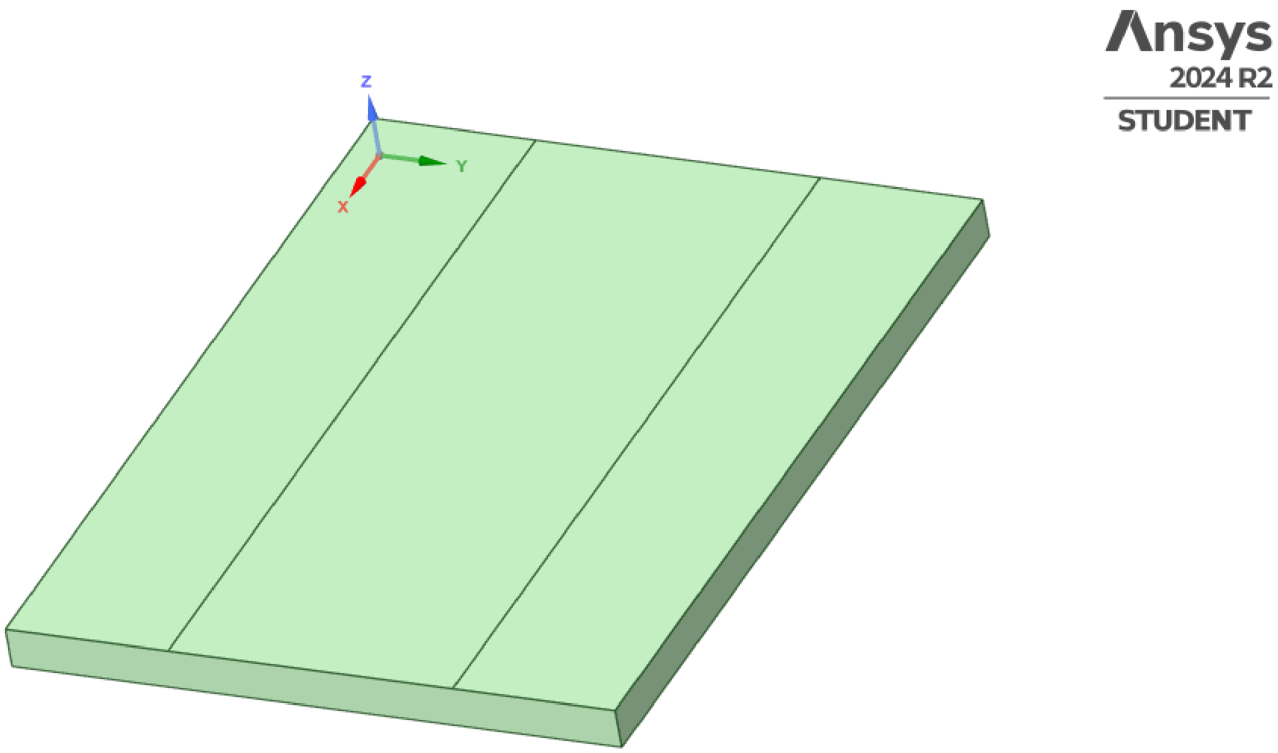
Project Objectives

After spectating a live road resurfacing project near Paddington Station in London during my work experience with FM Conway, 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. I aimed to analyse the stresses and strains affecting asphalt road surfaces over time. Looking at how factors like load, surface imperfections and environmental conditions contribute to wear and degradation. My primary goal was to develop a realistic model that could predict the lifespan of asphalt roads under average conditions.

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, density and Poisson's ratio.
- I set a fixed base support to simulate the layers beneath the asphalt layer.

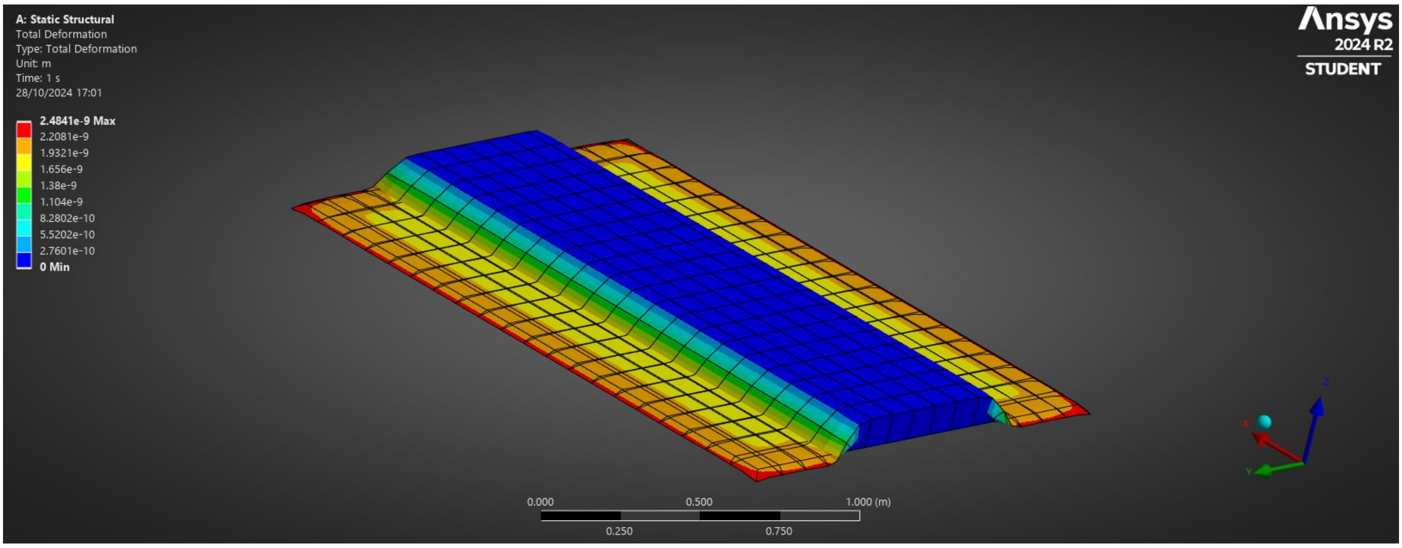


Applying Basic Loading Conditions

In my initial analysis, I applied a uniform load across the top surface of the asphalt model. 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.



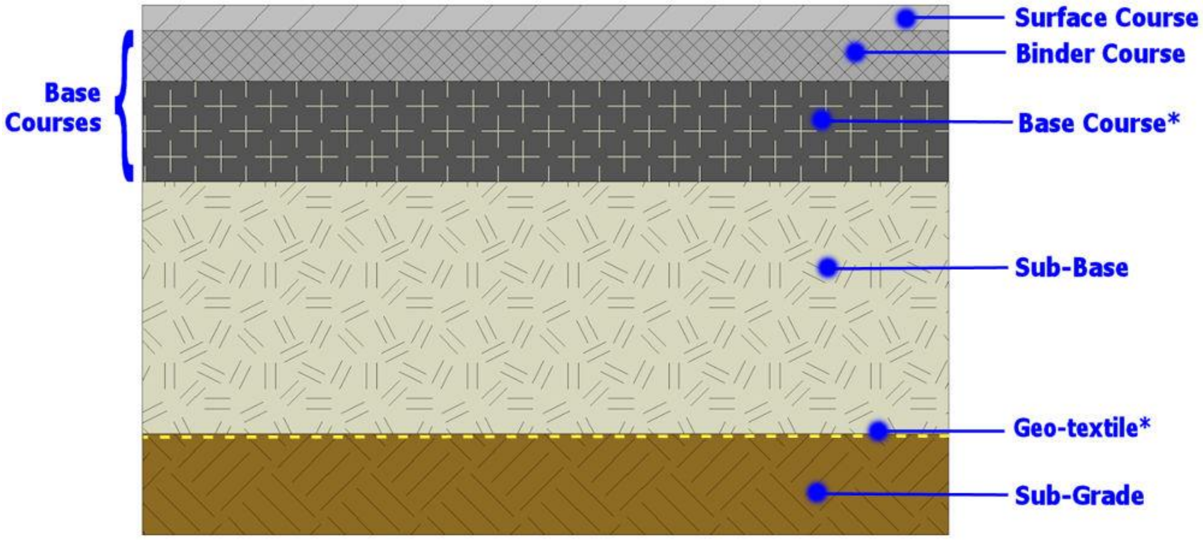
Assessing and Interpreting Improved Results

- 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, though they still showed a lifespan longer than expected.

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.

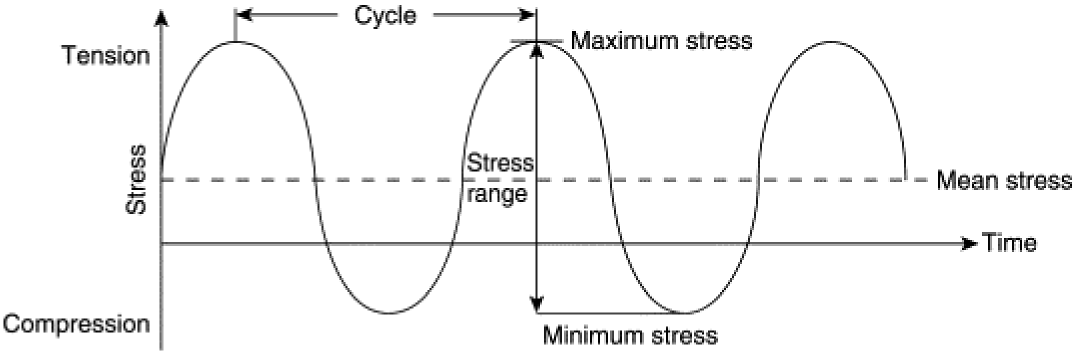
Comparing total deformation, I observed how different subgrade properties influenced the asphalt layer, noting that stiffer subgrades resulted in cracking and flexing in the asphalt, while softer subgrades led to more even but potentially damaging surface deflections.



Identifying Material Fatigue Properties and S-N Curve Referencing

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

I referenced industry-standard data for asphalt's S-N curve, indicating that at a stress level of around 2.5 MPa, asphalt typically fails after approximately 10 million cycles under ideal conditions.



Lifespan Prediction Calculations Based on S-N Curve Data

Using an estimate of 2000 load cycle daily I calculated a potential lifespan. Using 10 million cycles until failure at 2.5 MPa, the lifespan calculates to:

Using the S-N curve value of 10 million cycles until failure at 2.5 MPa, the lifespan calculation follows:

$$\text{Life span} = \frac{\text{Total cycles until failure}}{\text{Daily cycles}} = \frac{10000000}{2000} = 5000 \text{ days} \sim 13.7 \text{ years}$$

Factoring in thermal stresses (e.g., expansion and contraction) and moisture, which introduce additional stresses, the fatigue limit can drop to approximately 7 million cycles. Considering this

$$\text{Adjusted life span} = \frac{7000000}{2000} = 3500 \text{ days} \sim 9.6 \text{ years}$$

Use of Miner's Rule for Cumulative Damage

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%).

Using Miner's Rule to accumulate damage per day at 2,000 cycles:

$$\text{Daily damage} = \frac{\text{Daily cycles}}{\text{Total cycles until failure}} = \frac{2000}{7000000} = 0.000285$$

Total Time to Failure: Miner's Rule confirms failure at cumulative damage of 1.0 (100%), supporting the ~9.6-year adjusted lifespan.

$$0.000285 \times 3500 = 1$$

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.