COLD IN – PLACE ASPHALT RECYCLING, FULL DEPTH RECYCLING AND HOT IN – PLACE RECYCLING

CIR – FDR – HIR

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SEELEY CIR ONTARIO

LVM - JEGEL FDR COLOMBIA

MARTEC HIR OTTAWA

THE TECHNICAL ASSISTANCE OF ALAIN DUCLOS AND JESSICA HERNANDEZ OF LVM - JEGEL WITH THIS PRESENTATION IS GRATEFULLY ACKNOWLEDGED

SEPTEMBER 2009

OVERVIEW OF ASPHALT PAVEMENT RECYCLING

ARRA BASIC ASPHALT RECYCLING MANUAL IS A KEY REFERENCE

(COPIES AVAILABLE FROM ONTARIO ARRA COMPANY MEMBERS)

- **MILLING**
- **HOT-MIX ASPHALT PLANT RECYCLING**
- **HOT IN-PLACE RECYCLING (HIR)**
- **COLD IN-PLACE RECYCLING (CIR)**
- **COLD PLANT RECYCLING (CCPR)**
- **FULL DEPTH RECLAMATION (FDR)**

ASPHALT
100% RECYCLABLE

PRECISION MILLING

SEPTEMBER 2009

CITY OF TORONTO ELLESMERE ROAD
PRECISION MILLING TO REMOVE RUTTING

HMA PLANT RECYCLING (RHM)

SEPTEMBER 2009

HOT-MIX ASPHALT PLANT RECYCLING
COMBINED DRUM-BATCH PLANT

SEPTEMBER 2009

HOT IN-PLACE RECYCLING (HIR)

REMIX (FULL RECYCLING) – HEATING TO A DEPTH OF UP TO 75 mm, HOT MILLING, REJUVENATION/ NEW AGGREGATE/ NEW MIX (OPTIONAL – DESIGNED), MIXING, REPROFILING/PLACING WITH PAVER, AND COMPACTION
MARTEC AR2000, INTERSTATE 85, NORTH CAROLINA, OFC, 2001

CIR

SEPTEMBER 2009

COLD IN-PLACE RECYCLING

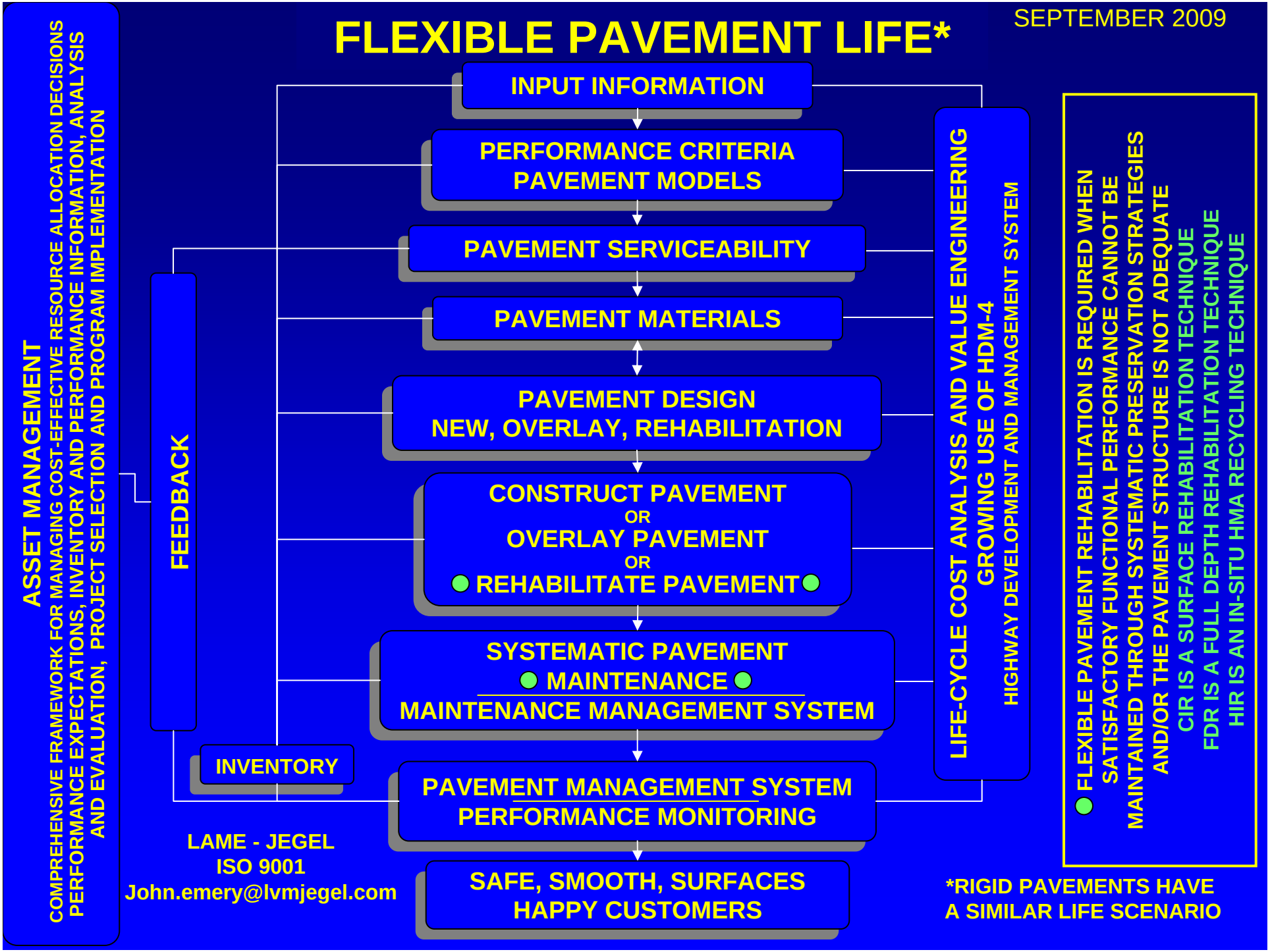
FDR

SEPTEMBER 2009

FOAMED (EXPANDED) ASPHALT FULL DEPTH RECLAMATION

FLEXIBLE PAVEMENT LIFE*

SEPTEMBER 2009



LAME - JEGEL
ISO 9001
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*RIGID PAVEMENTS HAVE A SIMILAR LIFE SCENARIO

CIR PROCESS

TYPICAL 1993 ONTARIO HIGHWAY CIR WITH EMULSION PROJECT

PAVEMENT MILLED/SIZED AND ABOUT 1.5 PERCENT HF EMULSION ADDED

PROCESSED RECYCLED MATERIAL PLACED WITH PAVER

COMPACTION COMPLETED WITH LARGE RUBBER TIRED ROLLER

- OLD ASPHALT PAVEMENT MILLED AND SIZED
  - MILLED TO AT LEAST 90 PERCENT OF DEPTH TO ENSURE REFLECTIVE CRACKING MITIGATION
  - 75 TO 125 mm DEPTH TYPICALLY
  - MINUS 37 mm TYPICALLY
- ABOUT 1.5 PERCENT EMULSION ADDED
- COMPACTION WITH HIGH COMPACTIVE EFFORT ROLLERS
- CURING AND TRAFFIC COMPACTION (~ 2 WEEKS)
- PLACEMENT OF WEARING SURFACE

CIR FEATURES

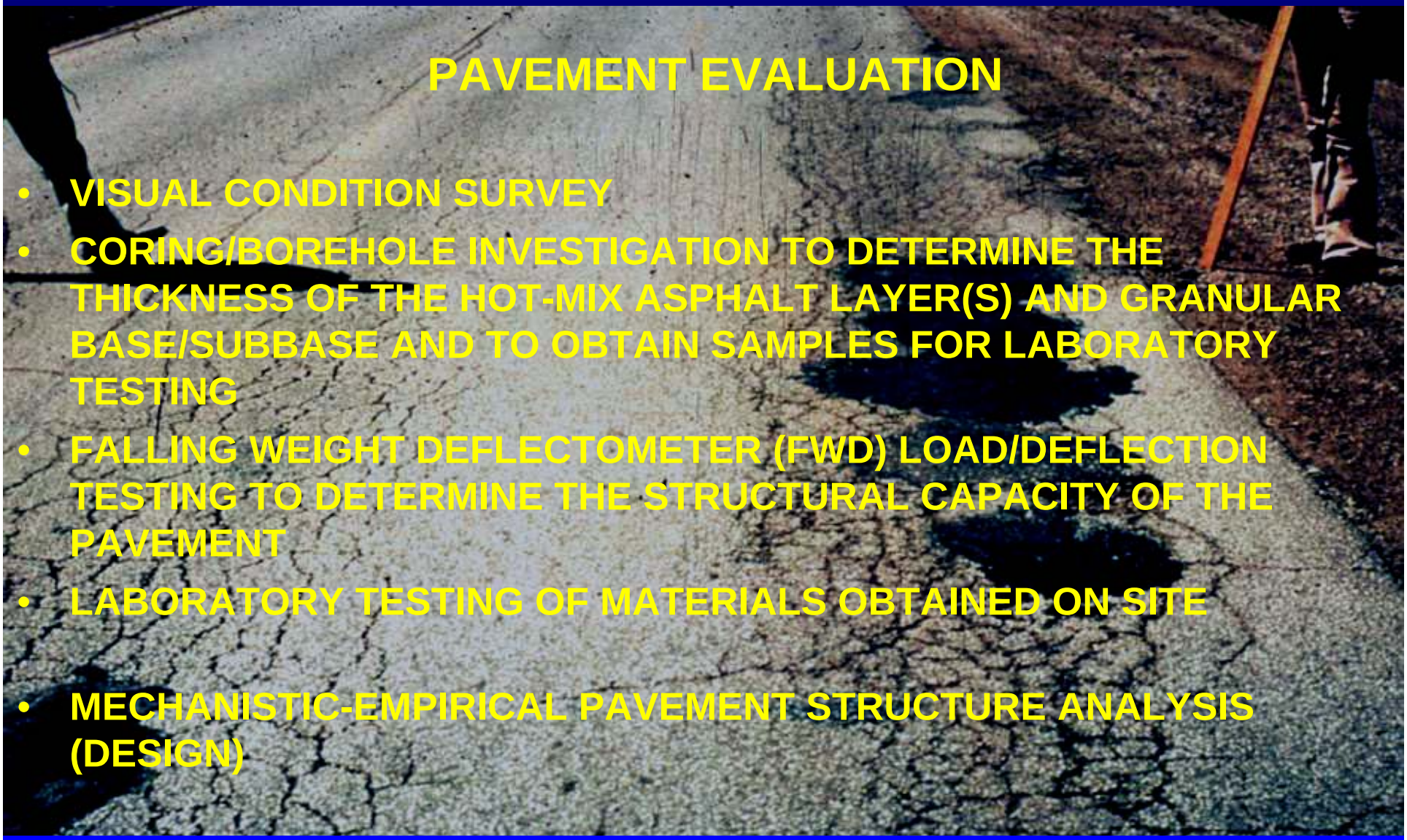
WIDE RANGE OF CIR EQUIPMENT AND PROCESSES AVAILABLE

1996 CIR WITH EMULSION AND FIRST ONTARIO SUPERPAVE HMA OVERLAY

1999 CIR WITH EMUSION EQUIPMENT CAN ADD CEMENT OR LIME SLURRY

2004 PAVER LAID CIR WITH FOAMED ASPHALT

- PAVEMENT EVALUATION AND STRUCTURAL DESIGN METHODS DEVELOPED
- CIR IS A 4 COMPONENT SYSTEM COMPARED TO HMA 3 COMPONENT SYSTEM
- COLD MARSHALL MIX DESIGN METHOD – SGC METHOD BEING DEVELOPED
- USED FOR A WIDE RANGE OF ESALs
- MODIFICATIONS FOR IMPROVED ECONOMICS AND/OR SPECIAL CONDITIONS
- CONSTRUCTION AND MATERIALS SPECIFICATION DEVELOPED
- STRUCTURAL COEFFICIENTS (GBE OR a_1) DEVELOPED
- LIFE-CYCLE COST EFFECTIVENESS SHOWN
- MITIGATION OF REFLECTIVE CRACKING DEMONSTRATED



PAVEMENT EVALUATION

- VISUAL CONDITION SURVEY
- CORING/BOREHOLE INVESTIGATION TO DETERMINE THE THICKNESS OF THE HOT-MIX ASPHALT LAYER(S) AND GRANULAR BASE/SUBBASE AND TO OBTAIN SAMPLES FOR LABORATORY TESTING
- FALLING WEIGHT DEFLECTOMETER (FWD) LOAD/DEFLECTION TESTING TO DETERMINE THE STRUCTURAL CAPACITY OF THE PAVEMENT
- LABORATORY TESTING OF MATERIALS OBTAINED ON SITE
- MECHANISTIC-EMPIRICAL PAVEMENT STRUCTURE ANALYSIS (DESIGN)

IS THIS A SUITABLE SECTION FOR CIR?

- DRAINAGE?
- STRUCTURAL ADEQUACY?

CIR PROCESS MODIFICATIONS

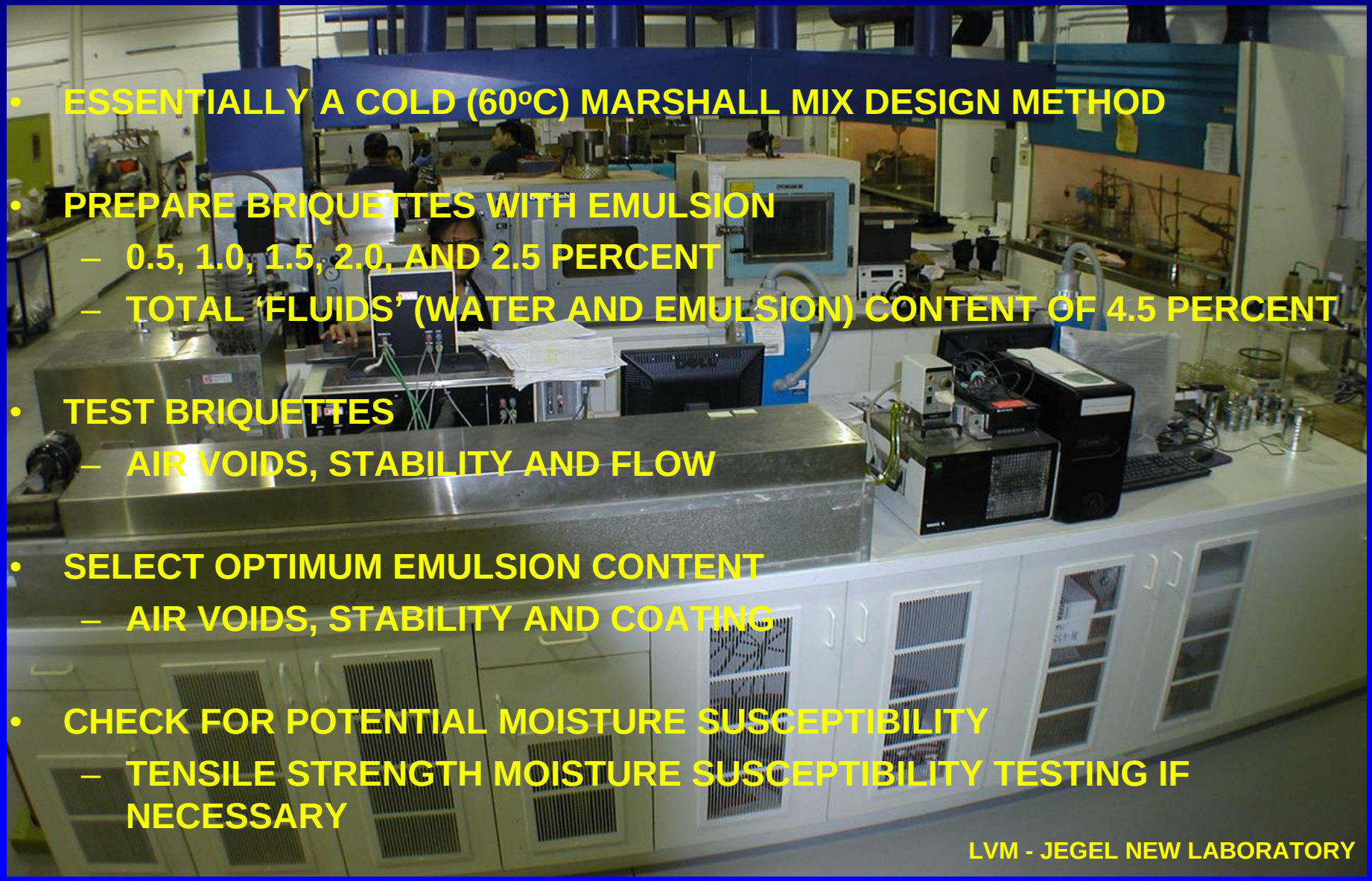
- ADDITION OF NEW COARSE AGGREGATE
  - CLOSER VOIDS AND STABILITY CONTROL
- USE OF DIFFERENT EMULSIONS (HFR FOR INSTANCE)
  - MORE OLD ASPHALT CEMENT EFFECTIVE
- PROCESS MODIFICATIONS
  - ADDITION OF CEMENT OR LIME FOR INSTANCE

FLUSHING AND RUTTING, WATERLOO COUNTY ROAD 1, 1993

SWIFT CIR (EMULSION), FDR AND HIR SEPTEMBER 2009

WATERLOO COUNTY ROAD 1 CONDITION IN JANUARY 2002

CIR MIX DESIGN



- ESSENTIALLY A COLD (60°C) MARSHALL MIX DESIGN METHOD
- PREPARE BRIQUETTES WITH EMULSION
  - 0.5, 1.0, 1.5, 2.0, AND 2.5 PERCENT
  - TOTAL 'FLUIDS' (WATER AND EMULSION) CONTENT OF 4.5 PERCENT
- TEST BRIQUETTES
  - AIR VOIDS, STABILITY AND FLOW
- SELECT OPTIMUM EMULSION CONTENT
  - AIR VOIDS, STABILITY AND COATING
- CHECK FOR POTENTIAL MOISTURE SUSCEPTIBILITY
  - TENSILE STRENGTH MOISTURE SUSCEPTIBILITY TESTING IF NECESSARY

LVM - JEGEL NEW LABORATORY

'SUPERPAVE PLUS'

MITIGATION OF REFLECTIVE CRACKING
CIR PLUS HMA OVERLAY

- CIR REFLECTIVE CRACKING MITIGATION
- SUPERPAVE TECHNOLOGY OVERLAY
  - THERMAL CRACKING RESISTANCE
  - RUTTING RESISTANCE
  - FATIGUE CRACKING RESISTANCE

MILLER

SUPERPAVE PLUS CIR PROJECT, FRONTENAC COUNTY, 1996
RECONSTRUCTION OF 30 kms OF HIGHWAY 2 NEAR KINGSTON, ONTARIO

SUPERPAVE SURFACE COURSE
HMA

TEXTURE OF SUPERPAVE SURFACE COURSE (~MODIFIED HL1)

CIR MITIGATION OF REFLECTIVE CRACKING

PERFORMANCE OF 1996 CIR WITH EMULSION AND SUPERPAVE OVERLAY

CONDITION OF SUPERPAVE HMA IN 2004
NO CRACKING

CONDITION OF ADJACENT 1997 MILL/HMA OVERLAY
WITHOUT CIR – SIGNIFICANT CRACKING

CIR PERFORMANCE REQUIREMENTS AND ACCEPTANCE

- PERFORMANCE REQUIREMENTS
  - REFLECTIVE CRACKING MITIGATED
  - PAVEMENT STRUCTURE STRENGTHENED
  - PAVEMENT SHAPE IMPROVED (CAN BE WIDENED)
- ACCEPTANCE
  - TYPICAL CONTRACTOR PRODUCING UNDER TYPICAL CONDITIONS
- PERFORMANCE PARAMETERS (ACCEPTANCE)
  - STRENGTH
  - DURABILITY
  - SMOOTHNESS

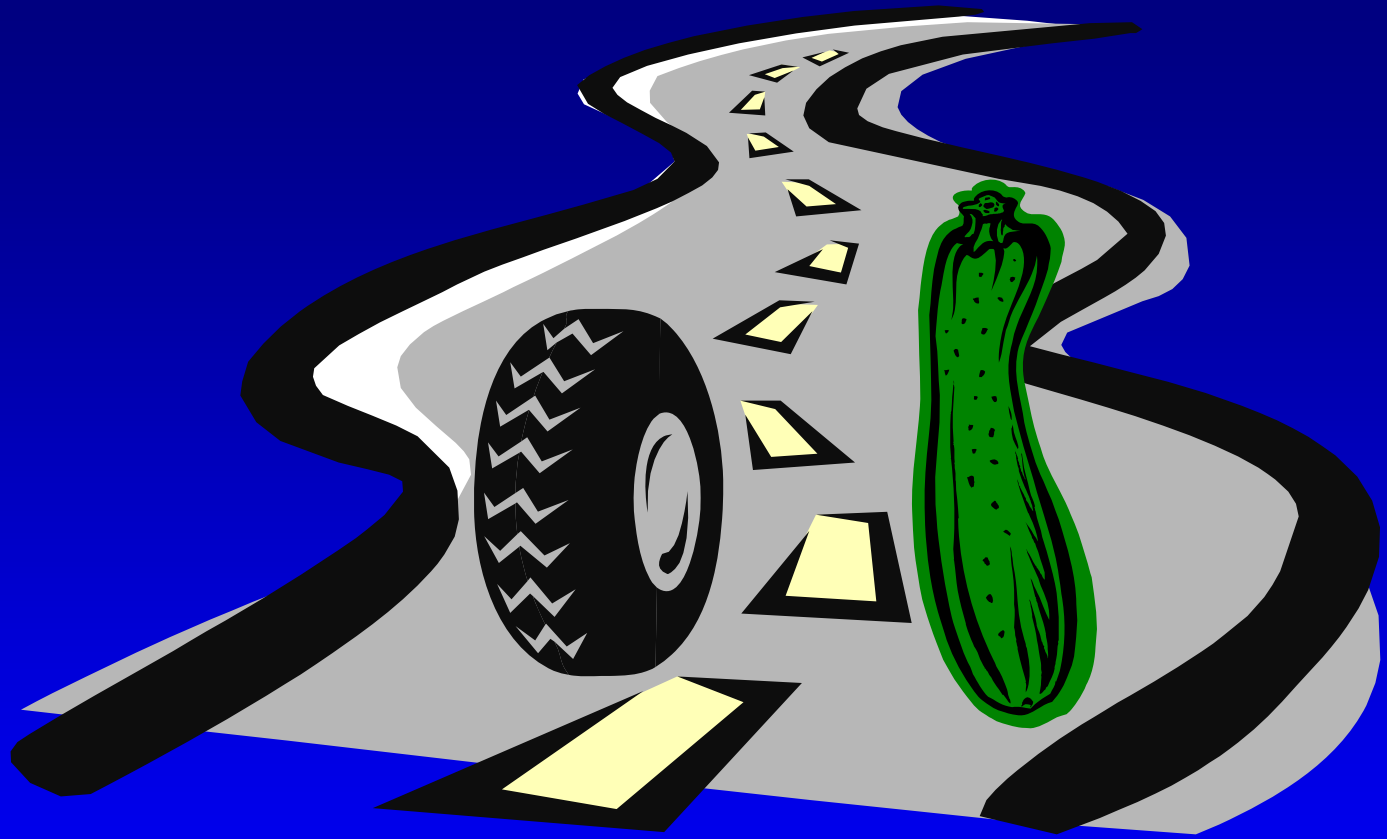
PERFORMANCE

BRUCE COUNTY ROAD 31 CIR PROJECT COMPLETED IN 1991
15 PERCENT COARSE AGGREGATE, 1.1 PERCENT HF150
CONDITION IN 1997

PERFORMANCE

BRUCE COUNTY ROAD 31
CONDITION IN 2002

LIFE-CYCLE COST ANALYSIS



"WE GO OUT AND BUY PAVEMENTS LIKE WE WOULD ZUCCHINI. ALL WE CARE ABOUT IS PRICE."

DAMIAN J. KULASH, EXECUTIVE DIRECTOR, STRATEGIC HIGHWAY RESEARCH PROGRAM, 1993

CIR FEATURES

- CIR AND MODIFIED CIR WELL ESTABLISHED AND PROVEN REHABILITATION TECHNIQUE
- RECOMMEND AGENCY COMPLETE PRELIMINARY PAVEMENT EVALUATION AND SET PERFORMANCE SPECIFICATION
- RECOMMEND CONTRACTOR MADE RESPONSIBLE FOR CIR MIX DESIGN, PROCESS AND PERFORMANCE
- RECOMMEND RECYCLING PROCESS, EMULSION AND MODIFICATION(S) BE SEPARATE PAY ITEMS
- USE FOR HIGH TRAFFIC LEVELS WELL ESTABLISHED
- a_1 OF ~ 0.30 TO 0.40 FOR AASHTO SN (GBE OF ~ 1.8) FOR QUALITY, FULLY CURED, CIR (EMULSION)
- **MITIGATION OF REFLECTIVE CRACKING**
- SIGNIFICANT COST SAVINGS
- APPLICATION TO AIRPORT ASPHALT PAVEMENTS (CURING TIME LOGISTICS)

FDR NEXT

FULL DEPTH RECLAMATION – FDR

PULVERIZING LIME CEMENT EMULSION FOAMED ASPHALT COMBINATION

LVM - JEGEL

PULVERIZING OLD ASPHALT CONCRETE PAVEMENT
FULL DEPTH METHOD WITHOUT STABILIZING ADDITIVE
ONTARIO

FULL DEPTH RECLAMATION – FDR

PULVERIZING **LIME** CEMENT EMULSION FOAMED ASPHALT COMBINATION

JEGEL

LIME STABILIZATION OF OLD ASPHALT PAVEMENT/GRANULAR BASE
DOMINICAN REPUBLIC

FULL DEPTH RECLAMATION – FDR

PULVERIZING LIME **CEMENT** EMULSION FOAMED ASPHALT COMBINATION

CEMENT STABILIZATION OF COLD ASPHALT PAVEMENT/GRANULAR BASE
NATCHEZ TRACE PARKWAY, MISSISSIPPI

FULL DEPTH RECLAMATION – FDR

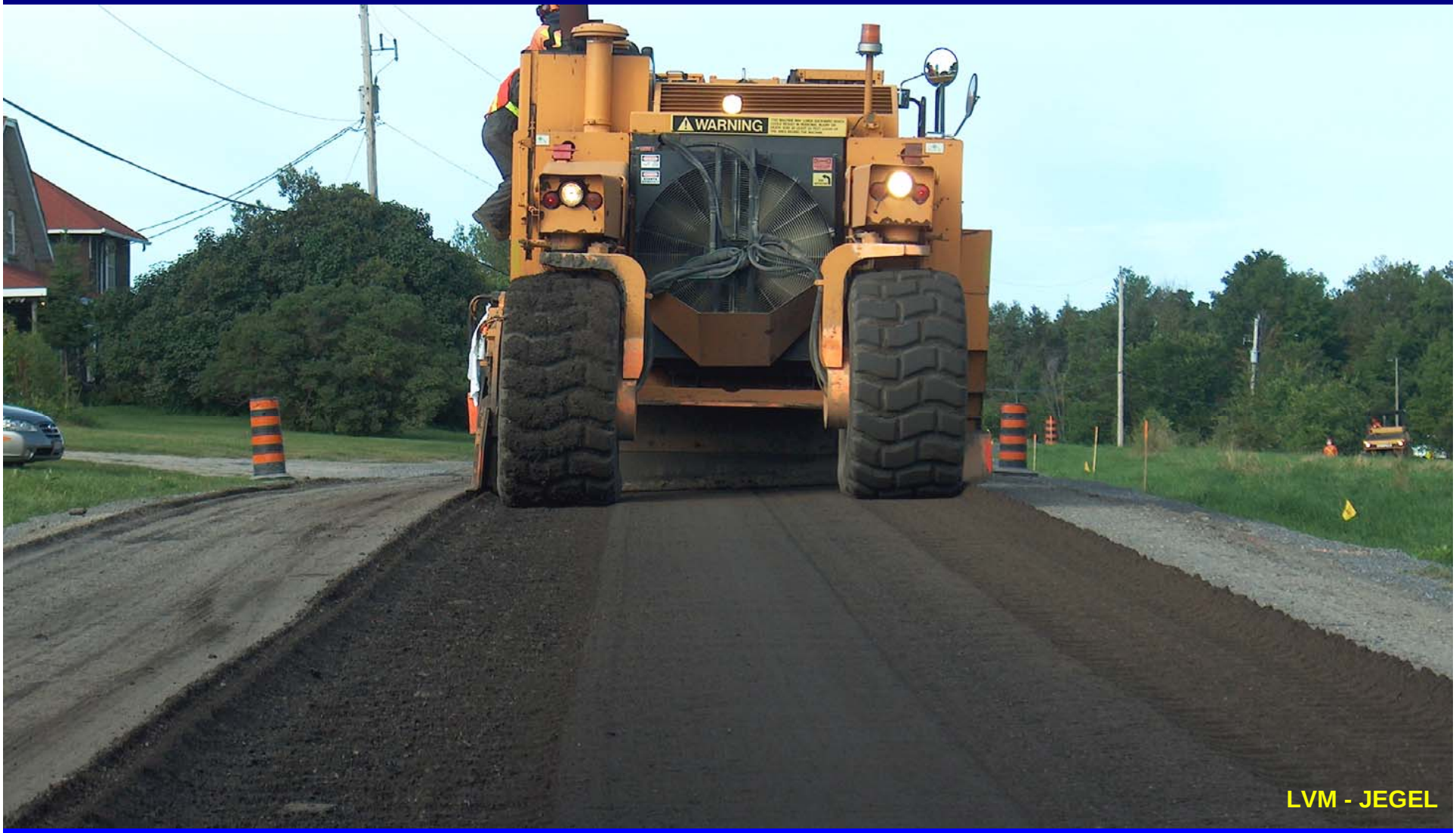
PULVERIZING LIME CEMENT EMULSION FOAMED ASPHALT COMBINATION

LVM - JEGEL

FDR EMULSION STABILIZATION
SS-1 WITH GRANULAR MATERIAL ADDED
NICARAGUA

FULL DEPTH RECLAMATION – FDR

PULVERIZING LIME CEMENT EMULSION FOAMED ASPHALT COMBINATION



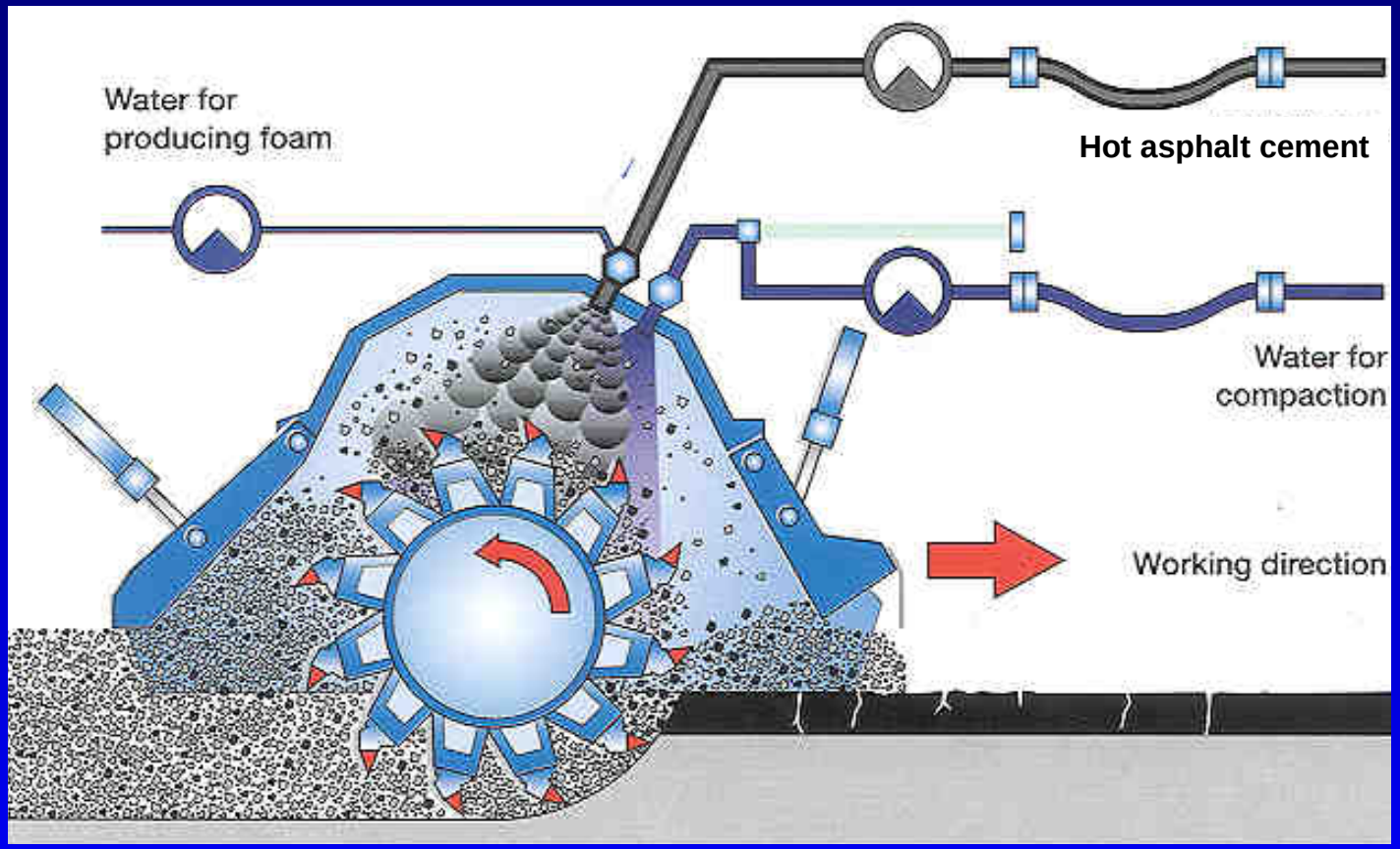
FDR WITH FOAMED ASPHALT
ONTARIO

FULL DEPTH RECLAMATION – FDR

PULVERIZING LIME CEMENT EMULSION FOAMED ASPHALT COMBINATION

FDR WITH FOAMED ASPHALT/LIME
GEORGIA

FDR FOAMED ASPHALT BASE STABILIZATION PROCESS



- OLD ASPHALT PAVEMENT PREPULVERIZED
  ADDITIONAL GRANULAR OR RAP MATERIAL MAY BE ADDED
- TYPICAL STABILIZATION DEPTH OF 125 TO 200 mm
- ABOUT 2.0 TO 3.5 PERCENT FOAMED ASPHALT ADDED
- SHAPING AND HEAVY COMPACTION
- PLACEMENT OF SURFACE TREATMENT OR HMA SURFACE

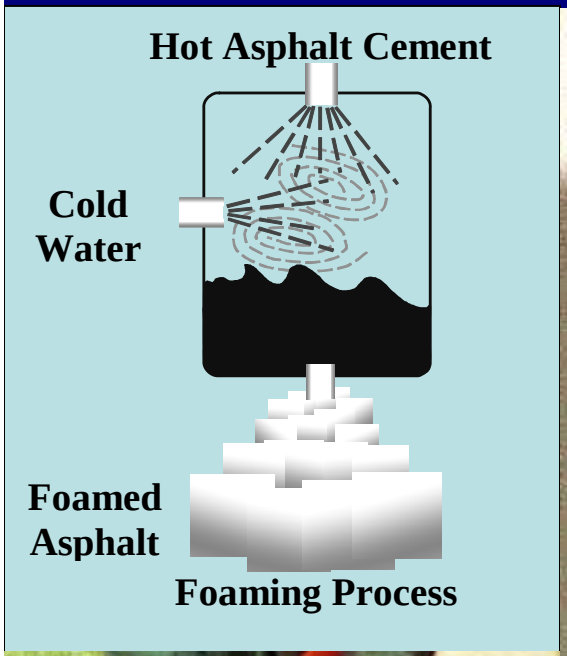
CIR AND FDR FOUR COMPONENT SYSTEM

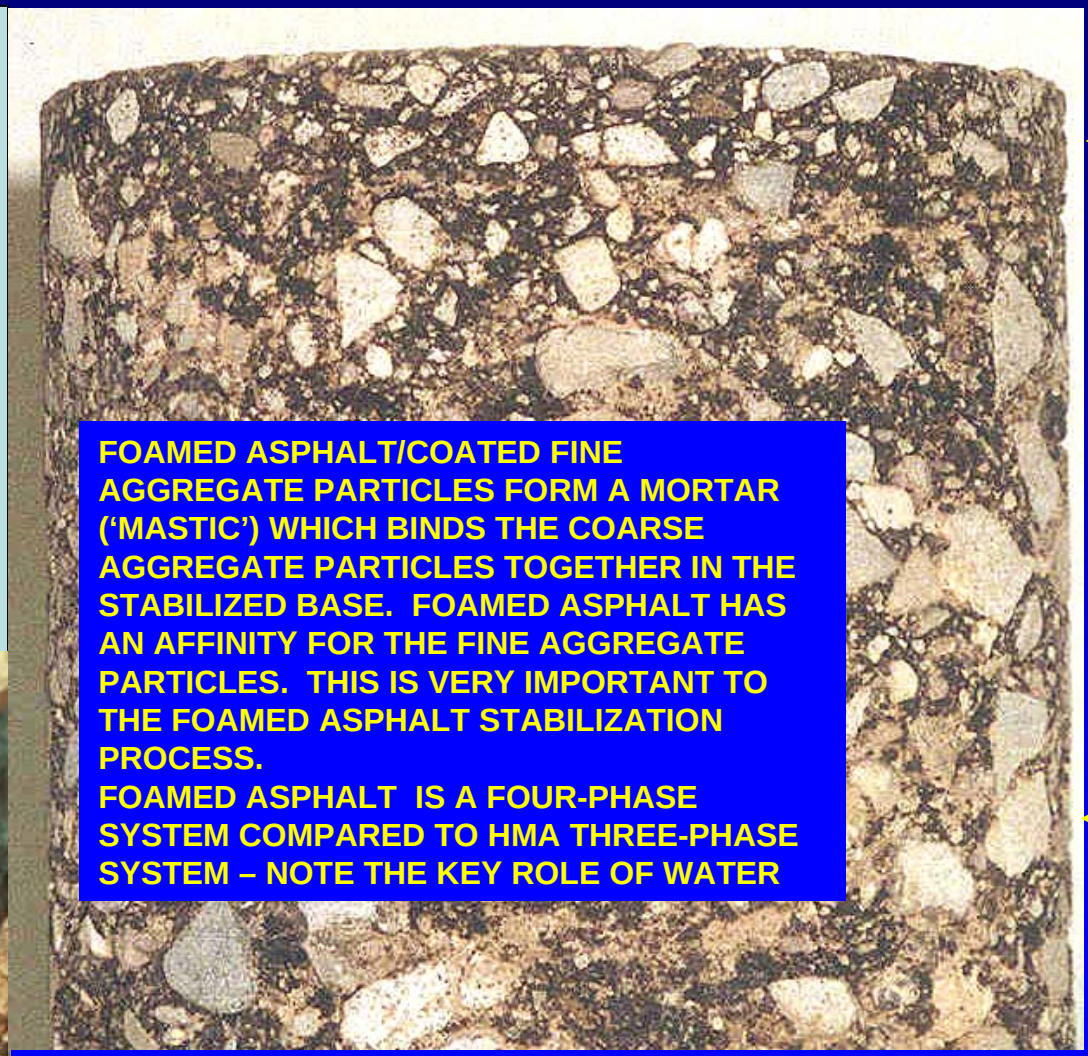
UNIQUE PROPERTIES OF FOAM

"Known as the foamed asphalt process, it utilizes the unique properties of foams. When an asphalt cement is foamed, it increases tremendously in volume, its viscosity is materially reduced, and it becomes much softer at lower temperatures. Foaming also introduces energy into the asphalt, thereby modifying its surface tension and making it more sticky. It increases its ability to displace moisture from a surface and to coat a surface with a comparatively thin film. When the foam breaks and the energy is dissipated, the asphalt cement recovers its original properties with no change in its chemical composition. Through modified surface tension, cold, wet aggregates or soils can be used, and wet clayey lumps of soil can be permeated with asphalt. Because of the ability of foamed asphalt to coat mineral particles with thin films, the use of ungraded local aggregates in mixes becomes possible and the production of mastics of mineral dusts and asphalt is also feasible. Thus, through the use of asphalt cements as a foam, materials heretofore considered unsuitable can now be used in the preparation of mixes for stabilized bases and surfacing for low-cost road construction."

FOAMED ASPHALT FOR ECONOMICAL ROAD CONSTRUCTION, CSANYI 1962, ASCE

CIR OR FDR FOAMED ASPHALT KEY FEATURES





SURFACE TREATMENT

FOAMED (EXPANDED ASPHALT STABILIZED BASE)

FOAMED ASPHALT/COATED FINE AGGREGATE PARTICLES FORM A MORTAR ('MASTIC') WHICH BINDS THE COARSE AGGREGATE PARTICLES TOGETHER IN THE STABILIZED BASE. FOAMED ASPHALT HAS AN AFFINITY FOR THE FINE AGGREGATE PARTICLES. THIS IS VERY IMPORTANT TO THE FOAMED ASPHALT STABILIZATION PROCESS.
FOAMED ASPHALT IS A FOUR-PHASE SYSTEM COMPARED TO HMA THREE-PHASE SYSTEM – NOTE THE KEY ROLE OF WATER

WELLINGTON COUNTY, ONTARIO, ROAD 50, 1997 FDR PROJECT

THE FOAMED ASPHALT EXPANSION RATIO AND HALF-LIFE ARE IMPORTANT STABILIZATION DESIGN AND CONSTRUCTION PARAMETERS. AN EXPANSION RATIO OF GREATER THAN 10 AND HALF-LIFE OF GREATER THAN 10 SECONDS ARE TYPICALLY SPECIFIED FOR FOAMED ASPHALT STABILIZATION

FDR FOAMED ASPHALT STABILIZED BASE DESIGN AND ESTIMATING GUIDE

- PREFERRED OVERALL GRADATION
  - MINUS 19 mm 60 - 100%
  - MINUS 4.75 mm 30 - 60%
  - MINUS 600 μm 15 - 30%
  - MINUS 75μm 7 - 15%

- ESTIMATED FOAMED ASPHALT CONTENT
  - 'MOISTURE SUSCEPTIBLE'
- AC% = (%AGG/100 x 4.5) + (%RAP/100 x 1.5)
  - NOT 'MOISTURE SUSCEPTIBLE'
- AC% = (%AGG/100 x 4.0) + (%RAP/100 x 1.5)

- GUIDELINES FOR USE OF HYDRATED LIME (SOTER GUIDE)
  - PLASTICITY INDEX (PI) < 4 NO HYDRATED LIME
  - PI 4 TO 8 1% HYDRATED LIME
  - PI > 8 2% HYDRATED LIME

ROTO-MILL

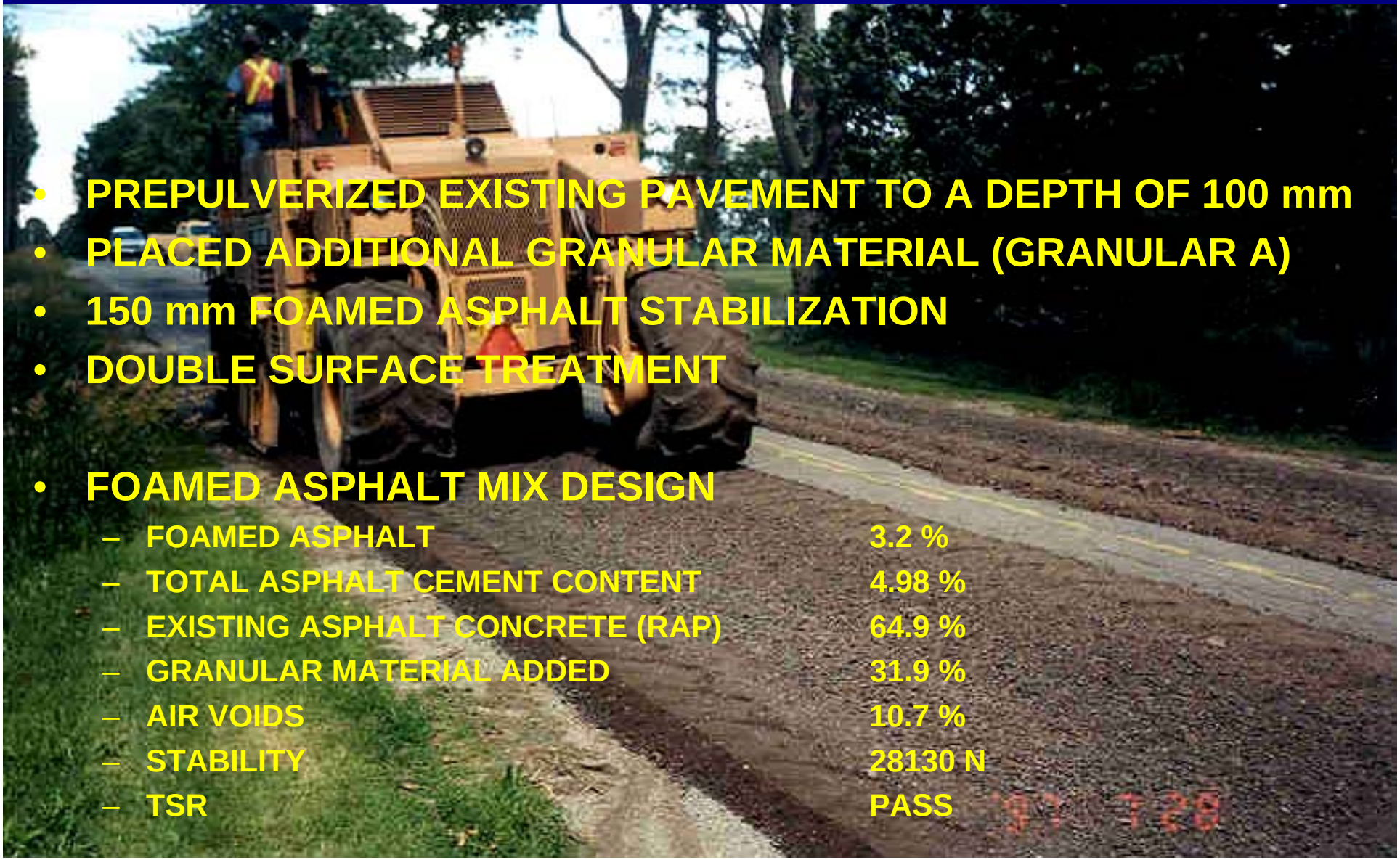
FOAMED ASPHALT STABILIZATION MIX DESIGN

- PROCESS RAP SAMPLE(S) AND AGGREGATES
- DETERMINE OPTIMUM COMPACTION
- CHECK FOAMED ASPHALT EXPANSION RATIO AND HALF LIFE
- PREPARE BRIQUETTES
  - 2.0%, 2.5%, 3.0%, 3.5%, 4.0% FOAMED ASPHALT (DEPENDING ON RICHNESS, HOT AC + ~ 2% WATER)
  - RAP + AGGREGATE + WATER + FA (TOTAL FLUIDS - 8.5%)
  - 75 BLOWS/FACE AT RESULTING TEMPERATURE (~25°C)
  - CURE 24 HOURS IN MOLD AT 25°C
  - REMOVE FROM MOLD
  - CURE 72 HOURS AT 60°C
- TEST BRIQUETTES AT 25°C (MARSHALL PROPERTIES)
- CHECK MOISTURE SUSCEPTABLITY, TSR (SATURATED, SOAKED 4 DAYS AT 25°C)

PTI PUGMILL MIXER

WIRTGEN FOAMER

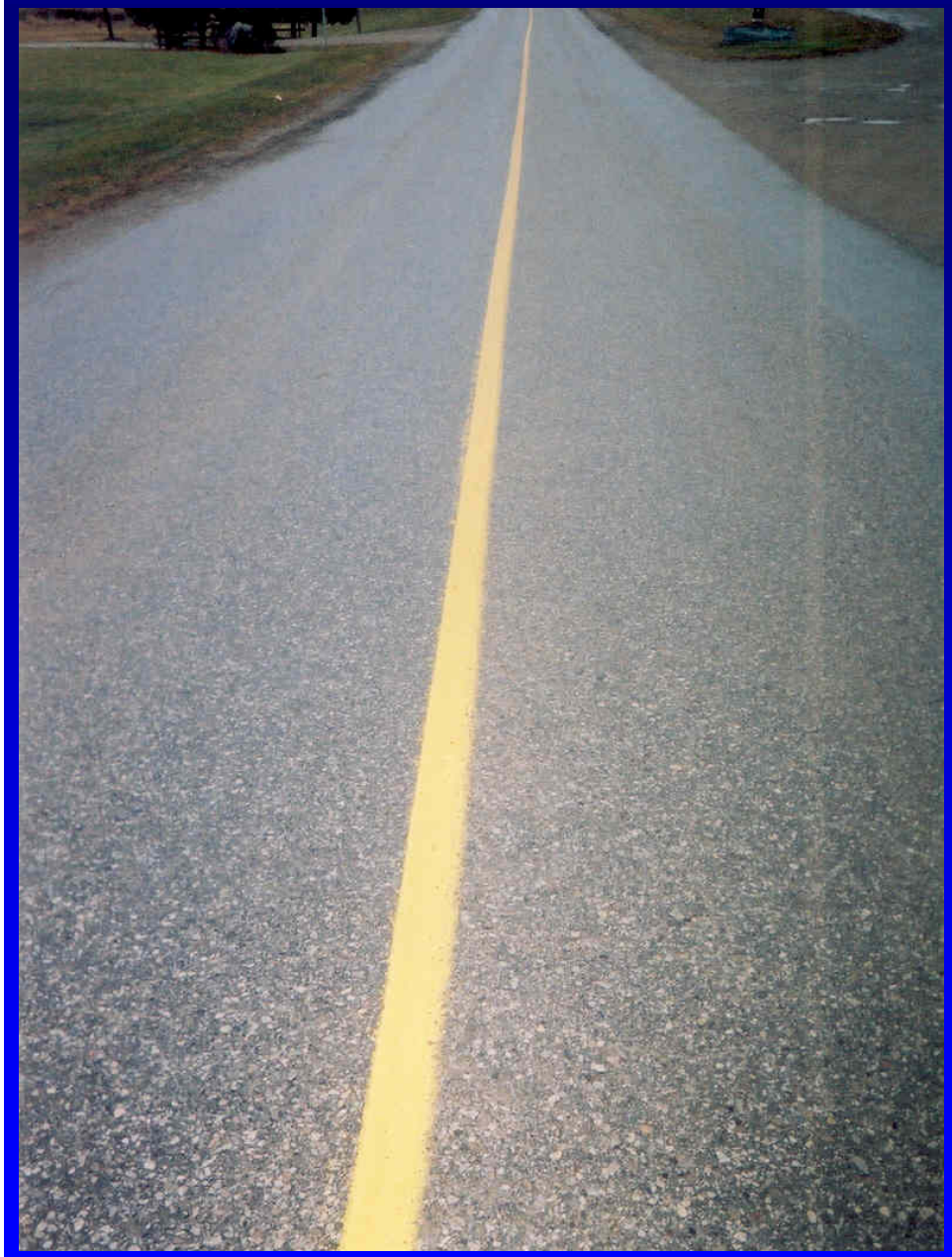
TYPICAL FOAMED ASPHALT PROJECT WELLINGTON COUNTY, ONTARIO, 1997



- PREPULVERIZED EXISTING PAVEMENT TO A DEPTH OF 100 mm
- PLACED ADDITIONAL GRANULAR MATERIAL (GRANULAR A)
- 150 mm FOAMED ASPHALT STABILIZATION
- DOUBLE SURFACE TREATMENT

- FOAMED ASPHALT MIX DESIGN
  - FOAMED ASPHALT 3.2 %
  - TOTAL ASPHALT CEMENT CONTENT 4.98 %
  - EXISTING ASPHALT CONCRETE (RAP) 64.9 %
  - GRANULAR MATERIAL ADDED 31.9 %
  - AIR VOIDS 10.7 %
  - STABILITY 28130 N
  - TSR PASS

CONDITION SHORTLY AFTER COMPLETION IN 1997

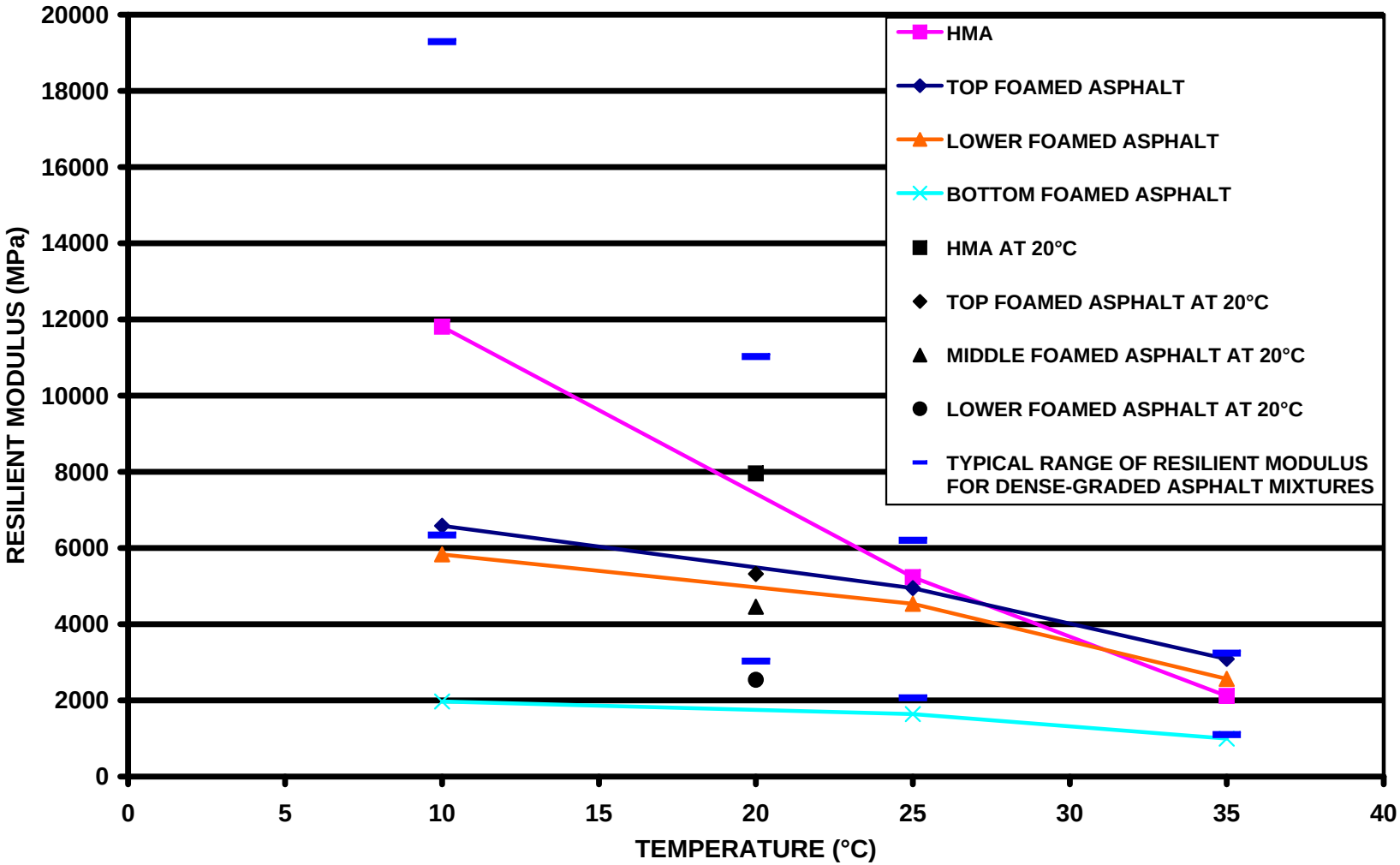


WR 50
CONDITION IN JANUARY 2007

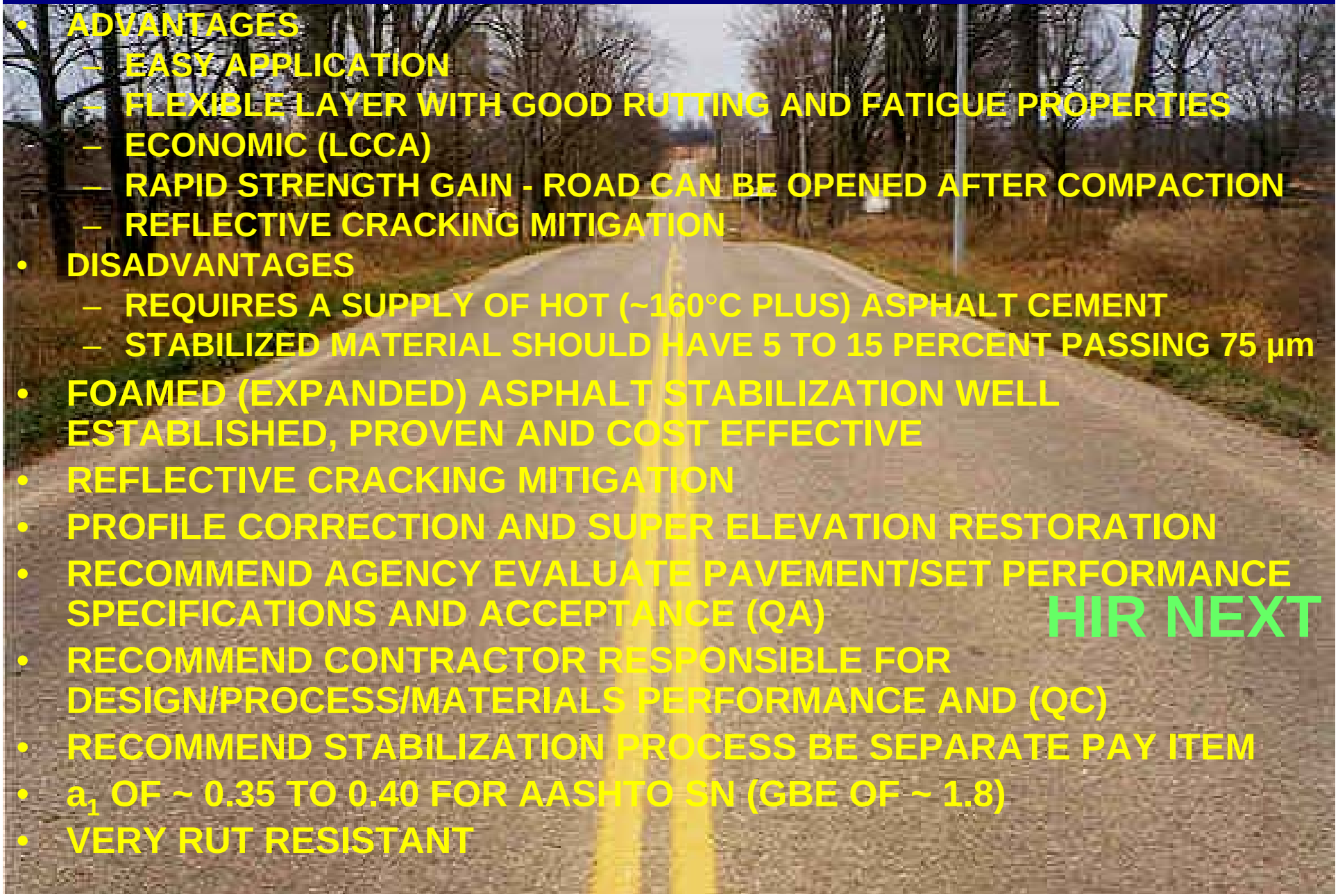
WR 50 CONDITION IN JANUARY 2007
NOTE DISTRESS IN POOR DRAINAGE AREA

CHARACTERIZATION OF HMA AND FOAMED ASPHALT

RESILIENT MODULUS VS. TEMPERATURE RELATIONSHIP HOT MIX ASPHALT AND EXPANDED ASPHALT MIX (HOUZE WAY, CITY OF ROSWELL, GEORGIA)



FDR FOAMED ASPHALT FEATURES



- ADVANTAGES
  - EASY APPLICATION
  - FLEXIBLE LAYER WITH GOOD RUTTING AND FATIGUE PROPERTIES
  - ECONOMIC (LCCA)
  - RAPID STRENGTH GAIN - ROAD CAN BE OPENED AFTER COMPACTION
  - REFLECTIVE CRACKING MITIGATION
- DISADVANTAGES
  - REQUIRES A SUPPLY OF HOT (~160°C PLUS) ASPHALT CEMENT
  - STABILIZED MATERIAL SHOULD HAVE 5 TO 15 PERCENT PASSING 75 µm
- FOAMED (EXPANDED) ASPHALT STABILIZATION WELL ESTABLISHED, PROVEN AND COST EFFECTIVE
- REFLECTIVE CRACKING MITIGATION
- PROFILE CORRECTION AND SUPER ELEVATION RESTORATION
- RECOMMEND AGENCY EVALUATE PAVEMENT/SET PERFORMANCE SPECIFICATIONS AND ACCEPTANCE (QA)
- RECOMMEND CONTRACTOR RESPONSIBLE FOR DESIGN/PROCESS/MATERIALS PERFORMANCE AND (QC)
- RECOMMEND STABILIZATION PROCESS BE SEPARATE PAY ITEM
- a_1 OF ~ 0.35 TO 0.40 FOR AASHTO SN (GBE OF ~ 1.8)
- VERY RUT RESISTANT

HIR NEXT

EVOLUTION OF HIR
FIRST GENERATION

REFORM (HEATER – SCARIFICATION) – HEATING TO A DEPTH OF 20 TO 25 mm, REJUVENATION (OPTIONAL), MIXING, LEVELLING, REPROFILING, AND COMPACTION

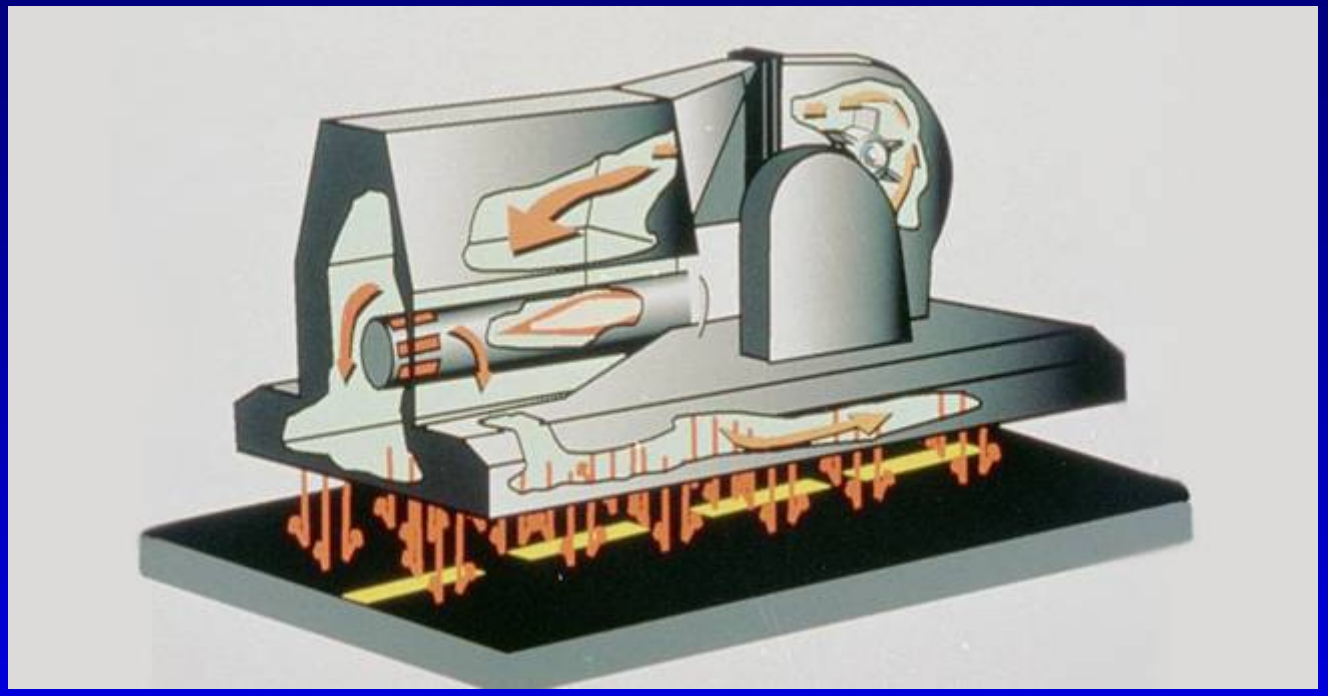
EVOLUTION OF HIR
SECOND GENERATION

REPAVE (PARTIAL RECYCLING) – HEATING TO A DEPTH OF 25 TO 50 mm, HOT MILLING, REJUVENATION (OPTIONAL), MIXING, LEVELLING, REPROFILING, AND ADDING A NEW THIN OVERLAY OF HOT-MIX ASPHALT
BRITISH COLUMBIA HIGHWAY 1, NEAR VANCOUVER 1988

EVOLUTION OF HIR
THIRD GENERATION

REMIX (FULL RECYCLING) – HEATING TO A DEPTH OF UP TO 75 mm, HOT MILLING, REJUVENATION/ NEW AGGREGATE/ NEW MIX (OPTIONAL – DESIGNED), MIXING, REPROFILING/PLACING WITH PAVER, AND COMPACTION
MARTEC AR2000, INTERSTATE 85, NORTH CAROLINA, OFC, 2001

HEATER TECHNOLOGY



THE AIR IN THE DIESEL-FUELED COMBUSTION CHAMBER IS HEATED TO UP TO 700˚C AND BLOWN ON THE PAVEMENT THROUGH HOLES IN THE MANIFOLD, WITH THE SPENT HOT AIR RECUPERATED AND REHEATED

THE SOFTENED OLD ASPHALT CONCRETE IS NOT DAMAGED ('BURNED') AND EMISSION LEVELS ARE VERY LOW

MARTEC AR2000 HIR PROCESS – A TRAVELLING ASPHALT RECYCLING PLANT

ONTARIO HIGHWAY 401 DEMONSTRATION PROJECT

COMPLETED MARTEC AR2000 HIR SECTION IN SEPTEMBER 1999 WITH TYPICAL HIGHWAY 401 TRUCK TRAFFIC ON THIS US-CANADA NAFTA ROUTE

ONTARIO HIGHWAY 401 DEMONSTRATION PROJECT

CURRENT CONDITION OF THE MARTEC AR2000 HIR SECTION IN FEBRUARY 2005
SHOWING THE EXCELLENT CONDITION OF THE TWO LANES INVOLVED

RUTTING AND FRICTION MONITORING TEST RESULTS HIGHWAY 401 DEMONSTRATION PROJECT

DEMONSTRATION SECTION	IRI	RUTTING (MM)	FRICTION (ASTM)	
	THREE YEARS 2002	BEFORE 1999	ONE YEAR 2000	THREE YEARS 2002
SECOND GENERATION HIR	1.29	4.2	41	44
NEW DENSE FRICTION COURSE (DFC)	1.12	2.9	41	44
MARTEC AR2000 HIR	0.98	2.3	41	47
RECYCLED HOT-MIX DFC	0.98	2.6	42	46
MICROSURFACING – 2000	0.90	4.2	49	44
MICROSURFACING - 1999	0.78	4.6	45	41

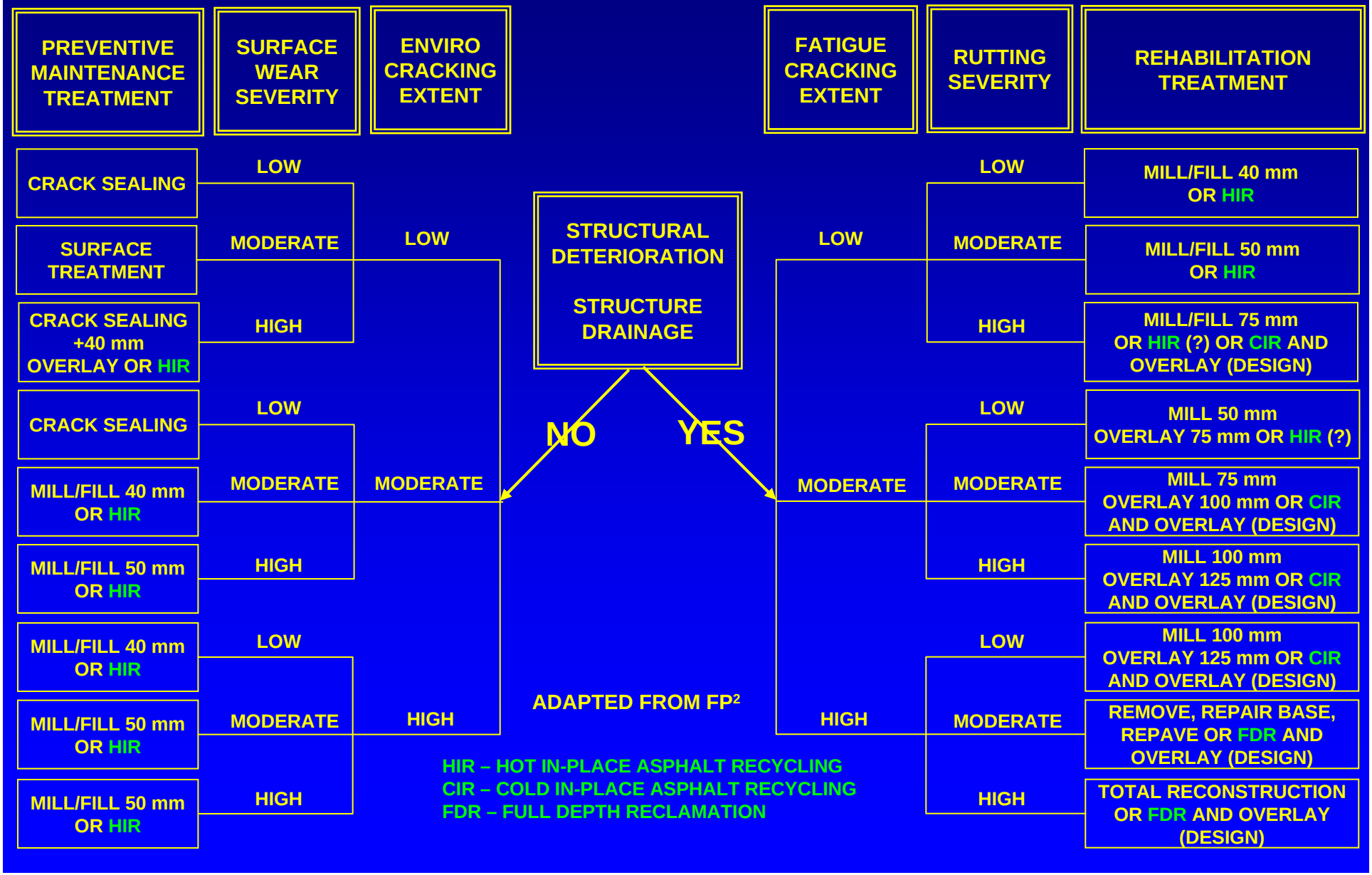
ONTARIO MINISTRY OF TRANSPORTATION 2002 FINDINGS FOR THIS HIGHLY TRAFFICKED ROUTE MARTEC AR2000 HIR SECTION IS IN EXCELLENT CONDITION AND

PERFORMING THE BEST OF ALL THE SECTIONS

CONFIRMED BY JEGEL FEBRUARY 2005 INSPECTIONS

SWIFT | CIR, FDR AND HIR | SEPTEMBER 2009

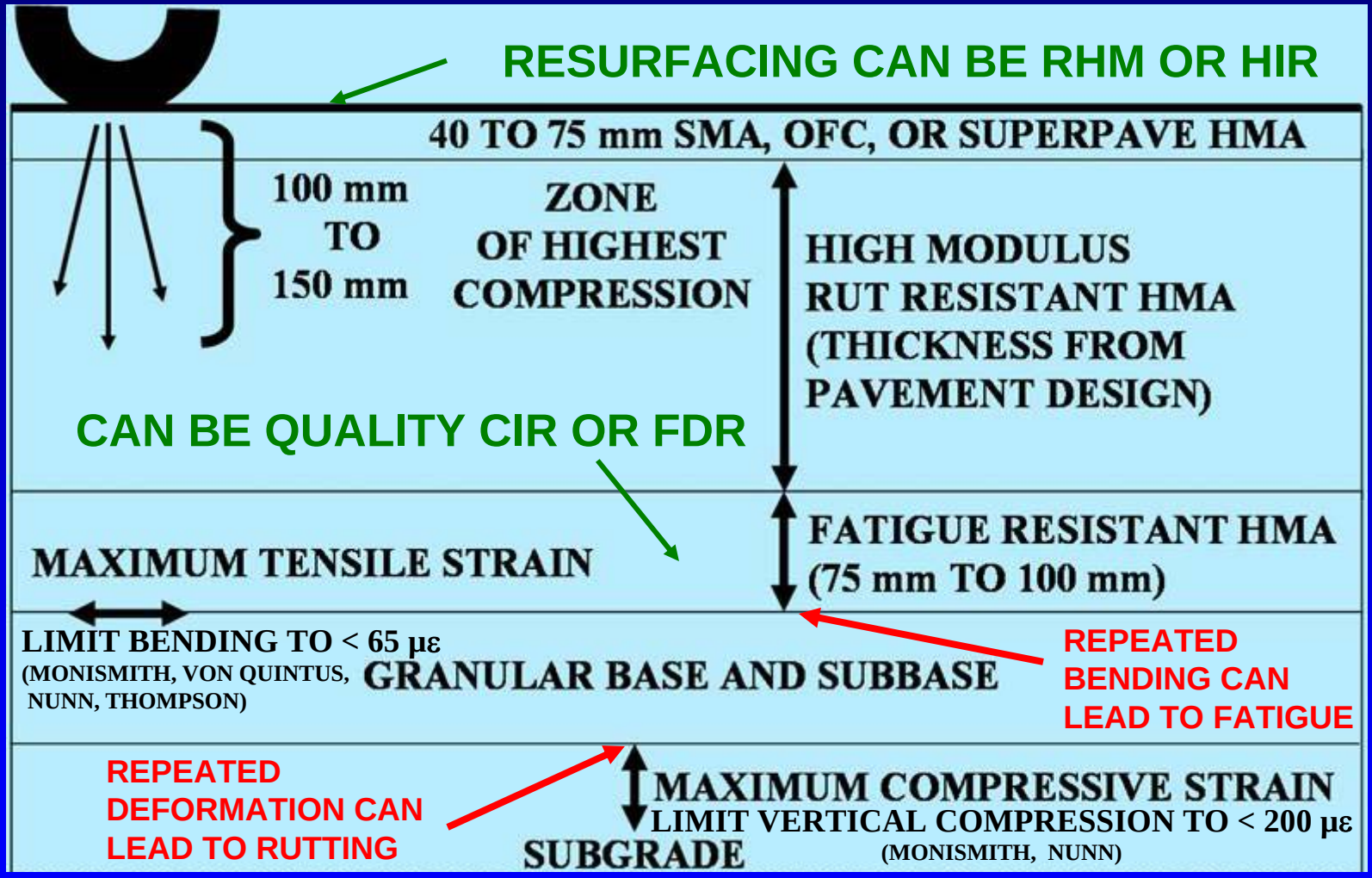
DECISION TREE FOR FLEXIBLE PAVEMENT MAINTENANCE AND REHABILITATION INCLUDING HIR, CIR AND FDR



ADAPTED FROM FP[2]

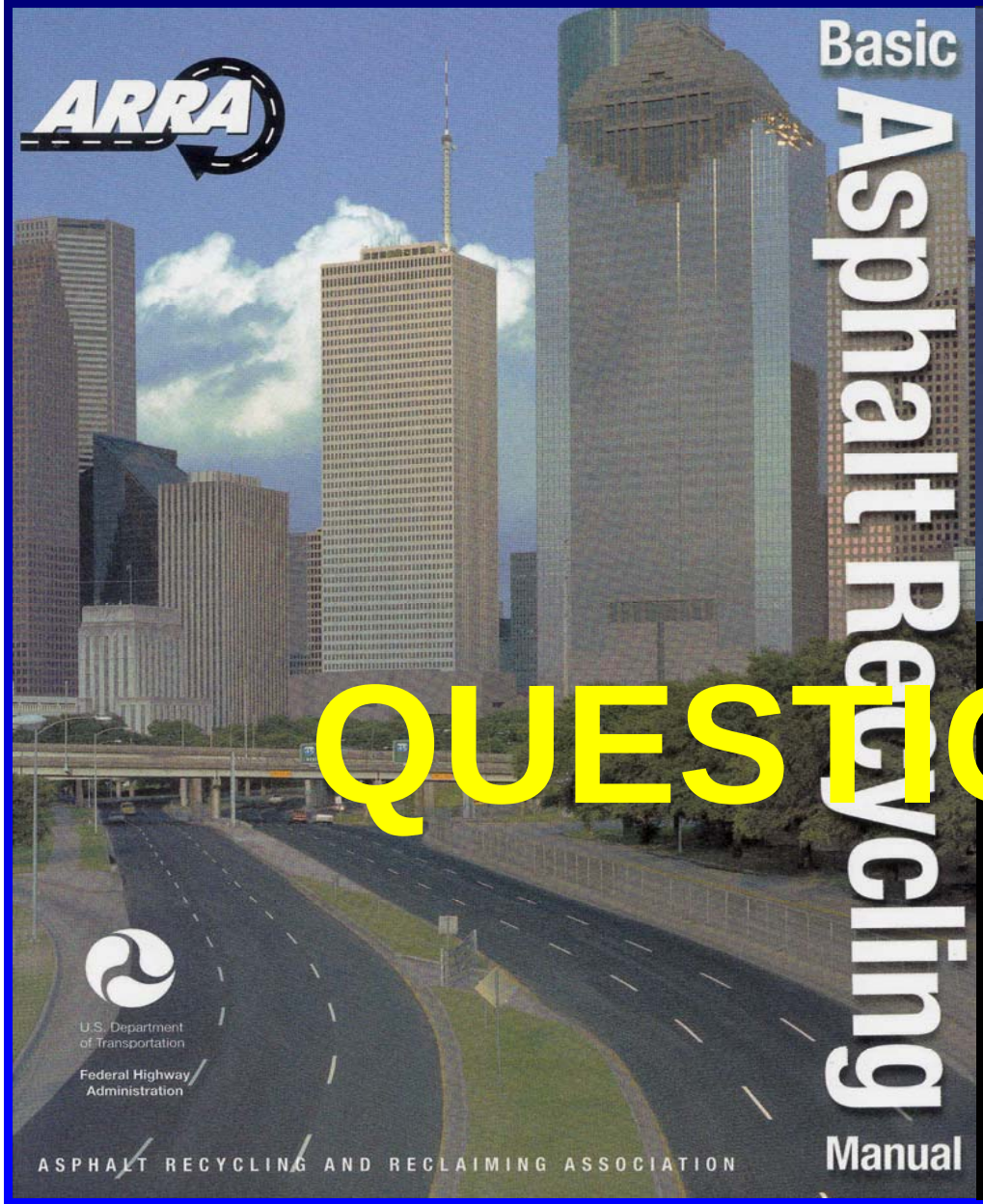
HIR – HOT IN-PLACE ASPHALT RECYCLING
CIR – COLD IN-PLACE ASPHALT RECYCLING
FDR – FULL DEPTH RECLAMATION

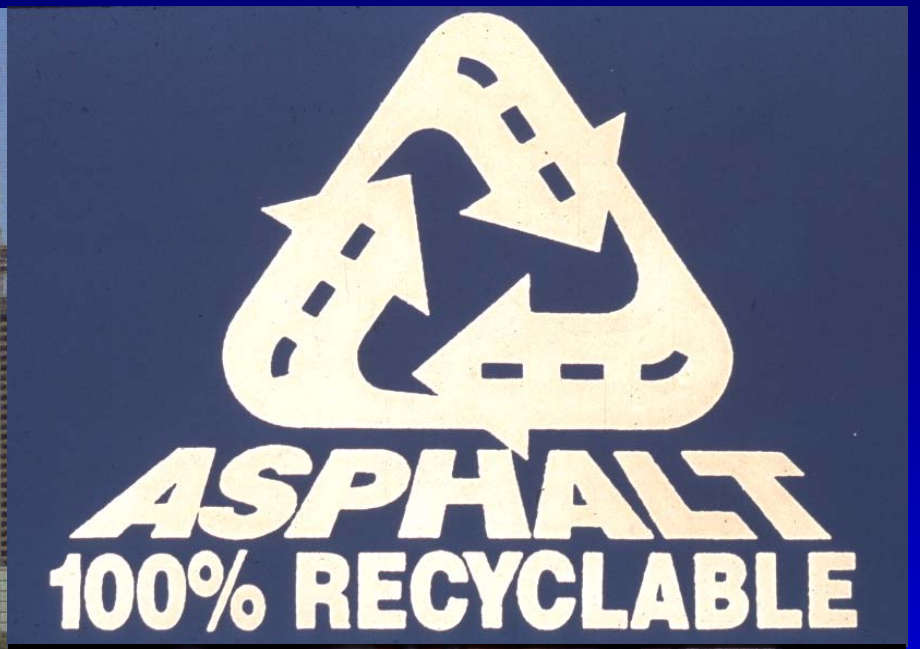
DESIGN OF LONG-LIFE FLEXIBLE PAVEMENTS



LONG-LIFE FLEXIBLE PAVEMENT DESIGN CONCEPT

SCHEMATIC OF A LONG-LIFE FLEXIBLE (ASPHALT) PAVEMENT SHOWING THE RENEWABLE SMA, OFC, OR SUPERPAVE HMA/RHM SURFACE COURSE





QUESTIONS ?

PLEASE CONTACT JOHN EMERY AT LVM - JEGEL WITH YOUR QUESTIONS
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