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Use of Recycled Asphalt in Mixtures for Pavement Base and Sub-base Layers

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Utilização de asfalto reciclado em misturas para camadas de base e sub-base de pavimentos

RESUMO

Objetivo – Esta pesquisa busca avaliar o desempenho mecânico de misturas entre solo natural RAP para aplicação em camadas de base e sub-base de pavimentos.

Metodologia – Foram realizados ensaios de granulometria, limites de consistência, compactação e índice de suporte Califórnia (ISC) para amostras de solo natural e misturas solo/RAP, substituindo o solo nas proporções 30%, 40% e 50% de RAP. Também foram ensaiadas misturas trocando o RAP por Resíduos de Construção e Demolição (RCD) nas mesmas proporções supracitadas, além das misturas RAP/pó de pedra/brita nas proporções 70%/30%/0%, 60%/40%/0% e 50%/40%/10%.

Originalidade/relevância – O estudo apresenta ensaios técnicos de laboratório com misturas a partir de solo com baixas capacidades de suporte, visando um aumento prático com vistas à utilização em camadas de sub-base e base de pavimentos. A utilização de diferentes tipos de materiais e de proporções de misturas apresentam uma maior variedade de resultados.

Resultados – A incorporação de RAP e RCD ao solo natural melhora suas propriedades geotécnicas, tornando-o mais adequado para pavimentação, aumentando em até seis vezes os valores originais de ISC. O RAP se destacou ao aumentar a capacidade de suporte, sendo eficaz para sub-bases. Já a combinação de RAP com brita atendeu aos requisitos para bases de tráfego leve e pesado, oferecendo uma solução sustentável e tecnicamente viável para pavimentos, com maior durabilidade e menor uso de recursos naturais.

Contribuições teóricas/metodológicas – Este estudo apresenta importantes contribuições teóricas ao aprofundar a compreensão sobre a estabilização de solos siltosos e argilosos com materiais reciclados, demonstrando a superioridade do RAP em relação ao RCD na melhoria da resistência e capacidade de suporte. Do ponto de vista metodológico, destaca-se pela utilização de ensaios normatizados do DNIT, pela investigação de diferentes composições de misturas e pela incorporação de critérios técnicos e sustentáveis. Os achados indicam alternativas viáveis e ambientalmente responsáveis para aplicação em camadas de sub-base e base de pavimentos, inclusive em vias de tráfego intenso, com potencial de uso prático na engenharia rodoviária.

Contribuições sociais e ambientais – Diante da carência de infraestrutura rodoviária e da escassez de materiais para pavimentação, a reutilização do resíduo de pavimento asfáltico (RAP) surge como uma solução sustentável. Essa prática contribui para a redução do passivo ambiental, promove o reaproveitamento de materiais descartados e apoia o desenvolvimento da infraestrutura nacional, gerando benefícios sociais e ambientais.

PALAVRAS-CHAVE: Pavimento flexível. Materiais asfálticos. Sustentabilidade.

Use of recycled asphalt in mixtures for pavement base and subbase layers

ABSTRACT

Objective – This research aims to evaluate the mechanical performance of mixtures composed of natural soil and Reclaimed Asphalt Pavement (RAP) for application in pavement base and sub-base layers.

Methodology – Laboratory tests were conducted, including grain size distribution, Atterberg limits, compaction, and California Bearing Ratio (CBR) on samples of natural soil and soil/RAP mixtures, replacing the soil with 30%, 40%, and 50% RAP. Additionally, mixtures with Construction and Demolition Waste (CDW) replacing RAP in the same proportions were tested, as well as RAP/stone dust/crushed stone mixtures in the ratios of 70%/30%/0%, 60%/40%/0%, and 50%/40%/10%.

Originality/Relevance – The study presents technical laboratory analyses involving low-support-capacity soils, aiming to enhance their performance for use in pavement base and sub-base layers. The inclusion of different material types and mix proportions provides a broader range of performance outcomes.

Results – The incorporation of RAP and CDW into natural soil improves its geotechnical properties, making it more suitable for pavement applications, with CBR values increasing by up to six times. RAP was especially effective in improving load-bearing capacity, making it suitable for sub-base layers. Moreover, combining RAP with crushed stone met the requirements for base layers under both light and heavy traffic, offering a sustainable and technically viable pavement solution with increased durability and reduced consumption of natural resources.

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Theoretical/Methodological Contributions – This study offers significant theoretical contributions by advancing the understanding of stabilizing silty and clayey soils using recycled materials, highlighting the superior performance of RAP over CDW in terms of strength and support capacity. Methodologically, the research stands out for employing standardized DNIT testing procedures, evaluating various material compositions, and integrating technical and sustainability criteria. The findings suggest practical and environmentally responsible alternatives for use in pavement base and sub-base layers, including those subjected to heavy traffic, with strong applicability in road engineering.
Social and Environmental Contributions – Considering the shortage of road infrastructure and the limited availability of natural paving materials, the reuse of asphalt waste (RAP) emerges as a sustainable solution. This approach helps reduce environmental liabilities, encourages the reuse of discarded materials, and supports the development of national infrastructure, generating both social and environmental benefits.

KEYWORDS: Flexible pavement. Asphalt materials. Sustainability.

Utilización de asfalto reciclado en mezclas para capas de base y sub-base de pavimentos

RESUMEN
Objetivo – Esta investigación tiene como objetivo evaluar el desempeño mecánico de mezclas compuestas por suelo natural y pavimento asfáltico reciclado (RAP) para su aplicación en capas de base y subbase de pavimentos.
Metodología – Se realizaron ensayos de granulometría, límites de consistencia, compactación e Índice de Soporte de California (CBR) en muestras de suelo natural y mezclas suelo/RAP, sustituyendo el suelo en proporciones del 30%, 40% y 50% de RAP. También se ensayaron mezclas sustituyendo el RAP por Residuos de Construcción y Demolición (RCD) en las mismas proporciones, así como mezclas RAP/polvo de piedra/piedra triturada en proporciones de 70%/30%/0%, 60%/40%/0% y 50%/40%/10%.
Originalidad/Relevancia – El estudio presenta análisis técnicos de laboratorio con mezclas elaboradas a partir de suelos con baja capacidad de soporte, con el objetivo de mejorar su desempeño para su uso práctico en capas de subbase y base de pavimentos. El uso de distintos tipos de materiales y proporciones de mezcla ofrece una mayor variedad de resultados.
Resultados – La incorporación de RAP y RCD al suelo natural mejora sus propiedades geotécnicas, haciéndolo más adecuado para la pavimentación, con incrementos de hasta seis veces en los valores originales de CBR. El RAP se destacó por mejorar significativamente la capacidad de soporte, siendo eficaz para capas de subbase. La combinación de RAP con piedra triturada cumplió los requisitos para capas de base en vías de tráfico liviano y pesado, representando una solución sostenible y técnicamente viable, con mayor durabilidad y menor consumo de recursos naturales.
Contribuciones teóricas/metodológicas – Este estudio aporta importantes contribuciones teóricas al profundizar la comprensión sobre la estabilización de suelos limosos y arcillosos con materiales reciclados, demostrando la superioridad del RAP respecto al RCD en la mejora de la resistencia y capacidad de soporte. Desde el punto de vista metodológico, se destaca por el uso de ensayos estandarizados según las normas del DNIT, la evaluación de distintas composiciones de mezcla y la incorporación de criterios técnicos y sostenibles. Los resultados indican alternativas viables y ambientalmente responsables para su aplicación en capas de base y subbase de pavimentos, incluso en vías de tráfico intenso, con alto potencial de aplicación en la ingeniería vial.
Contribuciones sociales y ambientales – Frente a la escasez de infraestructura vial y de materiales naturales para pavimentación, la reutilización del RAP se presenta como una solución sostenible. Esta práctica contribuye a la reducción del pasivo ambiental, fomenta el reaprovechamiento de materiales descartados y apoya el desarrollo de la infraestructura nacional, generando beneficios sociales y ambientales.

PALABRAS CLAVE: Pavimento flexible. Materiales asfálticos. Sostenibilidad.

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1 INTRODUCTION

The accelerated growth of infrastructure projects in both developed and developing countries has led to an intense demand for natural aggregates in the construction industry. This increasing demand has resulted in the depletion of natural resources, raising environmental concerns and contributing to the rising costs of these materials (Barmade; Patel; Dhamaniya, 2022).

With growing awareness regarding the implementation of sustainable transportation systems, there has been a significant increase in the use of recycled materials and industrial by-products in highway construction. Advancements and the emergence of new equipment on the market have brought innovative alternatives to pavement construction. One such practice is the complete removal of deteriorated asphalt pavements and the reuse of the resulting material as a base for new pavement structures, thereby reducing the need for virgin materials (Camargo et al., 2013; Bonfim, 2021).

Reclaimed Asphalt Pavement (RAP), also referred to as Recycled Asphalt Pavement, is derived from the milling process of deteriorated asphalt surfaces. When properly processed through crushing and screening, this material becomes a well-graded, high-quality aggregate. RAP has emerged as a more sustainable alternative to conventional materials, helping to reduce the consumption of natural resources in highway construction (Bilodeau; Gonzalez, 2021).

The service life of a roadway can vary depending on traffic intensity and maintenance frequency (Jullien; Dauvergne; Proust, 2015). Bernucci et al. (2022) argue that by monitoring a road segment over the years, the decline in its serviceability can be used to evaluate surface performance and identify the different phases of the pavement's life cycle, thus establishing criteria for timely maintenance interventions. According to Jiang et al. (2021), traditional asphalt pavements typically have an average lifespan of 15 years.

In recent years, several studies have proposed alternatives aimed at improving asphalt materials from both mechanical and environmental perspectives. Examples of research aligned with this approach include Bastos et al. (2020), who reported that the partial replacement of fine aggregate with polyethylene terephthalate (PET) waste in asphalt mixtures yields promising results, and Kowalski and Masiero (2020), who evaluated surface temperature measurement systems for urban pavements.

Studies by Saha and Mandal (2017), Seferoğlu, Seferoğlu, and Akpinar (2018), as well as Kolay and Singh (2016), demonstrate that using 100% RAP results in poor geotechnical properties, making it unsuitable for sub-base and base layers in pavement structures. Therefore, to improve the load-bearing characteristics of the mixture, it is necessary to blend RAP with local soils and aggregates. Stabilizing agents such as lime, cement, blast furnace slag, asphalt emulsions, and sugarcane bagasse may also be considered to enhance performance (Mohanty; Mohapatra; Nayak, 2022).

Given the national shortage of road infrastructure, the scarcity of suitable paving materials, and the environmental liability associated with the storage of asphalt waste, the reuse of RAP emerges as a sustainable solution. Its application in base and sub-base layers offers a way

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to address material shortages while supporting the development of national infrastructure in an environmentally responsible manner.

2 OBJECTIVE

The objective of this study is to evaluate the mechanical performance of mixtures of natural soil with Reclaimed Asphalt Pavement (RAP) for use in base and sub-base layers of road pavements. To this end, tests were conducted on grain size distribution, liquid and plastic limits, compaction, and California Bearing Ratio (CBR) for samples of natural soil, used as a reference, and natural soil/RAP mixtures, replacing the natural soil with 30%, 40%, and 50% RAP. Additionally, mixtures in which RAP was replaced by Construction and Demolition Waste (CDW) (natural soil/CDW) in the same proportions were also tested, along with RAP/stone dust/crushed stone mixtures in the ratios of 70%/30%/0%, 60%/40%/0%, and 50%/40%/10%, aiming to establish a comparative analysis between the results obtained.

3 METHODOLOGY

To support the development of the research, materials were collected from quarries and processing plants, followed by the definition of mixture proportions and the preparation of samples to be tested. Finally, laboratory tests were conducted on the samples, along with analysis of the respective results obtained.

3.1 Collection and Preparation of Materials Used

The natural soil, RAP, CDW, and crushed aggregate used in this study are commonly found in the Metropolitan Region of Recife, in the state of Pernambuco, Brazil. For the natural soil, nine samples were collected and tested from a local borrow pit. The RAP materials were collected from a local recycling plant, and their composition is shown in Table 1. Figure 1 presents the grain size distribution curve of the final RAP mixture used in the study.

Table 1 – Composition of the RAP mixture used in the study.

Materials used in the final RAP mixture composition	Proportion of each material in the RAP mixture
19 mm Crushed Stone – RAP	25%
9.5 mm Crushed Stone – RAP	25%
Stone Dust – Quarry	50%

Source: Authors (2025).

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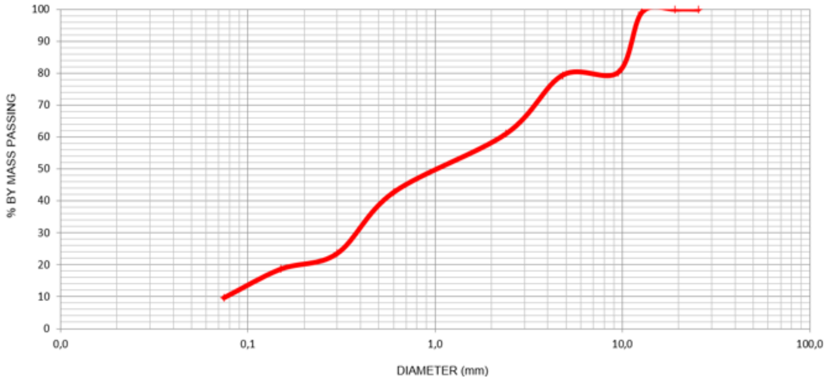
Figure 1 – Granulometric curve for the composition of the RAP mixture used.



Source: Authors (2025).

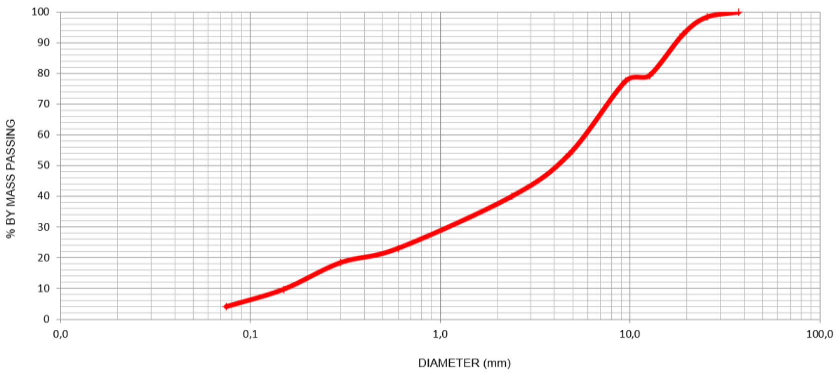
Similar to the RAP materials, the CDW (Construction and Demolition Waste) was also obtained from a recycling plant, with its respective composition presented in Table 2. The grain size distribution curve of the mixture is shown in Figure 2.

Table 2 - Composition of the CDW mixture used in the study.

Materials used in the final CDW mixture composition	Proportion of each material in the CDW mixture
19 mm Crushed Stone – CDW	20%
9.5 mm Crushed Stone – CDW	30%
Stone Dust – Quarry	50%

Source: Authors (2025).

Figure 2 – Granulometric curve for the composition of the CDW mixture used.



Source: Authors (2025).

For the purposes of this study, compositions including crushed aggregates (19 mm and 12.5 mm) and stone dust, sourced from a local quarry, were also incorporated.

One of the main objectives of the research is to analyze which type of mixture presents the most suitable geotechnical properties for application in pavement base and sub-base layers. Accordingly, different mixtures were tested in the laboratory to determine the influence of the materials used on the results obtained.

Based on the reviewed literature, mixtures were prepared in various proportions using the following materials: natural soil, RAP, CDW, 19.5 mm and 12.5 mm crushed stone, and stone dust.

As previously mentioned, reference tests were conducted using natural soil collected from the borrow pit, both individually and in mixtures with RAP and CDW. The soil/RAP and soil/CDW mixtures were prepared in the proportions of 70%/30%, 60%/40%, and 50%/50%. In

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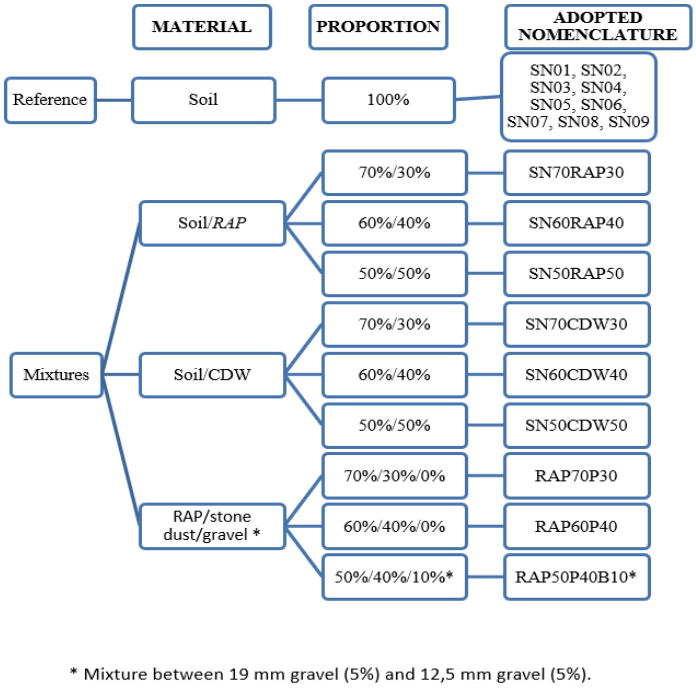
addition, RAP/stone dust/crushed stone mixtures were prepared in the same ratios: 70%/30%/0%, 60%/40%/0%, and 50%/40%/10%.

The detailed composition of all 18 samples tested (whether individual or composite mixtures) is presented in Figure 3.

Figure 3 – Details of the materials tested and their respective nomenclatures



Source: Authors (2025).

3.2 Laboratory Testing

The natural soil, RAP, CDW, and crushed aggregate used in this study are commonly found in the Metropolitan Region of Recife, in the state of Pernambuco, Brazil. For the natural soil, nine samples were collected from a local borrow pit and tested. The tests performed on these samples included: grain size analysis by sieving, liquid limit determination, plastic limit determination, compaction tests using Standard, Intermediate, and Modified Proctor energy levels, and California Bearing Ratio (CBR) tests—also using Standard, Intermediate, and Modified Proctor compaction energy.

In order to meet the specifications outlined in Table 3 for base and sub-base layers, tests were carried out using natural soil (as a reference) as well as soil/RAP and soil/CDW mixtures. The RAP/stone dust/crushed stone mixture was evaluated specifically for its application in base layers only. For the natural soil, 19 mm and 12.5 mm crushed stones, stone dust, RAP, and CDW, grain size distribution tests were performed to characterize the materials in accordance with the applicable technical standards.

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Table 3 - National Department of Transport Infrastructure (DNIT) normative specifications for the use of granular materials in base and sub-base layers of pavements.

Specification	Consistency Limits	CBR	Expansion
Pavement – Granulometrically Stabilized Sub-base – Service Specification	-	≥ 20%	≤ 1,0%
Pavement – Granulometrically Stabilized Base – Service Specification	Liquid Limit – LL ≤ 25% Plasticity Index – PI ≤ 6%	≥ 60% (light traffic) ≥ 80% (heavy traffic)	≤ 0,5%

Source: Authors (2025).

For the study involving natural soil samples from the borrow pit, the Standard Proctor compaction energy was used. In order to allow comparisons with the values obtained from the other mixtures, the correlation proposed by Sreelekshmypillai and Vinod (2019) was applied, whereby the results are converted to both Intermediate and Modified Proctor energy levels. The authors observed that the CBR value under Modified Proctor energy is approximately 25% higher than that obtained under Intermediate Proctor energy, which in turn is about 43% higher than the result from Standard Proctor energy.

4 RESULTS AND DISCUSSION

The natural materials tested, obtained from the borrow pit, exhibited average geotechnical characteristics typical of a sandy silt, non-plastic, with an average CBR value of 4% and average expansion of 2.3%, under Standard Proctor compaction energy. These values comply with the specifications of DNIT 108/2009 - ES for embankment fill layers (CBR ≥ 2% and Expansion ≤ 4.0%). Since the compaction and CBR tests were performed using Standard Proctor energy, it was necessary to convert the results to Intermediate and Modified Proctor energy levels to allow for comparison with the results of the RAP and CDW mixtures. After conversion, average CBR values of 6% for Intermediate Proctor energy and 8% for Modified Proctor energy were obtained.

The results from the tests conducted in this study revealed significant changes in the behavior of the samples after mixing with RAP and CDW. For natural soil/RAP mixtures with RAP contents of 30%, 40%, and 50%, an increase in CBR values was observed as the RAP content increased, with values of 21%, 27%, and 30% respectively, under Intermediate Proctor energy. In contrast, the converted value for the natural soil alone was approximately 6%. As a result, all three mixtures met the current specifications for sub-base layers, which require a minimum CBR of 20% under Intermediate Proctor energy.

With the increase in compaction energy to Modified Proctor, aiming at application in base layers, the CBR values obtained were 24%, 30%, and 34% for RAP additions of 30%, 40%, and 50%, respectively, compared to only 8% for the natural soil. Therefore, an increase was observed in relation to the values obtained under Intermediate Proctor energy for the same RAP contents, while the trend of increasing CBR with higher RAP proportions remained consistent. Despite the significant improvement, the results still did not meet the current specification for base layers, which requires CBR ≥ 60% for light traffic and ≥ 80% for heavy traffic. The CBR results

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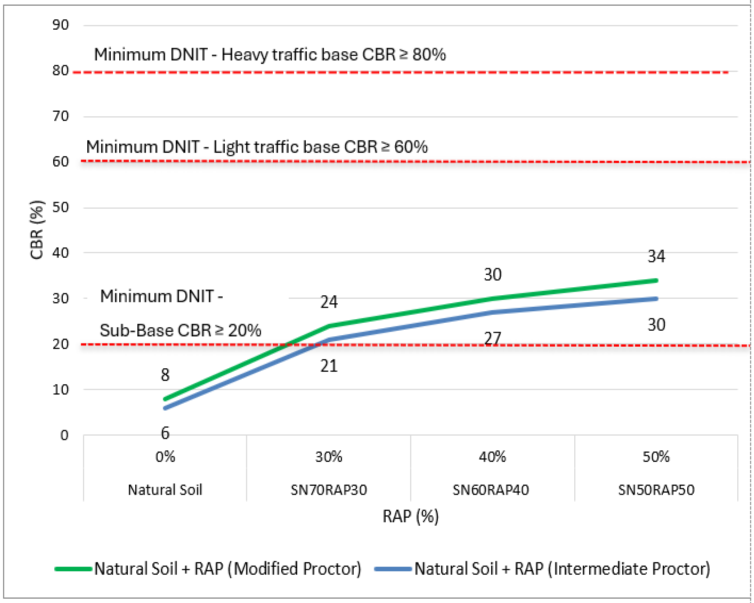
for the soil/RAP mixtures are shown in Figure 4.

Figura 4 – CBR values according to the mixing proportions between natural soil/RAP.



Source: Authors (2025).

Based on the results obtained, a linear growth trend in CBR can be observed as the RAP content in the mixture increases. Verified using Excel software, this linear behavior is confirmed by determination coefficients (R^2) of 0.9978 for the Modified Proctor energy samples and 0.9948 for the Intermediate Proctor energy samples. Thus, by fitting a line according to the function generated by the software, it is possible to extrapolate the CBR value for a sample composed solely of RAP, estimated at approximately 61% for Modified Proctor energy and 55% for Intermediate Proctor energy. This indicates that the behavior of RAP found in this study is consistent with that reported in the literature, confirming good alignment with the studied international standards.

Accordingly, as shown in Figure 5, the resistance growth trend of the mixture is directly related to the capacity of the natural soil; if the natural soil's CBR value is higher than that of RAP, there will be a tendency for the mixture's CBR to decrease. Conversely, if the natural soil's CBR is lower than that of RAP, the mixture's CBR value tends to increase.

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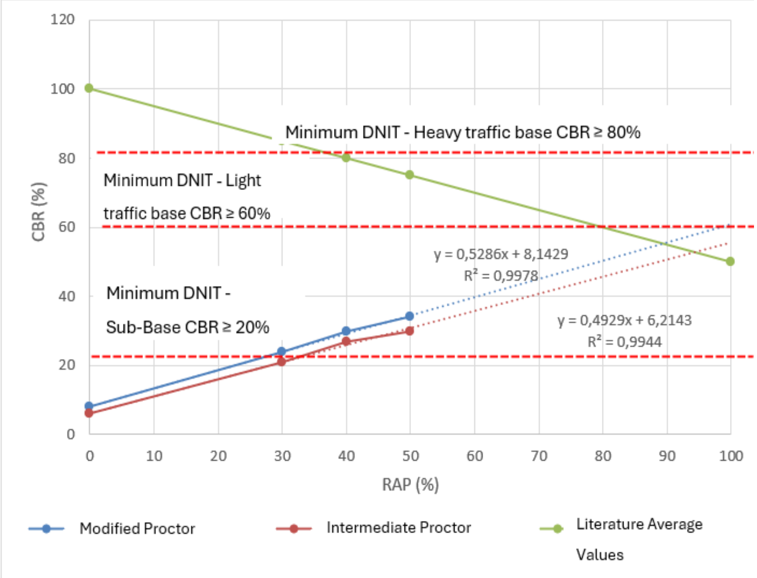
Figure 5 – Comparison of CBR values of natural soil/RAP with literature.



Source: Authors (2025).

For the natural soil/CDW mixtures, the CBR values obtained for the proportions of 70%/30%, 60%/40%, and 50%/50% were 16%, 17%, and 24%, respectively—significantly lower than the values obtained for natural soil/RAP mixtures at the same proportions. Nevertheless, there was a considerable increase compared to the natural soil alone, which had a CBR of 6%. Despite the improved load-bearing capacity with the addition of CDW, only the 50%/50% mixture with natural soil met the specification of CBR ≥ 20% for pavement sub-base layers.

For application in pavement base layers, natural soil/CDW mixtures tested under Modified Proctor compaction energy showed lower results compared to the natural soil/RAP study, with values of 22%, 32%, and 48% for the respective natural soil proportions of 70%/30%, 60%/40%, and 50%/50%. Despite the improvement over the natural condition, none of the mixtures met the specifications for use in pavement base layers, which require CBR ≥ 60% for light traffic and CBR ≥ 80% for heavy traffic. The CBR results for the natural soil/CDW mixtures, under both Intermediate and Modified Proctor energies, are shown in Figure 6.

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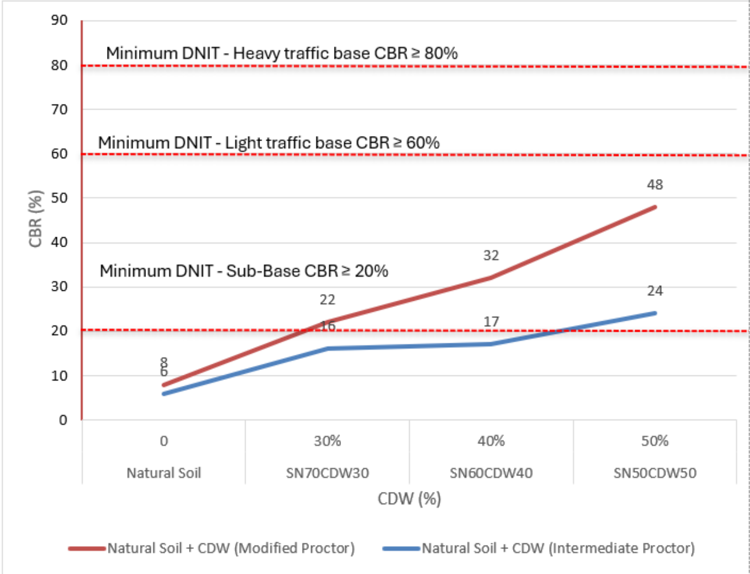
Figure 6 – CBR value as a function of the mixing proportions between natural soil/CDW.



Source: Authors (2025).

The expansion criterion was also influenced by the presence of RAP and CDW, reducing to values close to zero, thus meeting the specifications for pavement sub-base and base layers, which require maximum expansion values of 1.0% and 0.5%, respectively, except for the natural soil mixtures with RAP and CDW at the 70%/30% proportion.

Considering fundamental parameters for earthworks and pavement construction processes related to material homogenization and compaction, the results from compaction tests using Intermediate and Modified Proctor energies were also analyzed for natural soil/RAP and natural soil/CDW mixtures. The maximum dry density, together with the optimum moisture content, showed slight variations as the mixture proportions changed. While the maximum dry density increased with the addition of RAP, the optimum moisture content decreased.

With the addition of RAP and CDW, changes occurred in the plasticity characteristics of the materials. Samples SN03, SN04, and SN09, which were previously plastic with plasticity indices of 21%, 17%, and 19%, respectively, became non-plastic. Additionally, all samples that previously exhibited silty or clayey material characteristics shifted to predominantly granular properties, evidenced by a decrease in the percentage of material passing the No. 200 sieve (0.075 mm). This finding indicates an improvement in the material's properties for the intended pavement application, since fine materials like silt and clay have low support capacity and, in the case of clay, high plasticity and expansiveness.

For use in pavement base layers, new mixtures of RAP and crushed aggregates (19.5 mm, 9.5 mm crushed stone, and stone dust) were prepared in different proportions. The CBR values under Modified Proctor energy were 46%, 69%, and 90% for the proportions 70%/30%, 60%/40%, and 50%/50%, respectively. The RAP/stone dust proportion of 60%/40% met the specification for light traffic (CBR ≥ 60%), while the 50%/50% proportion met the specifications for both light and heavy traffic (CBR ≥ 80%). The test results are shown in Figure 7 along with the regulatory parameters.

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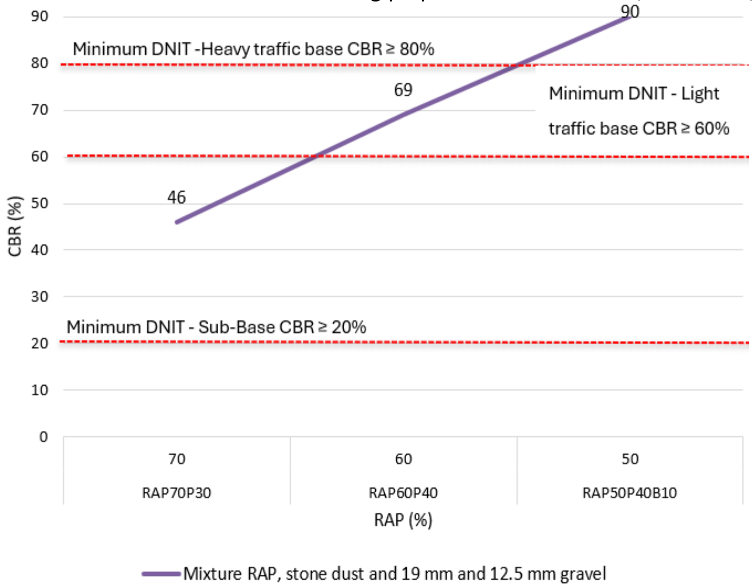
Figura 7 – CBR value as a function of the mixing proportions between RAP/stone dust/gravel.



Source: Authors (2025).

Thus, with the addition of RAP and CDW, the borrow pit materials—which previously had suitability only for use in embankment fill layers in their natural condition—acquired properties that meet the requirements for use in pavement sub-base and base layers. Similarly, the use of RAP in base layers is feasible when mixed with granular crushed materials. The proportions and their intended applications are presented in Table 4.

Quadro 4 - Proporções ensaiadas e suas finalidades de acordo com os resultados obtidos.

Proportion	Soil/RAP	Soil/CDW	RAP/stone dust/crushed stone
70%/30%	Subgrade Reinforcement Sub-base Layer	Subgrade Reinforcement	Subgrade Reinforcement Sub-base Layer
60%/40%	Subgrade Reinforcement Sub-base Layer	Subgrade Reinforcement	Subgrade Reinforcement Sub-base Layer Base Layer (Light Traffic)
50%/50%	Subgrade Reinforcement Sub-base Layer	Subgrade Reinforcement Sub-base Layer	Subgrade Reinforcement Sub-base Layer Base Layer (Light and Heavy Traffic)

Source: Authors (2025).

5 CONCLUSIONS

Based on tests conducted involving natural soil and materials such as RAP, CDW, and crushed aggregates, the following conclusions were drawn:

- The addition of RAP and CDW to natural soil modified its characteristics, transforming silty and clayey soils into predominantly granular soils, thereby improving their suitability for paving.

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- In compaction tests, the maximum dry density increased with the addition of RAP, while the optimum moisture content decreased, favoring the homogenization and compaction of the materials.
- The expansion criterion was reduced to values close to zero, meeting the specifications of DNIT 139/2010 and 141/2022 for pavement sub-base and base layers, respectively.
- Natural soil/RAP mixtures showed a significant increase in CBR as the RAP proportion increased, for both Intermediate and Modified Proctor compaction energies.
- Compared to RAP, natural soil/CDW mixtures showed inferior performance. Although the addition of CDW improved the load-bearing capacity compared to natural soil alone, results indicate that RAP is more efficient in enhancing the strength of the mixtures and better suited to meet DNIT specifications.
- The addition of crushed aggregates to RAP significantly improved the load-bearing capacity of the mixtures, allowing their application in pavement base layers for both light and heavy traffic, depending on the RAP content.
- It was also observed that the final strength of the mixture depends on the load-bearing capacity of the natural soil, which may increase or decrease depending on the relationship between the individual CBR values of the materials.

It is concluded that incorporating RAP and CDW into natural soil improves its geotechnical properties, making it more suitable for paving. RAP addition was more effective in enhancing load-bearing capacity, with natural soil/RAP mixtures meeting criteria for sub-base layers but falling short of the requirements for base layers. The combination of RAP with crushed aggregates proved to be the most viable alternative for base layers, meeting specifications for light and heavy traffic, representing a sustainable and technically feasible solution for pavement construction and rehabilitation, with greater structural durability and reduced consumption of natural resources.

Regarding the discussed topic, it is suggested that further mixtures including RAP and CDW be tested to validate the hypotheses presented. Additionally, tests with varying proportions are recommended to confirm the linear nature of CBR results for natural soil/RAP samples. Finally, it is suggested to use natural soils with different characteristics to verify the trend of increase or decrease in load-bearing capacity with RAP addition.

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DECLARATIONS

AUTHOR CONTRIBUTIONS

The contributions of each author to the manuscript are described below, according to the following criteria:

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CONFLICT OF INTEREST STATEMENT

We, [Raphael Britto Moura Lins, Yêda Vieira Póvoas, Micael Justino da Silva Júnior, and José Orlando Vieira Filho], hereby declare that the manuscript entitled *"Use of Recycled Asphalt in Mixtures for Pavement Base and Sub-base Layers"*:

1. **Financial Ties**: Does not have / has financial ties that could influence the results or interpretation of the work.
2. **Professional Relationships**: Does not have / has professional relationships that could impact the analysis, interpretation, or presentation of the results.
3. **Personal Conflicts**: Does not have / has personal conflicts of interest related to the content of the manuscript.