COLD RECYCLING OF ASPHALT PAVEMENT - MIX IN PLANT

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Abstract
In Sweden, a total of about 1 million tonnes of old pavement material is recycled each year. Various techniques are used (cold, semi-hot and hot) of which cold plant recycling has become the most common method for flexible pavements on roads with low traffic volumes (ADT_{total} <1500 vehicles/day). Cold recycling is an economical technique since the material does not need to be heated. The asphalt plants can easily be moved from place to place and are therefore suitable for small-scale production and for road construction in sparsely populated areas far from stationary plants. In cold recycling, up to 100% of the asphalt can be recovered, but for a good result it is important to crush and screen the old asphalt first. About 2.0–4.0% new bitumen emulsion is added, usually together with water and sometimes 10–20% virgin mineral aggregates. Various procedures have been developed to make the mix as homogeneous as possible and to ensure sufficiently good coverage with the emulsion. It is important that the quantities of new binder, water and mineral aggregate be determined through preliminary tests in the laboratory. A new test procedure for this type of mix has therefore been developed and is included in the new directives for cold recycling produced by the National Swedish Road Administration. The procedure comprises tests and specifications covering the following areas:

- sampling and evaluation of old asphalt material
- composition of the granulate (reclaimed asphalt pavement, RAP)
- guidelines for choosing a new binder and mixing water and mineral aggregate
- preparation and conditioning of test specimens
- mix design and quality assurance by testing mechanical properties and durability of recycled mix.

Asphalt recycling - general

Old asphalt materials can be recycled using cold, warm or hot production methods, and the addition of new binder, asphalt mixture, water or mineral aggregate in the old asphalt can be performed either in the plant or on site. Recycled asphalt can be used for wearing courses, basecourses or roadbases. Cold and warm methods are mainly intended for roads with low or medium traffic volumes, while hot recycling is also suitable for roads with high traffic volumes. In cold and warm recycling, the proportion of recycled asphalt may be up to 100%, while in heated plant recycling the proportion may be 10-40%. In Sweden, a total of just over 1 million tonnes of old asphalt pavements is recycled every year (approximately 20% of total production).

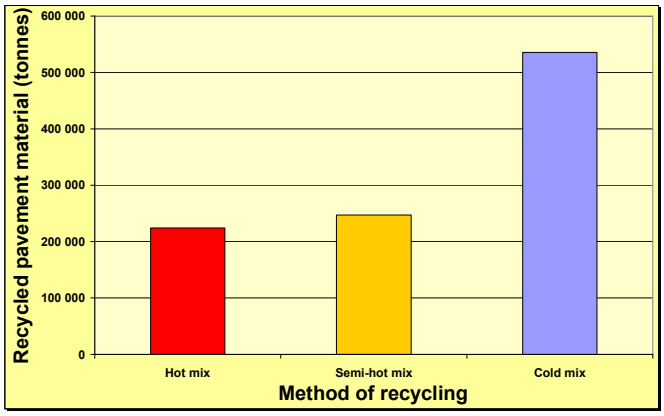

Figure 1 *Distribution between different recycling techniques in Sweden (1998).*

Cold plant recycling

Since the sixties, many types of cold mixing plant have been developed which are easily mobile and also suitable both for newly manufactured asphalt and recycled asphalt. Modern cold mixing plants have the same precision as plants for hot manufactured asphalt even if the control systems are less extensive. In cold manufacture, the granulate and aggregate are not heated but have the same temperature as the surroundings during mixing. The binder temperature is approximately 50-60°C. Although continuous mixing processes dominate; batch-mixing plants are also used. Normally, this type of plant can produce 100-150 tonnes of asphalt an hour. A common feature of the plants is a high degree of mobility and short commissioning time after being moved (a matter of a few hours). Consequently, the technique is suitable for small-scale operation, at the same time as close location to the construction site or temporary storage area can reduce transport needs.

Figure 2 *Plant for continuous production of cold recycled mix.*

In cold plant recycling, the new binder consists of bitumen emulsion. In most cases, water is added and in some cases 10-20% aggregate. Different variants of the mixing procedure have been developed in order for the asphalt to be as homogeneous as possible and for the particles to have a good degree of coating. It is important that the amount of new binder, water and aggregate be determined through appropriate mix design so that the asphalt has both a suitable composition and good material qualities.

Figure 3 *Plant for continuous production of cold mix.*

Figure 4 *Mixing plant for batch production of cold mix.*

Asphalt granulate

Asphalt granulate (RAP) is the name given to crushed or milled asphalt pavements. The particles in the granulate mainly consist of lumps of asphalt pavement with varying size, although a certain amount of aggregate may also be present. In order for the new mix to have consistently good quality, the old asphalt must be crushed and sorted. In the case of wearing courses, the largest particles should not exceed 16mm and for road bases 22mm. When the granulate is screened into fractions, it is normally sorted into a fine and a coarse fraction. Suitable screen sizes may be 0-8, 8-16 or 8-22mm.

Figure 5 *Rough sorting of asphalt granulate. Lumps larger than 22mm should be removed.*

Mixing water and aggregates

Water should be added to increase the mixability of the asphalt and at the same time make it easier to handle and compact. If the granulate has high moisture content (>5%) from the beginning, no water should be added. For the asphalt to have the best possible compaction properties, the optimal liquid ratio (water + emulsion) should be sought. The compaction curve according to heavy compaction (Proctor) or Marshall compaction may be used as the basis for choosing a suitable moisture content. On well graded granulate; the optimal moisture content is usually 6-7%.

Aggregate is added in order to increase the stability of the material if the granulate has an excessively high content of binder (> 6%) or to improve the consistency and layability (workability) of the asphalt.

New binder

In cold plant recycling, one or two binders are mixed in the granulate and the binder consists of bitumen emulsion. Several types of binder are available, but so far emulsions based on soft bitumen have been most commonly used. The following emulsions exist:

Table 1 *In Sweden existing bitumen emulsions.*

Emulsions	**Remarks**
Standard	
BE60M/V1500	Based on soft bitumen
BE60M/V6000	Based on soft bitumen
E	Based on soft bitumen
E	Based on harder bitumen

Emulsions based on soft bitumen are intended for roads where flexible qualities are required, e.g. roads with poor bearing capacity, uneven frost heave or where the winters are severe. Emulsions based on harder binders are intended for roads with higher requirements on stiffness and stability.

Transport, laying and compaction

Cold recycled asphalt consists of a high proportion of coarser particles, both granulate and aggregate, and therefore the segregation risk should be taken into account during loading, transport and unloading of the asphalt. The asphalt is not especially susceptible to wet weather since it contains water and is not heated. However, the pavement needs a period of dry, preferably warm weather so that the water has time to evaporate if the pavement is to harden. Therefore, cold recycled pavements should not be laid very late in the year and the temperature during laying should be over +5°C.

The pavers and rollers used for cold recycled asphalt are generally the same as those used for newly manufactured cold asphalt. Suitable layer thicknesses may be 80-120kg/m^2. Experience has shown that cold asphalt can be relatively slow to lay (poor workability), especially when stiffer binders are used. The result may be a certain undulation and unevenness of the road surface.

Compaction should be carried out both with a steel roller and a rubber tyred roller in separate units. Combi rollers can also be used. Steel rollers (step 1) provide compaction in depth while rubber tyred rollers (step 2) knead (seal) the road surface, which is important for durability and texture during the initial period. The number of passages and the need for rollers may be determined through test compaction of the road. Normally, 4-6 passages are used with steel rollers. Since the asphalt may be difficult to compact, the steel roller should have a relatively high linear load (total weight > 14 tonnes).

Figure 6 *Laying and compaction of a cold recycled road base. In this case, a combined steel roller and rubber tyred roller was used.*

After compaction, the surface should be sanded, partly to protect the surface from loose stones and also to protect road users from binder splashes.

Qualities of newly laid pavements

Initially, a road surface may be soft and sensitive to mechanical stresses, especially near edge of the roadway and in exposed areas. Examples of stresses that can cause damage include tyres and stabilizing legs on mobile plant (when braking or turning) and torque from heavy vehicles.

The pavement hardens with time, although it may take several weeks or even up to six months to harden properly if laying is carried out during the autumn. Cold mixed pavements usually demonstrate 2-4mm after-compaction during the first year, depending on the layer thickness, but when the pavement has hardened completely rutting will be the same as for hot asphalt.

Recommendations for binder content, moisture content and emulsion quantity

Granulate

The binder content in granulate should be 3.0–6.0 percent by weight. If the binder content exceeds 6.0%, the new mineral aggregate must be added to granulate so that the desired binder content is obtained. With an excessively high binder content, the pavement may develop plastic deformations.

The moisture content in the granulate should be within the following ranges:

- recycled asphalt for roadbases: 3.0–5.0 per cent by weight
- recycled asphalt for wearing courses: 2.0–4.0 per cent by weight

Emulsion quantities and residual bitumen content

Added emulsion content based on emulsion BE60M:

- recycled asphalt for roadbases: 1.2–2.7 (nominal value: 2,4) per cent by weight, residual bitumen content
  0.8–1.8 per cent by weight

- recycled asphalt for wearing courses: 2.2–4.2 (nominal value: 3,6) per cent by weight, residual content 1.4–2.7 per cent by weight

Asphalt
The total binder content in the asphalt (old and new binder) should be within the following ranges:
- road bases: 4.5–6.5 per cent by weight
- wearing courses: 5.0–7.5 per cent by weight

The liquid content, emulsion + water, should be slightly over 6.0 per cent by weight.

Laboratory tests and demands on granulate, asphalt and pavement
In order for the pavements with the recycled asphalt to have an acceptable quality and performance, the granulate needs a suitable grading and the recycled asphalt a suitable composition. Addition of a new binder is necessary for the asphalt to bind together and in some cases new aggregate also needs to be added for workability and stability. The particle grading and moisture content of the granulate are important for homogeneity, workability and compactability of the asphalt. Information on binder content and binder ageing in the granulate is necessary for choosing a suitable type and amount of new binder.

Preliminary checks in cold recycling

Sampling
- Samples are taken from road or stockpile (one sample per 4000 tonnes old pavement).

Characterising old pavement material
- Binder content and grading of extracted material
- Penetration, softening point or viscosity of recycled binder
- Grading and moisture content of granulate

The material checks form a basis for choosing recycling method and binder type. The composition of the material and the binder properties are used to determine a suitable binder content in mix design and the need to add water and aggregate.

Mix design (one sample per 8000 tonnes of asphalt)
- Manufacturing and storing of samples
- Void content, Marshall stability, indirect tensile strength or stiffness modulus, moisture susceptibility (in some cases freeze-thaw resistance)

The mix design will provide a basis for choosing a job mix formula

Quality checks on asphalt
- Binder content, grading and moisture content (one sample per 2000 tonnes of asphalt)
- Preparation and hardening of samples
- Void content, Marshall stability, indirect tensile strength or stiffness modulus and moisture susceptibility (one sample per 8000 tonnes of asphalt)

Since older asphalt pavements may be of widely varying origin and composition, requirements on performance related properties should be set on mix design of recycled asphalt. Properties, which may be important to measure, are stiffness modulus, indirect tensile strength, Marshall stability and durability. In testing, the preparation of the samples must be carefully controlled for relevant, comparable results to be obtained.

When preliminary checks have been completed, test laying of the asphalt should be performed in accordance with the working formula. Test laying is the best way of determining whether the asphalt can be handled and laid. According to earlier experience of cold asphalt, a certain correction of the job mix formula may be necessary after production has started.

A suitable granulate grading (wet sieving) for cold recycling is shown in Figure 7.

Preparation of samples

Mixing

- dough mixer or pug mill mixer

Manufacturing of samples

- static compaction at room temperature, or
- gyratory compaction at room temperature, or
- Marshall compaction at 60°C

Curing of samples

- 7 days at a temperature of +40°C, or
- 4 days at an increased temperature, +60°C

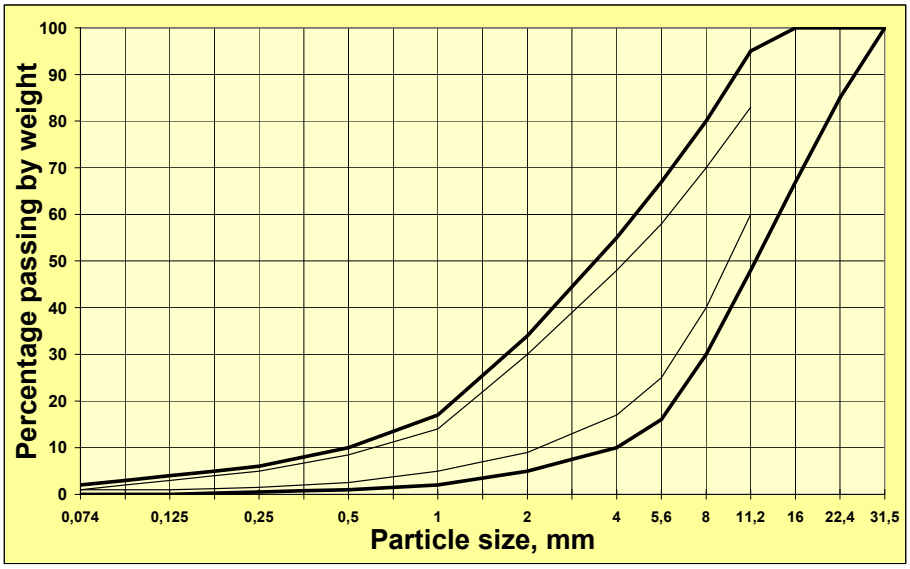

Figure 7 *Suitable particle grading for granulates*

Performance related mix design means that the job mix formula for the recycled asphalt is determined and based by relative, comparative tests on samples of granulate, binder and water in different proportions. After the samples have been stored/cured, they are tested with respect to mechanical qualities and durability. The mixture that best fulfils the stipulated demands is chosen.

Testing is performed with double specimens and a number of different binder contents. The binder contents are chosen on the basis of the binder contents and the particle curve in the granulate, in addition to ageing of the binder. This means, among other things, that a larger binder dose should be sought in the case of hardened, aged binder and a smaller dose when the binder is softer or less aged. The difference in the binder content (residual bitumen

content) between the tested formulas should be 0.4 percentage units. A combined sample of granulates from the stockpile may form the basis for mix design. The test procedure must be carefully controlled for the test specimens to be comparable.

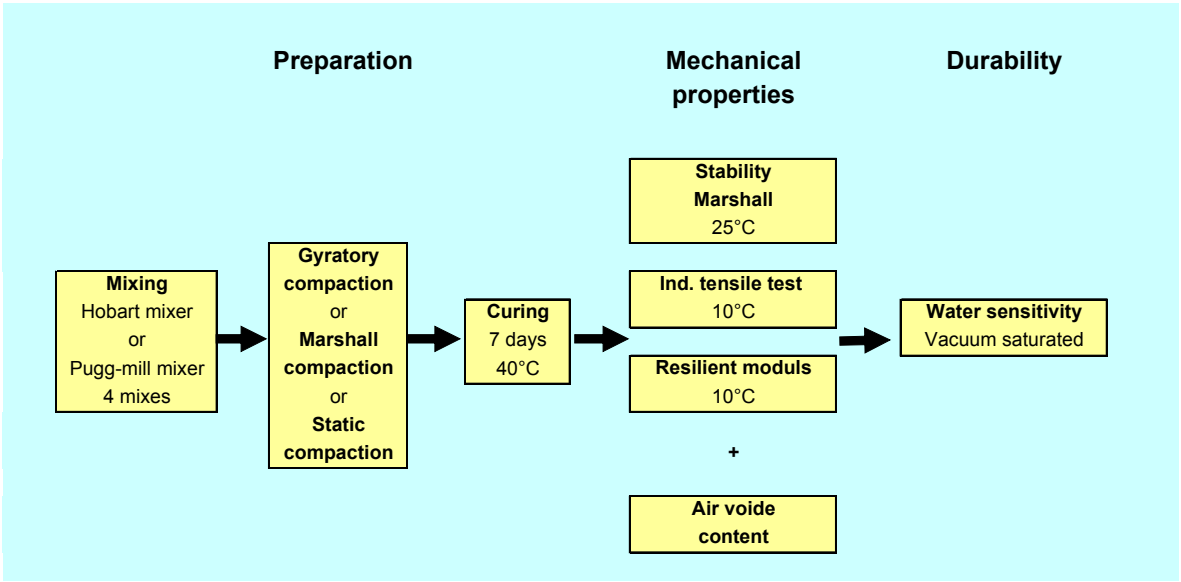

Figure 8 *Example of a function oriented mix design system for cold mix*

Specifications in mix design and quality control

Recycled asphalt in Sweden must have a mix design fulfilling the requirements in Table 2. The requirements on performance related mix design apply to roads with an ADT_{total} >500 vehicles per day. With less traffic, requirements are set only on binder content, particle grading and moisture content.

Table 2 *Requirements on cold mixed recycled asphalt*

Method	**Road-base**	**Wearing course**
Void content, % by vol.	6-14	4-12
Stability according to Marshall at 25°C, kN	>7	>5
Stiffness modulus at 10°C, MPa	>2000	-
Indirect tensile strength at 10°C, dry samples 7 days, kPa	-	>300
Water sensitivity, %, three samples	>50	>60

For roadbases, the mix giving the highest stability should be chosen, provided that the other criteria are fulfilled. The mix giving the highest adhesion coefficient should be chosen, provided that the other criteria are fulfilled.

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