Laboratory and field tests with stabilisation of a base layer using in-place milling

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ABSTRACT: Stabilisation of base layers using in place milling and foam bitumen is a very cost efficient method for rehabilitation of worn asphalt surfaced road and upgrading of gravel roads to paved surface. This method has been used successfully in Norway using mostly 3 - 5 % foam bitumen [Skoglund and Bakløkk, 2002]. To investigate use of less amounts of bitumen and an alternative stabilisation agent a field test was established. In connection to the field test extensive laboratory testing was performed. All the test sections has so far performed very well and no significant damages or differences between the test sections could be observed. The laboratory tests show that all the stabilised samples get a high increase in resistance against permanent deformations. The samples stabilised with 2 % bitumen was not significantly weaker than the ones stabilised with 4 %. The samples stabilised with DUSTEX showed a very high increase in both resilient modulus and resistance against permanent deformations after curing. However, more research is needed to verify the durability of this method of stabilisation, especially for use when the material is exposed to frost or high degree of saturation. (Støtterud and Dahlen, 2002)

KEY WORDS: Bitumen stabilisation, lignin stabilisation, triaxial testing, field test

1 BACKGROUND

Stabilisation of base layers using in place milling is a cost efficient method to upgrade a low volume road. This could be from gravel road to a road with asphalt surface, or for rehabilitating a road with an old cracked surface layer. This method has been used for several years in Norway using different types of bitumen as stabilisation (Skoglund and Bakløkk, 2002).

To investigate performance of base layers stabilised using this method a field test with four different sections was established in June 2003 in Budalen, Norway. The different sections was build using two different amounts of foamed bitumen and one section was stabilized using DUSTEX, a product made of lignin.

Earlier experience has given god results using 3 - 5 % foamed bitumen depending of the amounts of fines. In the field test significantly lower amounts of bitumen was applied (1.5 and 2.5 %). The construction process was monitored closely and material samples were gathered at different stages of the process. These material samples were investigated in the laboratory in the Modified Proctor density test, modified CBR-test and in cyclic triaxial tests.

The traffic volume is low (AADT ≈ 230 in 1999) with some heavy vehicle related to the agricultural activity in the area. After the rehabilitation the performance of the road is greatly improved, and now service the community even in the spring thaw period.

2 FIELD TEST

Four test sections were build as shown in Table 1.

Table 1: Test sections

Stabilisation method	**Start (km)**	**Stop (km)**	**Length (m)**
Foam bitumen 2.5 %	14.480	14.635	155
DUSTEX 1.6 %	14.635	15.300	665
Foam bitumen 1.5 %	15.300	15.700	400
Foam bitumen 2.5 %	15.700	16.165	465

2.1 Construction

The test sections were constructed as part of a rehabilitation of an old gravel road. The original top layer was rich on fines and very water susceptible. It was decided to stabilise the material to reduce water and frost susceptibility and increase bearing capacity. The stabilised layer was cowered with a thin flexible asphalt layer.

2.2 Bearing capacity measured with Falling Weight Deflectometer

The bearing capacity expressed in tonnes is an empirical value based on maximal deflection for a FWD-test.

The bearing capacity was measured using the FWD 2004-08-25. As can be seen from Figure 1 there are some differences between the different sections. The highest bearing capacity is measured for the two sections with the highest amount of foam bitumen. The section stabilised with DUSTEX shows approximately the same bearing capacity as the section with lowest amount of bitumen. The two sections with lowest bearing capacity have about 10 % lower values compared to the sections with highest.

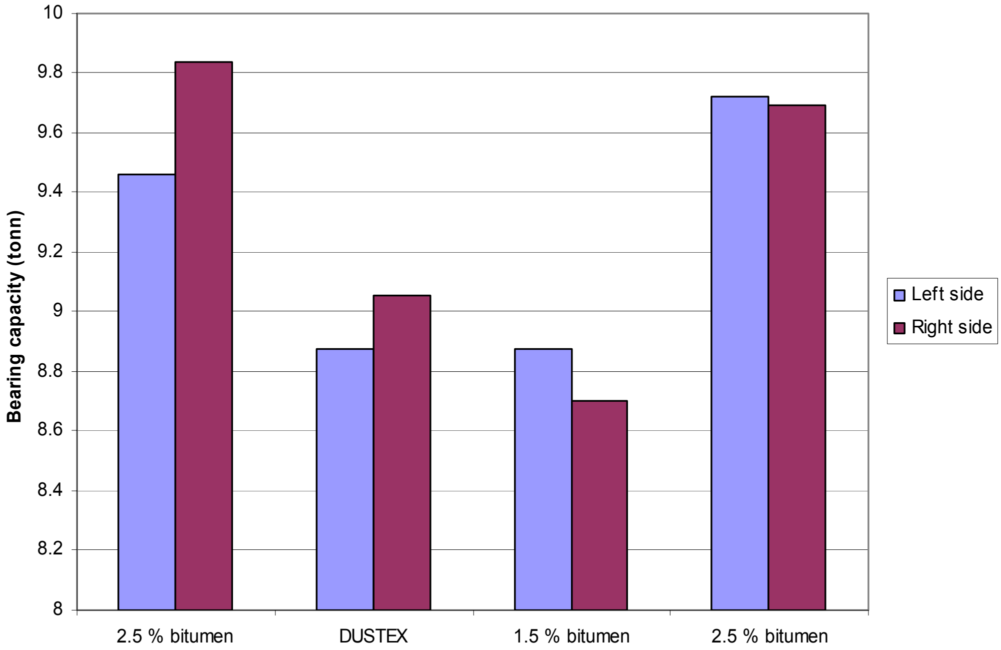

Figure 1: Bearing capacity measured with FWD

2.3 Visual inspection

The test sections were inspected during spring thaw 2004. The overall performance was very good and no visible damages could be found. In some places excess water was pressed through the asphalt surface (Figure 2) indicating potential future problems. This was observed for all sections independent of stabilisation method.

Figure 2: Water pressed through the surface in spring thaw

3 LABORATORY TESTING

The laboratory tests shown in Table 2 were performed to investigate how the different types of stabilization worked and how different kind of conditioning of the samples would influence the results.

Tabel 2: Performed laboratory tests

Material	Without conditioning	Soaked in water	7 days at 40^o C	21 days at 40^o C	21 days at 40^o C +8 freez/thaw cycles
Original gravel	CBR and Triax	CBR			
Foamed bitumen 2 %	CBR and Triax	CBR	Triax		Triax
Foamed bitumen 4 %	CBR and Triax	CBR	Triax		Triax
DUSTEX 1.6 %	CBR and Triax			Triax	Triax (samples did not survive conditioning)

All samples were compacted using the gyratory compactor at Modified Proctor optimum water content to the same density as measured in the field. It was noted that the samples stabilised with DUSTEX needed considerable less compaction energy to reach the target density compared to samples stabilised with foam bitumen. The optimal moisture content was also reduced for these samples.

3.1 Modified CBR-tests

A total of 16 samples were tested using the CBR-loading procedure either directly after compaction or after soaking in water for four days. The values obtained from this test method are not really CBR-values, because the sample preparation is not according to the standard. The values are only useful for internal comparison. Experience from testing other materials in this way has shown significantly higher values compared to the standard CBR-test (Hoff and Bakløkk, 1998)

The results of the tests are shown in Figure 3. The following observations can be made:

- The original material is not water susceptible. The samples tested directly after compaction showed approximately the same strength as the samples soaked for four days.
- Stabilisation with 2 % foam bitumen does not increase the strength of the samples significantly.
- Stabilisation with 4 % foam bitumen does increase the strength for the samples directly after compaction. This strength increase is reduced after soaking in water for four days.

- Stabilisation using DUSTEX increases the strength for the samples directly after compaction. These samples were not soaked.

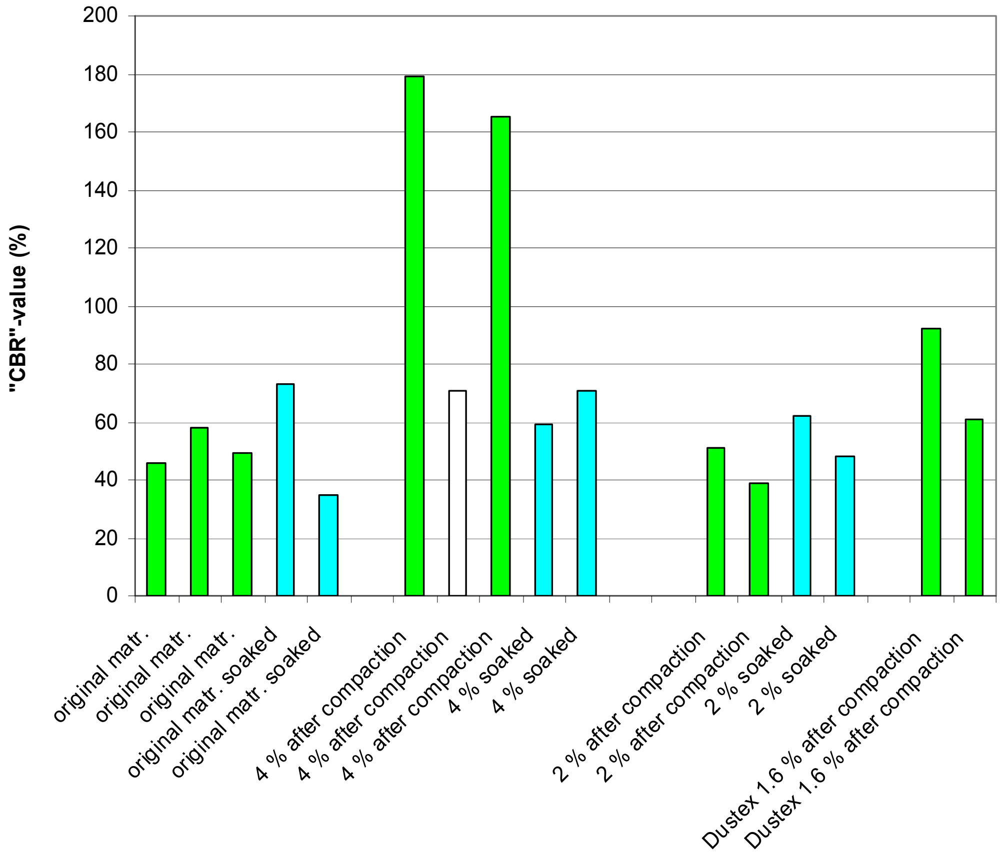

Figure 3: Results from modified CBR-tests

3.2 Cyclic triaxial tests

The cyclic triaxial test gives information about both the materials resilient (elastic) properties and their resistance against permanent deformations. By following the Multistage procedure described in the new EN-standard (CEN 2004) the materials are tested under a variety of different stress combinations simulating the stresses the materials are exposed to at different locations in a pavement structure.

The permanent deformation that develops after passing of a single vehicle is normally several orders of magnitude smaller than the resilient deformation caused by the same vehicle. Hence, it is practical to separate the analyses of the resilient properties from the analyses of the resistance against permanent deformations.

3.3 Resilient properties

As for unbound granular materials the resilient modulus is highly stress dependent. The stiffness increases for increased confining pressure. This is illustrated by Figure 4 where the resilient modulus is plotted versus the maximal mean stress for one of the samples.

For constant confining pressure the resilient modulus (Mr) can be determined by equation 1.

$$M_r = \frac{\Delta\sigma_d}{\Delta\varepsilon_a}$$ Equation 1

Where $\Delta\sigma_d$ is the cyclic deviatoric stress and $\Delta\varepsilon_a$ is the resilient axial strain.

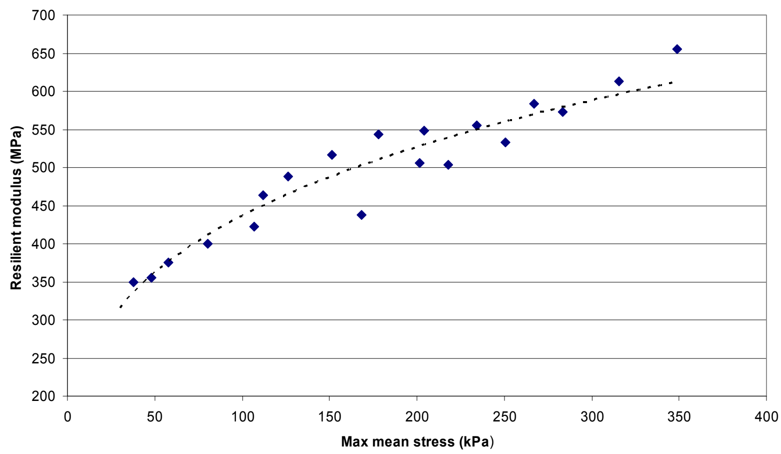

Figure 4 Non-linear resilient behaviour for one of the samples

To simplify the interpretation of the tests the resilient modulus for maximal mean stress of 200 kPa has been plotted in Figure 5 for all the samples.

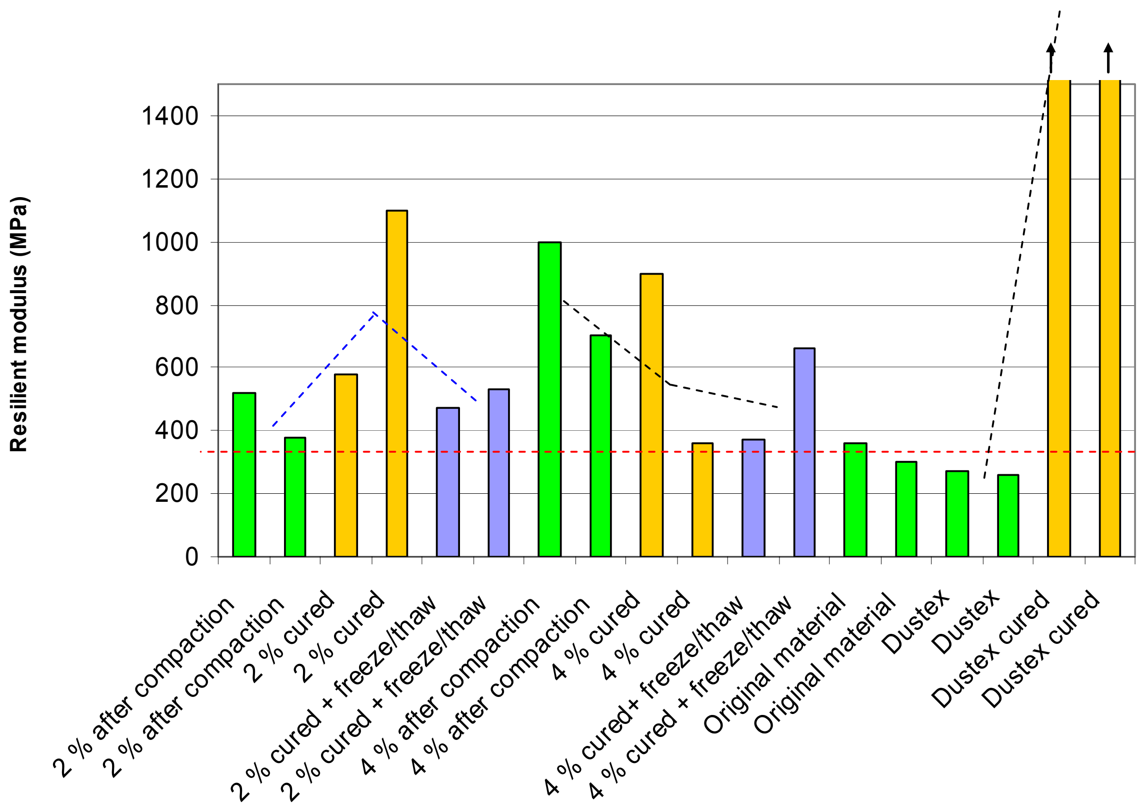

Figure 5: Resilient modules (E_{200}) for all samples

The following observations could be drawn from the resilient modulus tests:

- Stabilisation with foam bitumen increases the elastic stiffness compared to the orignal gravel material.
- 4 % bitumen produces significantly higher stiffness than 2 % for samples without consolidation. This difference is much less after curing and freeze/thaw cycles.
- Samples stabilized with 1.6 % DUSTEX show slightly lower initial stiffness but a very high increase in stiffness after curing.

3.4 Resistance against permanent deformations

To characterize the resistance against permanent deformations found from performing multistage loading is not straight forward, and several possible methods could be used. In this research the average strain rate (axial permanent strain per pulse) for the last half of each step (10 000 pulses) has been evaluated.

The permanent deformation has been placed in one of three categories for each step:

- Almost only elastic behaviour: strain rate < 2.5 10^{-8}/cycle (green square)
- Stabilizing behaviour: strain rate < 1.0 10^{-7}/cycle (yellow triangle)
- Incremental failure: strain rate > 1.0 10^{-7}/cycle (red circle)

When all steps are evaluated the three regions could be separated as shown in Figure 6

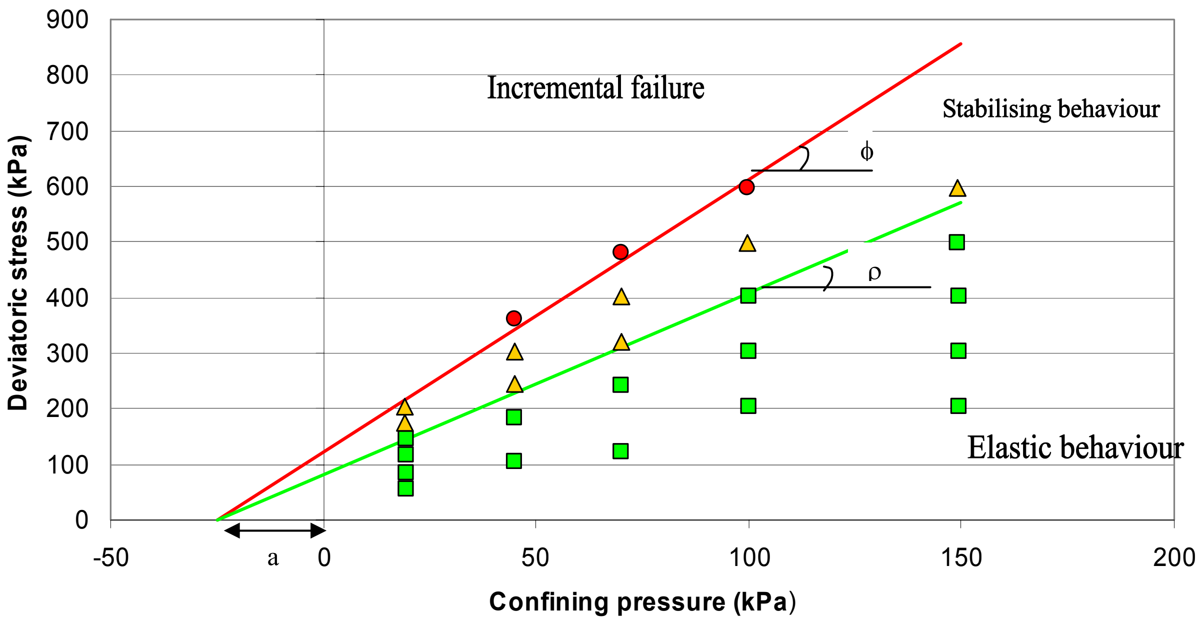

Figure 6: Interpretation of resistance against permanent deformations

The apparent attraction "a" was interpreted to be almost constant for all the samples and to make it easier to compare this value was fixed at 25 kPa for all samples. The values determining the limit lines are presented in Figures 7 and 8 for elastic limit and for incremental failure.

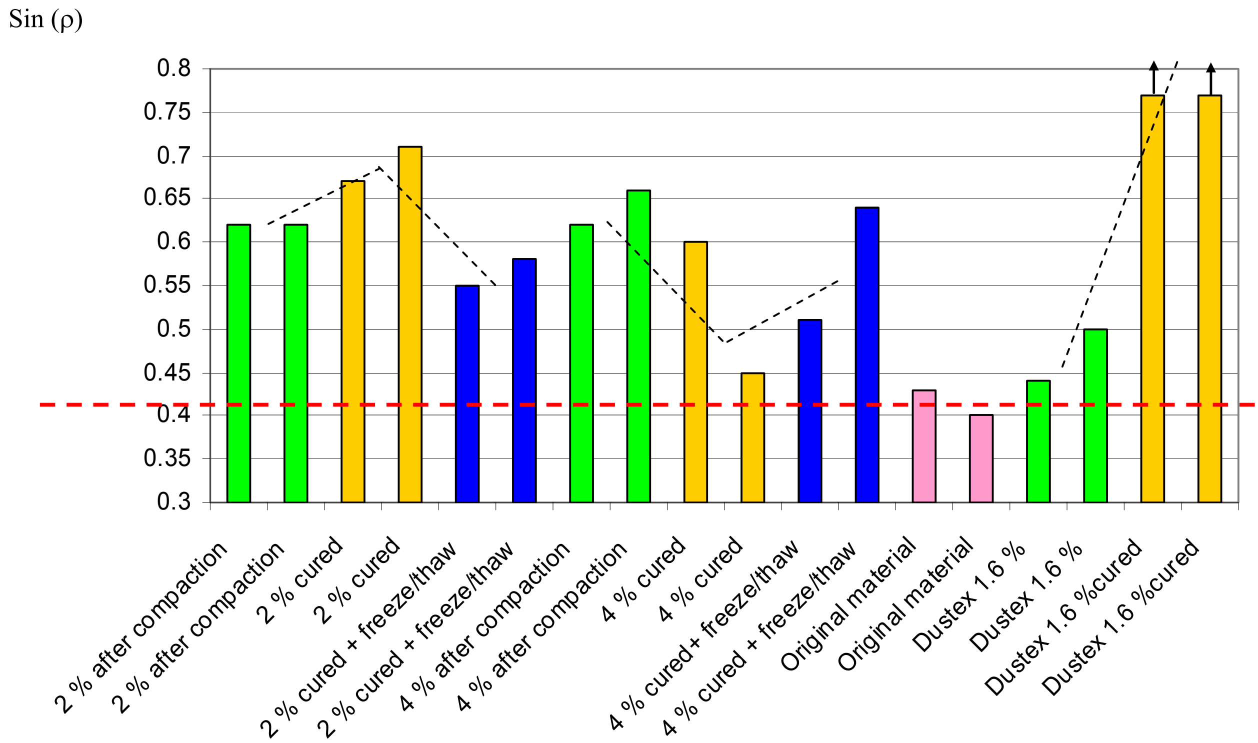

Figure 7: Elastic limit angles for all samples

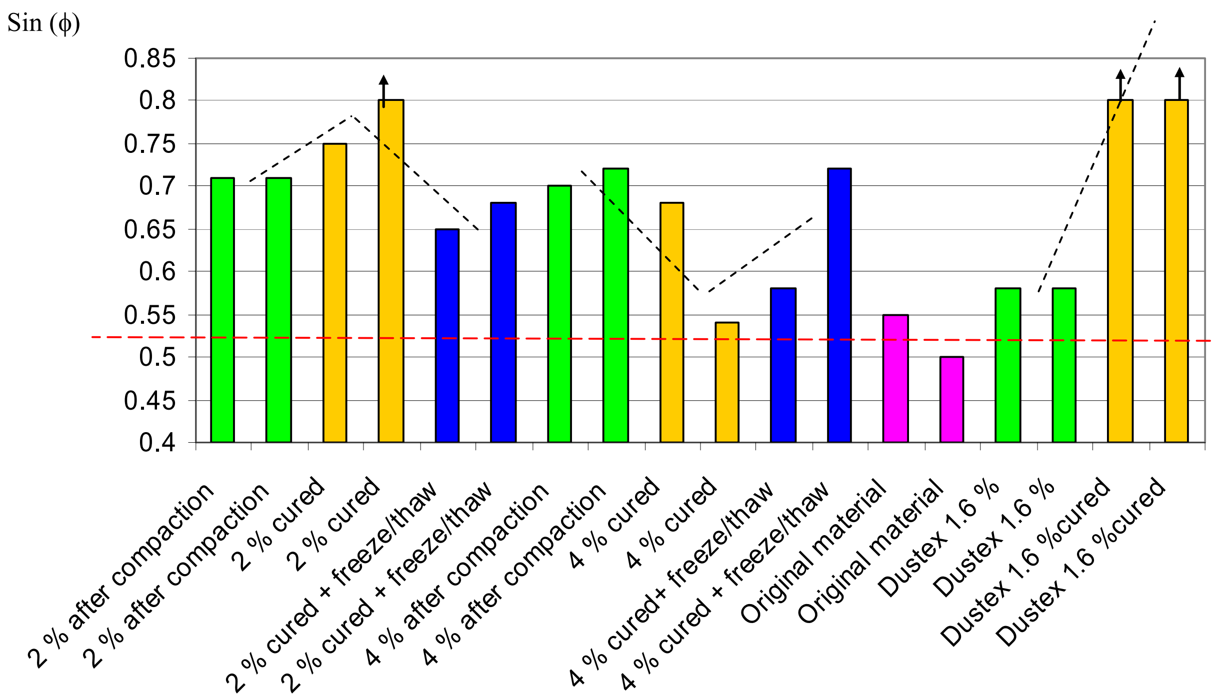

Figure 8: Limit angles for incremental failure

The following observations can be made from the permanent deformation tests:

- All of the stabilised samples show significant higher resistance against permanent deformations compared to the original gravel
- The samples with 2 % bitumen is not weaker than the samples with 4 % bitumen

- The samples stabilised with DUSTEX showed a very high increase in strength after the curing period. However, the samples did not survive the conditioning with repeated soaking in water and freeze/thaw cycles.

4 CONCLUSIONS

4.1 From the field test

- The FWD-measurements show highest bearing capacity for the materials stabilised with 2.5 % foam bitumen.
- No differences could be found so far for rutting and evenness
- Visual inspection show that the pavement surface has no damages and it is not possible to see any differences between the sections

4.2 From the laboratory tests

- Stabilisation gives samples with significantly higher resistance against permanent deformations
- It is no significant difference between samples stabilised with 2 % and 4 % foam bitumen for resilient modulus nor resistance against permanent deformations.
- Samples stabilised with DUSTEX gets very high resilient modulus and resistance against permanent deformation after curing.
- More research is needed to investigate the durability of DUSTEX stabilised materials in regions with frost penetration and freeze/thaw cycles.

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