AN EXAMINATION OF ASPHALT CEMENT PROPERTIES ON LOW TEMPERATURE CRACKING ON THE C-LTPP AND C-SHRP TEST SITES

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PRESENTATION OUTLINE

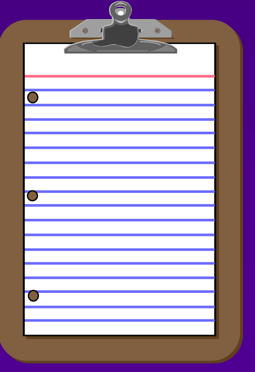
- Background - University of Waterloo,

  C-LTPP Experiment, C-SHRP Test Roads

- Research Project & Methodology

- Results and Discussion

- Conclusions and Recommendations



UNIVERSITY OF WATERLOO

- One of largest civil engineering programs in Canada
- Located in Ontario - 1 hour west of Toronto
- 33 tenured or tenure track professors
- 80 graduate; 75 undergrads/year; co-op

UNIVERSITY OF WATERLOO

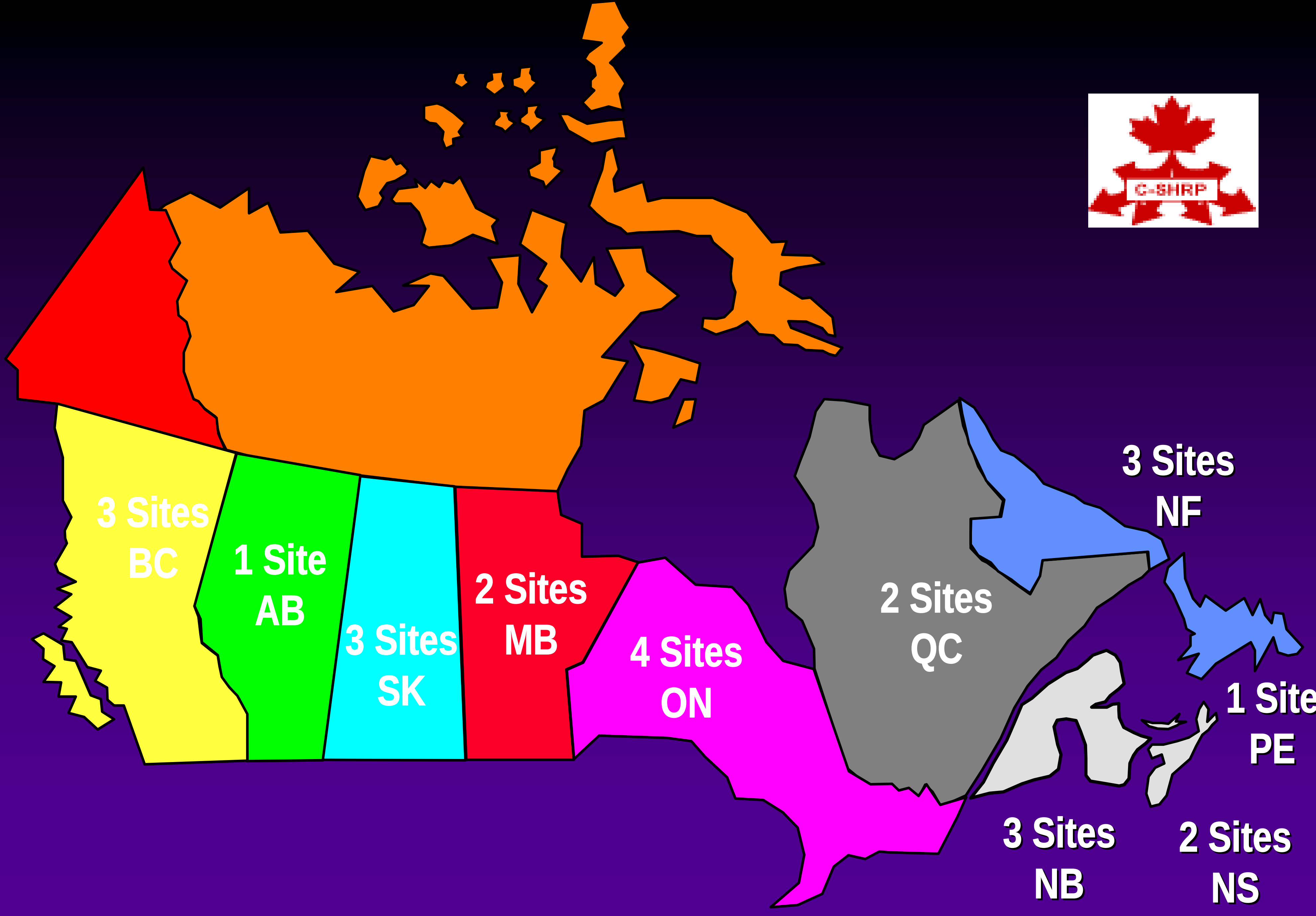
- Roads and pavements research and education
- Over 50 MA.Sc and Ph.D graduates
- Team: Profs. Ralph Haas, Susan Tighe
- Adjuncts: Drs. Norman McLeod, Gerhard Kennepohl

C-LTPP EXPERIMENT

24 Sites, 65 sections, Asphalt Overlays

Constructed 1989 - 1991

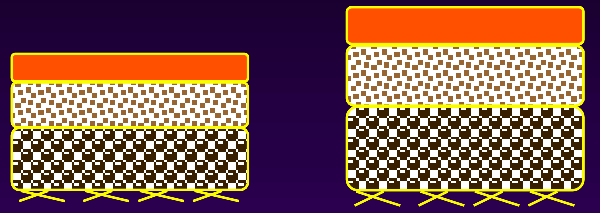
C-SHRP



3 Sites
BC
1 Site
AB
3 Sites
SK
2 Sites
MB
4 Sites
ON
2 Sites
QC
3 Sites
NF
1 Site
PE
3 Sites
NB
2 Sites
NS

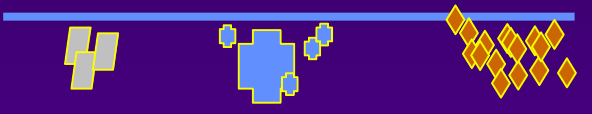
MAJOR FACTORS

Overlay Thickness (3 levels)

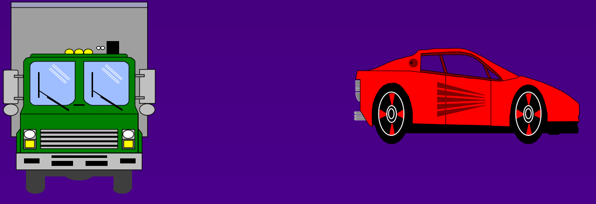


Climatic Zones (4 types)

Subgrade Types (2 types)



Traffic Levels (2 levels)



AC Types (2 types)

C-SHRP TEST SITES

- Test Roads - Lamont - Alberta (7 test sections), Hearst Ontario (4 test sections), Sherbrooke Quebec (4 test sections)
- Constructed in 1991, 1992
- Validate or suggest changes to binder and mixture specifications for Canadian climate

C-SHRP TEST SITES

- Validate or suggest changes to binder and mixture specifications for Canadian climate
- Investigate fracture temperature models
- W.D. Roberston TAC Report 1997 (TB #15)
- Anderson, Christison, Johnston TAC Report 1999 (TB #19),

www.cshrp.org

RESEARCH PROJECT

- Examine asphalt cement properties and low temperature cracking on C-LTPP, C-SHRP sites
- Existing data available for long term performance
- Validity of empirical low temperature susceptibility indices
- Low temperature model comparison

ACKNOWLEDGEMENTS

- C-SHRP C-LTPP Graduate Research Grant
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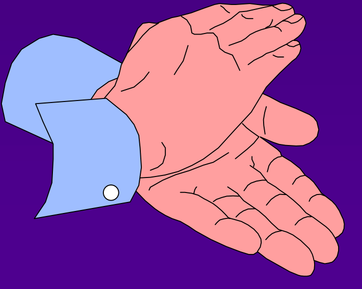
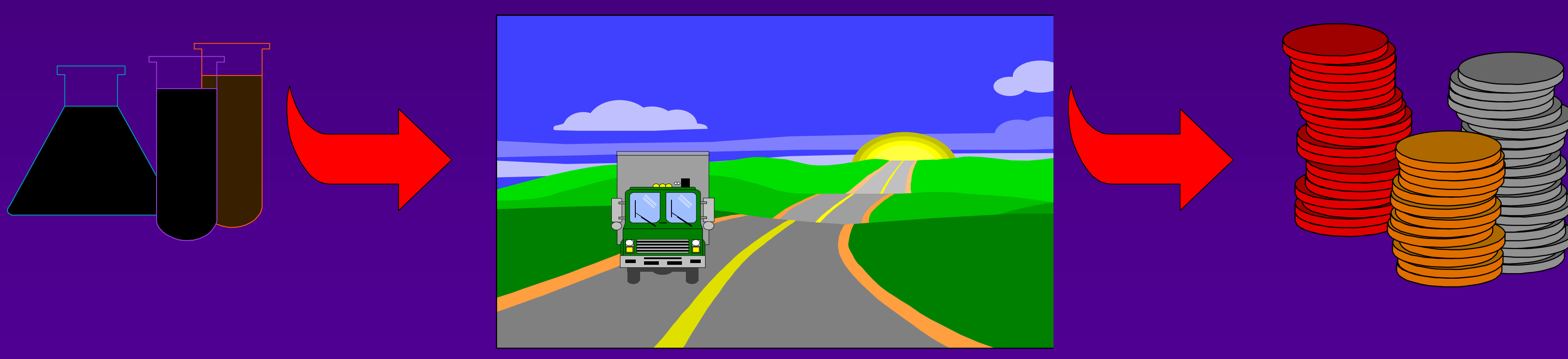
- Natural Science and Engineering Research Council
- Transportation Association of Canada Emery-Lindsay Scholarship
- Professors Ralph Haas and Park Reilly



RESEARCH PROJECT

- Examine asphalt cement properties and low temperature cracking on C-LTPP, C-SHRP sites
- Laboratory test data with in-service performance data
- Compare predicted performance with observed

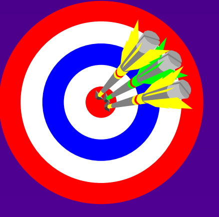


RESEARCH METHODOLOGY

- Validation of empirical low temperature susceptibility indices - mainly CGSB information available
- Statistical tests - ANOVA, Power Test
- Low temperature cracking models - used PVN and other variables to predict cracking
- Statistical tests to compare predictions to observed

VERIFICATION OF PVN

- Examining the literature - Validity?
- Statistical tests were established to examine:
  - Repeatability (absolute vs. kinematic viscosity)?
  - Influence of Ageing (short and long term)?
  - Practical Implication (does it make sense)?
  - Relate to Superpave PG asphalts?



VERIFICATION OF PVN

$$PVN = \frac{-1.5\,[L - \log X]}{[L - M]}$$

PVN = Penetration Viscosity Number

X = viscosity at 135C (cs)

L = 4.258 - 0.797log P (cs)

M = 3.463 - 0.611 log P

P = penetration at 25C

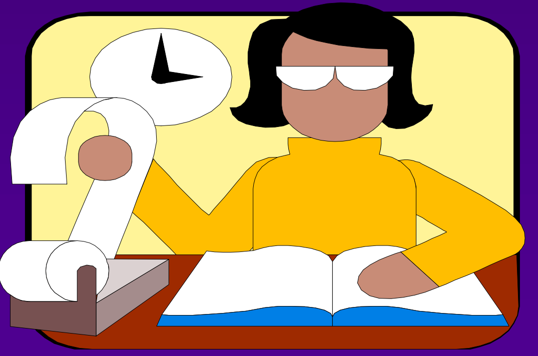
*Ranges from - 1.0 to + 1.0, higher the value the less temperature susceptible the asphalt cement

VERIFICATION OF PVN

- Series of ANOVA and Power Tests
- Repeatability: $PVN_{ORIGINAL@135C} = PVN_{ORIGINAL@60C}$
- Influence of Ageing - short term:

➡ $PVN_{ORIGINAL@135C} = PVN_{AGED@60C}$

➡ $PVN_{ORIGINAL@60C} = PVN_{AGED@60C}$



VERIFICATION OF PVN

- Influence of Ageing - long term:

$PVN_{ORIGINAL} = PVN_{AGED} = PVN_{CONSTRUCTION} = PVN_{7YEARS}$

- Engineering check - magnitude

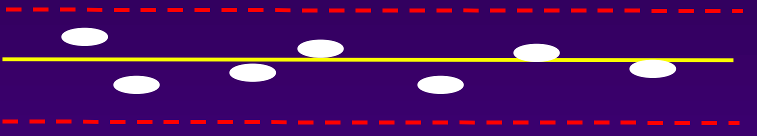
- Relate to Superpave PG asphalts - did a lower min PG temperature relate to PVN?:

$PVN_{58-22} < PVN_{58-28}$

VERIFICATION OF PVN

ANOVA

H_O $\mu_1 = \mu_2$, H_A, $F_{CALCULATED}$, $F_{CRITICAL}$, 95% confidence, degrees of freedom, within/between variation



POWER TEST

Type II error (β) - risk of accepting H_o when it is false, Monte Carlo simulation or φ calculation

RESULTS

ANOVA	TEST	$F_{CALCULATED}$	$F_{CRITICAL}$	Degrees Of Freedom
A	Between Within	55.46 0.36	1.68 3.16	28 2
B	Between Within	37.90 0.77	1.62 4.04	48 1

A $PVN_{ORIGINAL@135C} = PVN_{ORIGINAL@60C} = PVN_{AGED@60C}$

B $PVN_{ORIGINAL@135C} = PVN_{ORIGINAL@60C}$

RESULTS

ANOVA	TEST	$F_{CALCULATED}$	$F_{CRITICAL}$	Degrees Of Freedom
C	Between Within	7.35 3.61	1.62 4.04	47 1
D	Between Within	1.61 1.04	1.56 4.04	56 1

C $PVN_{ORIGINAL@60C} = PVN_{AGED@60C}$

D $PVN_{ORIGINAL@60C} = PVN_{AGED@60C}$

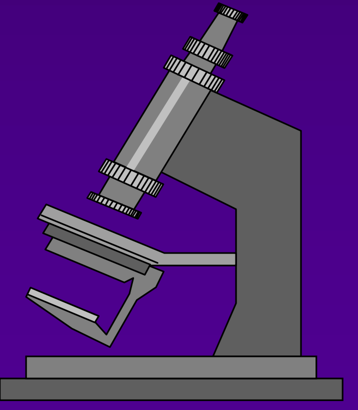
RESULTS

Kandahl data AAPT 1996 - (ANOVA E)

$PVN_{ORIGINAL} = PVN_{AGED} = PVN_{CONSTRUCTION} = PVN_{7YEARS}$

Within $F_{CALCULATED}$ 3.03 < $F_{CRITICAL}$ 3.29

Between $F_{CALCULATED}$ 67.24 > $F_{CRITICAL}$ 2.90



RESULTS

Results Indicate:

- PVN remains constant with time
- PVN is repeatable

However Type II Error:

- Performed power test to examine error
- Probability of rejecting H_o
- Power Curves were developed

POWER TEST

$Y_{ij} = \mu_{ij} + \alpha_{ij} + \beta_j + \varepsilon_{ij}$

Y_{ij} = probability of rejecting H_o

μ_{ij} = a x [row averages matrix]

α_{ij} = [column averages matrix]

β_j = iid N (μ, σ^2)

ε_{ij} = percent difference in the true population

POWER TEST

$$\varphi = [(1 / \upsilon_1 + 1)^{.5}) + 1/\sigma_R \times ((\upsilon_2) \Sigma \alpha_i - \alpha_m)^2)^{.5}]/(\sigma^2)$$

φ =coefficient Pearson & Hartley table

υ_1 = rows degrees of freedom

υ_2 = column degrees of freedom

σ_R = standard deviation of rows

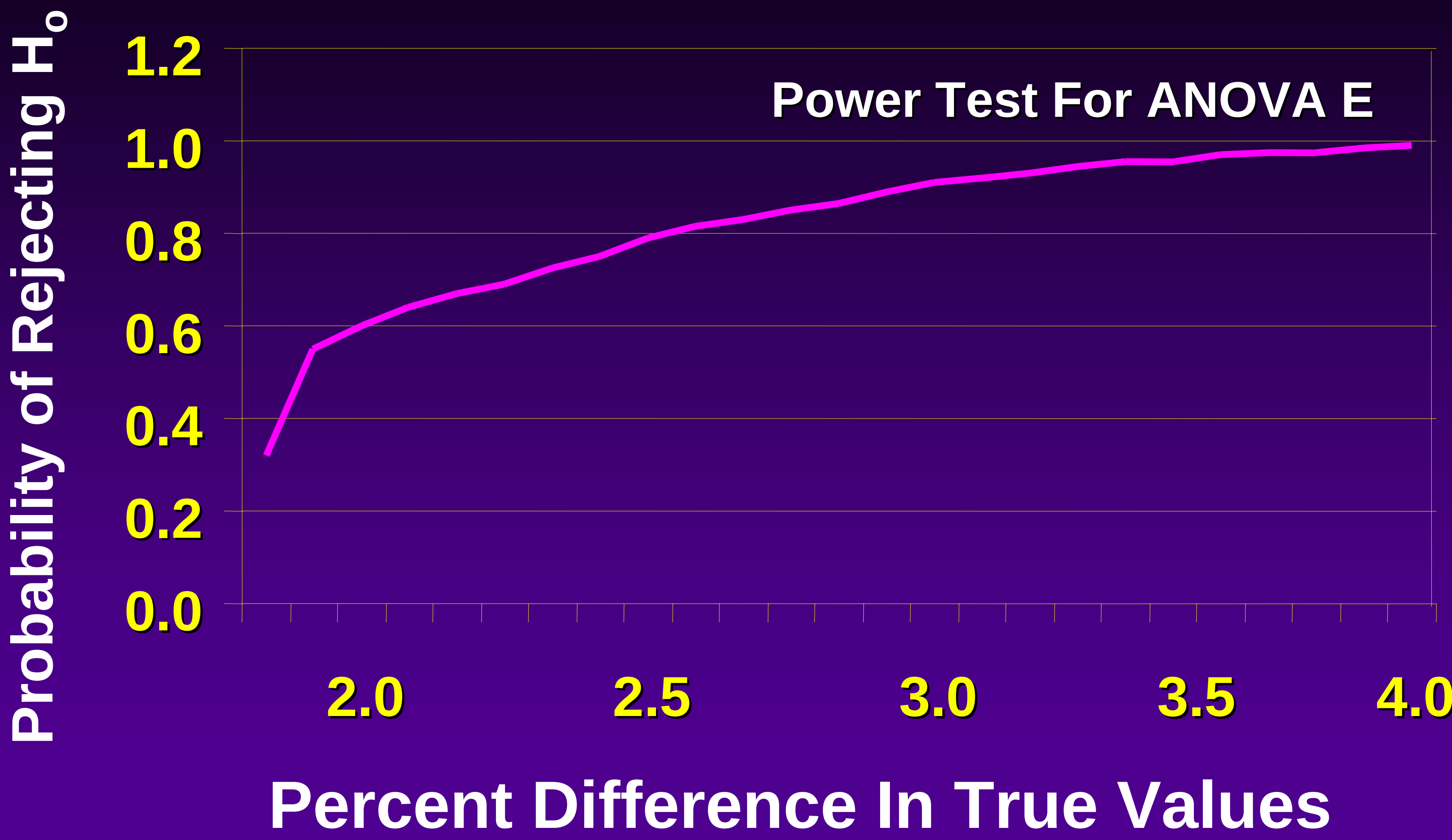
σ^2 = variance of entire sample

α_i = mean for the i^{th} row under H_A

α_m = a [row average matrix]

RESULTS

β


Power Test For ANOVA E
Probability of Rejecting H_o
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2.0
2.5
3.0
3.5
4.0
Percent Difference In True Values

RESULTS

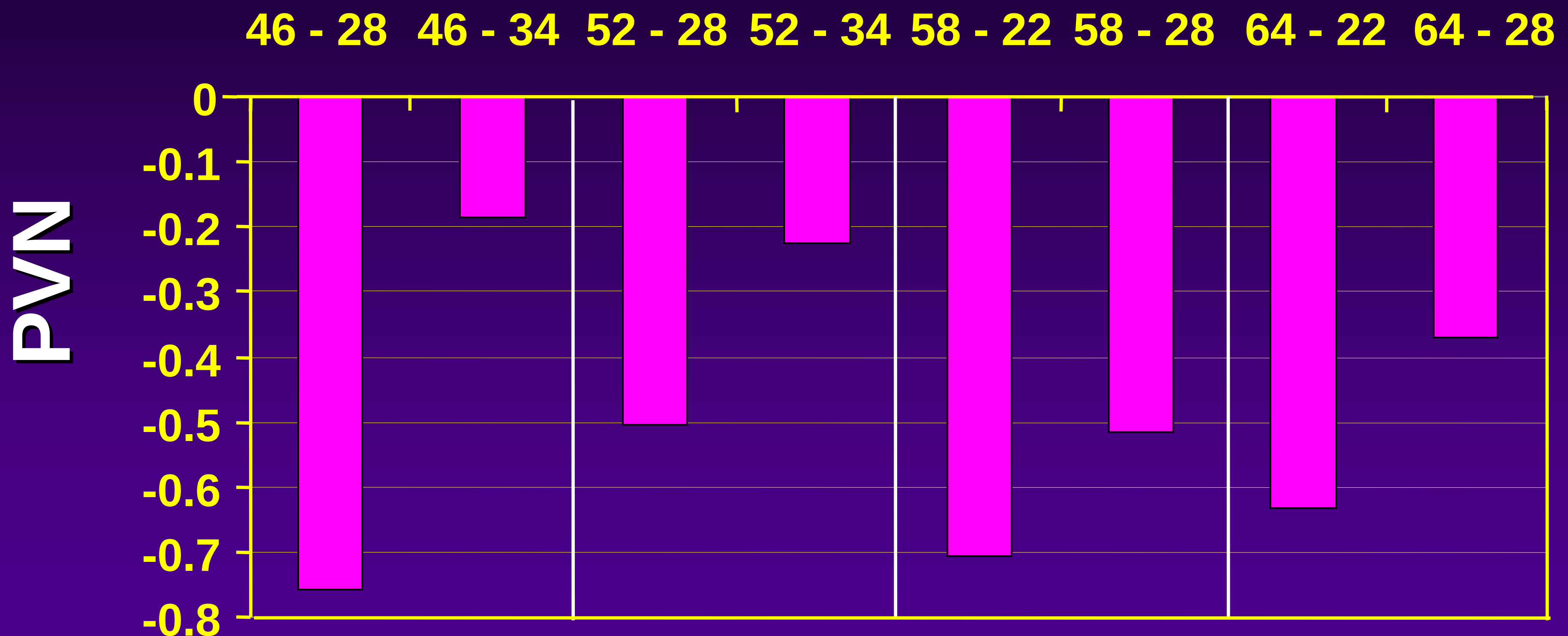
Power Analysis	% Difference @ 95%	υ_1	υ_2	Purpose of ANOVA
A	7.9%	2	28	Variability, Over Time(S)
B	6.7%	1	48	Variability
C	8.0%	1	47	Variability, Over Time(S)
D	45%	1	56	Over Time(S)
E	3.3%	3	5	Over Time (L)

RESULTS

ANOVA	Grade Test	$F_{CALCULATED}$	$F_{CRITICAL}$	Degrees Of Freedom
PG 58-22	Between	12.18	4.28	1
58-28	Within	1.35	2.01	23
PG 52-28	Between	20.93	6.61	1
52-34	Within	0.79	5.05	5
PG 64-22	Between	51.29	6.61	1
64-28	Within	3.33	5.05	5
PG 46-28	Between	5.64	10.13	1
46-34	Within	1.71	9.28	3

RESULTS

Superpave Performance Grades



RESULTS

Hajek Model - 42 observations Ontario, Manitoba

log CI = 30.397 + .603*S*log d - 12.50*m + 1.34 log S - 2.13 d - .87*t*log S + 6.80 log S

CI = cracking index (/500 ft)

S = stiffness - McLeod's method (PVN)

a = age (yrs)

m = winter design temperature (C)

d = subgrade strength (code 1, 2, 3)

t = thickness (in)

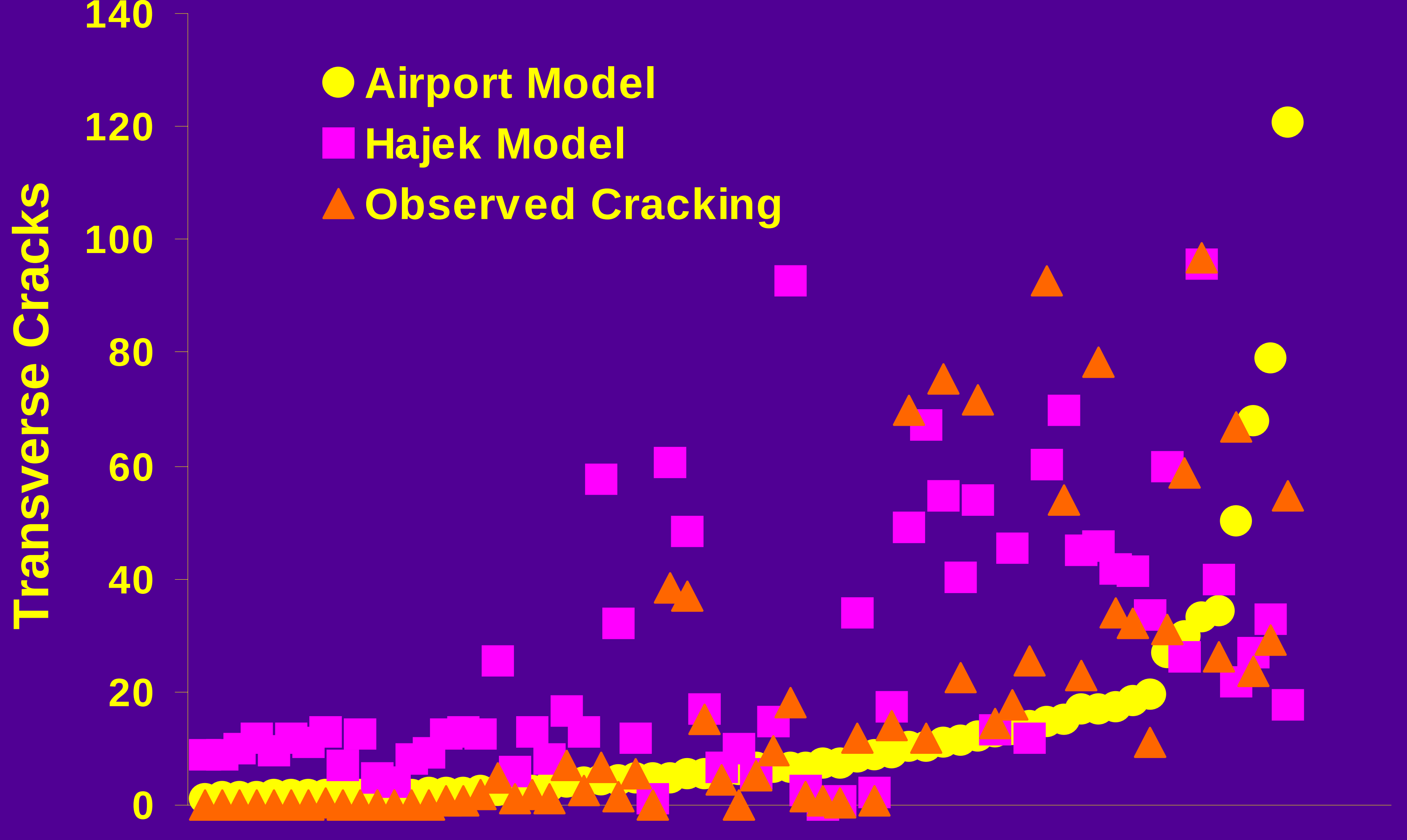
RESULTS

Canadian Airport Model - 22 airports across Canada

TRANCRACK = 218 + 1.28 ACTHICK + 2.52MINTEMP + 30 PVN - 60 COEFFX

TRANCRACK = transverse crack spacing (m)
ACTHICK = asphalt thickness (cm)
PVN = McLeod's Penetration Viscosity Number
MINTEMP = minimum temperature recorded at site (C)
COEFFX = thermal contraction coefficient (mm/1000mm/C)

CRACK COMPARISON RESULTS



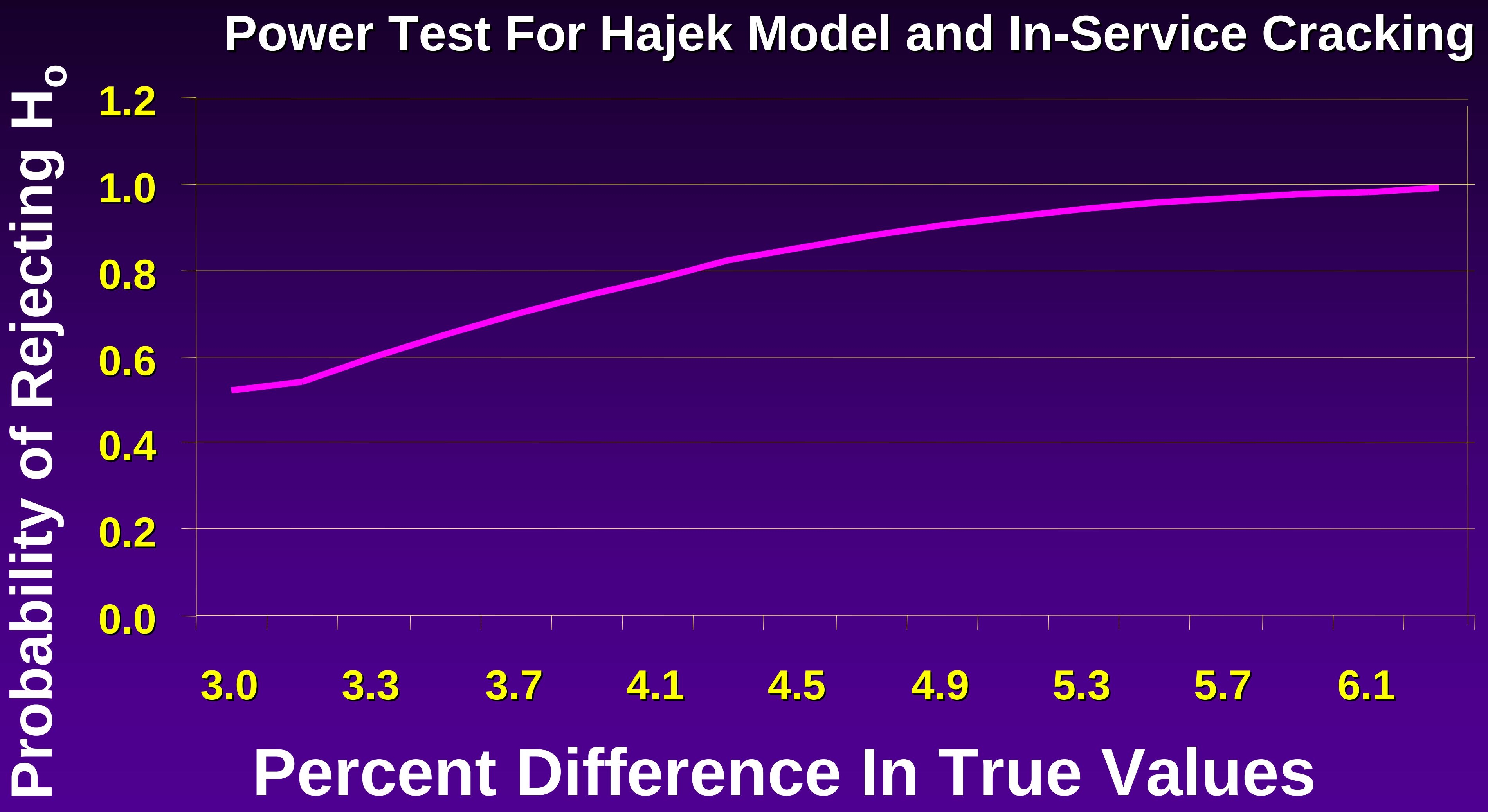
CRACK COMPARISON RESULTS

Crack Analysis	ANOVA Test	$F_{CALCULATED}$	$F_{CRITICAL}$	Degrees Of Freedom
Section 1 to 70	Between Sections	2.3621	1.4900	69
Hajek Prediction & In-Service Cracking	Between Model and Observed	0.4407	3.9798	1

ANOVA For Hajek Model and In-Service Cracking

CRACK COMPARISON RESULTS

β



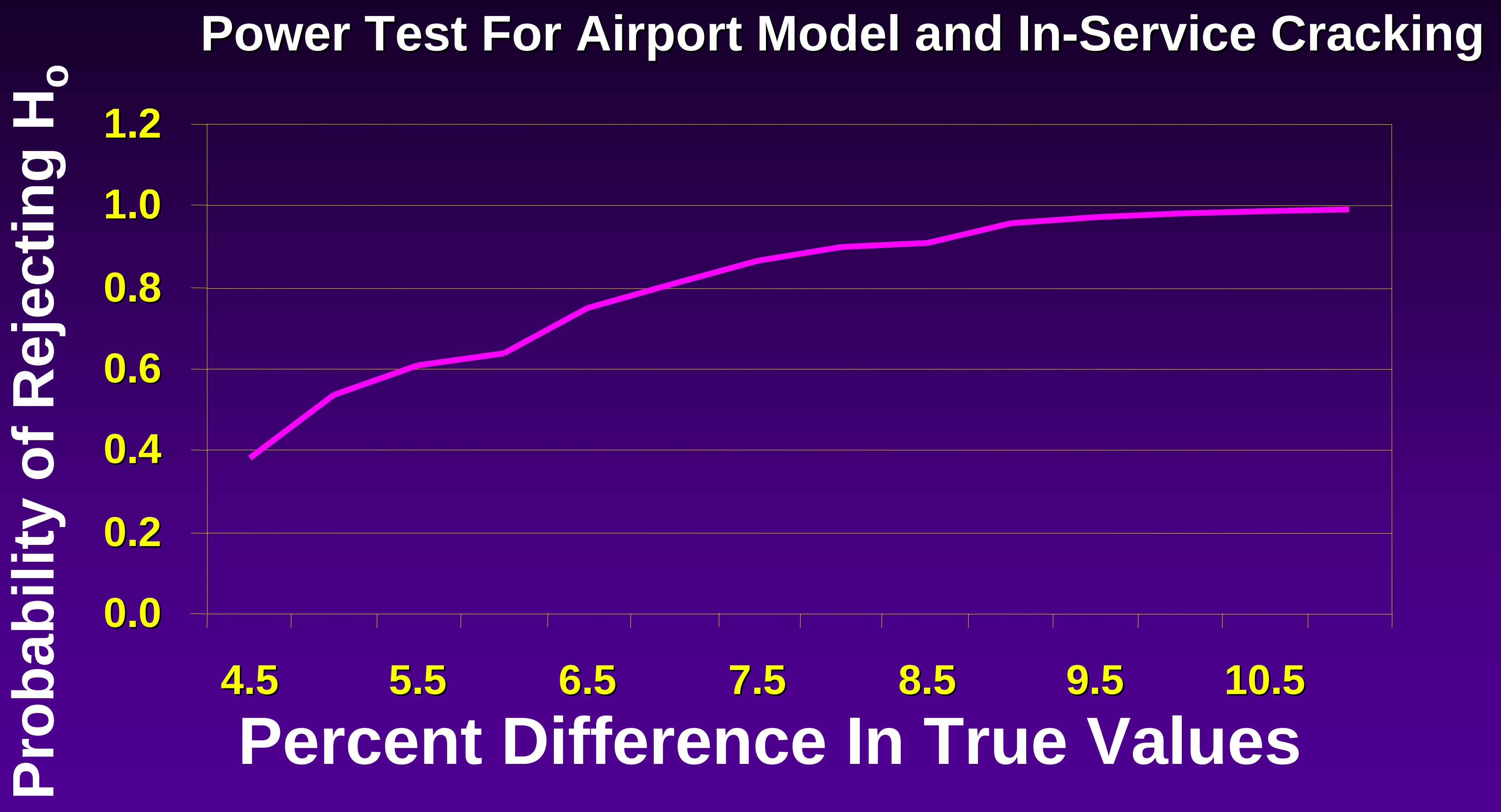
CRACK COMPARISON RESULTS

Crack Analysis	ANOVA Test	$F_{CALCULATED}$	$F_{CRITICAL}$	Degrees Of Freedom
Section 1 to 60	Between Sections	4.32	1.54	59
Airport Prediction & In-Service Cracking	Between Model and Observed	3.44	4.04	1

ANOVA For Airport Model and In-Service Cracking < 70 cracks

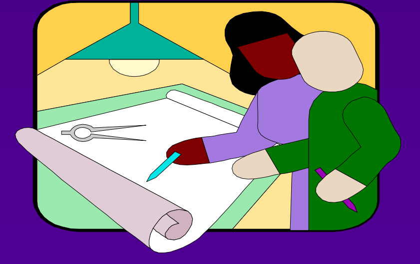
CRACK COMPARISON RESULTS

β



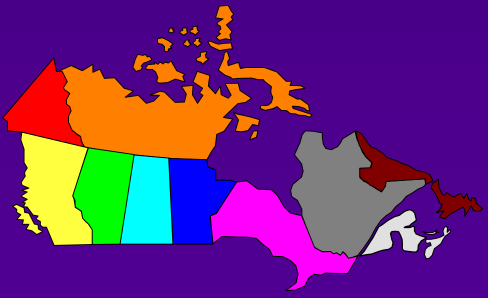
CRACK COMPARISON RESULTS

- Statistically Hajek Model same as observed cracking on C-LTPP and C-SHRP
- Power Tests Hajek is a good model with a small difference of 5.3%
- Statistically Canadian Airport Model same as observed less than 70 cracks / km
- Power test Canadian Airport Model less than 70 cracks/km 8.5%



CONCLUSIONS

- Methodology predicting low temperature cracking
- PVN temporal, repeatable and appears to be a relationship with Superpave PG asphalt
- Hajek model statistically same as observed on C-LTPP and C-SHRP
- Canadian Airport Model showed poor prediction with sites where more than 70 cracks were observed



CONCLUSIONS

- Continue monitoring at C-LTPP and C-SHRP
- Movement away from empirical tests: PVN may have some value: relatively simple, good repeatability and finite sample
- Good data available where Superpave tests results not available
- Pavement designers need tools:

DISTRESS → PERFORMANCE → COST