International Journal of Advanced Engineering, Management and Science (IJAEMS)
Peer-Reviewed Journal
ISSN: 2454-1311 | Vol-9, Issue-12; Dec, 2023
Journal Home Page: https://ijaems.com/
DOI: https://dx.doi.org/10.22161/ijaems.912.13

Effects of Fiberglass on the Strength of Reclaimed Asphalt Pavement (RAP) as a Subbase Materials

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Received: 05 Nov 2023; Received in revised form: 11 Dec 2023; Accepted: 22 Dec 2023; Available online: 30 Dec 2023

***Abstract*— This research study investigates the effect of fiberglass content on the strength of Reclaimed Asphalt Pavement (RAP) material as a subbase layer of flexible pavement. Laboratory modified proctor and California bearing ratio (CBR) tests were conducted on the mixture of RAP and fiberglass. The obtained results show that, 100% RAP material can be used as subbase material. In addition to that, there is a slight reduction in maximum dry density (γ_{dmax}) values when RAP is blended with fiberglass. Similarly, the soaked and unsoaked CBR values of the mixture decreased slightly. However, the mixture of RAP and fiberglass achieved the specification requirements as a subbase layer according to the Egyptian specifications. The relationship between fiberglass content and maximum dry density of RAP is found to be linear. Also, a linear relationship exists between percentage of fiberglass and unsoaked CBR. Finally, the relationship between the percentage of fiberglass and soaked CBR is found to be nonlinear.*

***Keywords*— Reclaimed Asphalt Pavement (RAP), California Bearing Ratio (CBR), Fiberglass.**

I. INTRODUCTION

The Reclaimed Asphalt Pavement (RAP) is defined as a deteriorated asphalt obtained as a result of rehabilitation and maintenance of roads. Or, it is a material obtained from the pavement [1, 2]. In the United States of America, over 50 million tons of RAP are produced annually, and in Egypt, over 3 million tons of RAP are produced annually. Despite significant amounts of RAP recycling in new asphalt paving mixtures, larger quantities of RAP remain unused [3]. Moreover, alternative RAP applications have emerged in highway construction. Saha and Mandal [4] indicated that RAP is suitable for use as subbase and base of flexible pavement when RAP is mixed with crushed stone aggregates in various proportions and stabilized with small percentages of cement. Suebsuk et al. [5] studied soil and RAP mixtures treated with cement. They demonstrated the ability of the treated mixtures to be used in the construction of pavement layers (base and subbase). Taha et al. [6] stated that the RAP and aggregate mixture provided good roadbed layers.

The effect of adding fibers on bitumen binder and Hot Mix Asphalt (HMA) has been studied previously in many studies, as it enhanced asphalt binder stiffness and stability of modified asphalt mix [7]. On the other hand, the air voids content decreased compared to the control mixture [8]. Therefore, the objective of this study is to investigate the effect of fiberglass content on the mechanical properties of cold Reclaimed Asphalt Pavement (RAP) material as a subbase layer. Fiberglass content varies between 0 and 10% by weight of dry constituents. The Optimum Moisture Content (OMC) was kept constant in order to study the effects of fiberglass content on the maximum dry density (γ_{dmax}) and strength of RAP material.

II. MATERIALS AND EXPERIMENTAL INVESTIGATION PROGRAM

Reclaimed Asphalt Pavement (RAP) was collected from an old pavement in Egypt, fiberglass chopped strands with a diameter of (10-13 μm) and a length of (15-25 mm).

The experimental investigation program consists of two specific tasks:

1. Physical characterization of RAP material.

2. Perform modified proctor and CBR tests.

Different percentages of fiberglass (0%, 2%, 4%, 6%, 8%, 10%) by weight of RAP were added, see Table 1.

Table 1 Proportions of the mixture between RAP and fiberglass

Sample No.	Mix composition
(1)	100% RAP + 0% fiberglass
(2)	100% RAP + 2% fiberglass
(3)	100% RAP + 4% fiberglass
(4)	100% RAP + 6% fiberglass
(5)	100% RAP + 8% fiberglass
(6)	100% RAP + 10% fiberglass

III. RAP PHYSICAL PROPERTIES

Table 2 shows a summary of the sieve analysis, specific gravity, water absorption, asphalt content, Los Angeles abrasion and soil classification results obtained from RAP material tests.

Table 2 Physical properties of RAP material

Property	RAP	References
Grain size	100% Passing Sieve 3/4-in. (Dia. 19mm)	ASTM C 136
Specific gravity	2.41	ASTM D 854
Water absorption (%)	3.57	ASTM C 128
Los Angles abrasion (%)	25.37	ASTM C 131
Asphalt content (%)	5.22	ASTM D 2172 Method A
Classification	A-1-a	AASHTO [9]

IV. COMPACTION RESULTS

Modified proctor compaction test followed the guidelines established in ASTM D1557 Method B [10]. The effect of fiberglass content on the maximum dry density (γ_{dmax}) of RAP at constant optimum moisture content (OMC) is summarized in Table 3.

Table 3 Compaction parameters for the mixture of RAP and fiberglass

Mixture	γ_{dmax} (gm/cm^3)	OMC (%)	Percent of reduction in γ_{dmax} (%)
100% RAP + 0% fiberglass	2.14	7.10	0
100% RAP + 2% fiberglass	2.13	7.10	0.47
100% RAP + 4% fiberglass	2.10	7.10	1.87
100% RAP + 6% fiberglass	2.07	7.10	3.27
100% RAP + 8% fiberglass	2.05	7.10	4.20
100% RAP + 10% fiberglass	2.01	7.10	6.07

According to Table 3, it is observed that, the maximum dry density (γ_{dmax}) of RAP decreased by 6% at fiberglass content 10%. The cause of decreased maximum dry density of RAP with increasing fiberglass contents is probably due to increased voids between the RAP particles.

The linear relationship between fiberglass content and maximum dry density (γ_{dmax}) of RAP is depicted in Fig. 1. This empirical formula is as follows:

$$\gamma_{dmax}\ (\text{gm/cm}^3) = 2.15 - 0.013*\text{fiberglass}\ (\%) \qquad (1)$$

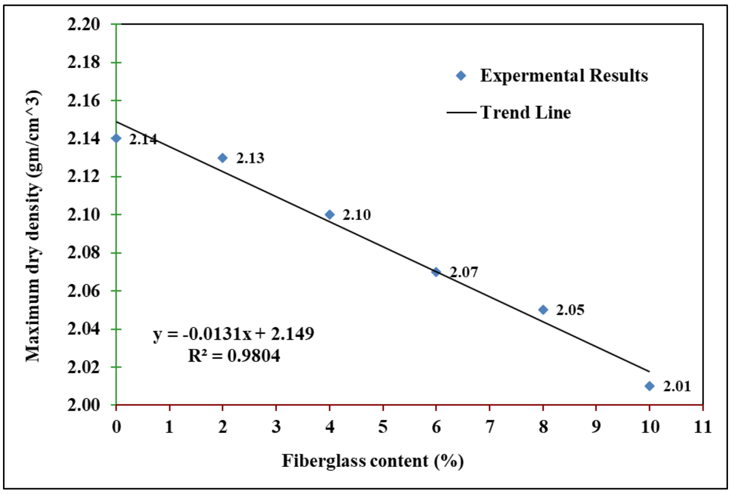

Fig. 1. Correlation between fiberglass content and maximum dry density of RAP

V. CALIFORNIA BEARING RATIO (CBR) RESULTS

The California bearing ratio (CBR) test was performed according to the guidelines established in ASTM D 1883 [11]. Results of unsoaked and 4 days soaked CBR test conducted on the mixture of RAP and fiberglass are indicated in Fig. 2. A summary of CBR values for the mixture of RAP and fiberglass are listed in Table 4.

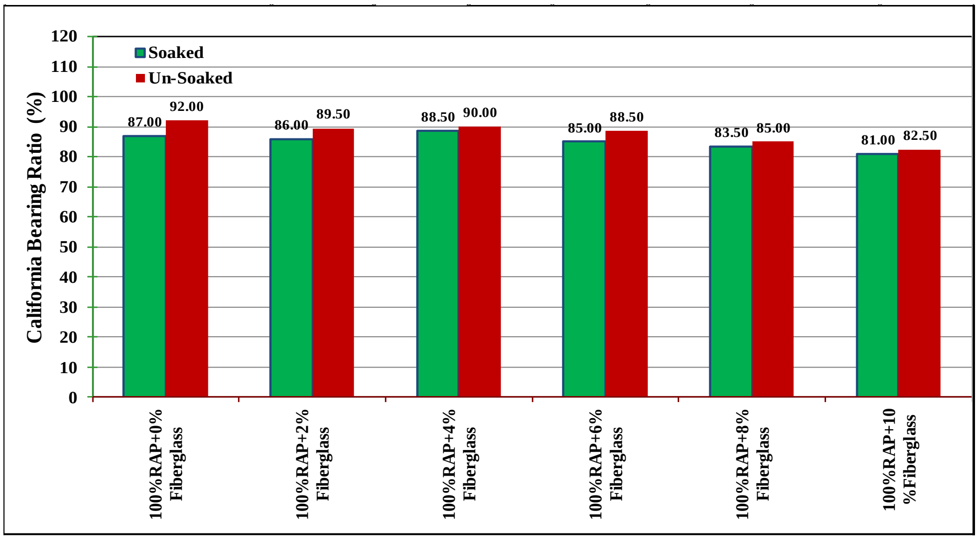

Fig. 2. CBR before and after soaking versus a mixture of RAP and fiberglass

Table 4 CBR values for the mixture of RAP and fiberglass

Mixture	CBR (%)		Reduction percentage in CBR (%)	
	Unsoaked	Soaked	Unsoaked	Soaked
100% RAP + 0% fiberglass	92.00	87.00	0	0
100% RAP + 2% fiberglass	89.50	86.00	2.71	1.15
100% RAP + 4% fiberglass	90.00	88.50	2.17	0
100% RAP + 6% fiberglass	88.50	85.00	3.80	2.30
100% RAP + 8% fiberglass	85.00	83.50	7.60	4.02
100% RAP + 10% fiberglass	82.50	81.00	10.32	6.90

Based on Table 4, it is remarkable that, the increase of fiberglass content from 0% to 10%, shows that the unsoaked CBR value decreases from 92% to 82.50% respectively, and the soaked CBR value decreases from 87% to 81% respectively. The reduction in unsoaked and soaked CBR value of RAP is associated with the reduction in the maximum dry density of RAP and fiberglass blend.

The graphical representation of the load deformation relationships for soaked and unsoaked CBR of RAP and fiberglass blend is shown in Fig. 3 and Fig. 4 respectively. Also, the relationship between the fiberglass content and CBR before and after soaking is depicted in Fig. 5. These empirical formulas are as follows:

1. For unsoaked CBR value (%) = 92.40 - 0.90*Fiberglass (%) (2)
2. For soaked CBR value (%) = -0.105*Fiberglass^2 (%) + 0.46*Fiberglass (%) + 86.70 (3)

Where: CBR = California bearing ratio (%), Fiberglass = fiberglass in the mixture of RAP and fiberglass (%).

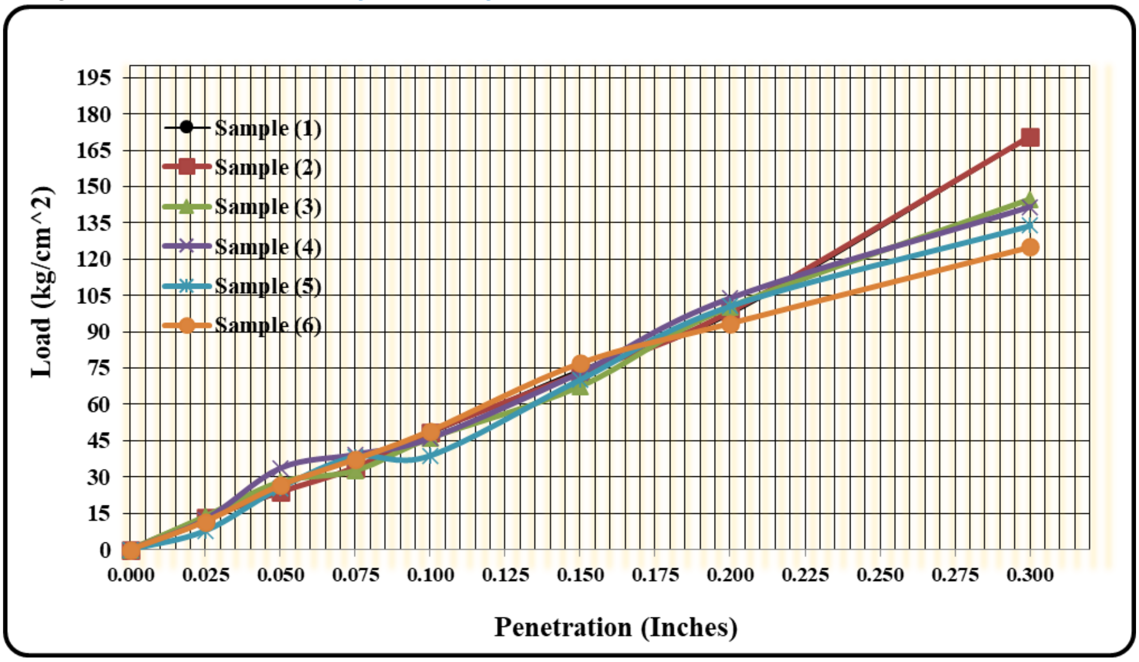

Fig. 3. Load versus Penetration (Soaked CBR)

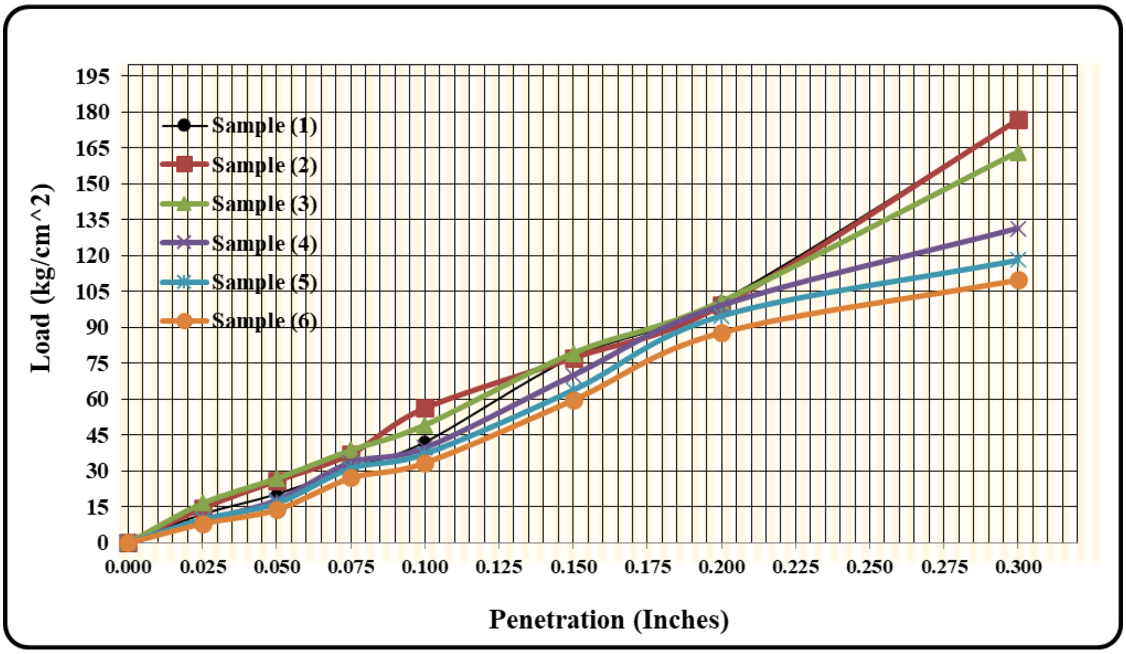

Fig. 4. Load versus Penetration (Unsoaked CBR)

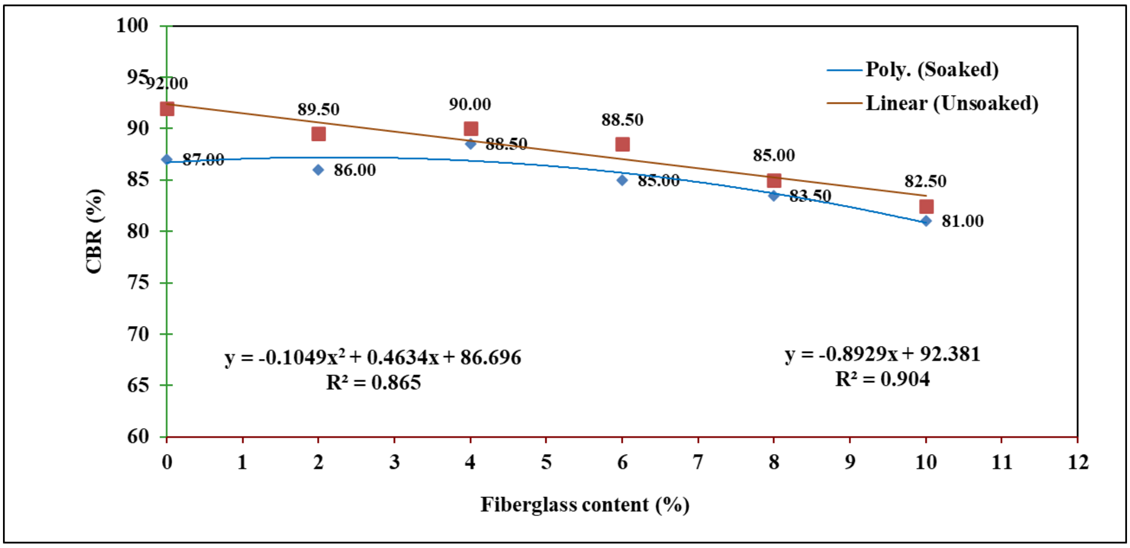

Fig. 5. Correlation between fiberglass content and CBR before and after soaking in the mixture of RAP and fiberglass

Fig. 6 shows the comparison of RAP gradation with Egyptian code standards requirements for granular subbase materials [12]. As seen in Fig. 6, it is observed that the gradation of the RAP material was nearly inside the specification limits. On the other side, the Egyptian specifications recommend a minimum CBR of 30% for a pavement subbase layer. In consequence, the mixture of RAP and fiberglass achieved the specification requirements as a subbase layer according to the Egyptian specifications.

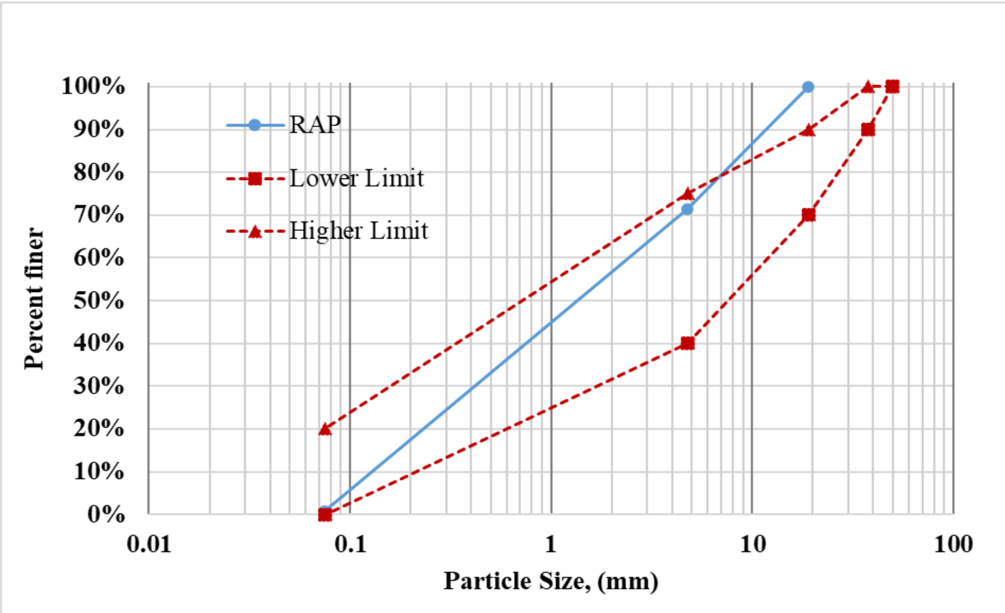

Fig. 6. Comparison of RAP gradation with Egyptian code standards requirements for granular subbase materials

VI. CONCLUSIONS

Based on the results of the research study, the following conclusions can be highlighted:

1. 100% RAP material can be used as subbase material.
2. The maximum dry density (γ_{dmax}) of RAP decreased by 6% with increasing fiberglass content to 10%. On the other hand, the relationship between fiberglass content and maximum dry density (γ_{dmax}) of RAP is found to be linear.
3. Increasing of fiberglass content from zero to 10%, shows that the unsoaked CBR value reduced by about 10%, and the soaked CBR value reduced by about 7%. The relationship between the percentage of fiberglass and soaked CBR is found to be nonlinear. On the other side, there is linear relationship between percentage of fiberglass and unsoaked CBR.

4. The Maximum dry density (γ_{dmax}) and CBR values of RAP decreased slightly when fiberglass is blended with RAP.

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