



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

Task 4. Cracking Models

Prof. Lev Khazanovich

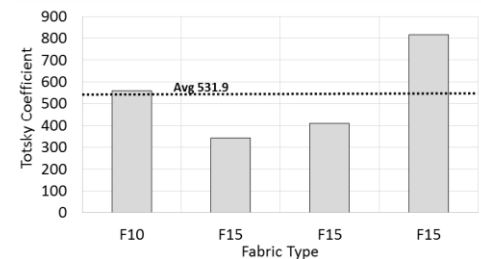
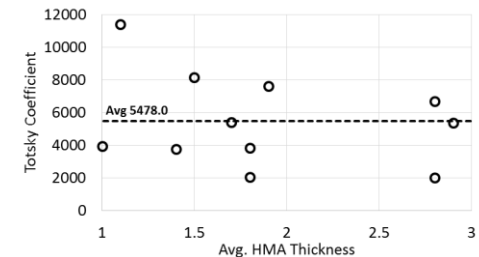
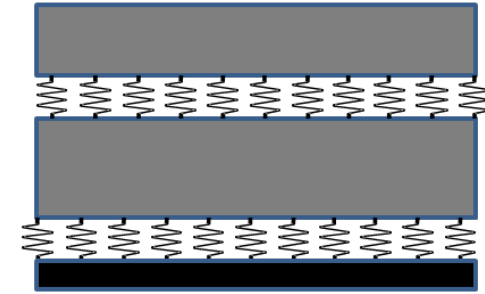
- 6x6 slabs
 - Develop Neural Networks
 - Climate characterization
 - Damage modeling- MEPDG cracking model with adjusted strength, if necessary
 - Model validation

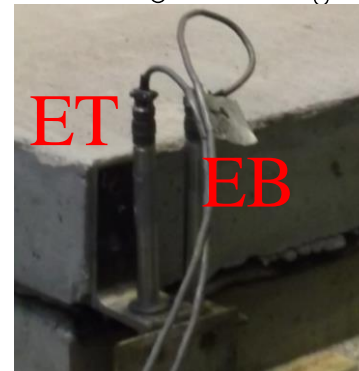
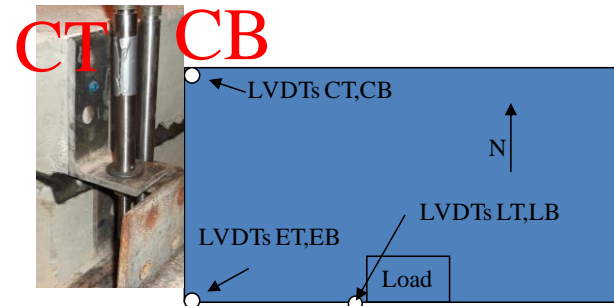
Task 4, Investigations (1)

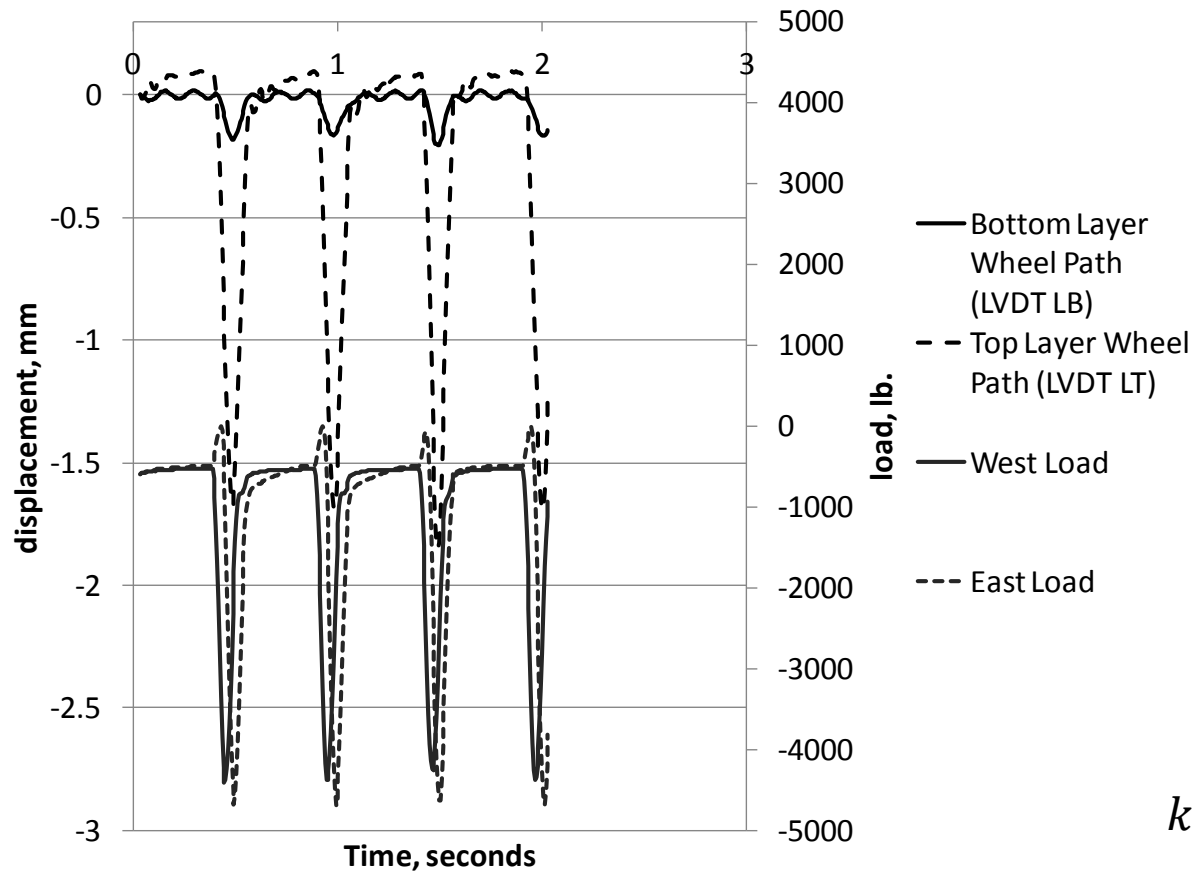
- Interlayer analysis: Validated Task 3 Totsky
 - Confirmed k_{totsky} for HMA and Fabric
- Mesh and interlayer values: Effect of mesh refinement and interlayer k-value on stress at critical location
 - 18-kip load + no thermal load and no axle load + thermal load
- Existing crack: Batch runs for 1L 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 $\sim 6.6''$ 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}



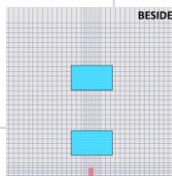
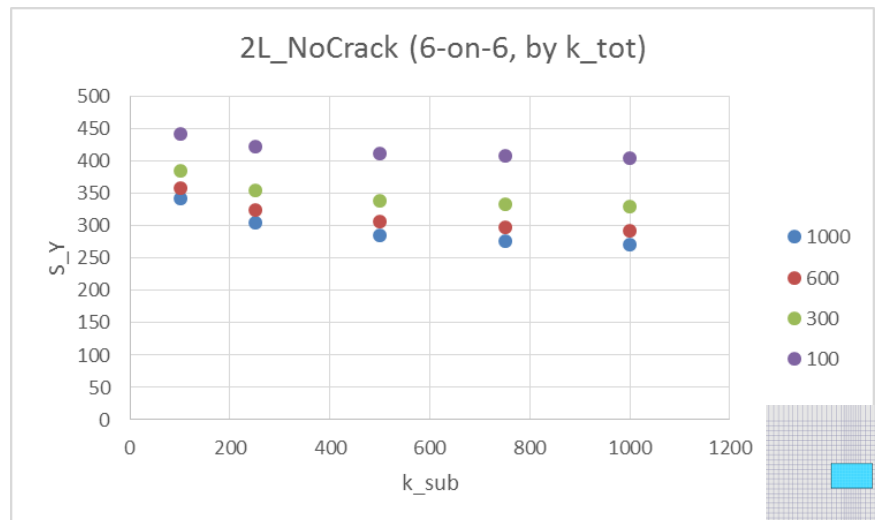
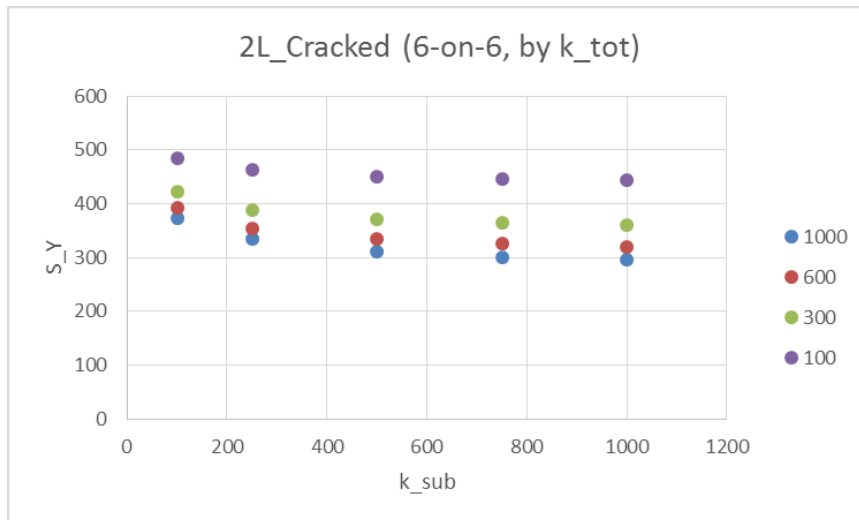
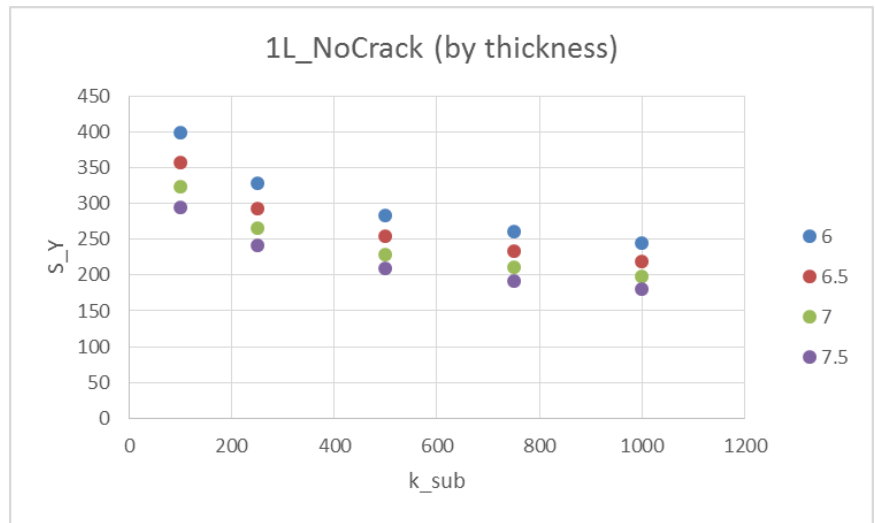
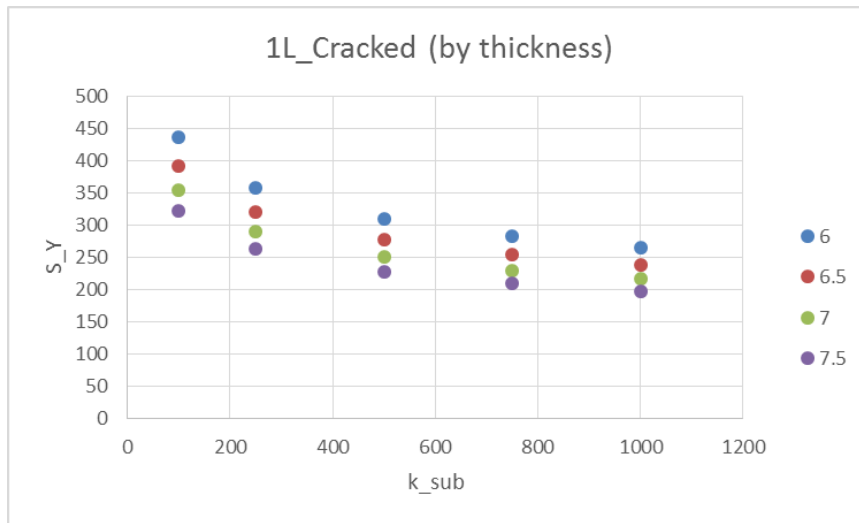




$$k_{int} \approx 500 \text{ psi}$$

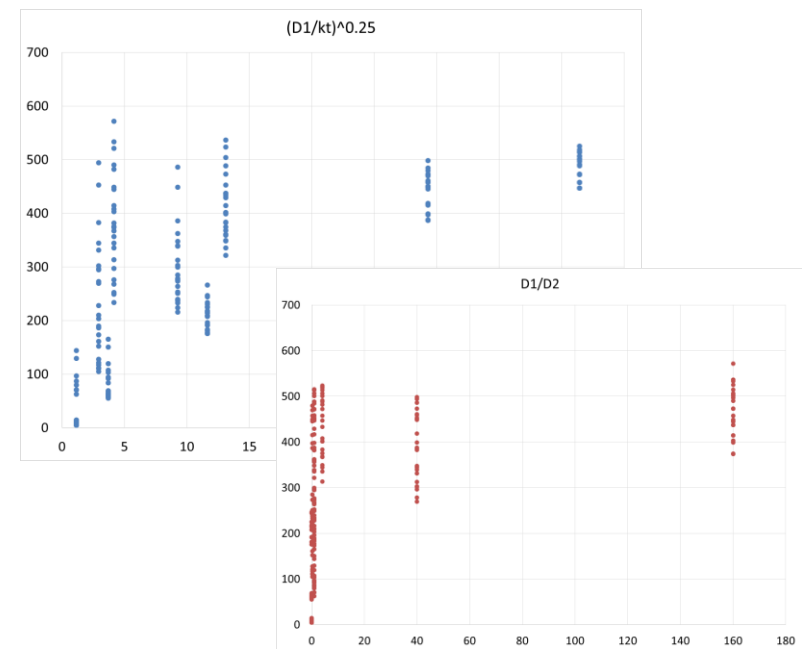
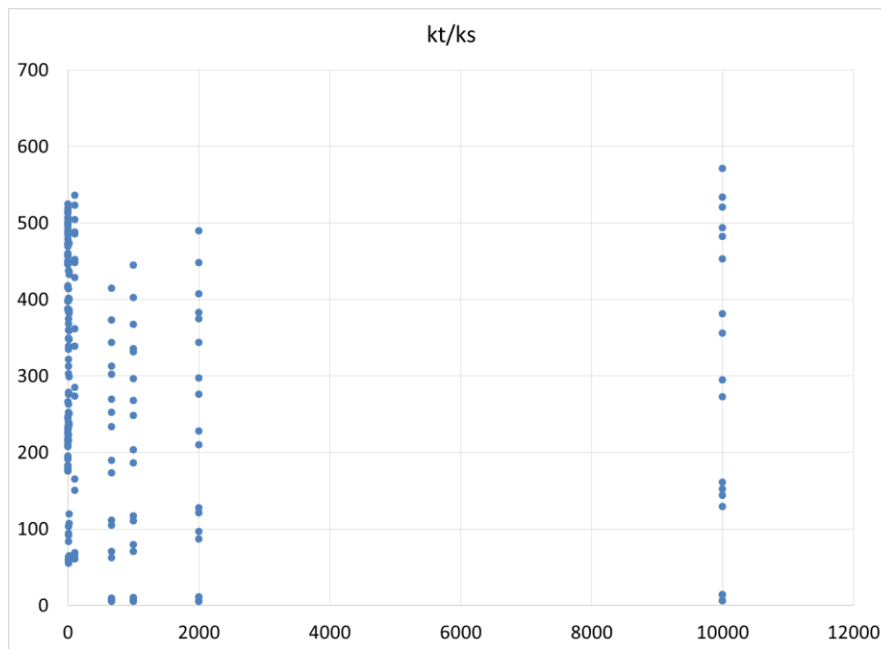
After 4 million load repetitions

Task 4, 1L/2L equivalent w cracking



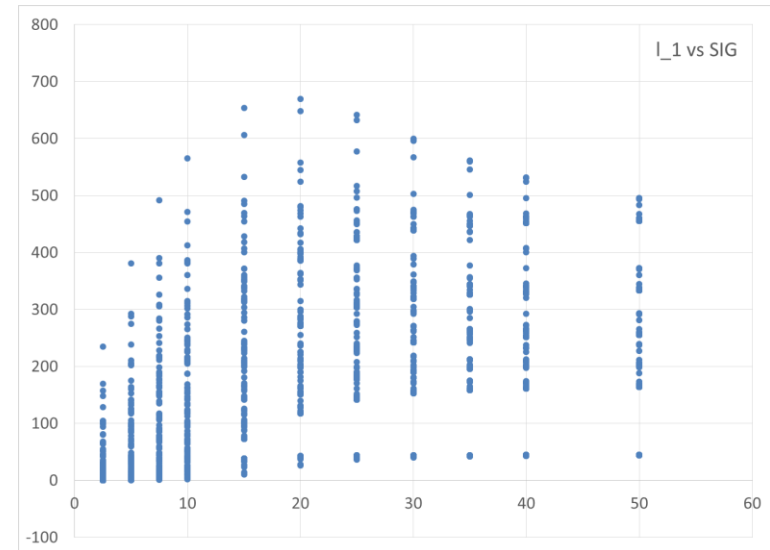
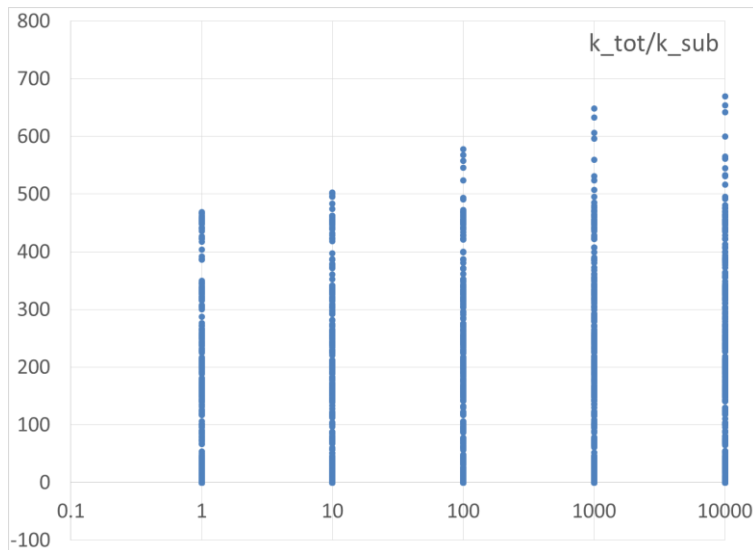
Task 4, Investigations (2)

- 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

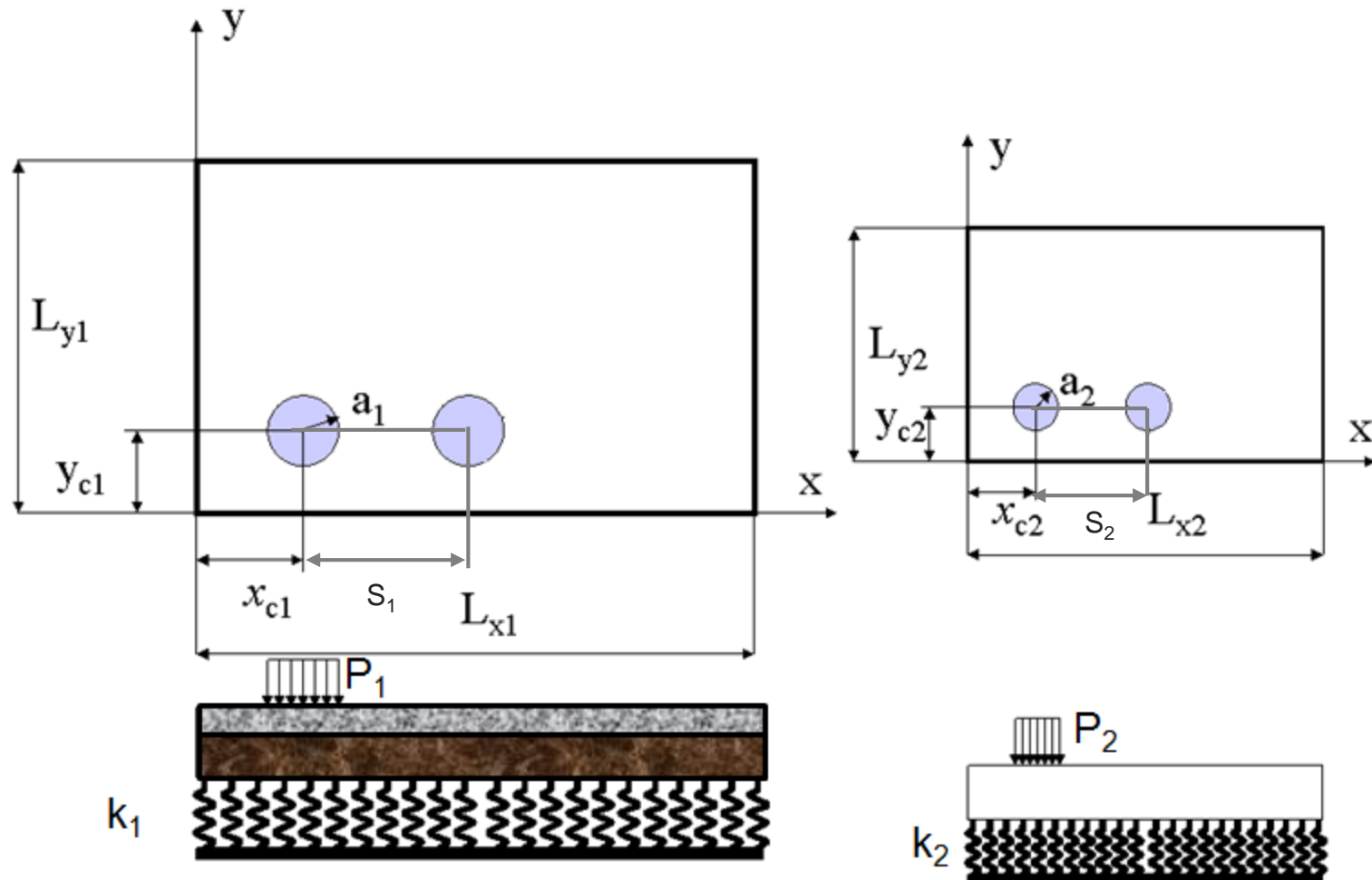


Task 4, Investigations (3)

- 6x6 stress response: Factorial of 1650 cases varied by $D1/D2$, k_t/k_s , $(D1/k_t)^{0.25}$ 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

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

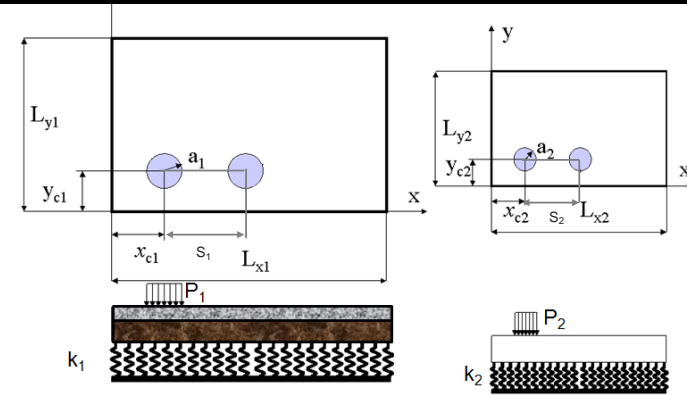
$$\frac{a_1}{\ell_1} = \frac{a_2}{\ell_2} \quad \frac{P_1}{\gamma_1 h_1} = \frac{P_2}{\gamma_2 h_2} \quad \varphi_1 = \varphi_2$$

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

$$\Delta T = h \frac{\int_0^h (T(z) - T_0) E(z) z dz}{\int_0^h E(z) z^2 dz}$$

and

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



γ = unit weight

Korenev's (1962) nondimensional temperature gradient

Temperature difference for the linear strain component of the temperature distribution

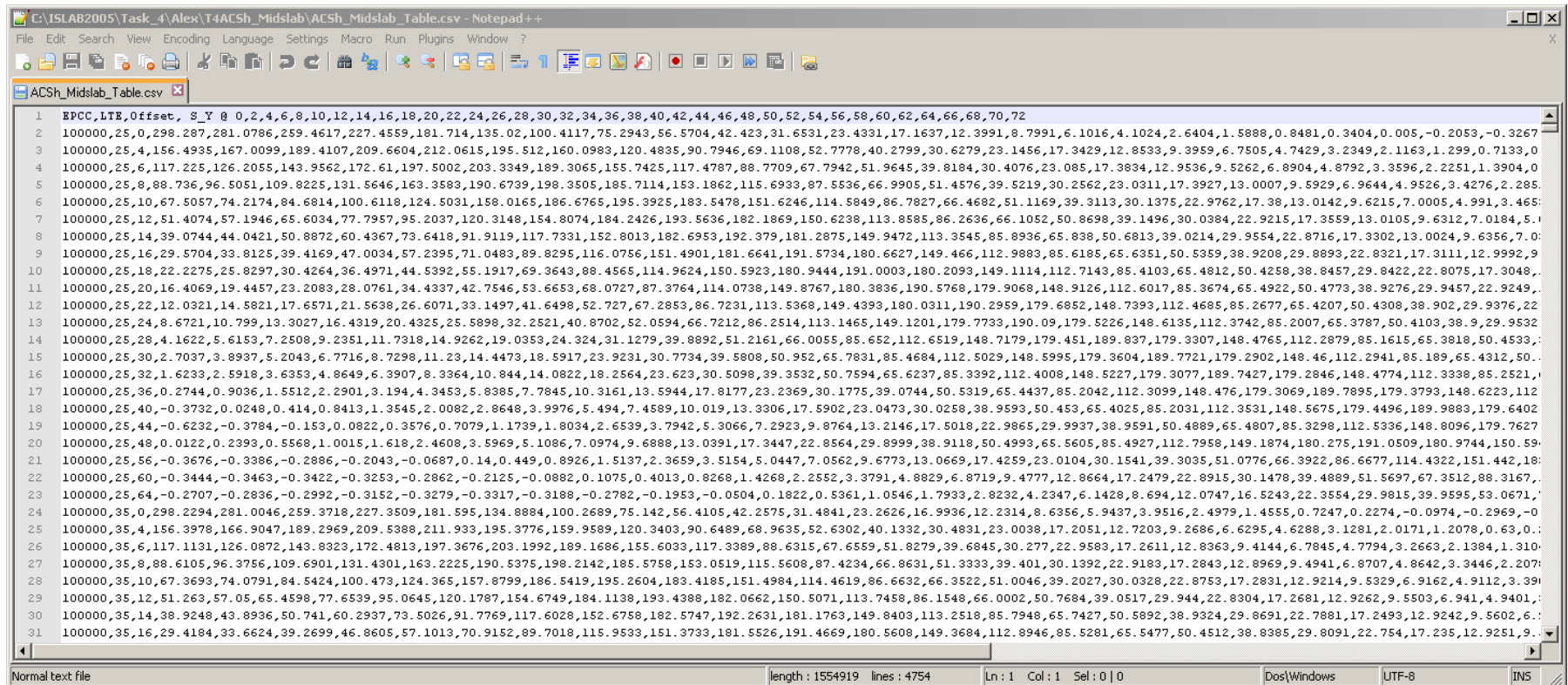
(Khazanovich et al. 2001)

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				

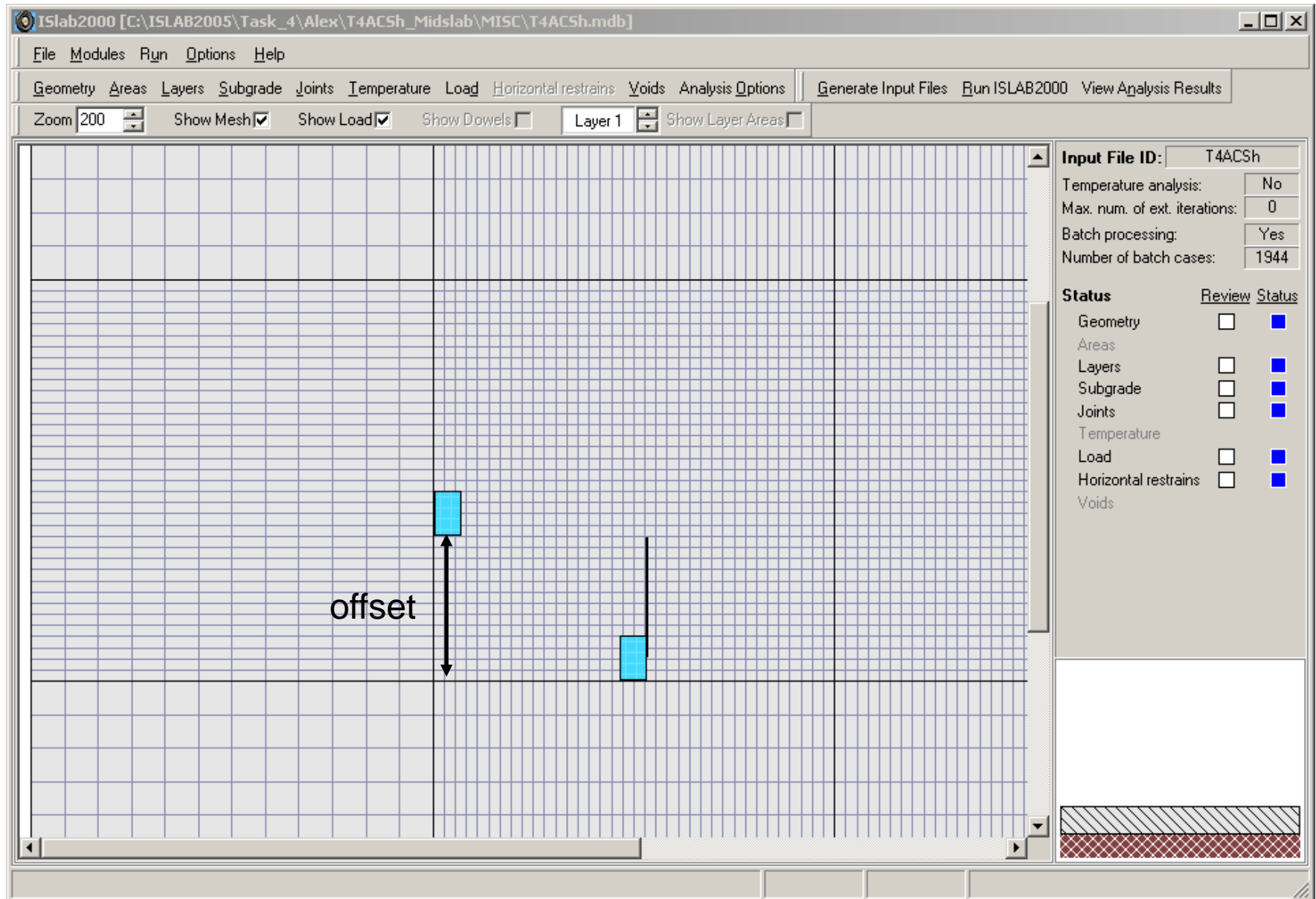
Task 4, Building database of responses

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

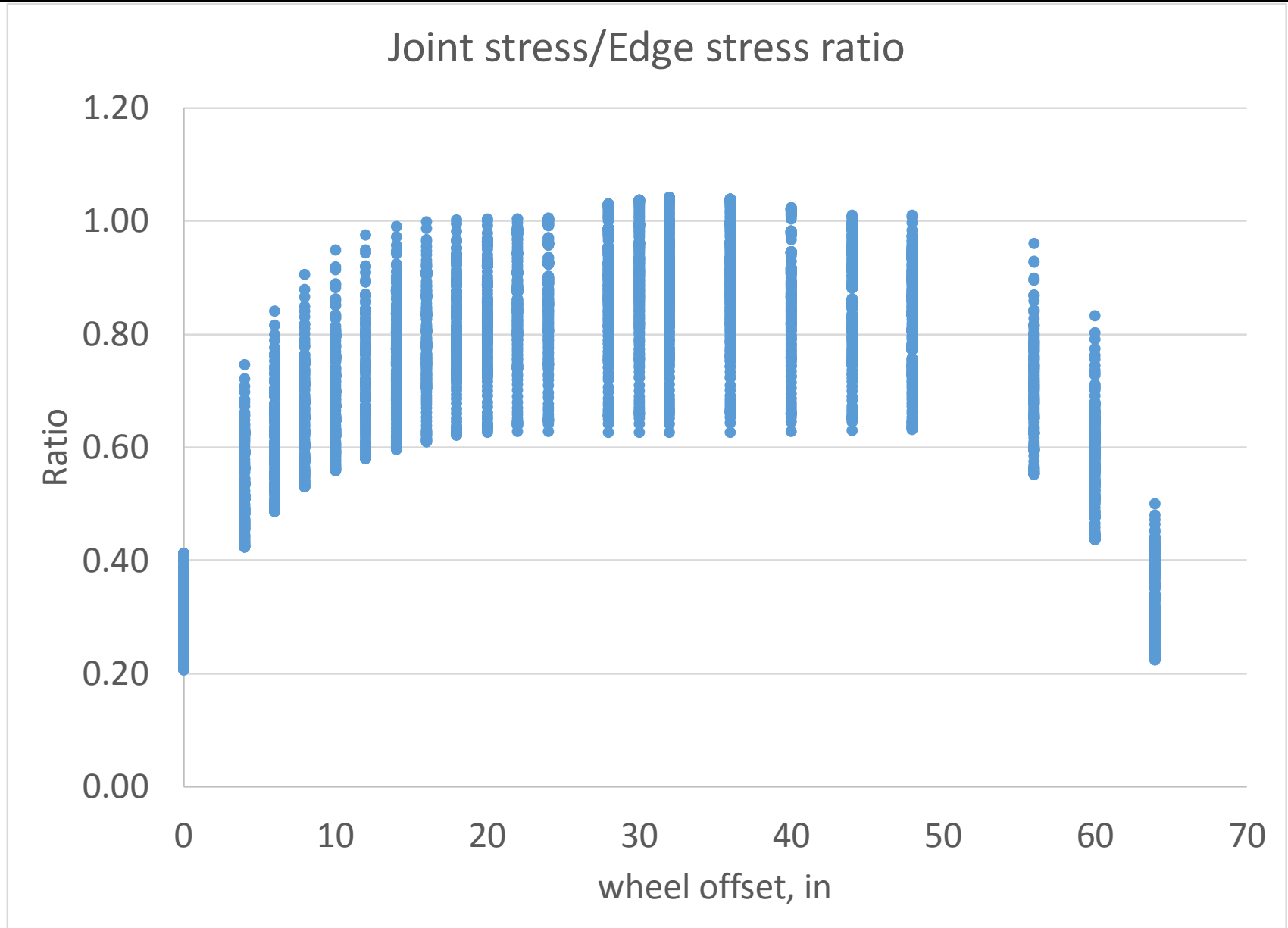


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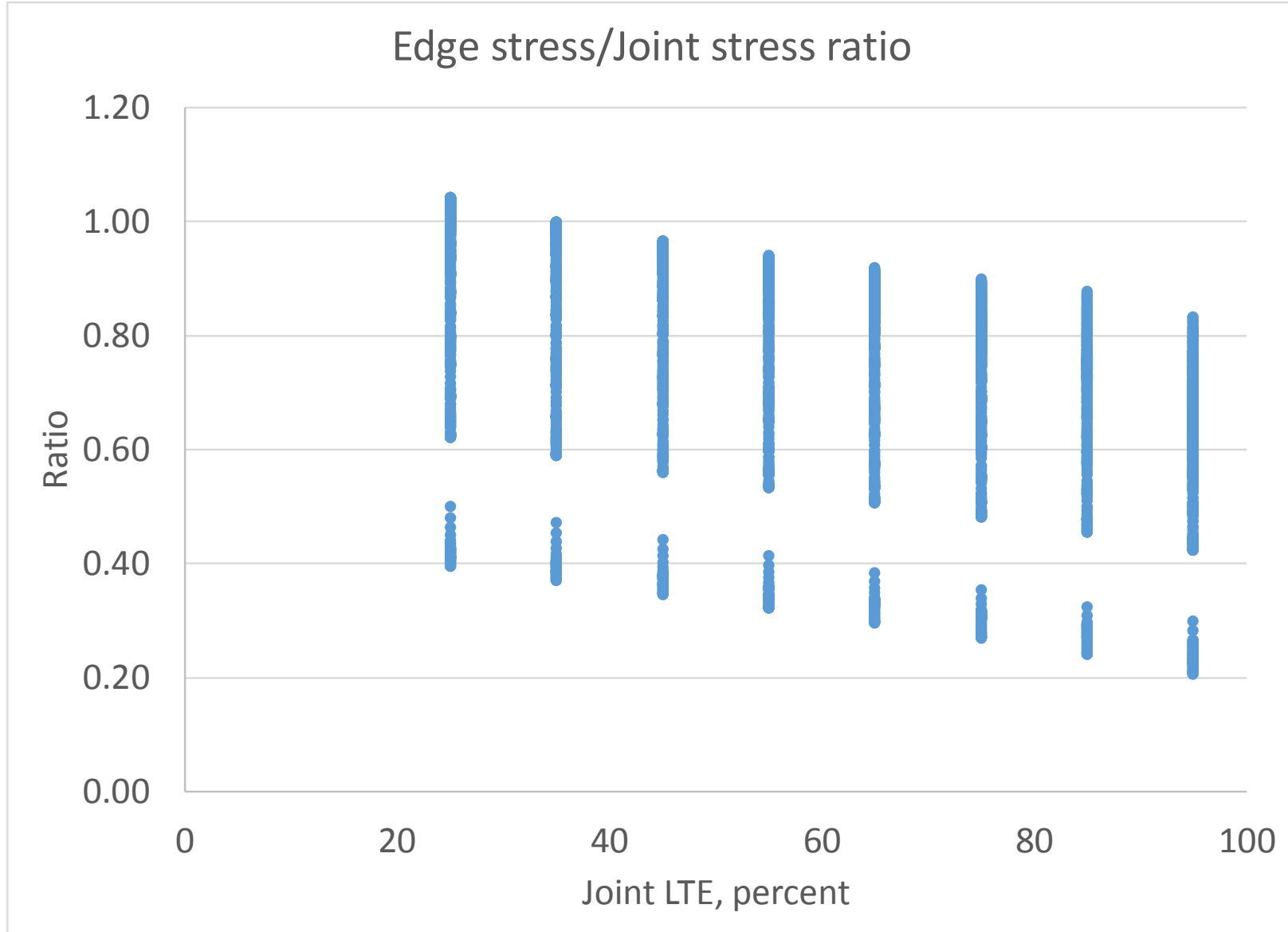
Task 4, Edge vs joint stresses



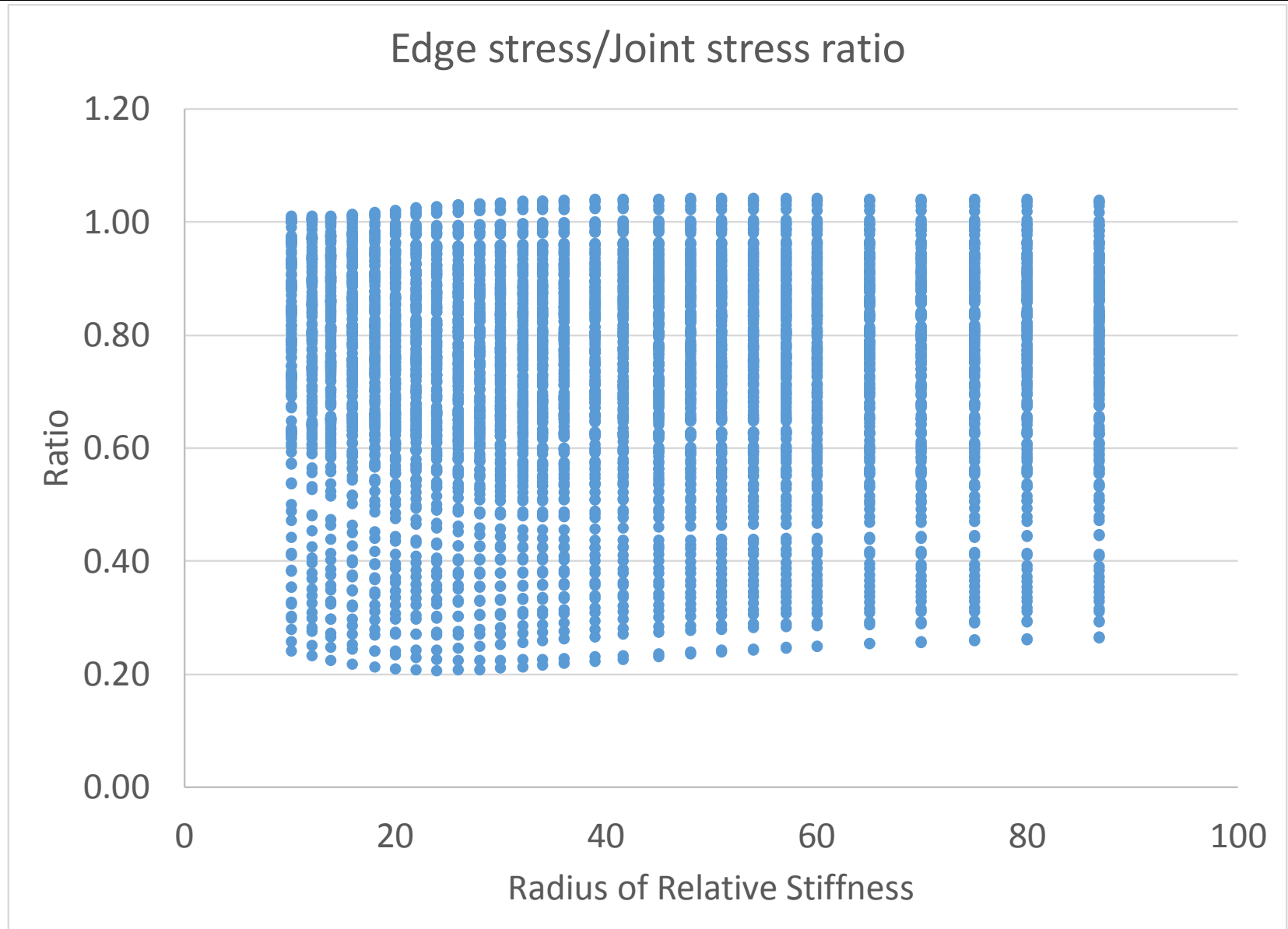
Task 4, Edge vs joint stresses



Task 4, Edge vs joint stresses

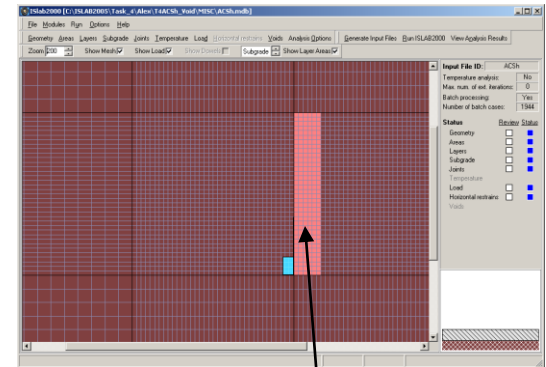
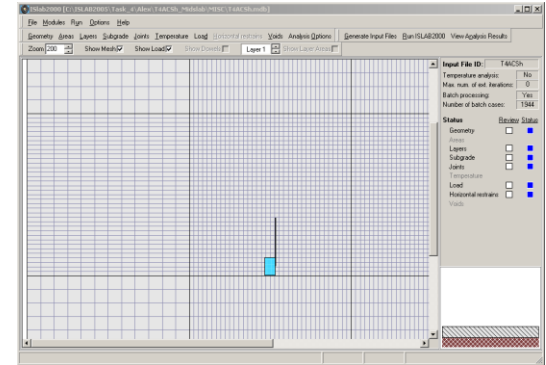


Task 4, Edge vs joint stresses



Task 4, Building database of responses

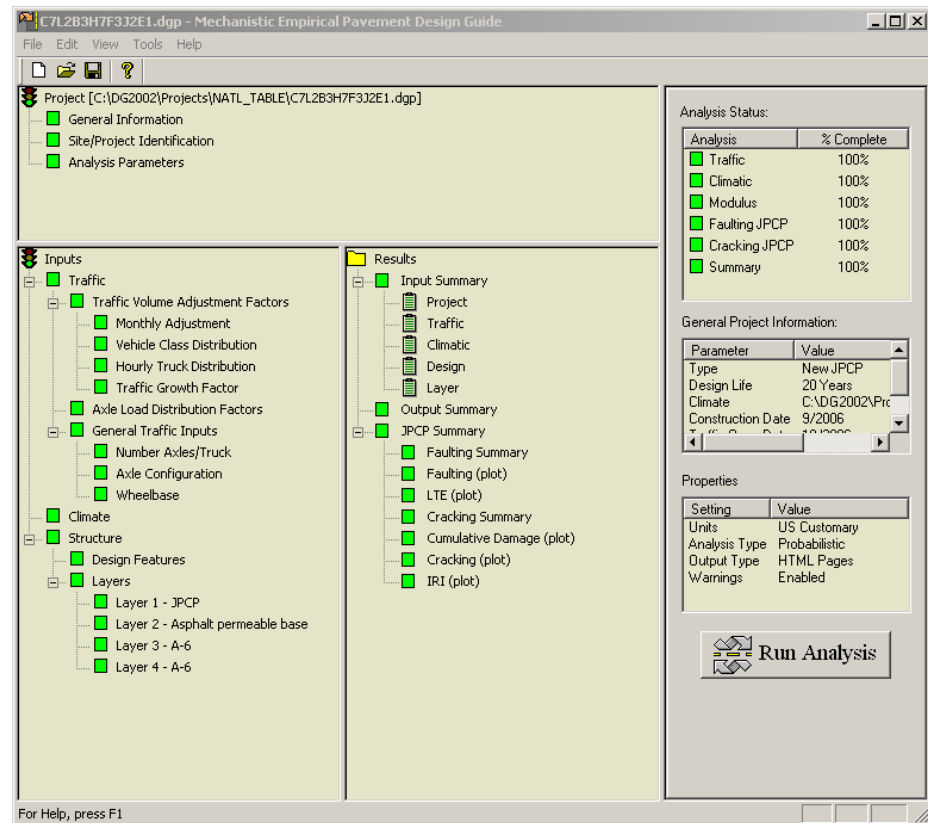
- Response of 6x6 panel system with asphalt shoulder to axle loading at midslab
- Response of 6x6 panel system with AC shoulder to axle loading at joint with interlayer void
- Additional factorials to be conducted with PCC shoulders



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



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

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

- 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