

出國報告（出國類別：開會）

參加「第六屆亞洲土木工程國際會議(The 6th Civil Engineering Conference in the Asian Region, CECAR6)」出國報告

服務機關：台灣電力公司供電處

姓名：黃建民

職稱：主辦土木設計專員

派赴國家：印尼

出國期間：102.8.19~102.8.24

報告日期：102.10.4



## 行政院及所屬各機關出國報告提要

出國報告名稱：參加「第六屆亞洲土木工程國際會議」

頁數 44 含附件：是 否

出國計畫主辦機關/聯絡人/電話

台灣電力公司/人力資源處/陳德隆/02-23667685

出國人員姓名/服務機關/單位/職稱/電話：

黃建民/台電公司/供電處/主辦土木設計專員/02-23666586

出國類別：1 考察 2 進修 3 研究 4 實習 5 其他：開會

出國期間：102.8.19~102.8.24                      出國地區：印尼

報告日期：102.09.24

分類號/目

關鍵詞：主柱材、橫擔、腹材

內容摘要：(二百至三百字)

1. 本次出國係依中國土木水利工程學會來函徵求投稿文章，投稿三年舉辦一次的亞洲土木工程國際會議，本公司供電處黃建民投稿文章獲選刊登，其投稿題目為結構分析軟體 MIDAS 應用於鐵塔結構分析(Study of structural analysis software MIDAS used in the power transmission tower)，並

於會議中發表簡報，藉此與國際交流分享知識、掌握國際技術潮流，同時展現本公司專業技術與能力。

2. 發表文章內容摘要如下：早期電子計算機不發達的年代，輸電鐵塔結構分析採用 2D 平面圖解法，該法依鐵塔構件幾何配置及鐵塔受力大小、受力角度，比例繪製產生受力後之力平衡圖，再藉由量取力平衡圖上線段長度得到桿件之軸力，以此法設計鐵塔結構可避免繁瑣計算式。然而鐵塔為 3D 立體空間結構，其實際受力情形必定與 2D 平面解析不同。取 161kV 四回線 4A1 型直線懸垂鐵塔為研究標的，運用 MIDAS 結構分析軟體建立其 3D 結構模型，輸入 CASE1~CASE6 載重條件進行分析，針對鐵塔之主柱材、橫擔、腹材等構件，分別探討其 2D 與 3D 解析值之差異。鐵塔主柱材之 2D 與 3D 分析結果相近，主要控制載重條件為 CASE2(60 度斜風狀況)，採 2D 平面分析保守安全。
3. 鐵塔腹材於節間 16(彎曲點)以下，其控制之載重條件為 CASE5-1(同邊一條地線及 C1~C3 未掛線)，交叉分析結果顯示 2D 解析不保守，應輔以 3D 解析為宜。
4. 整體而言傳統 2D 平面圖解法可以簡易快速的分析，並得到趨近於良好、安全的結構分析結果。另外應避免 CASE5-1 之架線配置方式使鐵塔結構安全性降低。

本文電子檔已傳至出國報告資訊網 (<http://open.nat.gov.tw/reportwork>)

# 目 錄

	頁次
壹 目的與過程-----	1
一 目的-----	1
二 行程-----	1
三 成員-----	2
貳 會議議程-----	2
一 CECAR 介紹-----	2
二 議程-----	3
三 國內獲獎工程捷運南港東延線-----	5
四 會場剪影-----	6
參 簡報內容-----	9
肆 心得與建議-----	27
伍 附錄-投稿文章-----	29

# 壹、目的與過程：參加「第六屆亞洲土木工程國際會議」

## 一、目的

本案係由中國土木水利工程學會來函邀請本公司參加第六屆亞洲土木工程會議（101年12月6日（101）土水（20）發字第192號），該會議徵求投稿文章並於會議中發表。

依本公司營建處轉知來函，供電處黃建民君投稿題目：Study of structural analysis software MIDAS used in the power transmission tower 獲選刊登(詳圖 1.1)，並經大會議程排定於102年8月22日代表本公司進行簡報，詳圖 1.2 邀請函。

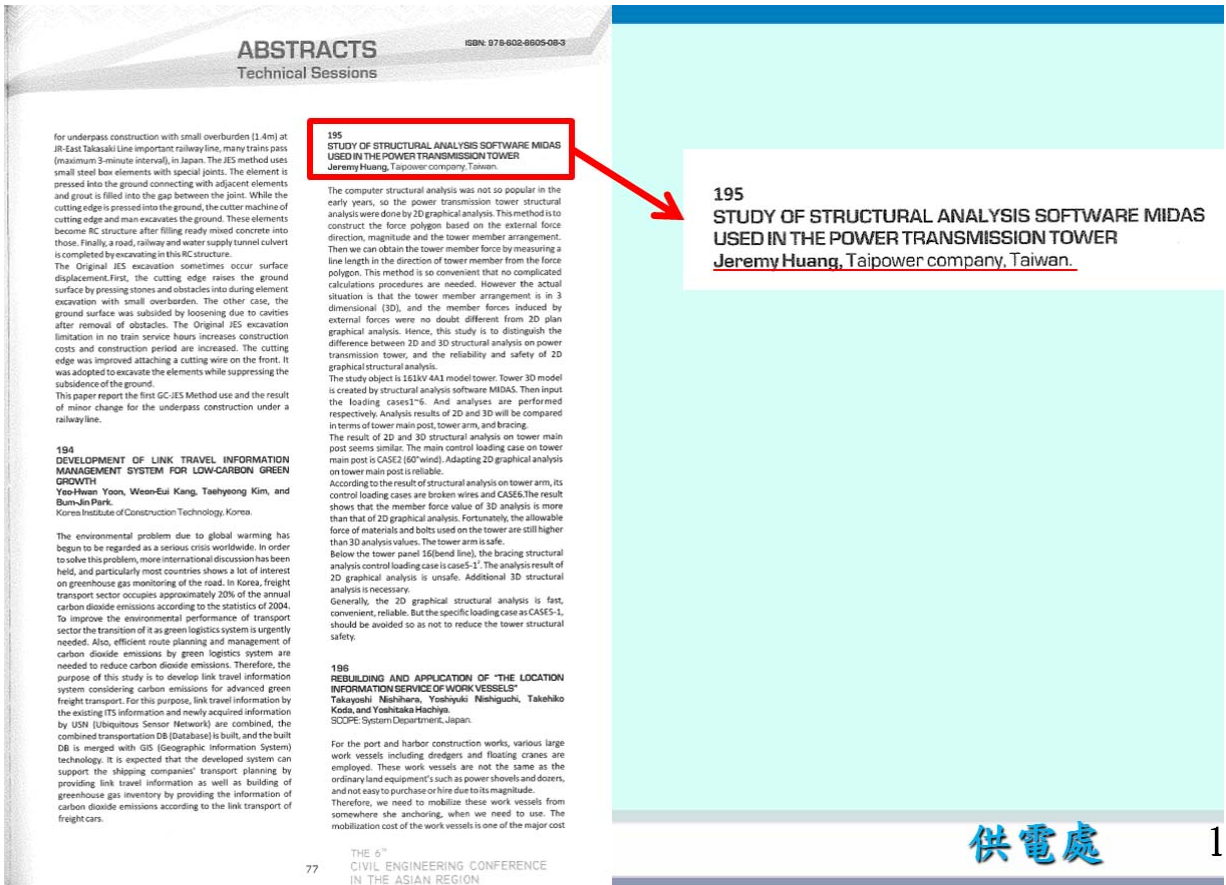


圖 1.1 獲選刊登

## 二、行程(102.8.19~102.8.24，合計6天)

日期	天數	起迄地點	內容
8/19(一)	1	台灣桃園->印尼雅加達	去程
8/20(二)	1	印尼雅加達	第六屆亞洲土木工程國際會議
8/21(三)	1	印尼雅加達	第六屆亞洲土木工程國際會議
8/22(四)	1	印尼雅加達	第六屆亞洲土木工程國際會議 簡報日
8/23(五)	1	印尼雅加達	City tour

8/24(六)	1	印尼雅加達->台灣桃園	返國
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### 三、成員

供電處 黃建民 主辦土木設計專員

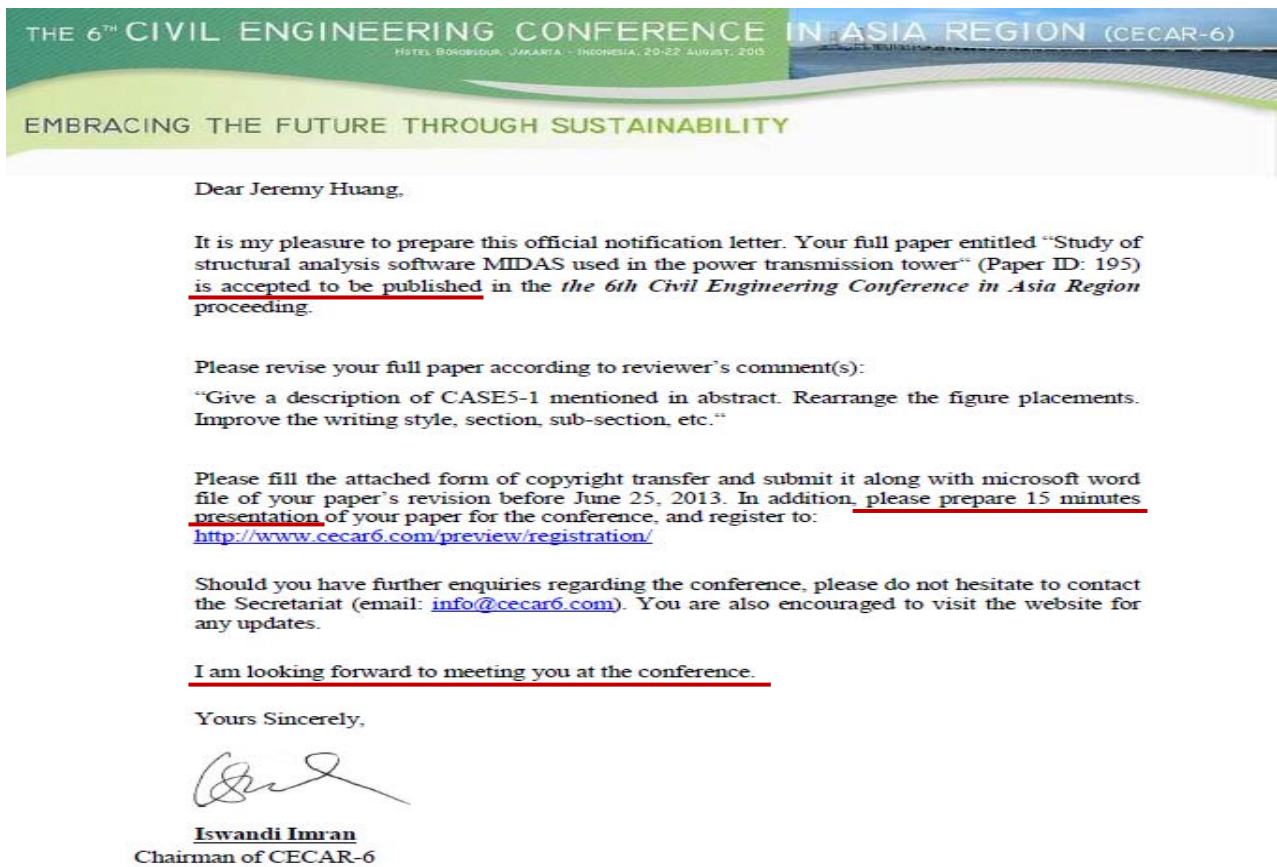


圖 1.2 邀請函

## 貳、 會議議程

### 一、CECAR 介紹

CECAR (Civil Engineering Conference in the Asian Region)亞洲土木工程國際研討會，是亞洲地區重要的土木工程國際性研討會，每三年舉辦一次，於1998年開始，該組織會員目前包括我國、美國、澳洲、日本、韓國、蒙古、菲律賓、越南、印尼、印度等十個國家之土木工程學會，曾於2007年於台北舉行第四屆亞洲土木工程國際會議，該會議已成為土木營建界全球最重要之國際會議。

CECAR 主要成員有：

1. Asia Civil Engineering Coordinating Council, ACECC 亞洲土木協會
2. Indonesian Society of Civil and Structural Engineers, HAKI 印尼土木協會

3. American Society of Civil Engineers, ASCE 美國土木協會
4. Chinese Institute of Civil and Hydraulic Engineering, CICHE 中國土木水利學會 (台灣)
5. Engineers Australia, EA 澳洲土木工程學會
6. The Institution of Civil Engineers, ICE India 印度土木學會
7. Japan Society of Civil Engineers, JSCE 日本土木協會
8. Korean Society of Civil Engineers, KSCE 韓國土木協會
9. Philippine Institute of Civil Engineers, PICE 菲律賓土木協會
10. Mongolian Association of Civil Engineers, MACE 蒙古土木協會
11. Vietnam Federation of Civil Engineering Associations, VIFCEA 越南土木聯合協會

本次會議為第六屆(CECAR6)，由印尼土木與結構協會主辦 (Indonesian Society of Civil and Structural Engineers, HAKI)，地點在印尼雅加達 Hotel Borobudur Jakarta。

本國際研討會每三年舉辦一次，第 1 屆 1998 年由菲律賓土木協會 (PICE) 主辦、第 2 屆 2001 年由日本土木協會 (JSCE) 主辦、第 3 屆 2004 年由韓國土木協會 (KSCE) 主辦、第 4 屆 2007 年由中國土木水利學會(CICHE 台灣)主辦、第 5 屆 2010 年由澳洲土木工程學會(EA)主辦。另第七屆亞洲土木工程國際會議將由美國土木工程協會 ASCE(American Society of Civil Engineers)主辦，時間為 2016 年 8 月 30 至 9 月 2 日，會議地點在夏威夷。

## 二、議程

今年第六屆亞洲土木工程國際會議主題為「Embracing the Future through Sustainability」永續發展，投稿文章主要來自上述成員國，會中由印尼公共工程部長 (Minister of Public Work) Ir. Djoko Kirmanto, Dipl. 開場發表演說，並邀請幾位國際知名學者進行專題演講，其中台灣大學林國峰教授也受邀發表專題演講。

除了專題演講外另有 technical section 技術分組投稿文章發表研討，其主要技術分組如下：

1. Climate Change, 氣候變遷



2. Sustainable Infrastructure, 永續基礎建設
3. Analytical, Design, and Testing Technologies, 分析、設計、試驗等技術
4. Advanced Construction Technologies, 先進的建設技術
5. Construction Engineering and Management, 工程管理
6. Operation and Maintenance Engineering, 運轉與維護
7. Urban Problems, 城市問題
8. Mega Projects, etc. 大眾運輸計畫

第六屆亞洲土木工程國際會議，議程詳如圖 2.1，主要會議舉行發表期間為 10/20-22 等 3 天。

本公司獲選刊登之文章編號為 195，使用英文名 Jeremy Huang，題目為 Study of structural analysis software MIDAS used in the power transmission tower(結構分析軟體 MIDAS 應用於鐵塔結構分析)，排定之技術分組為分析與設計方法(technical section-Analytical and Design Methods)，簡報日期為 2013/8/22 早上 10:30-12:10，本技術分組場次，計有 5 篇文章發表，2 篇來自日本、2 篇來自印尼，1 篇來自台灣(台灣電力公司)，詳細會議議程排定詳如圖 2.2。

Programs						
CECAR 6 Programs in general:						
	Sun, 18 Aug	Mon, 19 Aug	Tue, 20 Aug	Wed, 21 Aug	Thu, 22 Aug	Fri, 23 Aug
<b>Session I</b>	14th TCCM	25th ECM	Opening Ceremony	Keynote 3	Keynote 6	Post Conference Programme: City tour
			Keynote 1	Keynote 4	Keynote 7	
			Keynote 2	Keynote 5	Keynote 8	
<b>Break</b>						
<b>Session II</b>	14th TCCM	25th ECM	Technical Session	Technical Session	Technical Session	
<b>Lunch</b>						
<b>Session III</b>	19th PCM	25th ECM	Technical Session / Special Session	Technical Session / Work Shop	Technical Session / Special Session	
<b>Break</b>						
<b>Session IV</b>	19th PCM	Presidential Meeting	Technical Session / Special Session	Technical Session / Special Session	Technical Session / Special Session	
<b>Break</b>						
	Welcome Reception	Presidents Dinner	Welcome Reception	Gala Dinner	Closing Ceremony	

The tentative schedule of presentations and sessions can be downloaded [HERE](#).

圖 2.1 CECAR6 議程大綱

<b>SCHEDULE</b>	
<b>Day 3</b>	
<b>22</b> AUG 2013	<b>THURSDAY</b>
<b>10:30 - 12:10</b>	<b>7B Analytical and Design Methods</b>
	Chair: SINDUR MANGKOESOEBROTO (Institut Teknologi Bandung)
	063 <i>Kriging-Based Finite Element Methods for Analyses of Shear Deformable Beams and Plates</i> F.T.WONG
	156 <i>Long-Period Ground Motion Modeling Using FEM with Orthogonal Discontinuous Basis Functions</i> P. E. B. QUINAY, K. ABE, K. KORO, and T. ICHIMURA
<b>BANDAA</b>	043 <i>Large Displacement of Planar FGM Beam Structures Using Co-Rotational Finite Element Method</i> B. S. GAN and N. D. KIEN
	260 <i>3D Dynamic Analysis Practical Problems</i> H. R. TANUWIDJAJA
	195 <i>Study of Structural Analysis Software MIDAS Used in the Power Transmission Tower</i> J. HUANG

圖 2.2 簡報時間

### 三、國內獲獎工程捷運南港東延線

除了研討會的技術分組簡報分享知識外，另大會也選出亞洲地區較為傑出的土木工程建設予以表揚，來自台灣台北市府捷運局所主辦的南港捷運東延線榮獲此一殊榮，詳如圖 2.3。



圖 2.3 捷運局南港捷運東延線獲 ACECC CIVIL ENGINEERING PROJECT AWARD

#### 四、會場剪影

本次參加會議照片及簡述如下圖 2.4-圖 2.7。



圖 2.4 CECAR6 台灣與會人員

上圖 2.4 為台灣與會人員，包括主辦單位之一的中國土木工程學會，另學術單位計有：台灣大學、台灣科技大學、成功大學等教授群；參加領獎北市捷運局傳副局長及同仁；公營機關計有台電公司、榮工處；顧問公司：亞新、中興等。本報告作者位於照片左上。

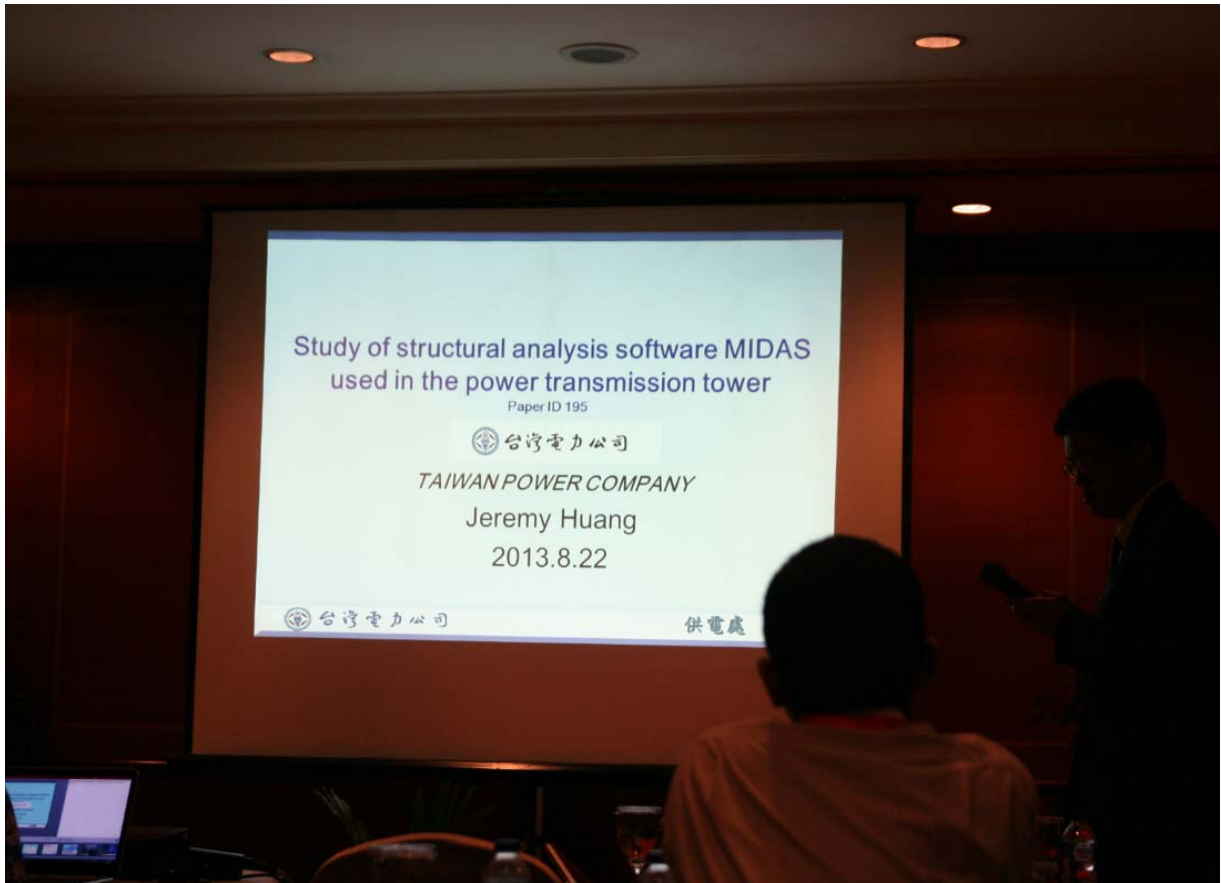


圖 2.5 簡報中 (一)

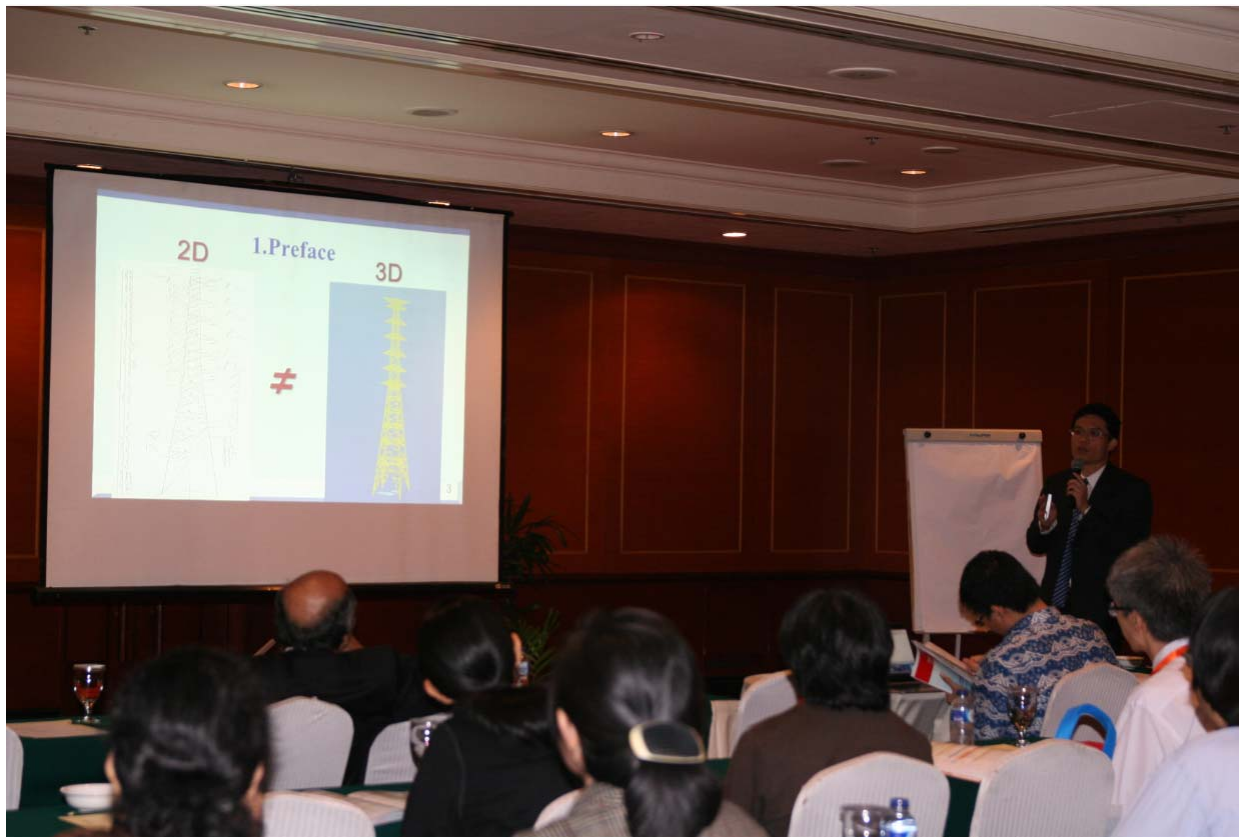


圖 2.6 簡報中 (二)



圖 2.7 交流



圖 2.8 印尼的鐵塔

## 參、 簡報內容

依簡報規定，簡報時間計有 15 分鐘，以下將按照正式簡報投影片，以中文依序說明。

# Study of structural analysis software MIDAS used in the power transmission tower

PaperID 195



台灣電力公司

*TAIWAN POWER COMPANY*

Jeremy Huang

2013.8.22



台灣電力公司

供電處

1

P1：主席、各位女士、先生大家早安，我的題目是結構分析軟體 Midas 應用於鐵塔 3D 結構分析，我來自台灣，我在台灣電力公司工作，投影片中間是我服務公司的標誌。

# Presentation Outline

1

• *Preface*

2

• *Tower Types*

3

• *Midas 3D Analysis*

4

• *Conclusion and Discussion*



台灣電力公司

供電處

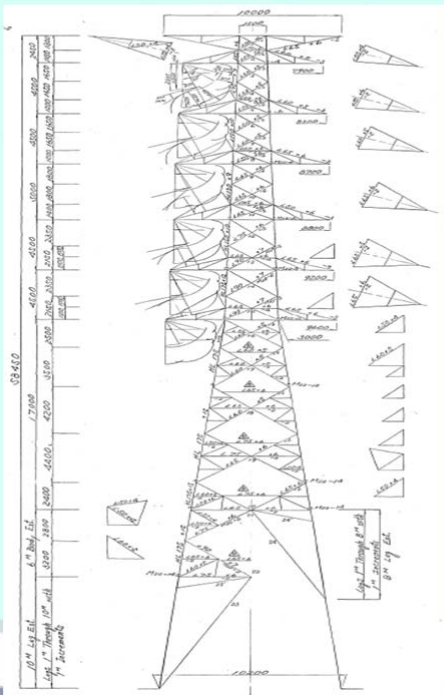
2

P2：簡報大綱共分為 4 大項，1 前言、2 塔型、3 主要部分 Midas 3D 分析、4 結論與討論。

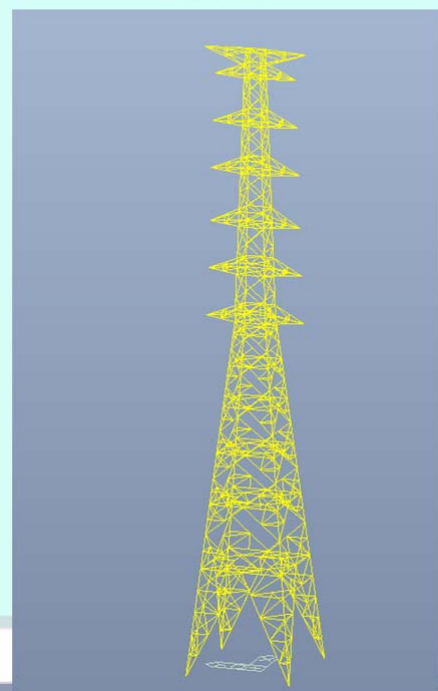
2D

1.Preface

3D



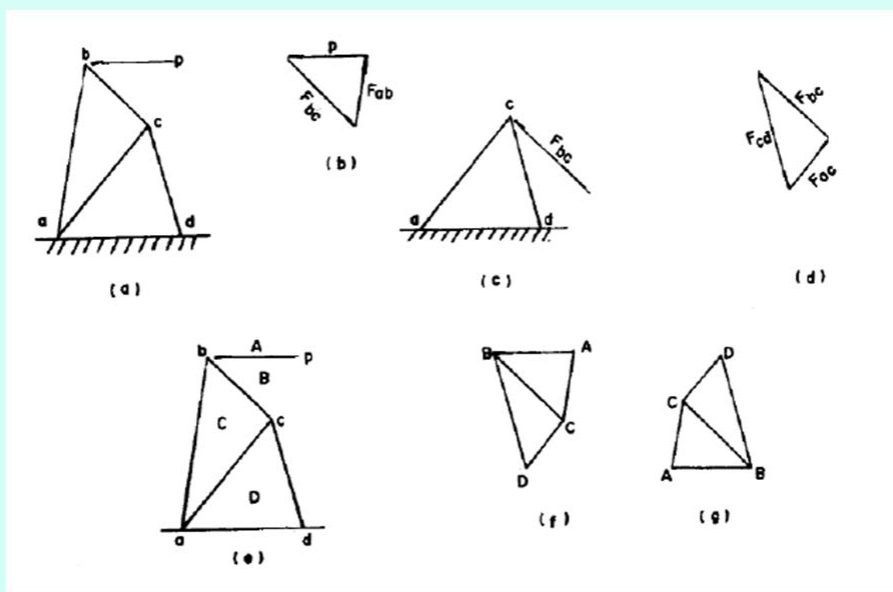
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3

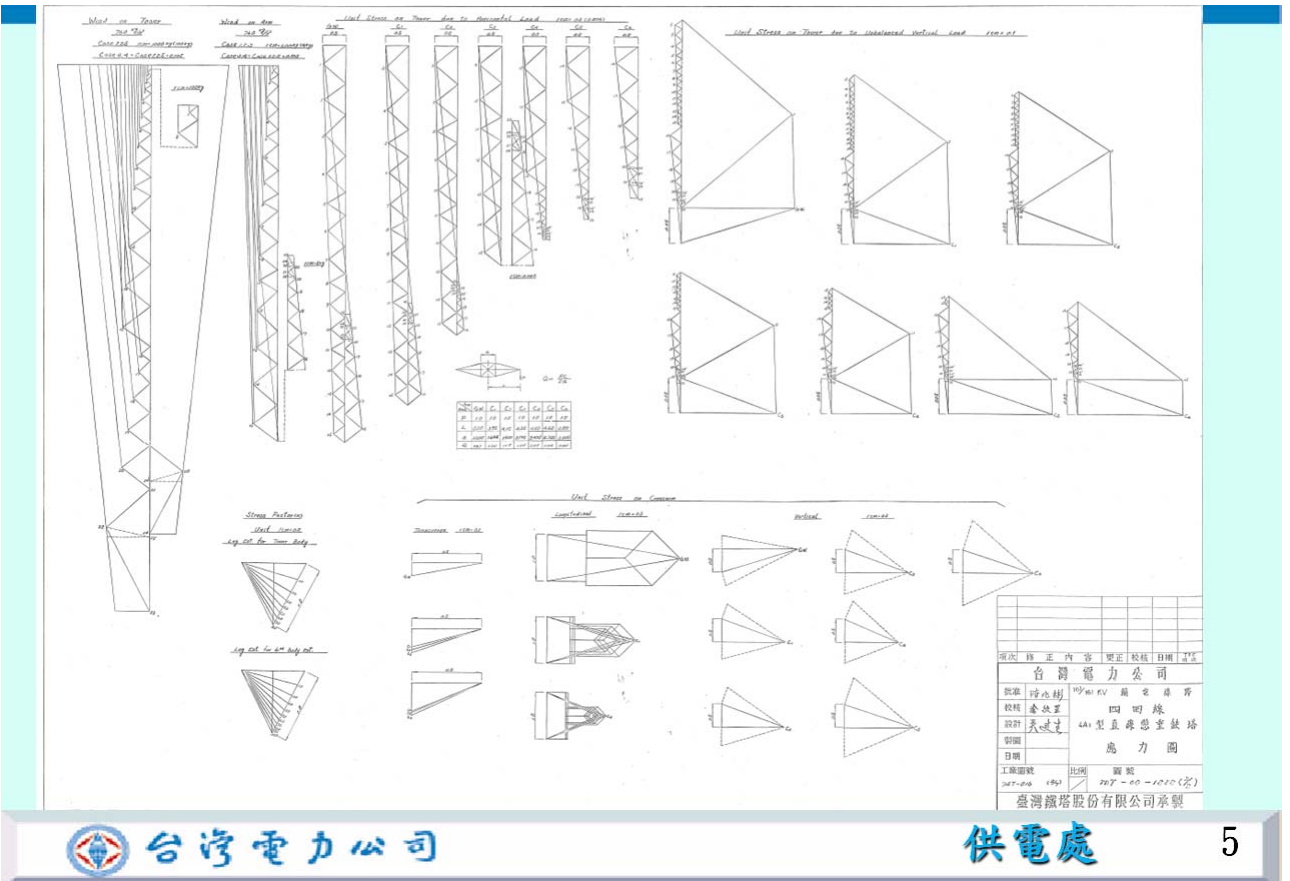
P3:1 前言，在以往電子計算機不發達的年代，鐵塔結構設計多採用二維圖解分析法，然而，實際鐵塔構件空間幾何配置為三度空間，毫無疑問的，真實狀況下3維空間中鐵塔受到外力後所引致的鐵塔桿件內力，勢必與2維分析情況有所不同，究竟差異有多大?2D分析結果是否可靠?所以，本研究的目的，即為探討2D與3D分析之差異。

## 1.1 Analysis method in early years



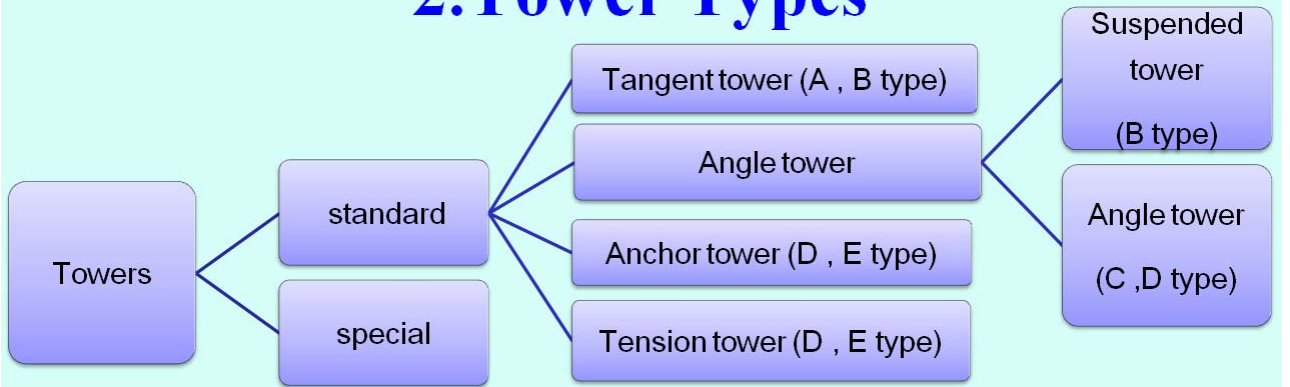
P4:1.1 此圖說明傳統2維鐵塔結構分析，此一圖解法非常簡便，不需要繁複計算步驟。左上圖(a)有一桁架受水平力  $p$ ，若要求得桁架任一桿件之受力，首先須建立其力平衡圖，力平衡圖依據受力大小、桁架幾何配置。首先依比例畫出線段  $p$  代表所受水平力  $p$ ，再依  $\triangle abc$  桁架幾何配置繪得圖(b)之力平衡圖，則  $F_{bc}$  代表  $bc$  桿之軸力， $F_{ab}$  代表  $ab$  桿軸力。依此法得到整個桁架之力平衡圖(g)，藉由比例量取線段長度，得到每根桿件軸力，此法非常方便且不須繁複計算步驟。





P5：依照上述介紹之 2D 圖解法，可得到整個鐵塔之力平衡圖，如上。

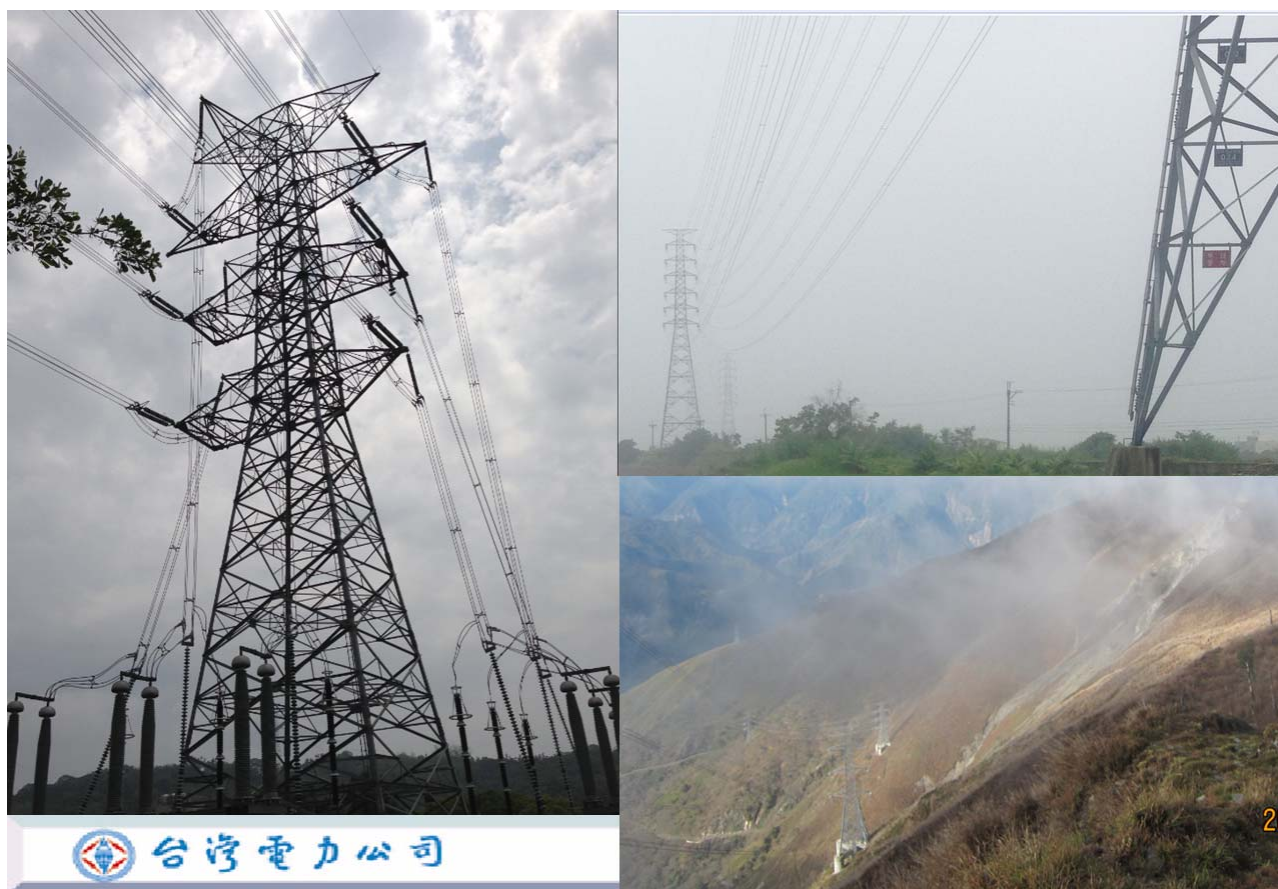
## 2. Tower Types



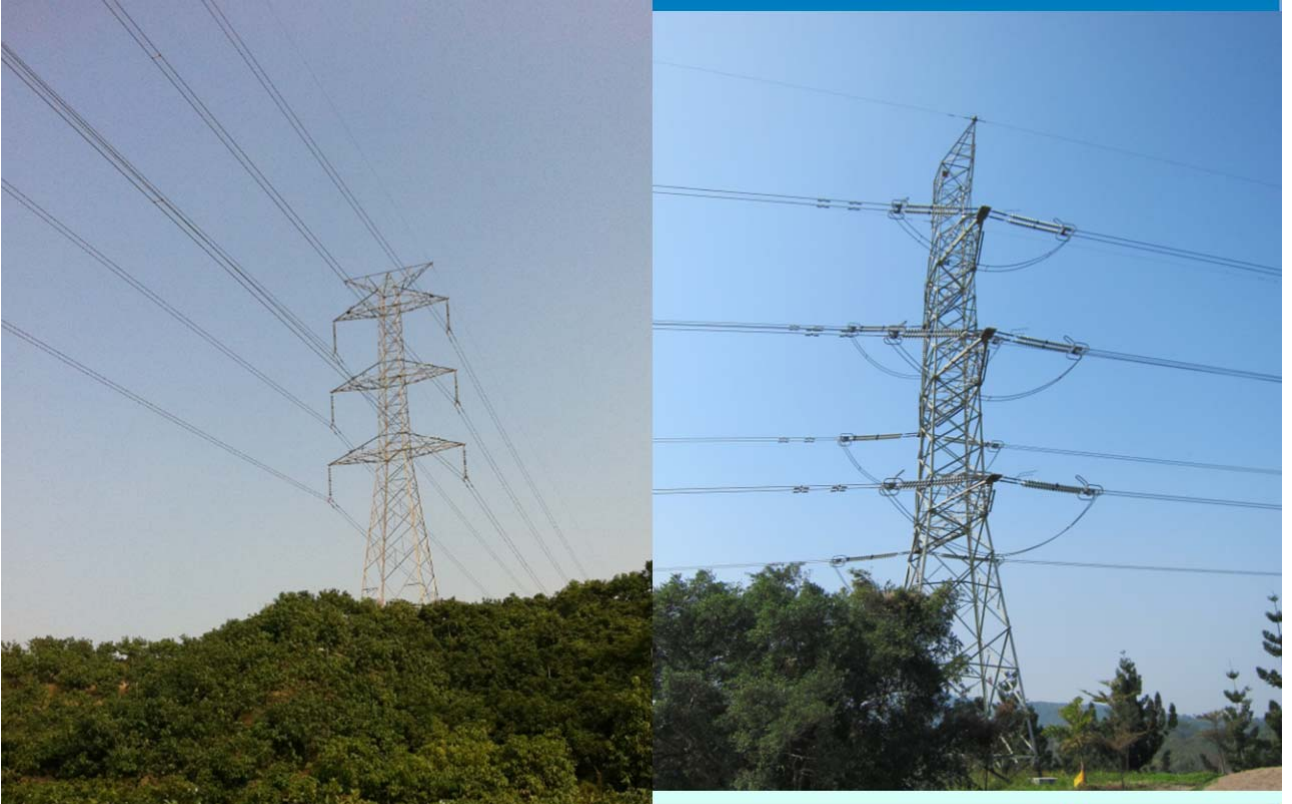
- **Tangent**: power transmission line rotate angle is small ( $3^{\circ}\sim 9^{\circ}$ ) (A,B type).
- **Angle**: used in the line direction changed, suspended type used in line rotate angle smaller than  $9^{\circ}$  (B type); for angle smaller than  $30^{\circ}$  (C or D type).
- **Anchor**: used at the two end of transmission line to support the transmission line of the whole towers (D or E type), also used in line rotate angle over than  $30^{\circ}$
- **Tension**: D or E type, used in fixed distance to insure the transmission line strength, or used in the terrain where elevation difference is big and long span.
- **Special** : overpass the river or mountain valley, long span or any other special spot.

P6：2. 鐵塔型式，本公司針對不同使用環境設定數種鐵塔塔型，如上表。主要有標準

型及特殊型 2 種。標準型區分為 5 種，依不同使用情形，A 及 B 塔型針對線路轉角較小、C 及 D 塔型針對線路轉角較大，D 及 E 塔型用於提升整條輸電線路強度。特殊型用於長跨距或終端鐵塔，接下來將會秀出鐵塔照片。



P7：左邊照片為特殊型，它是架空線路與地下電纜的連接點，右上為本公司鐵塔線路於平原，右下照片為本公司輸電線路於高山上。



台灣電力公司

供電處

8

P8：左邊照片為懸垂型鐵塔，右邊為耐張型鐵塔。

## 2.1 Tower Description

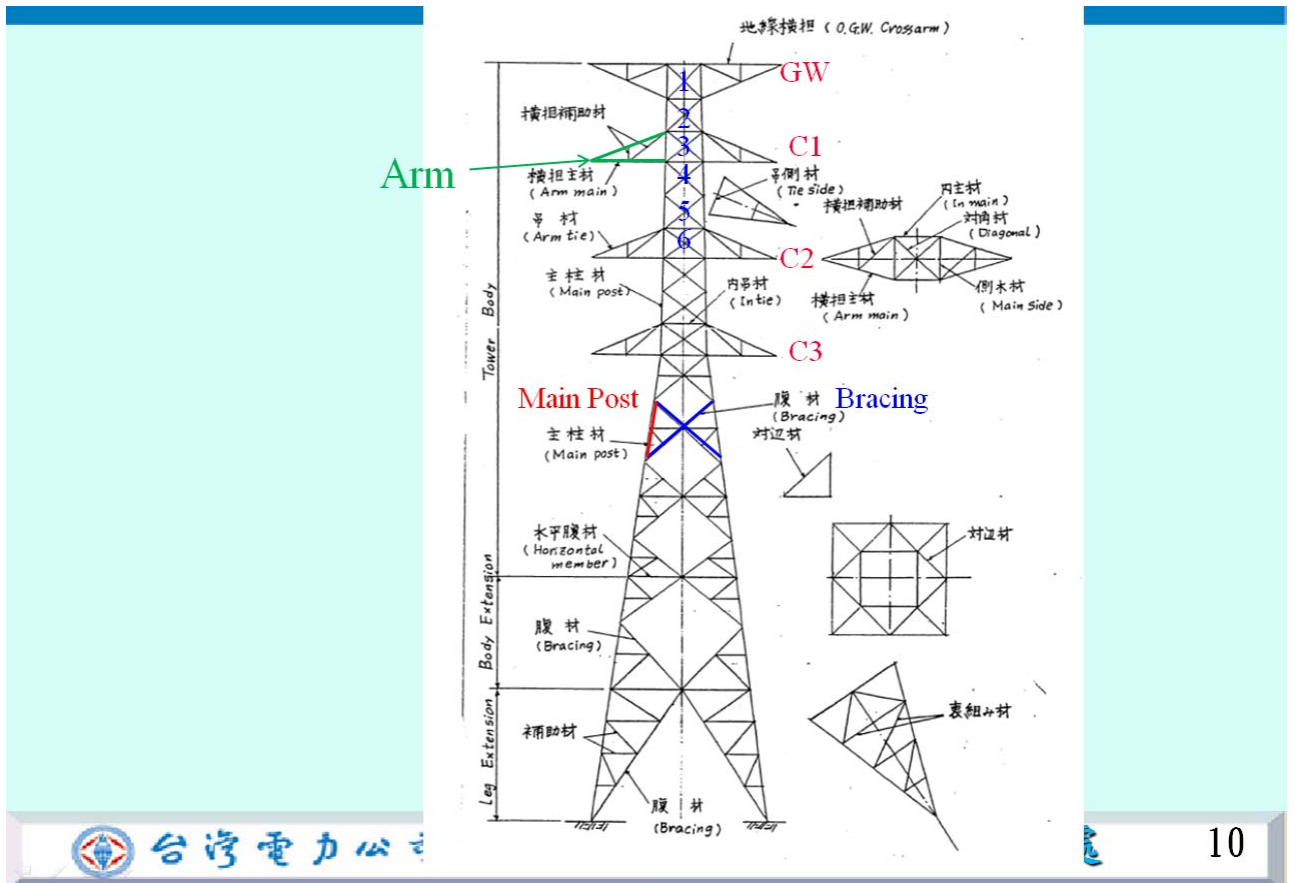


台灣電力公司

供電處

9

P9：2.1 鐵塔描述。



P10：本圖為鐵塔全圖，紅字部分，由上而下標示為 GW 是架空地線，C1~C3 是一番導線、二番導線、三番導線；標示綠色線條懸伸部分稱為 Arm 橫擔；左側標示紅色傾斜線稱為 Main Post 主柱材；中間部分標示藍色 X 稱為 Bracing 腹材；另外為方便定義每一根桿件，由上而下每節間依序編號。

**Tower Type 4A1**

**供電處 11**

附註：  
 1. 本塔明角鋼尺寸均為L45\*4。  
 2. 本塔明角鋼尺寸均為M16。本塔  
 明角鋼尺寸均為普通角鋼。  
 3. 塔身說明L2 塔身普通角鋼。  
 其材料規格按T15 Q235 SS41。

P11：上圖為本研究標的，塔型 4A1。

## 2.2 Applied Load

```

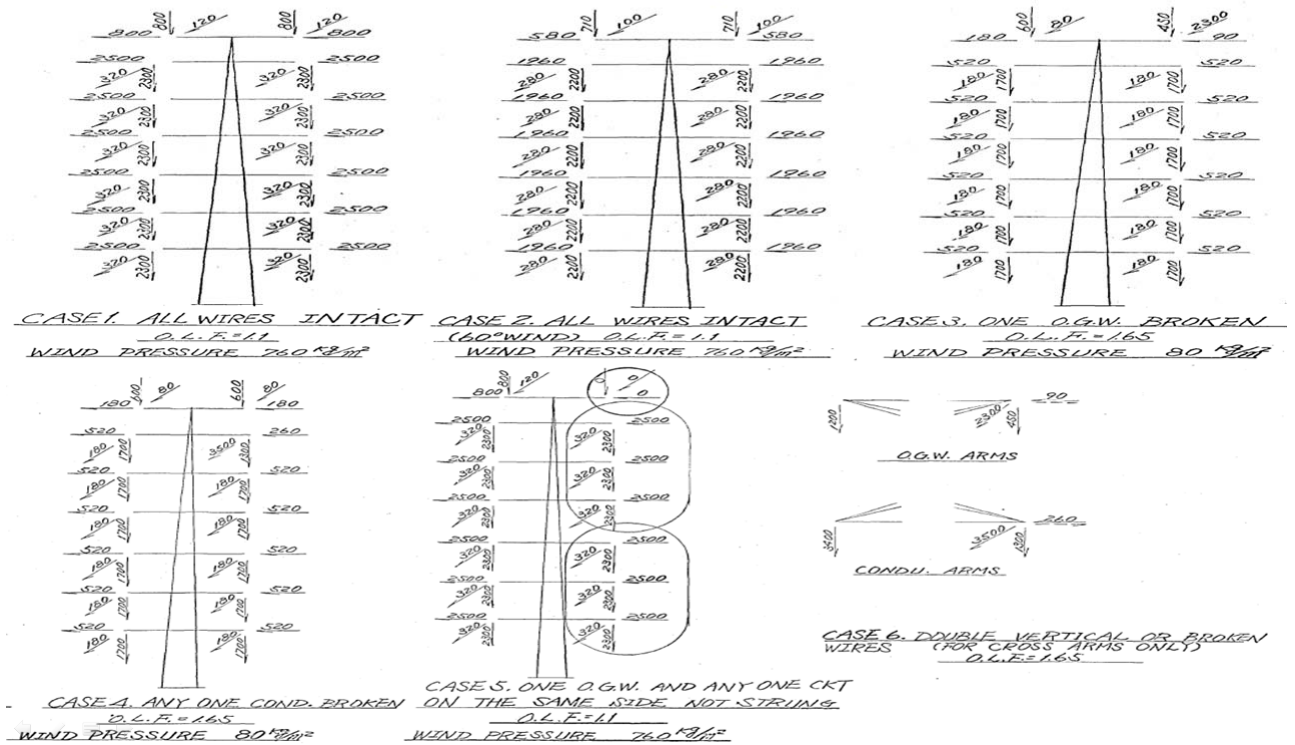
    graph LR
      Load[load] --- TowerWeight[Tower weight]
      Load --- Vertical[Vertical]
      Load --- WindTower[Wind on tower]
      Load --- WindArm[Wind on arm]
      Load --- Trans[Trans.]
      Load --- Longi[Longi.]
      Load --- Torsion[Torsion]
      Vertical --- CondWeight[Weight of Cond./GW/Ins./]
      Vertical --- StringLoad[string vertical direction load]
      Trans --- WindTrans[Wind on Cond./GW/Accessory]
      Trans --- StringTension[String line tension force in trans. direction]
      Longi --- CondTension[Cond./GW./tension force]
      Longi --- CondBroken[Cond./GW./broken wire force]
  
```

**供電處 12**

P12：2.2 鐵塔所受外力，鐵塔荷重來源有鐵塔自重、垂直力(導線、地線、礙子等重

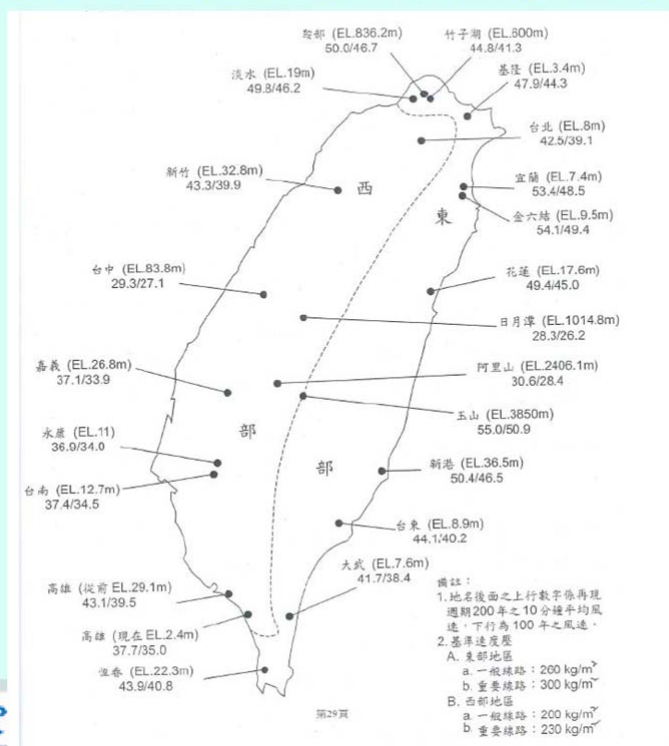
量及架線張力垂直分力)、風吹塔身、風吹橫擔、橫向力(風吹導線、地線、配件等橫向分力;架線張力橫向分力)、縱向力(導線、地線張力;導線、地線斷線張力)、扭力(架線力作用點不通過鐵塔中心時產生)。

## 2.3 Loading Cases



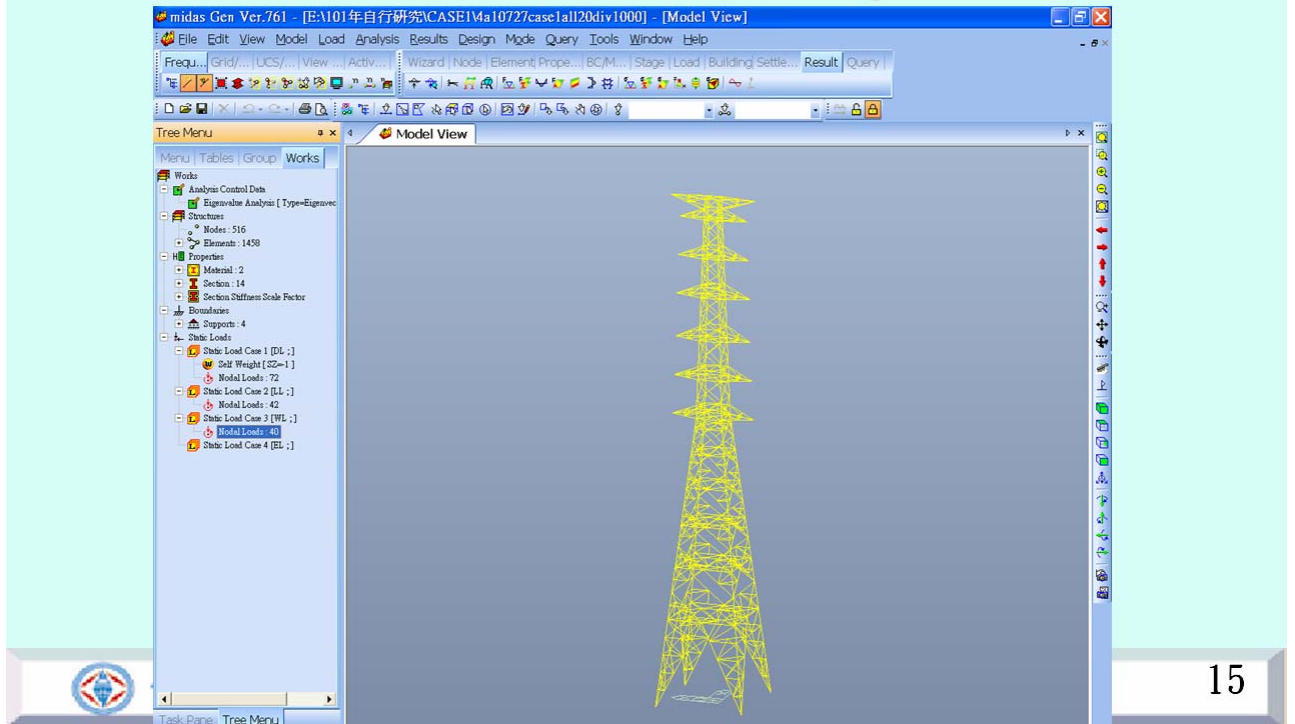
P13: 2.3 載重條件，鐵塔設計設定有 6 種不同的載重條件，CASE1 是全架線、CASE2 也是全架線不過風吹鐵塔角度為 60 度斜風、CASE3 為一條地線斷線、CASE4 為任一條導線斷線、CASE5 為同邊一條地線及一回線未架線、CASE6 專門針對橫擔設計。

## 2.4 Taiwan Wind Zone



P14：2.4 台灣風力分區，風力對鐵塔結構安全影響甚大，我們將台灣風力區分為東、西兩區，根據此圖來設計我們的鐵塔。

# 3. Midas 3D analysis



15

P15：以下進入研究主要部分 3.Midas 3D 分析，運用 Midas 建立標的 4A1 塔型的 3D 分析模型構架，再依序輸入 CASE1~CASE6 的載重條件。

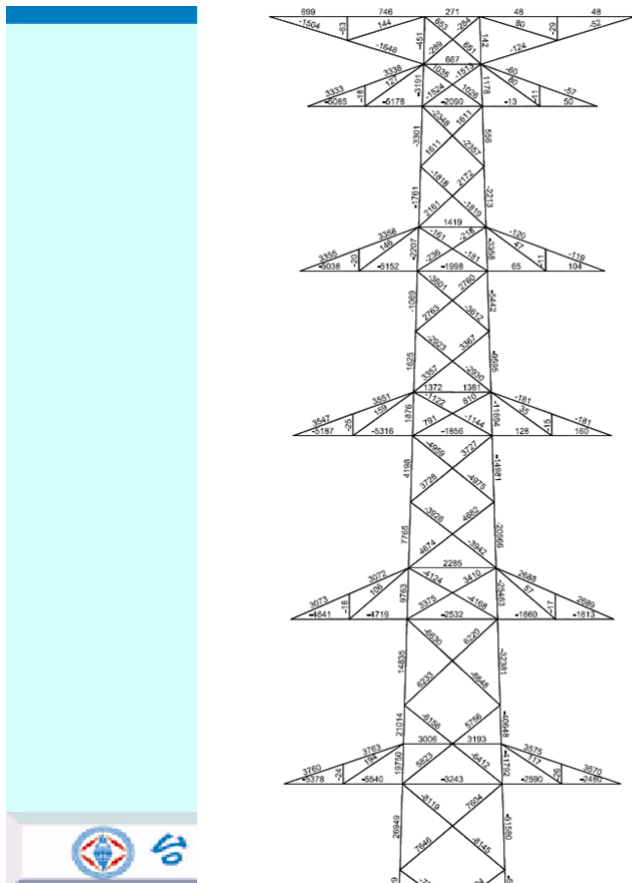


圖4.6.1 CASE5-1 梁構件解析 (FRONT SIDE)  
單位：kg  
負表壓力；正表張力

處

16



P16：3D 的分析結果可以圖像式呈現，如上圖，桿件旁的數字即為桿件的軸力。

+ : compression  
- : tension  
 Unit: kg

## 3.1 Tower Main Post

設計圖 2D
MIDAS 3D解析 3D

Material Strength

Mark	total stress		CASE	O.L.F. CASE	Mark	total stress		CASE	O.L.F. CASE	判定 O.L.F.	O.L.F. Ratio	材料強度 MEMBER		螺栓強度 BOLT		
	Load	O.L.F.				Load	O.L.F.					Strength	Material	BOLT bearing	shear	
Post	1	-500	-830	3	3	1	-737	-1220	6	6	OK	1.470	-13260	L65X6		
		1280	2120	6	6		762	1260	6	6	OK	0.594	11470			
	2	-2720	-3000	5-1	5-1	2	-1358	-2120	5-1	6	OK	0.707	-13260	L65X6		13160
		4860	5990	5-1	6		3311	5470	6	6	OK	0.913	12750			
	4	-7560	-8320	1	1	4	-6011	-6620	2	2	OK	0.796	-24070	L90X7		
		9930	10930	1	1		9869	10860	1	1	OK	0.994	20300			
	5	-10800	-11880	1	1	5	-7913	-8710	2	2	OK	0.733	-24070	L90X7		19740
		14540	16000	1	1		13762	15140	1	1	OK	0.946	24130			
	7	-21020	-23130	1	1	7	-18437	-20280	2	2	OK	0.877	-35250	L100X10		
		25060	27570	1	1		25045	27550	1	1	OK	0.999	33640			
	8	-25680	-28250	1	1	8	-21718	-23890	2	2	OK	0.846	-35250	L100X10	48630	
		31210	34340	1	1		30399	33440	1	1	OK	0.974	38850			
	10	-39410	-43360	1	1	10	-36016	-39620	2	2	OK	0.914	-70570	HL130X9		
		45320	49860	1	1		45392	49940	2	2	OK	1.002	63960			
	11	-45970	-50570	2	2	11	-40636	-44700	2	2	OK	0.884	-70570	HL130X9		65530
53340		58680	1	1	51870		57060	2	2	OK	0.972	73310				
12	-54680	-60150	2	2	12	-50613	-55680	2	2	OK	0.926	-93590	HL150X10			
	62210	68440	1	1		62225	68450	2	2	OK	1.000	72870				
13	-65530	-72090	2	2	13	-61657	-67830	2	2	OK	0.941	-93590	HL150X10		87370	
	74730	82210	2	2		74745	82220	2	2	OK	1.000	103810				
14	-77190	-84910	2	2	14	-72498	-79750	2	2	OK	0.939	-122040	HL175X12			
	86830	95520	2	2		87329	96070	2	2	OK	1.006	115270				
15	-89320	-98260	2	2	15	-84173	-92590	2	2	OK	0.942	-122040	HL175X12		131060	
	100700	110770	2	2		100286	110320	2	2	OK	0.996	147410				

P17：3.1 鐵塔主柱材比較表，分析的結果整理成表格比較，表中列出鐵塔每一節間 2D 及 3D 之桿件軸力比較，另外納入桿件及螺栓材料強度供對照比較。

Post	2D		3D		OK	0.940	24130	+ : compression - : tension Unit: kg
	14540	10000	13702	13140				
7	-21020	-23130	1	1	OK	0.877	-35250	
	25060	27570	1	1	OK	0.999	33640	
8	-25680	-28250	1	1	OK	0.846	-35250	
	31210	34340	1	1	OK	0.974	38850	
10	-43360	49860	1	1	OK	0.914		
	53340	58680	1	1	OK	1.002		
11	-50570	58680	2	2	OK	0.884		
	51870	57060	2	2	OK	0.972	73310	
12	-54680	-60150	2	2	OK	0.926	-93590	HL150X10
	62210	68440	1	1	OK	1.000	72870	
13	-65530	-72090	2	2	OK	0.941	-93590	HL150X10
	74730	82210	2	2	OK	1.000	103810	
14	-77190	-84910	2	2	OK	0.939	-122040	HL175X12
	86830	95520	2	2	OK	1.006	115270	
15	-89320	-98260	2	2	OK	0.942	-122040	HL175X12
	100700	110770	2	2	OK	0.996	147410	
16	-96880	-106570	2	2	OK	0.953	-122040	HL175X12
	108700	119570	2	2	OK	1.018	142500	
17	-99780	-109760	2	2	OK	0.935	-122040	HL175X12
	112140	123360	2	2	OK	0.995	136550	
18	-103370	-113710	2	2	OK	0.957	-122040	HL175X12
	116450	128100	2	2	OK	1.012	145420	
19	-107400	-118140	2	2	OK	0.946	-122040	HL175X12
	121340	133480	2	2	OK	0.998	145420	
20	-111730	-122910	2	2	OK	0.962	-150860	HL175X15
	128150	140970	2	2	OK	0.997	180200	
21	-111920	-123120	2	2	OK	0.958	-150860	HL175X15
	127060	139770	2	2	OK	1.007	174580	
22	-117550	-129310	2	2	OK	0.971	-150860	HL175X15
	136210	149840	2	2	OK	0.982	168050	
23	-117550	-129310	2	2	OK	0.965	-150860	HL175X15
	136210	149840	2	2	OK	0.992	156500	

P18：由表中顯示，2D 與 3D 鐵塔主柱材分析結果相似，主要控制的載重條件為 CASE2

鐵塔受 60 度斜風，結果顯示 2D 圖解分析快速而可靠。

# 3.2 Bracing

+ : compression  
 - : tension  
 Unit: kg

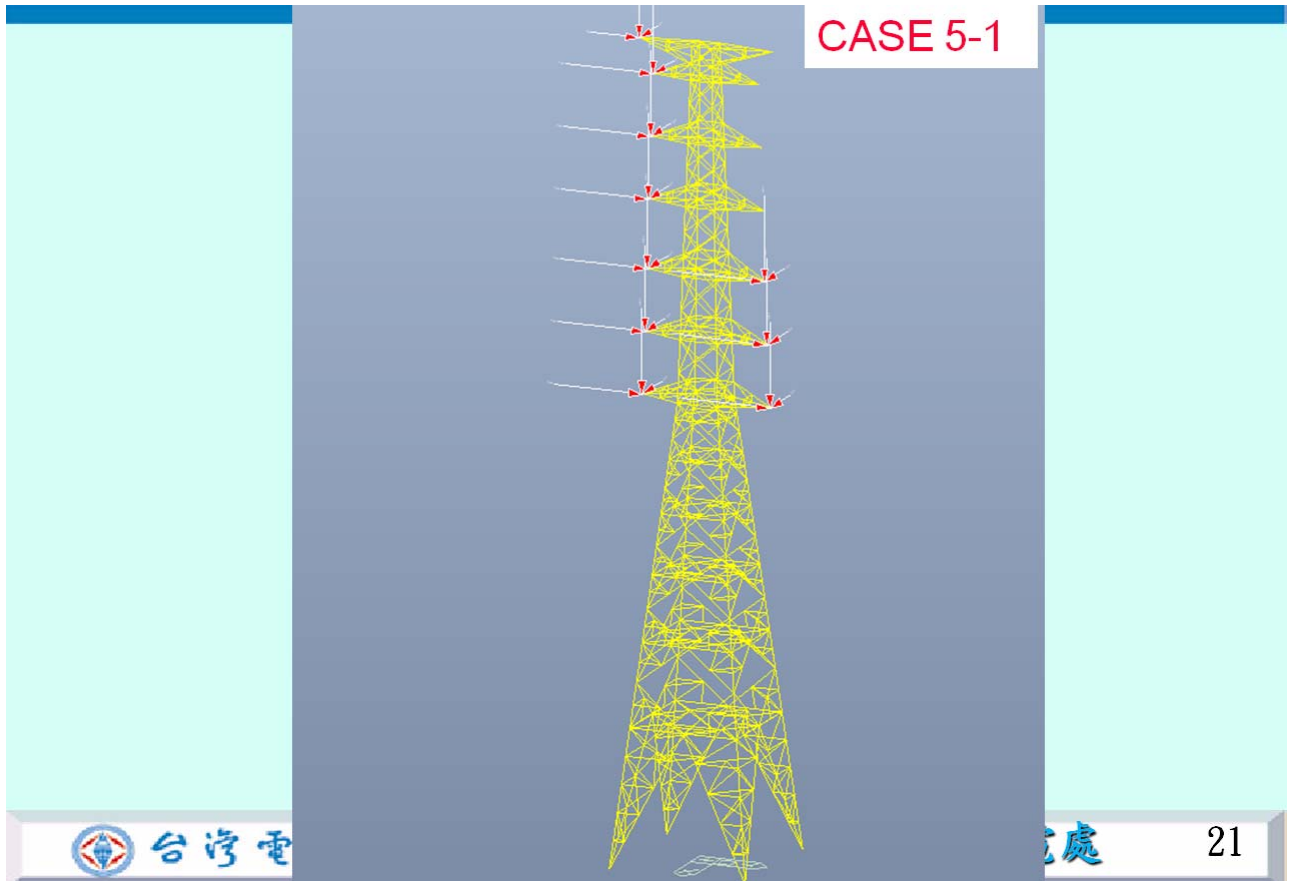
		2D				3D				Material Strength							
Mark	total stress		O.L.F.		Mark	total stress		O.L.F.		判定	O.L.F.	MEMBER		BOLT			
	Load		O.L.F.	CASE		CASE	Load		O.L.F.			CASE	CASE	O.L.F.	Ratio	Strength	material
		comp	tens	bearing	shear			comp	tens	bearing	shear						
Bracing	1	3180	5250	3	3	Bracing	1	1726	2850	3	3	OK	0.543	6810	-7800	L50X6	6580
	2	2860	4720	3	3		2	2766	4570	6	6	OK	0.968	4870	-5440	L50X4	6980
	3	4150	6850	4-1	4-1		3	3703	6110	4-1	4-1	OK	0.892	7400	-8560	L60X5	8730
	4	3860	6370	4-1	4-1		4	3711	6130	4-1	4-1	OK	0.962	7130	-8560	L60X5	8730
	5	3480	5320	5-1	4-1		5	3009	4970	4-1	4-1	OK	0.934	6150	-7800	L50X6	6580
	6	4310	6290	1	4-2		6	4803	5890	1	4-2	OK	0.936	6930	-8560	L60X5	8730
	7	4180	5930	1	4-2		7	3544	5670	1	4-2	OK	0.956	6660	-8560	L60X5	8730
	8	4430	5100	5-1	4-2		8	3704	4660	1	4-2	OK	0.914	5560	-7800	L50X6	6580
	9	5860	6450	1	1		9	6404	7050	1	1	NG	1.093	8460	-11330	L65X6	6580
	10	5720	6300	1	1		10	5086	5600	5-2	5-2	OK	0.889	8200	-11330	L65X6	6580
	11	6600	7260	5-2	5-2		11	5652	6220	1	1	OK	0.857	8730	-11330	L65X6	9870

P19：3.2 鐵塔腹材 2D 及 3D 分析結果比較。

		2D				3D				Material Strength							
Mark	total stress		O.L.F.		Mark	total stress		O.L.F.		判定	O.L.F.	MEMBER		BOLT			
	Load		O.L.F.	CASE		CASE	Load		O.L.F.			CASE	CASE	O.L.F.	Ratio	Strength	material
		comp	tens	bearing	shear			comp	tens	bearing	shear						
Bracing	10	5720	6300	1	1	Bracing	10	5086	5600	5-2	5-2	OK	0.889				
	11	7260	7260	5-2	5-2		11	6220	6220	1	1	OK	0.857				
	12	7870	8660	1	1		12	7832	8620	1	1	OK	0.995	9510	-13580	L75X6	9870
	13	8830	9720	5-2	5-2		13	7408	8150	1	1	OK	0.838	15880	-18970	L90X7	10190
	14	9210	10140	1	1		14	9176	10100	1	1	OK	0.996	15030	-18970	L90X7	10190
	15	9610	10580	5-2	5-2		15	8790	9670	1	1	OK	0.914	15170	-18970	L90X7	15280
	16	3910	4390	5-1	4-6		16	4119	4530	5-1	5-1	NG	1.032	6190	-8560	L60X5	5820
	17	3970	4370	5-1	5-1		17	4356	4800	5-1	5-1	NG	1.098	5720	-8560	L60X5	5820
	18	3880	4270	5-1	5-1		18	4306	4740	5-1	5-1	NG	1.110	4560	-8560	L60X5	5820
	19	3780	4160	5-1	5-1		19	4332	4770	5-1	5-1	NG	1.147	5500	-11330	L65X6	6580
	20	4500	4950	5-1	5-1		20	4590	5050	5-1	5-1	NG	1.020	5830	-11330	L65X6	6580
	21	4050	4460	5-1	5-1		21	4660	5130	5-1	5-1	NG	1.150	6200	-12980	L75X6	8730
	22	5470	6020	5-1	5-1		22	6888	7580	5-1	5-1	NG	1.259	10910	-18970	L90X7	10190
23	9020	9930	5-1	5-1	23	10334	11370	5-1	5-1	NG	1.145	12320	-18970	L90X7	10190		

P20：由分析結果比較表中可知，自鐵塔第 16 節間以下，2D 分析所得之桿件軸力值低

於 3D 分析桿件軸力值，且主要之控制載重條件為 CASE5-1(同邊一條地線及 C1~C3 導線未架線)，一般而言，我們認為，拆除未送電之一回線，會減輕鐵塔的負載，事實上，依據上述分析結果，反而使鐵塔偏向不安全，所以，在實務上應該儘量避免此一不安全的電力配置。2D 分析在腹材分析上較不保守，需要額外的 3D 立體分析輔助。



P21：上圖即是鐵塔腹材的主要控制載重條件 CASE5-1。

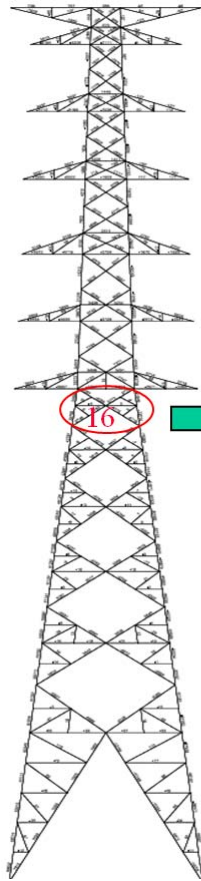
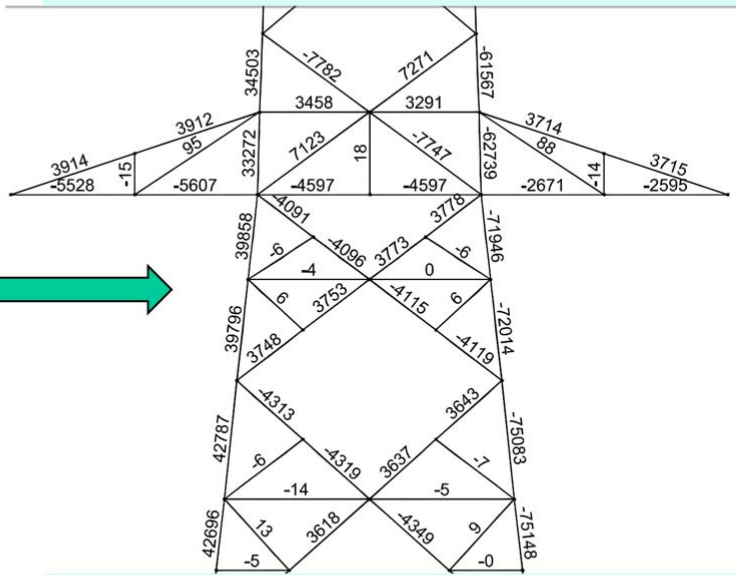


圖4.6.5 CASES-1 二力桿解析  
(FRONT SIDE)  
單位: kg  
負與壓力: 正表張力



- : compression  
+ : tension  
Unit: kg

P22: 上圖為 3D 分析結果，鐵塔腹材在第 16 節間之腹材軸力圖。

### 3.3 Arm

+ : compression  
- : tension  
Unit: kg  
Material Strength

設計圖 2D				MIDAS 3D 解析 3D				判定	O.L.F. Ratio	材料強度 MEMBER		螺栓強度 BOLT		
Mark	Load	O.L.F.	CASE	Mark	Load	O.L.F.	CASE			Strength	material	bearing	shear	
Main	G.W.	-7420	-12250	6	6	-2157	-3560	3	3	OK	0.291	-24070	L90X7	13160
		6580	11030	6	6	3925	6483	3	3	OK	0.587	14270		
	C1	-7040	-11820	6	6	-3659	-6040	4.1	4.1	OK	0.520	-24070	L90X7	16450
		8890	14670	6	6	7168	11830	4.1	4.1	OK	0.906	20500		
	C2	-6270	-10350	6	6	-3037	-5020	4.2	4.2	OK	0.485	-24070	L90X7	16450
		8090	13350	6	6	6522	10770	4.2	4.2	OK	0.807	20100		
Tie	G.W.	0	0	6	6	-177	-200	5.1	5.1	OK	0.021	-24070	L90X7	13160
	C1	-5100	-8420	6	6	5897	9730	4.3	4.3	OK	0.780	19490		
		0	0	6	6	0	0	6	6	OK	0.000	-16280	L75X6	13160
	C2	-5070	-8370	6	6	5013	8280	4.4	4.4	OK	0.764	11310		
		0	0	6	6	-1266	-2090	4.5	4.5	OK	0.274	-24070	L90X7	13160
	C3	-5210	-8600	6	6	5586	9220	6	6	OK	0.831	19060		
Diagonal	G.W.	0	0	6	6	-948	-1570	4.6	4.6	OK	0.217	-24070	L90X7	13160
	C1	-4490	-7250	6	6	5773	9530	6	6	OK	0.882	18630		
		6550	10810	6	6	-4432	-7320	3	3	NG	1.339	-11330	L65X6	6580
	C2	-5070	-8370	6	6	2776	4580	3	3	NG	1.007	4200	L60X6	8730
		0	0	6	6	-5136	-8480	6	6	NG	1.007	-8560	L60X6	8730
	C3	-5210	-8600	6	6	0	0	6	6	NG	1.002	-8560	L60X6	9730
Diagonal	G.W.	0	0	6	6	-5082	-8390	6	6	NG	1.060	-11330	L65X6	9870
	C1	-4490	-7250	6	6	-5524	-9120	6	6	NG	1.060	-11330	L65X6	9870
		0	0	6	6	0	0	6	6	NG	1.005	-7800	L50X6	9870
	C2	-4490	-7250	6	6	-4510	-7450	6	6	NG	1.005	-11330	L65X6	9870
		0	0	6	6	70	80	5.2	5.2	NG	1.005	-11330	L65X6	9870
	C3	-5210	-8600	6	6	-5748	-9490	6	6	NG	1.005	-11330	L65X6	9870
Diagonal	G.W.	0	0	6	6	5919	9770	6	6	NG	1.005	-11330	L65X6	9870
	C1	1750	2890	6	6	161	180	5.2	5.2	OK	0.413	-4690	L45X4	4650
		0	0	6	6	-998	-1480	3	3	OK	0.696	-4690	L45X4	4650
	C2	1440	2380	6	6	784	1290	3	3	OK	0.696	-4690	L45X4	4650
		0	0	6	6	-1047	-1730	4.1	4.1	OK	0.769	-4690	L45X4	4650
	C3	1230	2030	6	6	1218	2010	4.1	4.1	OK	0.611	-4690	L45X4	4650
Diagonal	G.W.	0	0	6	6	1109	1830	4.2	4.2	OK	0.667	-4690	L45X4	4650
	C1	0	0	6	6	-526	-870	4.3	4.3	OK	0.611	-4690	L45X4	4650
		0	0	6	6	747	1240	4.3	4.3	OK	0.611	-4690	L45X4	4650
	C2	0	0	6	6	-597	-990	4.4	4.4	OK	0.667	-4690	L45X4	4650
		0	0	6	6	652	1080	4.4	4.4	OK	0.667	-4690	L45X4	4650
	C3	0	0	6	6	-230	-380	4.5	4.5	OK	0.525	-4690	L45X4	4650
Diagonal	G.W.	0	0	6	6	44	730	4.5	4.5	OK	0.525	-4690	L45X4	4650
	C1	0	0	6	6	0	0	6	6	OK	0.525	-4690	L45X4	4650
		0	0	6	6	0	0	6	6	OK	0.525	-4690	L45X4	4650
	C2	0	0	6	6	0	0	6	6	OK	0.525	-4690	L45X4	4650
		0	0	6	6	0	0	6	6	OK	0.525	-4690	L45X4	4650
	C3	0	0	6	6	0	0	6	6	OK	0.525	-4690	L45X4	4650
Diagonal	G.W.	0	0	6	6	825	1370	4.6	4.6	NG	1.114	-8560	L60X6	5820
	C1	0	0	6	6	0	0	6	6	NG	1.114	-8560	L60X6	5820
		0	0	6	6	0	0	6	6	NG	1.114	-8560	L60X6	5820
	C2	0	0	6	6	0	0	6	6	NG	1.114	-8560	L60X6	5820
		0	0	6	6	0	0	6	6	NG	1.114	-8560	L60X6	5820
	C3	0	0	6	6	0	0	6	6	NG	1.114	-8560	L60X6	5820

P23: 3.3 橫擔比較表。

設計圖 2D					MIDAS 3D解析 3D					Material Strength								
Mark	Load	total stress		O.L.F.		Mark	Load	total stress		O.L.F.		判定	O.L.F. Ratio	MEMBER		BOLT		
		O.L.F.	CASE	CASE	CASE			O.L.F.	CASE	Strength	material			bearing	shear			
In Main	G.W.	-4240	-7000	3	3	In Main	G.W.	-2131	-2890	5-2	3	OK	0.413	-24070	L90X7		13160	
		3390	5600	3	3			795	1320	6	6	OK	0.236	21640				
	C1	-3570	-5890	4-6	4-6		C1	C1	-559	-930	4-1	4-1	OK	0.158	-24070	L90X7		16450
		5640	9310	4-6	4-6				4053	6690	4-1	4-1	OK	0.719	20300			
	C2	-3130	-5170	4-6	4-6		C2	C2	0	0	6	6	OK	0.000	-24070	L90X7		16450
		5170	8530	4-6	4-6				3626	5990	4-2	4-2	OK	0.702	17270			
	C3	-2830	-4670	4-6	4-6		C3	C3	0	0	6	6	OK	0.000	-24070	L90X7		13160
4900		8090	4-6	4-6	3270	5400			4-3	4-3	OK	0.667	14010					
C4	-2430	-4010	4-6	4-6	C4	C4	0	0	6	6	OK	0.000	-24070	L90X7		13160		
	4170	6880	4-6	4-6			2917	4620	2	4-4	OK	0.672	10870					
C5	-2250	-3720	4-6	4-6	C5	C5	0	0	6	6	OK	0.000	-27570	L100X7		13160		
	5040	8320	6	6			3754	6200	4-5	4-5	OK	0.745	12310					
C6	-2100	-3470	4-6	4-6	C6	C6	0	0	6	6	OK	0.000	-24070	L90X7		13160		
	5140	8490	6	6			6475	7370	2	4-6	OK	0.868	17040					
Main Side	G.W.	-80	-90	5-2	5-2	Main Side	G.W.	-560	-930	6	6	NG	10.333	-8560	L60X5		5820	
		350	580	6	6			524	580	5-2	5-2	NG	1.000	5850				
	C1	-1230	-2030	6	6		C1	C1	-1596	-2640	6	6	NG	1.300	-8560	L60X5		5820
		330	370	5-2	5-2				213	240	5-1	5-1	OK	0.649	5110			
	C2	-1360	-2250	6	6		C2	C2	-1572	-2600	6	6	NG	1.156	-8560	L60X5		5820
		380	420	5-2	5-2				14	30	6	6	OK	0.071	3840			
	C3	-1570	-2590	6	6		C3	C3	-1795	-2970	6	6	NG	1.147	-8560	L60X5		5820
430		480	5-2	5-2	0	0			6	6	OK	0.000	2940					
C4	-1540	-2530	5-2	6	C4	C4	-2627	-2890	1	1	NG	1.142	-11330	L65X6		6580		
	500	550	5-2	5-2			0	0	6	6	OK	0.000	3460					
C5	-2150	-3550	6	6	C5	C5	-2400	-3020	1	6	OK	0.851	-13580	L75X6		6580		
	530	590	5-2	5-2			251	280	5-2	5-2	OK	0.475	4420					
C6	-2350	-3880	6	6	C6	C6	-9350	-10290	1	1	NG	2.652	-19670	L90X7		9870		
	580	640	5-2	5-2			7053	7760	1	1	NG	12.125	14600					



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+ : compression  
- : tension Unit: kg

供電處

24

P24 : 3.3 橫擔比較表。

設計圖 2D					MIDAS 3D解析 3D					Material Strength								
Mark	Load	total stress		O.L.F.		Mark	Load	total stress		O.L.F.		判定	O.L.F. Ratio	MEMBER		BOLT		
		O.L.F.	CASE	CASE	CASE			O.L.F.	CASE	Strength	material			bearing	shear			
In Tie	G.W.	0	0	6	6	In Tie	G.W.	-2423	-4000	3	3	OK	0.621	-7800	L50X6		9870	
		1950	3220	6	6			1212	2000	3	3	OK	0.410	3640				
	C1	-4660	-7690	6	6		C1	C1	-2131	-3150	5-2	6	OK	0.504	-7800	L50X6		9870
		0	0	6	6				0	0	6	6	OK	0.504	3640			
	C2	-4590	-7580	6	6		C2	C2	-2817	-3820	2	3	OK	0.515	-7800	L50X6		9870
		0	0	6	6				0	0	6	6	OK	0.515	3640			
	C3	-4660	-7690	6	6		C3	C3	-2838	-3960	2	4-3	OK	0.515	-8560	L60X5		8730
0		0	6	6	0	0			6	6	OK	0.515	3640					
C4	-3910	-6460	6	6	C4	C4	-2849	-3650	2	4-1	OK	0.565	-11330	L65X6		6580		
	0	0	6	6			0	0	6	6	OK	0.565	3640					
C5	-5040	-8320	6	6	C5	C5	-5087	-8400	6	6	NG	1.010	-11330	L65X6		13160		
	0	0	6	6			0	0	6	6	NG	1.010	9250					
C6	-5140	-8490	6	6	C6	C6	-5199	-8580	6	6	NG	1.011	-11330	L65X6		13160		
	0	0	6	6			0	0	6	6	NG	1.011	8290					
Tie Side	G.W.	-360	-600	6	6	Tie Side	G.W.	-64	-70	5-2	5-2	OK	0.117	-5440	L50X4		4650	
		0	0	6	6			346	570	6	6	OK	0.117	2610				
	C1	1160	1920	6	6		C1	C1	643	1060	6	6	OK	0.552	-5440	L50X4		4650
		0	0	6	6				0	0	6	6	OK	0.552	2610			
	C2	1300	2150	6	6		C2	C2	-262	-290	5-1	5-1	OK	0.791	2690	L50X6		6580
		0	0	6	6				1408	1700	1	6	OK	0.791	2690			
	C3	1500	2480	6	6		C3	C3	-452	-500	5-1	5-1	OK	0.806	3120	L60X5		5820
0		0	6	6	1698	2000			1	6	OK	0.806	3120					
C4	1470	2430	6	6	C4	C4	-1852	-2040	5-2	5-2	NG	1.148	3680	L65X6		6580		
	0	0	6	6			2530	2790	1	1	NG	1.148	3680					
C5	2080	3440	6	6	C5	C5	0	0	6	6	NG	1.038	-8560	L60X5		5820		
	0	0	6	6			2161	3570	6	6	NG	1.038	6660					
C6	2280	3770	6	6	C6	C6	-32	-40	5-2	5-2	NG	1.040	-11330	L65X6		6580		
	0	0	6	6			2371	3920	6	6	NG	1.040	8290					



台灣電力公司

+ : compression  
- : tension Unit: kg

供電處

25

P25 : 3.3 橫擔比較表。由比較表得知，在橫擔結構中之各桿件(Tie/Main/In Tie/Tie

## 4. Conclusion and Discussion

- ✓ The result of 2D and 3D structural analysis on tower main post seems similar. The main control loading case on tower main post is CASE2(60°wind). Adapting 2D graphical analysis on tower main post is reliable.
- ✓ Below the tower panel 16(bend line), the bracing structural analysis control loading case is case5-1. The analysis result of 2D graphical analysis is unsafe. Additional 3D structural analysis is necessary.
- ✓ Generally, the 2D graphical structural analysis is fast, convenient, reliable. But the specific loading case as CASE5-1, should be avoided so as not to reduce the tower structural safety.



P26：4. 結論與討論。由上述的研究成果得到以下幾點結論：一般認為傳統 2D 圖解分析是安全的，事實上在鐵塔主柱材分析上確實如此，主柱材 2D 與 3D 分析結果類似，控制條件均為 CASE2，60 度斜風，2D 分析快速可靠。然而，在特別的條件下，額外的 3D 分析是需要的，例如在鐵塔腹材分析，CASE5-1(同邊一條地線及 C1~C3 導線未架線)之載重條件下，2D 分析結果較為不足，2D 分析偏不保守。一般而言，2D 圖解分析簡便快速，但是仍然需要電子計算機輔助 3D 分析，並且，於實務上應該避免類似 CASE5-1 的架線配置，確保鐵塔安全。



P27：謝謝各位專心聆聽。我來自美麗的國家台灣，我們擁有著名的地標台北 101 如右上照片，我在台灣電力公司工作，我們的員工所處的工作環境是艱困且具高風險，如左上照片，謝謝。

#### 肆、心得與建議

感謝公司能給予此次公務出國機會，得知奉派出國後即依出國題目，積極接洽出國行程，不斷的與印尼主辦單位相關人員連絡確認，辦理相關手續，準備英文簡報事宜，最後圓滿達成任務順利簡報完畢。此次參加的國內人員，大多為國內工程界的菁英與知名學者，同時也是國內土木工程相關規範的制定與研修重要人士，另外各國參與人員也均為各國工程界的一時之選，所以本次出國參與會議簡報可謂獲益良多。因為此行代表台灣電力公司與會，也得知亞太區如印尼的電力建設仍然缺乏，所以印尼方面也對於電力建設及交通建設等議題深感興趣，以下提出幾點心得與建議：

- 一、英文是重要的溝通工具。
- 二、專業能力及核心技術是根本。
- 三、積極參與國際會議能知識技術分享(Share knowledge)及適度展現本公司技術與能



力，同時了解國際技術演進，與時俱進。

四、本公司工程具參加評選獲獎實力。

五、未來展望：與國際接軌，拓展海外事業。

六、應長期參與，培育人才。人才是公司重要資產。

另外此次參與會議期間，針對會議內容較為印象深刻且可能成為未來趨勢者，一併紀錄於此報告，敘述如下：

一、變位控制設計法(Mete A. Sozen, Purdue University)：

在一般耐震設計法中，結構物的設計總是以「力」為唯一的依據，以產生多少「力」來設計結構物，這方法符合地心引力加上地震效應的概念，因為地心引力使結構物產生自重，再結合地震效應，模擬因為地震產生地震力(模擬成結構物自重乘上一定比率所得之水平力，當成地震水平力)，加載地震橫向力在結構物上，以此地震橫向力來設計結構物。

但是，今天換個角度來思考此一問題，地震搖晃結構物時，並非施加力量在結構物上，而是因為地震的搖晃，使結構物產生「變位」，造成結構物的損壞，「側向變形」的問題，才是耐震設計的主軸。結構物遭受強烈地震期間，會依據結構本身的勁度與強度，結構體本身因應地震變位，加載載重在自身結構物上產生力量的傳遞，如何抑制「變位」才是耐震設計的主軸，如何預測地震產生的變位是未來研究的新思考方向。

一般設計者均認為有「力」才能產生「變位」，變位和力相關連，如今以上述新觀念，「變位」是獨立的，變位的反應和結構的材料、勁度、阻尼、地表加速度等相關。

二、長跨距橋梁的振動控制(Yozo Fujino and Dionysius M. Siringoringo, University of Tokyo)：

在近年來，世界上建造越來越多的長跨距橋梁。風力，是影響長跨距橋梁最重要的因素，在以往僅考慮橋樑的強度是否足夠，忽略了因為風力使得橋梁產生振動之效應，雖然不至於使橋梁結構破壞，但卻影響了使用性。所以，新設計的長跨距橋梁，外觀造型必須考量流體力學，也因此外觀變得流線型，減低了風力振動的影響，降低橋面振動，增加使用性。

另外對於舊的橋梁，為抑制風所引致的振動，日本在這方面作了相當多的研究與實驗，日本方面的作法是在結構中加入阻尼，他們發現阻尼器的應用不僅可降低風力引致的振動效

應，也可應用於耐震設計的補強，所以目前的耐震補強作法即是採行加裝阻尼器的方式辦理。

上述 2 個議題，一者針對變位，一者針對振動控制，可能為現今土木工程設計與補強的兩大新思維與新作法，值得我們學習。

## 伍、 附錄-投稿文章

詳如次頁。

# STUDY OF STRUCTURAL ANALYSIS SOFTWARE MIDAS USED IN THE POWER TRANSMISSION TOWER

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## ABSTRACT

The computer structural analysis was not so popular in the early years, so the power transmission tower structural analysis were done by 2D graphical analysis. This method is to construct the force polygon based on the external force direction, magnitude and the tower member arrangement. Then we can obtain the tower member force by measuring a line length in the direction of tower member from the force polygon. This method is so convenient that no complicated calculations procedures are needed. However the actual situation is that the tower member arrangement is in 3 dimensional (3D), and the member forces induced by external forces were no doubt different from 2D plan graphical analysis. Hence, this study is to distinguish the difference between 2D and 3D structural analysis on power transmission tower, and the reliability and safety of 2D graphical structural analysis.

The study object is 161kV 4A1 model tower. Tower 3D model is created by structural analysis software MIDAS. Then input the loading cases1~6. And analyses are performed respectively. Analysis results of 2D and 3D will be compared in terms of tower main post, tower arm, and bracing.

The result of 2D and 3D structural analysis on tower main post seems similar. The main control loading case on tower main post is CASE2(60°wind). Adapting 2D graphical analysis on tower main post is reliable.

According to the result of structural analysis on tower arm, its control loading cases are broken wires and CASE6. The result shows that the member force value of 3D analysis is more than that of 2D graphical analysis. Fortunately, the allowable force of materials and bolts used on the tower are still higher than 3D analysis values. The tower arm is safe.

Below the tower panel 16(bend line), the bracing structural analysis control loading case is case5-1<sup>2</sup>. The analysis result of 2D graphical analysis is unsafe. Additional 3D structural analysis is necessary.

Generally, the 2D graphical structural analysis is fast, convenient, reliable. But the specific loading case as CASE5-1, should be avoided so as not to reduce the tower structural safety.

## BODY OF PAPER

This paper is to distinguish the differences between 2D and 3D analysis. The structural analysis software MIDAS is used in this paper to compare the 3D analysis results with traditional 2D analysis results. This paper mainly comprises of six sections, including tower types introduction, loading cases, material strength, safety factor, MIDAS 3D model and conclusions.

### Types of Power Transmission Tower

Taipower company's power transmission towers are divided into many types for all sorts of conditions. It is illustrated in Fig.1. and described as follows:

<sup>2</sup> one OGW(GW) any one CKT( C1~C3) on the same side not strung, please refer to Fig2.

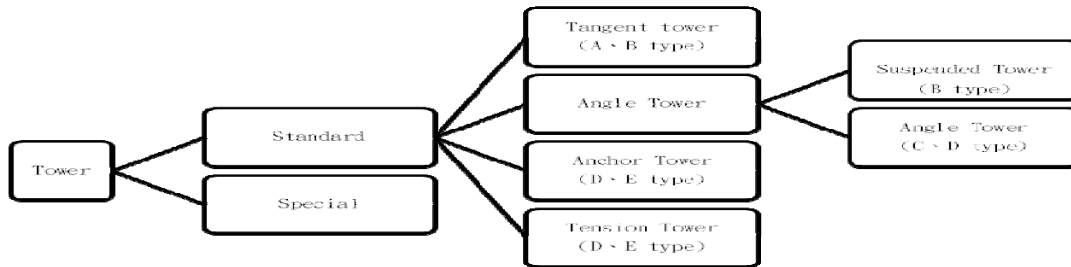


Fig. 1: Tower Types

Tangent: power transmission line rotate angle is small ( $3^{\circ}\sim 9^{\circ}$ ) (A,B type).

Angle: used in the line direction changed, suspended type used in line rotate angle smaller than  $9^{\circ}$  (B type); for angle smaller than  $30^{\circ}$  (C or D type).

Anchor: used at the two end of transmission line to support the transmission line of the whole towers (D or E type), also used in line rotate angle over than  $30^{\circ}$

Tension: D or E type, used in fixed distance to insure the transmission line strength, or used in the terrain where elevation difference is big and long span.

Special : overpass the river or mountain valley, long span or any other special spot.

## Tower Structure Description

Tower structure description as the following Fig.2. From top to bottom, every panel are numbered in sequence (such as 1 2 3 note on each panel ) so as to identify the tower member location, such as tower main post , bracing.

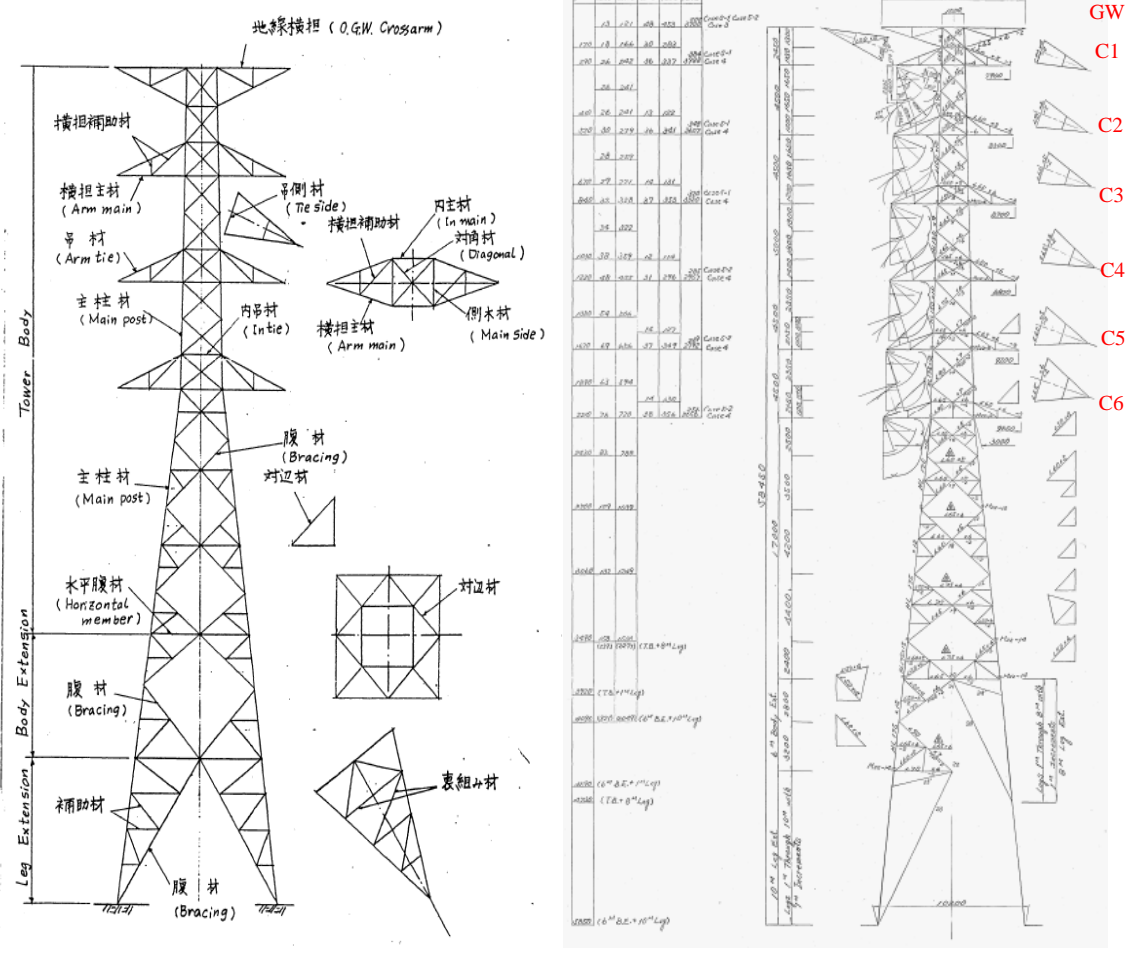


Fig. 2: Tower Structure Description

### Applied Loads

- Tower weight: bolt, gusset plate, angle, ladder, etc.
- Vertical load : conductor, insulator weight, and the conductor string’s vertical direction load.
- Transverse load: wind on conductor, insulator and string’s transverse direction load.
- Longitudinal load: the unbalance load of conductor and grounding wire.

### Taiwan Wind Zone

Taiwan wind zone are divided into 2 zones, east and west (see Fig3). The important transmission power line in east Taiwan, the design wind pressure is 300kg/m<sup>2</sup>. In the west zone, the important transmission power line’s design wind pressure is 260kg/m<sup>2</sup>.

(附錄四)  
輸電鐵塔設計標準基準速度壓劃分圖

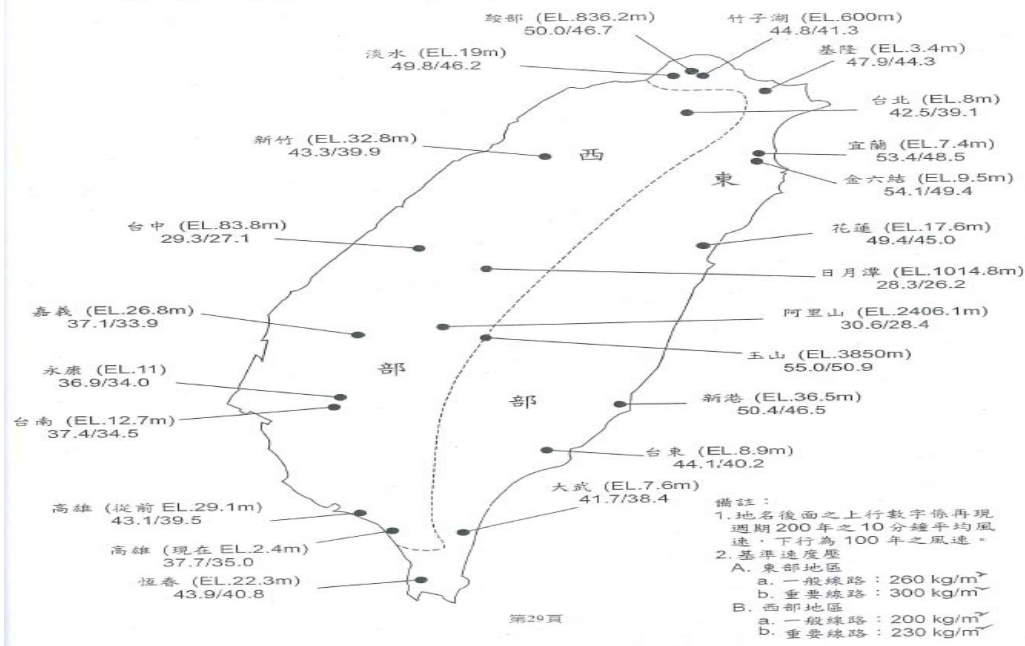


Fig. 3: Taiwan Wind Zone

## Loading Cases

The study object is 161kV 4A1 tower, and the input loading cases is shown on Fig.4.

Case1 : All wires Intact, O.L.F.=1.1, Wind pressure 760kg/m<sup>2</sup>.

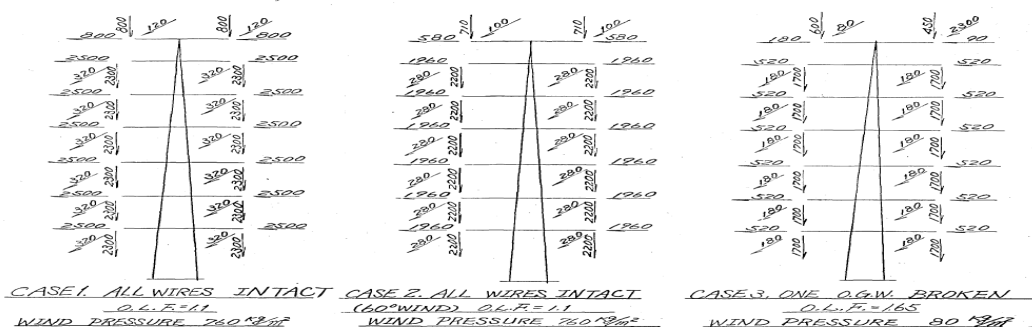
Case2 : All wires Intact(60° wind) ,O.L.F.=1.1 ,Wind pressure 760kg/m<sup>2</sup>.

Case3 : One O.G.W. broken, O.L.F.=1.65, Wind pressure 80kg/m<sup>2</sup>.

Case4 : Any one cond. Broken, O.L.F.=1.65, Wind pressure 80kg/m<sup>2</sup>.

Case5 : One O.G.W. and any one CKT one the same side not strung, O.L.F.=1.1, Wind pressure 760 kg/m<sup>2</sup>.

Case6 : Double vertical or broken wires (for cross arms only), O.L.F.=1.65.



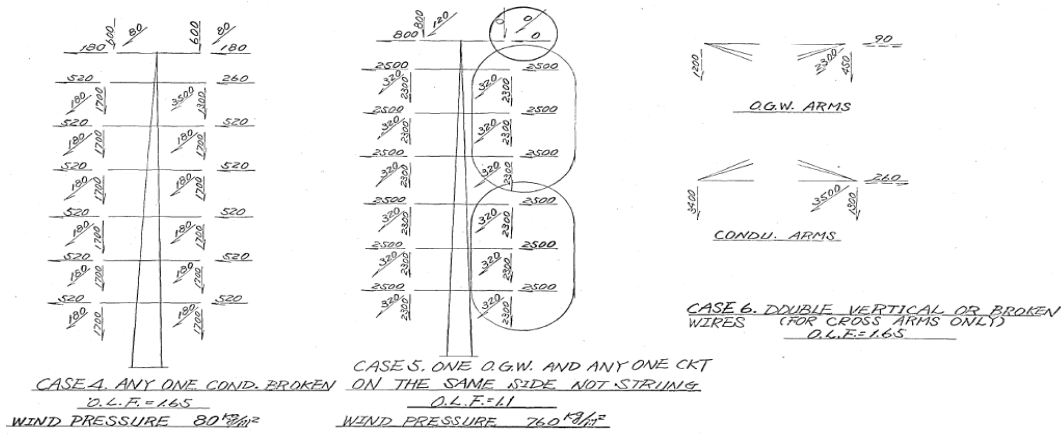


Fig. 4: Loading Diagram

## Material Allowable Strength

Compression :

$$C_s = F_c \cdot A$$

( $C_s$ : compression force,  $F_c$ : buckle stress,  $A$ : section area)

As to  $F_c$ , it is calculated as follows:

As  $0 < KL/R < C_c$ ,

$$F_c = F_y \left\{ k_0 - k_1 \left[ \frac{(KL/R)}{\pi \sqrt{E/F_y}} \right] - k_2 \left[ \frac{(KL/R)}{\sqrt{E/F_y}} \right]^2 \right\}$$

As  $C_c \leq KL/R$ ,

$$F_c = \frac{1.5 \pi^2 E}{2.2 (KL/R)^2}$$

For main post calculation ,

$$K=0.9, K_0=0.945, K_1=0.0123, K_2=0.316, K_k=0.5$$

For bracing calculation ,

$$F_c \leq 0.6F_y, K=0.9, K_0=0.939, K_1=0.424, K_2=0, K_k=0.3$$

Tension:

For the axial tension stress  $F_t = F_y$ , ( $F_t \leq 0.7F_u$ )

( $F_t$ : tension force,  $F_y$ : yield stress,  $F_u$ : ultimate stress)

Tension force  $T_s = F_t \cdot A_t$

( $T_s$ : tension force,  $F_t$ : tension stress,  $A_t$ : effective net section area)

## Over Load Factor (Safety Factor)

Gust, Over Load Factor=1.1.

Consider the wire broken, all wires intact, 60°wind, one circuit on.

Normal, Over Load Factor=1.65.

Considering the seasonal wind in Taiwan island and safety wind speed for working on tower, it is necessary to take broken wires into account while working on towers ( any ground wire or conductor broken).

## MIDAS 3D Calculation

161kV/161kV 4A1tower, height 58.45m (6m tower body extension, 10m leg), tower weight 23.4 ton. Use the MIDAS structural analysis software, build the tower 3D model, and then input the case1~6 loading cases. The MIDAS 3D interface is shown on Fig.5.

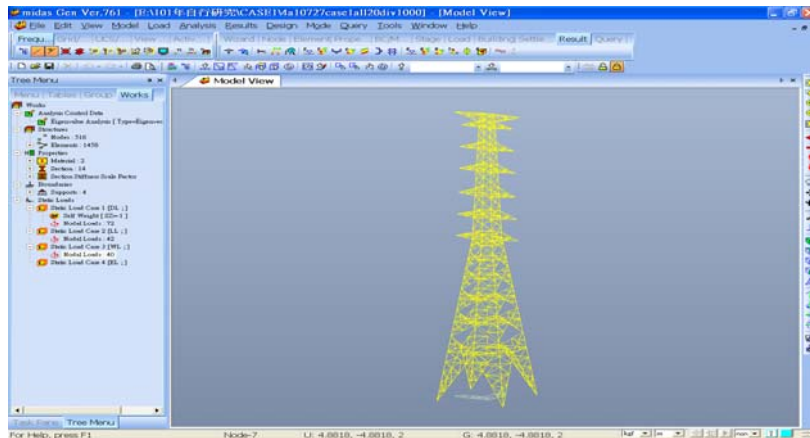


Fig. 5: Midas 3D interface

## Conclusion and Discussion

Whether the traditional 2D graphical analysis is reliable and safe as well as which loading cases might be influential to the tower safety are the main purposes of this research. The research results, which summarize the 2D's and 3D's analysis comparison regarding every panel's member force and the control loading cases, are shown on Table1, Table 2 and Table 3.

1. Main post: the 2D's and 3D's analysis result seems similar, the main control loading cases is CASE2(60°wind).
2. Bracing: under the panel 16, the main loading case is case5-1(one OGW any one CKT on the same side not strung), it shows the 2D analysis is unsafe. It is believed that unstringing one side will release the tower loading, but, in fact, it turns the tower to unsafety. Consequently, for practical loading cases, case5-1 should be avoided to keep towers safe.

Tab.1: Main Post Analysis Result Comparison

2D Analysis				3D analysis					Used Material Strength				
Mark	total stress		O.L.F.	Mark	total stress		O.L.F.	check	O.L.F.	Member strength		Bolt strength	
	Load	O.L.F.			Load	O.L.F.				Strength	Material	BOLT	
			CASE				O.L.F.	Ratio			bearing	shear	
Post	1	-500	-830	3	1	-737	-1220	6	NG	1.470	-13260	L65X6	13160
		1280	2120			6	OK				0.594		
	2	-2720	-3000	5-1	2	-1358	-2120	6	OK	0.707	-13260	L65X6	
		4860	5990			6	OK				0.913		
	3	0	0		3	-2671	-2940	2				L90X7	
		0	0			6200	1						



4	-7560	-8320	1	4	-6011	-6620	2	OK	0.796	-24070	L90X7	19740
	9930	10930	1		9869	10860	1	OK	0.994	20300		
5	-10800	-11880	1	5	-7913	-8710	2	OK	0.733	-24070	L90X7	19740
	14540	16000	1		13762	15140	1	OK	0.946	24130		
6	0	0		6	-13109	-14420	2				L100X10	19740
	0	0			18805	20690	1					
7	-21020	-23130	1	7	-18437	-20280	2	OK	0.877	-35250	L100X10	48630
	25060	27570	1		25045	27550	1	OK	0.999	33640		
8	-25680	-28250	1	8	-21718	-23890	2	OK	0.846	-35250	L100X10	48630
	31210	34340	1		30399	33440	1	OK	0.974	38850		
9	0	0		9	-28613	-31480	2				HL130X9	65530
	0	0			37042	40750	1					
10	-39410	-43360	1	10	-36016	-39620	2	OK	0.914	-70570	HL130X9	65530
	45320	49860	1		45392	49940	2	NG	1.002	63960		
11	-45970	-50570	2	11	-40636	-44700	2	OK	0.884	-70570	HL130X9	65530
	53340	58680	1		51870	57060	2	OK	0.972	73310		
12	-54680	-60150	2	12	-50613	-55680	2	OK	0.926	-93590	HL150X10	87370
	62210	68440	1		62225	68450	2	NG	1.000	72870		
13	-65530	-72090	2	13	-61657	-67830	2	OK	0.941	-93590	HL150X10	87370
	74730	82210	2		74745	82220	2	NG	1.000	103810		
14	-77190	-84910	2	14	-72498	-79750	2	OK	0.939	-122040	HL175X12	131060
	86830	95520	2		87329	96070	2	NG	1.006	115270		
15	-89320	-98260	2	15	-84173	-92590	2	OK	0.942	-122040	HL175X12	131060
	100700	110770	2		100286	110320	2	OK	0.996	147410		
16	-96880	-106570	2	16	-92339	-101580	2	OK	0.953	-122040	HL175X12	152900
	108700	119570	2		110632	121700	2	NG	1.018	142500		
17	-99780	-109760	2	17	-93292	-102630	2	OK	0.935	-122040	HL175X12	152900
	112140	123360	2		111560	122720	2	OK	0.995	136550		
18	-103370	-113710	2	18	-98973	-108870	2	OK	0.957	-122040	HL175X12	152900
	116450	128100	2		117861	129650	2	NG	1.012	145420		
19	-107400	-118140	2	19	-101585	-111750	2	OK	0.946	-122040	HL175X12	152900
	121340	133480	2		121101	133220	2	OK	0.998	145420		
20	-111730	-122910	2	20	-107465	-118220	2	OK	0.962	-150860	HL175X15	152900
	128150	140970	2		127763	140540	2	OK	0.997	180200		
21	-111920	-123120	2	21	-107254	-117980	2	OK	0.958	-150860	HL175X15	152900
	127060	139770	2		127973	140770	2	NG	1.007	174580		
22	-117550	-129310	2	22	-114157	-125580	2	OK	0.971	-150860	HL175X15	152900
	136210	149840	2		133729	147110	2	OK	0.982	168050		
23	-117550	-129310	2	23	-113417	-124760	2	OK	0.965	-150860	HL175X15	

	136210	149840	2		135120	148640	2	OK	0.992	156500	
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Unit : kg      Compression:+      Tension:-

Tab.2: Bracing Analysis Result Comparison

2D Analysis

3D analysis

Used Material Strength

Mark	total stress			O.L.F.	CASE	Mark	total stress			O.L.F.	check	O.L.F.	Member strength			Bolt strength	
	Load	O.L.F.	O.L.F.				Load	O.L.F.	O.L.F.				Ratio	MEMBER		BOLT	
														Strength	material	BOLT	
								comp	tens			bearing	shear				
Bracing	1	3180	5250	3		1	1726	2850	3	OK	0.543	6810	-7800	L50X6		6580	
	2	2860	4720	3		2	2766	4570	6	OK	0.968	4870	-5440	L50X4	6980		
	3	4150	6850	4-1		3	3703	6110	4-1	OK	0.892	7400	-8560	L60X5	8730		
	4	3860	6370	4-1		4	3711	6130	4-1	OK	0.962	7130	-8560	L60X5	8730		
	5	3480	5320	4-1		5	3009	4970	4-1	OK	0.934	6150	-7800	L50X6		6580	
	6	4310	6290	4-2		6	4803	5890	4-2	OK	0.936	6930	-8560	L60X5	8730		
	7	4180	5930	4-2		7	3544	5670	4-2	OK	0.956	6660	-8560	L60X5	8730		
	8	4430	5100	4-2		8	3704	4660	4-2	OK	0.914	5560	-7800	L50X6		6580	
	9	5860	6450	1		9	6404	7050	1	NG	1.093	8460	-11330	L65X6		6580	
	10	5720	6300	1		10	5086	5600	5-2	OK	0.889	8200	-11330	L65X6		6580	
	11	6600	7260	5-2		11	5652	6220	1	OK	0.857	8730	-11330	L65X6		9870	
	12	7870	8660	1		12	7832	8620	1	OK	0.995	9510	-13580	L75X6		9870	
	13	8830	9720	5-2		13	7408	8150	1	OK	0.838	15880	-18970	L90X7	10190		
	14	9210	10140	1		14	9176	10100	1	OK	0.996	15030	-18970	L90X7	10190		
	15	9610	10580	5-2		15	8790	9670	1	OK	0.914	15170	-18970	L90X7	15280		
	16	3910	4390	4-6		16	4119	4530	5-1	NG	1.032	6190	-8560	L60X5	5820		
	17	3970	4370	5-1		17	4356	4800	5-1	NG	1.098	5720	-8560	L60X5	5820		
	18	3880	4270	5-1		18	4306	4740	5-1	NG	1.110	4560	-8560	L60X5	5820		
	19	3780	4160	5-1		19	4332	4770	5-1	NG	1.147	5500	-11330	L65X6		6580	
	20	4500	4950	5-1		20	4590	5050	5-1	NG	1.020	5830	-11330	L65X6		6580	
	21	4050	4460	5-1		21	4660	5130	5-1	NG	1.150	6200	-12980	L75X6	8730		
	22	5470	6020	5-1		22	6888	7580	5-1	NG	1.259	10910	-18970	L90X7	10190		
	23	9020	9930	5-1		23	10334	11370	5-1	NG	1.145	12320	-18970	L90X7	10190		

Unit : kg      Compression: +      Tension: -

Tab.3: Arm Analysis Result Compassion

		2D analysis			MIDAS 3D analysis				Used Material Strength					
Mark	total stress		O.L.F.	CASE	Mark	total stress		O.L.F.	check	O.L.F.	Material strength		Bolt strength	
											MEMBER	BOLT	Strength	material
Load		O.L.F.			Load		O.L.F.	CASE		Ratio				
Main	G.W.	-7420	-12250	6	Main	G.W.	-2157	-3560	3	OK	0.291	-24070	L90X7	13160
		6680	11030	6			3925	6480	3	OK	0.587	14270		
	C1	-7040	-11620	6		C1	-3659	-6040	4-1	OK	0.520	-24070	L90X7	16450
		8890	14670	6										
	C2	-6270	-10350	6		C2	-3037	-5020	4-2	OK	0.485	-24070	L90X7	16450
		8090	13350	6										
	C3	-5670	-9360	6		C3	-177	-200	5-1	OK	0.021	-24070	L90X7	13160
		7560	12480	6										
	C4	-4970	-8200	6		C4	0	0	6	OK	0.000	-16260	L75X6	13160
		6570	10840	6										
	C5	-4620	-7630	6		C5	-1266	-2090	4-5	OK	0.274	-24070	L90X7	13160
		6720	11090	6										
C6	-4390	-7250	6	C6	-948	-1570	4-6	OK	0.217	-24070	L90X7	13160		
	6550	10810	6										5773	9530
Tie	G.W.	0	0	6	Tie	G.W.	-4432	-7320	3	NG	1.339	-11330	L65X6	6580
		2070	3420	6			2776	4580	3			4200		
	C1	-5100	-8420	6		C1	-5136	-8480	6	NG	1.007	-8560	L60X5	8730
		0	0	6										
	C2	-5070	-8370	6		C2	-5082	-8390	6	NG	1.002	-8560	L60X5	9730
		0	0	6										
	C3	-5210	-8600	6		C3	-5524	-9120	6	NG	1.060	-11330	L65X6	9870
		0	0	6										
	C4	-4490	-7410	6		C4	-4510	-7450	6	NG	1.005	-7800	L50X6	9870
		0	0	6										
	C5	-5720	-9440	6		C5	-5748	-9490	6	NG	1.005	-11330	L65X6	9870
		0	0	6										
	C6	-5890	-9720	6		C6	-5919	-9770	6	NG	1.005	-11330	L65X6	9870
		0	0	6										
		500	550	5-2			0	0	6	OK	0.000	3460		
	C5	-2150	-3550	6		C5	-2400	-3020	6	OK	0.851	-13580	L75X6	6580
530		590	5-2	251	280									

	C6	-2350	-3880	6		C6	-9350	-10290	1	NG	2.652	-19670	L90X7	9870
		580	640	5-2			7053	7760	1	NG	12.125	14600		

*Unit : kg                      Compression:+      Tension:-*

## **BRIEF BIOGRAPHY OF PRESENTER**

Jeremy Huang was born on 26 July 1976, in Lu-kang, central Taiwan. He graduated from National Central University, where he studied civil engineering. After completing his studies in graduate school, he worked in Taiwan High Speed Rail substructure construction contract C250. In 2005, he obtained the license of professional civil engineering and entered Taipower company working as a civil engineer.