Basic design theory for RC shear walls

A reinforced concrete (RC) shear wall can be considered as a vertical cantilever. To be conservative, the lateral load (the wind load for this project) can be considered as a uniformly distributed load on the cantilever, \( w_s \), where \( w_s \) is the wind load per vertical foot of wall evaluated at the top of the wall across the entire width of structure in lb/ft.

Assuming the wall thickness, \( t_w \), and length, \( l_w \), are constants from the bottom to the top and the height of the wall is \( h_w \), the deformation of the wall (the cantilever) can be calculated using the equations from mechanics of materials. For example, the rotation at the top of the cantilever \( \theta \) (the slope of the wall at the top), can be evaluated by using

\[
\theta = \frac{w_s h_w^3}{6E_c I_w}
\]

in which \( E_c \) is the modulus of elasticity of concrete in psi, \( I_w \) is the moment of inertia of the cross section of the wall. \( E_c \) can be calculated using the compressive strength \( f'_c \) of concrete in psi. Note: \( E_c \) needs to be converted from psi to psf if needed in order to be consistent with the unit used for the geometry of the wall.

\[
E_c = 57000 \sqrt{f'_c}
\]

\[
I_w = 0.7 I_g = 0.7 \left( \frac{t_w l_w^3}{12} \right)
\]

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\]

in which \( I_g \) is moment of inertia of uncracked shear wall, the factor of 0.7 is to consider the effect of cracks in the wall. Design codes requires that the slope (the rotation) at the top of wall is not larger than 1/500, therefore, by combining the requirement with Eqs. (1) and (3a), we have

\[
\theta = \frac{w_s h_w^3}{6E_c (0.7 I_g)} \leq \frac{1}{500}
\]

Then, assuming the modulus of elasticity of concrete as a constant, the moment of inertia of RC shear wall should satisfy the following equation
\[ I_g \geq \frac{500w_s h_w^3}{0.7(6E_c)} \]  

(5)

This is the design equation for RC shear walls.

**Design procedure**

1. Calculate the wind load \( w_s \)
2. Calculate the modulus of elasticity of concrete \( E_c \) using Eq. (2). \( f_c' \) of concrete is in psi.
3. Select a thickness of wall \( t_w \), which should be the larger one considering the following two cases
   - The width of columns framing the wall
   - 1/25 of the unsupported height or 1/25 of the width for load bearing walls. The unsupported height is the floor height + slab thickness, and the unsupported width is the wall width + column width.
4. Select a length of wall \( l_w \), calculate the moment of inertia of uncracked wall \( I_g \) using Eq. (3b).
5. Check to make sure the selected wall geometry satisfy Eq. (5)

**Multiple shear walls**

If more than one RC shear wall is used in the direction of consideration, Eq. (3a) becomes the sum of all moments of inertia of shear walls in the direction

\[ I_w = 0.7 \sum_{i=1}^{n} I_{gi} = 0.7 \sum_{i=1}^{n} \frac{t_w I_{gi}^3}{12} \]  

(6)

in which \( n \) is the number of walls in the direction, and subscript \( i \) is for the \( ith \) wall. Substituting Eq. (6) into Eq. (1) yields

\[ \theta = \frac{w_s h_w^3}{6E_c \left( 0.7 \sum_{i=1}^{n} I_{gi} \right)} \]  

(7)

Using the same design requirement for the rotation at the top of all walls

\[ \theta = \frac{w_s h_w^3}{6E_c \left( 0.7 \sum_{i=1}^{n} I_{gi} \right)} \leq \frac{1}{500} \]  

(8)

So, assuming the modulus of elasticity of concrete as a constant, the total moment of inertia of all walls should satisfy the following equation
\[
\sum_{i=1}^{n} I_{gi} \geq \frac{500 w_i h_i^3}{0.7(6E_c)}
\]  

(9)

The same design procedure should be used to check the rotation of each wall.

**Dividing the total lateral force among multiple shear walls**

The moment of inertia of each wall in a direction of the structure can be approximately estimated as proportional to the lateral tributary area of the wall, which is reflected in \( w_{si} \). \( w_{si} \) is the wind load calculated based on the tributary width of the structure per vertical foot of wall. So, Eq. (5) becomes

\[
I_{gi} \geq \frac{500 w_{ni} h_{ni}^3}{0.7(6E_c)}
\]  

(10)

in which \( i = 1, 2, ..., n \). Eq. (10) can be used to make sure each of the selected walls satisfy the code requirement.

**Mixed structure of RC shear walls and steel bracings**

If there are RC shear walls and steel bracings in the structure at the same time, \( w_{si} \) in Eq. (10) should be the wind load calculated based on the tributary width of the \( ith \) RC shear wall. The total lateral wind load is divided by tributary areas of the lateral load carrying systems among steel bracings and RC shear walls.

**Simplified method and accurate method**

The above method is based on lateral tributary areas of the lateral load carrying systems, which is a simplified method. A more accurate method is based on lateral stiffness of the load carrying systems, in which the lateral load \( w_{si} \) is calculated based on the \( ith \) fraction of the total stiffness of the shear walls.