8.1) Axial Compression
8.2) Lateral Ties and Spirals
8.1) Axial Compression

- Columns are structural members that carry loads mainly in \textit{compression}.

- Columns can carry \textit{bending} moments as well about \textit{one} or \textit{both} (\textit{biaxial}) axes of their cross section which may produce tensile stresses over some parts of their cross section, but they remain to be compression members because compression stresses dominate.

- The 3 main types of concrete columns based on reinforcement type are:
  1. Columns reinforced with longitudinal bars and lateral ties. (most common)
  2. Columns reinforced with longitudinal bars and continuous spirals. (common).
  3. Composite compression members reinforced longitudinally with structural steel shapes with or without additional longitudinal bars and lateral reinforcement. (less common)
Columns maybe divided into:

1. **Short Columns**: properly braced against sidesway so column strength is governed by material strength. (most common)

2. **Slender Columns**: not properly braced against sidesway so their strength is significantly reduced by lateral deflection. (less common)

- The ratio of the area of longitudinal steel to the gross cross sectional area \( \frac{A_{st}}{A_g} = 0.01 \) to 0.08 according to ACI code. The lower limit is to ensure resistance to bending moment not accounted for in the analysis and to reduce the effects of creep and shrinkage.

- \( \frac{A_{st}}{A_g} > 0.08 \) is uneconomical and causes congestion in the formwork.

- Most columns are designed with \( \frac{A_{st}}{A_g} < 0.04 \).

- Larger diameter bars are used to reduce congestion and placement cost. Some larger bars are used predominantly in columns.
For lower loads at which both materials remain elastic, the steel carries a relatively small portion of the load where the steel stress is:

\[ f_s = nf_c \]  \hspace{1cm} (8.1)

where \( n = \frac{E_s}{E_c} \) is the modular ratio. In this range, the axial load is:

\[ P = f_c[A_g + (n-1)A_{st}] \]  \hspace{1cm} (8.2)

When the response reaches nonlinear range, the nominal column strength is:

\[ P_n = 0.85f_c'A_c + A_{st}f_y \]  \hspace{1cm} (8.3a)

\[ P_n = 0.85f_c'(A_g - A_{st}) + A_{st}f_y \]  \hspace{1cm} (8.3b)

At this stage, the steel carries significantly larger portion of the load than it did in the elastic range.
ACI Code 10.3.6 imposes an upper limit to the strength of the column to allow for accidental eccentricities not accounted for in the calculation as following:

\[
\Phi P_{n(max)} = 0.85\Phi [0.85f'_c(A_g - A_{st}) + A_{st}f_y]
\]  \hspace{1cm} (8.4a)

where \(\Phi = 0.75\) for spirally reinforced columns, and:

\[
\Phi P_{n(max)} = 0.80\Phi [0.85f'_c(A_g - A_{st}) + A_{st}f_y]
\]  \hspace{1cm} (8.4b)
8.2) Lateral Ties and Spirals

- Column cross sections frequently found in construction are shown.

- Rebars in columns with small bending moment are spaced uniformly around the perimeter (a-d).

- When the bending moment is large, rebars are placed in maximum tension and compression regions (e-h).

- In order to avoid formwork congestions, bundled bars are frequently employed.
Lateral reinforcement, in the form of widely spaced ties or continuous closely spaced spiral, serve two main functions:

1. Hold longitudinal bars in position.
2. Prevent rebars from buckling and bursting out of concrete.

In order to serve these functions, while maintaining cost effectiveness by minimizing the number of ties, ACI Code 7.10.5 gives the rules governing the arrangement of ties, while Code 7.10.4 gives the requirements for spirals.

Note that the use of spiral significantly improves the structural performance of a column which is reflected by the ACI Code.
ACI Code 10.9.3 mandates that the ratio of spiral reinforcement shall not be less than:

$$\rho_s = 0.45 \left( \frac{A_g}{A_{ch}} - 1 \right) \frac{f_c'}{f_{yt}}$$

where $f_{yt}$ shall not be taken greater than 700 MPa, and the spiral reinforcement not be spliced if $f_{yt}$ is greater than 420 MPa.

It can be taken from (8.5) that for two concentrically loaded columns designed with ACI code one with tied and one with spiral but otherwise identical, will fail at about the same load, the former in a sudden and brittle manner while the latter gradually with prior spalling of the shell and with more ductile behavior. For this reason, then ACI permits somewhat larger design loads and spiral ($\phi = 0.75$) than on tied ($\phi = 0.65$) columns.

This advantage is deteriorated as the load becomes more eccentric and it is almost diminished at large eccentricities.

The design of spiral reinforcement to the ACI code provisions is easily reduced to a tabular form.
<table>
<thead>
<tr>
<th>Diameter of Column, mm</th>
<th>Out to Out of Spiral, mm</th>
<th>21</th>
<th>28</th>
<th>35</th>
<th>42</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f_y = 420 ) MPa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400–475</td>
<td>320–395</td>
<td>10-65</td>
<td>10-50</td>
<td>13-70</td>
<td>13-60</td>
</tr>
<tr>
<td>500</td>
<td>420</td>
<td>10-70</td>
<td>10-50</td>
<td>13-70</td>
<td>13-60</td>
</tr>
<tr>
<td>525–725</td>
<td>445–645</td>
<td>10-70</td>
<td>10-50</td>
<td>13-75</td>
<td>13-60</td>
</tr>
<tr>
<td>750</td>
<td>670</td>
<td>10-70</td>
<td>10-50</td>
<td>13-75</td>
<td>13-65</td>
</tr>
<tr>
<td>( f_y = 550 ) MPa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>450, 475</td>
<td>370, 395</td>
<td>10-85</td>
<td>10-65</td>
<td>10-50</td>
<td>13-80</td>
</tr>
<tr>
<td>575–700</td>
<td>495–620</td>
<td>10-85</td>
<td>10-70</td>
<td>10-55</td>
<td>13-80</td>
</tr>
<tr>
<td>725, 750</td>
<td>645, 670</td>
<td>10-85</td>
<td>10-70</td>
<td>10-55</td>
<td>13-85</td>
</tr>
</tbody>
</table>