In-Plant Cold Recycling and Cold Mix in Sweden - Developments in Laboratory Testing.

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Introduction.

About 0.6 million tons of cold recycled asphalt mix was produced in 1996 in Sweden, with the major part paved by the national Road Authority, and representing about 18% of all the asphalt mix used by the authority. The Road Authority is responsible for the planning of the stockpiling of the milled material and its use in subsequent maintenance jobs. The mix is produced in mobile mix plants placed at the site where the millings are stockpiled and is used as for reshaping and as wearing course on country roads with traffic up to 3000 vehicles per day. The normal thickness is 40-80mm, and the mix is laid with a paver within a day of production. A sealcoat is not usually applied.

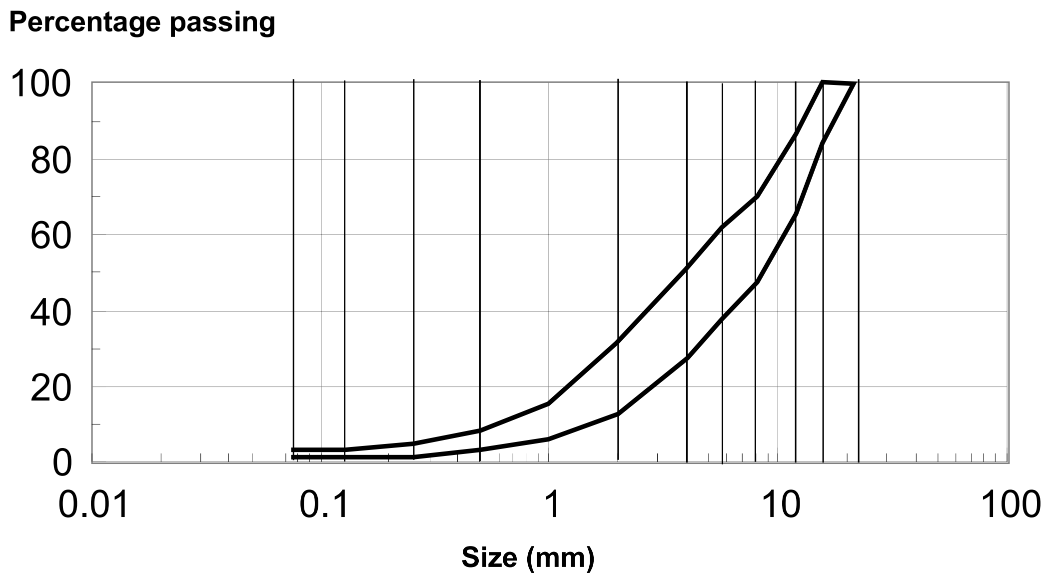
The asphalt applications group of Akzo Nobel in has been directly involved with the laboratory testing of these cold mixed materials and indirectly involved with their production through a minority shareholding in Vagmastarna a Swedish company concerned with the production of cold mixes and slurry surfacings. This paper describes their approach to the laboratory testing of cold mixed, cold laid materials for the Vagmastarna company.

Mobile mix plant

Specifications and Guidelines

The authority in Sweden provide guidelines for the production and applications of cold mixes. Although these are not mandatory , they form the basis for most contracts. One recommendation is that the residual binder on the old RAP should not be more viscous than 30pen and the grading of the RAP is given (Figure 1). Up to 15% virgin aggregate, typically -8mm coarse sand can be added to correct the grading and to improve the surface texture The guidelines set maximum total binder content (added plus original binder) depending on the mix gradation and application and contracts typically set a level to be used in cost calculations, but this level can be changed in the light of the laboratory tests. The guidelines recommend a MB 2000 soft bitumen (fluxed bitumen with a viscosity of 2000cSt at 60C) for recycling but often better results are obtained with more viscous binders like MB6000 and 10000 .

Figure 1: Recommended Grading Curve for RAP



Laboratory tests

The initial tests focus on the characterization of the RAP to ensure that the grading and binder for example meet the guidelines. At this stage it can be decided that virgin aggregate should be added. In this paper we will concentrate on the second phase of testing which is designed to select the right binder viscosity, the right emulsion recipe and the added binder content.
The factors on which this selection process is made are shown in Table 1. Essentially the same approach is taken with cold mixes made from virgin materials.

Table 1: Performance Testing of Cold Mixes

Factor	Test	Gives Information on:
Mixing		
Coating	Visual in lab mixer	emulsion ability to coat
Breaking of Emulsion	rinsing of mix	set time of emulsion
Application		
Workability	Nynas Workability	period of time mix can be stored before use
Compactability	Gyratory compactor	the ability of the mix to take compaction
Cohesion Building	Cohesion Test	period of time before opening to traffic
Service Life		
Stripping tendency	Boil test on cured mix	Water resistance of aggregate-asphalt bond
Load Bearing	NAT Stiffness Modulus	Stiffness of cured, compacted mix
Rutting Tendency	NAT RLAT	resistance of the cured compacted mix to permanent deformation

Figure 2 shows a flowchart illustrating the step by step approach to the mix design. Only those materials satisfying the relatively simple tests of coating, workability, adhesion, compactability and cohesion are subjected to structural testing. In many respects the approach follows those developed earlier , for examples the methods of Hveem[1] and Chevron[2] (see Table 2 for a comparison) but using more recently developed equipment. The main improvements in the Akzo Nobel method are the inclusion of a specific quantitative test for workability originally developed by Nynas[3], the use of Gyratory compaction for both specimen production and as a measure of 'compactability' as in the French Duriez method[4], the development of a new method for cohesion development, and the use of the Nottingham asphalt tester for permanent deformation and stiffness modulus [5].

Details of Test Procedures

Coating.

A laboratory pug mill (Skantek) capable of mixing up to 25kg of material is used to check the coating of the mixture. It is possible to do all the test work with this 25kg but it is usually more convenient to mix 10-15kg of mix sufficient for either the workability *or* compactability tests (see below). The RAP is generally prewetted with 2-5% water, the level of prewet necessary in the laboratory tests is determined by small scale hand mixing tests. The technician is looking for good coverage but no excess run off of water or emulsion when the mix is placed on a paper sheet. The level of pre wet water used on the production plant is determined by the operator from experience and observation of the mixture. Our experience is that the level of prewet water is not a critical issue for RAP, the grading is such that any excess water can escape the mix rather easily soon after production. Coating is visually determined after completion of mechanical mixing (30s).The coating test may eliminate emulsion recipes which are too fast-setting. Experience has shown that medium-setting to slow-setting cationic emulsions are adequate for RAP when soft binders are used, but that some virgin cold mixes require special emulsions.

Figure 2: Flowchart of Cold Mix testing

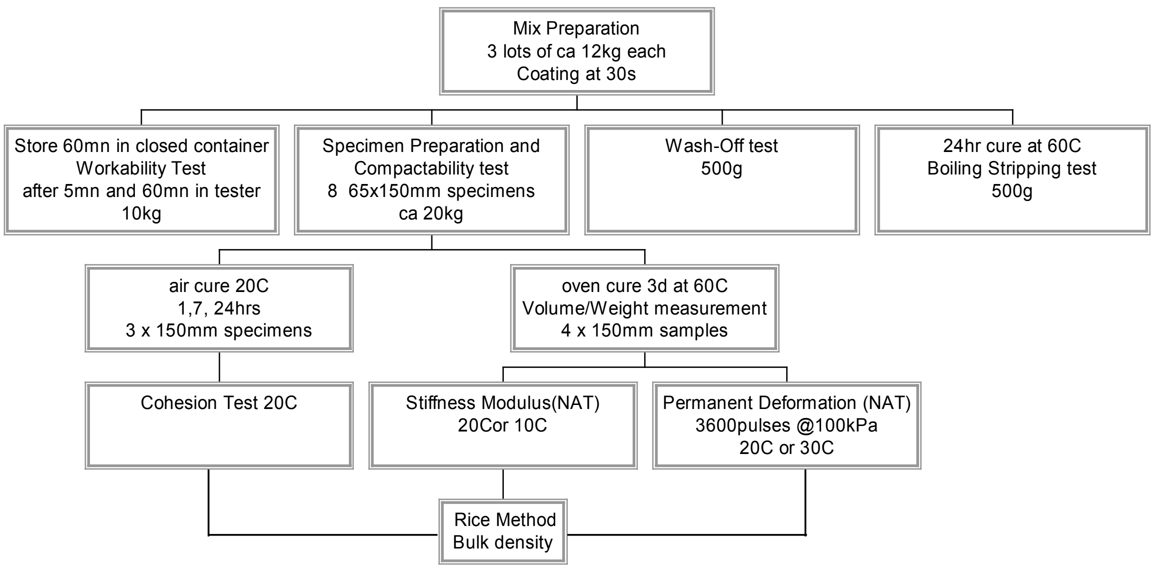


Table 2 : Comparison of Test Procedures (Surface Mixes)

	Hveem/Chevron	Akzo Nobel
Coating /mixing	hand or mechanical mix minimum 75% after 30s	laboratory pug mill minimum 85% after 30s
Run -off	<0.5%binder	not specified
Wash off	<0.5% binder on compacted mix	Coating >75% (uncompacted)
Adhesion	No test of uncompacted mix	Boil test
Workability	By hand/ subjective	Nynas workability test
Compaction	Kneading Compactor+ Static Load	Gyro compactor
Compactability	Maximum Dry Density	Gyro compactor
Curing	72h in mould + vacuum dessicator	on bench/in oven 60C
Cohesion	Hveem Cohesiometer	mod. ISSA cohesiometer
Load bearing	Resilient Modulus	Res. Mod (NAT)
Permanent Deformation	Stabilometer	RLAT (NAT)
Water Resistance of compacted mix	R-value after vacuum saturation	(Indirect Tensile Test)

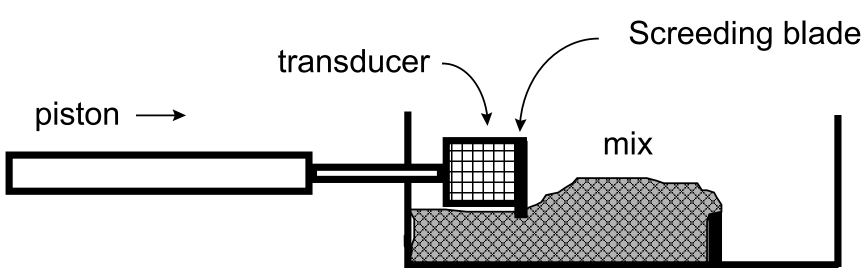
Water resistance of the uncompacted mixture.

The aim is that most of the emulsion will be broken soon after production (but without the development of cohesion which would cause stiffening of the mix). To check that the emulsion has broken and will not wash off with rainfall, the mix is rinsed with water and coating re-evaluated. A value less than 75% would be a cause for concern and maybe special handling (sheeting) but not necessarily rejection.

Workability

The workability test is primarily to see if the mixture can be paved successfully but will also give an idea of stockpile life. Mix is stored 60mn in a sealed container to avoid drying out and 10kg is placed in the Nynas workability tester. The action of placing the mix in the tester leads it to break up somewhat so it is left undisturbed for 5mn before the first test. The same material is taken out, rehomogenised and placed back in the tester for a further 55mn before the final test. The method involves the force required to shear an uncompacted mix. The workability is measured as the maximum resistance to a screeding blade moving at 10mm/s. A limit is put on the value for paving of ca. 150 -170 N [3], depending on the paver type. If values of >100 N are seen after 5mn the screed angle should be adjusted. Although the mix is to be paved soon after production, in practical terms a minimum workability 'window' of 2 hours from initial production (i.e. 60mn in storage and 60mn in the tester itself) is sought for to allow for delays and avoid waste. The difference between the 5mn and 60mn values shows the tendency of the mix to 'set-up' during the process of stockpiling, transport and paving.

Figure 3: Schematic of Nynas Workability Tester (from ref 3)



Some typical results (on cold mix) are shown in Table 3 and Figure 4. More viscous binders lead to a more rapid increase in the resistance to paving, but the choice of emulsifier is also an influence.

Adhesion

A simple boil test on uncompacted mix after curing in the oven shows up any tendency for water sensitivity and allows faulty emulsion recipes to be excluded at an early stage The CMS emulsions used generally have good adhesion to RAP but additional antistrip can help with virgin mixes containing highly acidic aggregates. The practice in Sweden is to add this antistrip to the binder before emulsification.

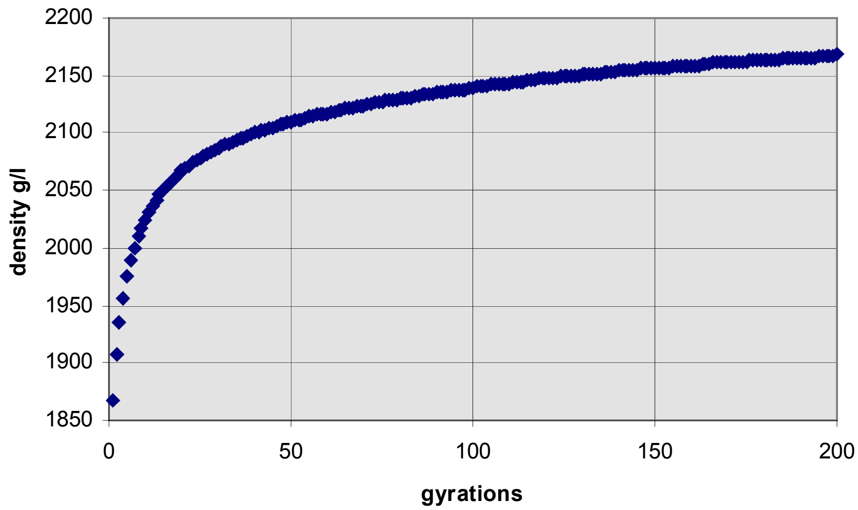
Compactibility
Compactability is measured by a Gyratory compactor in a similar way to the method used in France for Grave emulsion mixes. The Swedish laboratory of Akzo Nobel has a Gyrocomp from Cooper technology which is particularly suited to emulsion mixes. Slotted compaction moulds allow any excess water to escape and maximum density to be reached. The equipment allows either a target number of gyrations or a target density to be set. A test sample is compacted with a target cycles of ca 215 gyrations and the compaction curve used to determine the compactability (Figure 4). The density after 200 gyrations is taken as the target density. 96% of this target density should be reached after 35-70 gyrations. Values <35 show a tender mix difficult to compact with a vibratory roller, >70 represents a stiff mix.

In order to provide specimens for the structural tests it is most convenient to mix 10-12kg which is riffled into 4 samples of ca 2.45kg dry weight each for compaction, so there is not a large difference in curing time between the first and last sample to be compacted. Eight compacted samples for each mix are made in total (one for the compactability, four for structural testing and three for the cohesion tests). Specimens are compacted to a target density 96% of that achieved at 200 gyrations Although the data for the compactability is obtained from the Gyrocomp, the air voids are also measured independently (see below). The specimens are extruded immediately after compaction.

Compactability and workability are related for a particular mix and it could be that a compactability test at different storage times could provide a measure also of workability as proposed by Cabrera[7] and others.

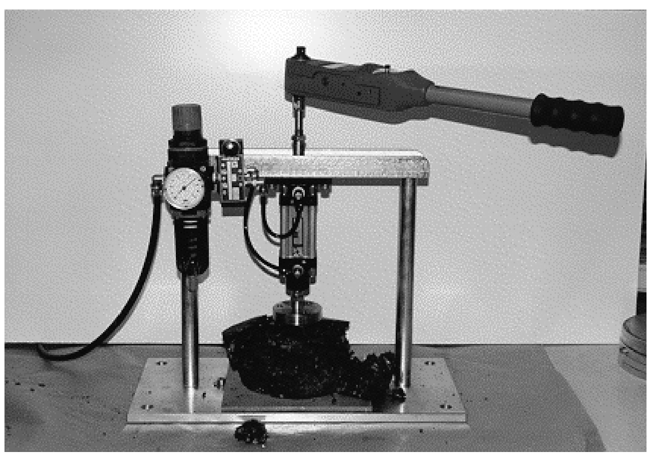
Cohesion development
To get the best performance in the field as a wearing course material the mix must develop cohesion quickly after compaction. The company Icopal in Norway have developed a novel method for measuring this cohesion development in the field. A spiked plate is driven into the roadway, and a torque wrench is used to measure the resistance of the surface to shearing forces. The wrench is only turned through a few degrees - not enough to destroy the surface. Akzo Nobel's Stockholm laboratory have taken this concept and remodeled the ISSA cohesion tester used to test slurry surfacings [8] (and incidentally originally designed in Akzo Nobel's Chicago laboratory) to create a laboratory version of this equipment (Figure 5) to estimate early cohesion.

Figure 4: Compaction Curve from Gyrocomp Compactor at 20C
Conditions: 150mm specimen, 32rpm,1.25^{o} angle, stress 600kPa



The density at 200 gyrations is taken as the target. The number of gyrations to reach 96% of this target is a measure of compactability

.Figure 5: Laboratory Cohesion tester



In the laboratory cohesion tester a spiked plate is driven into the surface of a 6" specimen which has been air cured for different times. Low values in this test may indicate a too low (added) binder content or too slow curing emulsion. A minimum cohesion of 30 Nm is reckoned if the surface is to be opened to traffic.

Structural testing

The structural testing is only carried out once a candidate mix has passed the other tests. It is performed on samples cured 3 days at 60C although similar results are obtained for samples air cured for 7days in the case of RAP mixes. No further compaction is applied to the specimens, unlike the draft ASTM method [6], although recompaction has been tried in the field.

The Nottingham asphalt tester (NAT) is used to generate information on the rutting tendency of the mixes. The repeated load axial test (Figure 6) is normally carried out at 20C but sometimes the authorities may require data at 30C. In the procedure for the RLAT the sample is first subjected to a 10kPa load for 10mn to level out any imperfections in the specimen surface before starting the repeated load. We are still gathering data on the acceptable limits to the microstrain. The main use is to limit the binder content. The NAT can also be used to measure the stiffness modulus of the specimens - at 10C for soft binders and 20C for penetration grades. Again we do not yet have set limits on the stiffness but use the results to compare the performance at different binder contents and viscosities. The results of these structural tests may lead to a selection of more viscous binders, the choice of an optimum binder content or the addition of virgin aggregate.

Some agencies in Sweden may require an indirect tensile test (similar to AASHTO T238) with soaking as a final confirmation of the water resistance of the mixture. The soaked value should not be less than 60% of the unsoaked.

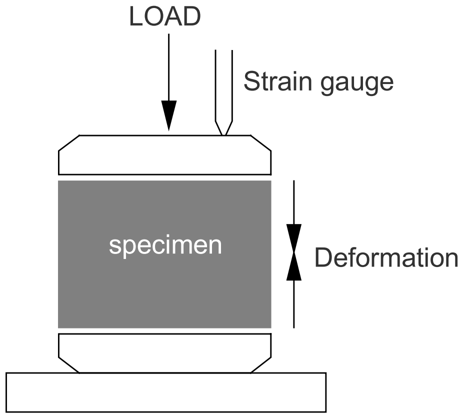
Voids Determination
The cured specimens are used to calculate density using the dimensions of the specimens and the broken up specimens from the cohesion and structural tests are used to measure the mix density using a pincnometer. These values are used to calculate the air voids.

Some Typical Results and Field Comparisons

Effect of Binder Viscosity

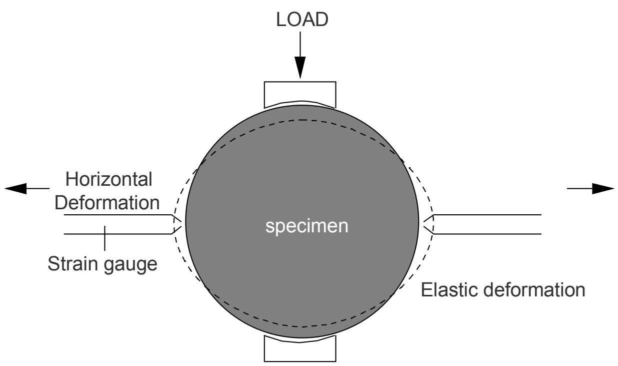
Table shows the results for three RAP mixes, the only difference being the binder viscosity. As expected, the most viscous binder gives the highest mix stiffness and resistance to deformation, but at the expense of a slight decrease in workability and borderline compactability.
Figure 6: Sample Orientation in the Nottingham Asphalt Tester

Repeated Load Axial Test (for Permanent Deformation) .



The microstrain after 3600 100kPa loads is measured.

Indirect Tensile Stiffness Modulus Test.



The average of five loads with 120ms rise time and a target deformation of 5-15micron (150mm specimen) is used to calculate stiffness modulus.

Table 2:Effect of Binder Viscosity on RAP emulsion mixes
Emulsion BE 65 S, content 2.8% on RAP, emulsifier 0.7% Redicote EM26

Binder	MB2000	MB4000	MB10 000
Mixing tests			
Coating 30s mix %	*95*	*95*	*95*
Coating after washing %	95	95	95
Boiling stripping test coating %	>90	>90	>90

Table 2 continued

Application tests			
Workability 5mn N	57	87	77
Workability 120mn N	116	107	146

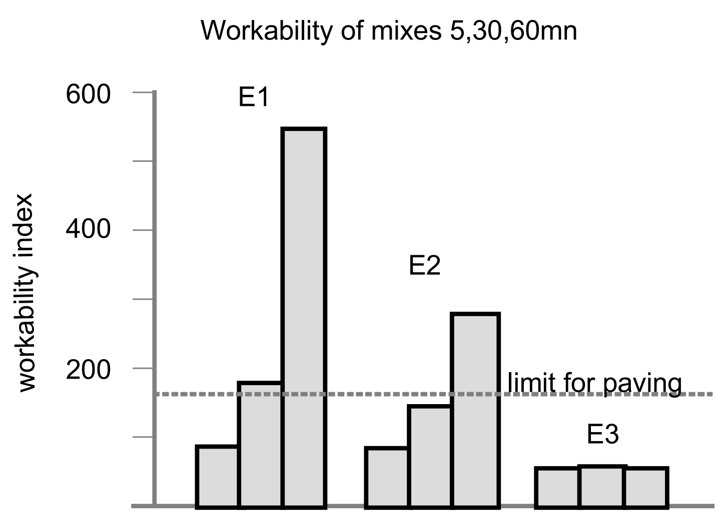
Compactability			
cycles to 96% of 200cycle density	64	75	76
air voids at 200 cycles vol %	7.7	8.2	8.3
Cohesion of compacted specimen			
after 1hour air cure Nm	39	>40	>40
after 2 hour air cure Nm	>40	>40	>40
Structural testing after 7d cure at 22C [a]			
permanent deformation (RLAT) 20C %	4.6	3.2	2.4
stiffness modulus 10C Mpa	750	720	1035
indirect tensile strength 10C kPa	435	460	420

a) We now recommend oven curing for 72h at 60C to achieve fully cured condition

Effect of Emulsifier Type

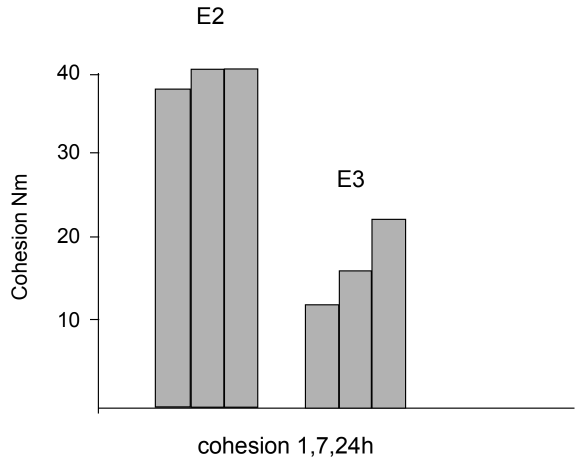
Figure 3 shows some data on the the use of the workability measurement to distinguish the behaviour of different emulsifiers. This was a virgin cold mix which has a higher added emulsion level and a relatively harder binder. The workability in this case is dependent on the breaking of the emulsion.

Figure 7 : Workability of Cold Mixes made with Emulsifiers E1-3 (320 pen binder)



The data for the cohesion development also aids in the selection of emulsion (Figure 8), although the data relates to different aggregate than that used above.

Figure 8: Effect of Emulsifier Choice on Cohesion Development



References

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