# 2011 AZ Pavements / Materials Conference

## *An Overview of the New AASHTO MEPDG Pavement Design Guide*

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***Arizona State University***
***Tempe, Arizona***

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***AMEC E&I***

# FEATURES OF THE AASHTO M-E PAVEMENT DESIGN GUIDE

- ***Developed under the US NAS (National Academy of Sciences)– NCHRP (National Cooperative Highway Research program)***

- ***$10,000,000 – 7 Year Effort (Largest Single US Transportation Research Project in the History of the US)***

- ***Project Team Leaders***
  - ***AC/Flexible Pavements: Dr. M.W.Witczak***
  - ***Rigid Pavements: Dr.M.Darter***

# Introduction

- ***Road and Highways are a very significant cost for agencies to construct, maintain and rehabilitate (US Infrastructure worth $1,000,000,000,000)***

- ***Pavement design is a very complex process that involves many variables as well as the variation of each variable. It is one of the most complex Civil Engineering structures to design because we demand a FS=1.0***

- ***Mechanistic concepts provide a more rational and realistic methodology for pavement design; however, pavement response models are mathematically very complex and do not have single closed form equation solution.***

- ***The M-E PDG provides a consistent and practical method to design a pavement for a desired level of reliability.***

# INTRODUCTION- AC FLEXIBLE PAVEMENTS

- ***The MEPDG considers a wide range of AC Flexible pavement structural sections for :***
  - ***New pavement systems***
  - ***Overlay pavement systems***

# NEW PAVEMENTS OPTIONS

- ***Conventional Flexible Pavements***
- ***Deep Strength HMA Pavements***
- ***Full-Depth HMA Pavements***
- ***"Semi-Rigid" Pavements***

# REHABILITATION OPTIONS

- ***HMA Overlay over Existing HMA:***

  ***<u>New</u>*** ***<u>Existing</u>***
  - ***AC*** ***Conventional AC***
  - ***AC*** ***Deep strength HMA pavements***
  - ***AC*** ***Full depth asphalt***
  - ***AC*** ***Semi-rigid pavements***
- ***HMA over JPCP***
- ***HMA over CRCP***

# REHABILITATION OPTIONS (CONT'D)

- ***HMA over Fractured JPCP***
  - ***Crack and Seat***
  - ***Rubbilization***

- ***HMA over Fractured CRCP***
  - ***Rubbilization***

# PAVEMENT DISTRESSES

- ***The primary distresses considered in the MEPDG for flexible pavements are:***
  - ***Permanent Deformation (rutting)***
    - ***AC Layers***
    - ***Unbound Base/Subbase/Subgrade Layers***
    - ***Total Rut Depth***
  - ***Fatigue Cracking***
    - ***Top  Down-Longitudinal Cracking***
    - ***Bottom Up- Alligator Cracking***
  - ***Thermal Cracking***

- ***In addition, pavement smoothness (IRI) is predicted based on these primary distresses and other factors.***

# *Major Asphalt Pavement Distresses*

- ***Major pavement distresses***
  - ***Permanent deformation***
  - ***Fatigue cracking***
  - ***Transverse (Thermal) cracking***

- ***How can we simulate these problems in the lab?***

# *Dynamic Modulus Test*

# Construction of E* Master Curve

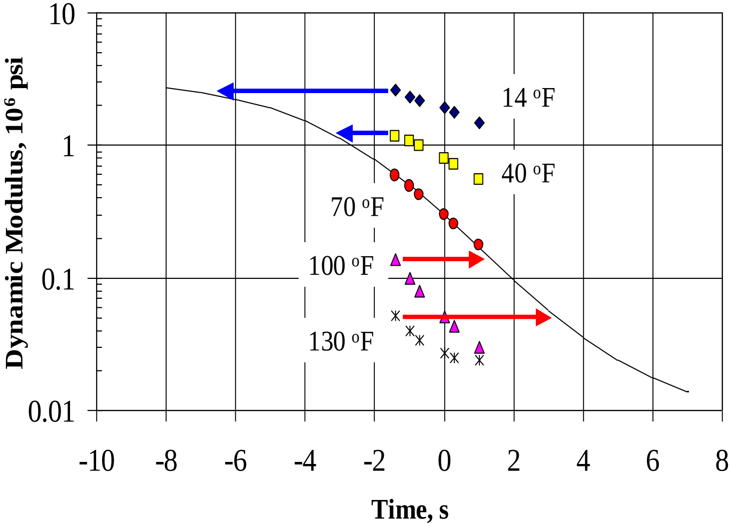
- ***Dynamic Modulus Test (Level 1)***
  - ✓ ***AASHTO TP62-03***
  - ✓ ***5 Temperatures: 14, 40, 70, 100 and 130 °F***
  - ✓ ***6 Frequencies: 25, 10, 5, 1, 0.5 and 0.1 Hz***

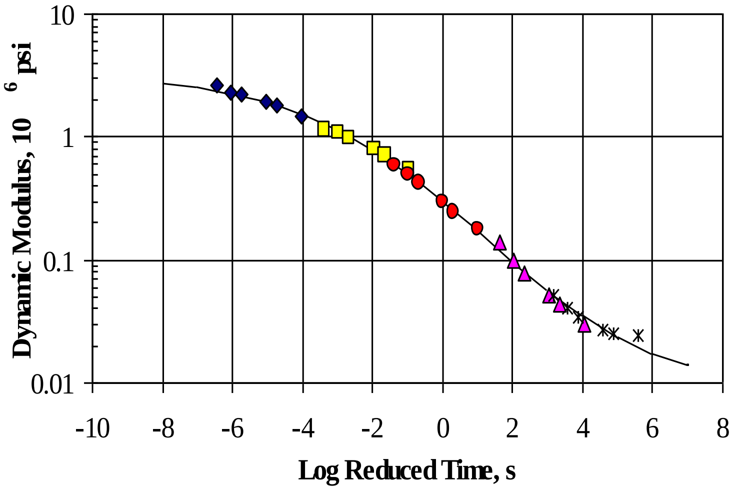
| Spec ID | Temp. (°F) | Freq. (Hz) | E* (ksi) |
|---|---|---|---|
| Avg. | 14 | 25 | 6469 |
| Avg. | 14 | 10 | 5665 |
| Avg. | 14 | 5 | 5103 |
| Avg. | 14 | 1 | 4289 |
| Avg. | 14 | 0.5 | 3747 |
| Avg. | 14 | 0.1 | 2684 |
| Avg. | 40 | 25 | 4453 |
| Avg. | 40 | 10 | 3623 |
| Avg. | 40 | 5 | 3113 |
| Avg. | 40 | 1 | 2378 |
| Avg. | 40 | 0.5 | 2016 |
| Avg. | 40 | 0.1 | 1347 |
| Avg. | 70 | 25 | 1465 |
| Avg. | 70 | 10 | 1194 |
| Avg. | 70 | 5 | 1013 |
| Avg. | 70 | 1 | 695 |
| Avg. | 70 | 0.5 | 560 |
| Avg. | 70 | 0.1 | 333 |

| Spec ID | Temp. (°F) | Freq. (Hz) | E* (ksi) |
|---|---|---|---|
| Avg. | 100 | 25 | 295 |
| Avg. | 100 | 10 | 207 |
| Avg. | 100 | 5 | 157 |
| Avg. | 100 | 1 | 92 |
| Avg. | 100 | 0.5 | 73 |
| Avg. | 100 | 0.1 | 48 |
| Avg. | 130 | 25 | 78 |
| Avg. | 130 | 10 | 59 |
| Avg. | 130 | 5 | 46 |
| Avg. | 130 | 1 | 34 |
| Avg. | 130 | 0.5 | 31 |
| Avg. | 130 | 0.1 | 28 |

# Construction of E* Master Curve

- ***Time-Temp. Superposition***
  - ***Use any arbitrary temperature value as a reference***
  - ***Normally this value is set to be at 70°F***
  - ***Shift E* test results at other temp. to reference temp. by time-temp superposition***
  - ***E* results are not changed***
  - ***Can calculate E* values at any temp. and freq. from master curve***



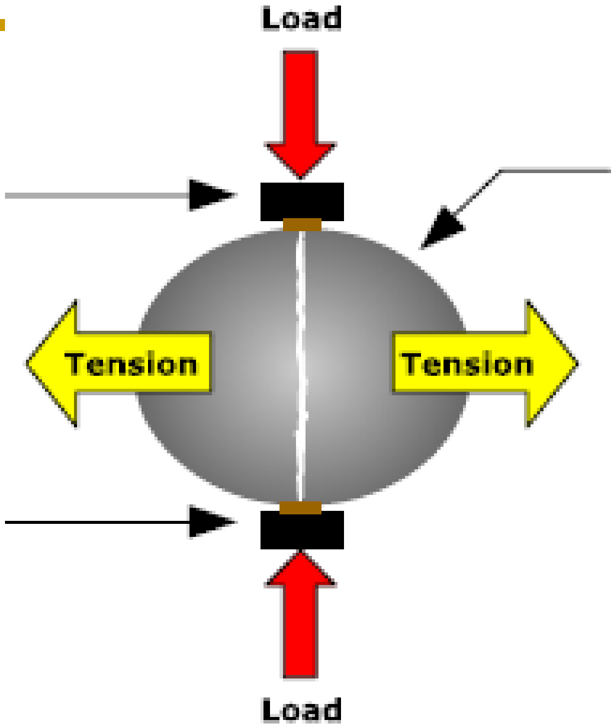



# Dynamic Modulus (E*)

***Advantages:***

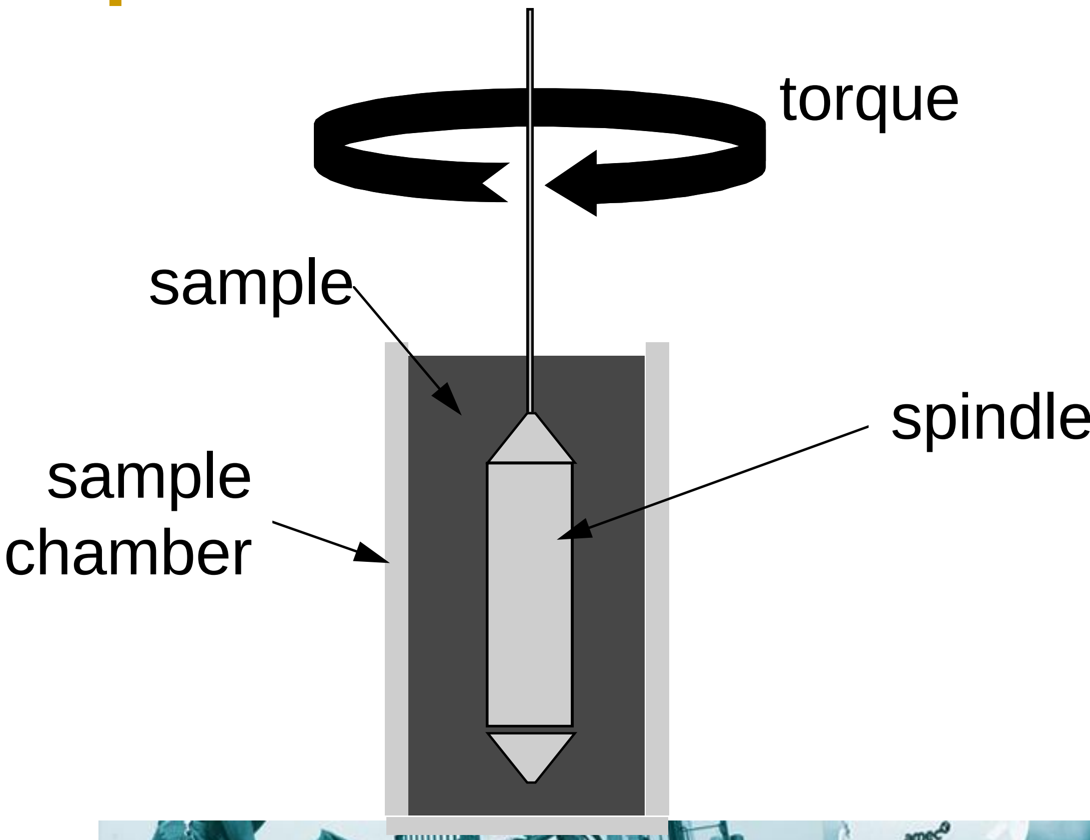
- ***E* allows hierarchical characterization***
- ***takes care of aging***
- ***takes care of vehicle speed***
- ***can be linked to PG  Binder***
- ***E* approximates FWD back-calculated modulus***
- ***provides rational mechanistic material property for distress prediction***
- ***FHWA – AASHTO test protocols available***
- ***Distress predictive models available***

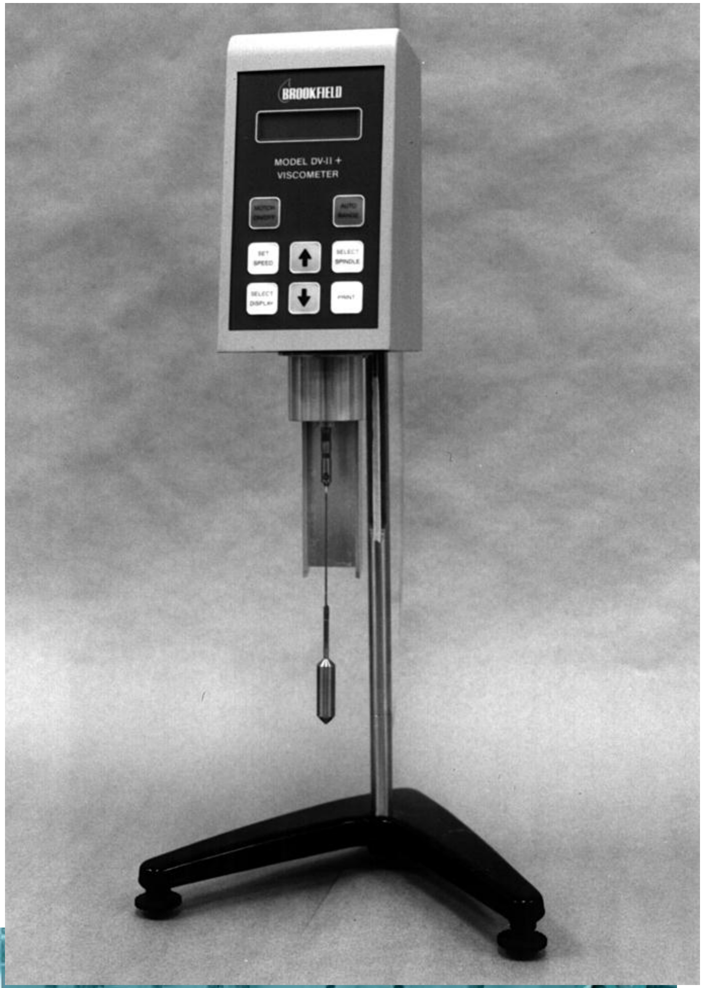
# Indirect Tension Creep Test



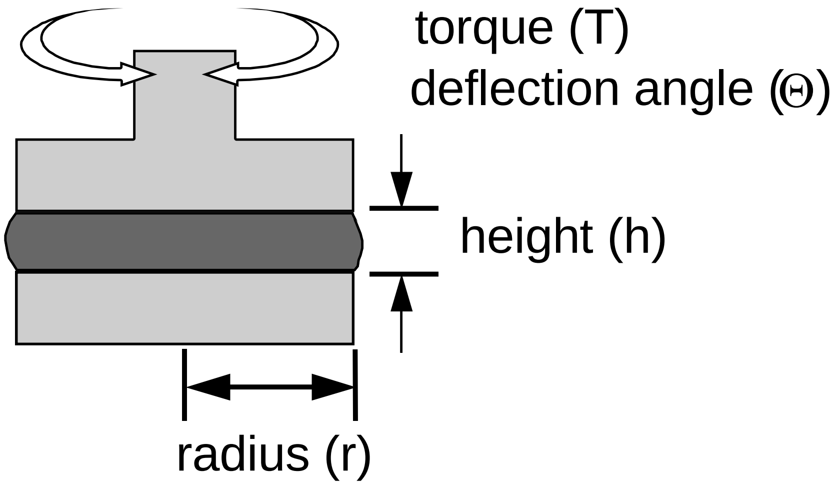
# Beam Fatigue Test

# Rotational Viscometer

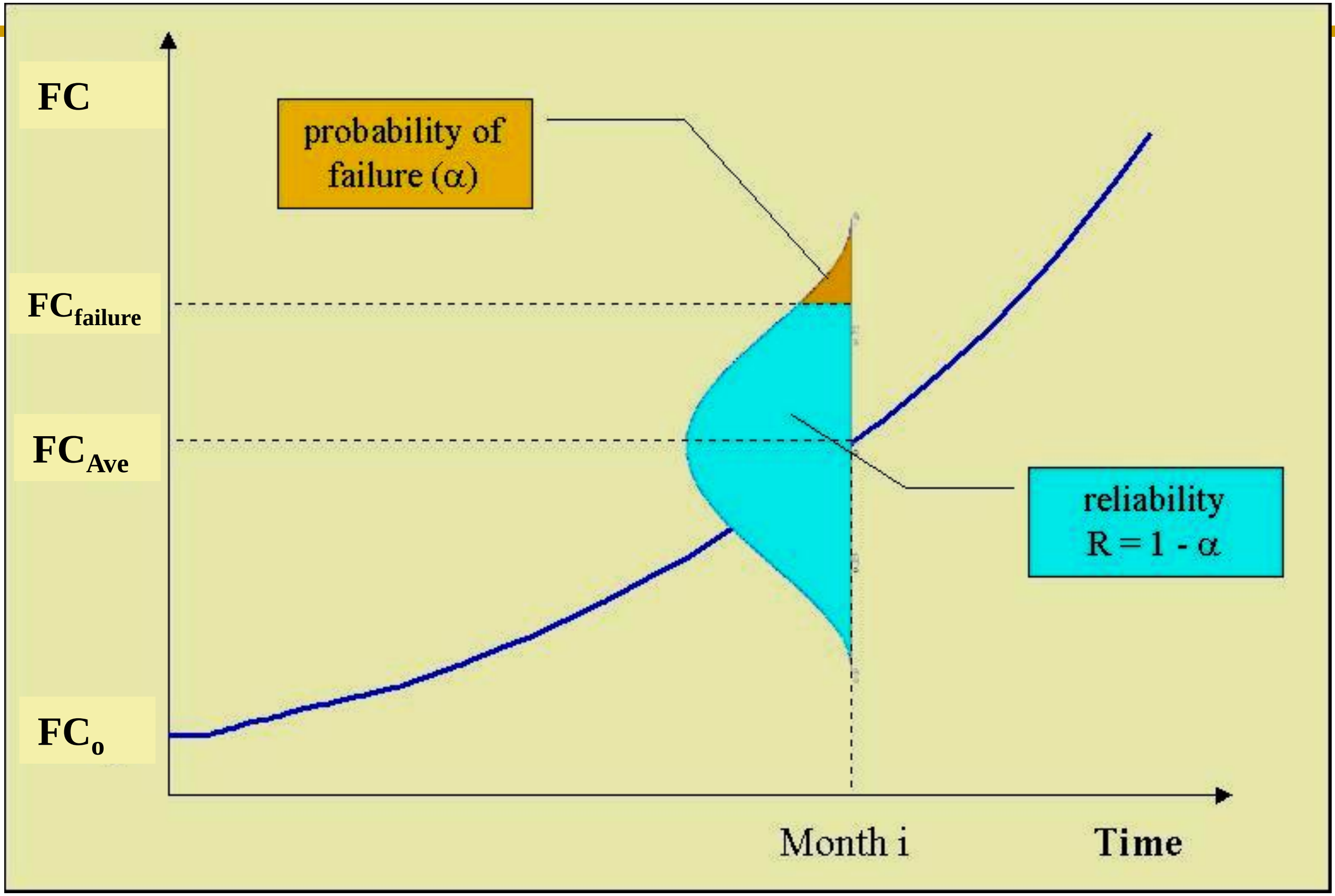


# *Dynamic Shear Rheometer*




# Assessment of Reliability




# Hierarchical Input Process

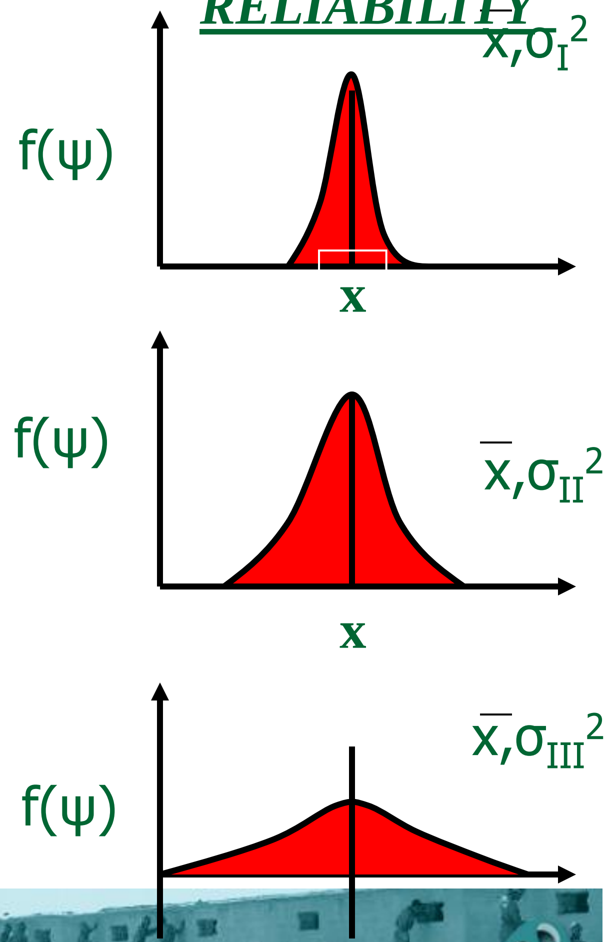
- ***Level   1 (High Reliability)***
  ***Analysis of special problems***
  ***Usually will incorporate Testing***
  ***High Visibility/Risk/Cost Projects***

- ***Level  2 (Medium Reliability)***
  ***Standard Design - Most Cases***
  ***(Rigorous but practical)***

- ***Level 3 (Lower Reliability)***
  ***Lower impact/risk projects***

# HIERARCHIAL APPROACH
# (AC MODULUS)

| LEVEL | MIX | BINDER | RELIABILITY |
|---|---|---|---|
| 1 | E* Lab Test | G*,δ Lab Test | |
| 2 | E*Predictive equation | G*,δ Lab Test | |
| 3 | E*Predictive equation | AC Grade to properties | |




# *Hierarchical Approach in NCHRP 1-37A*

- ***Major Reasons for Presence in M-E PDG***
  - ***Allows for a Quantifiable Decision to be Made, Based on Benefit / Costs Regarding the Utility of Using Detailed Engineering Tests and Data Collection / Analysis Techniques Relative to Simple, Empirical Correlations or Engineering Guesses***

# *Hierarchical Approach in MEPDG*

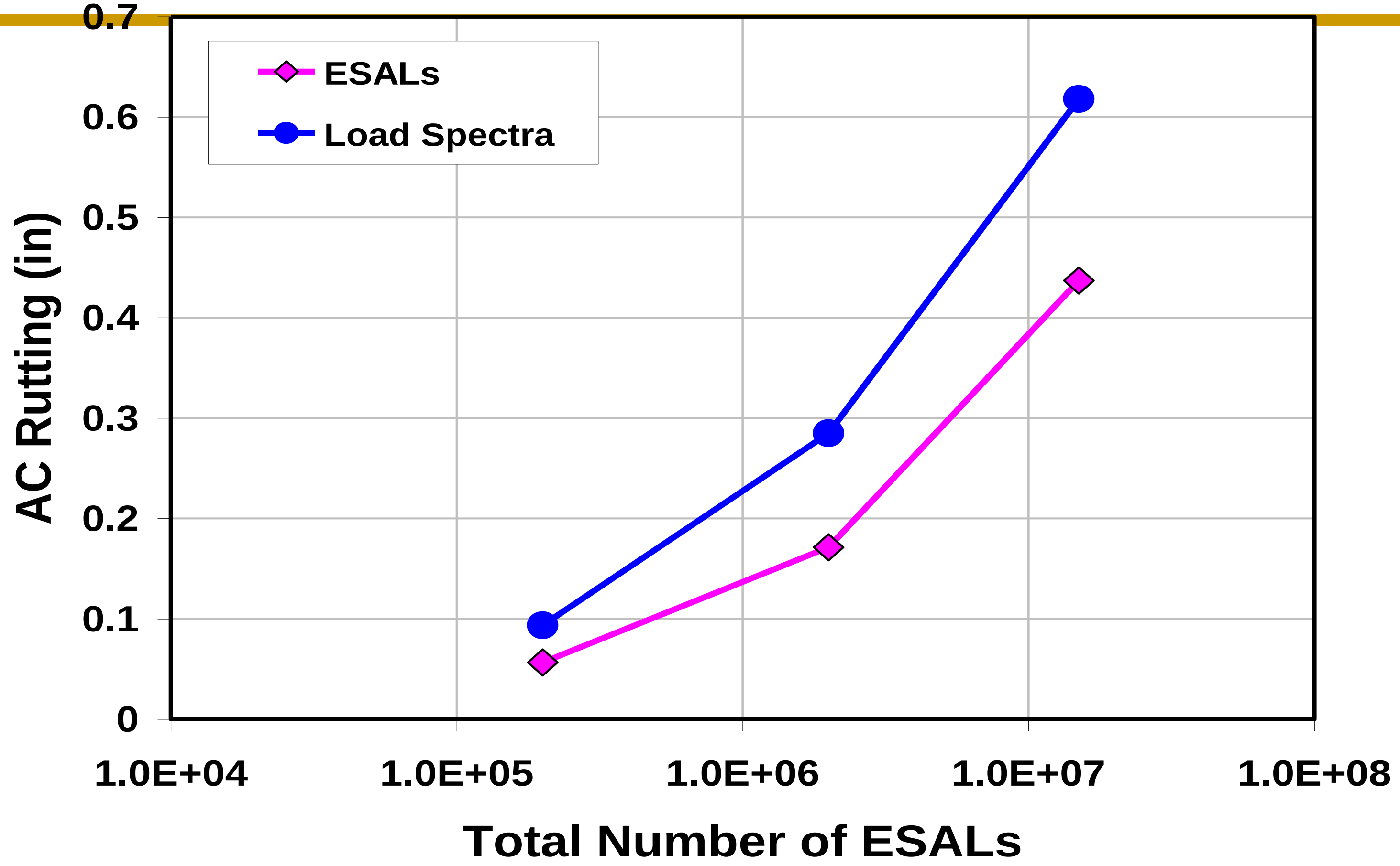
- ***Major Reasons for Presence in M-E PDG***
  - ***Provide Quantifiable Methodology for Agency to Prove Certain High Profile, High Importance and High Cost Projects Justified***
    - ***"Most Advanced State of the Art Technology is Mandated  to Save Significant Cost Benefits"***

# *Hierarchical Approach in MEPDG*

- ***Major Reasons for Presence in M-E PDG***
  - ***Collary is also True***
    - ***"Many Projects do not Require Sophisticated , Advanced Engineering Approaches"***

# EXAMPLES OF THE FLEXIBLE PAVEMENT DESIGN PROCESS

# INFLUENCE OF TRAFFIC ANALYSIS METHOD UPON AC RUTTING

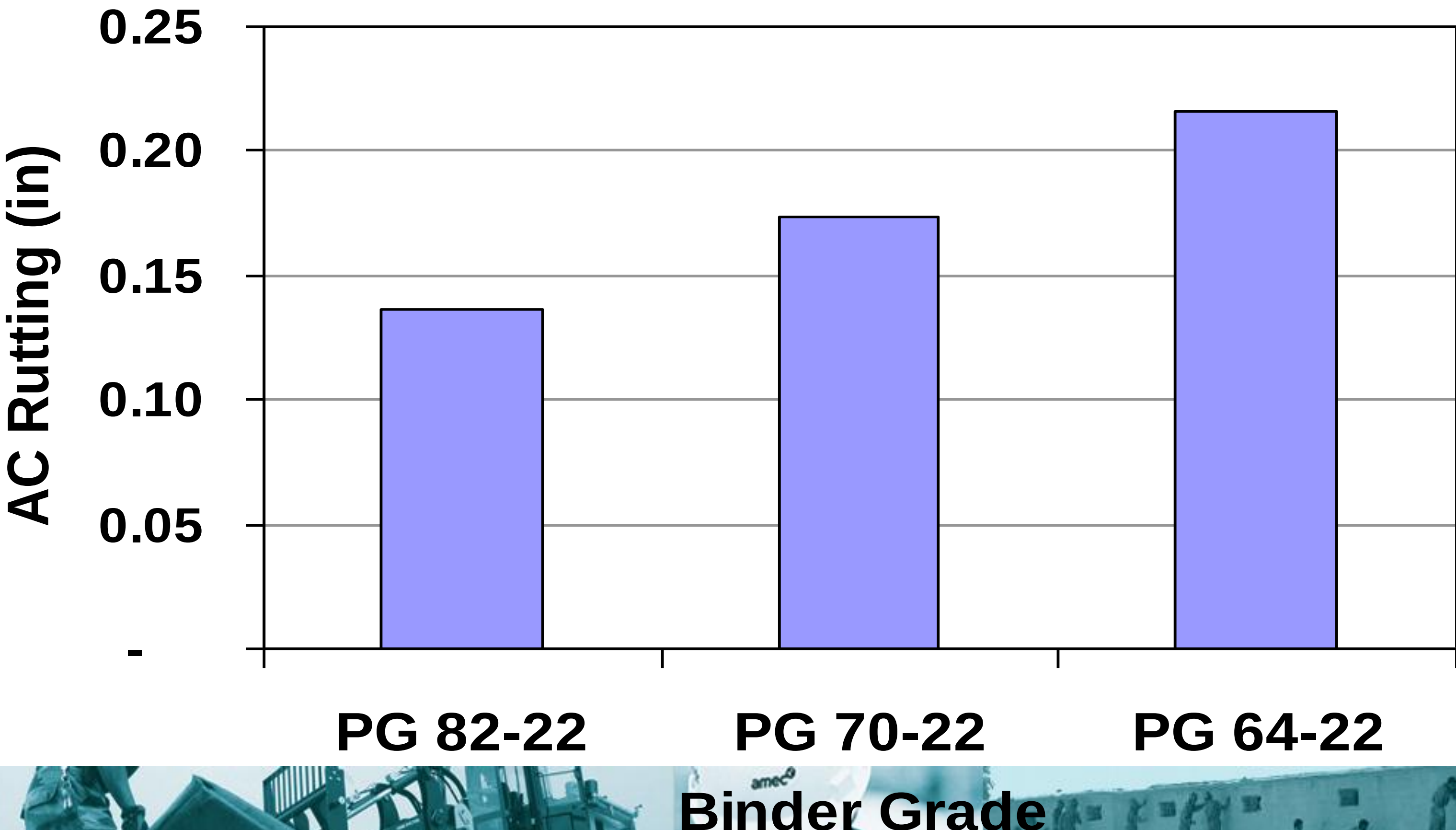



# *INFLUENCE OF TRAFFIC ANALYSIS METHOD UPON AC RUTTING AND CRACKING (SUMMARY)*

- ***Actual Traffic load spectra yields higher levels of rutting and cracking compared to the classical E18KSAL's.***

- ***Traffic repetitions is a significant parameter influencing pavement distress.***

# *INFLUENCE OF BINDER GRADE UPON AC RUTTING*



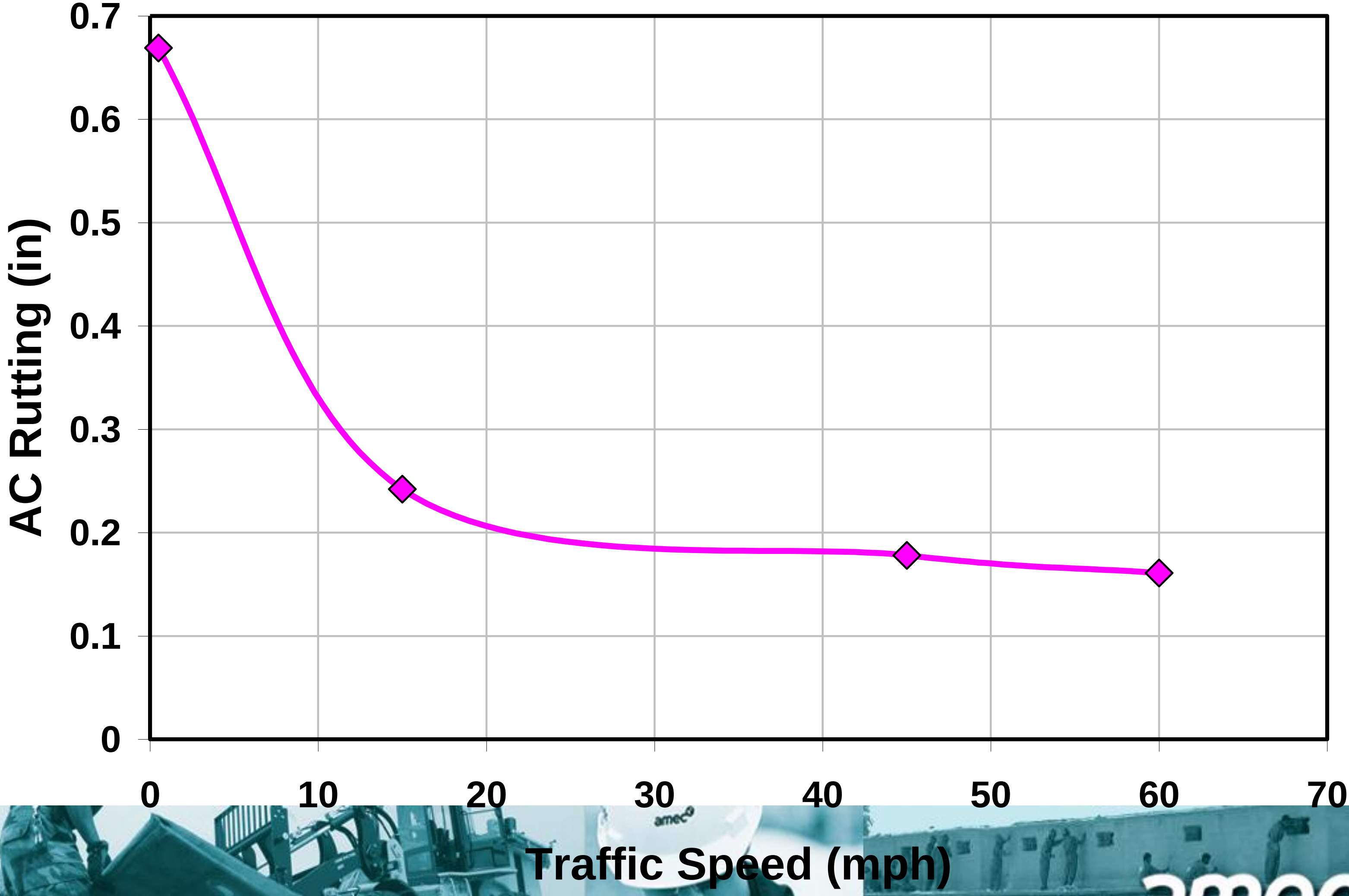

# INFLUENCE OF BINDER GRADE UPON AC RUTTING (SUMMARY)

- ***Binder stiffness has a significant influence upon AC rutting.***

- ***As the binder stiffness increases, AC rutting decreases.***

- ***In fact, as the entire HMA mix stiffness increases, AC rutting decreases.***

# *INFLUENCE OF TRAFFIC SPEED UPON AC RUTTING*

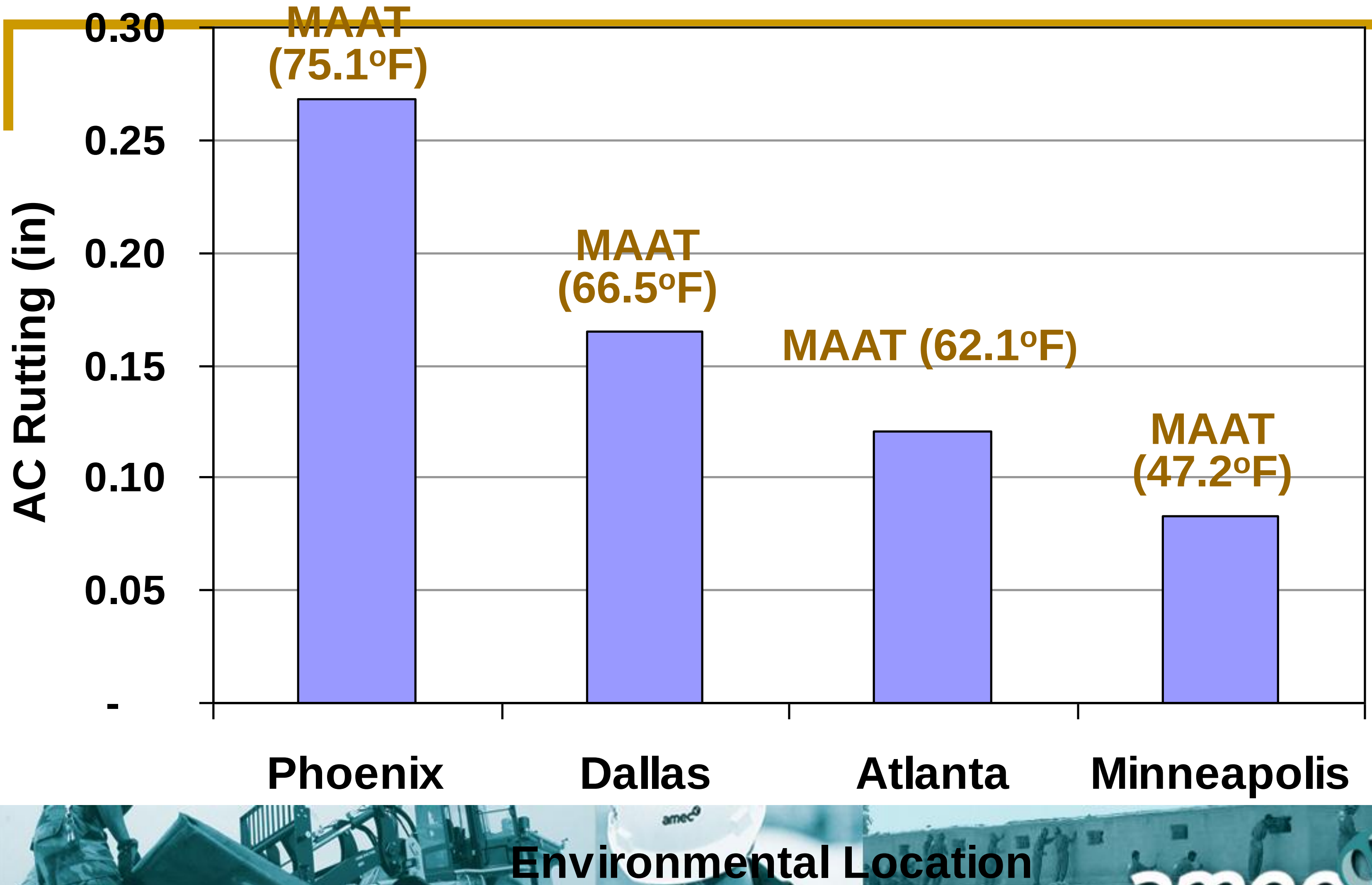


# *INFLUENCE OF TRAFFIC SPEED UPON AC RUTTING (SUMMARY)*

- ***Traffic Speed Influences The AC Rutting.***

- ***Creep Speed (Parking Lot, Intersection Analysis) Causes Much More Damage To The Pavement Compared To Faster Highway Speeds.***

# INFLUENCE OF ENVIRONMENTAL LOCATION UPON AC RUTTING

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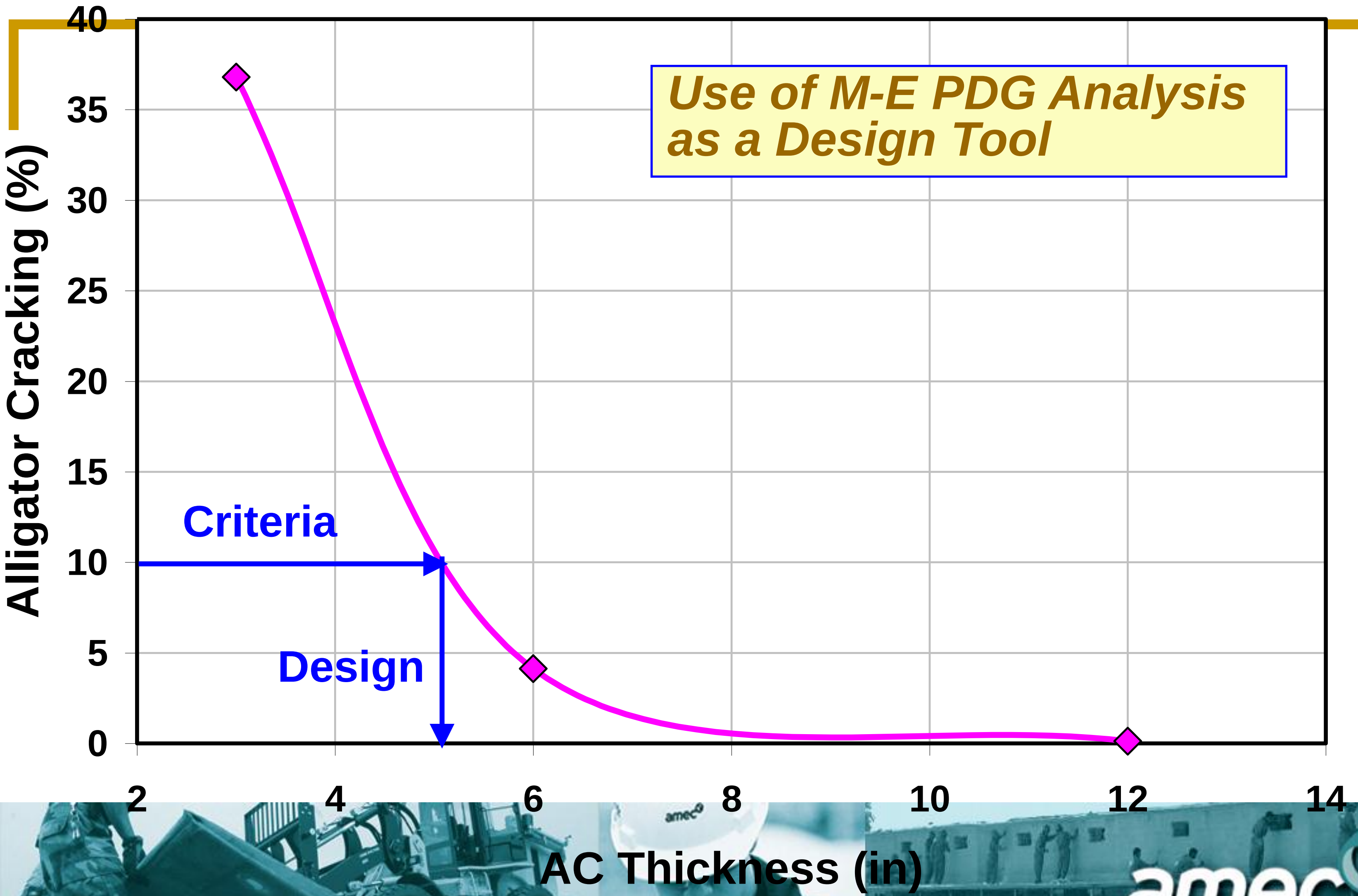
# INFLUENCE OF ENVIRONMENTAL LOCATION UPON AC RUTTING (SUMMARY)

- ***For all variables being the same, the higher the temperature of an environmental location, the higher the AC rutting becomes.***

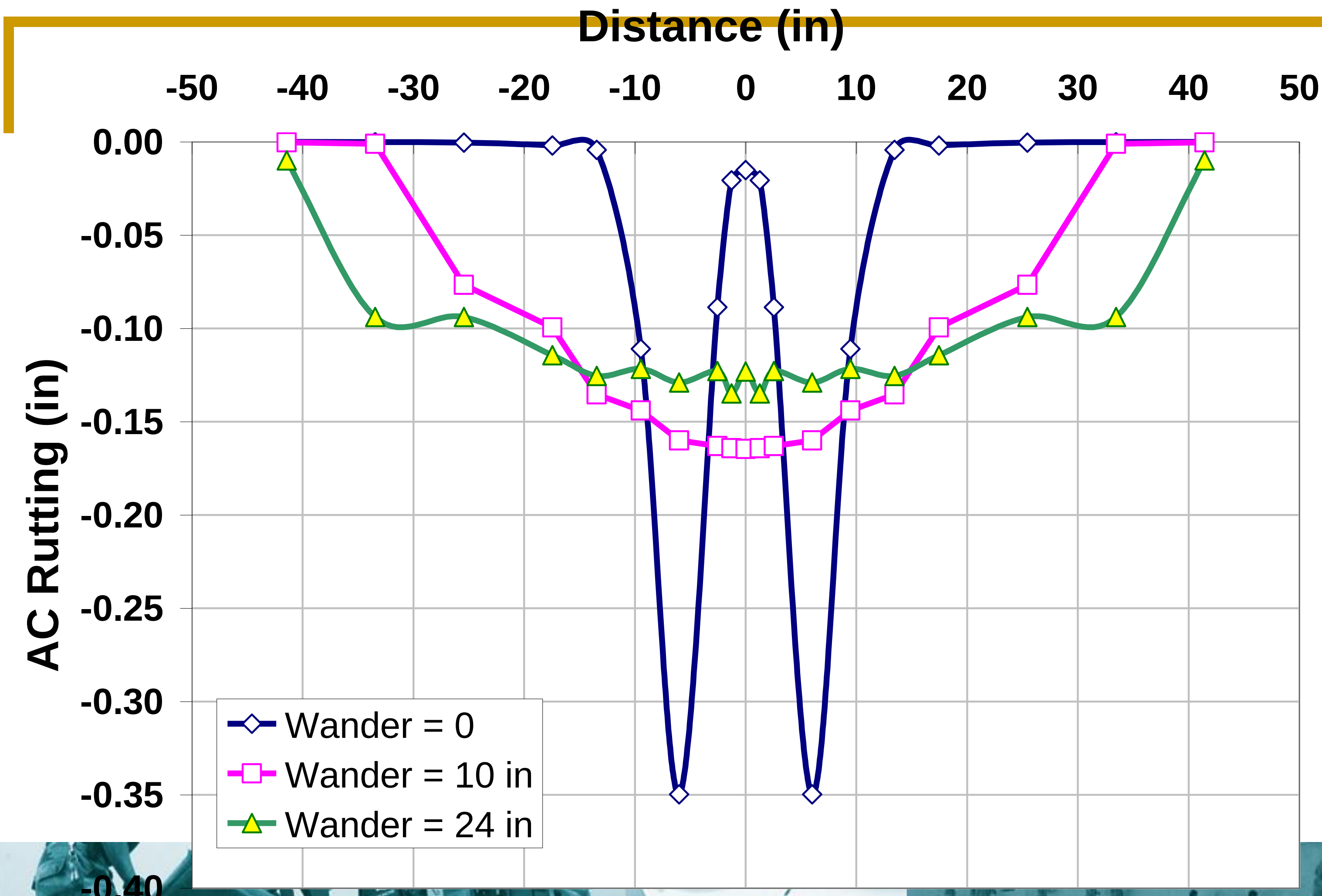
# INFLUENCE OF AC THICKNESS UPON AC ALLIGATOR FATIGUE CRACKING



## *INFLUENCE OF AC THICKNESS UPON AC ALLIGATOR FATIGUE CRACKING (SUMMARY)*

- ***AC thickness has a significant influence upon Alligator fatigue cracking. As the AC thickness increases, the amount of alligator (bottom-up) fatigue cracking decreases.***

# *INFLUENCE OF TRAFFIC WANDER UPON AC RUTTING*

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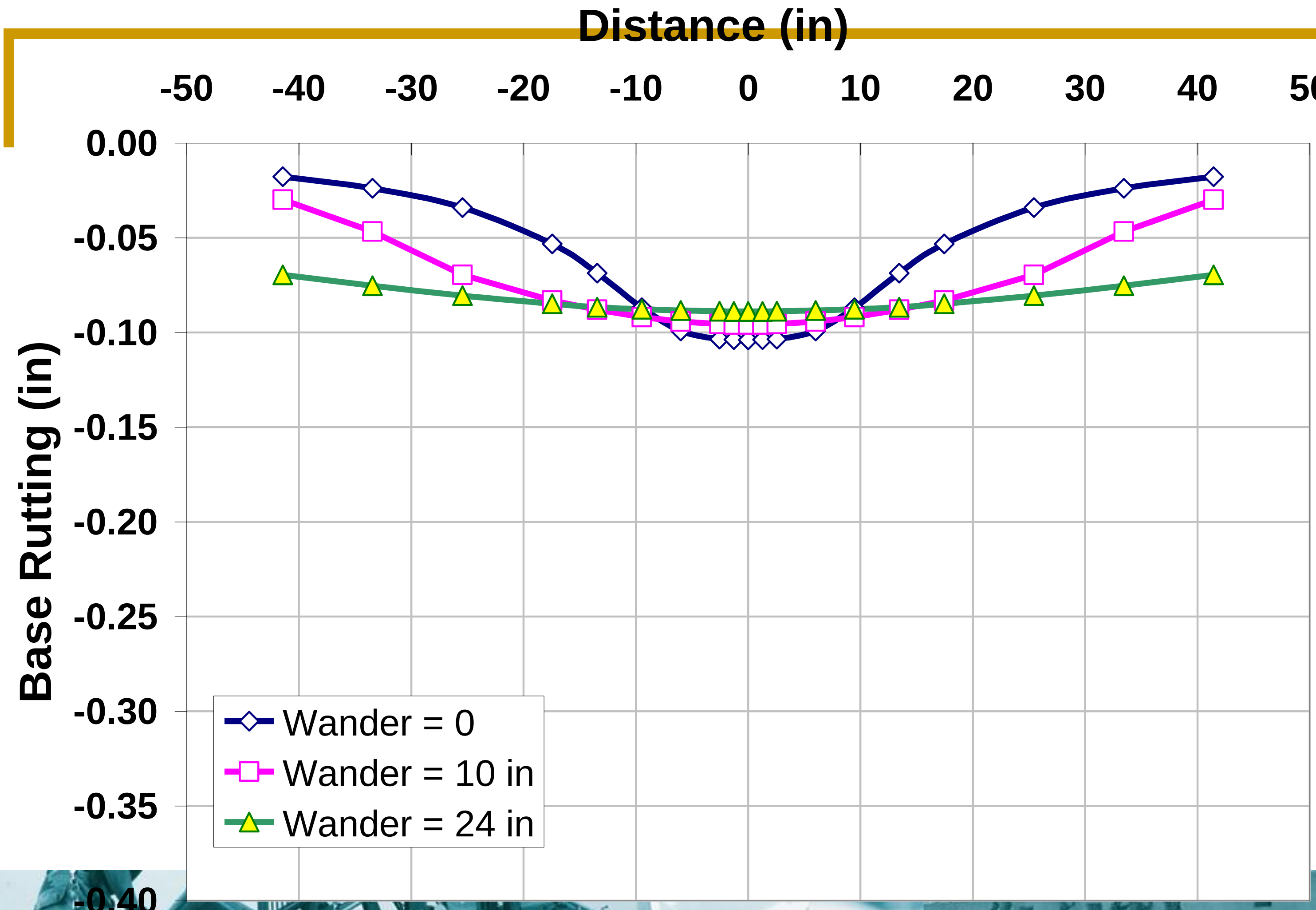
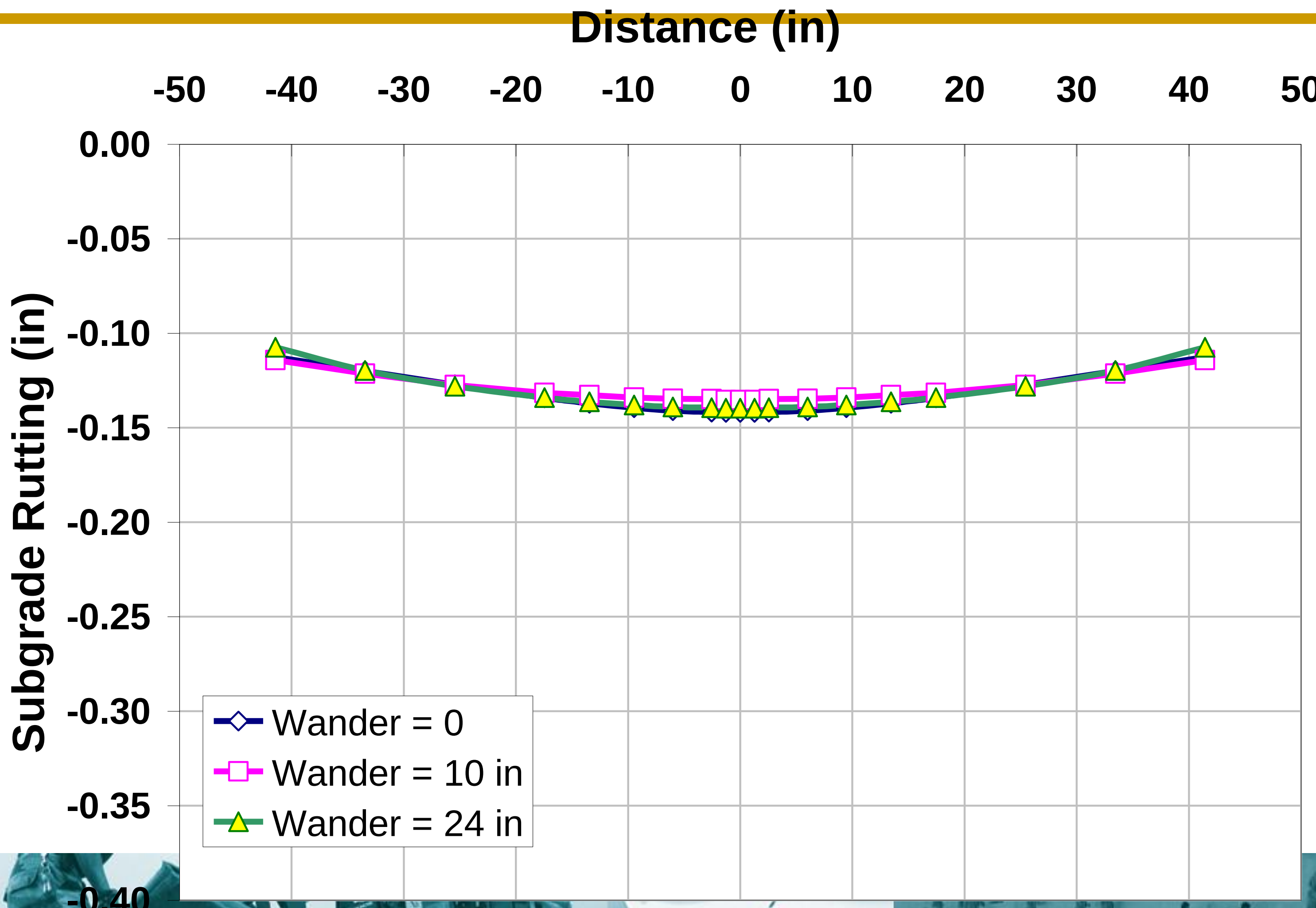
# INFLUENCE OF TRAFFIC WANDER UPON BASE LAYER RUTTING



# *INFLUENCE OF TRAFFIC WANDER UPON SUBGRADE LAYER RUTTING*

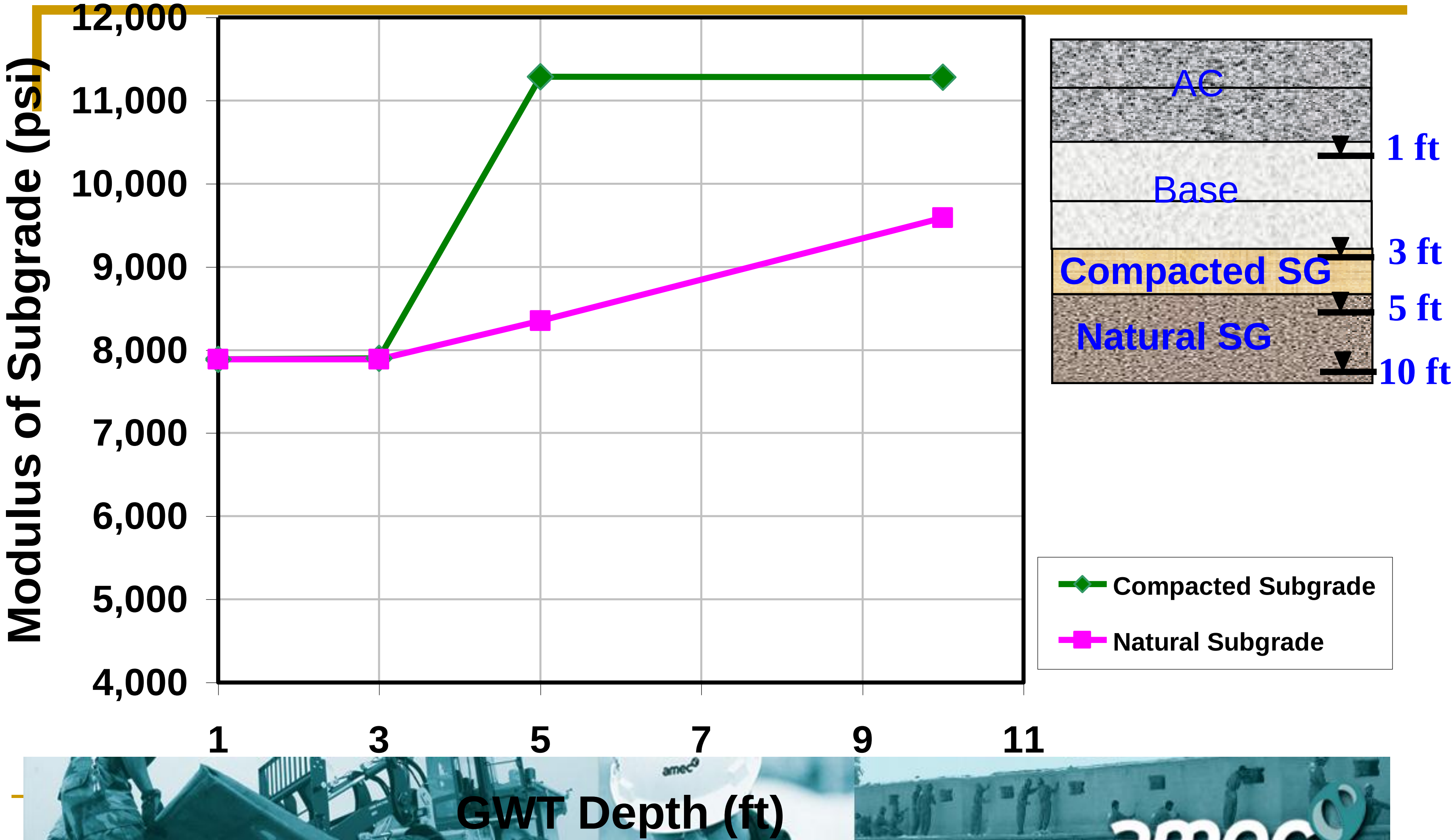


# *INFLUENCE OF TRAFFIC WANDER UPON AC RUTTING (SUMMARY)*

- ***The  more channelized that the vehicular traffic becomes, the more severe the pavement rutting becomes.***

- ***The severity of the rutting is magnified for layers near the surface.***

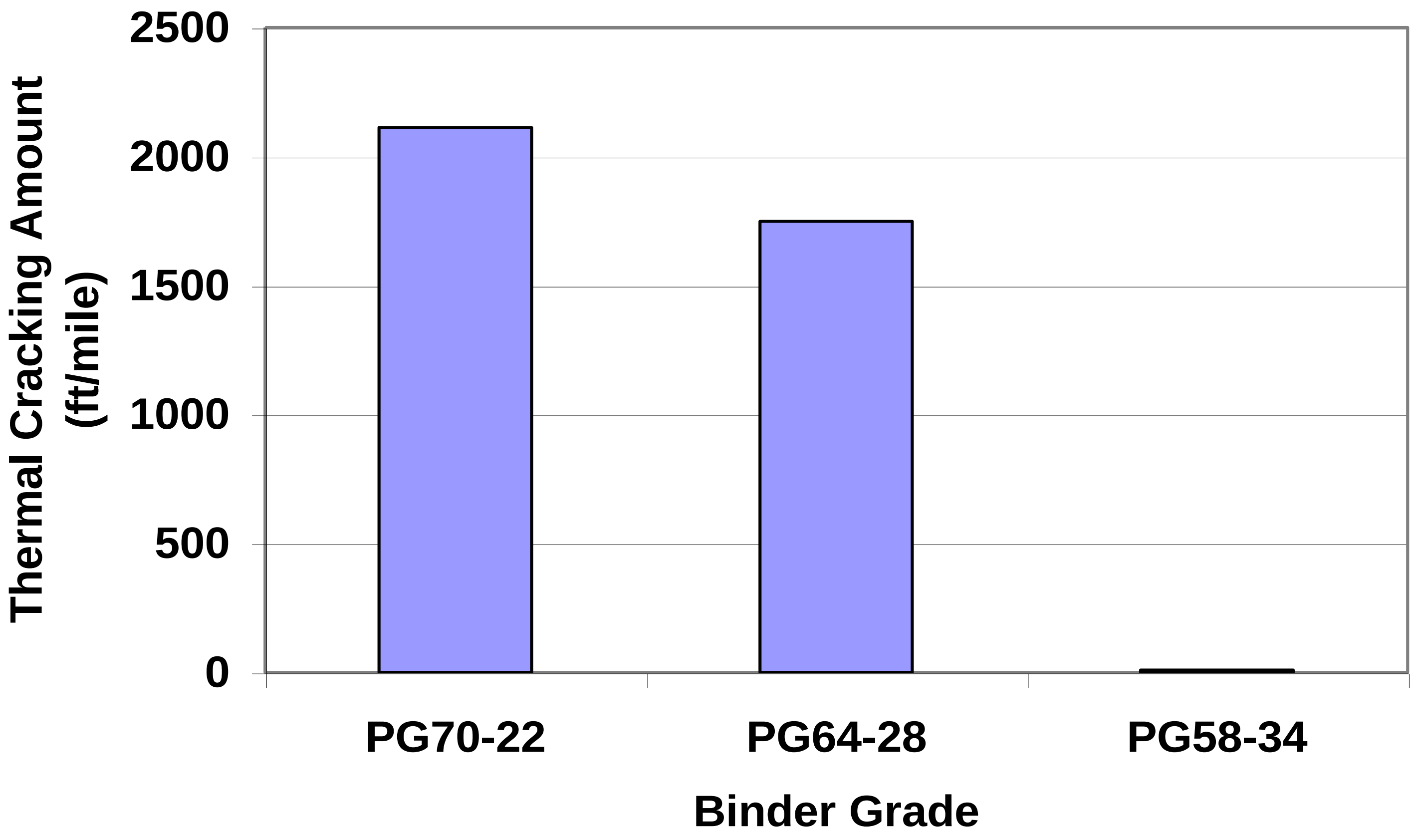
## *INFLUENCE OF GWT DEPTH UPON SUBGRADE LAYER MODULUS*



## *INFLUENCE OF GWT DEPTH UPON UNBOUND MATERIALS MODULI (SUMMARY)*

- ***Presence of GWT near / within unbound material layers can significantly alter the material moduli and hence increase pavement damage.***

# INFLUENCE OF BINDER GRADE UPON AC THERMAL FRACTURE (FARGO, ND)

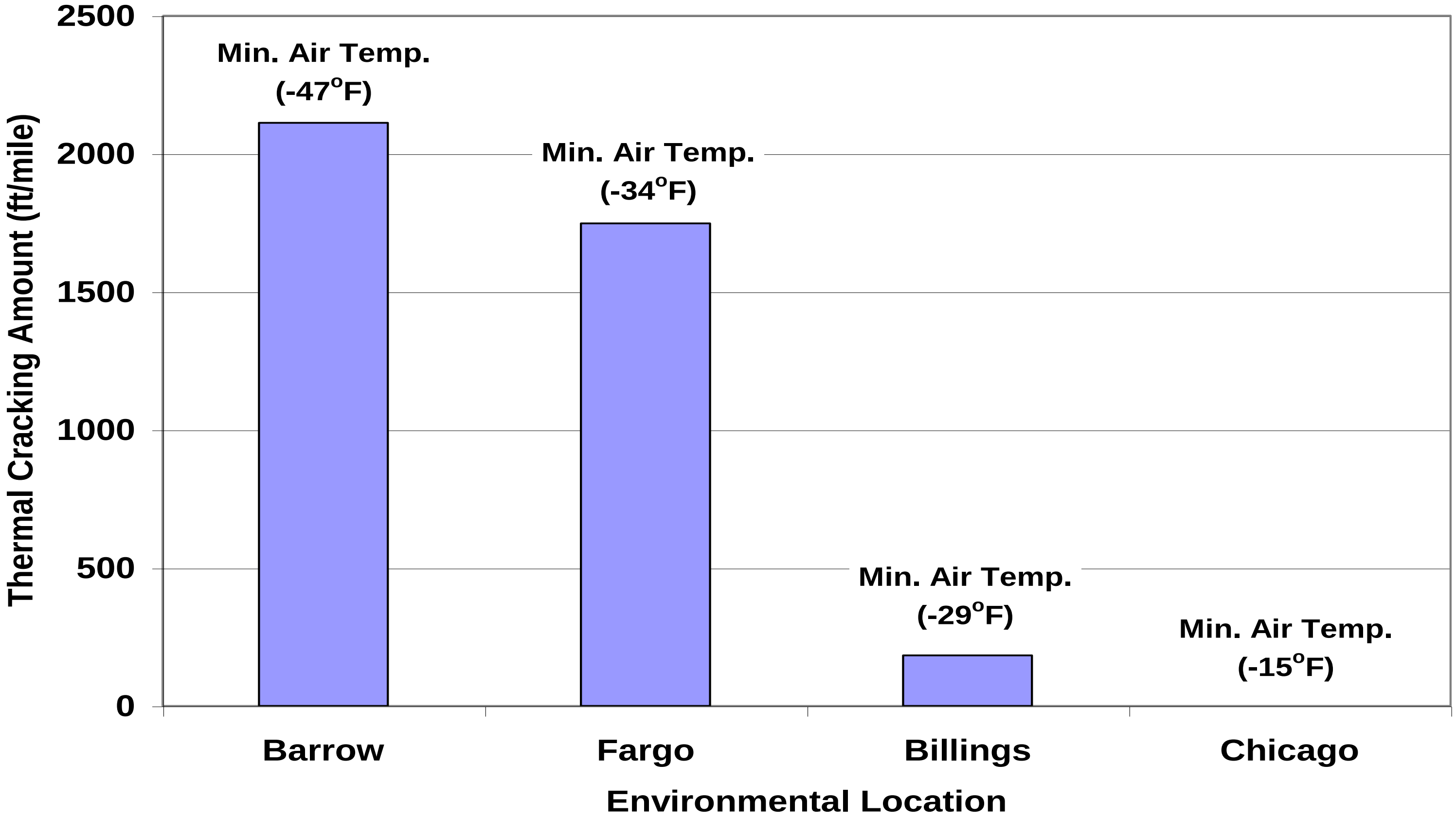


# INFLUENCE OF BINDER GRADE UPON AC THERMAL FRACTURE (SUMMARY)

- ***Binder stiffness has the greatest influence upon Thermal Fracture within a cold environment.***

- ***As the binder stiffness (or surface layer stiffness) increases, the AC Thermal Fracture increases.***

# INFLUENCE OF ENVIRONMENTAL LOCATION UPON AC THERMAL FRACTURE




# INFLUENCE OF TIME AND VARIOUS AC VOLUMETRIC PROPERTIES UPON AC THERMAL FRACTURE (SUMMARY)

- ***Thermal Cracking cumulatively increases over time.***
- ***Combined property of binder content and air void has an influence upon the Thermal Fracture.***
- ***In general, AC Thermal Fracture decreases with an increase of binder content and a decrease in air void.***

# OVERALL M-E PDG SUMMARY

- ***M-E PDG is the most powerful Pavement-Material Analysis-Design Tool ever developed.***
- ***M-E PDG will lead to a more fundamental analysis of the consequences associated with the material-structure - environmental interaction.***
- ***M-E PDG has the potential for increasing pavement performance and life while decreasing life cycle costs associated with new and rehab scenarios.***

# Implementation Considerations

- ***Be careful of blind application of Modified asphalts in MEPDG.***
- ***E* value may be okay***
  - ***Distress performance prediction models (ac rutting, fatigue cracking and thermal fracture) generally calibrated with conventional asphalt mixtures***
  - ***Performance prediction of Modified AC Mixtures questionable***
  - ***Suggest local calibration***

# Implementation Considerations

- ***MEPDG is an excellent product and major enhancement to current technology; however the technology is still evolving:***
  - ***Do not expect perfect predictions***
    - ***Need to locally calibrate to actual field performance***
      - ***Must be prepared to Conduct Trench Sections!!!!!!***
    - ***Need to have a well defined nationally coordinated approach to develop planned model enhancements***
      - ***Reflective cracking***
      - ***Rutting and fatigue cracking model enhancements***
      - ***Chemically Stabilized Materials Calibration***
      - ***Performance of modified mixtures***
      - ***Refinement of level standard deviations for use in reliability models***