Design and Field Performance of Cold-Constructed Asphalt Pavements (CCAP) with Gelled Asphalts

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ABSTRACT

Cold Constructed Asphalt Pavement (CCAP) is a unique asphalt product consisting of open-graded aggregates combined with a gelled multi-grade asphalt binder. Gelled asphalt binder produces thick asphalt films on the aggregate creating an improved form of cold mix asphalt with no risk of emulsion draindown often associated with conventional open-graded cold mixes. CCAP can be produced in a wide range of ambient temperatures and stockpiled for months until it is ready for use. This paper provides background information on the properties and benefits of gelled asphalt binder. Furthermore, this paper provides details on the design of CCAP, including (1) specification information on gelled asphalt binders and (2) selection of angular, open-graded aggregates for high level of stability. Case studies discussing production and paving experience with CCAP are also included in this paper, as well as discussion of field performance at different locations across the United States and the province of Ontario.

RÉSUMÉ

La chaussée en enrobé à froid (CCAP) est un enrobé unique composé d'agrégats à grains ouverts et d'un liant bitumineux multigrade gélifié. Le liant bitumineux gélifié produit des couches épaisses de bitume sur le granulat, ce qui crée une forme améliorée d'asphalte mélangé à froid sans risque de formation d'émulsion, souvent associé aux mélanges à froid classiques à grains ouverts. Le CCAP peut être produit dans une large gamme de températures ambiantes et stocké pendant des mois jusqu'à ce qu'il soit prêt à être utilisé. Ce document fournit des informations générales sur les propriétés et les avantages du liant bitumineux gélifié. En outre, ce document fournit des détails sur la conception du CCAP, y compris (1) des informations de spécification sur les liants bitumineux gélifiés et (2) une sélection d'agrégats angulaires à grains ouverts pour un niveau de stabilité élevé. Le présent document comprend également des études de cas sur la production et l'expérience de la pose de revêtements avec CCAP, ainsi que des discussions sur les performances sur le terrain à différents endroits des États-Unis et de la province de l'Ontario.

1.0 INTRODUCTION

1.1 Advantages of Cold Mix Asphalt

Transportation officials are continuously faced with challenges to build and maintain roadways that meet the demand of the traveling public. In the infancy of developing road networks, agencies constructed roads to accommodate not only the volume of vehicle traffic, but also the increased weight of the traffic. Many times, low to medium volume roadways, especially farm to market roads in rural areas, can be very difficult to build and maintain because of budget and material availability. Over time, multiple road building materials and systems were developed to be utilized in various scenarios to provide agencies viable options based on the available budget, geography and expected loading experienced on the given roadway. One of the tools used by many agencies over the past half decade or more, especially in low to medium rural farm to market roadways, is Cold Mix Asphalt (CMA).

CMA is very similar to Hot Mix Asphalt (HMA) in the sense that the primary components are mineral aggregates and an asphalt binder. Unlike HMA, CMA is produced in conditions that the aggregates are not heated and dried. Aggregates are introduced to the asphalt binding agent in mobile plants or pugmills that thoroughly mix the two components. According to the Asphalt Institute [1], cold mix asphalts have multiple advantages including versatility, economics and reduced environmental impact. CMA is versatile in the sense that materials can be manufactured and placed at different times not relying on haul times from fixed stationary plant locations. CMA is an economical option since high production rates can be achieved with low investment in equipment and operational costs. CMA has a reduced environmental impact from lower energy consumption. Aggregates are not dried and heated during production resulting in lower energy demands and reduced carbon footprint.

The primary types of asphalt binders used historically in CMAs are asphalt emulsion or cutback asphalt. Asphalt emulsions are used in many different applications in road building including tack coats, prime coats, chip seals, and patch mixes. Asphalt emulsion is a dispersion of asphalt particles in water being held in suspension by an emulsifier. Suspending the asphalt in the water phase enables the asphalt to be pumped, sprayed, and mixed at much lower temperatures than straight asphalt cement binder. The other asphalt binder option in CMAs is cutback asphalt. The Asphalt Institute defines and describes cutback asphalt as asphalt cement that has been liquified by blending petroleum solvents or diluents. Upon exposure to atmospheric conditions the diluents evaporate, leaving the asphalt to perform its function [1].

There are many limitations and issues when utilizing both of these types of systems. Cutback asphalts are no longer being used by many agencies due to the release of volatile materials into the environment. Asphalt emulsions continue to be utilized and, in many cases, successfully in many cold mix applications including cold central plant recycling, dense graded and open graded cold mixes. Asphalt emulsions in cold mix also have some disadvantages, however, including weather restrictions, moisture conditions and application restrictions. Asphalt emulsions may have difficulty coating and adhering to aggregates when temperatures are below 10°C, limiting its use as a winter patching type material. Asphalt emulsions can also run off or get washed off cold mix stockpiles if heavy rainfalls occur during production. Emulsion run off could lead to contamination of surrounding production area.

In the late 1980's Wissel and Kriech developed an asphalt binder that combined the benefits of both cutback and high float emulsified asphalt [2]. The goal was to develop an asphalt that had the thick gel and coating capability like a high float emulsion without the water phase. Gelled multigrade asphalt binder is chemically modified so that the binder could be introduced to aggregates in a low temperature or cold application and not be prone to stripping or draindown.

1.2 Gelled Multigrade Asphalt

Asphalt is a visco-elastic type of material containing both a solid component and a viscous liquid component. Even at room temperature, asphalt binder can flow. Gelled multigrade asphalt maintains it shape and structure more than typical asphalt. The comparison is similar to types of superglue available on the market. Using a conventional superglue on a vertical face is challenging since the viscosity of the glue is low enough that the material will run. However, a gelled superglue can maintain its shape and hold on a vertical face.

Figure 1 is a comparison of gelled multigrade asphalt alongside a typical asphalt. Over time, the asphalt cement begins to flow out of the pen can while the gelled multigrade asphalt maintains its shape. The ability for the gelled asphalt to hold its shape is extremely beneficial for cold mix applications. This allows for thicker asphalt films to coat the aggregates without the risk of draindown in the stockpile and on the roadway during rainfall. The thicker films also help with enhanced coating and reduced aging of the asphalt binder.

Figure 1. Conventional Asphalt Binder (right) Compared to Gelled Multigrade Asphalt Over Time

Gelled multigrade asphalt is manufactured with a percentage of diluents depending on the applications. However, unlike conventional cutback asphalts, the high levels of diluents and volatile compounds are not released into the environment. Table 1 shows specifications for multiple grades of chemically modified gelled asphalt. CM-90 would be applicable for a spray application or low temperature mix production in a stationary HMA plant. CM-150 is typically used for structural grade cold mixes and CM 300 is typical for winter patch mixes.

Table 1. Recommended Material Specification for Gelled Chemically Modified Asphalt

Chemically Modified Gelled Asphalt	Specifications		
	CM-90	**CM-150**	**CM-300**
Apparent Viscosity Modified Koppers, ASTM D4957, 25°C, P	1500-20000	800-10000	300-5000
Tag Flash Point, ASTM D3143-98, °C	66 min	66 min	66 min
Water in Petroleum, ASTM D95-05, %, max	1.0	1.0	1.0
Distillate Test			
Cut-Back Distillation, ASTM D402-02, volume % total to 360°C			
volume % total to 437°F (225°C)	0-4	0-5	0-5
volume % total to 500°F (260°C)[1]	0-5	0-5	0-5
volume % total to 600°F (316°C)	10–65	30-75	40-85
Residue from Distillate to 360°C, % volume by difference, min	80 min	75 min	70 min
Residue			
Softening Point, ASTM D36-95, °F	170°F min	170°F min	170°F min
Float Test, 60°C, ASTM D139-95	1200 min	1200 min	1200 min
Penetration, 77°F, dmm, ASTM D 5-05a	90-225	100-275	200 +
Solubility in Trichloroethylene (TCE), ASTM D 2042-01, %.	99.0 min	99.0 min	99.0 min

Notes: ASTM is ASTM International. [1]Meets Recommended Guidelines Established by United States Environmental Protection Agency (US EPA) for non-Volatile Organic Compounds (VOCs) Material.

It is critical to point out that the CM gelled materials do not release more than 5 percent of the total material volume when distilled at 260°C. This shows that the CM gelled asphalts meet the recommended guidelines established by the EPA for non-VOC materials.

The high viscosity gelled asphalt works extremely well with high quality open graded aggregates to produce a flexible cold mix layer that has been used by many agencies over the past thirty years. The specific system of gelled CM binders and high quality open graded aggregates is called Cold Constructed Asphalt Pavement or CCAP.

2.0 COLD CONSTRUCTED ASPHALT PAVEMENT (CCAP)

2.1 Uses of CCAP

The open-graded aggregate structure designed specifically for CCAP provides strength to the pavement structure. The use of gelled CM asphalt cement provides a thick, durable asphalt film, which slows the progression of aging and thereby promotes increased pavement life. The primary uses for CCAP mixture include: (1) overlays on existing pavements, (2) newly constructed pavements, and (3) patching of existing pavements.

Often, a chip seal coat or slurry seal is placed on the CCAP, sometimes two to three months, or in other scenarios a year or two, after placement of the mixture. Regardless of the length of time afterwards, it is important to do the work under acceptable weather conditions to increase the opportunity for acceptable service life of the surface treatment. Adding a surface treatment to the CCAP greatly reduces the opportunity for water, air, and debris infiltration. This serves to increase the service life of the CCAP and reduce the opportunity for traffic to disturb the surface of the mix, especially under turning movements. The CCAP mix can also be overlaid with HMA. It is generally best to wait 1-2 years after the cold mix was placed to allow the mix to undergo curing prior to capping it with hot mix asphalt.

The following sections provide a brief overview of design requirements and further provides guidelines on production and placement of CCAP.

2.2 CCAP Material Criteria

CCAP mixture is produced by using 100 percent crushed aggregate(s) blended with a gelled CM-150 asphalt with requirements listed in Table 1.

Quality (or particle strength/hardness) of the aggregate source(s) is very important due to the open-graded aggregate structure used in this mixture. The Los Angeles abrasion test is often used as a measure of coarse aggregate strength, which could be conducted as per ASTM C131. Particle shape is also important as it influences particle strength and overall mix compactability. A maximum of 10 percent flat and elongated particles is recommended with a ratio of 5:1 (maximum to minimum dimension) as determined by ASTM D5821.

Table 2 provides recommended gradation and bitumen (AC) content limits for the corresponding Nominal Maximum Aggregate Size (NMAS). PCS in Table 2 refers to the Primary Control Sieve, which is considered to be the break between coarse particles that create voids and fine particles that fill them. With an open-graded aggregate structure, it is especially important to control the amount passing the PCS.

2.3 Geometric Design Options

Regarding both new construction and overlays, it is generally recommended that the mix edges be exposed so that water that gets into the CCAP can exit into the ditches along each side of the pavement structure (Figure 2). If CCAP lay down thickness exceeds 37 mm, it is recommended to use a shoulder stone to hold the material in place along the edges to prevent edge dropoff. In some cases, longitudinal under drains adjacent to each pavement edge are necessary to remove this water [3].

Table 2. Aggregate Gradation and Asphalt Content for Different Cold Constructed Asphalt Pavement (CCAP) Mixtures

Property		CCAP 37.5		CCAP 19		CCAP 12.5		CCAP 9.5	
Gradation	Sieve Size (mm)	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
	37.5	90.0	100						
	19.0	45.0	65.0	90.0	100				
	12.5			55.0	75.0	90.0	100		
	9.50	15.0	30.0	30.0	50.0	60.0	80.0	90.0	100
	6.25					30.0	50.0		
	4.75			5.00	20.0	15.0	35.0	25.0	45.0
	2.36	1.00	8.00			5.00	20.0	5.00	20.0
	1.18			1.00	8.00				
	0.600	0.50	4.00			1.00	8.00	1.00	8.00
	0.300								
	0.075	0.00	2.00	0.00	4.00	0.00	4.00	0.00	4.00
Asphalt Content (%)		3.00	4.00	3.50	4.50	4.50	5.50	5.00	6.00
Primary Control Sieve (PCS)		9.5 mm		4.75 mm		2.36 mm		2.36 mm	
Application(s)		Underlying lift for a newly constructed or rehabilitated pavement		Surface lift for a newly constructed or rehabilitated pavement		• Surface lift for a newly constructed or rehabilitated pavement • Patching		• Surface lift for a newly constructed or rehabilitated pavement with low traffic • Patching	
Minimum Lift Thickness		100 mm		50 mm		35 mm		25 mm	

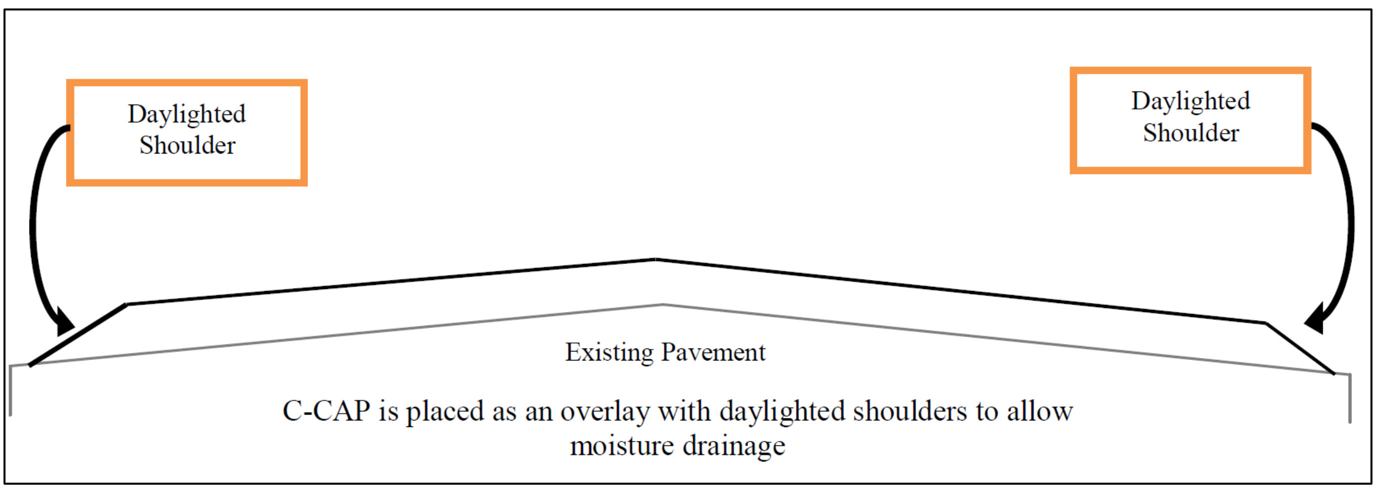


Figure 2. Cold Constructed Asphalt Pavement (CCAP) Overlay with Daylighted Shoulders

In cases where longitudinal edge drainage is not an option, the user should differentiate between pavements with a relatively flat grade (i.e. downhill slope) and pavements with a steep grade, which may include potential erosion issues that need to be addressed. When above ground and/or underground storm water drainage is not provided, the pavement should be placed with an inverted crown to prevent water from draining towards adjacent homes and business structures.

Water that gets into the CCAP pavement structure must be allowed to exit. Figure 3 shows an example of a typical pavement with a normal crown. In this case the edges of the open-graded cold mix are either left exposed to allow drainage into existing side ditches, or a trench is installed prior to placing the open-graded mixture. When a trench is used, it must be backfilled with a hard, angular aggregate that is open-graded. This trench may also include the use of a pipe underdrain. In either case, lateral drainage is required to allow the longitudinal trench to drain.

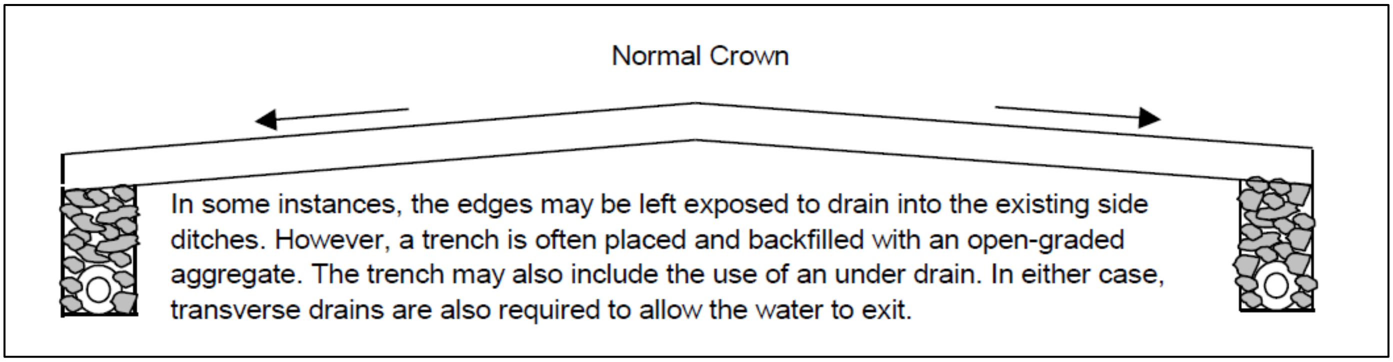


Figure 3. Cold Constructed Asphalt Pavement (CCAP) With Normal Crown and Longitudinal Drains

Figure 4 shows an example of a typical pavement with an inverted crown. Depending on the width of the pavement, the steepness of the grade and the length of the grade, a trench underneath the center of the pavement may be necessary to collect and control the flow of water that gets into the pavement structure. This trench must also be backfilled with a hard, angular aggregate that is open-graded. This trench may also require a pipe under drain. With or without the pipe, dimensions may need to be increased further down grade to accommodate the increased flow of water collected.

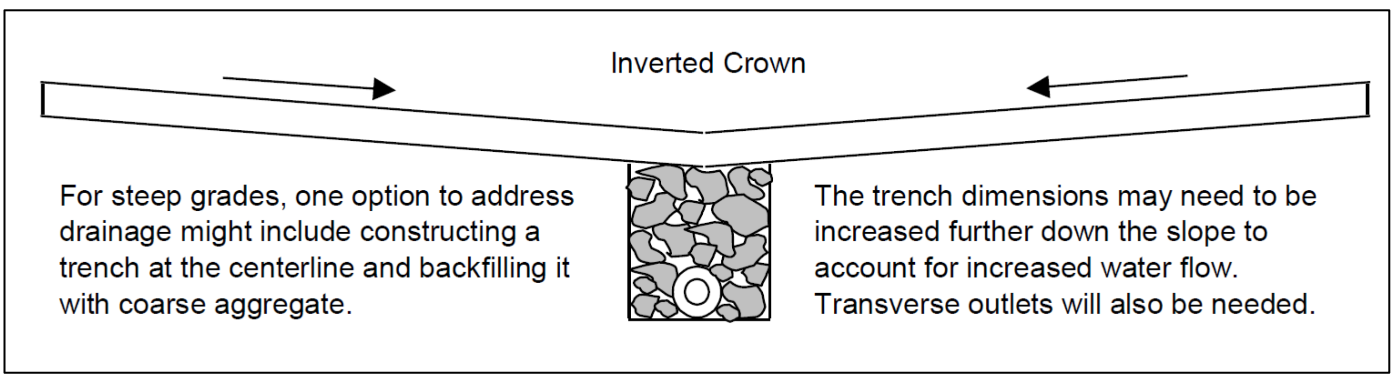


Figure 4. Cold Constructed Asphalt Pavement (CCAP) With an Inverted Crown

2.4 CCAP Production and Placement

The CCAP mixture can be produced with a conventional HMA plant (on low flame) or with a pugmill similar to that shown in Figure 5. In both options, the aggregate cold feeds and bitumen meter should be calibrated to ensure adequate control and accurate proportioning of the ingredient materials. If a HMA plant is used on "low flame" for mixture production, the average mix temperature should be approximately 60ºC and the maximum temperature should not exceed 80ºC.

During CCAP production, a minimum of two cold feeds is used for introducing the aggregate(s). If a single aggregate is being used, each cold feed should be set to the same gate opening and same belt speed. Each cold feed is then charged from a different location in the aggregate stockpile to minimize variability of the aggregate introduced into the mixture. If two different aggregates are being used to produce CCAP, the cold feeds should be set properly to ensure the combined blend gradation produced falls within the gradation bands required for the mixture.

Figure 5. Cold-Constructed Asphalt Pavement (CCAP) Production Using a Double-Bin Pugmill

If a pugmill is used with damp aggregate, the initial bitumen coating on the aggregate could be slightly less than 100 percent and therefore have a “salt and pepper” appearance as shown in Figure 6. This is normal and the bitumen content should generally not be increased, especially not beyond the maximum limit suggested for the corresponding mixture. Instead, the mixture stockpile can be reworked with a front-end loader as shown in Figure 7 to increase the uniformity of the bitumen coating. This, in addition to the mixture handling that occurs with loading the haul trucks and the handling through the mixture paver on the construction project, generally produces 100 percent bitumen coating on the aggregate.

Figure 6. Side by Side Comparison of Thoroughly Mixed Cold Constructed Asphalt Pavement (CCAP) Alongside Initial Coated CCAP

Figure 7. Manipulation of Cold Constructed Asphalt Pavement (CCAP) Stockpile to Increase Uniformity of the Bitumen Coating

CCAP mix can be placed on a prepared and properly compacted aggregate sub-base. The sub-base should be primed with diluted SS-1h (slow-set low viscosity) emulsion at a rate of 0.30 gal/yd^2. It is necessary to wet the sub-base to increase the penetration into the aggregate if the sub-base is too dry causing the emulsion to break on the surface. If the CCAP is to be placed on an existing bound pavement structure, any required patching should be completed prior to paving the CCAP. A single tack coat application should be applied by using a CSS-1h or SS-1h emulsion at a rate of 0.5-0.10 gal/yd^2.

CCAP mix is typically placed with a standard hot mix paver. Since this is an open-graded mixture, care must be taken during placement to prevent the paver screed from settling into the mat when the paver is stopped. Pavers are often equipped with lockouts on the hydraulics to “hold” the screed in place during stops. It is important to ensure the paver is equipped with this feature and that it is working properly. In general, good paving practices are just as important with CCAP mix, as with normal hot mix, including:

- Maintaining a uniform head of material in front of the screed, at the approximate mid-depth of the augers and across the entire width of the augers;
- Utilizing auger extensions whenever the screed is extended, so the auger ends are within 0.3 metres of the screed end;
- Paving at a consistent rate, to minimize paver stops and increase uniformity of material feed through the paver; and
- Maintaining the angle of attack on the screed, along with ensuring the grade and slope controls are working properly on the paver.

With a CCAP mix, it is important to not over-compact the mix. The primary intent is to seat the aggregate and not degrade it. Typically, two steel-wheeled rollers (breakdown and finish) are used for compaction during placement of the CCAP. At this time, all rollers should operate in the static mode. It is possible to use a pneumatic-tired roller, but only after the aggregate blotter (discussed below) has been placed. If a pneumatic-tired roller is used, the number of passes should be enough to remove the majority of longitudinal indentations left by the tires. Normally, each roller should make a minimum of two passes over each spot in the mat. The roller width and weight used should be as is normally done with hot mix asphalt. Occasionally, it may be necessary to add some liquid soap or detergent to the water used to wet the drums of the breakdown roller. This will help reduce the opportunity for CCAP mix to stick to the drums.

Aggregate blotting is necessary to: (1) stiffen the exposed surface of the CCAP mix and (2) to reduce water permeability at the exposed surface. This is generally done after the breakdown roller and in front of the finish roller by broadcasting the blotter aggregate. Compacting the aggregate blotter with the finish roller helps work the aggregate into the macro texture of the exposed surface and increase the opportunity for the aggregate to bond to the C-CAP and reduce loss due to traffic. For the 37.5 mm NMAS cold mix, a 9.5 mm NMAS should be used for blotting, at a spread rate of approximately 10-15 lbs/yd^2. For the 19.0 mm NMAS cold mix, a 50/50 blend of 5 – 10 mm aggregate and a 2.5 mm NMAS crushed sand should be used for blotting, at a spread rate of approximately 13-17 lbs/yd^2. For 12.5 and 9.5 mm NMAS cold mix, a 2.5 mm NMAS crushed fine aggregate should be used for blotting, at a spread rate of approximately 13-17 lbs/yd^2.

Figure 8 shows the application of a blotter aggregate on a CCAP pavement.

Figure 8. Blotter Aggregate Placed on the Cold Constructed Asphalt Pavement (CCAP) Surface

In most cases, the CCAP mix should receive two additional passes with a steel-wheeled roller the day after the cold mix was originally placed. At this time, it may be possible to apply one vibratory pass over each spot in the mat. However, caution must be exercised to prevent excessive aggregate breakage and/or mix displacement.

Traffic can be allowed on the mixture immediately after completing the finish compaction after the aggregate blotter placement. In no case should traffic be allowed on the cold mix prior to placement of the aggregate blotter. For projects where excessive turning movements are expected, such as residential streets, the pavement should be closed to traffic for 24 hours after mixture placement to allow additional stiffening of the mix. This will greatly reduce the opportunity for traffic turning movements to disturb the surface of the mix. In these cases, the application rate of the aggregate blotter should be slightly increased to ensure there is excess aggregate left on the mix surface. The additional (loose) aggregate will tend to move under the traffic tires as they turn, thereby reducing mix damage.

3.0 CASE STUDIES

3.1 Monroe County, Michigan

3.1.1 Specifications

The Monroe County Road Commission has long used CCAP as a pavement rehabilitation option since the early 1990s. Monroe is the Southeastern most county in the state of Michigan lying between Detroit and Toledo, Ohio. Climate in Monroe is typical for northern states in the upper Midwest United States with average temperatures around 30°C in the warmest summer month (July) and average low temperatures around -9°C in the winter. Annually, the county receives around 75 mm of snow per year. The predominate soil type in the county is heavy clay that is very susceptible to frost heave and climate fluctuation.

The county typically utilizes a blend of 75 percent Michigan DOT Classified 17A and 25 percent MDOT Classified 34CS. The gradation bands and expected CCAP gradation are shown in Table 3 from the Monroe County Road Commission Special Provision for CCAP [4]. For design and bidding purposes, the CCAP in Monroe is specified to contain 5.0 percent CM-150 binder with a tolerance of ±0.5 percent.

Table 2. Monroe County Road Commission Cold Constructed Asphalt Pavement (CCAP) Aggregate Specification

Sieve Size	Percent Passing Indicated Sieve		
	Material by Weight		
	75%	25%	100%
	MDOT 17A	MDOT 34CS	Blended Gradation
1-1/2”	–	–	–
1”	100	–	100
3/4”	90 – 100	–	90 – 100
1/2”	50 – 75	100	60 – 85
3/8”	–	90 – 100	20 – 30
#4	0 – 8	0 – 10	0 – 10
#8	–	0 – 5	0 – 5
#200	≤ 2.0	≤ 2.0	≤ 2.0
% Crushed	95	95	95

Three Monroe County case study projects are offered as examples displaying the long-term performance of CCAP: Dunbar Rd, South Huron River Rd and Sanford Rd.

3.1.2 Dunbar Rd, Monroe County

The original construction of Dunbar Road specified 7 to 9 inches of reinforced concrete pavement. Years later, a 2.5-foot HMA widening coupled with a 2.0-inch HMA overlay was performed to enhance the width and safety of the narrow concrete pavement. This method of widening typically results in a longitudinal construction joint crack reflecting up into the surface at the widening in later years. After the original overlay, another 2.5 inches of HMA was placed. The actual records on the timeline of treatments was not available. However, coring of the roadway prior to CCAP overlay confirmed the cross section. Figure 9 shows typical condition of the existing pavement prior to CCAP overlay. As expected with composite pavements, there were severe transverse cracks from the movement of the concrete panels reflecting up into the HMA surface layers. Pothole repair maintenance had been performed by MCRC forces on the pavement over time.

Figure 9. Existing Pavement Condition of Dunbar Road in 2012

In 2012, the MCRC placed 3.5 inches of CCAP on the existing pavement. MCRC also utilizes a blotter aggregate with a minimum 95 percent crushed content and 100-85 percent passing the number 4 sieve. A single chip seal was applied the following year in 2013. Three years later in 2016, overband crack filling was executed along with another single chip seal and a fog seal. As of 2019, no future maintenance is planned.

Figure 10 shows the pavement in 2019. Most of the crack pattern has not reflected through the more flexible CCAP overlay layer. The consecutive layers of chip seals and overband crack filling performed also have prevented many of these cracks reflecting through while providing a durable riding surface.

Figure 10. Dunbar Road After CCAP Overlay and PM Treatments in 2019

Figure 11 shows another before and after example picture of Dunbar Rd in 2012 and 2019. In the photograph on the left from 2012, the existing pavement surface was heavily distressed with multiple transverse cracks from the underlying concrete. Also note the longitudinal crack left of the outside striping in the outbound lane from the widening performed with HMA in years past. The photograph on the right, taken in 2019, shows that one of the transverse cracks may be working its way to the surface of the pavement. All other cracks after 7 years, including the longitudinal crack from widening and the other severe transverse cracks, are not reflecting through the CCAP layer. It is also noteworthy that the cracks in Figure 11 represent the worst case scenario during spring conditions when cracks are at their widest. MCRC typically sees many of these cracks heal and dissipate in the heat of the summer.

Figure 11. Dunbar Road at Keegan Road Before Cold Constructed Asphalt Pavement (CCAP) Overlay in 2012 (Left) and After CCAP/PM Treatments in 2019 (Right)

3.1.3 South Huron River Road, Monroe County

As of 2010, South Huron River Road in Monroe County was in poor condition. The existing cross section comprised of various thickness of HMA placed on aggregate base on subgrade. The drainage conditions, coupled with heavy tree canopy areas, did not provide the pavement with very good drainage. This resulted in many potholes developing, requiring heavy maintenance from MCRC forces. In 2010, MCRC placed 3.5 inches of CCAP directly on the existing surface with an application of blotter aggregate. In the following year (2011), MCRC self-performed a single chip seal on the CCAP overlay.

Since the first chip seal in 2011, the MCRC applied another chip seal in 2016 and performed overband crack filling in 2017. As of 2019, no future maintenance is scheduled for South Huron River Drive. Figure 12 shows a side by side comparison of a stretch of South Huron River Drive prior to CCAP overlay in 2010 and the same stretch as of spring 2019. The pavement prior to paving had severe potholing, transverse and block cracking from less than ideal drainage conditions and age. The same piece of pavement in 2019, after CCAP and the previously mentioned maintenance treatments, is shown in Figure 12. Some of the cracks in the wheel path show where the overband crack fill treatment had been applied in 2017. Ultimately, after nine years in service, the 3.5 inches of CCAP mix has not permitted many of the underlying distresses to reflect into the surface. This CCAP treatment with the scheduled maintenance has been a success in upgrading and maintaining the serviceability of the pavement over the past nine years.

Figure 12. South Huron River Road in 2010 Prior to Cold Constructed Asphalt Pavement (CCAP) Overlay (Above) and Same Location After Nine Years of Service

3.1.4 Sanford Road, Monroe County

Many roadways in Monroe County originated as stone macadam type pavements that eventually were widened over time with varying treatments including asphalt treated macadam, hot mix asphalt and chip seals. Over time the widened areas of the pavements consolidate due to increased loadings at the edge of pavement resulting in an excessive crown. Sanford Road in 2008 was experiencing this type of distress. Figure 13 shows the 3.5 inches of CCAP material being placed on Sanford Road.

Figure 13. Sanford Road During Cold Constructed Asphalt Pavement (CCAP) Overlay in 2008 (Top) and After CCAP Overlay and Maintenance Treatments in 2019 (Bottom)

The lane to the left shows the CCAP material being seated by the smooth drum roller prior to the blotter aggregate being applied. The lane on the right shows the condition of Sanford Road prior to the overlay. The pavement was suffering from severe crown resulting in the edge of the pavement holding water and potholing. The pavement crown was corrected and overlaid with CCAP. In some locations, 12 inches of CCAP was placed to correct the excessive crown and level the roadway. Chip seals were applied to the CCAP in 2010 (two years after initial paving) and in 2017. The bottom Portion of Figure 13 shows the same approximate location of Sanford Road after 11 years of service. Some minor longitudinal cracks are starting to show through the consecutive layers of chip seals. Many of these may heal over the summer months under traffic. The crown of the pavement is still in excellent condition. After 11 years of service and only two chip seals and minor scratch patching, this pavement is in excellent condition.

3.2 Boone County, Indiana

Boone County lies in central Indiana directly northwest of the Indianapolis metropolitan area. The County maintains a total of 750 centerline miles of roadway with approximately 420 miles paved roads and 330 miles of gravel roads [5]. The climate in Boone County is typical for Midwestern US with average low temperatures of -8°C in January and average highs of 30°C in the summer. On average, central Indiana receives around 65 cm of snowfall per year.

Like Monroe, Boone County has used open graded CCAP mixes on its roadway network since the early 1990s and CMA technologies long before that. Boone County utilizes CCAP mixtures in several different methods. The most prominent method of CCAP usage is the upgrading of gravel roadways into hard paved surfaces. Maintenance on gravel roadways can be very cumbersome for highway agencies by continuously importing and grading aggregate to maintain shape. The dust for gravel roadways can also be a topic of disdain from the travelling public and local residents.

Figure 14 shows an example gravel roadway in Boone County prior to being upgraded. The county goes through an extensive program to identify the best candidates for upgrading as outlined in [5]. Once candidates are identified, the county begins by cutting back vegetation, improving drainage of the roadway and making any necessary repairs to soft or yielding bases. CCAP cannot bridge soft or yielding subgrades.

Figure 14. Gravel Roadway Candidate for Cold Constructed Asphalt Pavement (CCAP) in Boone County

Boone County has a unique ability compared to many local agencies in the sense that it can self-perform the production of CCAP through a County-owned pugmill and also self-perform the paving with a county paving crew. The agency advertises and collects materials bids for the CM-150 asphalt binder and for the Indiana Size 9's and 11's for the coarse aggregates and blotter aggregates. Once the material is bid, then it is hauled to a County yard and awaits production. The advantageous ability with the CCAP material is that the County can produce the mixture and stockpile it onsite until the crew and roadway are ready to place the material. In some yeas of high production, the County will bid out the production and paving of the CCAP to local contractors.

Figure 15 shows a portion of 650 South in Boone County. The photograph was taken in 2017. Three inches of CCAP mix was placed on the existing gravel roadway in 2013. In 2014, the County performed a double chip seal.

Figure 15. Boone County 650 South: Four Years After Being Upgraded to Hard Surfaced Road

There are many instances, especially with rural local agencies in the Upper Midwestern United States, that paved roads or hard surface roads are being converted back to gravel roadways because of the cost to maintain many low-volume surfaced pavements. Boone County has found that the selection of CCAP materials, coupled with timely preventive maintenance treatments, can create a solution to this problem. The flexibility of the CCAP material makes it flexible enough to withstand any movement in the subgrades and base layers without cracking. The superior flexibility is prolonged with minimized aging and exposure to moisture intrusion with proper seal treatments.

Figure 16 is an example of how one of Boone County's older HMA pavements, after being overlaid with CCAP, (County Road 400 South) is performing after ten years of service.

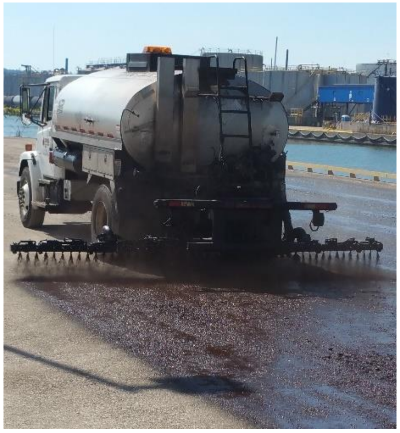
Figure 16. Boone County Road 400 South: Ten-Year-Old CCAP Overlay Pavement with Single Chip Seal

3.3 Hamilton, Ontario

The CCAP mixture has been placed at several locations throughout the province of Ontario. For the purpose of this paper, only production experience and field performance of two locations in Ontario is included.

In September 2015, approximately 900 tonnes of CCAP 19.0 mixture were placed on a parking lot at the McAsphalt Hamilton facility, located 70 km southwest of Toronto. The CCAP mixture was produced using locally-sourced aggregate and gelled asphalt produced by McAsphalt Industries Ltd. in collaboration with The Heritage Group. The mixture was produced by Miller Paving at a plant located in Brechin, Ontario (140 km North East of Toronto). The produced CCAP was stockpiled approximately for three weeks before being transferred to the job site.

The paving was completed by Pave-Al Company. The CCAP mixture was placed over a granular base, which was compacted and shaped properly to the desired grade. An application of diluted emulsion was used to prime the surface as shown in Figure 17(a), approximately 24 hours prior to paving CCAP. The prime coat was diluted to the targeted asphalt residue of 48 percent. Paving was completed by using a standard paving train as shown in Figure 17(c) without using Material Transfer Vehicle (MTV). The compaction was completed by using a five-tonne breakdown roller followed by a two-tonne steel finish roller in a static mode. A nine-tonne steel wheel roller with rear-spreading attachment was used to apply 5/16” crushed stone screenings as blotting aggregate (Figure 17(e)).



(a) Surface priming prior to paving.

(b) Loading of CCAP mix into the hauling truck.

(c) Placement of CCAP mix.

(d) Compaction of CCAP.

(e) Application of aggregate blotter.

Figure 17. Steps Involved in Placement and Compaction of Cold-Constructed Asphalt Pavement (CCAP) in Hamilton, Ontario, September 2015

The rolling patterns comprised two breakdown passes in static mode followed by the finished steel roller completing approximately three passes to take out lines. The roller operators were using good practices and when stopping, they parked the roller at an angle to the direction of rolling. The aggregate blotter received one (1) more pass of the finish roller. Weather during the paving was sunny with cloudy periods, ambient temperature was around 26°C in the afternoon. Overall, the job went smoothly, and the CCAP mixture was consistent in appearance with no rich spots.

Since 2015, several site visits were conducted to monitor the performance of the Hamilton section. The in-placed CCAP has not shown any sign of rutting or ravelling, nor any signs of weathering or cracking as shown in Figure 18.

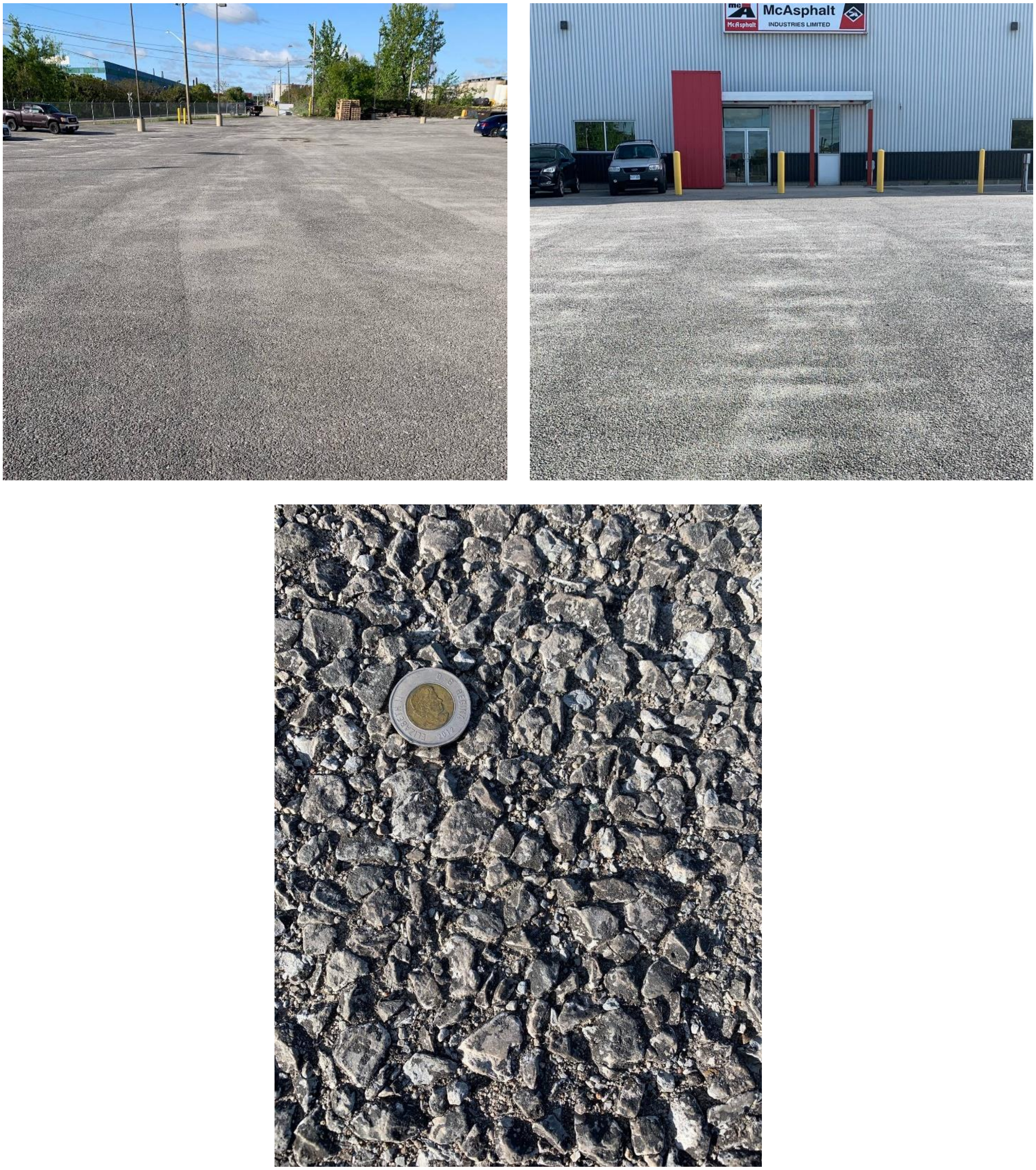


Figure 18. Cold-Constructed Asphalt Pavement in Hamilton, Ontario: Three-Year-Old CCAP Overlay

3.4 Muskoka, Ontario

The District Municipality of Muskoka in Central Ontario constructed a CCAP in summer of 2018. The climate in Muskoka is typical for the region with average low temperatures of -17°C in January and average highs of 25°C in the summer. Like other projects included in this paper, Muskoka used open graded CCAP mix on approximately 4-km stretch of a low-volume road. This section was composed of a badly distressed asphalt pavement, as shown in Figure 19, which was taken in 2015.

Figure 19. Windermere Road in Muskoka, Ontario (Google Photo from 2015): Prior to Being Upgraded to CCAP Surfaced Road

This road section was pulverized, mixed with cement and water, and compacted to produce a proper base. A minimum of 75 mm CCAP overlay was placed in September 2018. After overlay placement, granular materials were used on the shoulders to protect the edge-line. Manufactured sand was used as blotting aggregate. In March 2019, a visual assessment was conducted in which no distresses or cracks were observed for this project as shown in Figure 20.

Figure 20. Windermere Road in Muskoka, Ontario: After being Upgraded to CCAP Surfaced Road (Photo Taken in March 2019)

Figure 21 shows the surface texture of the CCAP on Windermere Road after 1 year in service.

Figure 21. Windermere Road in Muskoka, Ontario: CCAP Texture (Photo Taken in March 2019)

4.0 SUMMARY

CCAP is a cost effective and viable pavement system that has performed over time extremely well for numerous agencies, epically on low to medium volume highways. The optimal performance of the pavements is largely because of the selection of quality materials. The gelled asphalt used in CCAP can coat aggregates with higher film thicknesses reducing the effects of aging and oxidization without the risk of draindown. The gelled asphalt also has the low temperature coating and workability characteristics like a cutback asphalt without the high release of volatiles into the atmosphere. The selection of the aggregate source is also critical for performance. The open graded mixtures rely on angular stone on stone contact to carry the heavy loads and not deform or rut over time. As with any pavement, proper geometric design and drainage is pertinent for successful life.

CCAP is primarily produced in portable pugmill plants, but stationary HMA plants can also be used at significantly reduced temperatures. After the CCAP is mixed, the material can be stockpiled for later use and as long as ambient temperatures allow the mixture to be workable. Lay down of the CCAP material is performed with traditional paving equipment. Blotter aggregate is applied after compaction to help lock in the aggregate structure.

Performance from several various projects have been included to show how CCAP can be successfully applied to varying pavement conditions including overlay on distressed HMA pavements, excessive crown correction, gravel road upgrades and heavy volume parking facilities.

REFERENCES

[1] Asphalt Institute. Cold Mix Manual, Manual Series No. 14, Third Edition. Lexington, Kentucky (1997).

[2] Kriech AJ, Wissel HL. "Multigrade asphalt cement product and process", United States Patent 4,874,432, October 17 (1989).

[3] Heritage Research Group. "Guidelines for Cold Constructed Asphalt Pavement with Multigrade Asphalt", Internal Report, Indianapolis, Indiana (2005).

[4] Monroe Road Commission. "Special Provision for Cold Constructed Asphalt Pavement", Monore, Michigan, (2012).

[5] Parks C, Parr N. "Implementing a Gravel Road Conversion Program", Presented at 2019 Purdue RoadSchool, West Lafayette, Indiana (2019).