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Article

Hydro-Mechanical Characterization of AASHTO-57 and Newjersey GSB Layers under Rainfall-Induced Infiltration

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Abstract: Adequate drainage is essential for the long-term performance of flexible pavements, as water infiltration from the surface, sub-surface, and sides can lead to excess pore water pressure and structural failures. The Granular Sub-base (GSB) layer plays a crucial role in facilitating drainage and providing load distribution. This study investigates the permeability characteristics of non-plastic GSB mixes prepared as per two different specifications—AASHTO-57 (open graded) and New Jersey (dense graded). A model pavement of 1.5 m × 1.5 m was constructed to replicate field conditions, and the permeability of the GSB layers was evaluated under varying rainfall intensities for 15cm thickness of GSB. The strength properties were further evaluated through the CBR test. The results indicate that the open-graded AASHTO-57 mix exhibited significantly higher permeability compared to the dense-graded New Jersey mix, making it more effective in draining infiltrated water and preventing sub-grade saturation. The findings highlight the importance of selecting appropriate GSB gradation based on local climatic and loading conditions to enhance pavement durability and reduce maintenance costs.
Keywords: Granular sub-base (GSB), permeability, AASHTO-57, flexible pavement and drainage efficiency

1. INTRODUCTION

An effective drainage system for roads basically serves the purpose of draining off the surface water from the pavement and shoulders and other adjoining areas and leading it away to the water course in such a manner that only a minimum quantity/portion of surface water during rains get into the pavement layers. A below ground water dewatering system is used for water infiltration caused by seepage flow and capillary rise into the base layer or subgrade pavement. The pavement's drainage layer serves to effectively remove water that infiltrates the pavement layer, either from the surface, sides, shoulders, or median.

Many issues linked to the quick degradation and poor functioning of flexible pavements are caused by ineffective drain characteristics of the granular sub base layer. Presence of moisture in the pavement layers and the subgrade causes extensive damage to the pavements. Numerous research studies have shown water damage in pavements. Consequently, in addition to the structural role of the sub-base course, proper acting as a drainage layer is regarded as one of the most important factors for improving pavement performance. Poor drainage causes deterioration and failure of all types of pavements, but more in the flexible / bituminous pavements, in order to prevent premature failure of pavements Realizing the importance of drainage requirements, in several National Highway Development

Projects, modified specifications of GSB material has been adopted, generally by using crushed aggregates and avoiding the use of finer fractions of materials and plastic fines.

The failure of flexible pavements is frequently associated with improper drainage in the granular sub-base (GSB) layer. Studies confirm that moisture present in an underlying layer of pavement render them weaker structurally and damage them more quickly. Therefore, apart from supporting the structures, the sub-base should act as a drain. Ineffective drainage is one of the significant reasons for premature failure of pavements. To overcome this, changes have been made to the GSB specifications of National Highway Development Projects to promote crushed aggregates with less use of finer fractions and plastic fines. This guarantees permeability and stability to the concrete. In many highway projects in India, the naturally available granular soils (like moorum) which meet the CBR, liquid limit, plasticity index and gradation criteria of MORTH Tables 400-1 & 400-2, are still being employed. Drainage design and materials selection are critical for the long term performance of pavements

Does the permeability measured for different grades of GSB as specified by ministry suffices to act as an effective drainage layer or is there any modification required in the gradation in terms of changing the fines content, if so, what should be the right gradation to be considered? 2) What should the minimum permeability requirement be for different GSB gradations and how it is fixed for different regions based on their rainfall intensity? 3) Does the use of a separation layer have any effect on the drainage characteristics of the GSB layer? In that case, how? 4) Can the sub-base course use available suggested alternative materials like fly ash and building waste without compromising the drainage properties? 5) Is the pavement width, which reflects the length of the drainage path, a parameter? Millions of rupees are being invested each year across the world to construct upcoming roads with better quality and performance without even knowing how the pavement will respond in the above-mentioned situations. Consequently, there is a requirement for research studies which will be directed towards addressing all the above, which in turn will lead to the development of proper specifications for the GSB material suitable for different regions with different rainfall intensity, and thus avoiding failures of pavements due to poor drainage.

2. LITERATURE REVIEW

A permeameter for road drainage layers that constitute the "Design manual for roads and bridges" of the HA 41/90 and the Highways Agency published in 1990. The permeameter mentioned in the Department of Transport (DOT 1990). The permeameter features a steel box that can take a sample of size roughly 1000mm by 300mm by 300mm. The aforementioned test is suitable for determining the horizontal permeability of embankment drainage layers, capping materials and sub-bases. There were found to be a series of tests that gave much larger measured values in the horizontal permeameter than in the vertical permeameter.

Jones and Jones (1989) propose the horizontal permeameter to measure the permeability of drainage layer aggregates. This permeameter functions on materials whose D50 is up to 30 mm. The size of the permeameter cell is 1.0m x 0.3m x 0.3m. A vibrating hammer is used to compact the sample.

A permeability device is used to measure the hydraulic permeability of soil samples inside the apparatus. The Permeameter was 0.15m, 0.15m and 0.30m in dimensions. The design specifications matched those of the vertical permeameter proposed in ASTM D2434 except that, a flexible rubber membrane was used on the top of compaction mold, to give good seal against leaking. The sample is saturated with de-aired water before tests conducted at different hydraulic gradients.

Randolph and others Granular materials can be analyzed for their permeability using the developed horizontal permeameter byTeguh et al., (2000). Compaction of a sample is done vertically and the measurement of permeability is done horizontally, thereby representing the field condition of a vertical compaction and horizontal movement of water in bases. The cross-sectional dimensions of the permeameter mould are 0.3m X 0.3m. X 0.45m.

3. MATERIAL AND SAMPLE PREPARATION

3.1 Aggregates

The coarse and fine aggregates used in this research were collected from Tippagondanahalli quarry area near Magadi in Ramanagar district. Close and open graded GSB mix Specified by New Jersey and AASHTO – 57 were used. Each gradation consists of coarse aggregates and fine aggregate (silt and clay) meeting the specified gradation. Rothfutch's graphical method of proportioning is used for the study. Few physical properties of aggregates were tested in laboratory and the obtained results are shown in table 1 and 2. Figure 1 represents the gradation chart of AASHTo-57 and New Jersey.

Table 1: Physical properties of aggregates

Sl.No.	Property of Aggregates	Results (%)	IS Limits (%)
1	Aggregate Impact Value	18.30	< 25
2	Abrasion Value	21.54	< 30
3	Aggregate Shape Value	24.65	< 30

Table 2: Specific gravity of aggregates

Sieve Size (in)	Specific Gravity
1-1/2	2.670
1	2.635
3/4	2.610
1/2	2.585
3/8	2.625
No. 4	2.625
No. 8	2.510
No. 16	2.615
No. 50	2.655

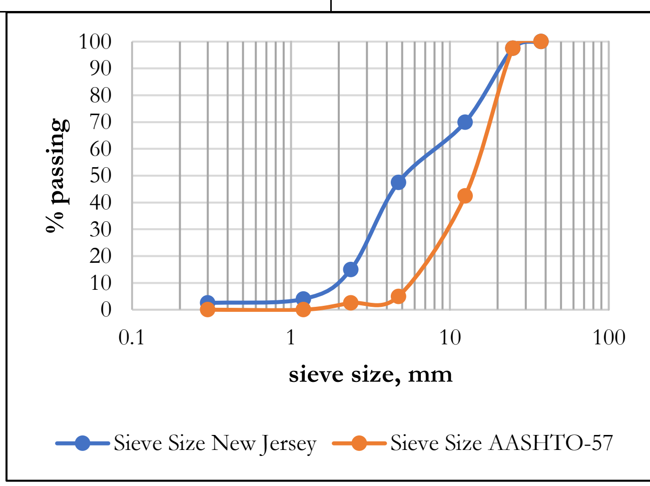

Figure 1: Gradation chart of AASHTO-57 and New Jersey materials

3.2 Compaction Test to determine OMC and MDD

Heavy compaction test was used to determine the OMC and MDD of AASHTO-57 and New Jersey gradations. Figure 2 (a) and (b) present the dry density versus water content curves used to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD), the values of which are reported in Table 3.

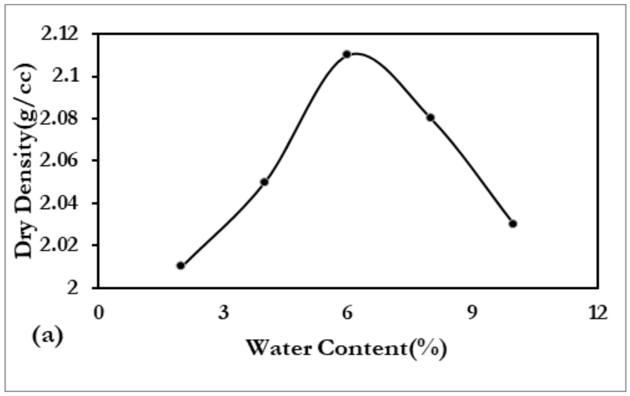

Figure 2(a): Dry density vs water content for New Jersey

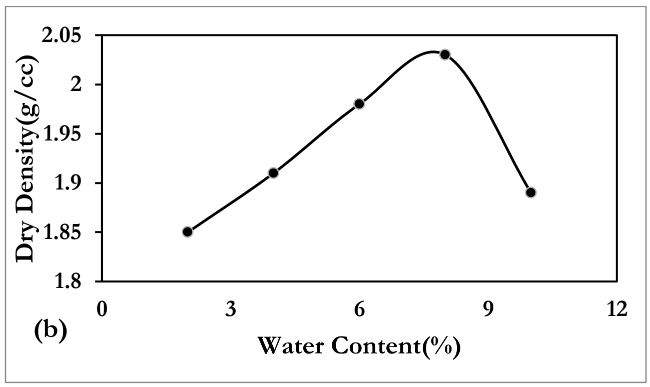

Figure 2(b): Dry density vs water content for AASHTO-57

Table 3: OMC and MDD of different gradations

Gradation	OMC (%)	MDD (gm/cc)
AASHTO - 57	8	2.03
New Jersey	6	2.11

3.3 Prototype Fabrication and Test Execution

Figure 3(a) and (b) shows the rainfall simulation and experimental set up in the field. A model pavement with dimensions of 1.5 m × 1.5 m was selected for the study. An area measuring 1.5 m × 2.0 m was marked and excavated accordingly. Within this, a 1.5 m × 1.5 m enclosure was constructed using brick bond masonry up to a height of 0.85 m. The masonry structure was then plastered to replicate field conditions, and permeability values were subsequently determined. A porous pipe was installed at the sub-grade level to act as an outlet for water drainage. The desired GSB layer was then placed above it and compacted using the Optimum Moisture Content (OMC). One end of the porous pipe was connected to a weep hole to facilitate water collection. Once a steady flow was achieved, the water collected through the pipe was measured to determine the permeability. To ensure structural stability, the three sides of the setup were backfilled and compacted. The porous pipe, measuring 63.5 mm in diameter and 1.5 m in length, was perforated with 5 mm diameter holes spaced at 10 mm intervals. Rainfall intensities ranging from 0.5 LPM to 8 LPM were simulated over the GSB layer using a pressure gauge and flow meter.

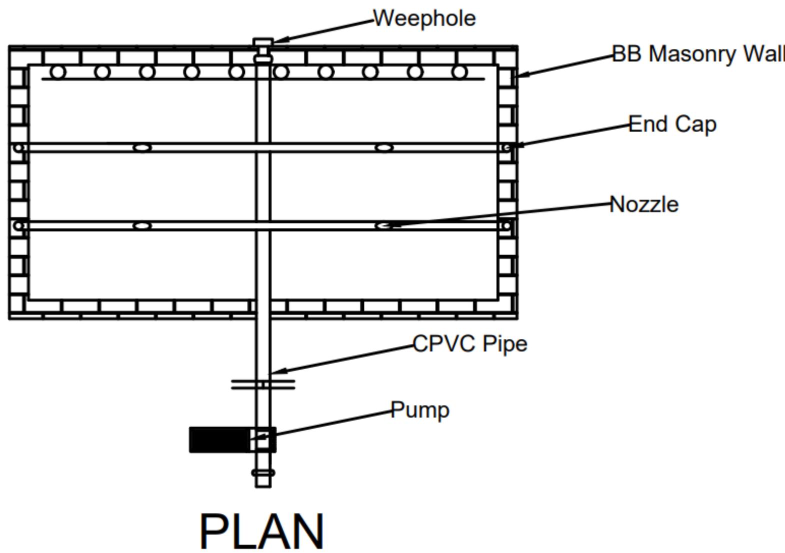

Figure 3(a.): Plan showing the (a) rainfall simulation

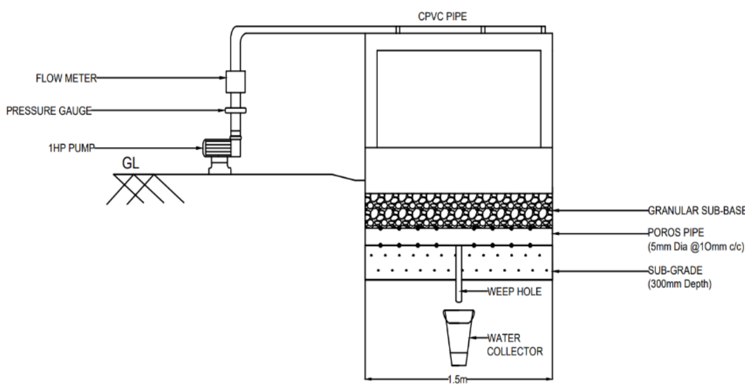

Figure 3(b): Plan showing the experimental field set up

The permeability characteristics of various Granular Sub-Base (GSB) mixes, as specified by different agencies such as AASHTO-57 and New Jersey, were investigated. After reaching a steady flow condition, water collected at the weep hole was measured, and the permeability was subsequently calculated.

4. RESULTS AND DISCUSSIONS

4.1 Strength Determination using CBR test

The strength characteristics of various GSB gradations were evaluated using the California Bearing Ratio (CBR) test. Both soaked and unsoaked CBR tests were carried out on samples prepared with two different GSB gradations, each compacted at their respective Optimum Moisture Contents (OMCs). As illustrated in Figure 4, all the GSB gradations exhibited only a minimal reduction in CBR values under soaked conditions compared to the unsoaked ones. This marginal decrease can be attributed to the high proportion of coarse aggregates present in the mixes, which are less susceptible to moisture-induced weakening.

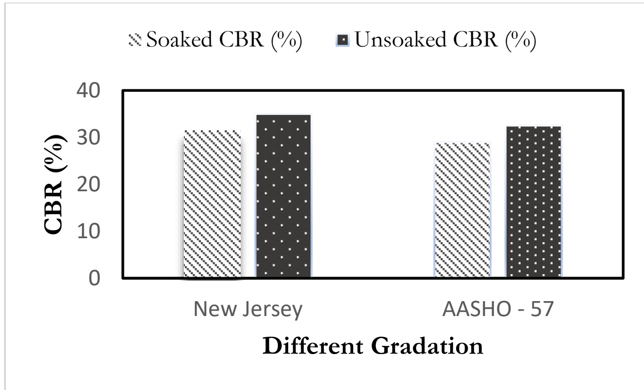

Figure 4: Soaked and Un-soaked CBR value of AASHTO-57 and New Jersey

4.2 Permeability Determination by Darcy's Law

Darcy's principle was used to calculate the coefficient of permeability (k) in the model pavement. The results of the 'k' for AASHTO – 57 and New Jersey gradation for 15 cm thickness of GSB mix with rainfall intensities from 0.5 to 8.0 LPM are given in table 4.

Table 4: Coefficient of permeability for 2 gradations with different rainfall intensity

Rainfall intensity (LPH)	**Coefficient of Permeability 'k' (m/day)**	
	AASHTO-57	New Jersey
30	372.09	337.58
60	420.36	372.09
90	475.83	444.95
120	540.08	499.02
240	688.17	623.37
360	918.66	821.39
480	1032.25	1021.28

The table 4 presents the permeability values (k in m/day) of two different GSB gradations - AASHTO-57 (open graded) and New Jersey (dense graded) - under varying rainfall intensities ranging from 0.5 to 8.0 LPM. It is observed that permeability increases with increasing rainfall intensity for both gradations (figure 5). AASHTO-57 consistently exhibits higher permeability than the New Jersey gradation, indicating better drainage capacity due to its open-graded structure. This trend highlights the influence of gradation type on water infiltration efficiency under simulated rainfall conditions.

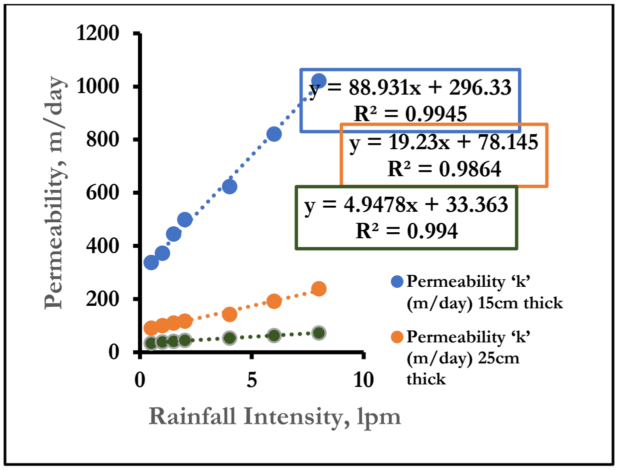

Figure 5: Coefficient of permeability for AASHTO-57 and New Jersey for different rainfall intensity

4.3 Determination of Porosity

Table 5 presents the results obtained of porosity and densities for the AASHTO-57 and New Jersey gradations considered in this study, along with the actual densities measured using laboratory apparatus during testing. Porosity was calculated using Equation (1). Experimental results showed that both porosity and permeability varied with different rainfall intensities, and in all cases, permeability increased with increasing porosity, as illustrated in Figure 6.

Table 5: Porosities and densities of AASHTO-57 and New Jersey

GSB Mix	Density from Lab (gm/cc)	Density achieved in semi model pavement (gm/cc)	Porosity (%)
AASHTO – 57	2.03	2.01	25.5
New Jersey	2.11	2.05	16.8

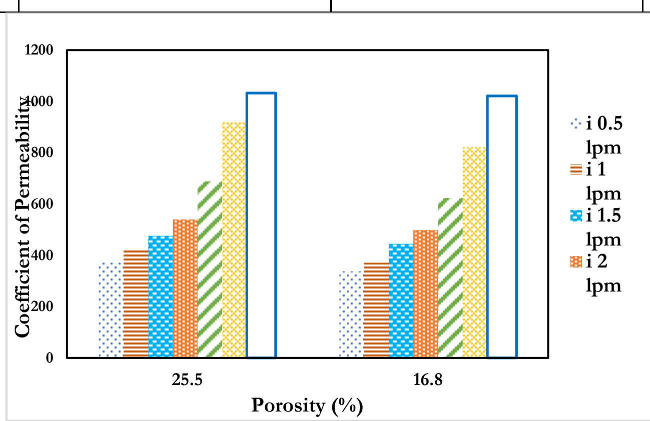

Figure 6: 'n' v/s 'k' of different gradations at 15cm thickness at various rainfall intensities (i)

5. CONCLUSIONS

This study was conducted to evaluate the strength and drainage properties of various GSB material gradations using a semi-model pavement setup. The conclusions are summarized as:

1. Permeability increases with rainfall intensity for both AASHTO-57 and New Jersey gradations, indicating that higher rainfall enhances water infiltration capacity.

2. AASHTO-57 consistently exhibits higher permeability than the New Jersey gradation across all rainfall intensities, reflecting its open-graded structure that allows better drainage.

3. The rate of increase in permeability is more pronounced at higher intensities (above 4.0 LPM), particularly for AASHTO-57, suggesting a non-linear relationship between rainfall intensity and permeability.

4. New Jersey gradation shows improved permeability at higher rainfall intensities, but remains slightly lower than AASHTO-57, which may influence its suitability in applications requiring rapid drainage.

Conflicts of Interest

The authors declares that there is no conflict of interest regarding the publication of this paper.

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