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EFFECT OF BASECOURSE AGGREGATE PROPERTIES ON STRENGTH OF FOAMED BITUMEN STABILIZED MATERIALS

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Foamed Bitumen Stabilization (FBS) is a treatment for strengthening pavements and improving road performance, either on newly constructed or existing roads. The FBS within pavements is typically used in the basecourse layer, where the basecourse material is mixed with cement, bitumen, and water through a milling operation on site. The performance of the Foamed Bitumen Stabilized basecourse can be highly affected by various parameters such as the cement content, bitumen content, the quality of the operation as well as the basecourse aggregate characteristics. In this research, a collection of existing historical FBS mix design data from New Zealand roads are analyzed. The Indirect Tensile Strength (ITS) of the FBS material made of aggregate sourced from two different regions are compared. The results show that the aggregate percentage of fine particles and the plasticity index contributes to the final strength of FBS material. The obtained results are valuable towards optimizing the FBS mix design based on the basecourse aggregate properties.

Keywords: Pavement, Basecourse stabilization, Road performance, Plasticity index, Moisture content, Particle size distribution.

1 INTRODUCTION

Foamed bitumen is a stabilizing agent used for cold in place or plant recycling of pavements. Foamed bitumen has been widely used in New Zealand, where the most common method to carry out FBS is in-situ stabilization using Wirtgen Recyclers (or milling machinery). Wirtgen recyclers have been developed to carry out foamed bitumen on roads and therefore, this method has been adopted by New Zealand construction industries. The "convoy" typically consists of a water truck, followed by a cement truck and the milling machinery with hot bitumen at the end.

In this process, hot bitumen is foamed in the expansion chambers of the spray bar and injected into the mixing chamber. During that process, water is added to the mixture to achieve optimum moisture content and sufficient compaction, which would be achieved with the help of roller compacting upper pavement as soon as stabilization is undertaken. The milling machine chews the existing (or new) pavement and mixes it with cement, foamed bitumen, and water. Cement is either pre-spread on the surface of the new pavement or is mixed during the milling operation.

The use of Foamed Bitumen Stabilization within pavements is typically used in the basecourse layer. Foamed bitumen covers fine particles and glues them together to create a bitumen-rich mortar that binds the larger particles in the pavement, increasing the pavement resistance to the stresses imposed by traffic. The NZ Transport Agency projects using bitumen-stabilized materials follow the applicable standards and specifications for design and construction, in particular the NZ Transport Agency specifications B/5 (2008) and B/7 (2012). The pavement layers under the foamed bitumen layer need to follow the design methodologies of Austroads (2017).

Figure 1. Freshly Foamed FBS Material on site.

The performance of FBS material in different contexts has been investigated by various researchers. Indirect Tensile Strength (ITS) or Unconfined Compressive Strength (UCS) is usually used to assess the strength or maximum admissible stress of foamed bitumen mixtures. The ITS results of stabilized materials using various foamed bitumen and cement contents have been reported in different studies such as Frobel and Hallet (2008), Browne (2008), and Gonzalez (2009).

However, the effect of aggregate on the ITS of FBS material is rarely discussed in the existing literature. In addition, the effect of foamed bitumen content on the ITS value is still unclear, with contradicting results reported in the literature. This paper is a part of ongoing research on the performance of the Foamed Bitumen Stabilized basecourse. In this paper, the Indirect Tensile Strength values (measured as per T19 (2016)) for the FBS material made of aggregate sourced from two different regions are analyzed using a collection of existing historical FBS mix design data. The ITS results obtained from consistent FBS mix designs from two regions are compared and the possible effects of aggregate properties on the ITS variation are discussed.

2 FBS MIX DESIGNS

A collection of existing historical FBS mix design data from New Zealand roads in two regions (where reasonably consistent FBS were used) are analyzed. The most common FBS design in New Zealand includes using 2.5% bitumen and 1% cement. However, in various regions in the south and north islands, different percentages of bitumen and cement have been tested in the lab to determine the optimum bitumen contents to use. In the dataset reviewed in this research, the bitumen content ranges between 1.7% to 3.5% and cement content ranges between 1% and 2%.

To be able to analyze the data consistently, two regions with the most consistent FBS designs in terms of binder rates (bitumen and cement) were chosen for the analysis. In total, 41 test data values from 13 FBS mix designs in these regions were used. This included 4 FBS mix designs with 13 tests in Region 1 and 9 mix designs with 28 tests in Region 2. Figure 2 shows the ITS values for each test conducted in regions 1 and 2. These results come from a range of FBS mix designs with different bitumen or cement contents. Therefore, the dataset is further categorized into four groups, as shown in Table 1.

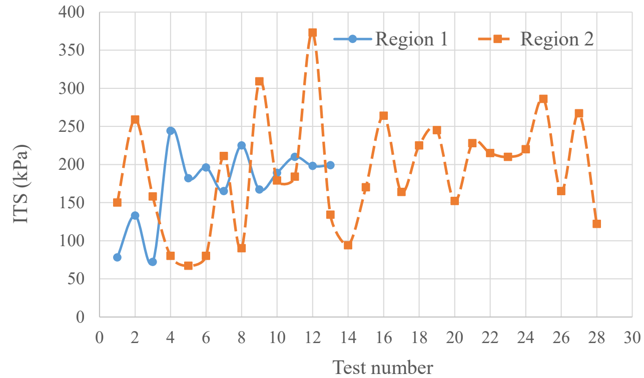


Figure 2. ITS test data in Regions 1 and 2.

Table 1. The datasets and FBS mix designs considered in this study.

Dataset group	Bitumen content	Cement content
Region 1-A	2.5%	1%
Region 2-A		
Region 1-B	1.7% to 2%	1%
Region 2-B		
Region 1-C	2.7% to 3.5%	1%
Region 2-C		
Region 1-D	2.5%	1.5% to 2%
Region 2-D		

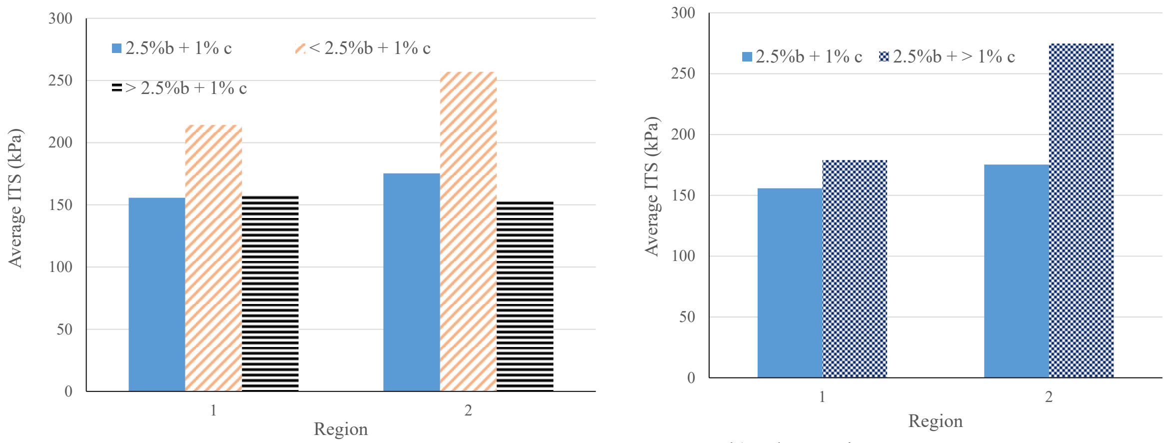
3 RESULTS AND DISCUSSION

3.1 Effect of Bitumen and Cement Contents

The average ITS values obtained from various sites in each region were used for comparison. The FBS mix (2.5% bitumen+1% cement) is considered as the benchmark. Figure 3 (a) compares the ITS values for the FBS mix designs with different bitumen content. It can be seen that in both regions, on average, the FBS mixes with bitumen content lower than 2.5% showed higher ITS values compared to the mixes with more than 2.5% bitumen content. In Figure 3, (b) the ITS values for the FBS mix designs with different cement contents are compared. It can be seen that in both regions, the FBS mixes with higher cement content show higher ITS values.

As shown in Figure 3, the average ITS values are generally higher in Region 2 compared to Region 1. For example, for the FBS mix (2.5%b+1%c), the average ITS in Region 2 is 12% higher than the average ITS in Region 1. Comparing the two regions, it can be observed that the changes in the ITS values are significant but still within the normal variability of ITS results.

For example, as shown in Figure 3 (b), increasing the cement content has led to a significant increase in ITS values obtained in Region 2; however, the improvement in the ITS values measured in Region 1 is relatively low. A similar pattern can be observed in Figure 3 (a), where the effect of changing the bitumen content is demonstrated. This variation between the two regions can be attributed to the effect of basecourse aggregate, which is further discussed in the next section.



a) Change in bitumen content

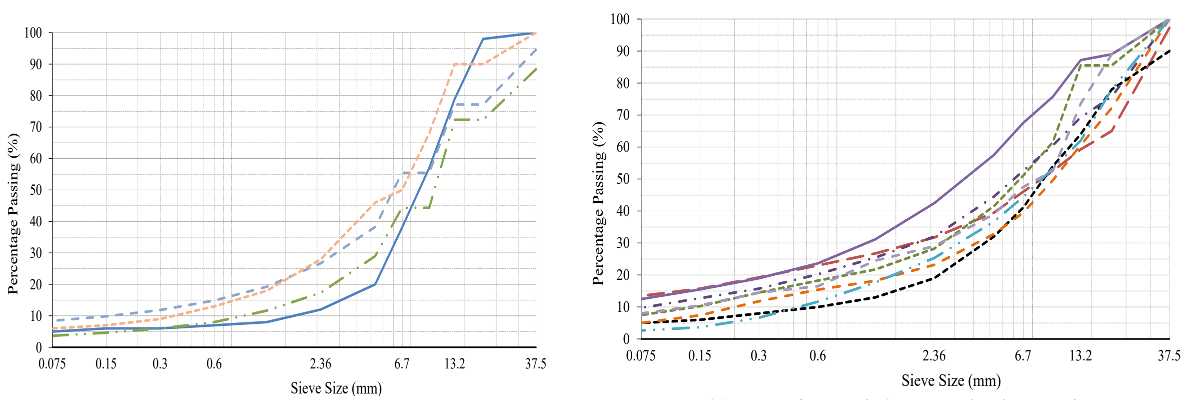
b) Change in cement content

Figure 3. ITS for different FBS mix designs in Regions 1 and 2.

3.2 Effect of Aggregate Properties

Each region has different aggregate properties, which can affect the FBS performance. In this study, the aggregate properties in terms of the Particle size distribution (PSD), Moisture Content, and Plasticity Index of the basecourse aggregates in each region are examined. Figure 4 shows the available PSD curves of the aggregate samples from two regions.

It can be seen in Figure 4 that the aggregate in Region 2 has relatively more fine particles compared to Region 1. The percentage of particles passing sieve 4.75mm is considered as a reference point for comparison here. The average percentage of fine particles (passing sieve 4.75mm) in Regions 1 and 2 is 34% and 46%, respectively.



a) PSD from four test pits in Region 1

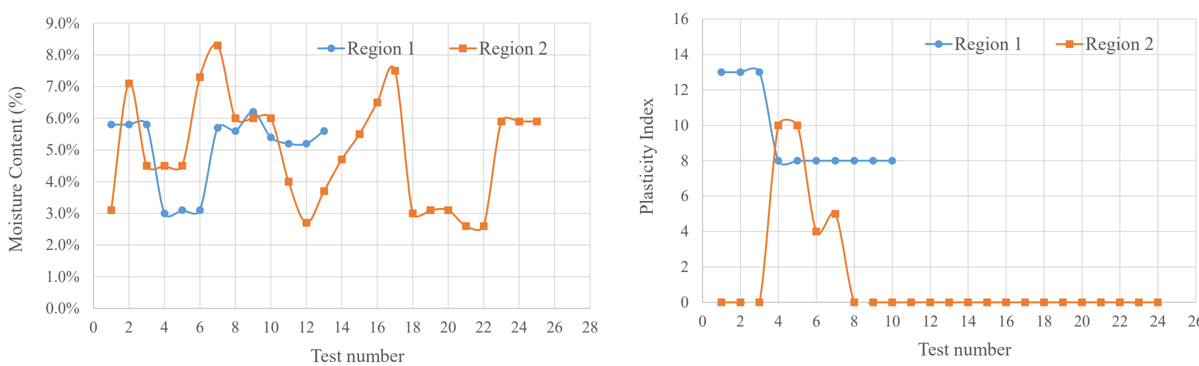
b) PSD from eight test pits in Region 2

Figure 4. Particle Size Distribution of basecourse aggregates in Regions 1 and 2.

Figure 5 shows the moisture content and plasticity index of aggregate samples obtained from Regions 1 and 2. It is shown that the Moisture content of aggregates in Regions 1 and 2 is reasonably consistent, but the Plasticity indices are quite different. To better compare the aggregate properties with the change in ITS, the average values of moisture contents and plasticity index are shown in Table 2. As shown in Table 2, the aggregate plasticity index in Region 2 is significantly lower than Region 1. The majority of aggregate samples in Region 2 were Non-plastic or showed very low plasticity, while the aggregates in Region 1 show medium plasticity.

It can be observed that the FBS design mixes in Region 2 show higher strength improvement (ITS) when the bitumen or cement content is changed. Considering reasonably consistent mix design and moisture content, different ITS values of FBS materials in these two regions can be attributed to the difference in the percentage of fines and the plasticity index of different aggregates. In other words, the higher percentage of fines and lower aggregate plasticity seems to have significantly contributed to the ITS improvement.

The obtained results are valuable towards optimizing the FBS mix design based on the basecourse aggregate material. Obtaining a better understanding of the effect of aggregate on the FBS performance can allow achieving the FBS target strength without necessarily increasing the cement and bitumen contents. Increased cement content can make the pavement susceptible to shrinkage cracking and premature failure. Therefore, achieving a high strength/performance for FBS through optimization of aggregate properties while maintaining the lower cement and bitumen content has substantial benefits for the industry.



a) Moisture Content

b) Plasticity Index

Figure 5. Moisture content and Plasticity Index of aggregates in Regions 1 and 2.

Table 2. Comparing the basecourse aggregates in two regions with the corresponding ITS improvement of FBS material.

Region	Basecourse Aggregate			Improvement in ITS (%) of FBS material	
	Average Moisture Content	Average Percentage of fine particles [1]	Average Plasticity Index	Decreasing the bitumen content [2]	Increasing the cement content [3]
1	5.0%	34%	10	37%	15%
2	4.9%	46%	1	47%	57%

Note:
[1] The average percentage of fine particles (passing sieve 4.75mm).
[2] Decreasing the bitumen content from 2.5% to minimum of 1.7%
[3] Increasing the cement content from 1% to maximum of 2%

4 CONCLUSIONS

As part of ongoing research, an attempt has been made to investigate the influence of basecourse aggregate properties on the strength of FBS material. A range of historical existing mix design data from a number of sites in two regions of New Zealand (where FBS were used) was analyzed. The two regions were chosen considering reasonably consistent FBS mix designs used. The sites and the corresponding test data in each region were categorized into four groups based on the bitumen and cement contents. The basecourse aggregate properties, including the moisture content, particle size distribution, and plasticity index recorded in various sites in Regions 1 and 2, were compared, and their potential effect on the average ITS of FBS material was examined. The following specific conclusions can be drawn from this research:

- For the FBS mixes considered in this study, it was observed that on average, the FBS mixes with bitumen content lower than 2.5% (1.7% to 2.2%) have higher ITS values compared to the mixes with more than 2.5% bitumen content (2.7% to 3.5%).
- Applying the same FBS mix design (bitumen and cement ratios) in different regions may lead to a fairly different FBS strength/performance. The aggregate properties in the region are significant contributing factors.
- The percentage of fine and the plasticity index of aggregate can contribute considerably to the final ITS results of the FBS material. A higher percentage of improvement in ITS (by either changing the bitumen or cement content) was observed in Region 2, where the basecourse aggregate has a relatively higher percentage of fine and lower plasticity index.

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