Application of DCP in Prediction of Resilient Modulus of Subgrade Soils

Louay Mohammad, Ph.D.

Louisiana Transportation Research Center

Louisiana State University

LTRC Louisiana Transportation Research Center

Louisiana State University LSU

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Topics

- Background
- Objective
- Scope
- Methodology
- Experimental program
- Results

What is Resilient Modulus?

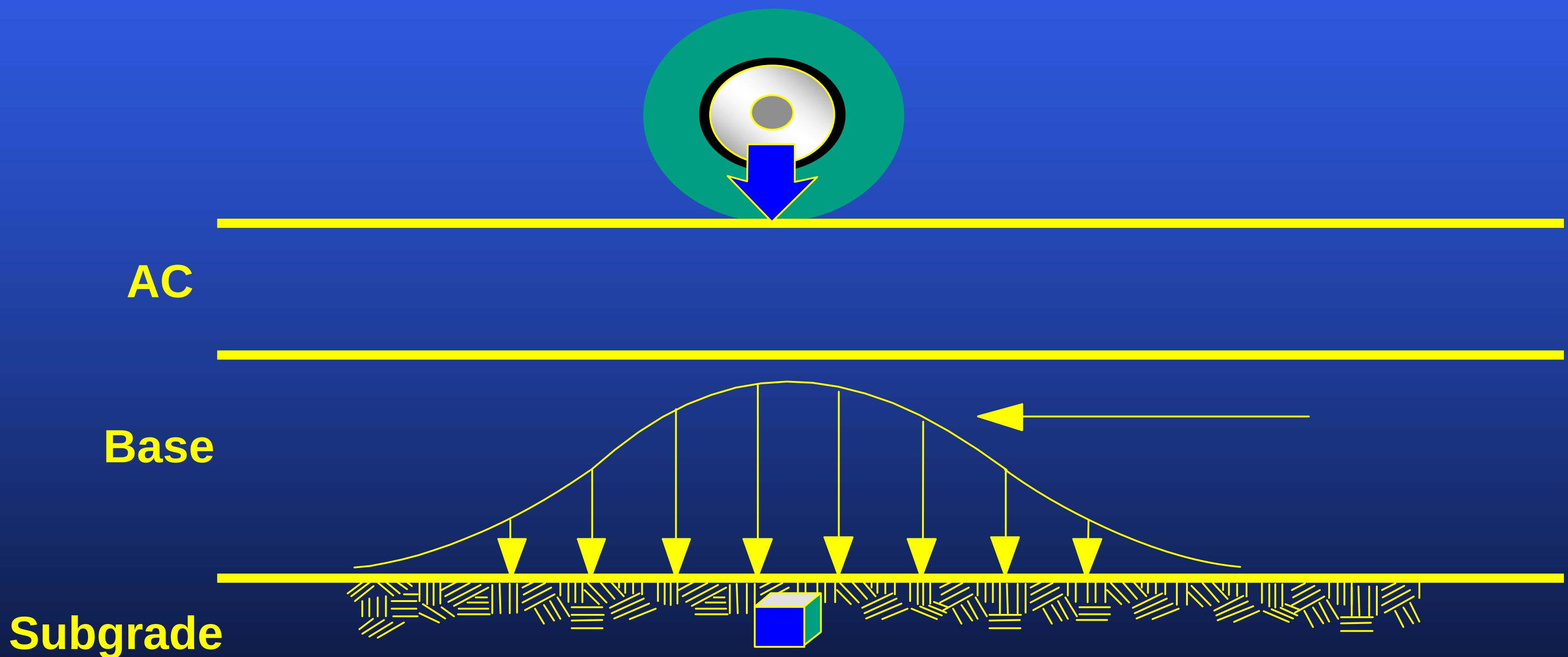
M_R

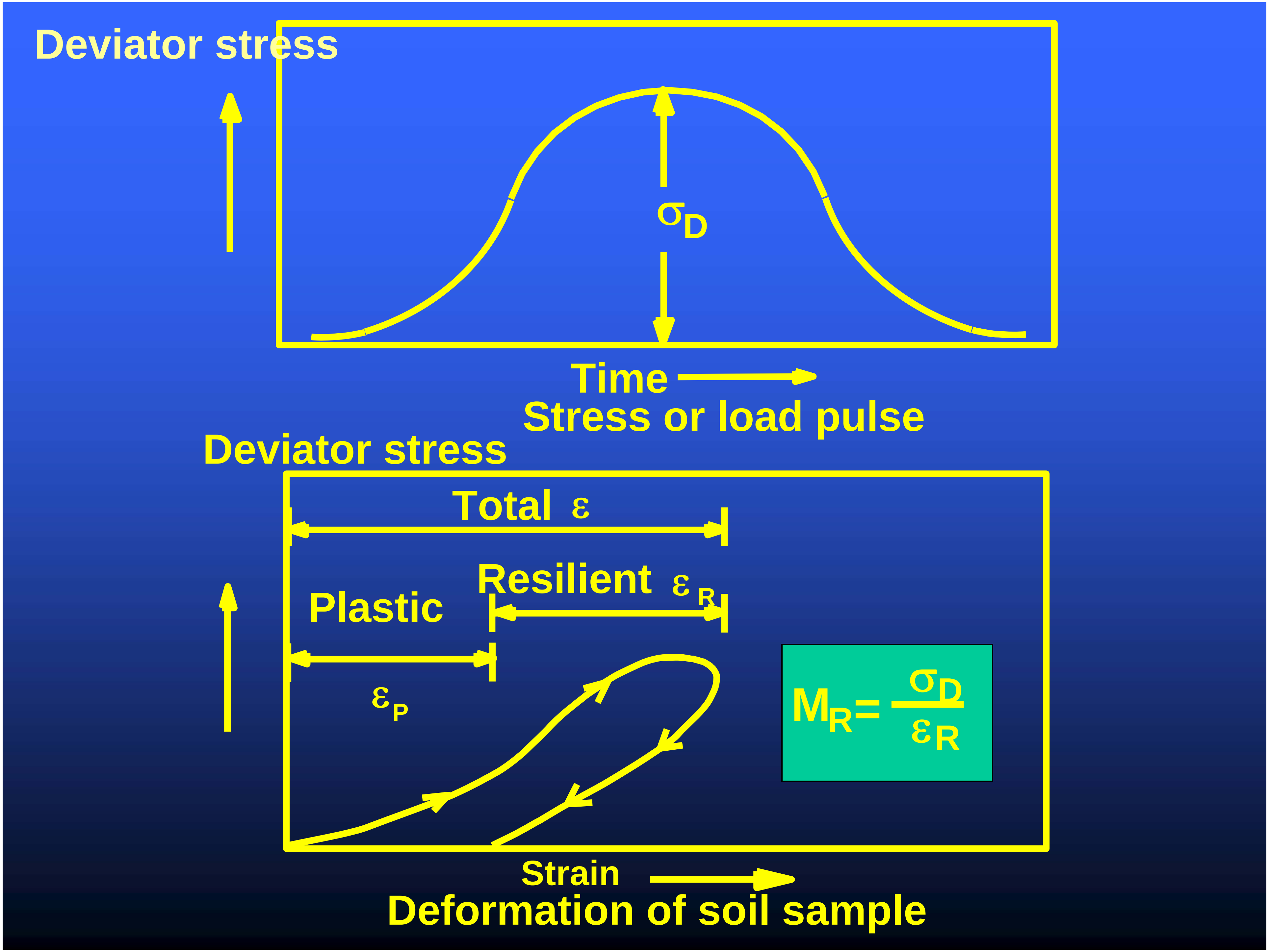
Stiffness of Soils

Under Dynamic Loading

Why Resilient Modulus was Selected?

- More realistic way to characterize moving wheel loads





Deviator stress
σD
Time
Stress or load pulse
Deviator stress
Total ε
Resilient ε R
Plastic
εP
MR= σD / εR
Strain
Deformation of soil sample

Where is M_R Used?

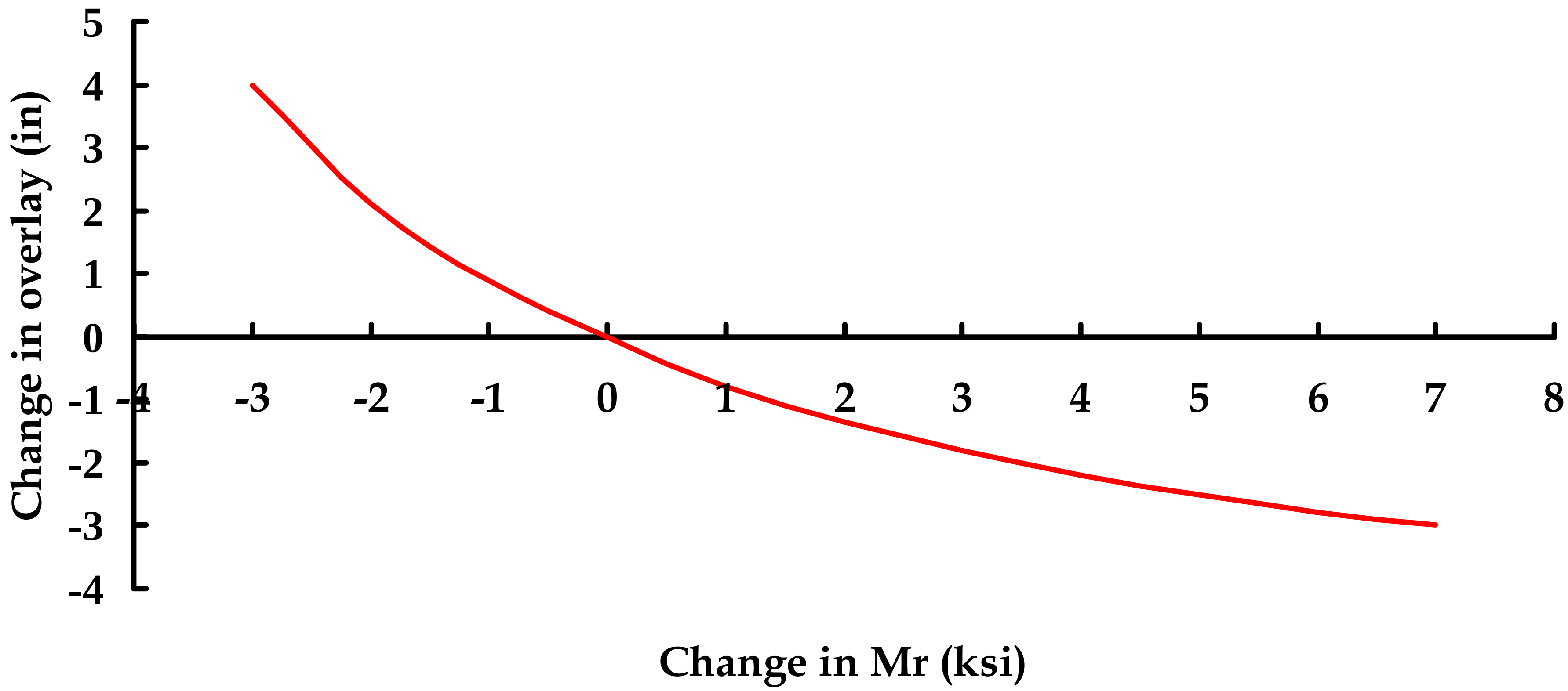
- **Design of New & Rehabilitated pavements**
- **Forensic analysis of Pavement Failures**
- **Quality Control for fill or cut sections**

Where is M_R Used?

- **Design of New & Rehabilitated pavements**
  - **LADOTD 1993 AASHTO**

$$\log_{10} W_{18} = Z_R S_o + 9.36 \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \log_{10}(M_R) - 8.07$$

Sensitivity Example of M_r to Flexible Pavement Thickness Design (1993)



Where is M_R Used?

- Design of New & Rehabilitated pavements
  - M-E Design Guide
    - Traffic
    - Climate
    - Structure
    - Thermal

Where is M_R Used?

- **Design of New & Rehabilitated pavements**
  - **M-E Design Guide**

Material	Input Level 1	Input Level 2	Input Level 3
Asphalt Concrete	Measured DM	Estimated DM	Default DM
PCC	Measured EM	Estimated EM	Default EM
Stabilized Materials	Measured M_R	Estimated M_R	Default M_R
Granular Materials	Measured M_R	Estimated M_R	Default M_R
Subgrade	Measured M_R	Estimated M_R	Default M_R

Where is M_R Used?

- Forensic analysis of Pavement Failures
  - Assessment of soil conditions
  - develop an appropriate rehabilitation strategy

Where is M_R Used?

- **Quality Control for fill or cut sections**
  - **pavement section is designed based upon a targeted resilient modulus**

How is Resilient Modulus Determined?

- *Direct Measurement*
  - *Lab Test: AASHTO T 307*
  - Undisturbed
  - Disturbed, remolded and compacted
- *Reverse Engineering*
  - *in-situ*
    - DCP, Minincone
  - *nondestructive test (NDT) methods*
    - FWD, Dynaflect
- *Prediction*
  - Soil properties
    - SSV (DOTD)
    - other
  - Unconfined compressive strength
  - CBR

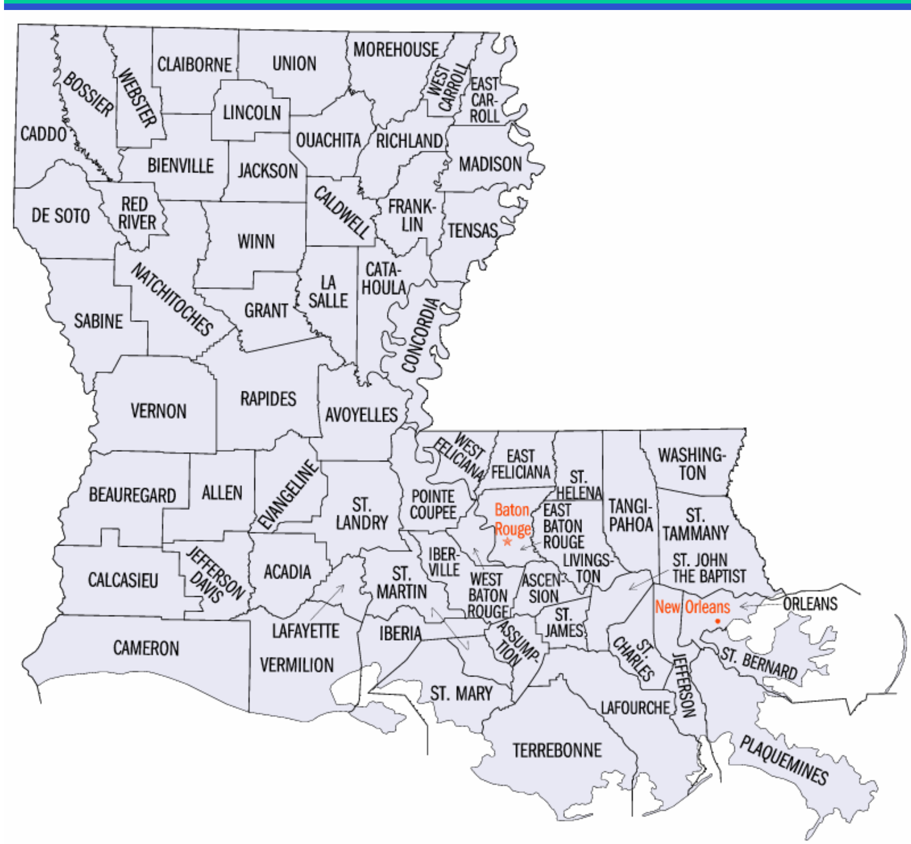
Limitations: Direct Measurement

- ***Direct Measurement***
  - ***triaxial type of test***
  - ***Laborious and time consuming***
  - ***Require advanced testing equipment***
  - ***Skilled Personnel***

Limitations: M_R Predictions Models

- **Static properties of soils**
  - **SSV, etc: average value for each Parish**
  - **Do not represent the dynamic behavior of traffic loading**

$$M_R = 1500 + 450[(53/5)(SSV-2)] - 2.5[(53/5)(SSV-2)]^2$$



Parish	Soil Suppo Value
Acadia	3.7
Allen	3.6
Ascension	3.6
Assumption	3.5
Avoyelles	3.8
Beauregard	3.7
Bienville	4.0
Bossier	3.7
Caddo	4.1
Calcasieu	3.8
Caldwell	4.0
Cameron	3.8
Catahoula	3.7
Claiborne	4.1
Concordia	3.6
Desoto	3.8
East Baton Rouge	3.6
East Carroll	3.8
East Feliciana	4.4
Evangeline	3.9
Franklin	4.0
Grant	4.0
Iberia	3.8
Iberville	3.6
Jackson	3.8
Jefferson	3.5
Jefferson Davis	3.6
Lafayette	4.0
Lafourche	3.8
Lasalle	3.8
Lincoln	4.1
Livingston	3.9

Alternative In-situ Technique

- M_R Prediction Models
- Dynamic cone penetration (DCP)
  - fast, simple, and economical
  - Geotechnical investigation

Objectives

Develop M_R prediction Models

- In-situ
  - DCP test results
  - Soil properties

Scope

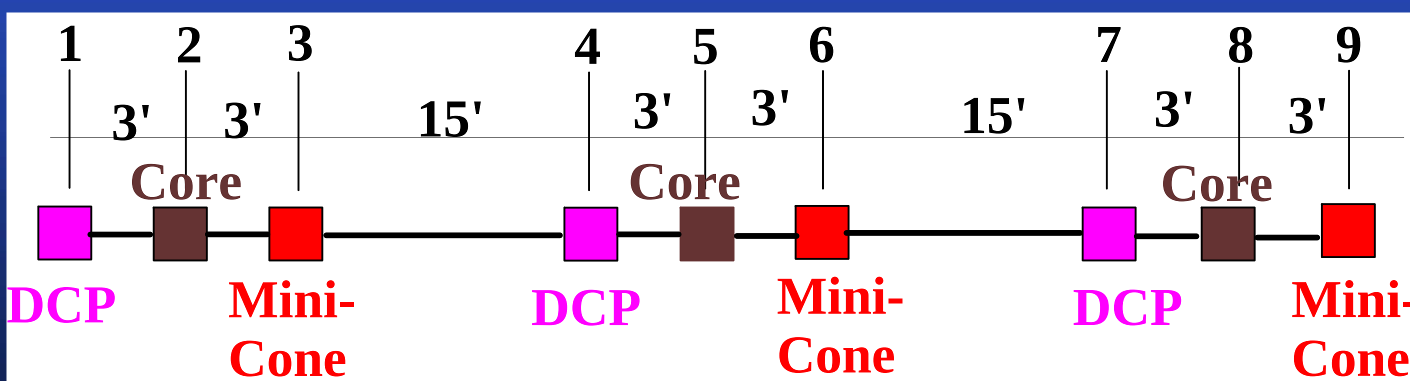
- Thirty one sites
- Four common cohesive soil types in Louisiana
  - A-4, A-6, A-7-5, and A-7-6
- Field DCP tests
  - Various moisture-density levels
- Laboratory test
  - Mr from RLTT
  - Soil physical properties
- Three tests per site

EXPERIMENTAL PROGRAM

- Field Activities
  - Field projects
    - DCP
    - Soil Sampling
- Laboratory tests
  - Repeated load triaxial test
  - Physical properties
  - Compaction and strength characteristics

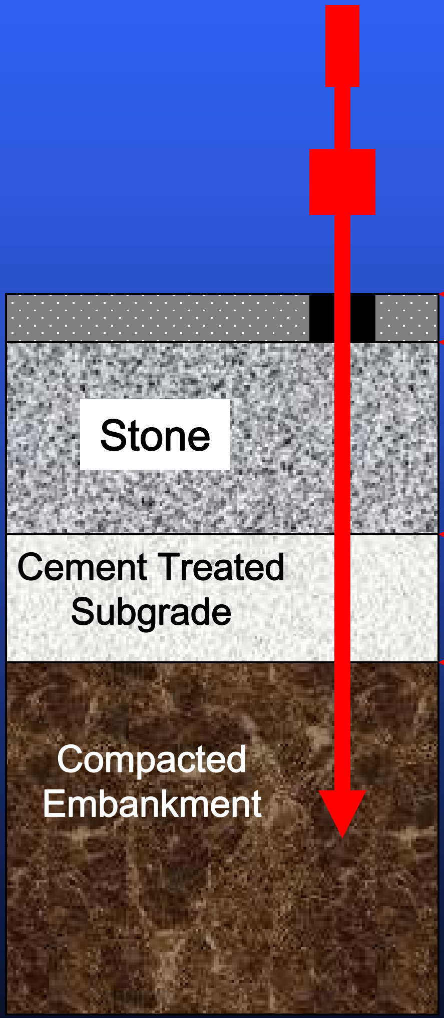
Field Testing Layout

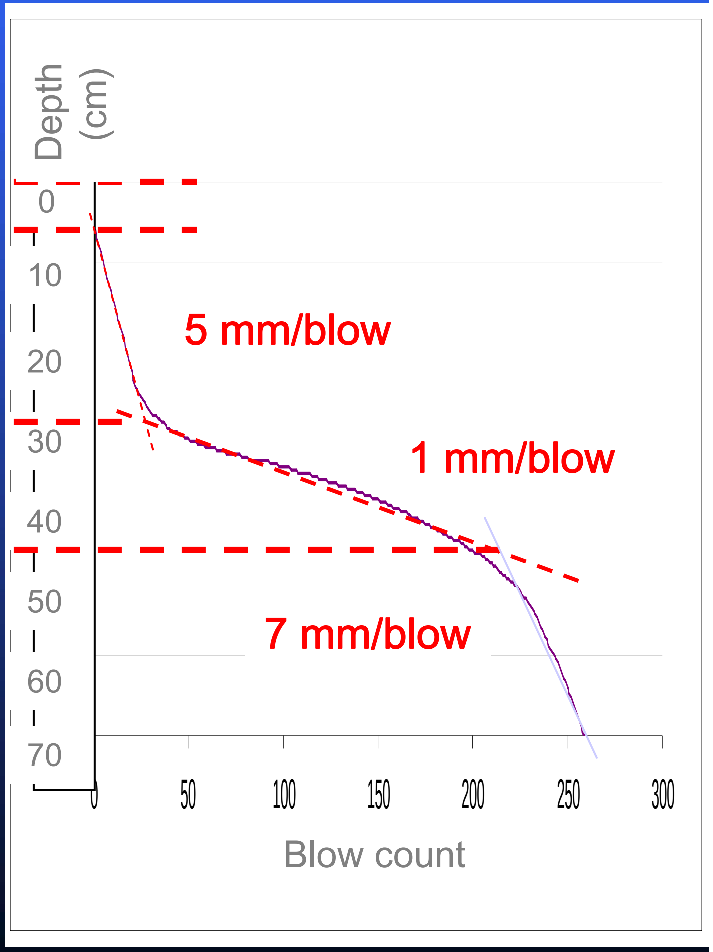
- **Three sections of testing at each field project**
  - **A, B, and C**
- **Each section contains nine points**



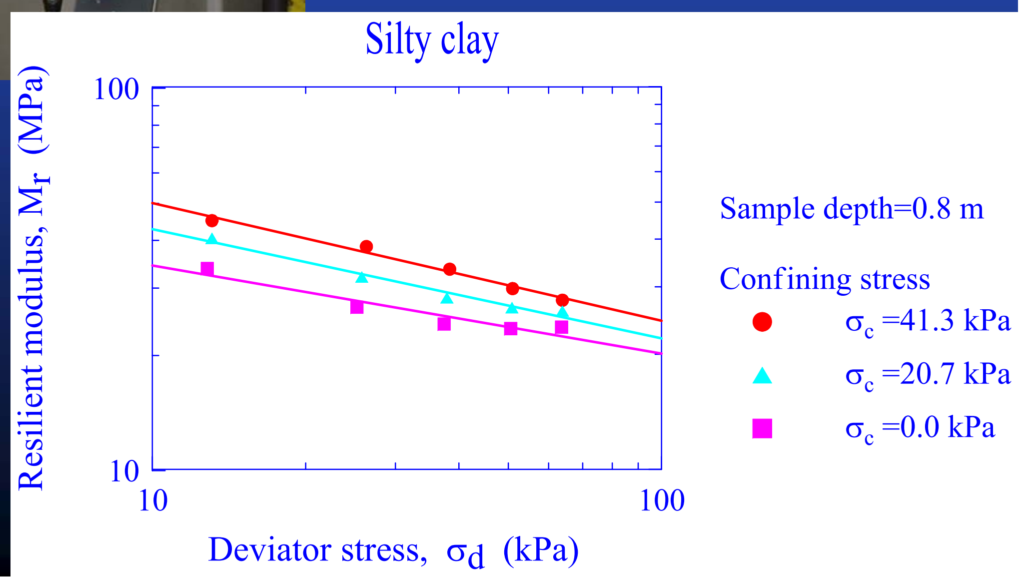
Set A

Dynamic Cone Penetrometer Test: *DCPI*

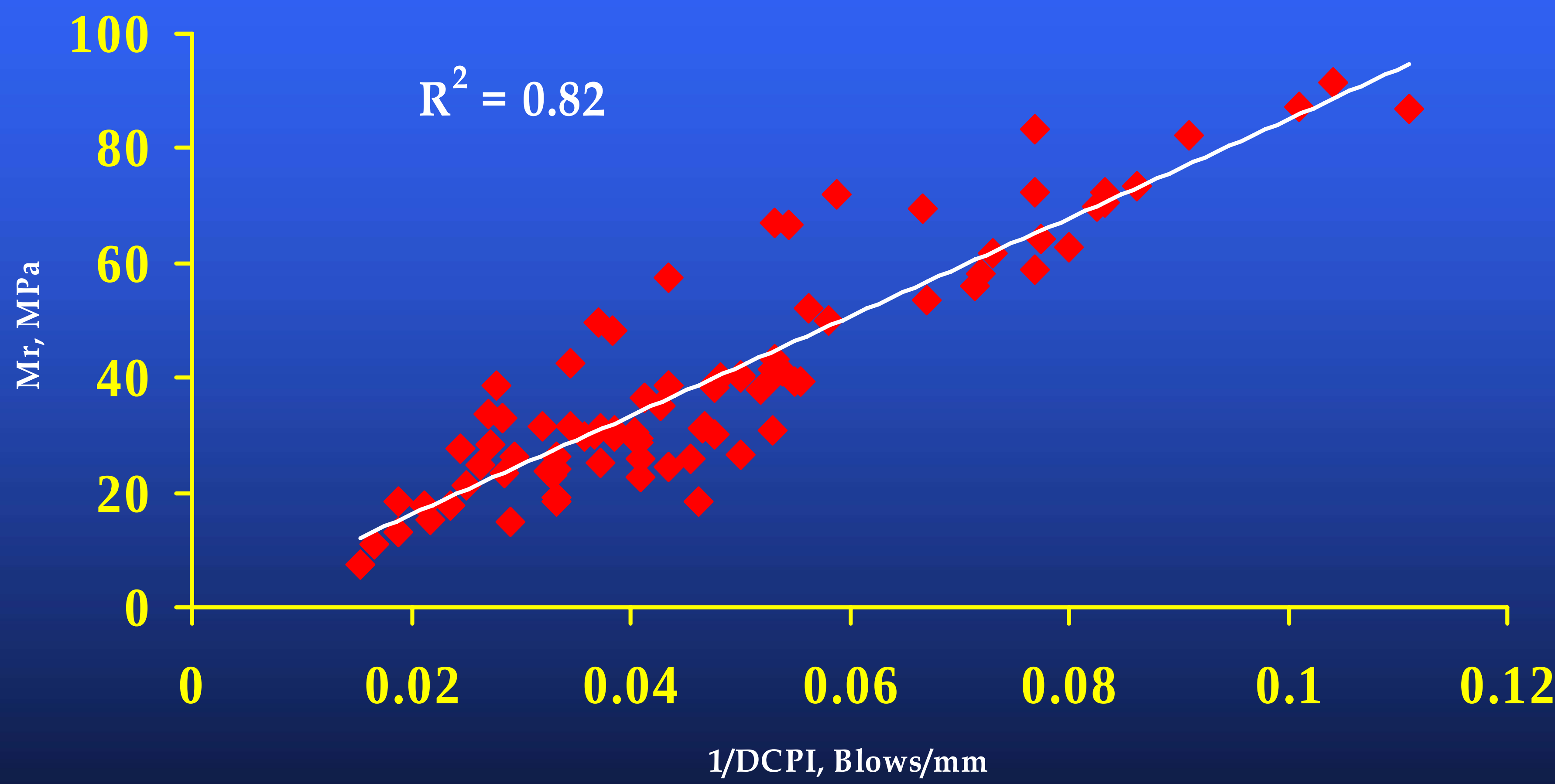




Repeated Load Triaxial Test: M_R



Relationship B/W Mr and 1/DCPI



Development of M_R Prediction Models

DCPI

M_R

Moisture Content
Density

M_R = f(DCPI, physical properties)

Resilient Modulus Prediction Models

Direct Model: $R^2=0.82$

$$M_R = 122.4\left(\frac{1}{DCPI}\right)$$

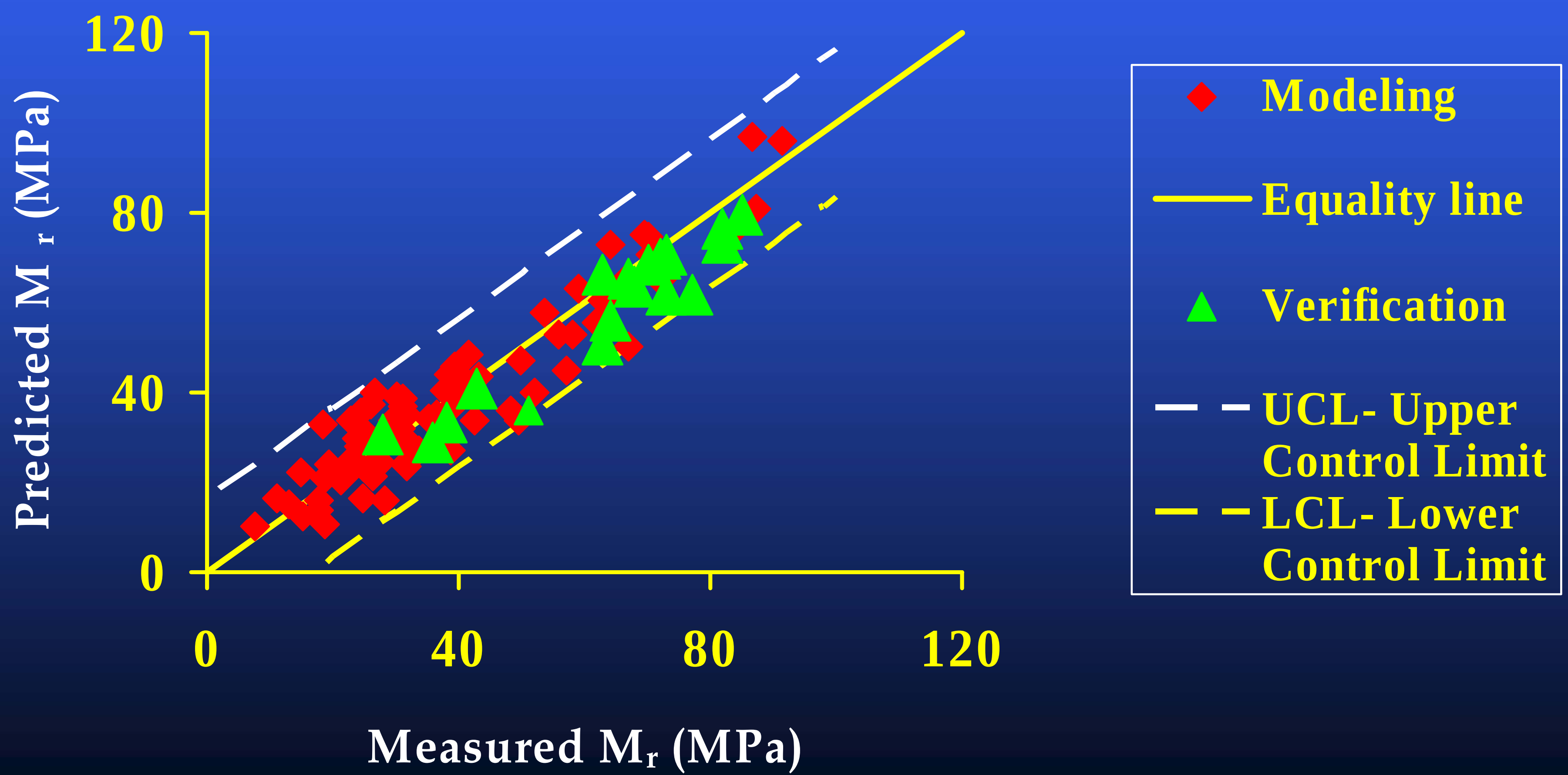
Soil Property Model: $R^2=0.89$

$$M_R = 221.0\left(\frac{1}{DCPI}\right)^{1.32} + 0.42\left(\frac{\gamma_d}{w}\right)$$

Parameter	Range
M_r (ksi)	1.0-14
DCPI (mm/blow)	9-85
PI (%)	4-61
γ_d (pcf)	50-115
W (%)	8-82
LL (%)	22-98
Silt (%)	9-72
Clay (%)	8-86
Passing #200 Sieve (%)	42-97

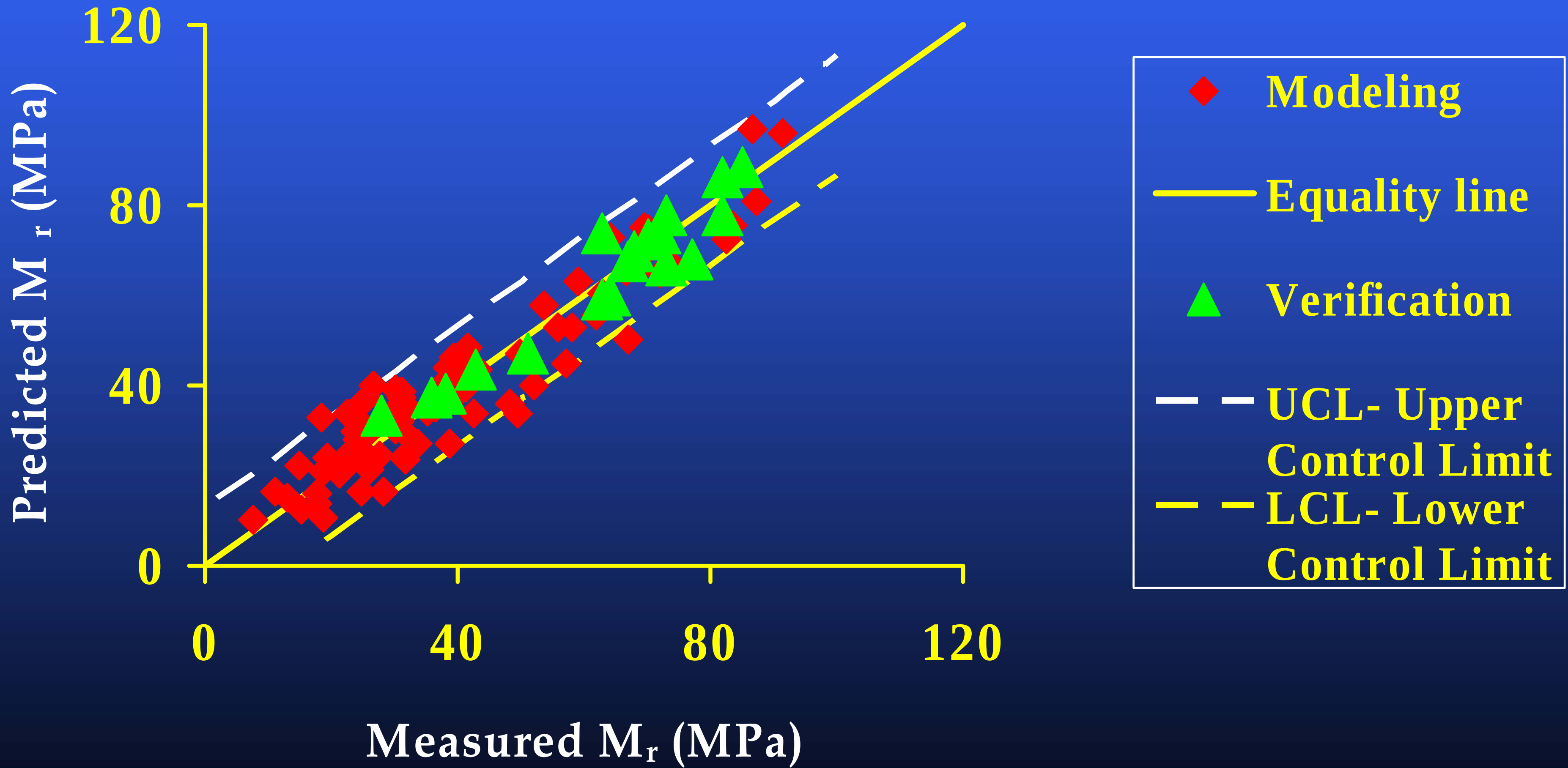
Measured vs. Predicted: Direct Model

$$M_R = 122.4\left(\frac{1}{DCPI}\right)$$

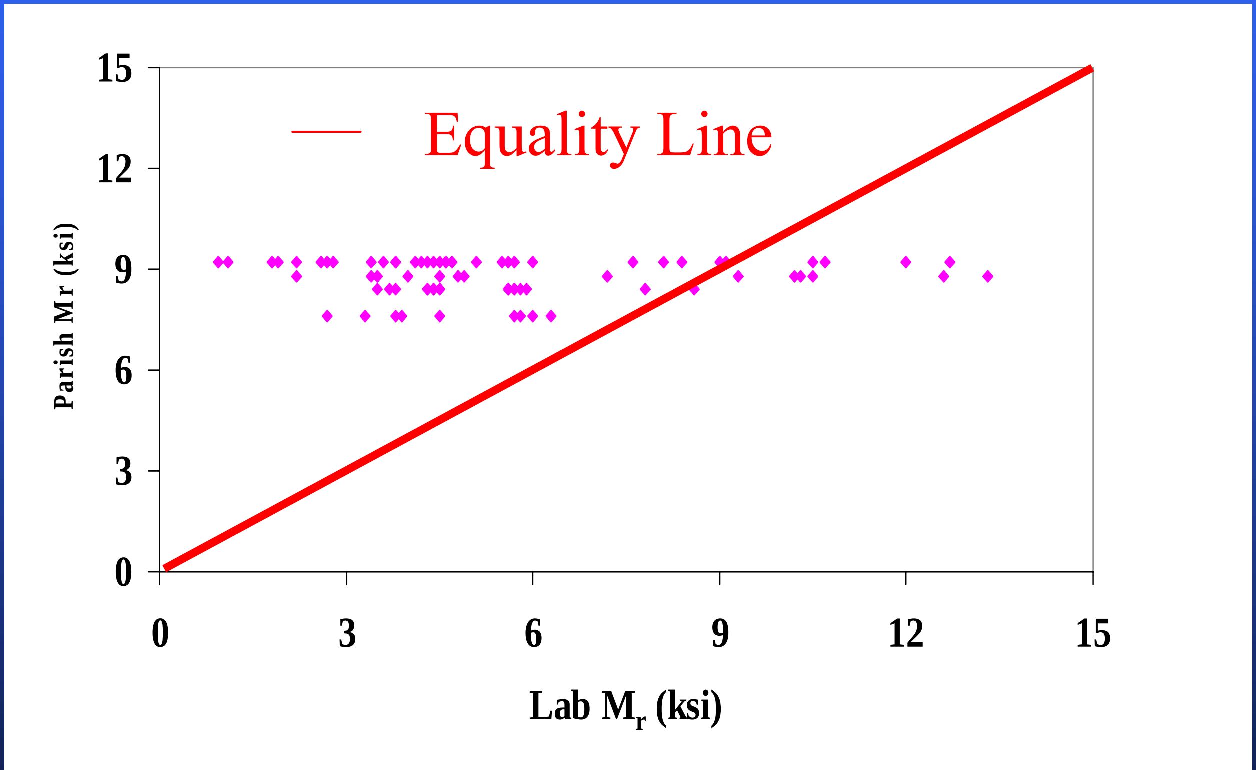


Measured vs. Predicted: Soil Property Model

$$M_R = 221.0\left(\frac{1}{DCPI}\right)^{1.32} + 0.42\left(\frac{\gamma_d}{w}\right)$$



Measured vs. Predicted: Parish Map



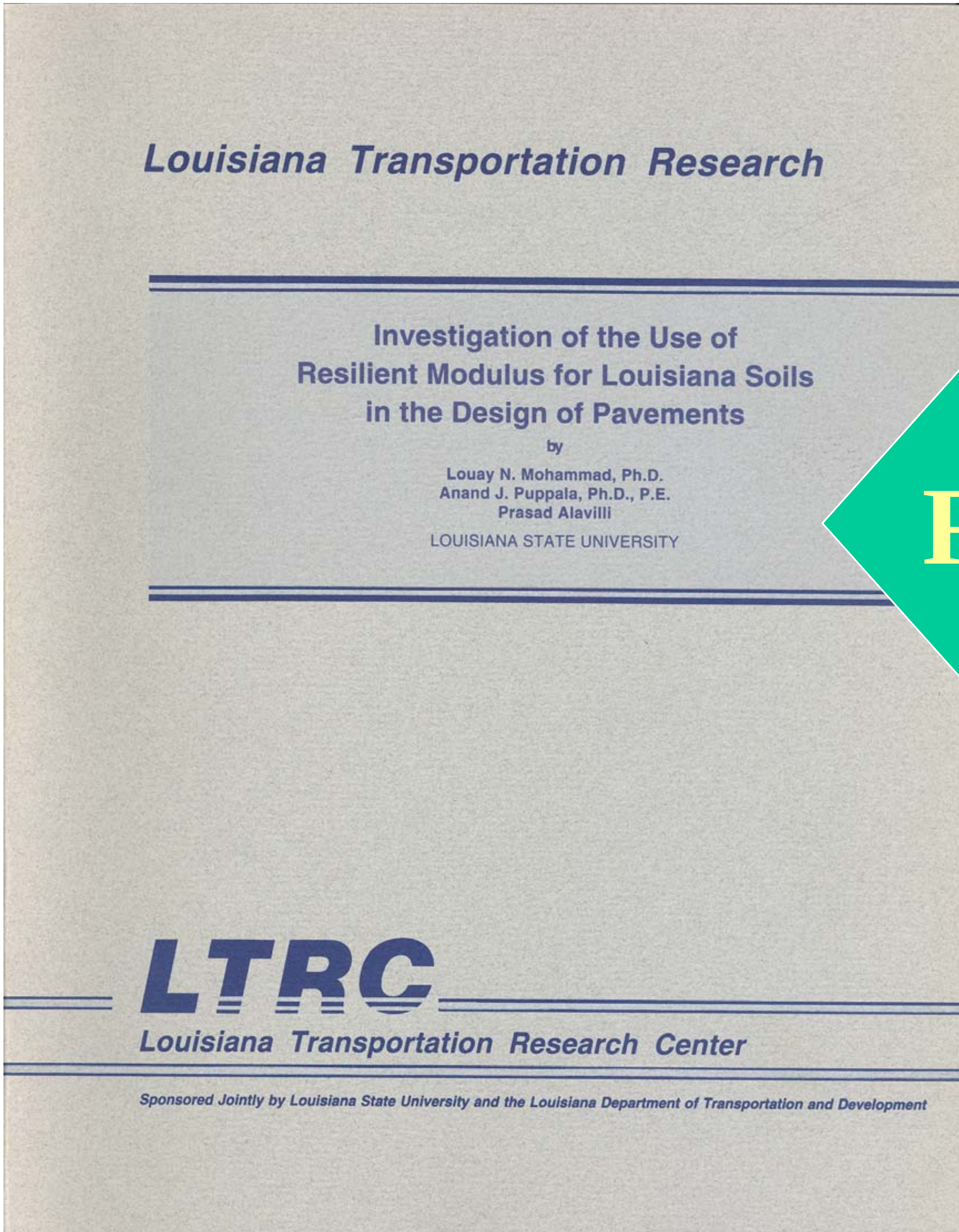
M_r	Range
Lab-M_r (ksi)	0.9-14
Parish-M_r (ksi)	7.6-9.2

Summary

- M_R prediction Models were developed
  - DCP
- Good agreement
  - Measured and predicted
  - Improvement
    - Current practice
- Tools
  - Design of New & Rehabilitated pavements
    - Current & M-E Design Guide
  - Forensic analysis of Pavement Failures
  - Quality Control for fill or cut sections

$$M_R = 122.4\left(\frac{1}{DCPI}\right)$$

$$M_R = 221.0\left(\frac{1}{DCPI}\right)^{1.32} + 0.42\left(\frac{\gamma_d}{w}\right)$$


Louisiana Transportation Research

Investigation of the Use of
Resilient Modulus for Louisiana Soils
in the Design of Pavements

by

Louay N. Mohammad, Ph.D.
Anand J. Puppala, Ph.D., P.E.
Prasad Alavilli

LOUISIANA STATE UNIVERSITY

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