مراجعه mid Term

Summary

Water Tanks

7

Structural Department

4th Year Civil
2ND TERM

Moment distribution method:

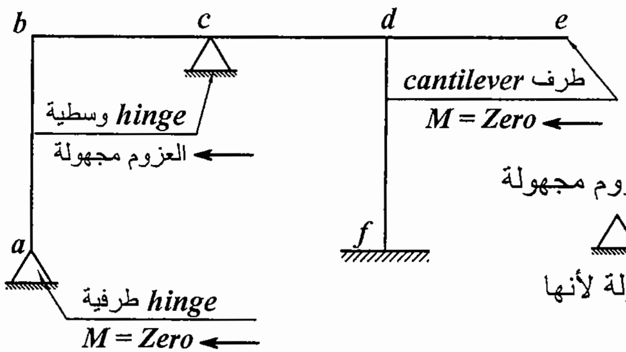
هي أحد الطرق المستخدمة لحل *Indeterminate structure* و التى تعتمد على توزيع العزوم الناتجة عند الـ *Joints* على الـ *members* المتصلة عند هذه الـ *Joint* بدلالة الـ *stiffness* للعناصر

في هذه الطريقة نقوم بملأ جدول لحل المسألة و هذا الجدول يضم مجموعة من الصفوف الثابتة التي يتم ملأها

Joint	
member	
D.F.	
F.E.M.	
Bal. M.	
C.O.M.	
Bal. M.	
M_f	

Joint

و هي النقاط التى تكون عندها العزوم مجهولة و يجب و ضعها بالترتيب في الجدول أي أن كل *Joint* بعدها التى تليها $b \rightarrow c \rightarrow d \rightarrow f$



- عند الـ *Joints b, c, d, f* العزوم مجهولة والـ *Joint c* بالرغم من وجود △ عندها إلا أن العزوم عندها مجهولة لأنها *hinge* في المنتصف
- عند الـ *Joints a,e* العزوم معلومة لذلك لا يتم وضعهم في الجدول حيث أن

a = Hinge support & e = End of cantilever

Members

هي جميع الـ *members* المتصلة بالـ *Joint*

مثال

at Joint d → *dc*, *df*, *de*

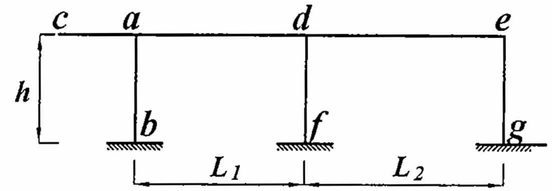
و يجب وضع كل *member* بجوار المناظر له في الاسم مثال *ab & ba*

و يكون شكل الجدول كالتالي

Joint	*b*		*c*		*d*			*f*
member	*ba*	*bc*	*cb*	*cd*	*dc*	*de*	*df*	*fd*

Distribution factor

$$D.F. = \frac{K_{member}}{\sum K_{members}}$$



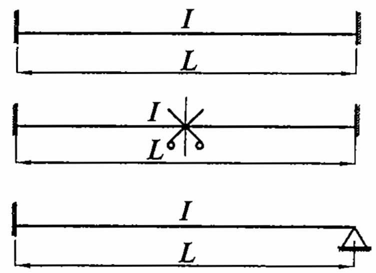
و هي نسبة التوزيع التى نقوم توزيع العزوم بها و هي تعتمد على الـ *Stiffness* للـ *members* المختلفة و بالتالي يجب حساب *Stiffness* قبل هذه الخطوة

Relative stiffness

Fixed Fixed $K = \frac{I}{L}$

Symmetrical $K = \frac{0.5I}{L}$

Fixed Hinged $K = \frac{0.75I}{L}$

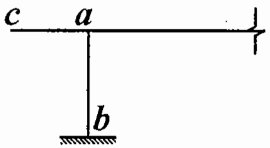


و منها يمكن حساب *D.F.* و وضعها في الجدول و يجب مراعاة أن

D.F. = Zero (for cantilever & fixation)

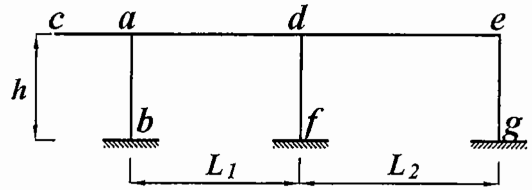
$D.F._{ba} = Zero$

$D.F._{ac} = Zero$



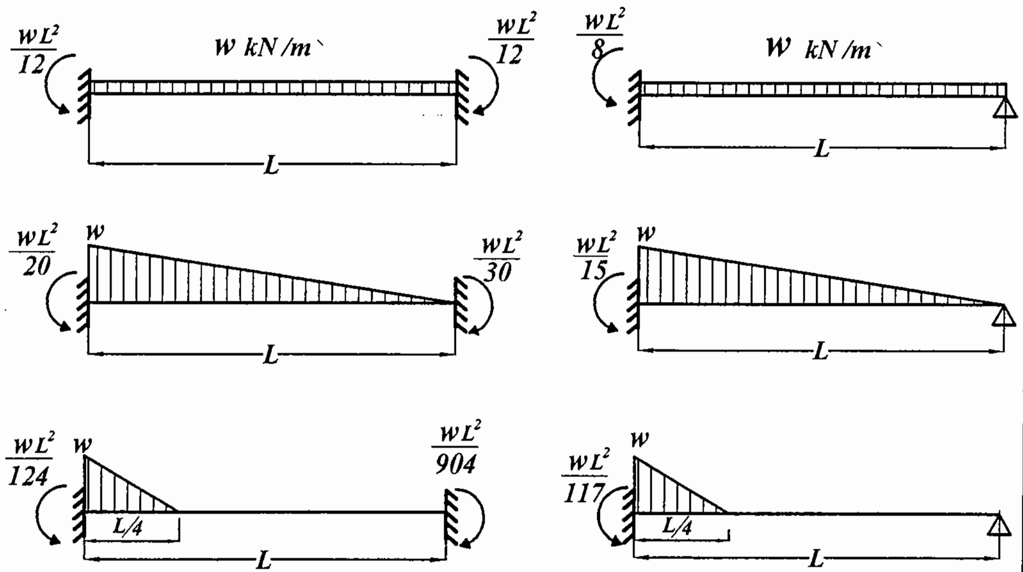
$$\longrightarrow D.F._{ab} = \frac{(I_c/h)}{(I_s/L_1)+(I_c/h)}$$

$$D.F._{ad} = \frac{(I_s/L_1)}{(I_s/L_1)+(I_c/h)}$$



F.E.M.

و هي قيم الصف الرابع و تحتوي على العزوم المتولدة على كل ***member*** بفرض أن الـ ***joint*** التى عندها العزوم مجهولة تمثل ***Fixed support*** و هذه العزوم تكون مجموعة من القيم المحفوظة



بعد ذلك يتم ملأ الجدول بطريقة تقليدية تعتمد على تجميع ***F.E.M.*** عند كل ***Joint*** و تغيير إشارتها و ضربها في ***D.F.*** لتوزيعها على الـ ***members*** المختلفة عند هذه الـ ***Joint*** أما بالنسبة لـ ***C.O.M.*** و فيه يعطي كل ***member*** للـ ***member*** المناظر له نصف قيمة ***Bal.M.*** الموجودة عنده كما هي بدون تغيير الإشارة ثم يتم تكرار ما تم عمله مع ***F.E.M.*** مع ***C.O.M.*** أي تجميعه و تغيير إشارته و ضربه في ***D.F.*** لتوزيعه على ***members*** ثم بعد ذلك يتم تجميع القيم الموجودة في كل عمود بدأ من ***F.E.M.*** إلى آخر صف للـ ***Bal.M.*** و يتم تجميع كلاً بإشارته و ذلك للحصول على العزوم النهائية و لابد من التأكد من أن مجموع العزوم النهائية عند كل ***Joint*** يساوي صفر أي أنها متزنة يتم بعد ذلك رسم ***B.M.D., S.F.D. & N.F.D.*** للشكل

Joint	b	a			d			
member	ba	ab	ac	ad	da	de	df	
D.F.	0	✓	0	✓	✓	✓	✓	
F.E.M.	0	0	✓	✓	✓	0	✓	
Bal. M.	0	✓	0	✓	✓	✓	✓	
C.O.M.	✓	0	0	✓	✓	✓	✓	
Bal. M.	0	✓	✓	✓	✓	✓	✓	
M_f	✓	✓	✓	✓	✓	✓	✓	

Design of Water Sections

① Section Subjected to Tension only

Stage① $b \times t_{(mm)} = 1000 \times K \times T_{(kN)}$ **Stage②** $A_s = \dfrac{T_u}{\beta_{cr} \; F_y/\delta_s}$

② Section Subjected To Moment only

Stage①

a) In case of Slabs $b = 1000$ mm $\quad t = \sqrt{\dfrac{M \times 10^3}{Factor}}$ $\quad M_{(kN.m.)}$ $\quad t_{(mm)}$

b) In case of Beams $b \neq 1000$ mm $\quad t = \sqrt{\dfrac{M \times 10^3}{Factor} \times \dfrac{1000}{b}}$

Stage② $d = t - c_{design} = C_1 \sqrt{\dfrac{M_u}{F_{cu}\, b}} \longrightarrow C_1 \rightarrow J$

Assume $\phi_{max} \longrightarrow$ Get $\beta_{cr} \longrightarrow A_{S\,(mm^2\backslash b)} = \dfrac{M_u}{\beta_{cr}\, J\, F_y\, d}$

③ Design Of Section Subjected To Eccentric forces

ⓐ Bending Moment And Tension Force (M , T)

① Get approximately (t_o) For moment only

Stage① $t_o = \sqrt{\dfrac{M \times 10^3}{Factor}}$

② Get(t) $t = t_o + \begin{cases} (15:30)\ mm & \text{For Slabs} \\ (15:60)\ mm & \text{For Beams} \end{cases}$ Check $(F_{ct})_{act} < (F_{ct})_{all}$

③ Get$(F_{ct})_{act}$ $(F_{ct})_{act} = \dfrac{M}{Z} + \dfrac{T}{A} = \dfrac{6M}{b \times t^2} + \dfrac{T}{b \times t}$

④ Get the virtual thickness(t_v) $t_V = t\left[1 + \dfrac{(F_{ct})_N}{(F_{ct})_M}\right]$

Get $F_{ct\,all} = \dfrac{F_{ctr}}{\eta}$ $F_{ctr} = 0.60\sqrt{F_{cu}}$ N/mm^2

IF $F_{ct\,act} > F_{ct\,all}$ Increase (t) And Check again

Stage② Get M_u & T_u

$e = \dfrac{M_u}{T_u} \longrightarrow \dfrac{e}{t} \begin{cases} < \frac{1}{2} - c & \text{Small Eccentricity} \\ \geq \frac{1}{2} - c & \text{Big Eccentricity} \end{cases}$

$* \dfrac{e}{t} \geq \dfrac{1}{2} - c$

$e_s = e - \dfrac{t}{2} + c_{design}$ $M_{s_u} = T_u \times e_s$

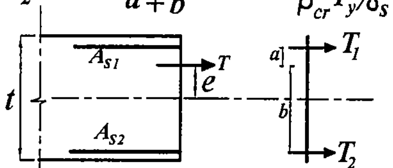
$d = C_1 \sqrt{\dfrac{M_{s_u}}{F_{cu}\ b}} \longrightarrow C_1 \longrightarrow J$

$A_S = \dfrac{1}{\beta_{cr}}\left[\dfrac{M_u}{J\ F_y\ d} + \dfrac{T_u}{F_y/\gamma_s}\right]$

$* \dfrac{e}{t} < \dfrac{1}{2} - c$

$T_1 = T \times \dfrac{b}{a+b}$ $A_{s1} = \dfrac{T_{u_1}}{\beta_{cr} F_y/\gamma_s}$

$T_2 = T \times \dfrac{a}{a+b}$ $A_{s2} = \dfrac{T_{u_2}}{\beta_{cr} F_y/\gamma_s}$



$a = \dfrac{t}{2} - e - c_{design}$ $b = \dfrac{t}{2} + e - c_{design}$

ⓑ Bending Moment And Compression Force (M , N)

① Get(t_o) For moment only

Stage① $t_o = \sqrt{\dfrac{M \times 10^3}{Factor}}$

② Get(t) $t = t_o - \begin{cases} (15:30)\ mm & \text{For Slabs} \\ (15:60)\ mm & \text{For Beams} \end{cases}$

Note You can use $t = t_o$

③ Get$(F_{ct})_{act}$ $(F_{ct})_{act} = \dfrac{M}{Z} - \dfrac{N}{A} = \dfrac{6M}{b \times t^2} - \dfrac{N}{b \times t}$

④ Get the virtual thickness(t_v) $t_V = t\left[1 - \dfrac{(F_{ct})_N}{(F_{ct})_M}\right]$

Get $F_{ct\,all}$ $(F_{ct})_{act} < (F_{ct})_{all}$

IF $F_{act} > F_{ct\,all}$ Increase (t) And Check again

* Note : You can get($F_{ct\,all}$) from Table

Stage② Get M_u & N_u

$e = \dfrac{M_u}{N_u} \longrightarrow \dfrac{e}{t} \begin{cases} < \frac{1}{2} & \text{Small Eccentricity} \\ \geq \frac{1}{2} & \text{Big Eccentricity} \end{cases}$

$* \dfrac{e}{t} < \dfrac{1}{2}$ (Small Eccentricity)

Use Interaction Diagram

Get $\dfrac{N_u}{F_{cu}\,b\,t}$ & $\dfrac{M_u}{F_{cu}\,b\,t^2} \longrightarrow \rho$

$\mu = \rho \times F_{cu} \times 10^{-5}$

$A_s = A_s' = \mu \times b \times t$

$* \dfrac{e}{t} \geq \dfrac{1}{2}$ (Big Eccentricity)

$e_s = e + \dfrac{t}{2} - c_{design}$

$M_{s_u} = N_u \times e_s$

$d = C_1 \sqrt{\dfrac{M_{s_u}}{F_{cu}\ b}} \longrightarrow C_1 \longrightarrow J$

$A_S = \dfrac{1}{\beta_{cr}}\left[\dfrac{M_u}{J\ F_y\ d} - \dfrac{N_u}{F_y/\gamma_s}\right]$

Design of Air Sections

Air Section designed as Cat II Section (Stage 2 only)

Note

- يمكن في الامتحان إهمال حساب $F_{ct\,all} = \dfrac{F_{ctr}}{\eta}$ و استخدام أقل $F_{ct\,all} = 1.7\ MPa$
و ذلك للخرسانة التى لها $F_{cu} = 25\ MPa$

- جميع الاحمال تكون **working loads** في **Stage (I)** بينما تكون **ultimate loads** في **Stage (II)**

Elevated Tanks

Steps of design:

1- Dimensioning

هي عملية فرض الأبعاد للعناصر الخرسانية المختلفة (الحائط و الأرضية).

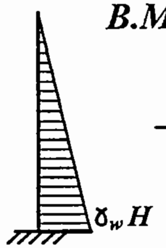
Wall thickness (t_w) & Floor thickness (t_f)

$$t_w = t_f = \frac{L}{16} = 250\ mm$$ للتسهيل يمكن دائماً فرض

2- Loads and straining actions

هي عملية حساب الأحمال على الشرائح المختلفة لـ *Tanks* و تكون هذه الأحمال *Working loads* و يتم حل هذه الشرائح باستخدام *Moment Distribution*

ثم يتم حساب القوى الداخلية في هذه الشرائح *B.M.D. & N.F.D.*



Moment Distribution → B.M.D. & N.F.D.

3- Design of sections

هي مرحلة تصميم القطاعات التى تم حساب القوى الداخلية فيها .

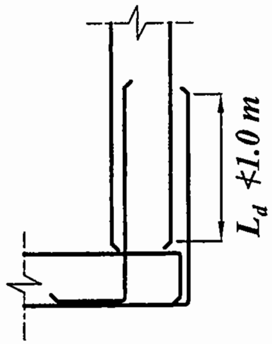
Water sections (Cat. III) → Stage (I) & Stage (II)

Air sections (Cat. II) → Stage (II)

→ All loads are working loads at Stage (I) & ultimate loads at Stage (II)

4- Details of RFT

رسم تفاصيل التسليح.

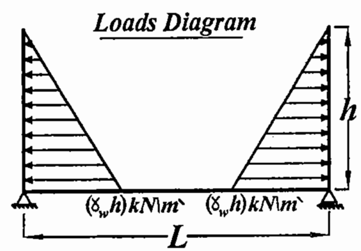


1 -Water Pressure on walls (Hz loads on walls)

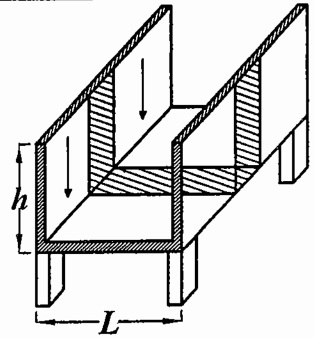
A - One way side walls

1- One way side wall in Vertical direction

a - Channel Tanks without Horizontal Beam (Cantilever Wall)

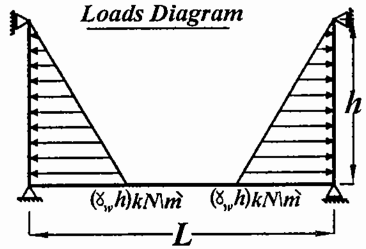


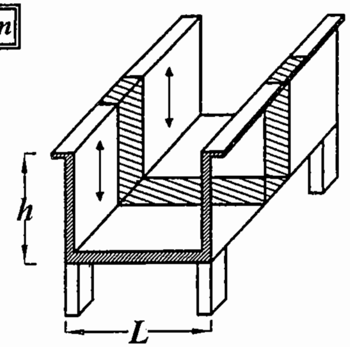
$h \leq 3.0\ m$



b - Channel Tanks with Horizontal Beam

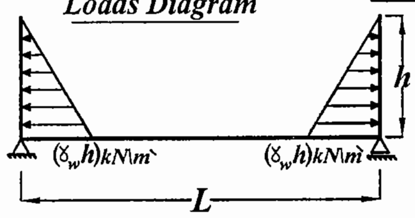
$3.0\ m < h \leq 5.0\ m$

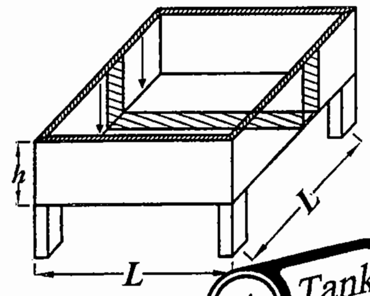




c - Shallow Tanks without Horizontal Beam (Cantilever Wall)

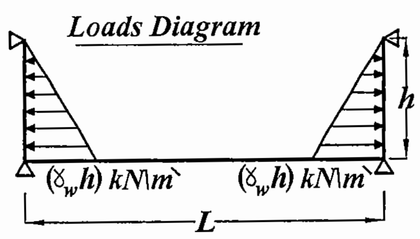
$4h \leq L$

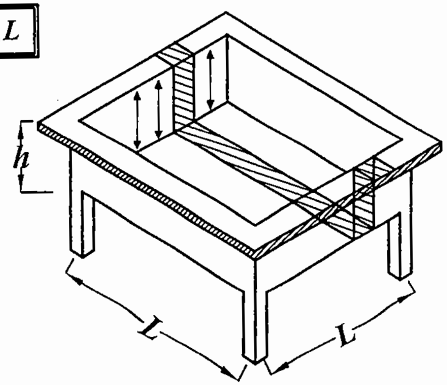




d - Shallow Tanks with Horizontal Beam

$2h \leq L$

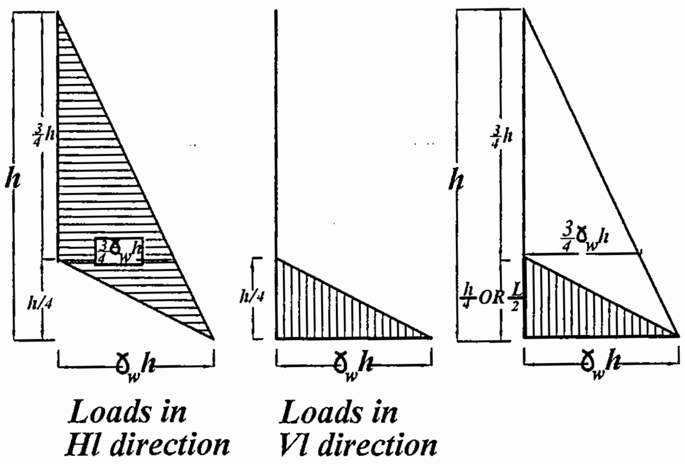


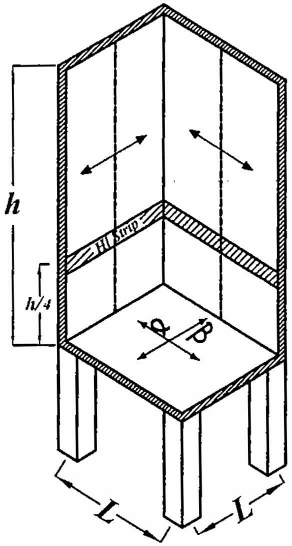


2- One way side wall in Horizontal direction

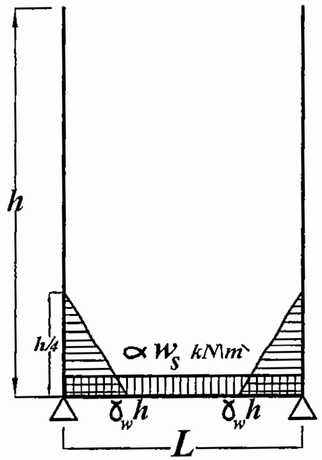
a- Deep Tanks without Horizontal Beam

$h \geq L$

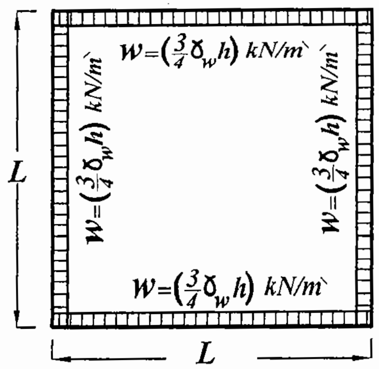




Vertical strip



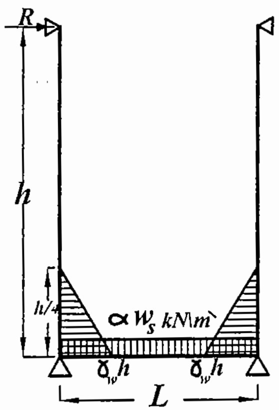
Horizontal strip at h/4



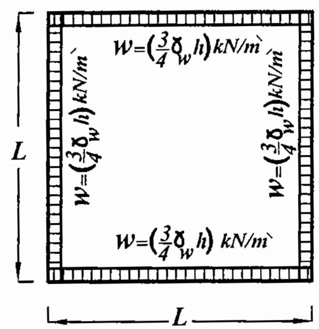
b - Deep Tank with Horizontal Beam

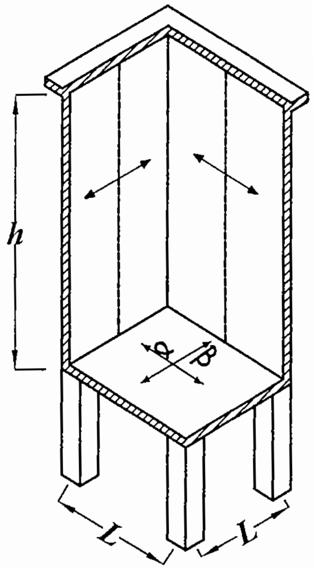
$h \geq 2L$

Vertical strip



Horizontal strip at h/4



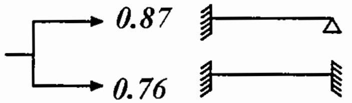


B - Two way side walls — Designed as 2 way solid slab

The wall considered as 2 way side wall if :-

$$\boxed{r < 2}$$

① Get (r) for each wall according to the end conditions

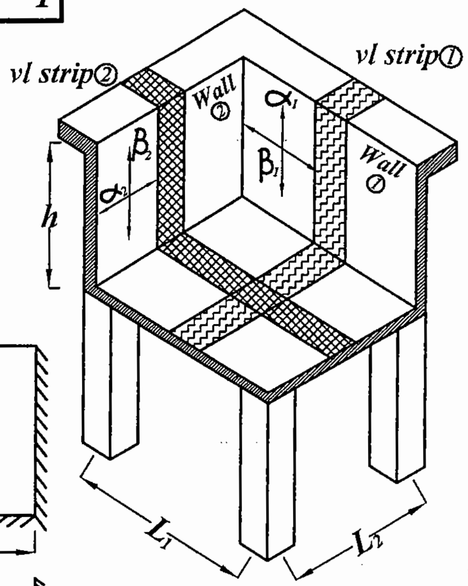


$$\boxed{r = \frac{m\,L}{m'\,L_s}} \qquad r \geqslant 1$$

② Get(α & β) according to the dimension of the wall (L_1 & h) or (L_2 & h)

$$\boxed{\alpha + \beta = 1}$$

$$\boxed{\alpha = \frac{r^4}{1 + r^4}} \qquad \boxed{\beta = \frac{1}{1 + r^4}}$$



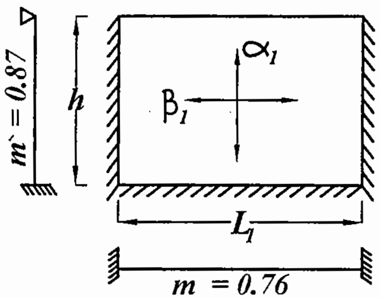
③ Vertical strip ①

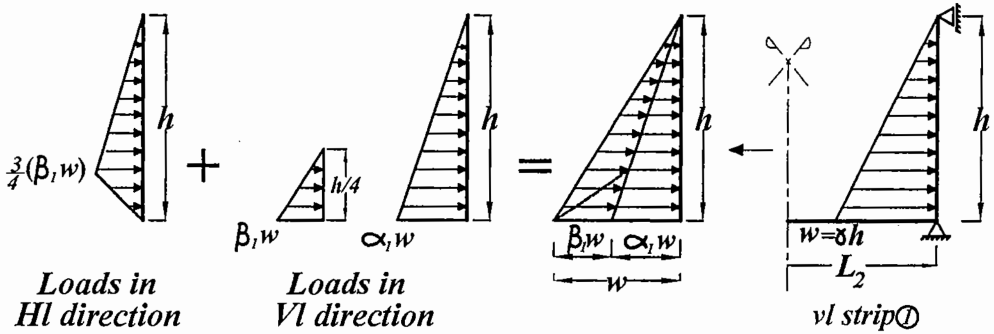
For example Assume $h < L_1$

Wall① (h & L_1)

$$r = \frac{m\,L_1}{m'\,h} \geqslant 1$$

Get(α_1 & β_1)



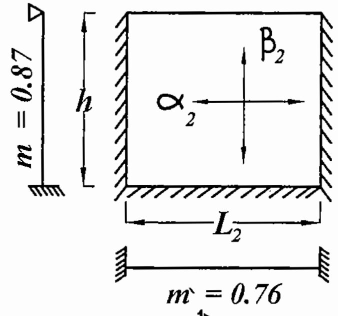


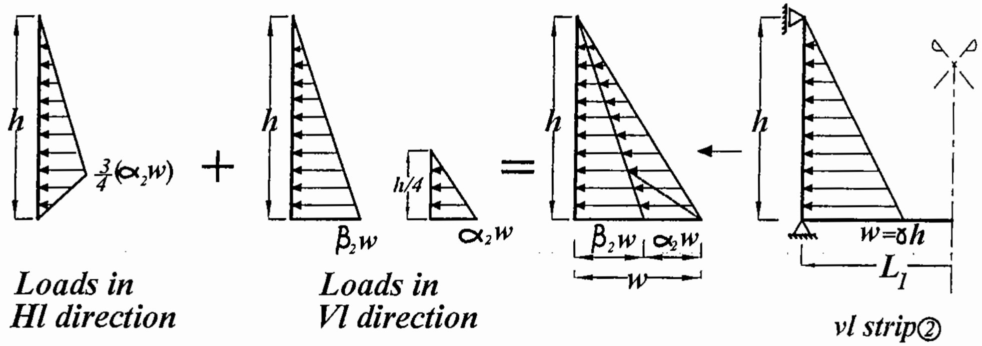
④ Vertical strip ②

For example assume $h > L_2$

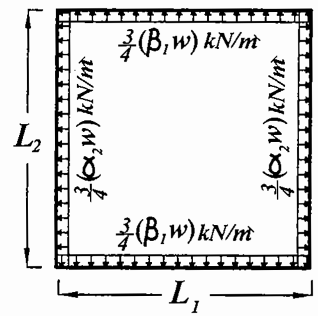
Wall② (h & L_2)

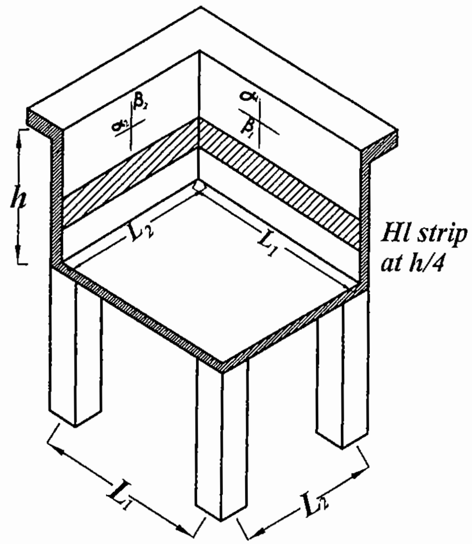
$$r = \frac{m\,h}{m'\,L_2} \geqslant 1 \qquad \text{Get}(\alpha_2 \,\&\, \beta_2)$$





⑤ HL strip at h/4



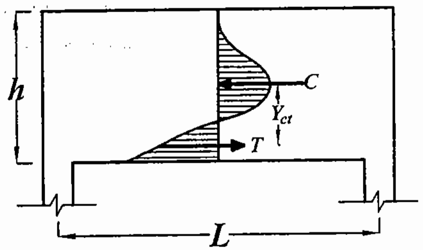


2 -(Vertical Load due to O.W of Wall + Load From the Floor)
(Wall act as a deep Beam)

The beam is considered to be a deep beam IF

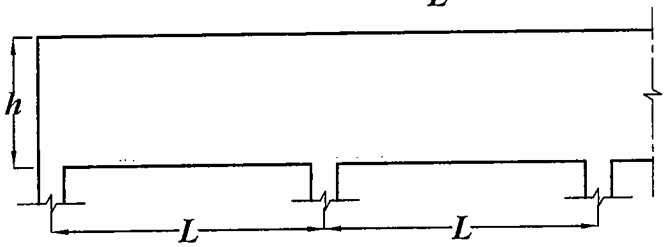
Simple beam

$$\frac{h}{L} \geqslant 0.8$$



Continuous Beam

$$\frac{h}{L} \geqslant 0.4$$

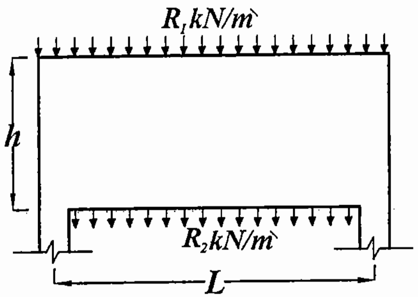


1- Loads acting on the deep Beam

① Reaction of the Cover (R_1)

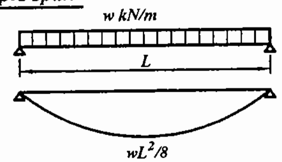
② Reaction of the Floor (R_2)

③ O.W. of the beam

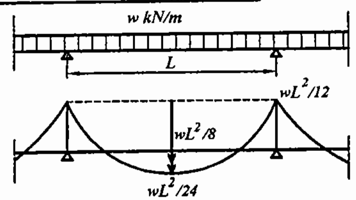


2- Get Bending Moment Using Moment Distribution OR 3-Moment Equation OR Empirical (In case of equal Spans)

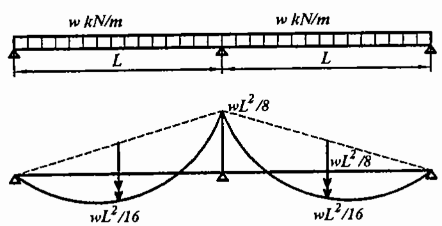
-Simple span



-Continuous more than two spans



-Continuous two spans



3- Calculate (Y_{ct})

	Simple beam	Continuous Beam	
		At the Support	At mid span
Y_{ct}	0.86 L	0.37 L	0.43 L

$Y_{ct} \ngtr 0.87\, d$

4- Get (T)

$$T = C = \frac{M}{Y_{ct}}$$

$$A_s = \frac{T_u}{\beta_{cr} F_y/\delta_s}$$

Check

- If $A_s > 0.225 \frac{\sqrt{F_{cu}}}{F_y}\, b\, d \longrightarrow$ Use A_s

If $A_s < 0.225 \frac{\sqrt{F_{cu}}}{F_y}\, b\, d \longrightarrow$ Check $A_{s\,min}$

$0.225 \frac{\sqrt{F_{cu}}}{F_y}\, b\, d \nless \frac{1.1}{F_y}\, b\, d$ (ECP 2007)

$A_{s\,min} =$
- $0.225 \frac{\sqrt{F_{cu}}}{F_y}\, b\, d \geqslant \frac{1.1}{F_y}\, b\, d$
- $1.3 A_{s\,req}$
- $\frac{0.25}{100}\, b\, d$ st. 240/350
- $\frac{0.15}{100}\, b\, d$ st. 360/520

(الاصغر of the first two values; الاكبر of that and the third/fourth value)

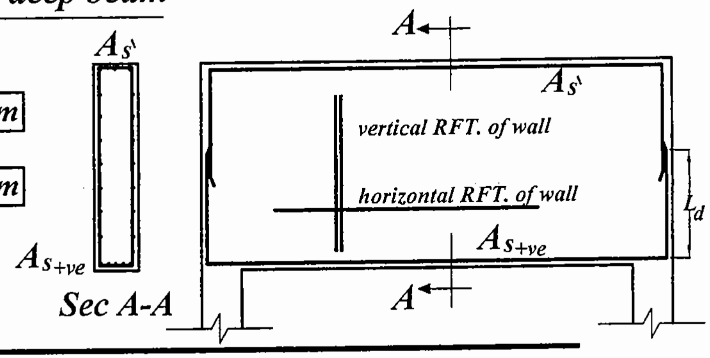
$$d = h - Cover$$

Details of RFT of deep beam

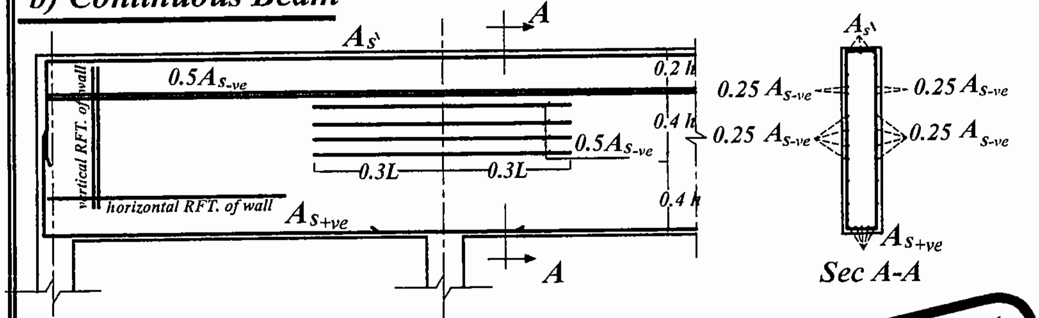
a) Simple beam

$A_{s'} = 3\phi16$ — $h \leqslant 3m$

$A_{s'} = 3\phi18$ — $h > 3m$



b) Continuous Beam



Loads On The Floor

Loads On The Floor = O.W of The Slab + Water Pressure

$$w = t_s \gamma_c + \gamma_w h$$

This Load will be distributed in One Way OR Two Way according to the slab dimension

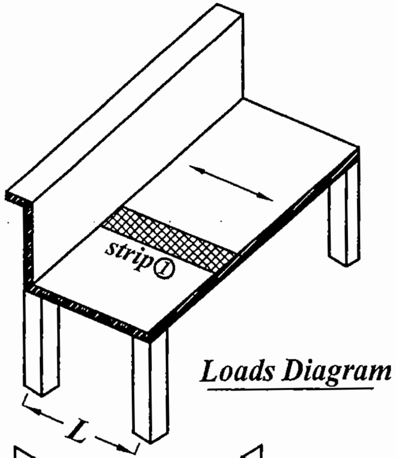
Note For Two way Slabs

$$r = \frac{m L}{m' L_s}$$

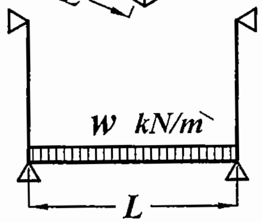
$$\boxed{m = m' = 0.76}$$

Get(α & β) $\quad \alpha = \frac{r^4}{1+r^4} \quad \beta = \frac{1}{1+r^4}$ $\quad \boxed{\alpha + \beta = 1}$

One Way Floor Slab

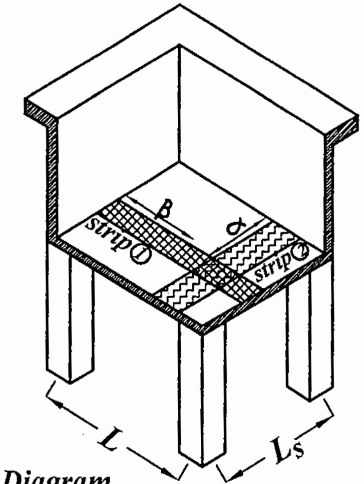


Loads Diagram

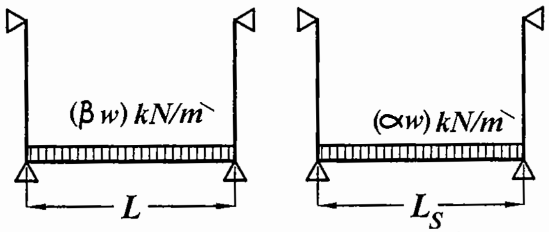


Strip ①

Two Way Floor Slab

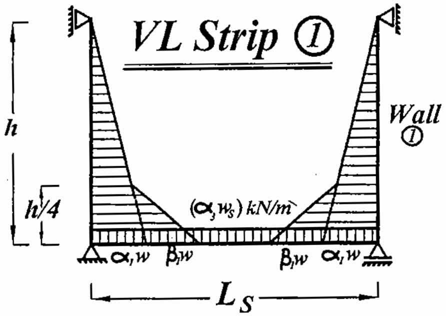


Loads Diagram

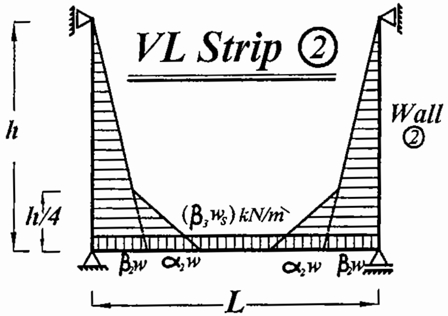


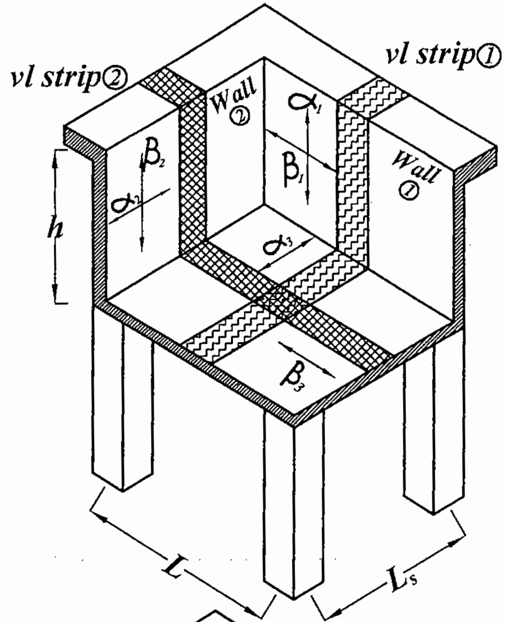
Strip ① Strip ②

VL Strip ①

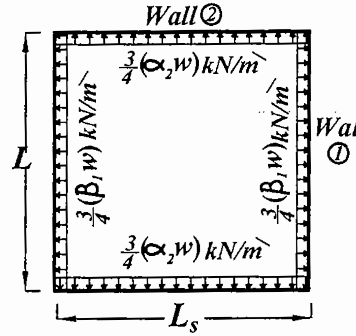


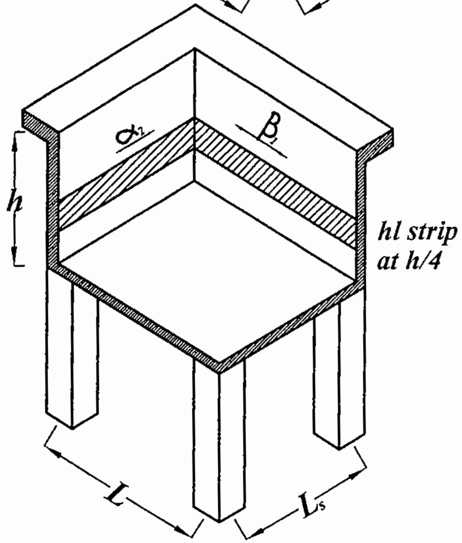
VL Strip ②





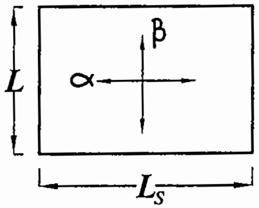
HL strip at $\frac{h}{4}$



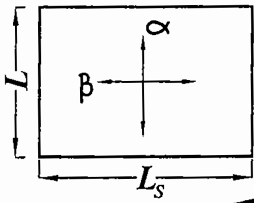


Note

$$r = \frac{m L}{m' L_s} \geq 1$$

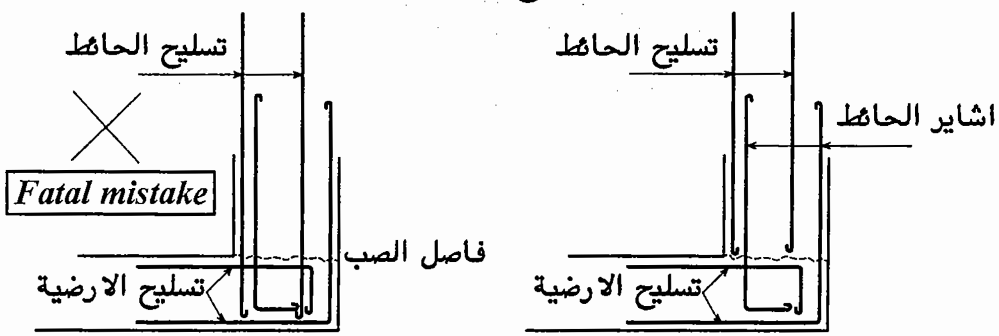


IF $\frac{m L}{m' L_s} < 1$ Take $r^* = \frac{m' L_s}{m L} \geq 1$



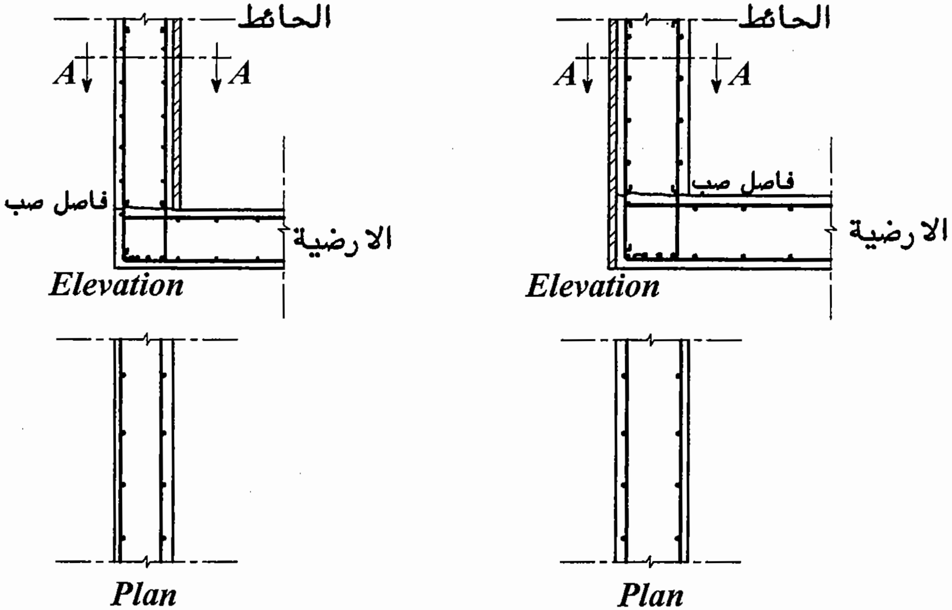
Details Of Reinforcement

① يجب مراعاة خطوات الصب اثناء رسم التسليح بمعنى انه نتيجة صب ارضية الخزان اولا ثم صب الحوائط بعد ذلك فإن اشاير الحائط تخرج من ارضية الخزان ولا يدخل تسليح الحائط فى الارضية .



② توجد عدة طرق لوضع حديد التسليح الافقى فى الخزانات وذلك حسب اسلوب التنفيذ و تجهيزات الموقع وطريقة تركيب الشدة .

③ يجب مراعاة إسقاط الحديدفى الـ *Plan* و علاقتة بالـ *Elevation*

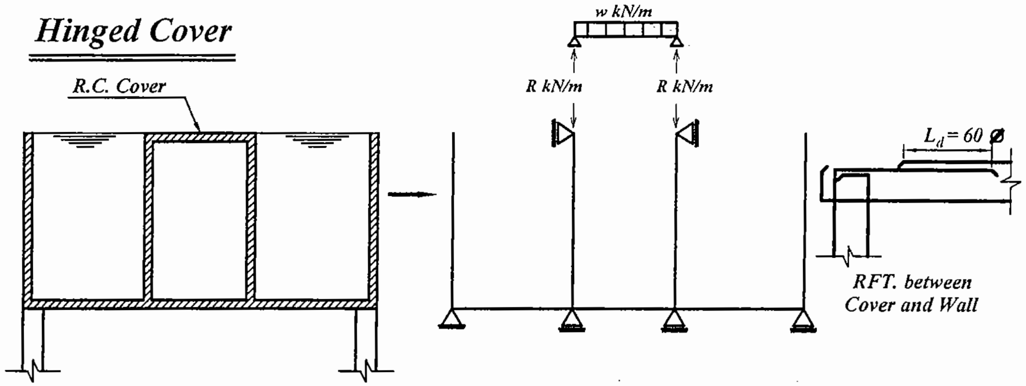


④ Minimum A_S = 5 ϕ12/m\` Main Steel (At Tension Side)
5 ϕ10/m\` Secondry Steel (At Compression Side)

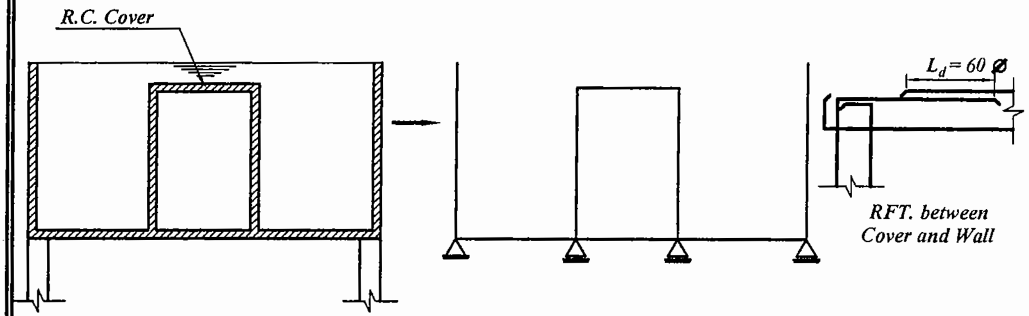
⑤ يتم تركيز حديد أسفل و أعلى الحائط لأن الحائط يعمل ككمرة بالنسبة للأرضية

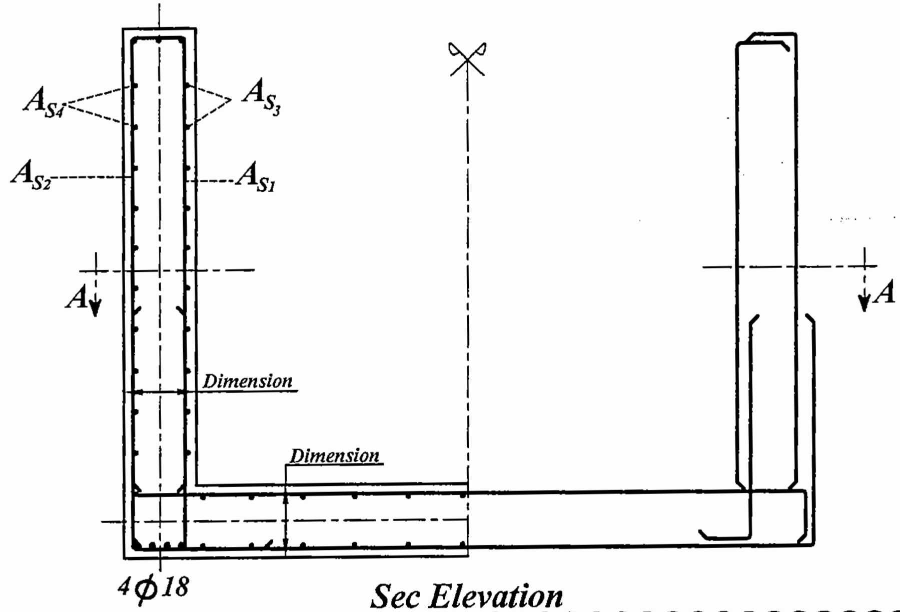
⑥ في حالة وجود غطاء للخزان يتم اعتباره ***Hinged cover*** في حالة أنه لا يوجد عليه أحمال ثقيلة أما إذا كان عليه وزن مياه فيتم اعتباره ***Fixed cover***

Hinged Cover



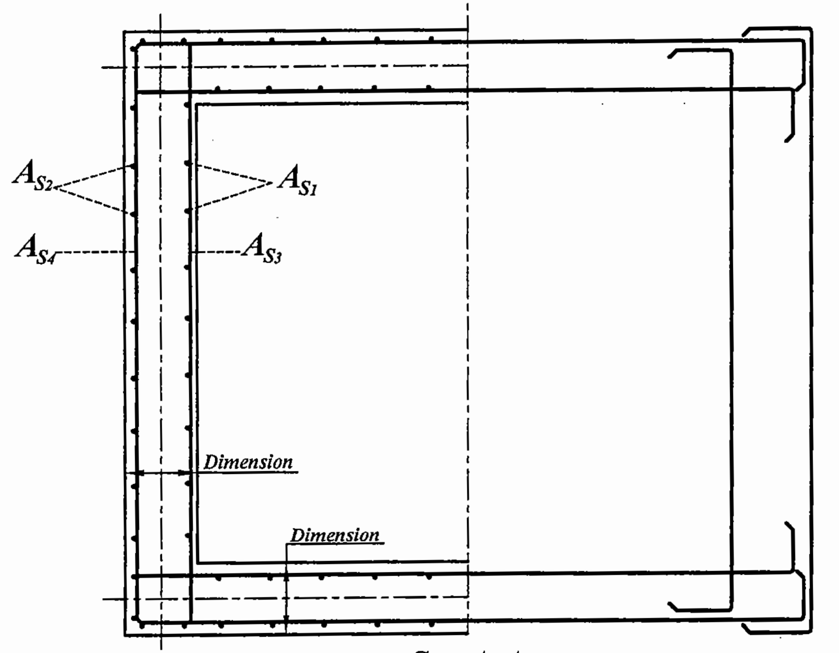
Fixed Cover





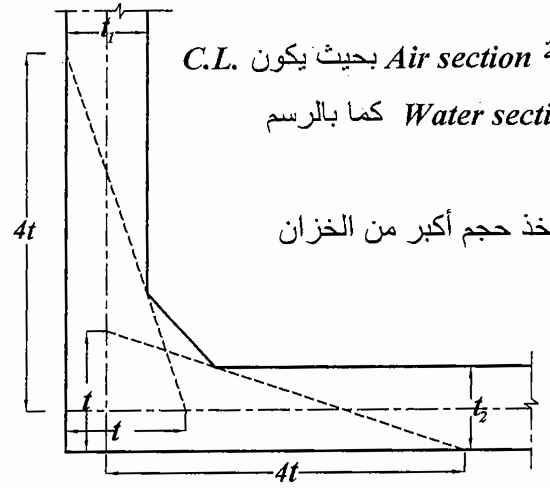
Sec Elevation

- يجب رسم C.L. للخزان و توقيع تخانات الحوائط عليه
- يجب تكثيف التسليح 4ϕ18 أسفل الحوائط



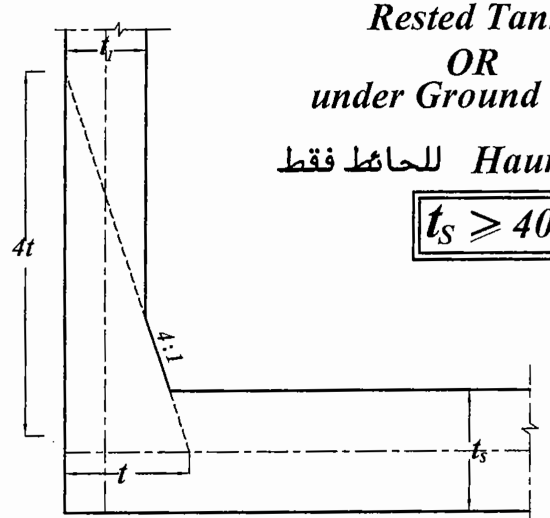
Sec A-A

Single Haunch



- نرسم C.L. للخزان و نوقع عليه تخانة *Air section* بحيث يكون C.L. في منتصف التخانة ثم نوقع تخانة *Water section* كما بالرسم و منها نرسم الخزان
- هذه الطريقة أسهل في التنفيذ و لكن تأخذ حجم أكبر من الخزان

Haunch in Wall



فى حالة *Rested Tanks* OR *under Ground Tanks*

يتم تنفيذ الـ *Haunch* للحائط فقط

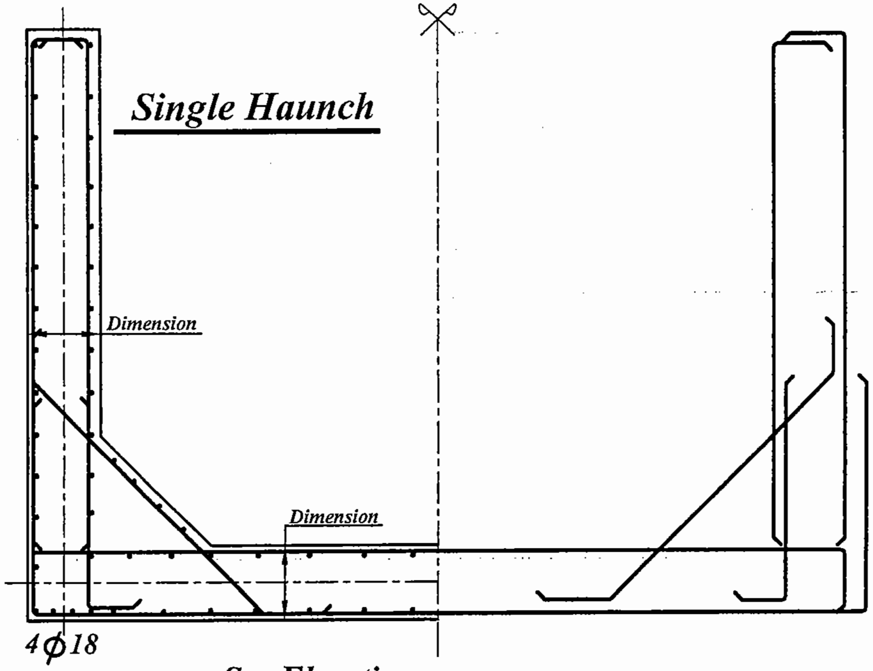
$t_S \geqslant 400\ mm$

MIN. RFT.

Rested Tanks & Under Ground Tanks → $5\phi 12/m$

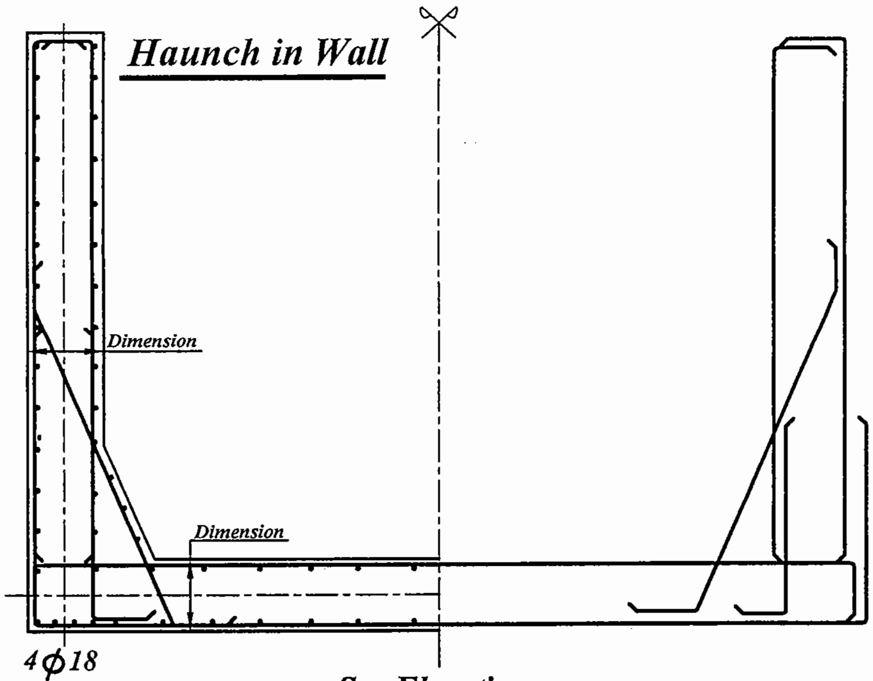
Elevated Tanks → $5\phi 10/m$

Single Haunch



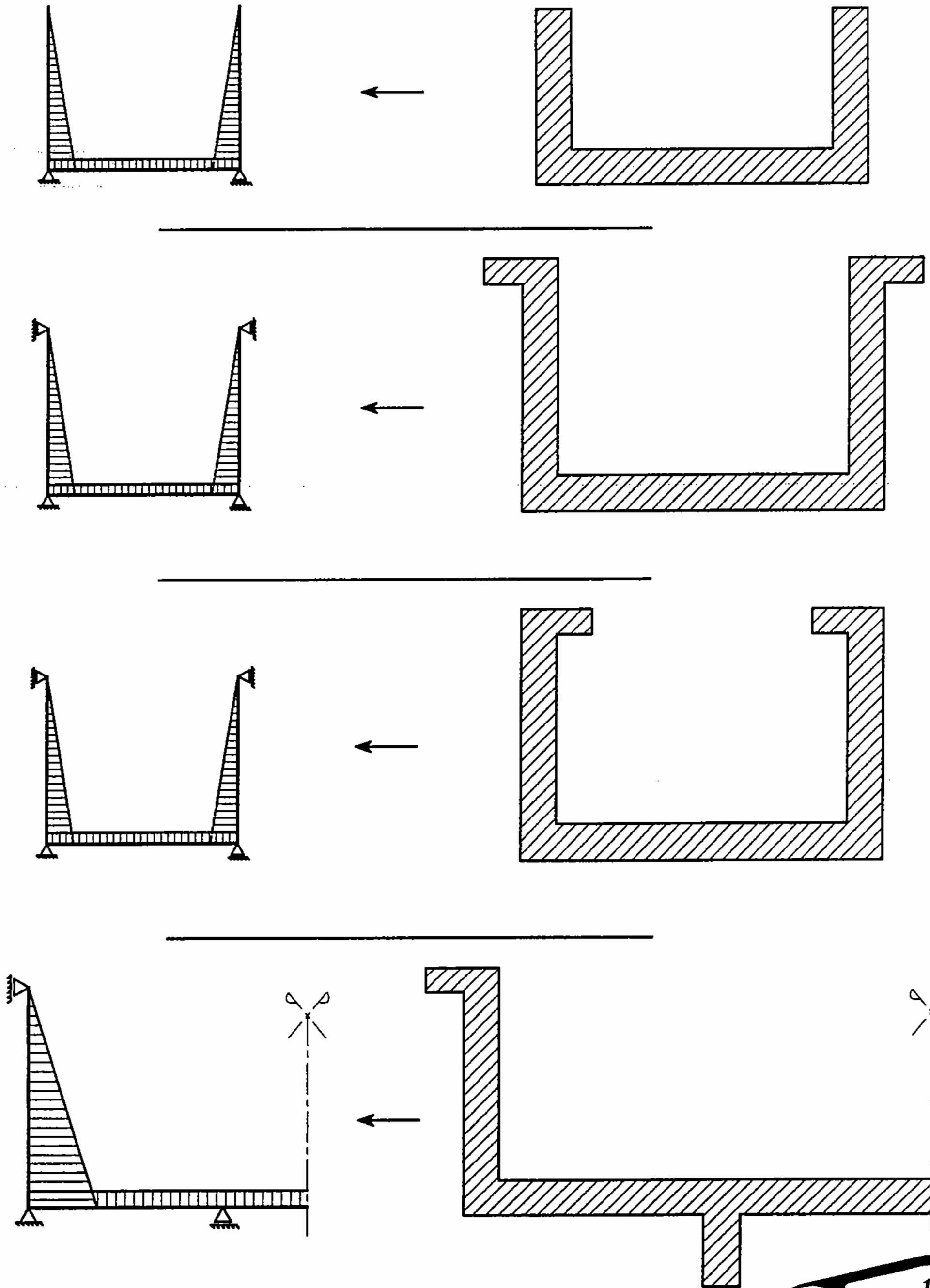
Sec Elevation

Haunch in Wall



Sec Elevation

Summary of Elevated Tanks Statical Systems



Special Cases

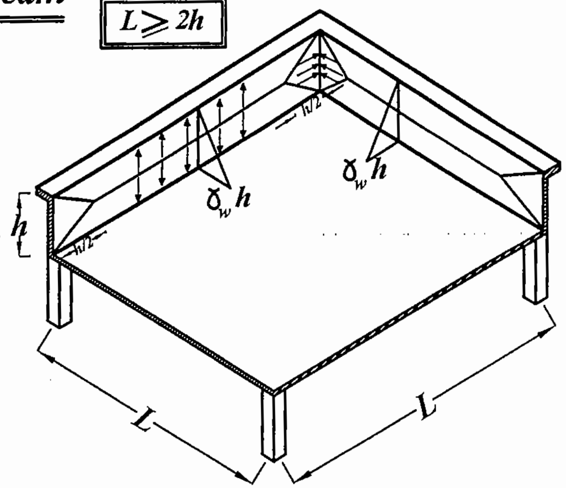
1-Corner Effect

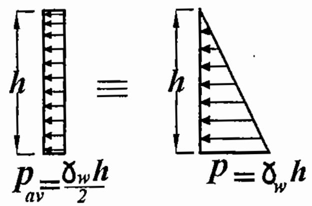
فى بعض الانوع من الخزانات و نتيجة لابعاد الحوائط الجانبية يتم اعتبار الحوائط (one way side wall in vertical direction) و بالتالى فان جزء من الاحمال الواقعة على الحائط تؤثر فى الاتجاه الافقى *Corner Effect*

1 - Walls with Horizontal Beam

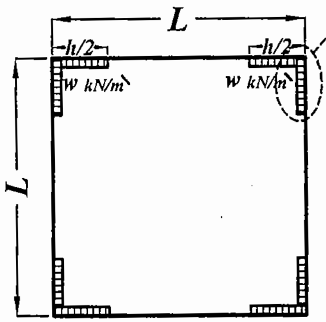
$L \geq 2h$

و لدراسة تاثير ال *Corner Effect* يتم اخذ شريحة افقية على ارتفاع $(\frac{h}{2})$

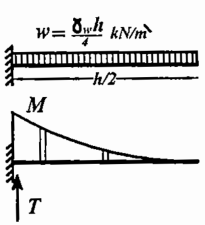


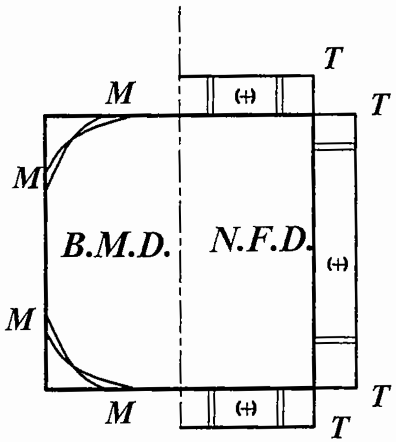


$$w = \frac{\frac{\gamma_w h}{2}(\frac{1}{2} \times h \times \frac{h}{2})}{(h \times \frac{h}{2})} = \frac{\gamma_w h}{4}$$



Cantilever يتم حل هذا الجزء كـ





Hl - strip at h/2

$$M = w \times \frac{(\frac{h}{2})^2}{2} = \frac{\gamma_w h}{4} \times \frac{(\frac{h}{2})^2}{2}$$

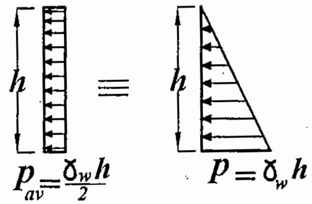
$$\boxed{M = \frac{\gamma_w h^3}{32}}$$

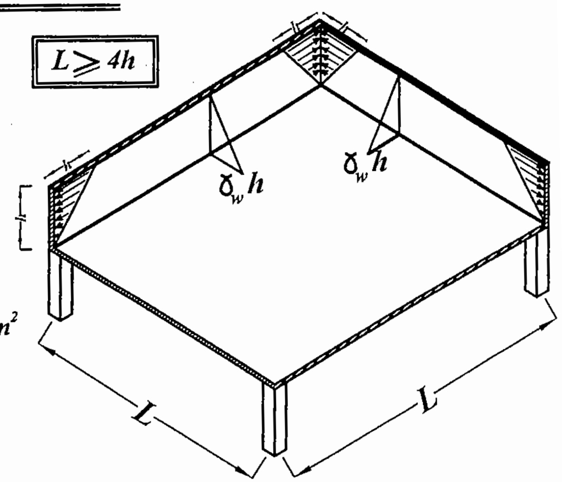
$$T = w \times (\frac{h}{2}) = \frac{\gamma_w h}{4} \times (\frac{h}{2})$$

$$\boxed{T = \frac{\gamma_w h^2}{8}}$$

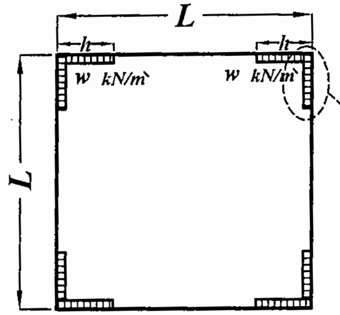
2 - Walls without Horizontal Beam

$L \geq 4h$

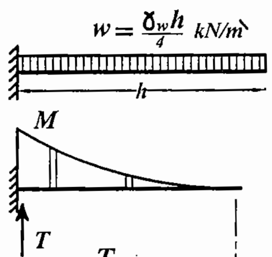




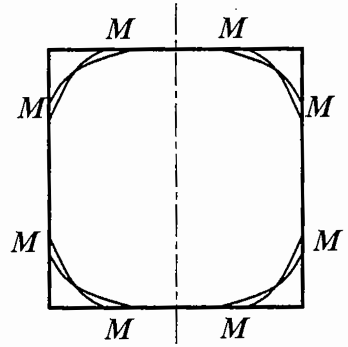
$$w = \frac{\frac{\gamma_w h}{2}(\frac{1}{2} \times h \times h)}{(h \times h)} = \frac{\gamma_w h}{4} \ kN/m^2$$



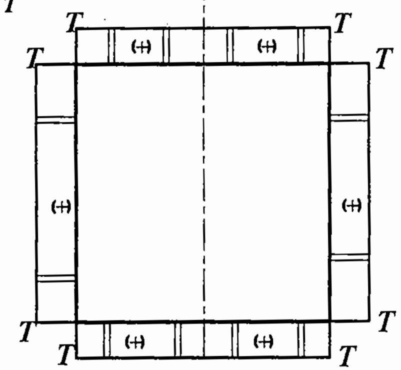
Cantilever يتم حل هذا الجزء كـ



Hl - strip



B.M.D.



N.F.D.

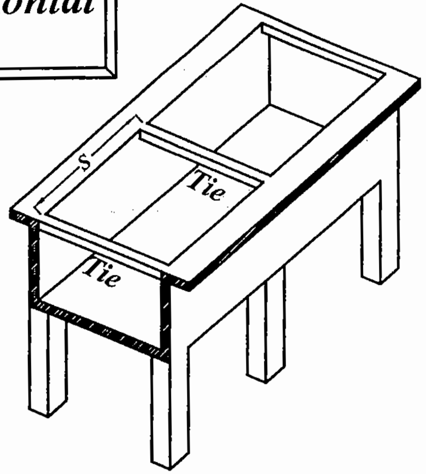
$$M = w \times \frac{(h)^2}{2} = \frac{\gamma_w h}{4} \times \frac{(h)^2}{2}$$

$$\boxed{M = \frac{\gamma_w h^3}{8}}$$

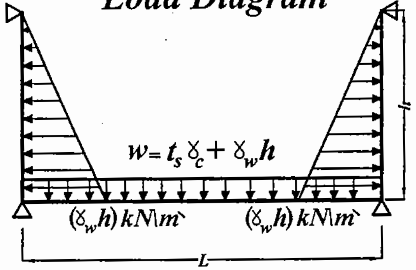
$$T = w \times (h) = \frac{\gamma_w h}{4} \times (h)$$

$$\boxed{T = \frac{\gamma_w h^2}{4}}$$

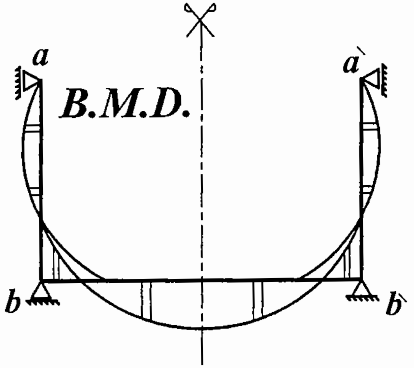
2- Channel Tank With Horizontal Beam And Ties

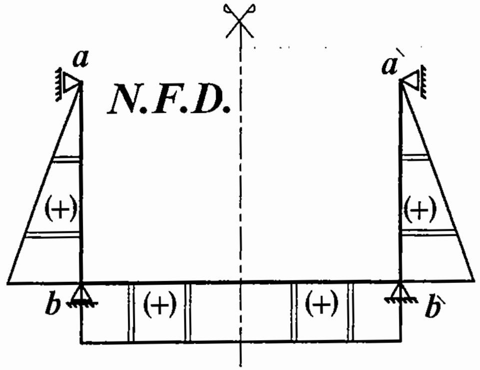


Load Diagram

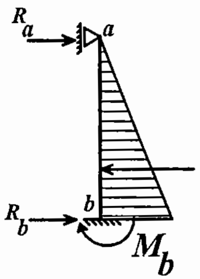


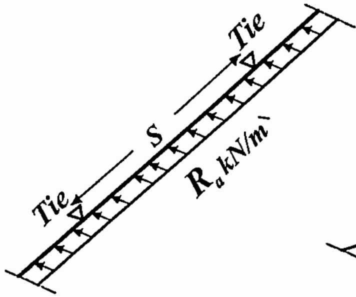
strip 1m width

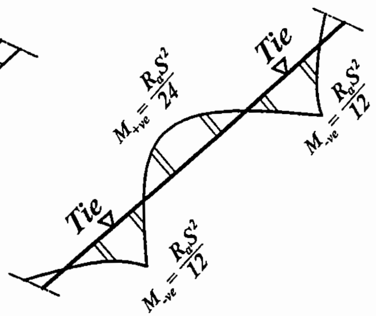




Load acting on Hl beam



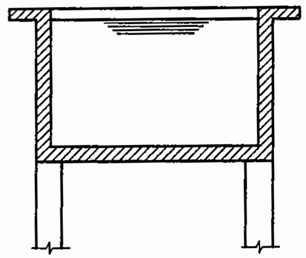


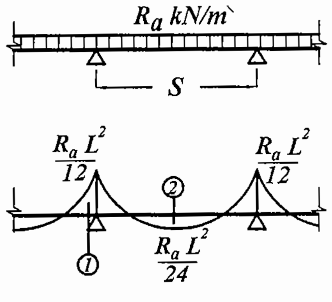


B.M.D.

Design of Horizontal beam

Case (a)





Sec ① Water L - Section Cat III

Stage ①

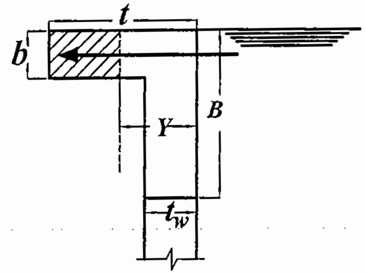
Get t Assume $b = 250$ mm

$$t = 0.6\sqrt{\frac{M \times 10^3}{Factor} \times \frac{1000}{b}}$$

Get $\frac{t_w}{t}$ & $\frac{b}{B}$ $\longrightarrow$ ζ & μ

$Y = \zeta \times t$ $I = \mu \times B \times t^3$

$$(F_{ct})_{act} = \frac{M \times Y}{I} \leq (F_{ct})_{all}$$



$$B = 3t_w + b$$

Stage ② R - Section

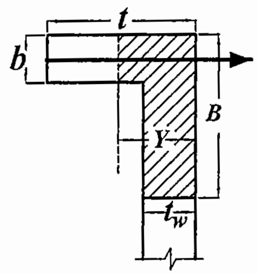
$$d = C_1\sqrt{\frac{M_u}{F_{cu}\ b}} \longrightarrow C_1 \longrightarrow J$$

$$A_s = \frac{1}{\beta_{cr}}\left[\frac{M_u}{J\ F_y\ d}\right]$$

Sec ② Air Section Cat II

Stage ② L - Section

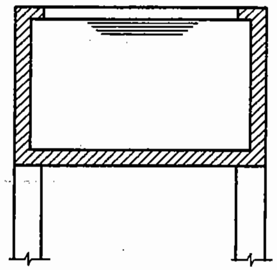
$$B = \left.\begin{array}{l} 6\ t_w + b \\ h_w/2 \\ K\frac{L}{10} + b \end{array}\right\} B = \text{الاقل}$$

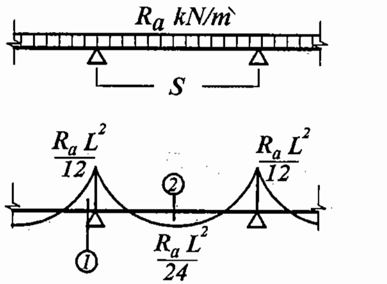


$$d = C_1\sqrt{\frac{M_u}{F_{cu}\ B}} \longrightarrow C_1 \longrightarrow J$$

$$A_s = \frac{1}{\beta_{cr}}\left[\frac{M_u}{J\ F_y\ d}\right]$$

Case (b)

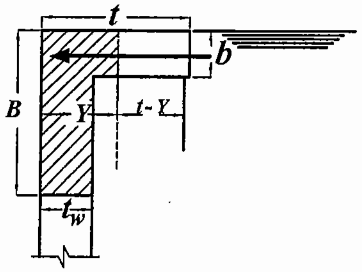




Sec ① Water L - Section Cat III

Stage ①

$$t = 0.6 \sqrt{\frac{M \times 10^3}{Factor} \times \frac{1000}{b}}$$



Get $\frac{t_w}{t}$ & $\frac{b}{B}$ $\longrightarrow$ ζ & μ

$Y = \zeta \times t$ $\quad I = \mu \times B \times t^3$

$$(F_{ct})_{act} = \frac{M \times (t-Y)}{I} \leqslant (F_{ct})_{all}$$

$B = 3\,t_w + b$

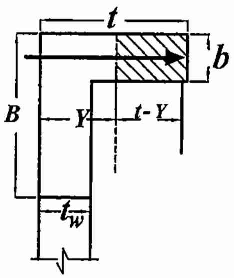
Stage ② L - Section

$$B = \begin{cases} 6\,t_w + b \\ h_w/2 \\ K\frac{L}{10} + b \end{cases} \quad B = \text{الاقل}$$

$$d = C_1 \sqrt{\frac{M_u}{F_{cu} B}} \longrightarrow C_1 \longrightarrow J \qquad A_s = \frac{1}{\beta_{cr}} \left[\frac{M_u}{J\, F_y\, d} \right]$$

Sec ② Air Section Cat II

Stage ② R - Section



$$d = C_1 \sqrt{\frac{M_u}{F_{cu}\, b}} \longrightarrow C_1 \longrightarrow J$$

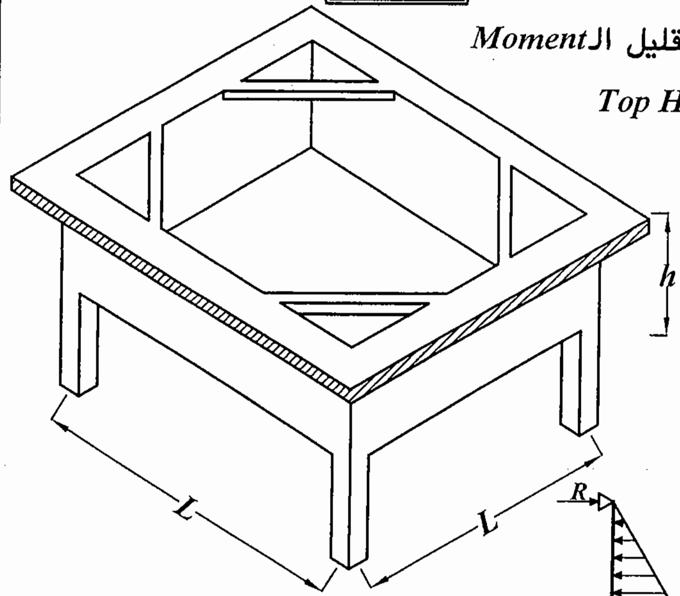
$$A_s = \frac{1}{\beta_{cr}} \left[\frac{M_u}{J\, F_y\, d} \right]$$

3-Wide Tanks

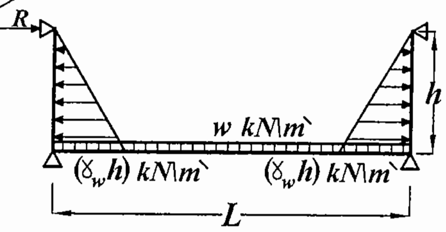
$L > 8m$

يتم استخدام ال *Ties* لتقليل ال*Moment*

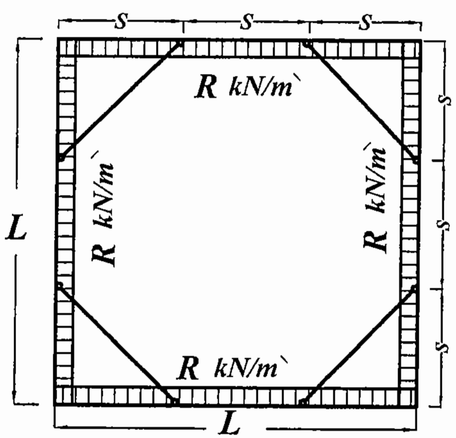
على ال *Top Horizontal Beam*

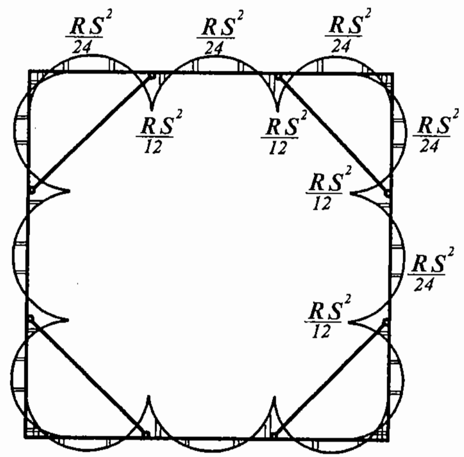


VL Strip

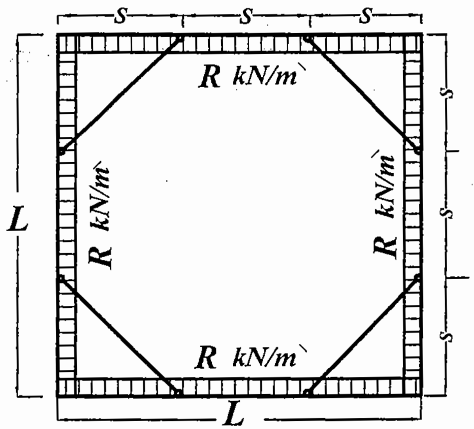


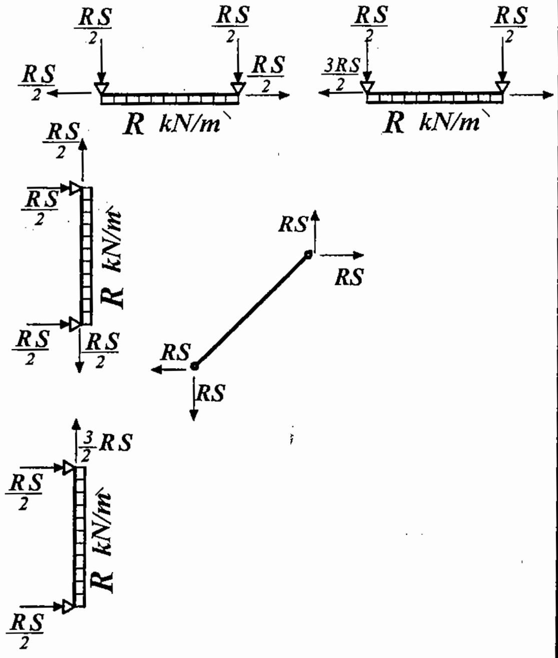
Symmetric Horizontal Beam

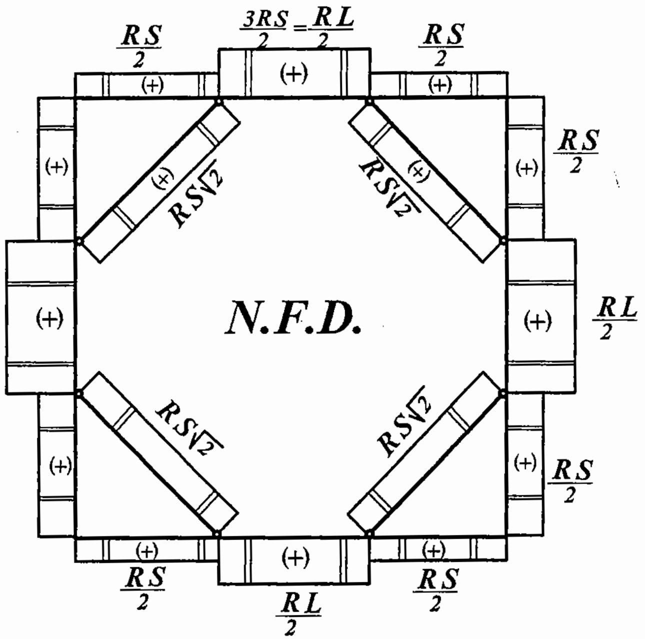




B.M.D.

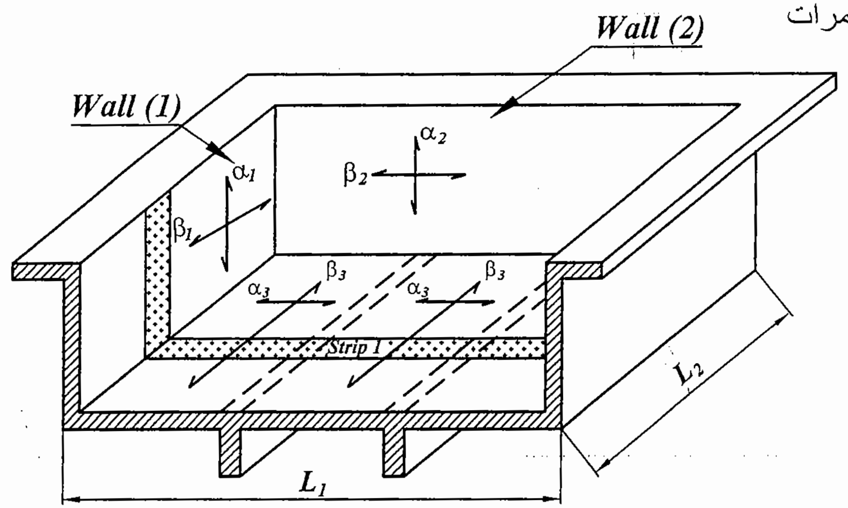






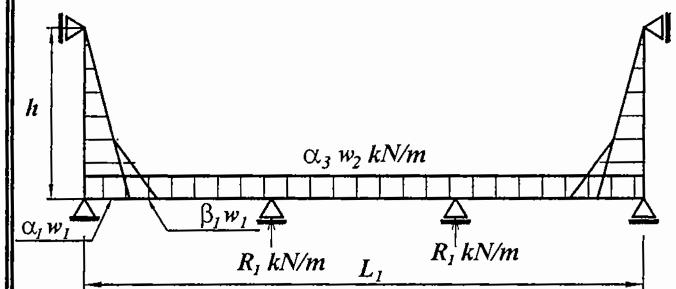
4-Floor beams

في بعض الحالات يتم تقسيم الأرضية بواسطة كمرات و توجد طريقتان لحساب الأحمال على هذه الكمرات



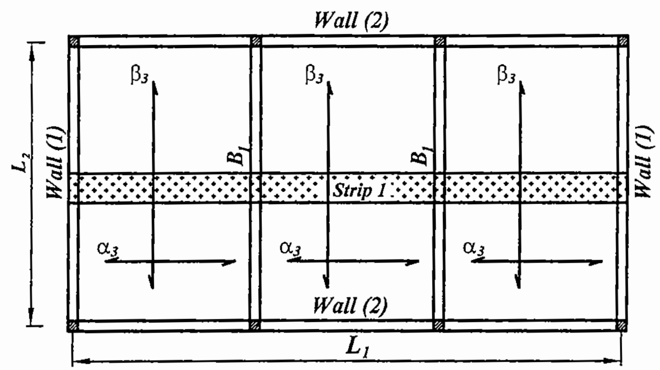
Method (1) (Approximate Method)

في هذه الطريقة نعكس ردود أفعال الشريحة العمودية على الكمرة $(R_1\ kN/m)$

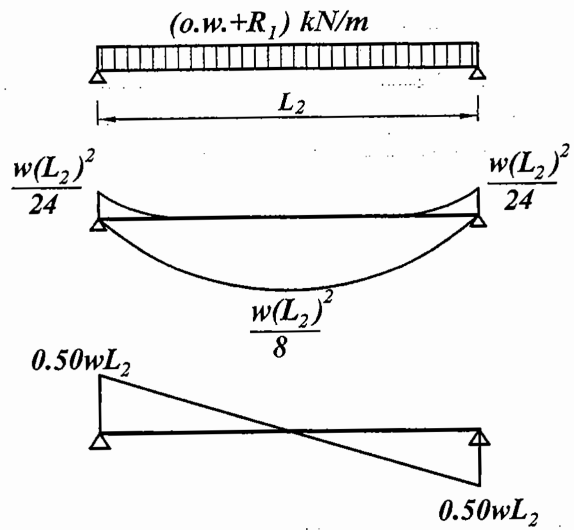


$w_1 = \gamma_w\, h \quad kN/m^2$

$w_2 = t_f\, \gamma_c + \gamma_w h \quad kN/m^2$



For B_1:

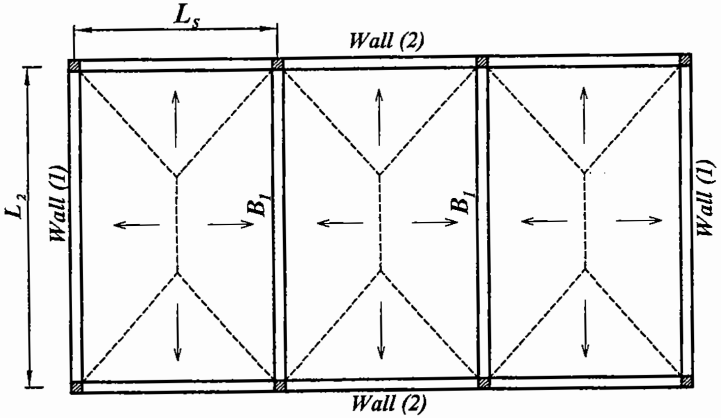


B.M.D.

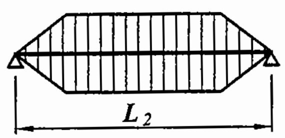
S.F.D.

Method (2)

في هذه الطريقة نقوم بعمل **Load distribution** لحساب الأحمال على الكمرة



For B_1:



Load for shear

$$w_a = o.w. + C_a \frac{L_s}{2} w_2 \times 2 \quad kN/m$$

$$C_a = 1 - \frac{1}{2} \left(\frac{L_s}{L_2}\right)$$

Load for moment

$$w_e = o.w. + C_e \frac{L_s}{2} w_2 \times 2 \quad kN/m$$

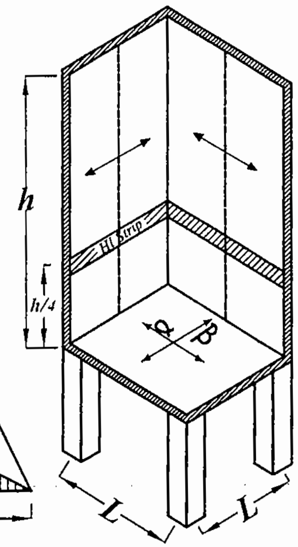
$$C_e = 1 - \frac{1}{3} \left(\frac{L_s}{L_2}\right)^2$$

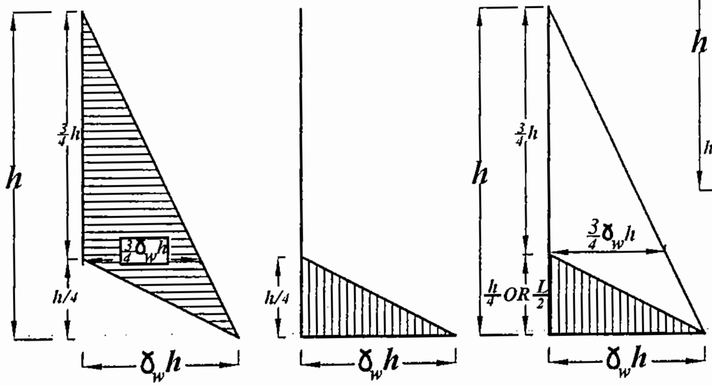
5- Deep Tanks

$h \geqslant L$

One way side wall in Horizontal direction

1 - Deep Tank without Horizontal Beam





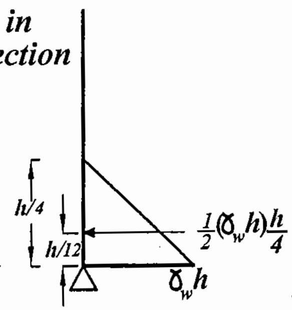
Loads in HI direction

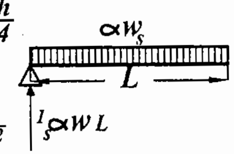
Loads in VI direction

Vertical strip

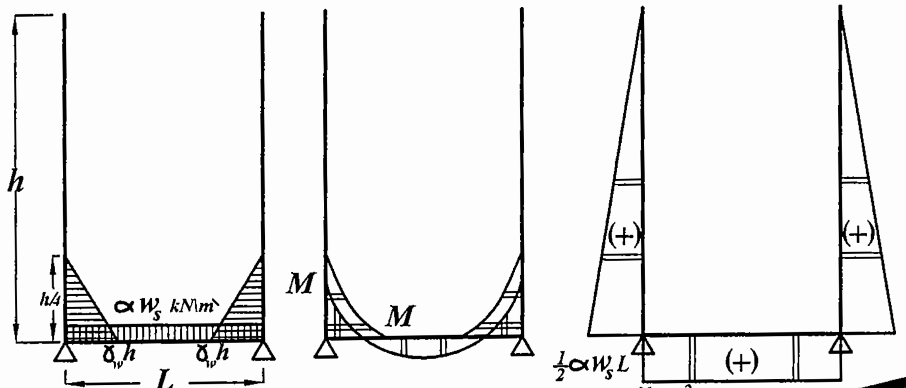
$$w_s = t_s \gamma_c + \gamma_w h$$

$$M = \frac{1}{2}(\gamma_w h)\frac{h}{4} \times \frac{h}{12} = \frac{\gamma_w h^3}{96}$$





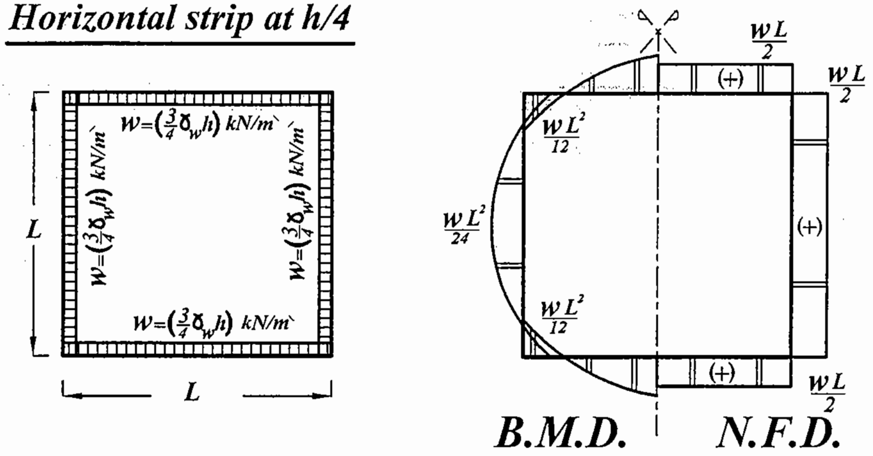
Load Diagram



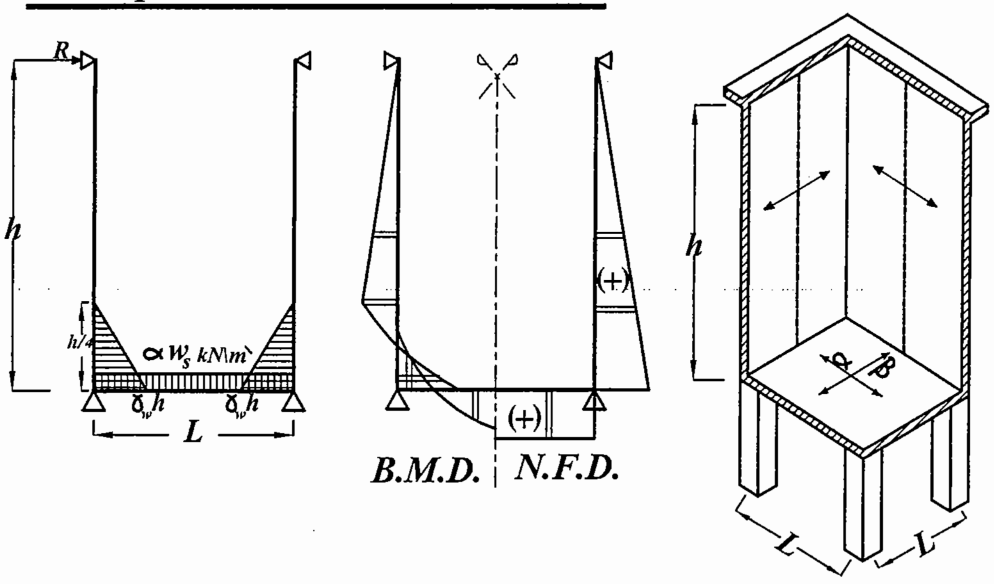
B.M.D.

$\frac{\gamma_w h^2}{8}$ N.F.D.

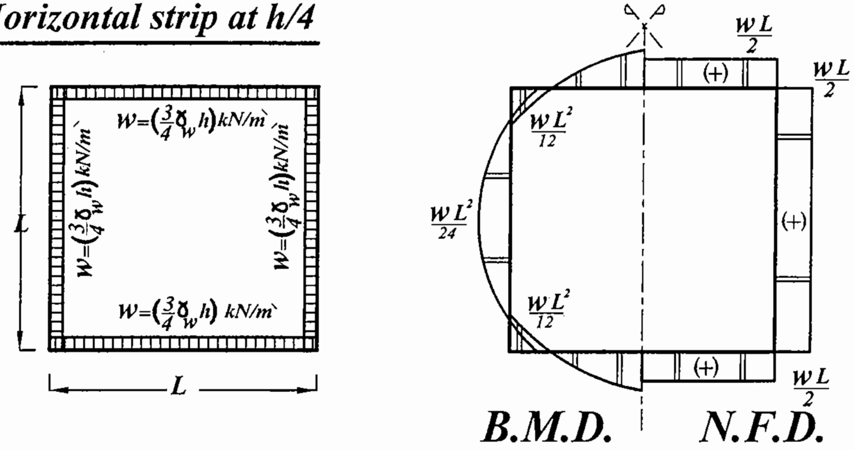
Horizontal strip at h/4



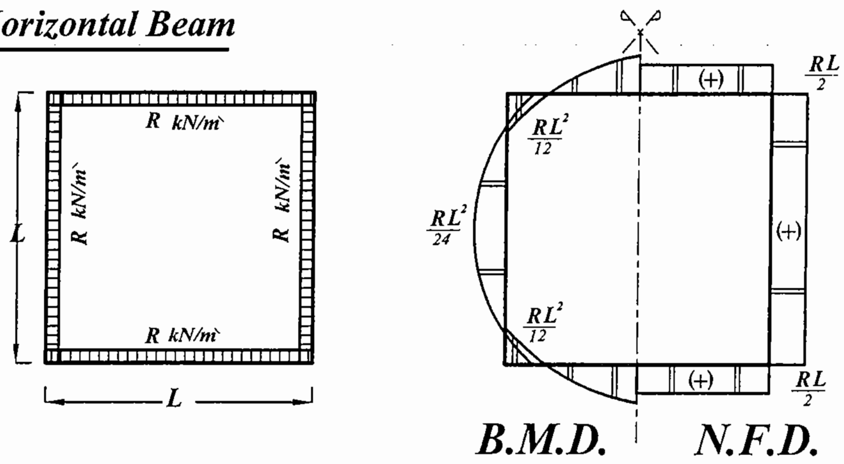
2 - Deep Tank with Horizontal Beam



Horizontal strip at h/4

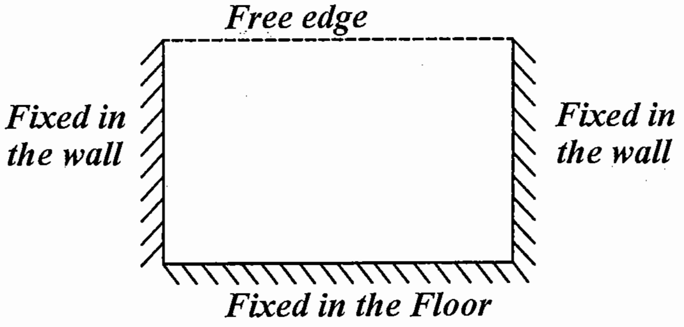


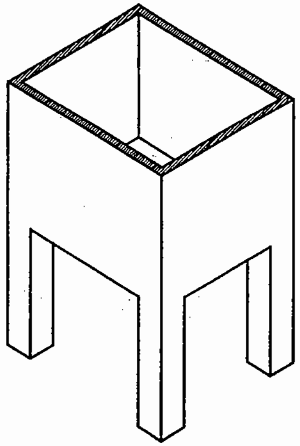
Horizontal Beam



6- Walls Supported onThree-sides

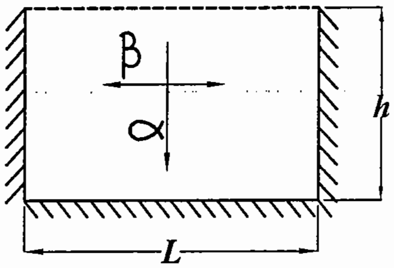
Rectangular Tank Without Horizontal Beam

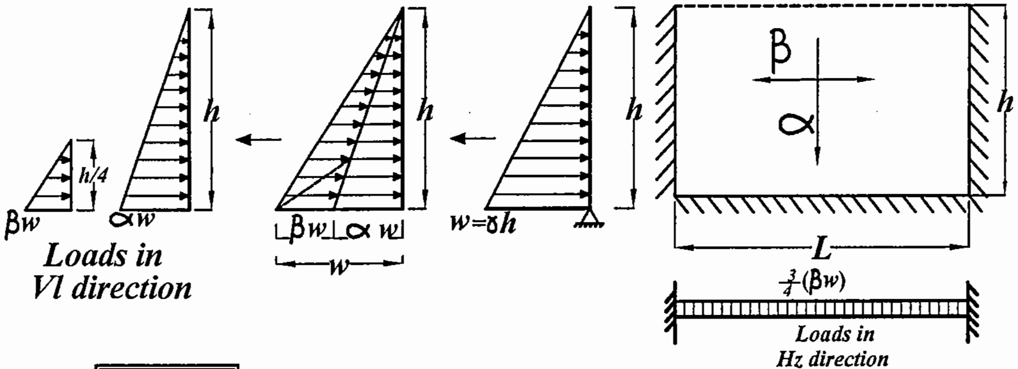




$$\alpha = \frac{L^4}{L^4 + 48h^4}$$ *in Vertical Direction*

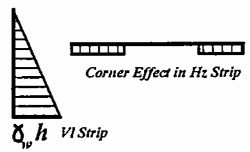
$$\beta = \frac{48h^4}{L^4 + 48h^4}$$ *in Horizontal Direction*





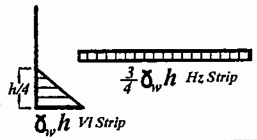
IF $L \geq 4h$

The Wall Considered as one way in Vertical direction

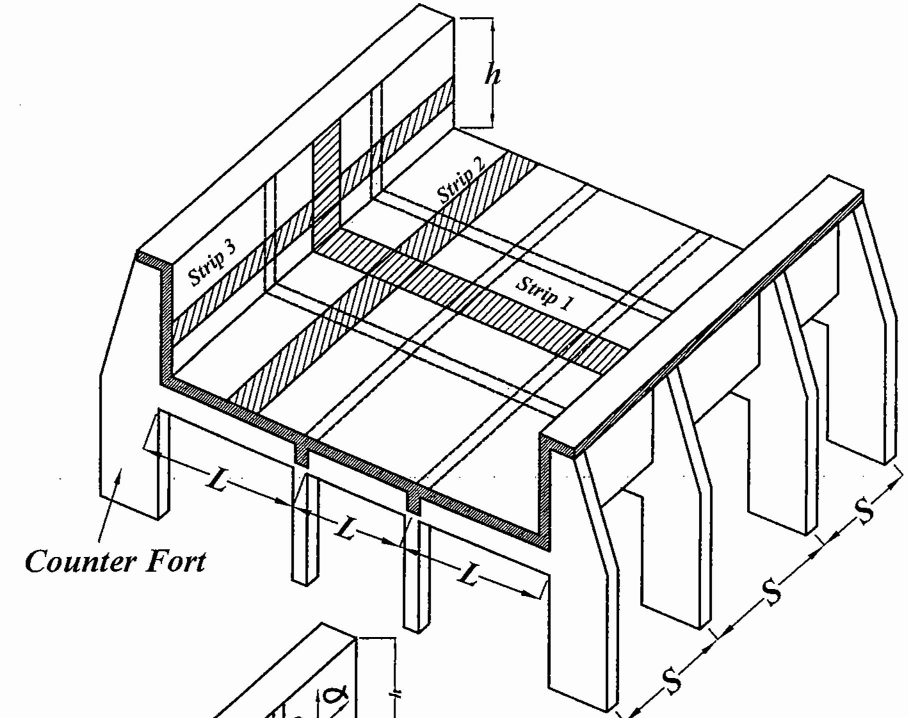


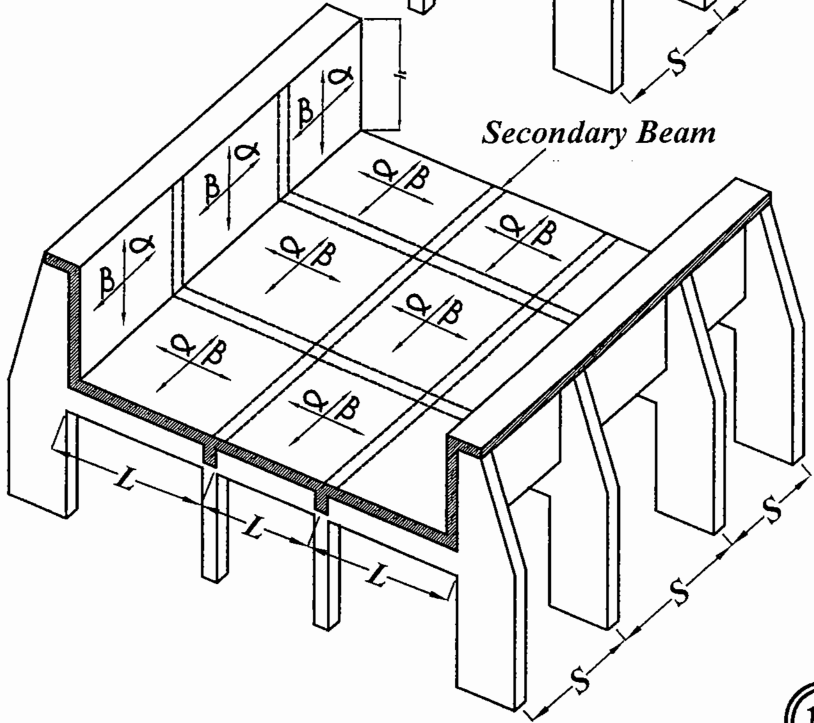
IF $L \leq h$

The Wall Considered as one way in Horizontal direction



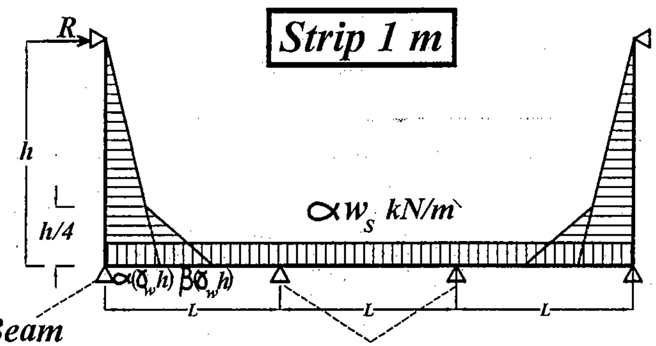
7- Open Channel With Counter Fort





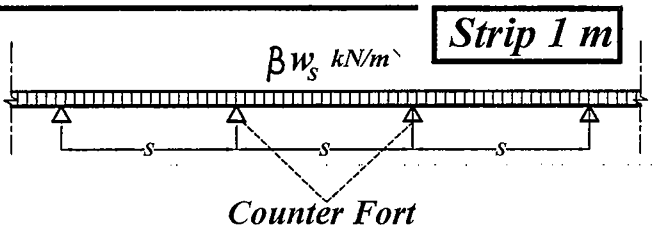
VL Strip ①

In The Floor & Side Walls



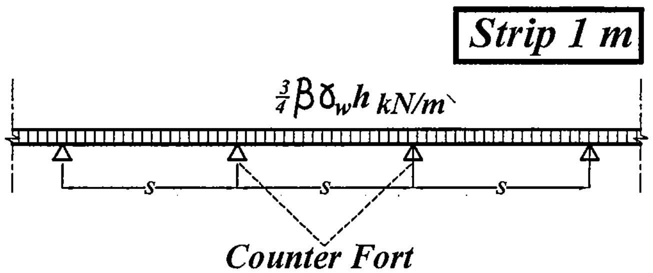
Strip ②

In The Floor

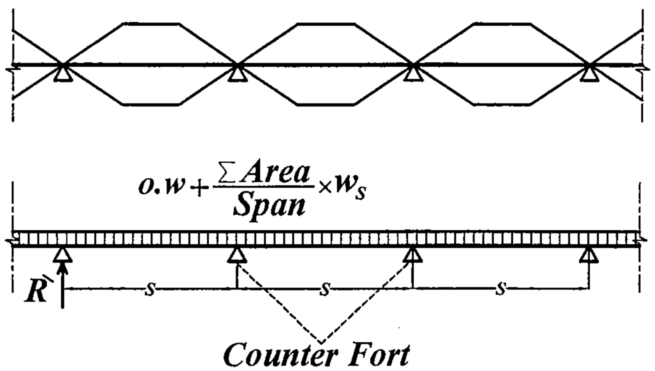


HL Strip ③

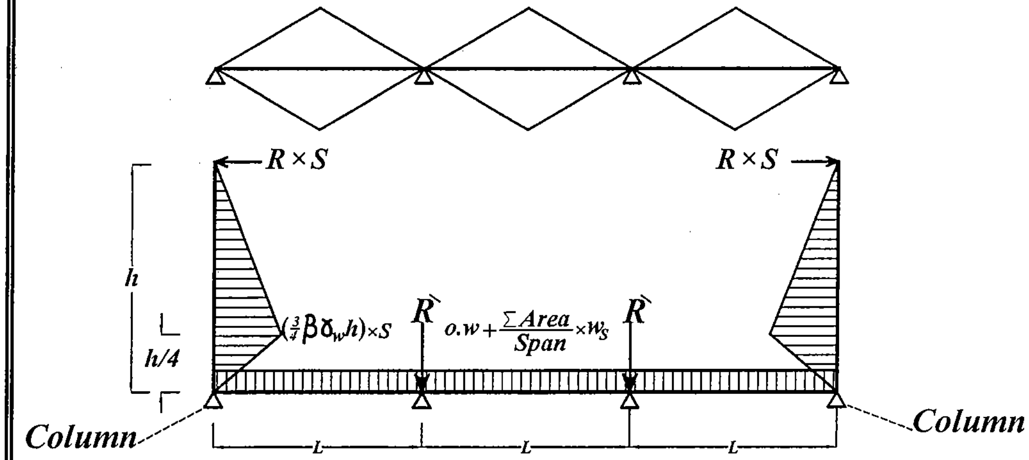
In Side Wall



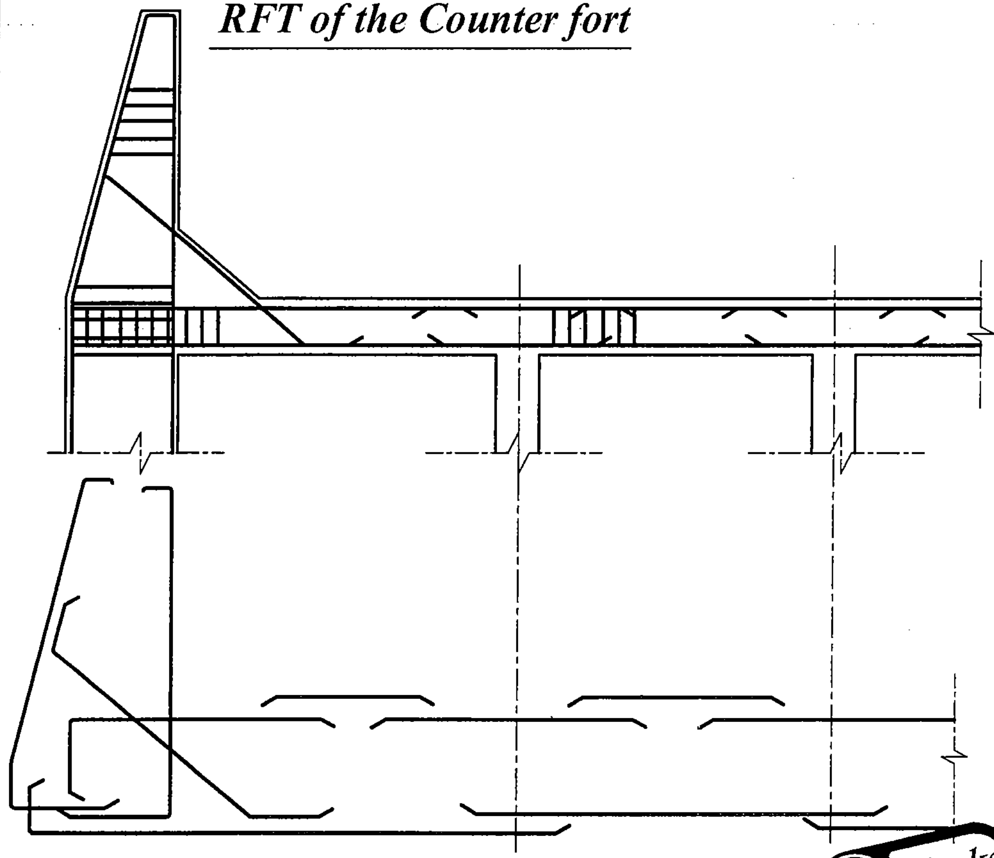
Secondary Beam



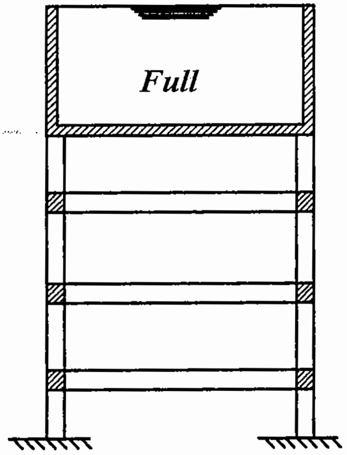
Counter Fort



RFT of the Counter fort

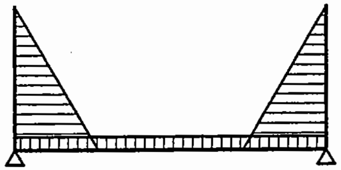


8- Towers Supporting Elevated Tanks



Case 1 (Full Tank)

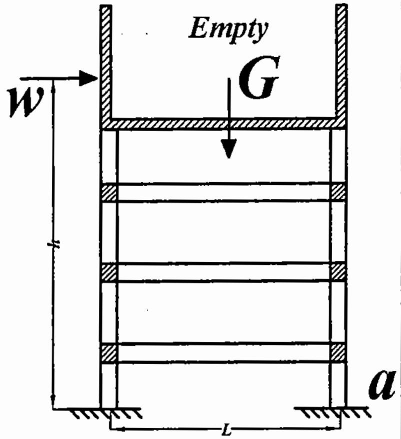
The tank will be designed as an elevated tank



Case 2 (Empty Tank)

(Just After Construction or During Repair)

This Case is a Critical Case for over turning due to wind pressure or Seismic loads



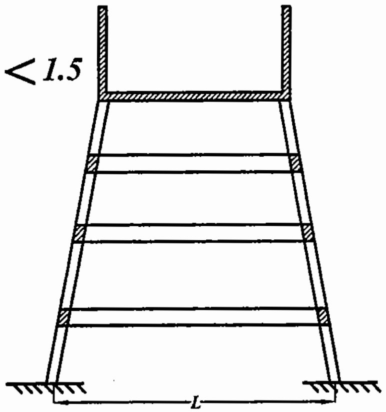
Stability Moment $= G \times \frac{L}{2}$

Over turning Moment $= w \times h$

$$F.O.S = \frac{\text{Stability Moment}}{\text{Over turning Moment}}$$

$F.O.S \nless 1.5$

If (F.O.S.) < 1.5



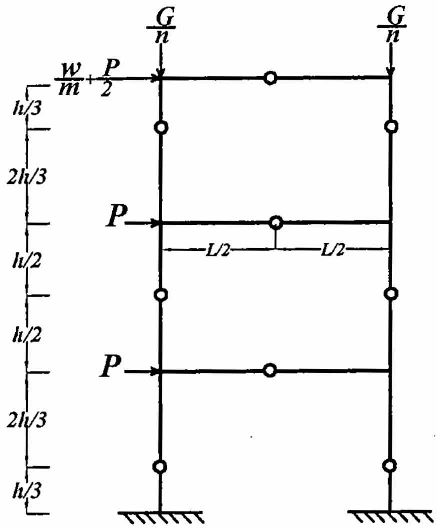
Note

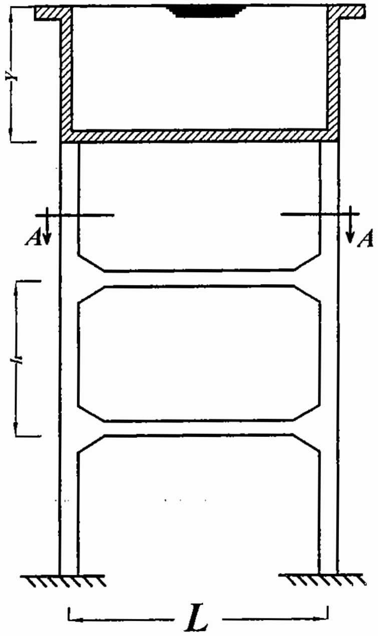
-Columns must be connected with Rigid Beams to decrease the Buckling of the Columns and get a Space Action between Columns .

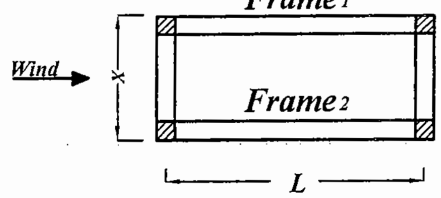
-In case of seismic case of full tank may be more critical as $F_b = S_d(T_1) \times \lambda \frac{W}{g}$

Tank Weight (G)

Design of the Supporting Tower







Sec A-A

(G) Total Weight of tank

(n) Number of Columns

(m) Number of Frames

(w) Lateral Load due to wind or seismic

$w =$ wind intensity $\times X \times Y$

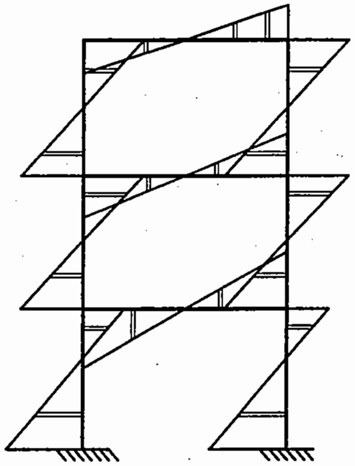
(P) wind force acting on the area of columns & beams

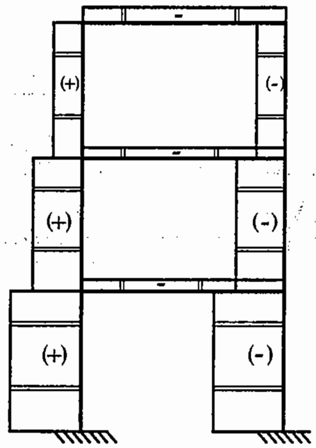
$P =$ Area of columns & beams $\times$ wind intensity

Area of columns & beams $= (0.10 - 0.15)(h \times X)$

Note

-Area of beams and columns can be neglected.





B.M.D. **N.F.D.**

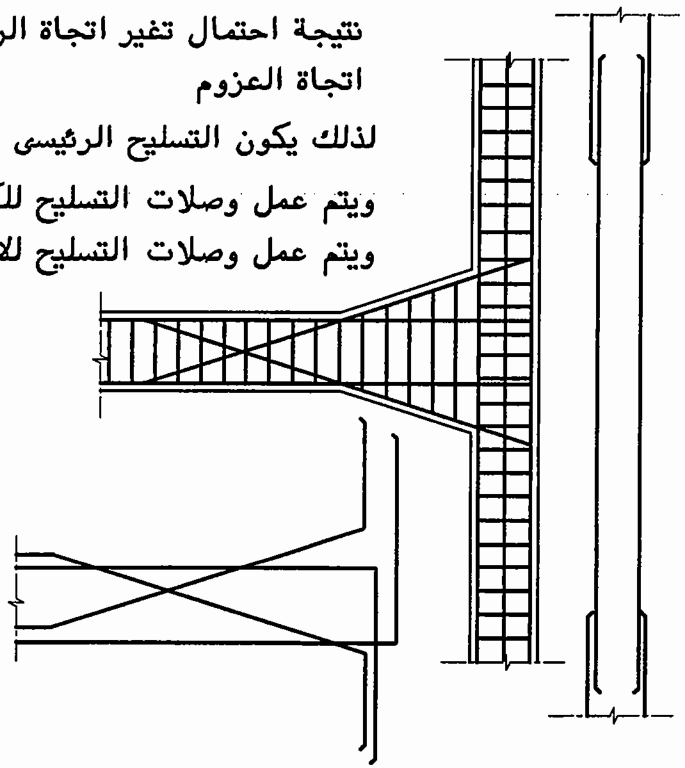
Details of R.F.T

نتيجة احتمال تغير اتجاة الرياح و بالتالى تغير اتجاة العزوم

لذلك يكون التسليح الرئيسى فى الكمرة علوى و سفلى

ويتم عمل وصلات التسليح للكمرات فى منتصف البحر

ويتم عمل وصلات التسليح للاعمدة فى منتصف الدور



Rested Tanks

Steps of design:

1- Dimensioning

هي عملية فرض الأبعاد للعناصر الخرسانية المختلفة (الحائط و الأرضية).

للتسهيل يمكن دائماً فرض $t_w = 300\ mm$ & $t_f = 400\ mm$

element	Cantilever	Two way	One way
walls t_w	$\frac{H}{10}$	$\frac{L\ or\ H}{16}$ الأقل	$\frac{L\ or\ H}{10}$ الأقل
slabs t_s	——	$\frac{L}{12}$	

2- Check for bearing capacity

لا يتم عمل هذا الـ *Check* في الامتحان إلا إذا طلب في المسألة أو كانت *Bearing capacity* معطاه في الامتحان و لكن في جميع الأحوال يتم حساب F_{gross}

Stress under the base of the tank must be less Than The allowable bearing Stresses (Bearing Capacity) of The Soil

$$F_{gross} = \frac{\Sigma W}{A} \qquad F_{gross} < \text{Bearing Capacity}$$

(F_{gross}) *The uniform stress on the soil*

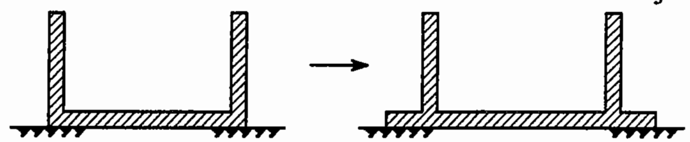
(ΣW) *Weight of (Beams+ walls + Roof + Water + Floor slab)*

(A) *Area of the base of The Tank*

$$\text{Bearing Capacity} \simeq 150\ kN/m^2$$

If $F_{gross} \leqslant$ *Bearing capacity of soil* ⟶ *Safe*

If $F_{gross} >$ *Bearing capacity of soil* ⟶ *Unsafe*
↓
Increase floor dimensions

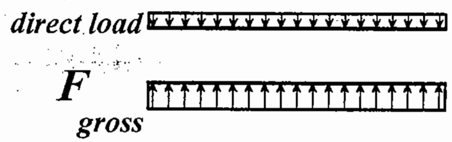


3- Loads and straining actions

هي عملية حساب الأحمال على الشرائح المختلفة للـ *Tanks* و تكون هذه الأحمال *Working loads* و يتم حل هذه الشرائح باستخدام *Moment distribution* ثم يتم حساب القوى الداخلية في هذه الشرائح.

→ $F_{gross} = \frac{\Sigma W}{A}$

→ $F_{net} = F_{gross}$ - Direct Load

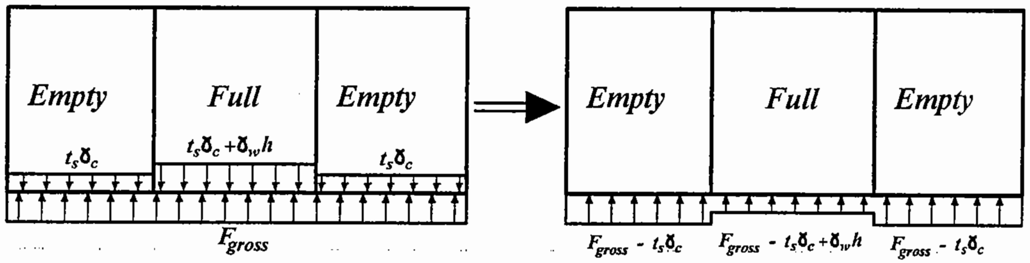


direct load = $t_F \gamma_c + \gamma_w h$ in case of Full Tank

direct load = $t_F \gamma_c$ in case of Empty Tank

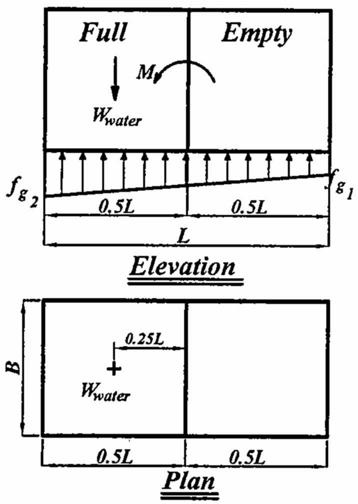
(F_{net}) will be distributed according to α, β of the floor Slab

Case of Symmetrical loading



Case of Unsymmetrical loading

تتولد عزوم على قاعدة الخزان في حالة عدم انطباق مركز الأحمال مع مركز القاعدة



$$F_{g_1} = -\frac{\Sigma W}{A} - \frac{M \times y}{I}$$

$$F_{g_2} = +\frac{\Sigma W}{A} + \frac{M \times y}{I}$$

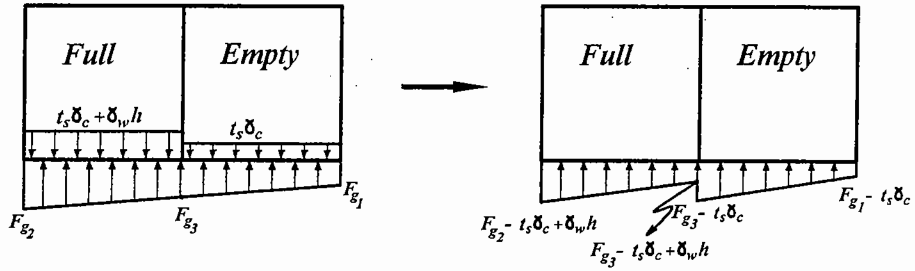
where

A = Area of tank base = $B \times L$

I = Inertia of tank base = $\frac{B \times L^3}{12}$

y = Distance from Center of Area to the required calculated point = L/2

M = Acting moment on the tank base = $W_{water} \times 0.25\,L$



- Relative inertia between walls and floor must be taken into consideration while getting straining actions on the tank using Moment Distribution Method

4- Design of sections

هي مرحلة تصميم القطاعات التي تم حساب القوى الداخلية فيها .

Water sections (Cat. III) → Stage (I) & Stage (II)

Air sections (Cat. II) → Stage (II)

→ All loads are working loads at Stage (I) & ultimate loads at Stage (II)

→ **If The Tension Side At The Soil Side Or Water Side The Section Will be Designed as a Water Sections**

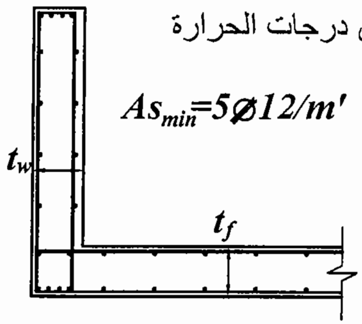
5- Details of RFT

رسم تفاصيل التسليح. *Same as Elevated Tanks*

*Note

١- يتم تركيز حديد أسفل الحائط لمقاومة *Differential settlement* و يتم تركيز حديد أعلى الحائط لمقاومة الاجهادات الناتجة عن فرق درجات الحرارة

٢- $As_{min} = 5\phi 12/m'$ at both tension & compression sides



Under Ground Tanks

Steps of design:

1- Dimensioning

هي عملية فرض الأبعاد للعناصر الخرسانية المختلفة (الحائط و الأرضية).

للتسهيل يمكن دائماً فرض $t_w = 300$ mm & $t_f = 400$ mm

element	Cantilever	Two way	One way
walls t_w	$\frac{H}{10}$	$\frac{L \text{ or } H}{16}$ الأقل	$\frac{L \text{ or } H}{10}$ الأقل
slabs t_s	——	$\frac{L}{12}$	

2- Checks

a- Check for bearing capacity (same as rested tanks)

لا يتم عمل هذا الـ *Check* في الامتحان إلا إذا طلب في المسألة أو كانت *Bearing capacity* معطاه في الامتحان و لكن في جميع الأحوال يتم حساب F_{gross}

b- Check for safety against uplift

To avoid floating of under ground tanks due to up lift, factor of safety against Up Lift must be greater than this value

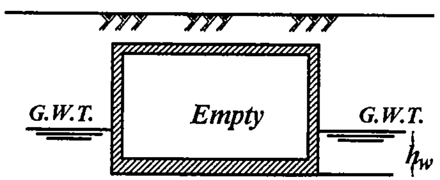
$$\text{Factor of Safety} = \frac{\text{Minimum weight of the tank}}{\text{Up Lift Force}} > \begin{cases} 1.5 \\ 1.2 \end{cases}$$

$$\text{Up Lift Force} = A \times \gamma_w h_w$$

(A) Area of The base of The Tank

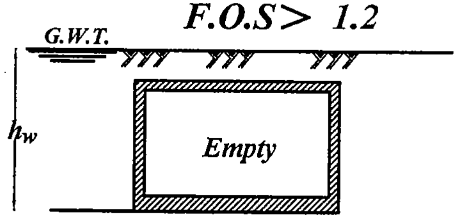
(h_w) Height of G.W.T. from the base of the tank

F.O.S> 1.5



يوجد احتمال لزيادة الـ G.W.T.

F.O.S> 1.2

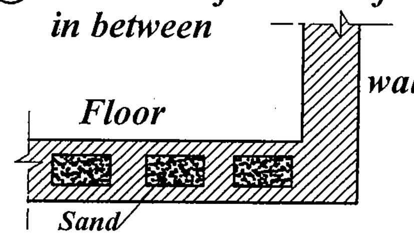


لا يمكن زيادة الـ G.W.T.

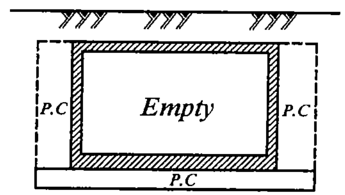
Factors to increase F.O.S. against uplift

① Increase the thickness of the slabs or walls

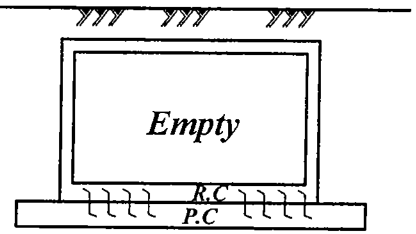
② Use double floor with filling in between



③ Use over weight around the tank



④ Anchors Between R.C & P.C



⑤ Use tension piles

3- Loads and straining actions

هي عملية حساب الأحمال على الشرائح المختلفة للـ *Tanks* و تكون هذه الأحمال *Working loads* و يتم حل هذه الشرائح باستخدام *Moment distribution* ثم يتم حساب القوى الداخلية في هذه الشرائح.

$$\longrightarrow F_{gross} = \frac{\Sigma W}{A} \longrightarrow F_{net} = F_{gross} - \text{Direct Load}$$

- *Relative inertia between walls and floor must be taken into consideration while getting straining actions on the tank using Moment Distribution Method*

- تتولد عزوم على قاعدة الخزان في حالة عدم انطباق مركز الأحمال مع مركز القاعدة

Loads on Under Ground Tanks

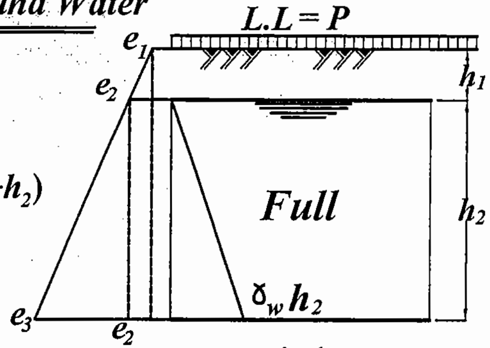
During Operation without Ground Water

$e_1 = K_a P$

$e_2 = e_1 + \gamma_{soil} K_a h_1 = K_a P + \gamma_{soil} K_a h_1$

$e_3 = e_2 + \gamma_{soil} K_a h_2 = K_a P + \gamma_{soil} K_a (h_1 + h_2)$

$$K_a = \frac{1-\sin\phi}{1+\sin\phi}$$

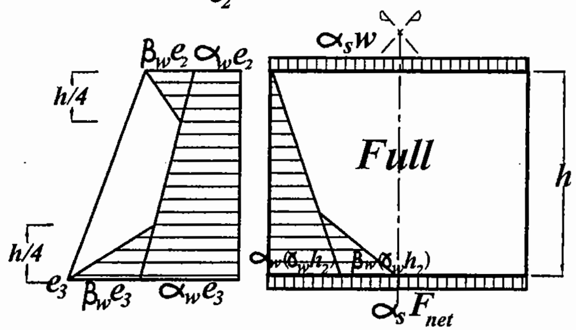


For Wall $\longrightarrow \beta_w \,\&\, \alpha_w$

For Slab $\longrightarrow \beta_s \,\&\, \alpha_s$

$W = t_{cover}\gamma_c + \gamma_{soil} h_1 + P$

$F_{net} = F_{gross}$ - (direct load)

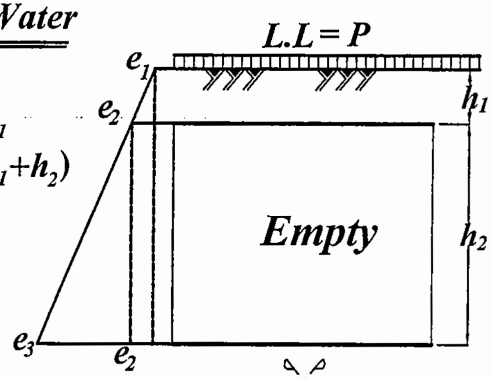


During Repair without Ground Water

$e_1 = K_a P$

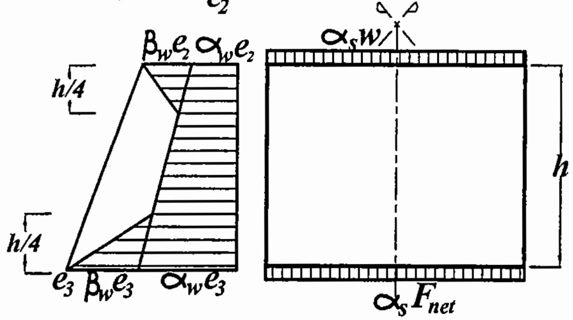
$e_2 = e_1 + \gamma_{soil} K_a h_1 = K_a P + \gamma_{soil} K_a h_1$

$e_3 = e_2 + \gamma_{soil} K_a h_2 = K_a P + \gamma_{soil} K_a (h_1 + h_2)$



$F_{net} = F_{gross}$ - (direct load)

$W = t_{cover}\gamma_c + \gamma_{soil} h_1 + P$



During Operation with Ground Water

$e_1 = K_a P$

$e_2 = e_1 + \gamma_{soil} K_a h_1 = K_a P + \gamma_{soil} K_a h_1$

$e_3 = e_2 + \gamma_{soil} K_a h_2$

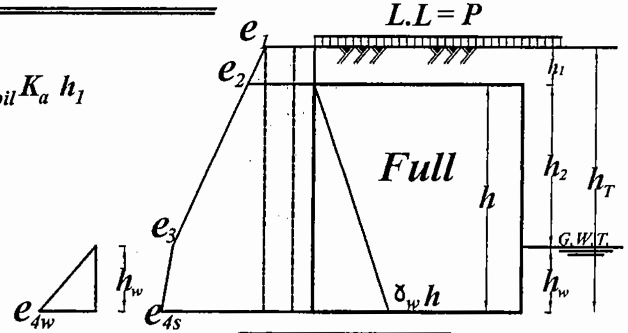
$= K_a P + \gamma_{soil} K_a (h_1 + h_2)$

$e_4 = e_{4s} + e_{4w}$

$e_{4s} = e_3 + \gamma_{sub} K_a h_w$

$= K_a P + \gamma_{soil} K_a (h_1 + h_2) + \gamma_{sub} K_a (h_w)$

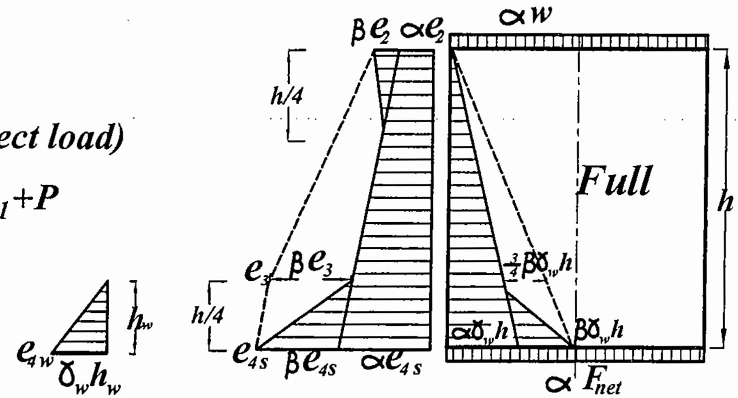
$e_{4w} = \gamma_w h_w$



$$\boxed{\gamma_{sub} = \gamma_{soil} - \gamma_w}$$

$F_{net} = F_{gross}$ - (direct load)

$W = t_{cover}\gamma_c + \gamma_{soil} h_1 + P$



Another method

$e_4 = e_{4s} + e_{4w} = e_3 + \gamma_{sub} K_a h_w + \gamma_w h_w$

$= e_3 + \gamma_{sub} K_a h_w + \gamma_w h_w + (\gamma_{soil} K_a h_w - \gamma_{soil} K_a h_w)$

$= (e_3 + \gamma_{soil} K_a h_w) + (\gamma_w h_w + \gamma_{sub} K_a h_w - \gamma_{soil} K_a h_w)$

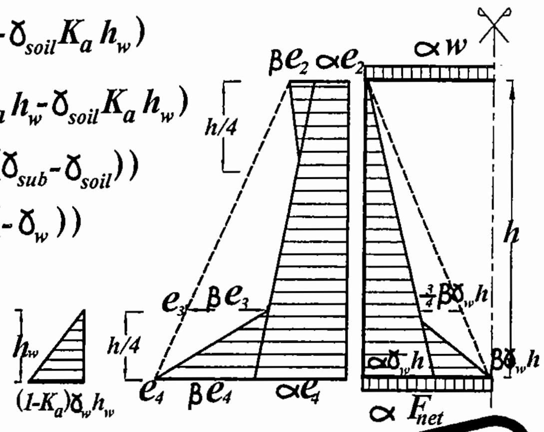
$= (e_3 + \gamma_{soil} K_a h_w) + (\gamma_w h_w + K_a h_w (\gamma_{sub} - \gamma_{soil}))$

$= (e_3 + \gamma_{soil} K_a h_w) + (\gamma_w h_w + K_a h_w (-\gamma_w))$

$= (e_3 + \gamma_{soil} K_a h_w) + (\gamma_w h_w - \gamma_w K_a h_w)$

$= (e_3 + \gamma_{soil} K_a h_w) + (1 - K_a)\gamma_w h_w$

$$\boxed{e_4 = \gamma_{soil} K_a h_T + (1 - K_a)\gamma_w h_w}$$



During Repair with Ground Water

$e_1 = K_a P$

$e_2 = e_1 + \gamma_{soil} K_a h_1 = K_a P + \gamma_{soil} K_a h_1$

$e_3 = e_2 + \gamma_{soil} K_a h_2$

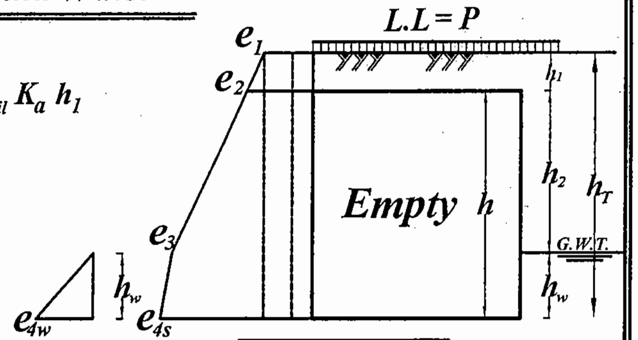
$= K_a P + \gamma_{soil} K_a (h_1 + h_2)$

$e_4 = e_{4s} + e_{4w}$

$e_{4s} = e_3 + \gamma_{sub} K_a h_w$

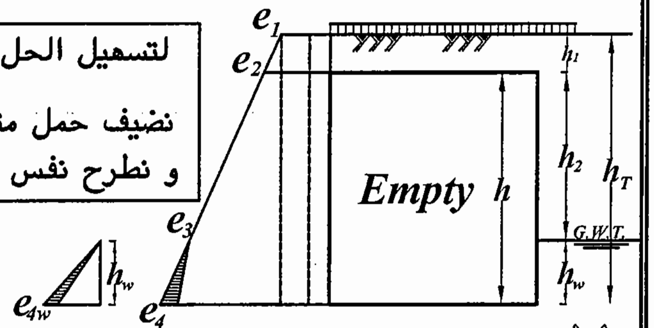
$= K_a P + \gamma_{soil} K_a (h_1 + h_2) + \gamma_{sub} K_a (h_w)$

$e_{4w} = \gamma_w h_w$



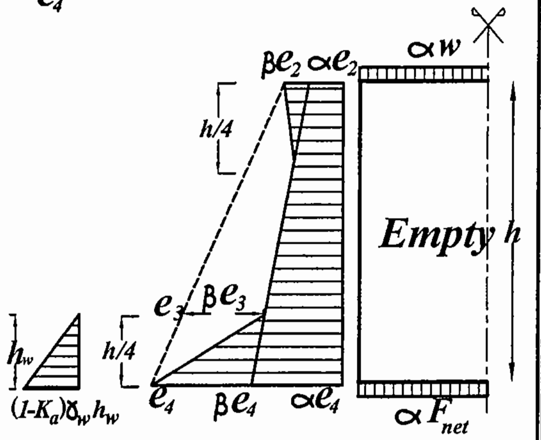
$\gamma_{sub} = \gamma_{soil} - \gamma_w$

لتسهيل الحل باستخدام ال
Moment distribution
نضيف حمل مثلث على ضغط التربة
و نطرح نفس القيمة من ضغط المياة



$F_{net} = F_{gross}$ - (direct load)

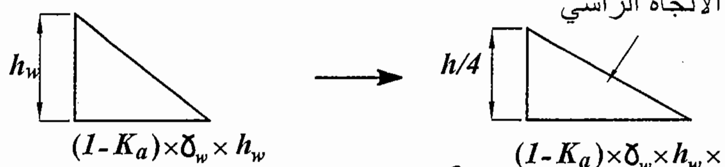
$w = t_{cover} \gamma_c + \gamma_{soil} h_1 + P$



*Note

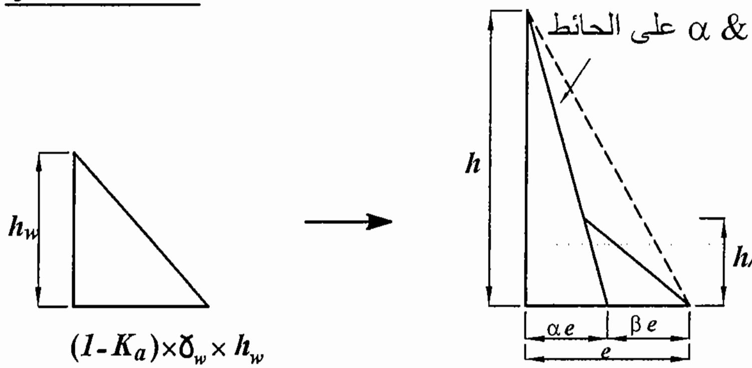
عادة يكون مثلث الماء على ارتفاع h/4 للحائط و بالتالي يذهب كله في التجاه الرأسي
أما في حالة أن مثلث الماء ليس على ارتفاع h/4 فنقوم بتقريبه كالآتي حتى يسهل التعامل معه

If $h_w \leq h/2$



$$e = \frac{(1-K_a)\times\gamma_w\times h_w\times h_w}{h/4}$$

If $h_w > h/2$



$$e = \frac{(1-K_a)\times\gamma_w\times h_w\times h_w}{h}$$

4- Design of sections

هي مرحلة تصميم القطاعات التى تم حساب القوى الداخلية فيها .

Water sections (Cat. III) ⟶ Stage (I) & Stage (II)

Air sections (Cat. II) ⟶ Stage (II)

⟶ All loads are working loads at Stage (I) & ultimate loads at Stage (II)

⟶ **If The Tension Side At The Soil Side Or Water Side The Section Will be Designed as a Water Sections**

5- Details of RFT

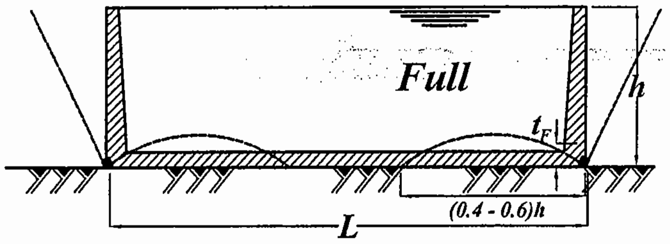
رسم تفاصيل التسليح. Same as Rested Tanks

Tanks Rested on Elastic Foundation

The Tank Considered to be Rested on Elastic Foundation if

① $L_{min} \geq 2h$

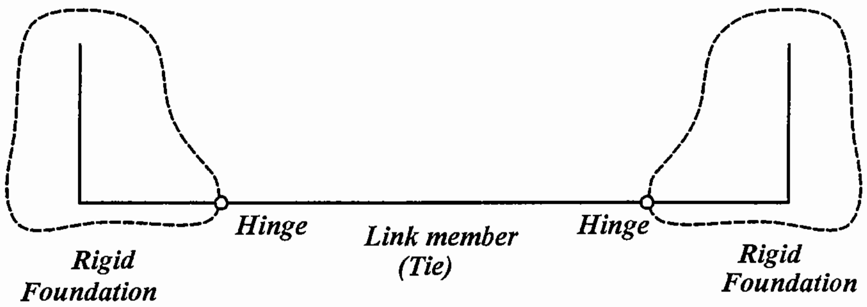
② $t_{floor} < 400$ mm



١ - نتيجة لان سمك البلاطة صغير فانه ينتج عن ذلك توزيع غير منتظم للاجهادات على التربه و تكون الاجهادات كبيرة جهة الأطراف و تقل فى منتصف البلاطة

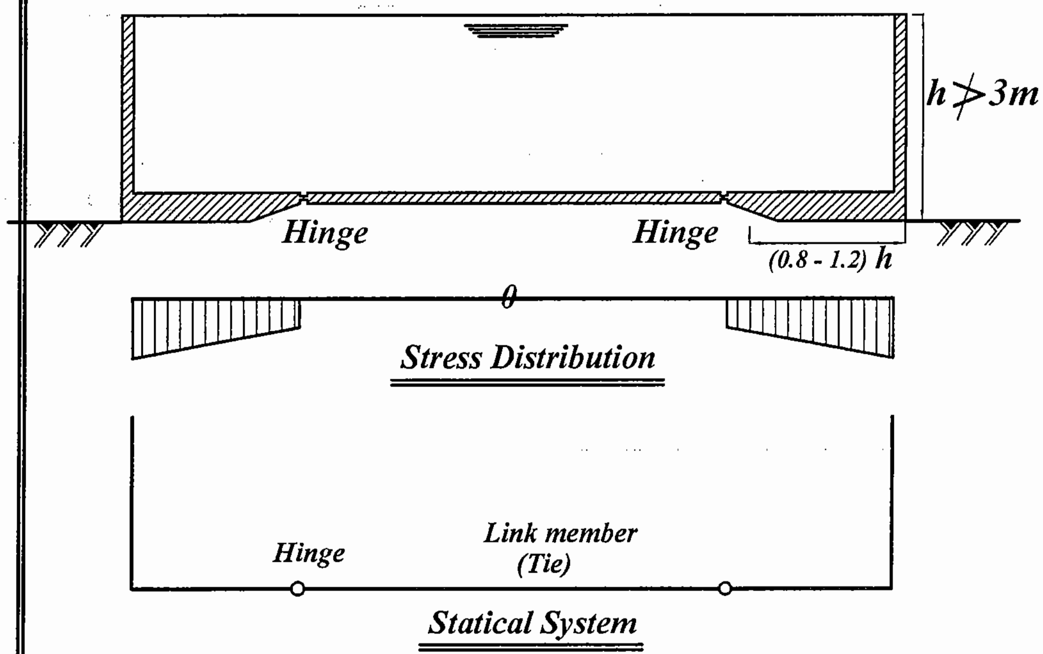
٢ - نتيجة لبعد المسافة بين الحائطين الرأسيين (L) فان ذلك يؤدى الى عدم تأثر بلاطة الأرضية بالكامل بالعزوم الواقعة على الحائط و لكن الجزء الذى يتأثر بهذه العزم يتراوح بين $(0.8 - 1.2)\ h$

أما باقي البلاطة يكون معرض لـ *Axial Tension* المنقولة من الحائط للأرضية



Swimming Pools

Case A (cantilever wall)



Taking strip 1m width

$N = o.w\ of\ wall + weight\ of\ water + o.w\ of\ floor = \checkmark\ kN$

$M_{C.G} = o.w\ of\ wall \times (\frac{X}{2}) + (\frac{1}{2}\gamma_w h^2) \times (\frac{h}{3}) = \checkmark\ kN.m.$

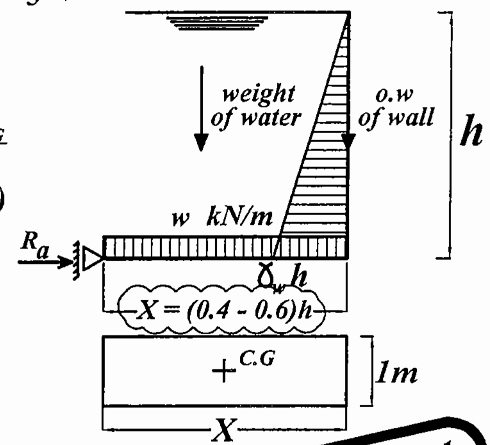
$q_{1\,gross} = -\frac{N}{A} - \frac{M}{Z} = -\frac{N}{A} - \frac{6M_{C.G}}{X^2}$

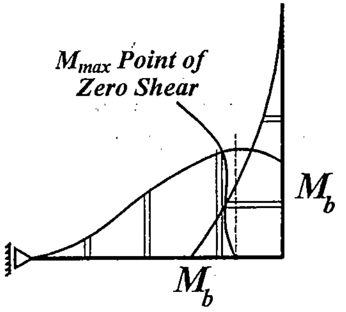
$q_{2\,gross} = -\frac{N}{A} + \frac{M}{Z} = -\frac{N}{A} + \frac{6M_{C.G}}{X^2}$

$w = t_s\gamma_c + \gamma_w h$ (Direct Load)

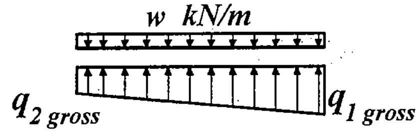
$q_{1\,net} = q_{1\,gross} - w$

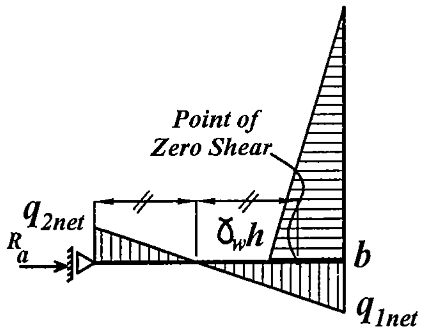
$q_{2\,net} = q_{2\,gross} - w$

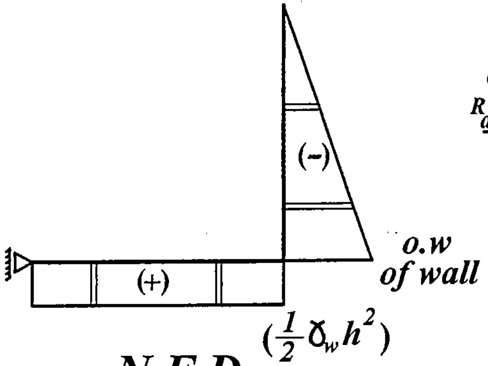




B.M.D







N.F.D

$$M_b = (\frac{1}{2}\gamma_w h) \times h \times (\frac{h}{3}) = \frac{\gamma_w h^3}{6}$$

$$R_a = (\frac{1}{2}\gamma_w h^2)$$

*** Note**

- يجب آلا تتولد إجهادات شد على القاعدة و إذا تولد $q_{gross} = -ve$ يجب زيادة أبعاد القاعدة

Details of RFT