Analysis and Design of Reinforced Concrete Shear Walls Using Mathematical Programming and Optimization

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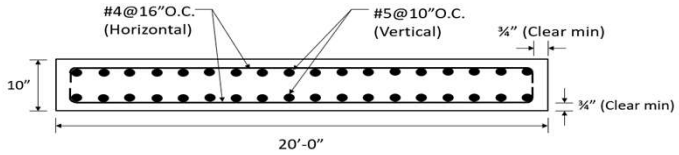
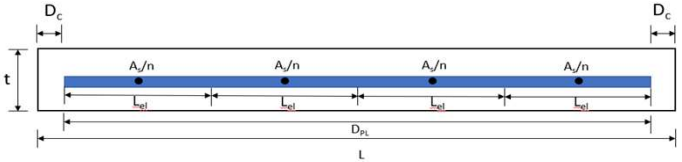
Introduction:

- This was an undergraduate research project (guided learning).
- The goal of this research was to develop a new alternative design approach of reinforced concrete shear walls using a numerical optimization technique.
- The new elemental design approach was successfully applied to one shear wall design example.
- Results were compared to hand calculation results based on the classic design method.

Method:

- The shear wall design problem was formulated as an optimization problem and elemental analysis was used.
- The design objective, variables, and constraints were defined.
- The solver in Microsoft Excel was used along with a nonlinear programming method to find the optimal design meeting all constraints.
- It allowed for straightforward applications by practicing engineers.





Formulation:

Minimize $C(c, A_s, n) = A_s$

Subject to

$$g_1(c, A_s, n) = E_{axial} = Cc - \Sigma(Fi)_I - Pu/\Phi = 0$$
$$g_2(c, A_s, n) = E_{moment} = Cc\,(L/2 - \bar{y}) - \Sigma Mni - Mu/\Phi = 0$$
$$g_3(c, A_s, n) = \rho \geq 0.15\%$$

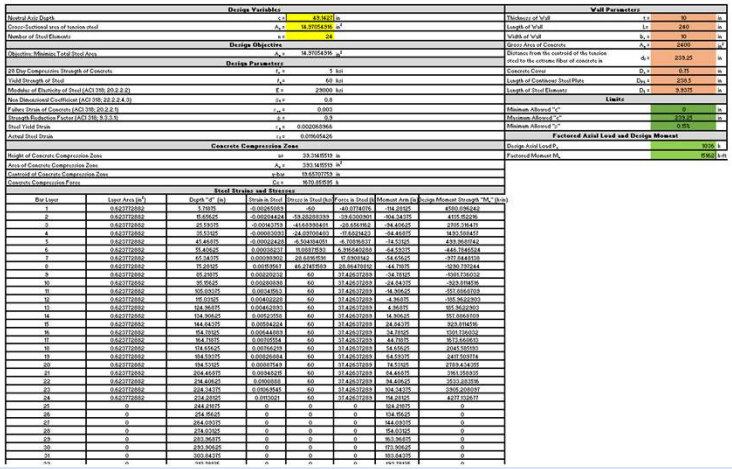
$$\varepsilon_s' = \varepsilon_{cu}\frac{(c - d')}{c}$$

d_{pl} = L – 2 × (Concrete Cover)

$L_{el} = d_{pl}/n$

$As_{el} = A_s/n$

d_{el} = Concrete Cover + $(n_i - 0.5) \times L_{el}$



Numerical Examples:

- One shear wall example was considered and was the design of a 20'-0" long reinforced concrete shear wall.
- The section was designed and was subject to a design bending moment and axial load.
- The problems had three design variables, i.e., the neutral axis depth, cross-sectional areas of tension steel and the number of elements used for analysis.
- Excel solver was used to calculate unknown design variables for the reinforced concrete shear wall.

Concluding Remarks:

- The new design approach using optimization worked very well. The same design was found as compared with the classic design method.
- The undergraduate research (guided learning) provided a new and unique learning experience to the student.
- Future research includes extension of the new approach to design of other concrete structures and members.