URBAN COLD RECYCLING

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ABSTRACT: Following is a general discussion of the basic procedures for asphalt pavement recycling covering (a) preparatory steps required, (b) description of a proper recycling agent, and (c) important steps in cold recycling affecting the mechanics of field procedures. It includes a description of two recent cold recycling projects performed in California, and a comparison of energy requirements for new construction with four different recycling procedures.

The subject assigned to me for discussion is "Urban Cold Recycling." The work to be performed on urban and rural roads is somewhat different because of differences in grade control, obstruction, traffic, access to adjacent property and other factors. However, contractors have moved from urban to rural, from congested to desolate areas, and from complicated to very simple projects with ease and hardly a ripple. Therefore, there should be no problems in adapting to recycling techniques, either rural or urban.

This paper presents an overall picture of the procedures followed on two typical cold recycling projects recently completed, one by the City of Victorville, California, and the other a Kern County, California project. The Victorville project involved breaking up and removing the asphalt concrete pavement to adjacent empty lots to allow correction of base problems, and hauling the crushed material back to the road to be mixed and laid. The Kern County project involved breaking up the existing asphalt concrete pavement, mixing and laying without moving it off the site. This was done within a 12 foot lane width with a concrete curb on one side and a concrete traveling lane on the other side. In other words, it was accomplished in a confined and controlled grade set-up similar to any city street.

Before going into the details of these two projects, I believe it appropriate to discuss briefly some facts and aspects basic to recycling and recycling agents in general.

There are three characteristics of any pavement to be recycled which must be known before the design engineer can develop the final mix formula. This is true for any pavement regardless of what recycling procedure is contemplated -- hot, cold, on- or off-site, 100% recycled pavement or a blend of recycled pavement and new aggregate. The three facts to be determined in the laboratory are:

1) Percent of residual asphalt in the existing pavement;
2) Consistency of the residual asphalt (penetration value or viscosity); and
3) Asphalt demand of the recycled aggregate.

With this information, the design engineer can determine amount and type of recycling agent required to achieve a final mix of the quality desired by the agency in charge.

After the laboratory investigation of the pavement to be recycled is completed and the design engineer has the necessary information to develop the final mix, the next step is to make certain that a properly formulated recycling agent is specified as the additive. This recycling agent must have characteristics which will result in a final mix exhibiting workability, stability and durability. Workability and stability can be achieved with many available additives; however, durability is by far a more difficult achievement. But it must be fulfilled. There is no point in going to all the trouble, effort and cost to recycle a pavement if durability is not achieved. This can be assured by the simple expediency of setting up meaningful material specifications with the proper limits for specific properties. The properties that must be specified in all specifications of general validity are: viscosity, flash point, weight change, saturates, compatability with residual asphalt as measured by the ratio N/P, aging ratio and specific gravity. We at Golden Bear have gone even further and included in our quality control specification tests, volatility and all values for chemical composition.

The emulsified versions of our commercial recycling agents must be made of the approved base oils and in addition must comply with set requirements for the emulsion including pumping stability and stability in the cement mixing test, must contain a minimum of 60% residual oil, and must be cationic. Tables 1 and 2 show our own laboratory acceptance specifications for recycling agents

Table 1. Specifications for Cyclogen Recycling Agents.

Property	Test Method	L[a]	M[a]	H[a]	22[a]	47[a]
Viscosity @ 140 F, cSt	ASTM D 2170-74	200-800	1000-4000	5000-10000	15000-35000	40000-60000
Flash Point, COC, F	ASTM D 92-72	400 min.	450 min.	450 min.	475 min.	500 min.
Volatility, IBP, F	ASTM D1160-61, 10	300 min.	325 min.	350 min.	--	--
2%, F		375 min.	400 min.	425 min.	475 min.	475 min.
5%, F		410 min.	430 min.	440 min.	500 min.	500 min.
RTFC weight change, %	ASTM D 2872-74	4.0 max.	2.0 max.	2.0 max.	0.5 max.	0.5 max
Compatibility, N/P	ASTM D 2006-70	0.5 min.	0.5 min.	0.5 min.	--	--
Saturates, % W	ASTM D 2007-75	28 max.	28 max.	28 max.	28 max.	28 max.
Chemical Composition $(N+A_1)/(P+A_2)$	ASTM D 2006-70	0.2 - 1.2	0.2 - 1.2	0.2 - 1.2	--	--
RTFC Ratio[b]	ASTM D 2872-74	2.5 max.	2.5 max.	2.5 max.	2.5 max.	2.5 max.
Specific Gravity[c]	ASTM D 70-72	0.98 - 1.02	0.98 - 1.02	0.98 - 1.02	0.98 - 1.02	0.98 - 1.02

[a]Suitable pumping temperatures are the following: L=140 F, M=190 F, H=200 F, 22=230 F, and 47=250 F

[b]Viscosity, RTFC Residue @ 140 F cSt/Viscosity, Original Material @ 140 F, cSt

[c]For conversion of the L, M & H Series use 242 gal./ton; for 22 & 47 use 238 gal./ton

Table 2. Specifications for Emulsified Cyclogen Recycling Agents, LE[a], ME[a], HE[a]

PROPERTY	TEST METHOD	SPECIFICATIONS
Viscosity @ 77 F, SFS	ASTM D 244-76	15-85
Pumping stability	G.B. method[b]	Pass
Emulsion coarseness, percent	Sieve Test ASTM D 244-76 (MOD)[c]	0.1 max.
Sensitivity to fines, percent	Cement Mixing ASTM D 244-76	2.0 max.
Particle charge	ASTM D 244-76	Positive
Concentration of oil phase, percent	ASTM D 244-76 (MOD)[d]	60 min.

Note: CYCLOGEN 22 and 47 are not furnished as an emulsion.

[a]Oils used for emulsions must meet specifications for the CYCLOGEN recycling agents L, M, H. For the conversion of LE, ME and HE use 242 gal./ton.

[b]Pumping stability is determined by charging -450 ml of emulsion into a one-liter beaker and circulating the emulsion through a gear pump (Roper 29 B2262) having ¼" inlet and outlet. The emulsion passes if there is no significant oil separation after circulating ten minutes.

[c]Test procedure identical with ASTM D 244 except that distilled water shall be used in place of two percent sodium oleate solution.

[d]ASTM D-244 Evaporation Test for percent of residue is modified by heating 50 gram sample to 300 F until foaming ceases, then cooling immediately and calculating results.

Table 3. Calculation of Asphalt Demand of Recovered Aggregate

$$P = \frac{4R + 7S + 12F}{100} \times 1.1$$

P = Total % asphalt required in recycled mix (old asphalt + recycling agent)

R = Rock (retained on #8 sieve)

S = Sand (passing #8 sieve; retained on #200)

F = Fines (passing #200 sieve)

(base oils and emulsified grades) which we manufacture and which, by our tests, will fulfill all the necessary and needed requirements to achieve workability, stability and durability.

To go into further detail on the chemistry of recycling agents would be outside the scope of this paper. For those interested in some of the details, I refer you to two review papers I presented recently on the chemical aspects of pavement recycling affecting engineering considerations: (1) a prepared discussion for the Symposium on Recycling of Asphalt Mixtures, published in the Proceedings of the Association of Asphalt Paving Technologists, Vol. 43, pp. 327-339, 1979, and (2) "Rejuvenating Materials," presented at the Conference on Recycling of Asphalt Pavements, University of Michigan, March 25-26, 1980. These two papers describe the asphalt chemistry as practiced by Golden Bear, in language easily understood by engineers as well as chemists.

It would be well to mention at this time the fallacy of specifying high penetration asphalts or asphalt emulsions as the sole additive for any recycling project. Although a high penetration asphalt contains all the components specified in a recycling agent, if the ratio of the components is uncontrolled, the composition of the cement in the final mix is unknown and end results are unpredictable. Recycling is a costly procedure. To consider workability only and ignore durability is wrong. Why gamble and waste all the effort, energy, money and time for what will in practically all cases be a pavement of questionable durability? Those who advocate using high penetration asphalts for recycling are in essence advocating a mix design which, in most cases, will contain a binder which might result in a pavement of impressive appearance when freshly laid, but which is a gamble as to future performance.

To return to the subject of actual field construction of urban cold recycling, I want to present to you now the pertinent facts of the City of Victorville and Kern County projects.

City of Victorville

For the City of Victorville, estimated savings of approximately $100,000 by cold recycling of residential streets was the main incentive. The existing pavement was 2½" thick and the design requirements in this area, due to soil conditions and traffic requirements, called for four inches of pavement. If the old time-honored procedure of removing and disposing of the existing pavement and replacing it with four inches of new pavement were to be followed, Victorville could not afford to proceed with the project.

A representative sample of the asphalt pavement was analyzed showing an asphalt content of 5.4% with a penetration value of 7 and a viscosity of 653,000 poises. The asphalt demand of the aggregate was 6.3%. This was arrived at by using the surface area formula shown in Table 3. This asphalt demand called for an addition of approximately 1% of a recycling agent. Since this was to be a cold recycling project, the emulsion form of the recycling agent was required. The emulsion contained 60% residual, meaning that the total amount of emulsion needed was 1.7% by weight. The recycling agent used by the contractor was CYCLOGEN LE, a one-component material developed, manufactured and supplied by Golden Bear Division-Witco. The specifications also required the old asphalt pavement to be broken up so that 100% would pass the 1½" sieve, 90-100% would pass the 1" sieve and 0-8% would pass the No. 200 sieve. Since base repair had to be performed, the old crushed pavement was stored in empty lots adjacent to the project. When the base work was completed, the old pavement was hauled back to the roadway, dumped into the hopper of a Midland mixer-paver. The Midland mixer-paver had the capability of introducing the CYCLOGEN LE into the mix at the predetermined rate, mixing and laying the 2½" depth 12 feet wide in one pass. Compaction followed with a vibrating roller. The street was opened immediately to traffic and received the final 1½" of new asphalt mix several days later.

The City of Victorville plans more cold on-grade recycling work; however, the final riding surface will be a slurry seal, which should be adequate under most conditions prevailing on residential streets.

Kern County Project

In the Kern County project, all preliminary work was the same as in the Victorville jobs, but the field procedure was slightly different. There was no base problem to correct. The total thickness of pavement was four inches. The specifications called for recycling the top three inches, leaving 1" undisturbed. Using a milling machine, the old pavement was broken up on the grade to the same gradation requirements as in Victorville. The crushed material was left on the roadbed and windrowed. A Midland mixer-paver with a Ko-Call on the front then moved down the grade, picking up, mixing and laying to grade in one pass. The recycling agent used on this project was again CYCLOGEN LE, supplied by Golden Bear, and was introduced into this mix at a rate of 2.7% by weight. This project is scheduled to have a chip seal as its final riding surface.

General Observations

Having been personally involved in many cold recycling projects, I believe I should mention several items regarding the actual mechanics and procedures that one must make sure are followed. The pavements must be crushed or milled so that 100% passes the 1½" sieve. This is necessary to assure a reasonable gradation, proper mixing and compaction. Oversize material can be detrimental to these requirements. It is advisable to use the amount of recycling agent calculated for the mix regardless of what the immediate visual appearance may be. It must be kept in mind that the recycling agent needs a certain amount of time to react completely with the residual asphalt, but the ability of the recycled mix to perform and function is in no way inhibited during this reaction time. Traffic should be allowed to use the facility as soon as possible after compaction. It is also usually required that some type of seal, such as conventional asphalt emulsion or rejuvenating agent be sprayed on the recycled mat prior to placing the final riding surface. The reason for the seal is that most cold recycling projects end up with voids in the area of 6%, and it is well to seal them off from the intrusion of air and water.

Features unique to urban projects are the obstructions, such as curbs, gutters, manhole covers, valves and other utility features which must be protected from damage and meet the final grade. Small, maneuverable milling equipment is available to grind around obstructions or in small areas so all the old pavement can be utilized. If it is impractical or impossible to recover material from small, inaccessible areas, it can be removed and hauled off to a central stockpile for further use. In other words, recycling can be performed economically and expeditiously regardless of the locality or conditions.

For recycling where a given grade must be maintained but traffic and soil conditions indicate need for additional thickness of pavement or strengthening the base, the following procedure may, and in most cases will, fulfill the structural requirements. In this case, the procedure would be to grind up the existing pavement and windrow it off to the side or stockpile it off the site. Using a standard asphalt emulsion, a black base can then be made of the existing material to the necessary thickness to meet the structural requirements. However, this can be done only if the existing base material meets requirements, such as a reasonable gradation and proper sand equivalent so that it can be converted from an untreated rock base to an asphalt treated base. This will allow the design engineer to assign a greater gravel equivalent thickness to the existing untreated base and will generally be sufficient to satisfy the structural thickness requirements in residential, secondary or collector streets, without removing or hauling base material.

There are those who advocate mixing the existing base with the crushed pavement for the recycling procedure. This should be considered only if the thickness of the pavement is less than two inches. Then the mixture of crushed pavement and base should be treated and mixed on the same basis as an untreated base due to the insignificant amount of residual asphalt. If the pavement is at least two inches thick and the structural design calls for additional overlay or load carrying capacity, the base should be separated from the surface and the two mixed separately.

There are also other advantages to cold recycling which are of utmost importance. No serious air pollution problems are involved, and there is a considerable savings in energy which in turn translates to a savings in money.

To point out the savings in energy, I want to give a brief review of a specific project setting forth the energy requirements for five different approaches - four recycling procedures and one procedure replacing the road with all new materials. The project comprises a three-mile long asphalt pavement, 24 feet wide, four inches thick. The plant where all off-site work (hot or cold) is to be performed or from where the new mix would originate, is 15 miles from the project.

Approximate BTU requirements for each construction function involved, generally accepted as reasonably accurate, are as follows:

2,500	BTU to produce one gallon paving asphalt
5,000	BTU to haul one ton one mile
20,000	BTU to mix one ton of cold-mix (no recycling agent)
70,000	BTU to produce one ton aggregate
150,000	BTU per gallon of paving asphalt
250,000	BTU to dry and mix one ton of hot-mix aggregate (no asphalt)

The weight of the asphalt mix is assumed to be 140 lbs./cu. ft. and is the same for all procedures.

Tests on the aged pavement indicate that 1.6% recycling agent is required. The new aggregate hot-mix will require 6% paving asphalt. Based on this information, energy requirements of the five different procedures can be compared in BTU values. However, BTU requirements, difficult to visualize, can be easily comprehended when converted to the equivalent in energy content of gallons of paving asphalt. The energy requirements of the four different recycling procedures and new aggregate hot-mix in terms of gallons of paving asphalt, are as follows:

100% recycled aggregate mix cold on-site	70,000 gallons
100% recycled aggregate mix cold off-site	79,000 gallons
70% recycled aggregate, 30% new aggregate hot off-site	88,000 gallons
50% recycled aggregate, 50% new aggregate hot off-site	106,000 gallons
100% new aggregate hot-mix	155,000 gallons

These figures do not include the energy requirements for breaking up the old pavement, laydown and compaction since these values would be approximately the same whichever procedure is used. The above figures speak for themselves and should require no further comment except that recycling, especially the cold procedure, saves energy - a most important consideration not only at this point in time, but also in the foreseeable future. And, as mentioned previously, saving energy relates directly to savings in dollars.