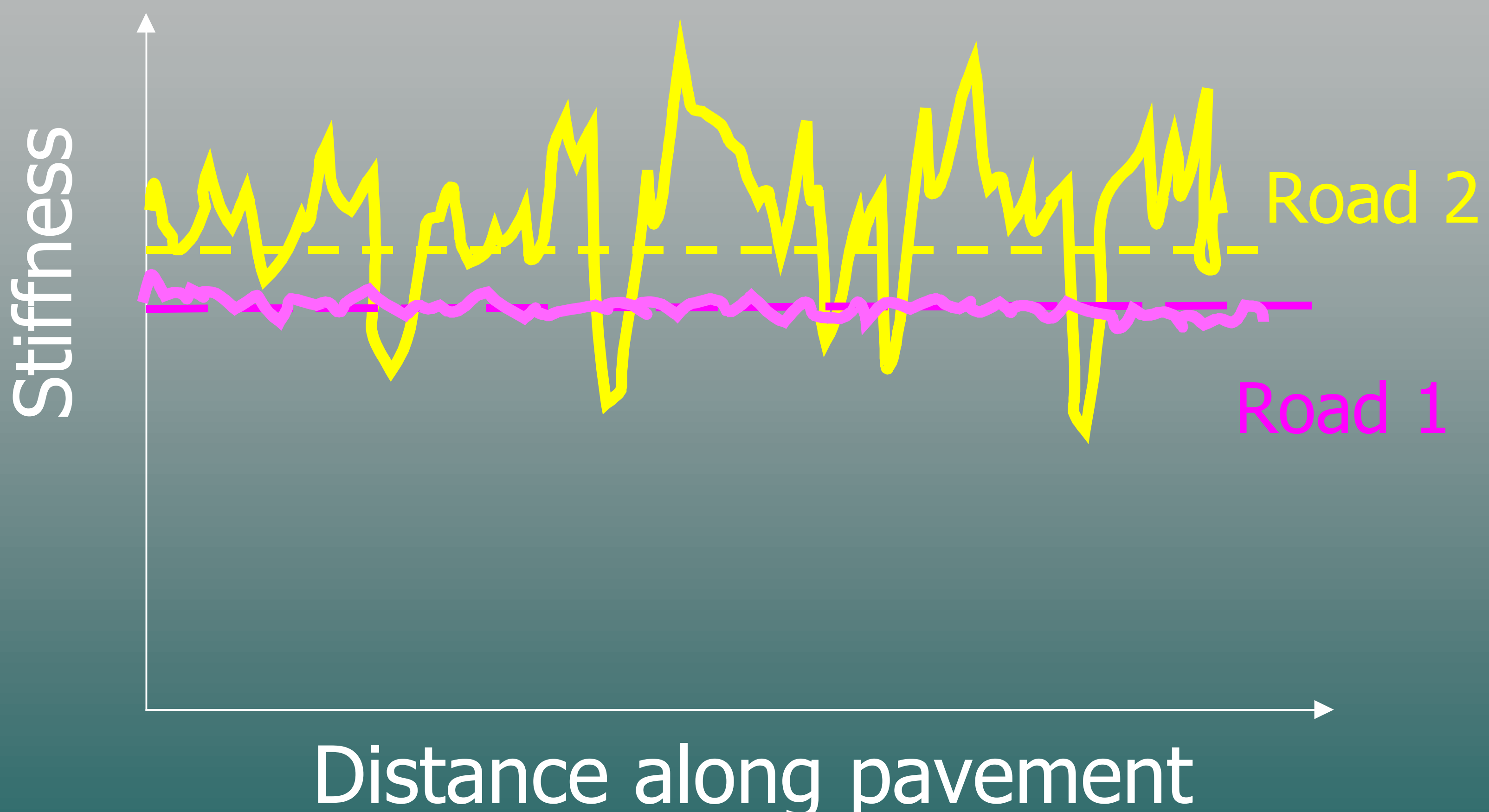
PAVEMENT VARIABILITY STUDY for SPR 2(212)

Federal Highway Administration
Truck Pavement Interaction

Objectives

Overall Objective: Investigate the possibility of using pavement layer stiffness (with Geo-Gauge or other) as a specification, in lieu of density, in pavement construction

Question: Which road is better?



Objective (cont'd)

The objective of pavement variability portion of the study is to investigate

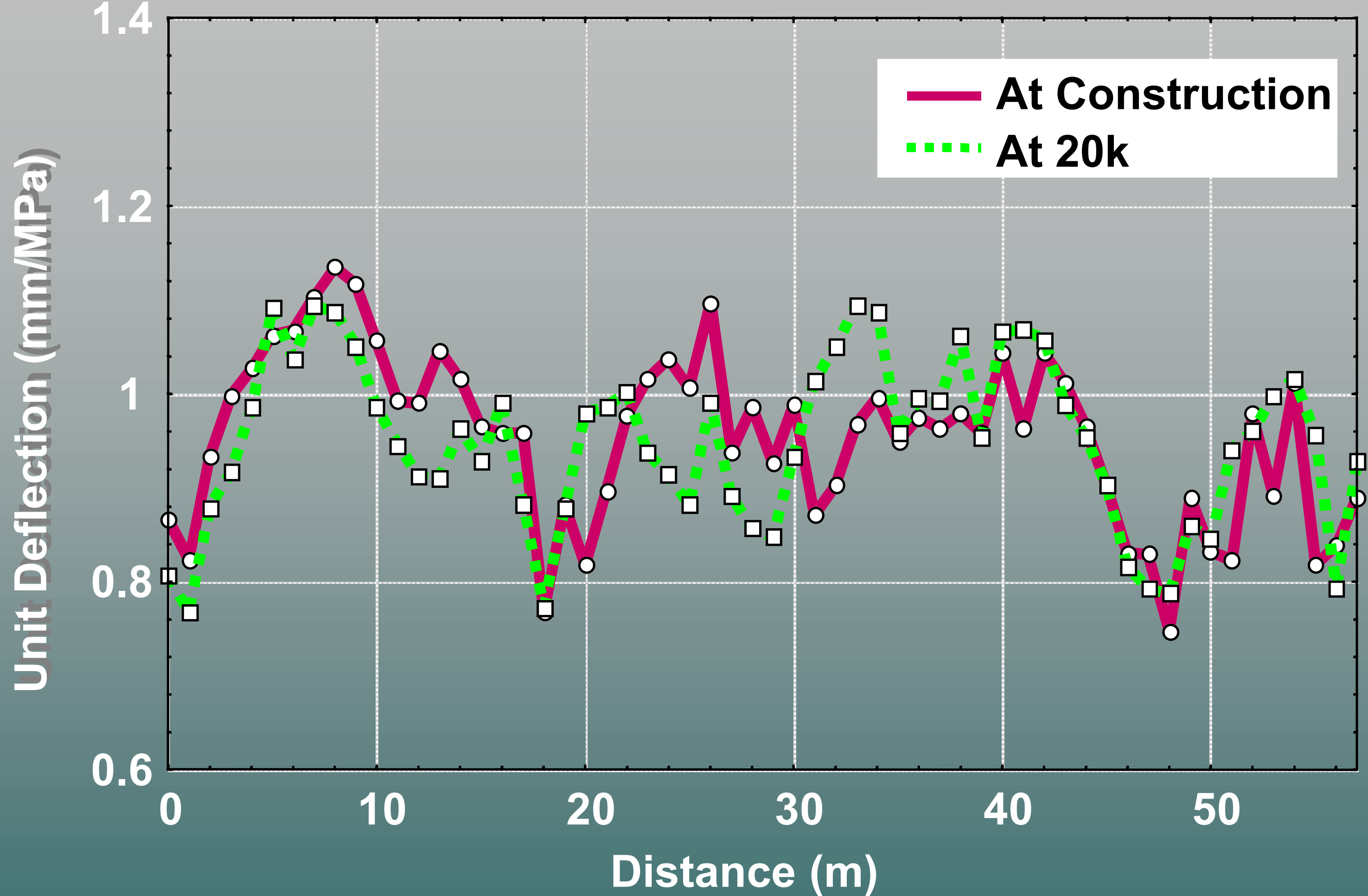
- if pavement structural integrity can be reflected by pavement stiffness
- the potential use of pavement stiffness as QA/QC in pavement construction
- the effect of pavement structural variability on pavement long term performance and reliability evaluations

Previous Pavement Variability Study

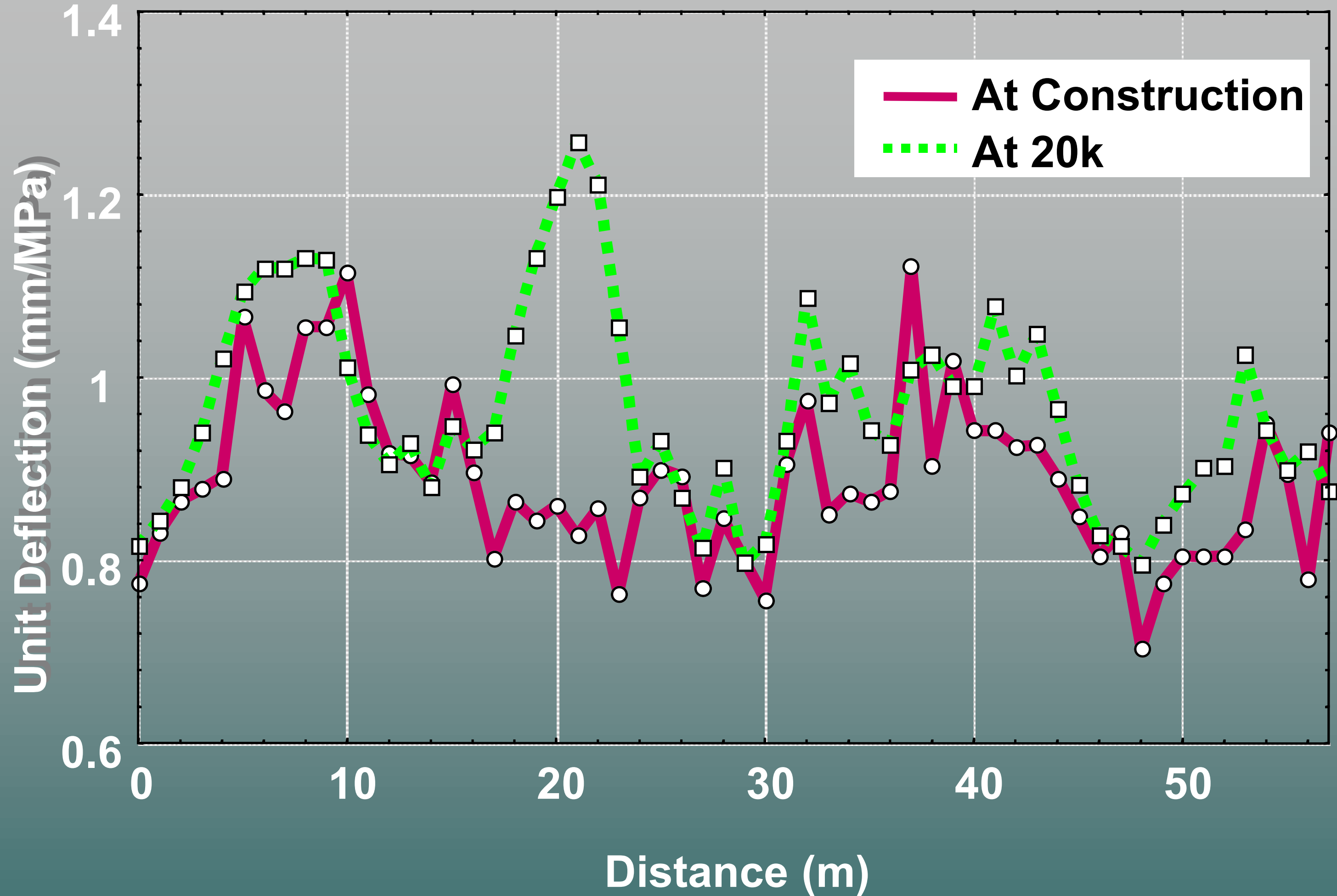
-Conducted at FHWA

OECD DIVINE PROJECT

Data collected from DIVINE accelerated loading tests was used to determine if initial structural capacity differences between the two test pavement paths influence pavement performance in addition to that damage caused by dynamic loading



FWD Surface Deflection at Construction and at 20k, Inner Track



FWD Surface Deflection at Construction and at 20k, Outer Track

Initial Structural Capacity

Unit FWD Surface Deflection Beginning of Test (20 k Preload), mm/MPa, SELECT Data

	MEAN	V
Outer Path	0.95	0.10
Inner Path	0.95	0.10

Variations Defining Performance at Different Repetitions

In terms of changes in the mean and variance of

- Surface profile
- Rut depth
- Cracking

Performance at Different Repetitions

Profile Change (mm) from 20 k to 1700 k (SELECT)

	Mean	STD
Inner	7	No Change
Outer	13 (~80% more)	No Change

(Standard Deviation: 3 ~ 4 mm)

Performance at Different Repetitions (cont'd)

Rut Depth Change (mm) from 20 k to 1700 k (SELECT)

	Mean	STD
Inner	9.2	1.07
Outer	8.1	1.36 (27% more)

(Standard Deviation: 1 ~ 2 mm)

Performance at Different Repetitions (cont'd)

Total Linear Cracking Change per Station (m) from 20k to 1700 k

	Mean	STD
Inner	1.168	1.027
Outer	1.143	1.188 (16% more)

(Standard Deviation: 0.5 ~ 1 m)

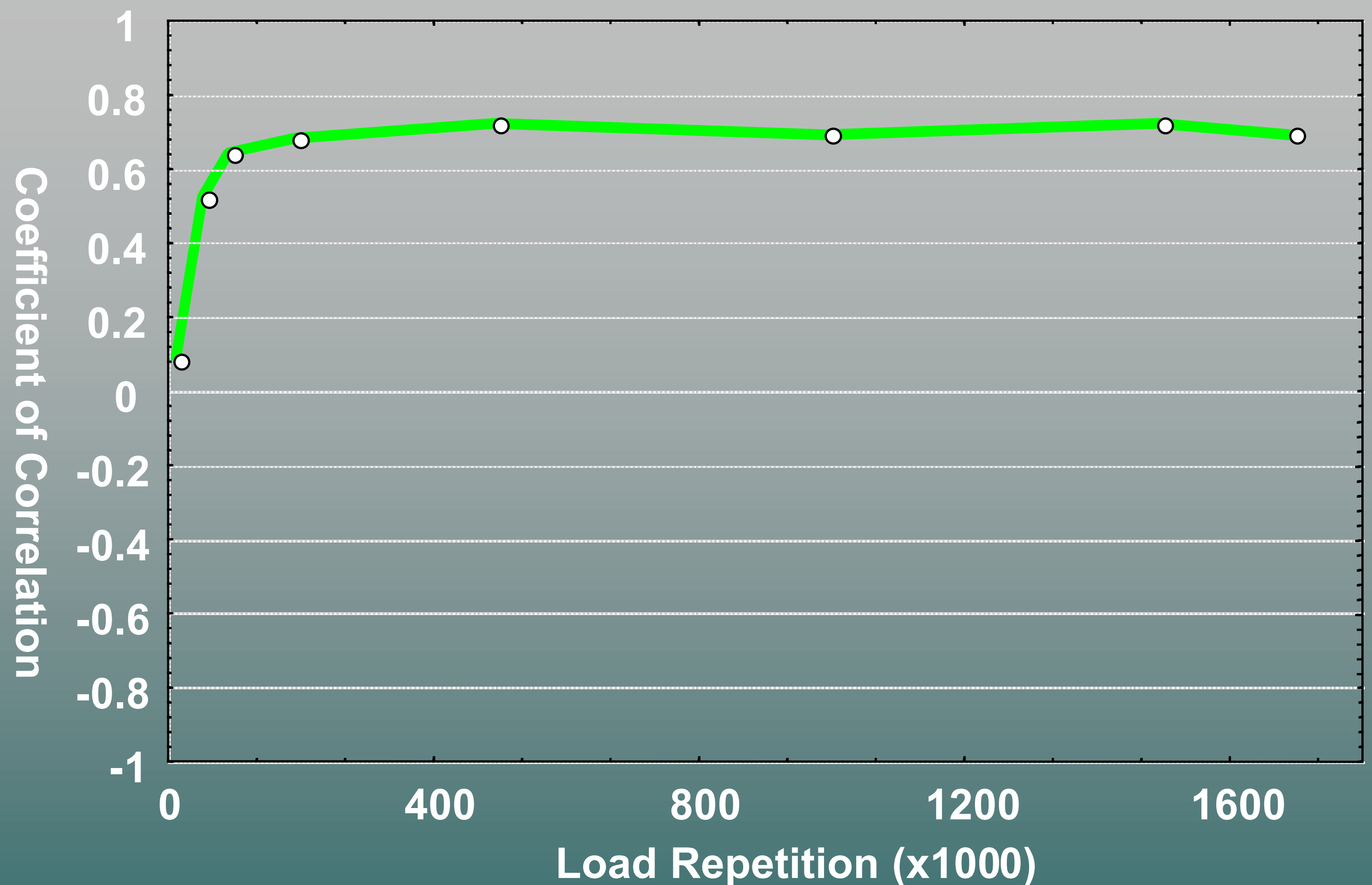
Findings

- 27% more roughness in outer track due to dynamic loading
- Only static loading affects mean elevation or rutting

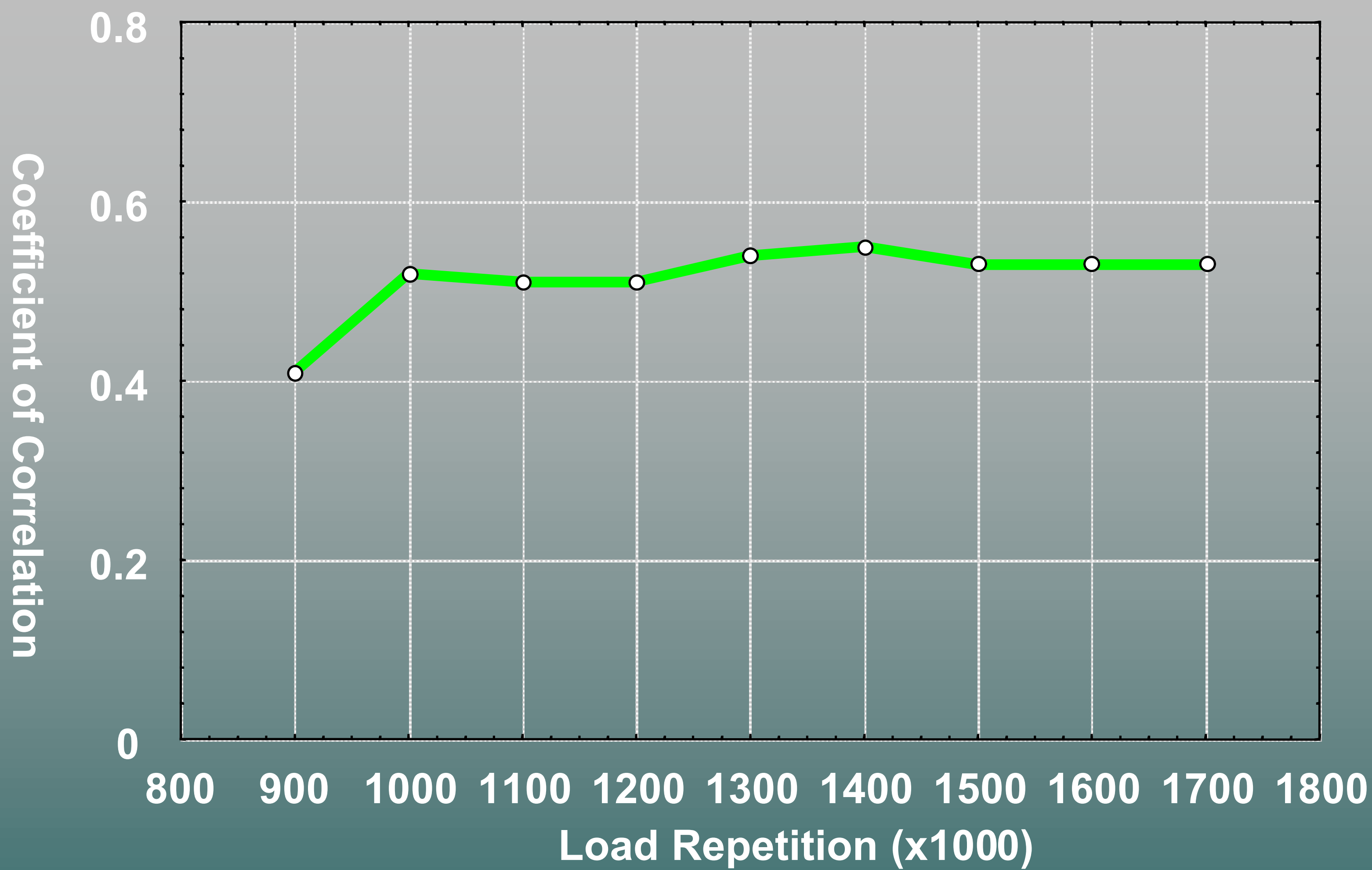
Cross Correlation

Cross Correlation Among Variables:

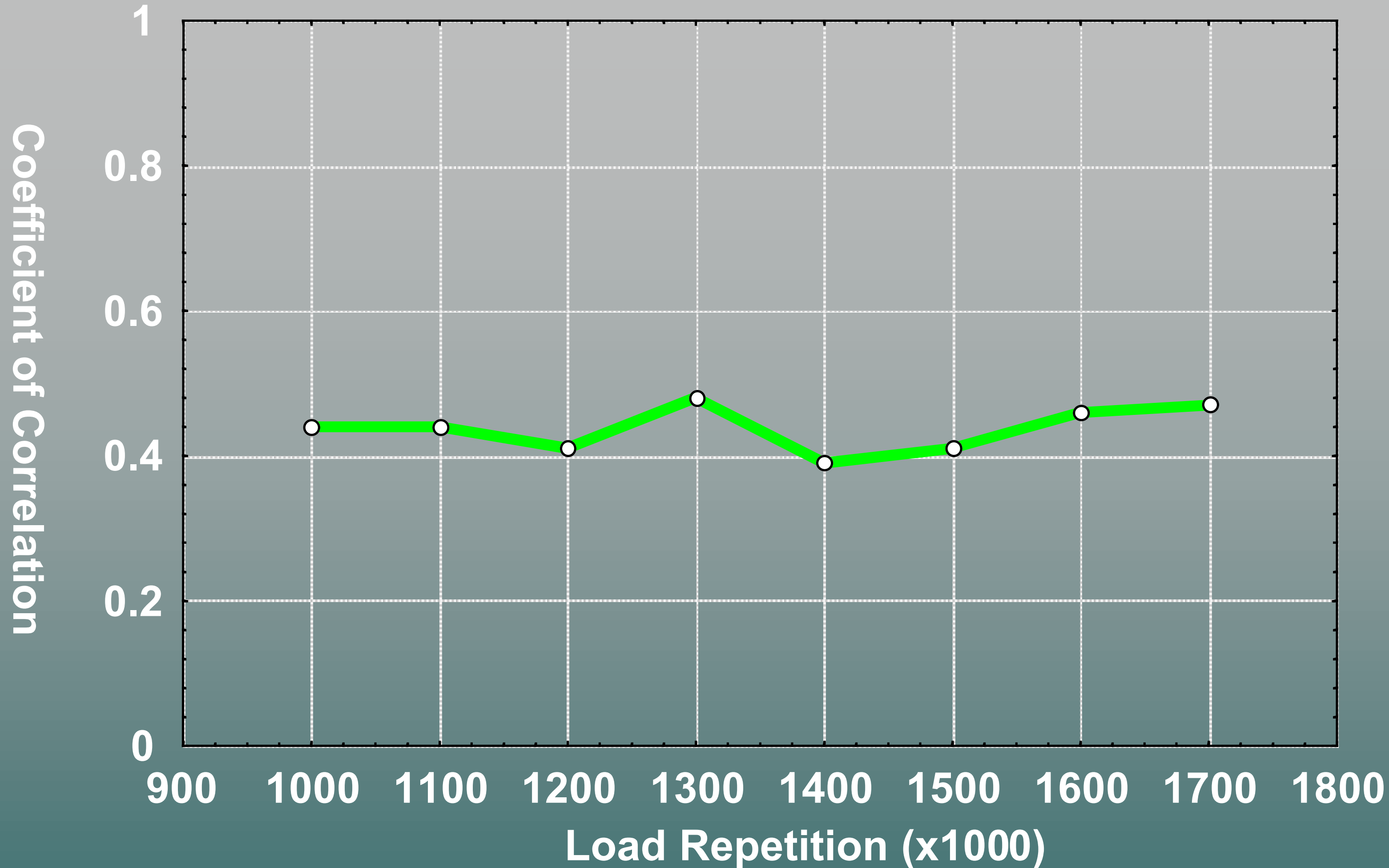
- FWD
- Profile
- Rut Depth
- Wheel Force
- Cracking



Cross Correlation between FWD Surface Deflection at 20k and Rut Depth



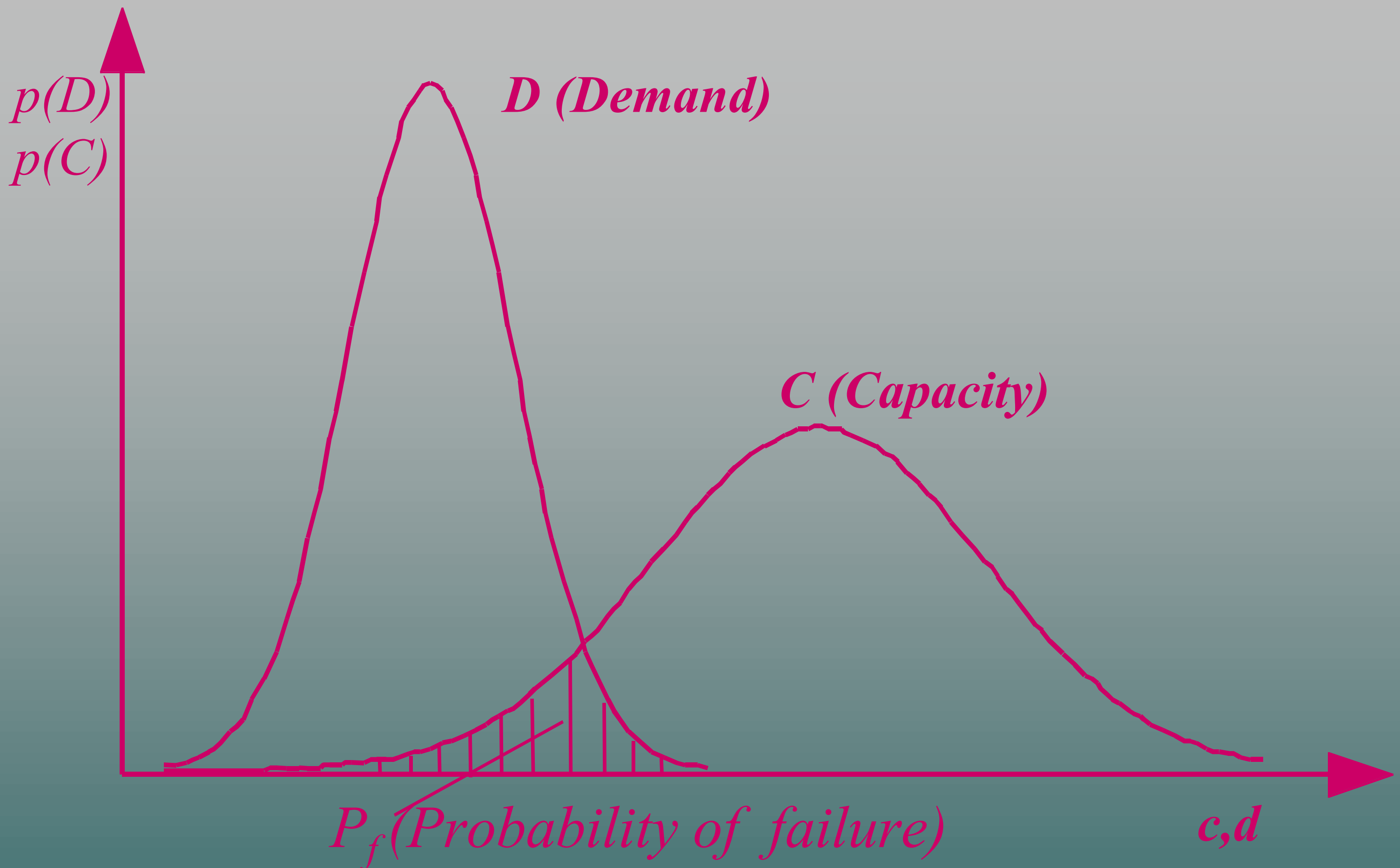
Cross Correlation between FWD Surface Deflection at 20k and Total Linear Cracking



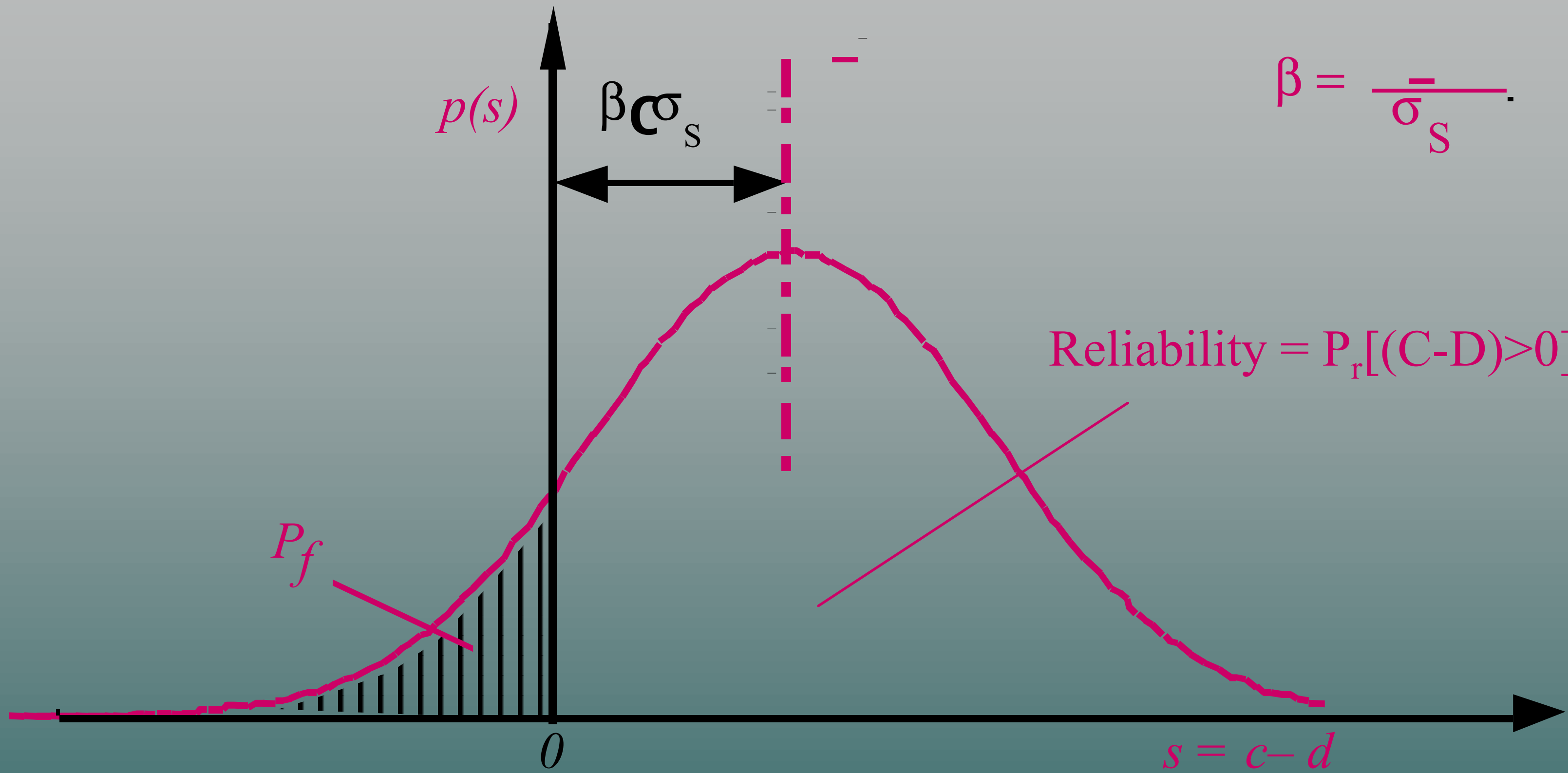
Cross Correlation between Total Linear Cracking and Rut Depth

RELIABILITY

The likelihood of the adequate performance of a system for a specified period of time.



Probability Distribution of Capacity and Demand



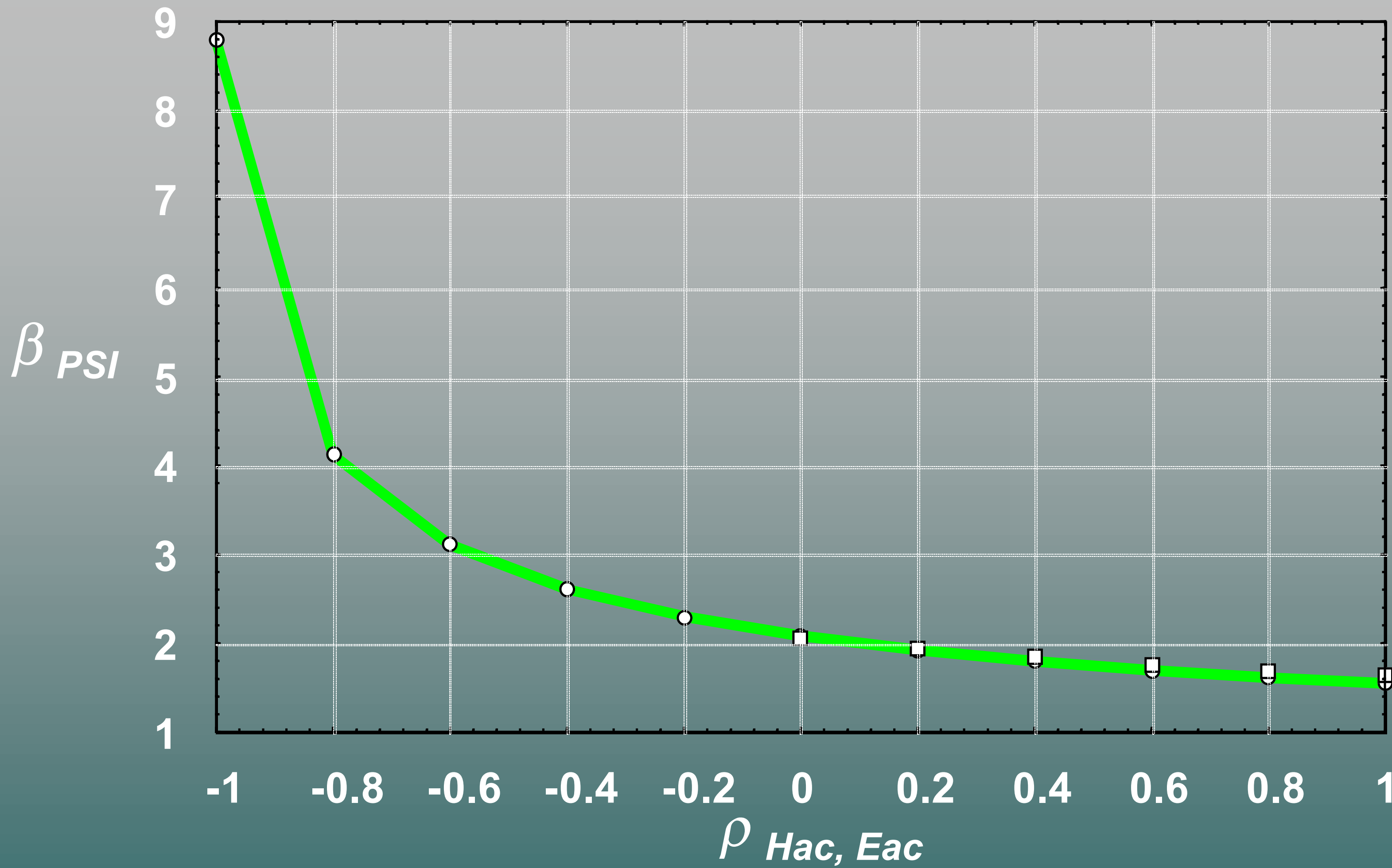
Reliability Index β of Safety Margin *S*

For normally distributed and correlated C and D, the reliability index is

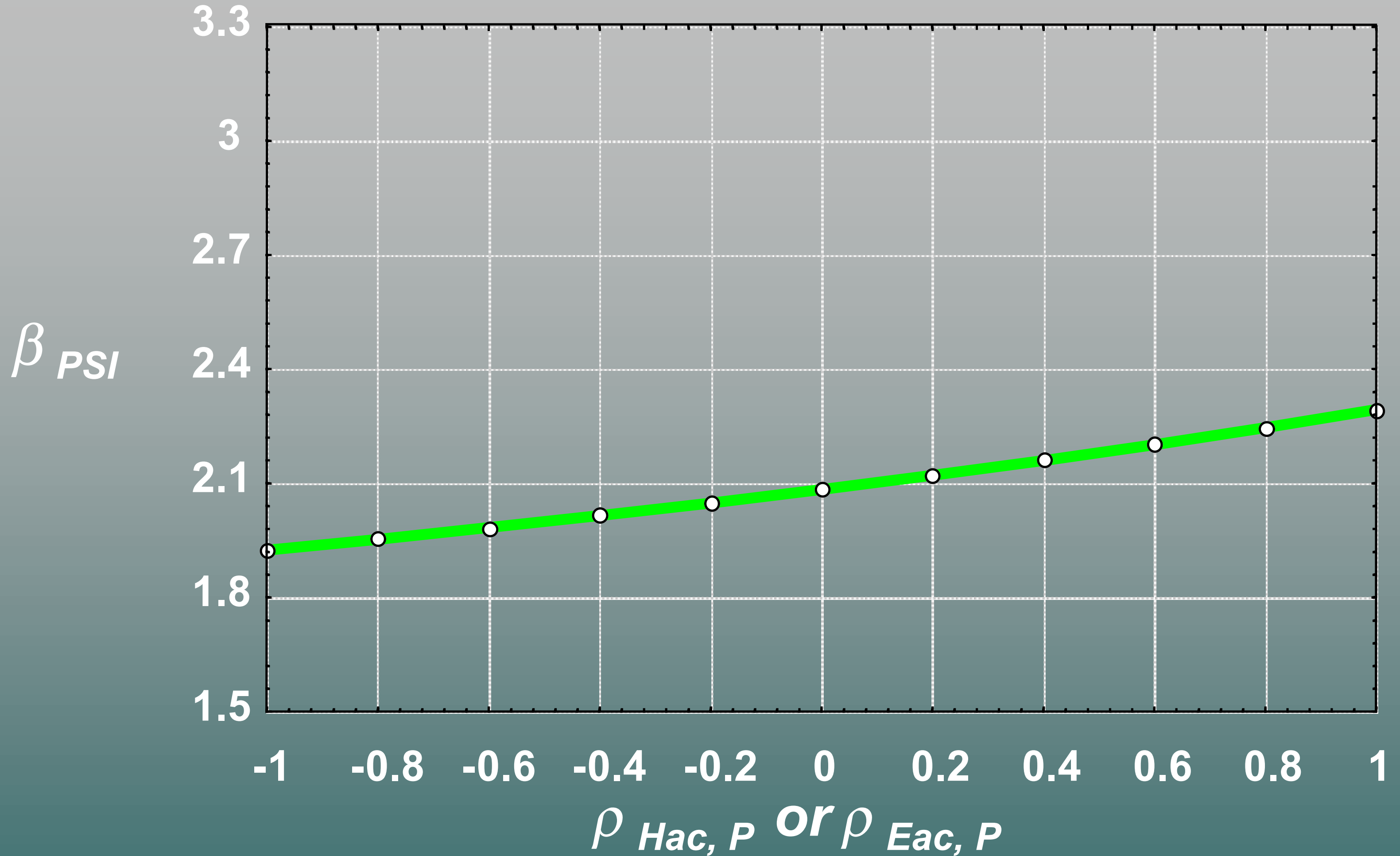
$$\beta = \frac{\overline{C} - \overline{D}}{\sqrt{\sigma_C^2 + \sigma_D^2 - 2\rho_{C,D}\sigma_C\sigma_D}}$$

For normally distributed C and a constant D, then

$$\beta = \frac{\overline{C} - D}{\sigma_C}$$



Effect of Correlation between H_{AC} and E_{AC} on Reliability Index



Effect of Correlation between E_{AC} and P_{dyn} and between H_{AC} and P_{dyn} on Reliability Index

SUMMARY AND CONCLUSIONS

- Pavement variability affects pavement performance
- Dynamic vehicle load affects pavement roughness
- Variation and correlation affect pavement reliability

Research Plan

(A detailed work plan will be Prepared)

Needed Facilities and Equipment

- A minimum 1000 m to be constructed, cut and filled pavement section
- Deflection, stiffness, density and profiling measurement equipment

Data to Be Collected

During Pavement Construction

- **Deflection (FWD), stiffness (GG), density (ND) and other stress/strain surrogate measurements**
- **Temperature and moisture**
- **Laboratory material property tests**
- **Surface profile**

Data to Be Collected (continued)

After Pavement Construction

- **Pavement surface profile**
- **Pavement surface deflection/stiffness**
- **Traffic and pavement performance data**

Analysis Methodologies

- Layer stiffness and modulus determination
- Statistical analysis of processed data
- Statistical and correlation analyses of significant variables
- Pavement performance prediction using mechanical model VESYS
- Pavement reliability analysis
- Economic life cost analysis (future)

Layer Stiffness and Modulus

- Measured and calculated layer stiffness
- The principle of Odemark to transform n different layers to a single equivalent layer for modulus determination (using FWD center deflection)

Formula - Stiffness

$$K = \frac{P}{\delta}$$

$$S = \frac{Eh^3}{12(1-\mu^2)}$$

Formula- Modulus

$$K = \frac{1.77RE}{(1-\mu^2)}$$

$$D_{0,2} = 2(1-\nu^2)\frac{qa}{E_1 E_2}[E_2 + F_b(E_1 - E_2)]$$

$$F_b = \left[\sqrt{1+\left(\frac{h_e}{a}\right)^2} - \frac{h_e}{a}\right]\left[1+\frac{\frac{h_e}{a}}{2(1-\nu_2)\sqrt{1+\left(\frac{h_e}{a}\right)^2}}\right]$$

$$h_e = h_1\left(\frac{E_1}{E_2}\right)^{1/3}$$

Analyses - Effort Level I

- Data processing
- Calculate significant variables, such as layer and pavement stiffness and layer moduli
- Variation analysis to define initial pavement structural capacity
- Data comparison: FWD, GG, ND, and other data

Analyses- Effort Level II

Level I effort plus:

- Correlation analysis on pavement structural measurements
- Prediction of pavement performance

Analyses- Effort Level III

Level II effort plus:

- Variation analysis of pavement performance
- Cross correlation analysis on pavement performance
- Reliability analysis of pavement performance

Analyses- Effort Level IV

Level III effort plus:

- Life cycle cost analysis

Thank You