Purpose of Review:

The purpose of this review was to capture, for technical deployment, the most advanced uses of Cold-In-Place recycling (CIR) and then transfer the knowledge to all State Transportation Agencies (STA).

Through this sharing of information, we intend to showcase how other STA overcame barriers and advanced the routine use of CIR as a pavement rehabilitation strategy. "Best Practices" will be identified along with barriers and benefits.

Specifications, construction practices, implementation challenges, and identification of ongoing and completed research have been documented. This information will be disseminated to all STA through technical guidance, training, and guide specifications, as necessary.

Introduction on CIR:

Reflecting back to the energy crises in mid 1970 where the industry needs to take a hard look at innovation to stretch the dollar and conserve or stretch oil supply. Wit OPEC nations imposing embargos on oil shipments, the price of gasoline increased fourfold. The supply of asphalt binder was in short supply. Then in 1979, revolution in Iran led to a second shortage of oil. These events at that time forced the asphalt industry to take a strong look at ways to effectively recycle, and the in-place recycling experienced an increase in demand. This jump started advancements in equipment and technology that has changed the process from windrowed pile mixing to sensitive measurement devices that control the additive of binders based on the amount of material being milled. Advancements in equipment and chemical advances in binders has led to a process that produces a long lasting, durable, cost effective cold in-place recycling technology. FHWA wanted to showcase this process, provided technical guidance, showcase some actual case studies done by owner agencies that would led to increased use of this highly adaptable process to increasing higher volumes of roads.

What the county engineers know that have been using CIR for some time, in some cases nearly twice as long as the state dot engineers have been using it, is that it performs as needed, cost less, conserves material, and returns the road to use sooner and the driving public are satisfied due to more roads being improved for the money and less down time to the roads.

Today the need for technology that can rehabilitate an existing road, help widen, reshape and doing so at a cost that can increase the amount of lane miles

rehabilitated due to economic savings is a must. With the shrinking budget for highway work, it is noted that the current SAFETEA-LU highway bill funding level when you factoring in inflation and the increased cost of materials (did price of oil go up after the bill was passed, you bet it did) is fewer funds are available then the prior bill had for highway construction. While the states are facing an every increasing need to improve their highway and bridges, they have to do so with less federal aid dollars to cover the cost. Any potential technology that can provide the needed long life performance at a savings is something a good manger will be interested in. From FHWA's review of the cold in-place technology we found a tool that could and should be in every Chief Engineers bag of tools to be used at the proper time. Again, the right process at the right time is our policy for all types of highway/bridge preservation technology. Cold In-place Recycling needs to be used when it fits the need, done correctly, with careful consideration for the existing roadway conditions, and with knowledge of the future needs of the roadway.

More and more the volume of roads having successfully used CIR rehabilitation technology process has been increasing. In the recent past CIR was thought to only be potentially useful on low volume with low percent of trucks. But the states we visited have been extending the use to higher volumes of traffic; they have used CIR process on interstate highways with substantial percentage of trucks. Factor in the constant technology improvements, couple that with the focus of several major material suppliers and equipment producers improving their products, CIR should be in every DOT, City/County transportation agencies pavement rehabilitation program.

General Findings:

Our purpose for the review was to capture good practices, and state of use of the technology. Following is the three states method of use, design, and expectations for CIR technology.

NEW YORK

- CIR is used as one of a series of pavement treatments for maintenance engineers, for nearly 30 years, primarily on rural roads in fair condition.

- CIR (4") with a 1 ½" overlay is expected to last 10-15 yrs with little maintenance as compare to a 5-8 year life with a 1 ½" traditional overlay.

- Decentralized decision-making process by Resident engineers.

- CIR has been used on about 300 projects Since1991. Since 1999, averaged $2x10^6$ m^2/yr with roadways having 8,000 AADT, 10% T or less.

- Strong support from central office for specification development, information dissemination, and training.

- CIR methods attract only high quality contractors because of the cost of equipment and unacceptable cost of failure with strong commitment to quality and performance.

NEVADA

- NDOT has used CIR successfully for over 20 years.

- CIR and full FDR vs. conventional methods has saved NDOT over $600 million while providing long lasting pavements.

- NDOT has effectively Cold In-place Recycled 770 centerline miles or 11% of its system since 1997.

- CIR is recommended if there are functional deficiencies (non-load related cracking) when the pavement is structurally sound.

- Pavement rehab-type selection is based on engineering evaluation.

- NDOT' typical CIR is three inches (3"). Additional structural overlay is required for roadways with greater than 300,000 ESALs.

- Double-chip seal can be used for ESALs up to 400 ADT (both dir. w/low %trucks).

- Open graded Friction Coarse can be used on roadways when ESALs are projected to greater than 500,000.

- NDOT does not perform laboratory mix design testing. NDOT relies on research performed by the University of Nevada, Reno.

- Field adjustments are made based on contractor's experience. Typically, field application rates of CMS-2S are 1.0% to 1.5% by mass of material.

- NDOT has established standard structural layer coefficients of 0.28 for a CIR layer, based on NDOT's field performance, back calc. Mr. from FWD testing.

KANSAS

- KDOT has used CIR successfully since 1977, for nearly 29 years.
- Pavement distress that they were addressing was early full depth cracking, low subgrade strength, and poor ride from transverse thermal cracking.
- Quality aggregate availability issues as well as asphalt stripping problems have significantly contributed to the use of CIR in Kansas.
- Use of CIR in Kansas has improved the pavement smoothness condition significantly to rank them in the top five in the nation for overall ride smoothness.
- Kansas has recognized the scarcity of quality aggregate and has effectively reused existing HMA pavement by using CIR.
- Kansas has a well-documented Bid Tab system to track project details since October of 1992 to date.
- KDOT conducts field testing. SemMaterials provides mix design, construction field adjustments, and provides technical guidance.
- 4" of CIR, using 3%± emulsion (PG 58-28), 1.5% Lime, and 1½" OL has approximate life expectancy of7 yrs.
- CIR is about 45% less cost then a 4" HMA overlay.
- The CIR effort would have not been successful without the strong support from the KDOT upper management, strong partnership with emulsion supplier, and CIR construction industry.
- Contractors that specialize in CIR have a large capital equipment investment and recognize the importance of high quality workmanship.
- A structural coefficient value of 0.25-0.28 is assigned to CIR layer.

Best Practices:

The team asked the states and industry what was making CIR valuable to them, what actions did they take that made a difference in using the process, making it work, and having the industry as a partner. Follow is best practices that they saw as why it is working, and what they did to insure it did and continued to work. Sometimes it seems that the most obvious practice should be done, but there is always a reason to restate the obvious to insure it is repeated by others interested in using a technology. Having industry involved in the whole process will greatly help smooth the way. It should be noted that simple statement of recognizing that a contractor will only bid on a project if he can make money on the bid will help point out why it is important in having the industry participate in process, if there is no economic reason to bid, you will not have bidders. Making the process overly difficult or having unusual performance criteria will stymie the use of any technology. So we offer up some best practices, those that should help in the use of CIR in your state.

New York

- Relationship between the Liquid Asphalt Distributors Association (LADA) and State.
- Construction/inspection standards that clearly identify all party responsibilities. Shared risk issue.
- Weekly pre-construction meeting prior to paving followed up with a pre-pavement meeting on the first day.
- NYSDOT develops the mix design, determines the percent "add stone" (20% Max), and either the agency or contractor establishes the emulsion content (3% Min) depending on the type of contract.
- 7-day traffic requirement, prior to OL, as a performance-like acceptance mechanism.
- When possible, operate the CIR train against the flow of traffic.
- CIR is considered as a standard pavement.

NEVADA

- Once Nevada adopted CIR as standard practice, they have moved ahead to test the limits of CIR to raise the bar.

- NDOT considers CIR material as an "asphalt treated base" rather than hot mix and treats it as such.

- NDOT requires Ride specifications, using a California type Profilograph. PRI of 5"/mile with HMA OL and 10"/mile without OL.

- NDOT is committed to a strong partnership with all parties involved in CIR and builds on this through constant communication.

- NDOT requires a mandatory 2-hour workshop for all personnel involved with CIR project

- The addition of lime slurry has improved the performance of CIR.
- NDOT has end-product specifications. Contractor performs QC and field adjustments. NDOT requires the contractor to overlay the cold in-place layer after min. 10 and max. 45 days of curing.

- NDOT requires relative density, for optimum compaction, by conducting a 1000' test strip during the first day of production.

- Equipment calibration prior to each project production to ensure proper application rates of materials, i.e. emulsion, lime, and aggregate weight pulled off the belt scale.

- NDOT is continuously monitoring all CIR projects and incorporating the data into a database that currently resides at UNR and NDOT Materials Division.

- NDOT's annual project list is available on monthly basis for contractors to anticipate how many CIR will be advertised on monthly basis. Contractors appreciate this and consider it a very reliable list.

KANSAS

- Relationship between emulsion suppliers, CIR construction industry, KDOT.

- KDOT primarily cold in-place recycle 4" of existing Hot Mix Asphalt (HMA) and overlay it with 1 ½" of new wearing course using PG 64-28 to PG 76-28.

- Using engineered emulsion with lime slurry is an improvement for overall performance.

- Lime slurry is providing early strength and anti-stripping, while the emulsion is providing a good bond.

- Proper project selection has resulted in a better CIR equipment/process assurance.
- KDOT reviewed the experiences from New Mexico to utilize their best practices and adapt them to KDOTs geographical condition of shortage of good aggregate and poor subgrade.

- KDOT ride specification on CIR has resulted in an overall better quality workmanship.

- KDOT relies on test strips to establish density targets.

Barriers Overcome

When a new process is used, there seems to be a variety of barriers that must be attacked to use, or continue to use. It is hoped that buy showing what the three states had as challenges, it will help other states that have concerns, or barriers that have prevented wider use of CIR to look to tackle them and include CIR as a tool for pavement rehabilitation.

NEW YORK

- Lack of knowledge, concerning performance and production processes, was overcome by educating contractors and NYSDOT personnel.

- Innovative contracting thru the use of an Office of General Services (OGS). Line-item contracts based on quantities, cost, and conditions.

NEVADA

- NDOT, now, corrects soft subgrade problems prior to CIR.

- Where ADT is greater than 400, a structural overlay rather than chip seal surface treatment is considered.

- NDOT has encountered non-uniform depth of existing pavements so they now take core samples across the entire width of the pavement to ensure structural section depth to better control the removal depth.

- Lack of knowledge, concerning CIR performance and production processes, was overcome through partnership with contractors and high emphasis on training.

KANSAS

- Early trials using various emulsions, dry lime, and various asphalt grades helped KDOT to learn and understand the overall CIR process and what should be used for their pavements, soils, and climate conditions.

- The performance of Fly Ash was found not to be acceptable. KDOT has overcome this by using lime slurry and engineered emulsion. Use of Fly Ash was discontinued in November 2001.

- KDOT improved proper project selection by identifying weak subgrade areas.

- Quick-set engineered emulsion corrected early raveling and rutting issues.

- KDOT improved issues related to wet weather conditions by the use of fast setting emulsions. Better curing speed can help in rain shower issues.

Current Barriers/Issues

As to be expected, even those states that have developed a strong confidence is using CIR, have questions that they would want to have addressed. It seems it is universally accepted that engineers need to have a design process that accounts for all the material properties, weather impacts and traffic loadings imparted to the finished pavement and how that all affects long term performance. Granted that a design process is needed, the details and the how too is what represents a degree of differences that changes based on who is asking. It is noted that a design process is warranted to provide degree of confidence in bidding, and getting a final product that meets expectations. FHWA understands and will strive to facilitate a process where the end results will be a national design guide for CIR design process. Following are observations that the states and reviewers noted during our

visits that can be useful in discussions on what the industry and federal/state governments need to accomplish for increase use of CIR.

New York

- CIR is as much an art as it is science.
- No nationally recognized mix design process.
- No construction oversight acceptance testing.
- Restricted use for low volume roads with less than 8,000 AADT.
- Reliance on skill and expertise of contractors.
- CIR is not taught traditionally. It is typically excluded from university curriculum.
- There are no density requirements.
- Capital-intensive investment for contractors vs. sufficient work volume.

NEVADA

- Limited number of CIR contractors in the western part of the US causes scheduling conflicts in multiple states
- CIR is more of an art rather than science.
- Contractors have difficulty maintaining qualified operators.
- Even with 20 years of experience, some NDOT and contract staff still has reluctance using CIR.
- Likely candidate projects that require nighttime construction cannot use this technology because of temperature concerns.
- Curing time limits CIR in urban areas.

KANSAS

- Lack of project to bid on, 12 in 2005 to a projected 3 in 2006, is a big concern for the CIR industry.

- KDOT is looking at future research on using 2" CIR vs. traditional 4" for cost and performance effectiveness.

- KDOT ride specification has resulted in better quality workmanship.

- A potential newer use of RAP or aggregate as a mean to increase pavement thickness to allow the use of CIR to potentially add structural capacity is a process that is being considered by state along with the contractors.

Future Needs:

When asked to the states, what they need for increasing the use of CIR or what they see as lacking to permit use of CIR in their states or other states that are not using CIR, they offered these ideas and observations. Again most of these are good items that FHWA and our partners should focus on and tackle in order to increase the use, have a higher degree of comfort for use, and use on higher and higher traffic volume roads. Having input from our states is critical in helping FHWA to focus on the needs, improving where of research and deployment dollars should go.

New York

- Synthesis of past research.

- Reports on long-term performance.

- Results of CIR uses on higher volume roads.

- CIR should be marketed as a pavement rehabilitation or pavement preservation tool depending on the magnitude of the project.

- Chip seal performance over CIR.

- The use of mineral fillers (e.g., fly ash or cement) and their effects on performance.

- Appropriate control parameters for this process

- Structural number

NEVADA

- NDOT will be completing new product evaluation, using Reflex and PASS, as substitute for CMS-2S binder currently required on all projects.

- NDOT would like to learn from other states' experiences using different binders.

- NDOT has recently used CIR for a 12 lane-mile of I-80. This section has 40% trucks and 7000 ADT with 6 percent grade. Performance characteristics of this section are closely monitored, and it will be reported.

KANSAS

- The need for better education and support to target pavement designers, consultants, and decision makers.

- Nationwide synthesis of past research.

- Effects of adding stone or RAP for CIR process improvement.

- Reports on long-term performance.

- Results of CIR uses on higher volume roads.

- CIR should be marketed as a "pavement rehabilitation" or "pavement preservation" tool depending on the magnitude of the project.

- Better documentation on performance of Chip seal and similar thin surface treatments over CIR.

- State DOT partnership with industry and contractors in working together to address:

    - Curing time,
    - Moisture content specification,
    - Overlay criteria, and
    - Alternate solutions such as fog seal, etc.

- The use of mineral fillers and their effects on performance.

- The capital-intensive investment for contractors, and maintenance of skilled labor pool specific to this industry, requires having a sufficient volume of work. This is difficult due to current funding constraints, and competing program needs.

- AASHTO specifications for CIR.