

出國報告（出國類別：其他）

參加 2016 年國際結構混凝土學會 研討會

服務機關：交通部臺灣區國道新建工程局

姓名職稱：彭繼賢幫工程司

派赴國家：南非

出國期間：105 年 11 月 18 日至 105 年 11 月 27 日

報告日期：106 年 2 月 10 日

摘要

國際結構混凝土學會(International Federation for Structural Concrete, fib) 目前致力於推動世界混凝土結構的科技、經濟、美學及環境影響等，藉由研究的推展、理論與實務的結合、各項出版品的發行、技術規範的編修、研討會的定期舉行，期望提升世界混凝土結構的水準。

國際結構混凝土研討會(fib symposium)為該組織每年的重大活動，由不同的會員國舉辦，今年舉辦的時間為 105 年 11 月 21 日至 23 日共 3 天，地點選在南非開普敦大學商業研究院(University of Cape Town’ s Graduate School of Business, GSB)，研討會主軸為” 以性能為基礎的混凝土結構”(performance-based approaches for concrete structures)，將世界各地的混凝土專家及工程師集合於當地，發表展示各項研究成果，另邀工程顧問公司、設備機具、材料廠商等當地的混凝土產業共襄盛舉，展示最新技術，藉以提升工程技術與品質。

本報告除將參加前述國際性研討會的目的、過程作一說明外，也針對開普敦當地的大眾運輸系統(IRT)及途經香港的青嶼幹線訪客中心作一簡單介紹，最後為筆者的心得與建議。

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一、前言與目的

國際結構混凝土學會(International Federation for Structural Concrete, fib)前身為歐洲混凝土委員會(Euro-International Committee for Concrete, CEB)及國際預力聯盟(International Federation for Prestressing, IFIP)，這兩個組織早期是各自運作，直到1998年才合併成為國際結構混凝土學會(fib)。國際結構混凝土學會為非官方認證的組織，目前有43個會員國，超過1,000名個人或團體會員，就像世界上大多數國際組織一樣，該學會的總部設在瑞士桑拿(Lausanne)。

國際結構混凝土學會(fib)目前致力於推動世界混凝土結構的科技、經濟、美學及環境影響等，藉由研究的推展、理論與實務的結合、各項出版品的發行、技術規範的編修、研討會的定期舉行，期望提升世界混凝土結構的水準。

國際結構混凝土研討會(fib symposium)為該組織每年的重大活動，由不同的會員國舉辦，將世界各地的混凝土專家及工程師集合於當地，發表各項研究成果，此外，活動也與當地的混凝土產業結合，以展示最新技術；研討會活動於每四年擴大舉行。

國際結構混凝土學會研討會(fib symposium)今年舉辦的時間為105年11月21日至23日，地點選在南非開普敦。本次研討會主軸為”以性能為基礎的混凝土結構”(performance-based approaches for concrete structures)，計253篇專題報告及研究論文全方位發表，藉由參加此次研討會，與國際結構、材料工程等專家學者直接交流並汲取新知，提供本局後續工程相關設計及施工參考。

二、過程

(一)行程概要介紹

本次會議舉辦的地點-南非開普敦，由於本國籍班機無直飛該地，經上網搜尋航空公司相關機票套票後發現，大部分航空公司皆安排一次或兩次轉機，由於一次轉機之交通費用較高，在預算考量下，選擇搭乘南非航空，所幸入境出關過程堪稱順利，惟轉機時需花費較多等待時間。

本次出國行程於 11 月 18 日自臺北出發，於香港、約翰尼斯堡(簡稱”約堡”)轉機，11 月 19 日中午抵達開普敦，因香港轉機等待時間較長，趁轉機空檔前往香港青洲幹線訪客中心，了解全球最長的公路及鐵路兩用懸索橋(吊橋)-青馬大橋建造過程。



本次研討會出國飛行路線圖

旅館休息一晚調整時差後，隔日 11 月 20 日前往研討會舉辦地點-開普敦大學辦理報到，參與主辦單位舉辦的歡迎酒會。11 月 21 日至 11 月 23 日為此次研討會的重心，筆者參加會議現場的專題演講、論文發表及廠商展覽等活動，聆聽各專家、學者及研究人員對於各議題研究之分享，以及各家廠商對於新型產品設備之介紹；研討會結束後，於 11 月 24 日至 11 月 25 日自行參訪當地建設，最後於 11 月 26 日搭乘南非航空返國，11 月 27 日抵達國門。

行程紀要表

日期	起訖地點	行程摘要
11月18日(五)~ 11月19日(六)	臺灣→香港 →約堡→開普敦	去程；參訪香港青嶼幹線訪客中心 (搭飛機於香港、約翰尼斯堡轉機)
11月20日(日)	開普敦	大會報到、歡迎酒會
11月21日(一)	開普敦	大會開幕式 專題演講、研討會論文發表、廠商展覽
11月22日(二)	開普敦	專題演講、研討會論文發表、廠商展覽
11月23日(三)	開普敦	專題演講、研討會論文發表、廠商展覽
11月24日(四)~ 11月25日(五)	開普敦	建設參訪
11月26日(六)~ 11月27日(日)	開普敦→約堡 →香港→臺灣	回程 (搭飛機於香港、約翰尼斯堡轉機)

(二)2016 國際混凝土學會研討會 (fib symposium 2016)

1.會議時間地點

國際結構混凝土學會研討會(fib symposium)今年舉辦的時間在 105 年 11 月 21 日至 23 日共 3 天,地點選在南非開普敦大學商業研究院(University of Cape Town's Graduate School of Business, GSB),開普敦大學是非洲最古老的大學之一,而其商業研究院(GSB)鄰近維多利亞和阿爾弗雷德水濱區(Victoria & Alfred Waterfront),附近還有桌山(Table Mountain)國家公園,位置便利,環境優美,學術氣息濃厚,再加上附近旅館飯店選擇性多,十分適合舉行相關研討會議。



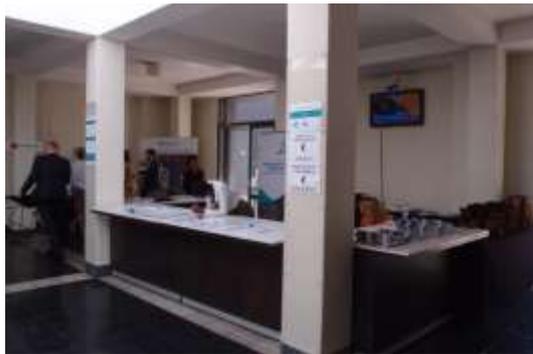
開普敦大學商業研究院位置圖



開普敦大學商業研究院實景照

2. 會議議程內容

本次研討會有來自 53 個國家，共計 420 人報名參加，研討會前一天，主辦單位提早辦理註冊及報到，可避免開幕當天報到的紛亂；另舉行歡迎酒會並介紹相關來賓，讓與會人士先行互相了解，會場上氣氛熱落，足見主辦單位之用心。



會場報到處



歡迎酒會



會議資料袋



研討會論文集及名牌

會議第 1 天上午先進行開幕式，由本次會議主席 Dr. H. Beushausen 發言，報告本次活動準備狀況、參與人數，也順便介紹自己的國家-南非，包含著名的作家、藝術家、著名的建設如拱橋、高鐵等等，讓與會人士更加了解南非。最後在專題演講開始前，主席介紹第一場專題來賓的求學過程、家庭、休閒活動、專長、職業以及對 fib 學會的貢獻等，足見主辦單位的體貼與細心。開幕式告一段落後，隨即展開 3 天的專題演講(Keynote lecture)與論文研討(Sessions)。



會議報到處



開幕式演講廳

本次研討會專題演講及論文研討，每天有四個場次，每日上午第一場次為專題演講，由主辦單位邀請各國著名的學者進行一系列的演講；論文研討則於專題演講後分於 5 個演講廳進行論文發表，每篇發表的時間約 15 分鐘，並讓參與人員自由發問，每個場次皆自由參加。

會議議程表

MONDAY 21 NOV					
SESSION 1 08:00-10:00	Welcome Keynote lectures				
SESSION 2 10:30-12:15	Structural analysis and design of members and structures	Structures exposed to seismic loading	Precast technology	Fibre-reinforced concrete	Analysis and design: Flexural and prestressed members
SESSION 3 13:15-14:15	Keynote lectures				
SESSION 4 14:20-15:30	Structural analysis and design of members and structures	Structures exposed to seismic loading	Precast technology	Fibre-reinforced concrete	Analysis and design: Flexural and prestressed members
SESSION 5 16:00-17:45	Structural analysis and design of members and structures	Case studies	Precast technology	Fibre-reinforced concrete	Analysis and design: Flexural and prestressed members
TUESDAY 22 NOV					
SESSION 6 08:30-10:00	Keynote lectures				
SESSION 7 10:30-12:15	Structural analysis and design of members and structures	Bridge structures	Materials, production, testing, modelling, construction	Analysis and design: Shear and torsion	Durability and service life
SESSION 8 13:15-15:00	Structural analysis and design of members and structures	Bridge structures	Materials, production, testing, modelling, construction	Analysis and design: Shear and torsion	Durability and service life
SESSION 9 15:30-17:15	Structural analysis and design of members and structures	Bridge structures	Materials, production, testing, modelling, construction	Analysis and design: Shear and torsion	Durability and service life
WEDNESDAY 23 NOV					
SESSION 10 08:30-10:00	Keynote lectures				
SESSION 11 10:30-12:15	Structural strengthening	Bridge structures	Materials, production, testing, modelling, construction	Deterioration mechanisms and reinforcement corrosion	Durability and service life
SESSION 12 13:15-15:00	Structural strengthening	Protection and repair of structures	Shrinkage and creep	Deterioration mechanisms and reinforcement corrosion	Condition assessment of structures
SESSION 13 15:30-17:15	Structural strengthening	Protection and repair of structures	Shrinkage and creep	Deterioration mechanisms and reinforcement corrosion	Condition assessment of structures



專題演講會場



論文發表會場

本次研討會除專題演講及論文發表外，另外在會場周圍還有廠商展覽 (Exhibits)，參展攤位種類繁多，包含檢測儀器展示、新型材料、設備介紹等，部分攤位也提供書面資料、光碟片及紀念品供與會者索取。下一屆研討會主辦國-荷蘭也設有攤位，熱情邀與會人士參與明年度的盛會。



廠商展覽攤位



展覽書籍刊物及紀念品

3.會議主題摘要

研討會主軸為”以性能為基礎的混凝土結構”(performance-based approaches for concrete structures)，計 253 篇專題報告及研究論文全方位發表，概分為 14 個主題類型如後：

- (1) Structural analysis and design of members and structures
(結構與桿件的分析與設計)
- (2) Structures exposed to seismic loading (承受地震荷載的結構)
- (3) Precast technology (預鑄技術)
- (4) Fibre-reinforced concrete (纖維混凝土)
- (5) Analysis and design: Flexural and prestressed members
(抗彎及預力桿件的分析與設計)
- (6) Bridge structures (橋梁結構)
- (7) Materials, production, testing, modelling, construction
(材料，生產，測試，模擬及施工)
- (8) Analysis and design: Shear and torsion (剪力及扭力的分析與設計)
- (9) Durability and service life (耐久性與服務年限)
- (10) Structural strengthening (結構強化)
- (11) Protection and repair of structures (結構的保護和修復)
- (12) Shrinkage and creep (乾縮及潛變)
- (13) Deterioration mechanisms and reinforcement corrosion (性能損失和鋼筋腐蝕)
- (14) Condition assessment of structures (結構狀態的評估)

以下針對幾個不同的議題論文，作概要性的介紹說明。

論文名稱：Concrete Bridge Design for Aesthetical Performance

(混凝土橋梁設計的美學)

本文著眼於混凝土橋梁設計的過去、現在和未來，以及從概念設計到最終成品的美學，然後最重要的是，社會大眾對於結構物應如何被建造完成？本文以一些計畫和建設作為案例研究，強調混凝土結構和橋梁結構的美學，從來沒有絕對

的答案。

在過去，南非的橋梁和世界上許多混凝土橋梁一樣，著重在其功能性，很少或完全缺乏視覺吸引力。除了指標性或特色橋梁外，建築師可能不一定參與橋梁設計過程，橋梁設計初期的主要重點通常在建築成本，很少注意美學。

本文重點在於橋梁美學，以過去十年創建的幾座橋梁為例，不論是特殊性橋梁或一般性橋梁，作者認為應更廣泛考慮規劃和設計問題。

橋梁設計者有責任充分發揮他們的創造力，證明自己在建造過程中，對美學細緻和發展產生影響作用。依作者的經驗是，只需多一點或根本不需要額外費用，就可以使混凝土橋梁兼具美感。



論文名稱：A MULTI-FEATURED ARCH BRIDGE IN INDIA

(印度的多特點拱橋介紹)

拱橋已經為美學和從遠古以來的優越力學行為而廣為人知。此外，最近的橋梁設計的發展和經驗已經看到一體性結構的出色性能，特別是在嚴重的地震和洪水易發區域。位於印度喜馬偕爾邦州國道 88 號 (NH88) 的 Baner khad 橋是這樣一個獨特的一體性拱橋，繼承了拱橋及一體性橋梁的優點。橋梁的不對稱形狀，靈感來自另一邊的小山丘，給橋梁添加了些許稚氣，因為它不涉及大規模破壞美麗的丘陵環境。本文描述橋梁主要工作項目的特徵、結構系統、設計細節、施工方法和數量。看著橋梁可以意識到，對自然環境投入一點點情感及用心，就可以創造一個特殊的橋梁，不僅優雅而且具有許多明顯的優點，例如增強力學性能以面對強烈的地震及洪水；在沒有支承和中間伸縮縫的情況下，提高了橋梁耐久性、

增加了車輛乘載的舒適度並減少了維護需求。

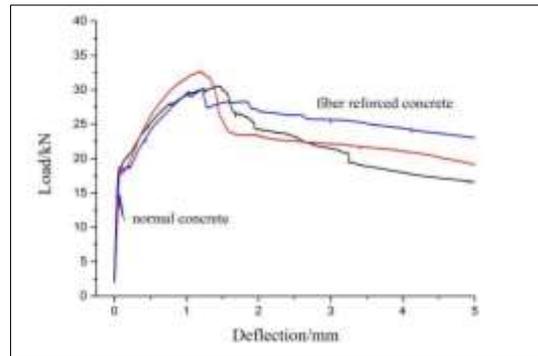


論文名稱：Performance-Based Design of Bridges and the Brenner Base Tunnel
(橋梁及布倫納隧道的性能設計)

性能設計法目前已把材料及載重不確定因子及潛變的行為納入考慮，並應用在已存在的橋梁及擁有 64 公里鐵路的布倫納隧道。其中半機率近似法正發展將隧道結構及設備納入考量；部分具體的安全係數把生命週期年限超過 200 年的隧道納入考量；既有橋梁的穩固性參數也納入本研究中。

論文名稱：FLEXURAL PERFORMANCE OF HYBRID FIBER REINFORCED
CONCRETE PRECAST TUNNEL SEGMENT
(混合型纖維鋼筋混凝土預鑄環片的延展性)

在本文中敘述混合纖維混凝土（HFRC）和 HFRC 隧道環片的彎曲性能測試結果，並且已能根據規範 RILEM TC 162-TDF 和 CJJ / T 164-2011 計算得出。結果表明，在縱向鋼筋比降低了 21.4% 狀況下，混合纖維混凝土的抗彎性能並不遜於一般混凝土，兩種類型混凝土跨度中間的荷載-變形曲線特性不同，混合纖維混凝土沒有明顯的降服點，達到降服荷載後，進一步加載則有限。混合纖維混凝土的極限應力狀態也可以根據“fib 混凝土結構規範(2010)”進行估算。



(三)開普敦地區大眾運輸系統

本次出國行程，筆者利用參加研討會之餘，參觀開普敦大眾運輸交通系統-MyCiTi，簡要介紹如下。



MyCiTi 是開普敦的綜合快速公車系統 (Integrated Rapid Transit, IRT)，提供快速、舒適和具有成本效益的城市運輸。它有著專用的基礎設施，快速和頻繁的運轉，以及卓越的經營和客戶服務。這個概念類似我們所熟悉的公車捷運系統(Bus Rapid Transit, BRT)。MyCiTi 幾乎具備與現代化的軌道運輸系統相同的性能和舒適，但其成本通常是電車或輕軌運輸系統的四分之一到二十分之一，鐵路系統的十分之一到百分之一。值得注意的是，通過設置安全人員和使用閉路電視攝像機，來維護旅客的安全和保安。

MyCiTi 包含主線與支線目前共有 44 條路線，主線行經開普敦重要地標及區域，擁有專用公車道、優先號誌系統，車體為雙節式公車，車站為封閉式車站，收費方式採車外收費，與我們一般所熟知的公車捷運系統(BRT)相似。



主線雙節式公車



主線封閉式車站



車站內部實景



站外收費閘門



公車專用道及優先號誌

支線通常行駛於偏遠或人口較少區域，以主線車站為起點，使用混合車道，車體為單節公車，車站為一般公車站牌，收費方式採車上收費，支線系統與臺灣目前城鎮所採用的公車系統相同。



支線公車等候站



單節式公車



公車內部實景

MyCiTi 第一階段建置歷程如下：

2007 年 開始系統建置。

2010 年 開通前往開普敦體育場、機場和內城附近的臨時服務。

2011 年 第一條路網推出。(包含市政中心站前往 Table View、Blaauwberg 和 Parklands)

2013 年 鹽河火車站和中央城市之間的線路開通，在 Oranjezicht、Tamboerskloof、Sea Point、Camps Bay 和 Hout Bay 等地區提供服務。

近期 延伸到中心城市北部地區，包括 Atlantis, Dunoon、Joe Slovo Park、Montague Gardens、Melkbosstrand 等地區。

接下來第二階段將提供更廣泛的服務於城市的東南地區，包括米切爾平原和卡雅利沙，目的地延伸整個半島；第三階段將包括貝爾維爾，代爾夫特等北方剩餘區域和斯泰倫博斯；第四階段擴大至 Helderberg 地區。

預計整個系統建設時間約需 20 年，每個階段都將在資金到位時開始施工，其中大部分資金來自國家交通部公共交通基礎設施和系統撥款，餘額由城市資助。

(四)香港青嶼幹線訪客中心簡介

本次出國行程，由於飛行航線途經香港，因此趁轉機之餘參訪青嶼幹線訪客中心，也順便了解青馬大橋及其所屬之香港機場核心計畫。

1.青嶼幹線訪客中心及觀景台

香港機場核心計畫（Hong Kong Airport Core Programme）是香港一件規模龐大的基礎建設發展計畫，1980 年代啟德機場的容量已經飽和，同時面對接近民居、無法 24 小時運作、飛航安全及擴建困難等問題，搬遷已經刻不容緩。因此 1989 年香港總督宣布興建新機場及相關配套設施(即香港機場核心計畫)，以穩定香港市民的信心。該計畫以大嶼山赤鱗角興建的新香港國際機場為核心，包括赤鱗角機場、機場鐵路、青嶼幹線、北大嶼山公路、西九龍填海計畫、西區海底隧道、3 號幹線（葵涌段及青衣段）、西九龍快速公路、中區填海計畫(第一期)、東涌新市鎮(第一期)等十項核心工程。



香港機場核心計畫工程分布圖

青嶼幹線訪客中心位於青衣島西北面，是香港一所介紹青嶼幹線的展覽館，占地面積 19,000 平方公尺，1997 年 5 月隨青嶼幹線通車正式對外開放。館裡有青嶼幹線的建造資料，包含青嶼幹線的模型、照片及展覽版。該處亦播放錄影帶，介紹青馬大橋建築過程和機場核心計畫，訪客中心內另設有兩部電腦，內置問答小遊戲，可增加訪客對青嶼幹線的認識。中心外面的觀景台擺放青馬大橋的一段主纜橫切面，以及相關橋梁組件戶外展覽，由於位置地點佳，旅客在此可以近距離或高角度，遠眺青馬大橋及汀九橋。



青嶼幹線訪客中心及觀景台



主纜實尺寸構件



望遠鏡

觀景台設施介紹



訪客中心外部實景



訪客中心內部實景



橋梁建造歷史介紹



橋梁細部構件介紹



橋梁模型



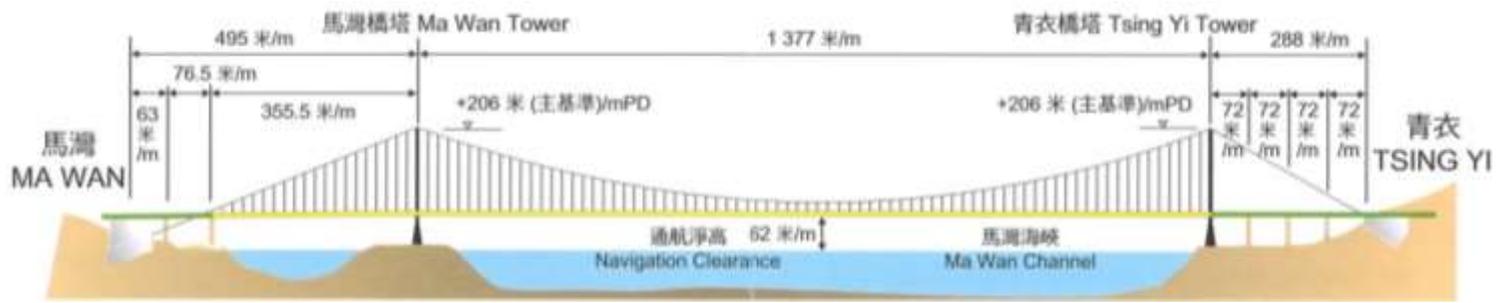
互動小遊戲

青嶼幹線訪客中心內部資料

2. 青馬大橋

青馬大橋屬於香港 8 號幹線青嶼幹線的一部分，跨越馬灣海峽，將青衣和馬灣連接起來，並聯同汲水門大橋，共同擔當著連接大嶼山、赤鱸角香港國際機場與市區的唯一行車通道。

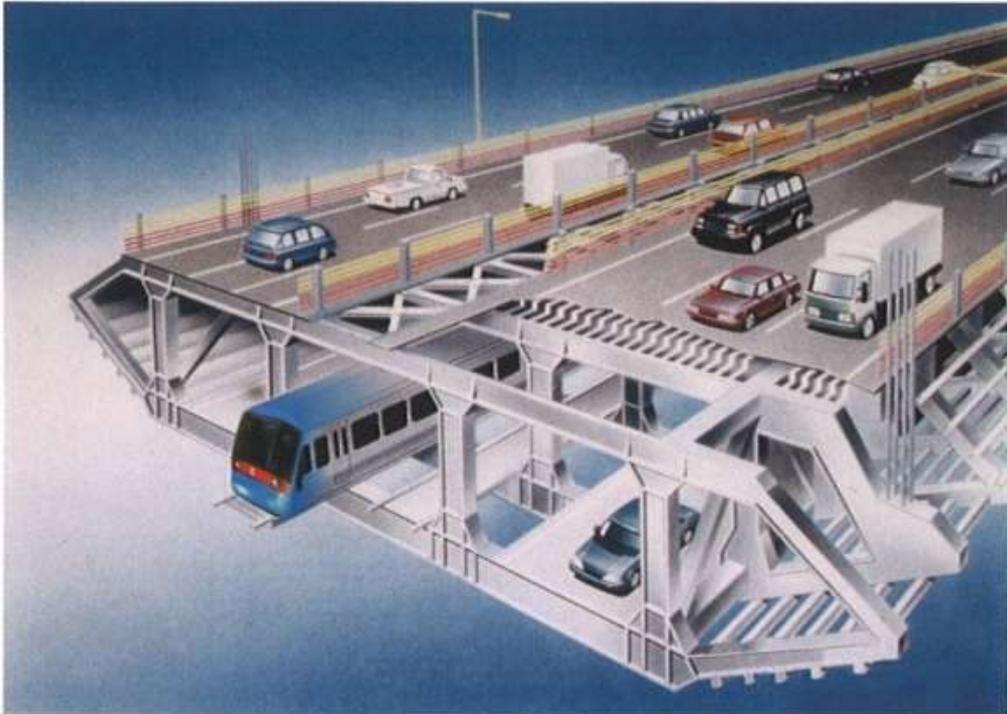
青馬大橋是全球最長的公路及鐵路兩用懸索橋(吊橋)。大橋採雙層設計，上層為雙向六車道的快速公路，下層設有兩條鐵路軌道，其外側各有一單線行車道，可作為維修通道或發生緊急事故時交通改道用。若遇颱風或風速太高，橋面將會封閉，而下層仍可行駛火車或汽車，接載旅客往返機場。流線型的橋身是經過精心設計，大橋上、下層橋梁的橫切面中央設有通氣隙，以增加大橋的氣體動力穩定性。



青馬大橋結構配置



青馬大橋現場實景



青馬大橋橫斷面配置

青馬大橋是香港引以為傲的地標建築，為 1999 年由美國建築界選出的「二十世紀十大建築成就獎」得主之一，與英法海峽隧道及舊金山金門大橋等其他九項世界級工程，共同享有這項殊榮。

三、心得及建議

- (一)混凝土結構物一般都與粗壯甚至醜陋畫上等號，但經由此次相關專家的分享，其實只要在規劃設計階段多用點心，花費微薄的費用，便能得到美感；對照國內土木工程也是如此，工程師往往以安全為導向，而忽略了美學、環境融合等議題，應以多方面思考的模式來面對國內重大工程。
- (二)纖維混凝土目前受限於材料專利問題，且對於新材料測試及相關規範制定較不熱衷，因此在臺灣發展受限。參照此次研討會各國對於纖維混凝土相關研究的發表，未來將會是國內須努力的方向。
- (三)目前國內鋼筋混凝土的設計以「極限強度設計法」為主，但已有部分的研究朝「性能設計法」來著手進行。對照本次研討會的主題”以性能為基礎的混凝土結構”(performance-based approaches for concrete structures)，顯示國內相關研究並不落後於國際潮流，但此次研討會，我國僅 1 位參加，建議能多參與相關國外活動，與國際研究交流接軌。
- (四)本次研討會贊助廠商多設置展覽攤位，除能讓與會者了解材料、設備、工法等最新資訊，也經由廠商的經費贊助，讓研討會能順利及盛大舉行，一舉數得，可作為國內相關研討會辦理參考。
- (五)開普敦的綜合快速公車系統，主線採用公車捷運系統，支線採用一般公車系統的整合模式，具輕軌的優勢也兼顧成本，可作為臺灣各城市大眾運輸系統整合之借鏡。
- (六)香港青嶼幹線訪客中心內有工程建設過程介紹、細部構造解說、工程小遊戲等，富含專業教育的內容；外側觀景台可讓民眾盡情觀賞青馬大橋、汀九橋、馬灣海峽等壯麗景觀，利用優美壯麗景色吸引民眾前來並順道了解工程歷史及細節，將公路建設之專業領域與旅遊觀光充分結合，此設置方式可供未來相關展示館建置參考。

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