A MATLAB based analysis of the effect of transverse reinforcement on unconfined concrete

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Objective

To analyze and visually display, through MATLAB, the influence of transverse and longitudinal reinforcement on the behavior of a column when it is subjected to a certain load.

Background and Problem

Steel reinforcement adds strength and ductility to an unconfined concrete column. It is therefore essential to ensure that the amount and configuration of reinforcement, should be able to support a concrete column subjected to loads in order to ensure ductile behavior during structural loadings. Using proven numerical studies and a unified stress-strain approach proposed by Mander et al., we will analyze the stress-strain curve given by the performance of these circular and rectangular shaped columns under compression and establish the relationship between the differing amounts of reinforcement and the overall performance of the column.

Methodology

Use the unified stress-strain approach proposed by Mander et al. and associated formulas to define values

Create MATLAB code for member with circular cross-section

Find relationships between concrete stress and reinforcement

Create MATLAB code for member with rectangular cross-section

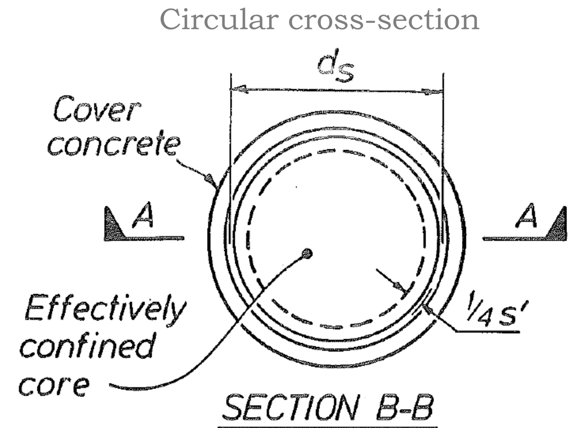
Find relationships between concrete stress and reinforcement

Make conclusions about the data

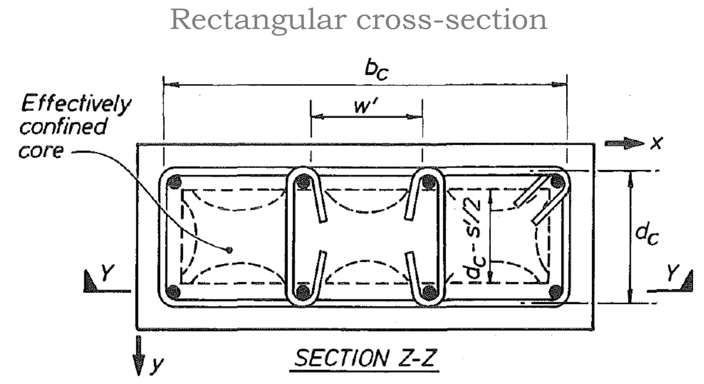
Mander's model for compressive concrete stress

$$f_c = \frac{f'_{cc} x r}{r - 1 + x^r}$$

Circular cross-section



Rectangular cross-section



Results

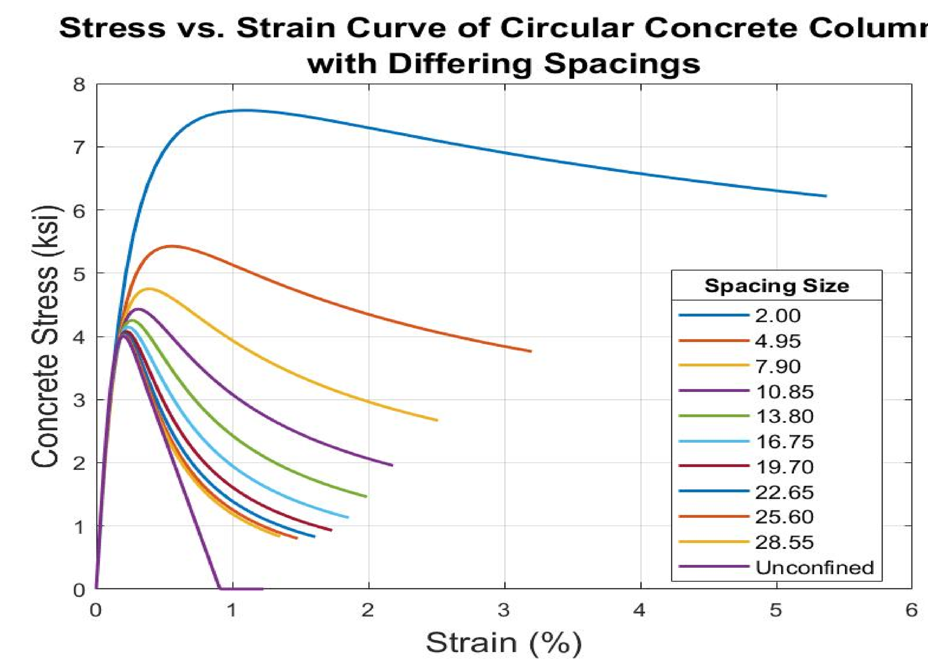


Figure 1.1: Stress-strain curve of circular cross-section with 20" diameter with increasing spacings between hoops.

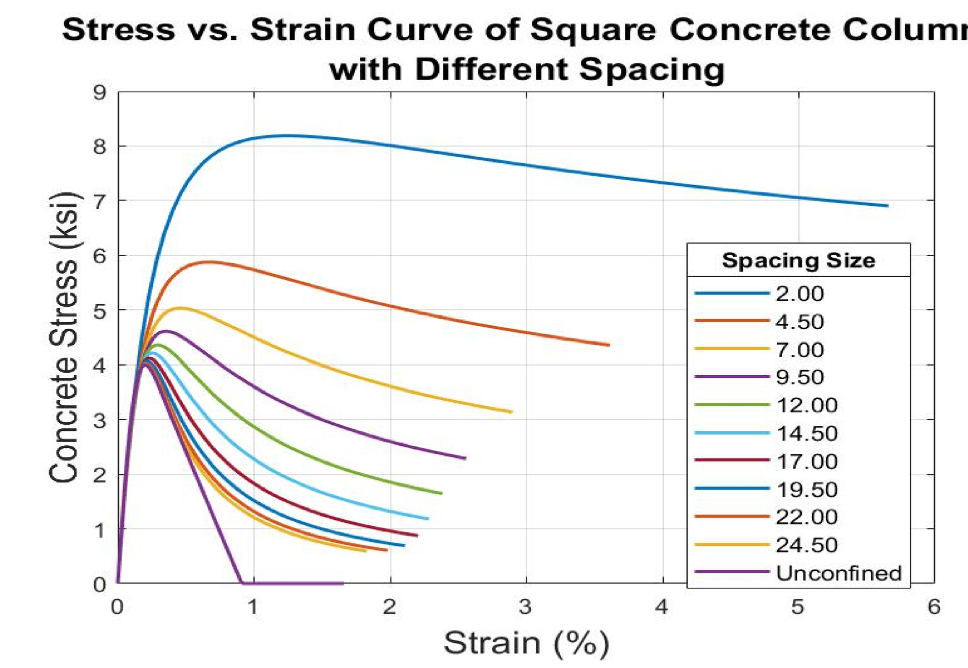


Figure 1.2: Stress-strain curve of 18" by 18" square cross-section with no crossties with increased spacings between hoops.

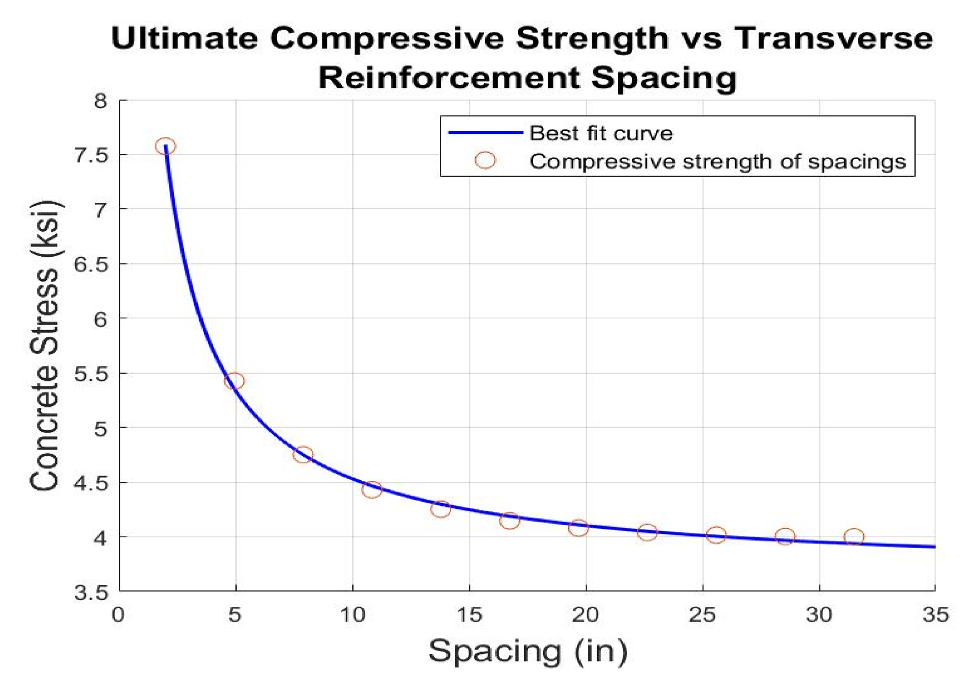


Figure 2.1: Stress-strain curve of circular cross-section showcasing relationship between spacings and their compressive strength.

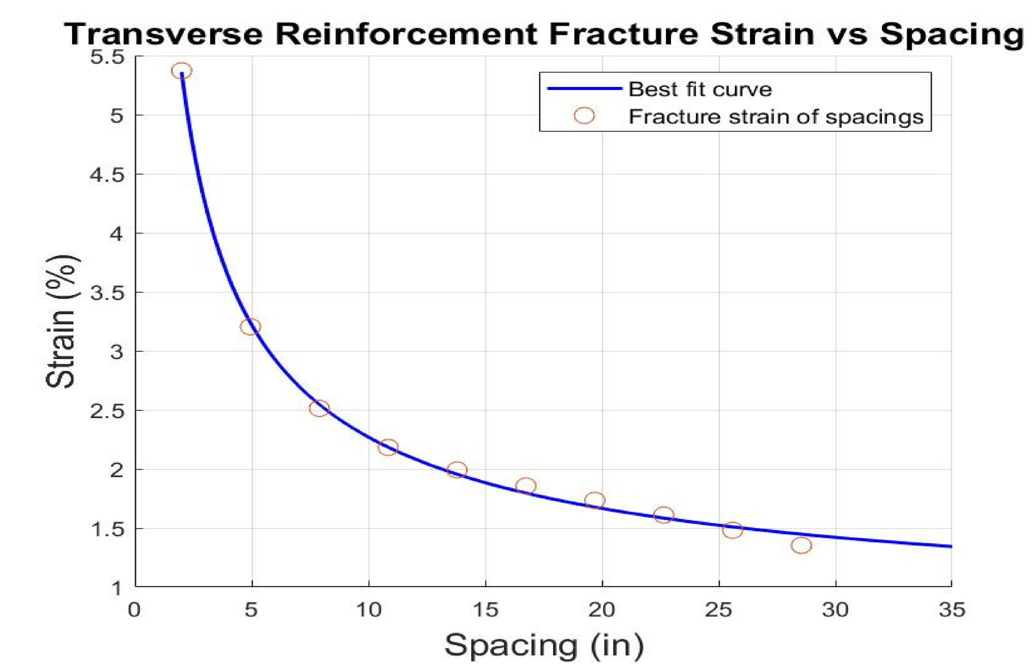


Figure 2.2: Stress-strain curve of circular cross-section showcasing relationship between spacings and their fracture strain.

Discussion

- Figure 1.1: For a circular cross-section, an increase in the center to center spacing between transverse reinforcement (hoops or spirals) leads to a weakening of the column.
- Figure 1.2: The same behavior is seen for a concrete column with a square or rectangular cross-section.

This relationship between the spacings and certain features of each stress-strain curve is demonstrated in Figure 2.1 and Figure 2.2:

- Figure 2.1: a decrease in spacings, significantly decreases the compressive strength. This relationship is modeled with MATLAB where $fc = 7.472x^{-0.9112} + 3.615$ with $R2 = 0.9984$ (fc is stress (ksi) and x is strain (%)).
- Figure 2.2: The same behavior is seen between the fracture strain and spacings and its relationship is modeled with the equation $fc = 7.468x^{-0.6543} + 6.143$ with $R2 = 0.9984$.
- Figure 3: An increase in crossties increases the number of longitudinal bars that are effectively confined, thereby increasing the overall compressive strength of the column.

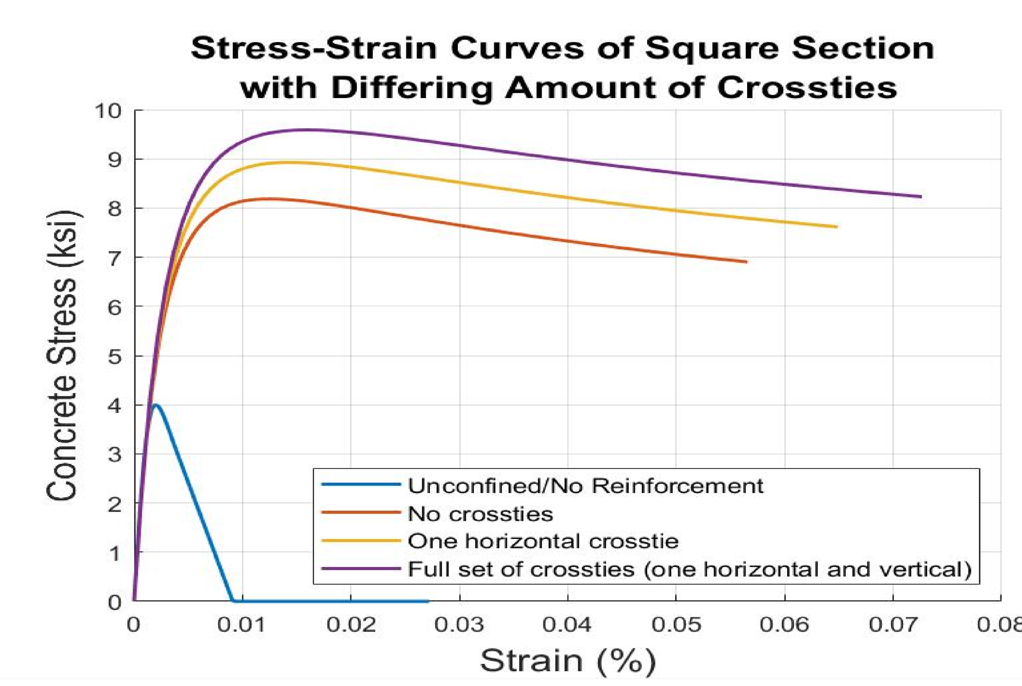


Figure 3: Stress-strain curve of 18" by 18" square cross-section with 3 longitudinal bars on each side (8 total), 2" spacing with differing amounts of crossties

Conclusion

- The compressive strength as well as the ultimate strain increases as the center-to-center spacing between the hoop bars decreases.
- Crossties prevent the buckling of longitudinal bars and thereby helps increase the strength of rectangular columns.
- Our results show that with more transverse and longitudinal reinforcement, the more ductile and stronger the column is as it can resist more load and deform more before it fractures.

Future Works

From our current findings and use of Mander's theoretical model:

- A material model can be created for concrete and steel that will predict and display the behavior of the material when it is subjected to loadings and unloadings.
- A pushover analysis can be created to demonstrate the moment required when a beam of a certain cross-section is subjected to a curvature (Φ).

Acknowledgements

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References

Mander, J. B., Priestly, M. J. N. and Park, R., 'Theoretical stress-strain model for confined concrete', ASCE J. Struct. Engng 114(8)(1988) 1804-1826