COLUMNS

Section

3-3

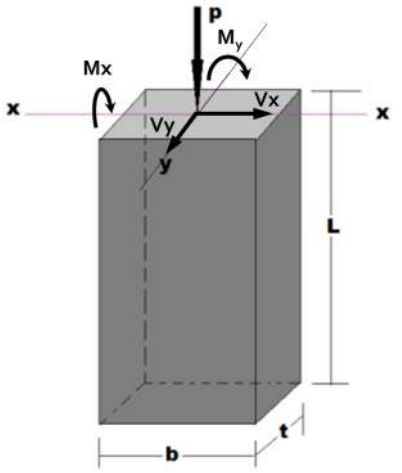
Columns – Definition & Materials

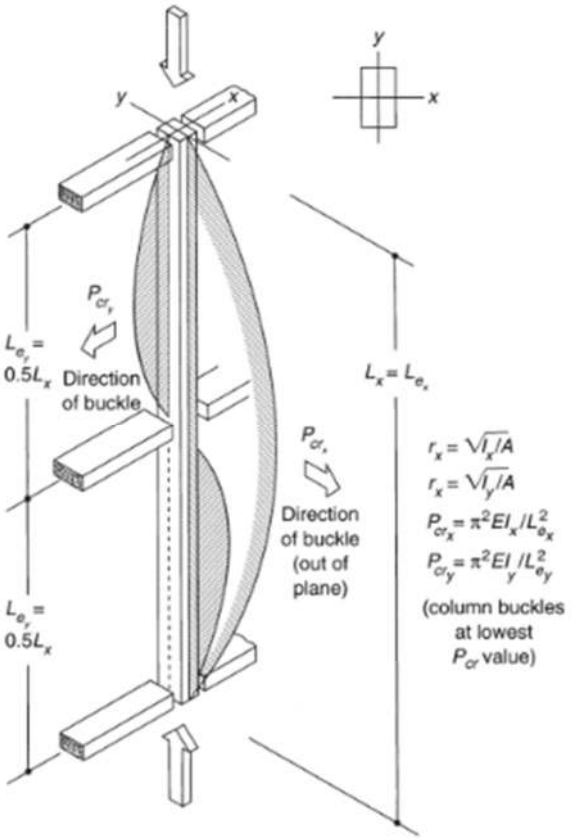
- **Definition**. Typically, columns are vertical structural elements that support loads from the floors and roof slabs and transfer these loads to the footings. Strictly speaking, columns need not be only vertical. Rather, they are rigid linear elements that can be inclined in any direction, but to which loads are applied solely at member ends.
- **Material.** Common column materials are:
  - Stones or block (Pillars)
  - Timber
  - Steel
  - Concrete

Columns designed to carry significant loads are made of structural steel , reinforced concrete or both (composite).

Column Stresses & Capacity

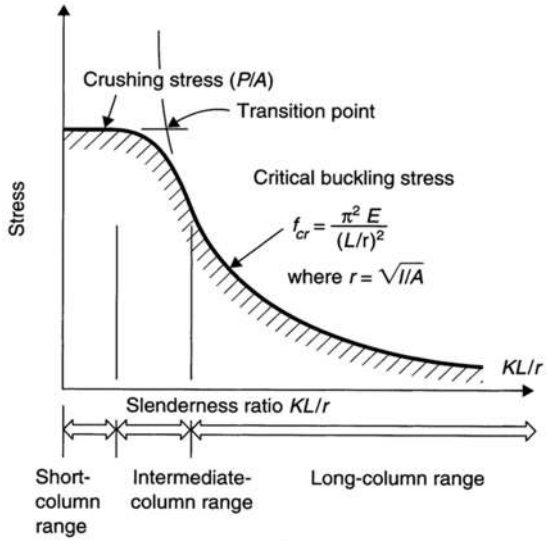
- Although columns are designed to carry vertical loads (P), the stress in columns also includes uniaxial bending, biaxial bending, and shear stress in addition to axial stress.
- The load-carrying capacity of a column is determined based on the cross section properties (area(A); Inertia (Ix and Iy); radius of gyration - $r = \sqrt{I/A}$; and the slenderness ratio $\frac{KL}{r}$, Where L is the unsupported length of the column and K is column effective length factor varies between 0.5 to 2.0 based on the column end conditions.

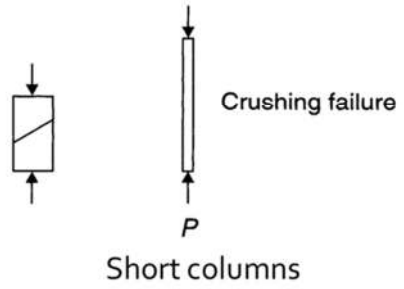


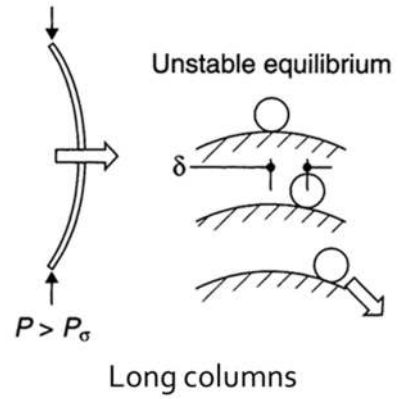


Column Stresses & Capacity

- The slenderness ratio has a detrimental effect on the load-carrying capacity of the column. As shown in the figure, the column load-carrying capacity decreases where the slenderness ratio increases.
- Accordingly, columns can be categorized in terms of their slenderness ratio as:
  1. Short columns tend to fail by crushing. The strength depend on cross sectional area and material strength. Those can be quite strong and carry high loads.
  2. Long columns tend to fail by buckling, which is an instability failure rather than a strength failure.



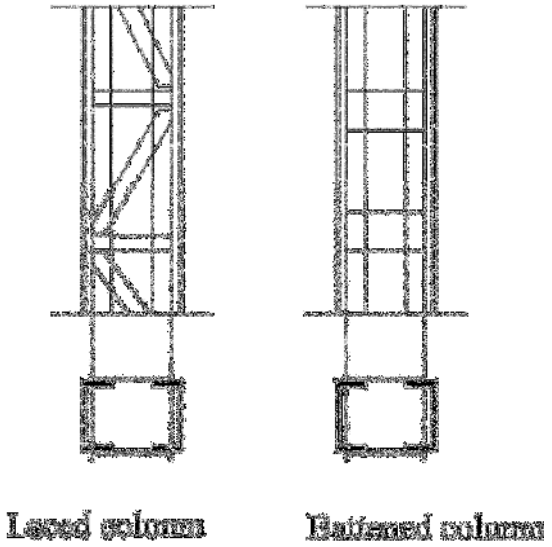




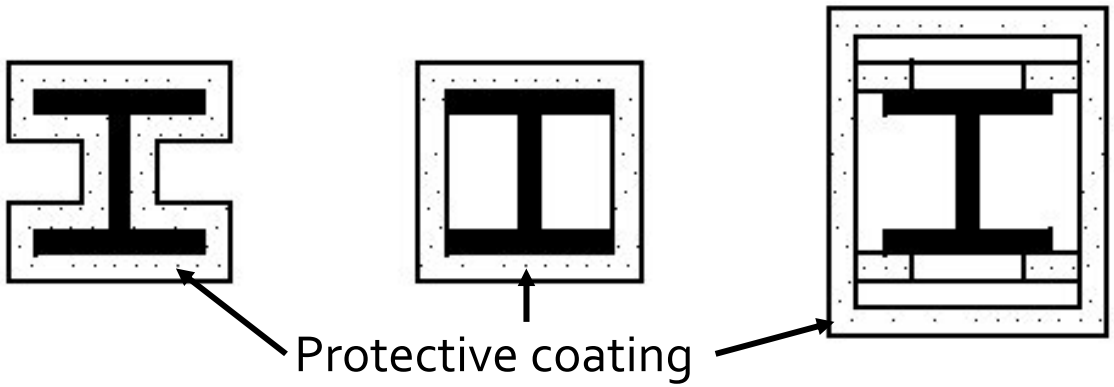
Steel Columns

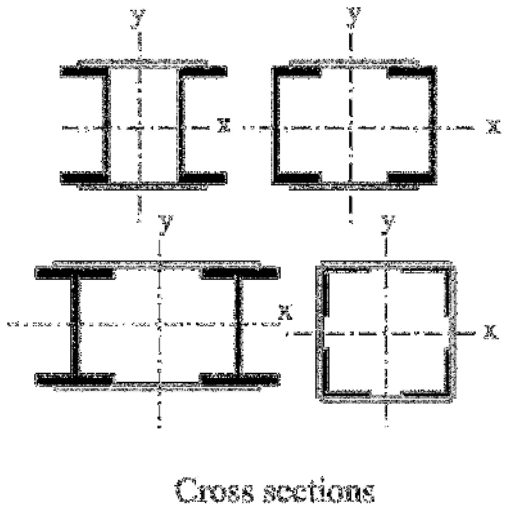
- Steel columns are fabricated:

1. Utilizing the standard structural steel sections such as H, I, tubes, or pipe sections.
2. Developing a built–up section by jointing several structural sections, as shown in the figure, or welding steel plates to the desired shape.



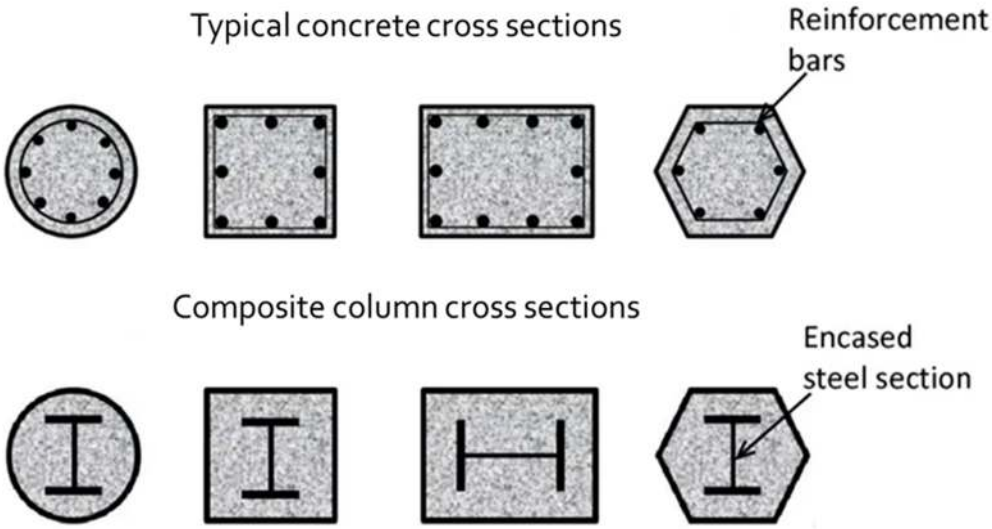
- In addition to buckling, steel is sensitive to temperature, so all structure steel members shall be fireproofed, as shown below.





Reinforced Concrete Columns

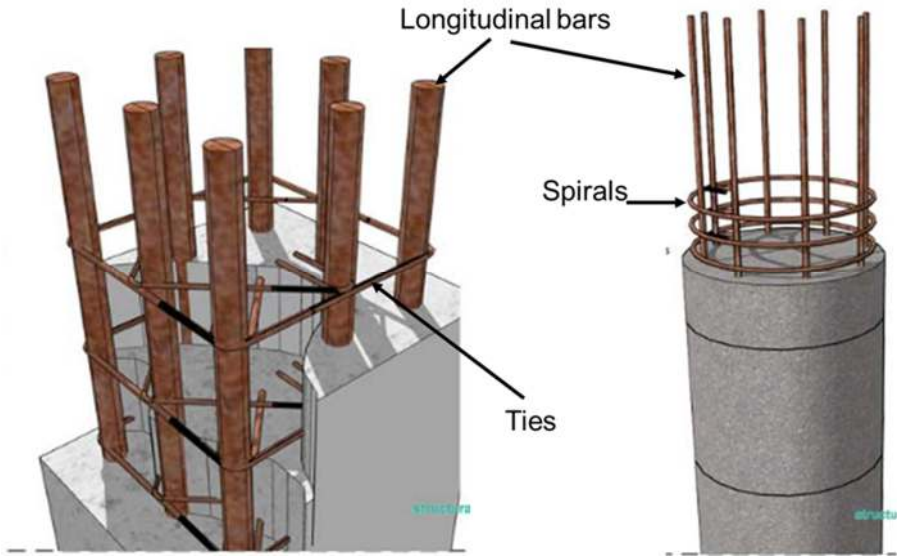
- Concrete columns have a breadth-to-thickness ratio of less than 3 to 4. Where the ratio exceeds 4, the element is considered a wall.
- Regarding cross-sections, they may be square, rectangular, circular, octagonal, or any of a variety of shapes in cross-section, such as T or L.



- Concrete columns may be classified as **long or short** columns. The column is considered long when the ratio of its height to the smallest cross-section dimension is more than 12. otherwise, it is considered short.

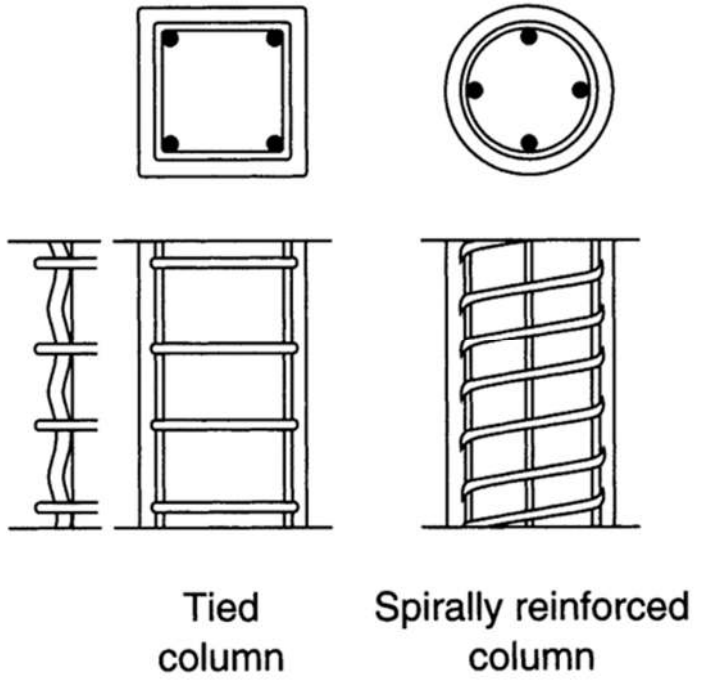
Concrete Columns Reinforcement

As shown in the figure, concrete columns are typically reinforced by:



1. Longitudinal bars - Main bars: resist compression loads and tension force due to bending.

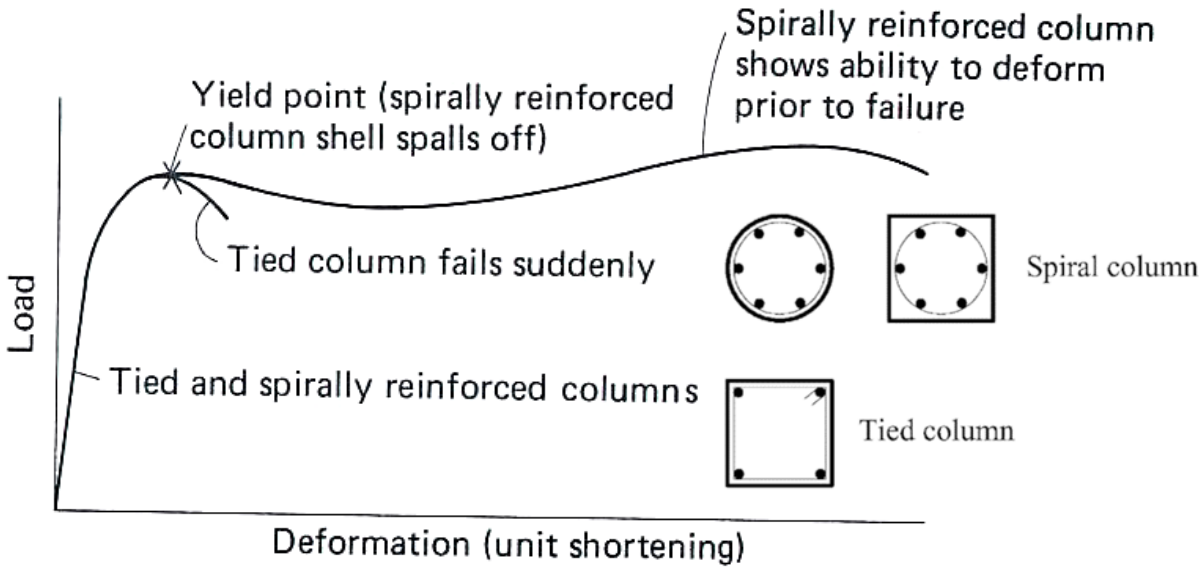
2. Transverse reinforcement: resist shear forces, if any, and laterally support longitudinal bars to prevent buckling. These include:
   - Ties (Tied Columns)
   - Spiral (Spirally-Reinforced Columns)
   - Links



Concrete Columns Reinforcement

Behavior of Tied and Spirally-Reinforced Columns

- After reaching the ultimate load, the tied column fails suddenly. On the other hand, the spirals provide a confining force to the concrete core in the spiral column, thus enabling the column to sustain large deformations before the final collapse occurs.



- Accordingly, ductility in columns can be ensured by providing spirals or closely spaced ties.

Design & Detailing Requirements

1. **Concrete grade**
   - It shall be noticed that Concrete grade is important in columns, as they are – mainly – compression members.
   - Concrete grades less than 28/35 MPa (cylinder strength/ cube strength) are not normally used.
2. **Maximum and Minimum Reinforcement Ratios**
   - Minimum 1 % and maximum 8 % of cross section area.
3. **Number of bars and bars distribution**
   - Minimum 4 and 6 bars for rectangular and circular columns respectively.
   - The recommended minimum bar diameter is 16mm.
   - Total number of bars shall be even to ensure symmetrical distribution to two or four sides.

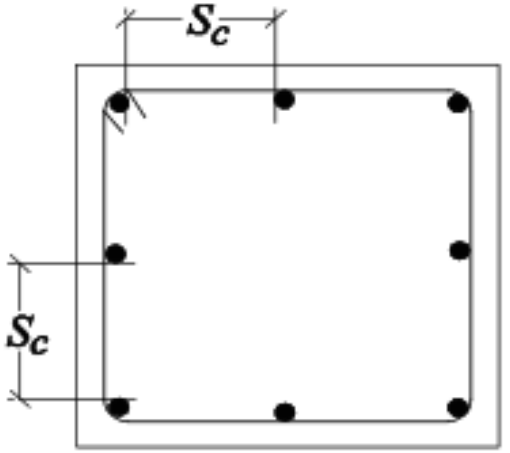
Design & Detailing Requirements

4. Minimum Cross Sectional Dimensions

- Although there is no limit to column size in the code for vertical load design, it is recommended that the least dimension of the column cross section shall be $\geq$ 250mm.
- For practical considerations, column dimensions are taken as multiples of 5 cm.

5. Clear Distance between Reinforcing Bars

- ACI specify that for tied or spirally reinforced columns, clear distance between bars (S_c) shall not to be less than the larger of 1.50 times bar diameter or 4 cm.



Lateral Reinforcement

- Column lateral reinforcement (Ties, Spirals) are effective in restraining the longitudinal bars from buckling out through the surface of the column, holding the reinforcement cage together during the construction process, confining the concrete core and when columns are subjected to horizontal forces, they serve as shear reinforcement.

- **Ties (stirrups) and links requirements**

- **Size**

i. Φ10 mm if longitudinal bar ≤ Φ32 mm
ii. Φ12 mm if longitudinal bar ≥ Φ36 mm
iii. Φ12 mm if longitudinal bars are bundled

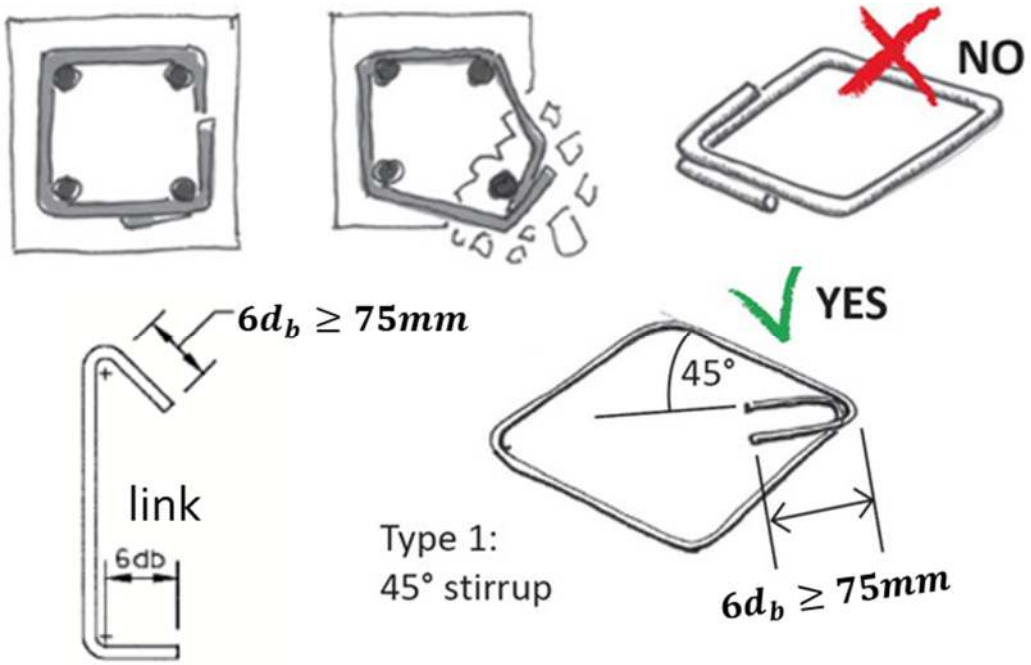
- **Vertical spacing (S), smallest of**

i. 16 times longitudinal bar diameter.
ii. 48 times tie diameter.
iii. Least cross sectional dimension.

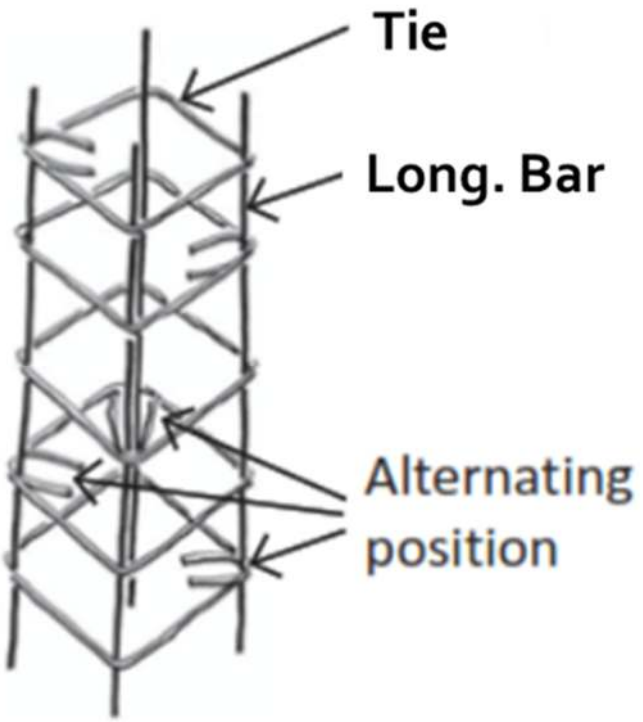
Buckling of main bars in columns due to ties large spacing

Lateral Reinforcement

- **Ties and links arrangement**



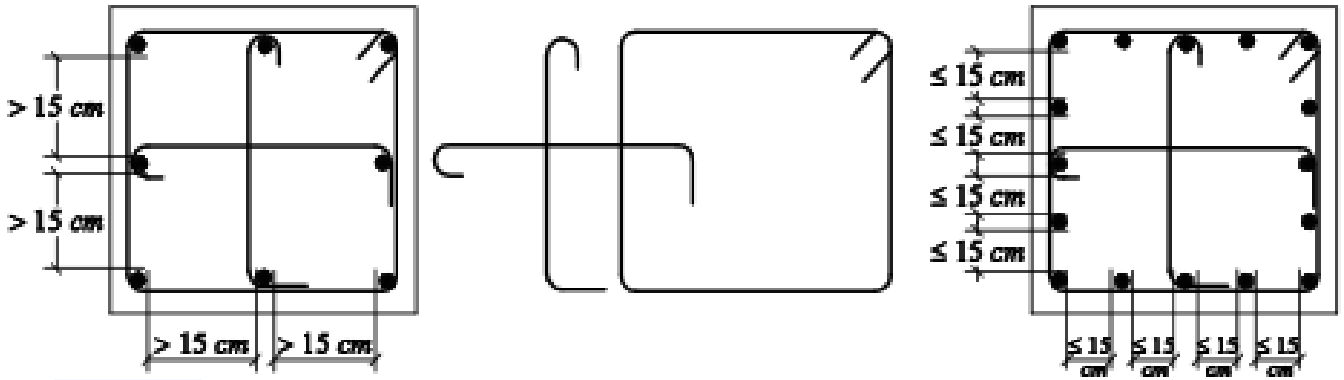
Standard hook requirements



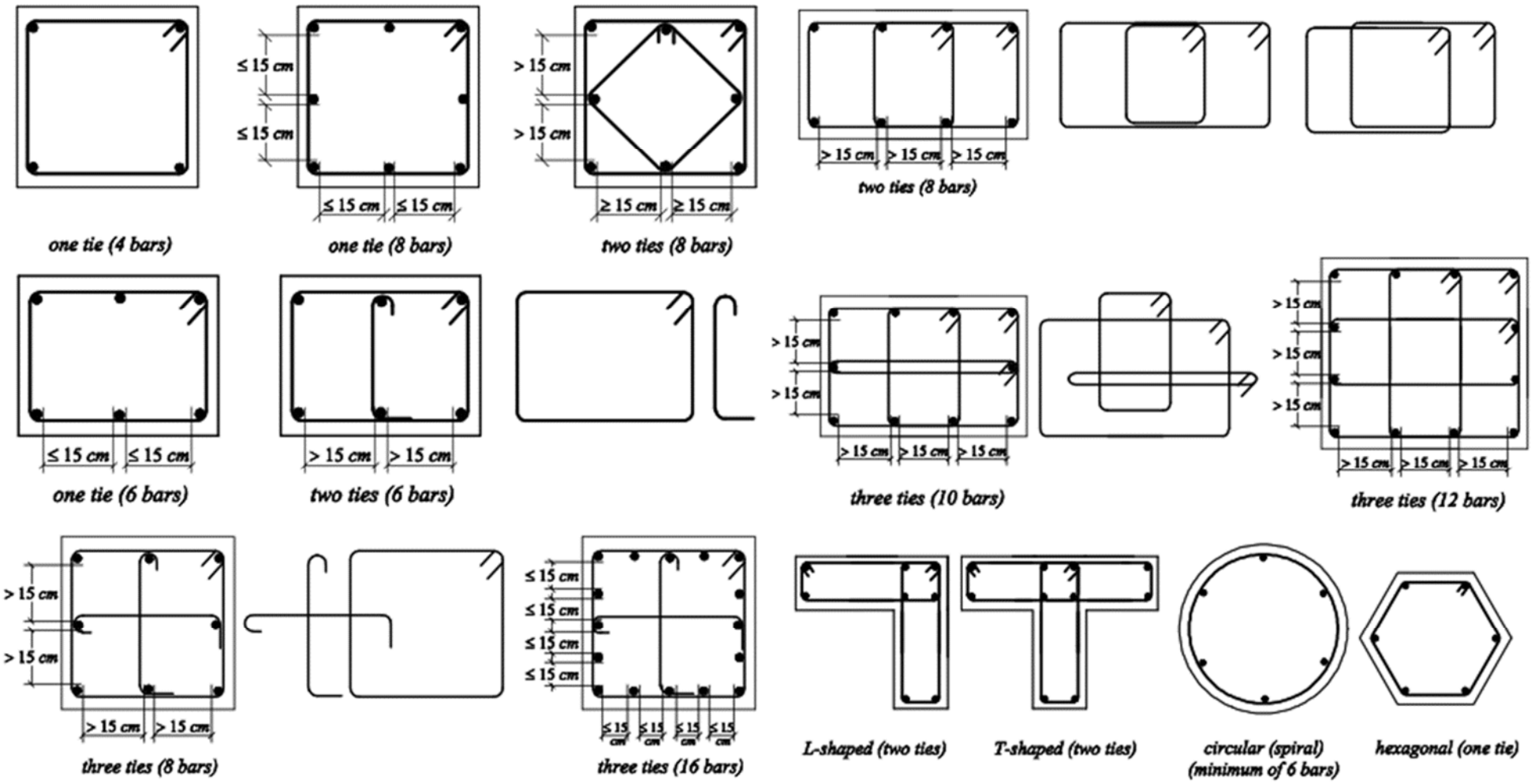
Alternating the position of hooks in the longitudinal direction

Lateral Reinforcement

- **<u>Minimum number of ties or links in the cross section:</u>** although number of ties shall be calculated based on shear stress, ACI specifies that ties and links shall be arranged in such a way to restrain every single longitudinal bar, so:
- Every corner bar shall be restrained by the corner of a tie with an included angle of not more than 135 degrees.
- All bars shall be restrained by link/ tie where bars are spaced at centers > 150 mm.
- At least every alternate bar shall be restrained by link/ tie where bar centers < 150mm.

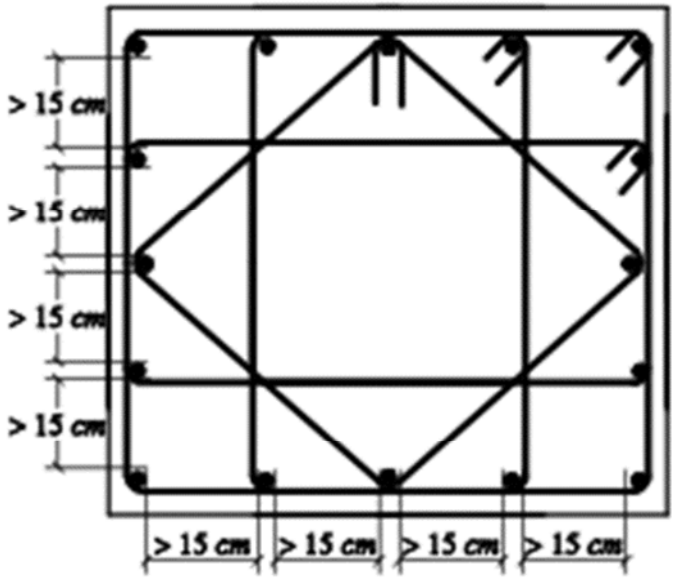


Lateral Reinforcement

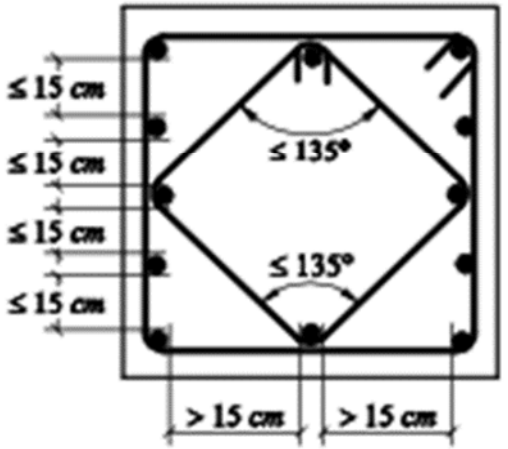


Ties and links arrangement in the cross section - Examples

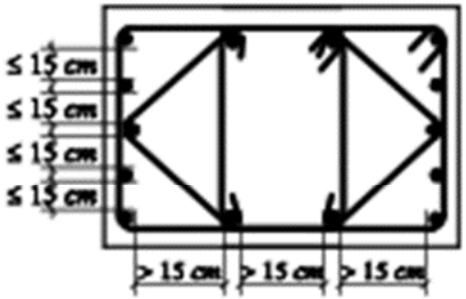
Lateral Reinforcement



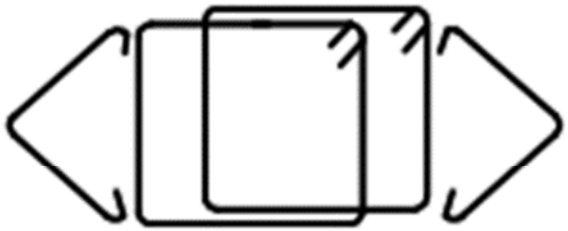
four ties (16 bars)

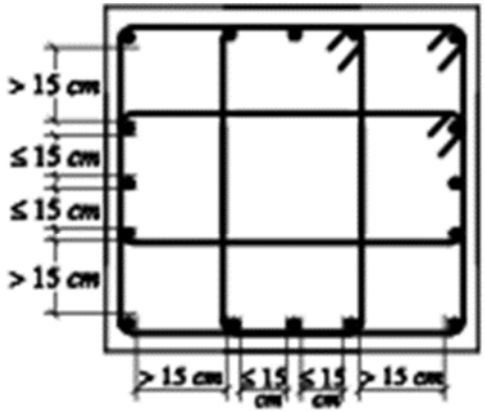


two ties (12 bars)



four ties (14 bars)



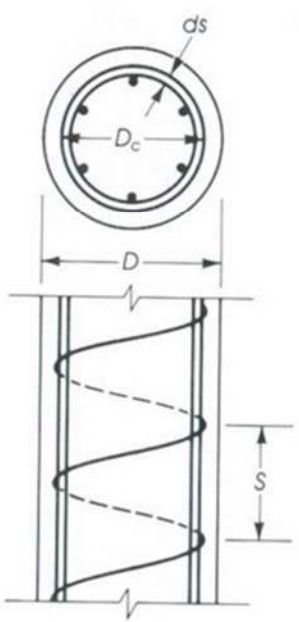


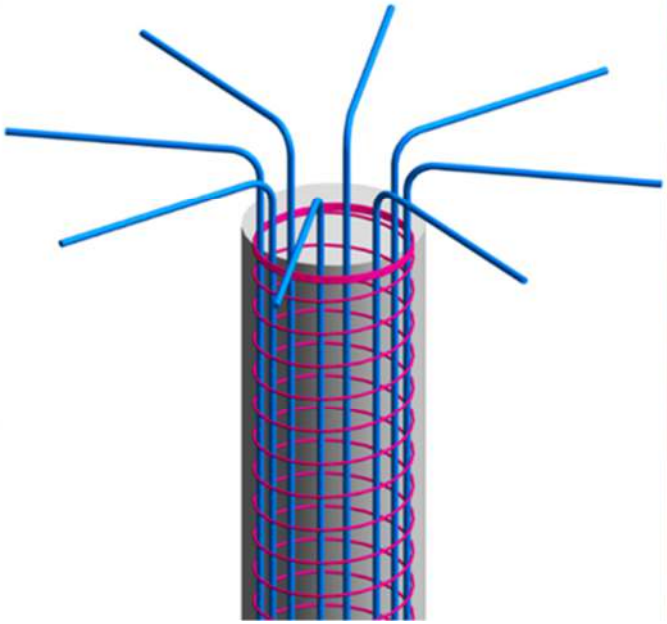
three ties (12 bars)

Ties and links arrangement in the cross section - Examples

Lateral Reinforcement

- **Spirals**
  - According to ACI:
    - Spirals shall not be less than 10 mm (ds) in diameter.
    - The clear pitch of the spiral (S) is not to be less than 2.5 cm and not more than 7.5 cm.





Lateral Reinforcement

- **Notes**

In any case, one should notice that the arrangement of ties, links, or spirals in the column cross-section may affect:

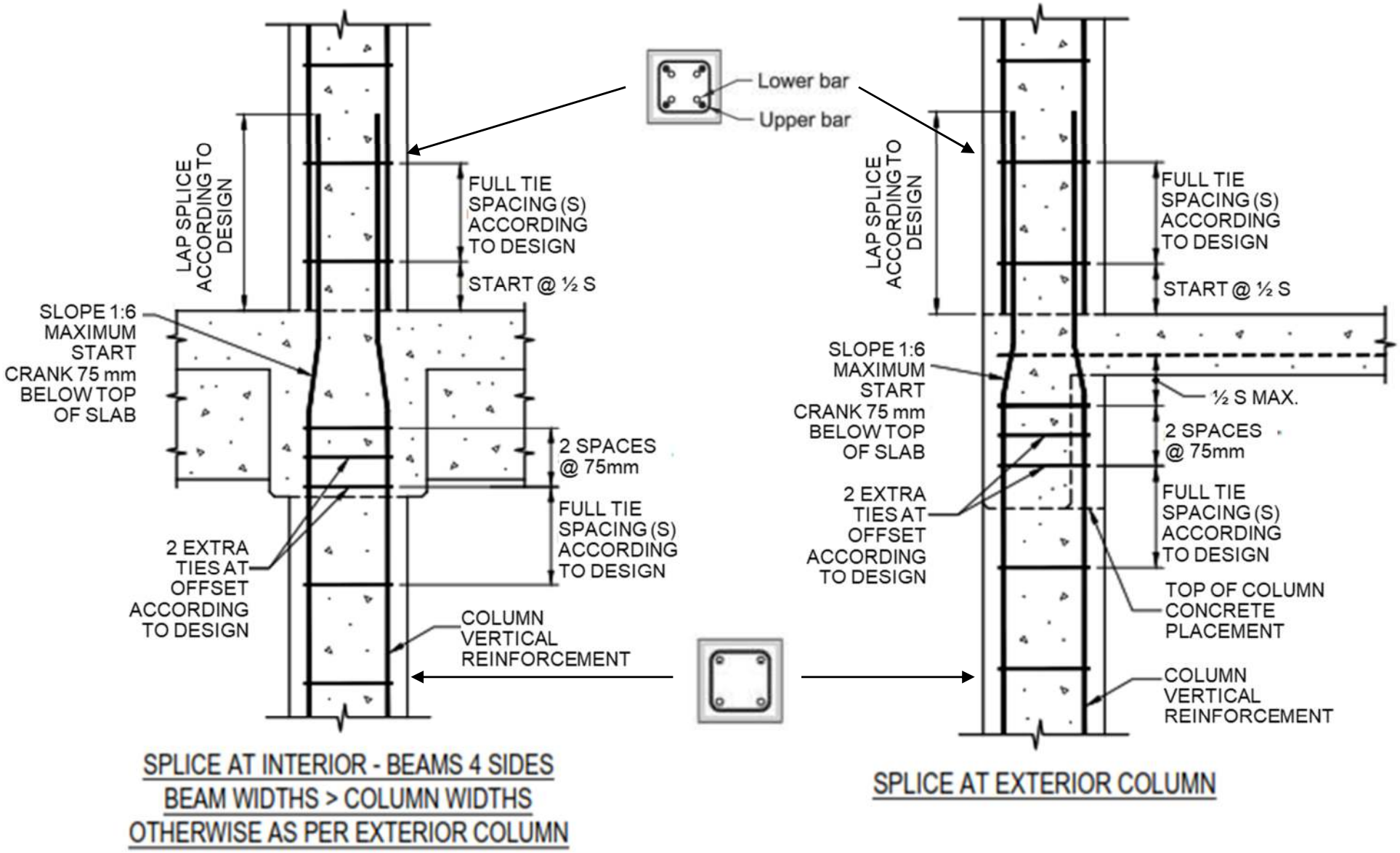
- Concrete mix parameters, including slump and maximum aggregate size.

- Method of concrete placing and compaction to minimize potential segregation and poor consolidation. It is recommended to provide a free space of 15 cm in diameter to allow the pump pipe to be lowered in the column up to 1m from the bottom.

Column splice and surface offset

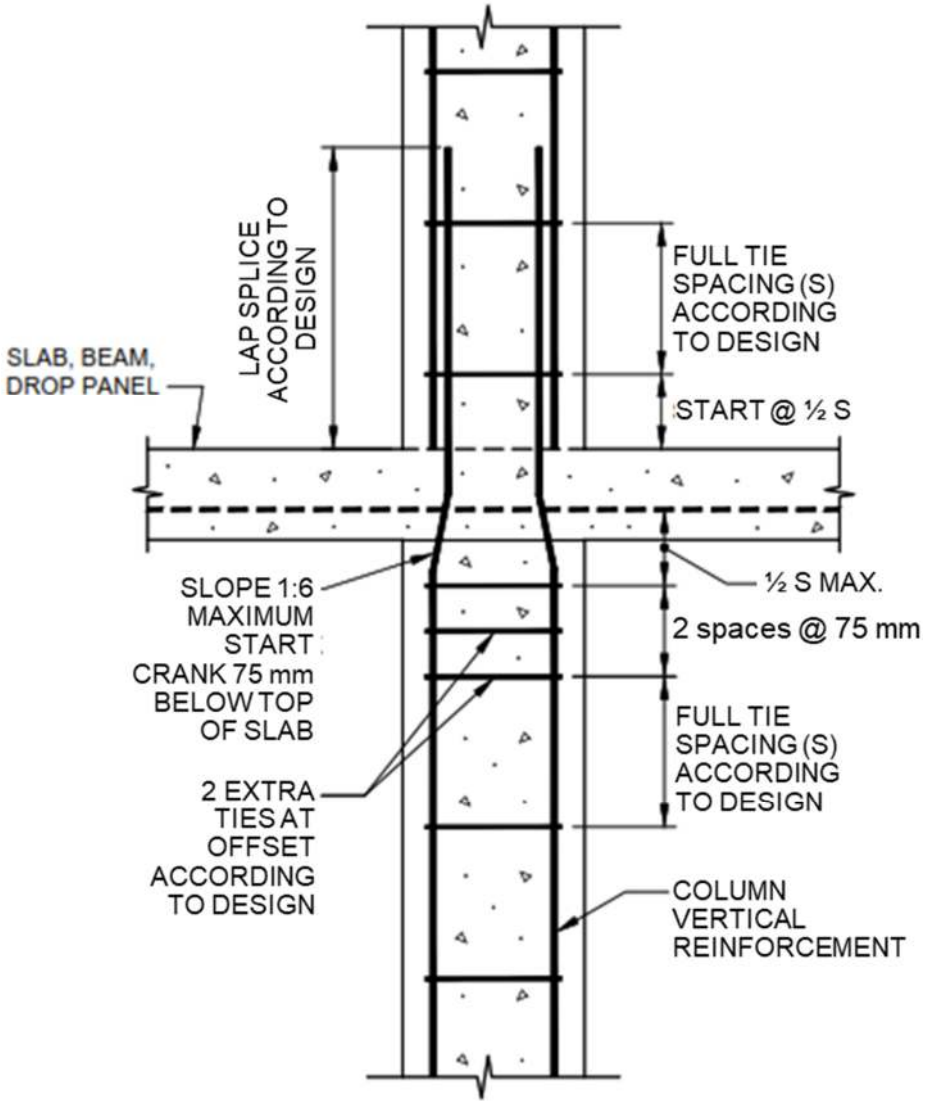
- In most cases, column reinforcement is spliced on every floor. The splice brings some problems during construction, such as steel congestion at the splice location. Mechanical couplers can solve the problem, yet it is not always feasible.
- Typical details of columns splices are shown I the following slides.

Typical Details of Column Splices

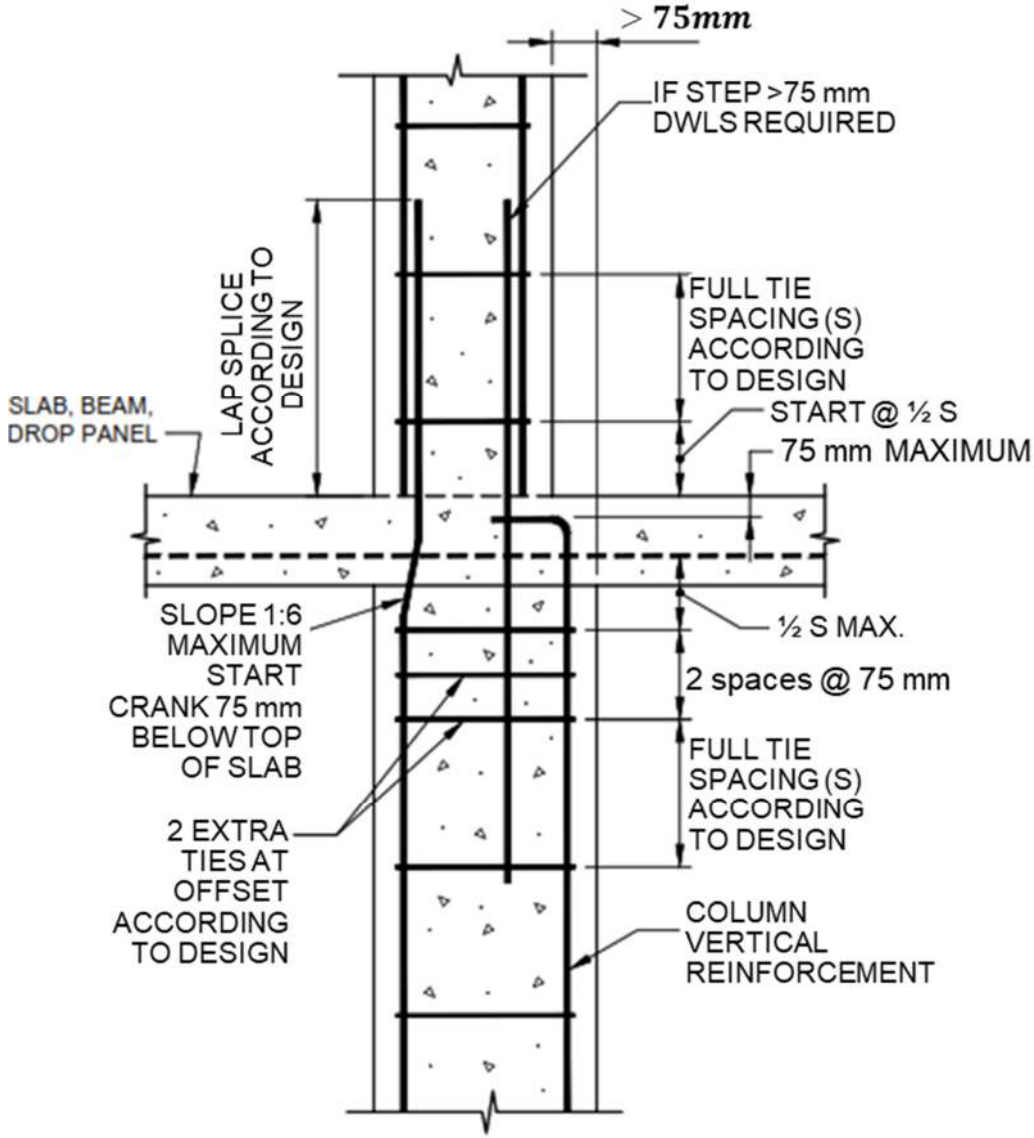


COLUMNS WITH DROP BEAMS

Typical Details of Column Splices

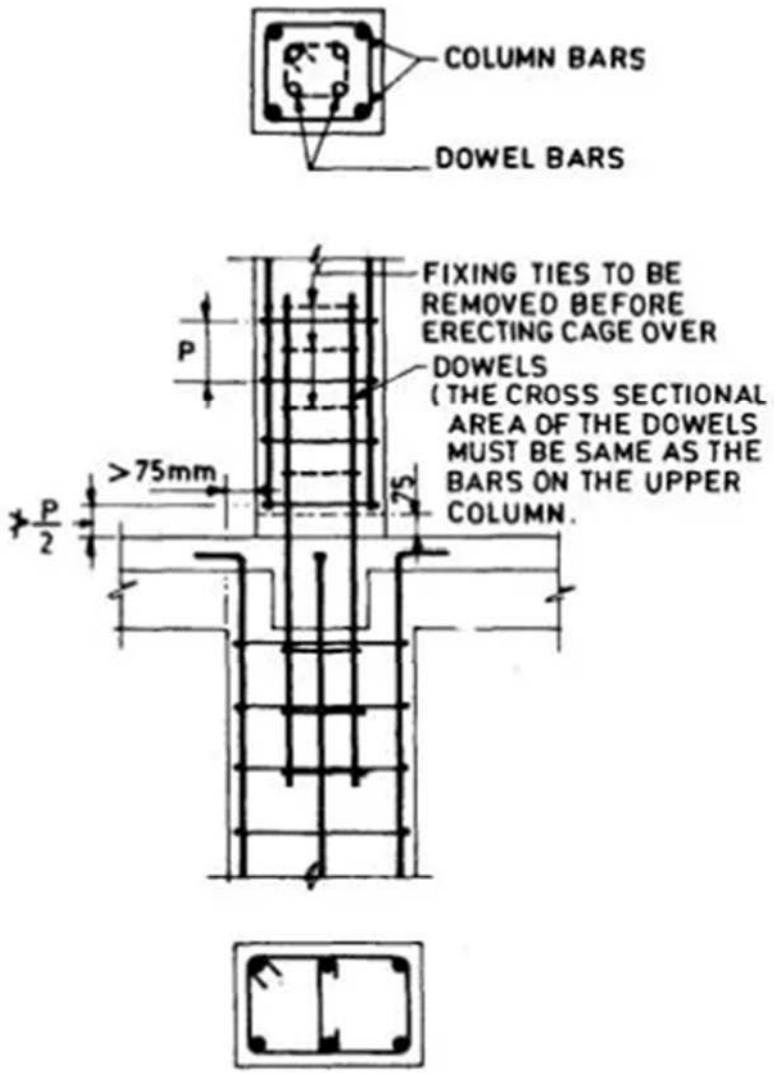


SPLICE AT SLABS, BEAMS, DROP PANELS

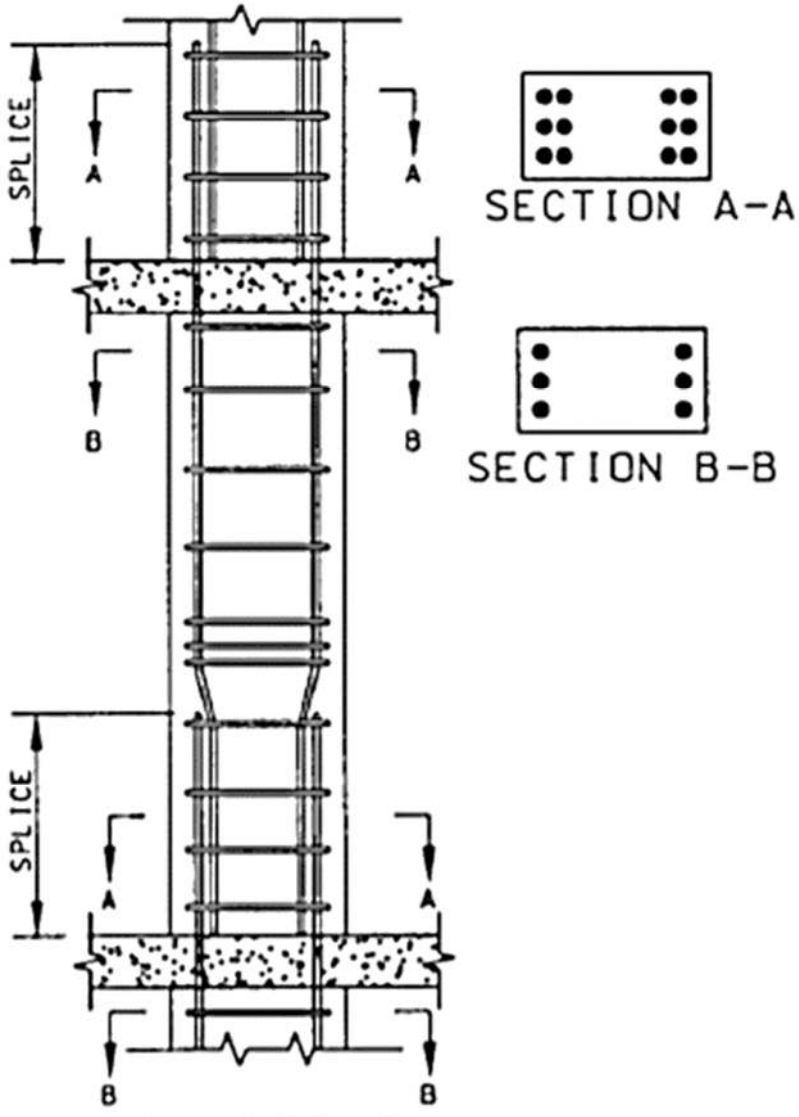


COLUMN STEP >75mm AT SLAP, BEAM, DROP PANELS

Typical Details of Column Splices

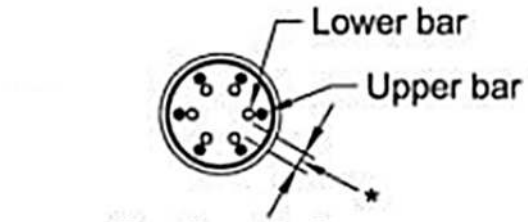


COLUMN SPLICE USING LOOSE DOWELS WHEN COLUMN STEP > 75 mm

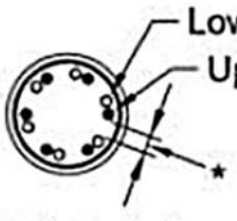


FULL MOMENT LAP SPLICES WITH NO OFFSET

Typical Details of Column Splices

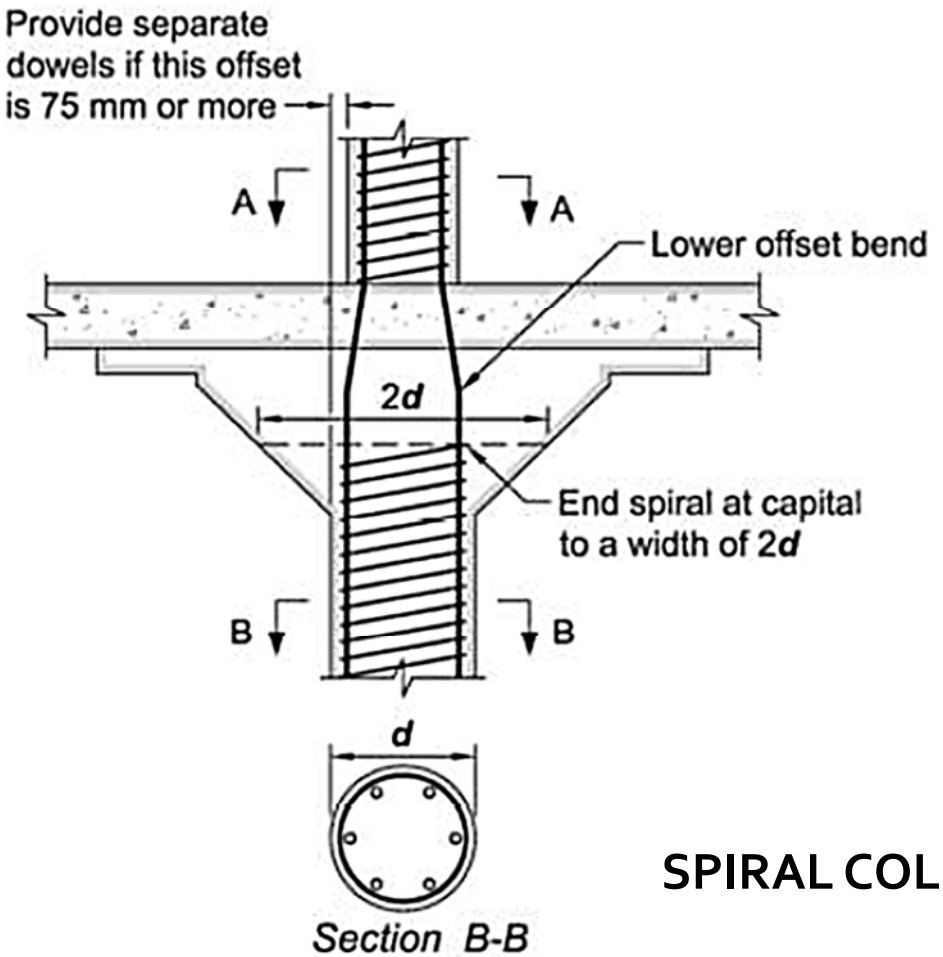


Section A-A
Acceptable arrangement



Section A-A
Preferred arrangement

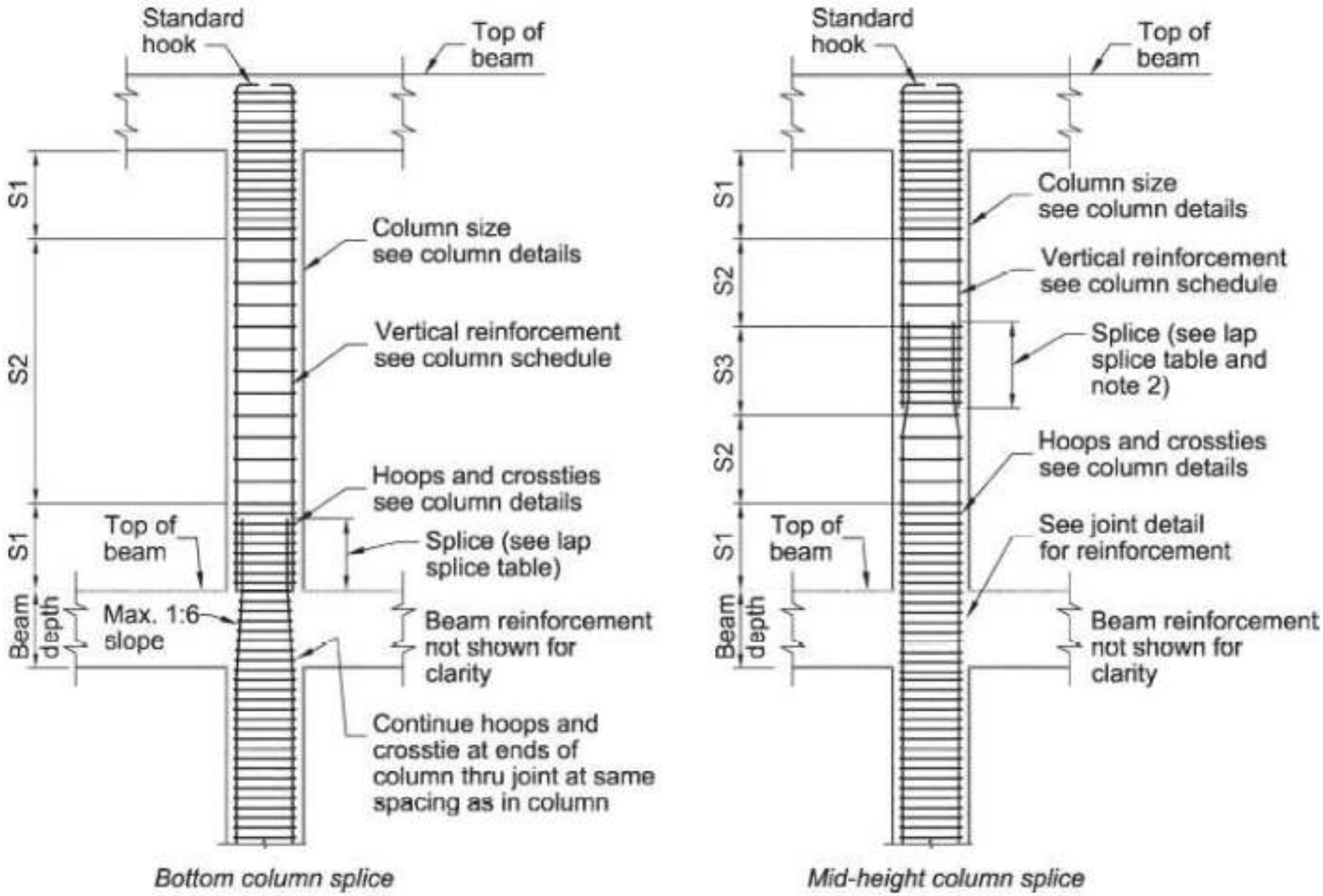
*s_{min} is the greatest of 40 mm, $1.5d_b$, and $(4/3)d_{agg}$



Section B-B

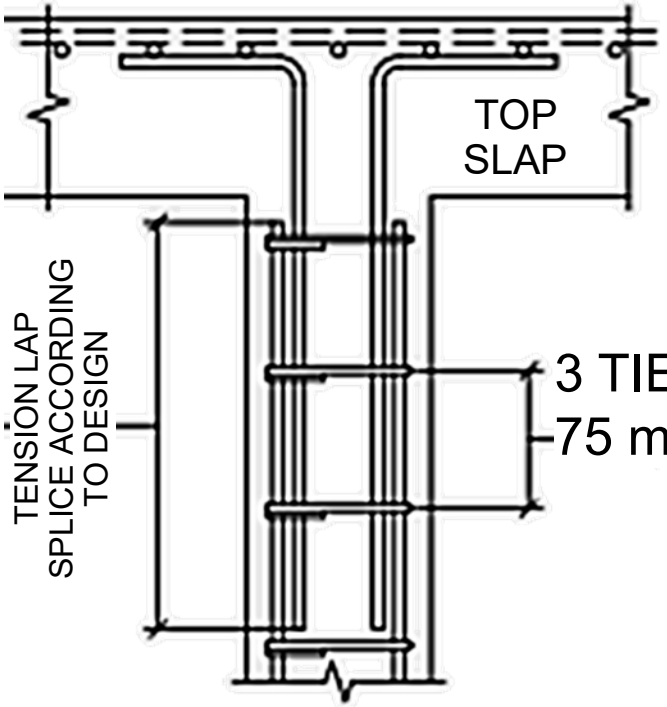
SPIRAL COLUMN LAP SPLICES

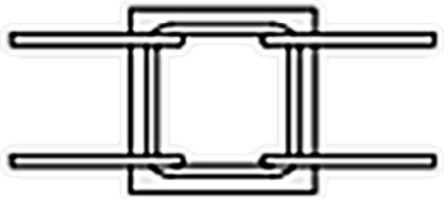
Typical Details of Column Splices



Splices and Longitudinal Section Details for Columns Designed As Part of The Lateral Load-resisting System

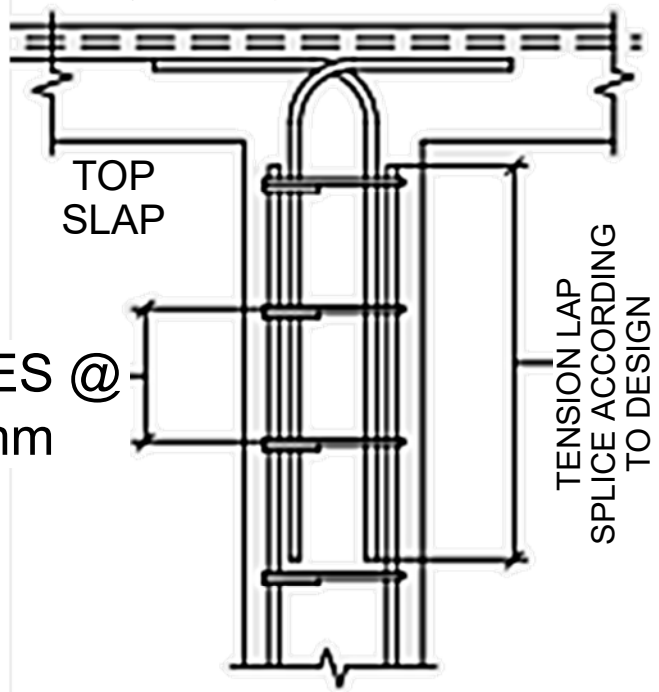
Column top detail

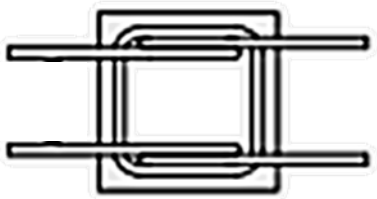




PLAN

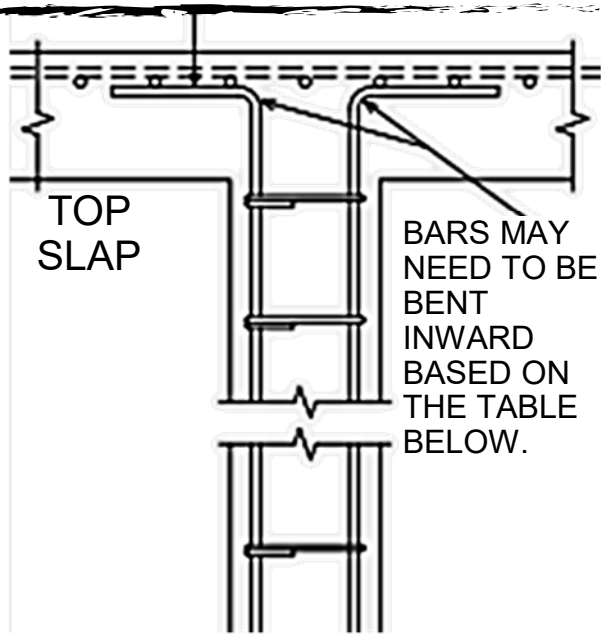
DETAIL 'A'





PLAN

DETAIL 'B'



DETAIL 'C'

CAN BE USED IF
REINFOREMENT IS SPLIED IN
THE LAST FLOOR

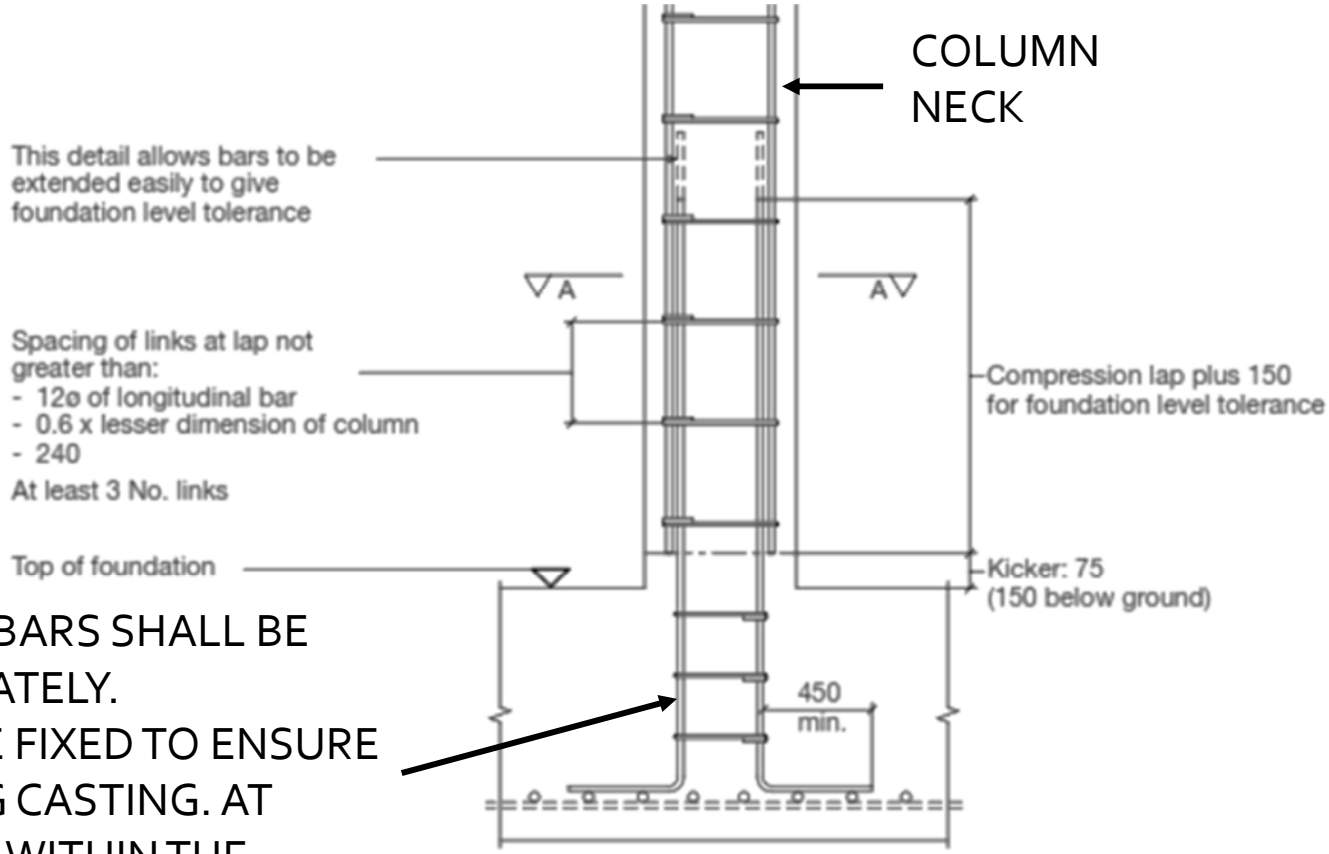
DETAIL 'A' APPLIES WHEN SLAB DEPTH IS NOT LESS THAN

- **200 mm AND COLUMN BARS 20mm**
- **250 mm AND COLUMN BARS 25mm**
- **300 mm AND COLUMN BARS 32mm**

OTHERWISE DETAIL 'B' APPLIES

Starter bars (column dwells)

- Usually, columns are connected to the foundations through column necks - the columns' extensions under the slab-on-grade. The dimensions of the column's neck cross sections are usually larger than those of the column to provide more cover to the reinforcement.



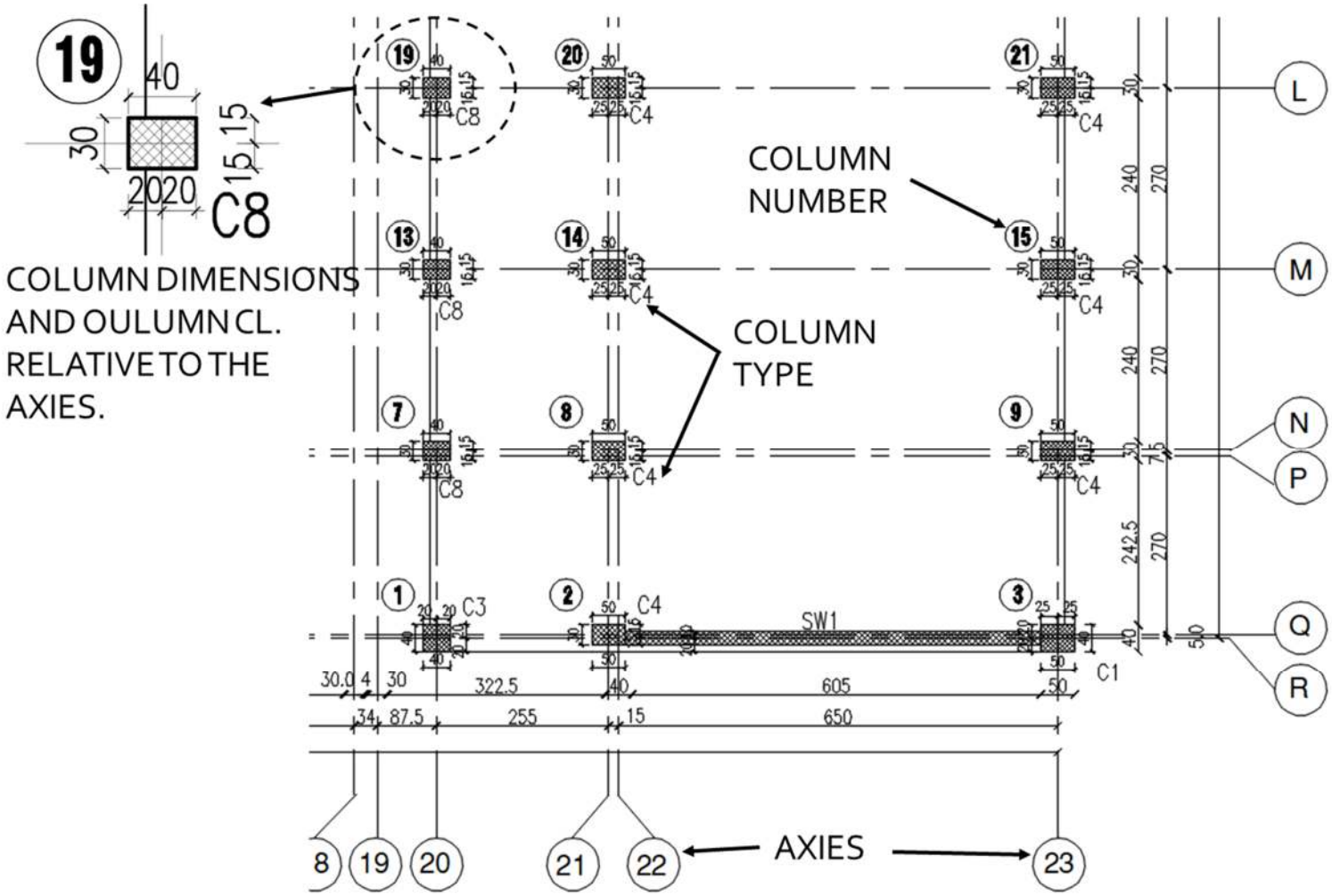
COLUMN STARTER BARS. THE BARS SHALL BE LOCATED IN POSITION ACCURATELY. FURTHERMORE, IT SHOULD BE FIXED TO ENSURE THEY WILL NOT MOVE DURING CASTING. AT LEAST 3 TIES SHALL BE ADDED WITHIN THE FOOTING.

Columns Drawings

- **Required information**. Drawings must show:
  - Locations of columns relevant to grid lines.
  - Size of columns in plan.
  - Height of columns (vert. section, elevations)
  - Reinforcement: number, location, grade, and size of reinforcing steel.
  - Method of splicing.
  - All necessary details where column section or reinforcement changes.
- **Typically the column drawing usually consist of**
  1. Grid lines plan
  2. Floors plans
  3. Longitudinal section
  4. Columns schedule.

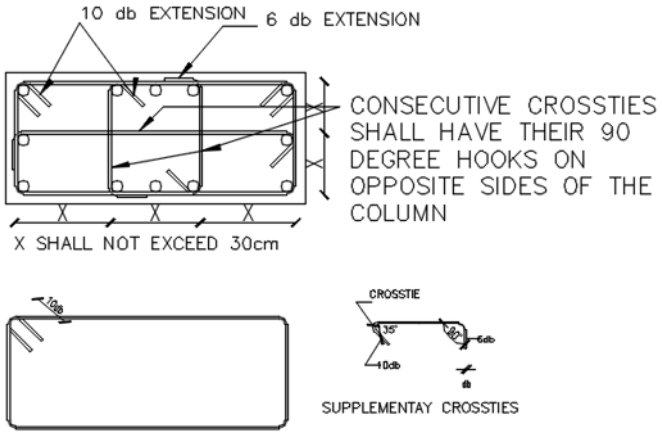
Grid Lines Plan

- Exhibits the dimension of the columns at the foundation level, columns number, type, and columns center lines relative to the grid lines.
- The plan is used for the setting out of the building's foundation and columns at the start of the works.

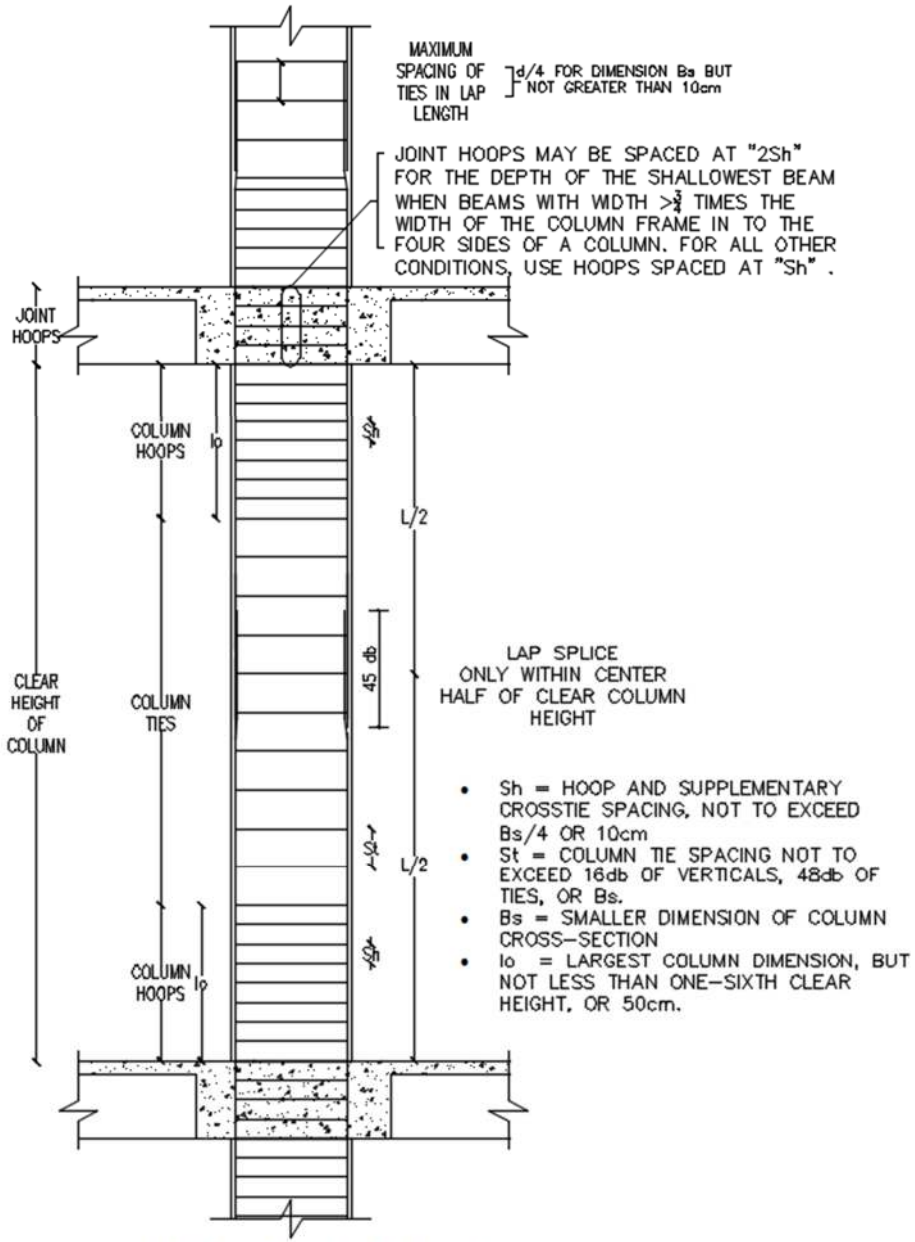


Longitudinal Section

- The drawing aims to show details of the vertical reinforcement splices, column height, and the details and distribution of transverse reinforcement.



TRANSVERSE REINFORCEMENT IN COLUMNS



TYPICAL LONGITUDINAL SECTION

SEISMIC DETAILS

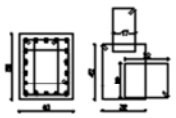
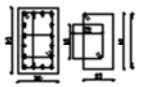
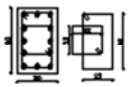
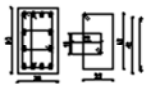
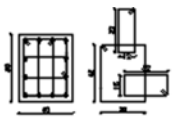
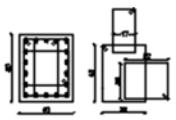
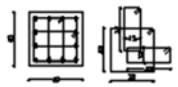
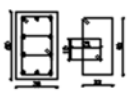
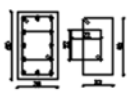
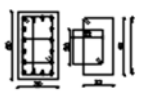
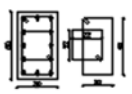
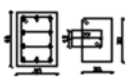
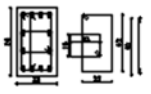
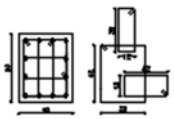
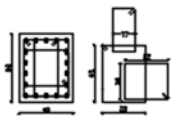
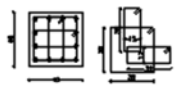
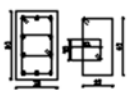
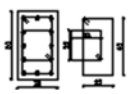
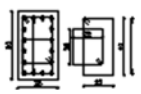
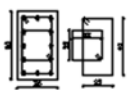
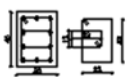
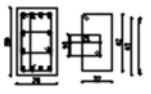
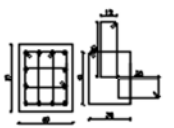
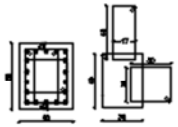
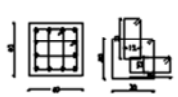
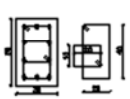
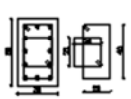
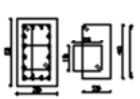
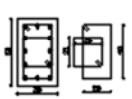
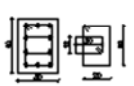
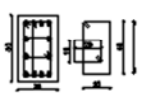
Column Schedule

Column schedule is a table showing, for each level, the following information:

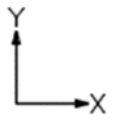
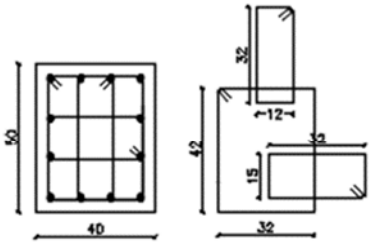
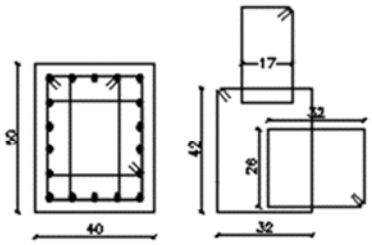
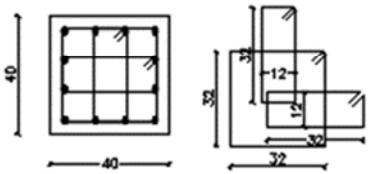
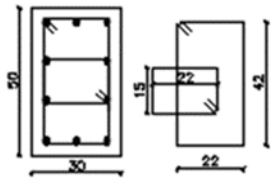
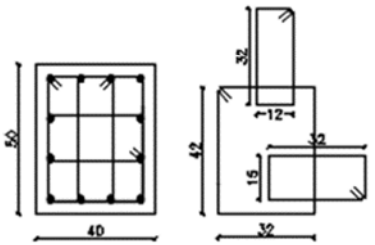
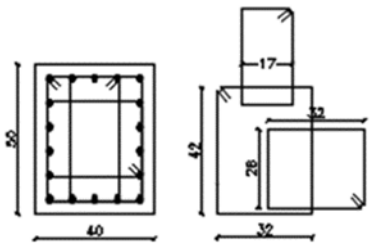
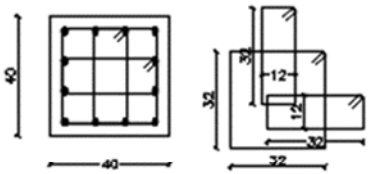
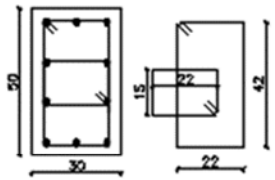
- Column types and number of columns of each type.
- Column dimensions and cross-section.
- Main (vertical) reinforcement details
- Transverse reinforcement details.

Column Schedule

COLUMNS SCHEDULE

TYPE	C1	C2	C3	C4	C5	C6	C7	C8	C9
LOCATION	ALL SECTION	ALL SECTION	ALL SECTION	ALL SECTION	ALL SECTION	ALL SECTION	ALL SECTION	ALL SECTION	ALL SECTION
No. of Columns	5	1	2	56	4	1	2	25	1
STAIR CASE									
D X B		40X50				30X50	30X50		30X50
MAIN BARS		18ø16				18ø16	12ø20		12ø20
HOOPS		3R10@10cm for Full column height				2R10@10cm for Full column height	2R10@10cm for Full column height		2R10@10cm for Full column height
TIE BARS }		**********				1R10@10cm for for Full column height	**********		1R10@10cm for for Full column height
OTHER FLOORS									
D X B	40X50	40X50	40X40	30X50	30X50	30X50	30X50	30X40	30X50
MAIN BARS	12ø16	18ø16	12ø16	10ø16	12ø16	18ø16	12ø16	10ø16	12ø20
HOOPS	3R10@10cm for Full column height	3R10@10cm for Full column height	3R10@10cm for Full column height	2R10@10cm for Full column height	2R10@10cm for Full column height	2R10@10cm for Full column height	2R10@10cm for Full column height	2R10@10cm for Full column height	2R10@10cm for Full column height
TIE BARS }	**********	**********	**********	**********	**********	1R10@10cm for for Full column height	**********	**********	1R10@10cm for for Full column height
GROUND FLOOR									
D X B	40X50	40X50	40X40	30X50	30X50	30X50	30X50	30X40	30X50
MAIN BARS	12ø16	18ø16	12ø16	10ø16	12ø16	16ø16	12ø16	10ø16	12ø20
HOOPS	3R10@10cm for Full column height	3R10@10cm for Full column height	3R10@10cm for Full column height	2R10@10cm for Full column height	2R10@10cm for Full column height	2R10@10cm for Full column height	2R10@10cm for Full column height	2R10@10cm for Full column height	2R10@10cm for Full column height
TIE BARS }	**********	**********	**********	**********	**********	1R10@10cm for for Full column height	**********	**********	1R10@10cm for for Full column height
STUMP									
D X B	40X50	40X50	40X40	30X50	30X50	30X50	30X50	30X40	30X50
MAIN BARS	12ø16	18ø16	12ø16	10ø16	12ø16	16ø16	12ø16	10ø16	12ø20
HOOPS	3R10@10cm for Full column height	3R10@10cm for Full column height	3R10@10cm for Full column height	2R10@10cm for Full column height	2R10@10cm for Full column height	2R10@10cm for Full column height	2R10@10cm for Full column height	2R10@10cm for Full column height	2R10@10cm for Full column height
TIE BARS }	**********	**********	**********	**********	**********	1R10@10cm for for Full column height	**********	**********	1R10@10cm for for Full column height

Column Schedule

OTHER FLOORS 				
D X B	40X50	40X50	40X40	30X50
MAIN BARS	12ø16	18ø16	12ø16	10ø16
HOOPS	3R10@10cm for Full column height	3R10@10cm for Full column height	3R10@10cm for Full column height	2R10@10cm for Full column height
TIE BARS	**********	**********	**********	**********
GROUND FLOOR 				
D X B	40X50	40X50	40X40	30X50
MAIN BARS	12ø16	18ø16	12ø16	10ø16
HOOPS	3R10@10cm for Full column height	3R10@10cm for Full column height	3R10@10cm for Full column height	2R10@10cm for Full column height
TIE BARS	**********	**********	**********	**********

طوبار الأعمدة (Columns Form)

- **الطوبار التقليدي**: عبارة عن هيكل خشبي بشكل العمود يصنع من الواح الخشب الأبيض (25X100,120 mm) التي تجمع معا بزوايا معدنيه أو عوارض خشبية (أساور) على طول الهيكل.
- يدعم الهيكل من موضعين على الأقل بعوارض مائله (دعامات) للحفاظ على ثباته وشاقوليته.
- في بعض الأحيان يستعاض عن الواح الخشب بالواح بعرض حنب العمود من الخشب الرقائقي (plywood) المطلي للحصول على سطح خرساني املس أو مصقول.

طوبار الأعمدة (Columns Form)

- **الطوبار الحديث:** على الأغلب مصنع من قطع معدنية يمكن تركيبها معا لتشكيل القالب بأبعاد مختلفة.
- **طوبار الأعمدة الدائرية:** أسطوانات بأبعاد مختلفة تصنع من الورق المقوى أو الحديد أو البلاستك
- تختلف أنواع هذا الطوبار باختلاف الشركات المصنعة وعادة ما يقدم من قبل الشركة دليل للتركيب و الأحمال التي يمكن حملها على الطوبار. يعتبر مكلفا لحد ما ولذا يقتصر استعماله على المشاريع الكبيرة.

استلام الأعمدة

يلزم خلال عملية استلام الأعمدة الانتباه لما يلي:

- فحص والتأكد من موقع العمود وأبعاده وبالذات في الطوابق العليا تفاديا لانحراف الأعمدة في الطوابق المختلفة.
- فحص تسليح العمود ويشمل التأكد من عدد وقطر الحديد الرئيسي ومواقع الأسياخ، فحص الحديد العرضي بما في ذلك أقطار الكانات وتباعدها وإحكام ربطها بالحديد الرئيسي، فحص الغطاء الخرساني والتأكد من اخذ الاحتياطات اللازمة لبقائه ثابتا أثناء الصب كل ذلك وفقا للمخططات الإنشائية.
- فحص الطوبار ومتانته وتراصه والتأكد من شاقوليته وثباته.
- فحص الخرسانة الموردة ومراقبة أعمال الصب للتأكد من عدم إسقاط الخرسانة لمسافات كبيره وعدم ارتطامها بالطوبار أو التسليح والتأكد من عمل الدمك بصورة صحيحة وكافيه.
- فحص العمود بعد فك الطوبار للتأكد من خلوه من العيوب كالتعشيش وفحص شاقوليته وأبعاده.
- متابعة أعمال الإيناع
- فحص الخرسانة المتصلدة والتأكد من جودتها