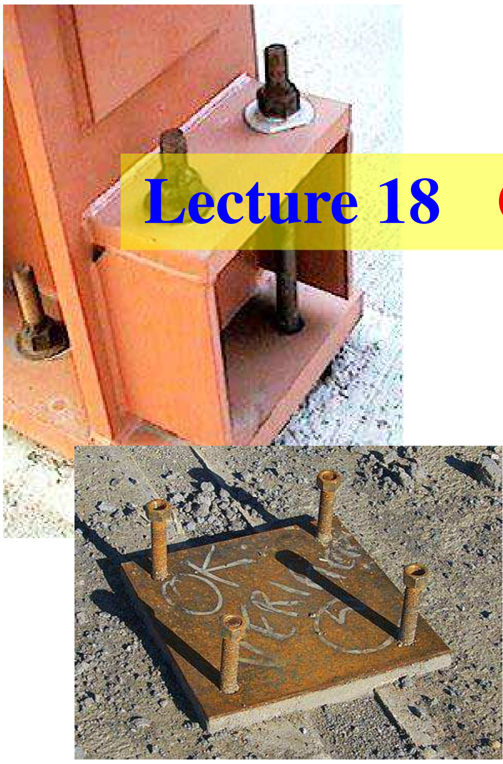
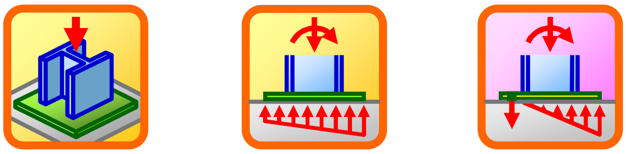
Timber and Steel Design



Lecture 18 Column Base Connections

- Compressive Axial Load
- Shear Design
- Base Plate with Small Moment
- Base Plate with Large Moment
- Anchor Rod

Visit www.tumcivil.com/DRMK/ for apps:



โดย ผศ.ดร.มงคล จิรวัชรเดช

SURANAREE INSTITUTE OF ENGINEERING

UNIVERSITY OF TECHNOLOGY SCHOOL OF CIVIL ENGINEERING

Column Bases

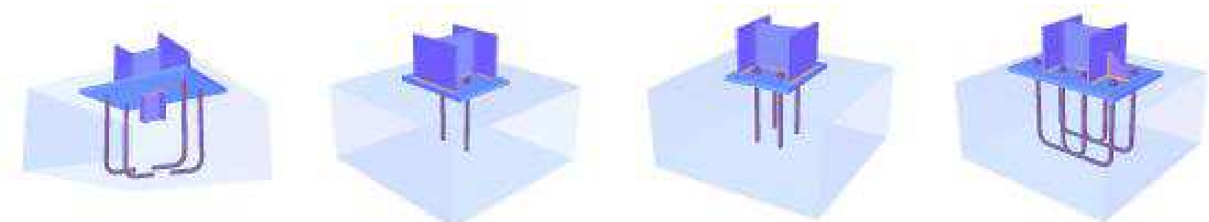
- Base plates and anchor rods are often the last structural steel items to be designed but the first items required on the jobsite
- Therefore the design of column base plate and connections are part of the critical path

Column Bases

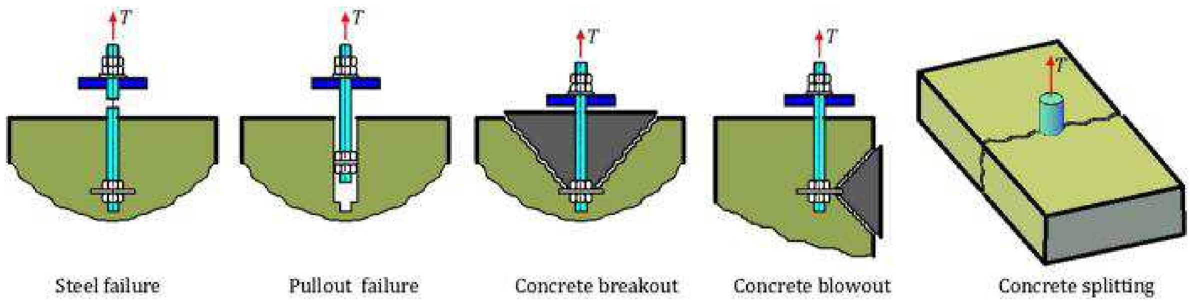
- Vast majority of column base plate connections are designed for axial compression with little or no tension.
- Column base plate connections can also transmit tension forces and shear forces through:
  - Anchor rods
  - Bearing end plate
  - Shear lugs under plate

Anchor Rod

- Anchor rods are needed for all base plates to prevent column from overturning during construction and in some cases to resist uplift or large moments

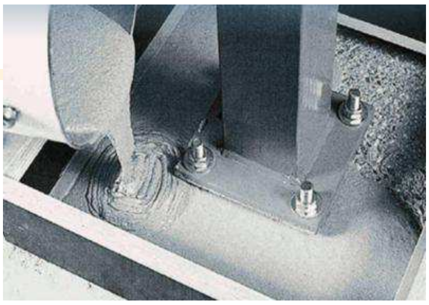


- Anchor rods are designed for pullout and breakout strength using ACI 318 Appendix D

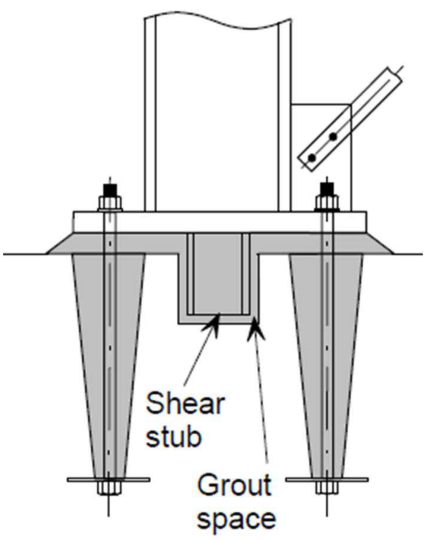


Column Erection Procedures

Grout

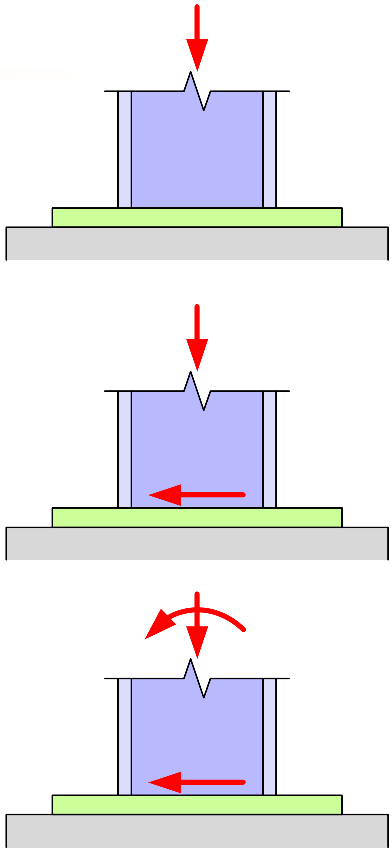


- Grout is needed to adjust the level and transfer the load from steel plate to foundation
- Grout should have at least twice compressive strength of foundation concrete
- When base plates larger than 600 mm, it is recommended that one or two grout holes be provided to allow the grout to flow easier

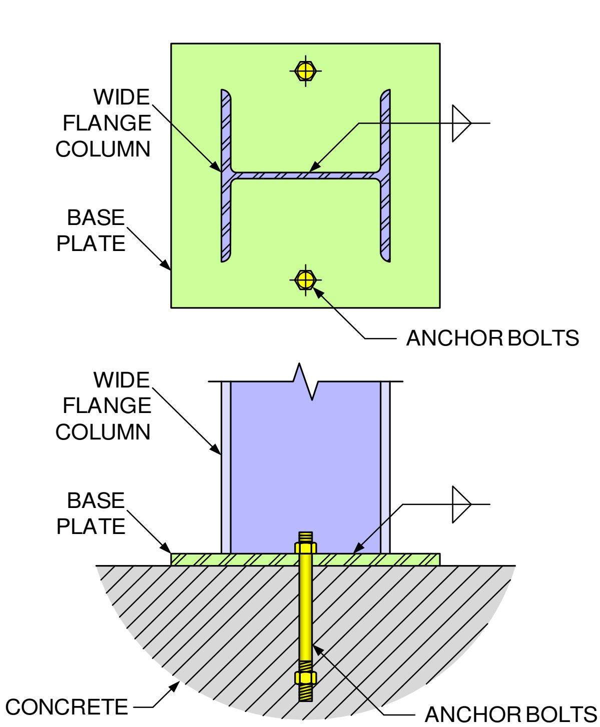


Column Bases

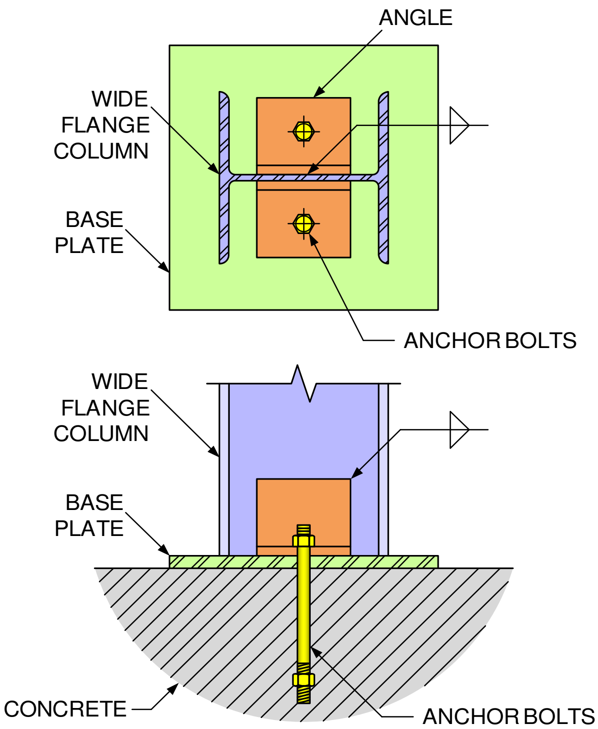
- Axial Load
- Axial Load + Shear
- Axial Load + Shear + Moment



Pin Connection Column Bases



TYPICAL DETAIL FOR PIN CONNECTION
BASE PLATE ABOVE FOOTING



TYPICAL DETAIL FOR PIN CONNECTION
BASE PLATE USING ANGLES

Pin Connection Column Bases

This pinned base connection has only one bolt going through a *lapped type* connection, but in this case the vertical member uses two plates rather than one. The two plates simply distribute the vertical load between the plates.

This base connection for a very tall column at the **Shanghai Expo** does just that. The rounded element that is added to the column as well as the cup shaped element at the base lead to the impression of movement.

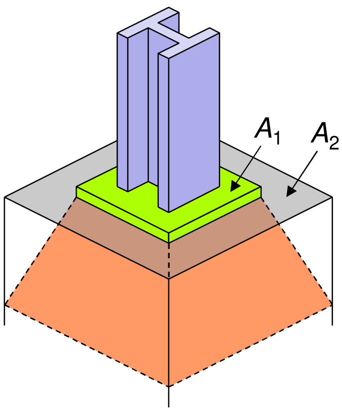
Axial Load Column Base

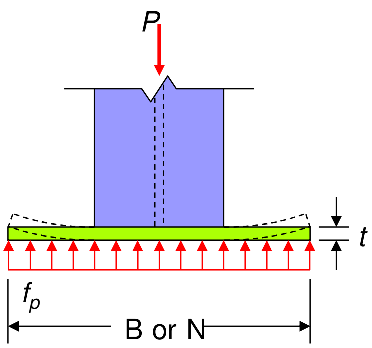
F_p = หน่วยแรงแบกทานที่ยอมให้ของคอนกรีต

f'_c = กำลังอัดประลัยของคอนกรีต

ถ้า $A_1 = A_2$, $\quad F_p = 0.35 f'_c$

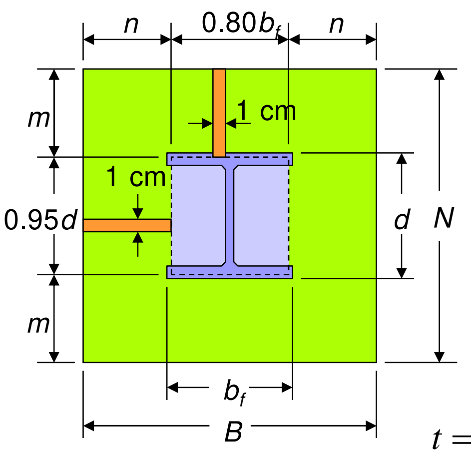
ถ้า A_1 น้อยกว่า A_2, $\quad F_p = 0.35 f'_c \sqrt{\dfrac{A_2}{A_1}} \le 0.7 f'_c$





แรงดันใต้แผ่นรองฐานเสา

$$\mathbf{f_p = P / (B \times N)}$$



โมเมนต์ดัดแต่ละทิศทาง:

$$M = f_p n \frac{n}{2} = \frac{f_p n^2}{2}$$

$$M = f_p m \frac{m}{2} = \frac{f_p m^2}{2}$$

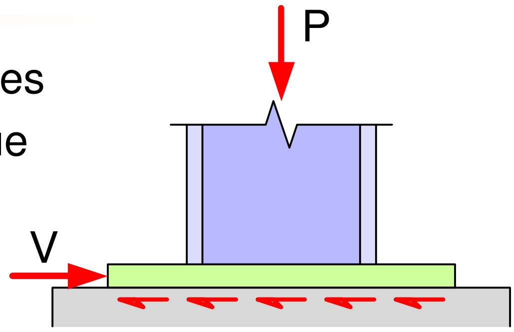
ความหนาแผ่นรอง:

$$t = 2m\sqrt{\frac{f_p}{F_y}} \quad \text{หรือ} \quad t = 2n\sqrt{\frac{f_p}{F_y}}$$

Shear Design

Normally, the column base shear forces are adequately resisted by friction, due to the axial compressive load.

But in some cases that shear force exceeds the friction resistance.



$F = \mu P$

4 ways to resist shear force :

- Friction
- Bolt shear/bearing
- Shear lugs
- Base embedment

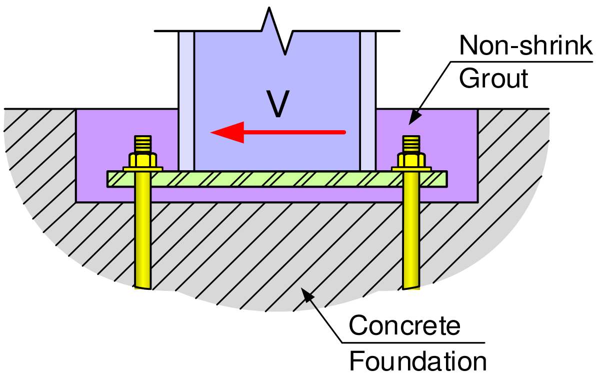
Coefficient of friction μ : (LRFD)

$\mu = 0.70$ for steel on concrete

$\mu = 0.55$ for steel on grout

For ASD these value of μ should be used with F.S. = 2.0

Transfer of Base Shears through Bearing

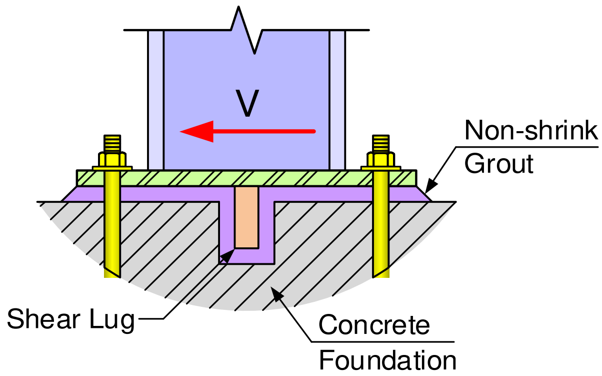


Column Embeded

Shear force resistance :

$$V_{em} = 0.35 f'_c A_{brg}$$

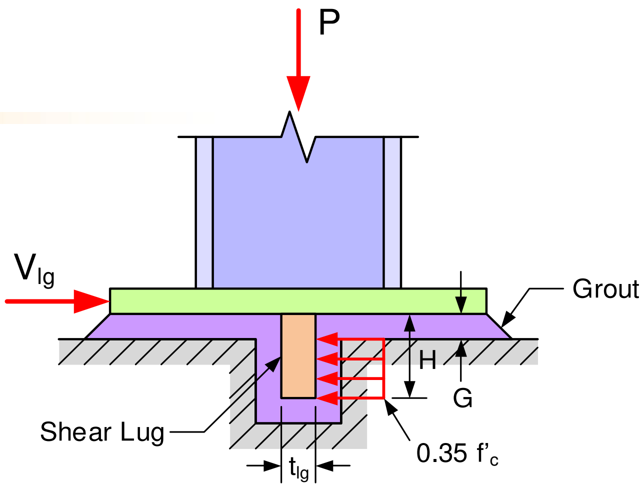
A_{brg} = Bearing area between base plate and/or column against concrete



Shear Lug

Shear Lug Design

ASD Procedure:



1. Determine the required V_{lg}

$$V_{lg} = V - \frac{\mu}{2} P_{DL}$$

2. The required bearing area A_{lg}

$$A_{lg} = \frac{V_{lg}}{0.35 f'_c}$$

3. Cantilever end moment M_{lg}

$$M_{lg} = \frac{V_{lg}}{W}\left(\frac{H+G}{2}\right)$$

4. Shear lug thickness t_{lg}

$$t_{lg} = \sqrt{\frac{6 M_{lg}}{0.75 F_y}}$$

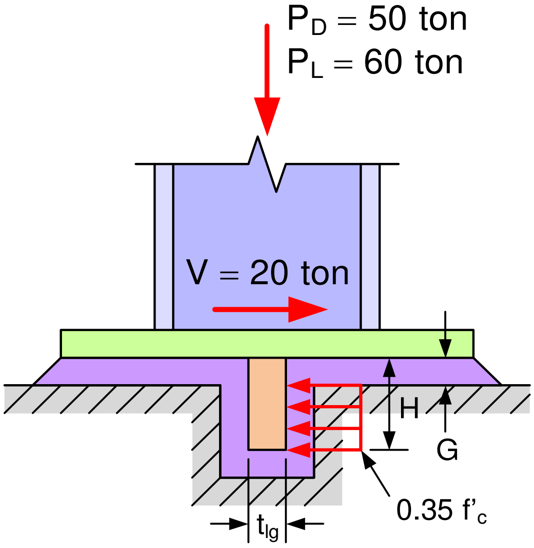
Where

W = Horizontal width of the lug

H = Vertical height of the lug

G = Grout thickness

ตัวอย่างที่ 18-1 ออกแบบแรงเฉือนสำหรับแผ่นรองใต้เสา ขนาด 35x35 ซม. รับน้ำหนักบรรทุกคงที่ 50 ตัน, น้ำหนักจร 60 ตัน และแรงเฉือน 20 ตัน โดยใช้เหล็ก A36 และคอนกรีต f'_c = 240 กก./ซม.^{2}



วิธีทำ แผ่นเหล็กวางอยู่บน grout ใช้ค่า $\mu = 0.55$

$$V_{lg} = 20 - (1/2)(0.55)(50) = 6.25 \text{ ton}$$

พื้นที่แผ่นเหล็กที่ต้องการ

$$A_{lg} = 6.25 / (0.35 \times 0.24) = 74.4 \text{ cm}^2$$

สมมุติความกว้างแผ่นเหล็ก $W = 20$ cm

ความสูงของส่วนที่รับแรงแบกทานจะเป็น

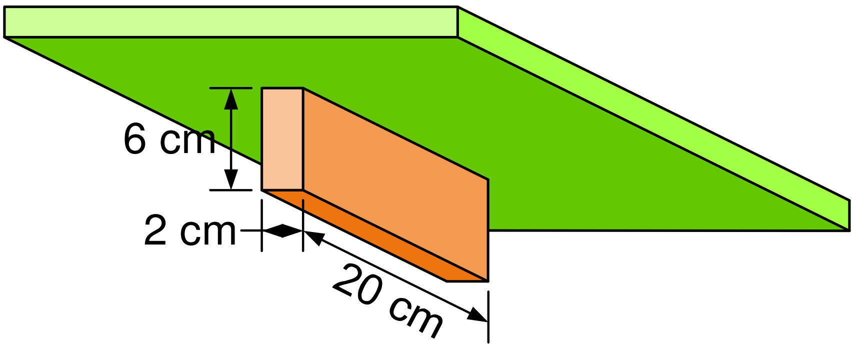
$$H - G = 74.4 / 20 = 3.72 \text{ cm}$$

ความหนา grout ใช้ $G = 2$ cm ดังนั้นความสูง H ของส่วนที่รับแรงแบกทานจะเป็น 6 cm

โมเมนต์ดัด $M_{lg} = \frac{V_{lg}}{W}\left(\frac{H+G}{2}\right) = \frac{6.25}{20}\left(\frac{6+2}{2}\right) = 1.25$ t-cm/cm

ความหนาแผ่น shear lug : $t_{lg} = \sqrt{\frac{6\,M_{lg}}{0.75\,F_y}} = \sqrt{\frac{6 \times 1.25}{0.75 \times 2.5}} = 2.0$ cm

∴ Use a shear lug 20 cm long × 6 cm high × 2 cm thick

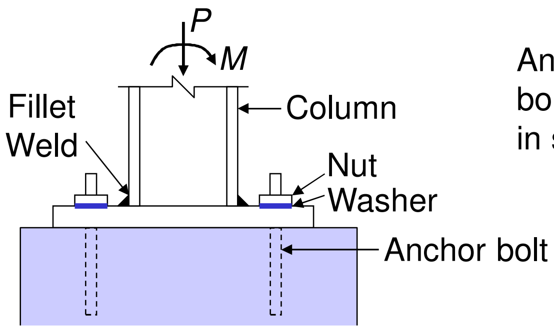


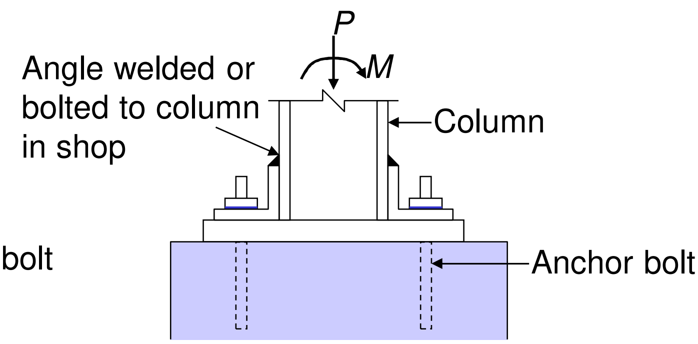
Moment Resisting Column Base

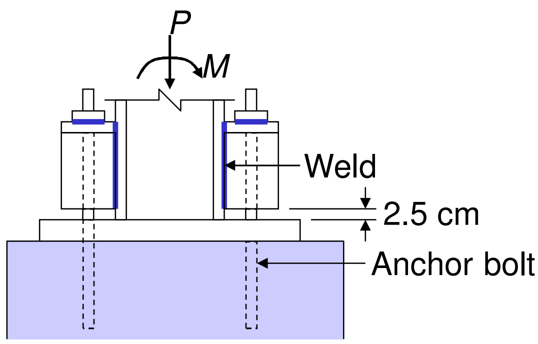
Car Park Roof Collapes under Wind

23 FEB 2015 กาฬสินธุ์ โรงจอดรถเสียหาย

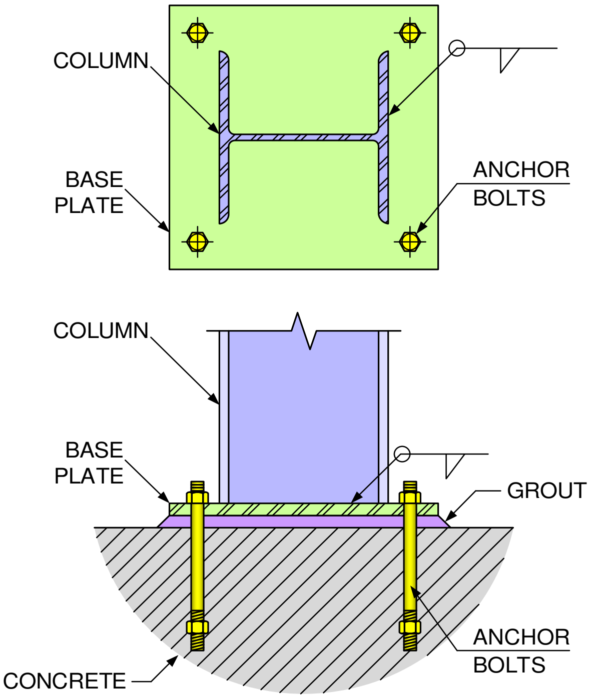
Moment-Resisting Column Bases



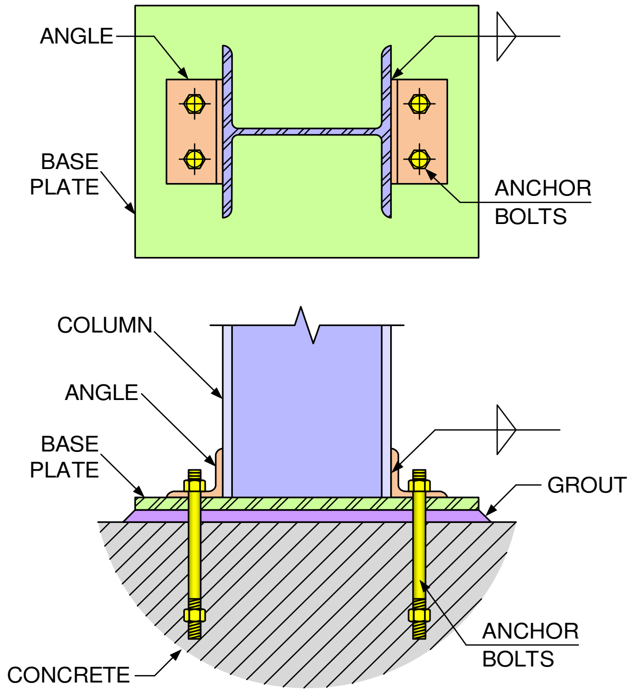




Moment Connection Column Bases



TYPICAL DETAIL FOR BASE PLATE
MOMENT CONNECTION USING BOLTS



TYPICAL DETAIL FOR BASE PLATE
MOMENT CONNECTION USING BOLTS
AND STEEL ANGLES

Bearing Pressure

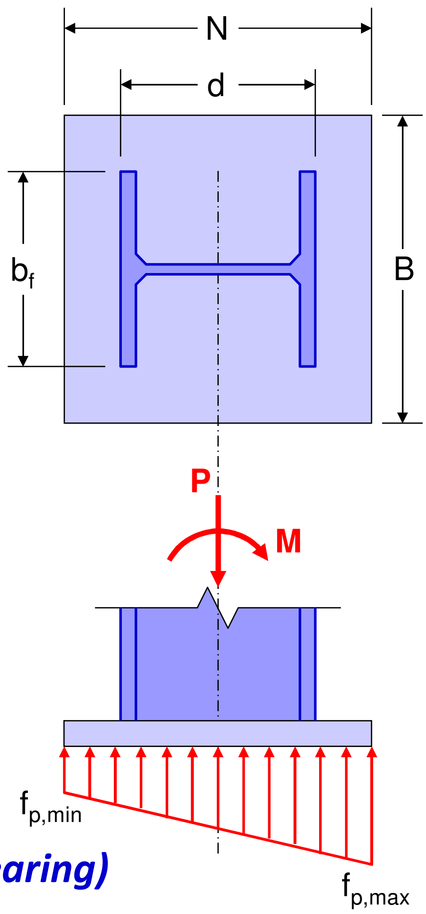
Pressure from axial load: $f_{pa} = P / A$

Pressure from moment: $f_{pb} = M / S$

where $A = B \times N$ and $S = B \times N^2 / 6$

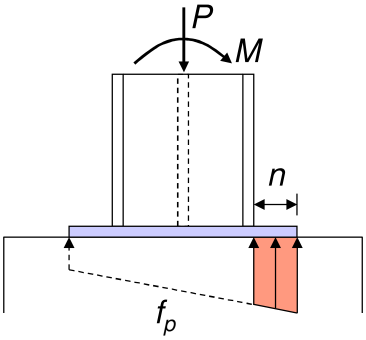
$$f_{p,min} = \frac{P}{BN} - \frac{6M}{BN^2} \geq 0$$

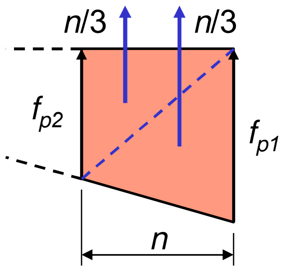
$$f_{p,max} = \frac{P}{BN} + \frac{6M}{BN^2} \leq F_p$$



Small Moment without Uplift (Full Plate Bearing)

Base Plate Design





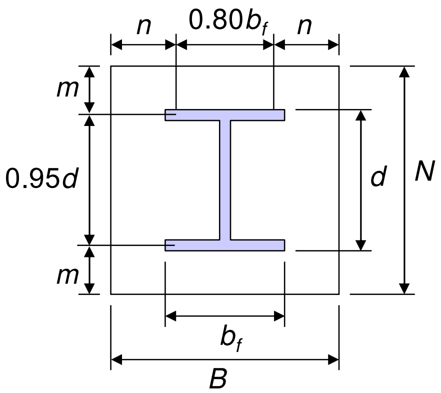
Moments at critical sections:

$$M = \frac{1}{2} f_{p1}\, n \left(\frac{2n}{3}\right) + \frac{1}{2} f_{p2}\, n \left(\frac{n}{3}\right)$$

$$= \frac{f_{p1}\, n^2}{3} + \frac{f_{p2}\, n^2}{6}$$

Another direction, $M = \dfrac{f_{p1}\, m^2}{3} + \dfrac{f_{p2}\, m^2}{6}$

โมดูลัสหน้าตัดของแผ่นรองกว้าง 1 ซม. หนา t คือ



$$S = \frac{I}{C} = \frac{\frac{1}{12}(1)(t^3)}{t/2} = \frac{t^2}{6} \longrightarrow F_b = \frac{M}{S} = \frac{6M}{t^2}$$

มาตรฐาน AISC กำหนดให้ $F_b = 0.75F_y$

$$0.75F_y = \frac{6M}{t^2} \rightarrow t = \sqrt{\frac{6M}{F_b}} = \sqrt{\frac{8M}{F_y}}$$

ตัวอย่างที่ 18-2 ออกแบบแผ่นรองใต้เสาต้านทานโมเมนต์เพื่อรองรับเสา W350x159 ซึ่งมีน้ำหนักตามแนวแกน 150 ตัน และโมเมนต์ดัด 15 ตัน-เมตร ใช้เหล็ก A36 และ $\mathbf{F_b}$ = 0.75(2,500) = 1,875 กก./ซม.^{2} คอนกรีตฐานรากมีค่า = 210 กก./ซม.^{2} และ $\mathbf{F_p}$ = 0.35(210) = 73.5 กก./ซม.^{2}

วิธีทำ W350x159 (d = 35.6 ซม., t_w = 14 มม., b_f = 35.2 ซม., t_f = 22 มม.)

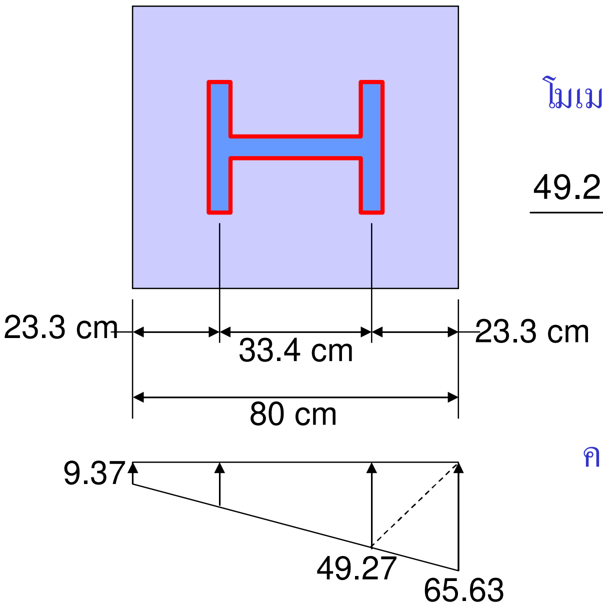
ระยะเยื้องศูนย์ $e = M/P = 15(100)/150 = 10$ ซม.

แรงลัพธ์อยู่ภายในปีกเสา พยายามจัดให้อยู่ในช่วง 1/3 กลางของแผ่นเหล็ก

ลองใช้แผ่นเหล็กขนาด **50 x 80** ซม.(หลังจากการลองหลายครั้ง)

$$f_p = \frac{P}{BN} \pm \frac{6M}{BN^2} = \frac{150\times10^3}{50\times80} \pm \frac{6\times15\times10^5}{50\times80^2}$$

$$= 37.5 \pm 28.13 = \begin{cases} 65.63\ \text{kg/cm}^2 < F_b = 73.5\ \text{kg/cm}^2 & \textbf{OK} \\ 9.37\ \text{kg/cm}^2 > 0 & \textbf{OK} \end{cases}$$



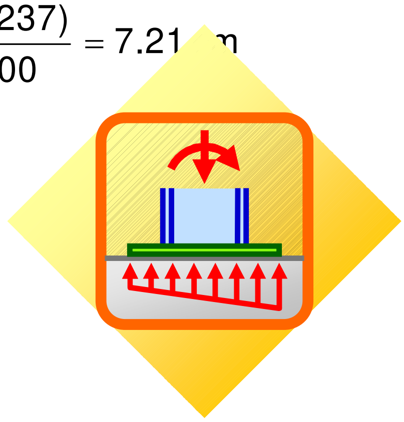
โมเมนต์ดัดในส่วนยื่น:

$$\frac{49.27(23.3)^2}{6} + \frac{65.63(23.23)^2}{3} = 16{,}237 \text{ kg-cm}$$

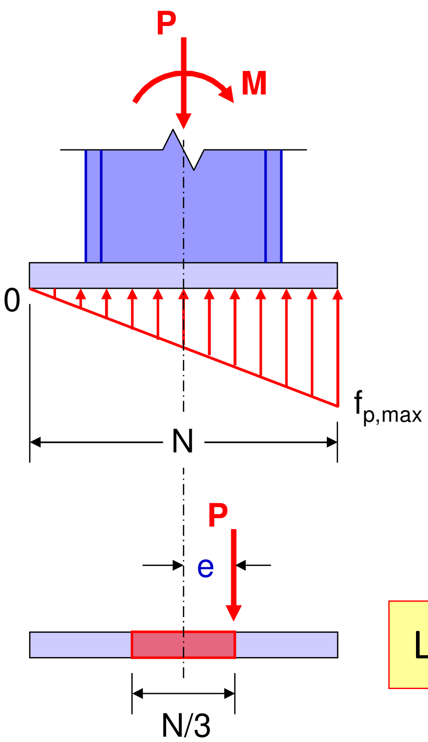
ความหนาของแผ่นเหล็กที่ต้องการ

$$t = \sqrt{\frac{8M}{F_y}} = \sqrt{\frac{8(16{,}237)}{2{,}500}} = 7.21 \ldots \text{m}$$

ใช้แผ่นเหล็ก 7.5 x 50 x 80 ซม.



Max Moment without Uplift



$$f_{p,min} = \frac{P}{BN} - \frac{6M}{BN^2} = 0$$

$$Pe = M = \frac{PN}{6}$$

$$e = \frac{N}{6}$$

Criteria for full plate bearing: $-\frac{N}{6} \le e \le \frac{N}{6}$

Load **P** within middle third of plate length **N**

Large Moment with Uplift

Eccentricity limit: $\frac{N}{6} \leq e \leq \frac{N}{2}$

$[\ \Sigma F_y = 0\ ]$ $$T + P = \frac{F_p N_p B}{2}$$

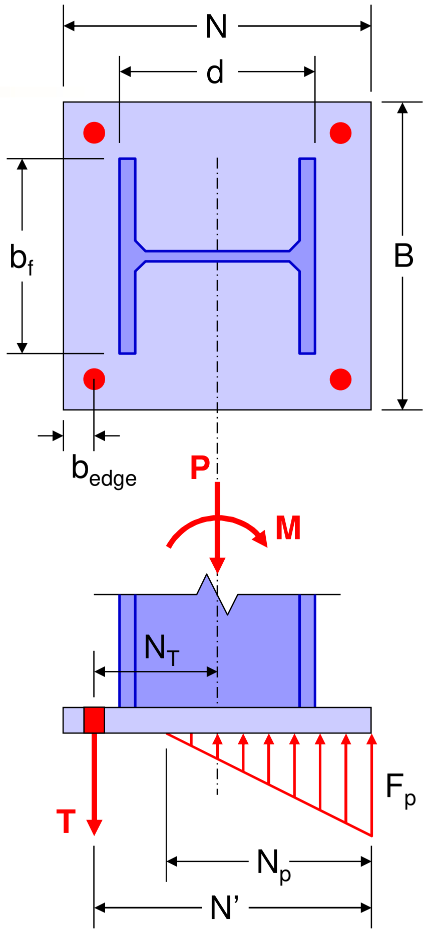
$[\ \Sigma M_T = 0\ ]$ $$P N_T + M = \frac{F_p N_p B}{2}\left(N' - \frac{N_p}{3}\right)$$

where **T** = Tensile force in anchor rod

N_T = Distance between anchor rod and column center

N_p = Bearing Length (< N)

N' = Distance between anchor rod and plate edge



From $[\ \Sigma M_T = 0\ ]$ $$P N_T + M = \frac{F_p N_p B}{2}\left(N' - \frac{N_p}{3}\right)$$

Solve quadratic function to determine the bearing length N_p :

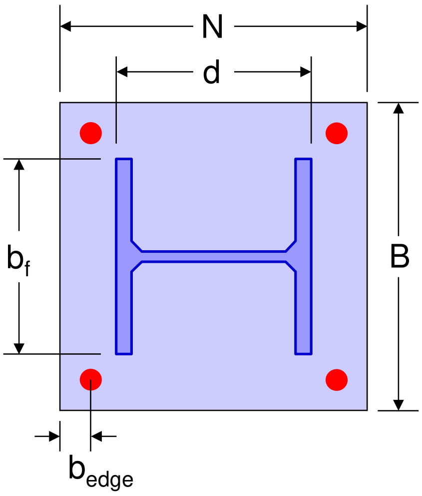
$$N_p = \frac{f' \pm \sqrt{f'^2 - 4(F_p B/6)(P N_T + M)}}{F_p B/3}$$

where **f'** = $F_p B N' / 2$

Tensile force in anchor rod: $$T = \frac{F_p N_p B}{2} - P$$

ตัวอย่างที่ 18-3 ทำตัวอย่างที่ 18-2 ซ้ำโดยใช้เสา W350x159 ต้นเดิม รับน้ำหนัก P = 50 ตัน และโมเมนต์ดัด M = 10 ตัน-เมตร ฐานคอนกรีตมีขนาดเท่าแผ่นเหล็ก f'_c = 240 ksc

วิธีทำ W350x159 (d = 35.6 ซม., t_w = 14 มม., b_f = 35.2 ซม., t_f = 22 มม.)



ลองเลือกขนาดแผ่นเหล็กจากขนาดเสาบวกระยะขอบสมอยึด

$$N > d + 2 \times 8 = 35.6 + 16 = 51.6 \text{ cm}$$

$$B > b_f + 2 \times 8 = 35.2 + 16 = 51.2 \text{ cm}$$

ลองแผ่นเหล็ก N = 52 cm, B = 52 cm

ระยะเยื้องศูนย์ e = M/P = 10x100/50 = 20 cm

$$N/6 = 8.67 \text{ cm} < e = 20 < N/2 = 26 \text{ cm}$$

∴ โมเมนต์มากจนทำให้เกิดแรงดึงในสมอยึด

พิจารณาความยาวแบกทาน:

$$F_p = 0.35 \times 240 = 84 \text{ kg/cm}^2$$

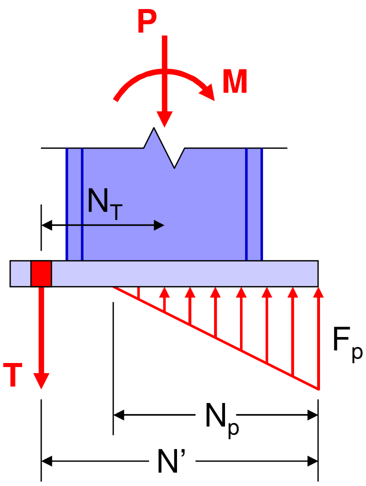
$$f' = F_p B N' / 2$$

$$= 84 \times 52 \times 48 / 2$$

$$= 104832 \text{ kg}$$

$$N_p = \frac{f' \pm \sqrt{f'^2 - 4(F_p B/6)(P N_T + M)}}{F_p B/3}$$

N_p = 24.0 cm

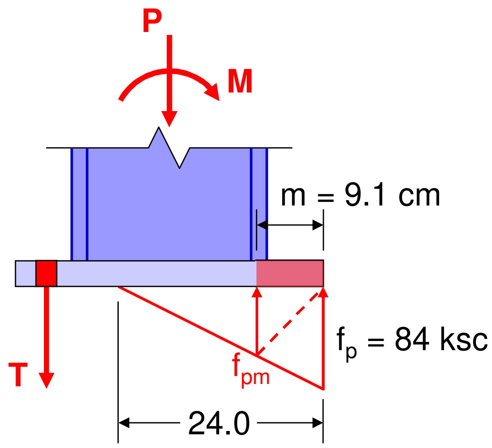


พิจารณาแรงดึงในสมอยึด: $T = \dfrac{F_p N_p B}{2} - P$

$T = 84 \times 24.0 \times 52 / 2 - 50\times10^3$

$= 2416$ kg

$\mathbf{T_{rod} = T/2 = 1208}$ **kg**



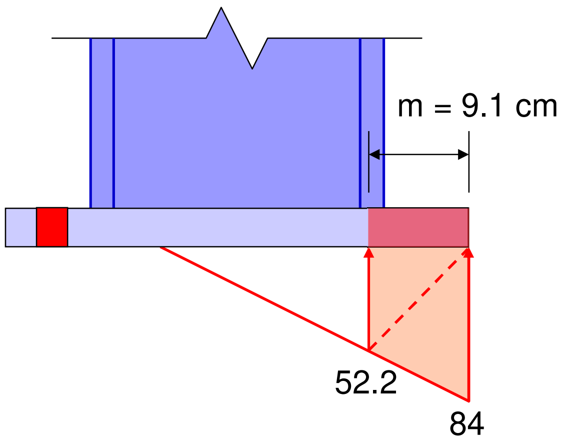
พิจารณาความหนาแผ่นเหล็ก:

ระยะยื่น $m = (N - 0.95d)/2$

$= (52 - 0.95\times35.6)/2$

$\mathbf{m = 9.1}$ **cm**

$f_{pm} = 84 \times (24.0 - 9.1) / 24.0 = 52.2$ ksc



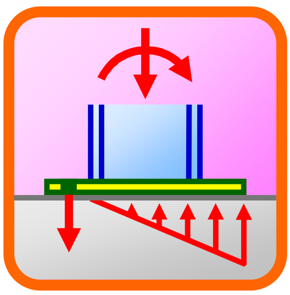
โมเมนต์ดัดในแผ่นเหล็ก:

$$M_{pl} = \frac{52.2\times9.1^2}{6} + \frac{84\times9.1^2}{3}$$

$= 3039$ kg-cm

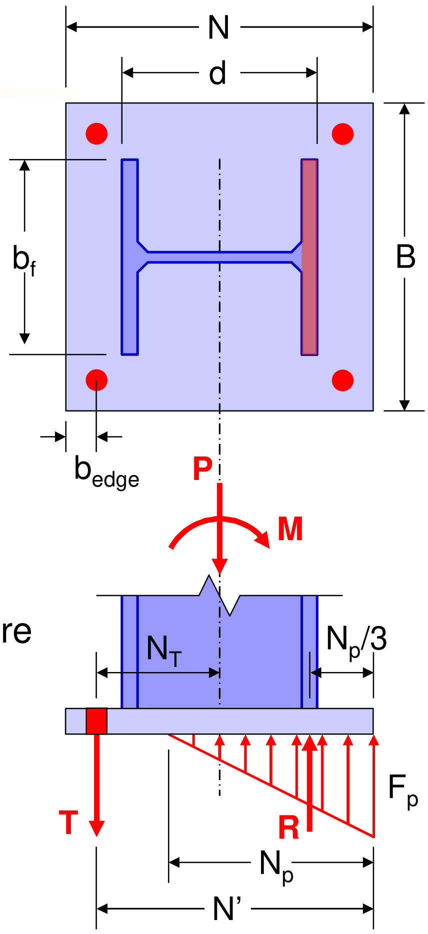
$$t = \sqrt{\frac{8\times3039}{2500}} = 3.1 \text{ cm}$$

ใช้แผ่นเหล็ก **PL 3.1 x 52 x 52** ซม.



Alternative Shorter Method

วิธีอย่างง่ายในการคำนวณความยาวแบกทานโดยสมมุติให้ศูนย์ถ่วงแรงดันใต้ฐานตรงกับปีกรับแรงอัด



$[\Sigma F_y = 0]$ $$T + P = R = \frac{F_p N_p B}{2}$$

$[\Sigma M_T = 0]$ $$PN_T + M = R\left(N' - \frac{N_p}{3}\right)$$

where **T** = Tensile force in anchor rod

R = Resultant force from bearing pressure

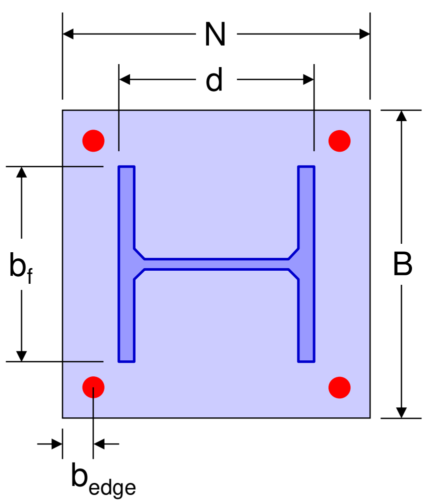
N_T = Distance between anchor rod and column center

N_p = Bearing Length (< N)

N' = Distance between anchor rod and plate edge

ตัวอย่างที่ 18-3 ทำตัวอย่างที่ 18-2 ซ้ำโดยใช้เสา W350x159 ต้นเดิม รับน้ำหนัก P = 50 ตัน และโมเมนต์ดัด M = 10 ตัน-เมตร ฐานคอนกรีตมีขนาดเท่าแผ่นเหล็ก f'_c = 240 ksc

วิธีทำ W350x159 (d = 35.6 ซม., t_w = 14 มม., b_f = 35.2 ซม., t_f = 22 มม.)



ลองแผ่นเหล็ก N = 52 cm, B = 52 cm

N/6 = 8.67 cm < e = 20 < N/2 = 26 cm

ความยาวแบกทาน N_p = 3 (52 – 35.6 + 2.2) / 2

= 27.9 cm

พิจารณาแรงดึงในสมอยึด: $$T = \frac{F_p N_p B}{2} - P$$

T = 84 x 27.9 x 52 / 2 – 50x10³ = 10934 kg

$$T_{rod} = T/2 = 5467 \text{ kg}$$

พิจารณาความหนาแผ่นเหล็ก:

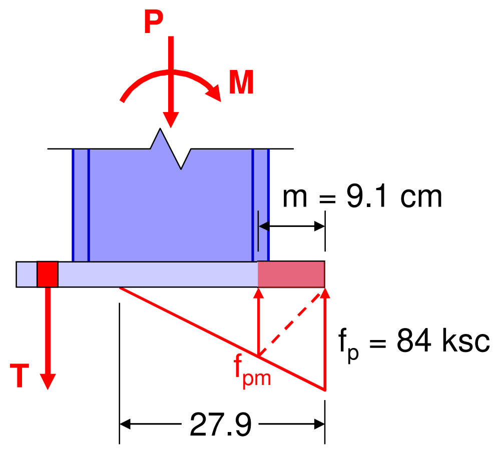
ระยะยื่น $m = (N - 0.95d)/2$

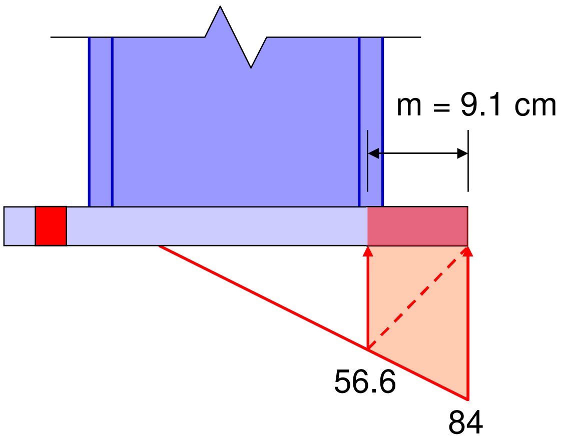
$= (52 - 0.95 \times 35.6)/2$

$m = 9.1$ cm

$f_{pm} = 84\,(27.9 - 9.1) / 27.9$

$= 56.6$ ksc





โมเมนต์ดัดในแผ่นเหล็ก:

$$M_{pl} = \frac{56.6 \times 9.1^2}{6} + \frac{84 \times 9.1^2}{3}$$

$$= 3100 \text{ kg-cm}$$

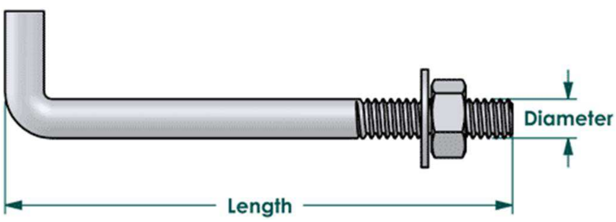
$$t = \sqrt{\frac{8 \times 3100}{2500}} = 3.2 \text{ cm}$$

ใช้แผ่นเหล็ก **PL 3.2 x 52 x 52** ซม.

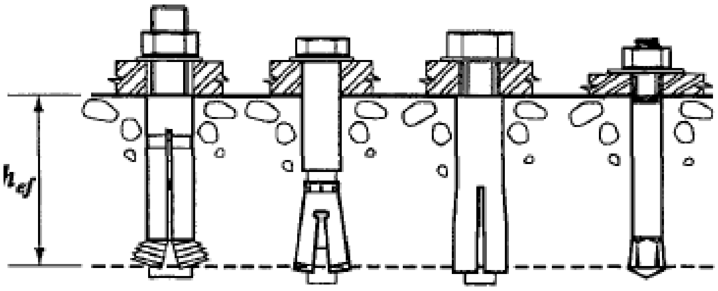
Anchor Rod

There are two general types of anchor bolts

- Cast-in-place bolts
- Drilled-in bolts

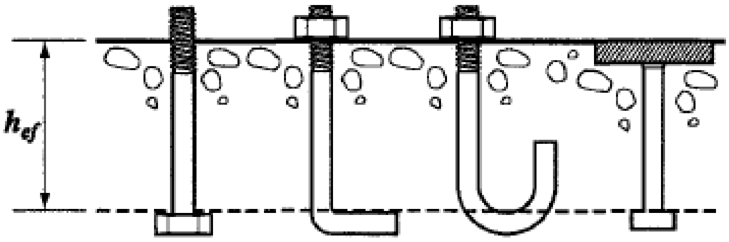


Anchor Rod



(a) Post-installed anchors

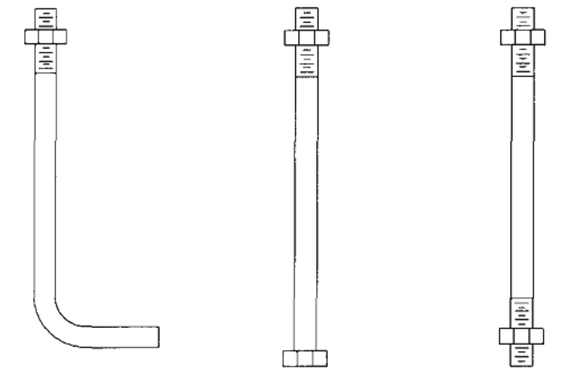
Drilled-in bolts are not normally used for base plates.
Their design is governed by manufacturer's specifications.



(b) Cast-in-place anchors

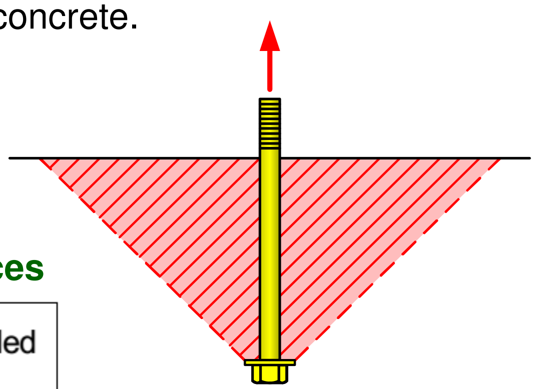
SUT Car Park

Types of Cast-in-place Anchor Rod



(a) Hooked Bar (b) Bolt (c) Threaded Bar with Nut

- Hooked bar resists tension through bond along the length and hook.
- Bolt-end rods have more positive anchorage from pull-out of a cone of concrete.

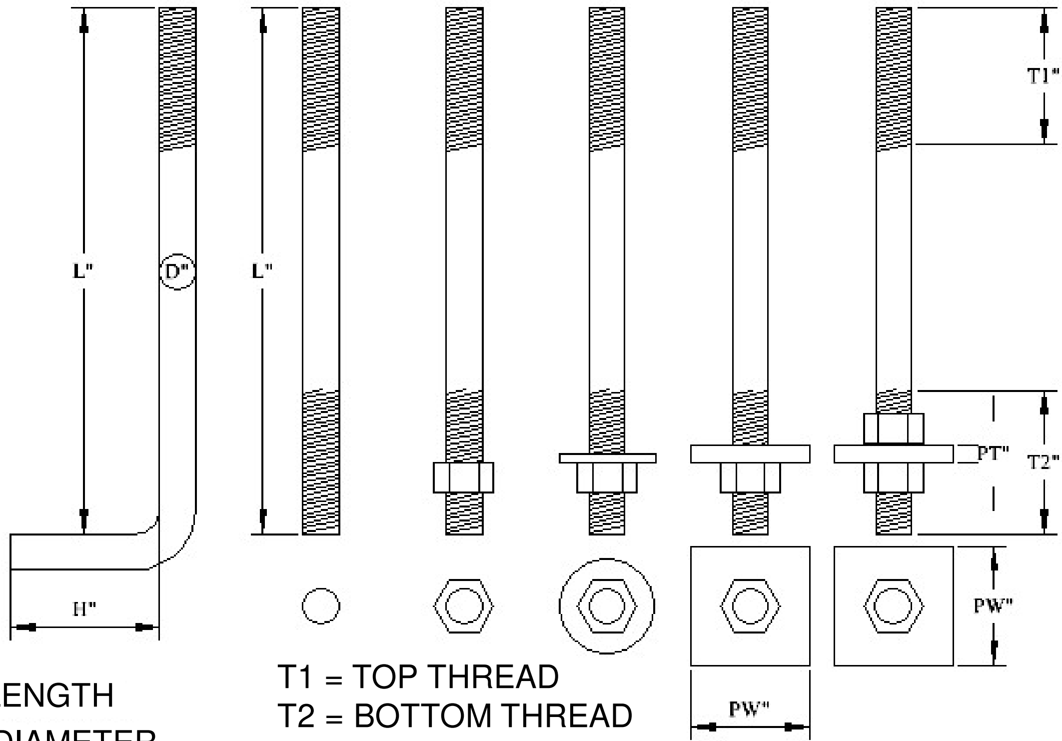


Minimum Bolt Lengths and Edge Distances

Bolt Type, Material	Minimum Embedded Length	Minimum Embedded Edge Distance
A307, A36	12 *d*	5 *d* > 10 cm
A325, A449	17 *d*	7 *d* > 10 cm

where *d* is the nominal diameter of the bolt or rod.

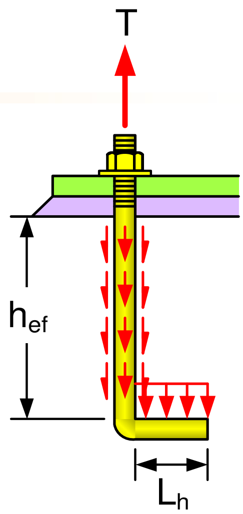
Anchor Bolt Dimensions



L = LENGTH
D = DIAMETER
H = HOOK LENGTH

T1 = TOP THREAD
T2 = BOTTOM THREAD
PW = PLATE WIDTH
PT = PLATE THICKNESS

Design of Hooked Bolts



The hook's tensile capacity is : $T_h = 0.7 f'_c \, d \, L_h$

where d = bolt diameter and L_h = hook length

For ASD, a factor of safety equal to 1.7 is used.

Hook should be design to have at least half bolt strength.

ASD Procedure:

1. Determine the allowable bolt tensile strength

$$T = A_b F_t \quad \text{where} \quad F_t = 0.33 F_u$$

2. The required length to develop half of T :

$$L_h = \frac{(T/2)}{(0.70 f'_c d / 1.7)}$$

3. Total length $= L_h + h_{ef}$

where h_{ef} = embedment length from the previous table

Bolt Type, Material	Minimum Embedded Length
A307, A36	12 *d*
A325, A449	17 *d*

ตัวอย่างที่ 18-4 พิจารณาความยาวของงอของสมอสลักขนาด 19 ม.ม. ทำด้วยเหล็ก A36 มีค่ากำลัง F_u = 4,000 กก./ซม.^{2} และคอนกรีต f'_c = 240 กก./ซม.^{2}

วิธีทำ 1. $T = A_b F_t = \frac{\pi}{4} \times 1.9^2 \times 0.33 \times 4.0 = 3.74$ ton

2. $L_h = \frac{(T/2)}{(0.70 f'_c d/1.7)} = \frac{(3.74/2)}{(0.70 \times 0.24 \times 1.9/1.7)} = 9.96$ cm

3. Total length = 9.96 + 12×1.9 = 32.76 cm   Say 33 cm

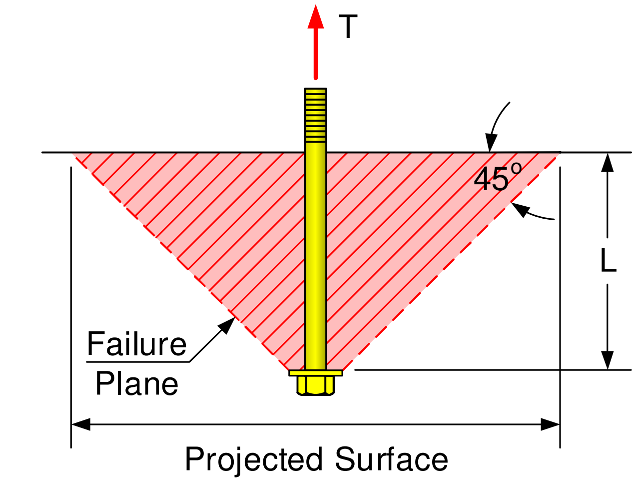
For A36 Bolt with f'_c = 240 kg/cm^2

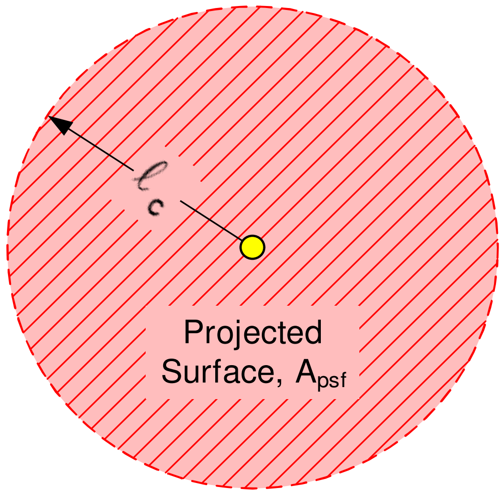
Bolt Size (mm)	Bolt Tension (ton)	Embed length (cm)	Hook length (cm)	Total length (cm)
12	1.49	14.4	6.28	20.7
16	2.65	19.2	8.38	27.6
19	3.74	22.8	9.96	32.8
22	5.02	26.4	11.5	37.9
25	6.48	30.0	13.1	43.1

Design of Bolts and Rod with a Nut

Recommended for base to resist moments or tensile(uplift) force.

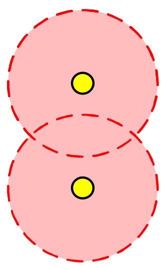
Failure occurs from bolt fails or concrete cone separation.





Projected Surface: $A_{psf} = \pi \, \ell_c^2$

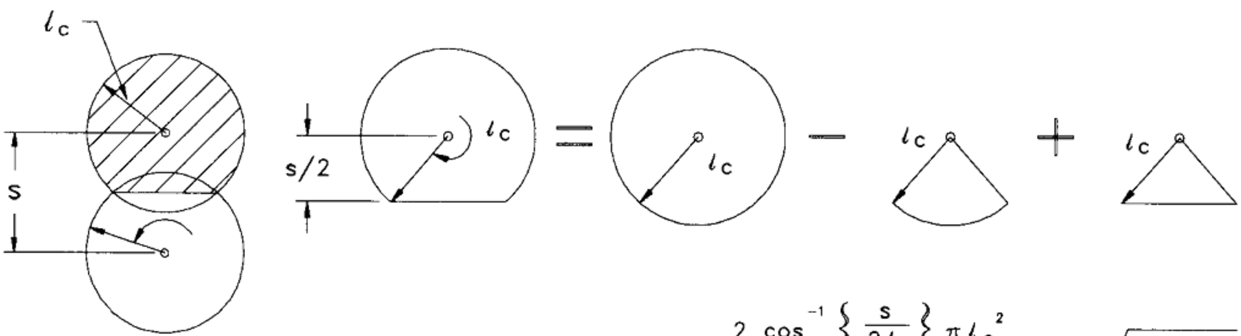
Overlap Failure Cones



For multiple anchorages, the separate failure cone may overlap.

or when a cone intersects a pedestal edge.

The effective area of the group should then be used.



$$\text{Area} = \pi l_c^2 - \frac{2\cos^{-1}\left\{\frac{s}{2 l_c}\right\} \pi l_c^2}{360^\circ} + \frac{s}{2}\sqrt{l_c^2 - \frac{s^2}{4}}$$

Circle   Sector   Triangle

Bolts and Rod with a Nut Design

ASD Procedure:

1. Determine the bolt area:

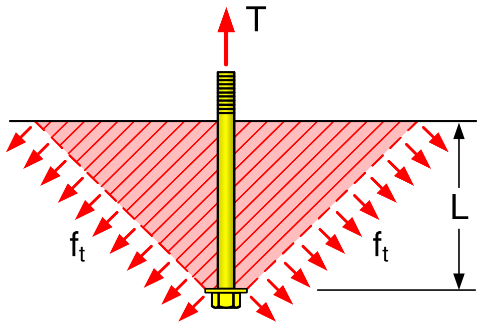
$$A_b = \frac{T}{0.33F_u}$$

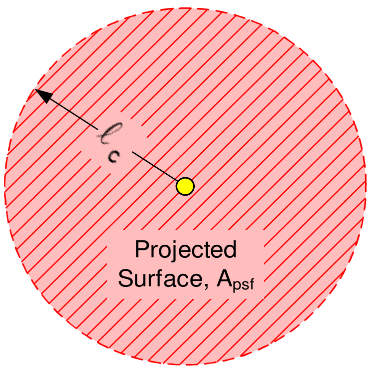
2. The required projected surface area:

$$A_{psf} = \frac{T}{0.53\sqrt{f'_c}}$$

3. Bolt length is equal to radius of area $\rightarrow$ $L = \ell_c$

$$L = \sqrt{\frac{A_{psf}}{\pi}}$$





ตัวอย่างที่ 18-5 พิจารณาความยาวสมอสลักเกลียวขนาด 19 ม.ม. ทำด้วยเหล็ก A36 มีค่ากำลัง F_u = 4,000 กก./ซม.^{2} และคอนกรีต f'_c = 240 กก./ซม.^{2}

วิธีทำ 1. $T = A_b F_t = \frac{\pi}{4} \times 1.9^2 \times 0.33 \times 4.0 = 3.74$ ton

2. $A_{psf} = \frac{T}{0.53\sqrt{f'_c}} = \frac{3.74 \times 1{,}000}{0.53\sqrt{240}} = 455.5$ cm^2

3. Required length $L = \sqrt{\frac{A_{psf}}{\pi}} = \sqrt{\frac{455.5}{\pi}} = 12.04$ cm

For A36 Bolt with $f'_c = 240$ kg/cm^2

Bolt Size (mm)	Bolt Tension (ton)	Bolt length (cm)	Min. Bolt length (12d, cm)
12	1.49	7.6	14.4
16	2.65	10.1	19.2
19	3.74	12.0	22.8
22	5.02	14.0	26.4
25	6.48	15.9	30.0

$\therefore$ **Use 23 cm**

Column Base Overturning

Base Overturning Resistance

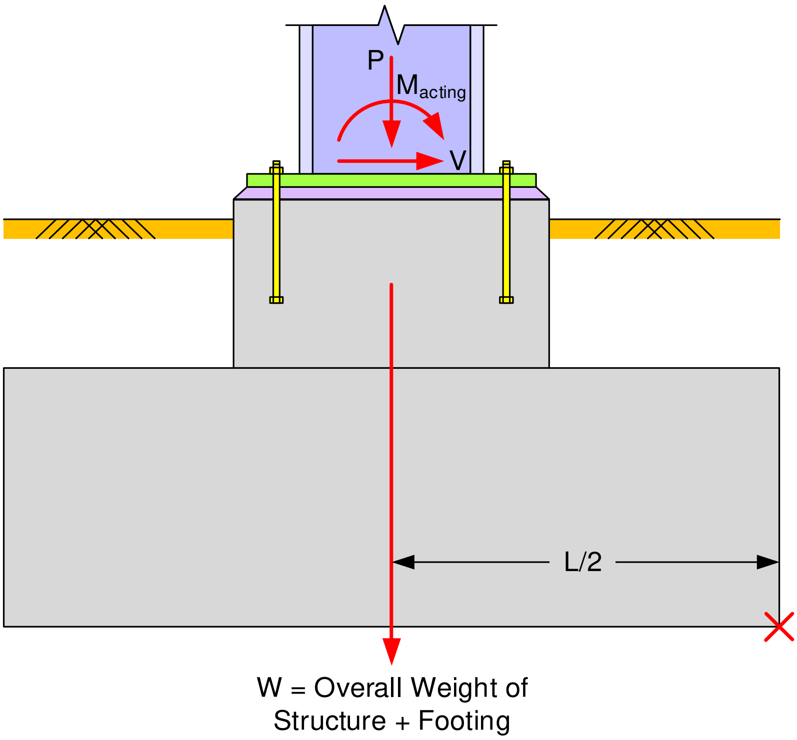
Resisted by weight of foundation

Resisting Moment :

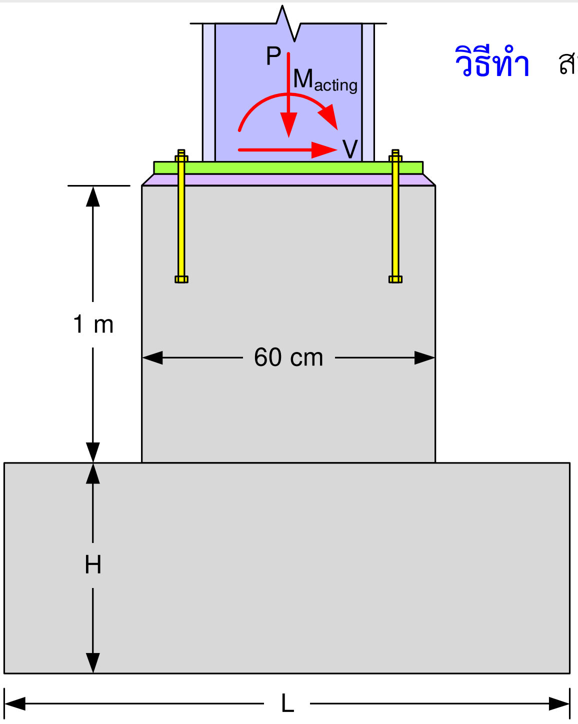
$$M_{resist} = W \times \frac{L}{2}$$

Overturning Safety :

$$F.S. = \frac{M_{resist}}{M_{acting}} > 1.5$$



ตัวอย่างที่ 18-6 ต่อเนื่องจากตัวอย่างที่ 18-3 เสา W350x159 รับน้ำหนัก P = 50 ตัน และโมเมนต์ดัด M = 10 ตัน-เมตร แผ่นรองมีขนาด 3.2 x 52 x 52 ซม. ตอม่อมีขนาด 60 x 60 ซม. ยาว 1 เมตร จงออกแบบขนาดฐานรากเพื่อต้านทานการพลิกคว่ำ



วิธีทำ สมมุติฐานรากขนาด $B = 2$ m, $L = 3$ m, $H = 1$ m

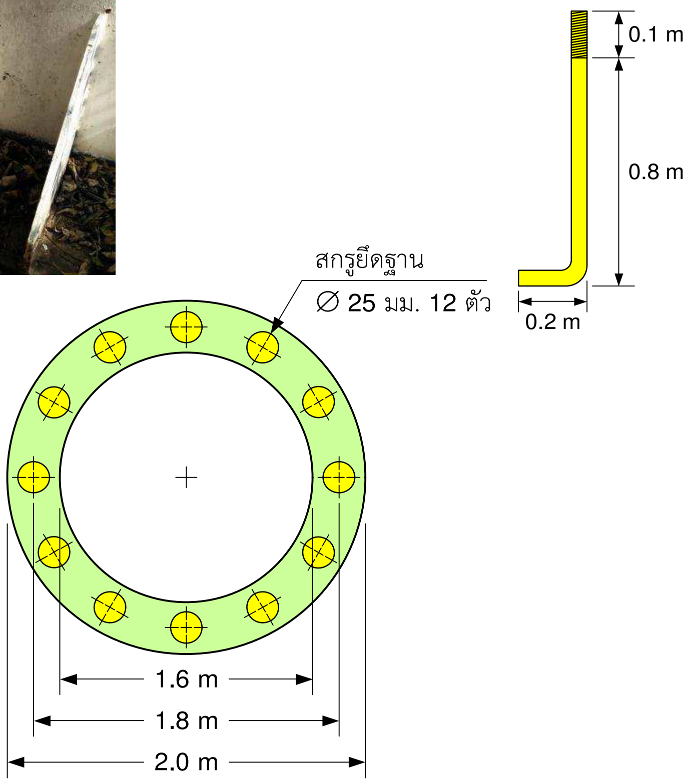
$$W = (0.6\times0.6\times1.0 + 2\times3\times1) \times 2.4$$

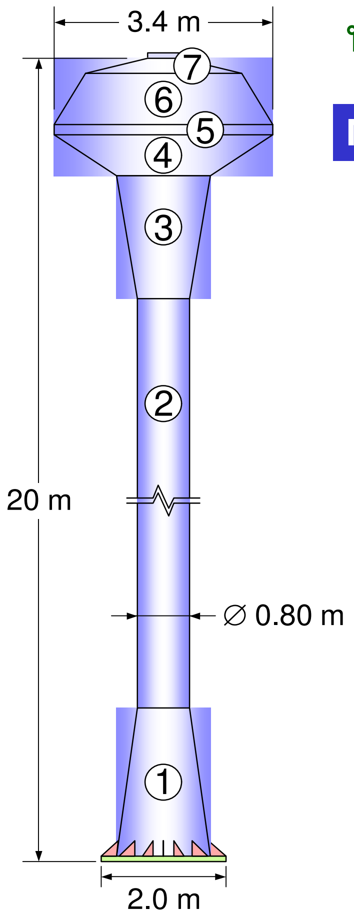
$$= 15.26 \text{ ton}$$

$$M_{resist} = 15.26 \times 3 / 2 = 22.9 \text{ t-m}$$

$$\frac{M_{resist}}{M_{acting}} = \frac{22.9}{10} = 2.29 > 1.5$$ **OK**

Water Tower Tank





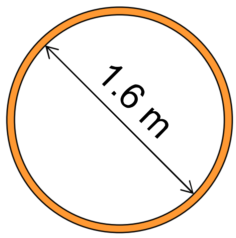
หอถังสูง (ถังแชมเปญ) ขนาด 20 ลบ.ม.

Moment due to Wind Load

Area No.	Area (m^2)	WL (kg/m^2)	Arm (m)	Moment (kg-m)
①	3.00	50	1.25	188
(2.1)	6.00	50	6.25	1,875
(2.2)	4.80	80	13.00	4,992
③	2.64	80	17.10	3,611
④	1.62	80	18.50	2,398
⑤	0.76	80	19.70	1,198
⑥	3.20	80	20.50	5,248
⑦	0.51	80	21.15	863

V = **1,532 kg** M = **20,373 kg-m**

ออกแบบรอยเชื่อม สมมุติรอยเชื่อมมีขนาด 1 ซม.



$A = 2 \pi r t = 2(3.1416)(80)(1.0) = 503 \text{ cm}^2$

$I = \pi r^3 = (3.1416)(160/2)^3 = 1,608,499 \text{ cm}^3$

$f_v = V / A = 1,532 / 503 = 3.1 \text{ kg/cm}^2$

$f_t = M r / I = 20,373(100)(80)/1,608,499$

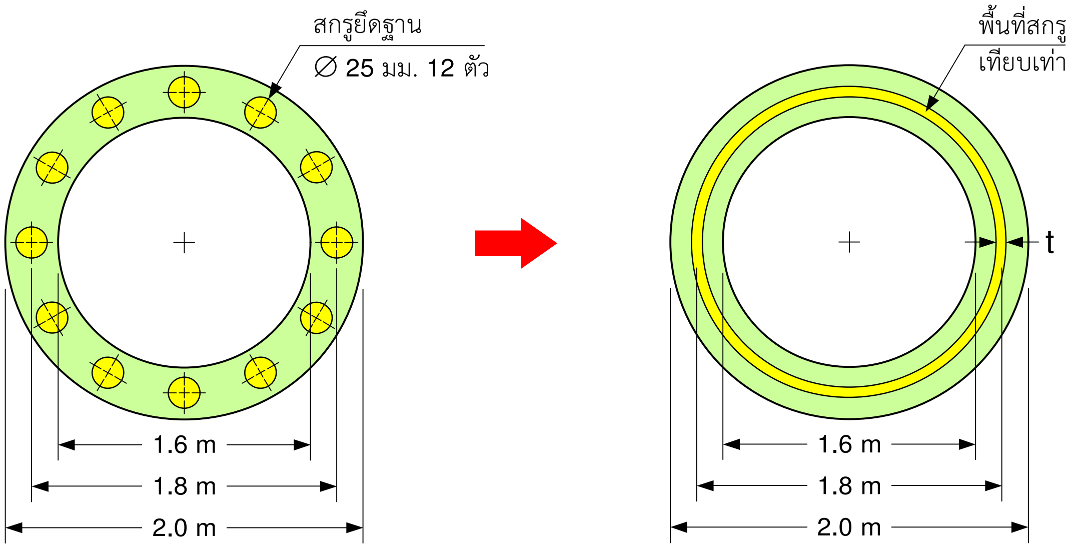
$= 101.3 \text{ kg/cm}^2$

$f_r = \sqrt{f_v^2 + f_t^2} = 101.4 \text{ kg/cm}^2$

ลวดเชื่อม E70 ขนาด 1 ซม. มีกำลัง 1,040 กก./ซม.

ขนาดรอยเชื่อมที่ต้องการ = 101.4 / 1,040 = 0.0975 ซม. **(ใช้ 5 มม.)**

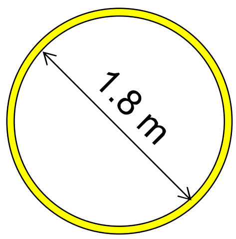
ออกแบบสลักเกลียว สมมุติเหมือนเป็นรอยเชื่อม



พื้นที่สลักเกลียว $= 12\times(\pi/4)\times2.5^2 = 58.9\ cm^2$

พื้นที่เทียบเท่า $= 2\,\pi\,(90)\times t = 58.9\ cm^2 \rightarrow t = 0.104\ cm$

ออกแบบพื้นที่สลัก สมมุติขนาด $t = 1$ ซม.



$I = \pi\, r^3 = (3.1416)(90)^3 = 2{,}290{,}226\ cm^3$

$f_t = M\,r / I = 20{,}373(100)(90)/2{,}290{,}226$

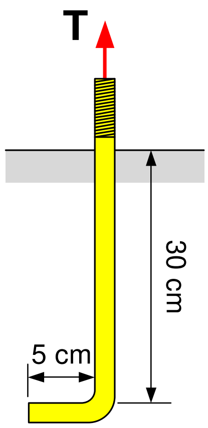
$= 80.1\ kg/cm^2$

สลัก A36 ขนาด 1 ซม. มีกำลัง $F_t = 0.33F_u = 0.33\times4{,}000 = 1{,}320$ กก./ซม.

ขนาดที่ต้องการ $t = 80.1 / 1{,}320$

$= 0.0607\ cm <$ ขนาดที่ใช้ $t = 0.104\ cm$ **OK**

แรงดึงใน 1 สลัก



$f_t = 80.1 / 0.104 = 770\ kg/cm^2$

$T = (\pi/4)\times2.5^2\times770 = 1{,}203\ kg$

$$L_h = \frac{(T/2)}{(0.70 f'_c d / 1.7)} = \frac{(1.203/2)}{(0.70\times0.24\times1.9/1.7)} = 3.2\ cm$$

Total length $= 3.2 + 12\times2.5 = 33.2$ cm **Say 35 cm**

End of Lecture