Session 63

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Elastomeric Bearing Pads Under Combined Loading

Topic Description

The AASHTO Specifications for elastomeric bearing pad under combined axial loading and rotation was deemed to be too conservative. As a result FDOT sponsored a study to rexamine the performance of there pads under the combined loading. Both experimental work and analytical work were conducted. In this presentation the results from the study will be presented and discussed.

Speaker Biography

Dr. Mtenga is an Associate Professor in Civil Engineering at FAMU-FSU College of Engineering. His research interests include structural condition assessment and structural retrofit, structural system performance and reliability, composite materials and wood structures.

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Project: Elastomeric Bearing Pads Under Combined Loading

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Project Manager: Marcus Ansley

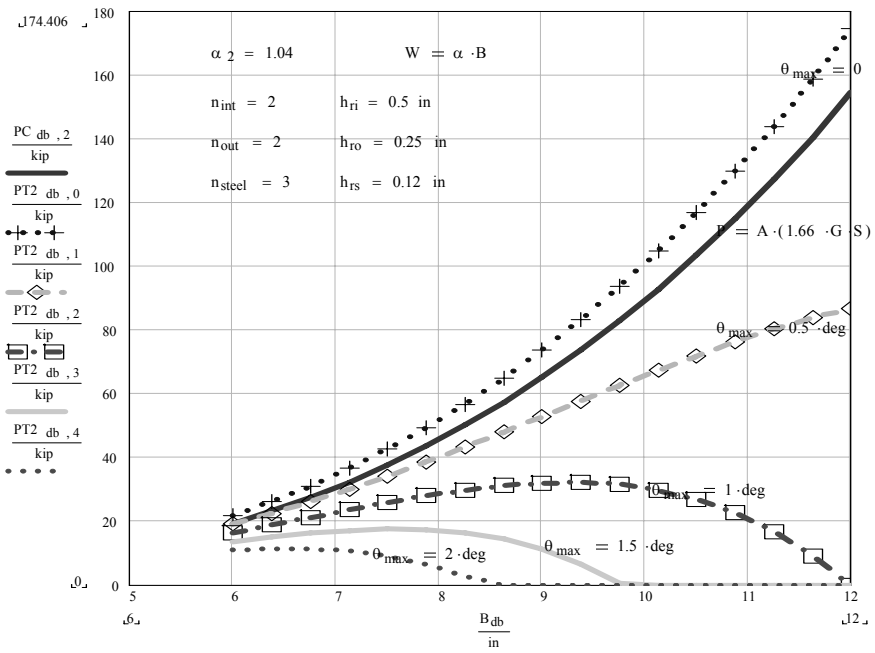
Introduction

- Presentation is on a part of an FDOT Sponsored project.: Steel Reinforced Elastomeric Bearing Pads (SRE-BP) Under Combined Loading.
- SRE-BP under axial and rotational loads: AASHTO Eq. 14.7.5.3.5-2

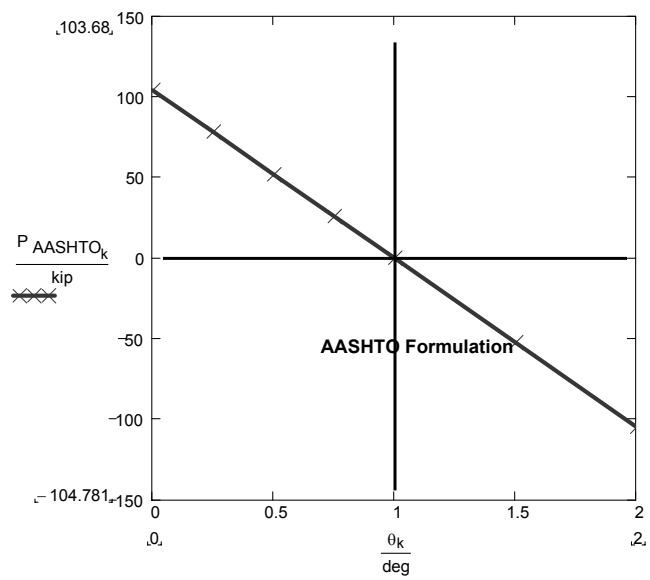
$$\mathrm{P} = \mathrm{A}\left[1.8754GS\left[1-0.2\left(\frac{\theta_{\max}}{n}\right)\left(\frac{B}{h_{ri}}\right)^2\right]\right]$$

- Perceived as too conservative by some at FDOT , and others, thus the need of study

•AASHTO equation Plots



•AASHTO equation Plot for a 20 by 20 Pad



SCOPE OF WORK

1. NCHRP Report 449 states ,".. a satisfactory bearing design needs the shear modulus (SM) of the material to be determined reliably". **New Method For Determining SM was developed.**
2. **Combined loading tests (cyclic loading up to 1-million cycles) conducted.**
3. **Finite element (FE) Analytical studies were conducted.**
4. **Develop a new combined loading capacity equation**

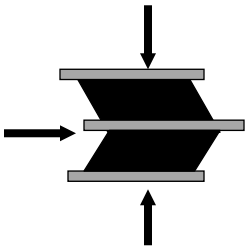
NEW METHOD FOR DETERMING the Value of G

✶Fast NDE method was needed.

Methods identified from Literature

Method 1: AASHTO NDE-Full-Size Test

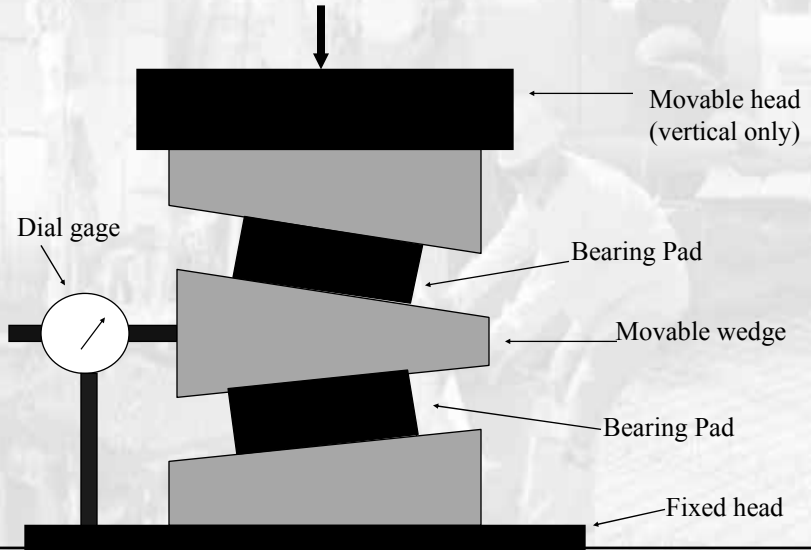
- In AASHTO M251-97 Presented a Full-Size Pads Test
  - Two "identical" test specimens sandwiched between three platens.
  - Compressive force applied and held constant while lateral force is applied.



  - Takes a long time, not NDE, expensive

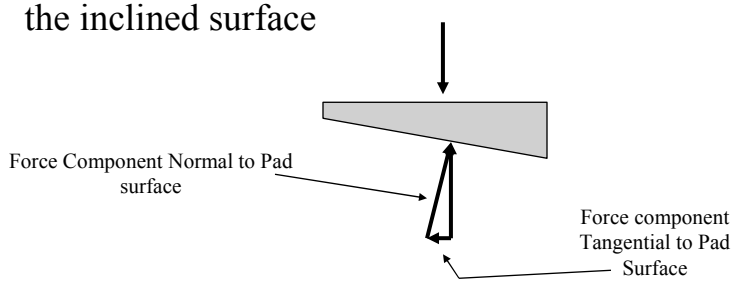
Methods identified from Literature (cont'd)

Method 2: Inclined Compression Test (by Yura et al)



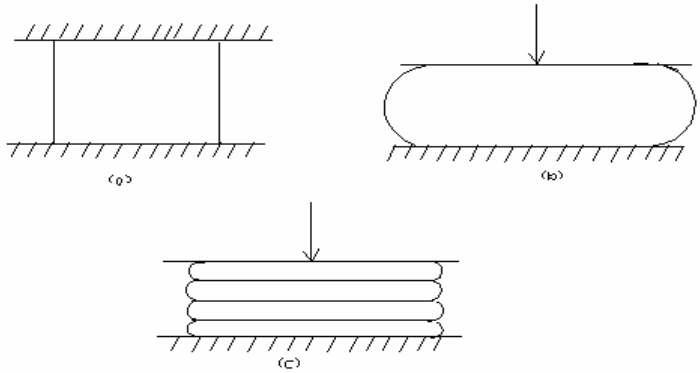
Methods identified from Literature (cont'd)

- Compressive force is applied to two specimen sandwiched three inclined surfaces.
- Lateral displacement of the middle wedge measured.
- Lateral displacement assumed to be caused by the tangential component as the vertical force act on the inclined surface



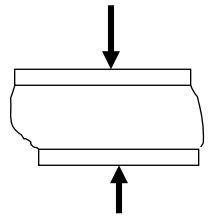
Bulging Behavior of BP due to Normal Force

- Axial load on elastomer held between two parallel surfaces that are NOT free to move laterally relative to one another. Symmetrical bulging.



Bulging Behavior of BP due to Normal Force (cont'd)

- ✶ Axial load on elastomer held between two parallel surfaces that are free to move laterally relative to one another.
- ✶ **Small** non-symmetry in load application or non-symmetrical material imperfections will cause non-symmetrical bulging.
- ✶ Thus lateral deformation (sidesway) without applied lateral (shear) force.

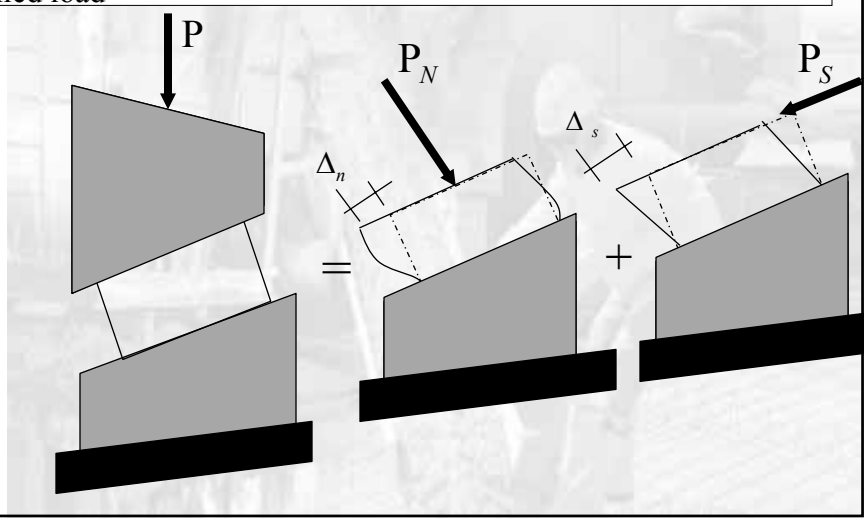


Further examination of Method 2:

-Normal force varies as the shear force is applied

-Lateral component will magnify the non-symmetrical bulging

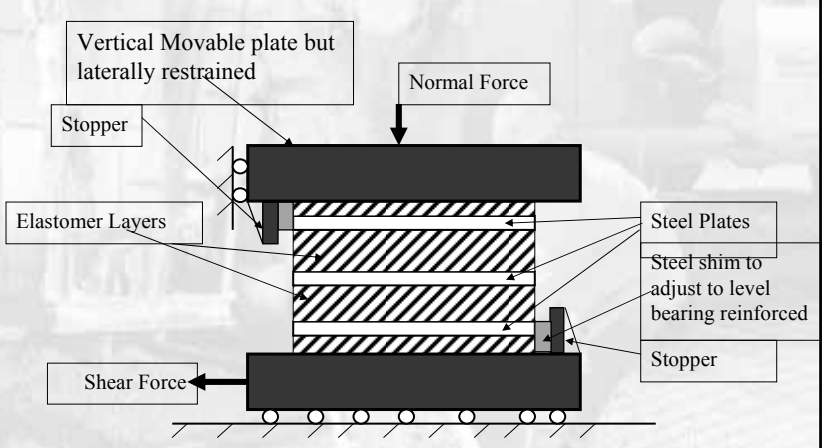
-Measured lateral displacement is due to normal and shear component of applied load



Not Satisfying our Objective

- ✶ Identified methods were not satisfying our needs
  - Both methods use two specimens. Obtained G value as the average of the two specimens (?).
  - Observed that the nonsymmetrical bulging due to the axial load that is not held constant in Method 2 need to be accounted for.
  - In the literature, G value reported to be dependent on Normal stress (Gent et al, 1970)
- ✶ This led us to the development of a different test-setup
  - Nondestructively test one specimen at a time
  - Shearing load applied with normal load held at a constant.

New Shear Testing Set-up

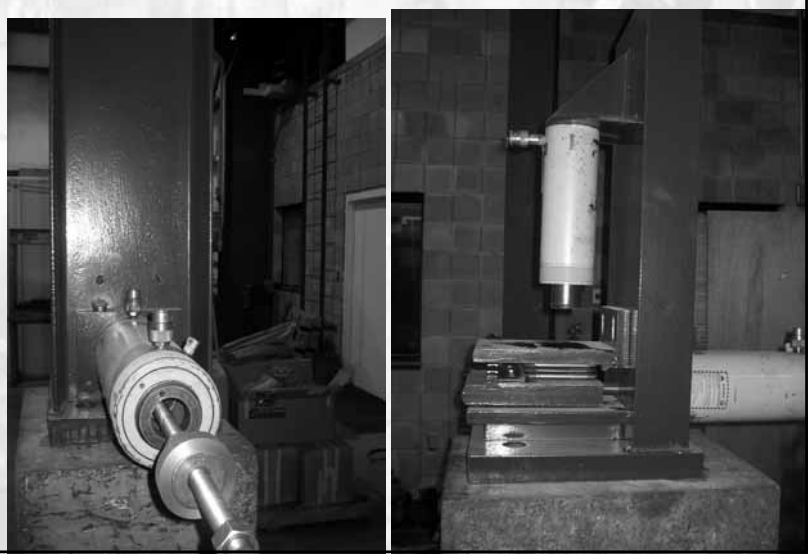


Developed Shear Modulus Test Setup (cont'd)

- Normal force first applied to desired stress level
- Normal force maintained at a relatively constant value (based on feedback from the data acquisition system)
- Lateral actuator applies the shearing force.
- An LVDT monitors the horizontal displacement as the shearing force is applied

Proposed Test Set-up

Proposed Test Set-up



COMBINED LOADING TESTS SETUP

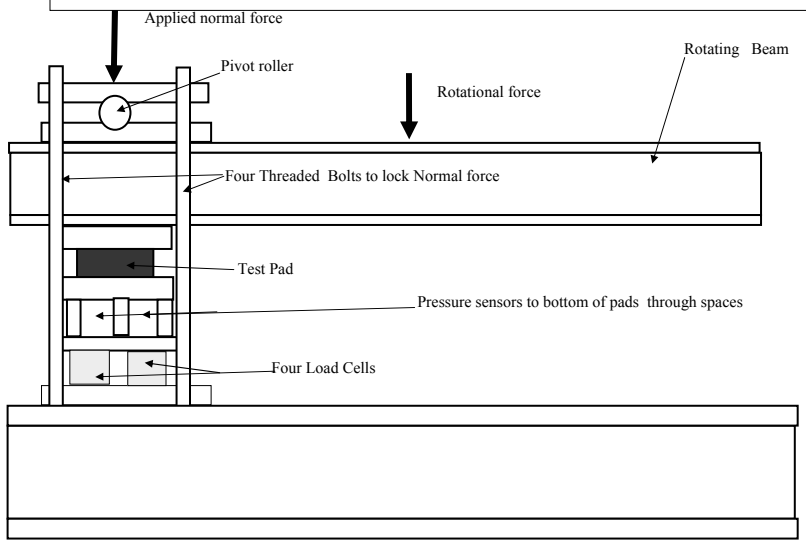
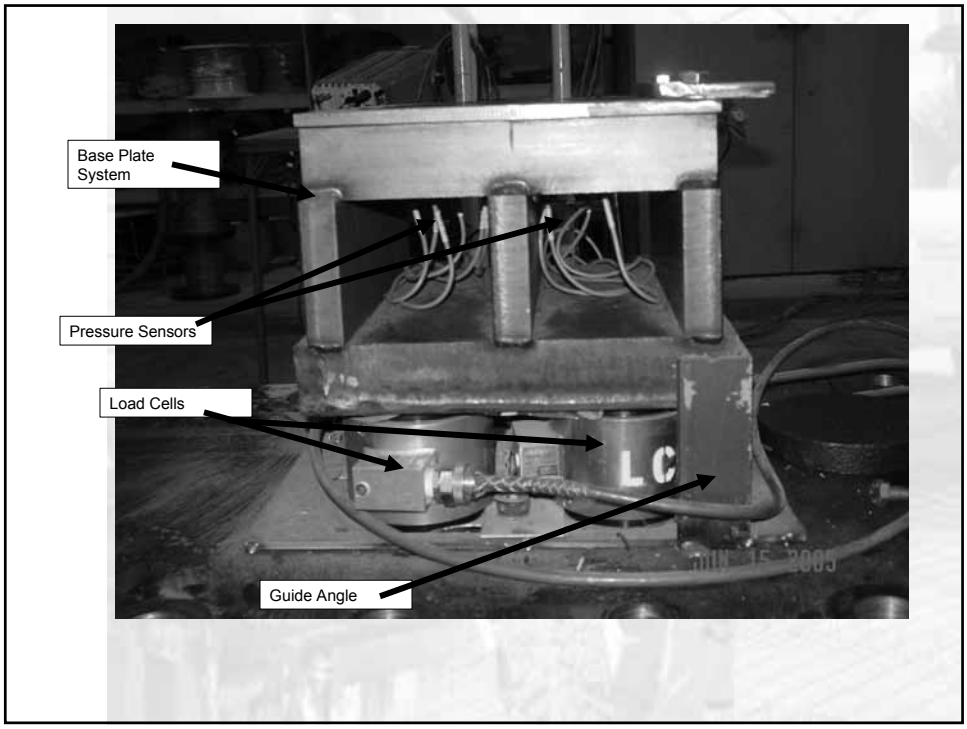
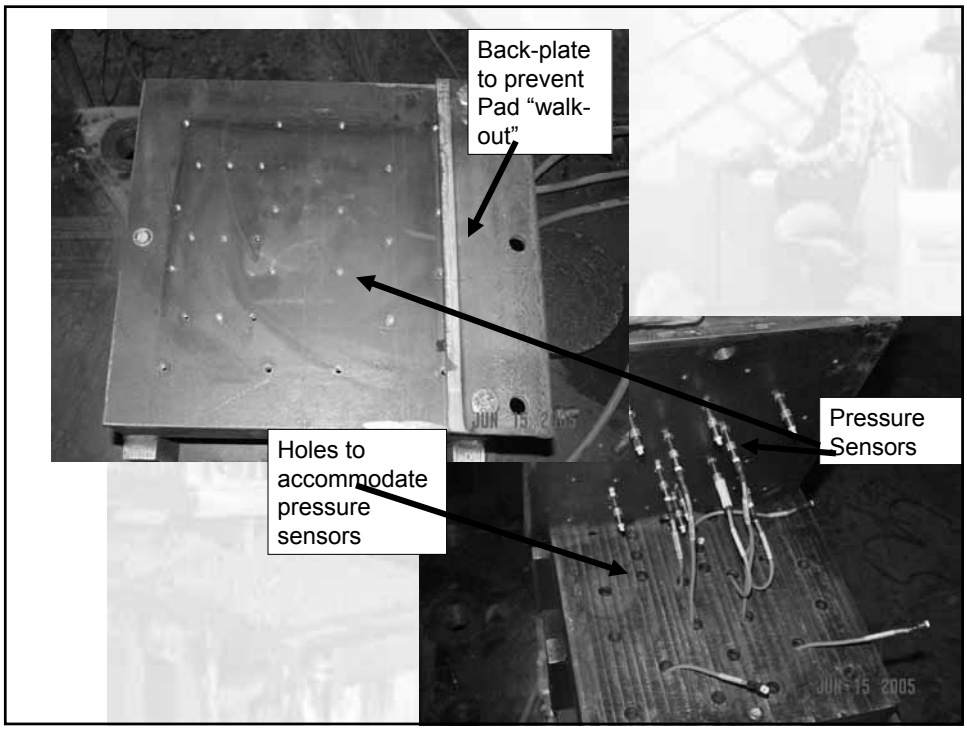
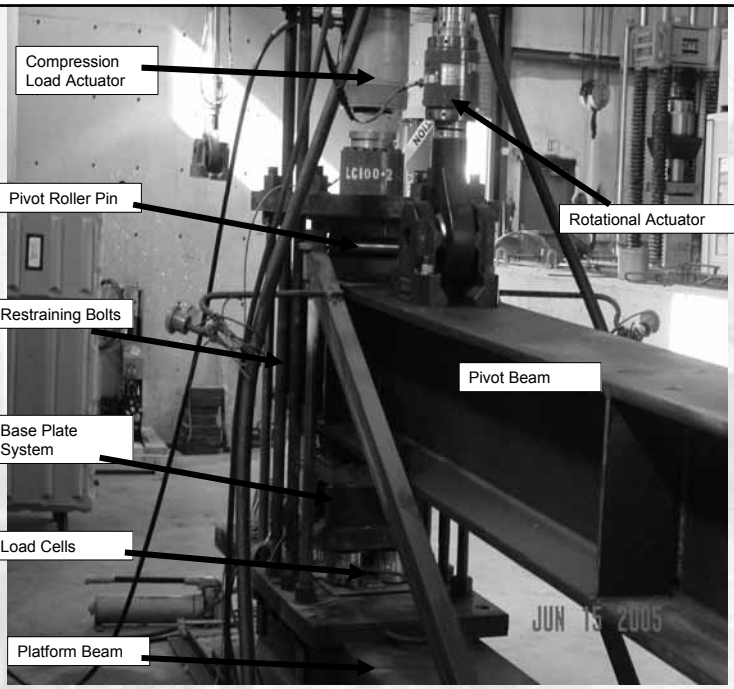


Fig. 5.1: Schematic of the Combined Loading Arrangement


Base Plate System
Pressure Sensors
Load Cells
Guide Angle
LC
JUN 15 2005


Back-plate to prevent Pad "walk-out"
Pressure Sensors
Holes to accommodate pressure sensors
JUN 15 2005



Pressure sensor locations (8 x 8 Pad)

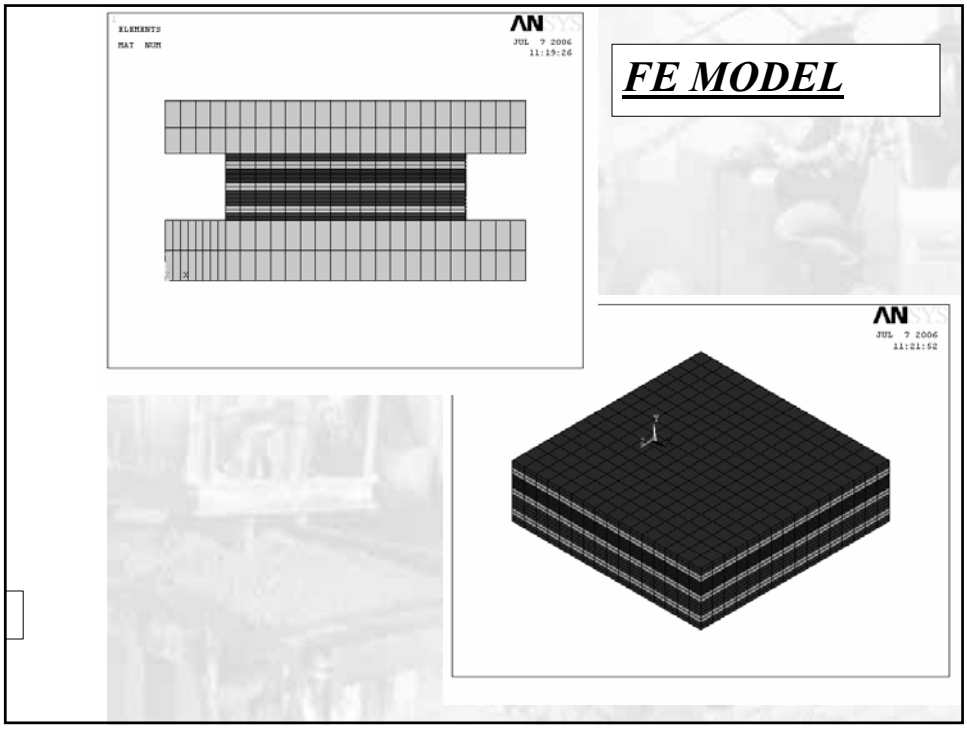
	X (in)	Y (in)	Max capacity ksi
5-K1	1.50	6.50	5
5-K2	1.50	4.00	5
5-K3	1.50	1.50	5
5-K4	3.00	5.00	5
5-K5	3.00	3.00	5
10-K1	6.50	6.50	10
10-K2	6.50	4.00	10
10-K3	6.50	1.50	10
10-K4	5.00	5.00	10
10-K5	5.00	3.00	10
10-K6	7.50	4.00	10

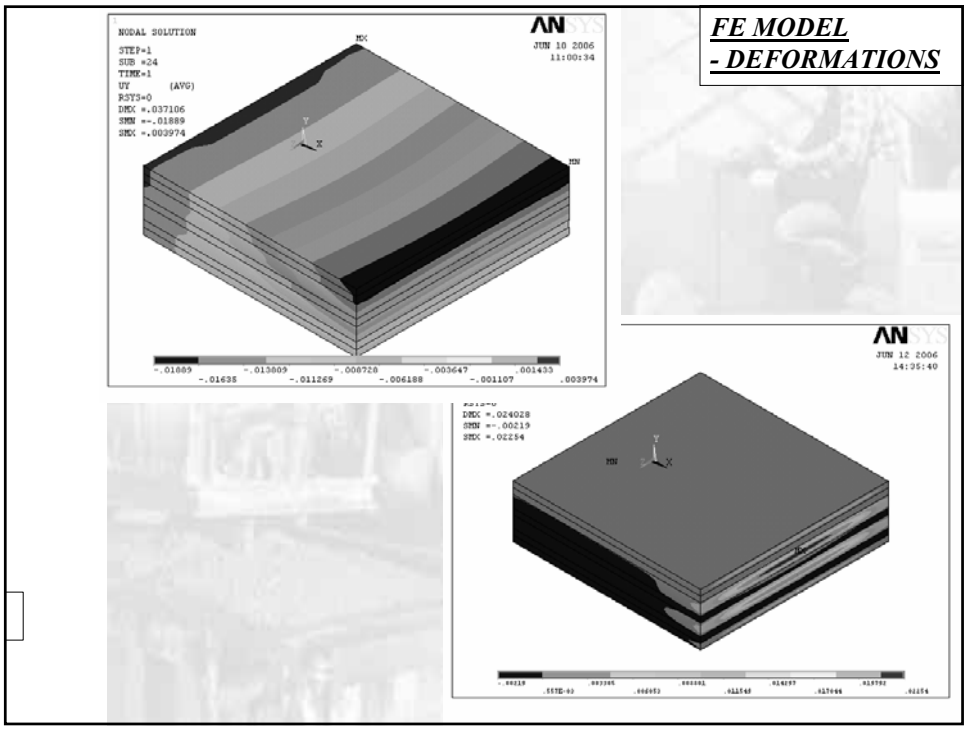
Loading Protocol

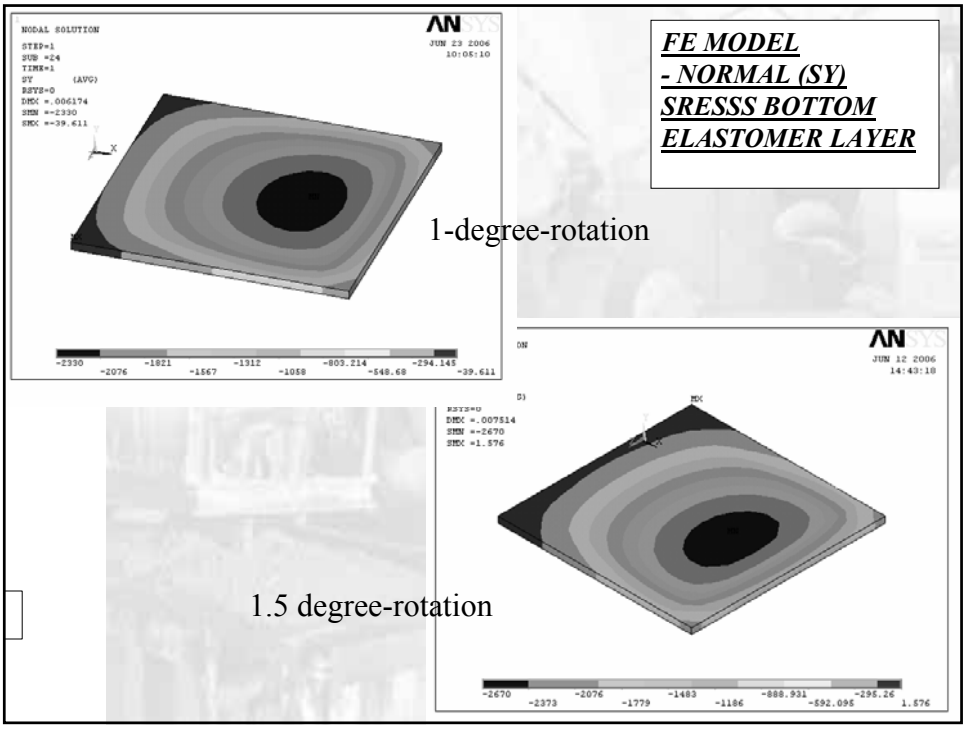
- Axial load applied and locked in place
  - Load cells monitored
- Controlled rotational displacement – 1 million cycles.
- Pressure sensors and load cells recorded for 2-minutes periods.
- Frequency of loading was influenced by the displacement stroke required.
- Sizes tested (BxW), 8x8, 6x6, 5x10

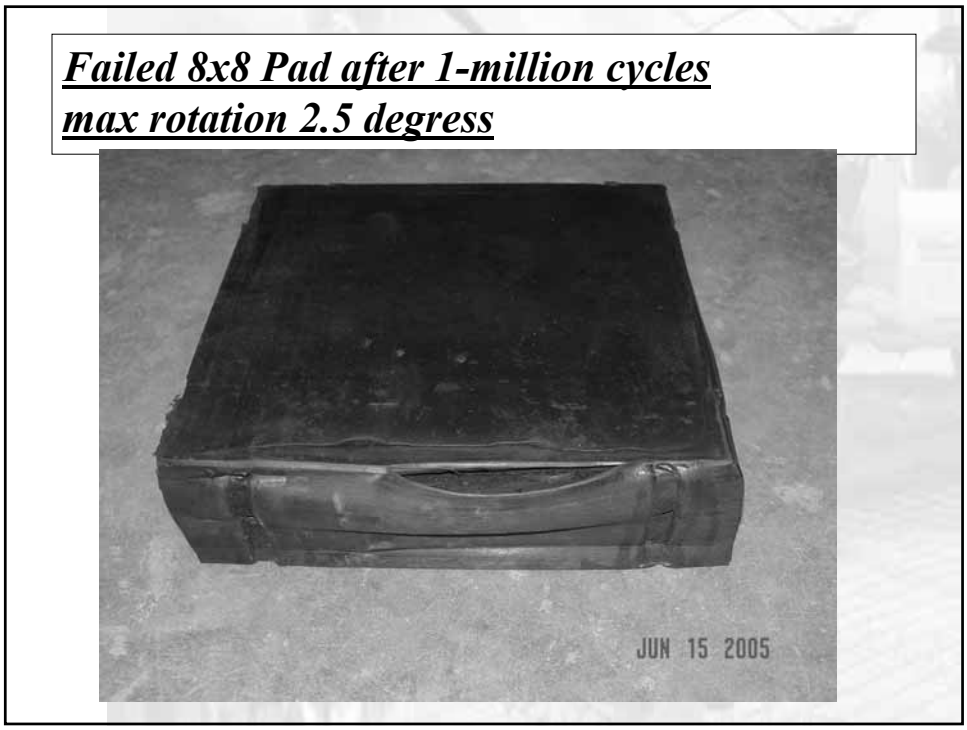
FE Analytical Studies

- ANSYS, a commercial FE software was used in the analytical study.
- The elastomer model by using **Solid 185** element. Element capable of hyperelastity, thus able to model large deformations.
- The steel was model using Solid 45 element.
- Contact elements (**CONTA 170** and **TARGE 174**) were used to model the interface between the pad and the bottom and top steel plates.


FE MODEL
ELEMENTS
MAT NUM
JUL 7 2006
11:19:26
JUL 7 2006
11:21:52


FE MODEL
- DEFORMATIONS
NODAL SOLUTION
STEP=1
SUB =24
TIME=1
UY (AVG)
RSYS=0
DMX =.037106
SMN =-.01889
SMX =.003974
JUN 10 2006
11:00:34
JUN 12 2006
14:35:40
DMX =.024028
SMN =-.00219
SMX =.02254


FE MODEL
- NORMAL (SY)
SRESSS BOTTOM
ELASTOMER LAYER
1-degree-rotation
1.5 degree-rotation


Failed 8x8 Pad after 1-million cycles
max rotation 2.5 degress
JUN 15 2005

RESULTS TestPressure/FEA Pressure (8x8 Pad)

	X (in)	Y (in)	007K -CYC	113K -CYC	127K -CYC	345K-CYC	685K -CYC	723K-CYC	799K -CYC	841K-CYC	918 K-CYC
5-K1	1.50	6.50	1.06	1.07	1.06	1.01	0.88	0.90	0.89	0.88	0.88
5-K2	1.50	4.00	1.10	1.07	1.07	1.05	0.89	0.91	0.91	0.92	0.92
5-K3	1.50	1.50	1.10	1.00	1.00	0.92	0.70	0.74	0.74	0.75	0.75
5-K4	3.00	5.00	1.09	1.04	1.04	1.00	0.90	0.91	0.90	0.90	0.90
5-K5	3.00	3.00	1.10	1.07	1.06	1.03	0.98	0.99	0.98	0.98	0.98
10-K1	6.50	6.50	0.92	0.73	0.72	0.63	0.44	0.45	0.44	0.46	0.46
10-K2	6.50	4.00	0.94	0.78	0.77	0.61	0.46	0.46	0.45	0.45	0.44
10-K3	6.50	1.50	0.88	0.67	0.65	0.50	0.18	0.19	0.18	0.20	0.19
10-K4	5.00	5.00	0.92	0.84	0.83	0.78	0.65	0.65	0.64	0.65	0.64
10-K5	5.00	3.00	0.92	0.85	0.84	0.77	0.61	0.62	0.60	0.61	0.61
10-K6	7.50	4.00	0.95	0.69	0.67	0.48	0.20	0.21	0.19	0.19	0.19

PROPOSED DESIGN PROCEDURE

STEP 1 : Compute the Youngs's modulus of the elastomer from the material shear modulus using the following relationship

$$E_0 = 4.515 \cdot G - 0.488 \cdot MPa$$ where G is in MPa (for SI units)

$$E_0 = 4.515 \cdot G - 0.071 \cdot ksi$$ where G is in ksi (for US customary units)

STEP 2 : Compute the shape factor using the following relationship

$$S := \frac{B \cdot W}{2 \cdot h_{ri} \cdot (B + W)}$$

PROPOSED DESIGN PROCEDURE (cont)

STEP 3: Compute the material compressibilty coeffient using the following relationship

$$\phi = 0.445 + \frac{0.16 \cdot MPa}{G}$$ where G is in MPa (for SI units)

$$\phi = 0.445 + \frac{0.023 \cdot ksi}{G}$$ where G is in ksi (for US customary units)

STEP 4: Compute the effective compression modulus using the following relationship

$$E_c := E_0 \cdot \left(1 + 2 \cdot \phi \cdot S^2\right)$$

PROPOSED DESIGN PROCEDURE (cont)

STEP 5: Compute the reduced dimension the pad due to rotation effect using the following relationship

$$B_{nw} = \frac{B \cdot E_c \cdot \theta + 1.66 \cdot G \cdot S \cdot h_{ri}}{2 \cdot E_c \cdot \theta} \le B$$

That is

$$B_{nw} := \begin{cases} B & \text{if } \theta = 0 \\ \dfrac{B \cdot E_c \cdot \theta + 1.66 \cdot G \cdot S \cdot h_{ri}}{2 \cdot E_c \cdot \theta} & \text{otherwise} \end{cases}$$

and

$$B_{nw} := \text{if}\left(B_{nw} > B, B, B_{nw}\right)$$

PROPOSED DESIGN PROCEDURE (cont)

STEP 6: Compute the shape factor for the reduced dimension the pad using the following relationship

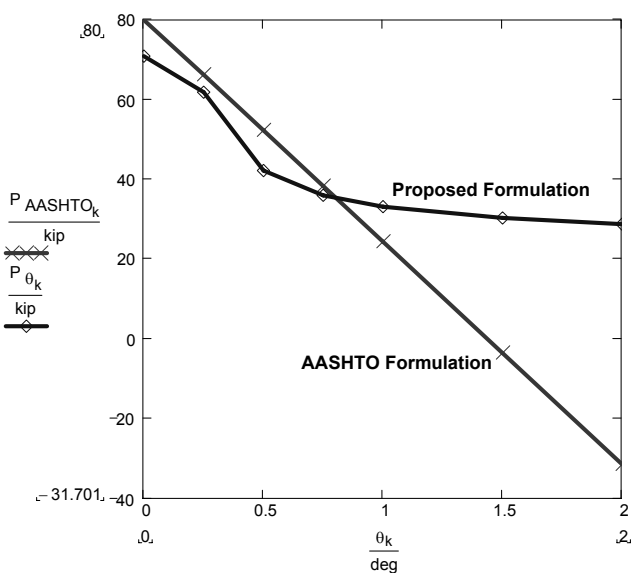
$$S_{nw} := \frac{B_{nw} \cdot W}{2 \cdot h_{ri} \cdot (B_{nw} + W)}$$

STEP 7: Compute the capacity of the bearing pad using the following relationship

$$P_{\theta} := 1.66 \cdot G \cdot S_{nw} \cdot A_{nw}$$

where $A_{nw} = B_{nw} \cdot W$

PROPOSED FORMULA Vs Current AASHTO



10 by 8 Pad

Conclusions

SHEAR MODULUS DETERMINATION

- The Shear Modulus value was found to be dependent on the normal stress level, just as reported by Gent et al.
- There is need of keeping the normal stress constant when applying the shearing stress.
- The Shear Modulus was found to be correlated to the Shape Factor value
- The proposed test setup was found to be satisfactory in determining the Shear modulus of individual SRE-BP, thus satisfying one of our objective in the on going project.

Conclusions

COMBINED LOADING STUDIES

- There was good correlation between tests and FE Modeling Results.
- Shear failure of the elastomer at the rotating end.
- Proposed formulation more rational than the existing AASHTO Formulation.

Acknowledgements

- Florida Department of Transportation
- Colleagues at the FL-DOT Structures Laboratory and at the FAMU-FSU College of Engineering for their positive criticism of the work on this project.
- Special thanks to Mr. Tony Johnston, Mr. Frank Cobb, Mr. Steve Eudy for the fabrication of the testing facility and data acquisition assistance.
- The opinions expressed in this paper are solely of the author and in no way implicate the sponsors of this work.

- THANKS FOR YOUR ATTENTION

- Any Questions?