In Situ Cold Recycling of Bituminous Pavements with Polymer-Modified High Float Emulsions

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The New Mexico State Highway and Transportation Department began an in situ cold recycling (ISCR) program in 1984. On more than 1,850 lane-mi of Interstate, primary, and secondary highways, this effort has been successful in reusing valuable resources (asphalt and aggregate), reducing the transportation and handling of materials, minimizing environmental pollution, and rehabilitating pavements with many types of distresses at minimal cost. The development of the ISCR design, specification and construction methods, and the selection of high float styrene-butadiene-styrene polymer-modified emulsions to overcome many of the problems (rutting, reflective cracking, and moisture damage) previously encountered with conventional rejuvenators are discussed. Annual statewide tours of ISCR projects have documented overall excellent rideability, minimal rutting, and a delay of reflective cracking by 5 to 6 years over that in control sections.

In 1984 New Mexico had many miles of roadway to be rehabilitated or reconstructed with limited funding. Faced with rising asphalt prices, falling revenues, and diminished quality aggregate sources in some areas, the New Mexico State Highway and Transportation Department (NMSHD) began an in situ cold recycling (ISCR) program. Because existing cold recycling practices and conventional emulsions did not give the desired results, NMSHD sought to improve the technique. New methods were adopted for design, construction, and quality control, and new rejuvenator emulsions (high float polymer modified) were used.

PROJECT DESIGN

To realize any benefit from ISCR, an appropriate mix design procedure and pertinent field quality control tests must be developed. Two widely different approaches have been used in cold mix recycling.

The first anticipates that the recycled asphalt pavement (RAP) will vary markedly with depth, history (age, environment, patches, seals, etc.), and the construction equipment used during the recycling process. It concludes, therefore, that a formal laboratory mix design approach is futile. The amount of recycling additive is estimated from previous experience or from a rudimentary Marshall procedure, but without serious consideration for the amount or hardness of the asphalt already in the RAP. Construction is begun, and field adjustments are made on the basis of experience, appearance, and workability. If the mix is too dry, it is often used as untreated base. If too much additive is applied, the mixture quickly loses air voids and becomes susceptible to deformation under traffic.

The second approach calls for a highly sophisticated design process coupled with rigorous quality control during every phase of ISCR. Milling machines are brought to the project long before the actual job to obtain numerous representative field samples for the design. The asphalt is extracted from each of the RAP samples to determine hardness, and then the rejuvenating additives are carefully chosen to provide a finished binder of some predetermined asphalt grade. Gradations of the extracted aggregate samples are carefully determined, and traditional volumetric designs are run to determine amounts of virgin aggregates and additive that will be used. This approach usually specifies rigorous quality control testing at the job site to guarantee that the laboratory design is achieved.

The no-design approach guarantees that the benefits of ISCR will not be optimized, and serious failures will almost certainly occur. Unfortunately, the highly sophisticated design method is extremely expensive and taxes already strained laboratory resources. The high variability of materials even within one project makes it extremely difficult to generate one perfect design. Costs for obtaining initial samples using milling equipment are also high, and these small milled areas may cause traffic problems or suffer structural failure before the project is begun. Thus the high cost and effort of the latter approach defeats the primary purpose of using ISCR as an inexpensive alternative for pavement rehabilitation.

NMSHD has adopted a site selection, mix design, quality control strategy that falls between these two extremes. Using the general guidelines discussed later, 105 ISCR projects incorporating 1,853.9 pavement lane-mi have been successfully completed since 1984. There have been no serious failures to date. These projects, some of which are listed in Table 1, consist of 1,331.7 lane-mi of primary and secondary roads and 522.2 lane-mi of Interstate pavement.

PROJECT SELECTION

Initial selection of a project suitable for ISCR is made by reviewing the original construction design documents and then discussing the maintenance history with appropriate district personnel. Information gathered includes traffic, original pavement thickness (including base materials), overlays, seal

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TABLE 1 SUMMARY OF IN SITU RECYCLING PROJECTS

Control	Highway	Lane	Recycle	Emulsion	Emulson	Average Compress	Average	Cost ($/sq yd)			Traffic Data Time of Rehab		Existing Pavement (inches)		New Wearing Course		
No		Miles	Thick (in)	Grade	Added (%)	Strength (psi)	Density	Recycle	Emulson	Total	ADT	%HC (Heavy Trucks)	Surface	Base	Type	OGFC	Thick (in)
807	I10	30.12	3	HFE 150	1.70	238	120.4	1.4	0.73	2.13	7655	30.6	0	W6,E6/6	PMBP	Y	3.5
1312	US 60	18.4	3	HFE 150	4.20	199	142	1.25	1.19	2.44	962	13.5	1.75	7	PMBP	Y	1.5
1721	NM 28	14.58	3	HFE 150S	1.50	380.2	131.9	1.25	0.29	1.54	2301	2.7	4.75	4	PMBP	Y	3
1730	NM 90	3.1	2.5	HFE 150S	1.08	438	123.5	1.95	0.34	2.29	1232	12	2	7	PMBP	Y	1.5
1856	US 70	52.96	4	HFE 150S	2.36	376	133	1.05	1.24	2.29	18809	4	4	14.5	PMBP	Y	2
910	US 70	9.12	3	HFE 150				1.16		1.16	2511	23	3	6	PMBP	Y	3.5
1130	US 82	8.6	3.5	HFE 150S	1.80	N/A	129.85	1		1					PMBP	Y	2
1301	NM 529	10.8	3	HFE 150S	3.00	379	124	0.95	0.94	1.89	1305	24.2	2.5	UTB3,Sub4	PMBP	Y	2.5
2301	US 82	8.1	5.5-7	HFE 300	2.44	N/A	142.1		181/TON								
1857	US 380	7.22	4.0	HFE 150S	1.49	294	131.6	1.5	0.54	2.04	1074	14.3	6	6.5	PMBP	Y	3
1939	US 70	16.04	3.5	HFE 150S	1.73	445.13	140.21	1.25	0.75	2	N/A	N/A	4	6	PMBP	Y	4
1722	US 380	15.38	3	HFE 150S	1.69	487	132	1.25	0.49	1.74	1243	8	4.8	4.5	PMBP	Y	2
1045	US 54	11.62	3.5	HFE 150S	2.16	378	137	1.3	1	2.3	4379	24.8	4	UTB3.5,Sub4	PMBP	Y	2
1564	US 70	12.78	4	HFE 150	2.78	336	135.5	1.45	1.13	2.58	3285	14.7	4.5	6	PMBP	Y	3
1541	US 180	16	4	HFE 150	1.94	227	136	1.45	0.61	2.06	1478	14.1	4.5	6	PMBP	Y	2.5
1313	US 70	19.54	3	HFE 150S	0.59	535	130.5	1.1	0.11	1.21	2114	22.5	2.0&2.5	11.0&12.0	PMBP	Y	2.5
1545	US 70	26.8	4	HFE 150S	2.80	273	134.8	1.13	1.27	2.4	3789	30	5.5	15	PMBP	Y	3
1568	US 70	19.6	4	HFE 150S	2.25	394	134.7	1.2	0.99	2.19	1849	23	4.5	6	PMBP	Y	2.5
1202	US 82	16.06	2	HFE 150	3.70	246	122.6	1.25	0.18	1.43	895	12.9	2	6	PMBP	Y	3
1539	US 82	16.14	3	HFE 150	4.44	277	123	1.3	1.13	2.43	740	27.1	2	6	PMBP	Y	3
1201	US 60	30.88	3	HFE 150	4.78	236	119	1.05	0.85	1.9	8028	13.1	3.5	9	PMBP	N	2
1202	US 82	27.88	4	HFE 150	3.10	236	122	1.35	0.29	1.64	2675	22	4	5.5	PMBP	Y	3
1718	US 380	11	3	HFE 150S	1.87	418	128.99	2	0.81	2.81	871	9	3	5	PMBP	Y	2.5
1542	US 70	19.8	4	HFE 150S	1.42	328.2	131	1	0.55	1.55	2070	22	4	6	PMBP	Y	3.5
1543	US 70	20	4	HFE 150S	1.41	344	131	1	0.55	1.55	1919	22	4	6	PMBP	Y	3.5
1538	US 60	12.8	3.5	HFE 150	3.70	330	131	1.35	1.21	2.56	286	12.9	3.5	6	PMBP	Y	1.5
525	US 285	24.64	3.5	HFE 150S	1.11	417	138	1.5	0.09	1.59	3093	10.6	3.6	4	PMBP	Y	3
1716	US 285	14.56	4.5	HFE 150	1.20	324	137.27	1.25	0.95	2.2	1194	15.4	4.5	6	PMBP	Y	2.5
1378	US 285	29.2	4.5	HFE 150	2.40	193	131	1.65	0.42	2.07	1954	13.5	4.5	6	PMBP	Y	3
1379	US 285	29.56	4.5	HFE 150	2.20	255	130	1.65	0.46	2.11	1582	13.5	4.5	6	PMBP	Y	3
1381	US 285	29.28	4	HFE 150	2.89	334	131.1	1.25	0.76	2.01			5.5	8	PMBP	Y	2.5
1380	US 285	30	4	HFE 150	2.90	243	127	1.25	0.93	2.18	1401	13.2	4.5	8	PMBP	Y	3
1382	US 285	17.16	4.5	HFE 150	2.35	367	133.5	1.25	1.15	2.4	1138	12.2	4.5	6	PMBP	Y	2
1720	NM 6	20.9	3	HFE 150S	3.30	213.17	140.2	1	1.1	2.1	717	3	2	6	PMBP	Y	2.5
1725	NM 4	6.1	3	HFE150S/3	2.42	194	134	1.2	0.89	2.09	755	10.2	2.0-4.5	3	PMBP	Y	2.5
1294	I 25	27.72	4	HFE 150S	1.44	78	124.5	1.2	0.76	1.96	2855	19.7	9	8	PMBP	Y	3
1257	I 25	20.36	3	HFE 150S	1.61	110.31	127.07	1.2		1.2	2532	19.7	8.0-8.5	8	PMBP	Y	3
1548	I 25	21.84	4	HFE 300S	1.21	229	145.3	1		1	2296	22.6	9.23	6	PMBP	Y	3.5
1437	I 25	27.6	4.5	HFE 300S	1.52	115	133.67	0.56	0.82	1.38	3146	22.6	4.5	4	PMBP	Y	4.5
1864	I 25	18	4	HFE 300S	0.65	122.5	138.15	0.8	0.32	1.12	2695	19.3	8.5	6	PMBP	Y	4
1825	I 25	28.36	4	HFE 300S	1.50	152.5	129.64	0.82	0.82	1.64	2643	22.6	5	ATB4,Sub7	PMBP	Y	4
615	I 40	30.16	4	HFE 150S	1.01	244	131	1.4	0.49	1.89	7937	50.7	6	4	PMBP	Y	3
	US 64/8	18	3.5	HFE 300S	1.69	274.38	147.44	0.9	0.85	1.75	1986	12.2			PMBP	Y	4.5
1284	US 54	39.72	4	HFE 150S	1.32	279	138.55	0.85	0.59	1.44	2202	24	4.35	5.04	PMBP	Y	3
1155	US 87	34.4	4	HFE 150	1.80	N/A	N/A	1.5	0.63	2.13	2010	10.5	3	6	PMBP	Y	4
1204	US 87	19.22	3	HFE 150	2.11	167	125	1.2	0.48	1.68	2151	11.2	3	6	PMBP	Y	3
652	US 64	20.38	3.5	HFE 150S	1.07	294	138	1	0.3	1.3	1635	12.2	4	8	PMBP	Y	4.5
1247	US 54	26.36	3	HFE 150	1.88	326	137	1.25	0.27	1.52	2312		2	3	PMBP	Y	3
1572	US 54	21.4	3	HFE 150	2.63	409.5	139.9	1.15		1.15	901	17.2	3	5	PMBP	Y	3
1317	NM 504	15.28	4	HFE 150S	1.79	709	144.2	2.5	0.33	2.83	1125	7	2.5	9	DBL P	N	DBST
797	US 84		3.5	HFE 150S				1.5	275/TON		2028	6.4	3.5	5	PMBP	Y	5
1372	US 285	8.8	3.5	HFE 150S				1.65	100/TON		845	20	3.5	8	PMBP	Y	3
970	I 40	11.44	4	HFE 150S				0.92		0.92	11624	25.1	6.5	CTB4,Sub8	PMBP	Y	3
1318	US 60		4	HFE 150S				1	245/TON		610	9.4	4	8	PMBP	Y	2
1268	US 60	25.18	3	HFE 150	2.50	N/A	N/A	1.4	0.63	2.03	461	10.3	2.25	6	PMBP	Y	1.5
1614	NM 44	16	3.5	HFE 150S	2.68	259	134	1.4	1.06	2.46	4691	15.5	3	4	PMBP	Y	3
1547	US 180	11.52	4	HFE 150	4.00	297	128	1.92	1.36	3.28	528	7	2	7	PMBP	Y	1.5
1652	NM 4	6.74	4	HFE 150	2.78	N/A	129	2	1.03	3.03	1250	10.2	1.5	8	PMBP	Y	2.5

coats, amount and type of patching, and so forth. There is also a thorough field examination of base and subgrade conditions. Pavements with extensive base or subgrade problems are not good candidates for ISCR and are immediately rejected.

Once the initial review indicates that a site is suitable for ISCR, 8 in. cores are taken every ½ mi in both wheelpaths and lane centers of the existing pavement for laboratory analysis and mix design. These samples are selected to be representative of the major portion of the project, not of isolated or failed areas.

LABORATORY ANALYSIS AND MIX DESIGN

There is no standard mix design procedure of ISCR. An NCHRP study of two proposed methods found that "a precise laboratory design (even if obtainable) is not critical for achieving a successful recycling project. At best, it can only serve as a general guideline for an initial job-mix formula, with adjustments being made following an evaluation of mix quality, including such factors as workability, coating, plasticity, and ease of compaction" (*1*).

However, certain basic principles applicable to all asphalt paving projects should be followed as part of the design-selection-specification process:

1. Examination of field samples for evidence of stripping;
2. Crushing of RAP to required size;
3. Selection of grade of recycling emulsion and prediction of approximate amount of additive required;
4. Mixing, compaction, and testing of trial mixtures using the appropriate additive to optimize formulation for binder content, density/air voids, and stability. Determination whether additional virgin aggregate, either from base course or blended during milling, is required to increase pavement thickness, increase air void content, or improve mixture stability;
5. Estimation of strength parameters for characterizing load-carrying capabilities of the ISCR mix. A study at Purdue University found that the structural coefficient for a layer of recycled emulsion mix should range from 0.17 to 0.44, with a median value of 0.29 (*2*). New Mexico uses 0.25. When the minimum unconfined compressive strength of the ISCR mix exceeds 250 psi, a structural coefficient of 0.30 appears to be a valid estimate. Other studies of performance conducted by Oregon State University and Oregon Department of Transportation indicate that the ISCR structural layer coefficient may be considered equivalent to that of a conventional hot-mix pavement (*3*); and
6. Field adjustments as necessary to achieve proper coating of emulsion on the aggregate, ensure sufficient workability and proper density, and so forth.

New Mexico no longer tests mixtures during the preliminary design phase, but rather delays all laboratory work until after the ISCR project has been let to contract.

NMSHD has determined that a 1.0 percent polymer-modified high float emulsion should be included as a bid item to establish a separate price for the liquid additive, but the exact quantity is not determined until the design and initial construction phases are completed. This system allows tailoring the job to the contractor and its equipment without unduly affecting material costs after the contract price has been established.

RECYCLING AGENT—HIGH FLOAT POLYMER-MODIFIED EMULSIONS

On the basis of extensive prior cold mix experience, NMSHD began ISCR operations in 1984 using conventional high float anionic mixing grade emulsions. This philosophy was somewhat different from the more specialized aromatic oil rejuvenating emulsions used widely at that time for cold recycling applications. High float asphalt emulsions were selected because they create a gel structure in the asphalt residue after the water evaporates. These materials are believed to improve temperature susceptibility, reduce draindown or flow of the asphalt cement, resist deformation due to traffic, and improve resistance to "washing off" when wetted (*4*). NMSHD specified two grades of high float emulsions (HFE-150 and HFE-300), which conform to AASHTO specifications but were slightly modified to provide greater flexibility in residue penetration and mixing ability to meet specific field conditions.

After using these conventional high float emulsions for approximately 2 years, a project was built using a styrene-butadiene-styrene (SBS) (STYRELF) polymer-modified high float emulsion. It was found that the polymer further enhanced the positive characteristics of the high float emulsion residue. The SBS polymer network develops a strong, elastic matrix within the asphalt residue (*5*). Only a very small amount of virgin binder can be added without overasphalting a 100 percent RAP mixture. Since this residue must be relatively soft to adequately coat the RAP (including fines generated by the mill head), the quality of this virgin binder is of utmost importance. The higher cohesive strength imparted by the polymer rapidly develops load bearing capacity, which prevents the recycled pavement from rutting soon after being opened to traffic. The polymer improves the long-term resistance of the finished product to moisture damage, which is particularly important for preventing raveling, cracking, and potholes (*6*). Although NMSHD normally covers ISCR projects with conventional hot mix or a double penetration surface treatment (double chip seal) to seal the pavement as soon as moisture conditions allow, this has not always been possible. In some cases the ISCR pavement has been left open to traffic during the winter, and no apparent deterioration was observed.

Polymers also allow the use of low viscosity (soft) asphalts, which are better able to soften the aged asphalt cement in the RAP over a period of time, without suffering the early distresses of permanent deformation commonly encountered with unmodified soft materials. The softer asphalts can be more easily dispersed in finely graded mixes, and they are particularly valuable when mixes contain highly absorptive aggregates. It is important to remember that cold recycling relies heavily on the consistency of a very small quantity of virgin binder. At ambient temperatures there is not the rapid blending of the recycling agent with the aged asphalt as when using hot recycling methods.

Table 2 gives the properties of the polymerized high float emulsions.

SPECIFICATIONS

The success of any in situ recycling program begins with the specifications, ideally simple and straightforward and providing flexibility to optimize materials and construction variables throughout each individual project. Given the wide variability encountered, specifications must be somewhat generic. One choice is method specification, which lays out precisely how the work will be performed, the type of equipment used, and the end result in general terms. An alternative is end-result specification, which defines the required mixture criteria and in-place density but leaves the means for achieving these results to the contractors and suppliers.

Since the RAP is typically nonuniform and critical field conditions (temperature, humidity, wind, moisture content in pavement, etc.) vary on an hourly basis, it is not possible to predefine all operational parameters. Hence, New Mexico has chosen a combination of methods and end-result specifications that covers the following topics:

1. Overall description of the job;
2. Job mix formula with an initial estimate of the emulsion grade and amount;
3. Pulverization requirements for the RAP, including strict limitations on the maximum allowable size in the recycle mix;
4. Laboratory mix design requirements, including methods to determine optimum emulsion content and grade;
5. Field change order flexibility, which enables the user agency to vary the amount and grade of emulsion (virgin binder) as required to meet existing conditions. This includes the right to request special emulsion additives such as coating enhancers, dispersants, and antistripping agents where laboratory or field results indicate they will enhance performance;
6. Mixture laydown and aeration standards;
7. Compaction requirements, including size, type, and sequence of rollers, in-place moisture content, and minimum density of the finished mix;
8. Quality control criteria, including inspection, sampling, and testing;
9. Weather limitations;
10. Traffic control and safety restrictions; and
11. Protection of the newly laid ISCR surface from traffic if required to prevent abrasion or raveling. This may include fog sealing with a dilute emulsion or other techniques acceptable to the user agency.

CONSTRUCTION PROCEDURES

The ISCR operation generally uses a train of portable equipment, including milling machine, crusher with suitable aggregate screening decks, pugmill mixing chamber with controls for quantity of aggregate and emulsion, and emulsion tank or attachments, which connect an emulsion transport directly to the recycling train. The laydown machine with attachment to pick up the windrow of recycled mix usually follows a short distance behind. The compaction equipment, primarily heavy pneumatic rollers, may follow at some distance behind the laydown operation, as moisture content and emulsion break rate are critical variables in achieving density.

An ISCR project is begun with the job mix formula developed by the laboratory. The recycled mixture is observed for coating, dispersion, and balling of the fines. The application rate is then adjusted up or down as needed to achieve desired results. Where necessary, the grade of emulsion may be changed, or specific emulsion additives may be used to improve the end product. It is important that metering equipment be calibrated periodically to ensure that the correct amount of emulsion is being introduced.

The amount of water added during the milling operation should also be carefully controlled. Some water is needed to cool the mill head, and the same moisture can help disperse the emulsion throughout the mix and aid compaction. However, too much moisture can inhibit compaction and may also cause the emulsion to coat only the fines. Spilling water on the subgrade is also to be avoided, because the excess moisture will eventually migrate to the surface, creating soft spots, rutting, shoving, or other problems typical of moisture damage.

The laydown machine should operate as close to the milling/mixing train as possible, because the recycled mix is generally most workable when the moisture content is high and the emulsion is not completely broken. However, it is preferable to operate the entire ISCR process at the lowest moisture content possible, because this reduces the required aeration/drying time before compaction can begin.

Another critical variable for ISCR is the compaction procedure. NMSHD determined early in its cold recycling work that conventional roller patterns established for hot mix asphalt concrete do not work and may create serious problems. Initial breakdown with a steel wheel roller seals the surface and traps water in the mix, resulting in the various moisture damage failures discussed previously. To prevent moisture entrapment, the compaction procedure requires breakdown to be done with pneumatic rollers. In addition, ISCR mixes tend to "fluff," which implies that the uncompacted lift is quite thick compared with the same amount of conventional hot mix. Heavier rollers are essential to good compaction. New Mexico specifies a minimum weight of 30 tons for the pneumatic rollers on ISCR jobs. The pneumatic roller continues to work a section until it has "walked out of the mix"

TABLE 2 PHYSICAL PROPERTIES OF POLYMER-MODIFIED HIGH FLOAT EMULSIONS USED FOR ISCR

Emulsion	HFE 150S		HFE 300S grade II		HFE 300S grade III	
	Min	Max	Min	Max	Min	Max
Saybolt Furol Viscosity 122 F (sfs)	50		50		50	
Sieve Test (%)		0.10		0.10		0.10
Oil distillate volume of emulsion(%)		3		7		7
Asphalt Content (%)	65		65		65	
Tests on Residue From Distillation:						
Float Test @ 140 F (seconds)	1200		1200		1200	
Penetration on residue @ 77 F	150	300	300		300	
Solubility in TCE (%)	97.5		97.5		97.5	
Tensile Stress @ 800% elongation:						
at 39.2 F (kg/cm2)	1					
at 14 F (kg/cm2)			0.05		0.15	

(i.e., indentations are leveled out and no further deformation occurs under the rubber tires).

Moisture content is also critical during compaction. If there is not enough, the mixture is harsh and will not compact. With too much moisture, the mixture cannot compact because of excess fluids and no air voids, or sealed-in water leads to future problems under traffic. If moisture levels are correct, compaction should begin just as the emulsion begins to "break," or lose moisture. This phenomenon is highly dependent on ambient air temperature and humidity and usually varies from 45 min to 2 hr. Compaction is rarely delayed more than 2 hr simply because the rollers fall too far behind the milling train. If the rollers are delayed longer than 2 hr, the mix begins to stiffen and additional passes are often required to achieve density.

When the pneumatic roller has "walked out" of a section, the density is checked with a nuclear density gauge. Then a steel wheel roller is used to level the surface and achieve final density. To ensure that this compactive effort is sufficient, the following procedure has been established to develop a target density for the recycled mix:

> A sample of loose recycled mix is collected from the roadway just ahead of the first roller. This material is placed in an oven at 140°F (60°C) for two hours or until the mixture reaches the prescribed temperature, whichever comes first. The mix is then compacted immediately using the standard 50 blow Marshall procedure. The bulk specific gravity of the compacted specimen is determined. The target for roadway compaction is 96% of the Marshall compacted field briquette.

Using this procedure, a rolling pattern is developed for the project. The same Marshall compacted specimens are also tested for unconfined compressive strength to confirm that the resulting field mix conforms to the original laboratory design or can withstand expected traffic loadings. Fortunately, the recycled mixture can be expected to gain strength with time. Table 3 gives results for unconfined compressive strength at time of construction and after some months time lapse for six ISCR projects. It seems reasonable to predict from these data that the unconfined compressive strength will approximately double during the first 2 months in service.

NMSHD has prepared a video tape covering ISCR procedures and guidelines as a training aid for construction personnel (7). Copies of this tape are available on request.

RESULTS AND CONCLUSIONS

Table 1 includes a partial listing of New Mexico's 1853.9 lane miles of ISCR projects with related details such as location, length, thickness, costs, amount and type of emulsion, pavement structural features, traffic, type of wearing surface, and laboratory results for such parameters as in-place densities and unconfined compressive strength. The authors will supply additional details on request. Records for each project are kept by the Materials Division of NMSHD.

To evaluate ISCR performance, annual statewide tours are made of the projects. To date, the rideability has been characterized as excellent, rutting minimal, and resistance to cracking greatly improved. For example on one project (US Route 64 at Raton Pass), the traffic lanes were rehabilitated using ISCR, whereas the shoulders were not. The entire road surface was then overlaid with hot mix. After 1 year reflective cracking was evidenced in the shoulders, but it was 5 years before there was any sign of cracking in the traffic lanes.

Although the ISCR pavements are generally sealed, in cases where it has been impossible to seal the same season because of weather conditions, there has been no evidence of pavement deterioration.

The construction-related details and early performance (no failures) of ISCR projects using polymer were so encouraging that polymer-modified high float emulsions have been specified for all ISCR projects in New Mexico since 1986. Initial compression strengths averaged 259 psi on studied projects, whereas cores taken after about 1 to 1.5 years averaged 490 psi. Table 3 indicates that the ISCR approximately doubles in strength with time.

ISCR is unquestionably an effective method to conserve valuable resources and save dollars by salvaging old, worn out asphalt pavements. To ensure success, specifications must be clear but flexible, laboratory design should be effective but limited in scope, the user-contractor-supplier communication channels must remain interactive, and quality control must permeate every portion of the field operation to overcome the extreme variability in pavement and environmental conditions encountered during construction.

Beyond the conventional guidelines commonly recommended for ISCR, NMSHD has developed certain practices that are believed to be critical to their unparalleled success with such techniques, including the following:

TABLE 3 TYPICAL POSTCONSTRUCTION STRENGTH GAINS EXPERIENCED USING HIGH FLOAT EMULSIONS FOR ISCR

Project	Compression Strength (psi) at construction	Compression Strength (psi) of core	Time lapse before coring (months)
ST-F-013-2(208	297	610	2
ST-ETF-033-1(205)	368	727	6
IR-010-1(43)13	238	432	17
SP-ETF-046-(2206)	167	360	12
ST-F-024-3(202)	328	676	4

During construction, 50 blow Marshall briquettes molded at 140 F and broken in straight down, unconfined compression. Roadway cores are also broken in straight down unconfined compression.

1. Careful selection of projects to avoid those few roadways that are not suitable for recycling. Factors such as excessive patching, base/subgrade failures, weak subgrades, and so forth eliminate a pavement from consideration for ISCR.

2. Selection of type, grade, and amount of virgin binder. SBS polymer-modified high float emulsions have performed well and now are used exclusively in New Mexico ISCR.

3. Size and sequencing of rollers. Specifications require that 30+ ton pneumatic rollers be used for breakdown and continue until the roller "walks out" of the mix. Steel wheel rollers, either static or vibratory, are used for finish rolling to smooth the surface and achieve final density.

4. A target density based on 96 percent of 50-blow Marshall specimens compacted from the field mix is used to predict adequate compaction of the roadway.

REFERENCES

1. V. P. Puzinauskas and R. N. Jester. *NCHRP Report 259: Design of Emulsified Asphalt Paving Mixtures*. TRB, National Research Council, Washington, D.C., 1983.
2. A. J. Van Wijk. Structural Comparison of Two Cold Recycled Pavement Layers. In *Transportation Research Record 954,* TRB, National Research Council, Washington, D. C., 1984.
3. T. V. Scholz, G. Hicks, D. F. Rogge, and D. Allen. Use of Cold In-Place Recycling on Low Volume Roads. Draft for *Proc., 5th International Conference on Low Volume Roads*, Oregon State University and Oregon Department of Transportation, April 1990.
4. J. C. Hardin, S. D. Ban, and H. E. Schweyer. Rheology of Asphalt Emulsion Residues. *Proc.*, Vol. 48, American Association of Asphalt Paving Technologists, 1979.
5. H. W. Muncy, G. N. King, and J. B. Prudhomme. Improved Rheological Properties of Polymer Modified Asphalts. *Asphalt Rheology: Relationship to Mixture*. ASTM STP 941 (O. E. Briscoe, ed.), 1985.
6. G. N. King, H. W. Muncy, and J. B. Prudhomme. Polymer Modification: Binder's Effect on Mix Properties. *Proc.*, Vol. 55, American Association of Asphalt Paving Technologists, 1986.
7. D. Dekker. *Cold Mix In Place Recycling* (video). New Mexico Engineering Research Institute, 1987.

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