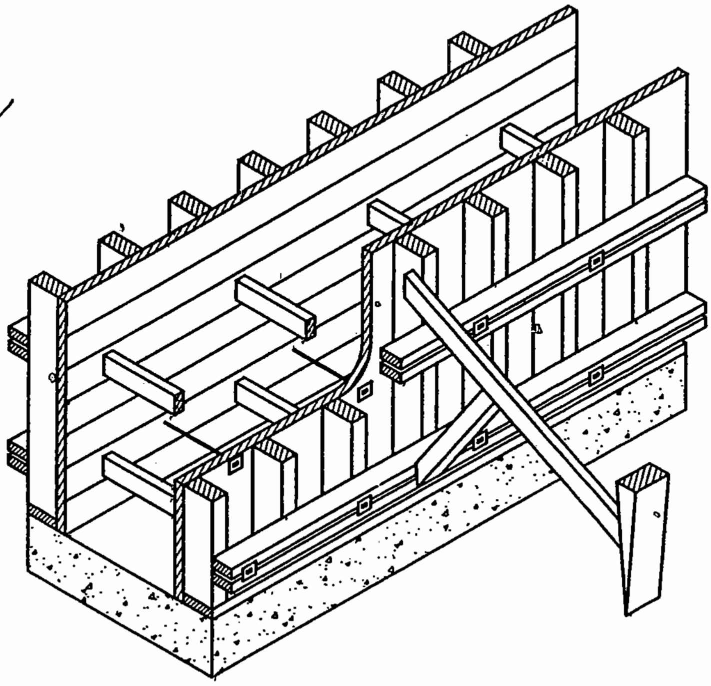
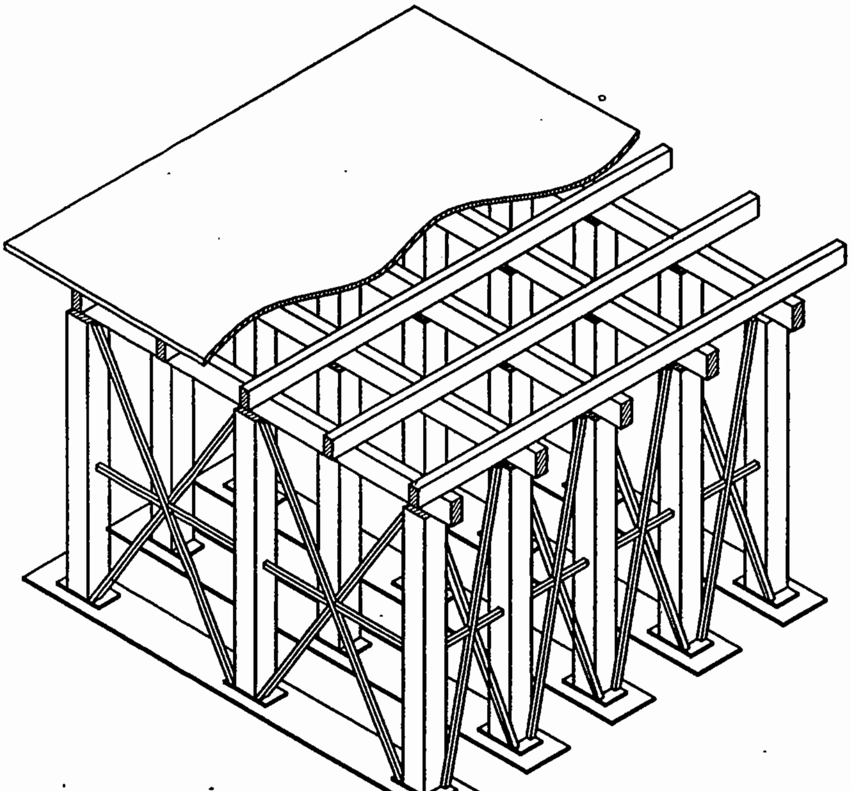


Construction Techniques (II)

2

Structural Department



4th year Civil

***

Bill of Quantity

حصر الكميات

حصر الكميات من المراحل الهامة فى المشروع واللازمة لتحديد كميات الحديد المستخدم وحجم الخرسانة ومساحة الشدات قبل الدخول فى آى مناقصة لتحديد الاسعار فى عقود البناء .

ويتم فى حصر الكميات حصر الاتى :

١ - كمية الحديد — *Weight of RFT (ton)*

٢ - حجم الخرسانة — *Volume of concrete* (m^3)

٣ - مساحة الشدات الخشبية — *Area of shuttering* (m^2)

1 - Weight of RFT (ton)

لعمل حصر لكميات الحديد :

١ - يجب رسم تفاصيل التسليح لتحديد شكل كل سيخ .

٢ - يتم ترقيم الاسياخ وإعطاء كود لكل سيخ .

٣ - يتم تحديد طول كل سيخ .

٤ - يتم تحديد عدد مرات تكرار كل سيخ .

٥ - يتم تجميع كل هذه البيانات فى جدول بالشكل التالى :

Element	Bar No. (code)	Shape	Length	No. of bars	Total length	ϕ	Weight of 1 m	Total weight
Slab	S1				Total length = Length × No. of bars			Total weight = Total length × weight of 1 m
	S2							
	S3							
Beam	B1							
	B2							
	B3							
	B4							

Where:

Element = يتم فيه تحديد نوع العنصر الذى يتم حصر الحديد به (بلاطة أو كمرة)

Bar No. (Code) = يتم فيه تحديد مسمى لكل سيخ تبعا لاختلاف شكل وعدد مرات تكراره ويجب كتابة هذا الترقيم على الـ ***Plan*** الإنشائى

Shape = يتم فيها رسم ***Sketch*** لشكل سيخ التسليح

Length = يتم فيها تحديد طول السيخ المستخدم

No. of bars = يتم فيها تحديد عدد مرات تكرار السيخ

Total length = يتم فيها تحديد الطول الكلى للأسياخ المستخدمة

$$\textit{Total length} = \textit{Length} \times \textit{No. of bars}$$

ϕ = يتم فيها تحديد القطر المستخدم

Weight of 1 m = يتم إيجاد وزن المتر من جدول أقطار أسياخ التسليح

ϕ 8 ⟶ 0.395 kg/m`

ϕ 10 ⟶ 0.617 kg/m`

ϕ 12 ⟶ 0.888 kg/m`

ϕ 16 ⟶ 1.580 kg/m`

Total weight = يتم فيها تحديد الوزن الكلى للأسياخ المستخدمة

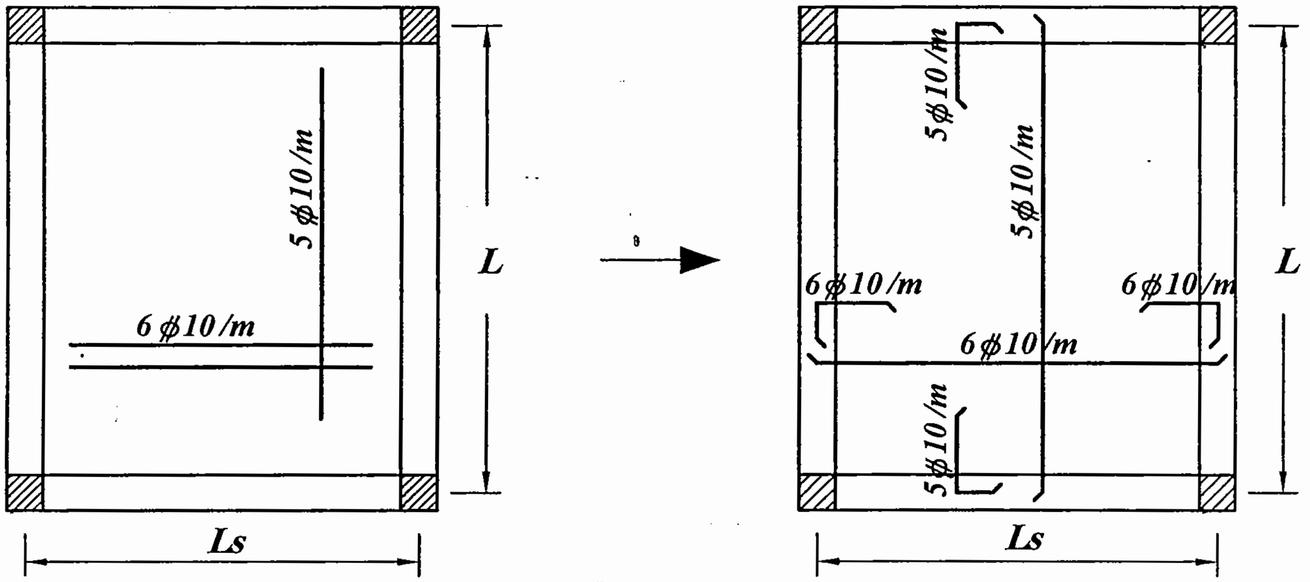
$$\textit{Total weight} = \textit{Total length} \times \textit{weight of 1 m}$$

$$\textit{Weight of 1.0 m length of bar} = \frac{\pi \phi^2}{4} \times \frac{7900}{10^6}$$

where ϕ = Bar Diameter (mm), 7900 = Density of Steel (kg/m^3)

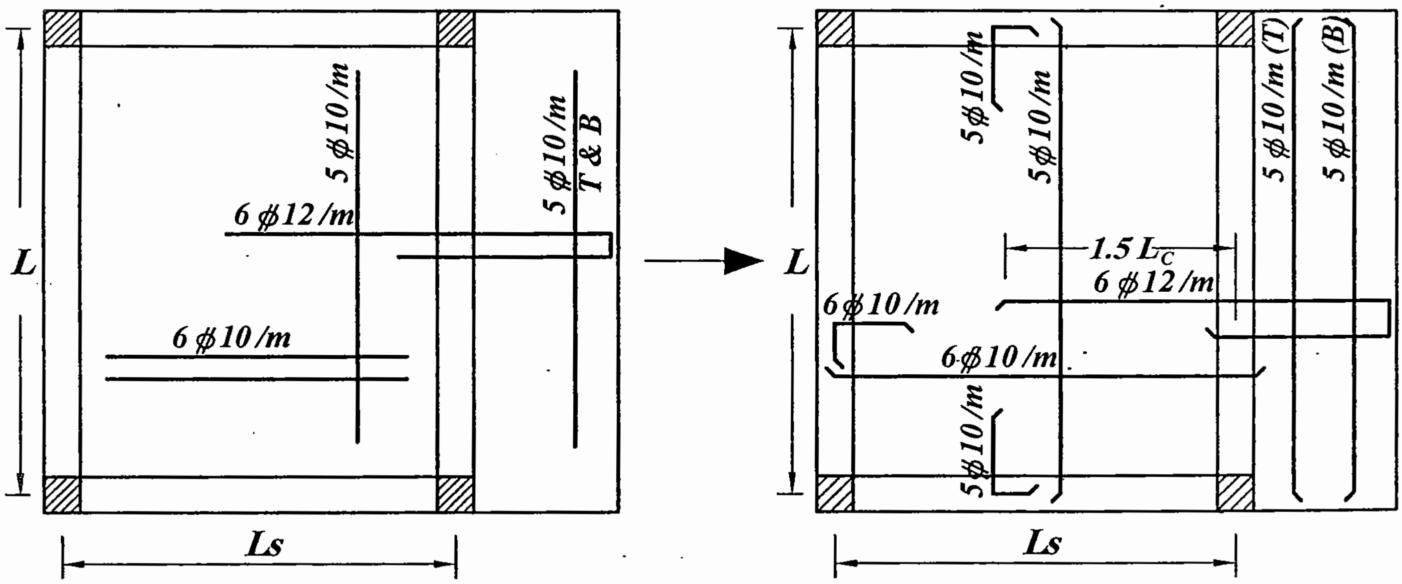
Important Notes

١ - يمكن تمثيل أسياخ التسليح بالشكل التالى



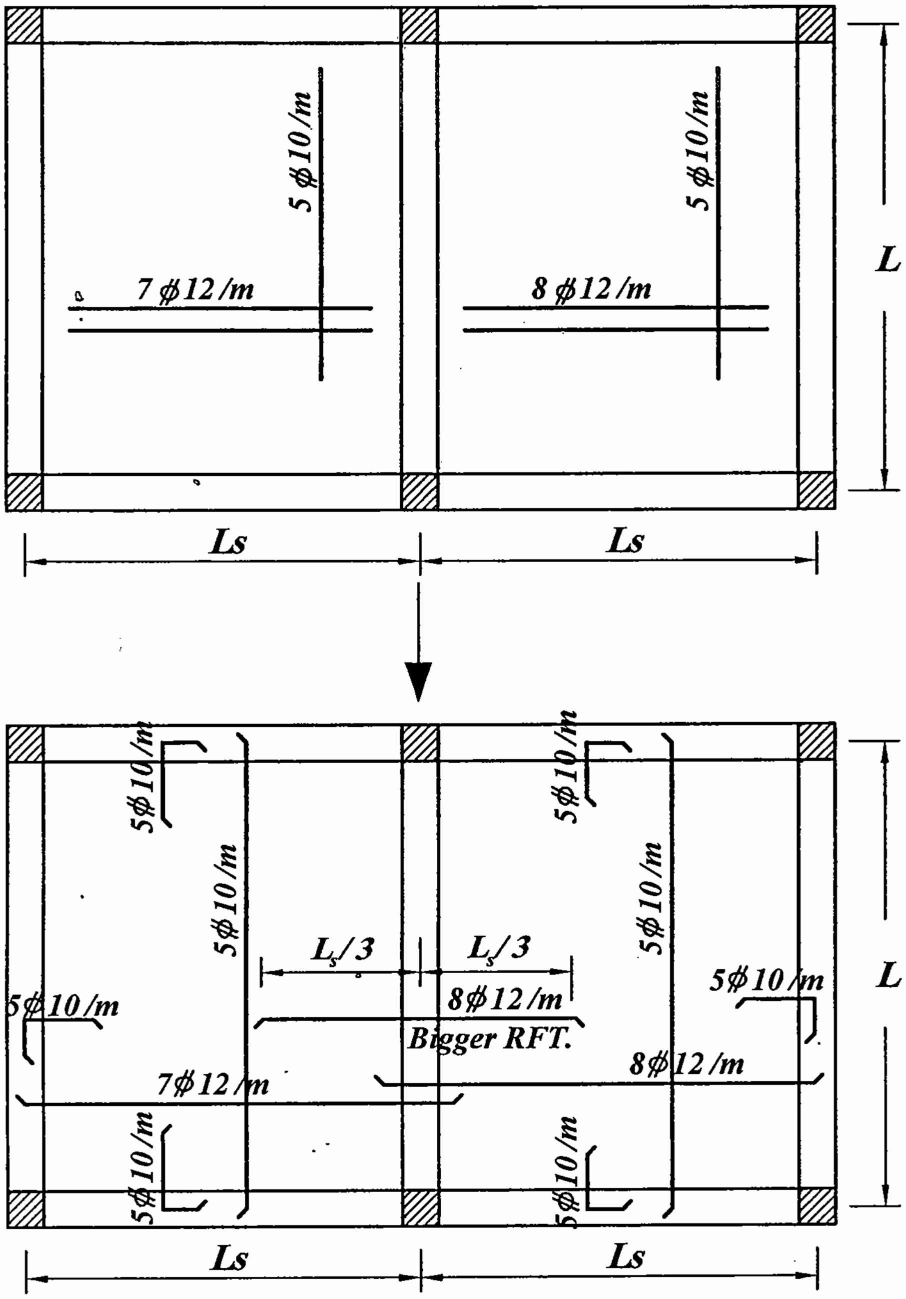
═══ يعبر عن التسليح الرئيسى (الفرش)

─── يعبر عن التسليح الثانوى (الغطاء)



═══ يعبر عن التسليح الرئيسى (الفرش)

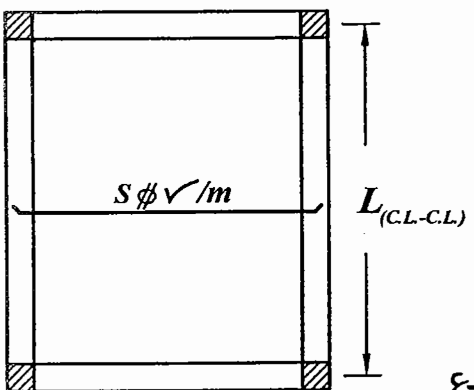
─── يعبر عن التسليح الثانوى (الغطاء)



٢- لتحديد عدد مرات تكرار كل سيخ يتم حساب عدد الأسياخ المستخدمة فى ١ م مضروبة فى المسافة التى تم خلالها تكرار هذا العدد

العدد الكلى للأسياخ= عدد مرات تكرار السيخ × المسافة (C.L. - C.L.)

و يتم تقريب هذا الرقم لأقرب عدد للأكبر



$$\textit{Total No. of bars} = S \times L_{(C.L.-C.L.)}$$

٣- لتحديد أطوال الاسياخ يتم حساب طول السيخ مع خصم ٢سم كغطاء خرسانى من كل جانب

NOTE

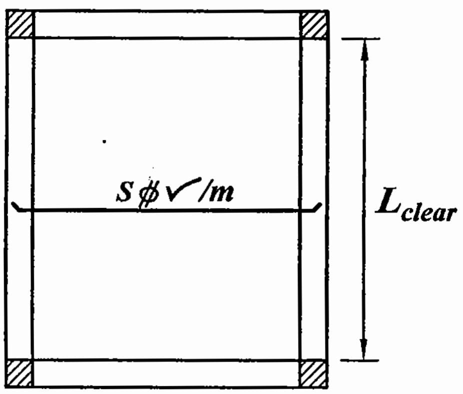
تعتبر الطريقة السابقة غير دقيقة ولكنها المستخدمة فى المحاضرة

للقراءة فقط

العدد الكلى للأسياخ=

[عدد مرات تكرار السيخ × الطول الصافى بين الكمرات] + السيخ البادئ

و يتم تقريب هذا الرقم لأقرب عدد للأكبر



$$\textit{Total No. of bars} = [S \times L_{Clear}] + 1$$

YELLOW TABLES.Page (2)

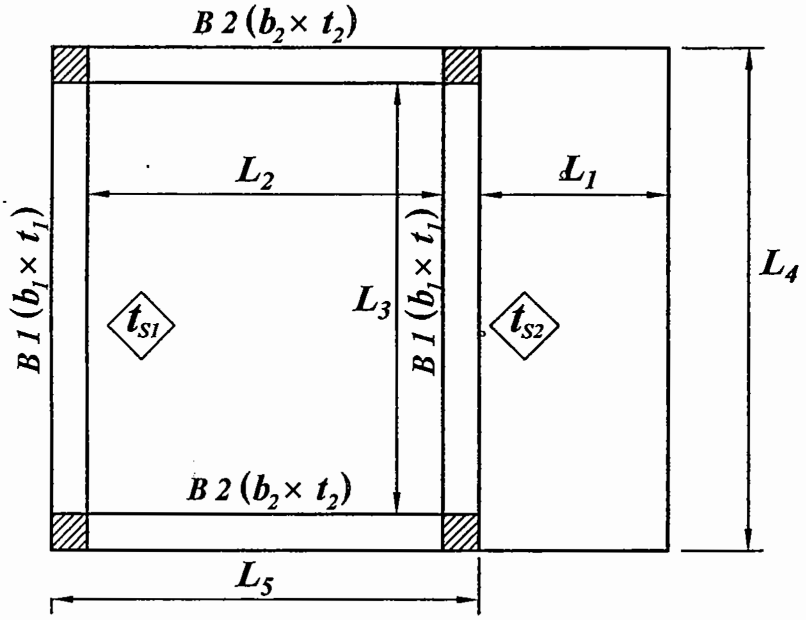
ϕ \ No.	Weight kg/m	1	2	3	4	5	6	7	8	9	10
8	0.395	50.3	100.6	150.9	201.2	251.5	301.8	352.1	402.4	452.7	503
10	0.617	78.5	157	235.5	314	392.5	471	549.5	628	706.5	785
12	0.888	113	226	339	452	565	678	791	904	1017	1130
16	1.58	201	402	603	804	1005	1206	1407	1608	1809	2010
18	2.00	254	508	762	1016	1270	1524	1778	2032	2286	2540
20	2.47	314	628	942	1256	1570	1884	2198	2512	2826	3140
22	2.98	380	760	1140	1520	1900	2280	2660	3040	3420	3800
25	3.85	491	982	1473	1964	2455	2946	3437	3928	4419	4910

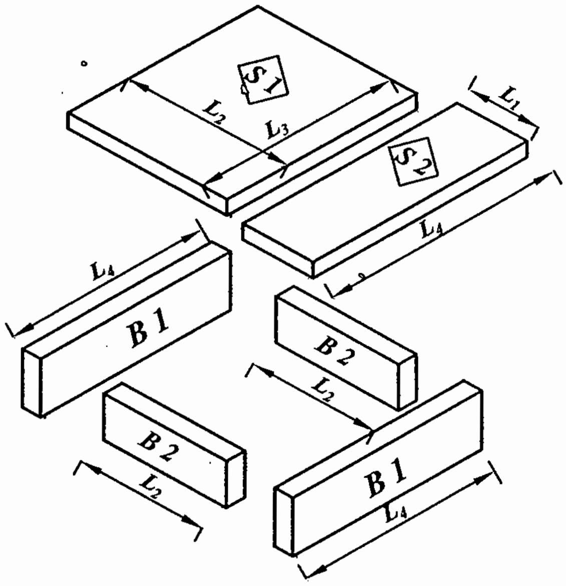
Bar Diameter (mm) — *Density of Steel (kg/m^3)*

$$\textit{Weight of 1.0 m length of bar} = \frac{\pi \phi^2}{4} \times \frac{7900}{10^6}$$

2- Volume of concrete (m^3)

يتم حساب حجم الخرسانة لكل عنصر على حدى





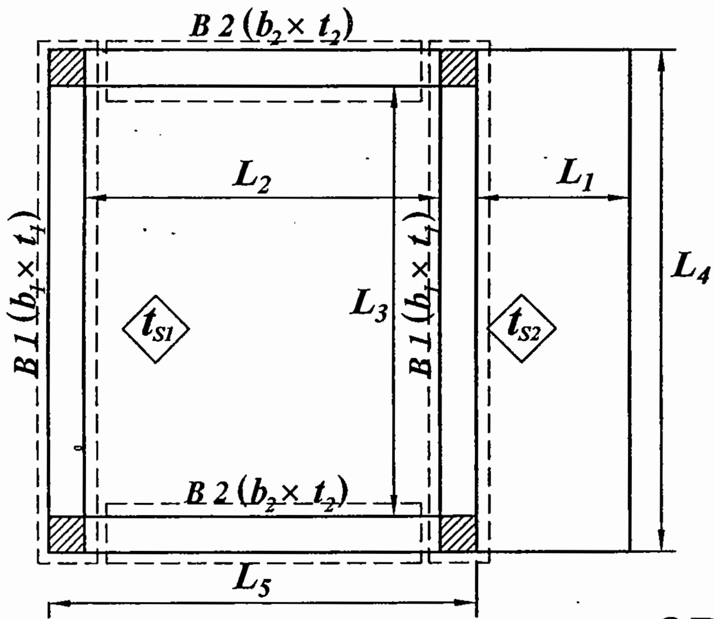
$$\text{Volume of slabs} = \text{Vol. of } S\,1 + \text{Vol. of } S\,2$$
$$= [L_2 \times L_3 \times t_{S1}] + [L_1 \times L_4 \times t_{S2}]$$

no. of beams

$$\text{Volume of beams} = \text{Vol. of } B\,1 \times ② + \text{Vol. of } B\,2 \times ②$$
$$= b_1 \times t_1 \times L_4 \times 2 + b_2 \times t_2 \times L_2 \times 2 \quad \text{(Case 1)}$$

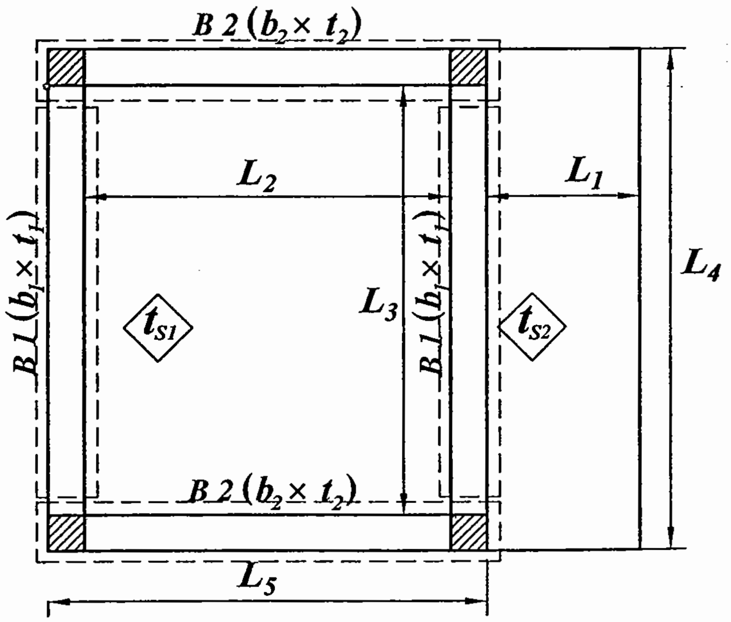
OR

$$= b_1 \times t_1 \times L_3 \times 2 + b_2 \times t_2 \times L_5 \times 2 \quad \text{(Case 2)}$$



$[b_1 \times t_1 \times L_4 \times 2 + b_2 \times t_2 \times L_2 \times 2]$

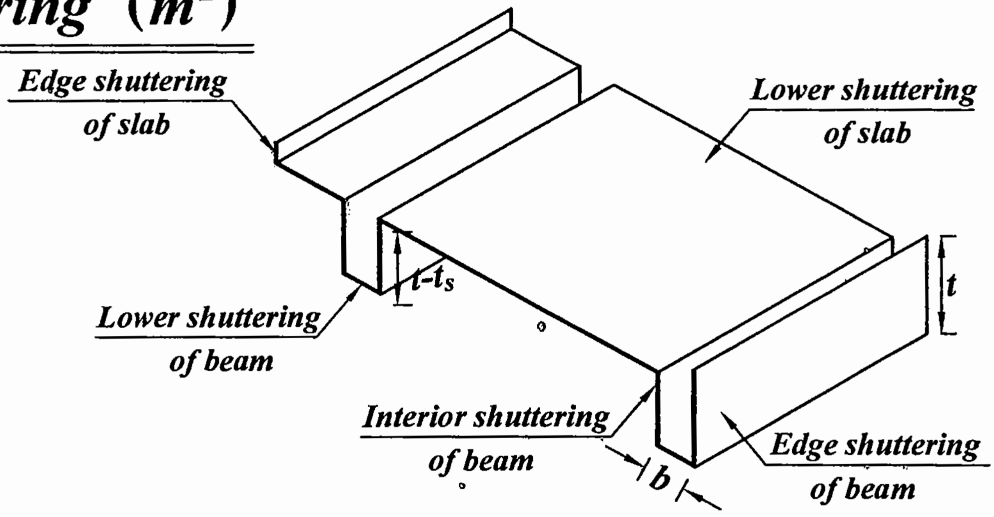
OR



$[b_1 \times t_1 \times L_3 \times 2 + b_2 \times t_2 \times L_5 \times 2]$

→ ***Volume of concrete = Volume of slabs + Volume of beams***

3- Area of shuttering (m^2)



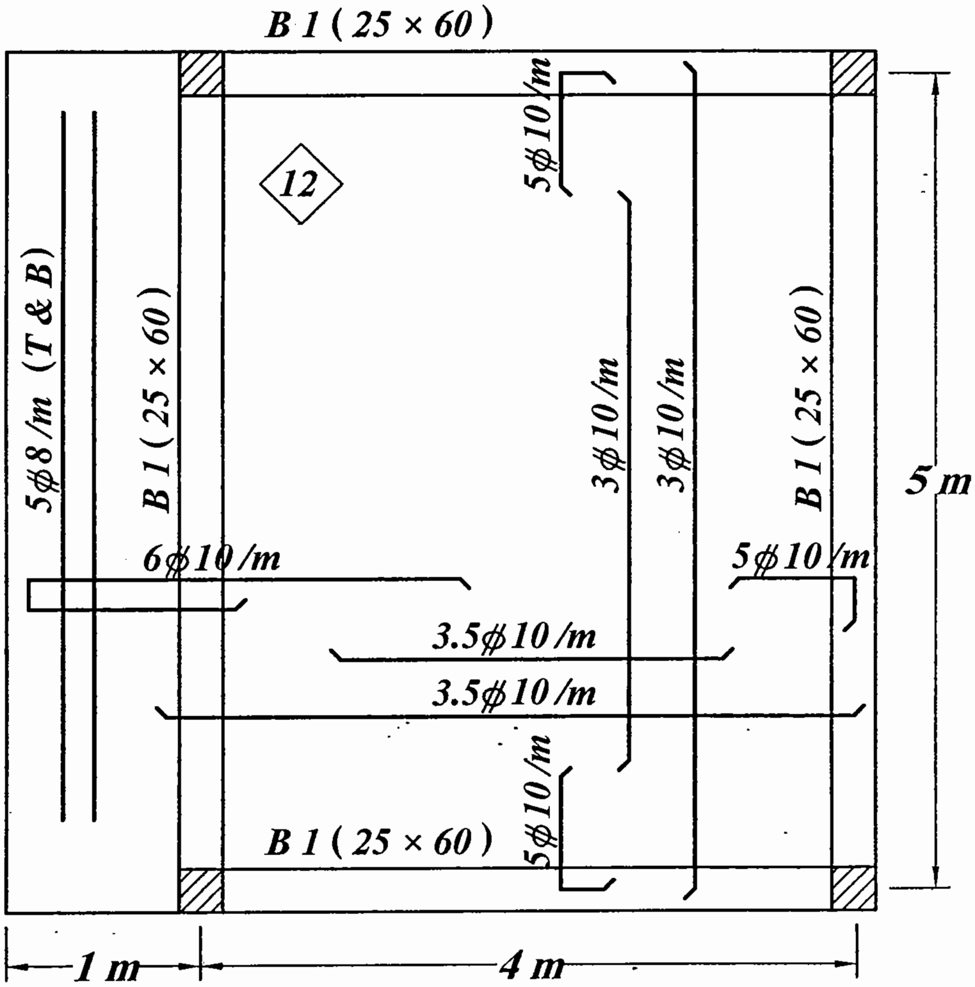
$$
\begin{aligned}
\text{Area of shuttering} = \; & \Sigma L_{clear} \times L_{clear} && \text{(Lower shuttering of slabs)} \\
+ \; & \Sigma L \times b && \text{(Lower shuttering of beam)} \\
+ \; & \Sigma L \times t && \text{(Edge shuttering of beam)} \\
+ \; & \Sigma L \times (t - t_s) && \text{(Interior shuttering of beam)} \\
+ \; & \Sigma L \times t_s && \text{(Edge shuttering of slab)}
\end{aligned}
$$

Example (1):

For the reinforced concrete slab in the shown figure ,
It is required to:

- ***Calculate the bill of quantities of all concrete slabs and beams.***
- ***Calculate the area of shuttering.***
- ***Comment on the shuttering area/m^3 of concrete and weight of RFT./m^3 of concrete .***
- ***Calculate the required time for shuttering removal .***

For all beams



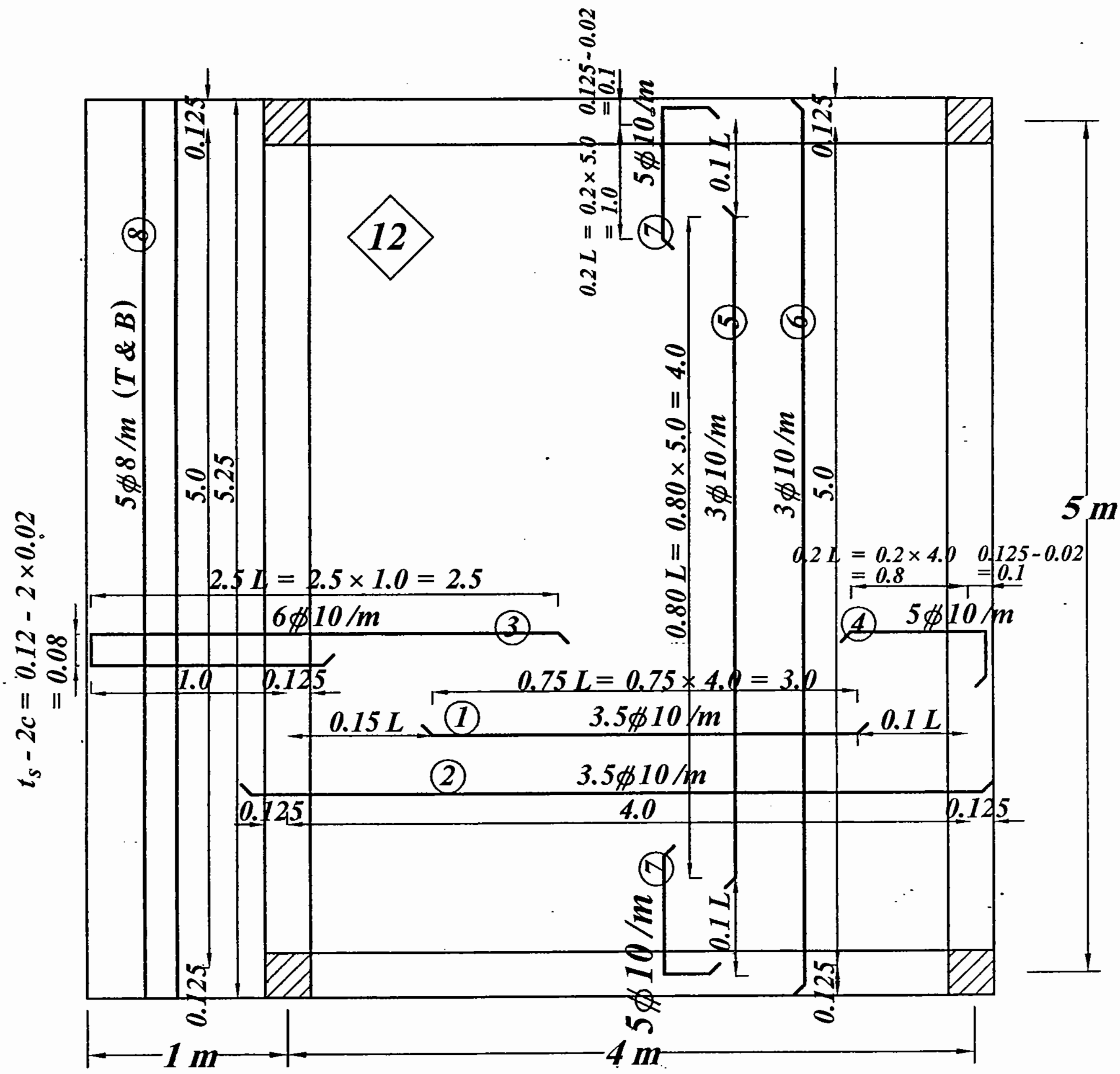
Beam Schedule

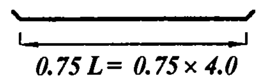
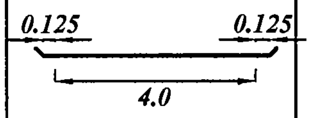
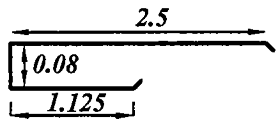
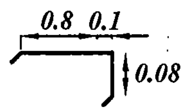
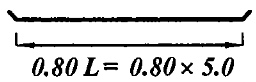
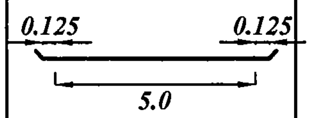
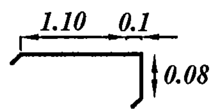
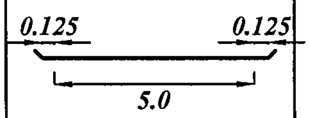
Beam	Bott. RFT.	Top RFT.	Stirrups
B1	4ϕ16	3ϕ12	5ϕ8 /m

Solution:

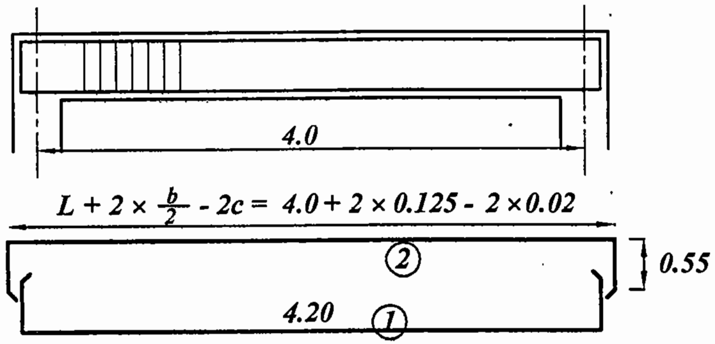
1 - Weight of RFT

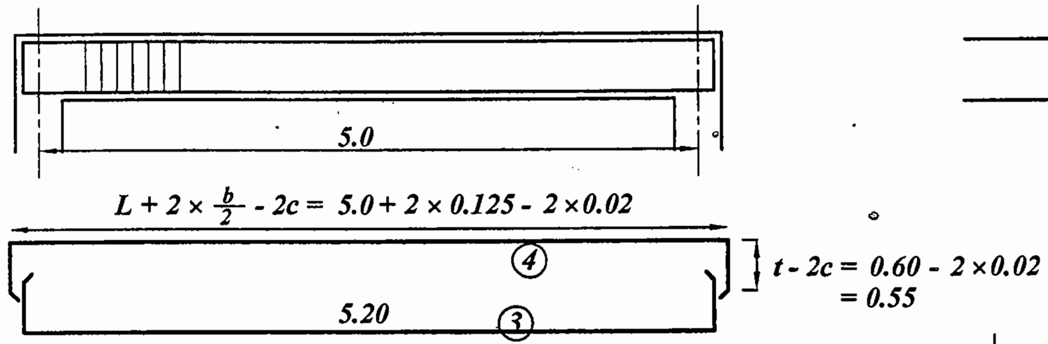
يتم رسم تفاصيل التسليح فى ال ***Plan*** موضح عليها أطوال وترقيم الاسياخ لضمان عدم حدوث آى خطأ

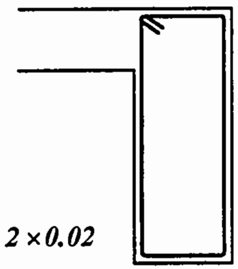


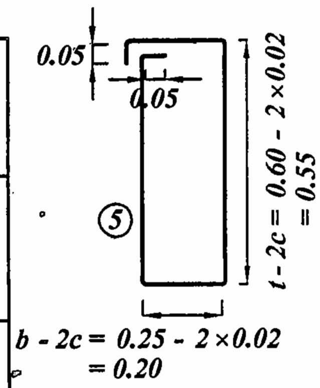
Element	Bar No. (code)	Shape	Length	No. of bars	Total length	ϕ	Weight of 1 m	Total weight
Slab	1		3.0	$3.5 \times 5 = 17.5$ تقريب للأكبر 18.0	54	10	0.617	33.32
	2		4.25	$3.5 \times 5 = 17.5$ تقريب للأكبر 18.0	76.5	10	0.617	47.2
	3		3.705	$6 \times 5 = 30$	111.15	10	0.617	68.58
	4		0.98	$5 \times 5 = 25$	24.5	10	0.617	15.12
	5		4.0	$3 \times 4 = 12$	48.0	10	0.617	29.62
	6		5.25	$3 \times 4 = 12$	63.0	10	0.617	38.87
	7		1.18	$5 \times 4 \times 2 = 40$ (2 Sides)	47.2	10	0.617	29.12
	8		5.25	$5 \times 1 \times 2 = 10$ (T & B)	52.5	8	0.395	20.74

Σ weight = 282.57 kg







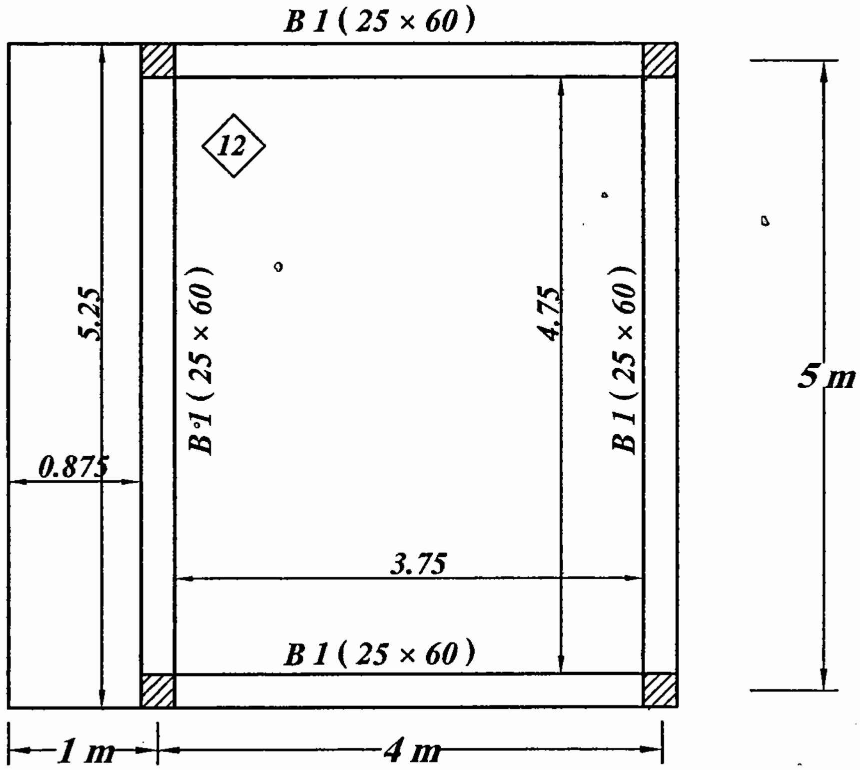


Element	Bar No. (code)	Shape	Length	No. of bars	Total length	ϕ	Weight of 1 m	Total weight
Beams	1	0.55 0.55 4.20	5.30	$4 \times 2 = 8$	42.40	16	1.58	66.99
	2	4.20 0.55 0.55	5.30	$3 \times 2 = 6$	31.80	12	0.888	28.24
	3	0.55 0.55 5.20	6.30	$4 \times 2 = 8$	50.40	16	1.58	79.63
	4	5.20 0.55 0.55	6.30	$3 \times 2 = 6$	37.80	12	0.888	33.57
	5	0.05 0.05 0.55 0.20	1.60	$5 \times 2 \times (5+4) = 90$	144	8	0.395	56.88

Σ weight = 265.31 kg

Weight of steel = 282.57 + 265.31 = 547.88 kg

2- Volume of concrete (m^3)



Volume of slabs $= 5.25 \times 0.875 \times 0.12 + 4.75 \times 3.75 \times 0.12$
$= 2.69\ m^3$

Volume of beams $= 0.25 \times 0.60 \times 5.25 \times 2 + 0.25 \times 0.60 \times 3.75 \times 2$
$= 2.70\ m^3$

→ Volume of concrete = Volume of slabs + Volume of beams
$= 2.69 + 2.7$

Volume of concrete = 5.39 m^3

→ $\dfrac{\text{Weight of steel}}{\text{Volume of concrete}} = \dfrac{547.88}{5.39} = 101.65\ kg/m^3$

NOTE

$\dfrac{\text{Weight of steel}}{\text{Volume of concrete}}$

- Footings → 60 - 70 kg/m^3
- Columns → 150 - 250 kg/m^3
- Solid slab + Beams → 90 - 100 kg/m^3
- Hollow block slab → 130 -140 kg/m^3
- Flat slab → 150 - 170 kg/m^3

$$\frac{Weight\ of\ steel}{Volume\ of\ concrete}$$

و يعبر هذا الرقم عن كم حديد التسليح المستخدم و مدى جودة و دقة التصميم و النظام الإنشائى

3- Area of shuttering (m^2)

$$\begin{aligned} Area\ of\ shuttering = & \sum L_{clear} \times L_{clear} && (Lower\ shuttering\ of\ slabs) \\ & + \sum L \times b && (Lower\ shuttering\ of\ beam) \\ & + \sum L \times t && (Edge\ shuttering\ of\ beam) \\ & + \sum L \times (t - t_s) && (Interior\ shuttering\ of\ beam) \\ & + \sum L \times t_s && (Edge\ shuttering\ of\ slab) \end{aligned}$$

$$\begin{aligned} Area\ of\ shuttering = & \ 5.25 \times 0.875 + 4.75 \times 3.75 \quad (Lower\ shuttering\ of\ slabs) \\ & + 0.25 \times 4.75 \times 2 + 0.25 \times 3.75 \times 2 \quad (Lower\ shuttering\ of\ beam) \\ & + 0.60 \times 5.25 + 0.60 \times 4.25 \times 2 \quad (Edge\ shuttering\ of\ beam) \\ & + (0.60 - 0.12) \times 4.75 \times 2 + (0.60 - 0.12) \times 3.75 \times 2 \\ & + (0.60 - 0.12) \times 5.25 \quad (Interior\ shuttering\ of\ beam) \\ & + 5.25 \times 0.12 + 0.875 \times 0.12 \times 2 \quad (Edge\ shuttering\ of\ slab) \\ = & \ 46.426\ m^2 \end{aligned}$$

$$\boxed{Area\ of\ shuttering = 46.426\ m^2}$$

$$\longrightarrow \frac{Area\ of\ Shuttering}{Volume\ of\ concrete} = \frac{46.426}{5.39} = 8.61\ m^2/m^3$$

$$\frac{Area\ of\ Shuttering}{Volume\ of\ concrete}$$

و يعبر هذا الرقم عن مدى صعوبة التنفيذ فكلما زادت مساحة الشدة الخشبية (م ٢) التى نحتاجها لصب (١ م٣) من الخرسانة كلما زادت صعوبة التنفيذ.

و يتراوح هذا الرقم من ٦-٩ م٢/م٣

$$\frac{Area\ of\ Shuttering}{Area\ of\ Roof} = \frac{46.426}{5.25 \times 5.125} = 1.725\ m^2/m^2$$

و يعبر هذا الرقم عن كمية الخشب التى نحتاجها لصب سقف بمساحة معينة.

و يتراوح هذا الرقم من ١,٤-١,٨ م٢/م٢

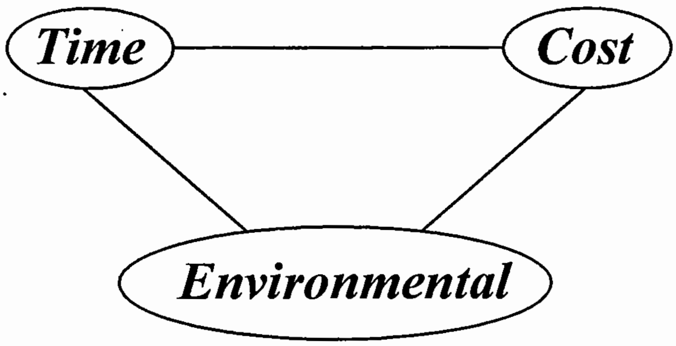
Bridge Construction

Main rule for the choice of the construction method:

The bridge should be constructed and / or erected with the most reasonable method to minimize direct and indirect costs of construction within required period of construction. The duration of construction is important factor that should be optimized.

Criteria of choice:

1- ***Economic facilities*** التوفير فى تكاليف الإنشاء
2- ***Construction schedule*** الاهتمام بالجدول الزمنى ومدة التنفيذ
3- ***Environmental aspects*** الاهتمام بمدي تأثير عملية التنفيذ على البيئة المحيطة



The choice of the most suitable method of bridge construction:

1- ***Max. span of the bridge and the total length.***
2- ***The degree of occupation under the bridge.***
3- ***The type of the bridge deck, e.g. concrete, steel, composite deck.***
4- ***The height of the bridge deck over the ground.***
5- ***The condition of the traffic and public situation in the surrounding region.***

Explain the main aspects for construction of bridge:

- ***Technically:*** ***The construction should be completed safely without any over-stressing and / or without any additional high residual stresses of the bridge elements which could affect the design of end bridge negatively.***
i.e. Construction should not govern the design of bridge different structural elements.

يتم اختيار طريقة تنفيذ مناسبة حتى لا تزيد الاجهادات الواقعة على المنشأ عن الاجهادات التصميمية.

- ***Economically:*** ***The bridge should be constructed and / or erected with the most reasonable method to minimize the direct and the indirect costs of construction within required time as the duration of construction is important factor that should be optimized.***

يجب التنفيذ بأقل تكاليف وفى أسرع وقت ممكن.

- ***Environmentally:*** ***The bridge construction shouldn't have a negative influnce on the surrounding environment of the site during construction.***

يجب ألا تكن طريقة التنفيذ لها تأثير سلبى على البيئة المحيطة.

- ***Aesthetically:*** ***For long period construction, the influnce of bridge construction on the overall view in the surrounding region should be considered.***

يجب ألا تؤثر طريقة التنفيذ على المنظر العام المحيط بالمشروع.

Designer main target and tasks:

1- Choose the most reasonable method for construction.

اختيار أفضل أنظمة الإنشاء .

2- Divide the construction method into stages.

تقسيم طريقة التنفيذ إلى مراحل .

3- Design each stage of construction stages and check stresses in both formwork and in constructed elements at every stage.

يتم تقسيم المراحل المختلفة مع التأكد من عدم زيادة الإجهادات عن المسموح بها فى كلا من المنشأ المنفذ أو المنشأ الحامل أثناء التنفيذ.

4- Design the temporary elements if needed.

تصميم العناصر المؤقتة أثناء التنفيذ عند الحاجة إليها.

5- Determine the required equipment and devices for the construction method.

تحديد الأدوات والمعدات المطلوبة أثناء التنفيذ.

6- Follow the progress of the construction.

متابعة مراحل التنفيذ المختلفة.

Different methods of construction:

1- ***Cast in-situ technique on fixed or movable shuttering supported on the ground.***

- ***Fixed shuttering over the whole length***
- ***Fixed shuttering supported on temporary columns***
- ***Movable shuttering on movable columns***

2- ***Precast technique.***

- ***Pre-cast beams and Cast in-situ slabs***
- ***Pre-cast beams and Pre-slabs***
- ***Pre-cast beams and Pre-cast slabs***
- ***Hybrid pre-cast technique***
- ***Pre-cast segmental bridge***

3- ***Deck push system for pre-cast concrete decks, steel decks and composite decks.***

4- ***Launching method using launching beams.***

- ***Launching system with launching girder under the deck***
- ***Launching system with launching girder over the deck***
- ***Launching system for construction of pre-cast girders***

5- ***Classic cantilever method.***

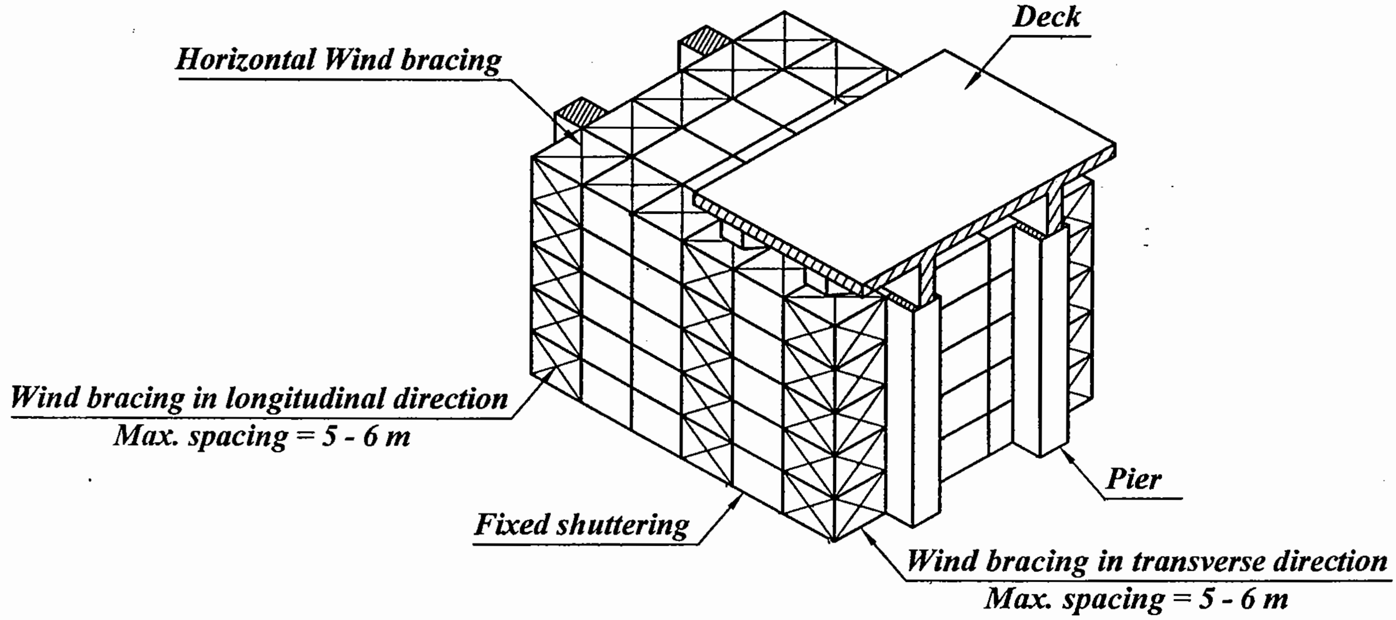
- ***Classic free cantilever method***
- ***Classic free cantilever method with additional launching beams***

1- Cast in-Situ Technique:

A- Fixed shuttering over the whole length

هى عبارة عن شدة خشبية أو معدنية توضع أسفل الكوبرى حتى نتمكن من تنفيذ ال **Deck** . وفى هذا النوع من الشدات تكون جميع أحمال الكوبرى منقولة إلى الشدة فقط أى أنه فى حالة تنفيذ أى عمود من أعمدة الكوبرى لا تنتقل اليه أى أحمال من ال **Deck** إلا بعد إزالة الشدة.

This system is suitable for small spans up to 30 .0 m

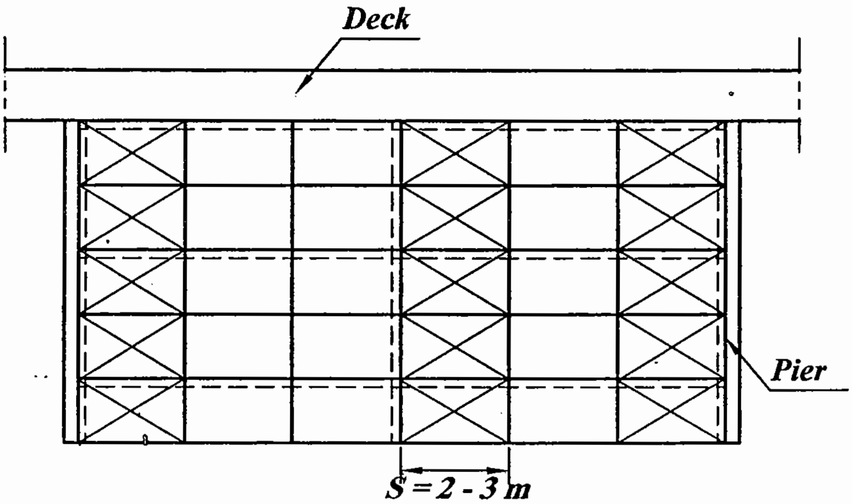


Vertical loads:

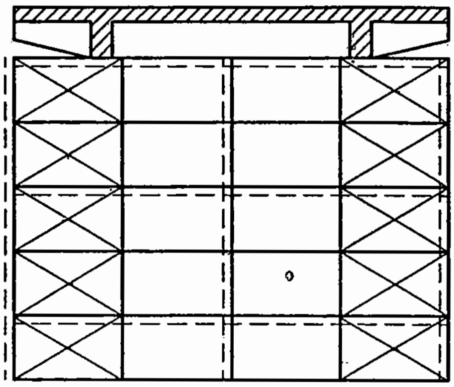
Vertical loads due to D.L., L.L., etc. will be carried by the verticals then load transfer to the ground through the P.C. foundation.

Horizontal loads:

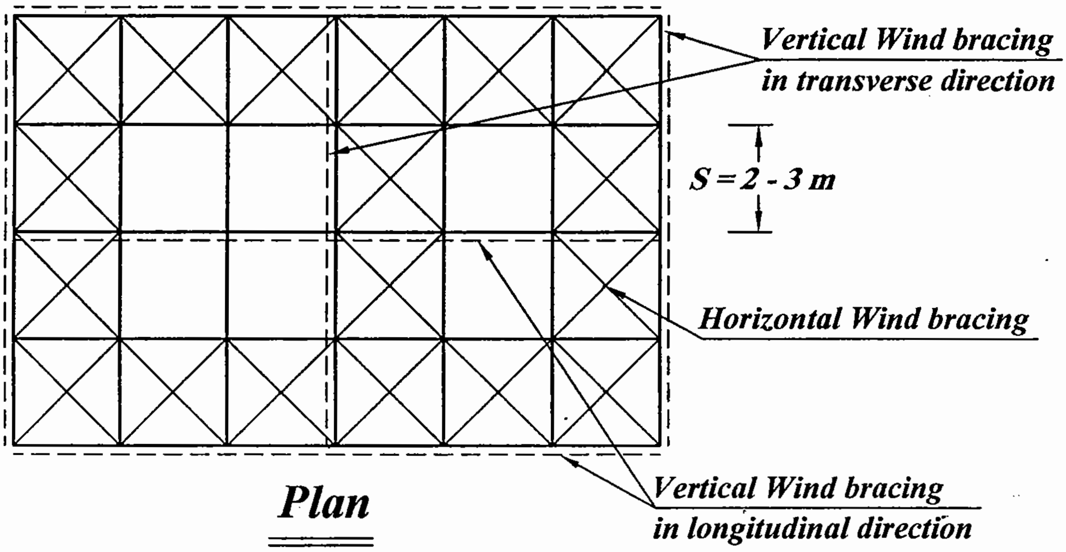
Hz. loads due to wind mainly will be carried by the diagonal members then loads transfer to verticals then to the ground.



Elevation (Longitudinal bracing)



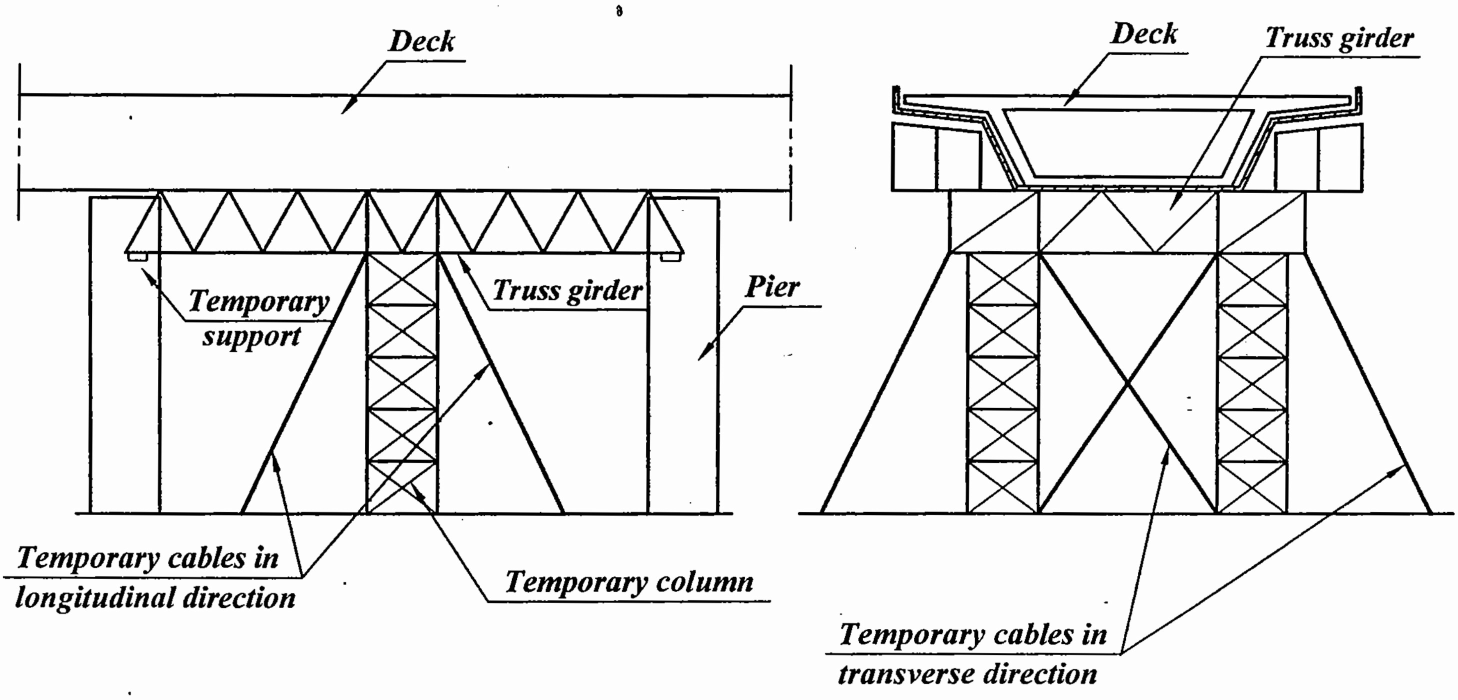
(Transverse bracing)



Plan

B- Fixed shuttering supported on temporary columns

هى عبارة عن شدة غالبا تكون معدنية ***Space truss*** وتكون مرتكزة على أعمدة الكوبرى فقط وفى حالة أن المسافة بين الاعمدة تكون كبيرة يمكن استخدام ***Temporary column*** عبارة عن ***Space truss*** . فى هذا النوع من الشدات لا تيم تنفيذ ***Deck*** إلا بعد إكتساب أعمدة الكوبرى مقاومتها القصوى حتى تستطيع حمل الشدة وتنفيذ ***Deck***



Vertical loads:

Vertical loads due to D.L., L.L., etc. will be carried by the piers and the temporary columns then transfered to the ground.

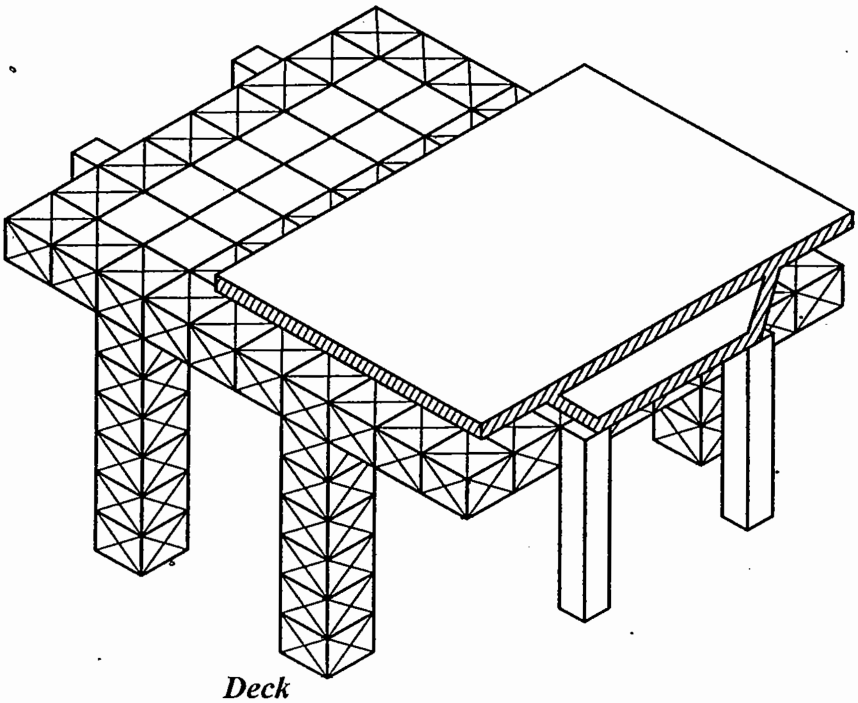
Horizontal loads:

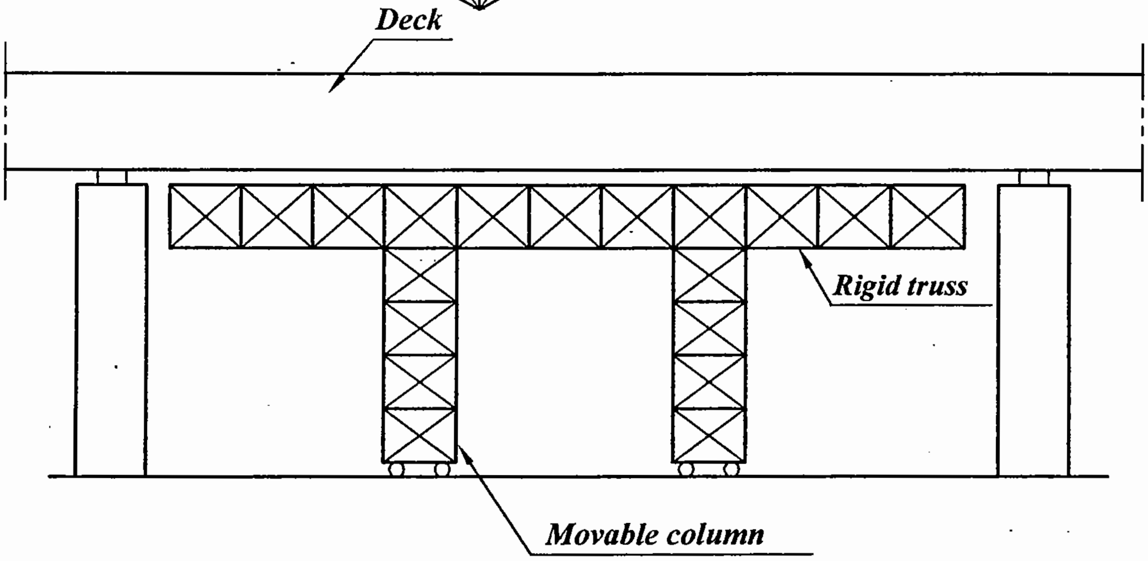
Hz. loads due to wind mainly will be carried by the temporary col. but in most cases the temporary columns can be stabilised by temporary cables to carry the hz. loads in the longitudinal direction and sometimes we can use temporary cables in transverse direction

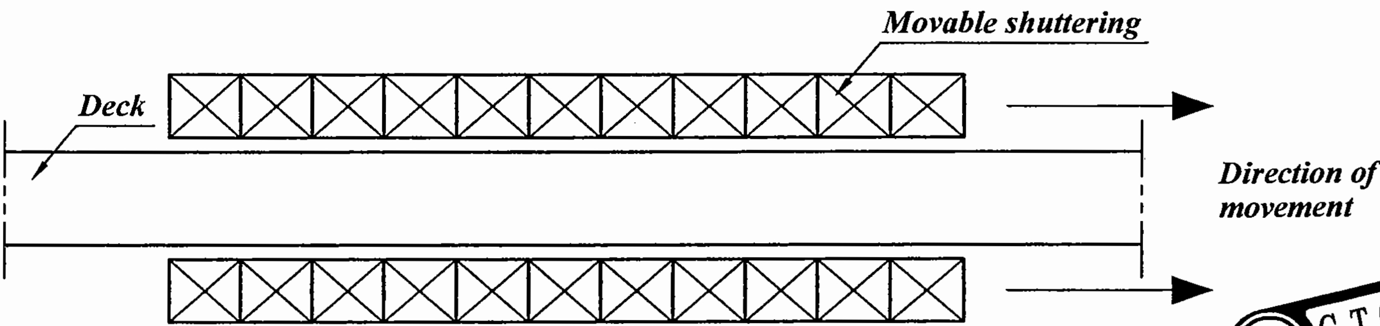
C- Movable shuttering on movable columns

هى عبارة عن شدة معدنية تكون مرتكزة على أعمدة الكوبرى مثل النوع السابق ولكن يكون الـ ***Temporary column*** متحرك مما يسرع عملية إنشاء الكوبرى.

- ***This system is suitable for large spans greater than 30 .0 m***
- ***Short time construction high construction rate***







Example (2):

Indicate if the following statements is right (✓) or is wrong (X)

1- Assuming the fulfillment of the technical safety during construction of a bridge, the aesthetical aspect is the most important aspect for the choice of the construction technique. (X)

Correct

Assuming the fulfillment of the technical safety during construction of a bridge, the economical aspect is the most important aspect for the choice of the construction technique.

2- Over-stressing and residual stresses of the different structural elements of the end bridge should be avoided during the construction of the bridge. (✓)

3- For bridge construction in Egypt, the deck push system is the most frequent used technique. (X)

Correct

For bridge construction in Egypt, the fixed shuttering system is the most frequent used technique.

4- Wooden shuttering is the much more durable than metal shuttering. (X)

Correct

Metal shuttering is the much more durable than wooden shuttering.

5- For the construction of a cable stayed bridge the launching method is the most suitable method. (X)

Correct

For the construction of a cable stayed bridge the cantilever method is the most suitable method.

6- For the application of the deck push system, the connection between deck and piers must be hinged. (✓)

7- The pre-slab technique can be adapted with a max. spacing between longitudinal beams of 6 m. (X)

Correct

The pre-slab technique can be adapted with a max. spacing between longitudinal beams of 3 m.

8- Launching method with truss girder over the deck level can be combined with the pre-cast technique to construct segmental concrete bridges with spans up to 60 m over very high valley. (✓)

9- If the area under the bridge location is not available to arrange shuttering during the construction of bridges with spans ranges between 30 and 60 m, the cantilever method is the most suitable technique to be adapted. (X)

Correct

If the area under the bridge location is not available to arrange shuttering during the construction of bridges with spans ranges between 30 and 60 m, the launching under the deck method is the most suitable technique to be adapted.

10- For construction of a composite deck of a bridge with a height of 30 m over the water level and spans up to 50 m, the push deck system is an alternative, which could be adapted. (X)

Correct

For construction of a composite deck of a bridge with a height of 30 m over the water level and spans up to 50 m, the launching over the deck system is an alternative, which could be adapted.

11- Pre-cast technique is the most suitable method for construction of bridges with steel decks and spans up to 30 m. (X)

Correct

<u>Deck Push System</u> is the most suitable method for construction of bridges with steel decks and spans up to 30 m.

12- The construction rate of high concrete towers using climbing (jumping) forms is faster than the use of the slip forms. (X)

Correct

The construction rate of high concrete towers using <u>slip forms</u> is faster than the use of <u>the climbing forms.</u>

13- During the deck pushing, the produced friction forces between the deck and piers are close to be zero. (X)

Correct

During the deck pushing, the produced friction forces between the deck and piers <u>must be considered in design.</u>

14- The use of additional beams (aids beams) with the launching system reduces the internal forces in the deck during the construction. (✓)

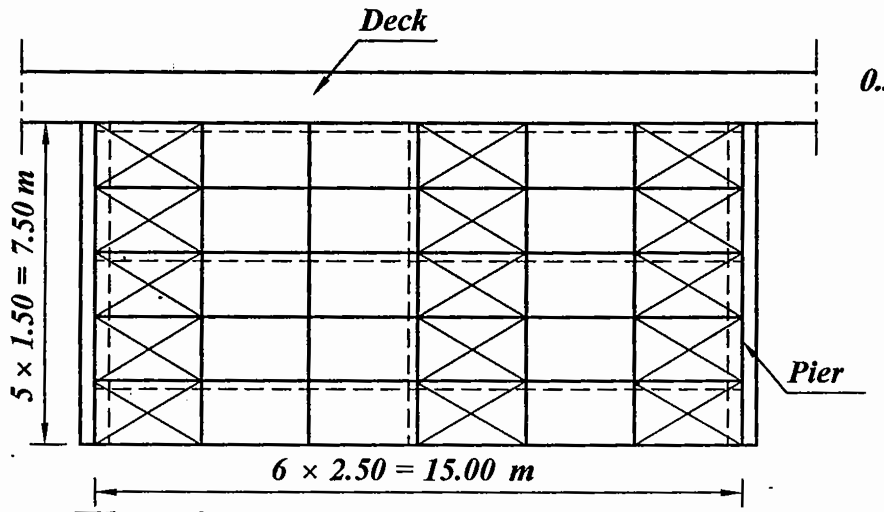
15- During the construction of a bridge using the classic cantilever method, the influnce of the wind load can be neglected. (X)

Correct

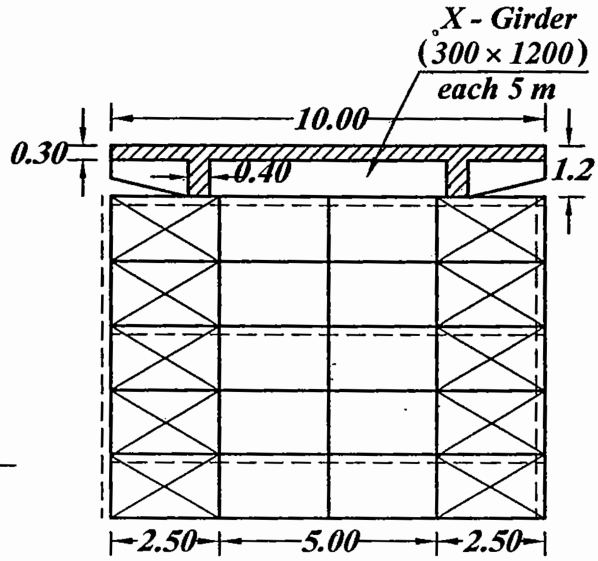
During the deck pushing, the produced friction forces between the deck the influnce of the wind load <u>can not be</u> neglected.

Example (3):

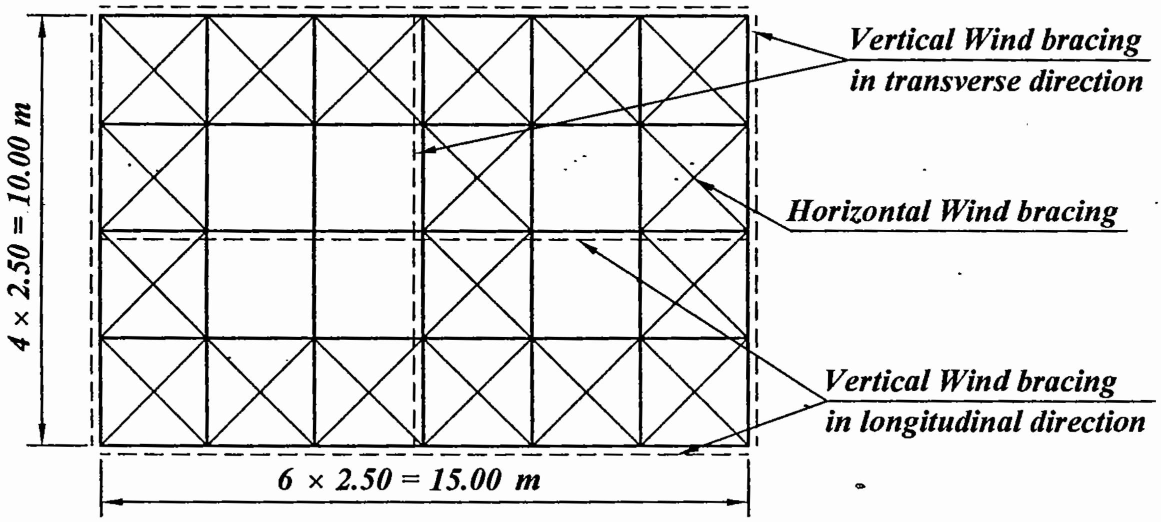
For the following bridge system, a fixed wooden shuttering on the whole length of the bridge was chosen for the construction of each bridge span. For all the shuttering elements, Calculate the design forces using the simplified method, Design the different structural elements of the shuttering system.



Elevation (Longitudinal bracing)



(Transverse bracing)



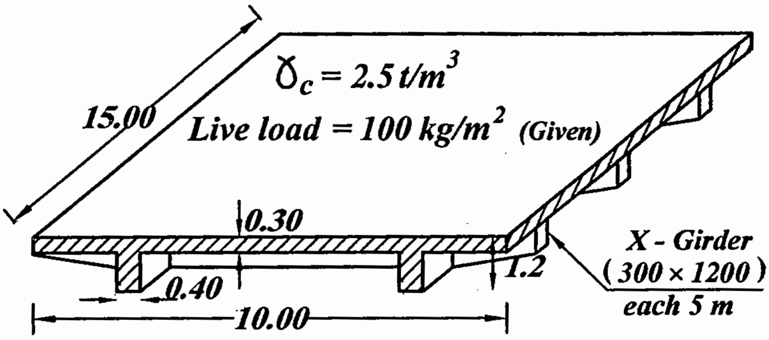
Plan

Given:

- ***For Wood***
  - ***Allowable strength in bending and tension*** $(F_b) = 72\ kg/cm^2$
  - ***Allowable strength in compression*** $(F_b) = 56\ kg/cm^2$
  - ***Allowable shear strength*** $(F_s) = 14\ kg/cm^2$
  - ***Available dimension of wood elements*** 8×8 , 10×10 , 12×12 ***cm***
- ***Live load*** $= 100\ kg/m^2$
- ***Wind load***
  - ***Pressure intensity of wind*** $(q) = 70\ kg/m^2$
  - ***Drag factor for deck*** $(c) = 1.50$
  - ***Drag factor for shuttering*** $(c) = 2.00$

Solution:

Vertical member:



$$P_{Total} = P_{D.L.} + P_{L.L.} + P_{Wind}$$

$$\text{No. of X-girder} = \frac{\text{Span}}{\text{Spacing}} = \frac{15}{5} = 3$$

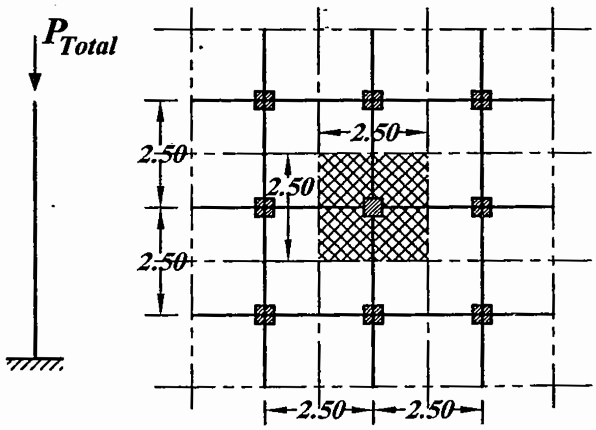
$$\text{Weight of X-girder} = \text{No. of X-girders} \times L \times b \times (t - t_s) \times \gamma_c$$

$$\text{Weight of X-girder} = 3 \times 10 \times 0.3 \times (1.2 - 0.3) \times 2.5 = 20.25\ t$$

$$\text{Own weight} = \frac{\text{wt. of slab + wt. of main beams + wt. of X-girders}}{\text{Area}}$$

$$= \frac{15 \times 10 \times 0.3 \times 2.5 + 2 \times 15 \times 0.4 \times (1.2 - 0.3) \times 2.5 + 20.25}{15 \times 10}$$

$$= 1.065\ t/m^2$$



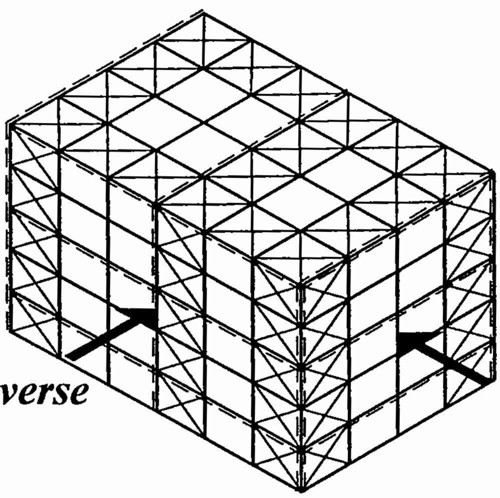
→ $P_{D.L.} = 1.065 \times 2.5 \times 2.5 = 6.66\ t$

$P_{L.L.} = 0.1 \times 2.5 \times 2.5 = 0.625\ t$

To get P_{Wind} we have to calculate the forces on the horizontal & vertical bracing

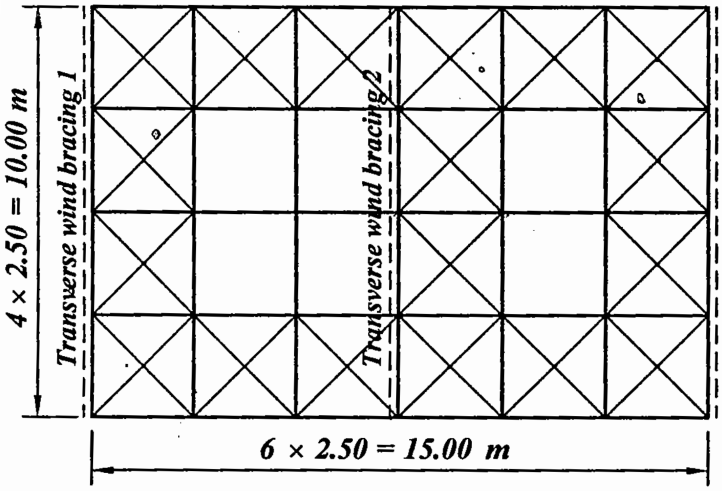
NOTE

يتم حساب القوى الناتجة عن الرياح فى **Vertical member** مرة نتيجة تأثير الرياح فى الاتجاه العرضى **Transverse direction** ومرة أخرى نتيجة تأثير الرياح فى الاتجاه الطولى **Longitudinal direction**

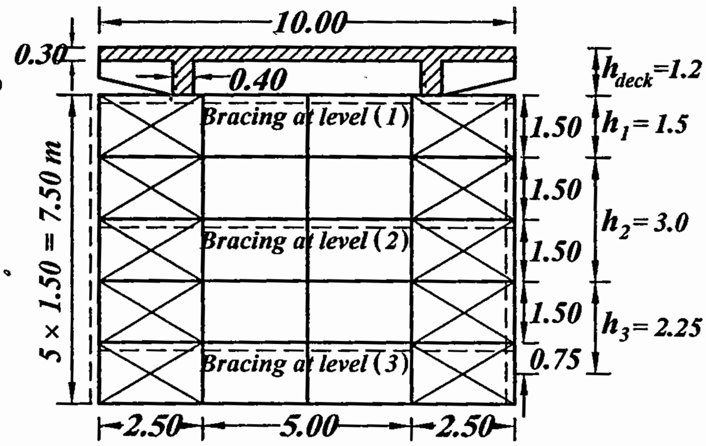


Horizontal bracing:

a- Wind in transverse direction

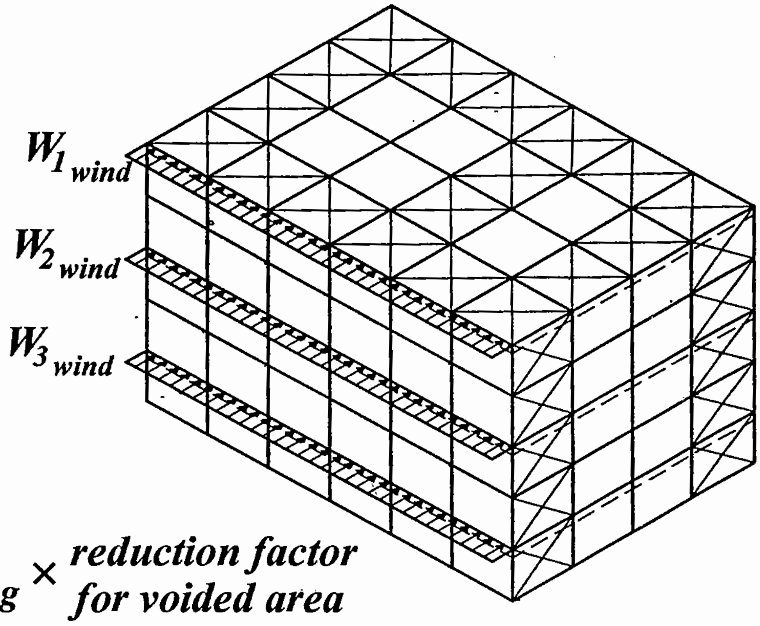


Plan



(Transverse bracing)

$$W_{wind} = C \times q \times h$$



يتم حساب القوى الناتجة عن الرياح
عند كل منسوب للـ **bracing**

For level (1)

$$W_{1\,wind} = C_{deck} \times q \times h_{deck} + C_{shuttering} \times q \times h_{shuttering} \times \text{reduction factor for voided area}$$

$$= 1.5 \times 0.07 \times 1.2 + 2.0 \times 0.07 \times 1.5 \times 0.3 = 0.189\ t/m'$$

NOTE

Assume reduction factor for voided area = 0.3 - 0.5 if not given

For level (2)

$$W_{2\,wind} = C_{shuttering} \times q \times h_{shuttering} \times \text{reduction factor for voided area}$$

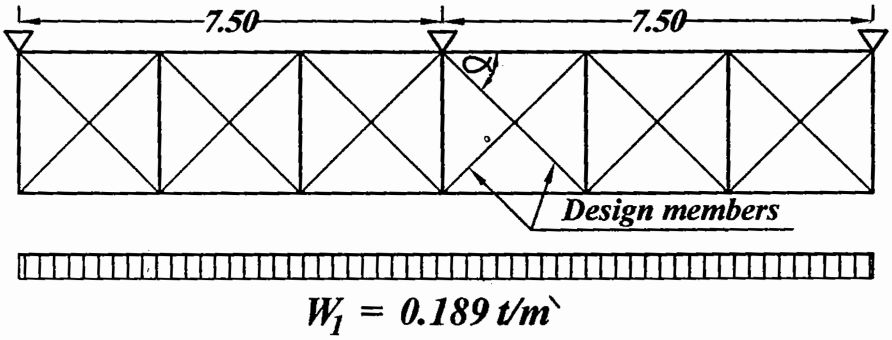
$$= 2.0 \times 0.07 \times 3.0 \times 0.3 = 0.126\ t/m'$$

For level (3)

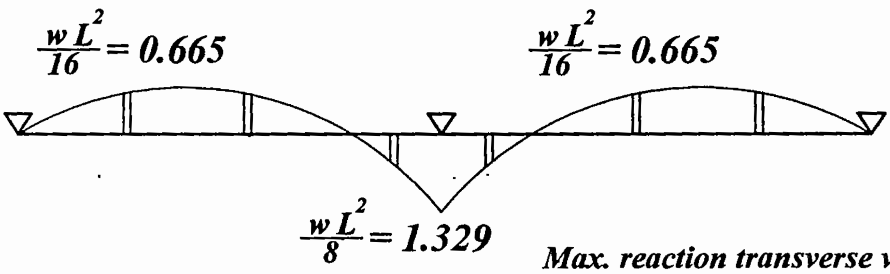
$$W_{3\,wind} = C_{shuttering} \times q \times h_{shuttering} \times \text{ reduction factor for voided area}$$

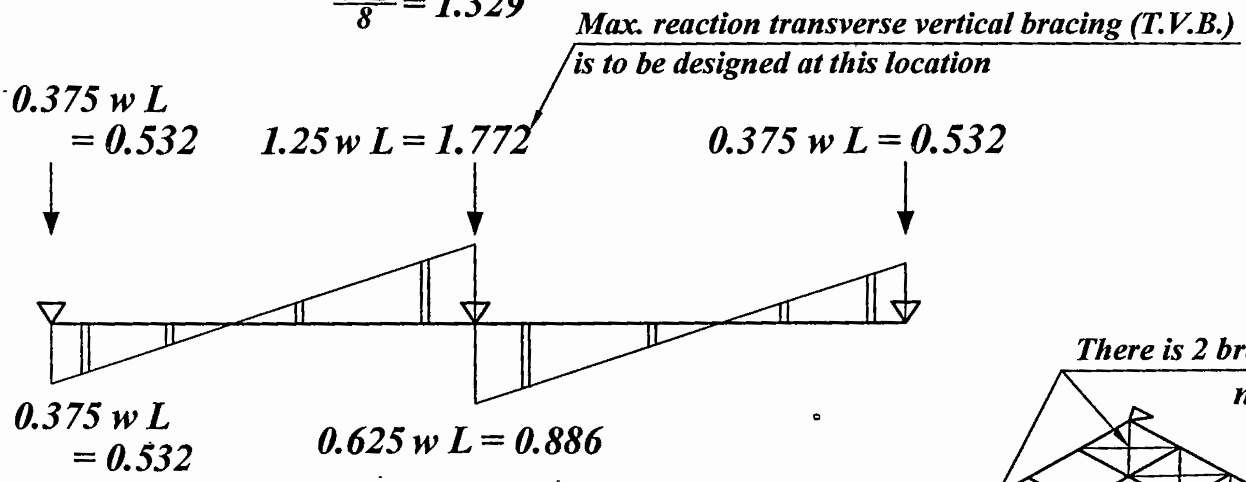
$$= 2.0 \times 0.07 \times 2.25 \times 0.3 = 0.0945 \ t/m'$$

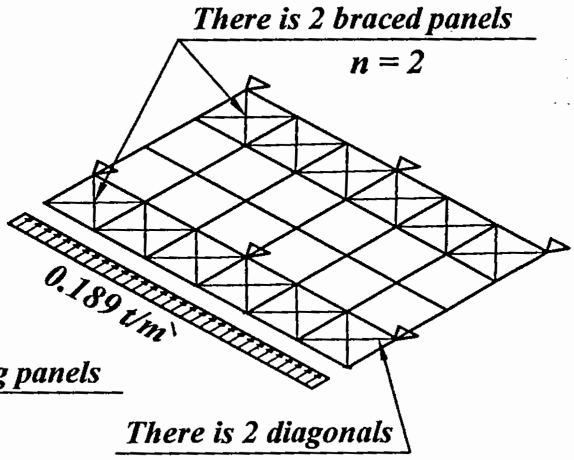
→ *Solve for bigger value of W_{Wind} which is on level 1*



Note:
α is the angle between the member and the loaded side direction (Hz. direction)







Max. force in diagonals

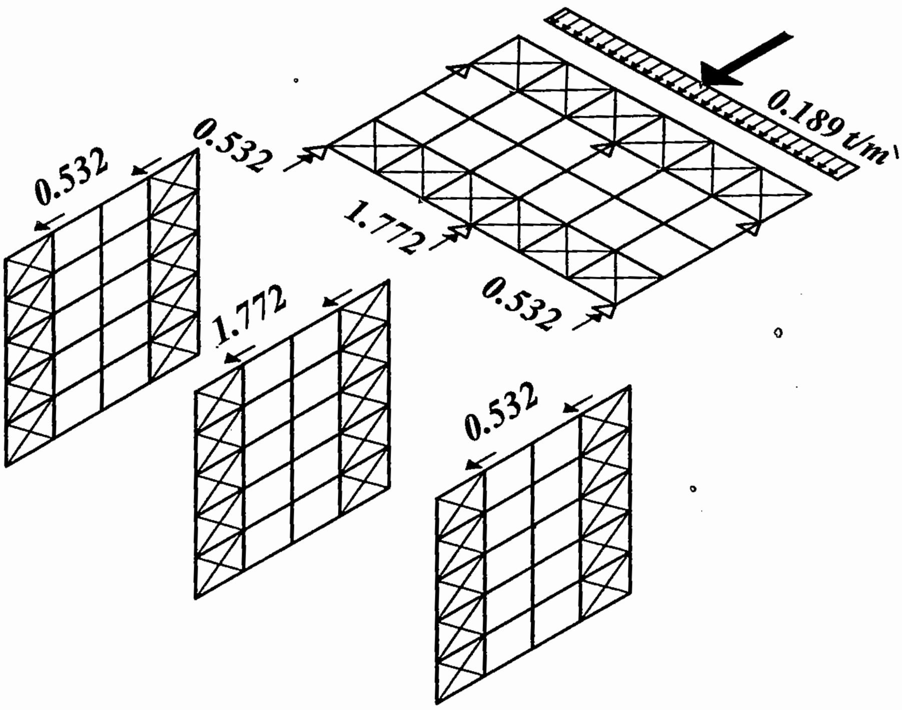
$$(F_{Diagonal\ max.}) = \frac{Q_{max.}}{2\ n\ \sin\alpha}$$

2 → No. of diagonals; n → No. of bracing panels

$$(F_{Diagonal\ max.}) = \frac{0.886}{2 \times 2 \times \sin 45} = 0.313\ t$$

$$A = \frac{F_{Diagonal\ max.}}{F_{all.}} = \frac{0.313 \times 1000}{56} = 5.593\ cm^2$$

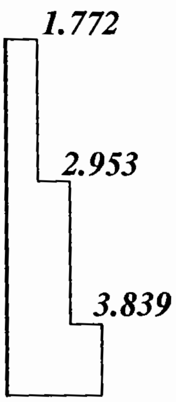
→ *Use 8 × 8 cm* $(A_{8\times8} = 64\ cm^2)$



NOTE

The design of the vertical bracing in transverse direction is to be carried out at the bracing resisting the max. reaction from the horizontal bracing i.e. transverse bracing no. 2

For transverse wind bracing (2)



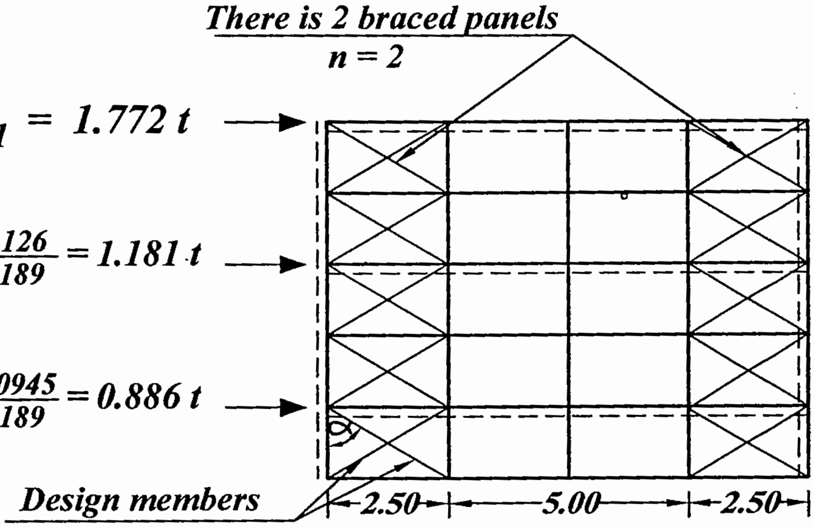
S.F.D.

$$\boxed{\frac{R_1}{w_1} = \frac{R_2}{w_2}}$$

$$R_1 = 1.772\ t$$

$$R_2 = R_1 \times \frac{w_2}{w_1} = 1.772 \times \frac{0.126}{0.189} = 1.181\ t$$

$$R_3 = R_1 \times \frac{w_3}{w_1} = 1.772 \times \frac{0.0945}{0.189} = 0.886\ t$$



$$\alpha = tan\ \frac{2.5}{1.5} = 59.04°$$

Note:

α is the angle between the member and the loaded side direction (Vl. direction)

Max. force in diagonals

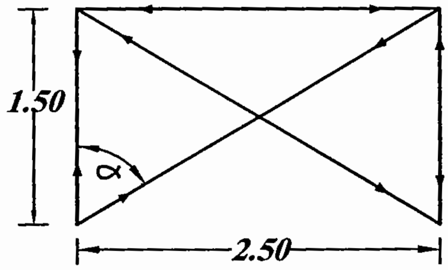
$$(F_{Diagonal\ max.}) = \frac{Q_{max.}}{2\ n\ \sin\alpha} = \frac{3.839}{2 \times 2 \times \sin 59.04} = 1.119\ t$$

No. of diagonals (2) — No. of bracing panels (n)

$$A = \frac{F_{Diagonal\ max.}}{F_{all.}} = \frac{1.119 \times 1000}{56} = 19.986\ cm^2$$

→ Use 8×8 cm $(A_{8 \times 8} = 64\ cm^2)$

Vertical member

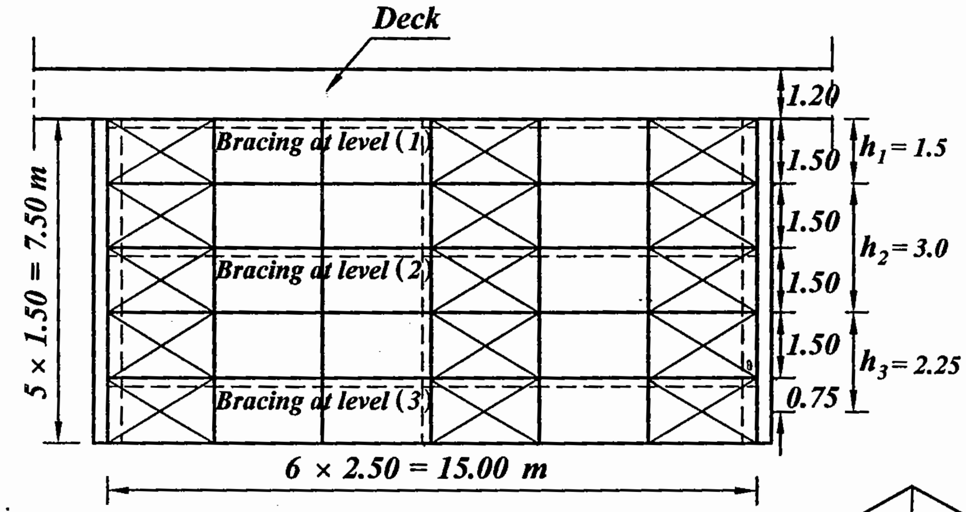


$$\alpha = \tan\frac{2.5}{1.5} = 59.04°$$

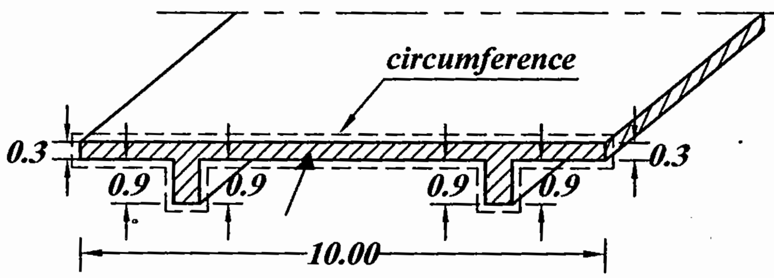
$$P_{wind\ Transverse} = F_{Diagonal\ max.} \times \cos\alpha$$

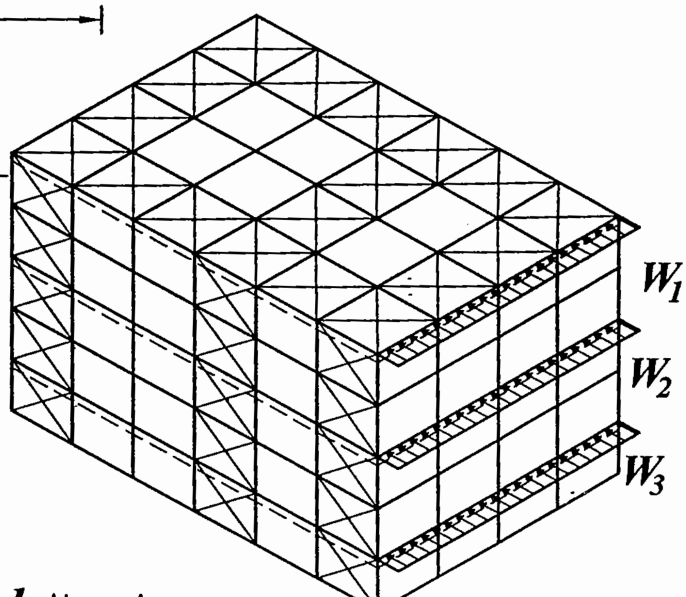
$$= 1.119 \times \cos 59.04 = 0.576\ t$$

b- Wind in longitudinal direction



$$W_{wind} = C \times q \times h$$





For level (1)

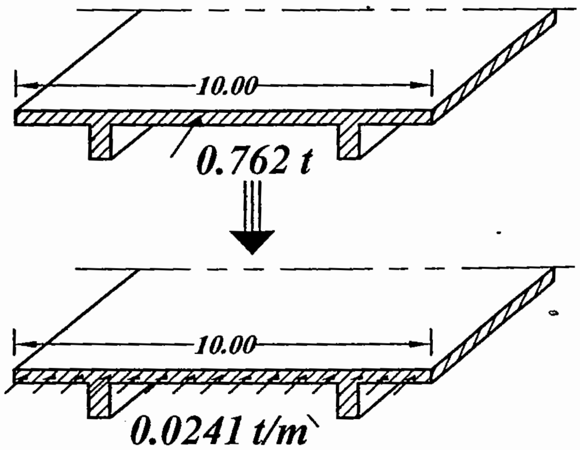
عند حساب ال *wind* فى الاتجاه الطولى للكوبرى

$$W_{\substack{wind\\deck}} = q \times A_{circumference} \times \text{Friction factor}$$

$$A_{circumference} = (10 \times 2 + 2 \times 0.3 + 4 \times 0.9) \times 15 = 363\ m^2$$

$$W_{\substack{wind\\deck}} = 0.07 \times 363 \times 0.03 = 0.762\ t$$

$$W_{\substack{wind\\deck}} = \frac{0.762}{3 \times 10} = 0.0241\ t/m`$$



the shuttering supports one third of the wind load on the deck in longitudinal direction

تتحمل الشدة الخشبية *1/3* الأحمال الناتجة عن الرياح فى الاتجاه الطولى للكوبرى بينما تتوزع *2/3* الأحمال على الأجزاء المصبوبة سابقا

NOTE

Assume Friction factor = 0.025 - 0.03 if not given

$$W_{\substack{wind \\ shuttering}} = C_{shuttering} \times q \times h_{shuttering} \times \text{reduction factor for voided area}$$

$$= 2.0 \times 0.07 \times 1.5 \times 0.3 = 0.063 \; t/m'$$

$$W_{1\,wind} = W_{\substack{wind \\ deck}} + W_{\substack{wind \\ shuttering}} = 0.025 + 0.063 = 0.0885 \; t/m'$$

For level (2)

$$W_{2\,wind} = C_{shuttering} \times q \times h_{shuttering} \times \text{reduction factor for voided area}$$

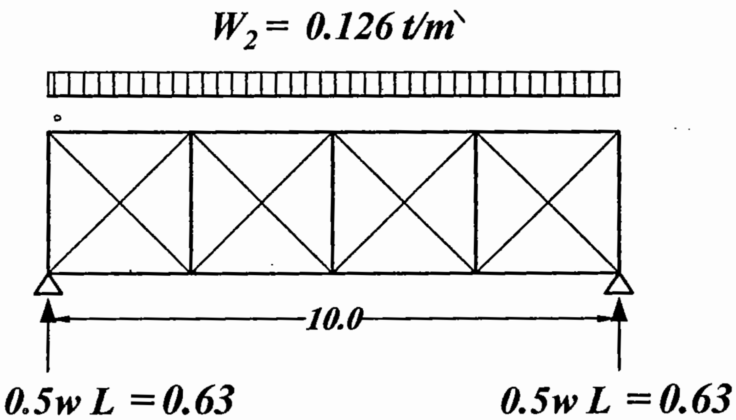
$$= 2.0 \times 0.07 \times 3.0 \times 0.3 = 0.126 \; t/m'$$

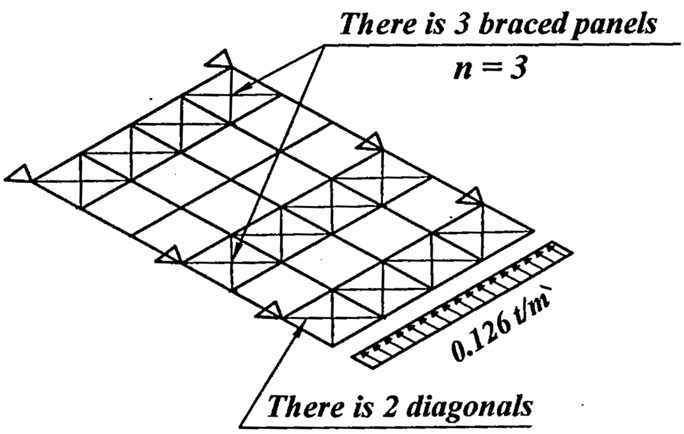
For level (3)

$$W_{3\,wind} = C_{shuttering} \times q \times h_{shuttering} \times \text{reduction factor for voided area}$$

$$= 2.0 \times 0.07 \times 2.25 \times 0.3 = 0.0945 \; t/m'$$

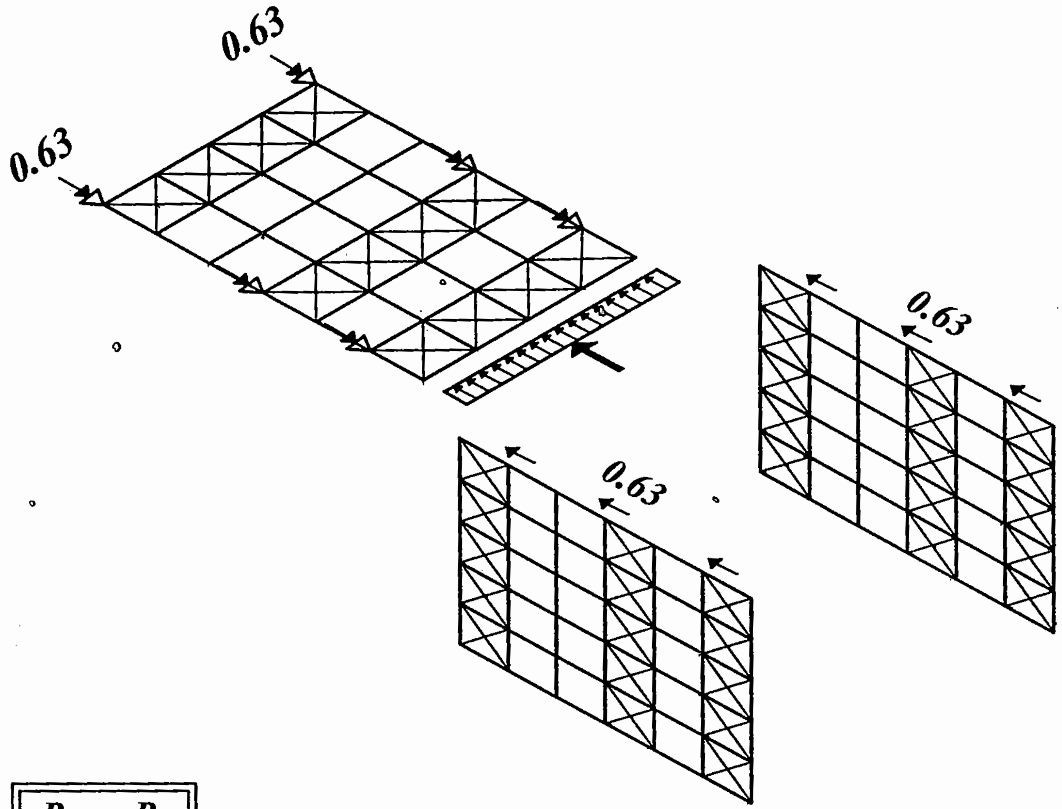
→ ***Solve for bigger value of*** W_{Wind} ***which is on level 2***





NOTE

لن يتم تصميم الـ ***Hz. diagonal*** وذلك لأن الـ ***shear*** الناتج عن أحمال الرياح
فى ***Longitudinal direction*** أقل من الـ ***shear*** الناتج عن أحمال الرياح
فى ***Transverse direction***



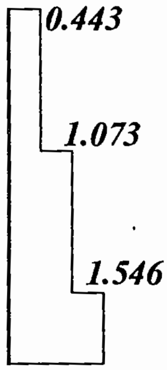
$$\boxed{\frac{R_1}{w_1} = \frac{R_2}{w_2}}$$

There is 3 braced panels
n = 3

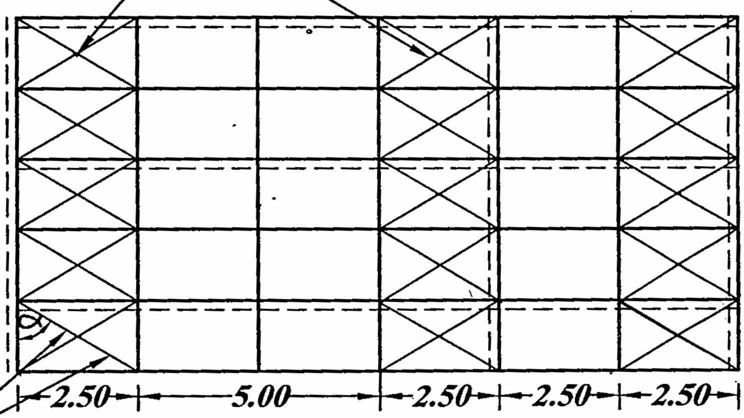
$$R_1 = R_2 \times \frac{w_1}{w_2} = 0.63 \times \frac{0.0885}{0.126} = 0.443\ t$$

$$R_2 = 0.63\ t$$

$$R_3 = R_2 \times \frac{w_3}{w_2} = 0.63 \times \frac{0.0945}{0.126} = 0.473\ t$$



S.F.D.



Design members

$$\alpha = \tan \frac{2.5}{1.5} = 59.04°$$

Max. force in diagonals

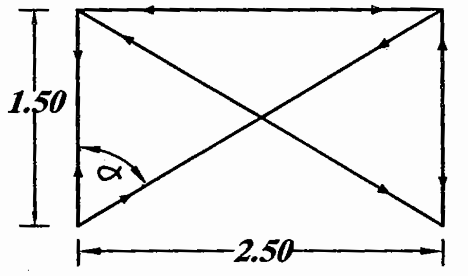
$$(F_{Diagonal\ max.}) = \frac{Q_{max.}}{2\ n\ \sin\alpha} = \frac{1.546}{2 \times 3 \times \sin 59.04} = 0.3\ t$$

No. of diagonals (2) — *No. of bracing panels* (n)

$$A = \frac{F_{Diagonal\ max.}}{F_{all.}} = \frac{0.3 \times 1000}{56} = 5.366\ cm^2$$

→ *Use* 8×8 *cm* $(A_{8 \times 8} = 64\ cm^2)$

Vertical member



$$P_{\substack{wind \\ Longitudinal}} = F_{Diagonal\ max.} \times \cos\alpha$$

$$= 0.3 \times \cos 59.04 = 0.154\ t$$

$$\alpha = \tan \frac{2.50}{1.5} = 59.04°$$

Design of vertical elements

→ Take P_{Wind} the max. of $P_{Wind\ transverse}$ & $P_{Wind\ longitudinal}$

$$P_{Total} = P_{D.L.} + P_{L.L.} + P_{\substack{Wind \\ Transverse}}$$

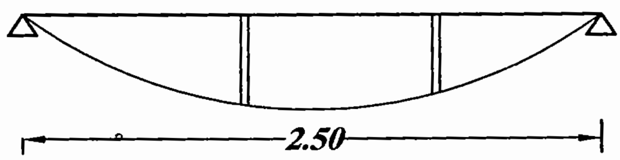
$$= 6.66 + 0.625 + 0.576 = 7.861\ t$$

$$A = \frac{P_{Total}}{F_{all.}} = \frac{7.861 \times 1000}{56} = 140.375\ cm^2$$

→ Use $12 \times 12\ cm$ $(A_{12\times12} = 144\ cm^2)$

Design of horizontal members

1- Dead load



→ Assume $10 \times 10\ cm$ $\qquad \gamma_{wood} = 500\ kg/m^2$

$$Own\ weight = b \times t \times \gamma_{wood}$$

$$= 0.10 \times 0.10 \times 0.5 = 0.005\ t/m'$$

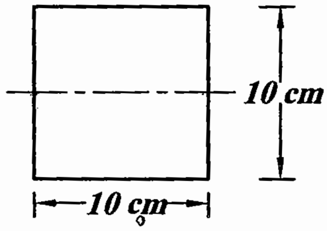
$$M_1 = 0.005 \times \frac{2.5^2}{8} = 0.0039\ m.t$$

2- Settlement of support

→ take $\delta = 0.5\ cm$

$E = 90\times10^3\ kg/cm^2$ & $L = 500\ cm$

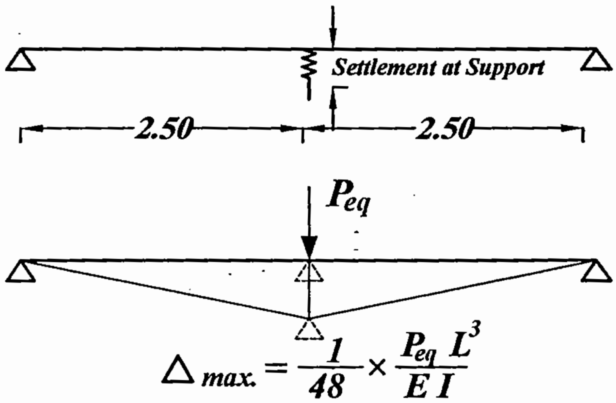
$$I = \frac{b\,t^3}{12} = \frac{10.0\times10.0^3}{12} = 833\ cm^4$$



$$\Delta_{max.} = \frac{1}{48}\times\frac{P_{eq}\,L^3}{E\,I}$$

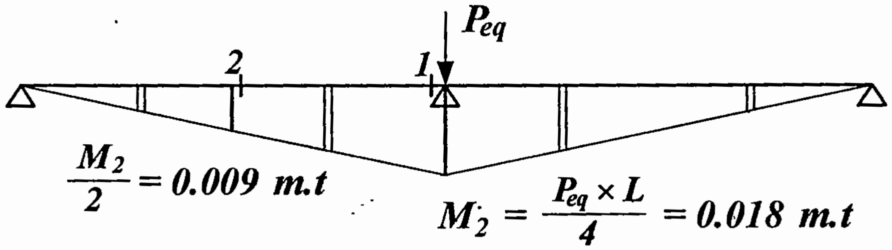
$$0.5 = \frac{1}{48}\times\frac{P_{eq}\times500^3}{90\times10^3\times833} \longrightarrow P_{eq} = 14.3942\ kg$$

$$M_2 = \frac{P_{eq}\times5}{4} = 0.018\ m.t$$

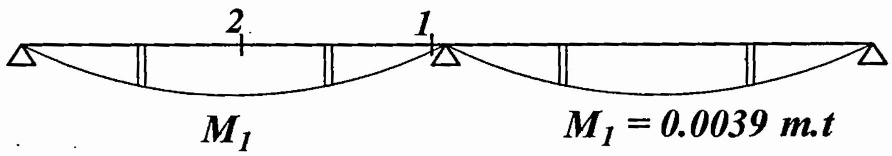


NOTE

Assume allowable settlement = 0.5 cm if not given



Moment due to settlement



Moment due to dead load

$$Sec.(1):\ M_1 + M_2 = 0 + 0.018 = 0.018\ m.t$$

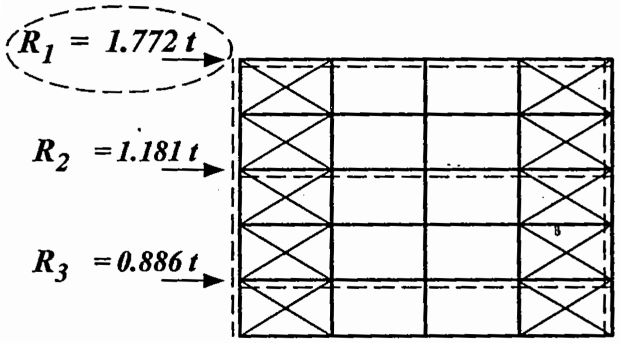
$$Sec.(2):\ M_1 + \frac{M_2}{2} = 0.0039 + \frac{0.018}{2} = 0.0129\ m.t$$

→ take bigger

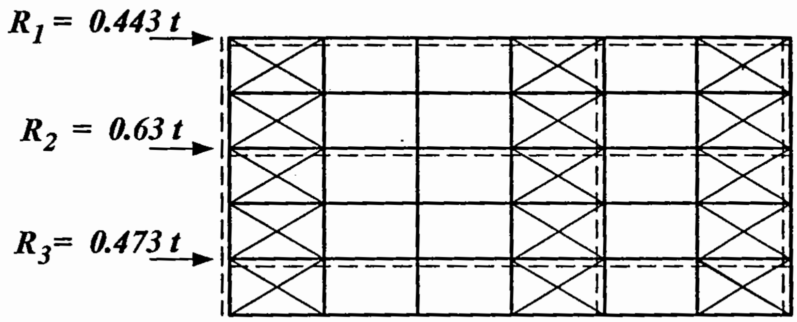
Design moment $= 0.018\ m.t$

Normal force due to wind

$N = 1.772\ t$ (max. reaction from both longitudinal and transverse direction)



Normal force due to wind in transverse direction



Normal force due to wind in longitudinal direction

Check stresses of M & N

$$f_c = -\frac{N}{A} \pm \frac{M \times y}{I}$$

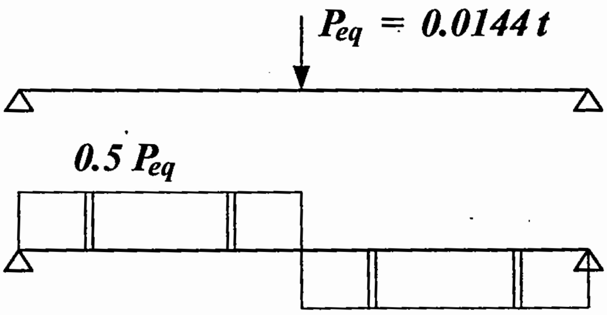
$$f_c = -\frac{1.778 \times 10^3}{10^2} - \frac{0.018 \times 10^5 \times 5}{833} = -28.24\ kg/cm^2$$

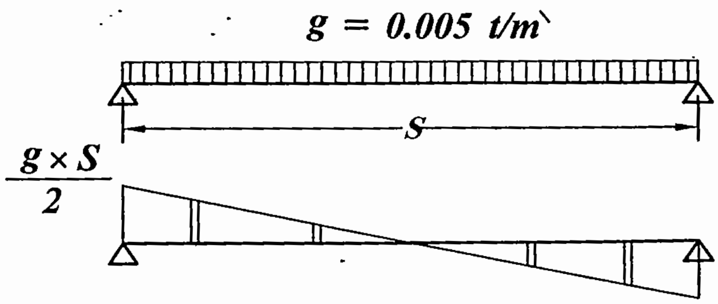
< 56 Safe

$$f_c = -\frac{1.778 \times 10^3}{10^2} + \frac{0.018 \times 10^5 \times 5}{833} = -6.916\ kg/cm^2$$

< 56 Safe

Check shear





$$Q = \frac{P_{eq}}{2} + \frac{g \times S}{2} = \frac{0.0144}{2} + \frac{0.005 \times 2.5}{2} = 0.0134\ t$$

$$q = \frac{0.0134 \times 10^3}{10 \times 10} = 0.13\ kg/cm^2$$

< 14 Safe