Improving Bitumen-Stabilized Mixtures

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The main purpose of this laboratory study was to research additives that could improve the early strength and water resistance of mixtures stabilized with bitumen emulsion. The study was performed on two materials: till with high fines content and recycled base-course material. Stabilization techniques have developed over the years, but some problems such as slow strengthening and low water resistance have occurred. In this laboratory study, it was found that a small amount of portland cement improves the early strength and water resistance. The early strength of mixtures treated with portland cement was 1.5 to 5.3 times higher compared with mixtures without additives. Also, water resistance was improved considerably when portland cement was added. Cementlike additives such as ground blast furnace slag also improved the early strength, whereas $Ca(OH)_2$ and gypsum did not. Additives also had an effect on the dry density of specimens when constant compaction energy was used. The bitumen-stabilized mixture is water susceptible, and in autumn, additives are often needed. One possible additive is portland cement; laboratory tests indicate very promising results with this additive. Further information and research are needed before the dimensioning of layers can be carried out using these kinds of mixtures.

The major problems of Finnish low-volume roads are surface cracking and deformation because of uneven bearing capacity and frost damage. Recycling of layer materials is a cost-effective and energy-efficient method of road reconstruction. Layer materials of low-volume roads are quite suitable for bitumen stabilization. In Finland the first bitumen stabilization was carried out in 1985. The stabilization technique and machinery have developed since those days. Field performance has been generally good, but, because of a lack of knowledge of mixture properties and design methods, some problems have occurred. Especially when stabilization is used in autumn, bitumen-stabilized layers possess some relatively unfavorable characteristics such as slow development of strength, low water susceptibility, and strength at early ages.

In Finland instructions for design and analytical dimensioning of bitumen-stabilized layers were published in 1994 (*1*). Further research is needed, however, before the mixture properties can be used as parameters in analytical dimensioning of layers.

Materials and Methods

In this laboratory study, two different kinds of aggregate were stabilized: till with high fines content, and recycled base-course material with low fines content. According to the natrium hydroxide test, both aggregates had a low content of organic matter. The gradation curves are shown in Figure 1. The binder was cationic bitumen emulsion with a medium setting rate. (The distillation residue was 65 percent.) The additives tested were ordinary portland cement (OPC), $Ca(OH)_2$,

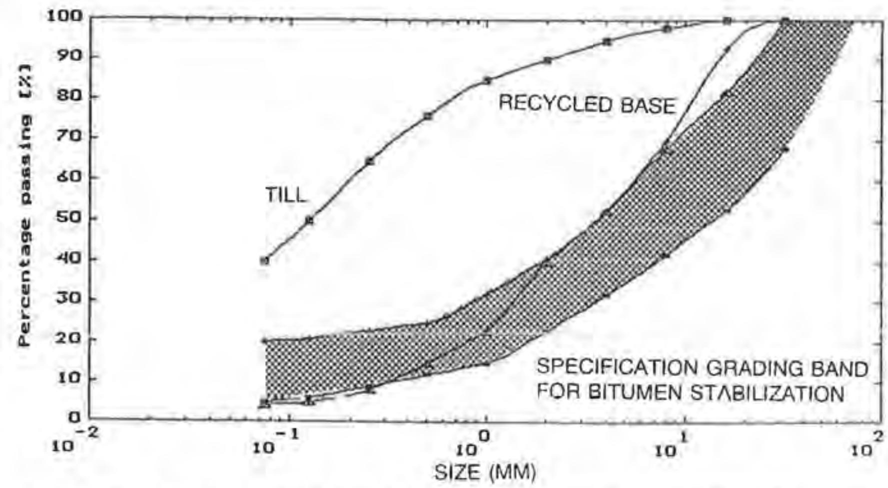

FIGURE 1 Gradation of till, recycled base course aggregate, and Finnish specification grading band for bitumen stabilization.

ground blast furnace slag (GBFS)(Blaine 400 m^2/kg), and gypsum (a power plant byproduct). The stabilized till material mixtures (1, 2, 3, and 4) and recycled aggregate mixtures (5, 6, 7, and 8) are shown in Table 1. All the proportions are calculated by weight of dry aggregate.

The moisture content of till material mixtures was 0.8 percent optimum moisture content while compacted. The moisture content of the recycled base course material was 2 percent in field conditions before reconstruction. This percentage was also the mixing water content used in laboratory tests. The total moisture content of the recycled layer mixtures was 4.2 percent. The water was added to the room-dried aggregate and mixed thoroughly. Bitumen emulsion was combined with the cold and wet aggregate by using a mechanical mixer. All the mixture specimens were made with a gyratory compacting machine. The till material mixtures were compacted by using constant compaction energy for each specimen. For that reason, there are differences in dry densities of specimens (Table 1, Mixes 1–4). The recycled base-course material mixtures were compacted until the fixed density of the specimen was reached (Table 1, Mixes 5–8). Curing was carried out at room temperature. The specimens were wrapped in plastic so that evaporation was possible from the top surface of the cylinder. All the specimens were characterized by an indirect tensile test at room temperature (22°C). The water susceptibility of till material mixtures was evaluated by a capillary water soak test for one day. After water soaking, the specimens were characterized by an indirect tensile test. The indirect tensile strength (ITS) loss was calculated as follows:

$$\text{Strength loss } (\%) = \frac{\text{ITS (unsoaked specimens)}}{\text{ITS (soaked specimens)}} * 100 \qquad (1)$$

TABLE 1 Mixture Design and Average Dry Density of Specimens

	till material				recycled base coarse aggregate			
mixture	mix1	mix2	mix3	mix4	mix5	mix6	mix7	mix8
water (%)	6	4.8	4.8	4.8	4.2	4.2	4.2	4.2
residue asphalt (%)		5	5	5	4	4	4	4
OPC (%)			1			1		
GBFS (%)							2	
$Ca(OH)^2$ (%)				1				
Gypsum (%)								3
Average dry density of specimens (kN/m^3)	21.7	20.9	20.4	19.6	22.0	22.0	22.0	22.0

Analysis of Results

The reference mixture (Mix 1, Table 1) gains strength without binder because of moisture evaporation, which improves the cohesion among fine particles. Because of their high water susceptibility, reference specimens could not resist the water damage. The till material with high fines content was suitable for bitumen stabilization, but the strength loss after the water soaking test was 80 percent (Figure 2). The effect of ordinary portland cement on indirect tensile strength was apparent only at early curing ages and after water soaking. The strength loss was only 40 percent after the water soak-

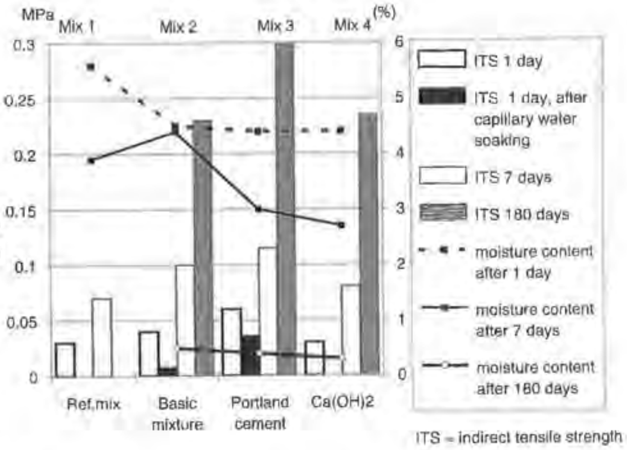

FIGURE 2 Indirect tensile strength and moisture content after 1, 7, and 180 days of curing.

ing test. The portland-cement-treated and one-day-cured unsoaked specimens had 1.5 times higher ITS than the specimens without additives (Mix 3, Table 1, and Figure 2). For the specimens cured 7 days, the differences in strength of mixtures were equalized. After 180 curing days, the portland-cement-treated mixture had 1.3 times higher ITS than that of the basic mixture (Figure 2). $Ca(OH)_2$ has no effect on strength or water susceptibility. This result may be a consequence of the low dry density of the specimens.

Moisture evaporation of the specimens was researched and is shown in Figures 2 and 3. Curing decreased the amount of moisture retained in the mixture. The increase in strength is related to the rate of moisture reduction.

Additives used with till material [OPC and $Ca(OH)_2$] decreased the density of specimens (Mixes 3 and 4, Table 1). Reduction of density was more significant when the additive was $Ca(OH)_2$ compared with ordinary

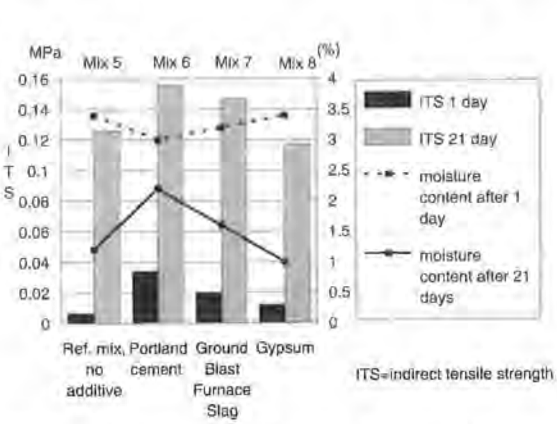

FIGURE 3 Indirect tensile strength and moisture content after 1 and 21 days of curing.

portland cement. This density reduction is caused by hydrophilic additives, which adsorb part of the moisture needed during compaction. When OPC was added, the density decreased by 0.5 kN/m^3 compared with the density of the bitumen-stabilized mixture. The reduction of density was 1.3 kN/m^3 when $Ca(OH)_2$ was added.

Four different mixtures were based on recycled aggregate (Mixes 5–8, Table 1, and Figure 3). One of the mixtures was a reference mixture without additives. The effect of OPC was significant at early ages as shown in Figure 3. The portland-cement-treated mixture had 5.3 times higher ITS than that of the reference mixture. GBFS also had an effect on indirect tensile strength after a one-day curing period. In this GBFS-added mixture (Figure 3), the ITS was 3.1 times higher than that of the mixture without additives. The gypsum could not improve ITS as well as OPC or GBFS. The strength gain was only 1.8 times higher than that of the basic mixture at early curing ages. After a 21-day curing period, no improvement was observed in the gypsum-treated specimen. The differences among mixtures characterized by ITS were equalized when the curing time was 21 days. The ITS of OPC- and GBFS-treated mixtures was only 1.2 to 1.3 times higher compared with that of the basic mixture without additive (Figure 3). The effect of additives seems to be negligible when the curing time is 21 days.

Conclusions

Curing increases the ITS and decreases the total moisture content. Ordinary portland cement improves the ITS more than ground blast furnace slag, $Ca(OH)_2$, or gypsum. This improvement is significant only at early curing ages. After a one-day curing period, portland-cement-treated unsoaked specimens had 1.5 to 5.3 times higher indirect tensile strength than that of the bitumen-stabilized mixtures without additives. After a longer curing period (7, 21, and 181 days), the indirect tensile strength was only 1.2 to 1.3 times higher than that of the reference mixtures.

The water soaking test results indicated an improvement in water resistance when portland cement was added. When 1 percent ordinary portland cement was mixed with the bitumen-stabilized aggregate, the strength gain (after water soaking) was 4.5 times higher than that of the mixture without cement. The optimum water content when compacted is usually higher than the ideal water content for bitumen stabilization. For that reason, a compromise concerning total moisture content must be accepted. In this study, it was found that when compaction is carried out using constant compaction energy, the bitumen-emulsion-stabilized specimens had 0.8 kN/m^3 lower dry density compared with that of till specimens compacted at optimum moisture content. The portland-cement-treated mixture has 1.3 kN/m^3 lower dry density compared with that of till aggregate without any binders. Calcium hydroxide caused the most significant reduction (2.1 kN/m^3) to the dry density.

In this study, the curing was conducted at room temperature, and moisture evaporation was allowed. The amount of moisture (1 to 2 percent) after a 21-day curing is likely to be slightly too low when long-period field conditions are duplicated.

Laboratory research results indicate the importance of moisture loss in the stabilized mixture. Another important matter is the compactibility of the mixture. In many cases, it is perhaps unnecessary to add portland cement to the mixtures if the weather is dry after stabilization and the stabilized layer is allowed to dry. If the base-course reconstruction must be done in autumn when the weather in Finland is changeable and wet, one should consider the use of cementlike additives in bitumen-stabilized mixtures.

REFERENCE

1. *Bitumistabilointi* (*Instructions for Bitumen Stabilization*). Finnish National Road Administration, Helsinki, 1994.