

Performance Evaluation of Reclaimed Asphalt Pavement as a Fine Aggregate Substitute in Dolomite Base Layers

¹ Mai M. Shams, ² Amany Emad Elawady, ³ Ahmed Mohamady Abdallah, ⁴ Mohamed A. Shalaby

1 Assistant Professor, Civil Engineering Department, Faculty of Engineering, Suez Canal University, Egypt

2 Demonstrator and M.Sc. Student, Civil Engineering Department, Faculty of Engineering, Suez Canal University, Egypt

3 Professor of Highways Engineering, Construction Engineering and Utilities Department, Faculty of Engineering, Zagazig University, Egypt

4 Lecturer of Highway and Airport Engineering, Construction Engineering and Utilities Department, Faculty of Engineering, Zagazig University, Egypt

ABSTRACT

The extensive use of natural quarry materials in pavement base layers raises growing concerns regarding resource depletion and environmental sustainability, particularly in Egypt, where dolomite aggregate is widely used in base course construction. This study evaluates the potential use of Reclaimed Asphalt Pavement (RAP) as a sustainable partial replacement for natural aggregate in pavement base course mixtures. Conventional dolomite aggregate was used as the control material, while RAP was incorporated at contents of 0%, 10%, 20%, and 30% by total mixture weight. Modified Proctor compaction and California Bearing Ratio (CBR) tests were conducted to investigate the influence of RAP content on compaction characteristics and load-bearing capacity. The experimental results showed a consistent reduction in compaction and strength parameters with increasing RAP content. The maximum dry density (MDD) decreased from 2.23 g/cm³ for the control mixture to 2.19, 2.13, and 2.10 g/cm³ at 10%, 20%, and 30% RAP, respectively. Similarly, the optimum moisture content (OMC) decreased from 5.99% to 5.25%, 4.41%, and 3.94%. A comparable trend was observed in CBR, which decreased from 96.9% for the control mixture to 77.2%, 67.1%, and 58.3% at 10%, 20%, and 30% RAP, respectively. These results demonstrate that increasing RAP content progressively influences both the compaction characteristics and load-bearing capacity of the RAP–aggregate mixtures. Regression analysis was conducted to quantify the influence of RAP content on the measured engineering properties. The developed linear relationships indicated that each one-percentage-point increase in RAP content resulted in an approximate decrease of 0.0045 g/cm³ in MDD, 0.073 percentage points in OMC, and 1.259 percentage points in CBR within the investigated range. These relationships provide a useful means of describing and estimating the performance trend of RAP–aggregate mixtures at intermediate RAP contents. Despite the observed reductions in density, moisture demand, and load-bearing capacity, the results demonstrate the potential for incorporating controlled proportions of RAP into granular pavement materials, subject to the performance requirements of the intended pavement layer. The findings support the partial replacement of natural aggregate with RAP as a sustainable approach for reducing the consumption of virgin quarry materials while promoting the reuse of reclaimed pavement materials in Egypt.

Keywords: Reclaimed Asphalt Pavement (RAP), RAP–Aggregate Mixtures, Base Course, Modified Proctor Test, Maximum Dry Density (MDD), Optimum Moisture Content (OMC), California Bearing Ratio (CBR), Sustainable Pavement Engineering.

1. Introduction

Reclaimed Asphalt Pavement (RAP) has become an important recycled material in pavement engineering due to the large quantities generated from pavement milling, maintenance, and rehabilitation activities. Reusing RAP reduces the demand for virgin aggregates and minimizes the disposal of pavement materials, thereby contributing to more sustainable pavement construction and improved utilization of available resources (Saha & Mandal, 2017).

RAP consists primarily of mineral aggregates coated with aged asphalt binder and therefore retains considerable potential for reuse in pavement construction. Previous laboratory investigations have demonstrated that RAP can be blended with natural aggregates and utilized in granular pavement layers, provided that the resulting mixture satisfies the required gradation and engineering performance criteria. This makes RAP a potential alternative material for reducing the consumption of virgin aggregates in base and subbase applications (Mousa et al, 2021).

The engineering characteristics of RAP differ from those of conventional virgin aggregates because of the presence of aged asphalt binder and the physical characteristics of the reclaimed particles. Consequently, incorporating RAP into virgin aggregate can influence the gradation, compaction behavior, strength, stiffness, and moisture-related properties of the resulting mixture. These characteristics emphasize the importance of laboratory evaluation when determining appropriate RAP contents for unbound pavement base applications (Mousa et al, 2021).

Compaction characteristics are particularly important when evaluating RAP–aggregate mixtures because adequate density is necessary for satisfactory pavement performance. Laboratory investigations using Modified Proctor compaction have demonstrated that the compaction behavior of RAP–aggregate blends varies with RAP content. Changes in RAP proportion can affect both maximum dry density (MDD) and optimum moisture content (OMC), highlighting the importance of determining the appropriate compaction conditions for each RAP–aggregate blend (Mousa et al, 2021).

The California Bearing Ratio (CBR) is widely used to evaluate the load-bearing capacity of granular pavement materials. Experimental investigations on RAP–aggregate base materials have demonstrated that CBR is significantly influenced by RAP content. Guthrie et al. reported that CBR values decreased, on average, by approximately 13% to 29% for each 25% increase in RAP content in the materials investigated, demonstrating that excessive RAP incorporation may adversely affect the load-bearing capacity of unbound base mixtures (Guthrie et al, 2007). (Guthrie et al., 2007).

Recent investigations have continued to demonstrate the potential of RAP for use as a granular road base material. The engineering performance of RAP depends on its physical characteristics, particle size distribution, compaction behavior, and mechanical properties. Appropriate characterization and control of these properties are therefore necessary to determine whether RAP-containing materials can satisfy the performance requirements of granular pavement layers (Guerrero-Bustamante et al, 2025).

In the Egyptian context, RAP has also been experimentally evaluated as a replacement for natural aggregate in pavement base and subbase materials. Laboratory investigations using RAP blended with crushed dolomite aggregate at different replacement levels included particle size distribution, Modified Proctor compaction, CBR, permeability, resilient modulus, and shear strength testing. The results demonstrated that RAP content significantly influences the engineering behavior of the blends and confirmed the potential for incorporating RAP into pavement base and subbase materials under appropriate mixture design and performance requirements (Mousa et al, 2021).

Based on the findings reported in the literature, the present study investigates the effect of partially replacing natural aggregate with RAP in pavement base course mixtures. Four RAP contents of 0%, 10%, 20%, and 30%

were evaluated to determine the influence of increasing RAP content on the engineering characteristics of the mixtures. The experimental investigation focuses on particle size distribution, Modified Proctor compaction characteristics, and California Bearing Ratio (CBR). The obtained results are compared with the applicable requirements of the Egyptian Code of Practice for Road Works to evaluate the suitability of the investigated RAP–aggregate mixtures for pavement base course applications and to identify acceptable RAP replacement levels.

2. Materials and Methods

2.1. Materials

Dolomite aggregate obtained from the *Ataka* Quarry, Suez Governorate, Egypt, was used as the primary virgin aggregate in this study due to its widespread use in pavement base course construction in Egypt. The physical properties of the crushed dolomite aggregate were evaluated through standard laboratory tests, including bulk specific gravity, saturated surface-dry (SSD) specific gravity, apparent specific gravity, water absorption, and Los Angeles abrasion resistance. These properties were determined to characterize the aggregate and evaluate its suitability for pavement base course applications. The corresponding test results and specification limits are presented in Table (1).

Table (1): Properties of Dolomite Aggregate.

Test	AASHTO Designation No.	Result	Specification Limits (%)
Bulk specific gravity	T-85	2.66	-
Saturated surface-Dry specific gravity	T-85	2.70	-
Apparent specific gravity	T-85	2.76	-
Water absorption	T-85	1.24 %	≤ 5
Loss Angeles Abrasion	T-96	32.8	≤ 40

Reclaimed Asphalt Pavement (RAP) was collected from the *Almalaha* region, Ismailia Governorate, Egypt. Prior to mixture preparation, the RAP material was processed to remove oversized particles and foreign materials and was prepared for laboratory testing. RAP was incorporated as a partial replacement for natural dolomite aggregate at four contents: 0%, 10%, 20%, and 30% by total dry mixture weight. The remaining proportion of each mixture consisted of natural dolomite aggregate. These mixtures were prepared to investigate the influence of increasing RAP content on the gradation, compaction characteristics, and load-bearing capacity of the base course material.

2.2. Experimental Laboratory Program

The experimental laboratory program was designed to evaluate the effect of incorporating Reclaimed Asphalt Pavement (RAP) on the engineering properties of pavement base course materials. Four mixtures containing 0%, 10%, 20%, and 30% RAP by total dry mixture weight were prepared, with natural dolomite aggregate constituting the remaining proportion of each mixture. To provide a consistent basis for comparison and isolate the influence of RAP content, the mixtures were proportioned so that their particle size distributions remained within the specified gradation limits for base course materials according to the Egyptian Code of Practice for Road Works (2021).

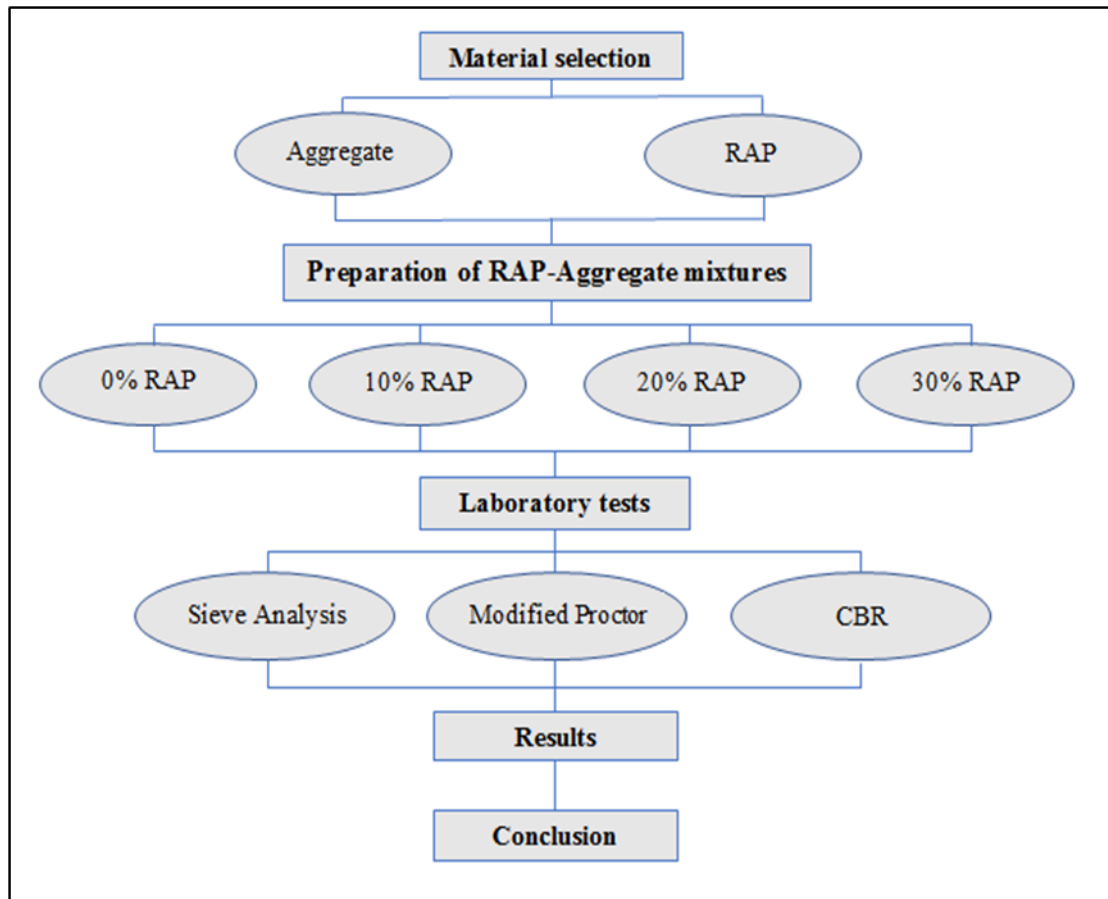


Figure (1): Experimental Methodology Flowchart for RAP–Aggregate Base Mixtures.

The overall experimental methodology adopted in this study is illustrated in Figure (1). The experimental program began with the selection and characterization of the constituent materials, including natural dolomite aggregate and RAP. The materials were subsequently proportioned to prepare four RAP–aggregate mixtures containing 0%, 10%, 20%, and 30% RAP. The prepared mixtures were then subjected to a laboratory testing program to investigate the influence of increasing RAP content on their gradation, compaction characteristics, and load-bearing capacity.

The laboratory testing program consisted of three main stages. First, sieve analysis was conducted to determine the particle size distribution of the natural aggregate, RAP, and the prepared RAP–aggregate mixtures. The resulting gradations were evaluated against the specified limits for base course materials. Table (2) presents the gradation limits for base course material according to the Egyptian Code of Practice for Road Works (2021).

The second stage consisted of Modified Proctor compaction testing for each mixture to determine the maximum dry density (MDD) and optimum moisture content (OMC). These parameters were used to evaluate the influence of RAP content on the compaction characteristics of the mixtures. In the third stage, California Bearing Ratio (CBR) tests were conducted to evaluate the load-bearing capacity of the mixtures and determine the effect of increasing RAP content on their mechanical performance.

All laboratory tests were conducted in accordance with the relevant standard test methods, and consistent material preparation and testing procedures were maintained for all mixtures to ensure reliable comparison of the experimental results. The obtained results were subsequently analyzed to evaluate the influence of RAP content on the engineering performance of RAP–aggregate mixtures and assess their potential suitability for pavement base course applications.

Table (2): Gradation of Base Course According to the Egyptian Specification.

Sieve Size	Specification limits (B)
	% Passing
2"	100
1.5"	70-100
1"	55-85
3/4"	50-80
3/8"	40-70
No. 4	30-60
No. 10	20-50
No. 40	Oct-30
No. 200	May-15

2.3. Test Methods

Three primary laboratory tests were conducted to evaluate the physical and mechanical characteristics of RAP–aggregate mixtures containing 0%, 10%, 20%, and 30% Reclaimed Asphalt Pavement (RAP).

The first test was sieve analysis, conducted in accordance with ASTM C136, to determine the particle size distribution of the natural dolomite aggregate, RAP, and the prepared RAP–aggregate mixtures. The obtained gradations were compared with the specified gradation limits for base course materials according to the Egyptian Code of Practice for Road Works (2021). This evaluation was used to verify the suitability of the particle size distributions of the prepared mixtures for the investigated base course application.

The second test was the Modified Proctor compaction test, conducted in accordance with ASTM D1557, to determine the maximum dry density (MDD) and optimum moisture content (OMC) of each mixture. The test was used to evaluate the influence of increasing RAP content on the compaction characteristics, density, and moisture requirements of the RAP–aggregate mixtures.

The third test was the California Bearing Ratio (CBR) test, conducted in accordance with ASTM D1883, to evaluate the load-bearing capacity of the prepared mixtures. The obtained CBR values were used to investigate the influence of increasing RAP content on the mechanical performance of the mixtures and to assess their suitability for pavement base course applications. Collectively, these tests offered a thorough assessment of how incorporating RAP influences the engineering performance of aggregate mixtures.

Collectively, these tests provided a comprehensive evaluation of the influence of RAP incorporation on the gradation, compaction characteristics, and load-bearing capacity of the investigated RAP–aggregate mixtures. The experimental results were subsequently used to assess the potential for partially replacing natural dolomite aggregate with RAP in pavement base course materials.

3. Results and Discussion

3.1. Gradation Analysis of Natural Aggregate, RAP, and RAP-Aggregate Mixtures

The sieve analysis results revealed clear differences between the particle size distributions of the natural dolomite aggregate and Reclaimed Asphalt Pavement (RAP). As presented in Table (3), the RAP material exhibited a relatively coarser gradation in the fine particle range compared with the natural aggregate. The percentages passing sieves No. 4, No. 10, No. 40, and No. 200 were 45%, 35%, 20%, and 10%, respectively, for the natural aggregate, compared with 24%, 16%, 6%, and 0%, respectively, for RAP. These results indicate that the RAP material used in this study contained a lower proportion of fine particles than the natural dolomite aggregate.

The incorporation of RAP progressively modified the particle size distribution of the blended mixtures. As the RAP content increased from 0% to 30%, the percentage passing sieve No. 4 decreased from 45% to 39%, while the percentage passing sieve No. 10 decreased from 35% to 29%. Similarly, the percentage passing sieve No. 40

decreased from 20% to 16%, and the percentage passing sieve No. 200 decreased from 10% to 7%. This trend reflects the lower fine-particle content of RAP and demonstrates that increasing RAP content gradually produced a coarser gradation within the fine fraction of the blended mixtures.

Despite the observed changes in particle size distribution, all mixtures containing 0%, 10%, 20%, and 30% RAP remained within the adopted gradation limits for base course materials. Even at the highest investigated RAP content of 30%, the percentages passing sieves No. 4, No. 10, No. 40, and No. 200 were 39%, 29%, 16%, and 7%, respectively, compared with the corresponding specification ranges of 30–60%, 20–50%, 10–30%, and 5–15%. Therefore, RAP incorporation up to 30% within the investigated range did not cause the blended mixtures to fall outside the adopted base course gradation envelope.

Table (3): Gradation of Natural Aggregate, RAP, and RAP–Aggregate Mixtures.

Sieve Size	Agg. Pass. (%)	RAP Pass. (%)	0% RAP Mixture Pass. (%)	10% RAP Mixture Pass. (%)	20% RAP Mixture Pass. (%)	30% RAP Mixture Pass. (%)	Specs. Limits (%)	
2"	100	100	100	100	100	100	100	
1.5"	85	99	85	86	88	89	70	100
1"	70	97	70	73	75	78	55	85
3/4"	65	90	65	67	70	72	50	80
3/8"	55	53	55	55	55	54	40	70
No. 4	45	24	45	43	41	39	30	60
No. 10	35	16	35	33	31	29	20	50
No. 40	20	6	20	19	17	16	10	30
No. 200	10	0	10	9	8	7	5	15

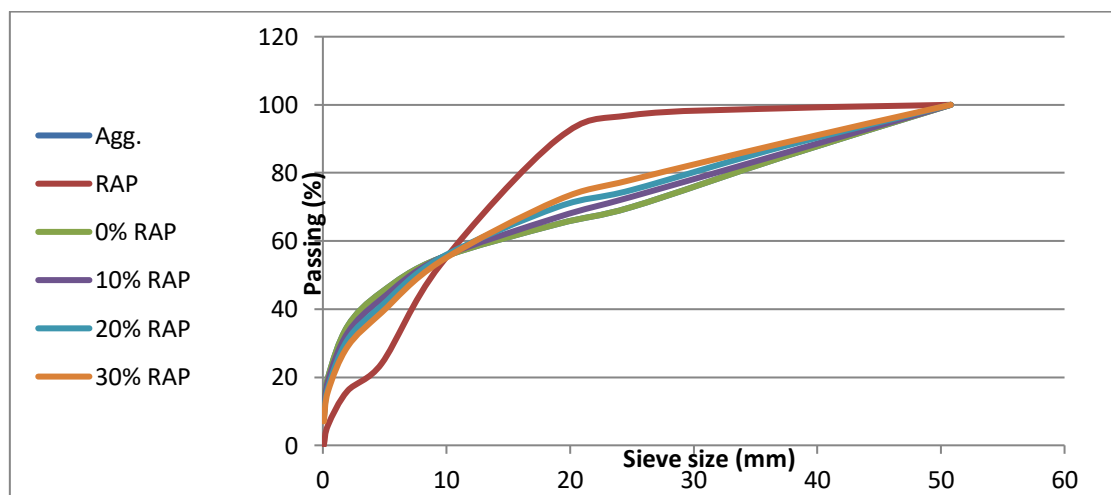


Figure (2): Particle Size Distribution Curves for Natural Aggregate, RAP, and RAP–Aggregate Mixtures

Figure (2) illustrates the particle size distribution curves of the natural dolomite aggregate, RAP, and the prepared RAP–aggregate mixtures. The RAP curve differs noticeably from that of the natural aggregate, particularly within the fine particle range, where RAP exhibited lower percentages passing the finer sieves. As RAP content increased from 0% to 30%, the gradation curves of the blended mixtures progressively reflected the particle size distribution characteristics of RAP, particularly at the No. 4, No. 10, No. 40, and No. 200 sieves.

Nevertheless, all investigated RAP–aggregate mixtures remained within the specified upper and lower gradation limits for the adopted base course material. The gradation results therefore demonstrate that RAP could be incorporated at contents up to 30% within the investigated range while maintaining an acceptable particle size distribution. This provides a consistent basis for evaluating the subsequent Modified Proctor and CBR results and assessing the influence of increasing RAP content on the compaction characteristics and load-bearing capacity of the mixtures.

3.2. Compaction Characteristics of RAP–Aggregate Base Mixtures

The Modified Proctor test results demonstrated a consistent reduction in both maximum dry density (MDD) and optimum moisture content (OMC) with increasing RAP content. As presented in Table (4), the MDD decreased from 2.23 g/cm³ for the control mixture containing 0% RAP to 2.19, 2.13, and 2.10 g/cm³ for mixtures containing 10%, 20%, and 30% RAP, respectively. Similarly, the OMC decreased from 5.99% for the control mixture to 5.25%, 4.41%, and 3.94% as the RAP content increased.

The reduction in MDD can be associated with the physical characteristics of RAP, particularly the presence of aged asphalt binder coating the aggregate particles and the resulting differences in specific gravity compared with natural aggregate. As the proportion of RAP increased, a greater quantity of natural dolomite aggregate was replaced by the relatively lighter RAP material, resulting in a progressive reduction in the achievable dry density of the mixtures. The reduction in OMC indicates that mixtures containing higher RAP contents required less water to reach their maximum dry density. This behavior can be associated with the lower affinity for water of asphalt-coated RAP particles compared with uncoated natural aggregate.

Table (4): Modified Proctor Test Results for RAP–Aggregate Mixtures.

Mixture Type RAP Content (%)	MDD (gm/cm ³)	OMC (%)
0% RAP	2.23	5.99
10% RAP	2.19	5.25
20% RAP	2.13	4.41
30% RAP	2.10	3.94

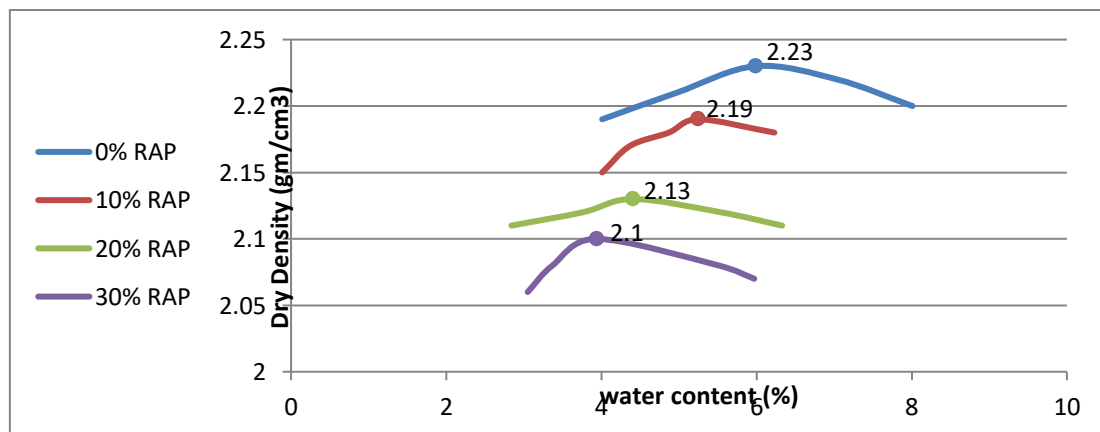


Figure (3): Modified Proctor Compaction Curves for RAP–Aggregate Mixtures

Figure (3) presents the dry density–moisture content relationships obtained from the Modified Proctor tests for the four RAP–aggregate mixtures. All mixtures exhibited the characteristic compaction behavior in which dry density increased with increasing moisture content until reaching a maximum value, followed by a reduction in

dry density beyond the optimum moisture content. The position of the compaction curves progressively shifted toward lower MDD and OMC values as RAP content increased.

The MDD values were 2.23, 2.19, 2.13, and 2.10 g/cm³ for RAP contents of 0%, 10%, 20%, and 30%, respectively, corresponding to an overall reduction of approximately 5.9% relative to the control mixture. Similarly, the OMC values were 5.99%, 5.25%, 4.41%, and 3.94%, respectively, representing an overall reduction of 2.15 percentage points, or approximately 35.2% relative to the control mixture. These results demonstrate that increasing RAP content influenced both the achievable dry density and moisture requirement of the investigated mixtures.

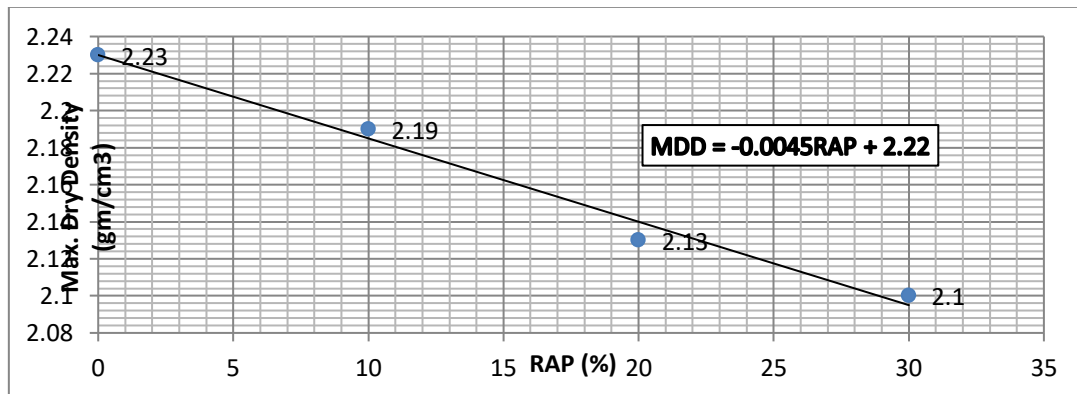


Figure (4): Relationship between maximum dry density and RAP%

Figure (4) illustrates the relationship between maximum dry density (MDD) and RAP content, showing a clear decreasing trend as the percentage of RAP increases. The fitted regression line follows the equation ($MDD = -0.0045RAP + 2.22$), indicating that the MDD decreases at an approximate rate of 0.0045 g/cm³ for every 1% increase in RAP content.

The experimental results support this trend, with the MDD decreasing from 2.23 g/cm³ for the control mixture to 2.19, 2.13, and 2.1 g/cm³ at RAP contents of 10%, 20%, and 30%, respectively. This corresponds to an overall reduction of approximately 5.9% in MDD between the control mixture and the mixture containing 30% RAP, demonstrating the influence of RAP incorporation on the compaction characteristics of the mixtures.

The reduction in MDD can be attributed to the different physical characteristics of RAP compared with natural crushed aggregate, particularly the presence of aged asphalt binder coating the RAP particles and the lower overall particle density of RAP. As RAP content increases, a greater proportion of the denser natural aggregate is replaced by RAP, resulting in progressively lower maximum dry density values. Overall, the results confirm a negative relationship between RAP content and MDD within the investigated range.

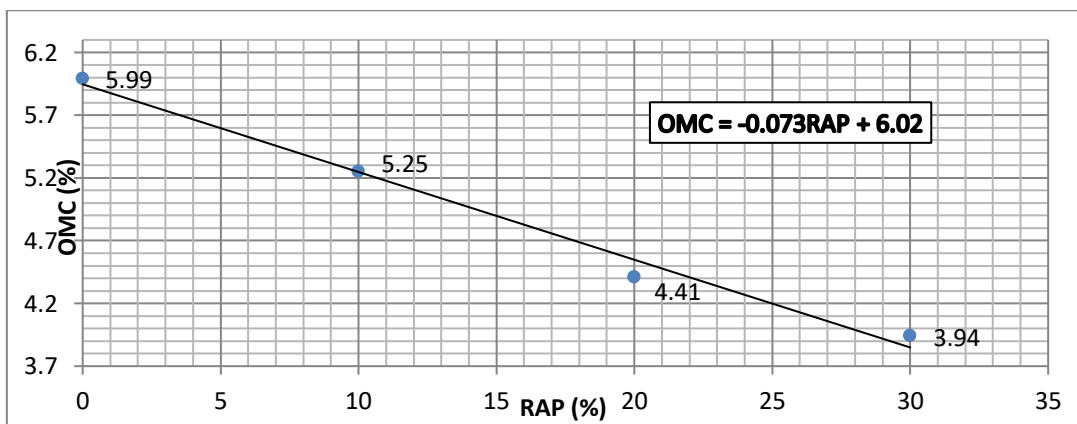


Figure (5): Relationship between optimum moisture content and RAP%

Figure (5) illustrates the relationship between optimum moisture content (OMC) and RAP content, showing a clear decreasing trend as the percentage of RAP increases. The fitted regression line follows the equation ($OMC = -0.073RAP + 6.02$), indicating that the OMC decreases at an approximate rate of 0.073 percentage points for every 1% increase in RAP content.

The experimental results support this trend, with the OMC decreasing from 5.99% for the control mixture to 5.25%, 4.41%, and 3.94% at RAP contents of 10%, 20%, and 30%, respectively. This corresponds to an overall reduction of approximately 35.2% in OMC between the control mixture and the mixture containing 30% RAP, demonstrating the influence of RAP incorporation on the moisture requirement of the mixtures.

The reduction in OMC can be attributed to the presence of aged asphalt binder coating the RAP particles, which reduces their affinity for water compared with uncoated natural aggregate. As RAP content increases, the proportion of asphalt-coated particles within the mixture increases, resulting in a progressively lower amount of moisture required to achieve maximum dry density. Overall, the results confirm a negative relationship between RAP content and OMC within the investigated range.

3.3. CBR Performance of RAP–Aggregate Base Mixtures

The California Bearing Ratio (CBR) test results demonstrated a progressive reduction in load-bearing capacity with increasing RAP content. As presented in Table (5), the CBR value decreased from 96.9% for the control mixture containing 0% RAP to 77.2%, 67.1%, and 58.3% for mixtures containing 10%, 20%, and 30% RAP, respectively. This corresponds to an overall reduction of approximately 39.8% in CBR between the control mixture and the mixture containing 30% RAP.

The reduction in CBR with increasing RAP content can be associated with the different mechanical and surface characteristics of RAP compared with natural crushed dolomite aggregate. The presence of aged asphalt binder coating the RAP particles can influence particle-to-particle interaction and interlock within the compacted mixture. Consequently, increasing the proportion of RAP resulted in a progressive reduction in the load-bearing capacity of the investigated mixtures.

Table (5): CBR Test Results for RAP–Aggregate Mixtures.

Mixture Type RAP Content (%)	CBR (%)
0% RAP	96.9
10% RAP	77.2
20% RAP	67.1
30% RAP	58.3

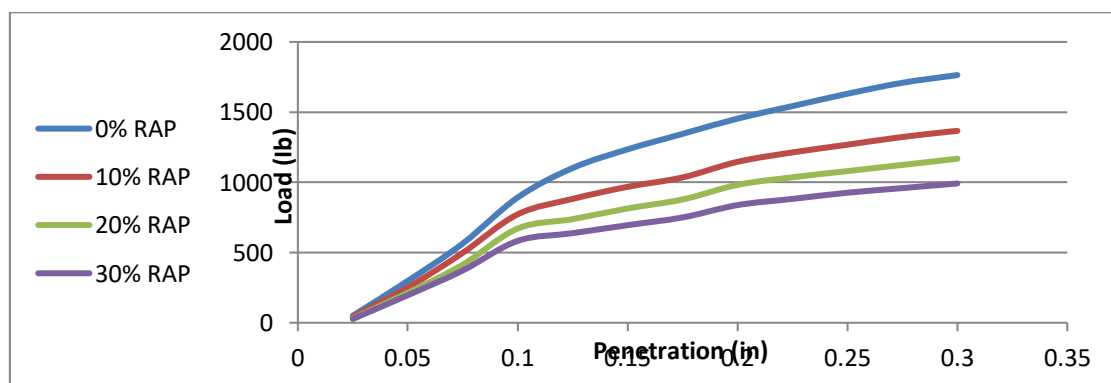


Figure (6): Load-Penetration Curves for RAP–Aggregate Mixtures

Figure (6) presents the load–penetration curves obtained from the CBR tests for the four RAP–aggregate mixtures. The results show a progressive reduction in load resistance as RAP content increased. The control mixture exhibited the highest CBR value of 96.9%, whereas the mixture containing 30% RAP exhibited the lowest value of 58.3%.

The greatest reduction occurred between 0% and 10% RAP, where the CBR decreased from 96.9% to 77.2%, corresponding to a relative reduction of approximately 20.3%. Further increases in RAP content resulted in smaller incremental reductions, with CBR decreasing to 67.1% at 20% RAP and 58.3% at 30% RAP. Although the magnitude of reduction varied between the investigated RAP intervals, the overall results demonstrate a clear decreasing relationship between RAP content and load-bearing capacity.

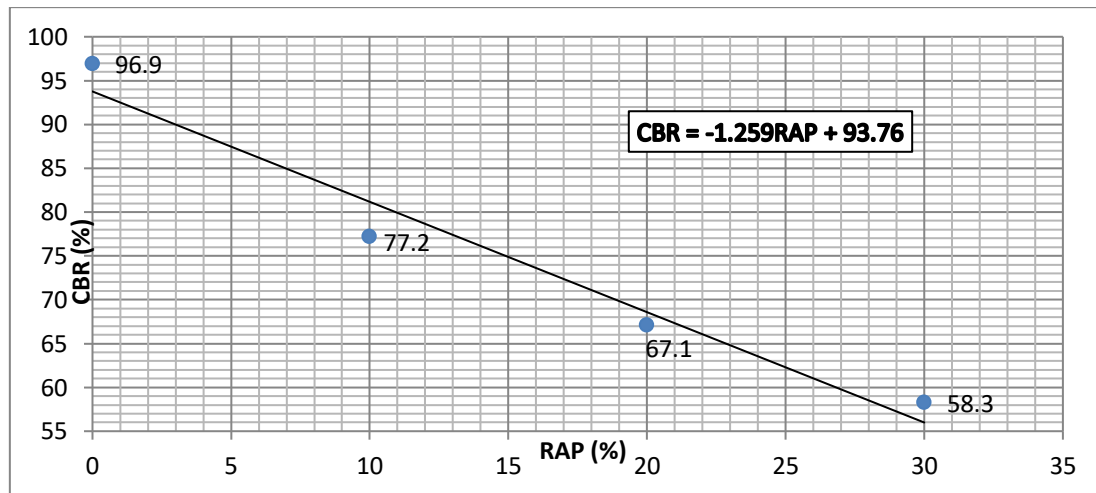


Figure (7): Relationship between California Bearing Ratio and RAP%

Figure (7) illustrates the relationship between California Bearing Ratio (CBR) and RAP content, showing a strong decreasing trend as the percentage of RAP increases. The fitted regression line follows the equation ($CBR = -1.259RAP + 93.76$), indicating that the CBR decreases at an approximate rate of 1.259 percentage points for every 1% increase in RAP content.

The experimental results support this trend, with the CBR decreasing from 96.9% for the control mixture to 77.2%, 67.1%, and 58.3% at RAP contents of 10%, 20%, and 30%, respectively. This corresponds to an overall reduction of approximately 39.8% in CBR between the control mixture and the mixture containing 30% RAP, demonstrating the significant influence of RAP incorporation on the load-bearing capacity of the mixtures.

The reduction in CBR can be attributed to the different mechanical and surface characteristics of RAP compared with natural crushed aggregate, particularly the presence of aged asphalt binder coating the RAP particles, which can reduce particle interlock and friction within the compacted mixture. As RAP content increases, these effects become more pronounced, resulting in progressively lower resistance to applied loads. Overall, the results confirm a strong negative relationship between RAP content and CBR within the investigated range.

4. CONCLUSION & RECOMMENDATIONS

This study investigated the feasibility of incorporating Reclaimed Asphalt Pavement (RAP) as a partial replacement for natural dolomite aggregate in pavement base course mixtures. RAP contents of 0%, 10%, 20%, and 30% by total dry mixture weight were investigated to evaluate their influence on particle size distribution, compaction characteristics, and load-bearing capacity. The experimental program included sieve analysis, Modified Proctor compaction testing, and California Bearing Ratio (CBR) testing to assess the engineering performance of the prepared RAP–aggregate mixtures.

The gradation results showed that RAP incorporation progressively influenced the particle size distribution of the mixtures, particularly within the fine particle range. The percentage passing sieve No. 4 decreased from 45%

for the control mixture to 43%, 41%, and 39% at RAP contents of 10%, 20%, and 30%, respectively. Similarly, the percentage passing sieve No. 200 decreased from 10% to 9%, 8%, and 7%. These results indicate that increasing RAP content reduced the proportion of fine particles in the mixtures. Despite these changes, all investigated RAP–aggregate mixtures remained within the adopted gradation limits for base course materials.

The Modified Proctor test results showed that increasing RAP content progressively reduced both maximum dry density (MDD) and optimum moisture content (OMC). The MDD decreased from 2.23 g/cm³ for the control mixture to 2.19, 2.13, and 2.10 g/cm³ at RAP contents of 10%, 20%, and 30%, respectively. Meanwhile, the OMC decreased from 5.99% to 5.25%, 4.41%, and 3.94%. This corresponds to overall reductions of approximately 5.9% in MDD and 35.2% in OMC between the control mixture and the mixture containing 30% RAP. These results demonstrate that increasing RAP content progressively reduces the achievable dry density and moisture requirement of the mixtures.

The CBR results demonstrated a substantial reduction in load-bearing capacity with increasing RAP content. The CBR decreased from 96.9% for the control mixture to 77.2%, 67.1%, and 58.3% at RAP contents of 10%, 20%, and 30%, respectively. This corresponds to an overall reduction of approximately 39.8% between the control mixture and the mixture containing 30% RAP. The reduction in CBR can be associated with the different mechanical and surface characteristics of RAP compared with natural crushed aggregate, particularly the presence of aged asphalt binder coating the RAP particles, which can influence particle interlock and friction within the compacted mixture.

Overall, the results demonstrate that RAP can be incorporated as a partial replacement for natural dolomite aggregate while maintaining acceptable gradation characteristics within the investigated range. However, increasing RAP content resulted in progressive reductions in MDD, OMC, and particularly CBR, indicating that the load-bearing capacity of the mixtures is significantly influenced by RAP incorporation. Among the investigated mixtures, the 30% RAP mixture exhibited the lowest MDD and CBR values, with an MDD of 2.10 g/cm³ and a CBR of 58.3%. These findings demonstrate the potential for utilizing controlled proportions of RAP in pavement materials while reducing the consumption of virgin aggregates and promoting the reuse of reclaimed pavement materials.

Based on the findings of this study, RAP is recommended as a potential partial replacement for natural aggregate in pavement applications, provided that the selected RAP content satisfies the required gradation and mechanical performance criteria for the intended pavement layer. The RAP percentage should therefore be selected according to the required engineering performance rather than gradation compliance alone. Further research is recommended to investigate RAP contents beyond 30% and to evaluate suitable stabilization techniques for improving the mechanical performance of mixtures containing higher RAP proportions. Additional studies involving resilient modulus, durability, permeability, repeated-load behavior, and field performance are also recommended to provide a more comprehensive assessment of the long-term behavior of RAP–aggregate mixtures under actual pavement conditions.

REFERENCES

1. ASTM International. ASTM C136/C136M. Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates. ASTM International, West Conshohocken, Pennsylvania, USA.
2. ASTM International. ASTM D1557. Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort. ASTM International, West Conshohocken, Pennsylvania, USA.
3. ASTM International. ASTM D1883. Standard Test Method for California Bearing Ratio (CBR) of Laboratory-Compacted Soils. ASTM International, West Conshohocken, Pennsylvania, USA.
4. Egyptian Code of Practice for Road Works. (2021). Egyptian Code of Practice for Road Works. Housing and Building National Research Center (HBRC), Ministry of Housing, Utilities and Urban Communities, Cairo, Egypt.
5. Guerrero-Bustamante, O., Guillen, A., Moreno-Navarro, F., Rubio-Gámez, M. C., & Sol-Sánchez, M. (2025). Suitable granular road base from reclaimed asphalt pavement. *Materials*, Vol. 18, No. 4, Article 854. MDPI.

6. Guthrie, W. S., Cooley, D., & Eggett, D. L. (2007). Effects of reclaimed asphalt pavement on mechanical properties of base materials. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2005, No. 1, pp. 44–52. Transportation Research Board, National Academies, Washington, D.C., USA.
7. Mousa, E., El-Badawy, S., & Azam, A. (2021). Evaluation of reclaimed asphalt pavement as base/subbase material in Egypt. *Transportation Geotechnics*, Vol. 26, Article 100414. Elsevier.
8. Saha, D. C., & Mandal, J. N. (2017). Laboratory investigations on reclaimed asphalt pavement (RAP) for using it as base course of flexible pavement. *Procedia Engineering*, Vol. 189, pp. 434–439. Elsevier.