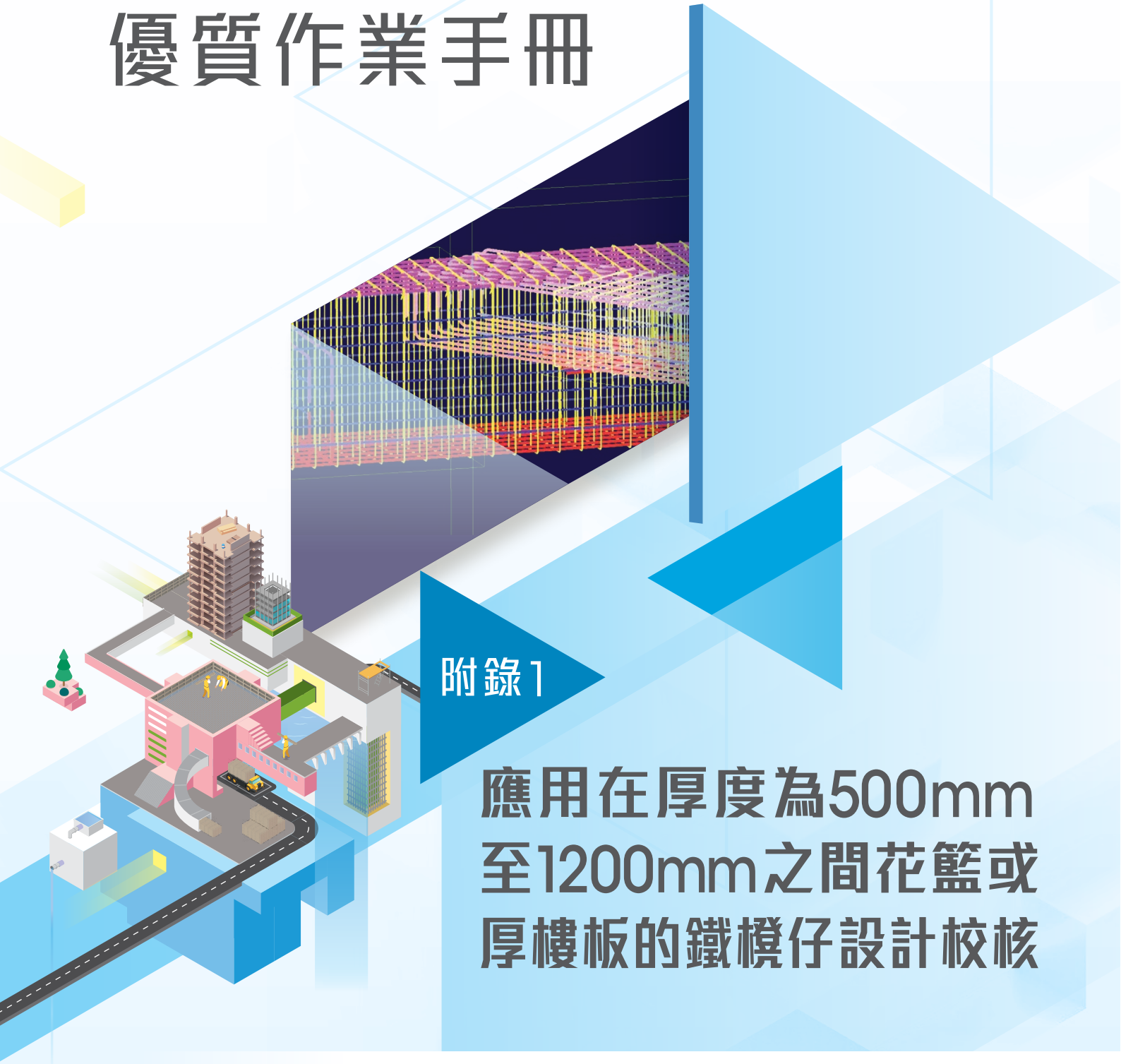
註冊專門行業承造商制度
Registered Specialist
Trade Contractors Scheme

扎鐵專門行業
優質作業手冊



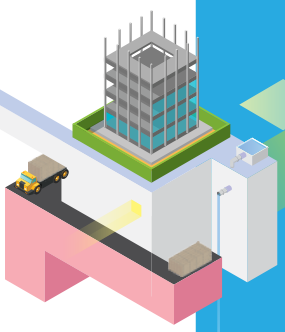
附錄1

應用在厚度為500mm至1200mm之間花籃或厚樓板的鐵樓仔設計校核

項目策劃

CONSTRUCTION INDUSTRY COUNCIL
建造業議會

註冊專門行業承造商聯會
Registered Specialist Trade Contractors Federation



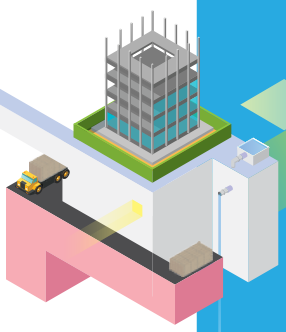
免責聲明

本出版物僅供一般參考。本出版物可能包括（但不限於）：(a) 使用第三方從不同來源提供的信息所準備的內容，(b) 第三方提供的訊息，以及 (c) 互聯網網站上指向第三方訊息的連結。建造業議會已盡合理努力確保本出版物的準確性。但讀者在使用本出版物訊息前應直接參考訊息原文和本出版物提及的法律要求，或向專業顧問尋求適當獨立建議。

讀者不應將本出版物視為或依賴本出版物來代替專業建議。本出版物如有更改，恕不另行通知。本出版物沒有就任何特定目的的可靠性、完整性、準確性或適用性作任何聲明、陳述或保證（明示或暗示）。

建造業議會根據合同法、侵權法或其他法律，對於任何一方可能因與本出版物提供訊息或因與本出版物的任何遺漏而引起或招致或遭受的任何損失、費用、損害或傷害，不會承擔任何責任。

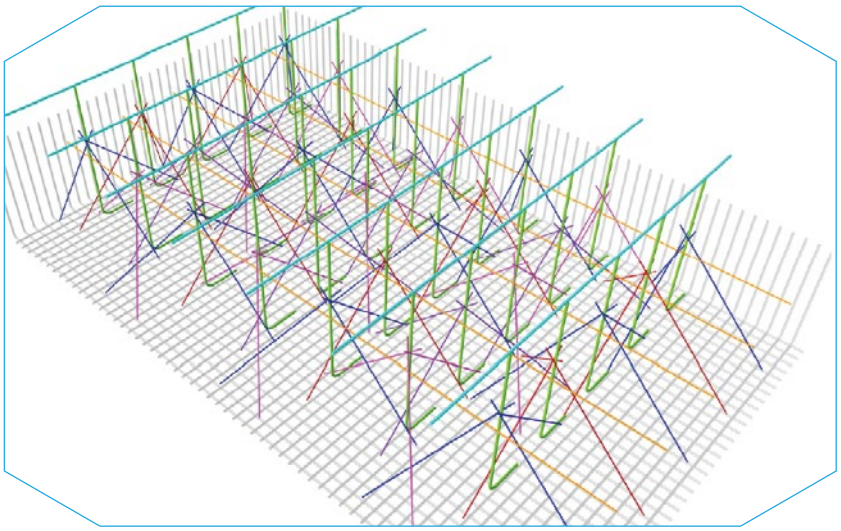
目錄



附頁 工程計算英漢常用辭彙

Area moment of inertia (I)	截面面積慣性矩
Bearer bar	承托鐵
Buckling capacity	壓曲承載力
Dead load	恒載（死荷載）
Effective length (Le)	有效長度
Factor of safety	安全系數
Imposed load	外加荷載
Layers of top reinforcement bar	面鐵層數
Length (L)	長度
Limit of deflection (y)	撓度極限
Load (w) / Load applied	荷載 / 施加的載荷
Maximum Bending moment (Mx)	最大彎矩
Maximum deflection	最大撓度
Maximum tensile stress	最大拉應力
Modulus of elasticity (E)	彈性模量
Nominal cross-sectional area	標稱截面面積
Nominal diameter	標稱直徑
Nominal mass per metre (m)	標稱每米質量
Radius of gyration (r)	回轉半徑
Slenderness ratio (l)	細高比
Steel chair	鐵櫈仔
Tensile stress	拉應力
Total load	總荷載
Tributary area	從屬面積
Weight of top reinforcement	重量
Yield strength (py)	屈服強度

1 概述



鐵樓仔支撐面鐵圖示

大型樁帽、厚地基結構或建築物中的轉換層涉及數百噸鋼筋帶來的抗受拉力。厚樓面鋼筋通常使用較大直徑和緊密的間距，樓板結構頂部的鋼筋必須得到適當支撐和固定，直到混凝土達到足夠強度支撐自身重量。

在香港，常用40mm的Type II型鋼筋來支撐結構鋼筋。豎直的40mm支撐鋼筋 (亦稱企身頂/ Vertical Supporting bars) 與交叉斜撐 (Racking Bars)、橫拉鐵(Lacing Bars) 和承托鐵（Bearer Bars)一起安裝，形成一個臨時平台支撐結構鋼筋（面鐵）的自重荷載和施工時形成的附加荷載（包括施工人員、工具、臨時散放的鋼筋等）。豎直40mm支撐鋼筋的佈置和間距取決於樓板厚度和頂部的結構鋼筋層數。不同尺寸的Type II型鋼筋也可彎曲成鐵樓仔來支撐較少層數的結構鋼筋。

在本設計校核報告中，我們根據現行標準、行業守則和臨時工作設計的優質作業，檢查鋼筋支撐系統的安全性，並提供關於鋼筋支撐系統強度、穩定性的設計計算、其安全系數及安裝時宜採取的措施。

2 設計假設

鋼筋臨時支架是一個臨時建造物，其設計基於BS 5975:2019 (Code of practice for temporary works procedures and the permissible stress design of falsework) 和BS EN 12811:2003 (Temporary works equipment – Part 1: Scaffolds – Performance requirements and general design) 標準。臨時支撐結構的高度小於10m，因此無需使用BS EN 12812規定的極限狀態設計方法（Limit State Design）。

本報告假定工作平台的附加荷載為1.5 KN/m^2，並施加2 KN集中荷載進行檢驗。由於鋼筋支架的頂部用於支撐結構鋼筋網（由多層鋼筋組成以滿足設計需求），而並非真正的工作平台（即僅作臨時支撐用途；沒有踏板及防護護欄等），因此1.5 KN/m^2的附加荷載應該足夠。

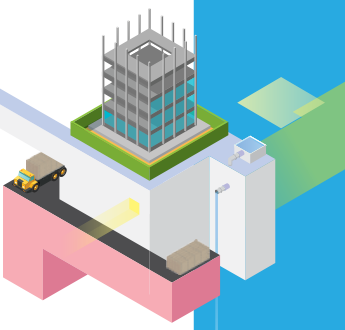
樓板底鐵由混凝土磚支撐，提供足夠強度抵抗鋼筋的縱向及橫向荷載，以及假設用於製作混凝土磚的混凝土强度等級等於或高於樓板混凝土。計算重點在於承托頂部結構鋼筋（面鐵）的鋼筋支架（鐵櫈仔），其高度可能高達2m[1]。本報告中承托面鐵的支撐鋼筋高度介乎1m到3m（使用單根鋼筋彎曲成鐵櫈仔可以提供較低的支撐高度，厚度超過3m的樓板並不常見）。

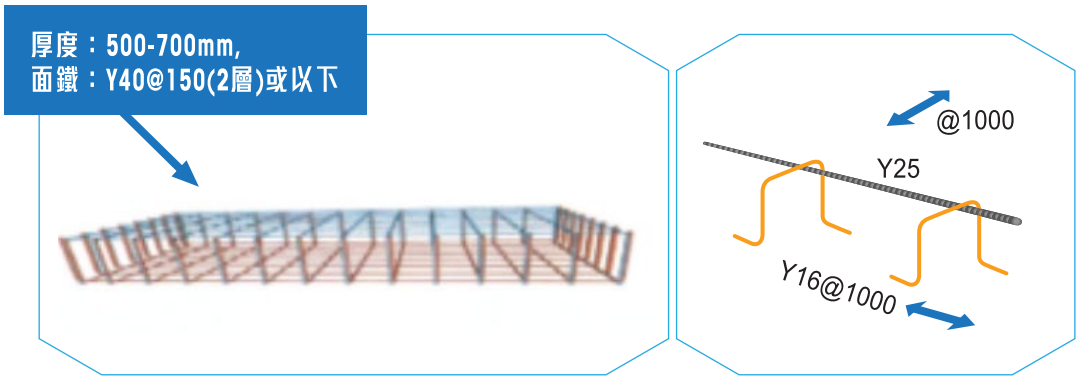
本出版物在考慮恆載和附加荷載所形成的複合荷載的前提下，對鋼筋支架（鐵櫈仔）的強度、剛度和穩定性進行檢查。

[1] 據勞工處(2008)的指南，任何高於 2M 的工作平台必須由合格結構工程師設計並獲批准使用。 詳情請參閱屋宇署《2009 年地盤監督作業守則》，了解有關處理臨時工作的詳細資訊。

3 類別1A

0.7m厚樓面；2 層面鐵；Y16mm Type II 鐵樓仔 @1000 x 1000；Y25 承托鐵





2層150mm間距鋼筋圖示

3.1 強度、剛度和穩定性檢查

面鐵由最多2層Y40鋼筋組成，間距為150mm。間距為1000mm的Y25承托鐵將垂直荷載傳遞到Y16支撐鋼筋上。已檢查Y16支撐鋼筋和Y25承托鐵的強度和撓度。

根據BS5975:2019規定，允許應力設計方法 (permissible stress design method) 的安全系數 (F.O.S) 採用以下原則計算：

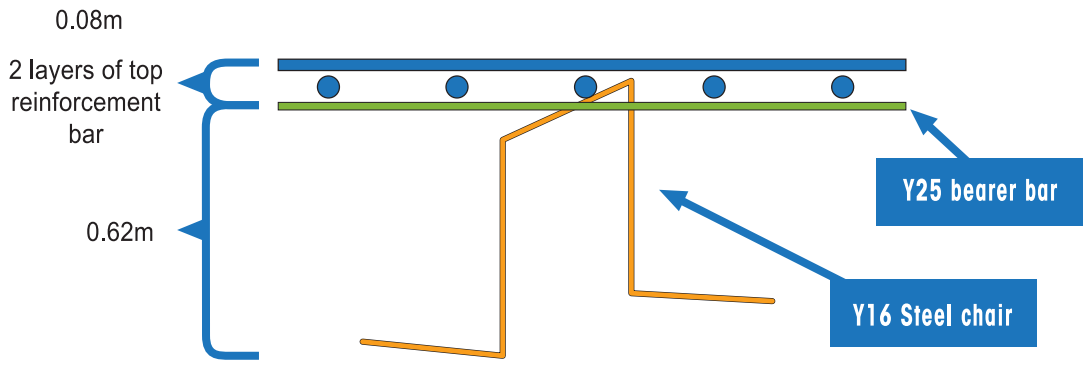
如果採用允許應力設計方法，屈服強度(yield strength)的失效安全系數 (F.O.S) 取1.60，例如承托鐵的彎曲失效 (bending failure)。對於上述情況如採用極限狀態設計法 (Limit state design method)，恒載載荷系數取1.4，外加荷載系數取1.6，可以得出與上述允許應力設計法相約的驗算結果；對於其他結構失效模式 (Failure modes) (例如結構失穩 (stability check) 等)，安全系數 (F.O.S) 取2.0。

3.1.1 Y16支撐鋼筋 (壓曲柱Buckling column)

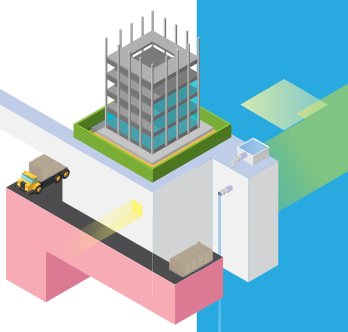
- **荷載類型**

荷載類型 (Type of Loads)	荷載的性質和取值 (Nature and Values of Loads)
恆載 (Dead Loads)	鋼筋總重量轉移到16mm支撐鋼筋
外加荷載 (Imposed Loads)	1.5 KN/m^2 設計 (2KN可移動集中荷載(movable point load)用於檢查)， 參見[3] 勞工處《金屬棚架工作安全守則（2013年3月第2版）》

表 1：Y16支撐鋼筋承載能力時需考慮的荷載類型



Y16支撐鋼筋的荷載圖示（保護層厚度並不計算在內）



- **設計資料及假設**

Loads applied	:	總計（不加權重的總和）
Radius of gyration (r)	:	R/2 = 8 mm
Length (L)	:	鐵樓仔長度 = 620mm
Effective length (Le)	:	Pin-pin = 620 mm (未顯示垂直鋼筋之間的交叉撐杆)
Slenderness ratio	:	87.5
Steel bar yield strength (py)	:	500 MPa
Modulus of elasticity (E)	:	205,000 N/mm^2
Area moment of inertia (I)	:	$I = \frac{1}{4}\pi r^4 = \frac{1}{4} \times 3.14 \times 8^4 \times 10^{-12}$ $= 3.217 \times 10^{-9} m^4$
Nominal mass per metre	:	表2 — 標稱截面面積和標稱每米質量= 1.579 kg

表 2：標稱截面面積和標稱每米質量

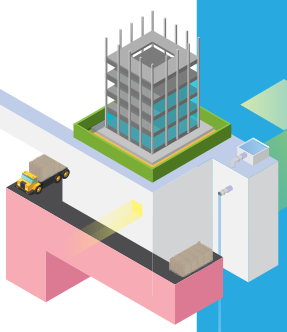
Nominal diameter,d (mm)	Nominal cross-sectional area, A_n (mm^2)	Nominal mass per metre (kg)
6[a]	28.3	0.222
8	50.3	0.395
10	78.5	0.617
12	113.1	0.888
16	201.1	1.579
20	314.2	2.466
25	490.9	3.854
32	804.3	6.313
40	1256.6	9.864
50[a]	1963.5	15.413

[a] These are non-preferred sizes

(參見 Construction Standard CS2:2012 - Steel Reinforcing Bars for the Reinforcement of Concrete)

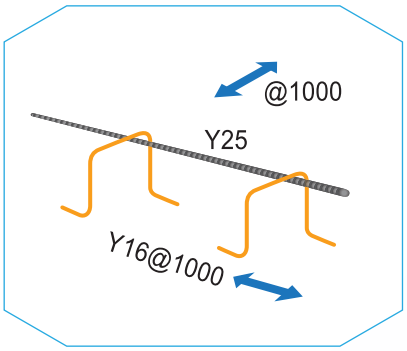
- **壓曲能力檢查**

Steel bar yield strength, py = 500 MPa
Length, L = 620 mm
Effective length,Le = 620 mm
Radius of gyration, r = 8 mm
Slenderness ratio, 1 = 87.5
Modulus of elasticity, E = 205000 N/mm^2



Area moment of inertia, I	= (pi r^4)/4 = 3.217 x 10^-9 m^4
Nominal mass per metre, m	= 1.579 kg
Weight of top reinforcement:	Y40 @ 150mm with 2 layers
Assume the tributary area is	1 m x 1 m
Load of Y40 bar	= 1.579 x 0.0098665
	= 0.01558 kN/m
Total load, w	= (1.5 + 2 x 0.01558 / 0.15) x 1 x 1
	= 1.708 kN
Buckling Capacity	$= \frac{\pi^2 EI}{KL^2}$
	= pi^2 x 205000 x 125600/ (1 x 620^2) x 1 / 1000
	= 661.09 kN
Factor of safety	= 661.09/1.708
	= 387.12
	> 2 O.K.

3.1.2 Y25承托鐵



承托鐵圖示（灰色部件）

- **設計假設**

  假設Y25承托鐵為簡單支撐樑(simply supported beam)，具有1,000mm跨度。

- **彎曲應力檢查**

  Weight of top reinforcement: Y40 @ 150mm with 2 layers
  Assume the tributary area is 1 m x 1 m

  Load of Y40 bar = 1.579 x 0.0098665
  = 0.01558 kN/m

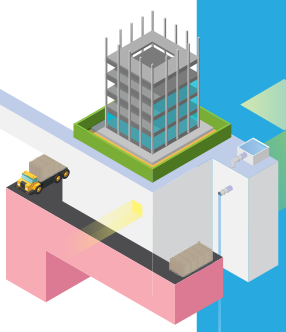
  Total load, w = (1.5 + 2 x 0.01558 / 0.15) x 1
  = 1.708 kN

  Steel bar yield strength, py = 500 MPa
  Total load, w = 1.708 k/m

  Maximum bending moment, Mx = 1/8 wL^2
  = 1.8 x 1.708 x 1^2
  = 0.213 kNm

  Max tensile stress = My/I
  = 0.213 x 10^6 x 12.5 / 125600
  = 21.24 Mpa

  Factor of Safety = 500/21.2
  = 23.54
  > 1.65 *O.K.* BS 5975:2019



- **剛度檢查**

Suggested limit of deflection, y = L/200
= 1000/200
= 5 mm

Maximum deflection = 5wL^4 / 384EI
= 5 x 1.5 x 1000^4 (384 x 205000 x 125600)
= 0.759 mm
< 5.00 mm *O.K.*

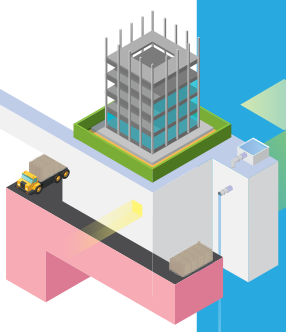
3.2 安全設計參考

Y16mm Type II 鐵樓仔常見設計間距為1000 x 1000(mm)，如特殊情況下（例如施工偏差、邊角處設計）須調整間距，採用2400 x 2400(mm) 間距仍可接受。

3.2.1 Y16支撐鋼筋 (壓曲柱Buckling column)

- **壓曲能力檢查**

Steel bar yield strength, py	=	500 MPa
Length, L	=	620 mm
Effective length,Le	=	620 mm
Radius of gyration, r	=	8 mm
Slenderness ratio, l	=	87.5
Modulus of elasticity, E	=	205000 N/mm^2
Area moment of inertia, I	=	(pi r^4)/4 = 3.217 x 10^-9 m^4
Nominal mass per metre, m	=	1.579 kg
Weight of top reinforcement:		Y40 @ 150mm with 2 layers
Assume the tributary area is		2.4 m x 2.4 m
Load of Y40 bar	=	1.579 x 0.0098665
	=	0.01558 kN/m
Total load, w	=	(1.5 + 2 x 0.01558 / 0.15) x 2.4 x 2.4
	=	9.836 kN
Buckling Capacity	=	$\frac{\pi^2 EI}{KL^2}$
	=	pi^2 x 205000 x 125600/ (1 x 620^2) x 1 / 1000
	=	661.09 kN
Factor of Safety	=	661.09/9.836
	=	67.21
	>	2 O.K.



3.2.2 Y25承托鐵

- **彎曲能力檢查**

Steel bar yield strength, py = 500 MPa
Weight of top reinforcement: Y40 @ 150mm with 2 layers
Assume the tributary area is 2.4 m x 1 m

Load of Y40 bar = 1.579 x 0.0098665
= 0.01558 kN/m

Total load, w = (1.5 + 2 x 0.01558 / 0.15) x 2.4
= 4.099 kN

Maximum bending moment, Mx = 1/8 wL^2
= 1/8 x 4.099 x 2.4^2
= 2.95 kN/m

Maximum tensile stress = My/I
= 2.951 x 10^6 x 12.5 / 125600
= 293.68 Mpa

Factor of Safety = 500/293.7
= 1.70
> 1.65 *O.K.* BS 5975:2019

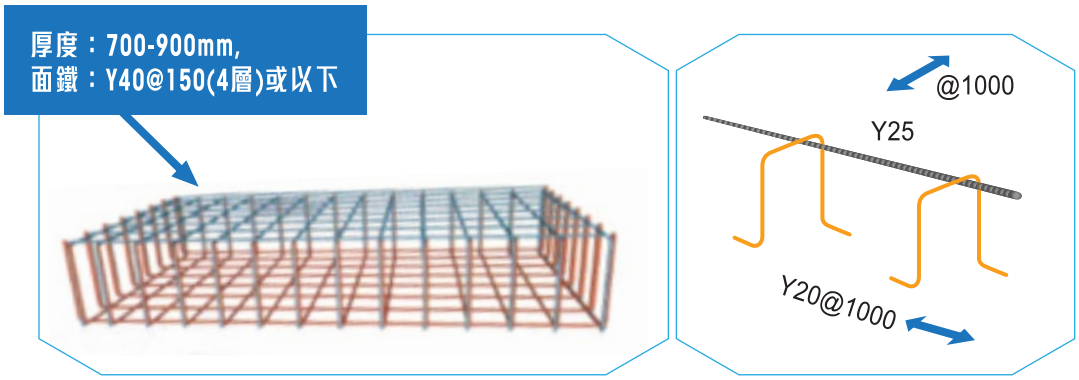
- **剛度檢查**

Suggested limit of deflection, y = L/200
= 2400/200
= 12 mm

Maximum deflection = 5wL^4 / 384EI
= 5 x 1.5 x 2400^4 (384 x 205000 x 125600)
= 25.17 mm
< 12.00 mm *O.K.*

4 類別1B

0.9m厚樓面；4 層面鐵；
Y20mm Type II 鐵樓仔 @1000 x 1000；Y25 承托鐵



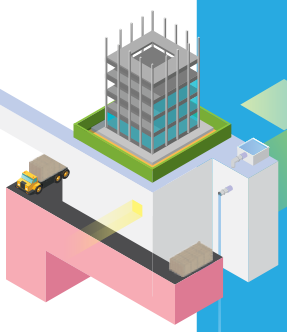
4層150mm間距鋼筋圖示

4.1 強度、剛度和穩定性檢查

面鐵由最多4層Y40鋼筋組成，間距為150mm。間距為1000mm的Y25承托鐵將垂直荷載傳遞到Y20支撐鋼筋上。已檢查Y20支撐鋼筋和承托鐵的強度和撓度。

根據BS5975:2019規定，允許應力設計方法 (permissible stress design method) 的安全系數 (F.O.S) 採用以下原則計算：

如果採用允許應力設計方法，屈服強度 (yield strength) 的失效安全系數(F.O.S)取1.60，例如承托鐵的彎曲失效 (bending failure) 。對於上述情況如採用極限狀態設計法 (Limit state design method) ，恆載載荷系數取1.4，外加荷載系數取1.6，可以得出與上述允許應力設計法相約的驗算結果；對於其他結構失效模式 (Failure modes) (例如結構失穩 (stability check) 等)，安全系數 (F.O.S) 取2.0。

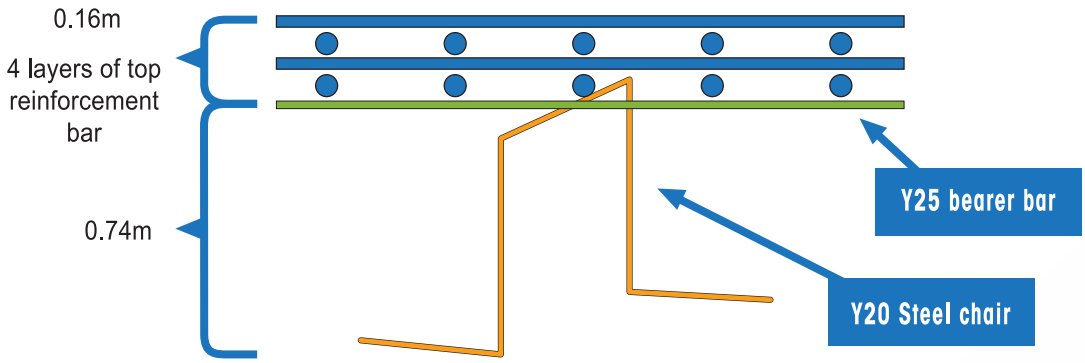


4.1.1 Y20支撐鋼筋 (壓曲柱Buckling column)

- **荷載類型**

荷載類型 (Type of Loads)	荷載的性質和取值 (Nature and Values of Loads)
恆載 (Dead Loads)	鋼筋總重量轉移到20mm支撐鋼筋
外加荷載 (Imposed Loads)	1.5 KN/m^2 設計 (2KN可移動集中荷載用於檢查)，參見[3] 勞工處 《金屬棚架工作安全守則（2013年3月第2版）》

表 3：計算Y20支撐鋼筋承載能力時需考慮的荷載類型



Y20支撐鋼筋的荷載圖示（保護層厚度並不計算在內）

- **設計數據及假設**

Loads applied	:	總計（不加權重的總和）
Radius of gyration (r)	:	R/2 = 10 mm
Length (L)	:	鐵樓仔長度 = 740mm
Effective length (Le)	:	Pin-pin = 740 mm (未顯示垂直鋼筋之間的交叉撐杆)
Slenderness ratio	:	90
Steel bar yield strength (py)	:	500 MPa
Modulus of elasticity (E)	:	205,000 N/mm^2
Area moment of inertia (I)	:	$I = \frac{1}{4}\pi r^4 = \frac{1}{4} \times 3.14 \times 10^4 \times 10^{-12}$ $= 7.854 \times 10^{-9} m^4$
Nominal mass per metre	:	表2 — 標稱截面面積和標稱每米質量= 2.466 kg

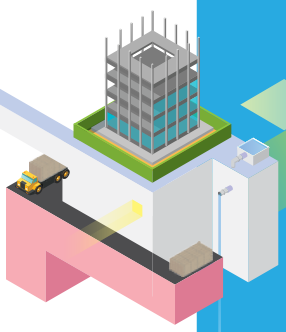


表 2：標稱截面面積和標稱每米質量

Nominal diameter,d (mm)	Nominal cross-sectional area, A_n (mm^2)	Nominal mass per metre (kg)
6[a]	28.3	0.222
8	50.3	0.395
10	78.5	0.617
12	113.1	0.888
16	201.1	1.579
20	314.2	2.466
25	490.9	3.854
32	804.3	6.313
40	1256.6	9.864
50[a]	1963.5	15.413

[a] These are non-preferred sizes

(參見 Construction Standard CS2:2012 - Steel Reinforcing Bars for the Reinforcement of Concrete)

- **壓曲能力檢查**

Steel bar yield strength, py	=	500 MPa
Length, L	=	740 mm
Effective length,Le	=	740 mm
Radius of gyration, r	=	10 mm
Slenderness ratio, 1	=	90
Modulus of elasticity, E	=	205000 N/mm^2

Area moment of inertia, I = (pi r^4)/4 = 7.854x10^9 m^4
Nominal mass per metre, m = 2.466 kg

Weight of top reinforcement: Y40 @ 150mm with 4 layers
Assume the tributary area is 1 m x 1 m

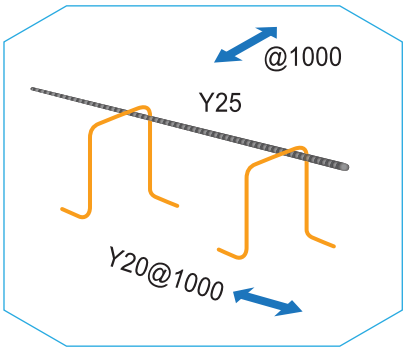
Load of Y40 bar = 2.466 x 0.0098665
= 0.02433 kN/m

Total load, w = (1.5 + 4 x 0.02433 / 0.15) x 1 x 1
= 2.149 kN

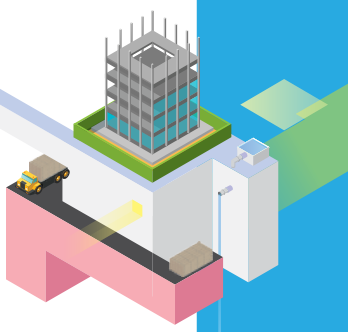
Buckling Capacity $= \frac{\pi^2 EI}{KL^2}$
= pi^2 x 205000 x 125600/ (1 x 740^2) x 1 / 1000
= 464.07 kN

Factor of safety = 464.07/2.149
= 215.96
> 2 *O.K.*

4.1.2 Y25承托鐵



承托鐵圖示（灰色部件）



- **設計假設**

  假設Y25承托鐵為簡單支撐樑(simply supported beam)，具有1,000mm跨度。

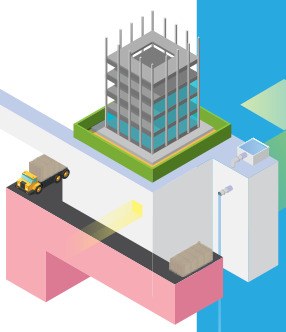
- **彎曲應力檢查**

Steel bar yield strength, py	=	500 MPa
Weight of top reinforcement:		Y40 @ 150mm with 4 layers
Assume the tributary area is		1 m x 1 m
Load of Y40 bar	=	2.466 x 0.0098665
	=	0.02433 kN/m
Total load, w	=	(1.5 + 4 x 0.02433/ 0.15) x 1
	=	2.149 kN
Maximum bending moment, Mx	=	1/8 wL^2
	=	1.8 x 2.149 x 1^2
	=	0.269 kNm
Max tensile stress	=	My/I
	=	0.269 x 10^6 x 12.5 / 125600
	=	26.73 Mpa
Factor of Safety	=	500/26.7
	=	18.70
	>	1.65 O.K. BS 5975:2019

- **剛度檢查**

Suggested limit of deflection, y = L/200
= 1000/200
= 5 mm

Maximum deflection = 5wL^4 / 384EI
= 5 x 1.5 x 1000^4 (384 x 205000 x 125600)
= 0.759 mm
< 5.00 mm *O.K.*



4.2 安全設計參考

Y20mm Type II 鐵櫈仔常見設計間距為1000 x 1000(mm)，如特殊情況下（例如施工偏差、邊角處設計）須調整間距，採用2200 x 2200(mm) 間距仍可接受。

4.2.1 Y20支撐鋼筋 (壓曲柱Buckling column)

- **壓曲能力檢查**

Steel bar yield strength, py	= 500 MPa
Length, L	= 740 mm
Effective length,Le	= 740 mm
Radius of gyration, r	= 10 mm
Slenderness ratio, 1	= 90
Modulus of elasticity, E	= 205000 N /mm^2
Area moment of inertia, I	= (pi r^4) /4 = 7.854 x 10^-9 m^4
Nominal mass per metre, m	= 2.466 kg
Weight of top reinforcement:	Y40 @ 150 mm with 4 layers
Assume the tributary area is	2.2 m x 2.2 m
Load of Y40 bar	= 2.466 x 0.0098665
	= 0.02433 kN /m
Total load, w	= (1.5 + 4 x 0.02433 / 0.15) x 2.2 x 2.2
	= 10.400 kN
Buckling Capacity	$= \frac{\pi^2 EI}{KL^2}$
	= pi^2 x 205000 x 125600 / (1 x 740^2) x 1 / 1000
	= 464.07 kN
Factor of Safety	= 464.07 / 10.4
	= 44.62
	> 2 O.K.

4.2.2 Y25承托鐵

- **彎曲能力檢查**

Steel bar yield strength, py = 500 MPa
Weight of top reinforcement: Y40 @ 150mm with 4 layers
Assume the tributary area is 2.2 m x 1 m

Load of Y40 bar = 2.466 x 0.0098665
= 0.02433 kN/m

Total load, w = (1.5 + 4 x 0.02433 / 0.15) x 2.2
= 4.727 kN

Maximum bending moment, Mx = 1/8 wL^2
= 1/8 x 4.727 x 2.2^2
= 2.86 kN/m

Maximum tensile stress = My/I
= 2.86 x 10^6 x 12.5 / 125600
= 284.64 Mpa

Factor of Safety = 500/284.6
= 1.76
> 1.65 *O.K.* BS 5975:2019

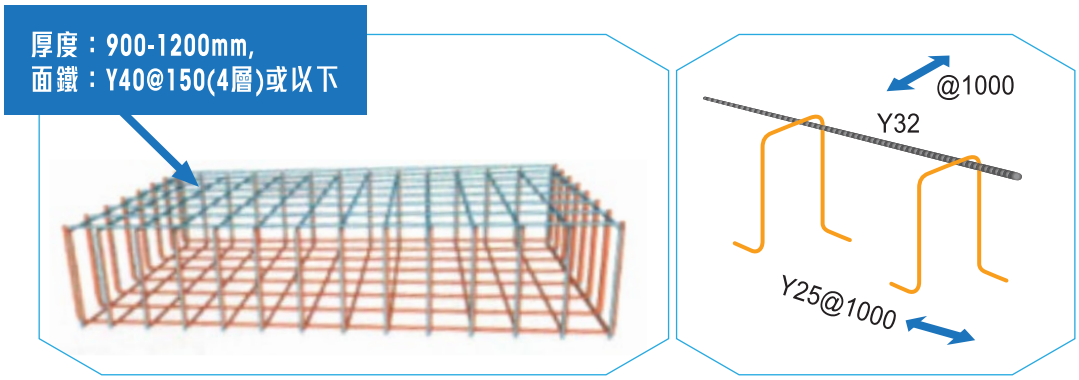
- **剛度檢查**

Suggested limit of deflection, y = L/200
= 2200/200
= 11 mm

Maximum deflection = 5wL^4 / 384EI
= 5 x 1.5 x 2200^4 (384 x 205000 x 125600)
= 17.77 mm
< 11.00 mm *O.K.*

5 類別1C

1.2m厚樓面；4 層面鐵；
Y25mm Type II 鐵樓仔 @1000 x 1000；Y32 承托鐵



4層150mm間距鋼筋圖示

5.1 強度、剛度和穩定性檢查

面鐵由最多4層Y40鋼筋組成，間距為150mm。間距為1000mm的Y32承托鐵將垂直荷載傳遞到Y25支撐鋼筋上。已檢查Y25支撐鋼筋和Y32承托鐵的強度和撓度。

根據BS5975:2019規定，允許應力設計方法 (permissible stress design method) 的安全系數 (F.O.S) 採用以下原則計算：

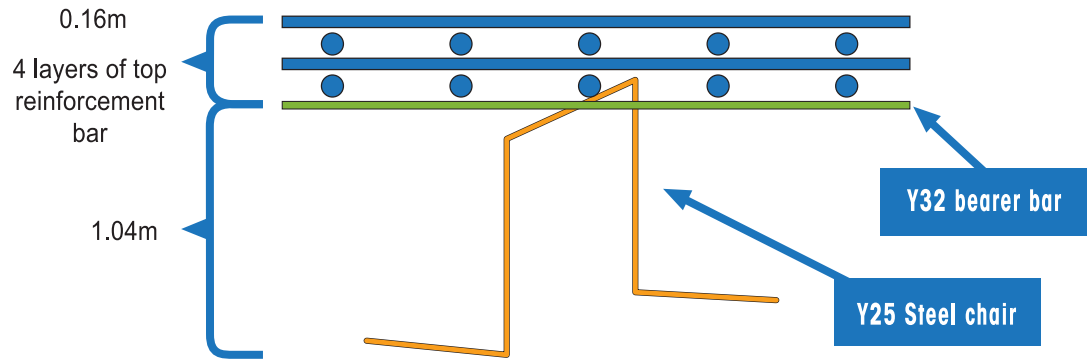
如果採用允許應力設計方法，屈服強度 (yield strength) 的失效安全系數 (F.O.S) 取1.60，例如承托鐵的彎曲失效 (bending failure) 。對於上述情況如採用極限狀態設計法 (Limit state design method) ，恆載載荷系數取1.4，外加荷載系數取1.6，可以得出與上述允許應力設計法相約的驗算結果；對於其他結構失效模式 (Failure modes)（例如結構失穩 (stability check) 等)，安全系數 (F.O.S) 取2.0。

5.1.1 Y25支撐鋼筋 (壓曲柱Buckling column)

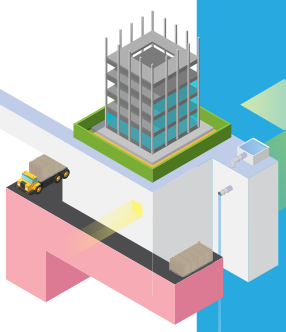
- **荷載類型**

荷載類型 (Type of Loads)	荷載的性質和取值 (Nature and Values of Loads)
恆載 (Dead Loads)	鋼筋總重量轉移到25mm支撐鋼筋
外加荷載 (Imposed Loads)	1.5 KN/m^2 設計 (2KN可移動集中荷載用於檢查)， 參見[3] 勞工處《金屬棚架工作安全守則（2013年3月第2版）》

表 4：Y25支撐鋼筋承載能力時需考慮的荷載類型



Y25支撐鋼筋的荷載圖示（保護層厚度並不計算在內）



- **設計數據及假設**

Loads applied	:	總計（不加權重的總和）
Radius of gyration (r)	:	R/2 = 12.5 mm
Length (L)	:	鐵樓仔長度 = 1040 mm
Effective length (Le)	:	Pin-pin = 1040 mm (未顯示垂直鋼筋之間的交叉撐杆)
Slenderness ratio	:	96
Steel bar yield strength (py)	:	500 MPa
Modulus of elasticity (E)	:	205,000 N/mm^2
Area moment of inertia (I)	:	$I = \frac{1}{4}\pi r^4 = \frac{1}{4} \times 3.14 \times 12.5^4 \times 10^{-12}$ $= 1.917 \times 10^{-8} m^4$
Nominal mass per metre	:	表2 — 標稱截面面積和標稱每米質量= 3.854 kg

表 2：標稱截面面積和標稱每米質量

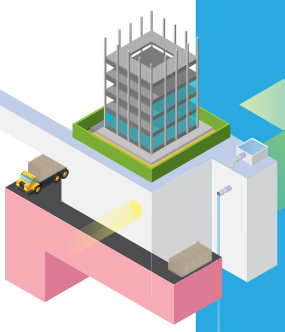
Nominal diameter,d (mm)	Nominal cross-sectional area, A_n (mm^2)	Nominal mass per metre (kg)
6[a]	28.3	0.222
8	50.3	0.395
10	78.5	0.617
12	113.1	0.888
16	201.1	1.579
20	314.2	2.466
25	490.9	3.854
32	804.3	6.313
40	1256.6	9.864
50[a]	1963.5	15.413

[a] These are non-preferred sizes

(參見 Construction Standard CS2:2012 - Steel Reinforcing Bars for the Reinforcement of Concrete)

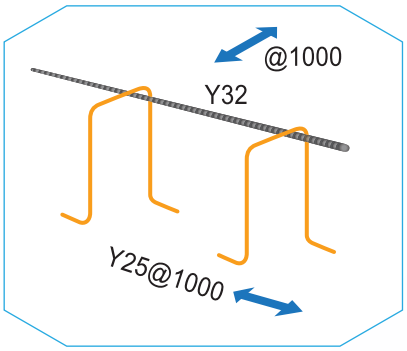
- **壓曲能力檢查**

Steel bar yield strength, py = 500 MPa
Length, L = 1040 mm
Effective length,Le = 1040 mm
Radius of gyration, r = 12.5 mm
Slenderness ratio, 1 = 96
Modulus of elasticity, E = 205000 N/mm^2



Area moment of inertia, I	=	(pi r^4)/4 = 1.917 x 10^-8 m^4
Nominal mass per metre, m	=	3.854 kg
Weight of top reinforcement:		Y40 @ 150mm with 4 layers
Assume the tributary area is		1 m x 1 m
Load of Y40 bar	=	3.854 x 0.0098665
	=	0.03803 kN/m
Total load, w	=	(1.5 + 4 x 0.03803 / 0.15) x 1 x 1
	=	2.514 kN
Buckling Capacity	=	$\frac{\pi^2 EI}{KL^2}$
	=	pi^2 x 205000 x 125600/ (1 x 1040^2) x 1 / 1000
	=	234.95 kN
Factor of safety	=	234.95/2.514
	=	93.46
	>	2 O.K.

5.1.2 Y32承托鐵



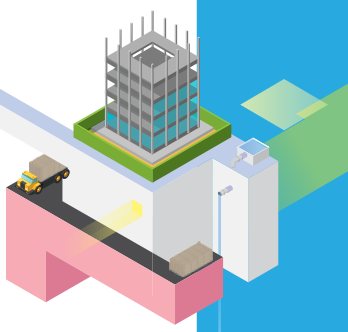
承托鐵圖示（灰色部件）

- **設計假設**

  假設Y32承托鐵為簡單支撐樑(simply supported beam)，具有1,000mm跨度。

- **彎曲應力檢查**

Steel bar yield strength, py	=	500 MPa
Weight of top reinforcement:		Y40 @ 150mm with 4 layers
Assume the tributary area is		1 m x 1 m
Load of Y40 bar	=	3.854 x 0.0098665
	=	0.03803 kN/m
Total load, w	=	(1.5 + 4 x 0.03803 / 0.15) x 1
	=	2.514 kN
Maximum bending moment, Mx	=	1/8 wL^2
	=	1.8 x 2.514 x 1^2
	=	0.314 kNm
Max tensile stress	=	My/I
	=	0.314 x 10^6 x 16 / 125600
	=	40.03 Mpa
Factor of Safety	=	500/40
	=	12.49
	>	1.65 *O.K.* BS 5975:2019



- **剛度檢查**

Suggested limit of deflection, y = L/200
= 1000/200
= 5 mm

Maximum deflection = 5wL^4 / 384EI
= 5 x 1.5 x 1000^4 (384 x 205000 x 125600)
= 0.759 mm
< 5.00 mm *O.K.*

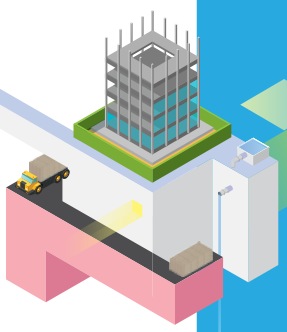
5.2 安全設計參考

Y25mm Type II 鐵樓仔常見設計間距為1000 x 1000(mm)，如特殊情況下（例如施工偏差、邊角處設計）須調整間距，採用1950 x 1950(mm) 間距仍可接受。

5.2.1 Y25支撐鋼筋 (壓曲柱Buckling column)

- **壓曲能力檢查**

Steel bar yield strength, py	=	500 MPa
Length, L	=	1040 mm
Effective length,Le	=	1040 mm
Radius of gyration, r	=	12.5 mm
Slenderness ratio, 1	=	96
Modulus of elasticity, E	=	205000 N/mm^2
Area moment of inertia, I	=	(pi r^4)/4 = 1.917 x 10^-8 m^4
Nominal mass per metre, m	=	3.854 kg
Weight of top reinforcement:		Y40 @ 150mm with 4 layers
Assume the tributary area is		1.95 m x 1.95 m
Load of Y40 bar	=	3.854 x 0.0098665
	=	0.03803 kN/m
Total load, w	=	(1.5 + 4 x 0.03803 / 0.15) x 1.95 x 1.95
	=	9.560 kN
Buckling Capacity	=	$\frac{\pi^2 EI}{KL^2}$
	=	pi^2 x 205000 x 125600/ (1 x 1040^2) x 1 / 1000
	=	234.95 kN
Factor of Safety	=	234.95/9.56
	=	24.58
	>	2 O.K.



5.2.2 Y32承托鐵

- **彎曲能力檢查**

Steel bar yield strength, py = 500 MPa
Weight of top reinforcement: Y40 @ 150mm with 4 layers
Assume the tributary area is 1.95 m x 1 m

Load of Y40 bar = 3.854 x 0.0098665
= 0.03803 kN/m

Total load, w = (1.5 + 4 x 0.03803 / 0.15) x 1.95
= 4.902 kN

Maximum bending moment, Mx = 1/8 wL^2
= 1/8 x 4.902 x 1.95^2
= 2.33 kN/m

Maximum tensile stress = My/I
= 2.33 x 10^6 x 16 / 125600
= 296.83 Mpa

Factor of Safety = 500/296.8
= 1.68
> 1.65 *O.K.* BS 5975:2019

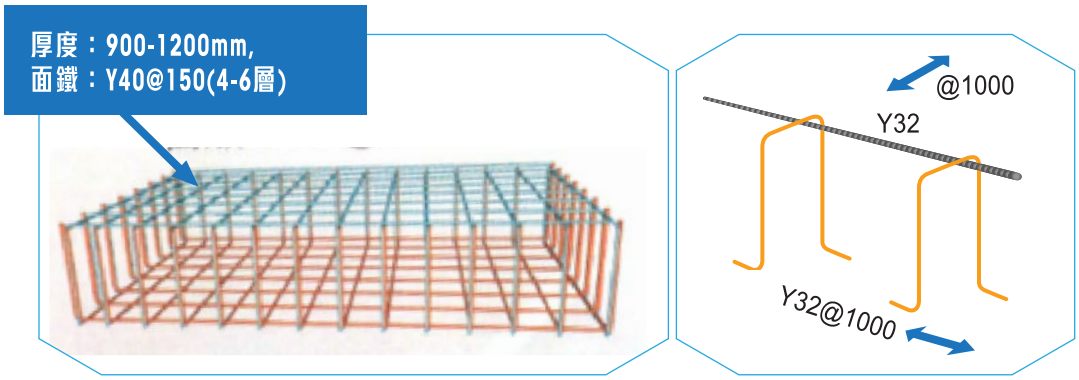
- **剛度檢查**

Suggested limit of deflection, y = L/200
= 1950/200
= 9.75 mm

Maximum deflection = 5wL^4 / 384EI
= 5 x 1.5 x 1950^4 (384 x 205000 x 125600)
= 10.97 mm
< 9.75 mm *O.K.*

6 類別1D

1.2m厚樓面；6 層面鐵；
Y32mm Type II 鐵樓仔 @1000 x 1000；Y32 承托鐵



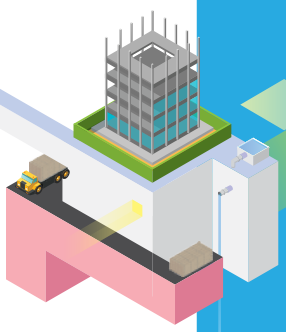
6層150mm間距鋼筋圖示

6.1 強度、剛度和穩定性檢查

面鐵由最多6層Y40鋼筋組成，間距為150mm。間距為1000mm的Y32承托鐵將垂直荷載傳遞到Y32支撐鋼筋上。已檢查Y32支撐鋼筋和Y32承托鐵的強度和撓度。

根據BS5975:2019規定，允許應力設計方法（permissible stress design method）的安全系數 (F.O.S) 採用以下原則計算：

如果採用允許應力設計方法，屈服強度（yield strength）的失效安全系數（F.O.S）取1.60，例如承托鐵的彎曲失效（bending failure）。對於上述情況如採用極限狀態設計法（Limit state design method），恆載載荷系數取1.4，外加荷載系數取1.6，可以得出與上述允許應力設計法相約的驗算結果；對於其他結構失效模式（Failure modes）（例如結構失穩（stability check）等），安全系數（F.O.S）取2.0。

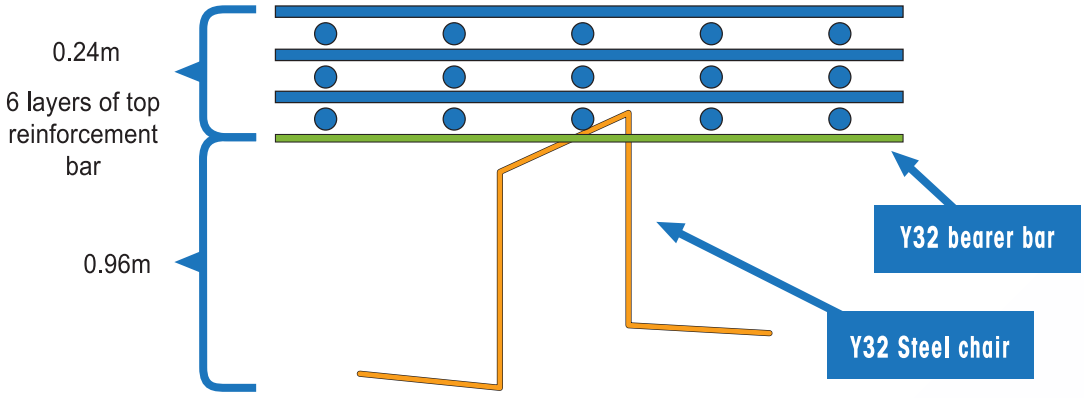


6.1.1 Y32支撐鋼筋 (壓曲柱Buckling column)

- **荷載類型**

荷載類型 (Type of Loads)	荷載的性質和取值 (Nature and Values of Loads)
恆載 (Dead Loads)	鋼筋總重量轉移到32mm支撐鋼筋
外加荷載 (Imposed Loads)	1.5 KN/m^2 設計 (2KN可移動集中荷載用於檢查)，參見[3] 勞工處 《金屬棚架工作安全守則（2013年3月第2版）》

表 5：計算Y32支撐鋼筋承載能力時需考慮的荷載類型



Y32支撐鋼筋的荷載圖示（保護層厚度並不計算在內）

- **設計資料及假設**

Loads applied	:	總計（不加權重的總和）
Radius of gyration (r)	:	R/2 = 16 mm
Length (L)	:	鐵樓仔長度 = 960mm
Effective length (Le)	:	Pin-pin = 960 mm (未顯示垂直鋼筋之間的交叉撐杆)
Slenderness ratio	:	75
Steel bar yield strength (py)	:	500 MPa
Modulus of elasticity (E)	:	205,000 N/mm^2
Area moment of inertia (I)	:	$I = \frac{1}{4}\pi r^4 = \frac{1}{4} \times 3.14 \times 16^4 \times 10^{-12}$ $= 5.147 \times 10^{-8} m^4$
Nominal mass per metre	:	表2 — 標稱截面面積和標稱每米質量= 6.313 kg

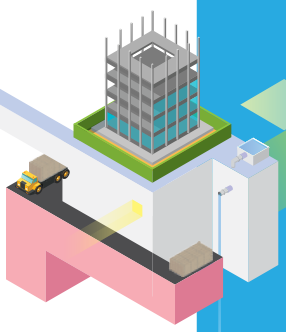


表 2：標稱截面面積和標稱每米質量

Nominal diameter,d (mm)	Nominal cross-sectional area, A_n (mm^2)	Nominal mass per metre (kg)
6[a]	28.3	0.222
8	50.3	0.395
10	78.5	0.617
12	113.1	0.888
16	201.1	1.579
20	314.2	2.466
25	490.9	3.854
32	804.3	6.313
40	1256.6	9.864
50[a]	1963.5	15.413

[a] These are non-preferred sizes

(參見 Construction Standard CS2:2012 - Steel Reinforcing Bars for the Reinforcement of Concrete)

- **壓曲能力檢查**

Steel bar yield strength, py = 500 MPa
Length, L = 960 mm
Effective length,Le = 960 mm
Radius of gyration, r = 16 mm
Slenderness ratio, 1 = 75
Modulus of elasticity, E = 205000 N/mm^2

Area moment of inertia, I = (pi r^4)/4 = 5.147 x 10^-8 m^4
Nominal mass per metre, m = 6.313 kg

Weight of top reinforcement: Y40 @ 150mm with 6 layers
Assume the tributary area is 1 m x 1 m

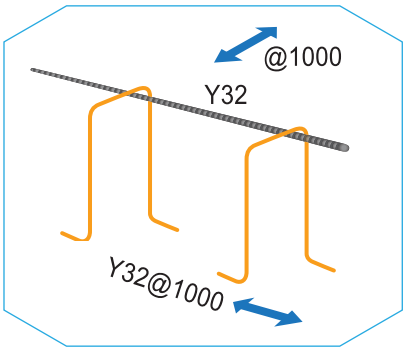
Load of Y40 bar = 6.313 x 0.0098665
= 0.06229 kN/m

Total load, w = (1.5 + 6 x 0.06229 / 0.15) x 1 x 1
= 3.991 kN

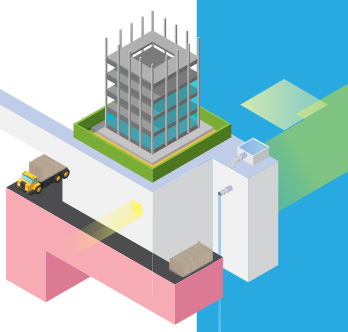
Buckling Capacity = $\frac{\pi^2 EI}{KL^2}$
= pi^2 x 205000 x 125600/ (1 x 960^2) x 1 / 1000
= 275.74 kN

Factor of safety = 275.74/3.991
= 69.08
> 2 *O.K.*

6.1.2 Y32承托鐵



承托鐵圖示（灰色部件）



- **設計假設**

  假設Y32承托鐵為簡單支撐樑(simply supported beam)，具有1,000mm跨度。

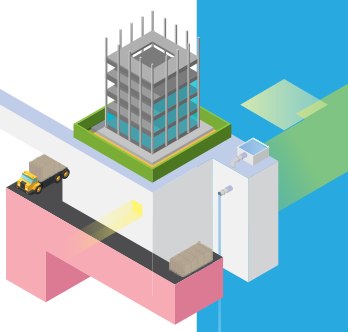
- **彎曲應力檢查**

Steel bar yield strength, py	=	500 MPa
Weight of top reinforcement:		Y40 @ 150mm with 6 layers
Assume the tributary area is		1 m x 1 m
Load of Y40 bar	=	6.313 x 0.0098665
	=	0.06229 kN/m
Total load, w	=	(1.5 + 6 x 0.06229/ 0.15) x 1
	=	3.991 kN
Maximum bending moment, Mx	=	1/8 wL^2
	=	1.8 x 3.991 x 1^2
	=	0.499 kNm
Max tensile stress	=	My/I
	=	0.499 x 10^6 x 16 / 125600
	=	63.56 Mpa
Factor of Safety	=	500/63.6
	=	7.87
	>	1.65 O.K. BS 5975:2019

- **剛度檢查**

Suggested limit of deflection, y = L/200
= 1000/200
= 5 mm

Maximum deflection = 5wL^4 / 384EI
= 5 x 1.5 x 1000^4 (384 x 205000 x 125600)
= 0.759 mm
< 5.00 mm *O.K.*



6.2 安全設計參考

Y32mm Type II 鐵樓仔常見設計間距為1000 x 1000(mm)，如特殊情況下（例如施工偏差、邊角處設計）須調整間距，採用1650 x 1650(mm) 間距仍可接受。

6.2.1 Y32支撐鋼筋 (壓曲柱Buckling column)

- **壓曲能力檢查**

Steel bar yield strength, py	= 500 MPa
Length, L	= 960 mm
Effective length,Le	= 960 mm
Radius of gyration, r	= 16 mm
Slenderness ratio, l	= 75
Modulus of elasticity, E	= 205000 N/mm^2
Area moment of inertia, I	= (pi r^4)/4 = 5.147 x 10^-8 m^4
Nominal mass per metre, m	= 6.313 kg
Weight of top reinforcement:	Y40 @ 150mm with 6 layers
Assume the tributary area is	1.65 m x 1.65 m
Load of Y40 bar	= 6.313 x 0.0098665
	= 0.06229 kN/m
Total load, w	= (1.5 + 6 x 0.06229 / 0.15) x 1.65 x 1.65
	= 10.867 kN
Buckling Capacity	$= \frac{\pi^2 EI}{KL^2}$
	= pi^2 x 205000 x 125600/ (1 x 960^2) x 1 / 1000
	= 275.74 kN
Factor of Safety	= 275.74/10.867
	= 25.37
	> 2 O.K.

6.2.2 Y32承托鐵

- **彎曲能力檢查**

Steel bar yield strength, py = 500 MPa
Weight of top reinforcement: Y40 @ 150mm with 6 layers
Assume the tributary area is 1.65 m x 1 m

Load of Y40 bar = 6.313 x 0.0098665
= 0.06229 kN/m

Total load, w = (1.5 + 6 x 0.06229 / 0.15) x 1.65
= 6.586 kN

Maximum bending moment, Mx = 1/8 wL^2
= 1/8 x 6.586 x 1.65^2
= 2.24 kN/m

Maximum tensile stress = My/I
= 2.241 x 10^6 x 16 / 125600
= 285.51 Mpa

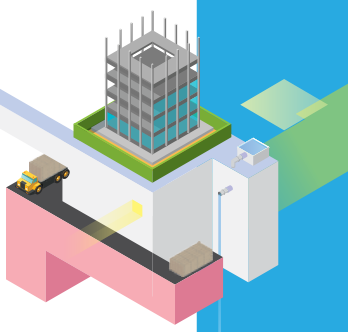
Factor of Safety = 500/285.5
= 1.75
> 1.65 *O.K.* BS 5975:2019

- **剛度檢查**

Suggested limit of deflection, y = L/200
= 1650/200
= 8.25 mm

Maximum deflection = 5wL^4 / 384EI
= 5 x 1.5 x 1650^4 (384 x 205000 x 125600)
= 5.622 mm
< 8.25 mm *O.K.*

7 參考資料



❶ 屋宇署（2023）：2011年鋼結構作業守則（2023年修訂版）（只提供英文版本）
❷ 屋宇署（2021）：2009年地盤監督作業守則（2021年修訂版）
❸ 勞工處（2013）：金屬棚架工作安全守則（2013年3月第2版）
❹ 勞工處（2002）：安全管理工作守則（2002年4月初版）
❺ The British Standards Institution (2003). Temporary works equipment —Part 1: Scaffolds — Performance requirements and general design (BS EN 12811:2003)（只提供英文版本）
❻ The British Standards Institution (2008). Falsework - Performance requirements and general design, 2008 (BS EN 12812:2008). United Kingdom.（只提供英文版本）
❼ The British Standards Institution (2019). Code of practice for temporary works procedures and the permissible stress design of falsework (BS 5975:2019). United Kingdom.（只提供英文版本）
❽ Labour Department (2008). A Guide to Ladders and Elevated Working Platforms, April 2008 .HKSAR.（只提供英文版本）
❾ The Concrete Society (2012). Formwork: A Guide to Good Practice, 3rd Edition. United Kingdom.（只提供英文版本）
❿ Pallet, P. F., & Filip, R. (Eds.). (2018). Temporary works: principles of design and construction. Ice Publishing.（只提供英文版本）