

Feasibility of Employing Triboelectric Energy Harvesting in Unbonded Concrete Overlays

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University of Pittsburgh

Unbonded concrete overlays

Existing concrete pavement

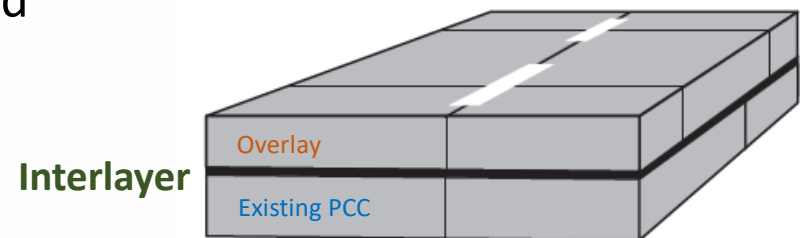
- Moderately to significantly deteriorated
 - Few, if any, pre-overlay repairs required
- Stable and uniform support layer

Interlayer

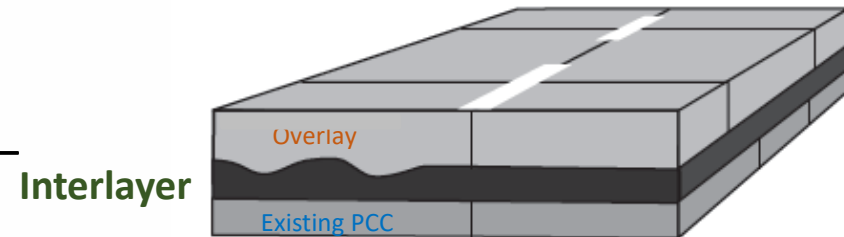
- HMA or nonwoven geotextile fabric

Overlay

- Thicker than bonded concrete overlays – typ. 150 to 200 mm
- Durable surface
- Increased structural capacity



Distressed concrete pavement



Composite pavement

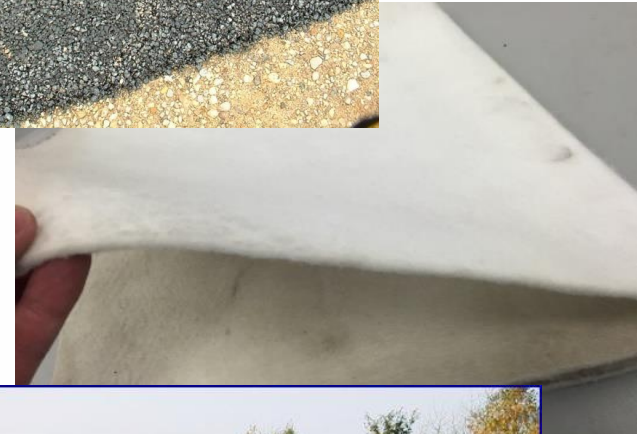
Types of interlayers

Interlayer materials:

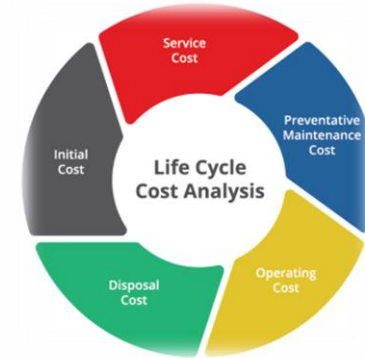
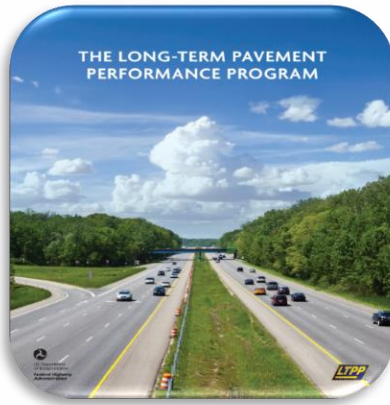
- Nonwoven geotextile fabric
- HMA
 - New: Dense or open graded
 - Old: Milled or unmilled

Factors affecting interlayer performance:

1. Resistance to reflective cracking
2. Stiffness
3. Erosion resistant



Circular Economy in Pavement Engineering



Huang, Y. & Parry, T., 2014. Pavement Life Cycle Assessment. In: *Climate Change, Energy, Sustainability and Pavements*. s.l.:Springer, pp. 1-40.



Geosynthetic Material

GOAL: Increase performance and energy harvesting

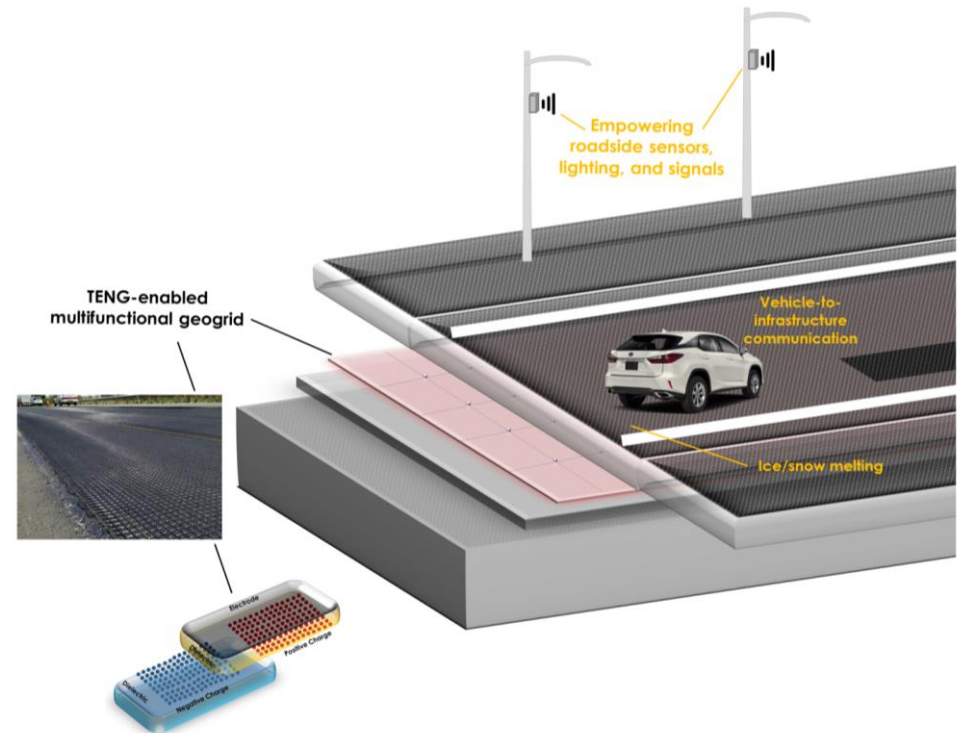
Circular Economy Benefits

- Prevent distress from under layer
- Made from up-cycled material
- Energy harvested reduces life-cycle cost
- Clean energy
- Safe to install
- Stakeholders/Supplier/Contractors implement

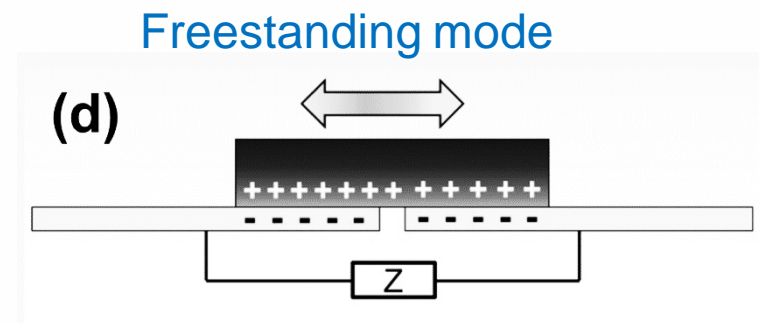
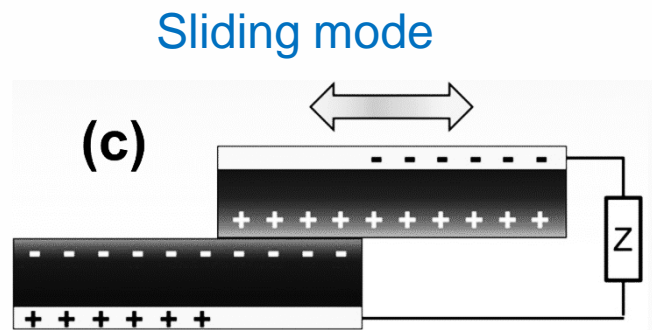
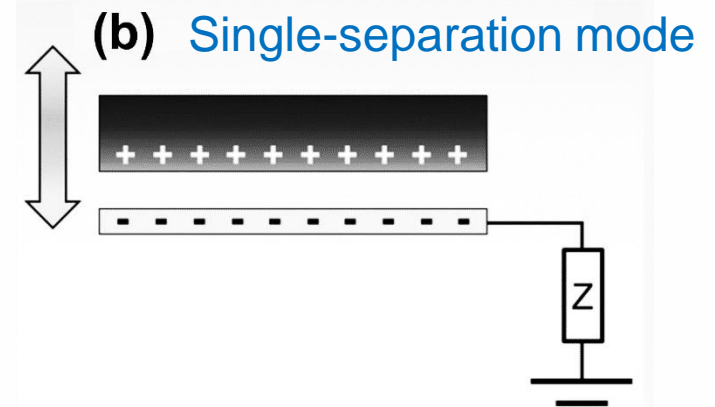
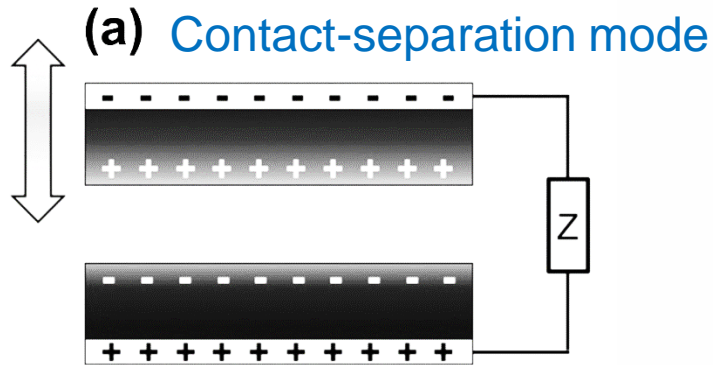


Energy Harvesting with Geosynthetic Separation Layers

- Harvest energy from mechanical excitation
- Store energy with energy harvesting kit
- Power roadside electrical devices

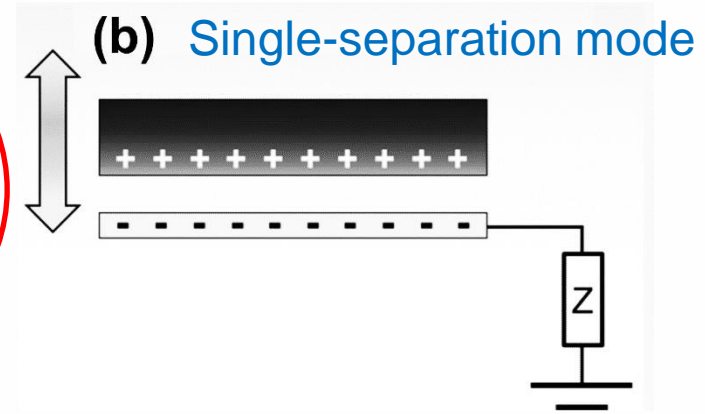
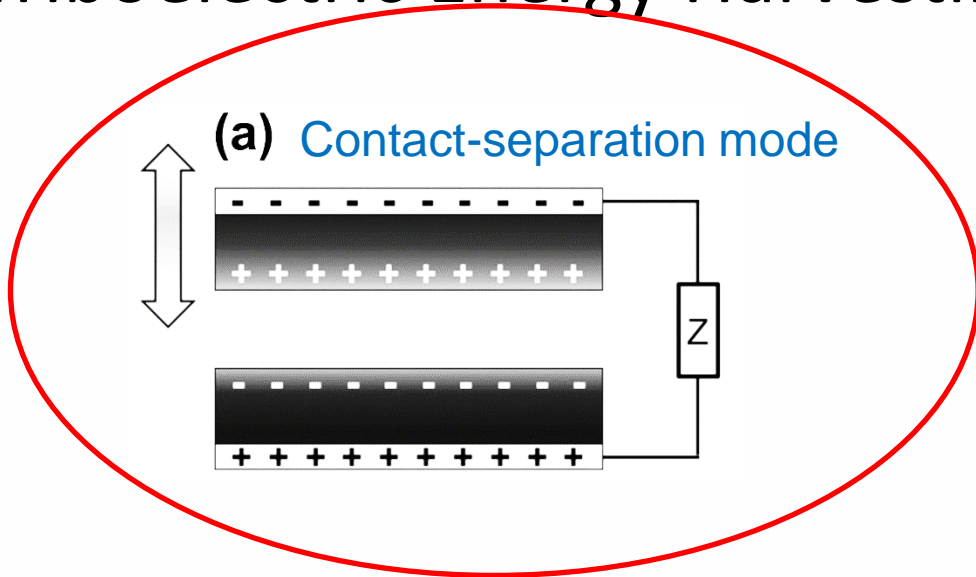


Triboelectric Energy Harvesting

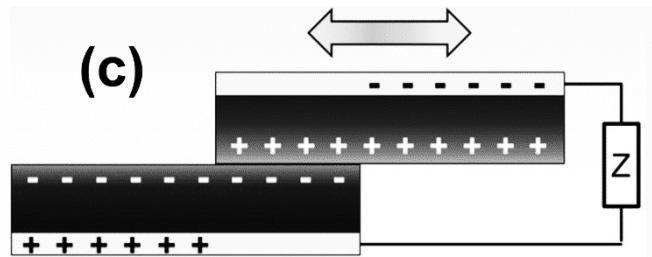


Dielectric material 1
 Dielectric material 2
 Electrode

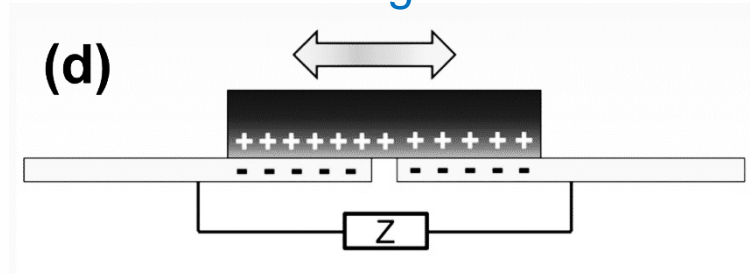
Triboelectric Energy Harvesting



Sliding mode



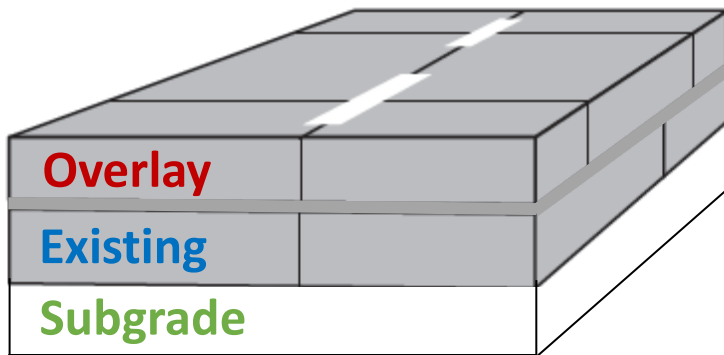
Freestanding mode



■ Dielectric material 1 ■ Dielectric material 2 □ Electrode

Energy Harvesting- Contact compression mode

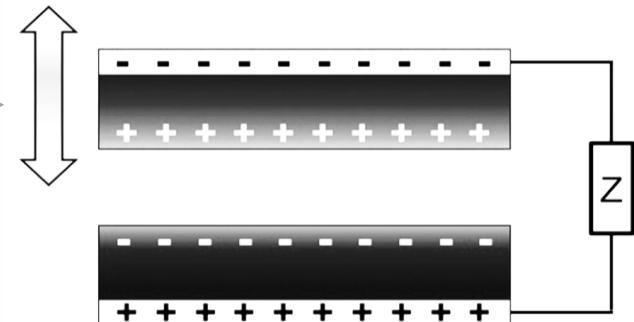
Unbounded Overlay



Interlayer



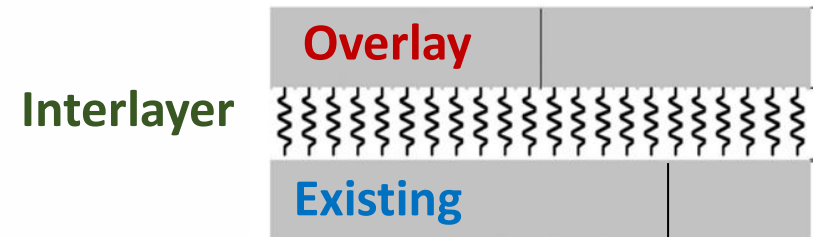
Interlayer Compression



Feasibility

Compressibility of interlayer:

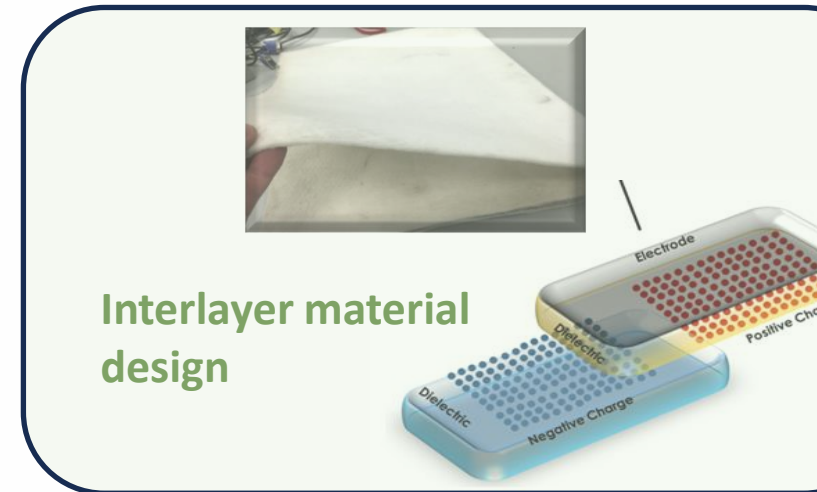
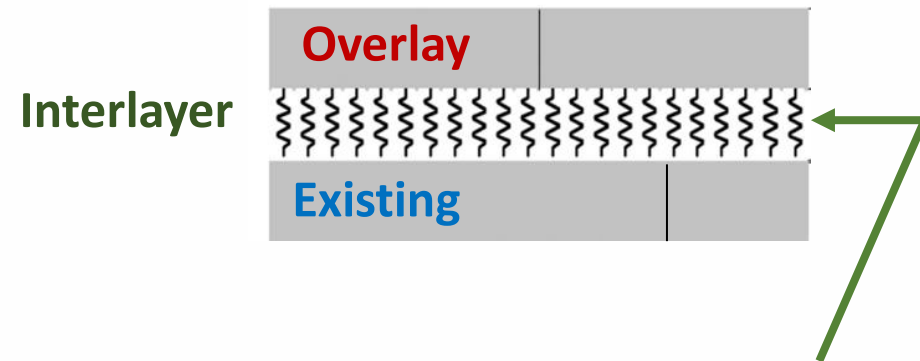
- Pavement structure
 - Existing pavement
 - Overlay design
 - Interlayer material design
- Loads
 - Temperature/moisture gradients
 - Vehicles



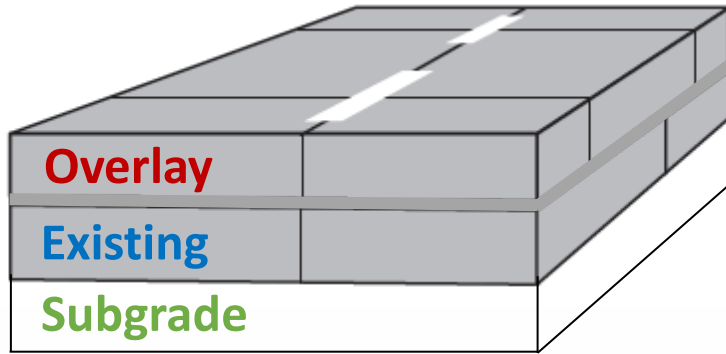
Feasibility

Compressibility of interlayer:

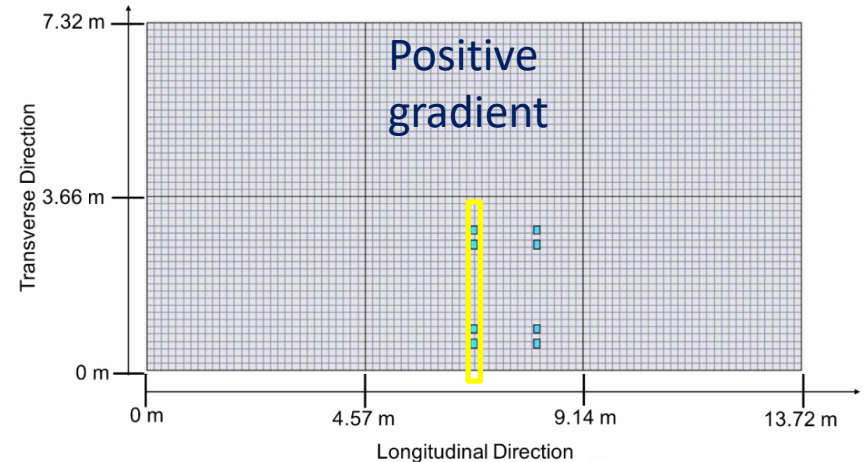
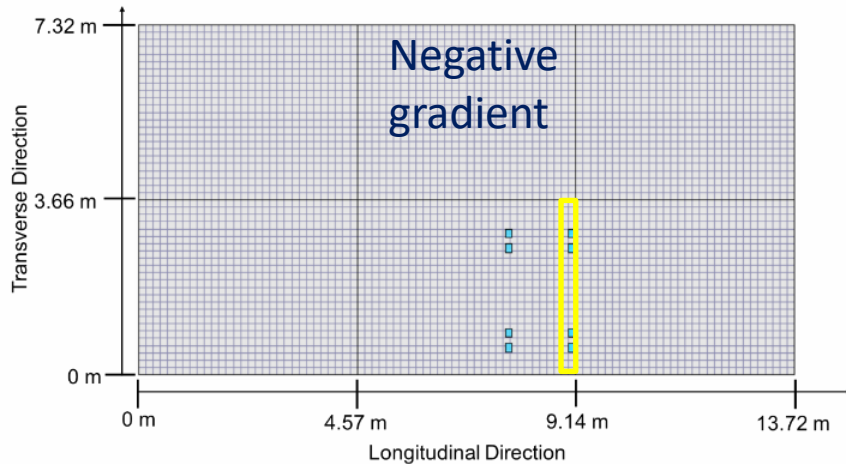
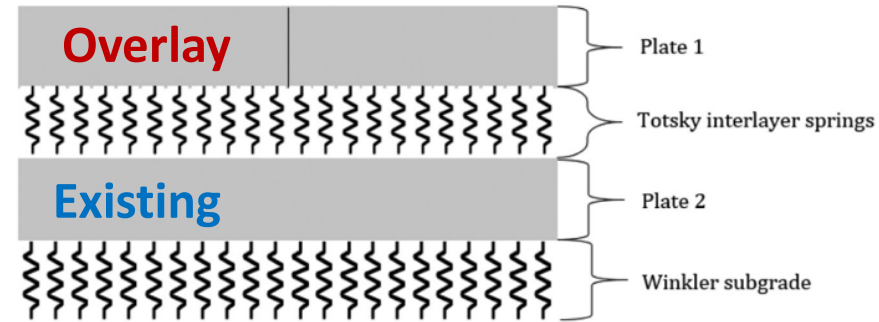
- Pavement structure
 - Existing pavement
 - Overlay design
 - **Interlayer material design**
- Loads
 - Temperature/moisture gradients
 - Vehicles



Compression of interlayer- FEM Analysis (ISLAB2004)



Interlayer
 Subgrade



ISLAB Parametric Study

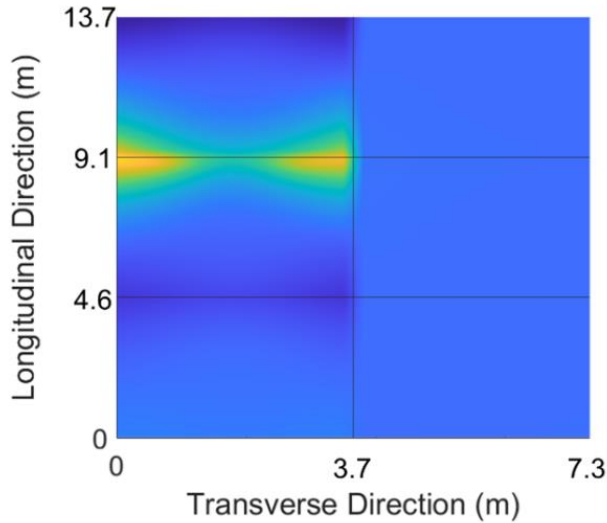
Parameter	Low volume traffic design	High volume traffic design
Layer 1 slab thickness	150 mm	230 mm
Layer 2 slab thickness	178 mm	230 mm
Slab length	3.04 m	4.57 m
Slab width	3.66 m	3.66 m
Elastic modulus of concrete	29.0 GPa	
Poisson ratio of concrete	0.18	
Coefficient of thermal expansion of concrete	$7.92 \times 10^{-6} / ^\circ\text{C}$	
Modulus of subgrade reaction	40.7 kPa/mm	
Tosky K-value	115.4 kPa/mm	
Transverse load transfer efficiency	50% ¹	90% ²
Longitudinal load transfer efficiency	0%	
Temperature gradient (ELTG)	-0.07, -0.03, 0, 0.03, and 0.07°C/mm	

¹Only aggregate interlock load transfer available (no dowels)

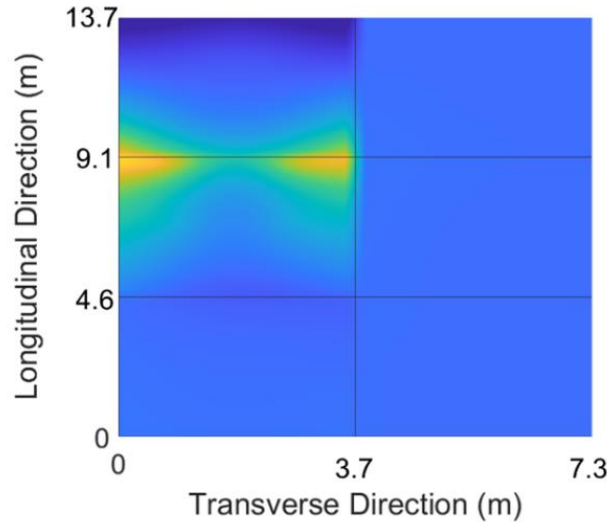
²Load transfer provided by 32 mm dia. dowel



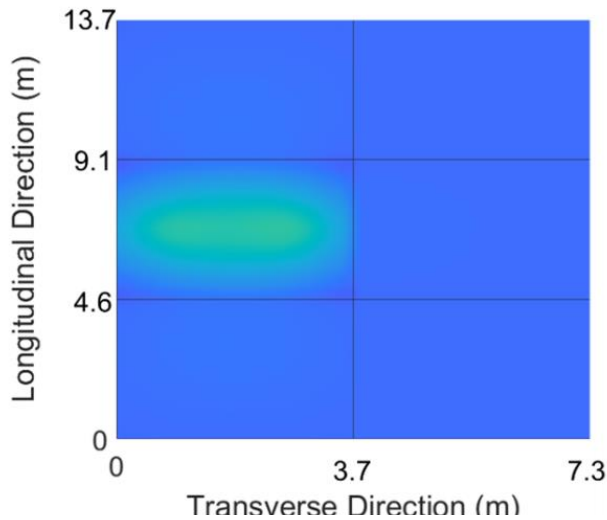
150 mm UBOL



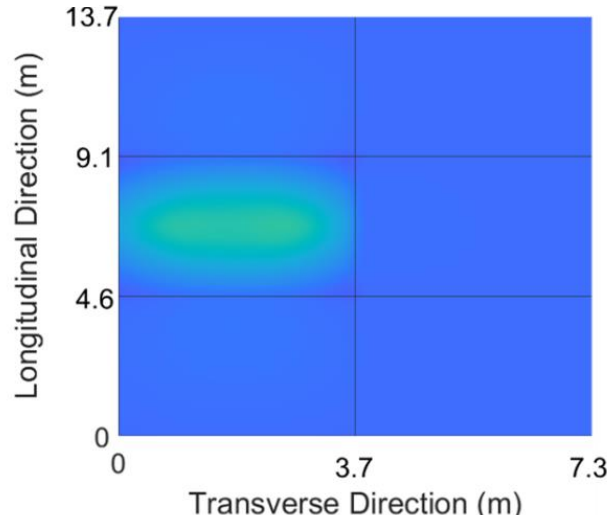
(a) Single Axle, $-0.07^{\circ}\text{C}/\text{mm}$



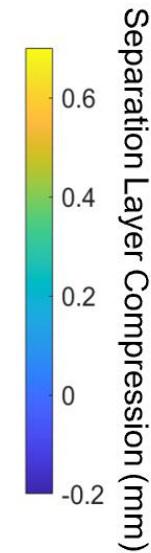
(b) Tandem Axle, $-0.07^{\circ}\text{C}/\text{mm}$



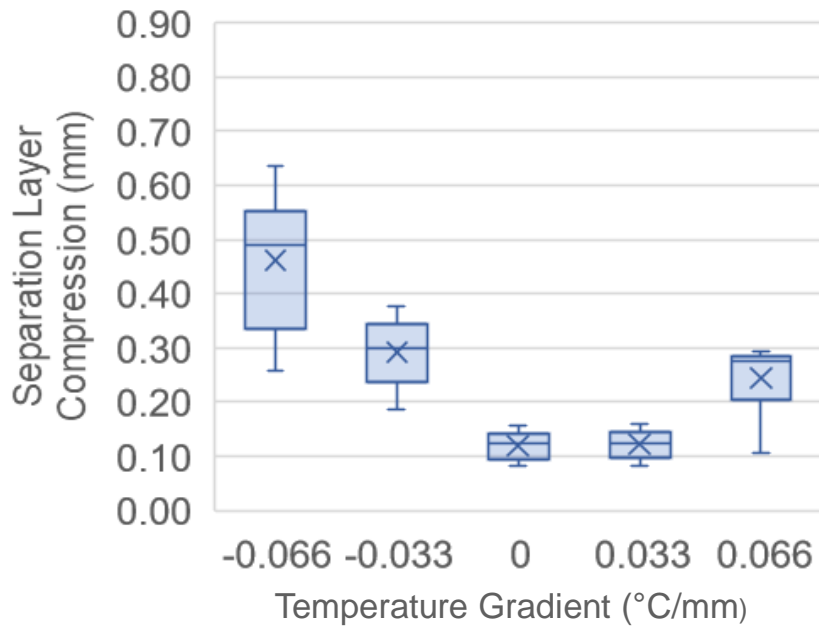
(c) Single Axle, $0.07^{\circ}\text{C}/\text{mm}$



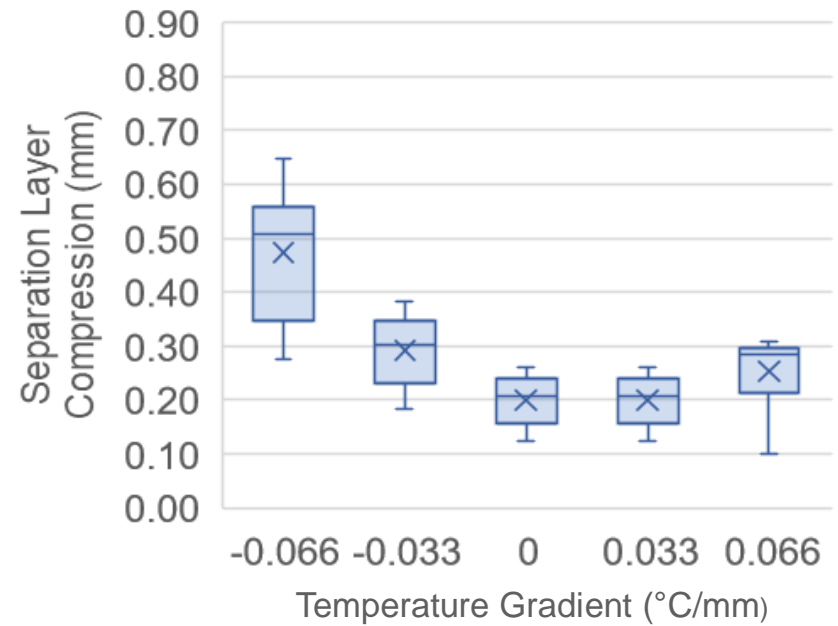
(d) Tandem Axle, $0.07^{\circ}\text{C}/\text{mm}$



Load analysis

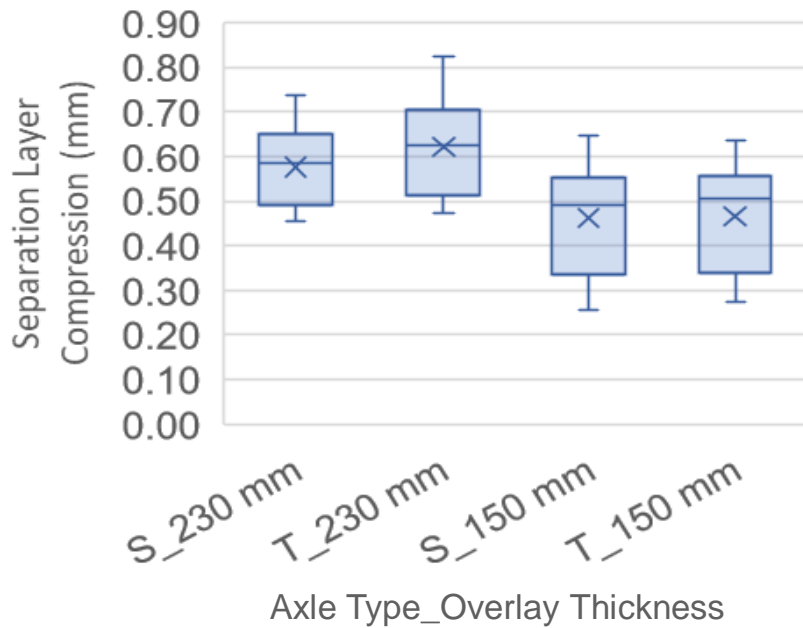


Single Axle

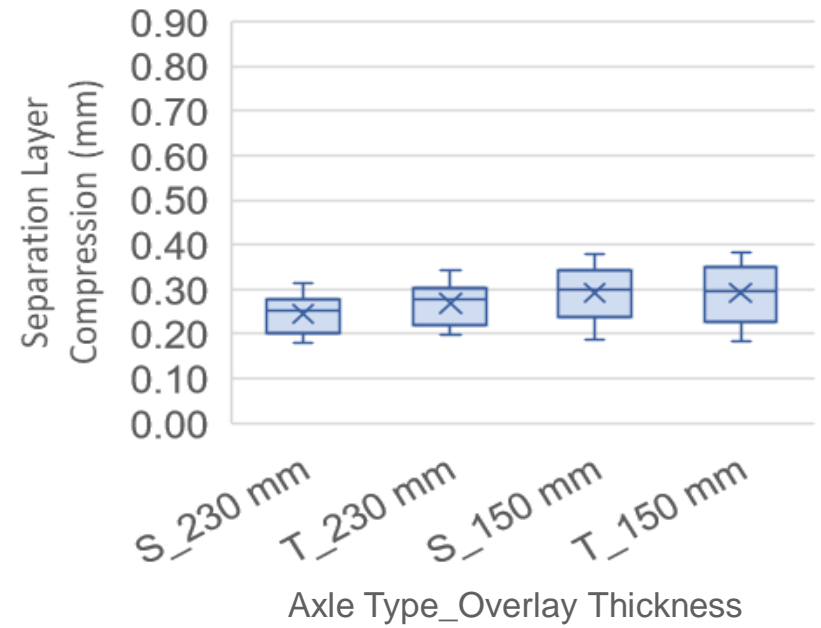


Tandem Axle

Pavement structure analysis

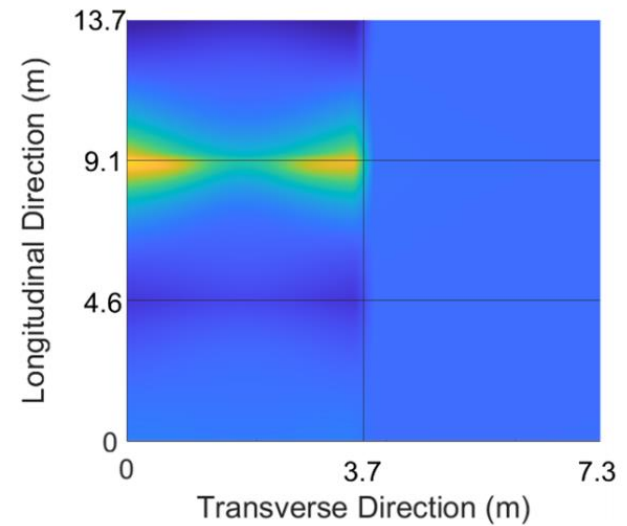
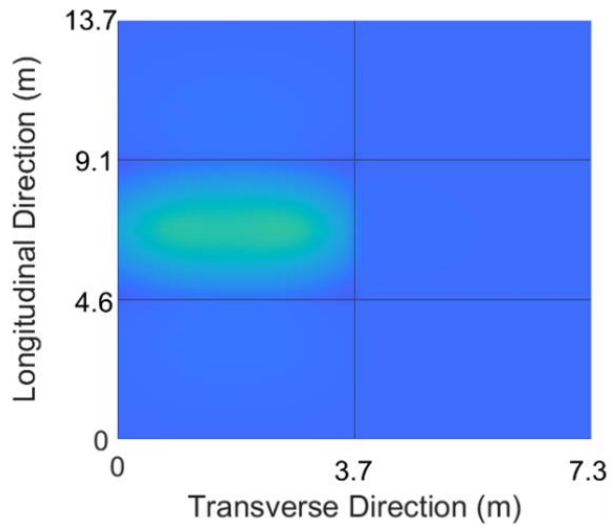
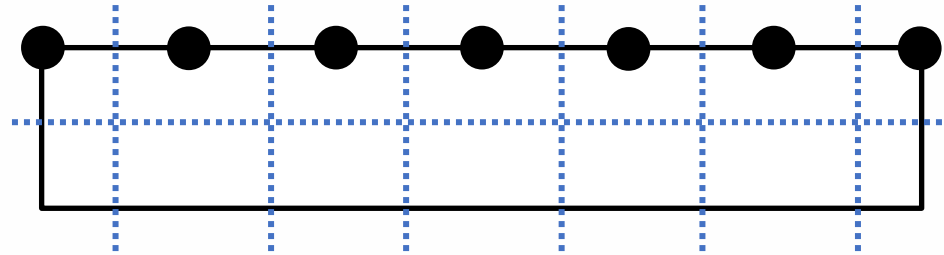


-0.07 °C/mm Gradient

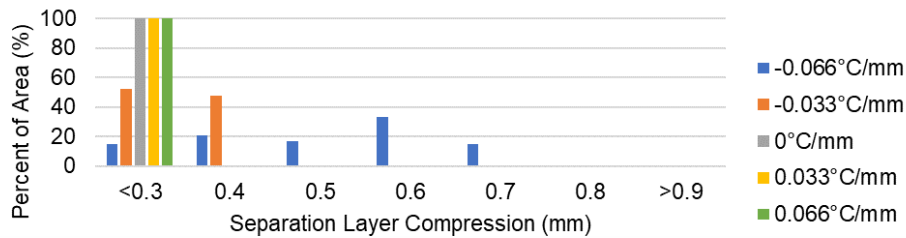


-0.03 °C/mm Gradient

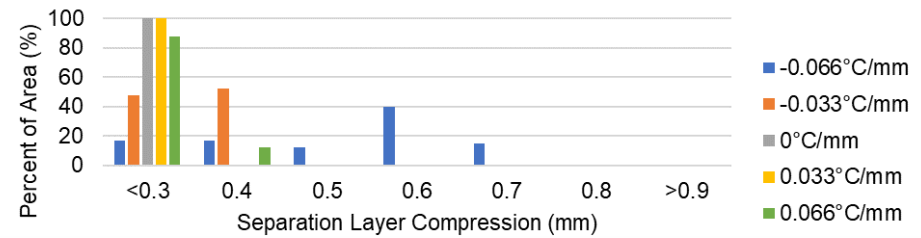
Tributary Areas



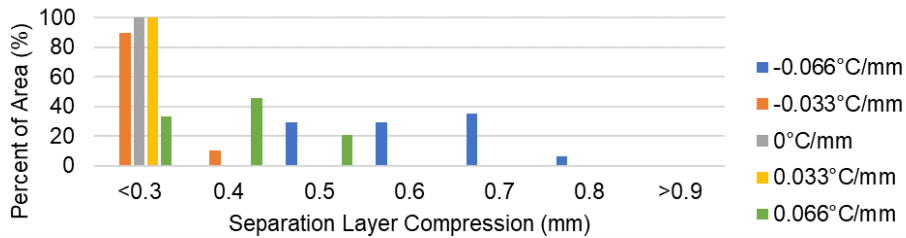
Tributary Areas



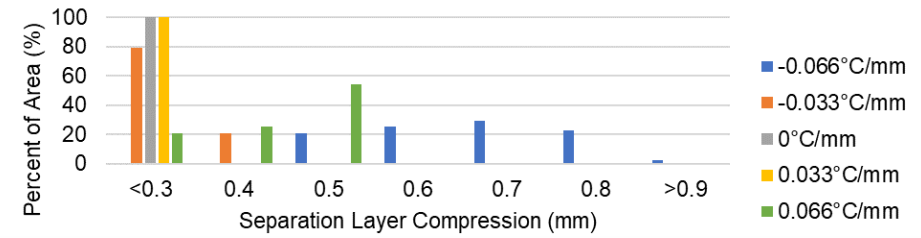
Single axle, 150-mm Overlay



Tandem axle, 150-mm Overlay



Single axle, 230-mm Overlay

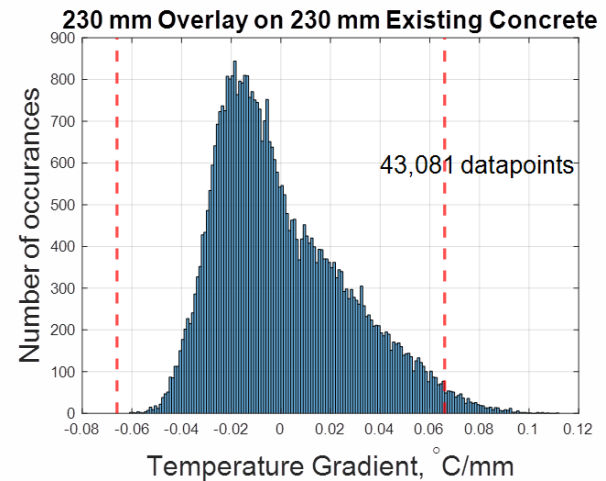
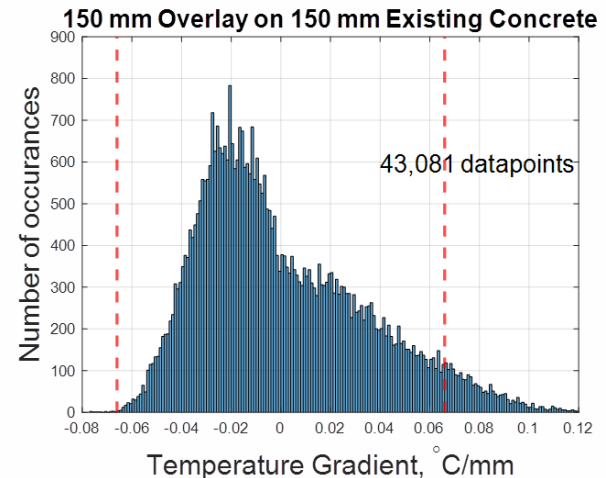


Tandem axle, 230-mm Overlay



Climate Data

- Large gradients ($\pm 0.07^{\circ}\text{C}/\text{mm}$): Infrequent
- Solution
 - Decrease stiffness of TENG interlayer
 - Increase resistance within TENG



Conclusions

- Interlayer compression was similar between axle types
- +/- 0.07°C/mm
 - Compressions > 0.05 mm over 50% of the time
 - Gradients not frequent in Pittsburgh, PA
- 0 and 0.03°C/mm
 - All compressions < 0.03 mm
 - Gradients frequently occur
- There is potential for energy harvesting, but need to
 - Decrease stiffness of separation layer
 - Increase resistance of energy harvesters
- Future work
 - Investigate other pavement structures
 - Reevaluate separation layer design

Acknowledgements

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Thank you

Questions?

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