

## Openings in Post-Tension Floor



In building construction, it is normal to have openings for system works or openings decorative purposes. In beamless floor, openings are significantly important which impact the load capacity of the floor especially at column heads where the slab requires excessive strength to take punching shear. Therefore, it is important to advise positioning worker of opening locations and if the opening is critically and inevitably crucial, it is imperative to know about the possible impact and design to fix such impact so that floor is sufficiently strong.

Determining of floor openings can be classified into two types:

1. Pre-construction predetermined openings
2. Post-construction drilled openings

### 1. Pre-construction predetermined openings

Since the openings affect the load capacity of the floor, if the problem is identified beforehand, it can be fixed or advised to switch to other least impacted location of the floor slab. According to the note in ACI318-05, positions and sizes of openings are exhibited in the image.

## Openings in Post-Tension Floor

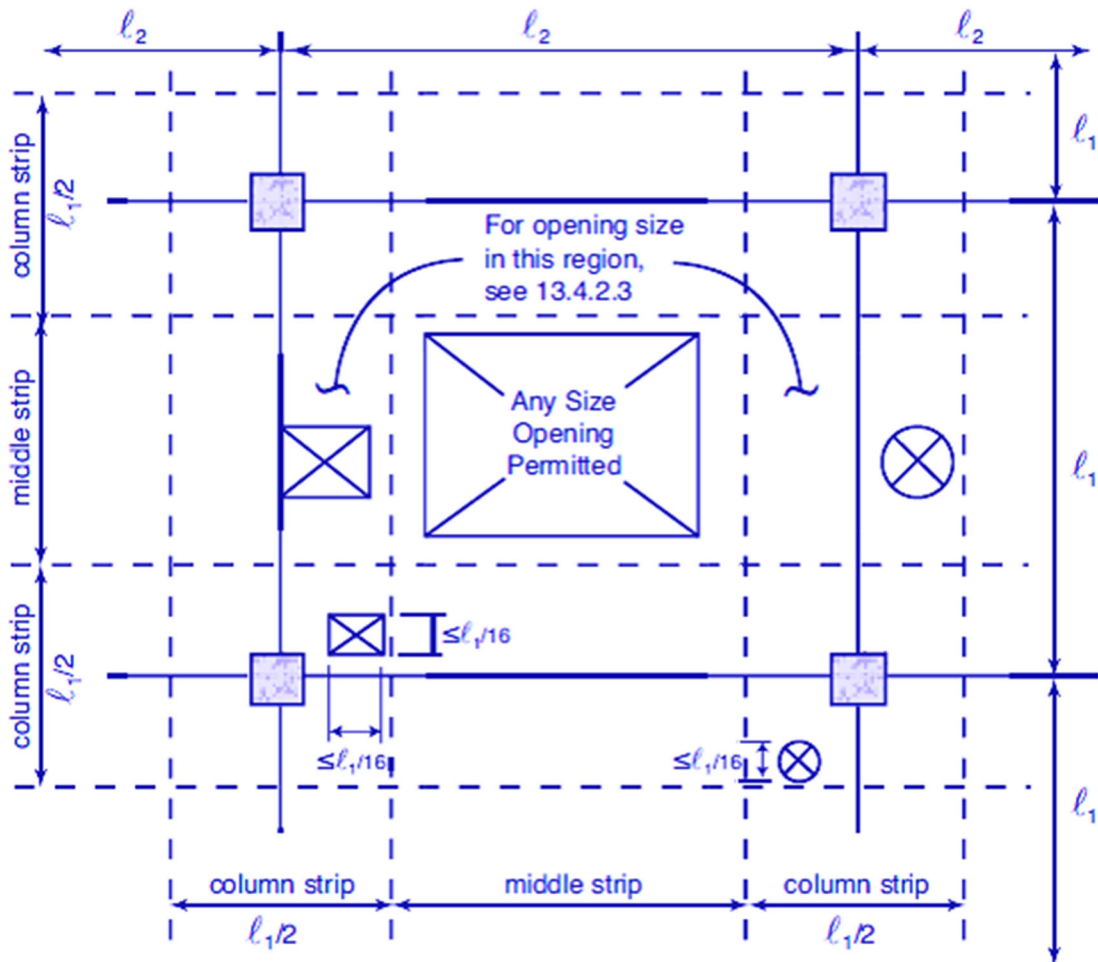


Image exhibiting the positions and sizes of the openings which do not affect the floor strength.

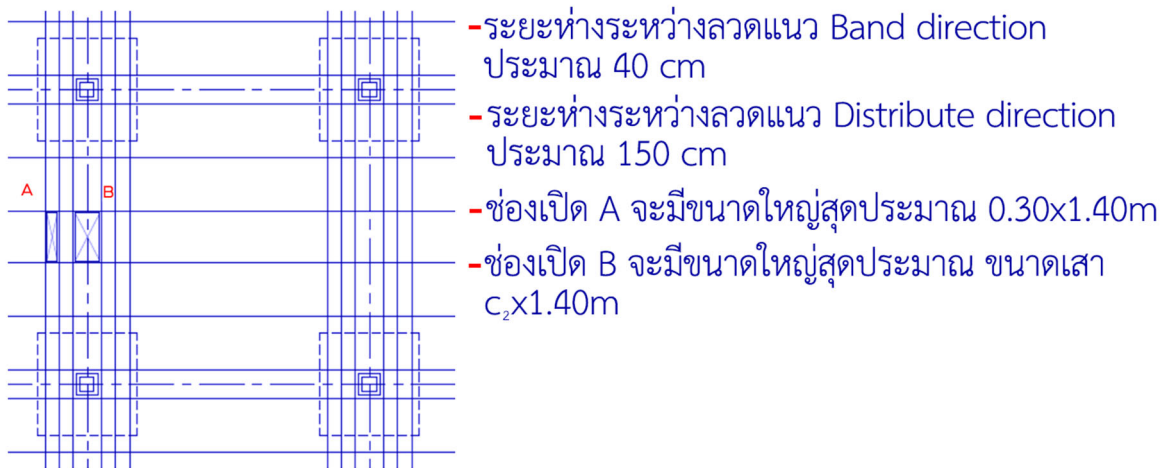
According to the figure, set  $L_2 > L_1$ .

- Middle strip intersects with another middle strip which allows any size of opening that does not affect the strand spacing. (ACI 13.4.2.1)

- Where column strip intersects with column strip, it is recommended that the opening must not be larger than  $L_1/16$ . (ACI 13.4.2.2)

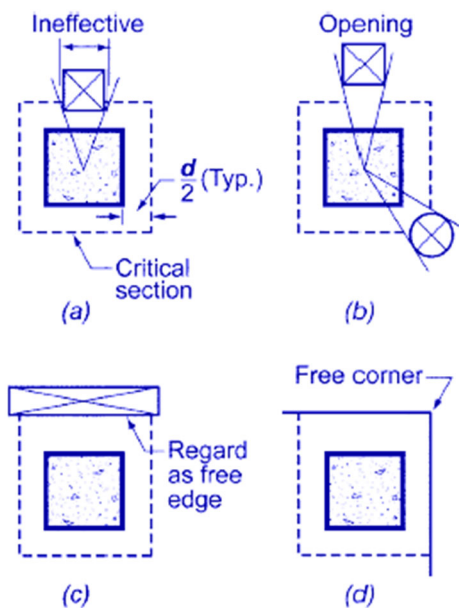
- For column strip area that intersects with the middle strip, ACI318, section 13.4.2.3 requires that reinforcing steel that is obstructed by an opening must not be larger than  $1/4$  of the entire amount of the reinforcing steel in that column strip or middle strip. (ACI 13.4.2.3) For post-tension floor in this area, strand alignment in band direction determines the size of the opening as exhibited in the image below. Therefore, post-tension floor design of such area must take into account the size of the opening.

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In addition, ACI 13.4.2.4 also requires to inspect shear reinforcement in areas with openings.

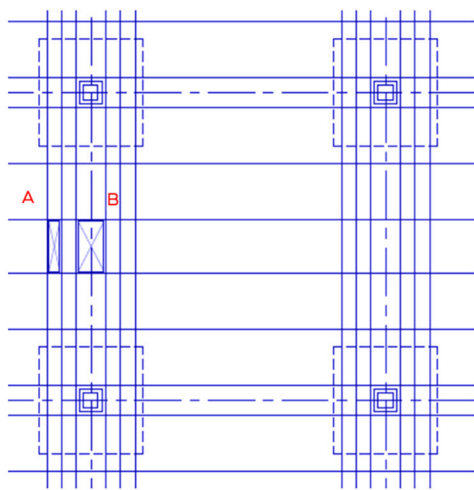
Openings that are in proximity of less than 10 times of the floor thickness (ACI 11.11.6) will affect the calculation of the perimeter of critical cross section, BO as shown in the picture.



## 2. Post-construction drilled openings

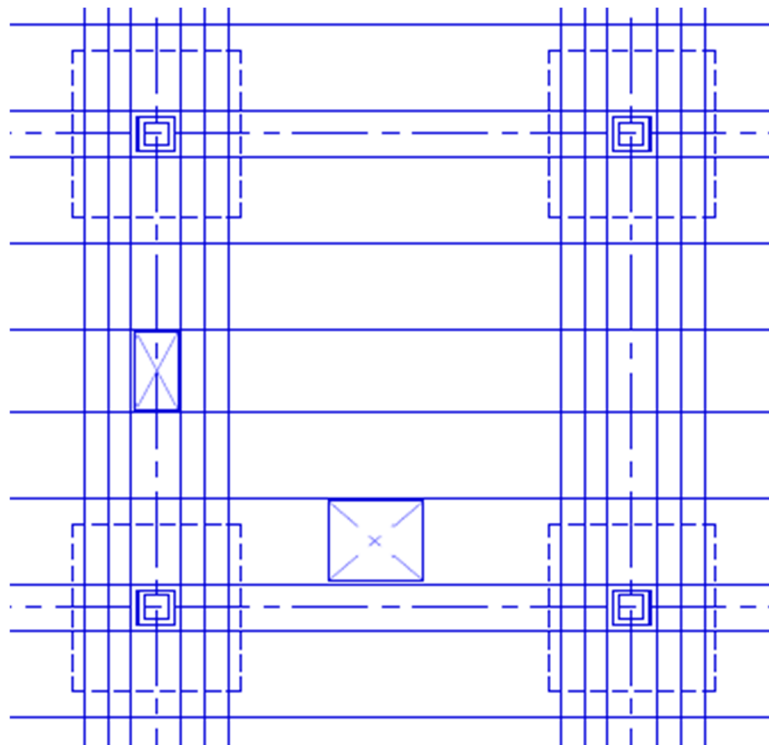
In drilling the openings after construction, it is necessary to analyze the new structure every time to verify the effect of openings which diminishes floor's load capacity. Opening area employs smaller width of design strip and if the new opening is near the column, it must be taken into account that the counter shear strength is also reduced. In general, it is best to opt to drill an opening in a position that affects the floor the least and most importantly, try not to cut the strands.

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- ระยะห่างระหว่างลวดแนว Band direction ประมาณ 40 cm
- ระยะห่างระหว่างลวดแนว Distribute direction ประมาณ 150 cm
- ช่องเปิด A จะมีขนาดใหญ่สุดประมาณ 0.30x1.40m
- ช่องเปิด B จะมีขนาดใหญ่สุดประมาณ ขนาดเสา  $c_2 \times 1.40m$

In similar fashion with the first case, locations to avoid opening drilling is the area number 3 as not only that it reduces load capacity but it also diminishes counter shear strength. Area number 1 is optimal with the least impact as when a new opening is drilled, inspection of load capacity has a high chance to pass.





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Area 2 is the area with strand alignment in band direction in one direction and strands in distributed direction in another direction. Opening size can generally be drilled larger, in area 2 with strands aligned in distributed direction. However, large openings will result in a decrease in the width of design strip. Cutting the floor to create an opening requires a cutting tool that can be controlled to cut to the desired length which does not damage the concrete in other areas including both rectangular openings and coring.



cutting the strands



cutting the strands

## Openings in Post-Tension Floor



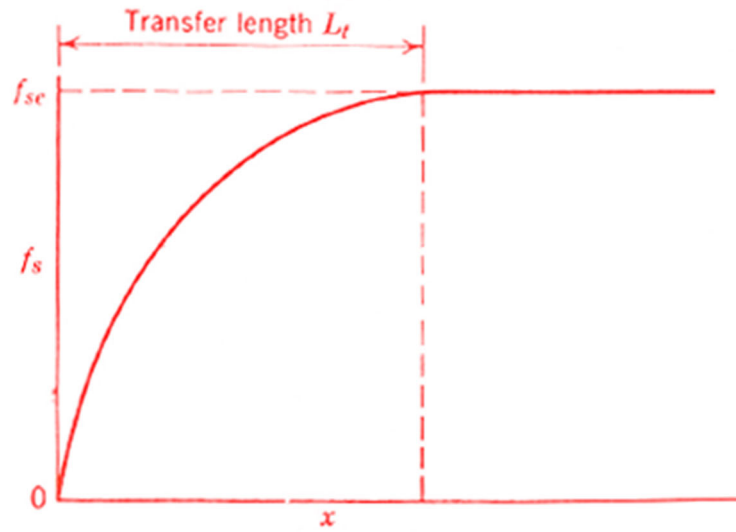
### cutting the strands

To prevent cutting the strands, prior to cutting, it is better to scan for strand location in the working area.

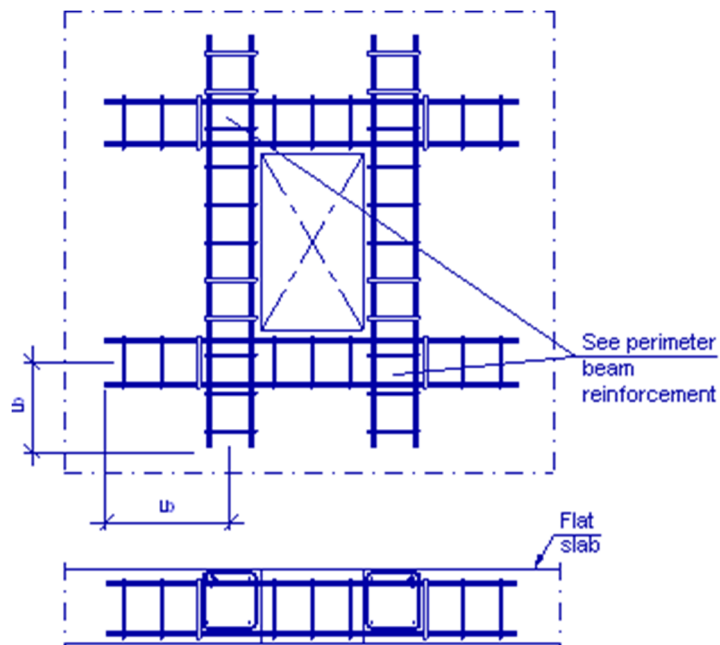
In case the newly drilled opening requires some strand to be cut, bonded beamless prestressed concrete can be operated without strand retraction since corrugated sheaths filled with grout hold the strands. Calculation of new openings must take into account the effect after the strands being cut off.

When the strands are cut off, load transfer of the remaining strands get shifted. Compressive force of strands at opening edge becomes zero and the value will go higher up to the original value at the distance of the transfer length, LT.

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It can be seen that the change pattern of force in strands is not linear. However, simple calculation formula can be made as follows:  $LT = 1.5F_{SI}/(F_{CI}^{\wedge})DB - 11.7$  in centimeters, where  $F_{SI}$  is an initial tensile stress in the strands and  $F_{CI}$  is concrete strength while stressing. While ACI recommends an approximate value of  $LT = 50DB$ , it would yield less value than the first formula when  $FC'$  value is low.



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Therefore, to make an opening with having strands cut off, a tool must be installed to hold the strand end to prevent it from future back-shrinking. Take into account the reduced compressive stress in the surrounding area of the opening with cut strands which may require additional reinforcement around the opening using crack-protecting steel reinforcement. It can be done by expand the opening larger than desired and install reinforcing steel around the opening and pour the concrete back according to the desired opening size.

Another way to reinforce the opening is to use a steel plate or CFRP to reinforce around the opening on both upper and lower surfaces as shown in the figure.



For new opening that is to be drilled near column which diminishes counter shear strength, shear reinforcement can be done using steel bracket as shown in the figure.



Figure: Additional shear reinforcement using steel bracket.



## Openings in Post-Tension Floor

It can be seen that the floor design with both types of openings require impact assessment on floor strength caused by the openings. If the opening is small or is not in the line where a column strip intersects with another column strip, equivalent frame method can generally be employed using the correct width of design strip. If the opening is large and located in a critical area, finite element method should be used to determine the best approximate effect of the actual behavior of the structure.

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### Reference document

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2. M.E. KAMARA, L.C. NOVAK; "NOTES ON ACI 318-11 BUILDING CODE REQUIREMENTS FOR STRUCTURAL CONCRETE WITH DESIGN APPLICATION"
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