COLD MIX DESIGN IN NORTH AMERICA	
FORMULATION DES ENROBES A FROID EN AMERIQUE DU NORD	

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RESUME

Il n'existe pas de méthode unique de formulation des enrobés à froid en Amérique du Nord. Les méthodes Marshall modifié et Hveem sont largement utilisées. De nouveaux tests sont développés pour la maniabilité, la cohésion et la compactibilité des enrobés à froid, ce dernier utilisant le Superpave Gyratory Compactor.

Le manque d'une méthode moderne de formulation est reconnu. Quelques nouvelles initiatives pour développer de meilleures méthodes de formulation des mélange, en particulier le recyclage à froid in-situ, ont démarré dans le cadre de l'ASTM, de la Foundation for Pavement Preservation, de l'AASHTO et de l'AEMA.

ABSTRACT

There is no single cold mix design method in North America; modified Marshall and Hveem methods are widely used. Some new tests are in development for workability, cohesion and compactability of cold mixes, the latter using the Superpave Gyratory compactor.

The lack of an up to date design method is recognized. Some new initiatives in the development of improved mix design methods especially for cold in-place recycling, are already begun within ASTM, the Foundation for Pavement Preservation, AASHTO and AEMA.

Mots clés maximum 5 : enrobés à froid,

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COLD MIX DESIGN IN NORTH AMERICA

1. Introduction

"Cold mix" describes a wide range of products, manufacturing methods and construction techniques. The components may include dense or open-graded virgin aggregates, reclaimed asphalt (RAP) or soils; cationic or anionic emulsions which may contain solvents, recycling oils or polymers; and in certain cases reactive fillers like lime, cement or fly ash may also be included. The mixtures may be made in place, or in-plant and may be (or may not be) stockpiled before being used. And lay-down may be with a conventional paver, a grader, or by hand in the case of some cold patching and reinstatement materials.

The diversity of products, coupled with the wide variety of user agencies in North America, means that it is not surprising that there is no single cold mix design methodology. In particular, the growth of in-place methods of cold mix in which much allowance for adjustments made in the field must be accepted, has to some extent reduced the importance of a well defined laboratory mix design. And most of the renewed interest in cold mix in North America has been in the area of recycling and in-place methods.

But despite the range of products and applications to be considered, which obviously have quite different requirements, there are common features which need to be considered in any cold mix design. After a brief review of the traditional mix design approaches (many of which are still in use) I intend to describe some of the more recent developments and activities in cold mix design in North America, particularly USA and Canada.

2. Traditional Methods

2.1 Dense Mixes

Much of the early work on cold mix was done by entities such as the US Forest Service, Asphalt Institute, Asphalt Emulsion Manufacturers Association (AEMA), and companies like Akzo Nobel, Chevron and McConnaughay. The 1979 edition of the AEMA/Asphalt Institute Basic Asphalt Emulsion Manual (1) describes two methods: one based on Hveem which was used in California, and the other on Marshall Mix Design, developed by Illinois Department of Transportation. The second edition of the AEMA manual in 1986 followed a report under the National Cooperative Highway Research Program (2) on the subject of cold mix and included updated versions of the above methods as well as a method used by McConnaughay, an emulsion producer active in the Mid-West and North East USA. The design approaches are still widely used. A task force representing AASHTO and the contracting industry recently recommended the Marshall and Hveem design methods, with some modifications, for use with recycled materials (3).

Traditional methods of mix design have typically addressed the following issues:

(a) Selection of correct emulsion grade and pre-wet water content for good coating
(b) Determination of total fluids/water content for optimal compaction
(c) Determination of optimum bitumen content for the desired structural properties and resistance to moisture damage.

The methods have been reviewed (4, 5). Methods for cold recycling may include additional steps to select the right viscosity/rejuvenating properties of the emulsified binder (6).

The steps in the traditional cold mix design approaches are as follows (1):

I. A starting asphalt content is calculated from the gradation of the aggregate or using the Centrifuge Kerosene Equivalent test, and small-scale hand mixes are then used to select the right emulsion grade and pre-wet water level for maximum coating.

II. The optimum fluid for compaction is determined. The approach is similar to that used for soils. By compacting specimens at a range of water contents either using the Marshall hammer (3) or compactors suitable for soils (7) the fluids giving maximum density can be determined. In another approach, the Marshall stabilities of specimens prepared at various water contents (1,8) are measured and the optimum water content determined in that manner. In some methods the emulsion itself was counted as ”fluid” and in other methods only the water content of the emulsion was counted. Aeration may be needed in the laboratory tests to reduce the moisture to the optimum level from the level present in the aggregate or added as pre-wet. This drying stage may involve heating the uncompacted mix before compaction (8,9). In simplified methods an optimum total fluids content (water plus added emulsion) is assumed: for example, 4.5% for cold in place recycling, (22), and 8% ± 0.5% for emulsion stabilized granular mixes (25).

III. The optimum asphalt content for structural properties is determined. Once the optimum fluids content for compaction is determined, specimens can be prepared at different bitumen contents for structural testing, while keeping the total water or fluids content constant at the determined or assumed optimum. Specimens have been prepared by Marshall hammer, by kneading compaction, by double plunger static load or combinations of more than one method. For example in the Dybalski method (10), specimens were prepared using Marshall hammer or California kneading compactor from fresh cold mix, followed by a partial curing in the mold (48hours at 60°C) and re-compaction by double plunger static load at 60°C to provide specimens for structural testing. In a method developed by in Canada the recompaction is by Marshall hammer (22). The idea is that these recompacted specimens represent the material after trafficking, and had voids contents similar to field cores. The same partial curing of 48 hours in the mold has also been used in the McConnahaughy method (without the recompaction step) to provide specimens representative of the early strength, i.e. immediately after compaction in the field.

Other curing regimes have been used to achieve “final” cured properties for structural testing (e.g. 3 days at 50°C, 2 days at 60°C etc). Vacuum dessication at room temperature has also been used to achieve the final cured state (1, 11). Structural tests like Marshall Stability and Hveem stability have often but not exclusively been measured at room temperature.

IV. Moisture susceptibility tests are specified in some of the procedures. It is often the case that an optimum asphalt content is more apparent with soaked specimens than with unsoaked.

2.2 Open Graded Mixes

The design approach to open-graded mixes has been to put as much bitumen into the mix as possible without run-off occurring. The Asphalt Institute method is widely used. The mix criteria are coating, run-off and (optionally) wash-off.

Selection of the right grade of emulsion for optimum coating has been addressed along similar lines as the dense mixes, for example according to ASTM D244. Small-scale hand mixes are used to optimize the emulsion formulation and the amount of pre-wet water. In practice the target has often been to avoid completely the use of pre-wet water or at least not to exceed a “saturated surface dry” state in order to avoid run off the emulsion (12). Run-off of emulsion is determined by placing the uncompacted mix in a sieve basket, collecting run-off and determining the asphalt content. Wash-off is measured by a similar test using compacted specimen (still in the mould), which is rinsed with fresh water, the wash-off is collected and asphalt content determined.

3. New Developments

The traditional methods allow the ratio of the components, asphalt, water, aggregate in the mix to be determined but generally do not address practical issues such as changes in the workability and compactability of the material during storage, or early cohesion of the freshly paved material.

3.1 *Use of Superpave Gyratory Compactor*

The early design methods used Marshall hammer, or the California kneading compactor. In many methods there may have been a recompaction, designed to simulate trafficking, and this recompaction could be done with either Marshall or static load. As laboratories in the USA move away from the Marshall compactor for hot mix design, there is a demand to use the Superpave gyratory compactor also to prepare cold mix specimens. The density that could or should be attained in the field with cold mixes is not defined in the traditional methods; most authors have taken the approach to reproduce typical field densities in the laboratory tests rather than to prescribe the densities based on expected traffic volumes.

In the Superpave approach, the optimum asphalt content is determined by the volumetrics of the mix. Depending on the expected traffic level and temperatures, the gyrations needed to produce a specimen representative of material at design or after long term trafficking are specified. Implicit is an assumption that 4% air voids for a dense graded mix is a target. At the same time the equipment gives information about the ease of compaction/workability. There is still some controversy in regards to the appropriate number of the gyrations for hot mix, and no guidance at all for cold mix. The 4% target voids is probably unreasonable for cold mixed materials.

In cold mix design, the compactor has been used both to make specimens for final structural testing and also to prepare specimens for determining optimum fluids for compaction. It has replaced the California Kneading compactor to prepare cold mixed specimens in some laboratories otherwise using the Hveem stabilometer method.

The key questions are what should be the number of gyrations to simulate the density of the mixture after lay down and compaction of the mixture and the number to simulate the maximum density after trafficking.

In work at the University of Rhode Island, an attempt was made to use also the methodology of the Superpave process (14) to cold-in place recycled materials. The gyratory compactor was used to compact the mix to approximately 11% air voids expected to represent the road material after compaction. Between 25 and 57 gyrations were required with the materials tested.

In another approach (15) the concept of locking point is applied. In the method described in the reference, samples with different asphalt contents are first compacted to 200 gyrations, representing maximum possible density after trafficking. The moulds are perforated to allow moisture to escape if necessary. Then the curve of height vs. gyrations is examined and the locking point determined. As the height of the specimen is decreased by each gyration, there comes a point where aggregate – aggregate contact prevents further consolidation and the height does not decrease rapidly. A locking point can be defined as the first 3 consecutive measurements at which there is no change in height followed by 3 more consecutive height measurements at the next lowest height. Typical values were between 40 and 75 gyrations for the materials studied. High values represent mixes which will require more compactive effort in the field. The target of the author was to achieve a density of 90 ± 1% of theoretical maximum at the locking point, which is meant to represent the density of the mix immediately after field compaction. The materials studied were reclaimed asphalt pavement, plus some virgin materials to correct the grading.

3.2 *Workability and Compactability Tests*

Once emulsion and aggregate have been mixed, there will be a tendency for the mix to gradually stiffen, either from the gradual breaking of the emulsion in solvent free mixes or from the loss of solvent and water from solvent containing mixes. This concept was not addressed in traditional methods. Eventually the mix will become too stiff to easily remove from a stockpile or to pave. Nynas developed a workability tester designed to measure the "workability window" between mixing and paving (16). The method involves placing the mixture in a box fitted with a ram. The force required to shear the materials at different times after storage is determined by the force required to push the ram through the mix. An improved version of the method has found use within the design laboratory of Koch Materials.

The Nynas method is designed to simulate the paver operation. A method designed to simulate the handling of cold patching stockpile materials resulted from the efforts of the ASTM sub-committee D04.27 *Cold Asphalt Mixtures*, and has recently been accepted by ASTM (17,18). The method uses the Marshall load frame or similar device to drive a blade through the mix. The force required is a measure of the workability. The method is primarily designed for cold mixes based on cutbacks used for pothole patching but can be applied to similar fine grained materials based on emulsions.

Workability is related also to compactability. In the "locking point" concept the number of gyrations needed to reach this point is also considered a measure of the compactability of the mix. Other points on the compaction curve obtained from the Superpave compacter can be used for the same purpose. In some mix design methods the mixture is stored for a period before preparing compacted specimens. Some attempts have been made to develop an accelerated laboratory curing regime for uncompacted mixes, designed to simulate long term stockpile life. For example in a method developed by Koch Materials for RAP mixes, 24 hours at 60°C in a covered pan is used to represent 14-75 days stockpile, and 72 hours at 60°C for an extended stockpile life of up to 18 months (19). The compactability of the stored materials is then determined using the density achieved in the Gyratory compactor (after 40 gyrations) as a measure.

3.3 Cohesion Tests

Once compacted, cold mixes may take time to develop sufficient cohesion to allow trafficking without ravelling. In the original Hveem design method (1) a Hveem cohesiometer was used to determine the early cohesion of cold mixed materials after 24 hours curing at 25°C. In microsurfacing cohesion is addressed by the cohesion tester, but although this method has been adapted for use in cold mix (20), it is not used in the Americas. But another test from the slurry surfacing area has been adapted by Koch Materials as a cohesion test for cold mix (21). The test involves abrasion of partly (4 hours) cured, compacted cold mix specimens (150mm) with the Wet Track Abrasion Tester used in slurry testing. The test is run dry for 15 minutes and simulates raveling, which could occur from too early trafficking. According to the author a properly cured mix ready for traffic should exhibit less than 2% abrasion loss in the test.

3.4 Structural tests

In principle the same structural tests designed for hot mix can be used for cold mix. As alternative methods have been developed for hot mix materials these have been applied to cold mixes, both laboratory specimens and cores from the field. For example, the Nottingham Asphalt tester has been used in Canada (22), the Asphalt Pavement Analyser (rutting equipment) has been used (15, 19, 21) as well as the Indirect tensile Test (21).

There is no consensus on the curing regime for cold mixed specimens in the laboratory, which could simulate curing of compacted mix in the field. Most workers aim for complete cure (water loss) before structural testing.

4. Current Initiatives

There does not exist today an accepted cold mix design method in ASTM or AASHTO methods, although there are some specifications for the mix properties for example in the Standard Specifications of the FHWA (23).

It has been recognized that the lack of a widely accepted design method and specifications, does impede the progress of emulsion mixes. And there are some initiatives to develop modern methods. The technical committee of AEMA has developed a draft cold mix method that follows closely the approach of traditional methods except that gyratory compaction is used for the preparation of samples for the determination of optimum fluids for compaction, and for structural testing. There is still an issue regarding the appropriate number of gyrations, (the draft specifies 50). Some limited validation has been carried out but further real-life experience of the method is needed

The FPP (Foundation for Pavement Preservation) recently defined future research objectives using input from FHWA, AASHTO, FPP and academia (24). One of the problem statements is listed as " Mix Design Procedures, Engineering Properties and Performance Characteristics of Emulsion Mixes, with and without RAP."

The D04.27 sub-committee of ASTM has established a second task group to look at a cold mix design method for cold in place recycling and is also looking at a standard practice for the preparation of specimens from dense graded emulsified asphalt cold mixtures.

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