International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 11 | Nov - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

Studies on Use of Reclaimed Asphalt Pavement (RAP) and Geosynthetics in Pavement Construction

***MODALAVALASA JAGADEESH KUMAR[1], V. HEMANTH KUMAR[2]**

[1]M.Tech Scholar (Transportation Engineering), Department of Civil Engineering,
Sanketika Vidya Parishad Engineering College, P.M. Palem, Visakhapatnam – 530041, Andhra Pradesh, India
[2]Assistant Professor, Department of Civil Engineering, Sanketika Vidya Parishad Engineering College,
P.M. Palem, Visakhapatnam – 530041, Andhra Pradesh, India

Abstract

Reclaimed asphalt pavement (RAP) generated by milling during highway strengthening can replace scarce virgin aggregates in pavement layers, but untreated RAP is generally unsuitable for granular subbase and base courses. This study examines two routes to its use. First, RAP was blended with crushed stone aggregate (CSA) in proportions of 100:0, 75:25, 50:50 and 25:75 and stabilised with 0–6% cement, and unsoaked and four-day soaked CBR were determined. Second, laboratory model tests in a 600 mm steel tank were conducted on a 150 mm RAP + wet mix macadam (WMM) (50:50) base over a 300 mm soft marine clay bed, unreinforced and reinforced with polymer geogrid, polymer geocell, bamboo geogrid, bamboo geocell and their geogrid + geocell combinations. Soaked CBR of 100% RAP rose from 19.85% to 74.90% with 6% cement, and the 50% RAP + 50% CSA blend reached 190.3% with 4% cement. In the model tests, the unreinforced RAP + WMM base carried 176.2 kPa at 50 mm settlement; polymer geogrid + geocell raised this by 183.7% (499.75 kPa) and bamboo geogrid + geocell by 43.7% (253.08 kPa). Compared with unreinforced WMM (182.1 kPa), reinforced RAP and RAP + WMM bases carried 24.3–174.4% more pressure. Cement-stabilised RAP–CSA blends and geosynthetic-reinforced RAP + WMM are therefore viable alternatives to conventional subbase and base materials.

Keywords: Reclaimed asphalt pavement; Cement stabilisation; Geogrid; Geocell; Bamboo reinforcement; Model test; Soft marine clay

1. Introduction

India's road network is about 5.90 million km long, and most national highways, state highways and major district roads are flexible pavements. Their maintenance, strengthening and widening consume large quantities of aggregates and bitumen, while milling of existing surfaces generates large volumes of RAP. Reusing RAP lowers construction cost, conserves natural aggregates, reduces disposal problems and saves an estimated 25–40% of energy. However, untreated RAP generally fails the CBR and gradation requirements for granular subbase and base courses, so it must be blended with virgin aggregates and/or stabilised with cement or fly ash.

Geosynthetics improve flexible pavements through separation, filtration, drainage and reinforcement, and geogrids and geocells placed in or beneath the base layer reduce the stresses transmitted to a weak subgrade. Bamboo geogrids and geocells offer a low-cost, locally available alternative to polymer products. The objectives of this study are to (i) assess the effect of blending RAP with CSA and stabilising it with cement on its CBR, (ii) evaluate the load-carrying capacity of a RAP + WMM (50:50) base over soft marine clay when reinforced with polymer and bamboo geogrids and geocells, and (iii) compare reinforced RAP bases with conventional unreinforced WMM.

2. Literature Review

Reviews of RAP recycling highlight management practices for high-RAP mixtures [3] and the performance and sustainability benefits of RAP across pavement layers [6]. For unbound and bound layers, Ghimire and Bheemasetti found that mixtures of 15% RAP with 4% cement and 20% RAP with 6% cement met the 7-day strength requirement for subgrade and subbase and retained over 70% of their strength after 14 wetting–drying cycles [2]. Arulrajah et al. reported a CBR of about 30% for 100% RAP and about 40% for a 50:50 RAP–recycled concrete aggregate blend [10], and Puppala et al. examined RAP with quarry fines for base and subbase layers [11] and the resilient moduli of moderately cement-treated RAP [12]. Geopolymer stabilisation of RAP bases has also been reviewed [7].

On reinforcement, incorporating geosynthetics in the AASHTO design method could reduce asphalt layer thickness by about 20–33% or allow 1.8–4.0 times the traffic [1]. Geogrids enable low-carbon, aggregate-efficient flexible pavements [4], improve laboratory and field pavement performance [5] and reduce rutting of asphalt mixtures [8], while geocell-reinforced RAP bases offer a sustainable base layer [9]. Few studies, however, compare polymer and bamboo geogrids and geocells in RAP-based layers over very soft subgrades, which this study addresses.

3. Materials and Methodology

3.1 Materials

RAP was obtained from milling on a nearby national highway project widened from four to six lanes. It had a compacted dry density of 19.8 kN/m³, a bitumen content of 3.2%, 100% passing the 37.5 mm sieve, and a modified Proctor MDD of 22.5 kN/m³ at 5.2% OMC. **CSA** was collected from crushers on a nearby highway project, and OPC-43 was used as the stabiliser. **Soft marine clay** from Karal Phata on NH-4B, Navi Mumbai, was used as the model subgrade. It contains 53% clay, 43% silt and 4% sand, with a liquid limit of 80%, plastic limit of 34% and plasticity index of 46%; its MDD and OMC are 1.49 g/cc and 27%, its unsoaked and soaked CBR are 4.2% and 1.7%, and its saturated undrained strength is 5–10 kPa. The reinforcement materials are listed in Table 1. The bamboo geogrids and geocells were made by local craftsmen and coated with bitumen emulsion for durability.

Table 1. Geosynthetic and bamboo materials used in the model tests

Material	Product	Properties reported
Nonwoven geotextile (separator)	STRATA 150 GSM	Tensile strength 4.75 kN/m (tested); mass 155.5 g/m²; thickness 0.895 mm; AOS 90 µm
Polymer geogrid	STRATA BX 80	Tensile strength 72.5 kN/m (tested)
Polymer geocell	STRATA SW 330	Thickness 10.6 mm; weld spacing 330 mm; expanded cell 244 × 210 mm; cell area 250 cm²
Bamboo geogrid	Locally made	Tensile strength about 93 kN/m; strip width 10 mm; thickness 2.51 mm; mass 471.54 g/m²; grid spacing 27 × 27 mm; opening 17 × 17 mm
Bamboo geocell	Locally made	Placed at the base in the same way as the polymer geocell; bitumen-emulsion coated

3.2 CBR Tests on RAP–CSA Blends

Unsoaked and four-day soaked CBR tests (ASTM D1883) were conducted on 100% RAP and on 75:25, 50:50 and 25:75 RAP–CSA blends, each stabilised with 0, 1, 2, 3, 4, 5 and 6% cement, and on 100% CSA.

3.3 Model Tests

Model tests were carried out in a 600 × 600 × 600 mm steel tank under a 10 t loading frame (Fig. 1). A 300 mm soft marine clay bed was prepared and covered with the 150 GSM geotextile as a separator. A 150 mm base of RAP + WMM (50:50) was then compacted at OMC in three 50 mm layers with a modified Proctor rammer. The gradation of this blend lies within the MoRT&H WMM envelope (Fig. 2). Geogrids were placed at the base of the layer (u/H = 1); geocells 100 mm high were placed over the separator, filled and topped with a 50 mm cushion; and combined models had a geogrid beneath the geocell. Load was applied through a 150 × 150 × 12 mm plate, and settlement was measured with two diagonally opposite LVDTs up to 50 mm. The seven models are listed in Table 2 and shown in Fig. 3. Unreinforced WMM and reinforced 100% RAP bases were tested in the same way for comparison.

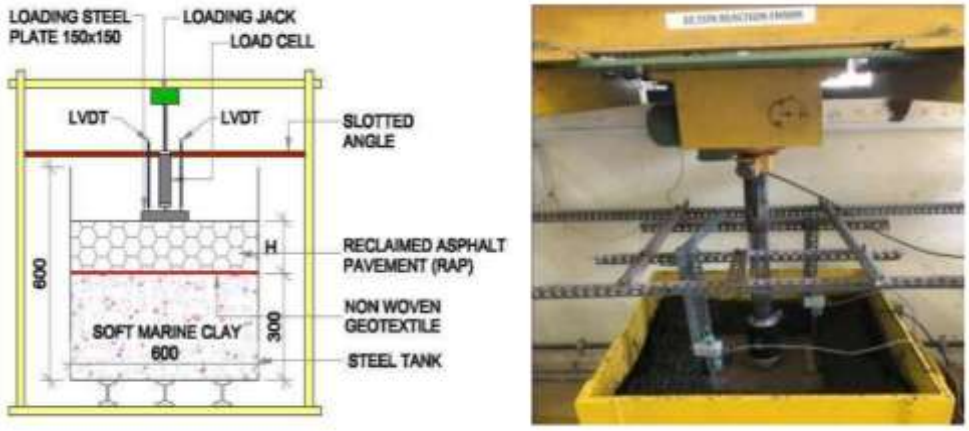


Fig. 1. Model test setup: (a) schematic diagram, (b) photograph

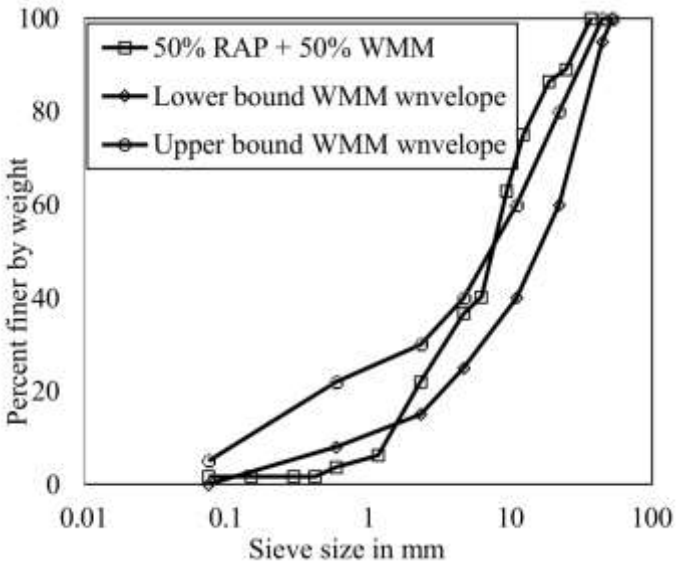


Fig. 2. Grain size distribution of RAP + WMM (50:50) within the WMM envelope (MoRT&H)

Table 2. Models of RAP + WMM (50:50) without/with geogrid and geocell reinforcements

Sr. No.	Reinforcing materials	Model description
1	Unreinforced	150 mm thick RAP+WMM (50:50) placed over soft marine clay
2	Polymer geogrid	150 mm thick RAP+WMM (50:50) reinforced with polymer geogrid at base, placed over soft marine clay
3	Polymer geocells	150 mm thick RAP+WMM (50:50) reinforced with polymer geocells at base, placed over soft marine clay
4	Polymer geogrid + polymer geocells	150 mm thick RAP+WMM (50:50) reinforced with polymer geogrid + polymer geocells at base, placed over soft marine clay
5	Bamboo geogrid	150 mm thick RAP+WMM (50:50) reinforced with bamboo geogrid at base, placed over soft marine clay
6	Bamboo geocells	150 mm thick RAP+WMM (50:50) reinforced with bamboo geocells at base, placed over soft marine clay
7	Bamboo geogrid + bamboo geocells	150 mm thick RAP+WMM (50:50) reinforced with bamboo geogrid + bamboo geocells at base, placed over soft marine clay

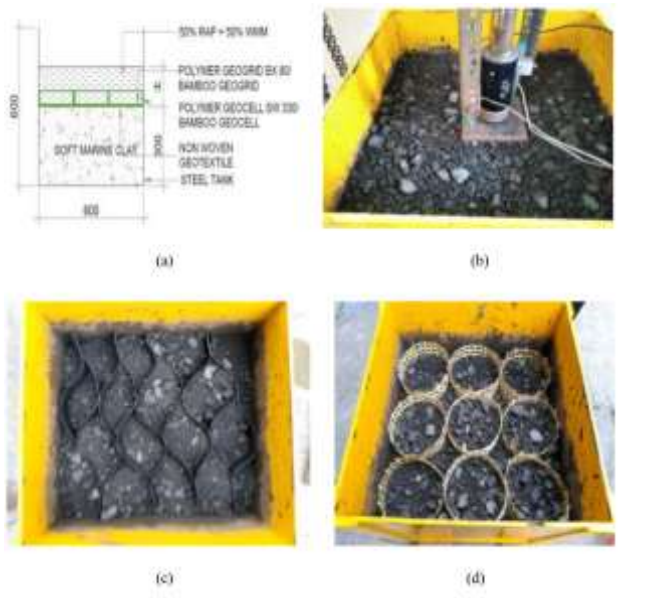


Fig. 3. (a) Schematic model of reinforced RAP + WMM (50:50); (b) unreinforced; (c) polymer geogrid + polymer geocell; (d) bamboo geogrid + bamboo geocell

4. Results and Discussion

4.1 CBR of RAP–CSA Blends

The CBR results are given in Table 3. Untreated RAP had an unsoaked CBR of only 6.47% and a soaked CBR of 19.85%. Both blending with CSA and adding cement increased the CBR, and the soaked values rose much more than the unsoaked values because the cement hydrated during the four-day soaking. With 6% cement, the soaked CBR of 100% RAP reached 74.90%. The 50% RAP + 50% CSA blend reached 161.7% with 3% cement and 190.3% with 4% cement, and the 25% RAP + 75% CSA blend reached 500% with 5–6% cement. For comparison, 100% CSA gave 53% unsoaked and 95% soaked CBR. The 50% RAP + 50% CSA + 4% cement mix was adopted in the study as the stabilised RAP subbase, as it uses an equal share of RAP while its soaked CBR is about twice that of 100% CSA.

Table 3. Unsoaked and four-day soaked CBR (%) of RAP–CSA blends with varying cement content

Blend	Condition	0%	1%	2%	3%	4%	5%	6%
100% RAP	Unsoaked	6.47	7.60	8.81	9.34	11.90	13.50	14.40
100% RAP	Soaked	19.85	20.00	32.60	35.62	38.00	67.20	74.90
75% RAP + 25% CSA	Unsoaked	9.2	12.1	14.0	19.9	21.3	26.5	28.1
75% RAP + 25% CSA	Soaked	13.6	29.2	81.6	90.2	100.6	158.2	162.4
50% RAP + 50% CSA	Unsoaked	18.0	27.4	28.1	29.9	32.1	35.8	37.3
50% RAP + 50% CSA	Soaked	28.3	56.4	80.1	161.7	190.3	199.6	253.1
25% RAP + 75% CSA	Unsoaked	18.0	31.7	52.1	60.5	60.7	61.2	77.4
25% RAP + 75% CSA	Soaked	35.0	80.4	183.2	331.1	346.0	500.0	500.0

Column headings give the cement content by weight.

4.2 Load–Settlement Behaviour of RAP + WMM (50:50)

The pressure–settlement responses of the seven models are shown in Fig. 4, and the pressures at 50 mm settlement in Fig. 5. The unreinforced RAP + WMM base carried 176.2 kPa. Polymer geogrid alone added only 11.3% (196.1 kPa), but polymer geocells raised the capacity by 143.1% (428.22 kPa) and the polymer geogrid + geocell combination by 183.7% (499.75 kPa). Bamboo geogrid, bamboo geocell and their combination raised the capacity by 21.8%, 25.1% and 43.7% (214.6, 220.4 and 253.08 kPa). In both materials the combined geogrid + geocell gave the largest gain. The geocell confines the infill laterally and spreads the load over a wider area of the soft clay, while the underlying geogrid adds membrane support. Polymer and bamboo results cannot be compared directly because their cell and grid dimensions differ.

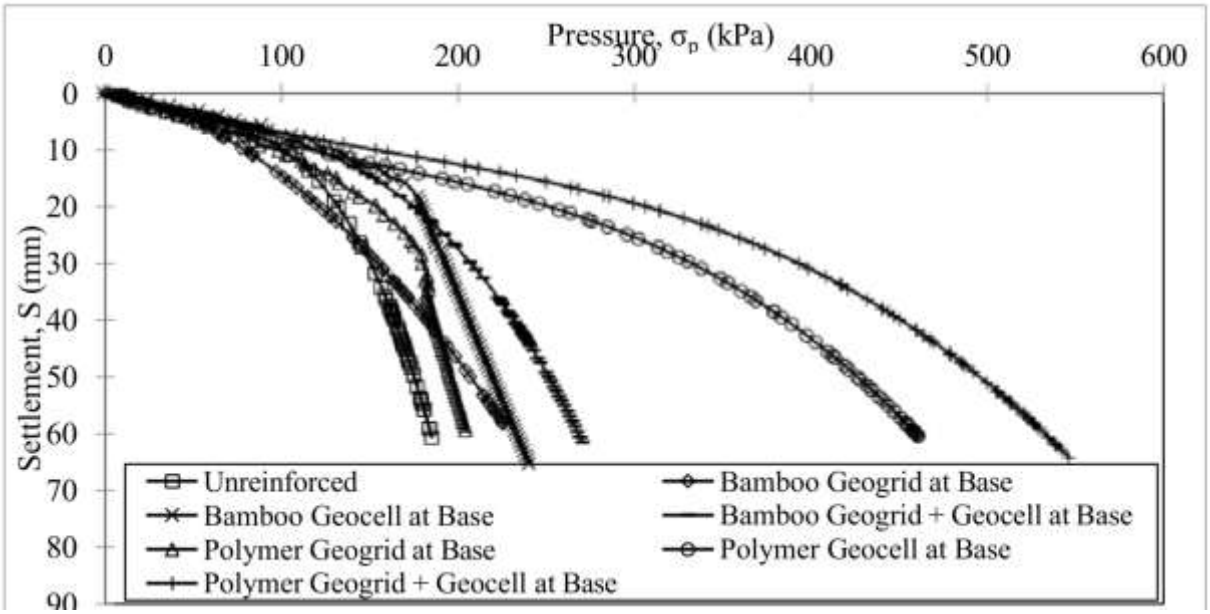


Fig. 4. Pressure versus settlement of RAP + WMM (50:50) without and with reinforcement

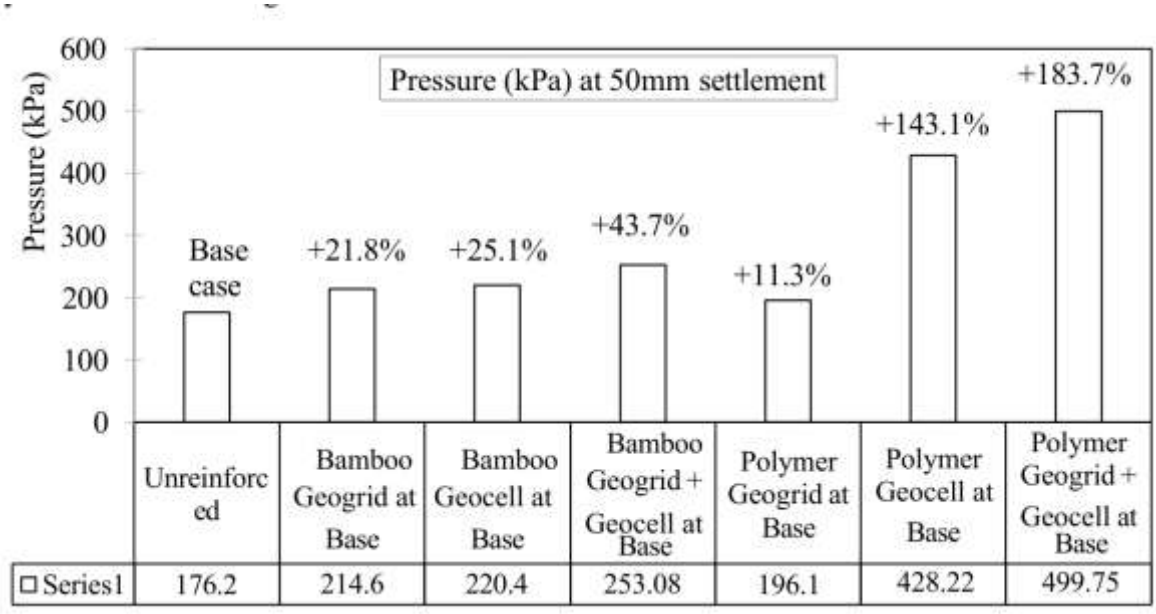


Fig. 5. Variation of pressure at 50 mm settlement of RAP + WMM (50:50) without and with reinforcement

The improvement factor, the ratio of reinforced to unreinforced pressure at the same normalised settlement S/B, is given in Table 4. For polymer geogrid + geocell it increased from 2.00 at S/B = 10% to 2.82 at S/B = 35%, and for polymer geocell alone from 1.60 to 2.40. Bamboo geogrid + geocell gave 1.25–1.47, peaking at S/B = 20%. The reinforcement effect therefore grows with settlement as the geocell and geogrid mobilise more tension.

Table 4. Improvement factor (Ifw) due to reinforcement types

S/B (%)	Normalised pressure (unreinforced RAP+WMM)	Geogrid – Polymer	Geogrid – Bamboo	Geocell – Polymer	Geocell – Bamboo	Geogrid + geocell – Polymer	Geogrid + geocell – Bamboo
10	40	1.10	1.00	1.60	1.35	2.00	1.25
15	46	1.22	1.00	2.00	1.35	2.39	1.35
20	47	1.28	1.11	2.38	1.36	2.81	1.47
25	54	1.15	1.07	2.30	1.26	2.70	1.39
30	58	1.10	1.12	2.34	1.21	2.76	1.41
35	60	1.10	1.20	2.40	1.25	2.82	1.43

4.3 Reinforced RAP Bases versus Unreinforced WMM

Unreinforced WMM, the conventional base material, carried 182.1 kPa at 50 mm settlement (Figs. 6 and 7). Every reinforced RAP-based layer outperformed it. With bamboo geogrid + geocell, 100% RAP carried 24.3% more and RAP + WMM (50:50) 39.0% more. With polymer geogrid + geocell, 100% RAP carried 83.4% more and RAP + WMM (50:50) 174.4% more. Reinforced RAP and RAP + WMM layers can therefore replace unreinforced WMM bases over weak subgrades. Polymer reinforcement gives the higher capacity, while bamboo offers a low-cost, biodegradable option for lower traffic.

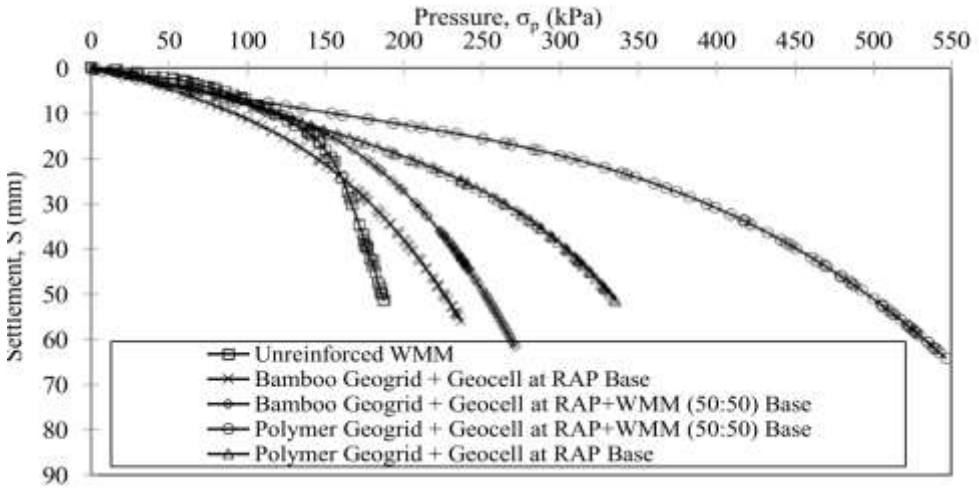


Fig. 6. Pressure–settlement response of unreinforced WMM versus reinforced RAP and RAP + WMM (50:50)

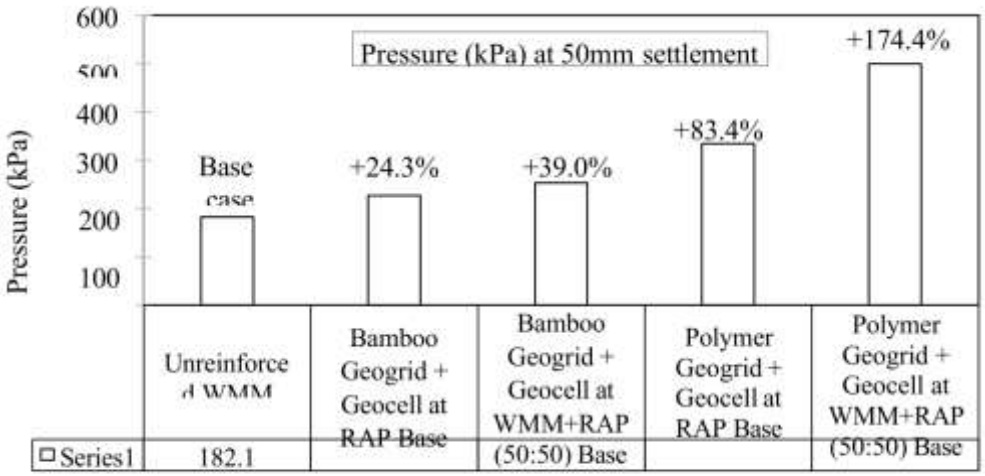


Fig. 7. Pressure variations of unreinforced WMM versus reinforced RAP and RAP + WMM (50:50)

5. Conclusions

1. Untreated RAP is unsuitable as a subbase material (unsoaked CBR 6.47%, soaked CBR 19.85%), but blending with CSA and stabilising with cement increases its CBR substantially.
2. The soaked CBR of 100% RAP rose to 74.90% with 6% cement, and the 50% RAP + 50% CSA blend reached 190.3% with 4% cement, about twice the soaked CBR of 100% CSA (95%).
3. Over soft marine clay, the 150 mm unreinforced RAP + WMM (50:50) base carried 176.2 kPa at 50 mm settlement. Polymer geogrid + geocell increased this by 183.7% and bamboo geogrid + geocell by 43.7%; the combined geogrid + geocell was the most effective arrangement for both materials.
4. The improvement factor increased with settlement, reaching 2.82 for polymer geogrid + geocell and 1.43 for bamboo geogrid + geocell at S/B = 35%.
5. Reinforced RAP and RAP + WMM (50:50) bases carried 24.3–174.4% more pressure than unreinforced WMM (182.1 kPa), so they can serve as alternatives to conventional WMM bases, conserving virgin aggregates and reusing RAP.

Field trials, long-term durability of bamboo reinforcement, and repeated-load behaviour should be investigated before large-scale use.

References

[1] G. H. Roodi, V. V. Kumar, and J. G. Zornberg, "Modified AASHTO empirical pavement design method for geosynthetic-reinforced asphalt," *Geosynthetics International*, vol. 33, no. 2, pp. 326–344, 2026, doi: 10.1680/jgein.25.00056.

[2] U. Ghimire and T. Bheemasetti, "Experimental studies and sustainability assessments of use of reclaimed asphalt pavement (RAP) in pavement layers," *Transportation Geotechnics*, vol. 52, Art. no. 101595, 2025, doi: 10.1016/j.trgeo.2025.101595.

[3] M. Sukhija and E. Coleri, "A review on the incorporation of reclaimed asphalt pavement material in asphalt pavements: Management practices and strategic techniques," *Road Materials and Pavement Design*, vol. 26, no. 12, pp. 2991–3030, 2025, doi: 10.1080/14680629.2025.2470889.

[4] S. M. Polisetti and R. Baadiga, "Engineering geogrid enabled low carbon and aggregate efficient flexible pavements," *Scientific Reports*, vol. 15, Art. no. 33944, 2025, doi: 10.1038/s41598-025-10066-2.

[5] S. Praveen Bodhanam, S. Meghana Polisetti, and R. Baadiga, "Laboratory and field studies on geogrid-reinforced pavements: Performance evaluation and carbon footprint analysis," *Indian Geotechnical Journal*, vol. 55, no. 4, 2025, doi: 10.1007/s40098-025-01291-7.

[6] Y. Liu, M. Mu, and J. Wang, "A systematic review on the role of reclaimed asphalt pavement materials: Insights into performance and sustainability," *Cleaner Materials*, vol. 16, Art. no. 100316, 2025, doi: 10.1016/j.clema.2025.100316.

[7] R. Panda and D. R. Biswal, "A systematic review of geo-polymer stabilised reclaimed asphalt pavement (RAP) as a base layer of pavement," *Road Materials and Pavement Design*, vol. 26, no. 2, pp. 231–253, 2025, doi: 10.1080/14680629.2024.2349021.

[8] L. Devulapalli, S. Sajikumar, and T. V. Sreekumar, "Rutting performance of geogrid reinforced asphalt mixtures," *Construction and Building Materials*, vol. 490, Art. no. 142560, 2025, doi: 10.1016/j.conbuildmat.2025.142560.

[9] M. A. Khan and A. J. Puppala, "Sustainable pavement with geocell reinforced reclaimed-asphalt-pavement (RAP) base layer," *Journal of Cleaner Production*, vol. 387, Art. no. 135802, 2023, doi: 10.1016/j.jclepro.2022.135802.

[10] A. Arulrajah, J. Piratheepan, and M. M. Disfani, "Reclaimed asphalt pavement and recycled concrete aggregate blends in pavement subbases: Laboratory and field evaluation," *Journal of Materials in Civil Engineering*, vol. 26, no. 2, pp. 349–357, 2014.

[11] A. J. Puppala, S. Saride, and R. Williammee, "Sustainable reuse of limestone quarry fines and RAP in pavement base/subbase layers," *Journal of Materials in Civil Engineering*, vol. 24, no. 4, pp. 418–429, 2012.

[12] A. J. Puppala, L. R. Hoyos, and A. K. Potturi, "Resilient moduli response of moderately cement-treated reclaimed asphalt pavement aggregates," *Journal of Materials in Civil Engineering*, vol. 23, no. 7, pp. 990–998, 2011.