Efficient Strengthening of Concrete Cylinders Using Additively Manufactured Auxetic TPU Metamaterials

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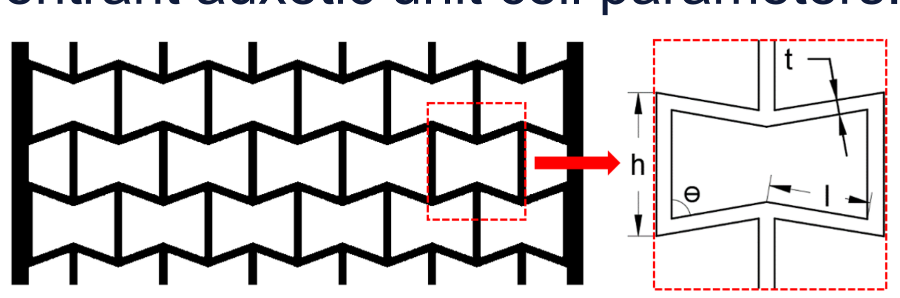
Goal

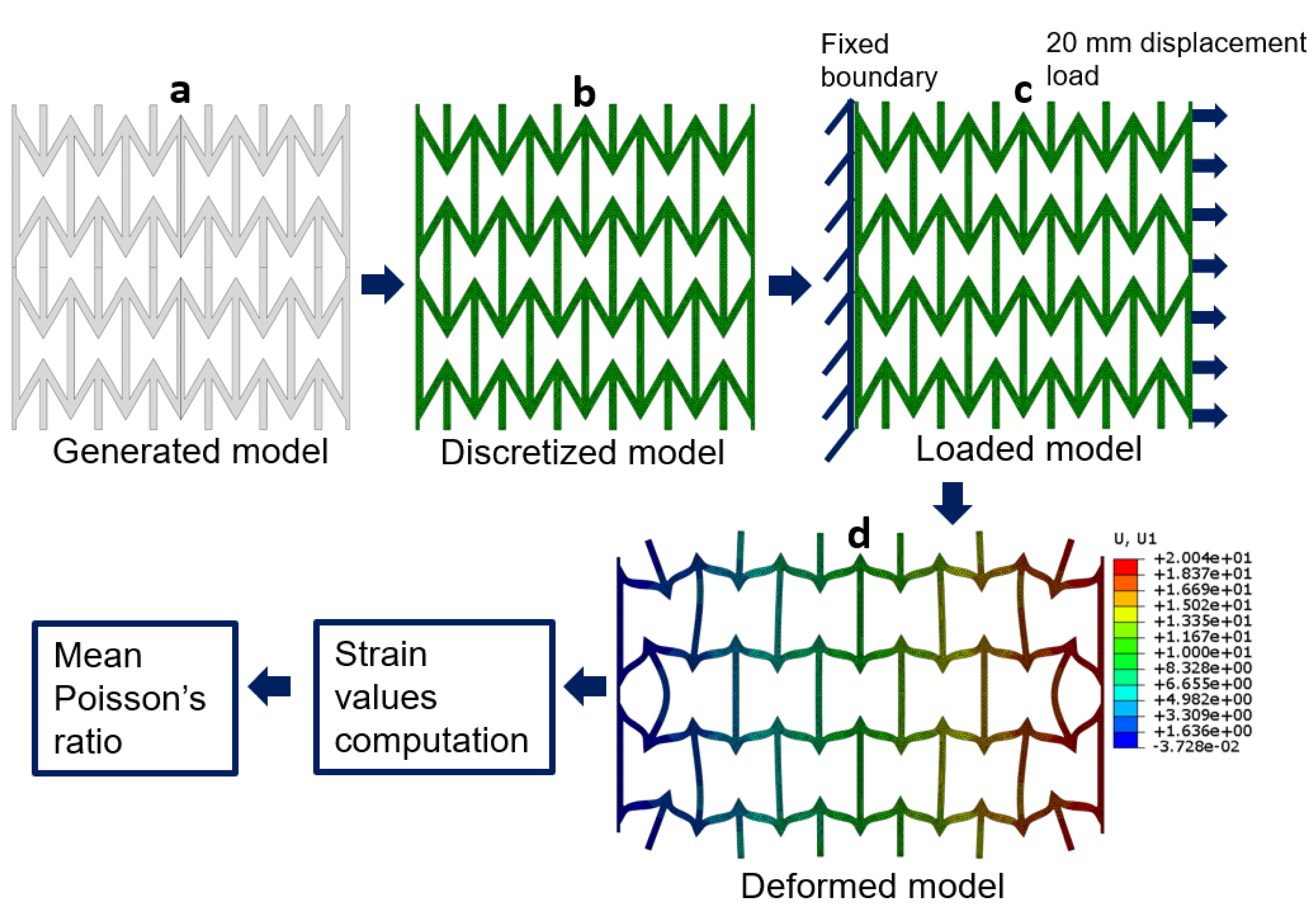
Compare and contrast strengthening design strategies based on the condition assessment of concrete cylinders. Perform finite element analysis (FEA) and experiments for the comparative assessment and evaluation of strengthening design strategies for the needs of concrete cylinders.

TPU Metamaterial

8096 auxetic geometry datasets using python scripts were generated and trained to determine the optimum reentrant auxetic unit cell parameters.



Auxetic geometry with reentrant honeycomb unit cell



Numerical Simulation Framework

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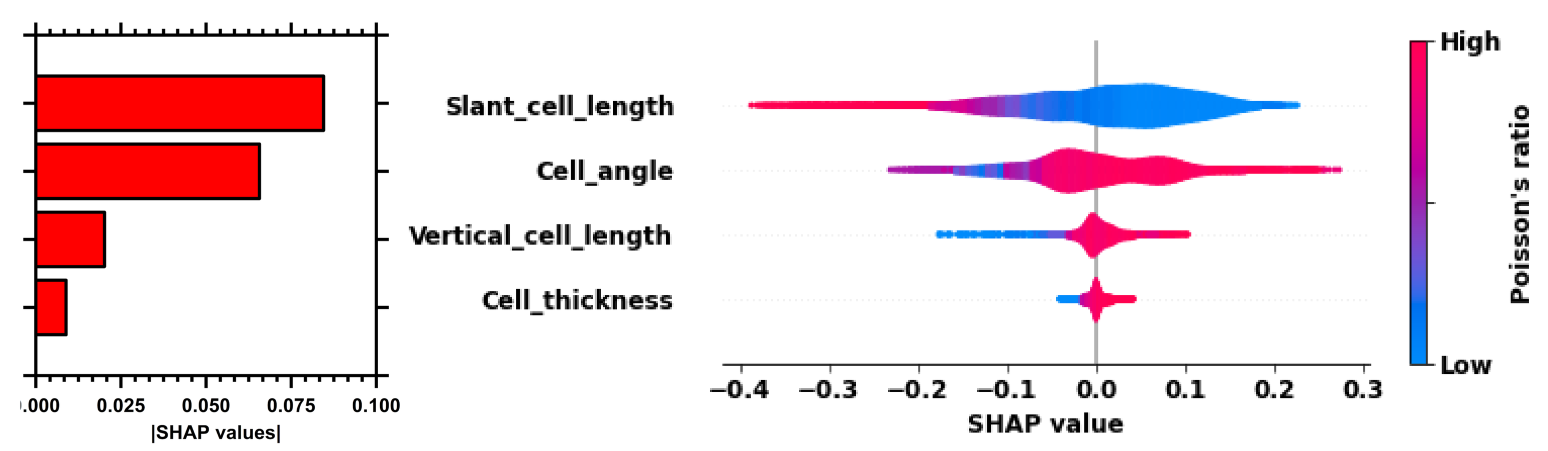
ML Implementation

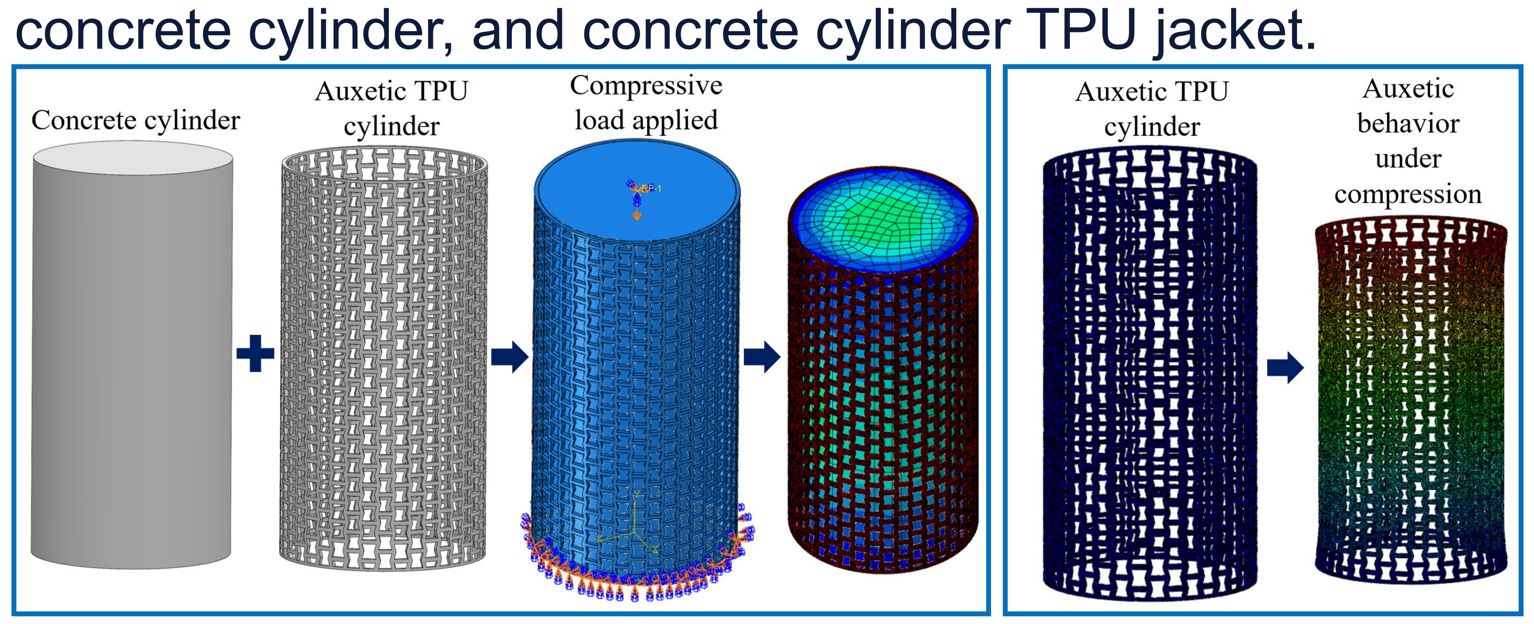
Machine Learning (ML) and SHAP violin to achieve the optimum input features combination for the Poisson's ratio.



SHAP Summary SHAP Violin

Methodology

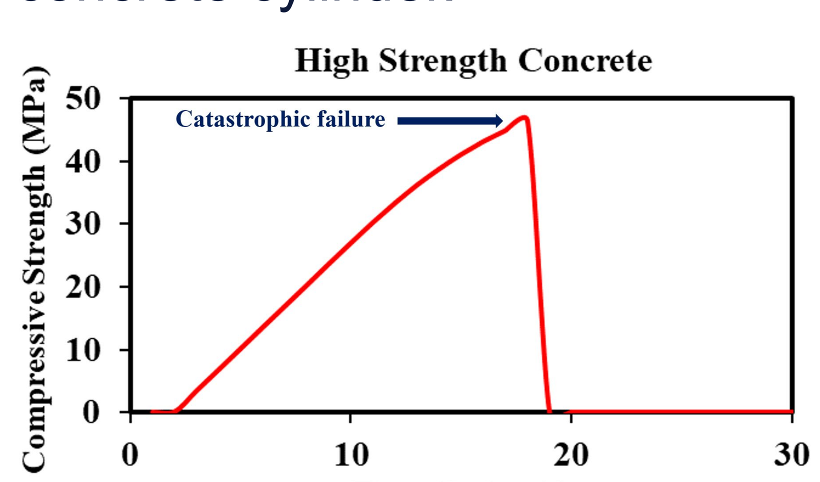
Abaqus CAE Concrete Damage Plasticity model was used for the numerical simulation of a compressive load on the concrete cylinder, and concrete cylinder TPU jacket.

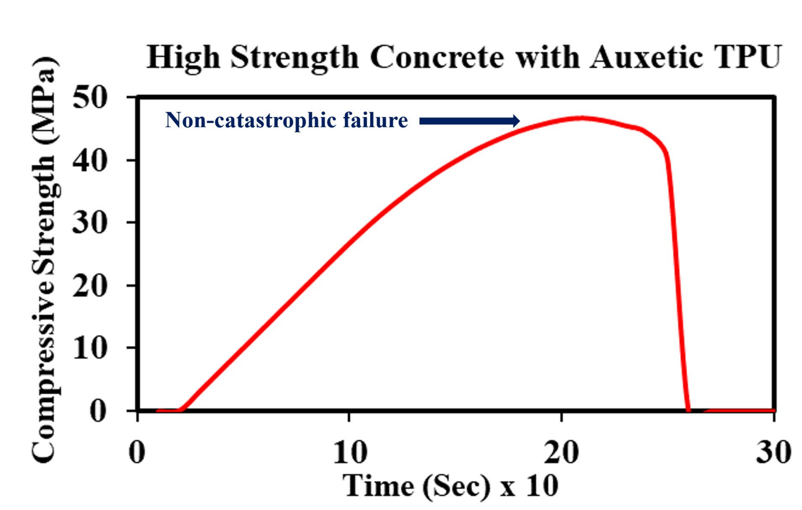


External jacketing of the concrete cylinder with an auxetic TPU cylinder. Uniaxial compressive load is applied on the TPU jacketed concrete cylinder

Preliminary Results

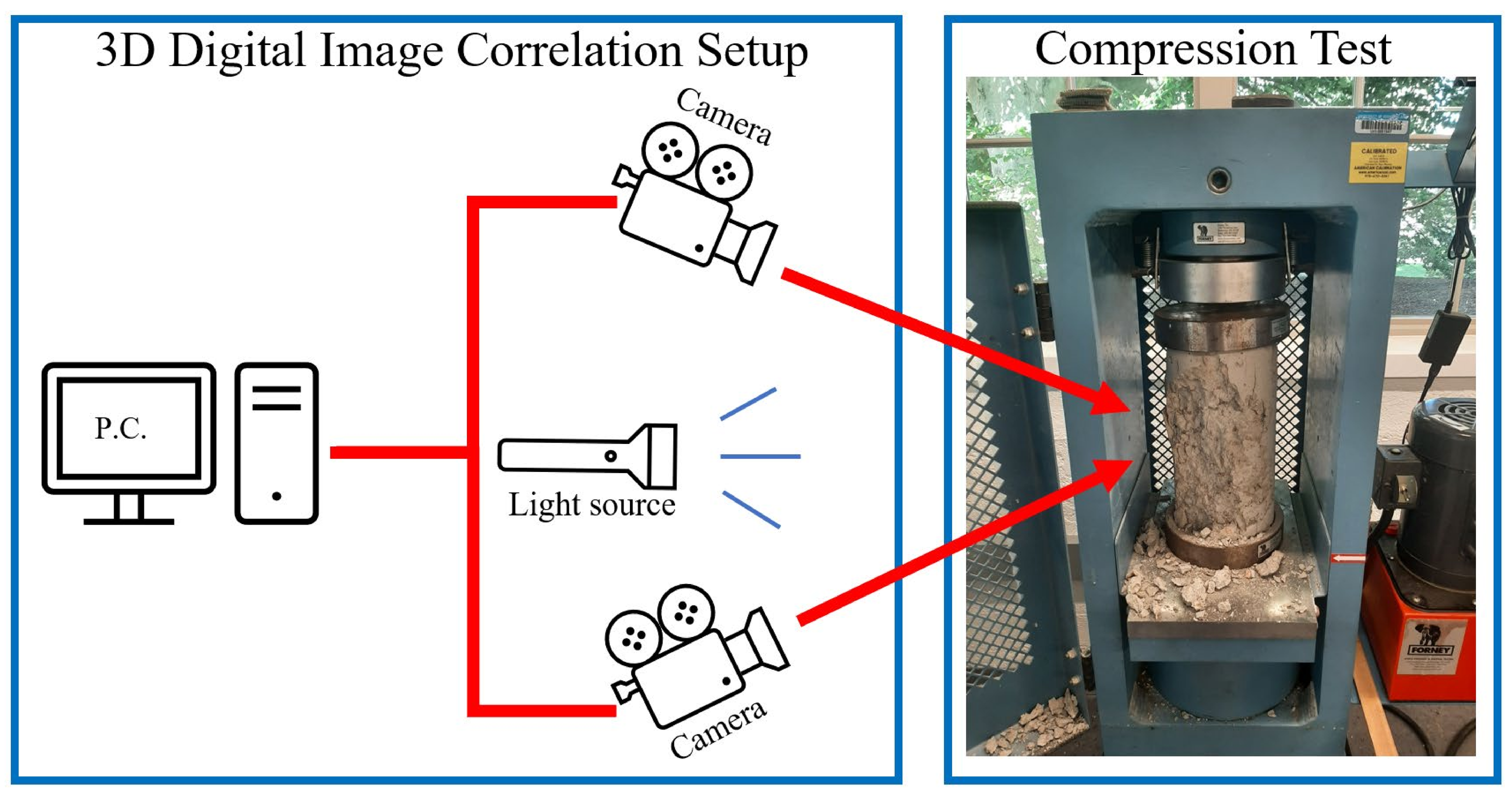
Catastrophic failure is not present in the auxetic TPU-jacketed concrete cylinder.





Experiment

3D DIC technique will be used to understand the process of damage of the unjacketed concrete cylinder, in comparison with the concrete cylinder jacketed with auxetic cylinder confinements, when tested under a quasi-static uniaxial compressive load.



Proposed 3D Digital Image Correlation setup on the auxetic cylinder jacketed concrete cylinder

Conclusion

- The results of the Poisson's ratios from the DIC analysis which are less than 3% in deviation from the mean Poisson's ratio of the corresponding auxetic structures from the FEA validated the FEA-generated mean Poisson's ratios.
- The Poisson's ratios are used to develop a predictive model for the auxetic behavior of reentrant honeycomb TPU structures using feed-forward multilayer perceptron and back propagation neural network algorithms.
- This study presents an efficient strengthening method using auxetic TPU metamaterials.

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