POUR STRIP

Closure strips (also known as Pour strips) are temporary gaps that allow sections of slabs on either side move freely under shrinkages in order to reduce stresses caused from shrinkage restraints. To get the maximum effective pour strips, it shall take some times until the both side of slabs reach the maximum shrinkages. Then pour concrete to fill the gapes to connect those slabs. For post-tensioned slab, there are 4 major reasons that cause shrinkage:

- Elastic shortening due to pre-compression
- Creep shortening due to pre-compression
- Shrinkage of concrete
- Temperature variation

PTI (Post-Tensioning Institute) Manual recommended the usage of closure strip as follows.

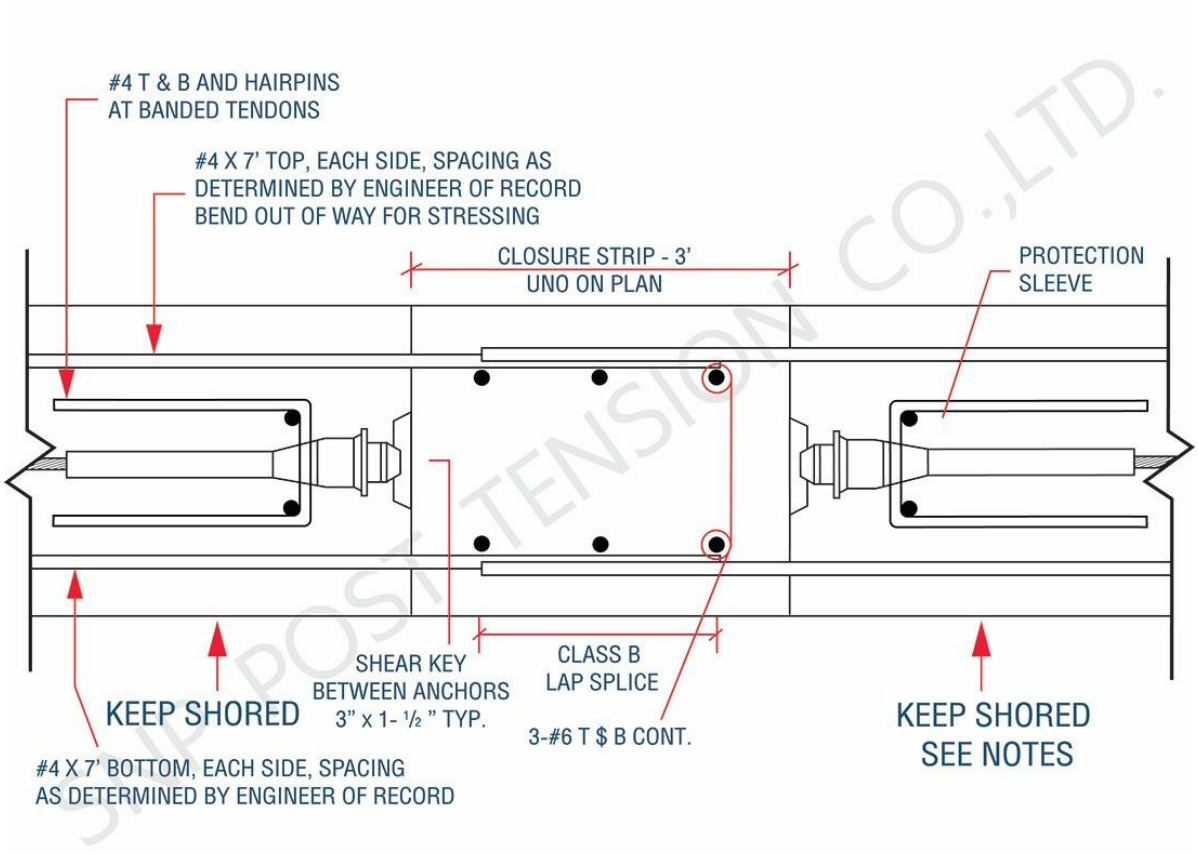
- If the slab is shorter than 250 ft (76 m), it does not it to use closure strip or expansion joint.

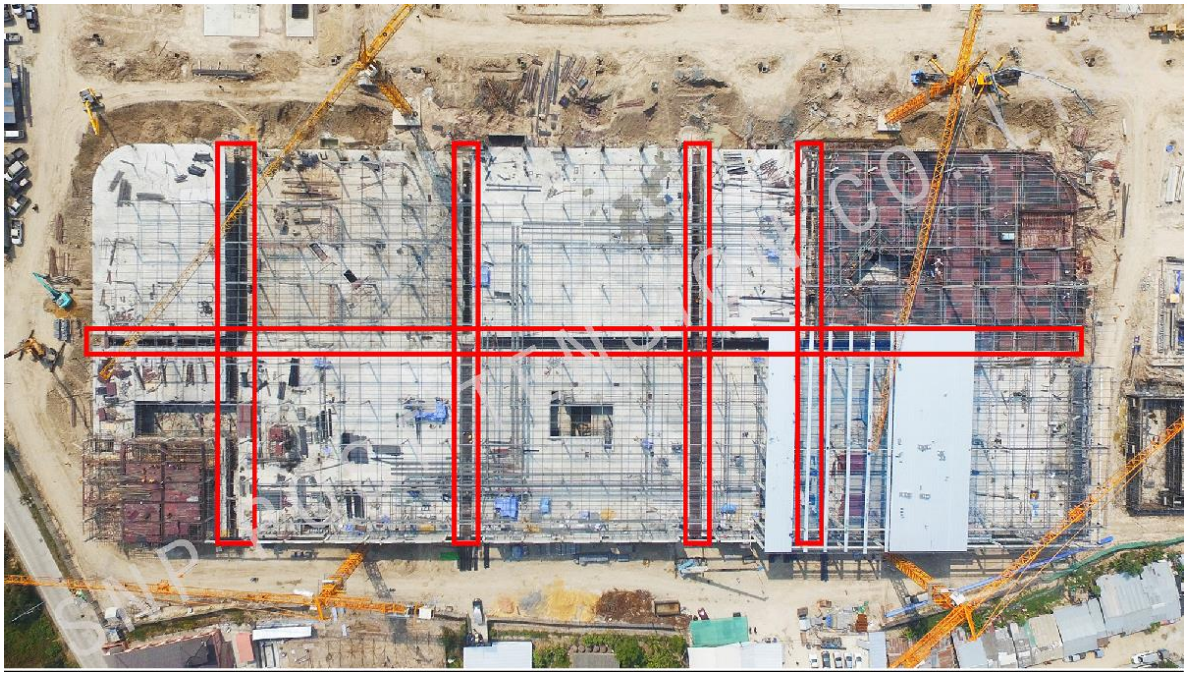
- If the slab lies between 250 ft to 325 ft (76 m to 99 m), the closure strip shall be provided at the middle.
- If the slab lies between 325 ft to 400 ft (99 m to 122 m), 2 gaps of closure strips shall be provided and wait 60 days before pouring concrete to close the gaps.
- If the slab is longer than 400 ft (122 m), expansion joints shall be provided.

According to the above recommendations, it is also necessary to consider about the plan view of slabs, locations and stiffness of columns or other lateral resistance members such as structural walls (also known as shear walls) and so on. These factors provide some effects on the behaviors of slab restraints.

The width of closure strip in post-tensioned slab is normally about 3 ft (0.9 m). This gap shall be wide enough to place the hydraulic jack if it needs to pull tendons in that area. The reinforcements shall be cantilevered out of the edge of slabs and over lapped to each other in the pour strip locations in order to make continuity for all slabs. Generally, the location of

closure strip is at $\frac{1}{4}$ to $\frac{1}{3}$ of the column spacing which is the small moment location. The details of reinforcements in a closure strip are as shown in **Figure** below.





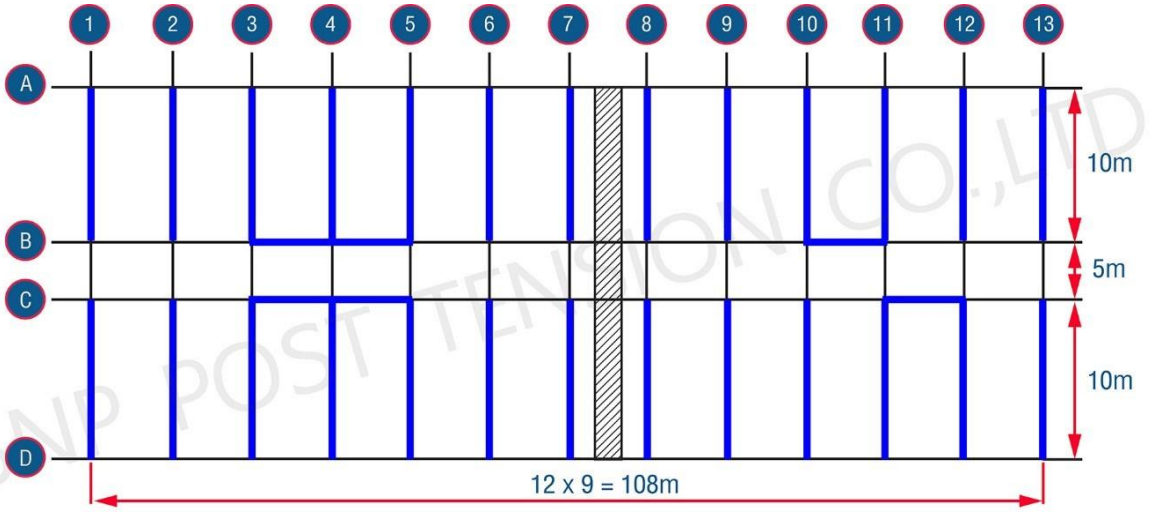
Note

1. Do not remove formworks until the compressive strength of concrete in closure strips reaches 75% of the designed strength.

2. Use the low concrete shrinkage.
3. Make the surface of slabs become rugged, clean and get them saturated before pouring concrete.
4. Be aware of the differentiation level of both side concrete slabs, use hydraulic jack to adjust the level if necessary.
5. Use water proof materials if leakage is not allowed.
6. If closure strips are in bad or difficult situations, it is necessary to close the anchorage by following the specifications of the work project and close the joints by using flexible sealant.
7. It shall be kept in mind that the formworks of both slabs between a closure strip shall be provided a special take care, especially for high-rise buildings.

EFFECTS OF CLOSURE STRIP AND SHRINGKAGE STRAIN

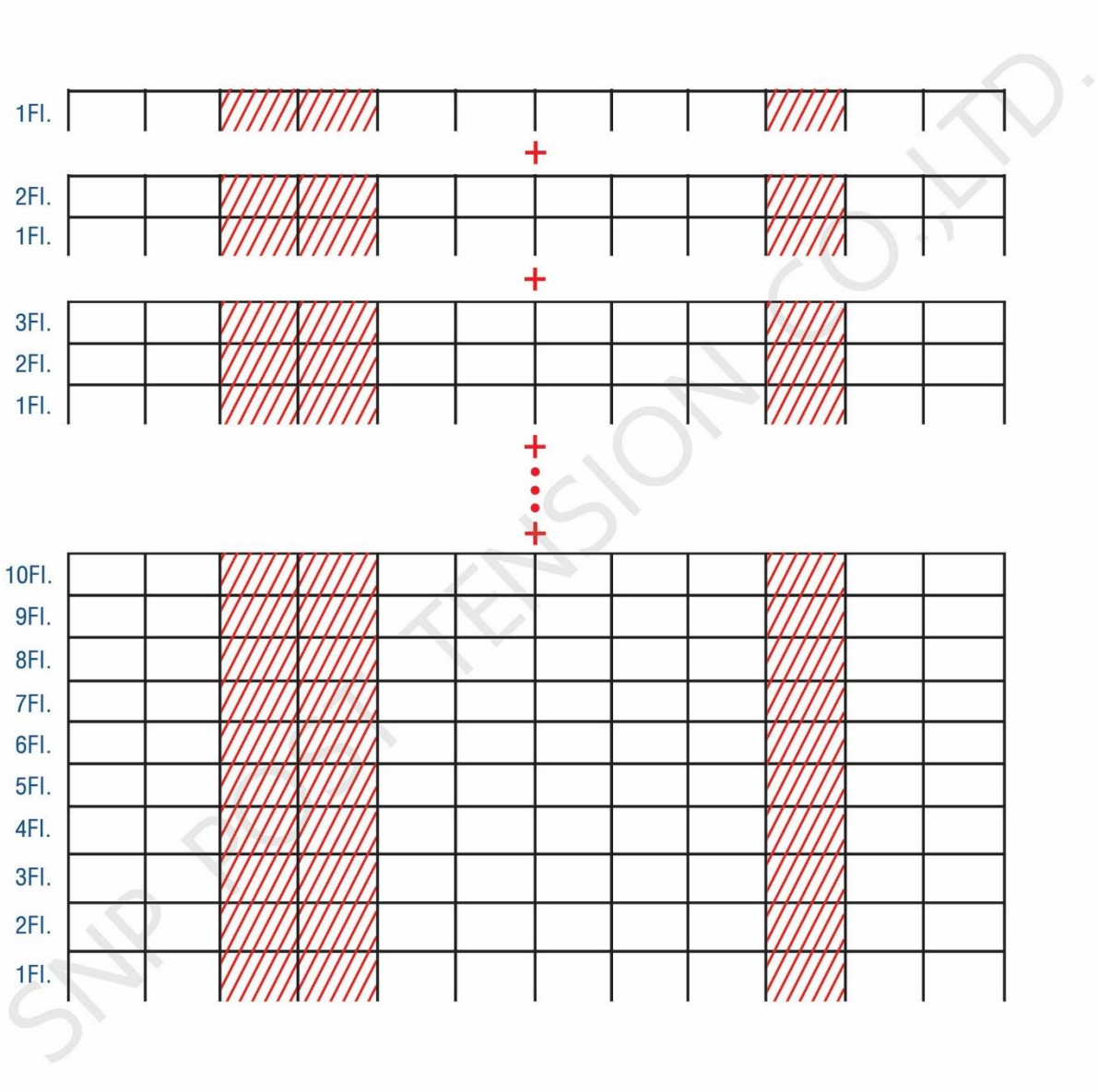
Han-Soo Kim and Suk-Hee Cho analyzed about the shrinkage of 10 stories reinforced concrete building as shown in the plan view below. The area of this building is 25 m x 108 m. Story height, thickness of slab, thickness of shear wall are 3 m, 270 mm, and 300 mm, respectively. The closure strip lies between grid line 7 and grid line 8 in order to reduce effect of shrinkage strain.



To calculate the shrinkage restrain, following ACI and CEB, the base supports are supposed to be fixed. The period of construction is 20 days per floor, and every floor gets 7 days of concrete curing.

1). In case the closure strip is not provided

Do the analysis 10 times to find the shrinkage strain as shown in **Figures** below.



First analysis: Calculate the shrinkage strain only for the 1st floor. **Second analysis**: calculate the shrinkage strain for the 1st and 2nd floors. Keep doing the analysis until the **Tenth analysis**, then the results are provided as shown in **Table** below.

Results of Analyses Using ACI and CEB Models

Story	ACI model				CEB model			
	σ_{cl}(MPa)	R_s	σ(MPa)	I_{cr}	σ_{cl}(MPa)	R_s	σ(MPa)	I_{cr}
10Fl.	2.51	0.463	1.16	0.437	0.36	0.454	0.16	0.061
9Fl.	1.20	0.463	0.56	0.208	0.14	0.454	0.07	0.024
8Fl.	0.47	0.463	0.22	0.082	0.10	0.454	0.05	0.017
7Fl.	0.19	0.463	0.09	0.032	0.20	0.454	0.09	0.033
6Fl.	0.21	0.463	0.10	0.037	0.46	0.454	0.21	0.078
5Fl.	0.50	0.463	0.23	0.086	0.95	0.454	0.43	0.163
4Fl.	1.18	0.463	0.52	0.195	1.84	0.454	0.84	0.314
3Fl.	2.30	0.463	1.06	0.400	3.39	0.454	1.54	0.578
2Fl.	4.53	0.463	2.10	0.187	6.03	0.454	2.74	1.031
1Fl.	8.55	0.463	3.96	1.493	10.39	0.454	4.71	1.754

Where,

σ = Shrinkage stress that considers creep

σ_{cl} = Shrinkage stress that does not considers creep

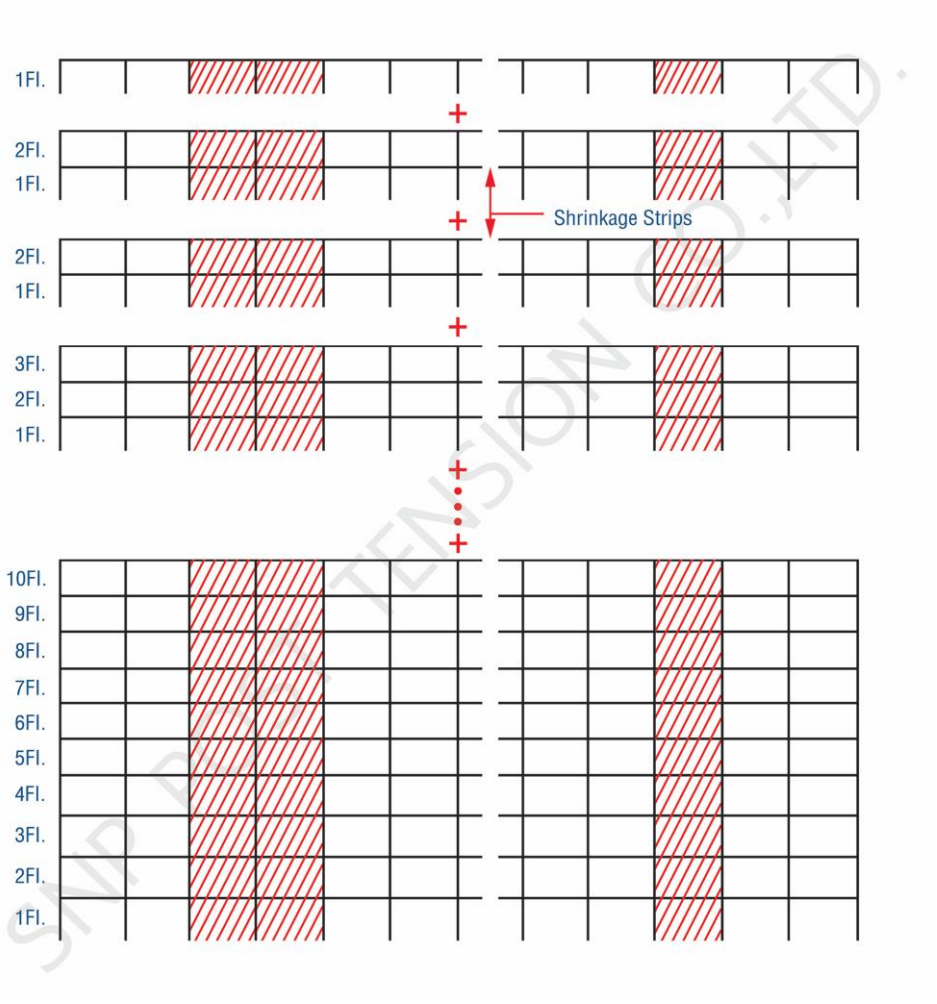
R_s = Relaxation coefficient of shrinkage stress, $R_s = \frac{\sigma}{\sigma_{cl}}$

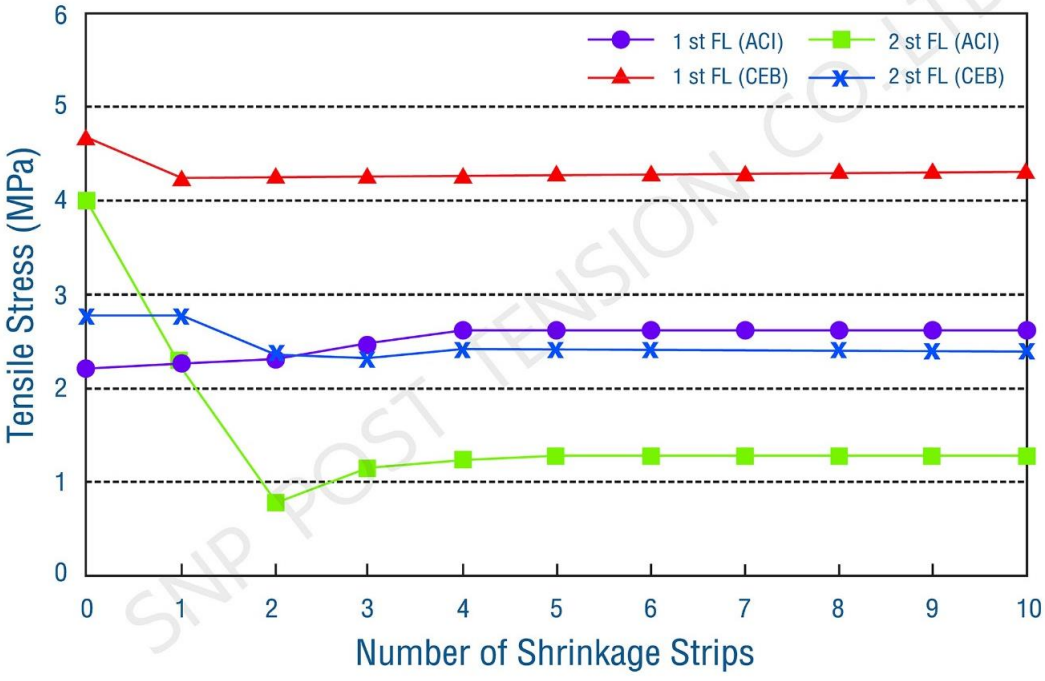
I_{cr} = Ratio of shrinkage stress considering creep to Tensile strength of concrete

The results show that the maximum stress occurs between grid line 5 and grid line 6. The maximum stress occurs at the Floor 1 and always decreases in the upper floors. The minimum stress occurs at Floor 7 when using ACI, and at Floor 8 when using CEB, and this stress does not increase much at the upper floors. Floor 1 and Floor 2 give I_{cr} greater than 1, which means that the occurred stress is greater than the allowable tensile stress of concrete. Therefore, the closure strips shall be provided at Floor 1 and 2.

2). Effects of Number of Floors That Use Closure Strips

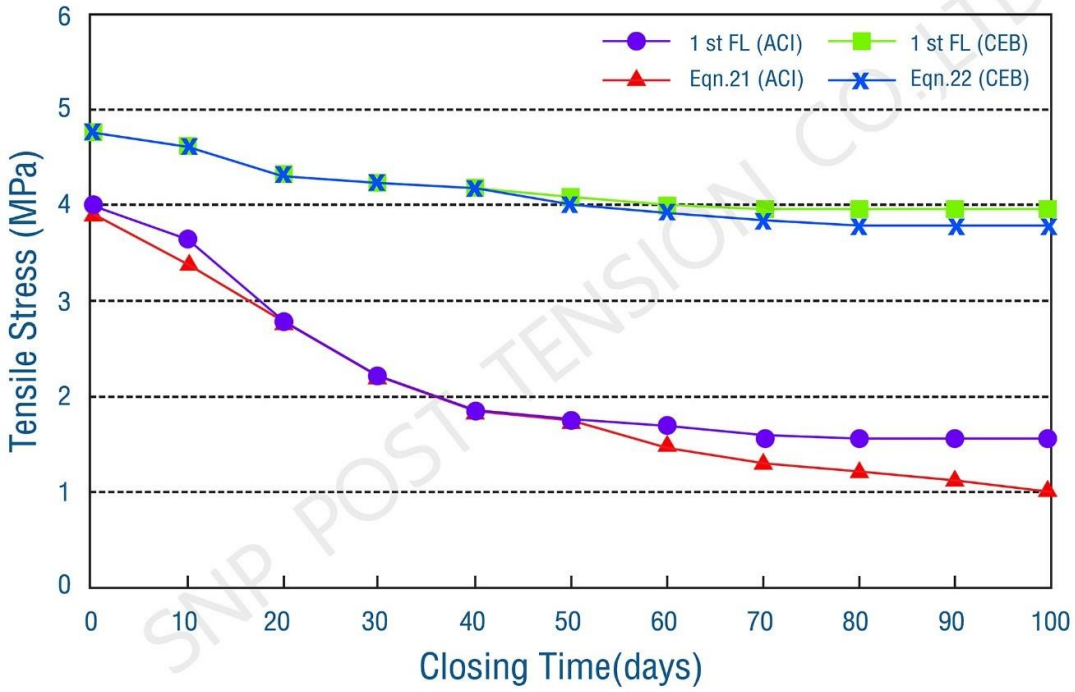
The closure strip with 1 m width is placed between grid line 7 and grid line 8. Then process the analysis for 10 times. The first analysis includes only the closure strip at Floor 1. The second analysis includes the closure strip at Floor 1 and Floor 2. Keep analyzing like this until the tenth analysis. The concrete will be poured to fill the closure strips at 30 days.


1Fl.
2Fl.
1Fl.
Shrinkage Strips
2Fl.
1Fl.
3Fl.
2Fl.
1Fl.
10Fl.
9Fl.
8Fl.
7Fl.
6Fl.
5Fl.
4Fl.
3Fl.
2Fl.
1Fl.


1 st FL (ACI)
2 st FL (ACI)
1 st FL (CEB)
2 st FL (CEB)
Tensile Stress (MPa)
0
1
2
3
4
5
6
0
1
2
3
4
5
6
7
8
9
10
Number of Shrinkage Strips

From the above graph, it is shown that when the closure strip is presented at Floor 1, the tensile stress is significantly decreased and it increases a little bit when the closure strip is provided in the upper floor (Floor 2).

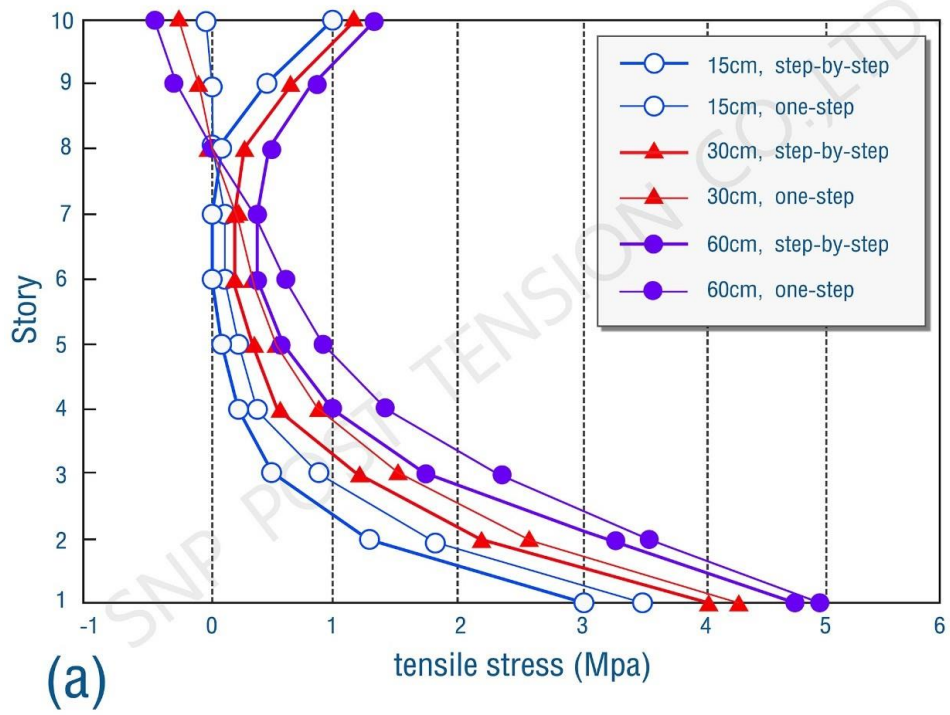
3). Effects of Period of Pouring Concrete to Close the Closure Strips

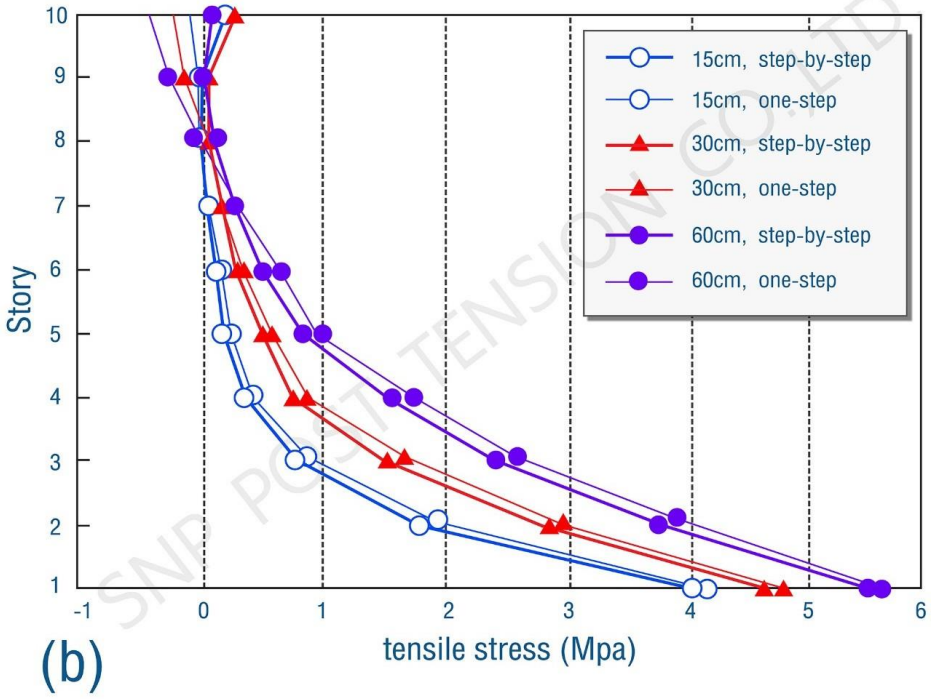


Calculate the stress at Floor 1 subjected to the period of closing the closure strips from 1 to 100 days by adding the calculation every 10 days. From the graph, it is shown that the value of stress calculated by ACI decreases more than the one calculated by CEB.

4). Effects of Construction Sequence

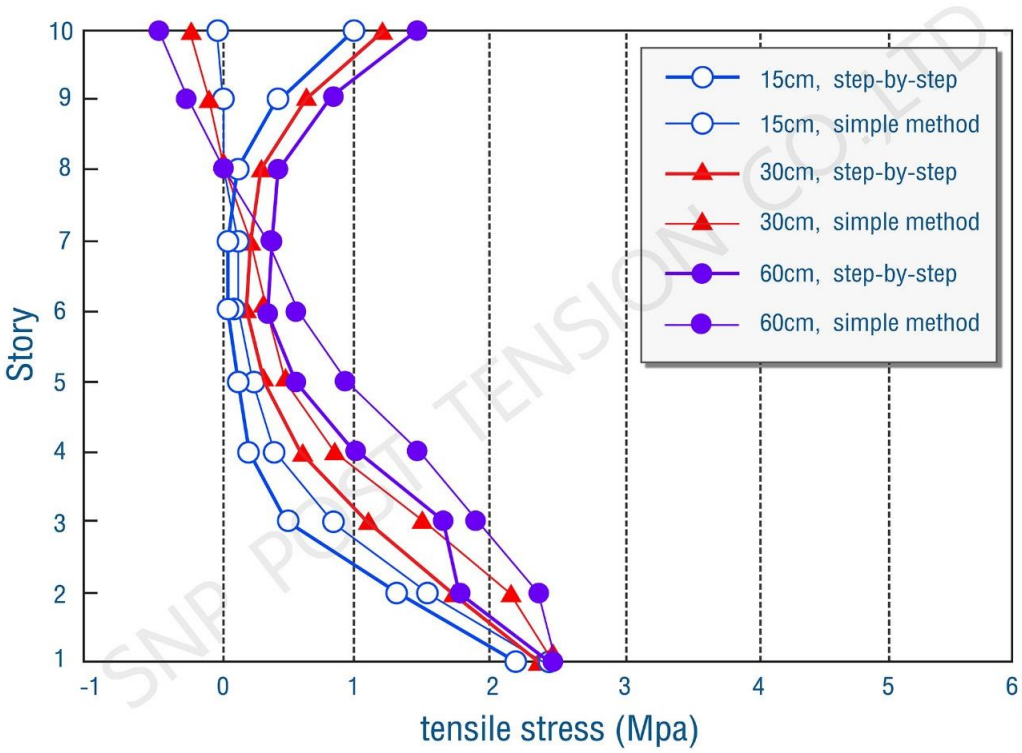
The graph below shows about the comparation between the calculation of the entire building at once and the step by step method varying subjected to the thickness of shear walls, 15cm, 30cm and 60cm using ACI and CEB by ignoring closure strip.





According to the graph above, at the bottom floor, the effects of construction sequence is not as much as the upper floors.

In case the closure strips are provided, the stress is significantly decreased as shown in the graph below.

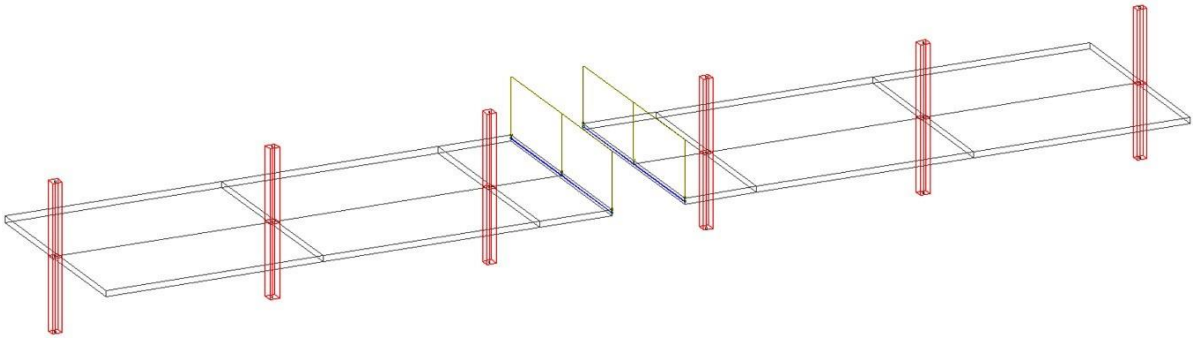


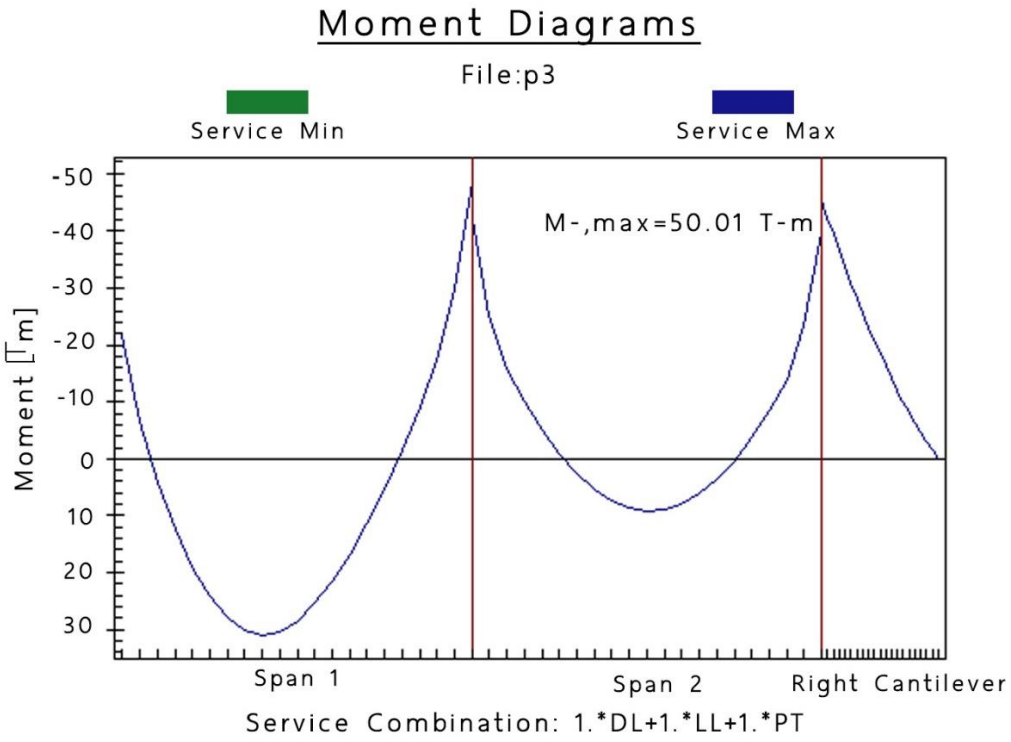
SNP POST TENSION CO.,LTD

Design of Post-Tensioned Slab Consisting of Closure Strips

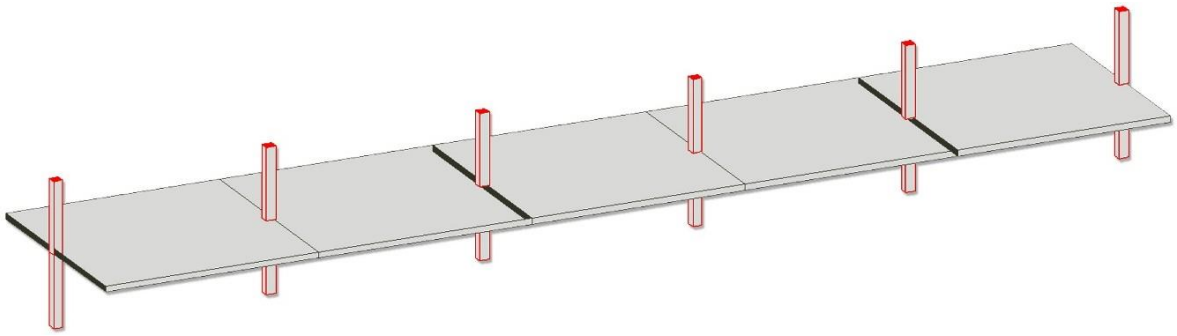
Concepts of Pour Strip Calculations

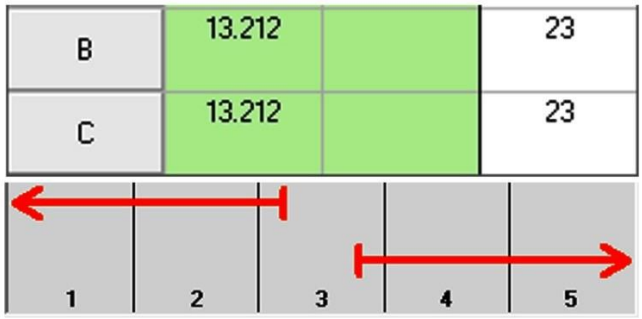
Concept 1: When pouring concrete to close the closure strip, assume the both sides slab as cantilevered hanging slabs.

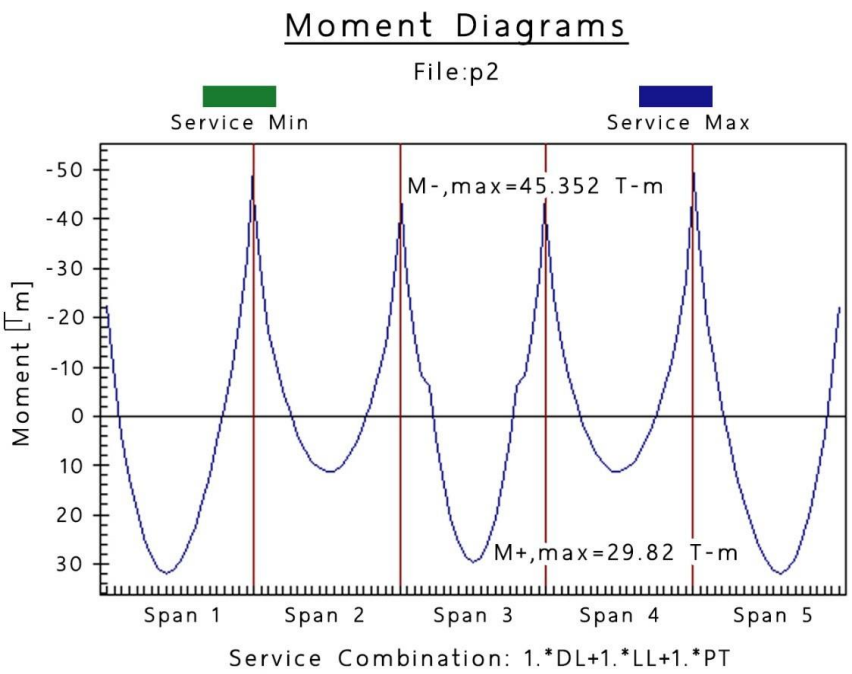


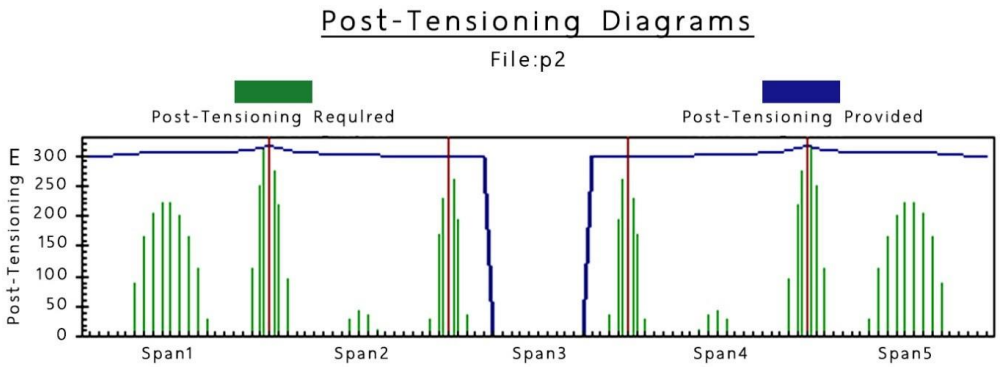


Concept 2: Design the slab as a continuous slab, and so, the joint between a slab and closure strip shall be able to resist the transferred moment. In the area of closure strips shall not occur any balancing force since it does not have any tendon in this area. The formworks in the area of closure strips can be removed if the compressive strength of concrete reaches 75% of its designed strength.




B
13.212
23
C
13.212
23
1
2
3
4
5


Moment Diagrams
File:p2
Service Min
Service Max
M-,max=45.352 T-m
M+,max=29.82 T-m
Moment [T-m]
-50
-40
-30
-20
-10
0
10
20
30
Span 1
Span 2
Span 3
Span 4
Span 5
Service Combination: 1.*DL+1.*LL+1.*PT


Post-Tensioning Diagrams
File:p2
Post-Tensioning Requlred
Post-Tensioning Provided
Post-Tensioning E
300
250
200
150
100
50
0
Span1
Span2
Span3
Span4
Span5

Other Factors Lead to Use Closure Strips

Besides the reduction of shrinkage restraints, closure strips can help to reduce some problems in the construction processes as follows.

1. The length of tendons. Normally, if the slab is long, the friction loss occurred in tendons is much. Generally, the length of tendon will be 30m if jacking one side, and between 30m to 60m if jacking both sides.
2. In case the construction site is far away from the concrete factory or the traffic is bad (traffic jams) which leads the concrete cannot be poured for the entire slab at once, the closure strips also shall be used.
3. If it does not have enough formworks for the hold slab, the slab shall be divided into two.
4. If a slab is divided into two parts by a closure strip, it helps the slab become smaller and spends short time for the construction of every slab. Meanwhile, if the time of construction between these two slabs is overlapped, the construction time of these two slabs is shorter than doing the entire slab at once.

References

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2. "Detailing Corner: Closure strips and lapped reinforcement"; Concrete International, V.33 No.4, April 2011, pp.45-53
3. "Closure strip strategies"; Concrete International, V.39, July 2017, pp. 29-35
4. "Shrinkage stress analysis of concrete slabs with shrinkage strips in a multistory building"; Computers and Structures, March 2004, PP.1143-1152
5. "Shrinkage and Temperature Reinforcement"; B.Suprenant, Concrete International, V.24, No.9, September 2002, pp. 72-76

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