Department of
Civil, Environmental,
and Geo- Engineering

COLLEGE OF
Science & Engineering
UNIVERSITY OF MINNESOTA

TPF(5)-169, Development of an Improved Design Procedure for Unbonded Concrete Overlays

Task 4. Cracking Models

Prof. Lev Khazanovich

Cracking Model development

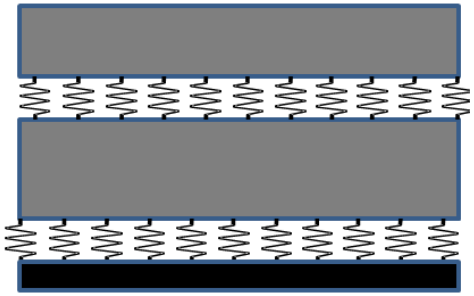
- **6x6 slabs**
  - Develop Neural Networks
  - Climate characterization
  - Damage modeling- MEPDG cracking model with adjusted strength, if necessary
  - Model validation

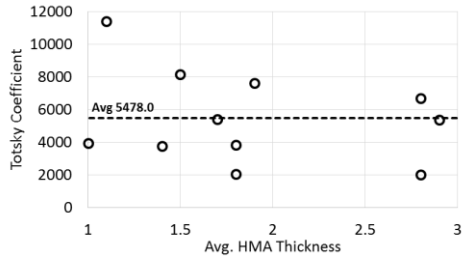
Task 4, Investigations (1)

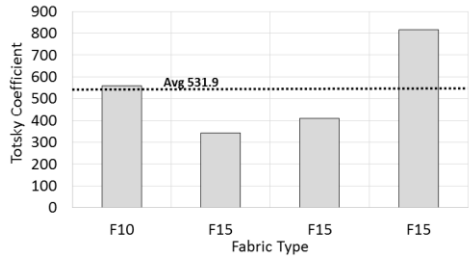
- Interlayer analysis: Validated Task 3 Totsky
  - Confirmed k_totsky for HMA and Fabric
- Mesh and interlayer values: Effect of mesh refinement and interlayer k-value on stress at critical location
  - 18-kip load + no thermal load and no axle load + thermal load
- Existing crack: Batch runs for 1L undamaged system of varied slab thickness and 2L with existing crack
  - Assumes 18 kip load, no thermal load in 6x6 and 12x15
  - 6-on-6 performs equivalently to ~6.6" either with or without crack

Totsky approach for interlayer modeling

- Totsky approach models "cushioning" property of the interlayer using springs
- Estimate Totsky coefficients for HMA and fabric interlayers from lab data
- Investigate 2-layer system with varied k_tot *versus* 1-layer system with varied k_sub







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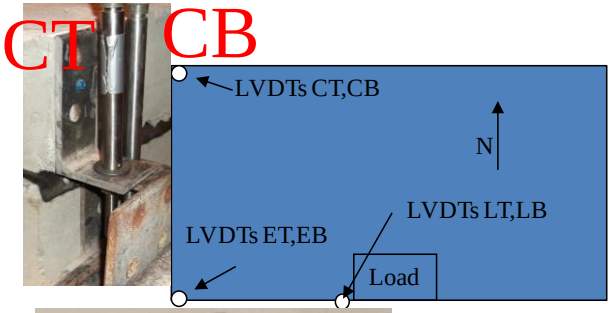

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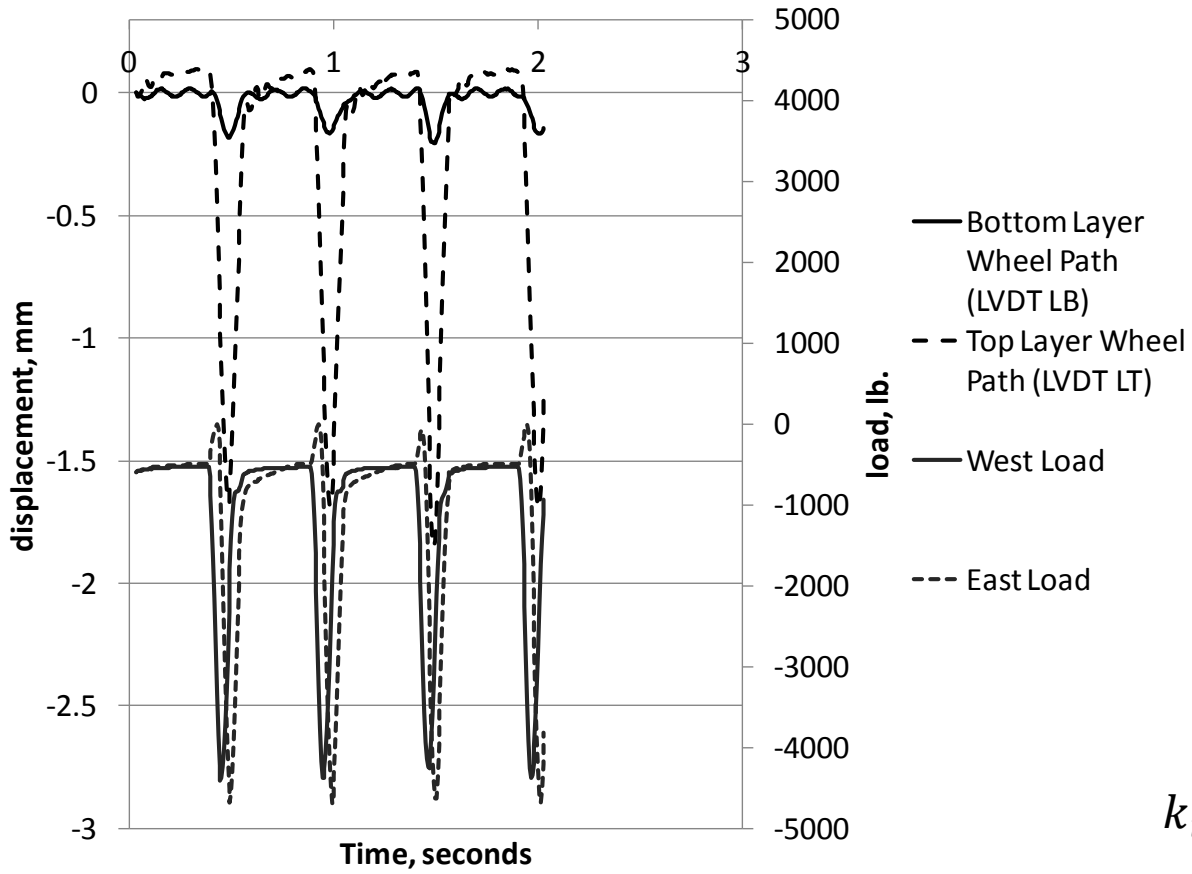
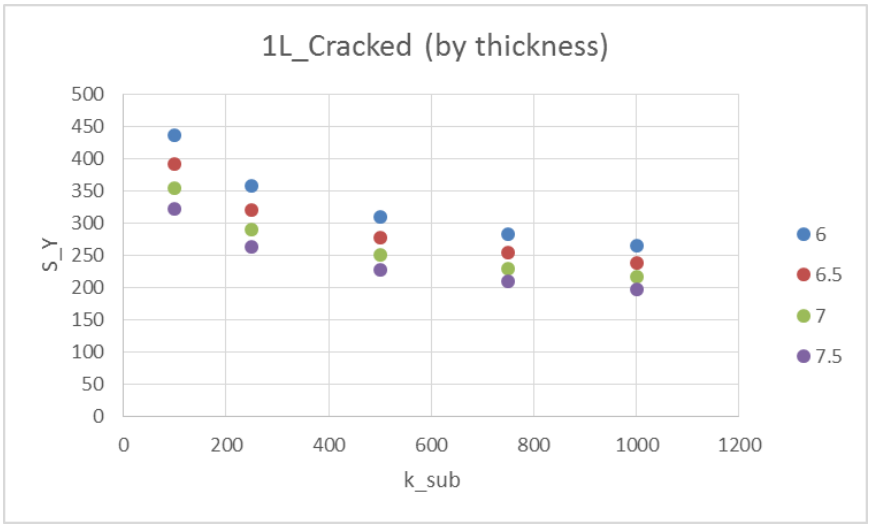
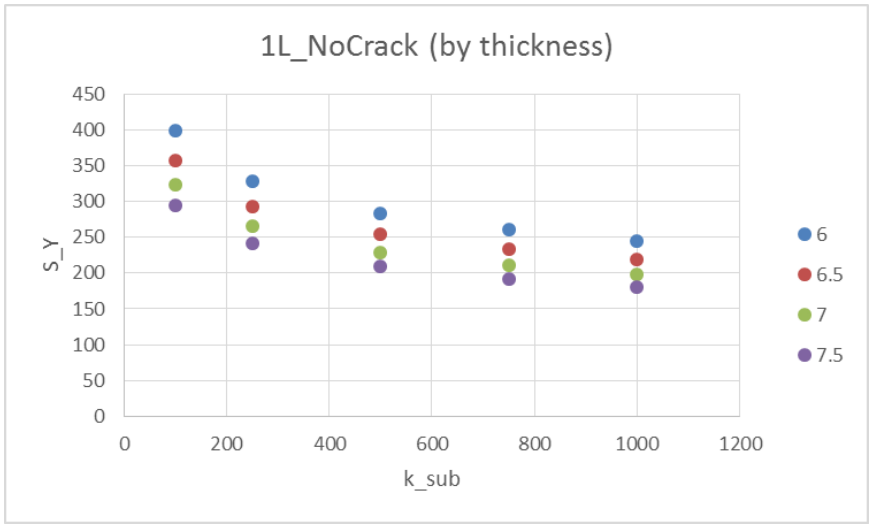


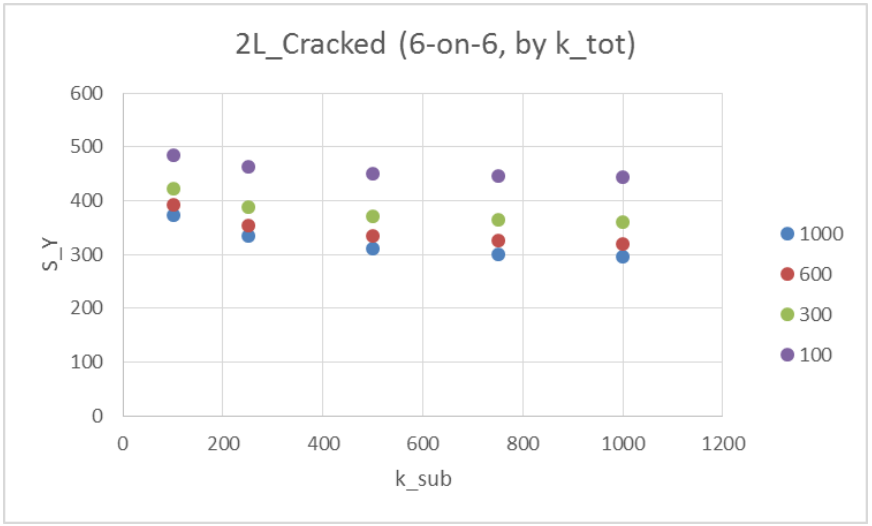
$$k_{int} \approx 500\ psi$$

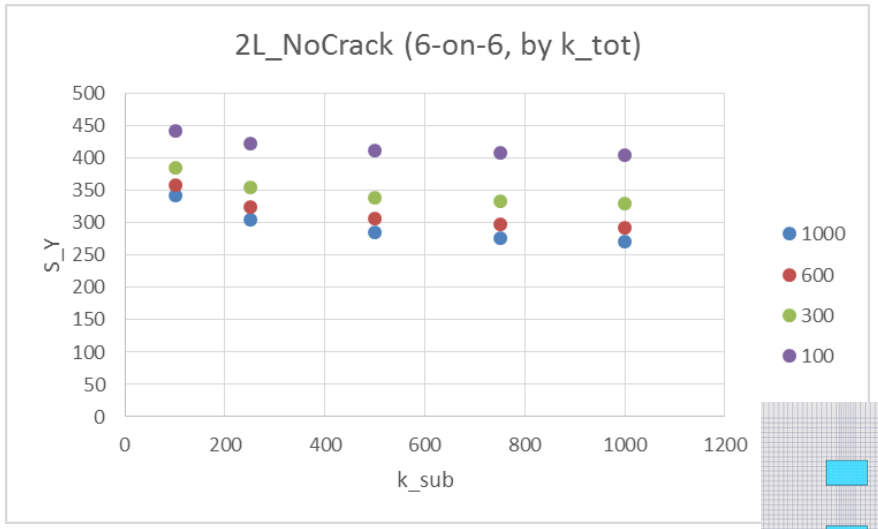
After 4 million load repetitions

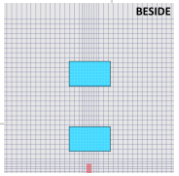
Task 4, 1L/2L equivalent w cracking





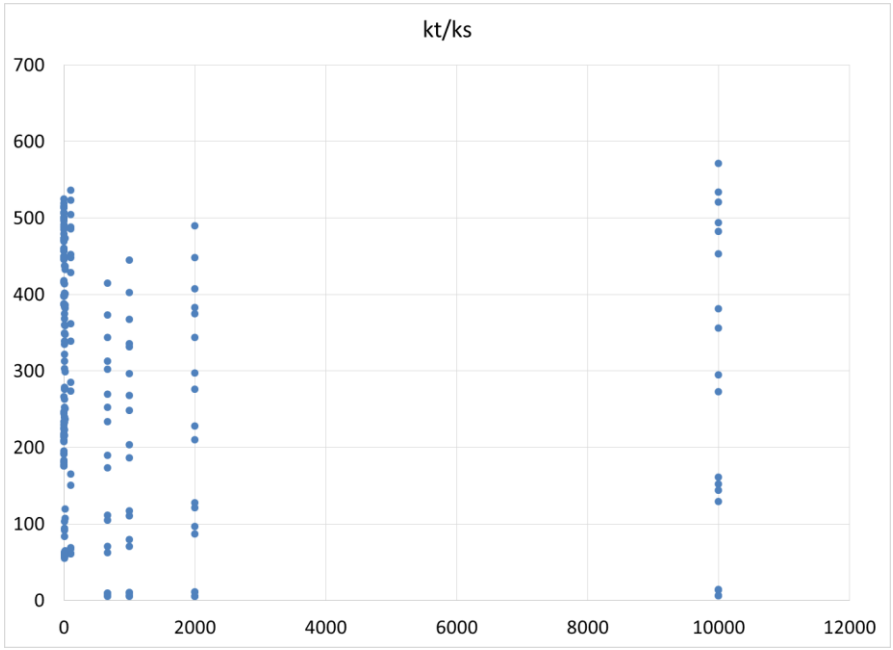


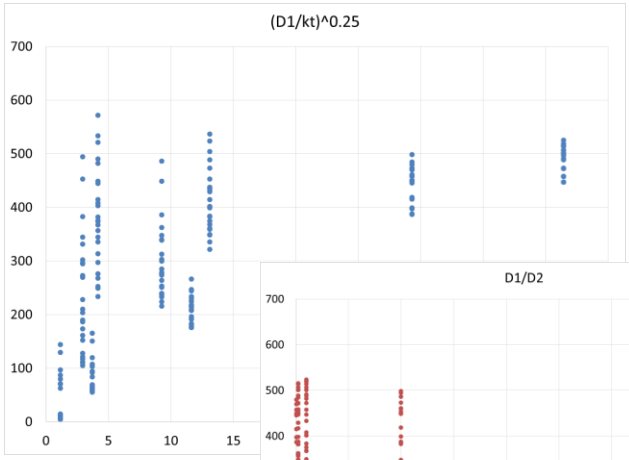


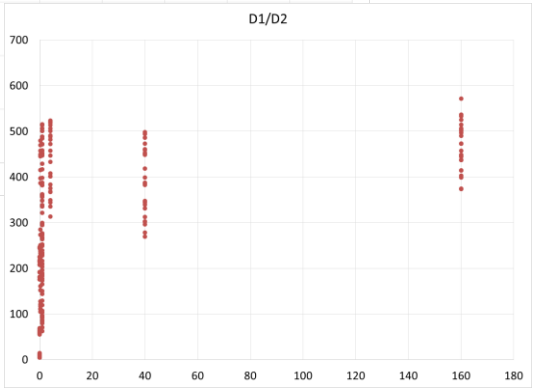


Task 4, Investigations (2)

- 6x6 stress response: Factorial of 216 cases varied by D1/D2, kt/ks, (D1/kt)^0.25 for stress response of 6x6, 2L system
  - 18-kip load, no thermal, 6-on-10 inch system

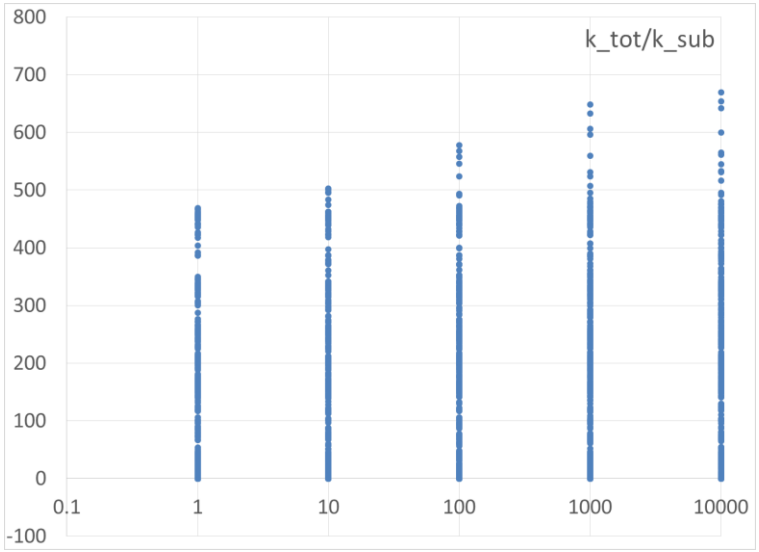


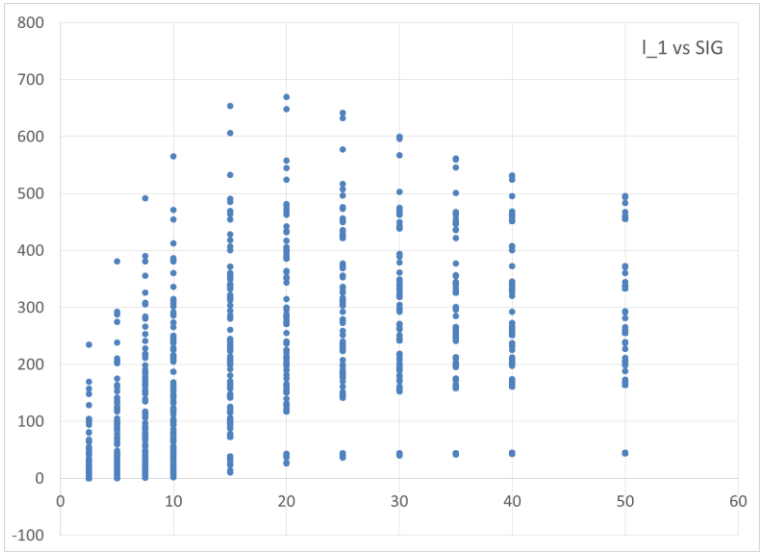




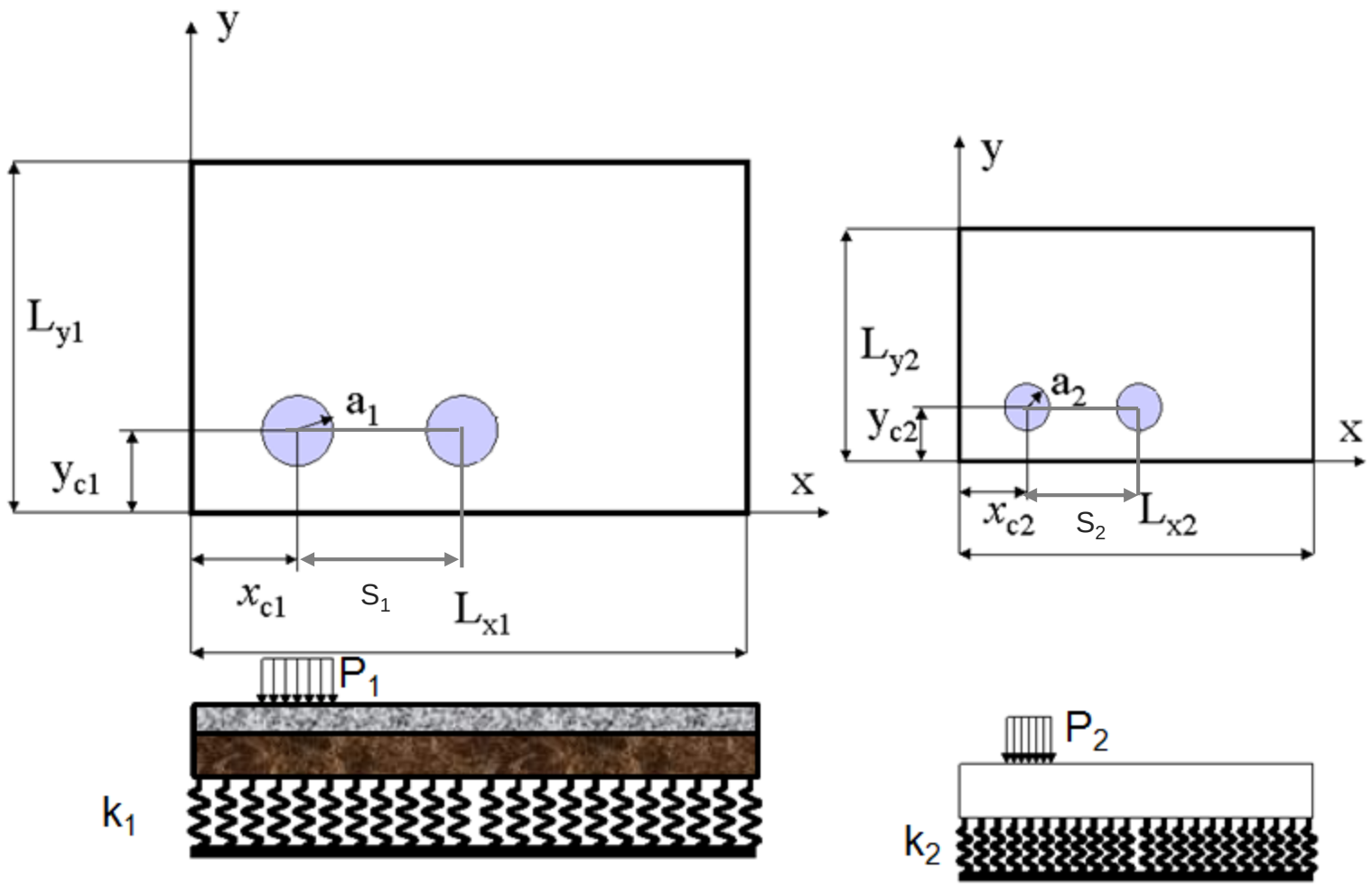
Task 4, Investigations (3)

- 6x6 stress response: Factorial of 1650 cases varied by D1/D2, kt/ks, (D1/kt)^0.25 for response of 6x6, 2L system
  - 18-kip load, no thermal, 6-on-8 inch system





Similarity Concept

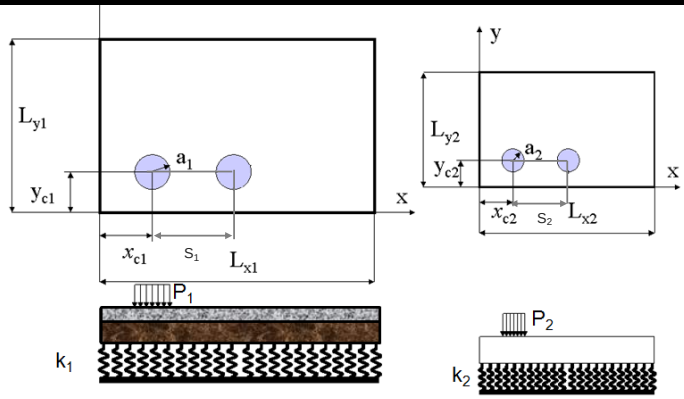


Similarity Concept

Two pavement structures are *similar* if

$$\frac{L_{x1}}{\ell_1} = \frac{L_{x2}}{\ell_2} \quad \frac{L_{y1}}{\ell_1} = \frac{L_{y2}}{\ell_2} \quad \frac{AGG_1}{k_1\ell_1} = \frac{AGG_2}{k_2\ell_2}$$

$$\frac{a_1}{\ell_1} = \frac{a_2}{\ell_2} \quad \frac{P_1}{\gamma_1 h_1} = \frac{P_2}{\gamma_2 h_2} \quad \varphi_1 = \varphi_2$$



γ = unit weight

$$\varphi = \frac{2\alpha(1+\mu)\ell^2}{h^2}\frac{k}{\gamma}\Delta T$$

Korenev's (1962) nondimensional temperature gradient

$$\Delta T = h\frac{\int_h^{h}(T(z)-T_0)E(z)\,z\,dz}{\int_h E(z)\,z^2\,dz}$$

Temperature difference for the linear strain component of the temperature distribution

and

$$\sigma_2 = \frac{h_1\gamma_2{\ell_2}^2}{h_2\gamma_1{\ell_1}^2}\sigma_1 + \Delta\sigma_{NLT}$$

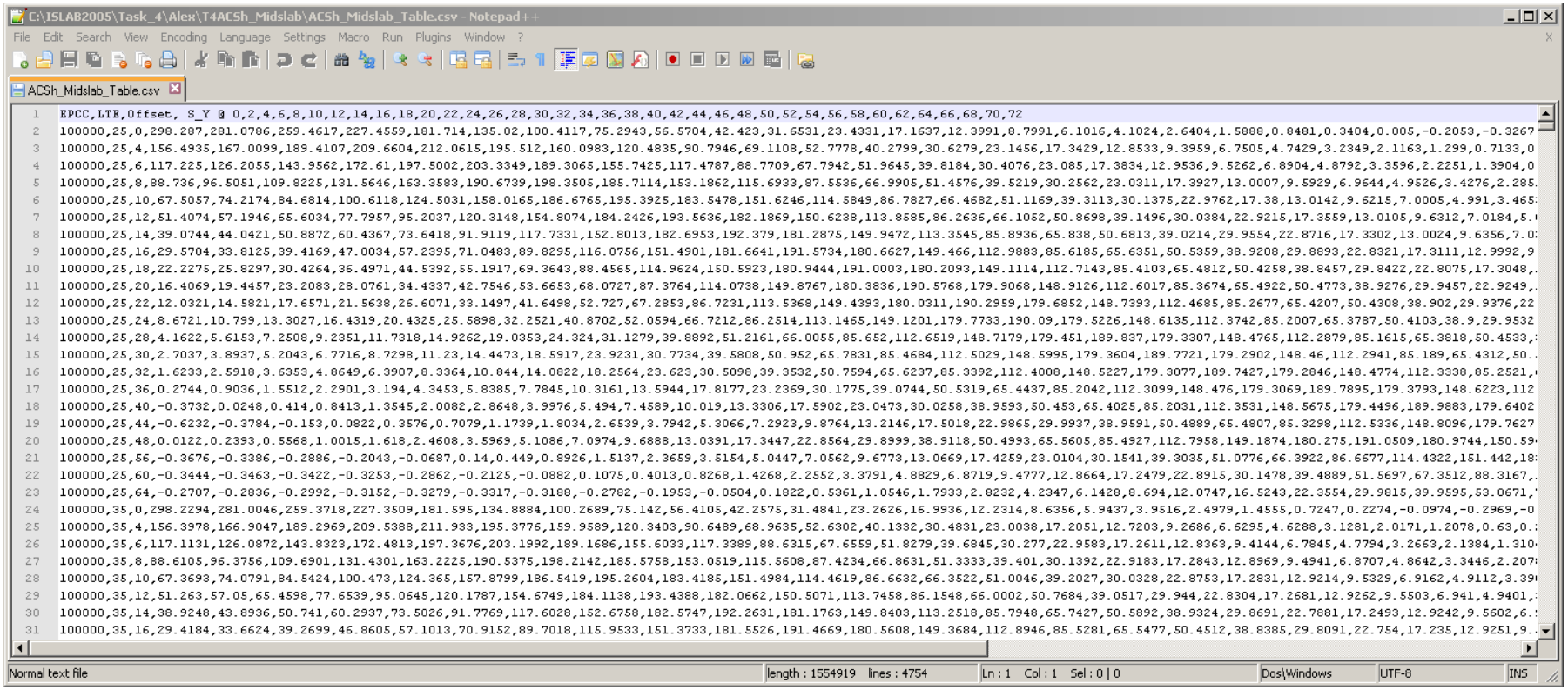
(Khazanovich et al. 2001)

Factorial

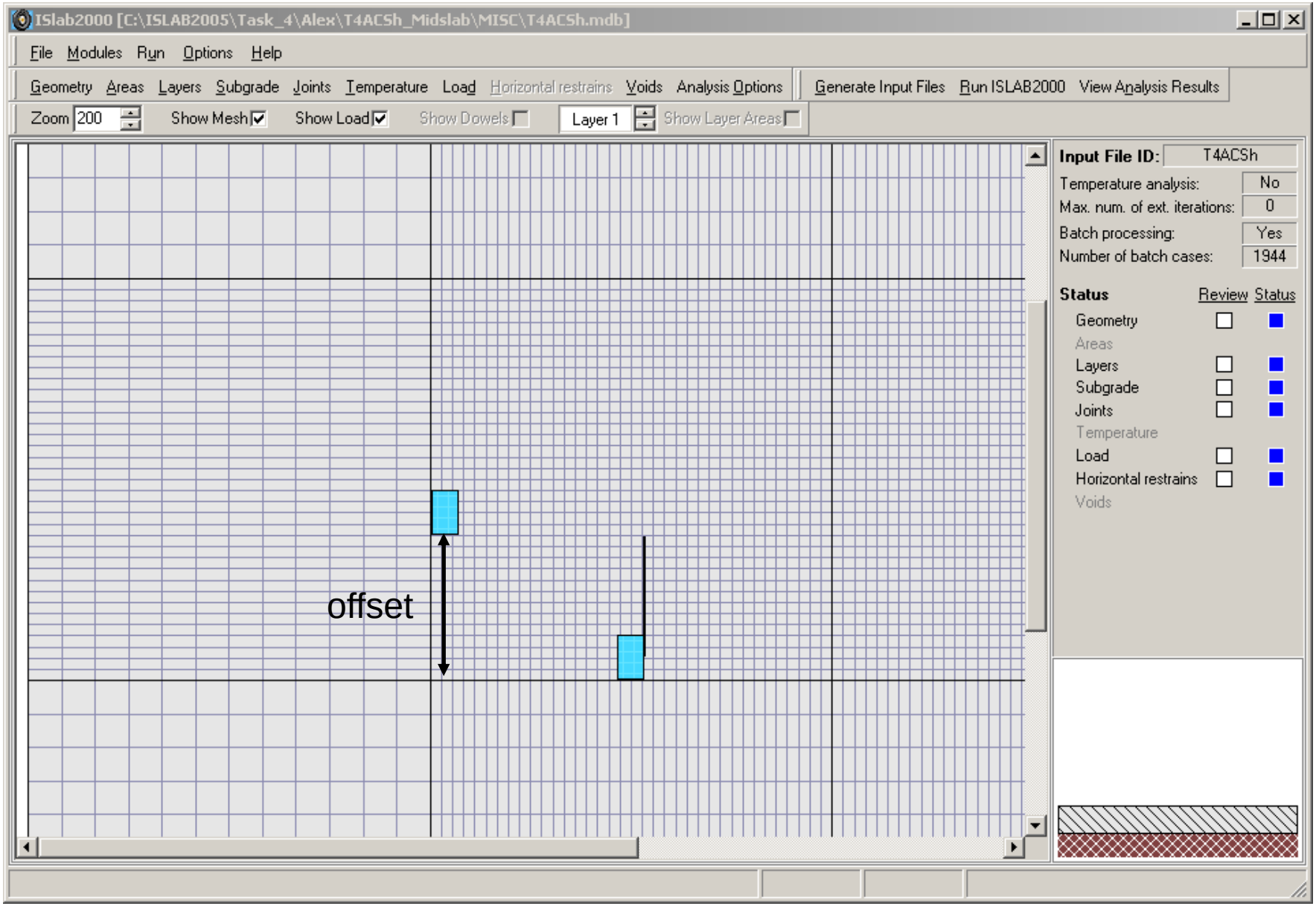
Case	Slab size, ft	Elastic Modulus, psi	Transverse Joint LTE, %	Lane/Shoulder LTE, %	Axle Reference Point Transverse Position*	
					a. dual wheel	b. single wheel
1	5 x 5	100,000	25	20	+0	+0
2	6 x 6	200,000	35	35	+4	+4
3	7 x 7	350,000	45	50	+6	+6
4	8 x 8	600,000	55		+8	+8
5		1,000,000	65		+10	+10
6		1,500,000	75		+12	+12
7		2,200,000	85		+14	+14
8		3,100,000	95		+16	+16
9		4,300,000			+18	+18
10		5,800,000			+20	+20
11		7,600,000			+22	+22
12		10,000,000			+24	+24
13		12,500,000			+28	+28
14		15,750,000			+32	+32
15		21,700,000			+36	+36
16		28,200,000			+40	+40
17		38,500,000			+44	+44
18		50,000,000				+48
19		63,500,000				+56
20		80,000,000				+60
21		100,000,000				+64
22		122,000,000				
23		168,000,000				
24		225,000,000				

Task 4, Building database of responses

- Stress response in slab according to EPCC, offset, joint LTE for 4500+ cases



Task 4, Edge vs joint stresses



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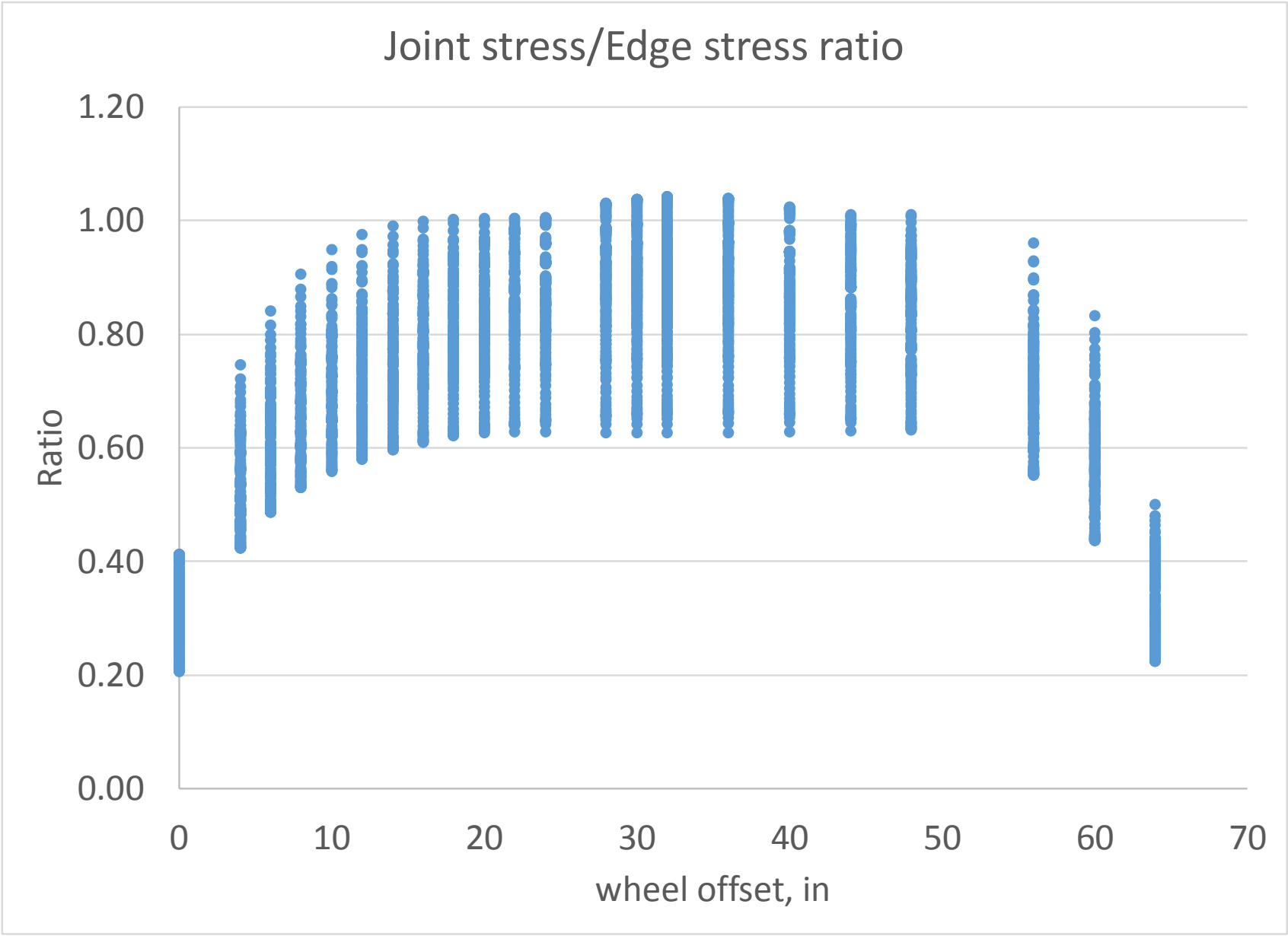

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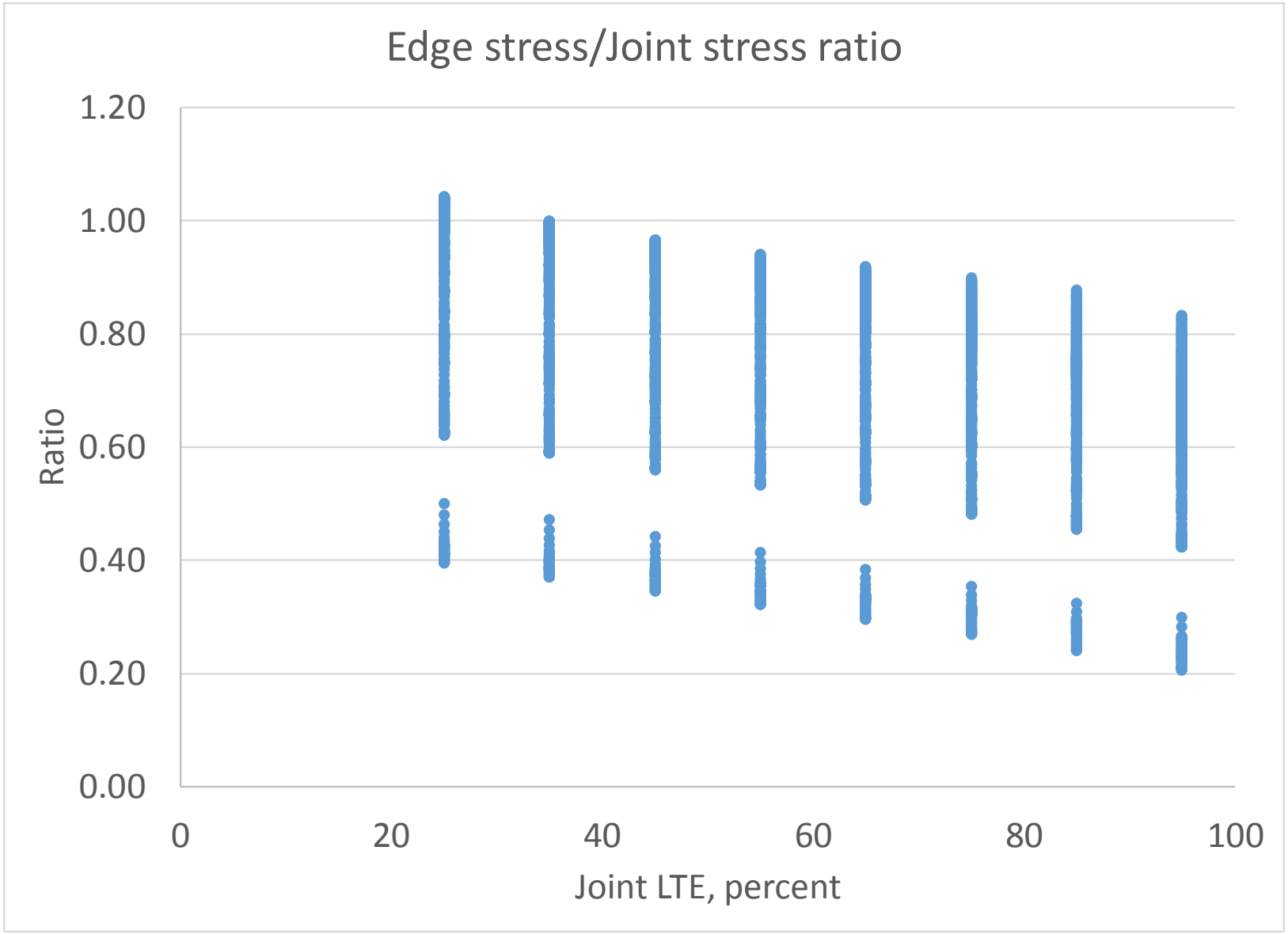

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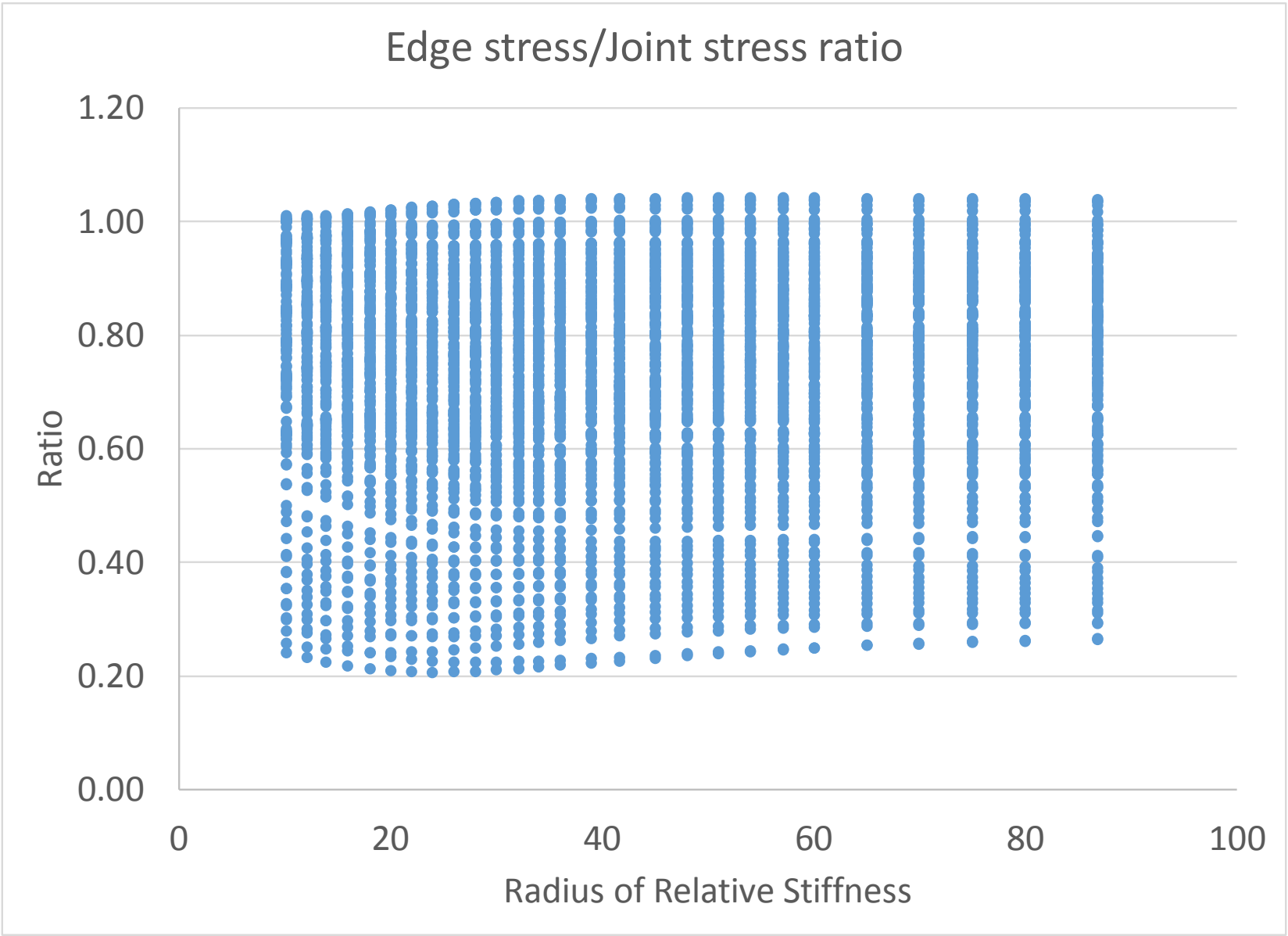
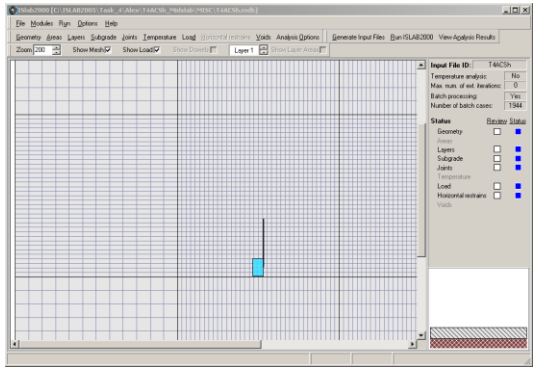
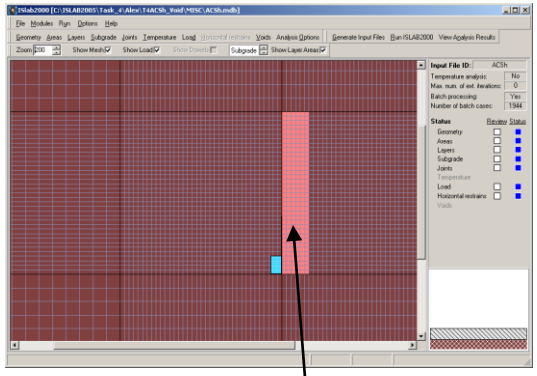


Task 4, Building database of responses

- Response of 6x6 panel system with asphalt shoulder to axle loading at midslab
- Response of 6x6 panel system with AC shoulder to axle loading at joint with interlayer void
- Additional factorials to be conducted with PCC shoulders

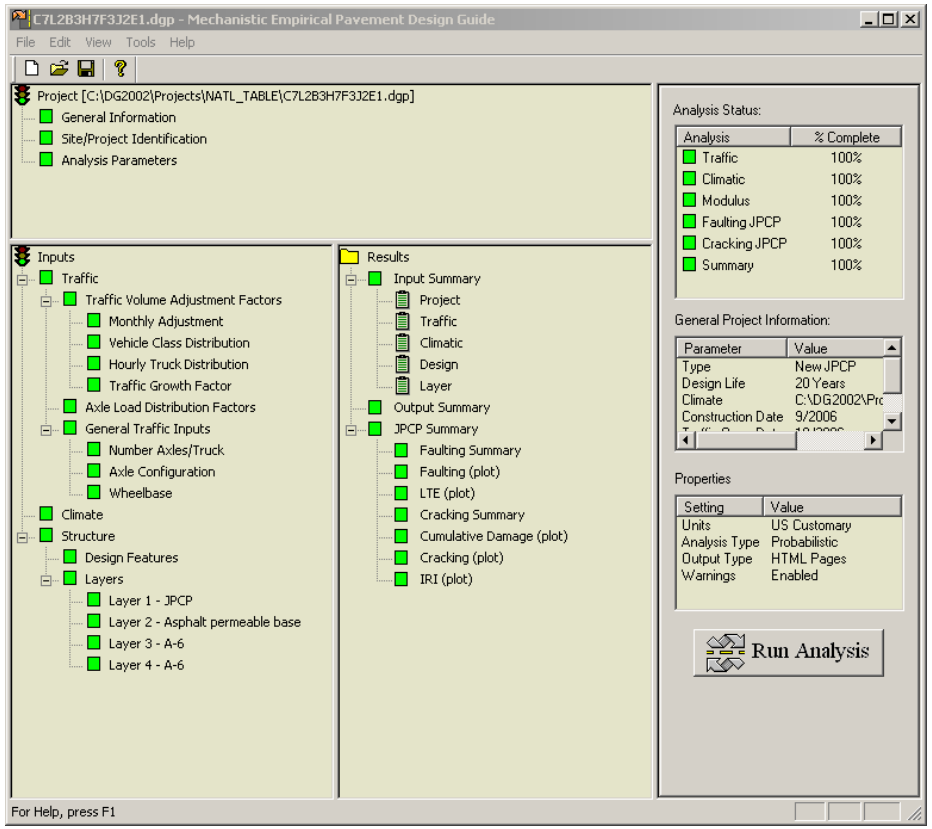




Wrong void location

Task 4, MEPDG national database

- Database of 170k MEPDG 1.1 projects summarizing:
  - 7 climates, 8 PCC overlay thicknesses
  - 2 existing PCC thicknesses, 2 subgrade types
  - 2 lane widths, 2 joint spacing
  - Interpolate for EPCC, Mod Rupture, COTE



- Determine single-layer equivalent of two-layer UBOL systems, use with database to evaluate top-down/bottom-up damage

Remaining work

- Finalize NNs, correct void analysis
- Integrate with erosion in the faulting model
- Assemble the model

Remaining work

Contract modification will be required:

- To allow more time to complete the project
- To account for PI's move to another institution
  - Move project to UPitt
  - Appoint an interim PI at the University of Minnesota and modify the contract with UPitt

Remaining work

- Task 4: UBOL procedure development – April 30, 2017
- Task 5: Procedure user guide development – July 31, 2017
- Task 6: Evaluate guidelines on suitability of UBOL – August 31, 2017
- Task 7: Draft final report – September 30, 2017
- Task 8: Final report – December 31, 2017