LONG TERM PERFORMANCE OF COLD MIX ASPHALT

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ABSTRACT

In the early nineties Nynas developed a system for high performance cold mix asphalt based on bitumen emulsions. The key elements of the development were a breaking additive which was mixed with the bitumen emulsion immediately before contacting with the stone material. The breaking additive did also contain a thickener which permitted thick layers of bitumen films on the stone material without risk for so called "run off". The third element of the technique was to use a very mild mixing technique, so the bitumen emulsions was just contacted with the aggregate before transportation and laying of the asphalt to avoid pre-breaking of the emulsion. A further development of the same technique was a system for using recycled asphalt pavements (RAP) for making new roads. In these cases we did not use any additive, but the gentle mixing technique was still required to get good workability and compactability of the mix. The major advantage with the recycling was the use of harder binder compared with the traditional systems used in Sweden. By this we could improve the strength of the road, and use the RAP on roads with more traffic. The two cold paving techniques were demonstrated in more than 20 test sections during the mid nineties. Many of them are still (2011) performing well. In this paper we will demonstrate the performance of the more than 15 years old roads made with cold mix techniques.

Keywords: Cold mix, asphalt, emulsion, durability, field performance

1. INTRODUCTION

In the days of concern about high energy consumption, all sectors of our society are scrutinized for potential savings of energy. Also road construction technologies are considered for finding more energy efficient ways for new constructions as well as maintenance. Two of the most energy consuming steps are the drying and heating of the aggregate during manufacturing of hot mix asphalt and the transport of aggregate and asphalt to and from the mixing plant and work site. During the last ten years improvements have been made through the development of so called Warm mix techniques, where the mixing temperature have been reduced from the normal hot mix temperature of 140°C - 160°C to typical warm mix temperatures of 100°C - 130°C. The ultimate goal is however to be able to make high quality asphalt at ambient temperature, without any heating of the aggregate at all. One obvious way of building roads at ambient temperature is cold mix asphalt made with bitumen emulsions. Although bitumen emulsions have been known for more than 100 years, and many emulsion techniques for maintenance of roads are well established, the use of cold high quality asphalt have not yet been generally accepted.

In the development of high quality cold mix asphalt with emulsion technology several factors need to be controlled:

- The workability of the mix must permit laying and compaction with normal equipment (pavers and roller).
- After compaction the development of good strength should be quick to permit immediate traffic.
- The gradation of the aggregate must have enough voids to give room for the binder and the water.
- High binder content requires a high viscosity of the emulsion to prevent “run off” from the aggregates.

Over the years several technical solutions how to make cold mix asphalt have been presented. The basic principles of the different techniques are summarised in Fig 1.
Broken systems are characterised by using relatively fast breaking emulsions which brakes immediately in contact with stone surfaces. To be able to have a reasonable workability for paving, the binder has to be soft or heavily fluxed. Non broken systems are characterised by stable emulsions which do not break immediately in contact with stone surfaces. Usually the time before the road can be opened for normal traffic may be rather long.

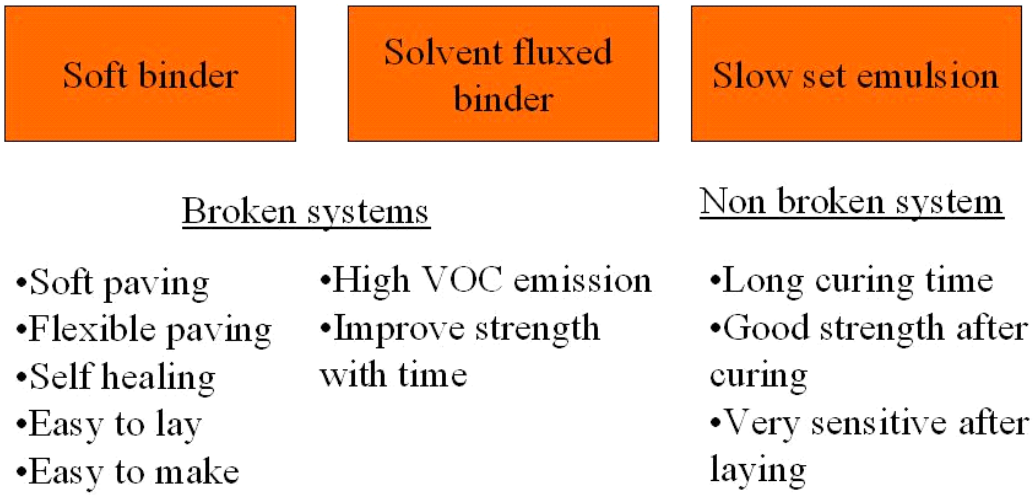

Figure 1: Summary of different ways to assure good workability for cold mix asphalt and some advantages and disadvantages.

2. IMPROVED COLD MIX ASPHALT

During the early years of 1990th Nynas AB developed a system for high quality cold mix asphalt which consisted of some unique components:

- A slow breaking bitumen emulsion which permitted mixing and laying before breaking.
- A breaking additive which was mixed with the emulsion immediately before contact with the aggregate
- A thickener which permitted high binder content in the cold mix without risk for "run off".
- A gradation of the stone material with enough voids to host the binder and the water.
- A gentle mixing process which prevented premature breaking of the emulsion

2.1 Bitumen emulsion

The bitumen emulsions used is a slow breaking emulsion. It is manufactured with different types of base binders. The most common types which are used in the field trials discussed in this paper are Nymix 630 which has a base binder B160/220 and Nymix 240 with a base binder B330/430. This is typical binders for hot mix asphalt in the area of Umeå in the north part of Sweden, since the climate is rather cold and relatively soft binder is preferred to avoid low temperature cracking during winter. The same type of emulsions may also be used for recycling (Ref 5).

2.2 Breaking additive

The improved cold mix technology includes a breaking additive. The additive consists of water in oil emulsion having two functions; to break the bitumen emulsion in such a way that the breaking is delayed, and to provide a thickening effect to the bitumen emulsion. The breaking function consists of a basic salt solution in water which is dispersed in oil (Fig 2 and Ref 3 and 4). The salt solution will eventually leak out to the bitumen emulsion and neutralise the acid. When the emulsion becomes neutral it breaks. The delay time is the time it takes for the salt to diffuse through the oil into the bitumen emulsions. The breaking additive also contains a thickener of the type associative thickeners. It provides a thickening effect, which effectively prevents "run off" from the stone surfaces also with rather open gradations and high emulsion content. The thickening effect is however not so strong that it destroys workability but strong enough to prevent wash-off of the emulsion in case of rain.

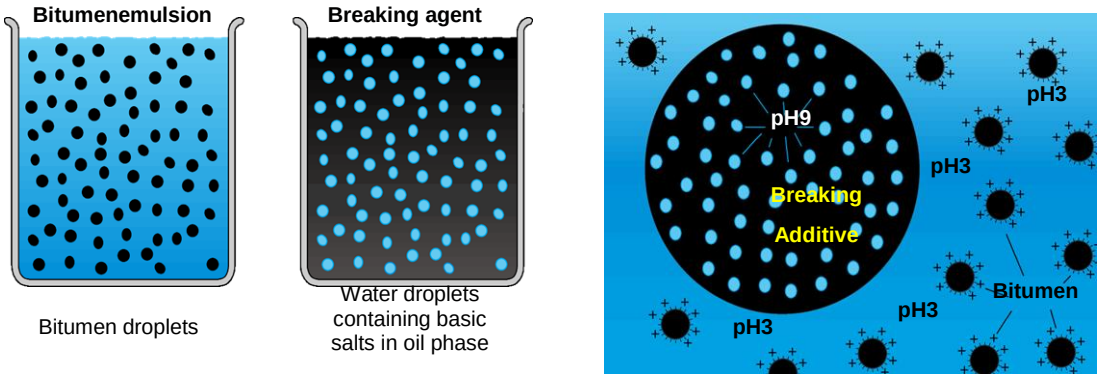

Figure 2: Principle of the breaking agent.

Efficient use of the breaking additive requires some modification of the cold mix plant with an extra tank and pump for mixing of the breaking additive into the emulsion line immediately before spraying on the aggregate. Typical concentration of breaking additive is 2% on bitumen emulsion. The breaking additive is usually not necessary at recycling provided the amount of extra binder is not too high (<3,5%).

2.3 Gradation

In cold mix applications the void content of the aggregate must be enough to host all liquid added to the aggregate. The amount of emulsion could be as high as 9% for a final binder content of 6%. A specially designed gradation was developed (Fig 3). Already with this gradation, occasionally wet spots could appear on the road surface on compaction, due to slight segregation during laying. This gradation is the densest gradation advised, but it is always possible to use more open gradation. The thickener effectively prevents run off from stones even with very low amounts of fines.

2.4 Gentle mixing

To avoid too early breaking of the emulsion it is advised to use gentle mixing. Most types of mixers are too strong to give the desired delay after the addition of the breaking additive. Best results are achieved with paddle mixer or free fall mixers, where the emulsion and aggregate is just brought into contact. If the mixing has been gentle enough, there can be several hours for transport and paving before the emulsion breaks.

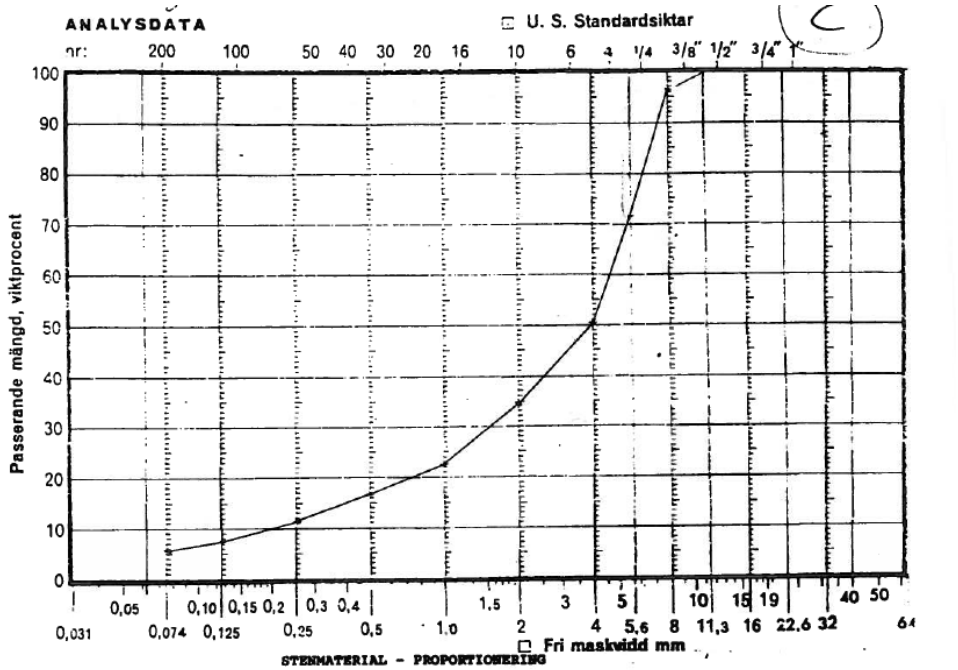

Figure 3: Typical gradation of aggregates for cold mix asphalt.

3. TEST ROADS

During the late 1990th a large number of test roads were constructed by NCC Roads and others to further develop the technique and to adapt it for practical use. Demonstration objects were constructed on several places, not only in Sweden but also in Norway and France.

In this presentation we will examine the conditions after 13 years in service of two test roads Trinnan and Överboda, both located close to Umeå in the north of Sweden. They were both made by NCC roads. Table 1.

Although the test sections reported in this paper were built with virgin stone material many test roads was also built using recycled asphalt pavement (RAP). The long time performance of these trials have been reported elsewhere (ref 2, 3) and will not be further discussed here.

Table 1: Test sites for Cold Paving Technology.

Place	Year	Emulsion	Breaking additive	Status
Trinnan, SE	1997	Slow set with base binder B160/220 and B330/430	2%	In service
Överboda, SE	1998	Slow set with base binder B160/220	2%	In service

3.1 Production of cold mix asphalt

The cold mix asphalt for the test roads Trinnan and Överboda was produced with the same mobile cold mix plant (Figure 4). It consist of three dosing bins for aggregate, a specially designed paddle mixer (a schematic drawing in Figure 5), binder tank, water tank and feeding system for mixing breaking additive into the bitumen emulsion line and finally a generator for electricity. The paddle mixer is designed to give a very gentle mixing of the aggregates and the binder. The capacity of the plant is 150 ton/hour. The emulsion is added to the stone material from a nozzle bar and to achieve a mixing as careful as possible, the material is aerated and folded rather than sheared vigorously. Since the process is completely unheated, the energy consumption is low (the electric generator consumes only one litre of diesel oil per tonne of asphalt). Although the big advantage with cold mix asphalt is the possibility to produce the mix close to the work site, this was not the case in these trials where the cold mix plant was located about 40 km from the work site which put extra requirements on the stability of the emulsion.

Figure 4: Cold mix plant

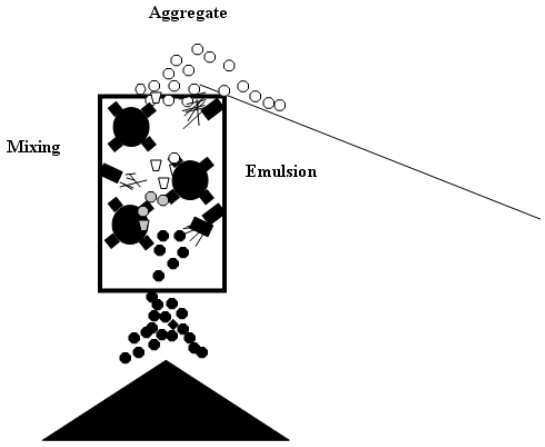

Figure 5: Schematic picture of low energy cold asphalt mixer.

3.2 Trinnan

Trinnan is a secondary low traffic road. The test road was built September 10-11 1997. The weather was partly cloudy, windy and the temperature 10-15°C. The base course is soft sand on which a cold mix wearing course of 50-60 mm is placed. The binder content was typically 5,5% and two types of slow set emulsions were tested, one based on binder B160/220 and the other on B330/430. The stone material was granite with a relatively open gradation (Fig 3). The moisture content was originally 2,2 % in the aggregate, more water was added on mixing to a target value of 4-5%. The length of the road is 1200 m (Figure 6). The lowest temperature in Umeå between 1997 and 2011 is -32,5°C which was reached two times, 2003 and 2010.

Figure 6: Testroad Trinnan directly after paving 1997.

After two years the first follow up was made. It was concluded that the road performed well. Drill cores were taken and the binder extracted and analysed (Table 2). After 12 years of service, a visual inspection concluded that the road was still in good shape (Figure 7).

Table 2: Test results on cores taken from Cold Mix road Trinnan after 2 years.

	Emulsion with B160/220	**Emulsion with B330/430**
Void Content	10,2 vol%	9,6 vol%
Indirect tensile test 10°C	540 kPa	350 kPa
Stiffness modulus 2°C	3200 MPa	1800 MPa
Recovered binder 2 years		
Softening point R&B	41,1°C	33,7°C
Penetration 25°C	124 mm/10	
Viscosity 60°C	36000 mm^2/s	

After 14 years in service, during summer 2011 we took new cores from the road. The results are listed in Table 3. It was noticed that the binder was relatively unaffected after 14 years in spite of the relatively high void content.

Table 3: Test results on cores taken after 14 years of service.

	Emulsion with B160/220	**Emulsion with B330/430**
Void Content	11,3 %	6,2 %
Indirect tensile test 10°C	570 kPa	547 kPa
Recovered binder 14 years		
Softening point R&B	39,8 °C	37,4 °C
Penetration 25°C	136 mm/10	178 mm/10

Figure 7: Appearance of the Trinnan road 2009 (after 12 years of service)

3.3 Överboda

A small secondary road in the forest was paved with cold mix during late season 1998. The traffic was measured 1999 to 200 VPD of which 35 is heavy. The length of the section was 1772 m and it is located west of Umeå. The same type of cold mix plant was used for the Överboda work as for Trinnan.

Three test sections were constructed using two different bitumen emulsions. The emulsions differed with respect to base binder which was B160/220 and B330/430 respectively. The major construction was made with virgin stone material with special gradation for cold mix asphalt shown in Fig 3. The binder content for the section with Nymix 630 was 6% and for the section with B330/430 5,5% and thickness 4,5 cm. One test section was also made using RAP as part of the aggregates. Drill cores were taken after about one month (noted time = 0) after 2 years 5 years and finally after 13 years. A visual inspection was made 2009, concluding that the road was in good shape (Figure 8). The following data was recorded:

- Void content (Table 4)
- Indirect tensile testing at +10°C (Table 5)
- Stiffness modulus +2°C (Table 6)
- Properties of recovered binder (Table 7 and 8)

Table 4: Void content

	Year 0	**Year 2**	**Year 5**	**Year 13**
Emulsion with B330/430	12,4 vol%	12,1 vol%	11,3 vol%	11,1 %
Emulsion with B160/220	10,4 vol%	9,1 vol%	10,3 vol%	No data

Table 5: Indirect Tensile Test at +10°C

	Year 0	**Year 2**	**Year 5**	**Year 13**
Emulsion with B330/430	185 kPa	290 kPa	507 kPa	313 kPa
Emulsion with B160/220	325 kPa	400 kPa	764 kPa	No data

Table 6: Stiffness modulus at +2°C

	Year 0	**Year 2**	**Year 5**	**Year 13**
Emulsion with B330/430	750 MPa	1450 MPa	1736 MPa	No data
Emulsion with B160/220	1450 MPa	2700 MPa	4646 MPa	No data

Binder was recovered by FAS method 419 and penetration and softening point was measured. There are no values for binder recovered from emulsion directly after production, so specification values are shown as “Year 0”

Table 7: Penetration at +25°C

	Year 0	Year 2	Year 5	Year 13
Emulsion with B330/430	330/430	240 mm/10	178 mm/10	175 mm/10
Emulsion with B160/220	160/220	148 mm/10	114 mm/10	No data

Table 8: Softening point R&B

	Year 0	Year 2	Year 5	Year 13
Emulsion with B330/430	33°C	34,2 °C	38 °C	37,4 °C
Emulsion with B160/220	39°C	40 °C	42 °C	No data

Figure 8: Pictures of test road Överboda 2009 (after 11 years in service)

4. Discussion

The roads are typical rural roads with two lanes one in each direction. During construction they were never completely closed, only the lane under construction. So the finished lane had to be opened to traffic immediately after compaction. The asphalt was able to carry the traffic well, even heavy trucks without any noticeable rutting.

It is obvious that the cold mix asphalt has a good durability. It was feared that the high void content could make the asphalt vulnerable for frost cracking, but this have not happened. And this has generally not been reported from any of the cold mix test roads.

It is also obvious that there is no delayed compaction under traffic, although the void content is relatively high. It shows a good stability of the road, which is also reflected in low rutting (not reported in this paper).

In hot mix asphalt there is considerable hardening during mixing and laying which do not take place in cold mix asphalt. Typically a binder with original penetration of 190 mm/10 hardens to around 120-140 mm/10 during hot mixing. In the example of Överboda we notice that in cold mix asphalt this value have been reached after about 5 years in service.

5. Conclusions

Cold mix asphalt has shown to perform very well over 14 years in service as a wearing course.

The age hardening of the binder is extremely low in spite of the open gradation.

No frost damage is noted.

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