity because each particle's mass is significantly bigger than its surface area. On the other hand, due to their high surface to mass ratio, clay soil particles are more affected by the electrical forces operating on their surfaces.

The American Association of State Highway and Transportation Officials (AASTHO) system, founded in 1929 as the Public Road Administration classification system, has classified the area as stated in Table 2.7

Table 2.7: American Association of State Highway and Transportation Officials (AASTHO) classification

Criteria	Description
Grain Size	Gravel: Fraction passing the 75mm sieve and retained on the No.10 US sieve
	Sand: Fraction passing the No.10 US sieve and retained on the No.200 US sieve
	Clay and Silt: Fraction passing the No.200 US sieve

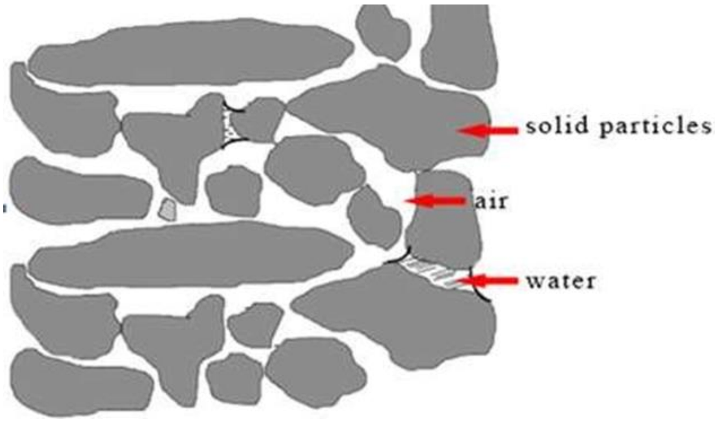

Figure 2.3: Component in soil (Hopmans and Rolston, 2000)

The Unified Soil Classification System's classification of soil is shown in Table 2.8. (USCS). According to the American Society for Testing and Materials (ASTM) D-2487 standard requirement, the geotechnical engineer uses this system. Whitlow (2001) asserts that soils are distinguished based on the letter of the group symbol.

Table 2.8: First and second letters of group symbols (Whitlow, 2001)

Soil Identification	First Letter of Group Symbol	Second Letter of Group Symbol
Coarse grained soil	G: gravel, S: sand	W: Well graded P: Poorly graded
Fine grained soil	M: silt, C: clay	L: Low plasticity (LL less than 50) H: High plasticity (LL more than 50)

Table 2.8: First and second letters of group symbols (Whitlow, 2001) (Continue)

Organic soil	O	L: Low plasticity (LL less than 50) H: High plasticity (LL more than 50)
Highly organic soils	Pt	No second letter

Figure 2.3 depicts the soils, which typically contain three elements: air, water, and solid particles. The interrelationship of the various elements is crucial for defining the state or physical characteristics of the soil.

Figure 2.3 depicts the soils, which typically contain three elements: air, water, and solid particles. The interrelationship of the various elements is crucial for defining the state or physical characteristics of the soil.

2.3.1. Laterite soil

Engineers frequently struggle with the limited bearing capacity of soft soils in geotechnical engineering design and are unable to meet the necessary specifications. Soil improvement is a crucial area of research in geotechnical engineering to address this issue. Therefore, site investigations should be done to determine the type of soil improvement on the site before any building begins. Soil stabilization or consolidation are two methods for improving the soil.

The laterite soil used in this study was collected from the region around Kuantan, Pahang. To achieve the best blended proportion, laterite soil was combined with RAP in this study. Typically, tropical and subtropical regions are home to lateritic soils. More than half of Peninsular Malaysia in Malaysia is covered by iron- and alumina-rich residual sedimentary rock soil, giving it a lateritic nature (Aun, 1982). Climate, parent rock, and the level of lateralization all have an impact on the geotechnical characteristics of these materials. Iron oxide and aluminum oxide cover and bind the clay particles during lateralization, changing the soil's microstructure. The geotechnical characteristics of lateritic soil are influenced by the mineralogy and microstructure (Mahalinga-Iyer and Willams, 1991).

Laterite is a substance that is highly worn and is rich in optional oxides of iron, aluminum, or both, according to Alexander and Cady (1962). It is virtually entirely devoid of bases and necessary silicates, yet it may be rich in quartz and kaolinite. When exposed to wetness and drying, it either solidifies or is hard. According to research by Nixon and Skipp (1957), Graft-Johnson et al. (1972), and Gidigasu (1969), laterite soils may have molecule-measure qualities similar to those of any other type of soil. These qualities include the ability of the parent material's way of origin, degree of weathering, geologic origin, area in the topographic site, and depth in the profile. Bawa (1957) characterised all fine-grained laterite soils inside the accompanying fraction of size parts as appeared in Table 2.9.

Table 2.9. Ranges of size fraction for fine-grained laterite soil

Table 2.9. Ranges of size fraction for fine-grained laterite soil (Continue)

Type	**Grain size**	**Percentage**
Sand	**2.0 - 0.05 mm**	**50 ±**
Silt	**0.05 - 0.002 mm**	**30 - 40**
Clay	**< 0.002 mm**	**20 - 30**

Each type of soil behaves differently in terms of appropriate wetness and thickest layer. In this approach, each type of soil has unique requirements and controls for both fieldwork and testing.

When exposed to wetness and drying, it either solidifies or is hard. According to research by Nixon and Skipp (1957), Graft-Johnson et al. (1972), and Gidigasu (1969), laterite soils may have molecule-measure qualities similar to those of any other type of soil. These qualities include the ability of the parent material's way of origin, degree of weathering, geologic origin, area in the topographic site, and depth in the profile. Bawa (1957) characterised all fine-grained laterite soils inside the accompanying fraction of size parts as appeared in Table 2.8.

2.3.1. Plasticity of laterite soil

Problem laterite soil often has very high natural moisture contents that are much beyond the plastic limit and frequently even beyond the liquid limit, but in their unaltered natural state, they resemble a solid mass rather than a plastic or liquid mass (Hirashima, 1948). Liquidity index should therefore be taken into account. Equation 2.1's derivation of the natural moisture content, plastic limit, and liquid limit yields the liquidity index:

$$L = (w - PL)/(L - +PL) \tag{2.1.}$$

When the natural moisture content of the sample is equal to the liquid limit, the liquidity index is equal to unity; and when the natural moisture content is equal to the plastic limit, the liquidity index is zero (Figure 2.5).

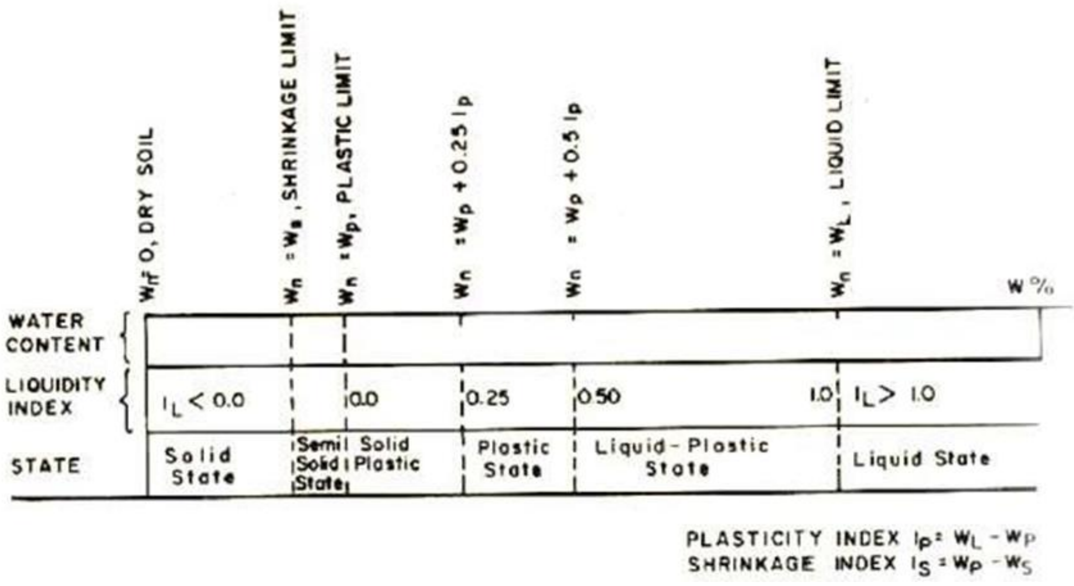

Figure 2.5: Plasticity characteristics and limits of soils (Gidigasu, 196 distinctive grain sizes.

2.3.1.Compaction of laterite soil

By mechanically pressing the sturdy soil particles even more tightly together during the compaction process, the dry thickness of the soil is increased (Markwick, 1944). It is achieved by reducing the amount of air gaps in the soil, with almost no water content loss. The process of compaction works to reduce the soil's compressibility and porosity while increasing the soil's strength and bearing capacity.

For soil ranging in texture from red clays of volcanic origin (Hirashima, 1948; Newill, 1961; Tateishi, 1967) to gravels and gravelly soils of varied genetic origin (Brand and Hongsnoi, 1969; Gidigasu, 1969; Gidigasu and Teboa, 1972), the impact of the method of drying on the compaction characteristics of some laterite soil has been studied. It has been discovered that the initial moisture content of laterite soil has a significant impact on the shape of the moisture-density curve. It was discovered that oven drying, followed by air drying, generally tends to offer the highest maximum dry density and the lowest optimal moisture content. Additionally, the amount of swelling and the final moisture content of laterite soil are both influenced by the degree of drying. Therefore, a detailed research in the lab and on the ground is required to determine the importance of the influence of the pre-test preparations on the compaction properties.

2.3.2Classes of Sub-Grade Strength based on CBR

The "Manual for the Structural Design of Flexible Pavement" (ATJ 5/85-Pindaan 2013), which is made available by Jabatan Kerja Raya Malaysia, serves as the basis for road pavement design and construction in Malaysia (JKR). This guide is intended to provide JKR and professionals working on asphalt construction projects in Malaysia with a uniform method of defining asphalts for all classes of movement. The California Bearing Ratio (CBR) has been widely used to classify subgrade support in asphalt planning.

The versatile solidness estimation of the subgrade is prescribed at whatever point plausible. The flexible firmness esteems utilized for the plan of the asphalt structures are introduced in Table 2.9.

Table 2.9: Classes of Sub-Grade Strength based on CBR (ATJ 5/85-Pindaan 2013)

Sub-Grade Category	**CBR (%)**	**Elastic Modulus (MPa)**	
		Range	**Design Input Value**
SG 1	5 to 12	50 to 120	60
SG 2	12.1 to 20	80 to 140	120
SG 3	20.1 to 30.0	100 to 160	140
SG 4	> 30.0	120 to 180	180

Pavements for Subgrade Category of SG 1 roads, which have very low traffic volume support, are advised to have a minimum CBR of 5%. The road will be supported by the high volume of traffic for subgrade category 4 (SG 4). With an elastic modulus between 120 MPa and 180 MPa, the CBR value must at least be 30%. The procedure and design of road construction can be more standard thanks to the manual provided by JKR.

3. RESULT AND CONCLUSION

The conclusions that can be made according to the result and analysis of this study are stated in the following section.

3.1. Material properties of soil and reclaimed asphalt pavement (RAP)

According to the results, the soil type was Brown Clayey Sand with a fineness modulus of 2.84 mm. The soil sample's plastic limit was in the 22–23 range and its liquid limit was in the 43–53 range, while the plastic index value was 21. While the sieve analysis from extraction was defined, the bitumen content from the extraction operations for RAP fulfilled the criterion from JKR/SPJ2008/S4.

3.2. Moisture content and degree of compaction

The OMC of soil from this investigation was 20% added to all mixed proportion.

3.3. Optimum mix proportion under california bearing ratio (CBR)

In this study, the 8S2RAP mixture provided the best mix proportion under CBR. As RAP increases, the MDD and OMC of this soil mixture will decrease. As the value content of RAP rises, the effectiveness of this combo will decrease.

In order to build a road shoulder, 20% RAP material is suggested. As more RAP is added, the road shoulder's strength and stability will deteriorate. Conclusion: RAP has the potential to be used as a replacement material to build the road shoulder with the right mix, which will substantially reduce RAP waste disposal and help to reduce environmental pollution.

Ethics Committee Approval
N/A

Peer-review
Externally peer-reviewed.

Author Contributions

Conflict of Interest
The authors have no conflicts of interest to declare.

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