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Design of stabilised bitumen mixes for cold recycling of pavements in Estonia

Approximately 100 kilometres of asphalt or asphalt-grouted surfacing are repaired in Estonia annually since 1995. The causes necessitating the report are usually the faults of longitudinal or cross-section, unevenness in surfacing and longitudinal or cross cracks. Insufficient load-bearing capacity of the pavement is also observed.

Most of our roads have been paved with asphalt-grouted surfacing made of crushed limestone aggregate or gravel mixed with shale oil bitumen. The shale oil bitumen being used has good elongation features and very high adhesion with stone materials, but despite this, due to rapid ageing, the bitumen in old surfacing has become extremely hard and the surfacing needs softening. The method generally used is bitumen stabilisation.

The cold and wearing resistance of the limestone used in Estonia is low, therefore the asphalt-grouted surfacing using these materials always undergoes surface dressing. The low cold resistance of the mineral aggregate also poses a problem in case of road beds stabilised with new crushed aggregate and added bitumen; therefore they have been covered with one or two layers of bituminous concrete in the recent years. This procedure results in an even surface, improved qualities of the existing surfacing mix and increased bearing capacity of the pavement.

The quality of the stabilised base primarily depends on the design of the mix. In the designing of the mix, the grain composition of the pavement being recycled and the content and qualities of the bitumen should be considered above all. The data registered during the construction (even if they exist) are of little use, because the mineral aggregate has become more fine-grained due to the influence of the weather and the traffic. Besides, the mineral aggregate will be further crushed by the stabilisation milling machine. For this reason, it is better to take the samples of the existing surfacing with the milling machine. The use of the milling machine to take samples is too expensive and damages the existing road, while it mixes up the materials of different layers in case of multi-layer surfacing. The pavement material is studied in Estonia by taking samples of drill cores, where the grain composition of the mineral aggregate approximately corresponds to the grain composition before milling. In order to consider the effect of milling the empirical equations have been derived from the regression analysis of the grain composition of the pavement and the milled asphalt.

Based on results of regression analysis an important conclusion can be made – the amount of mineral aggregate passing through all the openings of the mesh screen increases to 6,6 % of total mass of rock material. The qualities of bitumen change little during milling, besides temporary heating. Consequently, the qualities of bitumen should be the same before and after milling. In order to characterise the surfacing being recycled, it is necessary to determine its content of bitumen and the viscosity of the latter. The recycled surfacing always contains viscous bitumen, whose viscosity is characterised by the softening point and penetration. The determination of penetration requires more than five times more bitumen than that of the softening point. Consequently, in order to reduce the volume of laboratory testing, attempts were made to determine the penetration by calculations using the softening point. Regression analysis has derived sufficiently clear ties between these indicators for practical use.

The penetration of bitumen can be determined at any temperature if the softening point or penetration are known.

There are two principally different positions in the design of stabilised mixes. In the first case the crushed asphalt is considered an independent grain material. Its grain composition is improved by adding new mineral aggregate with the necessary amount being calculated as a mixture of dense rock material.

It is presumed that the added bitumen is only necessary for the adhesion of the grain and does not influence the viscosity of the bitumen existing in the crushed asphalt. This requires ***2 … 3 %*** of relatively viscous bitumen. Foam bitumen or foam-emulsion are used for the ease of mixing.

On out view, this approach is acceptable unless the bitumen in the old surfacing has lost its plastic capabilities (for example, penetration above 70 … 80). Bitumen is usually harder in our old surfacings, therefore we use another approach. In such a case the old asphalt is seen as composite material consisting of mineral aggregate and bitumen. Stabilisation is needed to improve both the grain composition of the old material and to reduce the viscosity of the bitumen.

The grain composition of the mineral aggregate is designed by including crushed stone according to the grain composition of the mineral aggregate in the crushed asphalt. The amount of crushed stole to be added is determined as in the design of the usual mix and accordingly shall not be discussed in detail.

The amount of bitumen to be added *B* (% of the weight of the mix) depends on a number of factors and is dependent on:

- The share of milled asphalt of the mixture, %
- Penetration of bitumen in the milled asphalt
- Bitumen content of the milled asphalt, % of weight of milled asphalt
- The proportion of material passing through the 0,063 mesh screen opening of the designed rock material, %

The largest amount of bitumen to be added depends on the amount of fine components of the mineral aggregate (grain cross-section not above 0.063 mm). All the other considered factors (share of milled asphalt of the mixture, penetration of bitumen and bitumen content of the milled asphalt) reduce the need for bitumen to be added.

Together with the calculation of the bitumen amount the viscosity of the bitumen to be added needs to be determined as well. As had been mentioned previously, the bitumen in the old surfacing has aged too much; therefore the bitumen added to it must be sufficiently liquid to soften it. The added bitumen reacts to the old bitumen very slowly. Thanks to this the mixture can be mixed. The negative aspect is that there will be liquid bitumen around the pieces of old asphalt for some time after the completion of the road until the surfacing achieves the necessary hardness. A threat of plastic deformation exists until then, if too much or too liquid bitumen has been added.

The likelihood of plastic deformations is also increased by moisture in the stabilised bed, which may reach there due to rainy weather. Moisture may not exceed 1.5 % prior to the laying of the bituminous concrete dressing or it will enter the pores of the bed.

The determination by calculation of the mixture viscosity of new and old bitumen is an individual and troublesome task. It is relatively easy when the new and old bitumen are viscous and their softening point can be determined. In such a case the softening point equals the weighed average of the components softening points. The average softening point enables, for example, to calculate penetration as described before. In most cases, the added bitumen is not viscous but liquid shale oil bitumen, where conditional or cinematic viscosity can be determined. In this case the calculation of the average must be based on the cinematic viscosity, which is significantly more complicated, but can be easily completed with a calculator.

The bitumen stabilised mixes in Estonia have norms for permanent void content and moisture sensitivity. The composition of the mixture (primarily the bitumen content and viscosity) were previously chosen according to experience and the result was tested in the laboratory. The test results did not always meet the expectations and had to be repeated after the change of the composition of the mixture. Based on the gathered test results, we managed to derive the empirical correlations for the calculation of the permanent void content and moisture sensitivity during design.

Moisture sensibility is determined in Estonia as the ratio of compressive strength of test bodies seven days old held in dry place and placed in water on the 6^{th} day for 24 hours (at 20 °C) and must exceed 0.6.

The moisture sensibility is influenced most by the amount of mineral aggregate passing through the 0.25 mm mesh screen. If this is below 10 %, moisture sensitivity will sharply drop, while its change above the 15 % limit has little influence on moisture sensitivity.

All the above formulas are used in Estonia in the design of bitumen stabilised mixes. The correlations shown here consider the materials used in Estonia; therefore they can be different elsewhere. It is important, however, that there exist some mathematically expressed regularities, which enable to ease and speed up the design work.