Project Objectives

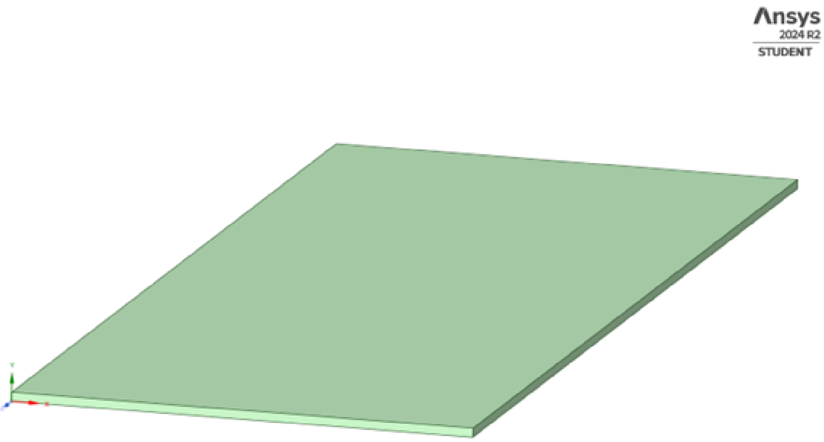
After spectating a live road resurfacing project near Paddington Station in London during work experience with an infrastructure firm, I wanted to learn more about the engineering behind roads. Something we use every day and has been a fundamental part of societies for centuries. My primary goal was to develop a realistic model that could predict the lifespan of asphalt roads under average conditions. Extending the project scope to look at how factors like surface imperfections and environmental conditions contribute to wear and degradation.

Creating the first model

- I constructed a simple rectangular model using Ansys. The initial dimensions were based on a standard 1 lane road.
- I used realistic material properties such as the Young's modulus and Poisson's ratio.
- I set a fixed base support to simulate the layers beneath the asphalt layer.

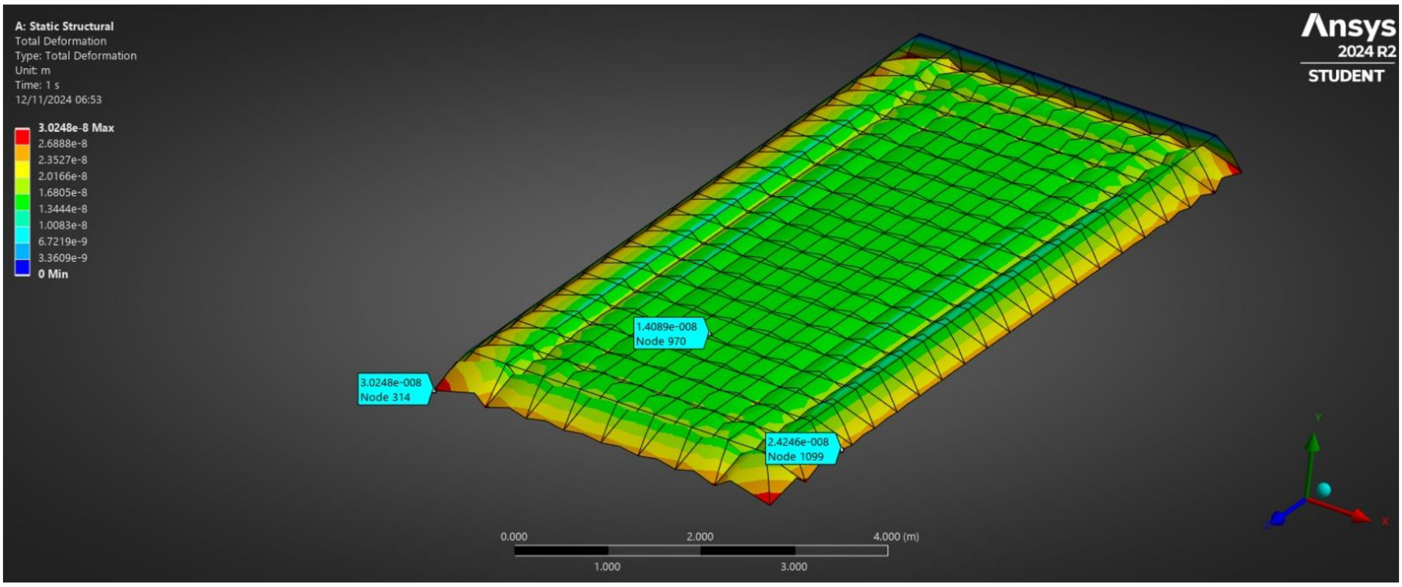
Properties of Outline Row 3: Asphalt

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	2400	kg m^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
5	Coefficient of Thermal Expansion	4E-05	C^-1		
6	Isotropic Elasticity				
7	Derive from	Young's Modulus...			
8	Young's Modulus	1000	MPa		
9	Poisson's Ratio	0.3			
10	Bulk Modulus	8.3333E+08	Pa		
11	Shear Modulus	3.8462E+08	Pa		
12	Strain-Life Parameters				
13	Display Curve Type	Strain-Life			
14	Strength Coefficient	400	MPa		
15	Strength Exponent	-0.1			
16	Ductility Coefficient	0.15			
17	Ductility Exponent	-0.5			
18	Cyclic Strength Coefficient	400	MPa		
19	Cyclic Strain Hardening Exponent	0.2			
20	Tensile Yield Strength	1	MPa		
21	Compressive Yield Strength	15	MPa		
22	Tensile Ultimate Strength	2	MPa		
23	Compressive Ultimate Strength	25	MPa		
24	Isotropic Thermal Conductivity	0.9	W m^-1 K^-1		
25	Specific Heat Constant Pressure, C_p	1000	J kg^-1 K^-1		
26	Isotropic Resistivity	1E+12	ohm m		
27	Isotropic Relative Permeability	1			



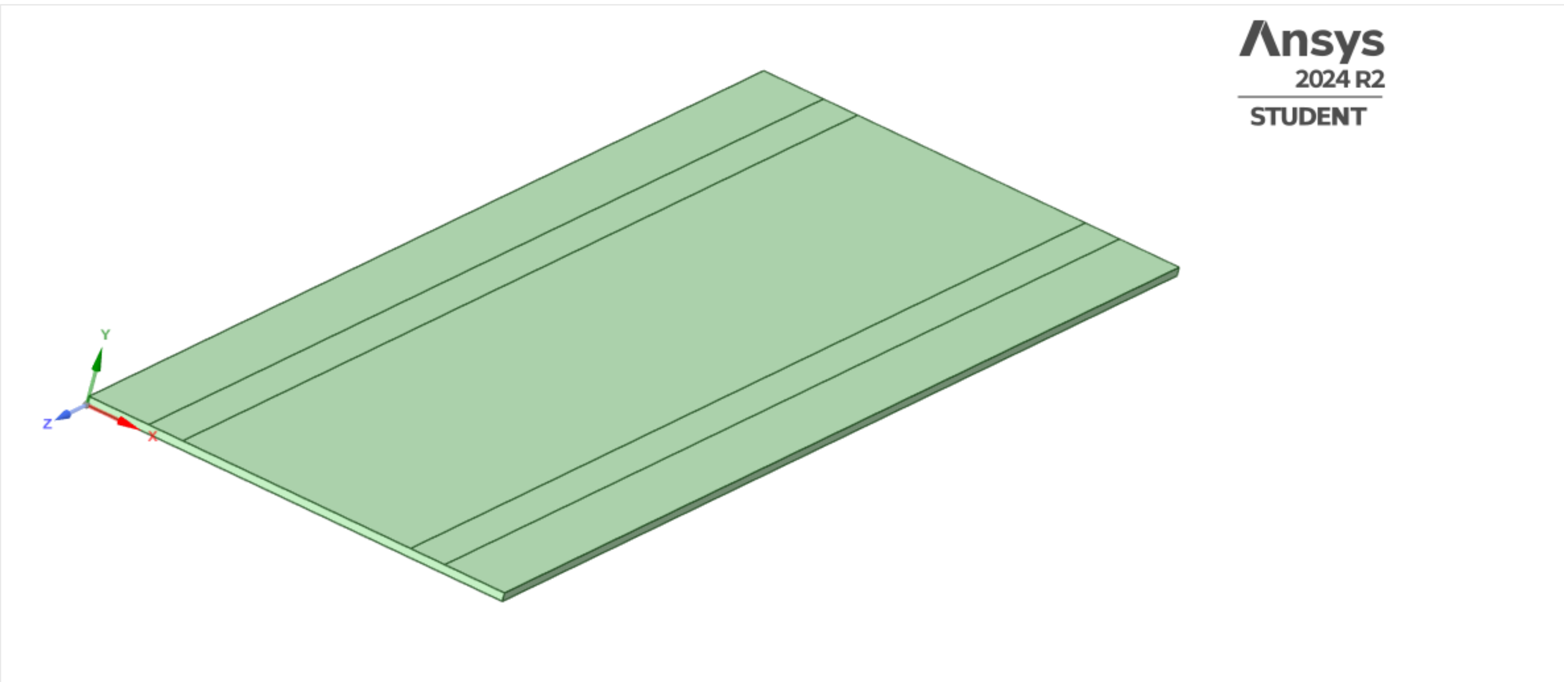
Applying Basic Loading Conditions

In my initial analysis, I applied a uniform load across the top surface of the asphalt model, in the areas where vehicles would be in contact with the road. This load represented a simplified version of vehicular weight, allowing me to observe basic stress patterns.



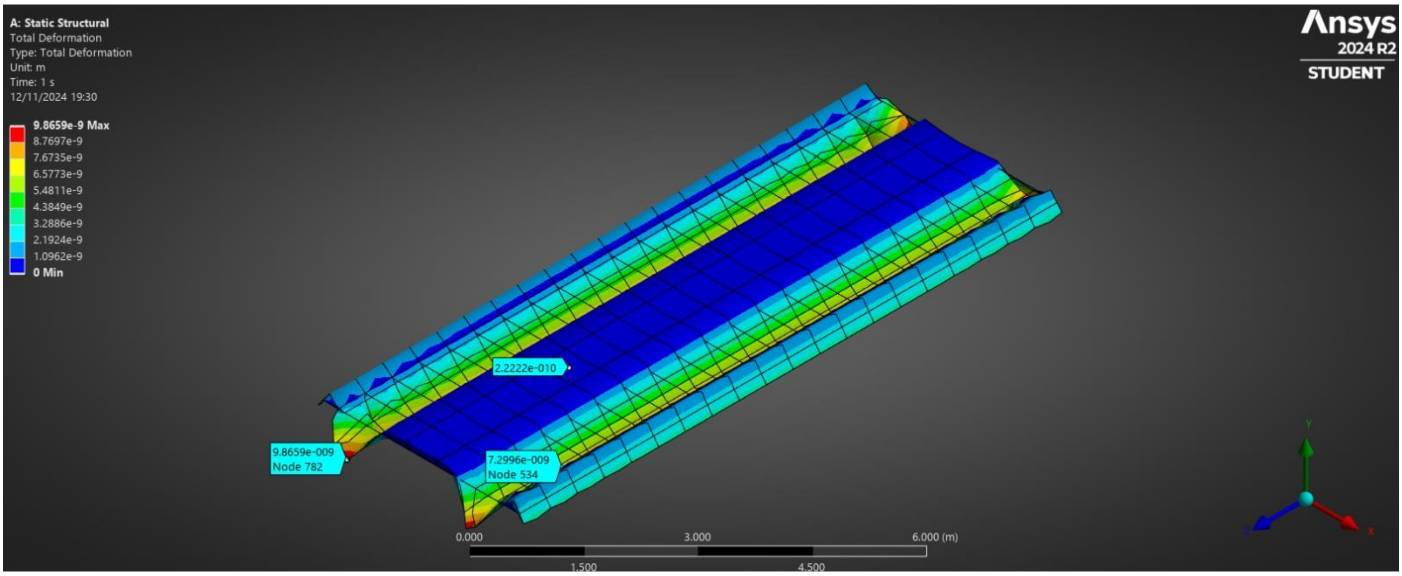
Initial Results and Evaluation

After completing the first analysis, which revealed a uniform stress distribution across the surface, I realised that it didn't represent a real-life scenario. Load spread shouldn't be uniform across the surface since most of the stress is at the points of vehicle contact with the road. I decided to refine the model by adjusting load concentration across the surface.



Assessing and Interpreting Improved Results

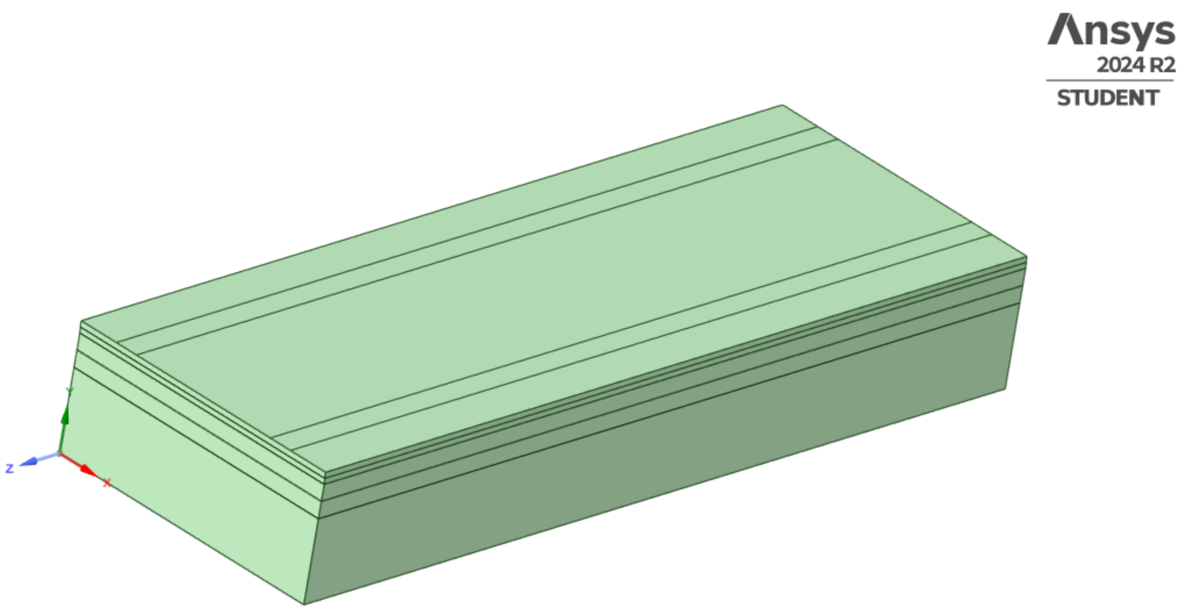
- With refined loading and mesh improvements, the results showed higher stress concentrations under the tire paths, which aligned more closely with realistic road wear patterns.
- The results suggested a more plausible road surface lifespan because damage will tend to develop in recurringly damaged areas.

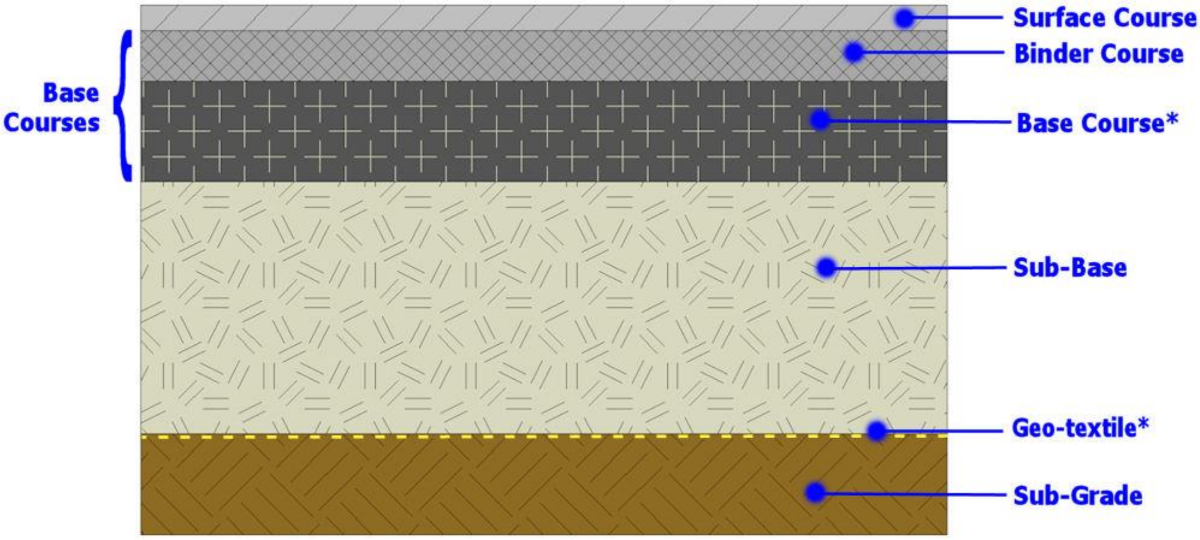


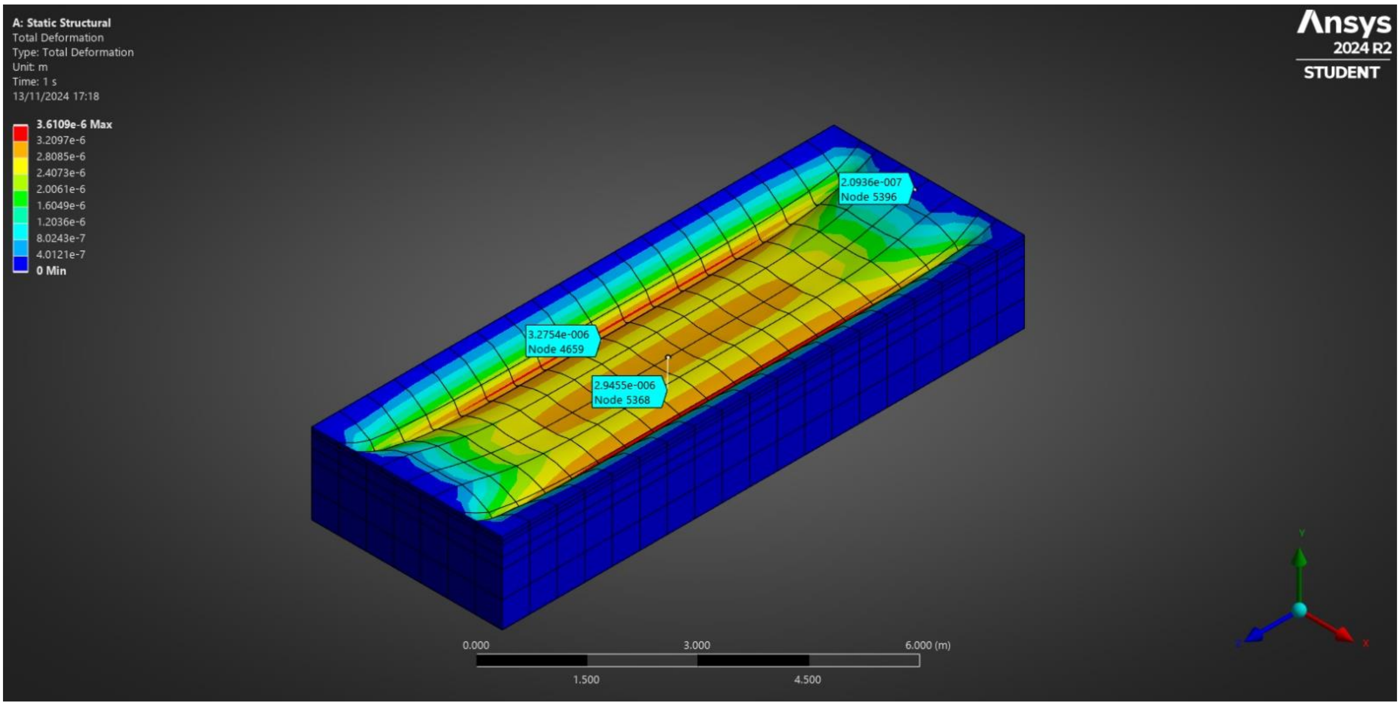
Expanding the Model to Include Subgrade Layers

I expanded the model by adding layers beneath the asphalt, including a subgrade layer to represent underlying soil. Each layer was assigned material properties according to typical values for road subgrades. This allowed the subgrade layer to respond to the stress applied on the asphalt. Mirroring a more realistic behaviour under load.

Comparing total deformation, I observed how different subgrade properties influenced the asphalt layer, noting that stiffer subgrades resulted in cracking and flexing in the asphalt, while softer subgrades led to more even but potentially damaging surface deflections.







Results

On all side and bottom faces, I included fixed supports which would mimic the surrounding material that would prevent any horizontal deformation. For the same force applied in the same region, in this model there was more deformation than previously. Although I used accurate material properties for all 5 layers, there could be an error somewhere.

Calculations

To predict the road's lifespan, I needed the fatigue properties of asphalt, specifically from a S-N curve (Stress vs. Number of cycles) to show how long asphalt can endure cyclic stresses before failure.

From data calculated in my model, the S-N curve indicated that the average stress level my model was working at, asphalt typically fails after approximately 10 million cycles.

$$\text{Life span} = \frac{\text{Total cycles until failure}}{\text{Daily cycles}}$$

With an average of 2000 daily cycles my calculated life span was ~ 13.7 years. This suggested a slight overestimate. Considering thermal stresses due to temperature change or other external factors, I dropped the number of maximum cycles until failure to 7 million. Resulting in ~9.6 years which seemed fairer.

I could also use the Miners rule which takes a similar calculation but under a different context. The rule assumes that fatigue damage accumulates linearly, meaning that each load cycle contributes a fraction of the material's total life, and failure occurs when the cumulative damage reaches a threshold (typically 1.0, or 100%).

$$\text{Daily damage} = \frac{\text{Daily cycles}}{\text{Total cycles until failure}}$$

This approximated to 0.000285 using

Final conclusions

The model, now including cyclic loading, temperature fluctuations, and environmental wear, predicts a realistic road surface lifespan of around 9-10 years, aligning with real-world expectations. I am interested to see how this could be further improved. Potentially collecting data and using it for further analysis could increase the accuracy.