Chapter 13
In-Place-Recycling

From… Maintenance Technical Advisory Guide (MTAG)

In-Place Recycling
Manager's Overview

From… Maintenance Technical Advisory Guide (MTAG)

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Introduction to In-Place Recycling

- What is In-Place Recycling?
  - Cold In-Place Recycling (CIR)
  - Hot In-Place Recycling (HIR)
- Why use In-Place Recycling?
- When to use In-Place Recycling?
- Where to use In-Place Recycling?

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What is Cold In-Place Recycling?

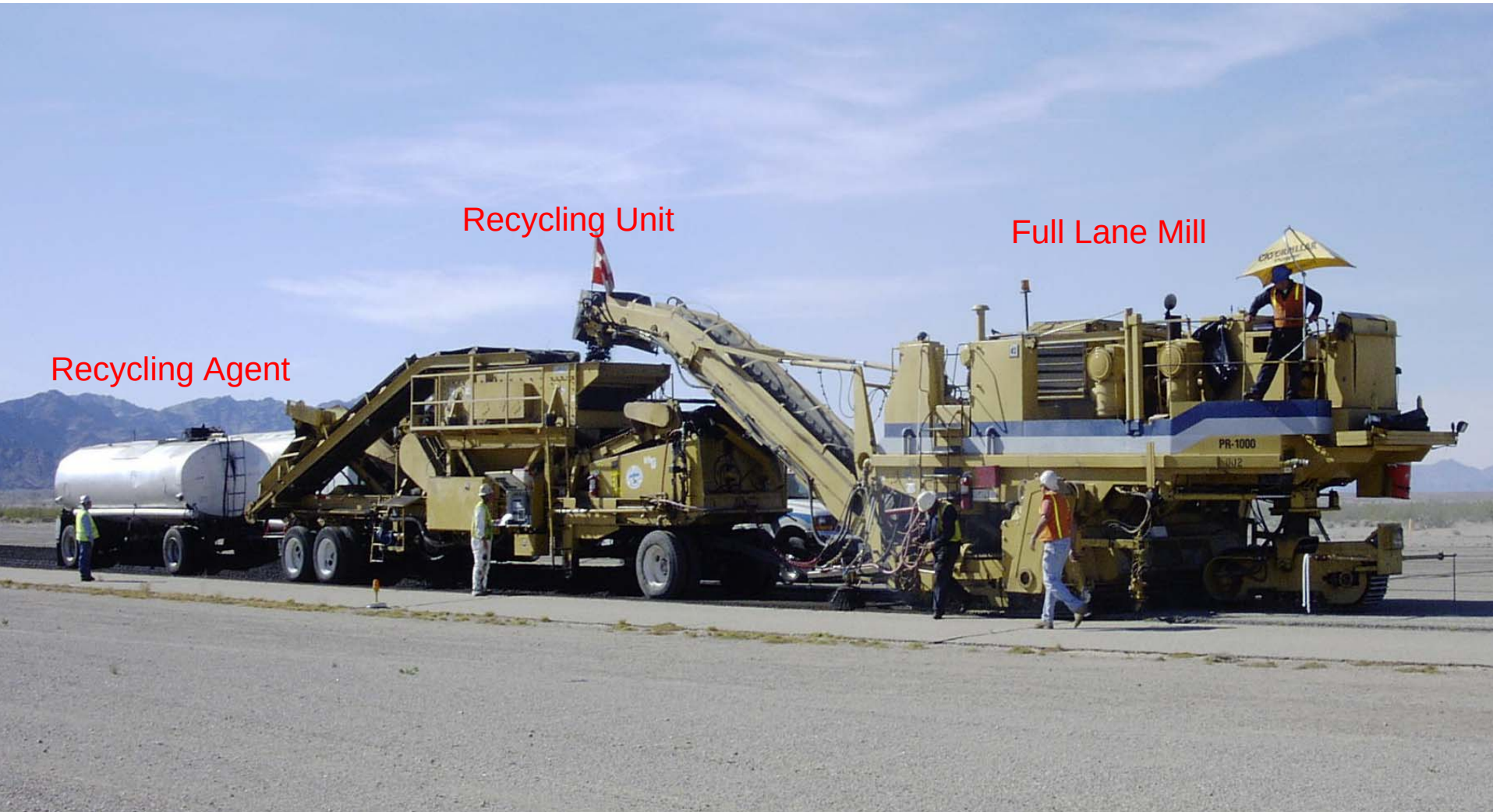
Distressed converted to New pavement using a train of equipment that:

- **Mills deteriorated pavement**
  - **Reclaimed asphalt pavement (RAP)**
- **Crushes RAP to gradation**
- **Mixes with recycling agent**
- **Re-Paves recycled mix**
- **Compacts to specified density**
- **Readies for surface treatment**

Cold In-Place Recycling

- Generally two methods:
  - Crushing and sizing unit with separate paving spread (multi unit)
  - Breaker bar system with attached screed (single unit)
- Typical depth: 2 to 4 inches
- RAP mixed with recycling agents
  - Emulsified Recycling Agent
  - Cold Foamed Asphalt
- Other additives may be added for quick strength or quick release to traffic.
  - Cement or Lime (Typically slurry form)
- Relaid and compacted
- Fog seal and sand blotter applied
- Opened to traffic at the end of shift
- Applicable for all traffic levels
- Surface in 7-10 days

CIR Crushing and Sizing Train (Variations But Same Concept)



Material Windrowed and Picked Up

Laid Down and Rolled

Another System with Breaker Bar

With Screed Attached

Because of higher void ratio's CIR surfaces must be sealed.

Chip Sealed – Low Volume Highways

Fog Sealed or Slurry Sealed
Low volume – Shoulders and Lots

HMA Overlaid – Higher Volume highways

What is HIR?

Distressed converted to New pavement using a train of equipment that:

- **Heats deteriorated pavement surface**
- **Mills Reclaimed asphalt pavement (RAP)**
- **Mixes with rejuvenating agent and possibly new HMA**
- **Re-Paves recycled mix**
- **Compacts to specified density**

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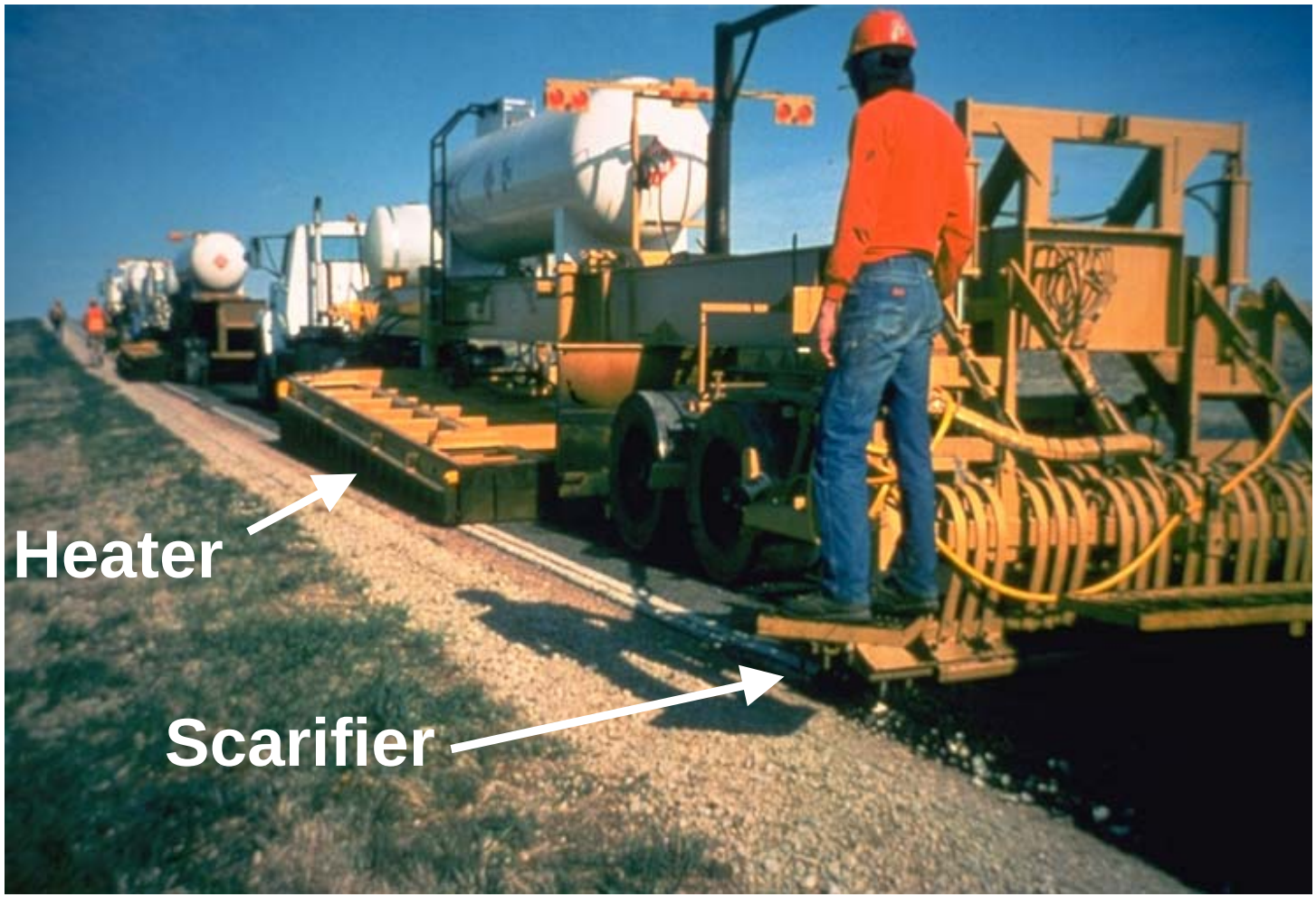
Hot In-Place Recycling

- Three methods
  - Surface recycling
  - Remixing (NSSP)
  - Repaving (NSSP)
- Typical depth: 0.6 to 2.0 in
- RAP mixed with rejuvenating additives
- Admix - Additional hot mix AC may be added
- Relaid and compacted
- Immediate opening to traffic
- Applicable for all traffic levels

HIR Construction

Surface Recycling—Equipment



HIR Construction

Remix – Multiple Stage

HIR Construction

Repaving—Single Stage Method

Why use In-Place Recycling?

- **Maintains and Restores Deteriorated Pavements**
- **Disrupts Reflective Cracking**
- **Cost Effective up to 50% Less than Traditional Method of Mill and Fill**
- **Reduction in Working Days**
- **Lowers User Delays**
- **Conserves Natural Resources**
- **Energy Efficient**
- **Eliminates 90% of Construction Truck Traffic**
- **Recycling Credits**

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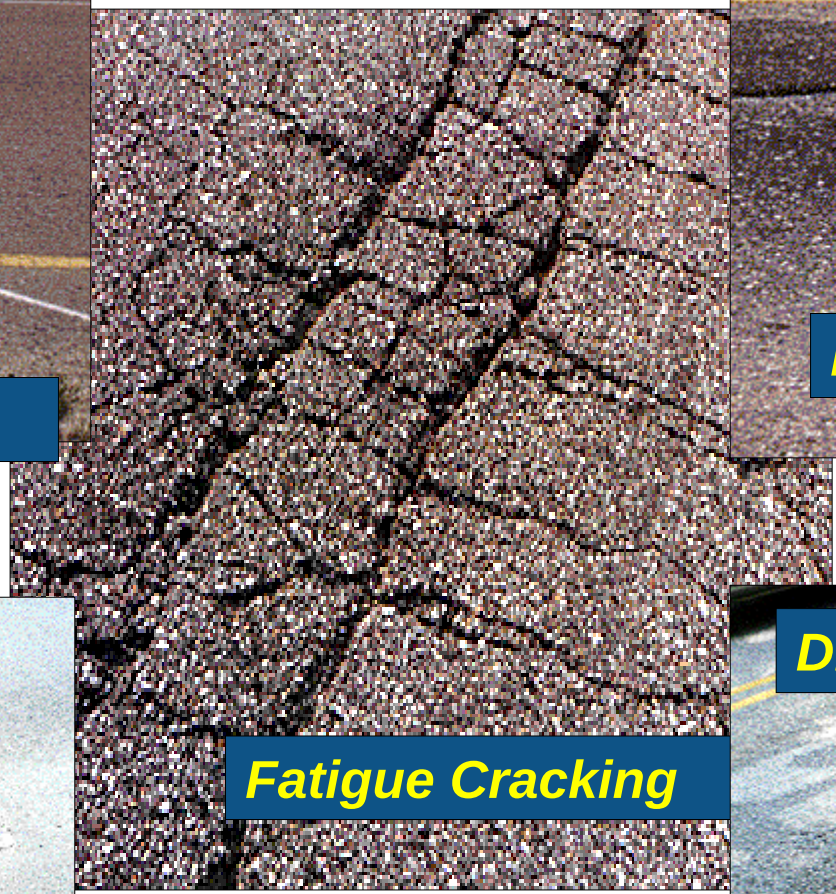
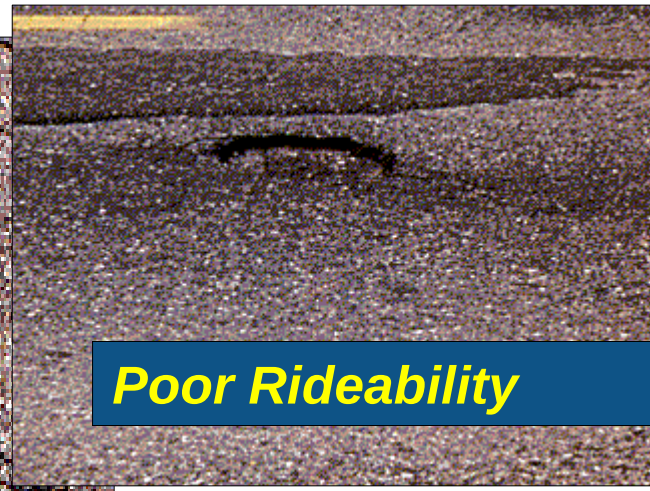
When to use In-Place Recycling?





Where to use In-Place Recycling?

City Streets

Interstate Highways

Virtually No Traffic Limitations

Airports

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Where to use In-Place Recycling

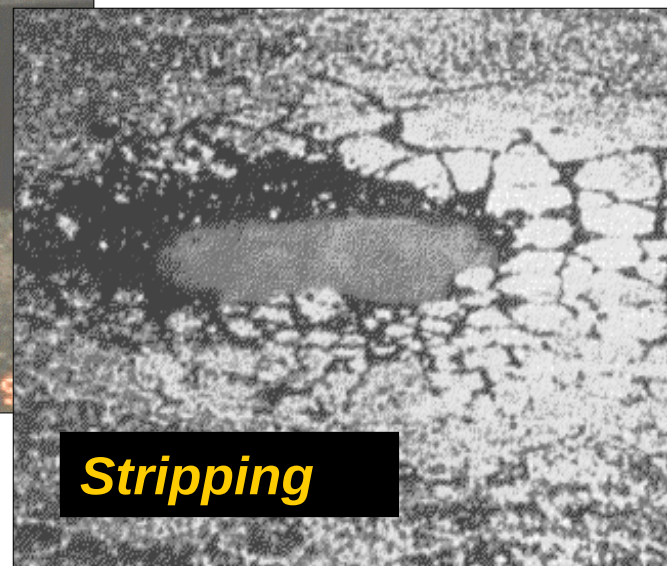
- Anywhere mill and fill is considered
- Will handle all cracking distress provided not base related
- Where surface maintenance is no longer effective
- To repair raveling & potholes
- Where safety is a concern
- When life cycle costs dictate
- No limitation to traffic/ADT

Pavements not to be In-place Recycled

Paving fabric makes it tough!

- ***Possible but messy for CIR***
- ***Not good for HIR***

Asphalt Rubber Type G or O



Will not fix base problems!

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Training Modules Available

1. Cold In-Place Recycling
   - Design, Materials & Specifications - Module 13-1a
   - Construction & Inspection - Module 13-1b

2. Hot In-Place Recycling
   - Design, Materials & Specifications - Module 13-2a
   - Construction & Inspection - Module 13-2b

End Overview

Begin Project Design, Materials & Specifications

Module 13-1a

Cold In-Place Recycling

Design, Materials & Specifications

From… Maintenance Technical Advisory Guide (MTAG)

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Topics to be covered

- Project Selection
  - Distress and Other Application Considerations
  - Performance
  - Cost
- Design Considerations
  - Mobilization
  - Typical Materials Items
  - Quantity Calculations
  - Production Rates
    - Roadway Widths
    - Roadway Geometry
  - Traffic Control
  - Sample Project
- Materials and Specifications (including SSP's)

Three Basic Steps In The Selection Process

1. Assess the existing conditions.
2. Determine the feasible treatment options.
3. Analyze and compare the feasible options with each other.

Initial Site Assessment – *Distress Identification*

- Types of Distresses and Definitions
- Definitions from:

"**DISTRESS IDENTIFICATION MANUAL** *for the Long-Term Pavement Performance Program*"

PUBLICATION NO.
FHWA-RD-03-031
JUNE 2003

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MTAG Chapter 3 , Figures 3-3 and 3-4

Factors to Consider When Choosing a Maintenance Treatment

- Will the treatment address the distresses present? (i.e., Will it work?)
- Can the required preparation for the treatment be carried out?
- Is the treatment affordable and cost effective?
- Will the treatment be performed before the situation being addressed changes?

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Evaluation for Suitability of Cold In-Place Recycling

- Perform Visual Site Inspection
  - CIR suitable for all levels of cracking provided cracking is not induced by structural deficiency/base failure.
  - Suitable for rutting < 3/4” Rutting not associated with unstable mix.
  - Suitable for severe raveling and oxidation.
  - Anywhere a mill and fill is considered.
  - Structurally sound base.
    - CIR will not correct unstable base problems
    - Can be used for areas of isolated base failure
- Determine Existing Pavement Thickness
  - CIR typically 2 to 4 inches in thickness.
  - Thick enough to take to stable base or leave 1” of existing pavement over native soils.
- Project Large Enough to Accommodate Train

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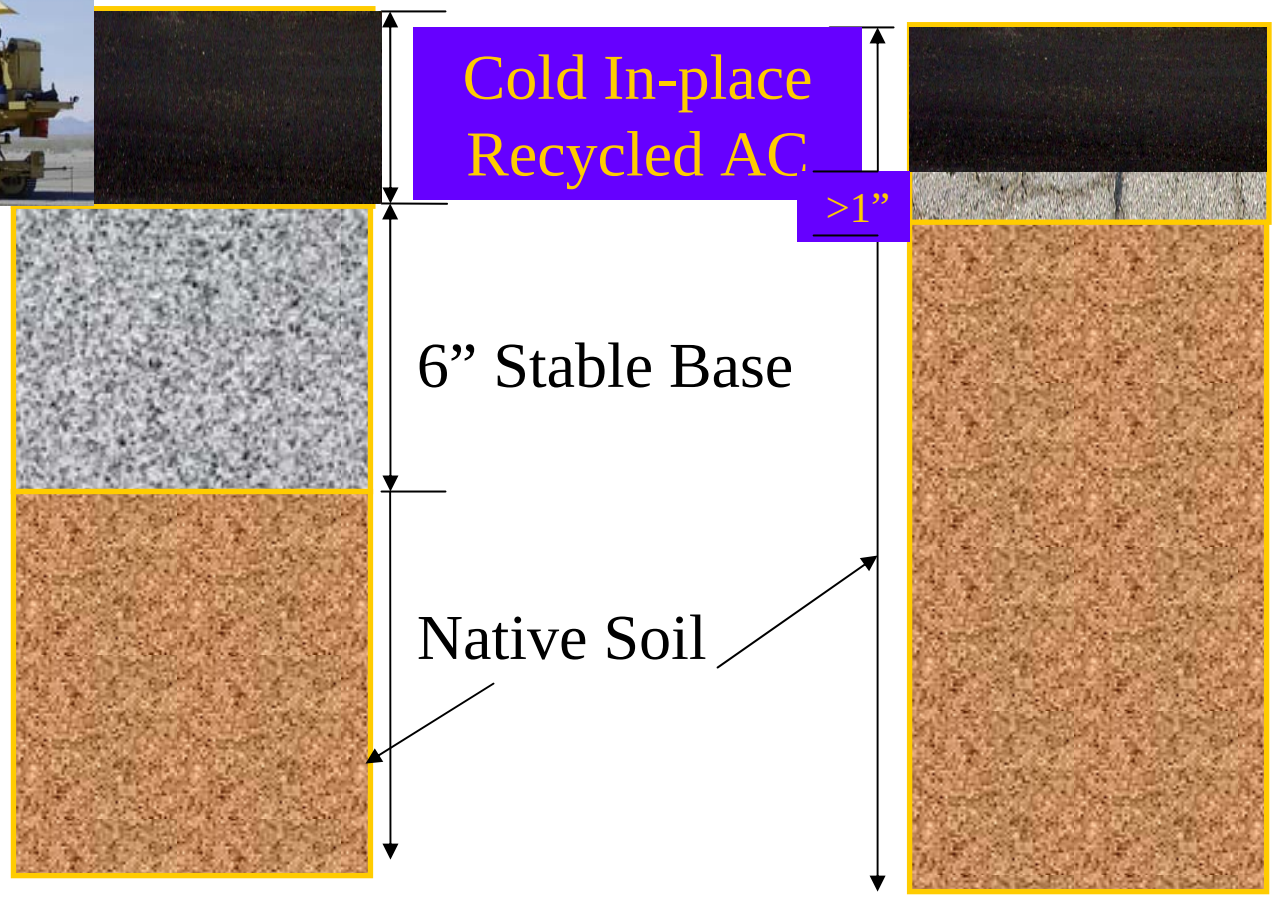
Cold In-Place Recycling

Recycle AC to:

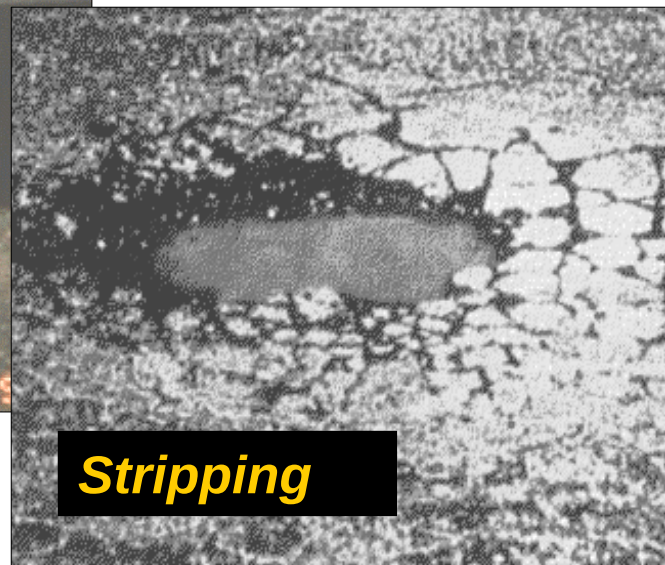
- Stable Base
- Within 1” of less Supportive Material



Pavements not to be Cold In-place Recycled

Paving fabric makes it messy!

~~***Asphalt Rubber Type G or O***~~



Avoid base problems!

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Summary of Pavement Conditions that can be addressed by Cold In-Place Recycling

Ruts	< 3/4 in	√
Crack	Fatigue	?[1]
	Longitudinal	√
	Transverse	√
	Block	√
Surface	Dry	√
	Flushing	√
	Bleeding	√
	Variable	√
Raveling		√
Potholes		√
Texture - Rough		√

Ride - Poor	√
Poor Drainage	no
Snow Plow Use	√
Low Skid Resistance	√
Asphalt Rubber	
Type O or Type G	no
Terminal Blend	√
Stripping Pavement	?[2]
Paving Fabrics	?[3]
Structural Deficiency	no
Base Failure	no

Questions?

1. Provided not base, subgrade or unstable mix related.
2. Depends on severity. May be able to add antistrip additive.
3. No problem if properly installed. If not, logistical issue with additional costs for disposal.

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Performance Expectations

- Life Expectancy
  - 10-15 years (with chip seal, longer with overlay)
  - Restores old pavement
  - Restarts design life
- Improves Ride Quality (Smoothness)
- Mitigate Refection Cracking
- Preventive Maintenance Activities are similar to that for HMA

Issues Affecting Performance

- Decreased service life if treatment is applied at the wrong time of year. Adequate cohesive strength is not achieved if curing is incomplete.
- Failure to recognize under designed pavements. CIR will restore existing pavement but will not restore structurally deficient roads.
- Using insufficient rollers or rollers without working water.
- Insufficient sunlight for cure.
- The main method of failure is excessive raveling during initial traffic wear. Minor raveling/shedding is expected and mitigated by a flush coat.
- Secondary compaction from traffic can be caused by insufficient rolling during both the initial compaction and re-rolling stages.

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Future Maintenance Activities Recommended

- Future PM applications may include:
  - Fog Seal
  - Chip Seal
  - Micro Surfacing/Slurry
  - Thin Overlay/BWC
  - Cold in-Place Recycling
  - Mill and Replace
  - Crack Sealing
  - Re-Striping

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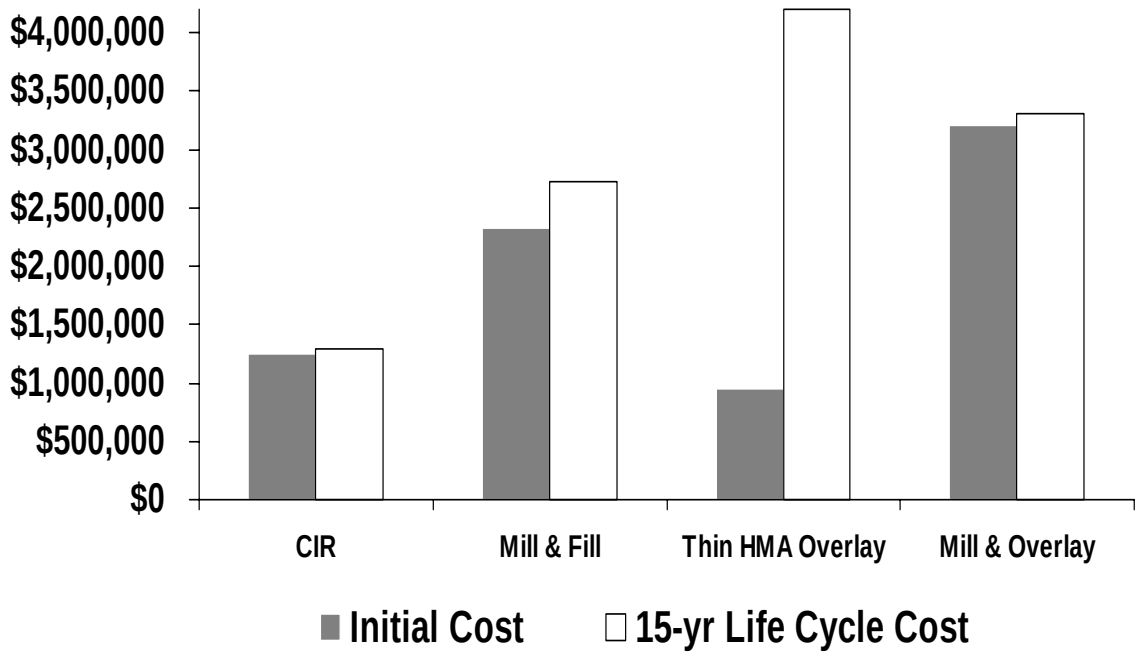
Application Cost and Life Cycle Data (from Handout)

- Expected Life and Cost Data from Strategy Selection Group

CIR is Typically Utilized for the Initial and Life Cycle Cost Savings

- Costs up to 50% of traditional method of mill and fill (same thickness)
- Cost savings are a result of:
  - Value of existing aggregate and binder
  - Cost of milling
  - Trucking of millings
  - Dump fees of RAP
  - Cost of new AC



Cost Dependent On:

- Length of Project
- Depth of the Recycle (2” – 4”)
- Road Geometry
  - Shoulders at different cross slope and variable width
- Work Window
  - Emulsified recycling agent must be during daylight hours
  - Asphalt foam possible to be done at night
  - Significant costs associated with moving recycle train on and off the roadway each shift
- Accessibility of Water and Staging Areas
- Oxidation of Existing Asphalt Binder
  - More recycling agent needed
- Environmental Conditions
  - Temperature
  - Humidity
  - Shading from trees
- Need for Recycling Additive
  - Quick cure required
  - Poor curing conditions

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Costs Generally Independent Of:

- Width of Project
  - Supplemental mill can be added
- Distress of Pavement
- Traffic Conditions

Estimated Costs 2007

- 2” deep CIR $4 to $8 per sq yard
- 3” deep CIR $5 to $9 per sq yard
- 4” deep CIR $6 to $10 per sq yard
- Typical Costs for Milling,Processing, Delivery to Paver
  - $35.00 to $45.00/Ton

Design Considerations

- Mobilization
- Typical Materials Items
- Quantity Calculations
- Production Rates
  - Roadway Widths
  - Roadway Geometry
- Traffic Control
- Sample Project

Mobilization

- Recycle train, which may include large mill, smaller mill, recycle unit, asphalt/emulsion trailers, distributor truck, slurry or spreading equipment for recycling additive, asphalt paver, pickup machine and rollers

- At the end of each shift, must have nearby site to park the train to minimize cost associated with breaking the train down and moving on and off project. Milling machine cannot travel effectively more than a few hundred yards. If it requires removal from the site a specialized lowbed and disassembling and reassembling will be necessary.

- Approximately 4,000 gallons of water per hour is utilized for CIR

Typical Materials Items

- Recycling Agent (Bid Item by Ton)
  - Emulsified Recycling Agent
    - Typically 2% to 4%
  - Cold Foam
    - Typically 1% to 3%
- Recycling Additive (Bid Item by Ton)
  - Cement or Lime
    - Typically 0.5% to 1%
- Cold In-place Recycling (Bid Item by SY)
  - Flush Coat
    - Diluted (1:1) Emulsified Recycling Agent
    - Diluted (1:1) SS1h, CQS, CS1h
      - Typically 0.07 to 0.13 gals/sy
  - Sand Blotter
    - Typically 2 to 3 pounds/sy

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Quantity Calculations

- Lane Mile (LM) (Centerline to Fog Line)
  - 5280 ft x 13 ft = 63,360 SF = 7040 SY
  - When calculating quantities, application should extend beyond fog line
  - Shoulder quantities need to be calculated independently
  - Shoulder application may vary from mainline application
  - Typical Shoulder calculation:
    - 3 ft wide x 5280 ft length = 15,840 SF = 1760 SY
  - Typical 2 Lane Roadway Calculation
    - (2 x 7040) + (2 x 1760) = 17,600 SY

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Quantity Calculations

- When calculating quantities for each application use highest application rate per SY for estimate purposes
  - Example:
    - Specification 37-1.06 Spreading of screenings for chip seal application. Range is 13-20 lb per SY. ***Use 20 lb for estimating quantities***

Example of Actual Cold In-Place Recycling Calculation

Job Conditions

- Typical 2 Lane Roadway 1 mile long with 3 foot shoulders = 17,600 SY
- 5 mile section of roadway = 88,000 SY
- CIR Depth of 3” at 3.5% Emulsified Recycling Agent and 0.75% Recycling Additive

Calculation of Quantities

- Emulsified Recycling Agent Tons
  - 88,000 x 9 sf/sy x 3-inches / 12-inches/ft x 145 lbs/sf / 2000 lbs/ton x 0.035 = 503 Tons of Emulsified Recycling Agent
- Recycling Additive Tons
  - 88,000 x 9 sf/sy x 3-inches / 12-inches/ft x 145 lbs/sf / 2000 lbs/ ton x 0.0075 = 108 Tons of Additive

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Production Rates and Paving Days

- Production Rate
  - Mainline Paving - 350 tons per hour.
  - About 2.25 miles per day at 13 to 17 ft wide.
- (# of Paving Days)
  - Minimum of 2 to 4 days to make cost effective.

Roadway Geometry and Widths

- Main mill is 12.5-feet wide. Allows for full lane width and overlap per specifications. Shoulders up to 5-feet wide can be accomplished with a supplemental mill that works in parallel.
- Wider shoulder passes are accomplished by a pass with the main mill and large overlaps. Some inefficiency.
- In urban areas:
  - Curbs and gutters are header cut to allow for the overlay.
  - Utilities are adjusted down prior to recycling and then up thorough the overlay
  - Equipment is 14-feet tall in most cases. Watch for low power lines and tree limbs.

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Traffic Control

- Typical release to traffic 2 to 3 hours behind paver after flush coat and sand blotter.
- Two-lane roadways 3 to 4 mile closure. Pilot traffic around train in operation.

Sample Design Example

- Item codes
- Item descriptions
- Unit of measure

Typical Contract Items - CIR with Emulsified Recycling Agent

ITEM NO.		ITEM CODE	ITEM DESCRIPTION		UNIT OF MEASURE	ESTIMATED QUANTITY
1		074016	CONSTRUCTION SITE MANAGEMENT		LS	LUMP SUM
2		074019	PREPARE STORM WATER POLLUTION PREVENTION PLAN		LS	LUMP SUM
3	(S)	120090	CONSTRUCTION AREA SIGNS		LS	LUMP SUM
4	(S)	120100	TRAFFIC CONTROL SYSTEM		LS	LUMP SUM
5	(S)	128650	PORTABLE CHANGEABLE MESSAGE SIGN		LS	LUMP SUM
6	(S)	150662	REMOVE METAL BEAM GUARD RAILING		M	65
7		150771	REMOVE ASPHALT CONCRETE DIKE		M	1,180
8	(S)	151572	RECONSTRUCT METAL BEAM GUARD RAILING		M	1,830
9	(S)	153103	COLD PLANE ASPHALT CONCRETE PAVEMENT		M2	570
10		198007	IMPORTED MATERIAL (SHOULDER BACKING)		TONN	470
11		390095	REPLACE ASPHALT CONCRETE SURFACING		M3	87
12		390102	ASPHALT CONCRETE (TYPE A)		TONN	3,860
13		394044	PLACE ASPHALT CONCRETE DIKE (TYPE C)		M	19
14		394046	PLACE ASPHALT CONCRETE DIKE (TYPE D)		M	160
15		394048	PLACE ASPHALT CONCRETE DIKE (TYPE E)		M	230
16		394049	PLACE ASPHALT CONCRETE DIKE (TYPE F)		M	790
17		011871	EMULSIFIED RECYCLING AGENT	CIR	TONN	220
18		011872	COLD IN-PLACE RECYCLING ADDITIVE	CIR	TONN	54
19		011873	COLD IN-PLACE RECYCLING	CIR	M2	45,000
20		820107	DELINEATOR (CLASS 1)		EA	280
21		820151	OBJECT MARKER (TYPE L-1)		EA	3
22	(S)	011874	END CAP (TYPE C)		EA	5
23	(S)	839581	END ANCHOR ASSEMBLY (TYPE SFT)		EA	5
24	(S)	839584	ALTERNATIVE IN-LINE TERMINAL SYSTEM		EA	2
25	(S)	839585	ALTERNATIVE FLARED TERMINAL SYSTEM		EA	3
26	(S)	840561	100 MM THERMOPLASTIC TRAFFIC STRIPE		M	24,500
27	(S)	840570	100 MM THERMOPLASTIC TRAFFIC STRIPE (BROKEN 10.98 M - 3.66 M)		M	550
28	(S)	850111	PAVEMENT MARKER (RETROREFLECTIVE)		EA	1,680

Material and Specifications

- NSSP for Cold In-Place Recycling Using Emulsified Recycling Agent.

- Lab Procedure 8, “Method of Test for Determining the Percent of Emulsified Recycling Agent to Use for Cold Recycling of Asphalt Concrete,” available on the internet at www.dot.ca.gov/hq/esc/Translab/fpmlab.htm.

- NSSP for Cold Foam Asphalt Recycling. Mix design incorporated into specification.

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Mix Design Cold In-Place Recycling

- Prior to bidding the project State should core.
  - Check existing pavement for adequate thickness.
  - Look for fabric and pavement type.
- Part of the contract is for contractor to core pavement to obtain samples for mix design using a systematic engineered system.
- Contactor optimizes the percentage and type of recycling agent unless state specifies asphalt foam. For asphalt foam the optimum percent asphalt is determined in a mix design by the Contractor
- Contactor determined the need for, percentage of and type of recycling additive at the mix design.

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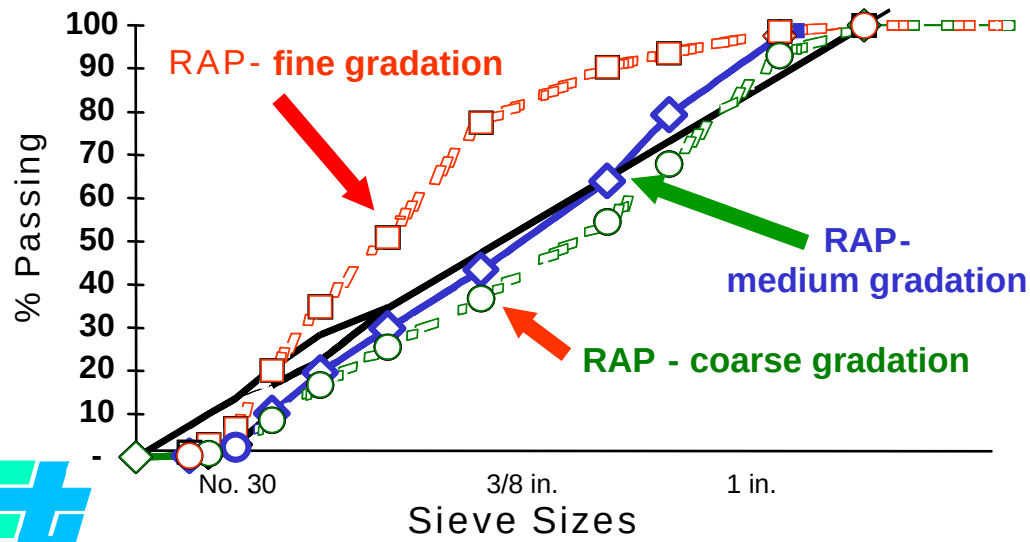
Mix Design

- Defined sampling procedure

Lab RAP Analysis

- Lab
  - Field cores crushed to specific gradation bands
  - A design made for 2 of the gradations



- Field
  - Field gradation depends upon multitude of factors: milling, weather, etc.
  - Gradation compared to lab tested band
  - Recycling agent percentage based on applicable gradation

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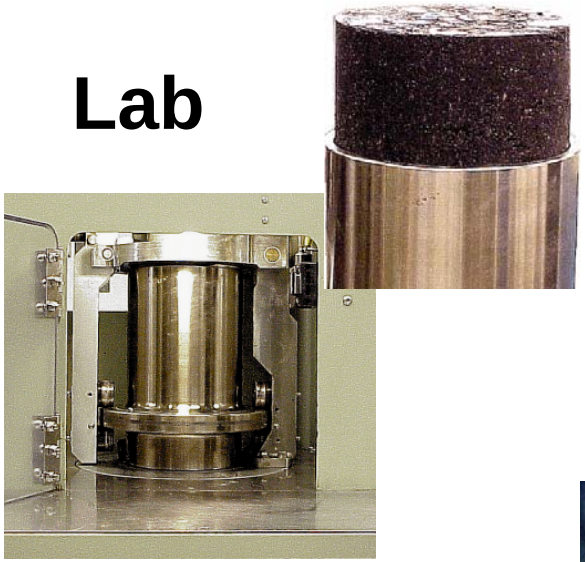
Density Compaction Effort

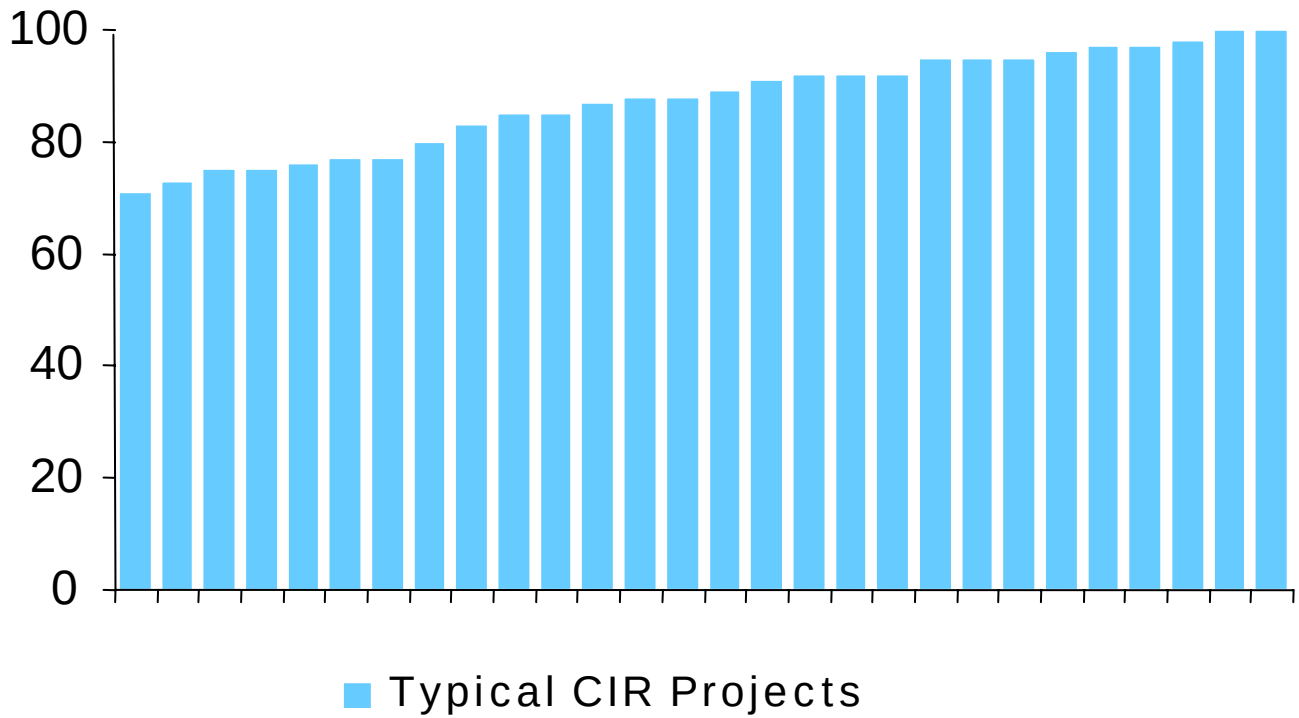
Superpave Gyratory Compactor or Marshal Compactor

Lab



Field

Moisture Sensitivity by Retained Marshal Stability



Raveling Test

Proper CIR

Inadequate CIR

End Project Design, Materials & Specifications

Begin Construction Inspection

Module 13-1b

Cold In-Place Recycling
Construction & Inspection

From… Maintenance Technical Advisory Guide (MTAG)

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Topics to be covered

- Understand/Review Specifications
- Safety and Traffic Control
- Surface Preparation
- Equipment Requirements
- Construction Sequencing
- Required Application Conditions
- Application of Materials
  - Production Rates
  - Roadway Geometry and Paving Widths
- QA/QC
- Application Problems and Solutions

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Understand/Review Specifications

- Review Construction Manual Chapter
- Project special provisions

Safety and Traffic Control

- Traffic control is required both for the safety of the traveling public and the personnel performing the work. It is also used to ensure the new surface is compacted and cured sufficiently prior to reopening the surface to traffic.

- Traffic control includes placing construction signs, construction cones and/or barricades, flag personnel, and pilot cars required to direct traffic clear of the maintenance operation.

Traffic Control

- Prior to opening the recycled pavement to traffic, signs shall be furnished and placed adjacent to both sides of the traveled way where recycling operations are being performed. The first C6 sign in each direction shall be placed where traffic first encounters a recycling location, regardless of which lane the recycling is being performed on. The W6 (35) signs placed in those areas with posted speed limits of less than 40 MPH. The signs shall be placed at maximum 600-m intervals along each side of the traveled way and at public roads or streets entering the recycled pavement surface area as directed by the Engineer.

- The C6 and W6 signs shall be maintained in place at each location until the final surface course is applied.

- The Contractor shall be responsible for protecting and maintaining the recycled pavement material layer until the initial layer of asphalt surfacing is placed.

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OPENING TO TRAFFIC

- After rolling is completed.
  - Generally after some cure (2 hours).
  - After the flush coat and sand blotter has been applied.
  - After signs are furnished and placed adjacent to both sides of the traveled way where recycling operations are being performed.

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Surface Preparation

Before any recycling work begins, the Contractor shall prepare the existing roadway by:

1. Removing from the entire roadway width dirt, vegetation, standing water, combustible materials, oils, raised roadway markings, and other objectionable materials approved method;
2. Accurately referencing the profile and cross slope as shown on the plans for the finished surface of the recycled pavement material;
3. Accurately marking the proposed longitudinal cut lines on the existing roadway surface prior to commencement of cold in-place recycling operations.

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- **Crushes RAP to gradation**
- **Mixes with recycling agent**
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- **Compacts to specified density**
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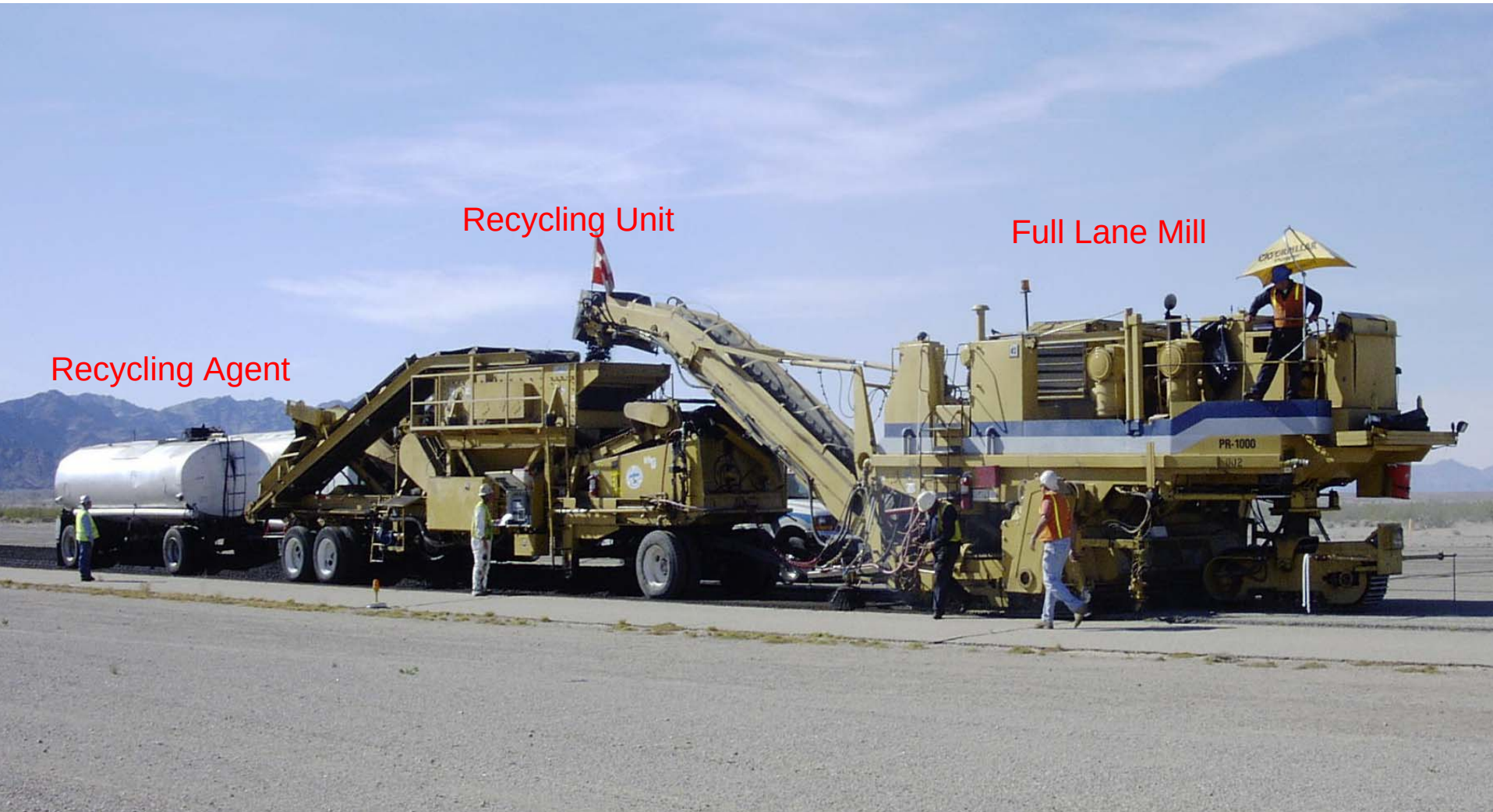
  - Cement or Lime (Typically slurry form)
- Relaid and compacted
- Fog seal and sand blotter applied
- Opened to traffic at the end of shift.
- Applicable for all traffic levels

Cold In-Place Recycling Equipment

- Pavement Milling Machine
- Supplemental Milling Machine
- Crushing or Sizing Equipment
- Mixing and Proportioning Equipment (Pugmill)
- Water Storage and Supply Equipment
- Cement or Lime Slurry Storage and Supply Equip.
- Spreading Equipment
- Compacting Equipment

CIR Crushing and Sizing Train (Variations But Same Concept)



Pavement Milling Machine

- Main Mill
  - Self-propelled
  - Minimum 12.5 ft cutter
  - Automatic depth controls to maintain the depth
  - Control cross slope
- Supplemental Mill
  - Put millings in front of main mill to pickup and process
  - Shoulders and misc. areas

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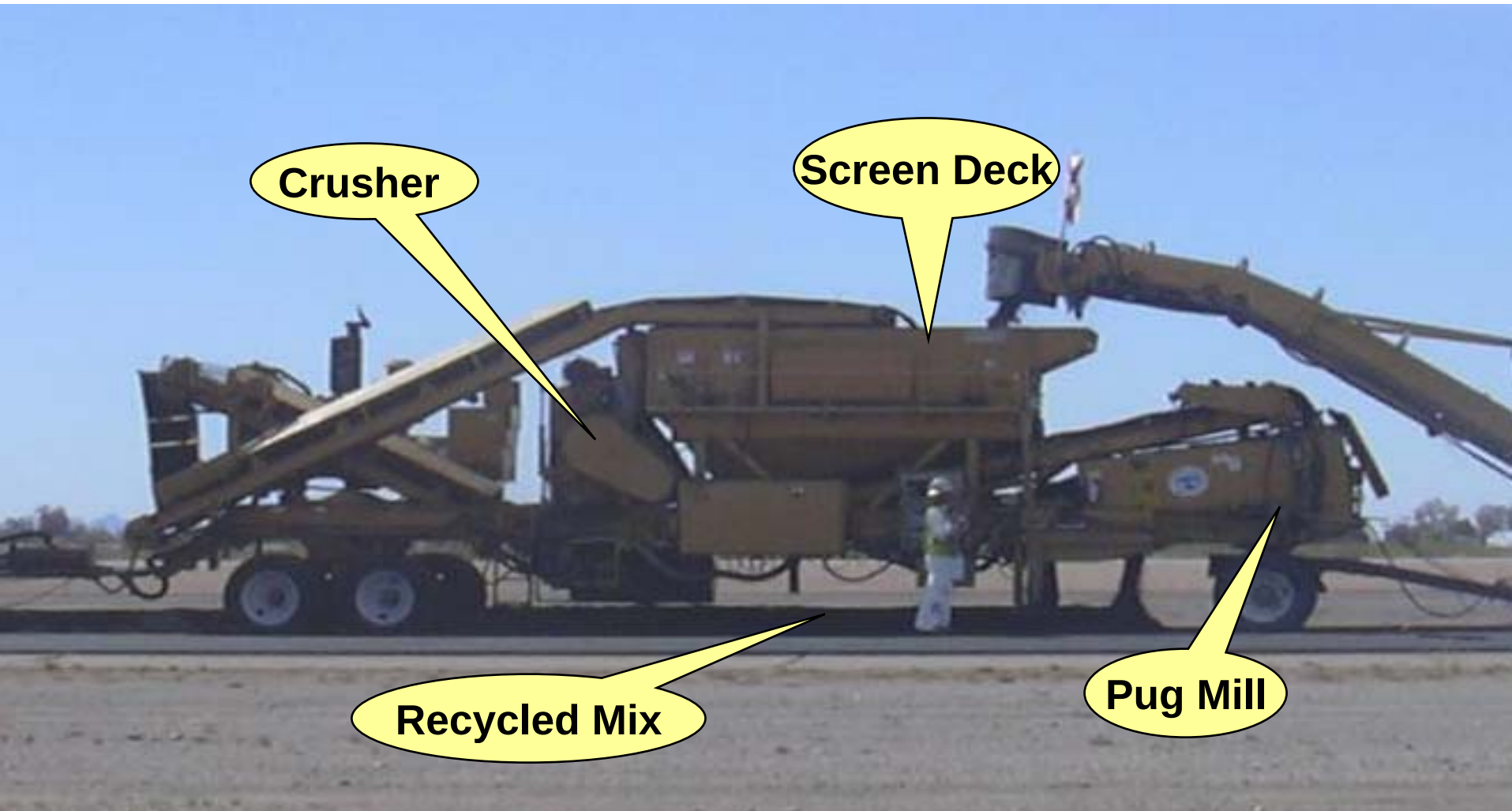
Recycle Unit

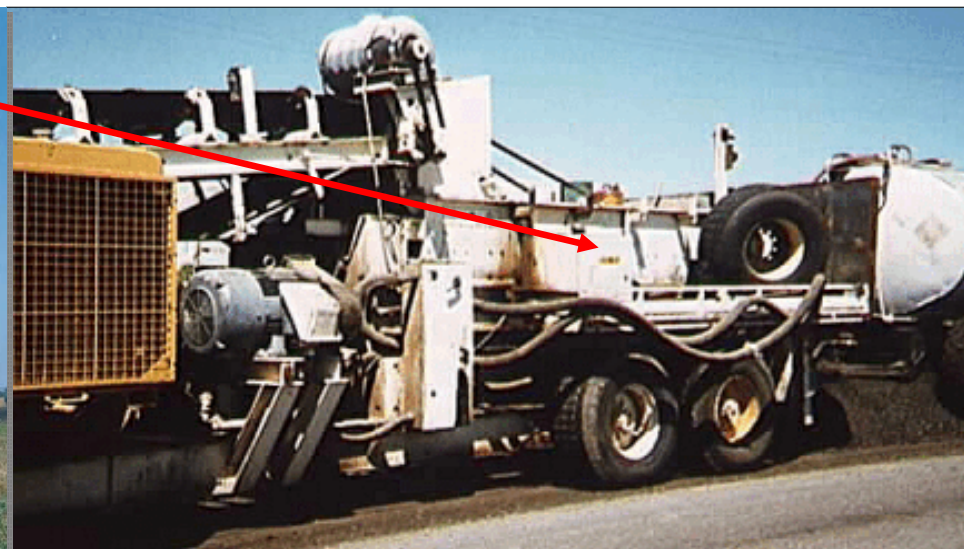


Crushing and Sizing Equipment

Crushing or sizing equipment capable of reducing RAP to the 100% passing 1-inch sieve prior to mixing millings with recycling agent.

Mixing and Proportioning Equipment

- Continuous pugmill
- Equipped with paddles to provide sufficient mixing.
- Belt scale and integrated microprocessor control.
- Automatic controls to obtain the proper amount of recycling agent and additives.
- Weighing and measuring devices must be tested in conformance with California Test 109.



Water and Additive Equipment

- Water Storage and Supply Equipment
  - Independent source of water to disperse the recycling agent.
  - Interlocked with the weighing device of the millings.

- Portland Cement or Lime Slurry
  - Manufacture and supply equipment must have agitators to keep slurry in suspension.
  - Produced at the jobsite.
  - Added directly to the pugmill or sprayed over the cutting teeth of the milling machine.

Paving Compacting

- Spreading Equipment
  - Paver with minimum power of 170 Hp
  - Paver loading machine (windrow elevator)

- Compacting Equipment
  - Minimum 1 pneumatic-tired roller at least 25 tons
  - At least 2 double drum vibratory steel-wheeled rollers at least 10 tons
  - Minimum width at least 66-inches.
  - All rollers must have working water spray systems.

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Another System with Breaker Bar

With Screed Attached

Because of higher void ratio's CIR surfaces must be sealed.

Chip Sealed – Low Volume Highways

Fog Sealed or Slurry Sealed
Low volume – Shoulders and Lots

HMA Overlaid – Higher Volume highways

Contractor Plan Submittals

- Mix design 14 days prior to start in conformance of the requirements in:
  - Lab Procedure 8, “Method of Test for Determining the Percent of Emulsified Recycling Agent to Use for Cold Recycling of Asphalt Concrete,” available on the internet at www.dot.ca.gov/hq/esc/Translab/fpmlab.htm
- Quality control (QC) plan 14 days prior to the start.
  - Includes a recycling and paving plan outlining the sequence of work and maximum production rate.
  - Contractor and Engineer shall meet 7 days prior to the start to review the QC plan.
- Name and accreditation of testing laboratory to perform quality control sampling and testing.
- Contingency plan 14 days prior to start.
  - Describes corrective actions in the event of equipment break down.

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CP² Task Group

Quality Control

- Contractor is responsible for final product.
- Adjustments may be made based upon the opinion of the Contractor.
- Final compacted surface of the recycled pavement mixture shall be free from ruts, bumps, indentations, raveling, irregularities or segregation and shall meet smoothness requirements.
- Any repairs required shall be at the Contractor's expense.

Quality Control

- Adjustments may be made based upon the opinion of the Contractor. Need to be documented.
- QA/QC results submitted to Engineer on a daily basis
- Each Lot 3,000 square yards record:
  - Depth of cut on both ends of drum every 300 ft
  - Length, width and depth of cut
  - Mass of water, dry RAP and emulsion
  - Percent Emulsion
  - Ambient and compacted recycled surface temperatures
  - Maximum particle size of recycled material – Field Sieve over 1-inch
  - In-place density from nuclear gauge readings in 10 random locations
  - Relative Compaction of lot compared to rolling vs. density chart
  - Every third lot field gradation through the No. 4 sieve. Compare to mix design

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CP² Task Group

Test Strip

- First day construct single lane 5,000 ft in length within the limits to be cold in-place recycled.

- Demonstrate:
  - Planer clean cuts and proper width.
  - Pugmill good mixing and coating of recycling agent and water.
  - Pickup machine picking up windrow.
  - Paver proper horsepower and leaving a smooth mat.
  - Rollers proper weight with working water.
  - Crushing and screening meets maximum gradation.

- Determine rolling pattern and maximum density (Breakover Point) by testing in same location.

- Determine moisture content before and after recycling.

- Cold in-place recycling operations may continue through the first day after successful test strip.

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Required Application Conditions

- Not performed during wet conditions, nor started if rain is imminent.
- Minimum pavement temperature of 60°F (16°C).
- Minimum ambient temperature of 50°F (10°C) and rising.
- Recycling operations other than compaction completed a minimum of 2 hours before sunset.
- Longitudinal joints between successive cuts shall overlap a minimum of 4 inches (100 mm).
- The recycled pavement shall remain in place prior to surface course either:
  - A minimum of 2 days and until there is less than 1.5 percent moisture remaining in the CIR pavement mixture
  - A minimum of 10 days without rainfall.

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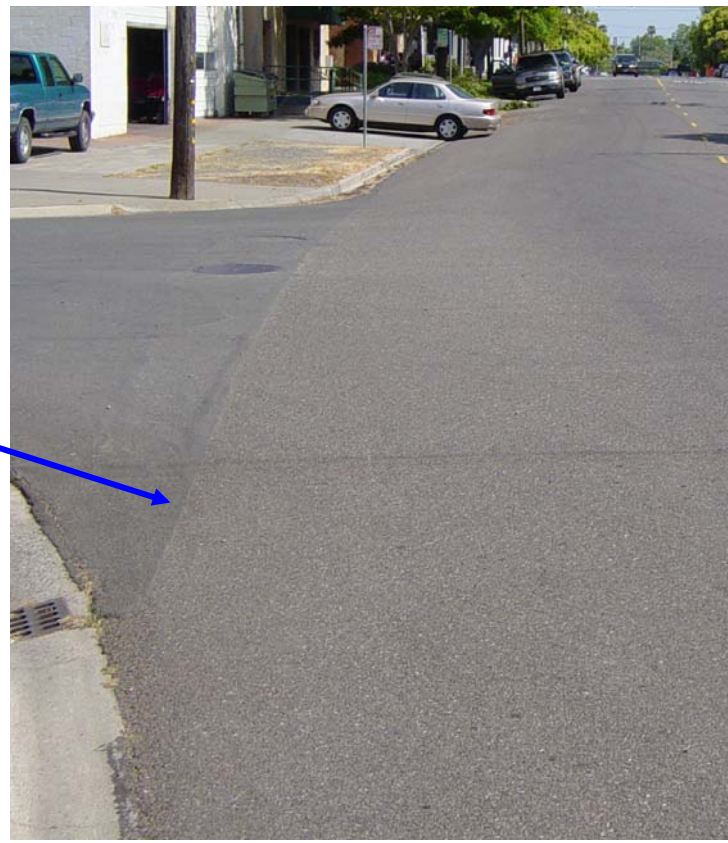
CP² TASK GROUP

Other Application Considerations

- Work Hour Windows - Need to be minimum 8 hours to be cost effect.
- Night Work – Must be during daylight hours for curing for emulsified recycling agent. Asphalt foam recycling agent may be done and night with cement additive.
- Temperature – Min Temp 50º F and rising. Shaded areas will require longer curing.
- Curing Time – Minimum of 2 days and until there is less than 1.5 percent moisture remaining in recycled mixture or 10 days without rainfall.
- Returns/Hand Work – No setbacks or require supplemental mill.
- Turn Pockets – Require supplemental mill.
- Prep Work Required – Isolated base failures repaired ahead of time or after recycle prior to surface seal.
- Fog seal required – At the end of shift to minimize raveling during curing.
- Sand blotter required – To avoid pickup of flush coat.
- ReRoll Required - To reduce voids after curing.
- Final Surface Seal Required – Such as chip seal, thin lift AC etc… Need to seal voids.



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CP² Task Group

Application Problems and Solutions

Problem	Typical Cause(s)	Typical Solution(s)
Flushing of asphalt at surface after laydown and before compaction	Excessive mix water	Reduce the target water content in the mix
	Excessive asphalt emulsion or recycling additive	Reduce asphalt content
	Inadequate mixing of materials	Hold the material in the mixing chamber longer Increase the blade processing to insure proper distribution of the recycling agent
Mix segregation	Inadequate asphalt coating of the aggregate due to inadequate water content in the mix	Increasing the water content in the mix or use softer grade asphalt in the emulsion
	Variation of existing materials	Add new graded base and redo mix design
Mat raveling after compaction	Too little asphalt emulsion (or recycling additive) in the mix	Increase the amount of asphalt emulsion or emulsified recycling additive in the mix Reprocess the problem areas
Shiny black mat after compaction	Too much asphalt emulsion or emulsified recycling additive in the mix	Reduce the amount of asphalt emulsion or emulsified recycling additive in the mix Reprocess the mix adding virgin material

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CP² TASK GROUP

Application Problems and Solutions

Poorly graded RAP behind recycling unit and change in existing pavement	Variation in depth of existing materials	Add new graded base to keep constant depth and redo mix design
	Teeth on the milling machine are worn or broken	Change the teeth
	Speed of the operation is too fast	Slow the operation down
Variable depth	Poor control of grade	Repair (or use improved) grade controls
Varying dry and wet spots in RAP	Poor water and/or recycling agent control. Varying existing pavement and gradation changes	Check and calibrate pulverizing and mixing operations
Appearance of fines in RAP material	Milling into subsurface layers	Provide better control of depth. Confirm thickness of existing HMA layer
	Speed of the milling machine too slow	Increase speed of operation
Oversize RAP in the mix	Screen or breaker bar not functioning properly	Repair the screen or breaker bar
New mat stays spongy and/or will not densify	Steel wheel rollers may be sealing the top and causing moisture retention	Use a heavy pneumatic tire roller for breakdown and compaction rolling
	Excess moisture in mix	Confirm liquid contents in emulsion Revise target moisture in mix as necessary

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CP² Task Group

End
Construction and Inspection

Module 13-2a

Hot In-Place Recycling

Design, Materials & Specifications

From… Maintenance Technical Advisory Guide (MTAG)

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CP² Task Group

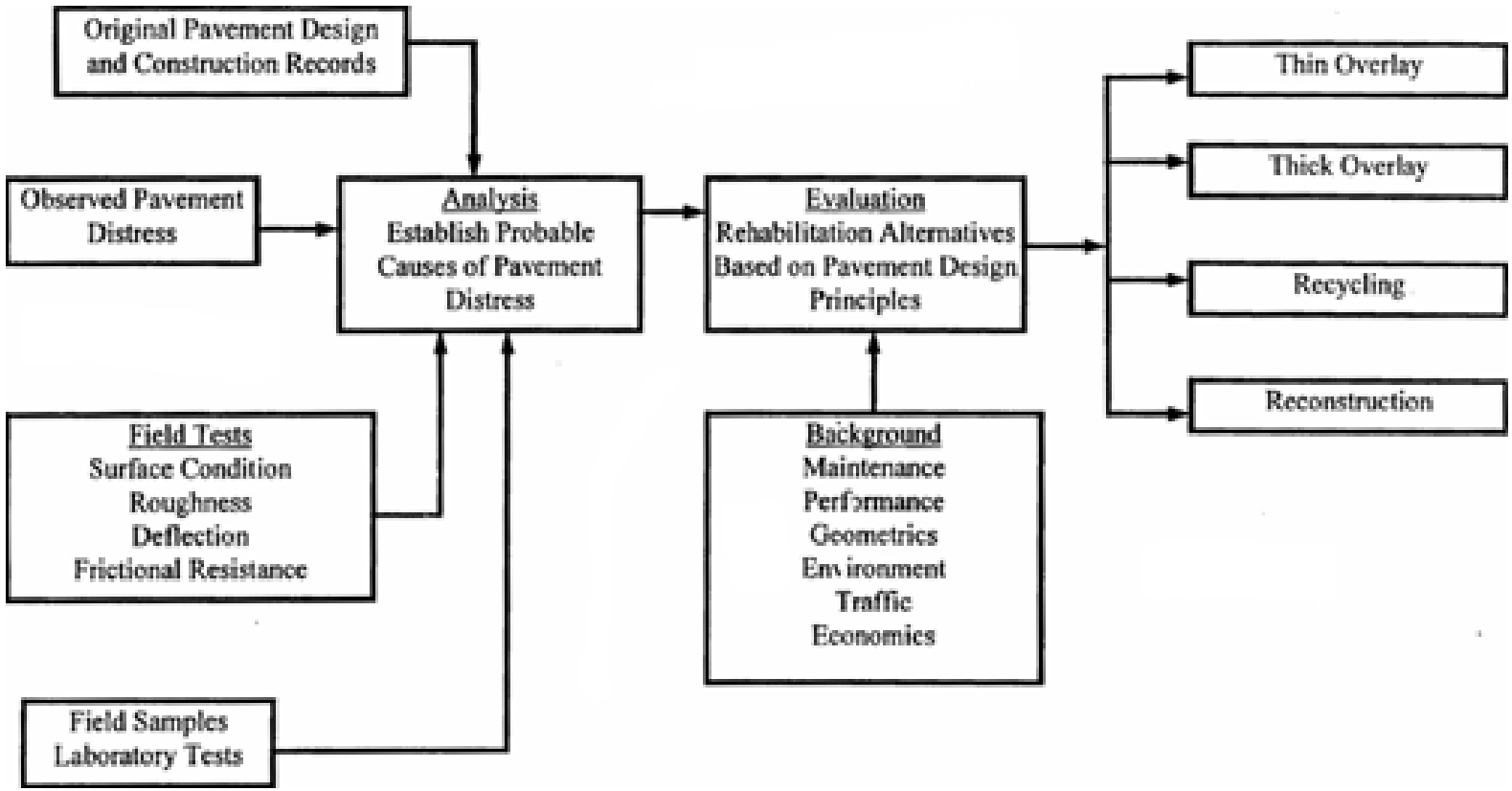
HIR Presentation Checklist

- [x] Overview
- [ ] Project and material selection, and mix design
- [ ] Construction
- [ ] Quality control
- [ ] Troubleshooting

Basic Steps In The Selection Process

1. Assess the existing pavement conditions.
2. Determine the feasible of treatment options.
3. Analyze and compare the feasible options.

Process and information for selection of maintenance option



Factors to consider when selecting a maintenance treatment

- Will the proposed treatment address the distress present?
- Can the required preparation for the treatment be carried out?
- Is the treatment affordable and cost effective?
- Will the treatment be completed before the situation being addressed changes?

Assessment of Distress

- Types of Distresses and Definitions
- Definitions from:
  - “Guide to the Investigation and Remediation of Distress in Flexible Pavements,” Caltrans, July 2003
  - “Distress Identification Manual for the Long-Term Pavement Performance Program,” FHWA, June 2003

Evaluation of Suitability for HIR

- Perform visual site inspection
  - HIR suitable for all levels of distress provided cracking is not induced by structural failure/base failure
  - Suitable for rutting not associated with unstable mix.
  - Suitable for severe raveling and oxidation
  - Anywhere a Mill and Fill would work
  - Structurally Sound Base
- Determine existing pavement thickness
- Project should be large enough to accommodate train

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CP² TASK GROUP

HIR Candidate Processes

Distress Type	Surface Recycling	Remix	Repave
Raveling			
Bleeding			
Friction			
Rutting, Corrugations			
Linear Cracking			
Fatigue Cracking			
Swells, Bumps, Sags			
Ride Quality			

More Appropriate → Less Appropriate

HIR

Costs (Approx., 2007)

HIR Operation	Cost, $/m² ($/sy)
Heater scarification 25-mm (1-in) depth & recycling agent	$2.40/m² ($2.00/sy)
Repaving 25-mm (1-in) depth & 25-mm (1-in) HMA overlay	$7.00/m² ($6.00/sy)
Remixing 25-mm (1-in) depth and 10 to 20 mm (0.4 to 0.8 in) new HMA added	$5.50/m² ($4.60/sy)
Remixing 50-mm (2 in) depth and 10 to 20 mm (0.4 to 0.8 in) new HMA added	$6.50/m² ($5.45/sy)

HIR

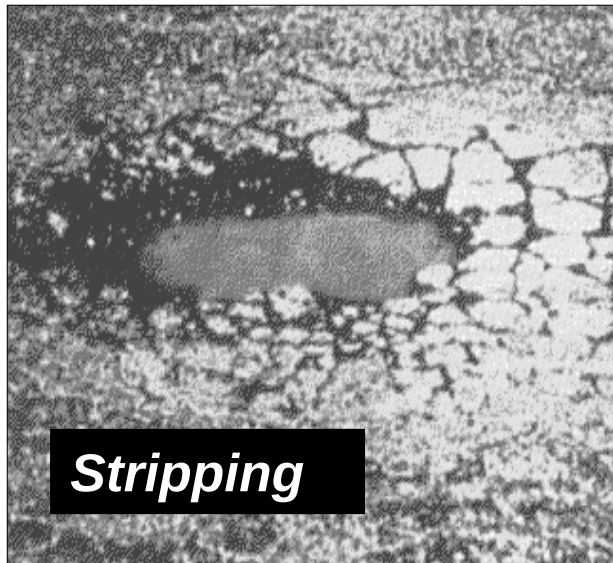
Disadvantages

- Influence of mix variation
- Cannot recycle fabrics or interlayers
- Problems with deep ruts
- Trouble recycling large stone mixes
- Difficulties from rubber in the mix
- Higher moisture content reduces production rate

HIR

Disadvantages

Pavements not to recycle in-place



Asphalt Rubber Type G or O

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HIR Performance Expectations

- Life Expectancy
  - 10-15 (same as CIR)
  - Restores old pavement
  - Restarts Design Life
- Improves ride quality (Smoothness)
- Preventive maintenance activities recommended are similar to that for HMA

HIR Material Selection

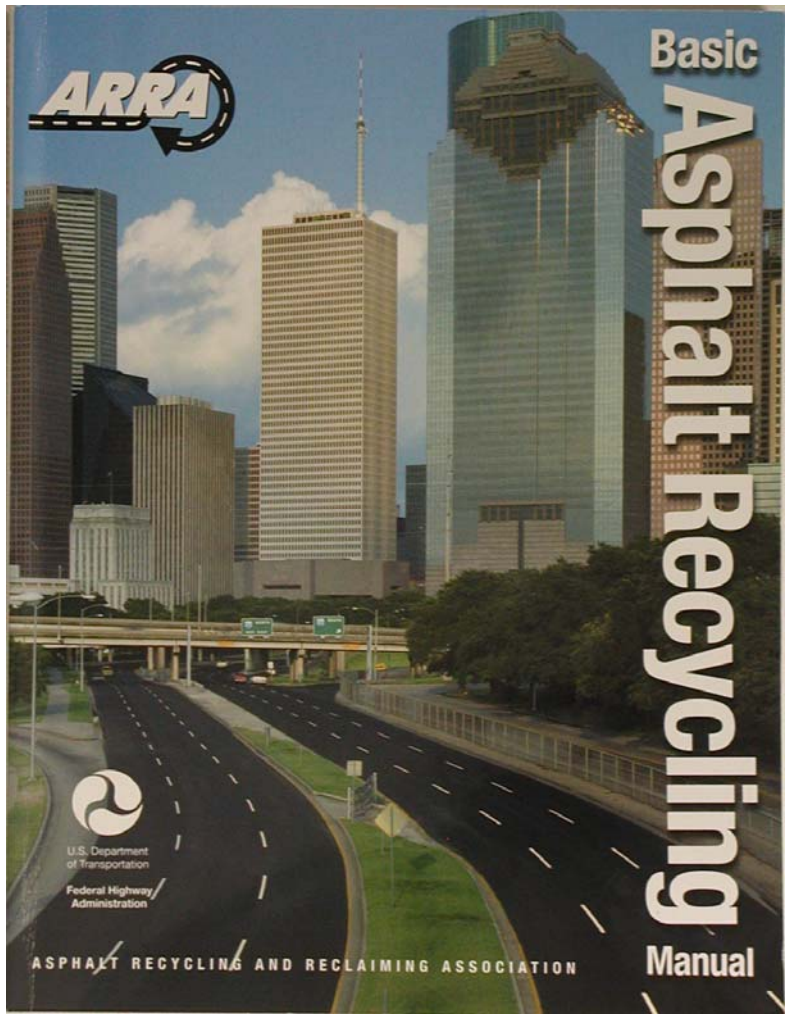
- Existing HMA
- Asphalt binder
- Recycling agents
- New aggregate

HIR Mix Design

General Information

- Thorough pavement evaluation
- Influenced by:
  - Pavement condition
  - Quantity/quality of materials
- Reference: *"Basic Asphalt Recycling Manual" (BARM)*

Basic Asphalt Recycling Manual (BARM)



HIR Mix Design

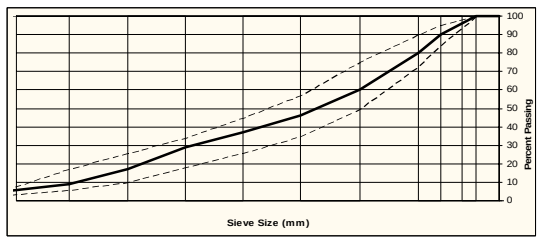
1. Evaluate existing HMA and determine mix properties
2. Determine rejuvenation method and select type and amount of recycling agent
3. Determine admix amount and gradation
4. Prepare and test mix specimens
5. Establish job mix formula
6. Make adjustments in field

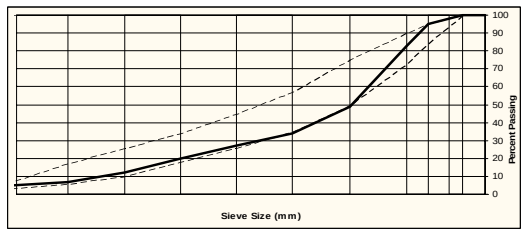
HIR Design Considerations

- Mobilization
- Typical materials items
- Quantity calculations
- Production rates
  - Roadway Widths
  - Roadway Geometry
- Traffic control
- Sample Project information

HIR Addition of HMA admix options

- **Increase air voids**
- **Reduce filler content**
- **Improve stability**
- **Reduce AC content**





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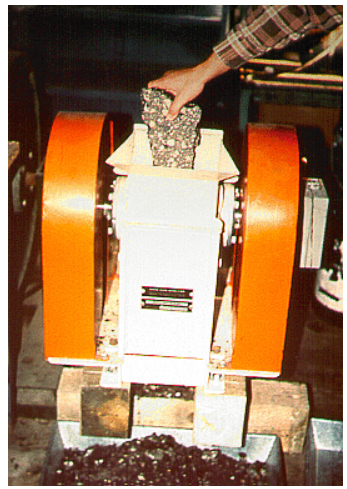
HIR Field sampling procedure

HIR Laboratory Design

- **Mix design**
  - Soften mix and extract gradations
  - Aggregate or new HMA added to meet gradation needs
  - Recycling agent **optimized**
  - Laboratory samples fabricated
- Performance-related tests



Module 13-2b

Hot In-Place Recycling
Construction & Inspection

From… Maintenance Technical Advisory Guide (MTAG)

Caltrans

CP² Task Group

HIR Presentation Checklist

- [x] Overview
- [x] Project and material selection and mix design
- [ ] Construction
- [ ] Quality control
- [ ] Troubleshooting

HIR Construction Process

1. Preparation of construction area
2. Mix recycling and laydown
3. Three methods:
   - Surface Recycling (Heater-scarifier)
   - Remixing (Caltrans Spec)
   - Repaving (Caltrans Spec for HITone)
4. Compaction

HIR Construction

Surface Recycling—Process

1. Dry and heat upper layer
2. Scarify the heated/softened asphalt
3. Add recycling agent
4. Mix the loose recycled mixture
5. Spread and place material with free floating screed
6. Compact recycled mix

HIR Construction

Surface Recycling—Benefits

- Eliminates surface irregularities
- Eliminates cracks
- Restores uniform grade line and cross-section

HIR Construction

Surface Recycling—Limitations

- May overheat the asphalt binder
- Little opportunity to adjust the mix and aggregate gradation
- Air quality concerns
- Note: Caltrans does not use Surface Recycling

HIR Construction

Surface Recycling—Characteristics

- Depth: 0.75 to 1.0 in
- No added aggregate or HMA
- Production rate: 5 to 50 ft/min
- Single vs. two pass operations

HIR Construction

Surface Recycling—Equipment

HIR Construction

Surface Recycling—Scarifiers

HIR Construction

Surface Recycling—Scarifiers

HIR Construction

Remixing—Process

1. Dry and heat upper layer
2. Scarify and/or mill the heated/softened RAP
3. Add virgin aggregate, recycling agent, and/or virgin HMA mix
4. Blend into a homogenous mix
5. Spread and place material
6. Compact recycled mix

HIR Construction

Remixing—Benefits

- Eliminates distress in upper portion of pavement
- Restores existing asphalt mix to desired mix composition or strength
- Recycled mix may serve as wearing course
- Provides modest amount of strengthening

HIR Construction

Remixing—Methods

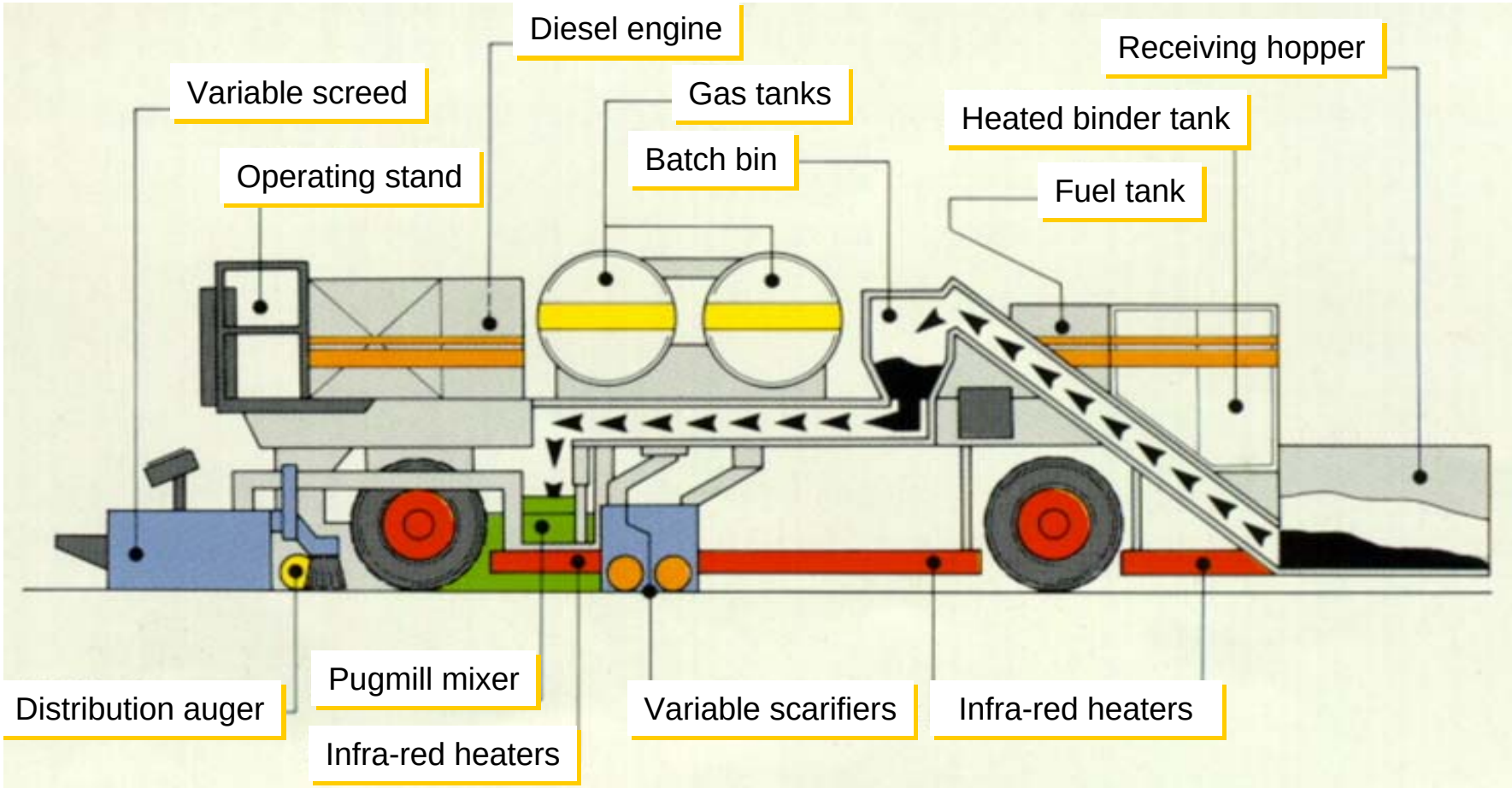
Single Stage Process	Multiple Stage Process
Scarification of full treatment depth at one time	Scarification in layers (material placed in windrow)
Depth range:25 to 50 mm (1 to 2 in)	Depth range:40 to 75 mm (1.5 to 3 in)

HIR Construction

Remixing—Equipment

HIR Construction

Single Stage *Remixing* Equipment

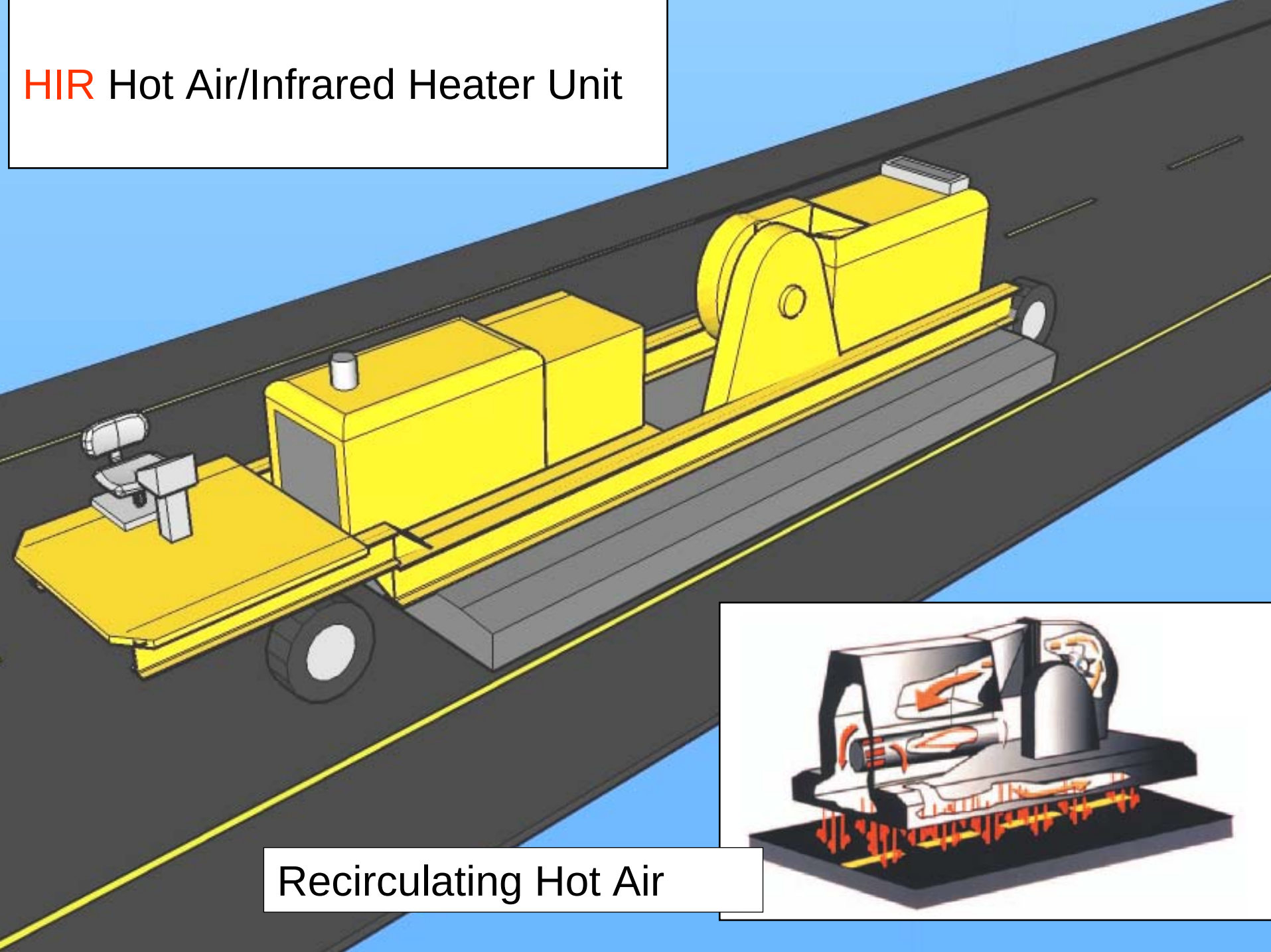


Direction of paving

HIR Construction

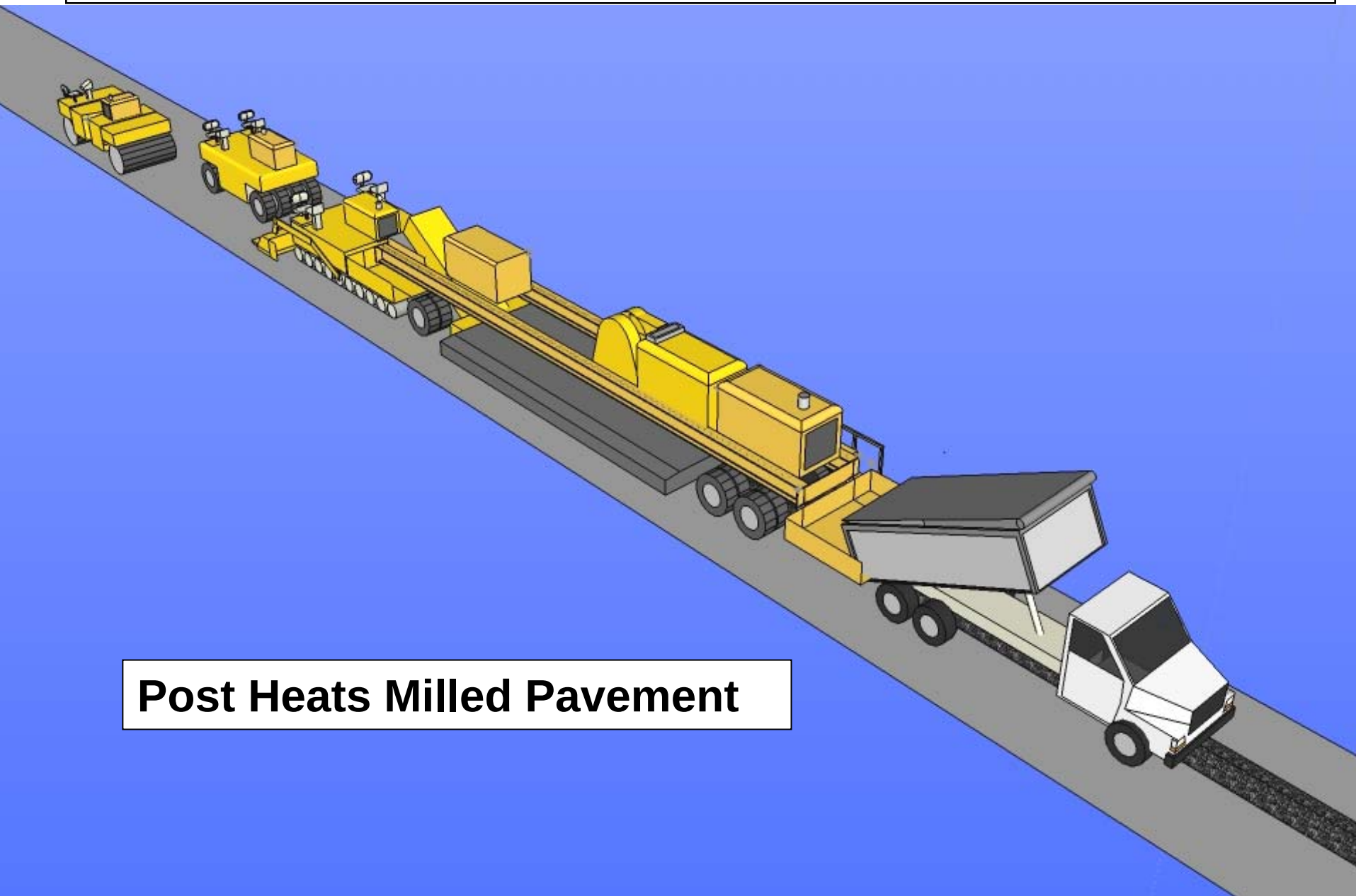
Remix – Multiple Stage

HIR Hot Air/Infrared Heater Unit



Recirculating Hot Air

HIR Stage-Two Unit



HIR Construction

Before and After Remixing

HIR Construction

Repaving—Single Pass Method

- Existing asphalt is recycled and screeded
- Last unit in HIR train places integrated overlay on recycled material
- Layers are compacted simultaneously

HIR Construction

Repaving—Single Stage Method

HIR Construction

Repaving - *Two stage remixing using infrared heaters*

HIR Construction

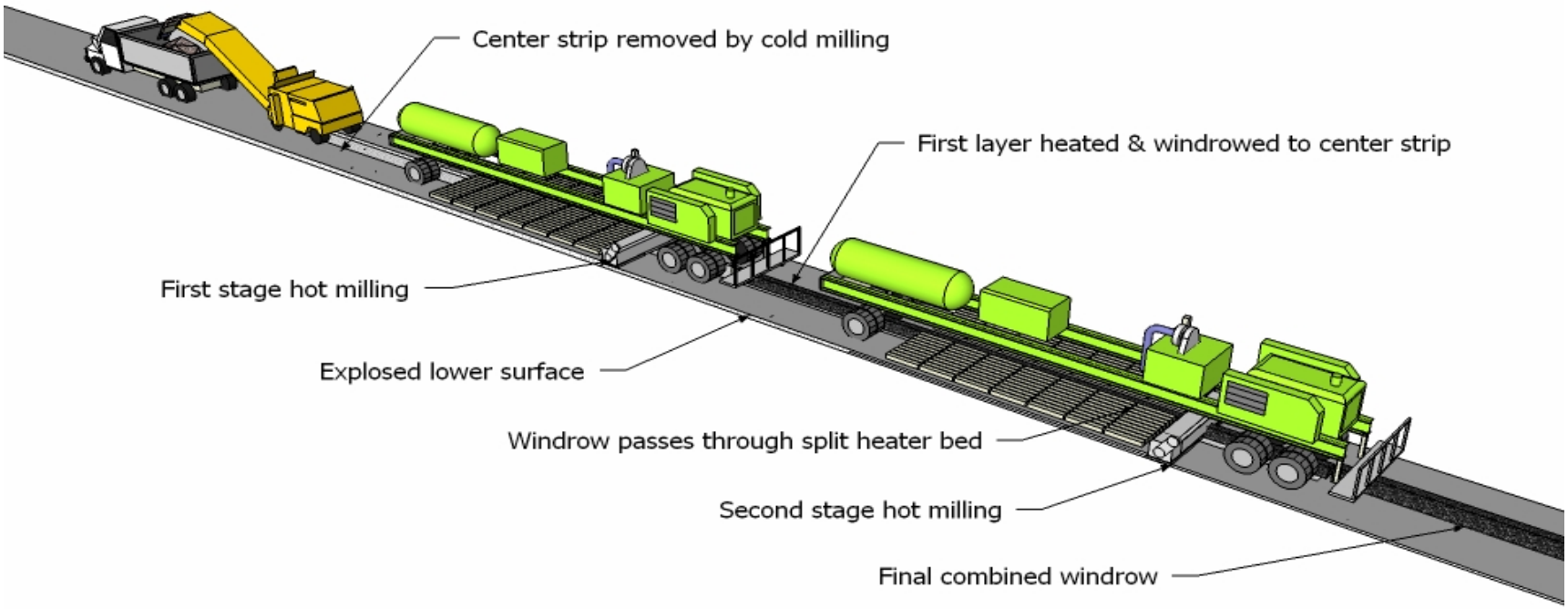
Remixing – Multiple stage with hot air heaters

HIR Construction

Remixing – Mainline recycling

HIR Construction

Remixing – System removes RAP to make room for more virgin HMA, and improving heating efficiency



HIR Construction

Repaving—Multiple Pass Method

- Last unit in HIR train places recycled mix
- Separate paver places overlay on uncompacted recycled material
- Both layers compacted as one thick lift

HIR Construction

Repaving—Layer Thicknesses

- Recycled depth: 25 to 50 mm
  (1 to 2 in)
- Overlay thickness: 25 to 50 mm
  (1 to 2 in)
- Increasing thickness creates problems with placement, compaction, and smoothness

HIR Construction

Repave – Final overlay being placed

HIR Construction

Pavement After Repaving

HIR Construction

Repaving – Completed lanes

HIR Presentation Checklist

- [x] Introduction
- [x] Project and Material selection and mix design
- [x] Construction
- [ ] Quality control
- [ ] Troubleshooting

HIR Quality Control

- Should be similar to conventional HMA
- Tailor to variable nature of pavement
- Recommendations included in *Basic Asphalt Recycling Manual (BARM)*

HIR Quality Control

Areas of Concern

- Heating of the existing surface
- Treatment depth
- Addition of recycling agent and admixture
- Placement
- Compaction

HIR Quality Control

Sampling and Testing

- Depth of scarification or milling
- Recycling agent application rate
- New mixture addition rate
- Temperature of mix before compaction
- Properties of asphalt binder in recycled mix
- Density of final pavement mixture

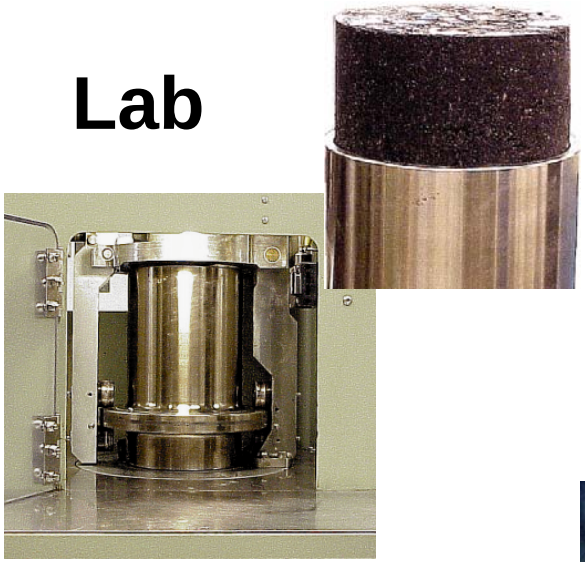
HIR Quality Control

Depth Test and sampling

HIR Quality Control

Measurement of field density

Lab



Field

HIR Presentation Checklist

- [x] Introduction
- [x] Project and Material selection and mix design
- [x] Construction
- [x] Quality control
- [ ] Troubleshooting

HIR Troubleshooting

- Reference: Table 2-13, MTAG Vol.1, Flexible Pavement Preservation, 2nd Edition
- Approach:

HIR Troubleshooting

- Problem:

  Flash fires or blue/black smoke being emitted from heating units

- Potential causes?

HIR Troubleshooting

- Problem:
  Difficulty in heating to desired depth

- Potential causes?

HIR Troubleshooting

Other Potential Problems

- Wet appearance of surface after recycling
- Poor or variable gradation of RAP
- Variable/insufficient milling depth
- Inadequate density
- Wet spots on finished mat
- Dry spots on finished mat

HIR Presentation Checklist

- ☑ Introduction
- ☑ Project and Material selection and mix design
- ☑ Construction
- ☑ Quality control
- ☑ Troubleshooting

HIR Review: Learning Outcomes

1. List benefits of hot-in-place recycling
2. Describe recommended materials and mixtures
3. Describe recommended construction procedures
4. List key quality control activities

HIR

THE END