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A Review of the Asphalt Mixtures Containing Recycled Solid Waste Materials

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ABSTRACT

Landfill and incineration are the most common and widely used methods to dispose of solid wastes; both of these techniques are considered the main sources of pollution in the world due to the harmful toxic emissions that are considered an environmental problem. Because of the large areas used by landfills, they are not always considered an economical method. With the increase in the production of solid materials, solid wastes increase the pressure on incinerators and landfills, making the environmental pollution hazard more serious. Instead, these waste materials can be used in some other applications. One of the most important of these applications is asphalt pavements, which are the most used types of pavements in the world. This study is to review the properties and performance of asphalt mixtures that contain different ratios of recycled PET and glass waste as a filler, partial replacement of fine aggregate, and binder modifier .These mixtures showed positive and accepted results for standard specifications.

Keywords: solid wastes, asphalt, environment, plastic, glass.

مراجعة للخلطات الاسفلتية الحاوية على المخلفات الصلبة المعاد تدويرها

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الخلاصة

المطامر والمحارق هي اكثر الطرق شيوعاً واستعمالاً للتخلص من المخلفات الصلبة ، كلا الطريقتين يعتبران من مصادر التلوث الرئيسية في العالم بسبب الانبعاثات السامة و المؤذية التي تعتبر مشكلة بيئية . ايضاً بسبب المساحة الواسعة التي تستغل بواسطة المطامر ،التي لا تعتبر دائماً طريقة اقتصادية . مع زيادة انتاج المواد الصلبة ، يزداد الضغط على المطامر و المحارق

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جاعلاً خطر التلوث البيئي اكثر جدية ، بدلا من ذلك هذه المواد يمكن استخدامها في تطبيقات اخرى ، واحدة من اهم هذه التطبيقات هي الطرق الاسفلتية التي تعتبر اكثر الطرق استخداما في العالم . هذه الدراسة لمراجعة الخصائص و الاداء للخلطات الاسفلتية الحاوية على نسب مختلفة من الزجاج والبلاستك كماد رابطة ، بدل الركام الناعم بشكل جزئي ، كمعدِّلات الاسفلت التي بدورها اظهرت هذه الخلطات نتائج ايجابية ومطابقة للمواصفات القياسية .
الكلمات الرئيسية: المخلفات الصلبة، الاسفلت، البيئة، الزجاج

1. INTRODUCTION

In 2016, Iraq produced 31 KT/day of solid waste. Approximately 1,4 Kg/day are produced per person. The Baghdad government produces around 1.5 MT/year of waste **(Al-mohammed et al., 2021)**. With the rapid growth of the population, virgin materials have started to deplete. Incinerators release 210 different hazardous chemicals, including fluorides, hydrogen chloride, sulfuric acid, nitrous oxide, and mercury, into the atmosphere each time they dispose of rubbish. (**The European commission's science and knowledge service**). Several benefits when using solid wastes in asphalt roads are substantially lower cost, reuse materials instead of sending them to landfills. In addition to these benefits, improving some properties of asphalt when using solid waste as additives.

Highway construction or repairing existing damaged highways needs a strong economy and costs a lot of money. Alternatively, you can use asphalt that contains solid waste to give the most economical way to design the pavements **(Ahmed and Lovell, 1991)**.

Using solid waste in the pavement made of asphalt minimizes the negative waste disposal side effects also the need for natural resources, resulting in cost savings and economic benefits. Furthermore, including recycled materials into the asphalt top layer may help to enhance the technical features of asphalt pavement materials, resulting in the addition of value used for solid waste. However, using solid waste materials for highway construction, especially the surface layer, is critical since trash inclusion should not compromise the pavement's functional and structural features **(Chen et al. 2011, Julian and ZhanpingYou 2010, Silva et al. 2012)**.

2. ASPHALT MIXTURE

The word "asphalt" has various connotations in various areas of the globe. Asphalt is, for example, identical in Europe to what is known in the United States as Hot Mix Asphalt (HMA) or Asphalt Concrete (AC). In Europe, "bitumen" is an asphalt binder. The goal of asphalt mixture designing is to obtain an Affordability mixture of bitumen with aggregate that is useable, with enough bitumen binder to ensure satisfying durableness, tiredness efficiency, and adequate aggregate configuration to adjust the bitumen and help stop bleeding and permanent deformation (**Abedali, 2014**).

According to (**AASHTO**): there are three types of asphalt pavement. The first one is a flexible pavement, and the second is rigid pavement. In most cases, Flexible pavement includes roadbed, subbase, base, and asphalt surface layers. In contrast, rigid types include roadbed, subbase, base, pavement slab (reinforced concrete), and thin asphalt surface.

From a practical standpoint, the bitumen must be liquid at high temperatures to be pumped and easy to work with, allowing for a uniform aggregate covering after mixing. Furthermore, The bitumen used on roads must be able to handle rutting in hot weather (60 °C according to local conditions). Finally, bitumen must stay supple and have adequate elasticity to avoid thermal fracture in a cold climate **(Melo and Taylor, 2015)**.

2.1 Asphalt mixture behaviour

Vertical stress concentration, shear forces on the base of the pavement surface, and tension forces are the principal forces conveyed to the HMA after taking a vehicle load on the road. To avoid permanent deformation inside the mixture, the HMA must be internally hard and resilient to compression and shear forces.

The materials must also have sufficient tensile resistance to sustain tensile forces at the asphalt layer's base to avoid cracks, leading to fatigue failure after repeated load application. Top-down cracking may be caused by tensile stress at the edge of high-pressure radial tires. In addition, the asphalt must be able to withstand contraction forces caused by rapidly dropping temperatures or excessively low temperatures **(Abedali, 2014)**.

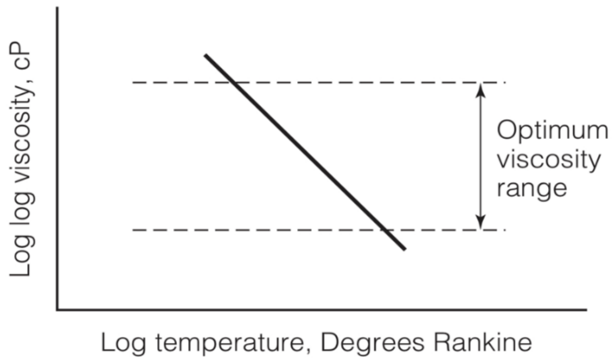
Several properties are required in asphalt mixture after being constructed and compacted, which are considered as the index of mixture quality, **Table 1**.

Table 1. Desired properties considered for mix design**.**

Properties	Description
Stability	Permanent deformation resistance.
Fatigue resistance	The pavement's resistance to repetitive bending under tyre loads is referred to as fatigue resistance (traffic).
Low-temperature cracking	Law value temperature cracking resistance.
Moisture resistance impermeability	Moisture resistance
Durability	The capacity of an asphalt surface to withstand elements such as aging is referred to as its durability.
Skid resistance	An asphalt surface's capacity to reduce skidding or slippage of car tyres is known as skid resistance.
Workability	The flexibility with which a pavement mixture may be laid and compacted is referred to as workability

2.2. Temperature Susceptibility of Asphalt

Asphalt's consistency is strongly influenced by temperature. Low temperatures cause asphalt to become hard and brittle, whereas high temperatures cause it to become mushy. **Fig. 1** depicts a conceptual relationship between temperature and viscosity logarithm. When the temperature rises, the viscosity of the bitumen drops. The line slope in **Fig**. **2** represents the temperature sensitivity of asphalt; Asphalt sensitivity is higher at a steep slope. On the other hand, Additives may be used to lower susceptibility **(Mamlouk and Zaniewski 2011).**



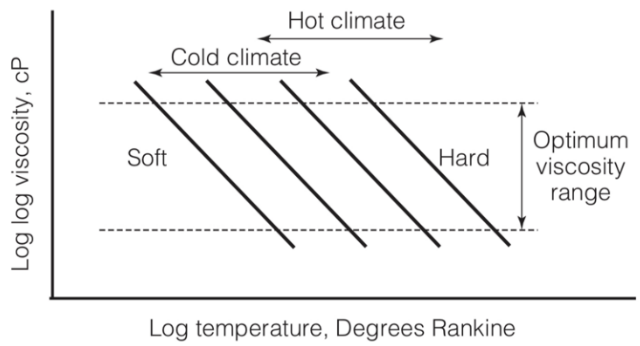


Figure 1. relationship of bitumen viscosity with temperature.

Figure 2. relationship of bitumen viscosity with temperature.

When combined asphalt and aggregates, the combination will only work correctly if the bitumen viscosity is under a specific range. The combination will be excessively brittle and vulnerable to l ow-temperature cracking if the asphalt viscosity is greater than optimal, as in **Fig. 4**.

However, if its viscosity is very, the mix will be hard to control, leading to permanent deformatio n (rutting), as illustrated in **Fig. 5**. Because of its temperature sensitivity, the asphalt cement grad e should be chosen by the local climate. The bitumen viscosity must primarily meet the ideal leve l for the average yearly temperature range; law grading asphalts are used in cold climates, while h igh grading asphalts are used in hot environments, as in **Fig. 3 (Mamlouk and Zaniewski 2011).**

Figure 3. Cracking : the fracture that grows perpendicular to the pavement's axis.

Figure 4. Rutting : longitudinal depression caused by the passage of vehicles in the wheel tracks path of a flexible pavement.

2.3. Asphalt pavements distress

Like most structures, asphalt pavements can be exposed to many failures for several reasons, incl uding the type of materials, mixing conditions, and mixing ratios. The most common of these dist resses are tabled in **Table 2 (Neero and Thangmuansang 2007)**.

Table 2. Most common failures of asphalt paving**.**

Distress	Description
Fatigue cracking	Fatigue failure under repetitive traffic loads causes a number of interconnecting fractures.
Rutting	Depression on the surface of the path
Bleeding	The pavement is coated with a layer of asphalt binder.
Potholes	On the pavement surface, tiny, bowl-shaped holes that penetrate all the way down to the base course are found.
Thermal cracking	Thermal cracking occurs when cracks appear opposite to the pavement's centerline or lay-down direction.
Depression	Areas of pavement that are somewhat lower than the rest of the pavement
Raveling	Breakdown of an HMA layer from the top to the depths due to aggregate particle dislodgment

2.4. Classifications of mixes

1. Dense-graded AC

The aggregate gradation of dense-graded asphalt is evenly dispersed over the whole range of sieves utilized. It is the most usually stated form of mix and may be utilized in the pavement structure's foundation, intermediate layers, and surface. The techniques of constructing dense-graded mixes are known as Superpave," "Marshall, and "Hveem, **Fig. 5 (Abedali Abdulha, 2014).**

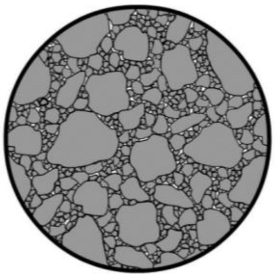


Figure 5. Dense-graded AC)

2. Open-graded AC

An asphalt mix with a high proportion of voids (usually 18% to 22 %) allows water to flow freely into the asphalt layer. It's utilized as an (OGFC) to offer a skid-resistant pavement surface and as a porous foundation layer (also known as Asphalt Treated Permeable Base, or ATPB) to promote good drainage under asphalt concrete pavement surfaces, **Fig. 6 (Abedali Abdulha, 2014).**

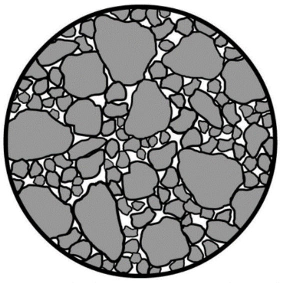


Figure 6. Open-graded AC

3. Stone matrix AC (SMA)

An Asphalt mix contains a high proportion of coarse aggregate (often 70% - 80%), a high proportion of asphalt (generally over 6 %), and a higher proportion of filler. It is known as gap-graded or SMA (approximate 10 % by weight). As a consequence, you get a long-lasting combination with good stone-on-stone contact and rut resistance, **Fig. 7 (Abedali Abdulha, 2014)**.

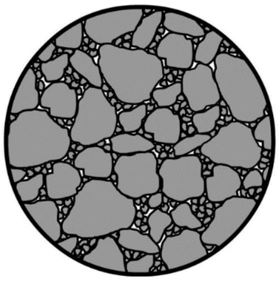


Figure 7. Stone matrix AC (SMA)

3. PLASTIC PET WASTE

PET is considered one of the most widely used plastic. It is one type of polyester family called "long-chain". PET is a thermoplastic polyester with a semi-crystalline structure **(Webb et al., 2013)**. PET is a polyester that is created through a polymerization process between an alcohol and an acid **(Sinha and Patel 2010)**. A study by **(Thachnatharen et al., 2021)** confirmed that PET has a lot of advantages, such as being lightweight, having a low production price, and its thermal stability is excellent. Because of their low cost, PET materials are cheap and easily available for the majority of people all over the world. As a result of this, PET materials are mass-produced in large quantities. It is in high demand all across the world. Because of the enormous number of people involved, this negatively influences the environment. PET waste is dumped in large quantities in landfills, drains, and rivers. This has a negative impact on the environment. PET waste materials do not degrade since they are not biodegradable. PET pollution impacts humans, animals, and non-living things like soil, air, and water. The PET generation in 2008 was estimated to be 50 million MTA globally. Polyester fiber production accounts for approximately 65 percent of global consumption, while PET bottle resins account for roughly 30 percent. The remaining fraction, which includes poly film and polyester engineering resins, is used for other purposes **(The European Association of Plastics Recycling and Recovery Organizations 2008)**. According to (AZO materials), PET plastic properties are tabulated in **Table 3.**

Table 3 PET plastic properties.

Properties	value
The density of PET (g/cm^3)	1.3-1.4
Equilibrium in moisture absorption	< 0.7 %
Viscosity at T=75^0 C	600 mPa.sec
Flashpoints	above 200 ^{0} C
Friction of Coefficient	0.2-0.4
Modulus of tensile (GPA)	2 – 4
Crystallinity	≥ 45%

3.1. Using powder of recycled plastic PET waste in asphalt mixture as binder modification

The current investigation by **(Fikri et al., 2020)** is carried out on an asphalt mix surface layer compound utilizing a 60-70 bitumen penetration that has been amended with 0 percent, 3 percent, 6 percent, 9 percent, and 13 percent of waste bottles powder. This research aims to look at the Marshall standard of asphalt mix properties with different asphalt PET changes. According to the Marshall criteria, the optimal asphalt level for PET asphalt 0 percent is approximately 5.9, but when adding a ratio of PET of 3 percent, 6 percent, 9 percent, and 12 percent, it increased the (AOL) to 5.95. According to the findings, the optimal amount of asphalt mixture mixed with 9 percent PET enhanced the stability by 33% when compared to the control 60-70 mix. PET was added to 60-70 penetration bitumen as standard bitumen and compared to the asphalt to generate an asphalt mix that has been modified in this study, as in **Table 4**.

Table 4. Tests results of bitumen and PET modified bitumen **.**

Test	Requirement	PET level (%)				
		0%	3%	6%	9%	12%
Penetration (0,1 mm)	Min .40	63	54	46	42	34
Soft point (°C)	≥54	48.5	54.1	55.2	56.4	58.5
Ductility (cm)	≥ 100	140	140	140	127	109
Weight	≥ 1.0	1.03	1.03	1.04	1.05	1.06
Bright point (°C)	≥ 232	330	318	306	294	275
Storage Stability (°C)	≤ 2.2	0.3	1.4	1.3	1.2	1.3
Kinematic Viscosity (°C)	≤ 3000	360	330	375	430	495

The results analysis listed in **Fig. 8**: The research found that when 9 percent of PET treated asphalt was compared to pure asphalt, the stability value rose by 33%. The flow value has improved due to the inclusion of waste PET bottle waste in the AC-WC compound. The flow test of asphalt mix without waste PET adding (0 percent) is around 3.29 millimeters, and it continues to rise until it reaches 3.96 mm, virtually exceeding the flow criterion of 4 mm. The AC-WC compound's plasticity has an influence on the increased flow. The test results with a PET value of 0-9 percent have a Marshall Immersion result which meets the criteria of **(The 3rd edition Bina Marga 2010)**. Marshall Immerse was less than 90 percent. The Specimen with a PET ratio of 12 percent and a Marshall immersion value of 84.4 percent does not fulfill the Indonesia Standards.

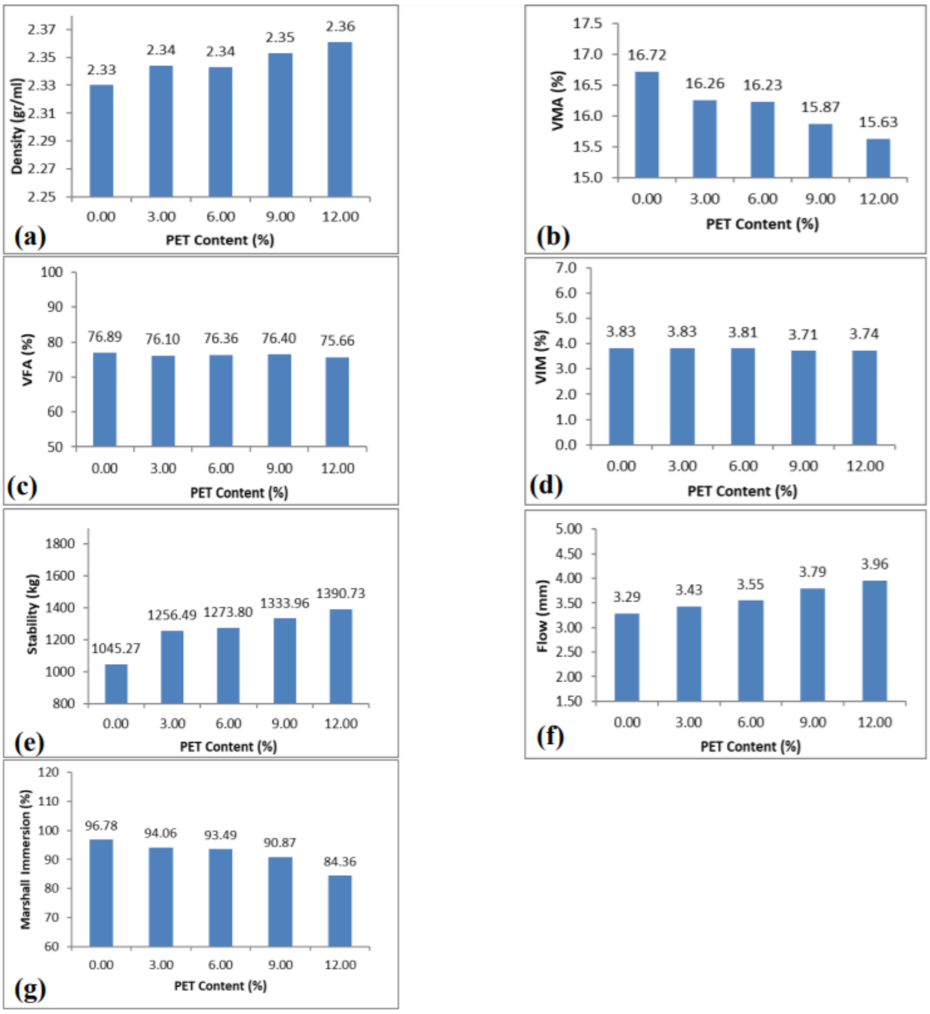


Figure 8. Analysis of modified asphalt mixture; (a) density, (b) *VMA*, (c) VFA, (d) VIM, (e)Stability, (f) Flow, (g) Marshall Immersion.

3.2. Impact of modified bitumen with waste PET

(Mashaan et al., 2021) investigated and assessed the impact of modifying C320 bitumen with a waste polyethylene terephthalate (PET). The evaluation of numerous PET-modified bitumen contents is categorized into a modified binder and modified asphalt mixes. The technical characteristics and viscoelasticity of PET-modified bitumen were investigated using (DSR) test. (RTFOT), M.S, M.F, rutting, and MQ tests were used to evaluate the plastic-asphalt mixtures' engineering capabilities.

A compression between unmodified and pet-modified bitumen asphalt mixtures tests: Rutting test **Fig. 9**, Marshall quotient **Fig. 10**, Marshall flow **Fig. 11**, Marshall stability **Fig. 12**: all results showed improvement at high addition ratio decreasing with lowering the PET content until it reaches the lowest value at control asphalt mixture.

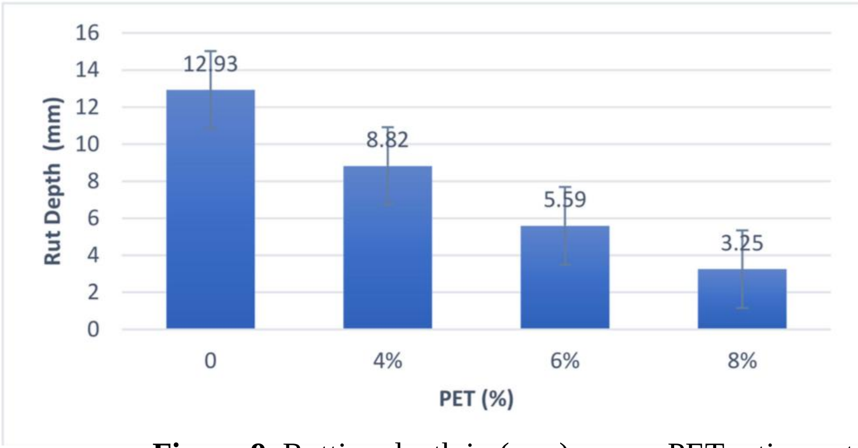


Figure 9. Rutting depth in (mm) versus PET ratio content.

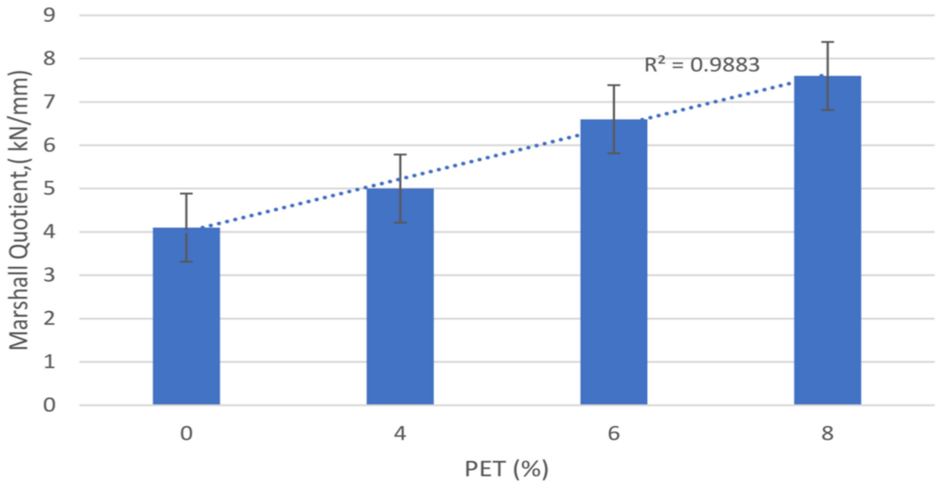


Figure 10. Marshal quotient (kN/mm) versus PET ratio content.

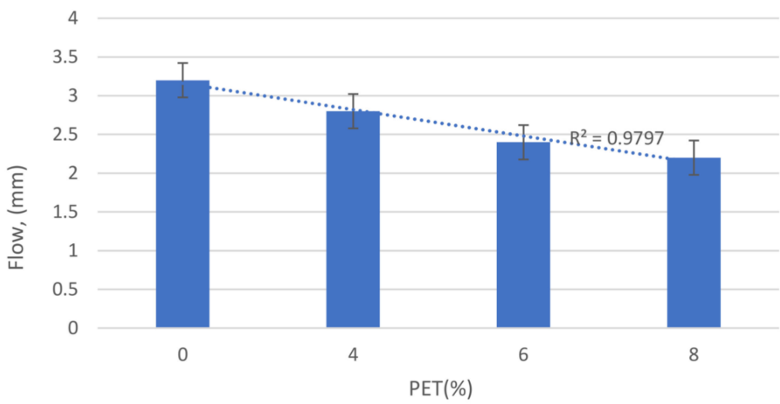


Figure 11. Flow (mm) versus PET ratio content.

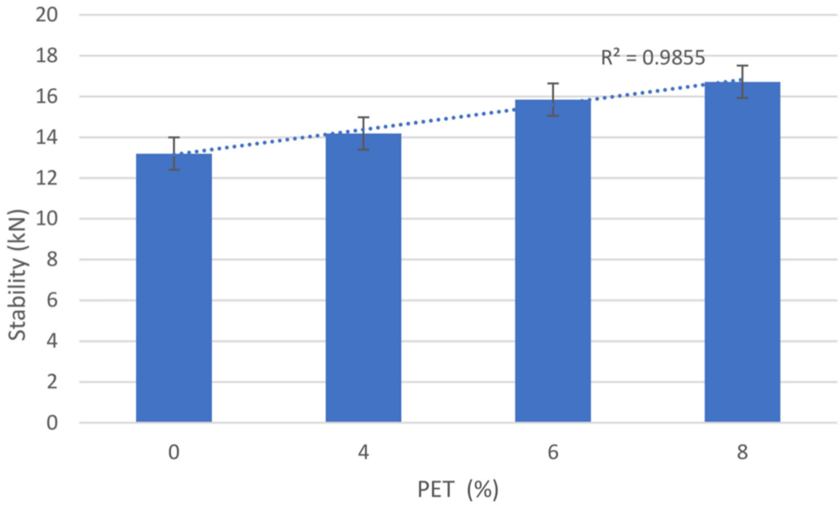


Figure 12. Stability (kN) versus PET ratio content.

The following are some of the main findings from the present investigation:
Following the DSR's tests, modified asphalt-PET samples show higher efficiency in reducing the asphalt sensitivity to high-temperature deformation, resulting in improved resistance rutting. Adding PET to the bitumen raised the complex shear modulus while lowering the phase angle values. Rutting resistance was improved at temperatures of 50°C –70°C, which may be ascribed to material flexibility.

PET additions had lower aging, a higher shear resistance, and greater flexibility with an acceptable phase angle, according to RTFOT data. These findings suggest that asphalt pavements have the capacity to avoid damage during the building process and provide improved resilience during long-term use.

The waste PET-modified mixes demonstrate excellent stiffness and enhanced stability, providing higher shear stress resistance under severe load. The results of the M.S, including all PET-asphalt mixes, were greater than the normal mixture (C320); even so, the waste PET had less influence on M.F; the greater MQ value, the PET-asphalt stiffer giving more resistance to deformation of modified asphalt.

3.3. Using recycled plastic PET waste in asphalt mixture as an additive

(Machsus et al., 2020) studied effects of adding recycling PET waste to asphalt mix, The objective of their study is to see how PET affects Marshall characteristics on asphalt pavement. In this study, the wet process is used. When asphalt is heated, PET plastic material is put straight into it, and aggregates are subsequently added. Asphalt with penetration of 60/70 has been applied in this study. It has an optimal bitumen content of 5.7 percent, and the additional PET percent are as follows:3% 4,% 5,% 6 %, and 7% of the total weight of asphalt. The following conclusions are drawn from the literature study, analysis, and discussion: (i) The mix of combined aggregates from the asphalt concrete-wearing coarse mix might be expressed as the details: 12 percent coarse aggregate, 48 percent medium size aggregate, 38 percent sand, and 2 percent filler. (ii) According to the Marshall parameters test result variable, the optimal binder content was determined to be 5.7 percent. This bitumen content optimal value will then be utilized as a standard value for future

(3 %, 4 %, 5 %, 6 %, and 7 %) PET add difference ratios. (iii) The Marshall Test standard on AC-WC mixture with no PET addition was then proven to fit the Indonesian code. (iv) The Marshall Test standards on the mix, which includes a variance PET ratio, are also shown to comply with the Indonesian code. (v) This study will lead to a substantial outcome in the development of a sustainable road infrastructure material.

3.4. Influence of crushed waste pet bottles on asphalt mixture

(Choudhary et al., 2018) studied the influence of crushed waste bottles on mixtures of asphalt on features such as (i) PET method described, (ii) content of PET (iii) size of PET was explored in this research. Two procedures (dry and modified), PET ratio (2.5, 5.0, and 7.5 percent of weight of bitumen), and PET dimensions (2.36–1.18, 0.30–0.15) mm were included in the experimental design. PET modified mixtures were examined and compared to a control mix of Marshall parameters, volumetric properties, and moisture susceptibility characteristics (without PET). Variables' primary effects and interactions were assessed using an analysis of variance (ANOVA).

The study's major conclusions are summarized as follows, based on data and analyses:
For all types and sizes of PET ratio, the modified dry method achieved greater Marshall stability than the dry procedure. The PET stability modified mixtures manufactured using both techniques were considerably greater than the conventional mix up to 5% PET content. Generally, modified mixtures had stronger resistance to deformation, were more stable, had less flow, and had a larger M.Q than conventional mixes. The bulk density of coarse PET was greater than that of fine PET. For mixtures with coarse PET, this was inverse in decreased air voids, voids in mineral aggregate, and percentage of voids in the compaction aggregate. Mixes made with the modified dry technique had much higher TSR values and were more resistant to moisture damage than mixes made using the dry approach. The TSR values for coarse PET size were greater. For both PET sizes, the modified dry method provided conditioned ITS values greater than the dry mix and controlled up to a PET proportion of 5%. Regardless of the manufacturing technique, PET content, or PET size, all PET modified mixes fulfilled the volumetrics, Marshall criteria, and TSR requirements. Overall, modified mixes prepared using a modified dry method with larger PET sizes (2.36mm–1.18mm) performed comparably better in volumetrics, Marshall standard, and water-induced resistance.

4. GLASS WASTE

Glass, according **(Morey 1939)** is an inorganic material in a state that is consistent with soluble state, but that has acquired such a high degree of viscous as though it were, for all intents and purposes, at low temperature, it tending to be solid due to viscosity inverse relationship." Glass is defined as material that has been chilled to a hard state without the formation of crystals, according to "ASTM".
Glass is a widely utilized commodity that has a wide range of glass uses, including cutlery, lights, Shelves in the windows, floors, apparatus, solar panels, and optical fiber cables. Due to the rising demand for landfilling and a growing focus on reducing carbon footprints in the building industry, waste glass disposal has become a major environmental challenge. Because of its inert nature, glass is not biodegradable. Non-recyclable waste glass decomposes in around a million years and takes up valuable landfill space. Because of the increased need for landfills and the building industry's increasing focus on carbon footprint reduction, waste glass disposal has arisen as a major environmental challenge. It is one of the most commonly used materials, with an estimated annual worldwide output of more than 130 million tons (Gielen, 2007). Recycling and reusing waste

products can help to lower the demand for natural resources, resulting in environmental protection. Crushed glass (CG) is one of the most economically negligible recyclable resources, with billions of tons buried in landfalls worldwide. For example, in the United States, about 11 MT of waste glasses reached the urban waste stream in 2001, but only 2.4 million tons (22 percent) were recovered and recycled. Roughly 850 KT of glass material is used in Australia, but only 350 KT (40 percent) are recycled **(Austroads. 2009).**

4.1. Using glass waste powder in asphalt mixture as filler

As stated by **(Choudhary et al. 2021),** glass powder shows good results when using it as a filler because of its law clay contenting and hydrophobic nature. Also, glass powder content exhibited an increase in the resistance to cracking and rutting. On the other hand, the resistance to moisture and adhesive properties showed poor performance. Because of their smoothness, low clay ratio, and hydrophobicity, powder of waste glass, the dust of stone, and hydrated lime showed characteristics of suitable fillers. All asphalt mixtures made with glass powder and glass lime fillers (excluding glass lime mixes made with an 8.5 percent filler ratio) outperformed conventional SD mixes in terms of Marshall and volumetric characteristics.
The filler content enhanced the resistance to cracking and rutting. Because of the granular character of glass lime and the low VMA of the created mixes, glass lime mixes showed greater resilience. At lower filler proportions, glass lime and glass powder mixtures also showed good resistance to raveling. The resilient modulus of GL and GP mixes was greater, and the load distribution behaviour was better than that of SD mixtures. The pavement structure sustained similar design traffic, including these mixtures at substantially lower pavement thicknesses.

4.2. Using recycled glass waste in asphalt mixture as fine aggregate

(Latief, 2017) used crushed waste glass to 2.36 mm particle as a fine aggregate in asphalt mix. She replaced the fine aggregate with crushed glass as these percentages ratios 60%, 45 %, 30, and 15 by weight of size. Three tests were performed (Marshal test, ITST, Modified Lottman test). Marshal test results show acceptable stability values for all glass content ratios except for 60 % glass content. It showed a value of 7.7 on less than the required 8kn. The flow number result, which represents resistance to vertical deformation, showed that all tested ratios meet standard requirements. She observed air voids decreasing in both mineral aggregate and Marshall mix, which leads to reducing asphalt content.
When the glass content of three sizes exceeded 30% by total weight, the indirect tensile strengths and Marshall quotient values were substantially reduced. She observed that The moisture resistance of the glass-modified asphalt mix was satisfactory, and it met the criteria for glass replacement percentages up to 30%. Adding 2% hydrated lime also improves water resistance and decreases apparent stripping.

4.3. Effects of replacing the crushed glass with aggregate.

(Shafabakhsh and Sajed, 2014) conducted asphalt tests used to investigate the effect of replacing crushed glass to 4.75 mm particle size, the content of asphalt was 4.5-6.6%, the percentage of glass content was 20, 15, 10, 5, and 0% of the total weight of the aggregate. Each ratio's stiffness module is shown in **Fig. 12**. Hydrated lime was also added. To resist moisture damage to the asphalt mixture. The following tests were used: Marshall Test, indirect tensile modulus, and dynamic creep test.

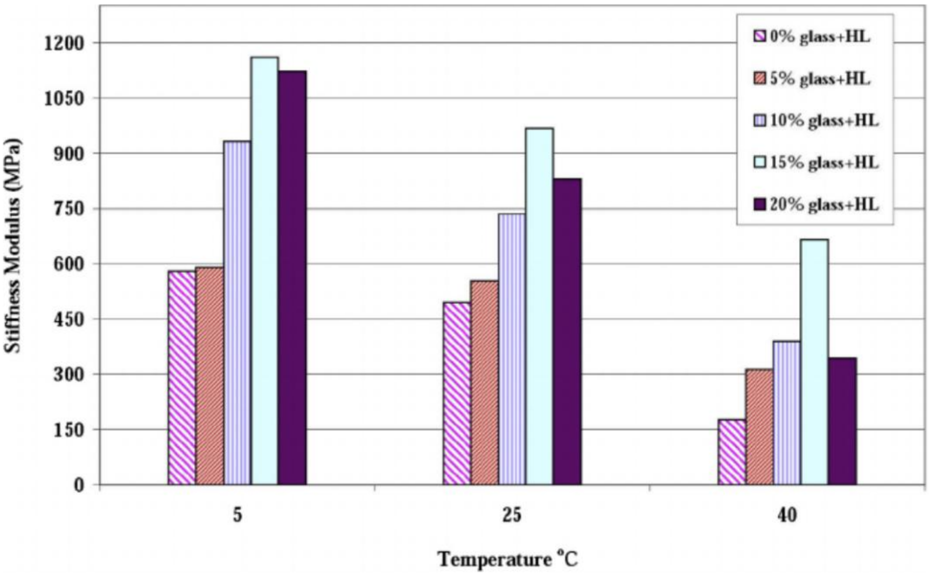


Figure 13. Stiffens modulus (MPa) of mixtures vs each mixture temperature (°C).

The results showed a higher proportion of glass has a lower stiffness modulus. Compared to standard asphalt concrete, the dynamic qualities of glass–asphalt concrete can be enhanced. The quantity of glass cullet in asphalt samples is increased, which lowers permanent deformation. These deformations are lessened by stiffness modulus. Deformations are gradually reduced due to factors such as greater interaction between aggregate particles with coarser glass cullet particles. The permanent deformation of glasphalt samples rises when the glass cullet percentage increases above the ideal value. This study's overall findings suggest that glass cullet can improve the dynamic characteristics of asphalt mix.

4.4. Hot mix asphalt contenting crushed glass and sawyer wood properties

(Haq and Saadi, 2011) studied sawyer wood and crushed glass as an addition to see how they affected the physical characteristics of bitumen and the top layer of an HMA pavement. In this investigation, bitumen with a penetration grading of 40-50 and a maximum aggregate size gradation of 19mm was utilized, with an optimal asphalt content of 4.9 percent (25 °C). Broken glass and sawdust (stay on sieve number 200) are employed in four different percentages (0 percent, 3 percent, 6 percent, and 9 percent by weight of total aggregate). A creep test is used to evaluate the mixtures. When the percentage of broken glass in the mixture is increased, the percentage of VFA lowers. The creep strain decreases as the ratio of broken glass and sawyer wood increases. The creep stiffness increases as the broken glass or sawyer wood ratio increases. From the results, they observed: The percentage of air voids increases as the number of crushed glass increases. The VMA percentage rises as the percentage of broken glass components rises.

CONCLUSIONS

The following are the conclusions based on the approach adopted in this research:

1. Using PET as a bitumen modification showed obvious enhanced bitumen characteristics and improvement in asphalt mixture properties such as rutting resistance, Marshal parameters, and flexibility.
2. Utilization of PET as additive to asphalt mixture as follow ratios: 3 %, 4 %, 5 %, 6 %, and 7 %. Asphalt mixture with all additives ratios met the standard specifications of Indonesia and showed better properties. Larger PET sizes were used in the modified dry technique, and the changed mixes performed relatively better in terms of volumetrics, Marshall standard, and water-induced resistance.
3. Asphalt mixture contenting powder of waste glass as a filler showed greater resilient modulus, better load distribution, and higher resistance to cracking and rutting bit; it showed poor performances in terms of adhesive property and resistance to the moisture.
4. Using recycled glass waste in asphalt mixture as partial replacement to fine aggregate showed perfect stiffness modules at a 15 % glass ratio. Also, reducing deformation with glass increases until the optimum ratio. In general, glass enhanced the dynamic properties of the mixture. For asphalt-glass-wood mixture had higher stiffness, and the creep strain with glass wood sawyer increased but had an inverse relationship with an air void.

In the end, the findings of this review are summarized as follows: using PET and glass wastes in asphalt pavement has a positive impact in terms of:

1. Environment protection and reducing the quantity of S.W at landfills and incinerations then reuse them in asphalt mixtures.
2. Obvious improvement of asphalt mixture properties in most PET and glass mixtures ratios.
3. From an economic point of view: The use of recycled glass and PET in the pavement is economical because it reduces the amount of asphalt binder (which is more expensive than solid wastes) in the mixture, in addition to the high costs of transporting and operating landfills and incinerators.

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