

Progress in Cold Mix Processes in Canada

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ABSTRACT

The concept of cold mix processes has been around for many decades and many different forms have come and gone as the cold technology evolved. In recent years the cold mix technology has made significant improvements in quality and performance. These improvements especially in the chemicals utilized in the production of the asphalt emulsions have allowed for more innovative uses of the cold mix technology. The use of cold mix processes has expanded the toolbox available to agencies to solve their problems. The tightening of highway budgets has altered the way agencies handle construction and rehabilitation. For instance the cold in place recycling technology has become a standard rehabilitation process used by highway departments and county agencies across the country.

The use of cold processes can help in filling a void in reconstruction/rehabilitation. Cold processes can help to lower the greenhouse gases in the atmosphere as they use less energy, as well as cut down on the use of non renewable resources such as aggregates and oil based products. Cold mix processes can help to meet the requirements of the Kyoto Accord and still provide a technologically sound solution to highway agency problems.

This paper presents an overview of the various cold mix processes being utilized across the country and state to which these processes have been elevated as cold technology has expanded and improved.

RÉSUMÉ

Le concept des procédés d'enrobés à froid existe depuis plusieurs décennies et plusieurs formes différentes sont apparues et disparues avec l'évolution de la technique. Au cours des dernières années la technique des enrobés à froid a fait des progrès importants en qualité et en performance. Ces progrès spécialement dans les produits chimiques utilisés dans la production des émulsions de bitume ont permis des utilisations plus innovantes de la technique des enrobés à froid. L'emploi des procédés d'enrobés à froid a agrandi la boîte d'outils des agences pour résoudre leurs problèmes. Le resserrement des budgets routiers a modifié la façon dont les agences traitent la construction et la réhabilitation. Par exemple la technique du recyclage en place à froid est devenue un procédé standard de réhabilitation utilisé par les ministères de voirie et les agences de comté à travers le pays.

L'emploi des procédés à froid peut aider à combler un vide dans la reconstruction ou la réhabilitation. Les procédés à froid peuvent aider à diminuer l'effet de serre des gaz dans l'atmosphère car ils utilisent moins d'énergie, aussi bien qu'à diminuer l'utilisation des ressources non renouvelables telles que les granulats et les produits pétroliers. Les procédés d'enrobés à froid peuvent aider à rencontrer les exigences de l'accord de Kyoto et fournir encore une solution technique valable aux problèmes des agences routières.

Cet article présente une vue générale des divers procédés d'enrobés à froid utilisés à travers le pays et le niveau atteint par ces procédés à mesure que la technique s'est étendue et améliorée.

1.0 BACKGROUND

Cold mix is the generic term for many different bituminous processes which utilizes asphalt emulsions and a mixing plant, which does not have an aggregate dryer.

The majority of the different types of cold mix processes have been used since the sixties with varying degrees of success. The current practice of Cold In-place Recycling (CIR) of bituminous pavements dates from the late 1970's [1] with the State of California being the first road agency to utilize this process. Since then CIR technology has become a standard rehabilitation process used by highway departments, county agencies and municipalities across the country, and throughout North America.

During the early 1970's many counties and townships used Open Graded Emulsion Mixes (OGEM) and Dense Graded Emulsion Mixes (DGEM) on their low volume road network [2]. These roads were then typically covered with a surface treatment of some kind usually a chip seal or dense graded high float type surface. In the 1960's and 70's a number of agencies used cutback asphalt cement as the binder in dense graded mixes and utilized a single bin pugmill to mix the material. The finished mix was then placed using graders or hot mix spreaders. As the use of cationic asphalt emulsions increased the trend in the industry shifted to their use over the old traditional anionic emulsions and cutback asphalts.

Cationic emulsions allowed for faster setting times and less susceptibility to weather conditions due to their chemical break. In the late 1970's the usage of Reclaimed Asphalt Pavement (RAP) started to become very popular in the hot mix industry. The usage of RAP was confined to base type mixes and not allowed in surface courses. This caused an issue in that stockpiles of RAP started to grow throughout the country. In order to utilize this valuable resource the emulsion industry started to develop products to allow the usage of RAP in cold mix processes. Mix processes were developed which used 100 percent RAP, as well as blends of RAP and virgin aggregate using asphalt emulsions. The development of rejuvenation-type emulsions opened up an area of recycling which did not exist before. These emulsions were also utilized in the hot mix industry on roads and airports which had been heater scarified. As the technology progressed cold mix processes evolved through the usage of combinations of emulsions such as, rejuvenators being blended with conventional asphalt emulsions.

The suppliers of the asphalt emulsifiers used in the industry to produce the asphalt emulsions have become more aware of the technological advances in cold mixes. These suppliers work with the industry to develop specialty chemicals, which give added benefits to the cold mix processes. These new chemicals have raised the bar in the usage of cold mix processes.

The following sections of the paper present an overview of the various cold mix processes being utilized across the country and the state to which these processes have been elevated as cold technology has expanded and improved.

2.0 COLD IN-PLACE RECYCLING

The CIR process started in Canada in the late 1980's and has grown steadily since. The Regional Municipality of Ottawa-Carleton (now known as the City of Ottawa) was the first agency to utilize the process as a rehabilitation tool. The process fits very nicely in the rehabilitation alternatives as shown in Figure 1.

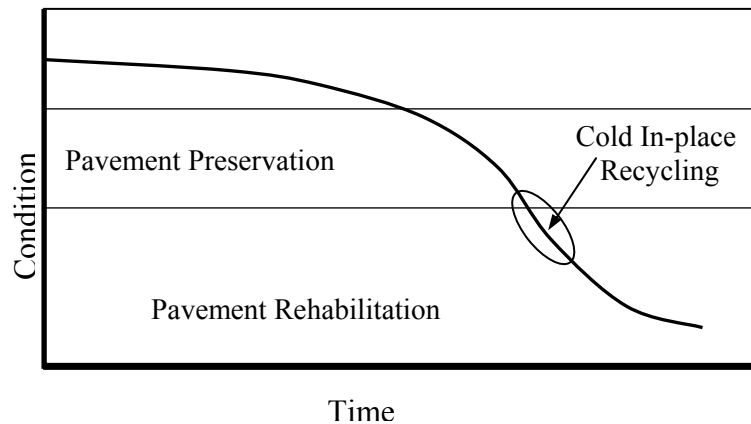


Figure 1. Rehabilitation Alternatives

The CIR process involves producing a new base cold mix through the in-place recycling of the existing bituminous material. The depth of recycling typically ranges between 70 and 125 mm. The process uses the following steps: reclamation/sizing of the bituminous aggregate; addition of new aggregate (if required); introduction of the new binder and mixing; lay-down and compaction of the new mixture; curing of the mixture; and finally, placement of the wearing surface. The CIR process can be done using a variety of recycling trains from a single unit to a multiple unit type as shown in Figure 2.



2a. Multi Unit Train



2b. Single Unit Train



2c. Urban Train – 2 Piece

Figure 2. Types of Processing Trains used in Cold in-Place Recycling

The original CIR process, in the southwest United States (US), used the polymer high float type emulsion as the binder. The quantity used in the mix ranged from 1 to 2 percent. In the US Pacific Northwest cationic emulsions were used as well as the high float type. When the process was first brought to Canada in the late 1980's the emulsion of choice was the polymer modified high float. With time the regular high float version was used and both are still used today. The CIR process is used on a fairly regular basis in almost every province in Canada. The interesting point to be made is that each province uses different choices for the binder. British Columbia uses a rejuvenator or blends (discussed later in the paper in Section 6), Ontario uses high floats as well as cationic emulsions, Quebec uses cationic emulsions, and the Maritimes use high float and cationic emulsions.

As more knowledge was obtained about the process different emulsions were tried. In Quebec the emulsion of choice is CSS-1P with the use of Portland cement as an additive for quick strength and

stripping resistance. In the province of Nova Scotia the use of CSS-1 emulsion is the norm. Table 1 shows a list of the emulsions used with the CIR process.

Table 1. Emulsion Types used in the Cold In-place Recycling (CIR) Process across Canada

| Province | Emulsion Type |
|------------------|---|
| British Columbia | Rejuvenators/Rejuvenator-Emulsion Blends |
| Ontario | High Float, CSS-1h, CSS-1, Specialty Type |
| Quebec | CSS-1P |
| New Brunswick | High Float, CSS-1 |
| Nova Scotia | High Float, CSS-1 |

Note: CSS-1= Cationic Slow Set, CSS-1h = Cationic Slow Set (harder base),
CSS-1P = Polymer Modified Cationic Slow Set

CIR provides many advantages in pavement rehabilitation such as [3]:

- Conserves energy.
- Conserves pavement material.
- Preserves the environment.
- Provides life cycle cost savings as well as initial cost savings.
- Controls and mitigates reflective cracking.

The CIR process has made great strides as a rehabilitation tool and further research is ongoing to improve the process even more. The use of performance criteria on the mix itself will go along way to improve the process and the research is focusing on this aspect.

3.0 VIRGIN COLD MIX

The use of virgin cold mix has been around for many years. The binders used in the early days were mainly cutback asphalts like MC1 and 2, which were the fore runners to MC 70 and 250. The first paved roads in the province of Saskatchewan (early 1930's) were road mulch made by blade mixing gravel with cutback asphalts. The cold mix process has come along way since those early days. Blade mixing of gravels using an anionic emulsion (SS-1) was the normal procedure in the forties and fifties. The development of the pugmill improved the overall performance of cold mixes. The concept of using only coarse aggregate in the mix, Open Graded Emulsion Mix (OGEM), with emulsion started in the late sixties and early seventies in the US Pacific northwest [4, 5]. The development of the Midland Mix-Paver in the early seventies revolutionized the OGEM market.

The following two sections give a description of the two cold processes; Open Graded Emulsion Mix and Dense Graded Emulsion Mix.

3.1 Open Graded Emulsion Cold Mix

The definition of an Open Graded Emulsion Mix (OGEM) is a gap graded mix with an air void content of greater than 15 percent. Typically the coarse aggregate used is a 16 mm stone that is used in the hot mix industry. The material passing the 75 micron sieve is less than 2 percent.

The early mixes were produced in a simple pugmill, transported to the job site, placed, and compacted using conventional asphalt hot mix equipment. The open graded mat was then covered with a choke aggregate (typically sand or screenings) to protect the surface from tire pick up. The finished OGEM after curing was then covered with a chip seal or sand seal as the final riding surface. A number of the OGEM were left uncovered and performed very well.



3a. Mixing in Pugmill



3b. Placement



3c. Addition of Choke

Figure 3. Early Open Graded Emulsion Mix Process

The OGEM material is used on township and county roads to upgrade the riding surface from either gravel or surface treatment. The pavement lifts are typically 50 to 60 mm thick after compaction. The most common method of placement is with the Midland Mix-Paver. Over the years the paver has evolved and become more accurate and places a smoother and more uniform mat. The use of OGEM has decreased in the last few years due to budget restraints and the lack of aggressive marketing, as well as more competitive pricing from the hot mix industry.



4a. OGEM Placement



4b. OGEM Close-up

Figure 4. Placement of Open Graded Emulsion Mix (OGEM) using Midland Mix-Paver

A few of the benefits of the open graded process are as follows:

- 1.0 Resistance to cracking. Experience has shown that these mixes are highly resistant to cracking and generally knit back together.
- 2.0 Reduced pollution. Dust pollution at the mixing plant is minimized and air pollution associated

with the drying of aggregates is eliminated.

- 3.0 Reduced asphalt oxidation. The aggregate and the emulsion are mixed cold. Therefore, the oxidation of the asphalt in the mixing process is eliminated. The thick asphalt films developed in the process also retard the oxidation process.
- 4.0 Safety. Skid resistance is increased and the hydroplaning aspect is reduced due to the rough surface texture.

3.2 Dense Graded Cold Mix

The definition of a Dense Graded Emulsion Mix (DGEM) is a graded mix with an air void content of less than 10 percent. The mix typically has 40 to 50 percent coarse aggregate and between 5 and 10 percent material passing the 75 micron sieve.

The usage of DGEM goes back many years. The original mixes used cutback asphalt as the binder. As asphalt emulsions came on the scene the DGEM used slow setting anionic emulsions (SS-1). The original mixes were windrowed and blade mixed. As the industry changed with new processing equipment and the emulsion industry evolved the DGEM mixes became more sophisticated. The arrival of the pugmill increased the usage of DGEM and it became a well recognized process. Through the late seventies and early eighties the process was used quite extensively on township and county roads to provide some structural strength to the road network. In most cases the cold mix was covered with a surface treatment of some sort such as chip seal, sand seal, or hot mix in order to protect the surface.

The process disappeared for about twenty years and only in the last six or seven years has it made a return. Originally the DGEM was made with crusher run type aggregate and SS-1 emulsion. Later the asphalt emulsion switched to cationic and the mixes were made with medium setting (CMS) and slow setting (CSS) type emulsions. The process used single bin pugmills for mixing and placement using conventional hot mix spreaders. The Midland Mix-Paver was also used to some extent but there were more problems using that equipment. At times, fat spots occurred in the mat and it was difficult to remove and replace. With the pugmill operation, if fat mixes occurred, the load could be disposed of prior to placement.

Currently the DGEM process is used in a number of provinces: Ontario; Manitoba; British Columbia; and Alberta. In Ontario (Figure 5) the process has been used successfully to upgrade county roads [6]. The material was mixed in multiple bin pugmills and then placed using conventional hot mix pavers. The mix design developed in the laboratory separated the mix into coarse and fine aggregates. The use of more than one aggregate bin gives the finished mixes a more uniform finish and more consistent results in the field. The use of the proper emulsion is critical to the overall performance. In some instances a specially manufactured emulsion is needed in order to give the proper properties needed. In most cases off the shelf emulsion can satisfy the requirements.

**5a. Aggregate Feed for DGEM****5b. Pugmill Mixing of DGEM****5c. Placement of DGEM****5d. Breakdown Rolling of DGEM****5e. Intermediate Rolling of DGEM****5f. Finished DGEM****Figure 5. Dense Graded Emulsion Mix (DGEM) Process in Ontario**

In Manitoba, the highway department utilizes their small portable drum plants to make dense graded cold mix. In the past the department used SC 3000 cutback asphalt to make their cold mix, but with the new regulations on Volatile Organic Compound (VOC) emissions a switch was made to a special emulsion

called HF500LD. The material produced in a warm (100°C) condition can be paver laid, grader laid, or stockpiled for future use. This particular process has been in place for four to five years and has steadily improved with time. The aggregate used is from various sources around the province and the highway department moves their three drum plants from aggregate source to aggregate source as needed. The DGEM is used as a levelling course to improve the road profile or as the finished riding surface (Figure 6).



6a. Drum Plant and Stockpile 6b. Finished Paver Laid Mat 6c. Finished Grader Laid Mat

Figure 6. Dense Graded Emulsion Mix Process in Manitoba

With the new emulsion technology the asphalt emulsion can be formulated to provide better end result properties and also could allow the use of aggregate sources that could lower costs, which in the past could not be used. The technology can now allow for quicker setup and strength gain, as well as allow earlier application of the finished riding surface.

4.0 RAP COLD MIX

The use of RAP in cold mix has been around since the development of the grinding process and hot mix recycling. Highway agencies throughout the country have stockpiles of RAP. There is a cost associated with these piles and the use of RAP cold mix can greatly reduce these piles. During the seventies RAP cold mix paving was done in a number of jurisdictions. The material has been produced using cutback asphalts, but is now strictly an asphalt emulsion based product. The RAP mix has been placed using various asphalt emulsion products such as High Floats, SS-1, CSS-1, and CMS-2. The quantity added to the mix is determined through laboratory design and typically varies between 1 and 2 percent depending on the properties of the RAP material being used. The properties of the RAP that are important are the asphalt content, the recovered penetration of the asphalt cement, the gradation of the RAP itself, as well as the aggregate extracted from the RAP (Figure 7).

**7a. RAP Mix Placement****7b. Finished Mat – RAP Cold Mix****Figure 7. RAP Cold Mix in Nova Scotia**

Based on the RAP properties an asphalt emulsion can be developed to work with the RAP. If, for example, the RAP penetration is high (say > 50 dmm) and the asphalt content is normal then an emulsion, which has harder base asphalt cement, may have to be used to ensure the finished mixture does not experience rutting or pushing in the pavement structure. As mentioned earlier, emulsion chemistry has made great strides in the development of tailor-made emulsion products to be used with the various processes. The current trend in RAP cold mix is using a rejuvenator in combination with an asphalt emulsion and this will be discussed later in Section 6.

In the last few years the RAP cold mix, as well as the other processes discussed in this paper have evolved with the use of more engineering of the asphalt emulsions and more detailed design procedures. The design of the cold mix processes in general will be discussed in Section 7 of this paper.

5.0 RAP/VIRGIN COLD MIX

A logical step in the development of RAP cold mix was to add virgin aggregate to the mix to enhance the overall properties of the mix, if needed (Figure 8). The addition of virgin aggregate could be required to improve the gradation, to improve the physical properties of the final mix (because the RAP was deficient in some way), or to increase the thickness or width of the road platform.

The minimum requirement needed to mix the material is a two bin pugmill, a bin for the RAP and a bin for the virgin aggregate. A water source is also required to give extra liquid to the mix for compaction purposes. The RAP material is typically screened through a 25 mm screen to remove any large pieces, which could interfere with the texture of the finished mat surface.

**8a. Cold Mix Plant****8b. Cold Mix Stockpile****8c. Placement of Cold Mix****8d. Finished Recycled Cold Mix****Figure 8. RAP/Virgin Cold Mix Process in Ontario**

The amount of asphalt emulsion needed would depend on the quantity of virgin aggregate being added to the RAP. In most cases the quantity is less than 25 percent of the total mix [7]. There are cases where the virgin aggregate quantity could reach 50 percent. The mix design procedure is the same no matter what the RAP to virgin aggregate ratio.

The RAP and the new aggregate have to be monitored closely so that the finished cold mix will have a uniform texture and finish. The type of asphalt emulsion used is a cationic, which is specially formulated for each project. The design procedure used is similar to the procedure used for the other cold mix processes except the OGEM product.

6.0 REJUVENATION

The concept of asphalt rejuvenation has been around for many years and has become a more important issue after the development of the hot mix recycling industry. The use of recycling agents and softer grades of asphalt cement as the rejuvenators were investigated [8]. In the area of cold mixes and

especially the cold mixes containing RAP, the idea of using rejuvenators as part of the new binder in the mix has been investigated and used successfully.

Asphalt cement is made up of two fractions; asphaltenes and maltenes. The asphaltenes are the solid component and the maltenes are the oily component of the asphalt cement (Figure 9). The maltenes fraction is comprised of four ingredients: Nitrogen Bases (N); First Acidifins (A_1); Second Acidifins (A_2); and Paraffins (Saturated Hydrocarbons). Each asphalt cement has its own unique maltenes to asphaltenes ratio and as the asphalt cement ages this ratio decreases. As the asphalt cement ages the maltenes gradually turn into low-end asphaltenes and the asphalt cement hardens. A rejuvenator emulsion is comprised of water, emulsifier, and the maltenes oils. In the rejuvenation process, a rejuvenator returns the maltenes to asphaltenes ratio back into balance and restores the asphalt cement to its original state (or as close to it as possible). In cold mixes there are two ways to use the rejuvenator products; the use of a straight rejuvenator in the mix, or a blend of a rejuvenator and an asphalt emulsion. The following two sub sections describe these processes.

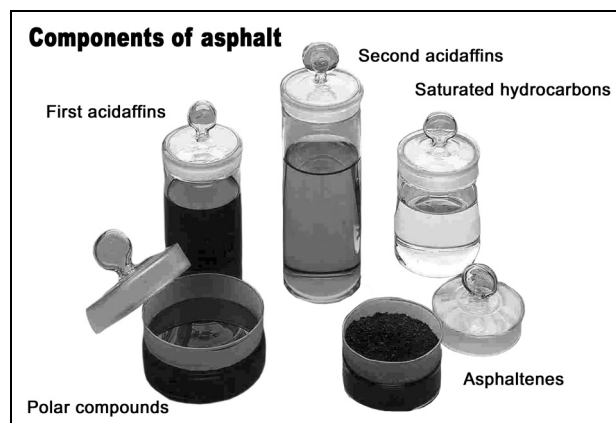


Figure 9. Asphalt Cement Components

6.1 Rejuvenator Mixes

The use of straight rejuvenation is done extensively in British Columbia. The rejuvenator cold mix process is typically done using 100 percent RAP material. The process is being evaluated in other areas of the country but currently British Columbia is the only jurisdiction using this process. The use of the rejuvenator in a RAP/virgin cold process is being evaluated but has not been field tested yet. The British Columbia rejuvenator process is to remove the top layer of asphalt pavement and then CIR the next layer using a rejuvenator. The standard CIR process is used and 35 litres of rejuvenator emulsion is added to each tonne of RAP. The grindings that were removed are pugmill mixed with same rejuvenator as the CIR process then placed and compacted on secondary or county roads.

**10a. Grinding/Crushing Operation****10b. Mixing and Windrowing****10c. Pickup and Placement****10d. Compaction and Finished Mat****Figure 10. Rejuvenator Cold Mix in British Columbia**

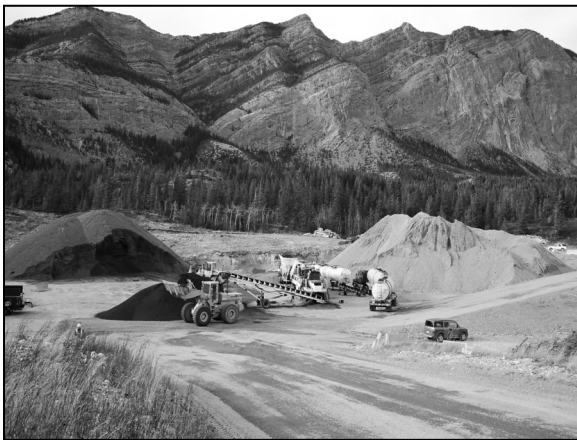
After the CIR has cured the material is covered with hot mix to provide a finished riding surface. This process has been used for a number of years and is working very successfully. Currently, they are evaluating the use of a rejuvenator/emulsion as the new binder. The trials have been placed and are being monitored.

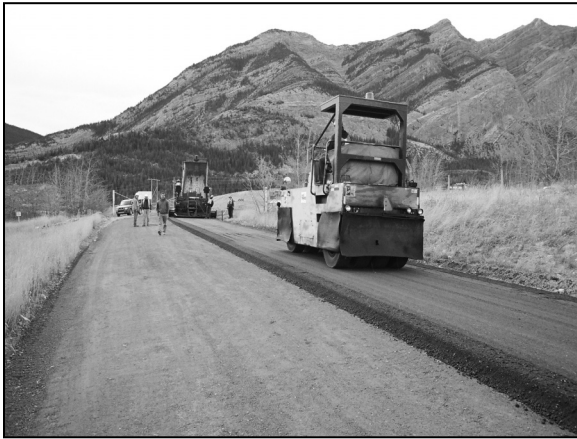
6.2 Rejuvenator/Emulsion Mixes

The use of a rejuvenator/emulsion cold mixes in Canada started in the late seventies to early eighties in Ontario. The City of Toronto used the process on the rehabilitation of a number of major roads in the city. Bayview Avenue, Don Mills Road, and Bloor Street were three of a number of streets, which were rejuvenated. The existing hot mix was removed by grinding, hauled away, screened to 37 millimetre minus, and returned and placed through the Midland Mix-Paver (Figure 11).

**11a. Placement of Rejuvenated Cold Mix****11b. Compaction of Rejuvenated Cold Mix****Figure 11. Rejuvenator/Emulsion Cold Mix in Toronto (Don Mills Road)**

Over the next twenty-five years very little work was done using this process. In the last few years the process has been resurrected in British Columbia and Alberta. As mentioned in the earlier section, the combination process has been used and is being monitored in British Columbia. In Alberta the process is being used to help get the large stockpiles of RAP decreased. In order to develop a cold mix product RAP is obtained from the stockpile and analysed in the laboratory to establish what the ratio of rejuvenator to asphalt cement should be in the finished emulsion. Once this ratio is established the project can proceed.

**12a. Pugmill Operation****12b. Stockpiling Finished Cold Mix**

**12c. Placement and Compaction****12d. Finished Mat****Figure 12. Rejuvenator/Emulsion Cold Mix in Alberta (Exshaw)**

7.0 DESIGN PARAMETERS

The design of cold mixes has evolved over the years from just adding the oil, mixing it, laying it, and compacting it to the point where the designs have become as detailed as the Superpave™ (Superpave) hot mix. The main areas of design that are very important to the success of the job are the emulsion-aggregate interaction, the role of the water, the air voids and density, aggregate coating, mix compaction, and curing.

7.1 Emulsion-Aggregate Interaction

The compatibility of the aggregate with the emulsion will have a large bearing on the overall long-term durability of the cold mix. Obviously if the two materials are not compatible stripping will occur and in some instances no strength will be developed. Between the aggregate and the emulsion there is a physio-chemical interaction. The chemical interaction is dependent upon the compatibility of the aggregate with the asphalt emulsion. In the cold mixes where virgin aggregate is used the chemical attraction between the emulsion and the virgin aggregate must be evaluated very closely. Depending on whether the aggregate is calcareous or siliceous, the appropriate chemical charge of the asphalt emulsion will be selected to ensure coating of the aggregate.

The physical interaction is related to the gradation of the aggregate surface area. The fine portion of the aggregate, especially the dust portion, affects the surface. The more dust in the material, the larger the surface area. With a larger surface area the chemistry of the asphalt emulsion has to be adjusted for proper coating. Each cold mix can be an individual case due to this physio-chemical interaction and therefore, require a special emulsion to be formulated.

7.2 Role of Water

The role of the water is critical to the cold mix. It is very important in the early life of the cold mix but subsequently, it is a detriment after the placement and compaction of the cold mix.

Water is present in the asphalt emulsion but this is not enough to give the optimum fluid level for the mix. Extra water has to be added during the mixing process to give optimum results. The water plays a large role in getting the asphalt emulsion binder to uniformly coat the aggregate and/or RAP particles. The water also plays a role in lubricating the mixture to make it easier to compact. During the early stages of the mix design the total fluids content has to be established prior to final design.

Once the mix has been produced, placed, and compacted the water becomes the enemy. The presence of the water delays the build-up of cohesion and strength in the cold mix. The removal of the water is essential to ensure the success of the cold mix. Water increases the fragile nature of the mix and can cause problems in the field under traffic conditions. Typically with mixes containing RAP the total fluid content is in the 4.5 to 5 percent range and for virgin mixes a total fluids content of approximately 8 percent is desirable.

7.3 Air Voids and Density

When you compare the air voids in cold mix to the voids in hot mix there is a large difference. The voids in a cold mix design (except for the OGEM) are typically between 10 and 12 percent compared to the 3 to 5 percent in hot mix. The OGEM are normally greater than 20 percent due to the aggregate makeup. If the voids in cold mix were at the same level as hot mix, the cold mix would flush and bleed with rutting likely to occur.

The individual air voids tend to be smaller in cold mix and are in the mastic of the material. The density of the mix increases as the mastic shrinks with time. The overall curing is a long-term process and can vary from mix type to mix type. Figure 13 shows the effects that an increase in density has upon the properties of the mix in relation to water and air voids.

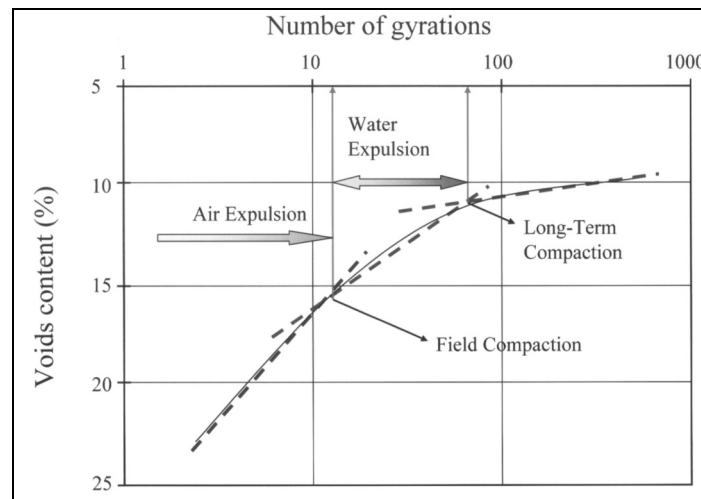


Figure 13. Effect of Density Increase on Cold Mix Properties

7.4 Coating

The coating of cold mixes can vary without a detrimental effect on the service life performance. Depending on the type of asphalt emulsion being utilized the coating varies. If slow setting types are used

such as CSS-1 the mix generally is 100 percent coated whereas if a medium set high float is used on a RAP mix there is selective coating of the finer particles. A binder rich mastic is developed which holds the cold mix together. The binder rich mastic also contributes to longer service life because of the thick binder film, which slows the age hardening of the binder.

7.5 Compaction

The compaction of the cold mixes can be accomplished using only static steel rollers as in the case of OGEM or both vibratory steel and pneumatic tire rollers in the case of DGEM (both virgin and RAP/virgin mixes). As shown in Figure 13, there are essentially three phases to the compaction process. In the first phase, the rollers are lowering the air voids as they compact. In the second phase, the mix is curing and under trafficking the excess water is being pumped out and the density is further increasing. The last phase, is the long-term compaction and this increases the density at a much slower rate whether it is the riding surface or under some sort of surface treatment.

7.6 Curing

The curing of the cold mix can take a long period of time. The curing process can be divided into two phases; early age and long-term. The early age curing usually takes about seven to twelve days and this is when most of the water is removed from the mix. At this point the cold mix can be covered with a surface treatment if the mix is to be covered.

The long-term curing can take anywhere from six months to a year to fully cure. This long-term curing can be a shorter period if the cold mix is the finished surface course. The curing period also varies due to the type of emulsion that is used. If the emulsion contains some cutter stock the curing could take longer than an emulsion that does not contain any solvent. Also some of the newer emulsifier chemical technology allows for faster curing rates and this will be discussed in Section 9.

8.0 PERFORMANCE

The performance of cold mix over the years has been variable. The more recent processes are performing very well. The OGEM mixes are excellent for rut resistance, skid resistance, and the ability to self heal in areas of high deflection and subgrade movement. The rut resistance is due to the stone-on-stone contact which does not allow for any deformation to occur. The ability to self heal is based on the emulsion properties and the thick films of binder on the stone.

The CIR mixes have proven to be very effective in the reduction of reflective cracking in the hot mix overlays [9]. The service life of the roads, which have been cold in-place recycled have increased dramatically. The mixes have good fatigue resistance due to the binder rich mastic that is formed. The CIR mixes have allowed the pavement width to be expanded with limited disruption to the traveling public and improved safety.

The DGEM type cold mixes have good fatigue resistance and can be designed to withstand high deflection and subgrade movements. The stiffness of the DGEM mixes increases as the density increases and can reach equivalent stiffness to hot mix after a curing period.

9.0 NEW TECHNOLOGIES

In the last few years there have been great strides in the technology of the emulsifiers being used to manufacture the asphalt emulsions and in the development of new production equipment to manufacture the cold mixes.

As shown in Figure 14, there are new cold mix plants being fabricated that have two or three bins for different aggregates or RAP. These provide a more uniform mix and tighter control. The emulsion system is highly computer controlled and the weigh bridge systems have been greatly improved. The plants are very easy and fast to set up and can be moved with little effort. The mixing units are becoming more sophisticated with better aggregate material coating processes.



Figure 14. New Generation of Cold Mix Plant

Figure 15 shows a new type of mixer that has the capability to separate the aggregate feed as well as the emulsion spray system to provide a more uniform mix.

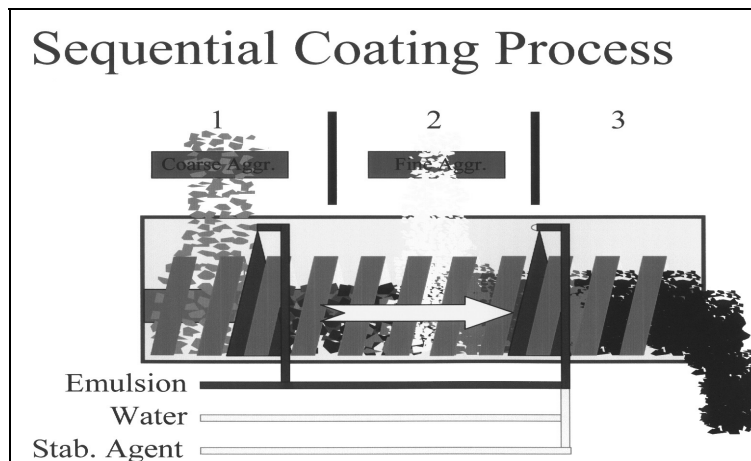


Figure 15. New Generation of Cold Mix Pug-mill Mixers

The manufacturers of emulsifiers have developed more specific type emulsifiers to improve the performance of cold mixes. These engineered emulsifiers have the capability to control the coating of the

mixture, control the break and set time of the mixture as well as provide adhesion and stripping resistance. There are also new additives, which can be incorporated into the mixtures through the asphalt emulsion or at the mixing stage, which will promote the expulsion of the water at the time of compaction.

10.0 BENEFITS

The benefits of using cold mix processes are now discussed.

First, the facilities used to manufacture these processes have high production. Plants are self-contained, extremely mobile, and can be set up rapidly. The mixes can be placed many different ways. A self-propelled traveling plant (such as the Midland Mix-Paver) can be used, or the mix can be placed using a grader. The use of conventional hot mix spreaders is very common. For many of the processes the compaction does not have to be done right away. The mixes are not temperature restricted, as they are already cold.

The various types of cold mixes can be manufactured using many different types of asphalt emulsions. The emulsion can be tailor-made for a specific material or situation. On occasion, over ten different products are used to make the cold mixes. Each job is unique and pre-engineering is required. The mixes can be used for a specific engineering property. The OGEM is an excellent mix to use where the subgrade is not in the best of condition. Because of its unique self-healing property and capability to withstand high deflections the OGEM is ideally suited.

The cold mix process is very energy efficient. The amount of energy to produce the mix is very low compared to the other road construction processes as Figure 16 shows. There are no concerns about smog days where hot mix production is not allowed. The Kyoto Accord requires that greenhouse gas emissions be reduced and the cold process is an excellent way to achieve that goal. There is very low or negligible “blue smoke” emission during manufacture of the cold mix. There is typically less fugitive dust present in the air because the aggregate does not have to be dried and the damp aggregate encapsulates all the dust particles.

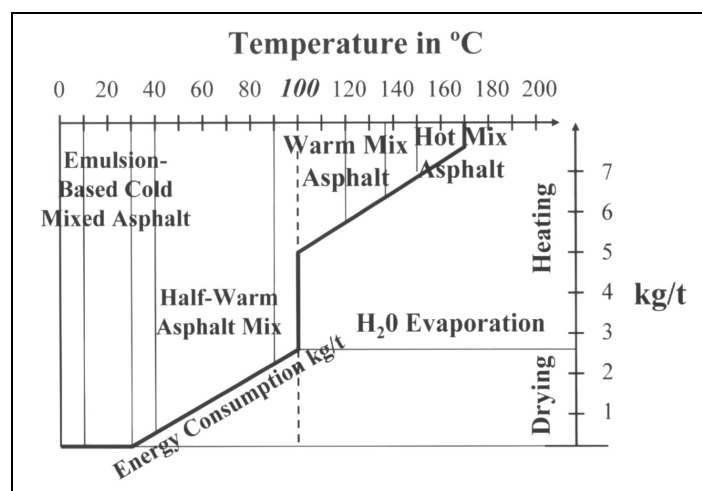


Figure 16. Energy Requirements for Various Road Construction Processes

Since the aggregate does not have to be heated there is reduced fossil fuel consumption during the manufacturing process. The use of RAP and RAP/virgin cold mixes conserves the dwindling aggregate resources, as well as the petroleum resources since the quantities of asphalt emulsion are reduced. These reductions will help to meet the new emission requirements as outlined in the Kyoto Accord.

11.0 CONCLUSIONS

Emulsion based cold mixes have come along way in the last few years. The mixes are made up for a variety of uses and provide a lot of options for road construction and maintenance. There are still a lot of areas of cold mix that have yet to be fully explored. Many companies are investigating the potentials of cold mix and innovation is the key.

The different cold mix processes have a place in the designer's tool box. With limited budgets being the norm the use of cold mix processes for certain applications can stretch the dollars. Depending on the process it can be used as base or as a surface course. As placement of cold mix is accomplished at ambient temperature, the need to keep hot mix at high temperatures does not apply. This means that a project has more flexibility and the construction deadlines can be more easily managed. This is especially true when using cold mix products that can be stockpiled.

The potential for using cold mix processes is growing as the emulsion technology expands. Researchers are investigating the short coming of the processes and great strides are being made to overcome these hurdles.

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