公務出國報告（出國類別：國際會議）

參加 2018 年第 40 屆國際橋梁及結構工程學會研討會 (40th IABSE Symposium) 出國報告

服務機關：交通部高速公路局
姓名職稱：陳宏仁 規劃組組長
派赴國家/地區：法國南特
出國期間：107.09.16~107.09.23
報告日期：107.11.29

摘　要

「國際橋梁及結構工程學會」（International Association for Bridge and Structural Engineering,IABSE）於 2018 年 9 月 17~21 日（計 5 日）在法國南特之 La Cité de Nantes Events Center 辦理「2018 年國際橋梁及結構工程學會研討會」,本次研討會主題為 Tomorrow's Megastructures (未來巨型結構物)，主要探討現有的解決方案及環境變遷的限制，希望在服務年限能提供良好效能，增進社會福祉。

本次專題研討內容包含重大交通建設的推動、巨型結構的研討、大跨度橋梁維護及安全等議題，本局派員參加此次國際性工程研討會，希望能吸取歐美等先進國家之技術新知及經驗，提供國內基礎建設設計及施工之參考。

本次會議主辦單位安排有主題演講、論文研討、技術參訪及廠商展覽等項目，除參與會場各項活動，亦報名參加技術參訪行程，希望能實地了解法國南特當地工程實際執行情形。本報告即就參加前述國際性研討會目的、過程、心得及建議等作說明。

目　次

一、　目的 1

二、　行程紀要 3

三、　參加第 40 屆 IABSE 研討會紀要 5

四、　心得及建議 41

五、　附錄 43

一、目的

(一)IABSE 簡介

國際橋梁及結構工程協會 (International Association for Bridge and Structural Engineering，簡稱 IABSE) 係有關橋梁和結構工程的國際學術性組織，創立於 1929 年 10 月 29 日，永久會址設在瑞士蘇黎世，現任主席（2016-2019）是葡萄牙籍的 Fernando Branco(詳圖 3-1)，現有來自 100 多個國家超過 4000 名的會員，是目前會員國最多的國際土木類協會。協會設立宗旨係促進國際學術交流、結構工程技術，增進科技界、工業界和公共團體代表之間的國際合作，並提高會員對社會的自覺性和責任感。

IABSE 每年舉辦國際專題研討會，四年舉辦一次大會以及小型會議。在這些活動中，來自學界和業界的專家交流知識，會議有特定的主題及相關的科學技術。

IABSE 涉及結構工程的各個面向包括：規劃設計、施工營運、監控和維修等科學，並考慮到技術、經濟、環境、美學和社會方面。“結構”一詞包括橋梁、建築物和所有類型的土木工程結構，由任何結構材料組成。

此外，協會也出版相關研究成果與經驗的刊物，包括「國際結構工程」（Structural Engineering International, SEI）季刊、專題論文(Structural Engineering Documents,SED)及各研討會文集等。該協會也建立免費網路電子學習平臺，提供有關結構工程講義、短期課程及影片等，供有興趣之專業同好線上學習相關知識及技術新知。

(二)參與 IABSE 研討會之目的

本次 IABSE 在法國南特舉辦第 40 屆 IABSE 研討會，主題為”Tomorrow’s Megastructures”，在 20 世紀 60 年代是作為一種建築概念而被推廣，係指一種人造的巨型結構物，在現代可以應用於任何特別大或高的建築物，包含橋梁結構物。在本次研討會中，特別邀請各國結構工程界的人士來分享對於現今巨型結構物的看法，以及未來的前景。藉由參與 IABSE 研討會，與來自世界各地之顧問、承包商、業主、研究人員及從業人員，就結構設計、施工和維護等問題來交換意見，並從中吸取技術新知及經驗，提供國內橋梁工程設計及施工之參考。

圖 3- 1 IABSE 主席致詞

二、行程紀要

(一)行程表

本次奉派參加 IABSE 法國南特會議核定行程自 107 年 9 月 16 日至 9 月 23 日共計 8 日，其中研討會主要議程自法國時間 9 月 19 日至 9 月 21 日共計 3 日，相關行程謹彙整如表 2-1。

表 2-1 奉派參加第 40 屆 IABSE 研討會行程表

日期	起迄地點	行程紀要
9 月 16 日 (日)	臺北－法國巴黎（去程）	桃園機場－法國巴黎機場
9 月 17 日 (一)	臺北-法國巴黎	去程及參觀巴黎地區橋梁建設
9 月 18 日 (二)	法國巴黎-法國南特	路程及報到
9 月 19 日 (三)	法國南特	參加專題研討會、論文研討會及參觀廠商展覽
9 月 20 日 (四)	法國南特	參加專題研討會、論文研討會、技術參訪
9 月 21 日 (五)	法國南特 法國南特－法國巴黎	參加專題研討會、論文研討會 法國南特－法國巴黎
9 月 22 日 (六)	法國巴黎－臺北 (返程)	法國巴黎機場－桃園機場
9 月 23 日 (日)	法國巴黎－臺北（返程）	法國巴黎機場－桃園機場

(二)行程概述

配合航空公司航班時間晚去早回及時差，在法國實際停留時間僅有 5 天，第 1 天抵達法國後順道參觀巴黎地區橋梁建設，第 2 天自巴黎搭乘高鐵前往南特報到，參加為期 3 天的研討會，會議結束即搭乘高鐵到巴黎，隔天搭乘班機返台。

三、參加第 40 屆 IABSE 研討會紀要

(一)舉辦時間、地點

本次會議舉辦地點在法國南特會展中心(詳圖 3-2~3-5)，舉辦時間為當地時間 9 月 17 日(星期一)至 21 日(星期五)，南特是法國西部最大的城市，位於盧瓦爾河畔，距離大西洋海岸 50 公里。該市是法國第六大城市，擁有大約 90 萬居民。它是歷史悠久的布列塔尼省和布列塔尼古代公國的主要城市之一，曾被雜誌票選為「法國最綠的城市」、「歐洲最適合居住的城市」。

圖 3-2 法國南特市所在位置

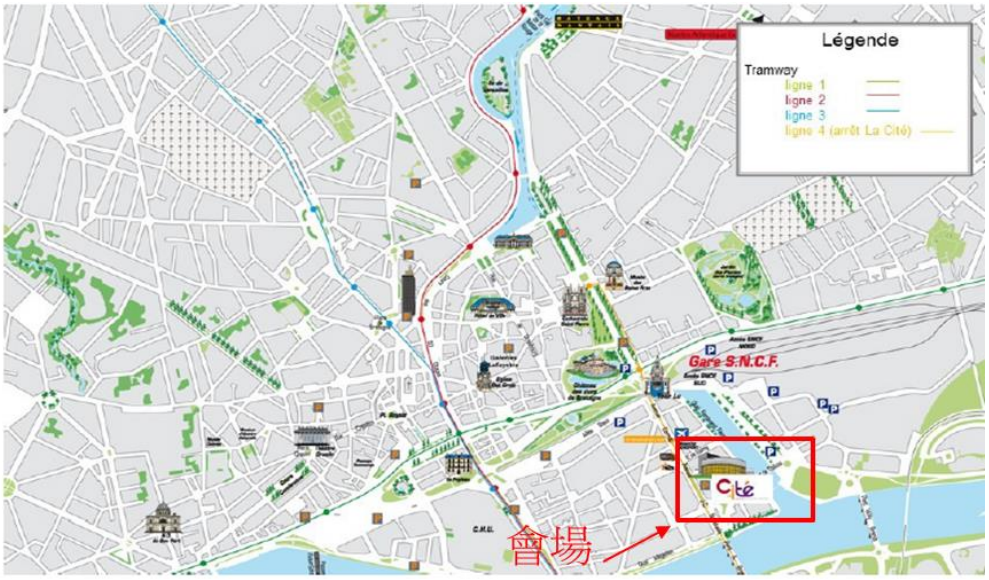

圖 3-3 本屆IABSE 研討會舉辦會場及附近街道地圖

圖 3-4 法國南特會展中心實景圖

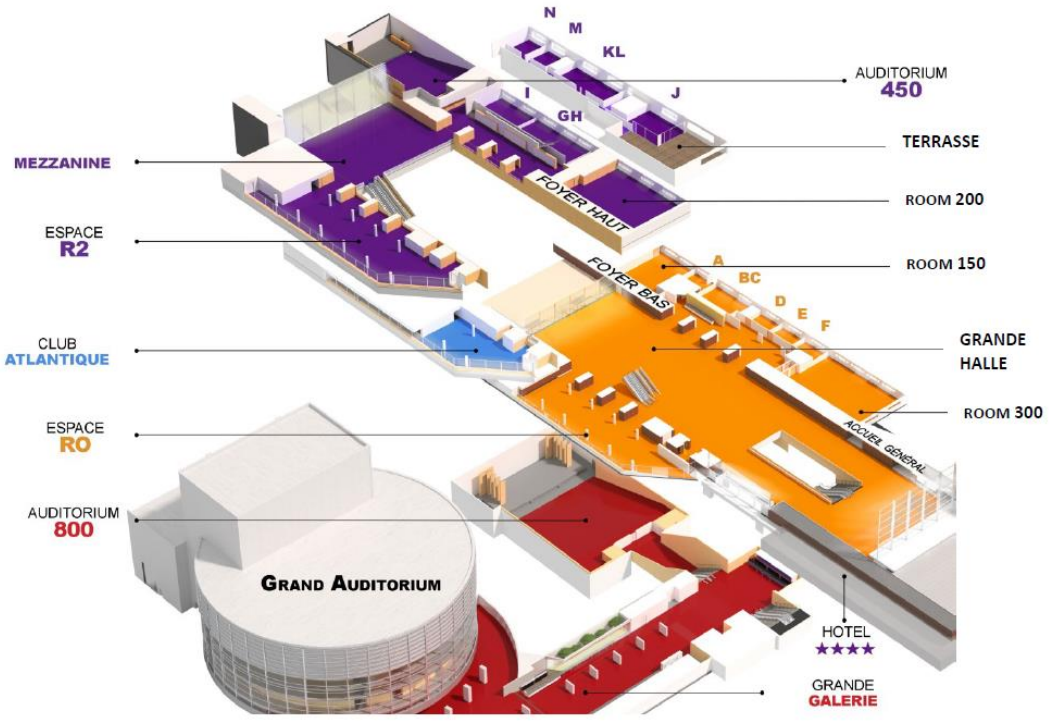

圖 3-5 法國南特會展中心會場平面圖

(二)IABSE 研討會議程

本屆年會議程詳表 3-1 所示，共計 5 日，包含 IABSE 年度會議、工作坊(Workshops)、專題演講(Keynote Lecture)、論文研討會(Technical Program)、技術參訪(Technical Visits)、廠商展覽(Exhibition)，會議場次均可視需求自由參加。

表 3- 1 IABSE 研討會議程表

<table>
<tr><th>日期
時間</th><th>9 月 17 日
星期一</th><th>9 月 18 日
星期二</th><th colspan="2">9 月 19 日
星期三</th><th colspan="2">9 月 20 日
星期四</th><th colspan="2">9 月 21 日
星期五</th></tr>
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10:00</td><td rowspan="3">IABSE
年度會議</td><td rowspan="3">IABSE
年度會議
工作坊</td><td colspan="2">開幕儀式
專題演講</td><td colspan="2">專題演講</td><td colspan="2">專題演講</td></tr>
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10:30</td><td colspan="2">中場休息</td><td colspan="2">中場休息</td><td colspan="2">中場休息</td></tr>
<tr><td>10:30
12:00</td><td>論文研討會</td><td>廠商展覽</td><td>論文研討會</td><td>廠商展覽</td><td>論文研討會</td><td>廠商展覽</td></tr>
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15:00</td><td rowspan="3">IABSE
年度會議</td><td rowspan="3">IABSE
年度會議
工作坊</td><td>論文研討會</td><td>廠商展覽</td><td>論文研討會</td><td>廠商展覽</td><td>論文研討會</td><td>廠商展覽</td></tr>
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<tr><td>15:30
17:00</td><td>論文研討會</td><td>廠商展覽</td><td>論文研討會</td><td>廠商展覽</td><td>論文研討會</td><td>廠商展覽
閉幕儀式</td></tr>
<tr><td>晚會</td><td></td><td></td><td colspan="2">歡迎會</td><td colspan="2">晚宴</td><td colspan="2"></td></tr>
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(三)各類研討會議簡介

本次研討會之研討議題，涵蓋各領域範疇，內容相當廣泛，茲分別簡介說明如下。

1. 專題演講(Keynote Lecture)

本次研討會安排了 6 個場次的專題演講,主題含括推動中的大型公路及建築計畫、安全議題、及大跨度橋梁等。

表 3-2 專題演講主題表：

項次	主題(中文)	講者
主題演講 1：	埃及推動中的大型計畫	Ibrahim MAHLAB
MEGA PROJECTS TOWARDS EGYPTIAN CONSTRUCTION RENASCENCE		
主題演講 2：	一公里高的 JEDDAH 塔樓	Robert SINN
THE ONE-KILOMETER TALL JEDDAH TOWER		
主題演講 3：	法國新的海岸公路：從設計過程到建築	Jean-Marc TANIS
THE NEW COASTAL ROAD IN LA REUNION ISLAND (France): From the Design Process to Construction		
主題演講 4：	安全約束的巨型結構	Denis ETIENNE
THE CHERNOBYL SHELTER: A MEGA-STRUCTURE FOR A SAFE CONFINEMENT		
主題演講 5：	摩納哥的海上延伸計畫	Régis ADELINE
THE PORTIER COVE SEAWARD EXTENSION PROJECT IN MONACO		
主題演講 6：	大跨度橋梁	Michel VIRLOGEUX
LONG SPAN BRIDGES		

圖 3- 6 專題演講

圖 3- 7 專題演講

圖 3- 8 專題演講

圖 3- 9 專題演講

2. 論文研討會(Technical Program)

論文研討會共三天,議題涵蓋橋梁及結構工程相關之各類範疇，包羅萬象，內容廣泛，本次研討會發表論文超過 300 篇以上，會議場次超過 60 場次，每日皆有不同論文議題在各會議室舉辦(各議題一覽表如表 3-3 及圖 3-10~16 所示)。

表 3-3　主要議題一覽表

主要議題名稱(英文)	主要議題名稱(中文)
Bearings and expansion joints	支承墊和伸縮縫
Composite structures and systems	複合結構和系統
Concrete behaviour and technologies	混凝土行為和技術
Damping systems	阻尼系統
Design methods	設計方法
Dynamic Monitoring	動態監控
Fatigue	疲勞
Fiber reinforced structures	纖維加強結構
Fire	火害
Focus on specific megaprojects	特定的巨型計畫議題
Innovative buildings	創新的建築
Innovative cable structures	創新的鋼索結構
Innovative designs	創新設計
Maintenance and management	維護和管理
Marine structures	海上結構物

Metro projects	地鐵計畫
Novelty in construction	新穎建築
“Nouvelle Route du Littoral” viaduct	濱海公路高架橋
Queensferry and Bosphorus bridges	跨海大橋
Railway bridges	鐵路橋梁
Retrofitting and repair	改建和維修
Risk management	風險管理
Seismic design and retrofitting	抗震設計和改建
Structural Health Monitoring	結構監測
Special session on Forensic engineering	工程特別議題
Special session on Innovations towards improved seismic resilience and upgrade of existing structures	關於提高抗震能力和現有結構升級的創新特別議題
Special session on Structural health monitoring	結構監測特別議題
Special structures	特殊結構
Steel structures and technologies	鋼結構和技術
Tall buildings	高層建築
The Mega-floating city	巨型浮動城市
Timber construction	木構造
Tunnels	隧道
Wind effects on structures	結構風力影響

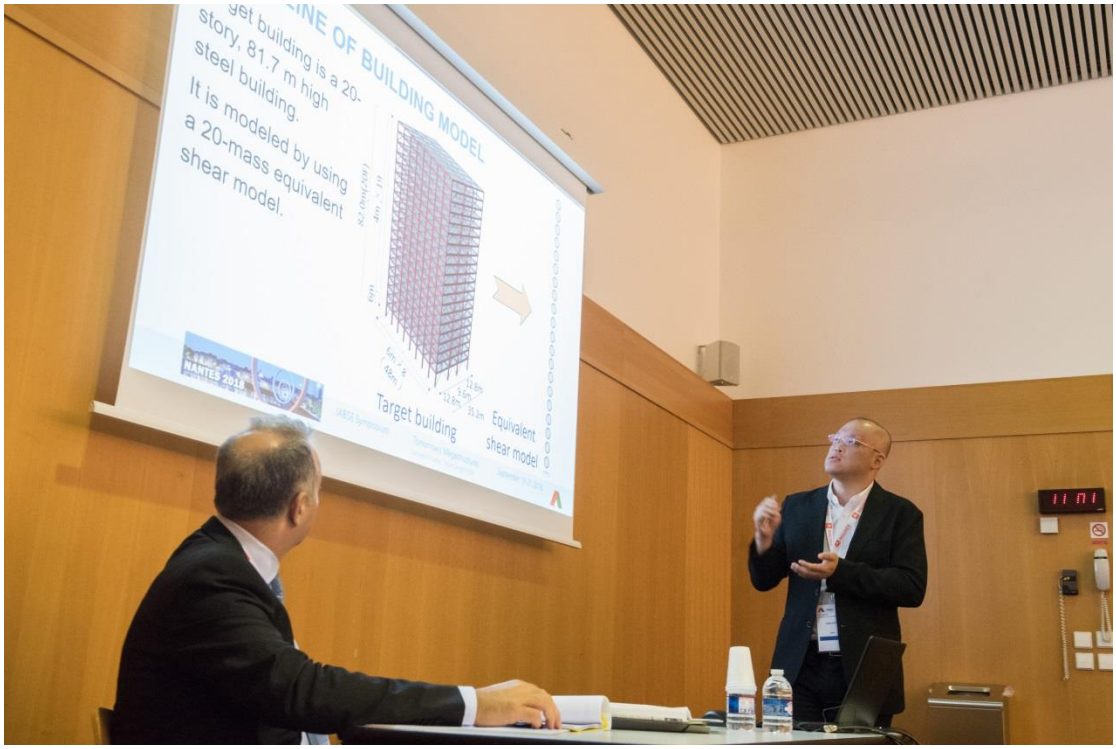

圖 3- 10 論文研討會

圖 3- 11 論文研討會

圖 3- 12 論文研討會

圖 3- 13 論文研討會

Wednesday September 19								
08:15 10:00	Auditorium 800 Opening ceremony Mega Projects towards Egyptian Construction Renascence - Ibrahim Mahlab, *Former Prime Minister of Egypt, Egypt*							
10:00 10:30	Coffee break in Grande Halle (Exhibition area)							
	Room J	Rooms B+C	Auditorium 800	Room 300	Room 200	Rooms K+L	Room 150	Rooms G+H
10:30 12:00	Bearings and expansion joints I	Innovative cable structures I	Innovative buildings	Composite structures and system I	Concrete behaviour and technologies I	Novelty in construction I	Design methods I	Damping systems I
12:00 13:30	Lunch in Grande Halle (Exhibition area)							
	Room J	Rooms B+C	Auditorium 800	Room 300	Room 200	Rooms K+L	Room 150	Rooms G+H
13:30 15:00	Marine structures I	Railway bridges I	Special session The mega floating city	Special session Metro projects	Structural health monitoring I	Innovative designs I	Wind effects on structures I	Special structures I
15:00 15:30	Coffee break in Grande Halle (Exhibition area) CONSTRUIRACIER ASSOCIATION D'IDÉES POUR L'ARCHITECTURE							
	Room J	Rooms B+C	Auditorium 800	Room 300	Room 200	Rooms K+L	Room 150	Rooms G+H
15:30 17:00	Seismic design and retrofitting I	Steel structures and technologies, I	Special session IABSE Task Group 1.1 part 1	Tunnels	Structural health monitoring II	Innovative designs II	Design methods II	Retrofitting and repair I
17:15 18:15	My thesis in 180s in Auditorium 800							
18:30 22:30	**Welcome reception in Machines de l'ile**							

圖 3- 14 論文研討會 DAY1

Thursday September 20								
08:30 10:00	Auditorium 800 The One-Kilometer Tall Jeddah Tower - Robert Sinn, *Thornton Tomasetti, Chicago, USA* The New Coastal Road in La Réunion Island (France) – Jean Marc Tanis, *EGIS-JMI, France*							
10:00 10:30	Coffee break in Grande Halle (Exhibition area)							
	Room J	Rooms B+C	Auditorium 800	Room 300	Room 200	Rooms K+L	Room 150	Rooms G+H
10:30- 12:00	Special session on forensic engineering	Innovative cable structures II	Composite structures and systems II	Concrete behaviour and technologies II	Novelty in construction II	Damping systems II	Design methods III	Dynamic monitoring I
12:00 12:30	Bentley Session							
12:00 13:30	Lunch in Grande Halle (Exhibition area)							
	Room J	Rooms B+C	Auditorium 800	Room 300	Room 200	Rooms K+L	Room 150	Rooms G+H
13:30 15:00	Seismic design and retrofitting II	Maintenance and management	Focus on specific megaprojects	Special session NRL project	Fatigue	Railway bridges II	Wind effects on structures II	Retrofitting and repair II
15:00 15:30	Coffee break in Grande Halle (Exhibition area) offered by CIVETEA							
	Room J	Rooms B+C	Auditorium 800	Room 300	Room 200	Rooms K+L	Room 150	Rooms G+H
15:30 17:00	Marine structures II	Steel structures and technologies II	Special session on structural health monitoring I	Special session IABSE Task Group 1.1 part 2	Structural health monitoring III	Timber construction	Design methods IV	Special structures II
17:15 18:00				Special session				
18:30 23:00	**Gala Dinner in Château de la Pigossière**							

圖 3- 15 論文研討會 DAY 2

Friday September 21

08:30 10:00	Auditorium 800 The Chernobyl shelter: a mega-structure for a safe confinement – Denis Etienne, *Bouygues TP, France* The Portier Cove seaward extension project in Monaco – Régis Adeline, *SAM, Monaco*							
10:00 10:30	Coffee break in Grande Halle (Exhibition area)							
	Room J	Rooms B+C	Auditorium 800	Room 300	Room 200	Rooms K+L	Room 150	Rooms G+H
10:30 12:00	Seismic design and retrofitting III	Tall buildings	Special structure III	Special session Queensferry and Bosphorus bridges	Seismic design and retrofitting IV	Railway bridges III	Design methods V	Retrofitting and repair III
12:00 13:30	Lunch in Grande Halle (Exhibition area)							
	Room J	Rooms B+C	Auditorium 800	Room 300	Room 200	Rooms K+L	Room 150	Rooms G+H
13:30 15:00	Fire	Special structures IV	Special session on structural health monitoring II	Fiber reinforced structures	Structural health monitoring IV	Risk management	Design methods VI	Dynamic monitoring II
15:00 15:30	Coffee break in Grande Halle (Exhibition area)							
15:30 17:00	Auditorium 800 Closing ceremony Long span bridges, Michel Virlogeux, *French Academy of Technology and UK Royal Academy of Engineering, France*							

圖 3- 16 論文研討會 DAY3

3. 技術參訪

(1) IFSTTAR 實驗室

9月20日上午由主辦單位帶領前往參觀法國交通發展規劃和交通網絡科技研究院(IFSTTAR)在南特的實驗室(詳圖3-17)，IFSTTAR研究院共有五個研究方向，分別為MAST(Materials and Structures，材料和結構)、GERS(Geotechnics, environment, natural hazards and earth sciences，地工、環境、自然災害和地球科學)、COSYS(Components and Systems，組件和系統)、TS2(Transport health and safety，運輸健康和安全)、AME(Development, mobility and environment，發展、流動性和環境)，本次參訪實驗室的地工離心機、路面疲勞試驗軌道和鋼纜疲勞試驗設備。

圖 3-17 IFSTTAR 南特實驗室位置示意圖

IFSTTAR 的**地工離心機**配備了地震模擬器和機器人操縱器，使用小型模型研究岩土結構的行為，如基礎擋土牆、海上錨地。結果可以直接轉換為全尺寸結構，並提供驗證數值模擬的方法。在受控的宏觀重力條件下的測試也用於航空和醫療設備的認可測試。CEA-Cesta 離心機是法國唯一的地工離心機，也是世界上最大的離心機之一（半徑 5.5 米，最大負荷 2 噸，最大加速度 100g）(詳圖 3-18)。

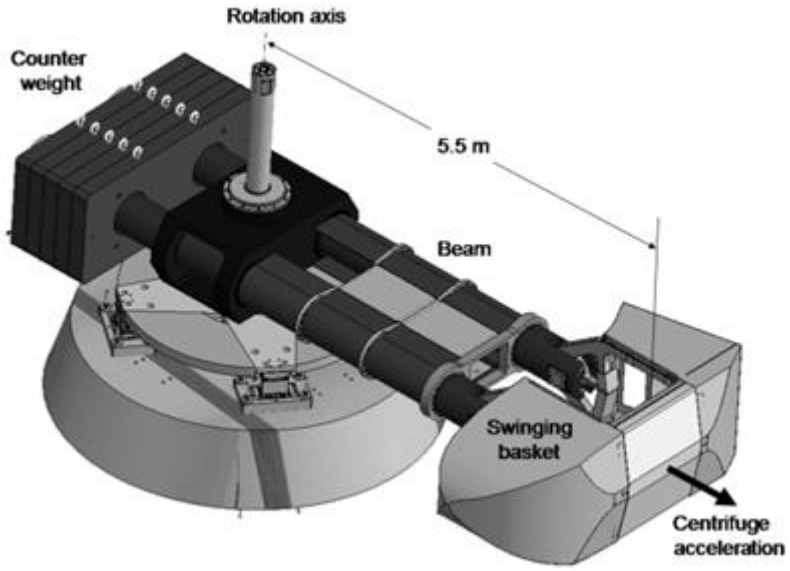

圖 3-18 地工離心機配置圖

地工離心機用於測試岩土工程問題的模型(詳圖 3-19)，例如橋梁和建築物的基礎強度、路堤的沉降、斜坡的穩定性、土方支撐結構、隧道穩定性和海堤。其他應用包括爆炸性隕石坑、地下水中的污染物遷移、凍脹和海冰。由於土壤行為的高度非線性的行為，模擬這些現象的模型非常複雜並且需要大量驗證，離心機測試的實驗數據可用於驗證計算所做的假設。如果結果顯示模型不準確，則離心機測試數據可提供對物理過程的深入了解，進而提供更好的模型建置。

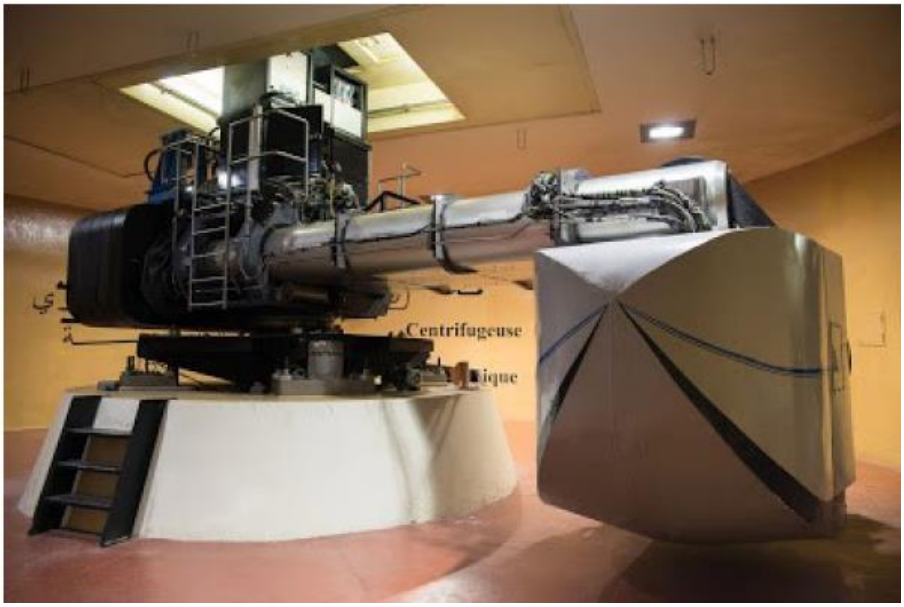

圖 3- 19 地工離心機實體

路面疲勞試驗軌道提供 IFSTTAR 在重載荷下對真實路面結構進行加速試驗(詳圖 3-20)，直至達到嚴重的損壞程度。該轉盤的性能（四個 20 米臂，每個軸承載荷在 45 至 130 kN 之間，最大速度為 100 km / h），是世界上最大的此類設施之一。除圓形測試跑道外，實驗室還有兩個線性交通模擬器，用於小規模測試(詳圖 3-21)，以測量能夠承受交通負荷的能力或道路結構。

圖 3- 20 路面疲勞試驗軌道

圖 3- 21 小規模測試機

鋼纜疲勞試驗設備(詳圖 3-22~23)能夠對土木工程或其他應用（鋼絞線和錨碇設施，海上設施）使用的鋼纜進行全面測試。靜載測試由三個液壓千斤頂配有機械定位，最大張力：24,000 kN，彎曲應力由 1 個液壓缸，100 mm 衝程，最大載荷 250 kN，這些測試係確保測試產品實際操作負載（靜態拉伸應力和力、拉伸及彎曲的受力與應力循環變化）下保持其完整性，對於驗證創新工程解決方案是必要的。聲音傳測器用於檢測和定位測試期間發生的任何故障，這是法國唯一的此類設施，也是全球僅有的三家設施之一。

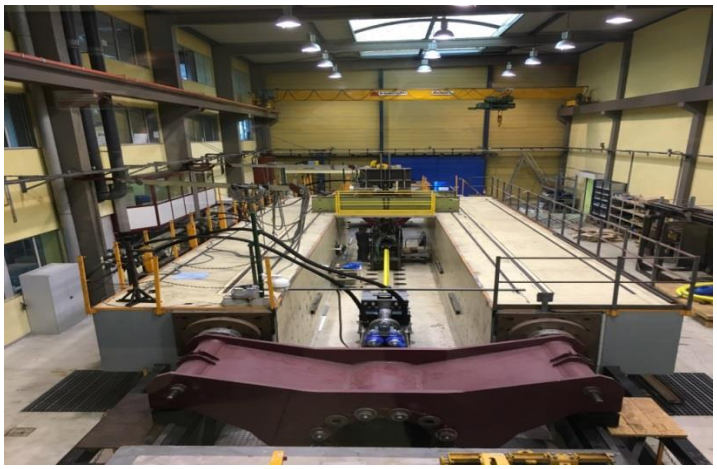

圖 3- 22 鋼纜疲勞試驗設備

圖 3- 23 鋼纜疲勞試驗設備彎曲應力試驗

(2)Cheviré大橋

9 月 20 日下午隨著主辦單位前往參觀法國著名的 Cheviré 大橋(詳圖 3-24)，這座橋梁歷史悠久，1991 年 4 月完工至今已有 27 年的橋齡，位於法國南特市，橫跨盧瓦爾河，全長 1563m。採雙向三車道橋面設計，橋面寬為 24.60m，主跨 242m 採鋼梁與混凝土梁接合(詳圖 3-25)，其中鋼梁跨徑為 162m，橋高 52m，主要是讓大型船隻行駛於盧瓦爾河時能夠穿越進入內陸碼頭港口，預力混凝土箱型梁採用懸臂工法建造，共 22 跨 (詳圖 3-26)。

圖 3- 24 Cheviré大橋位置示意圖

由於鋼梁支撐於混凝土懸臂端處，有研究指出在混凝土懸臂端處正以緩慢地速率產生垂直變形現象。該研究在 Chevir'e 橋上安裝了結構監測系統，針對下垂的變形量進行量測並與理論值進行了比較，結果顯示其測量值超過了理論計算值，研究認為是材料的延遲行為而導致將額外的應力重新分配到結構

中，使得在懸臂末端產生了高出理論值的變形。因此，為了能夠評估結構的當前狀況及預測其極限狀態，此研究進而提出了針對材料的經驗修正方法，有關研究詳細資料可參考 J-P. Sellin, J-F. Barth´el´emy, G. Bondonet, B. Cauvin Delayed, J-M. Torrenti. “Delayed deformations of concrete structures: the Savines bridge and the Chevire bridge” 。

圖 3- 25 Cheviré大橋現況

圖 3- 26 Cheviré大橋施工照片

4. 廠商展覽(Exhibion)

廠商展覽於會場大會堂舉行，共有 30 家參展廠商，展覽內容與本局業務較相關者包含交通規劃及交通模擬軟體、排水、交通安全設施、施工交通維持規劃、結構或地工檢測儀器設備、伸縮縫等產品展示，相關展覽成果相當豐富多元，或以實體展示，或以影片播放，更有實景模擬等方式；部分展示攤位亦提供書面簡介供與會者索取參考。

圖 3- 27 參展廠商攤位平面圖

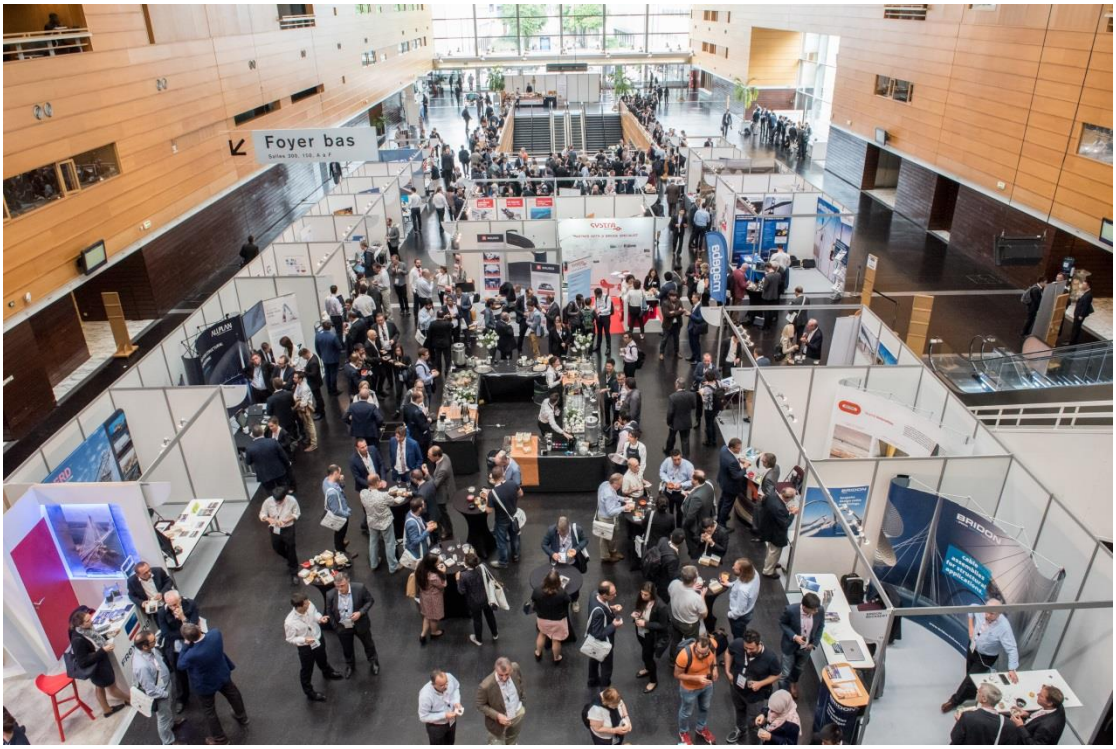

圖 3- 28 廠商展覽會場

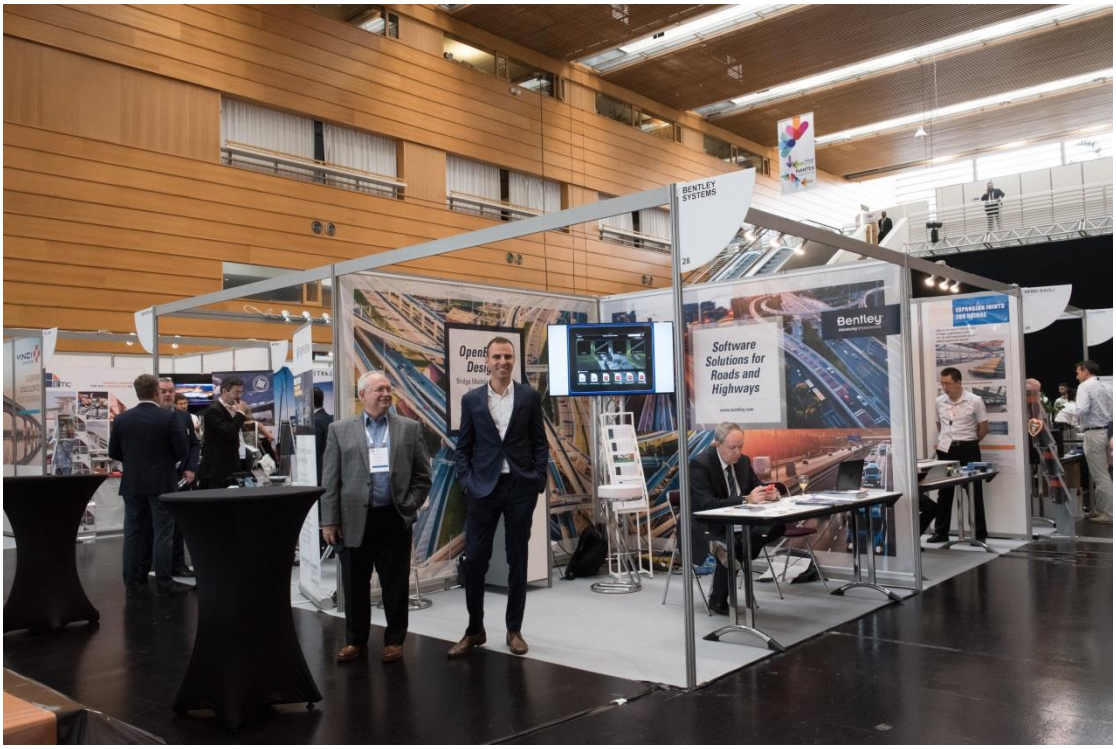

圖 3- 29 BENTLEY 展覽攤位

(四)研討會議題概述

本屆研討會中安排了 6 個場次的專題演講以及 34 項議題，因內容廣泛，以下擇幾篇與橋梁結構有關之論文作重點摘要介紹說明。

1. 專題演講(Keynote Lecture)

論文名稱：Mega Projects towards Egyptian Construction Renascence

作　　者：Ibrahim MAHLAB, CEO and President, The Arab Contractors Osman Ahmed Osman & Co Former Prime Minister of Egypt

道路、隧道和橋梁對於蓬勃發展的國民經濟至關重要，為了服務近 1 億人的國民,埃及需要更多現代化和高效率的貨運基礎設施，包括港口，鐵路和最重要的公路網絡。在這方面，埃及最近啟動了一項大型的政府計畫，旨在改善許多道路網絡的基礎設施。

本文介紹 Rod El-Farg 廊道公路其中的 Rod El-Farag 斜張橋，總長 540 米，及近 64 米的寬度(目前最寬的斜張橋)，連接尼羅河東部大橋與開羅北部的 Shubra 地區，它將為擁擠的道路提供一條替代路線，並解決了開羅大量的交通問題。

該橋由七個跨距組成，主跨距為 300 米，兩側邊跨長度均為 3x40 米 (圖 3-30)。

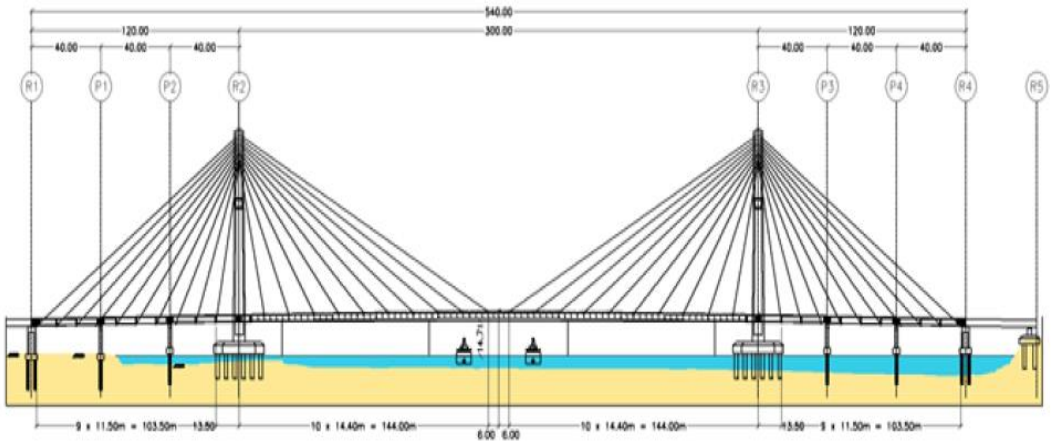

圖 3- 30 Rod El-Farag 斜張橋跨徑配置

主跨由兩個主要鋼梁、橫梁、縱梁及預鑄的混凝土板的複合截面(圖 3-31)

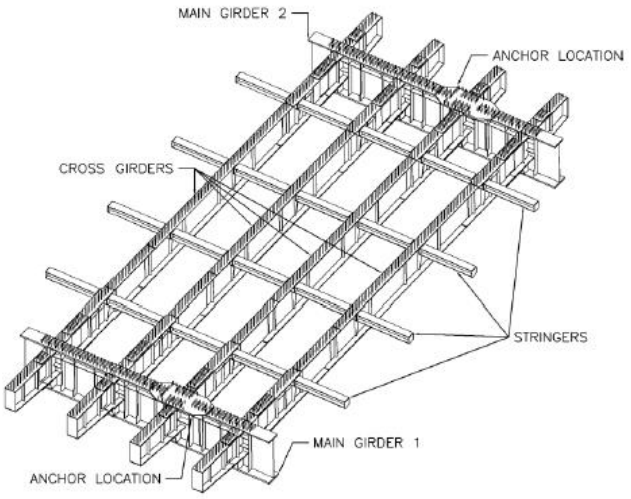

圖 3- 31 主跨複合梁配置

邊跨系統為現場澆築的混凝土箱梁。 主塔位於 R2 和 R3 處，高度為 95 米，每個橋塔由三根柱組成，並透過一中空的混凝土橫梁相互連接；塔柱建立在厚度為 5 米的樁帽上，樁帽下則使用 80 個直徑為 2 米的樁作為基礎(圖 3-32)。

圖 3- 32 Rod El-Farag 斜張橋願景圖

95 米高的兩座橋塔具有中空的混凝土橫截面，並使用自爬升式模板進行塔柱的建構。 每個塔柱被分成 20 個鑄造節塊，每個節塊的高度約為 4.5m。 圖 3-33 分別顯示了橋塔橫斷面及塔柱採用的自爬升式模板。

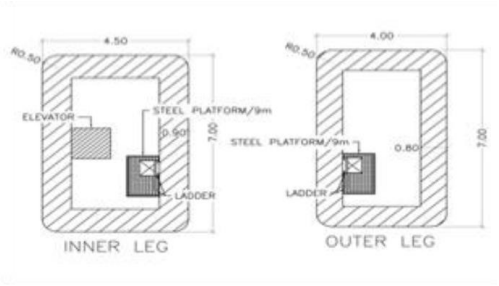

圖 3- 33 橋塔橫斷面及自爬升式模板

為了減少橋面板結構振動並承載由於地震作用而產生在橋面板上的側向荷載，在橋面版和兩個橋塔之間設置了 12 個粘滯性阻尼器。

本文介紹了埃及目前在基礎設施領域展開的的一部分。 這些計畫皆在設計、施工、項目管理方面有相當的創新，同時本計畫可以成為日後巨型結構的良好範例，並造就 Rod El-Farag 斜張橋成為世界上同類型中最寬的橋梁。目前其他幾個計畫正在埃及展開，為埃及重生之路鋪築。

2. 特定巨型計畫議題 (Focus on specific megaprojects)

論文名稱：Megastructures for a Long Marine Bridge in Kuwait

作　　者：Mohamed Akraa, Georges Mauris, Aurelie Vivier, Trinh Duong, Delphine Challant, Elodie Faivre,Serge Montens

科威特將在未來幾年內在科威特灣東北端建造一個新的城市，名為“絲綢之城”在布比延島附近的 Subiyah 地區。為了促進這個新城市與科威特城之間的交流，科威特決定在建造一條跨海大橋(圖 3-34)，一旦完成，該橋將把科威特市和 Subiyah 地區之間的行駛距離從現在的 104 公里縮短到 36 公里。

圖 3- 34 計畫示意圖

本計畫完工後，將成為世界上最長的海上橋梁之一。總長度為 48.5 公里，包括主線及多哈路段線，主線的總長度為 36 公里，其中 27 公里為跨海橋梁結構，使用預鑄節塊，每塊長 40 至 60 米、寬 17 米、高 2.5 至 4 米，主跨以斜張橋及其精緻的拱形塔將在科威特灣重要航道中作為顯著地標(圖 3-35)；多哈路段長 13 公里，主要是跨海橋梁結構。該計畫於 2013 年初開始建設，預計於 2018 年 11 月通車。

圖 3- 35 斜張橋

計畫包括 Shuwaikh 港灣方面的遊客中心管理大樓(圖 3-36)，其特殊的構造將成為科威特市的重要地標，另外包括兩個 30 公頃的人工島嶼(圖 3-37)：一個位於北側，另一個位於橋梁的南側，將容納維護和交通緊急建築，加油站和碼頭設施等，這些島嶼也具有視覺及美學作用，打破橋梁長而均勻的單調。

圖 3- 36 遊客中心管理大樓

圖 3- 37 人工島嶼

對於這個計畫，Systra 顧問公司提出並設計了創新的解決方案，方案一為預鑄節塊工法，有兩種節塊尺寸，寬度皆為 17 米， 40 米跨度深度為 2.5 米； 60 米跨度深度為 4.0 米，並在縱向和橫向進行預力拉伸。Systra 認為從經濟和規劃角度來看，預鑄節塊的重複性是本計畫成功的關鍵。預製節塊在 Subiyah 一側的鑄造場（圖 3-38）預製，由駁船帶來，其創新解決方案二在具有足夠航行潮汐的區域中使用浮式起重機(圖 3-39)，對於航行潮程較低的地區，使用龍門起重架(圖 3-40)，這種施工方法顯著降低了對海洋生態系統的影響。

圖 3- 38 預鑄場

圖 3- 39 浮式起重機

圖 3- 40 龍門起重架

創新解決方案三，Systra 顧問公司提出了一個直徑為 3,0m（60m 跨度）和 2.5m 直徑（40m 跨度）的單樁系統(圖 3-41)。單樁的使用與多樁解決方案相比，減少了地震力，還減少了對海洋動物的影響，並避免了海洋環境中樁帽建造的安全問題。

在樁的施工過程中，在挖掘地面之前安裝了厚 19 mm 的永久鋼套管。這些套管允許在挖掘過程中，安裝鋼筋籠（圖 3-42）和混凝土澆製。

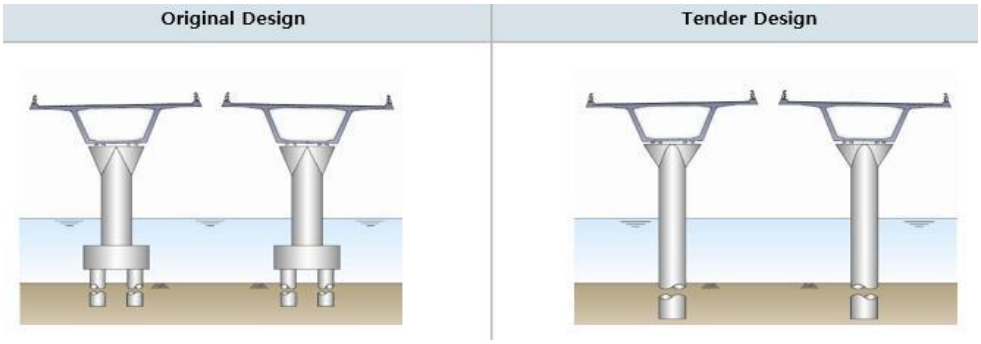

圖 3- 41 單樁系統

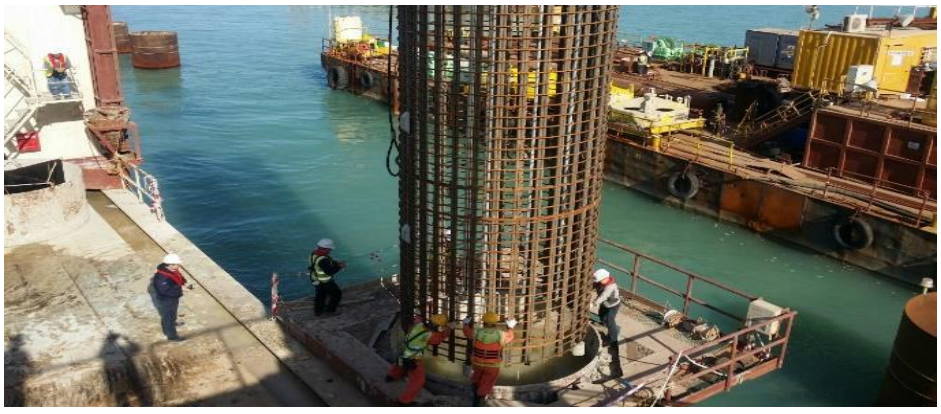

圖 3- 42 安裝鋼筋籠

3. 創新之鋼纜結構 (Innovative cable structures)

論文名稱：Crossing the Ganges: The World’s Longest Extradosed Bridge

作　　者: Brook R. Robazza, Morgan T. Trowland

隨著國家的轉型經濟持續增長，許多大型結構物將在印度完成，東北部比哈爾邦的 1.17 億人民正因 Veer Kunwar Singh 大橋橫跨恒河而受益(詳圖 3-43~3-44)。在橋梁建成之前，這條長達 400 公里的河流上僅有三座橋梁共六條公路車道。這座四車道大橋於 2017 年落成，成為世界上最長的脊背橋，同時也代表了比哈爾邦橋梁技術和建築工藝的進步。

圖 3- 43 Veer Kunwar Singh 大橋

圖 3- 44 Veer Kunwar Singh 大橋跨越恆河的全貌

本研究描述 4.35km 橋梁的設計和建造，其中 16 個單元，共 1920m，採用斜拉鋼索系統來承載上部結構的自重。由於箱梁是預鑄製成，與先前恒河橋上使用的現場澆鑄混凝土結構相比，可以更快速，更容易地安裝。從歷史上看，印度的主要橋梁皆是用了十多年才完成，但由於採設計-施工統包採購，以及施工人員和設計師之間的合作加速施工，Veer Kunwar Singh 大橋僅用了五年時間就完成了。

脊背橋對於多跨橋梁應用具有多種好處，包括橫跨恒河洪氾平原的交叉口。多跨橋梁必須利用減少基礎數量來平衡因較長跨度所增加之成本，同時，鋼纜系統對於超過 100 米長跨度的橋梁可以顯著地提高其成本效益，因此，脊背橋在多跨橋梁的應用中越來越受歡迎，一系列重要的例子如圖 3-45 所示。

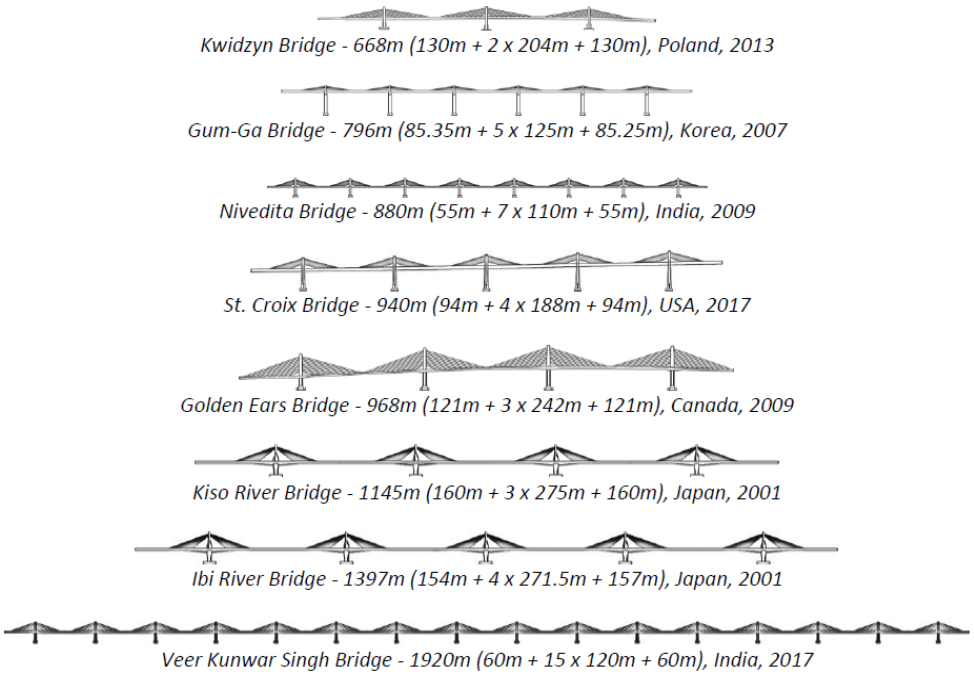

圖 3- 45 世界最長的多跨脊背橋梁

利用脊背系統來設計和建設 Veer Kunwar Singh 橋，與一般梁設計方案相較下更具有多項優勢，透過引入這種相對較新的橋梁類型及其相關的施工方法，有許多好處，進一步推進比哈爾邦的發展：

- 安裝速度：一旦脊背橋的構件在預鑄場中製造，他們可以在 1 天內的時間到現地完成安裝。既使河流中運輸遇到困難而導致安裝速度減慢到 3 天，但這仍然比在現地場鑄澆置施工之週期快大約三倍。
- 經濟型設備：較小的構件不需要專門的起重設備。
- 減少材料體積：對於超過約 150 米的跨度，脊背系統可以更顯著地減少施工所需的混凝土、鋼筋及高強度鋼筋的體積。
- 基礎設計：對於較長的跨距，由於鋼纜支撐的存在，構件尺寸可以更小，導致上部結構更輕，基礎要求比具有漸變梁深之橋梁來的更低，大大減少了基礎的施工時間和成本。

4. 濱海公路高架橋（“Nouvelle Route du Littoral” viaduct)

論文名稱：Zourite, a Kraken for Maritime Works

作　　者：Olivier Jestin. David Compte.

為了避免岩石掉落到留尼旺島沿海公路的車道上並降低年度維護成本，當地政府決定在海上和沿海建造一座高架橋，新沿海公路由 5.4 公里的橋梁結構組成，與海岸平行，距離海岸線 100 米至 200 米。它位於法國海外領土的北側印度洋，如圖 3-46~3-47 所示。

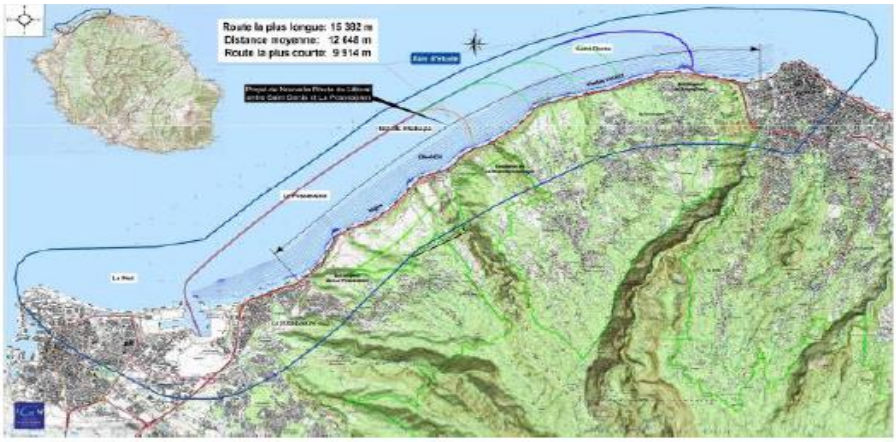

圖 3- 46 留尼旺島沿海公路位置概述

圖 3- 47 留尼旺島沿海公路施工示意圖

由於印度洋的天氣條件限制，團隊選擇使用預鑄段並最大限度地減少海上工程。在海上工程中，留尼旺島因其非常高的海浪和強風而以其惡劣的天氣條件而聞名，因此，該團隊不得不想像一艘新的駁船能夠承受更高的天氣條件，並提供高架橋所需的精度安裝預製構件。就在這樣的背景下，重型自升式駁船(如圖 3-48)因此而產生，能夠裝載，運輸和裝載預製段（最大重量 4600 t），動態定位系統可以準確地將駁船放置在現場，它配備了 8 千升的頂升系統，允許駁船在留尼旺島的海浪上站立，以實現分段安裝或海上土建工程。

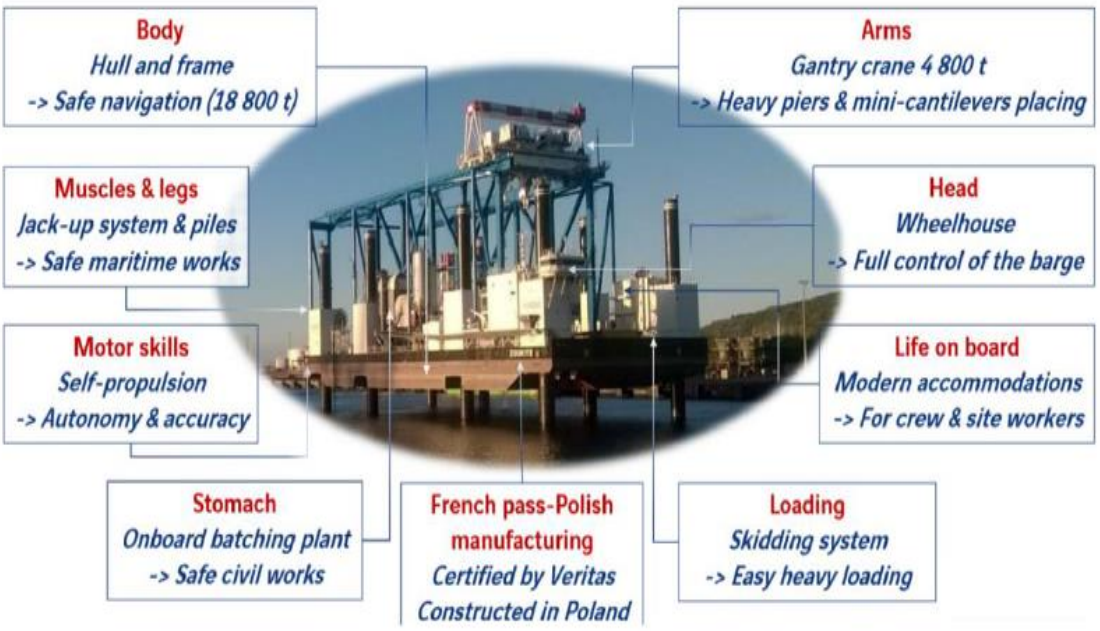

圖 3- 48 重型自升式駁船

5. 設計方法 (Design methods)

論文名稱：Design and Construction of the New “La Unidad” Bridge, Mexico

作　　者：Samuel Vásquez, Manuel Martínez

La Unidad 橋位於墨西哥灣南部的墨西哥坎佩切州，該橋建於 1980 年代，這座橋位於墨西哥石油工業中心的一條非常重要的海上公路上(如圖 3-49)，因該橋橋墩腐蝕裂化嚴重(圖 3-50)，故將新建一座新的 La Unidad 大橋將取代現有的橋梁，新的 “La Unidad” 大橋全長 3285 米，橫跨大海，水高 4 至 15 米。這座橋有 73 跨，每跨為 45 米;由 6 個 I 型預力梁及混凝土板組成，梁 2,2 米高，混凝土版為 22 公分厚。橋墩為樁基。橋梁所在的區域容易發生颶風和地震，橋梁的土壤相對較軟。該橋現在正在建設中，將於 2018 年底完工。

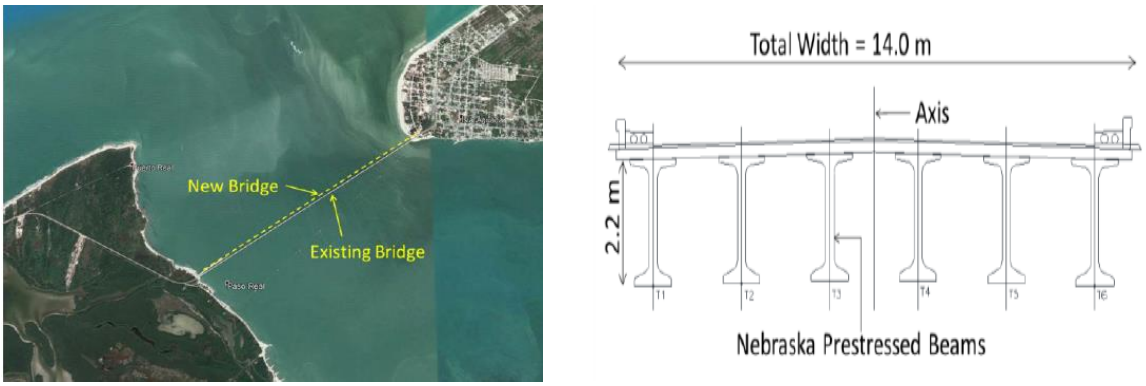

圖 3- 49 La Unidad 橋位置示意圖及橋梁型式

圖 3- 50La Unidad 舊橋腐蝕情形

新的 La Unidad 橋是一座非常長的橋梁，其特點是在海上建造，其具有複雜岩石土層，且位於地震區域。本論文進行了地震風險研究，同時進行了橋梁地震響應的非線性時程計算，這些計算顯示了橋梁在強烈地震運動期間耗散能量的能力，並允許橋墩設計的優化。同時將岩土工程計算的結果與載荷試驗中的結果進行了比較。

四、心得及建議

(一)本次研討會透過專題演講者的簡報可瞭解埃及、美國、法國、烏克蘭、摩納哥等國目前推動中的幾項大型道路及建築計畫，此外研討會有超過 300 篇投稿論文發表，涵蓋橋梁、隧道、建築等領域，從設計、施工到維護、管理、監測，內容豐富可提供國內推動公共工程規設、施工、維管參考。

(二)本次研討會有來自世界各地產、官、學界超過 500 人參加，亞洲國家包括大陸、日本、韓國、印度、印尼等均踴躍派員積極參與研究論文成果發表，分享專業經驗，相形之下，臺灣並無其他人員參加，實值得省思，建議未來仍應多鼓勵國內顧問公司、學界、工程機關踴躍參與類似國際研討會，吸收新知，以提升工程水準及臺灣知名度。

(三)研討會主辦單位考慮環保、節能減碳，將所有論文資料儲存於隨身碟，不再列印書面報告。並於會場提供免費 Wi-Fi 及 APP，讓參加人員瞭解研討會相關資訊，達到無紙化會議目標，可供國內日後舉辦類似大型研討會參考。

(四)主辦單位安排參訪 IFSTTAR 南特實驗室的 Geotechnical Centrifuge (地工離心機)、Pavement fatigue test track (舖面疲勞試驗軌道)、及 Cable fatigue test bench (鋼纜疲勞試驗設備)都是世界上少有的大型實驗設備，可透過實際試驗來驗證理論及設計成果，實驗室相關資料可提供未來國內地工、路面材料、橋梁需進行相關試驗參考。

(五)參訪的 Cheviré大橋主跨採 PC-鋼混合橋，高度 52 公尺，跨度 242 公尺、鋼梁長 162 公尺，在 1991 年完工。國內第一座 PC-鋼混合橋位於台 74 線大里路段，跨度 85 公尺、鋼梁

長 65 公尺，在 2011 年完工。兩項工程完工時間及規模雖有差異，不過 Cheviré大橋的檢測、監測及維修經驗可供國內養護單位參考。

(六)南特市區廣設自行車友善設施(包括類似 Ubike 租車服務、停車設施、專用道設置) ，並積極推動各項 BRT 及輕軌建設，提供市民便捷的公共運輸服務，有效降低私人交通工具使用，減少市區交通壅塞，值得國內類似規模之城市推動公共運輸政策參考。

五、附錄

附錄一、南特市區街景照

附錄.圖- 1

附錄.圖- 2

附錄.圖- 3

附錄.圖- 4

附錄.圖- 5

附錄.圖- 6

附錄二、研討會議題

Table of contents

Keynote lectures

Mega Projects towards Egyptian Construction Renascence

Ibrahim Mahlab, Fathy Saad

K-1

The One-Kilometer Tall Jeddah Tower

Robert Sinn, John Peronto

K-17

The New Coastal Road in La Réunion Island (France): From the Design Process to Construction

Jean Marc Tanis, Christophe Outteryck, Guillaume Danan, Jimmy Jacquot, Cyril Bailly

K-25

The Chernobyl Shelter: a Mega-structure for a Safe Confinement

Denis Etienne

K-37

The Portier Cove Seaward Extension Project in Monaco

Régis Adeline

K-55

Long Span Bridges

Michel Virlogeux

K-65

Bearings and expansion joints

Experimental and Numerical Studies on the Shear Properties of Rubber Bearing Supports with Parameters of Axial Stress

Joon-Ho Choi, Nobuhiko Hara, Takashi Imai, Kensuke Ueda, Hyunwoo Sung

S1-1

The Modular Expansion Joints of the Sheikh Jaber Causeway in Kuwait

Achilleas Athanasiou, Niculin Meng, Colm O'Suilleabhain

S1-9

The Quick-Exchange Expansion Joints of the Köhlbrand Bridge in Hamburg

Stefan Adam, Gianni Moor, Simon Hoffmann

S1-17

The bearings and integrated SHM system of the Johan Sverdrup offshore platform facility

Masoud Malekzadeh, Gianni Moor, Niculin Meng

S1-25

Chernobyl new safe confinement project - steel arch permanent bearings

Roberta Vitale, Philippe Salmon

S1-33

Composite structures and systems

A Critical Assessment of the Fatigue Verification Concept of Stud Shear Connectors in Steel-Concrete-Composite Members for Bridges

Eric Brehm, Robert Hertle

S2-1

Planning and Design of a Two-story Arch Bridge with Solid-spandrel Upper Arches Built withCFRP Reinforced Concrete

Takeshi Oshiro, Makoto Nakamura, Michiaki Sakate, Tadahiro Yoshida

S2-9

Performance Study of a Steel-Concrete Joint for Hybrid Cable-Stayed Bridge with 800m Main Span

Xiangmin Yu, Dewei Chen

S2-17

Experimental Studies on the Cooperative Performance of Steel-concrete Composite Largespan Bridge Tower

Yaoyu Zhu, Jiansheng Fan, Xin Nie, Bing Cui, Liji Huang

S2-25

Bending Mechanical Properties of Composite Bridge Deck with Bulb Flat Ribs

Xinyi He, Qintian Su, Chen Xu

S2-33

U-shaped Steel-concrete Hybrid Beams: an Alternative Solution for Long-span Beams

Clémence Lepourry, Franck Palas, Piseth Heng, Hugues Somja

S2-41

Recent Structures and Bridges built with the CL Steel-concrete Connection

Jacques Berthellemy, Günter Seidl, Wojciech Lorenc

S2-51

Form Optimized CFRP Reinforced and Post-tensioned Integral Concrete Bridge using Precast Girders

Mike Schlaich, Andreas Apitz, Arndt Goldack

Concrete behaviour and technologies

Spatial Correlation Characterization using Windowing Method, Transfer through Concrete Carbonation Models

N. Rakotovao Ravahatra, E. Bastidas-Arteaga, F. Schoefs, T. de Larrard, F. Duprat

S3-1

Shear Tests on RC Beams without Stirrups under Uniformly Distributed Load

Alexander Beck, Walter Kaufmann, Daniel Konradi

S3-11

Estimation of Prestress Losses in Concrete Structures over a Long time

Suryakantha Biswal, Ananth Ramaswamy

S3-21
Linear Regression Analysis of the Eurocode 2 Creep Model with Bayesian Update
Elise Zgheib,Wassim Raphael, Rafic Faddoul
S3-29
Response of Structural Concrete Assemblages to Thermo-Mechanical Loads
V.Svetha, D. Harinadha Reddy, Ananth Ramaswamy
S3-37
Multifunctional Inhomogeneous Lightweight Concrete Elements – Outline and Structural Behaviour
Claudia Lösch, Arno Richter, Mike Schlaich
S3-45
A Decision Model for the Investment in Technology to Reduce Concrete Rework
Tian Martin Podges, Jan Andries Wium
S3-53
On-site Study of the Time-dependent Behaviour of Concrete: Evaluation of the Application of EC2 Prediction Models in Algeria
Luís Oliveira Santos, Min Xu, Tiago Vieira
S3-61
Yield Design Based Numerical Analysis of Three-dimensional Reinforced Concrete
Hugues Vincent, Mathieu Arquier, Jérémy Bleyer, Patrick de Buhan
S3-69
Modelling of the Long Term Behaviour of Prestressed Concrete Structures: the Case of Nuclear Power Plants
Jean Michel Torrenti, Abdushalamu Aili
S3-77

Damping systems

Seismic Isolator, Damper and Expansion Joint System for two Viaducts of Toluca – Mexico City Intercity Train
Luca Paroli, Peter Huber
S4-1
New Adaptive Pendulum: Reduced Structural Acceleration, Base Shear, Displacement Capacity and Improved Rotation Capability
Felix Weber, Florian Obholzer, Peter Huber, Christian Braun, Leopold Meier, Manfred Hartinger, Johann Distl
S4-9
Response Prediction of Passive Controlled Building with Viscous Dampers Considering its Performance Decrement under Long-Period Ground Motion
Daiki Sato, Kazuhiko Kasai, Nagayama Sho, Kazuhiro Matuda
S4-19

Seismic Isolation of Greater Jakarta LRT
Charles Cynober, Tri Suryadi, Mauro Sartori
S4-25
Near-fault Isolation of Cable-stayed Bridge in Longitudinal Direction using Linear Friction Damper
Junjun Guo, Wancheng Yuan
S4-31
Experimental Investigation on Transverse Steel Damper Seismic System for Cable-stayed Bridges
Lianxu Zhou, Aijun Ye, Xiaowei Wang
S4-39
Characterization of Dissipative Behaviour of a Reinforced Concrete Mock-up after Soft Impact Tests through Wavelet Analysis
Nicolas Vacca, Christophe Rouzaud, Guillaume Hervé-Secourgeon, Mathieu Galan, Pierre Argoul, Claude Rospars
S4-47
BRB and Viscous Damper Hybrid Vibration Mitigation Structural System: Seismic Performance Analysis Method and Case Studies
Xin Zhao, Hao Li
S4-55
Optimized Design of Seismic Isolation Systems for Existing Bridges
Marco Furinghetti, Simone Peloso, Igor Lanese, Simone Lenzo, Alberto Pavese
S4-63
Seismic Performance Evaluation of Fabricated Concrete Frame with Replaceable Energy Dissipation Connectors
Chunyu Li, Jing Wu, Luqi Xie
S4-71

Design methods

Design and Construction of the New “La Unidad” Bridge, Mexico
Edilberto Buenfil Montalvo, Alvaro Buenfil Bermudez, José Antonio Pinto Elías Samuel Vásquez, Manuel Martínez, Alberto Patron, Eduardo Reyes, Ernesto Morales, Miguel Ibarra, Fabian Martinez
S5-1
Chacao Bridge Foundations
Bénédicte Pich, Emilie Cousteix, Habib Kata’a, Mathieu Muls, Aymen Cheikh-Mahmed, Svein Erik Jakobsen
S5-9
Juan José Arenas: a Philosophy of Bridge Design
Guillermo Capellán, Miguel Sacristán, Santiago Guerra, Emilio Merino, Javier Martínez

S5-17
Mawaiya CLC: Technical Challenges in Design & Construction
Shekhar Mehta, Ashutosh Kumar Singh
S5-25
Large Span V-shaped Pier Continuous Rigid Structure Design of China-Maldives Friendship Bridge
Xiao Haizhu
S5-33
Variations of Safety Factors for Bridges over their Lifetime considering Changing Live Load Definitions
Ciarán Hanley, Dan M. Frangopol, Denis Kelliher, Vikram Pakrashi
S5-41
Increasing Planning Quality for a Project
Peter Seitz
S5-49
Fragility Analysis of Girder Bridges Subjected to Multi-hazards
Jingyu Wang, Wancheng Yuan
S5-55
Proposals to make Complex Structures Affordable
Jean-François Caron, Olivier Baverel, Cyril Douthe, Romain Mesnil, Tristan Gobin
S5-63
Parametric Non-linear Models for Buried Structures with Full Soil-structure Interaction
Marcin Bulkowski, Pawel Ogonowski, Marcos Sanchez
S5-71
From a decrease of web thickness to a reinforcement optimization
A. Simon, T. Duclos, R. Lelonard
S5-79
Form Dynamics at Concrete Overpass Bridges
Michael Kleiser
S5-87
Reliability of Pre-stressed Elliptical Paraboloidal Concrete Shells
Gnida Sossou
S5-95
Parametric, adaptive Design and Analysis of standardized Steel Composite Bridges
Semjon Giebat, Andreas Bach, Markus Nöldgen, James Lim
S5-103
Development of Simplified Analytical Model for Predicting the Time-history of Ship Impact Loading on the Bridge
Yanchen Song, Junjie Wang, Hao Gao

S5-111
A 3D Modelling for Transversal Analysis and Local Effects
Jocelyn Meyer, Laurent Bailly, Fahed Chebbi, Anthony Scaramozzino
S5-119
The design of two Large Span Arch Bridges in the Port of Rotterdam
Arjen Steenbrink, Mark van der Burg
S5-127
Adoption of Precast Column-Base Pocket Connections with Rough Surface Interface in Long Span Bridges
Abdelrahman H. Farouk, Khaled H. Riad, Fathy Saad
S5-135
Managing Data workflow from Concept to Commission – BIM for Bridges
Jean-Pierre Chanard
S5-143
Numerical Analysis of Pre-fabricated Reinforced Concrete Beams with Longitudinal Cavities
Tor Gunnar Vilke, Samindi Samarakoon
S5-149
Non-conventional Cable System in Multi-span Cable-stayed Bridges
Clara Cid, Aitor Baldomir, Santiago Hernández
S5-157
An Initialization Model with Reference to Finite Number of Failures
Atsukuni Kajima, Kiyoshi Kobayashi, Kengo Obama, Kiyoyuki Kaito
S5-165
A Novel Method for Assessing the Critical Excitation Direction of Curved Bridges
Ruiwei Feng, Tianpeng Lao, Wancheng Yuan, Tongfa Deng
S5-173
Skew Placement of Arches with respect to the Bridge Deck
Hans De Backer, Amelie Outtier, Gilles Van Staen, Evy Van Puymbroeck, Zain Ul-Abdin
S5-183
The Steel Railway Arch Bridge Behaviour under Short-time Brake and Acceleration Loading
Pavel Ryjáček, Martin Werunský, Michal Polák
S5-191
Experimental and Numerical Study on the Shear Performance of RC Shear Walls Confined with Welded Reinforcement Grids
Mingzhe Cui, Jiansheng Fan, Jianguo Nie, Jun Liufu, Shengyong Li, Zhonghai Huang
S5-199
The Arched Strut – a Tool for Modelling Column-Slab Connections
Scott Alexander, Eva Lantsoght
S5-207

Applying a Set-based Parametric Design Method to Structural Design of Bridges
Alexandre Mathern, Rasmus Rempling, David Tarazona Ramos, Santiago Luis Fernández
S5-215
Innovative Method for the Production of Deck Slabs of Steel-concrete-Composite Bridges
Johann Kollegger, Kerstin Fuchs
S5-223

Dynamic Monitoring

Preservation of an Existing Original Building by Studying its Dynamic Properties
Nisrine Makhoul
S6-1
Bridge Displacement Monitoring using Acceleration Measurement and Development of Efficient Bridge Management System
Yutaro Umekawa, Hisatada Suganuma
S6-11
Causes of Resonance in PPC Girder when Shinkansen Passing and External Cable Reinforcement
Keishi Chikami, Kiyotaka Sugita, Daisuke Tsukishima
S6-19
Methodology for the Dynamic Identification of Damaged Unreinforced Masonry Walls through Vibrations Tests
Silvia Ientile, Antonella Cecchi, Giosuè Boscato, Pierre Argoul, Franziska Schmidt, Boumediene Nedjar, Dominique Siegert
S6-29
Multi-setup Operational Modal Testing of a Multi-span Viaduct
Jie Zhang, Kristof Maes, Guido De Roeck, Geert Lombaert
S6-37
Highly Sensitive Damage Detection of Reinforced Concrete Bridge Slab by “Time-Variant Deconvolution” of SHF-Band Radar Signal
Takahiro Yamaguchi, Tsukasa Mizutani, Minoru Tarumi
S6-45
Finite Element Modeling and Verification of a Retrofitted Member of a Long-span Truss Bridge by Employing Stochastic System Identification
Daiki Tashiro, Takafumi Nishikawa, Shozo Nakamura, Makoto Shimizu
S6-55
Automatic Modal Operational Analysis of a Long-span Suspended Bridge using Pattern Recognition
João Santos, Christian Crémona, Paulo Silveira
S6-63
Statistical Vibration-based Damage Localization on Saint-Nazaire Bridge Mock-up

Md Delwar Hossain Bhuyan, Yann Lecieux, Jean-Christophe Thomas, Cyril Lupi, Franck Schoefs, Michael Döhler, Laurent Mevel
S6-71

Fatigue

Evaluation regarding Fatigue for Various Types of Hangers used for Tied Arch Bridges
Jacques Berthellemy
S7-1
Fatigue Crack Propagation Analysis of Rib-to-deck Welded Joint in OSDs using Linear Elastic Fracture Mechanics
Weijian Wu, Henk Kolstein, Milan Veljković
S7-9
Fatigue Performance of Rib-to-deck Joint in Orthotropic Steel Bridge Deck with New Type of Both-Side Fillet Welded Joints
Qinghua Zhang, Jun Li, Daoyun Yuan, Yizhi Bu, Gongyi Xu
S7-19
An analytical Method for Evaluating the Fatigue Life of Perfobond Leisten Shear Connector Group under Cyclic Loading
Qinghua Zhang, Donglin Jia, Lin Xiao, Yizhi Bu, Qiao Li
S7-27
Comparison of Different Design Codes on Fatigue Assessment of Typical Welded Joints in Orthotropic Steel Bridge Decks
Yun Huang, Qinghua Zhang, Yawen Guo, Yizhi Bu
S7-35

Fiber reinforced structures

An Update of Past Visions of Fiber Reinforced Megastructures
Urs Meier
S8-1
Repair of an Orthotropic Slab with UHPFRC Slab: Bridge at Illzach in France, Return from Experience after 5 years
Grégory Généreux, Damien Champenoy, Thibaut Perrin, Sébastien Fyon, Alain Simon, Simon Pouget
S8-9
Design and Construction of UHPFRC Deck for Replacement of Deteriorated Concrete Slab
Yojiro Murakami, Takashi Kosaka, Akinori Sato, Seisuke Muragishi, Kimio Saito, Yasuo Kawabata
S8-17
Crack Resistance Test and Analysis of Steel–UHPC Lightweight Composite Deck Structure
Jun Luo, Xudong Shao, Wei Fan, Junhui Cao
S8-25

Negative Bending Fatigue Damage on the Steel Fiber Reinforced Concrete Composite Girder
Chen Xu, Boyu Zhang, Qingtian Su, Hiroshi Masuya
S8-33

Fire

Performance-based Evaluation of Fire Resistance for Steel Bridges
Di Su, Ryuta Kuniyoshi, Hiroki Kawasaki, Tomonori Nagayama
S9-1
Analysis of the Fire Resistance of a Jack Arch Flooring System submitted to the Standard Fire Curve
Ester García Castillo, Ignacio Paya-Zaforteza, Antonio Hospitaler
S9-9
Performance-Based Fire Engineering for Hazard Assessment of Tall Buildings
Pierre Ghisbain, Jenny Sideri, Reza Imani, Luciana Balsamo, Ali Ashrafi
S9-19
Structural Analysis of the Fire Response of a Cut and Cover Tunnel
Juan Pagan-Martinez, Ignacio Payá-Zaforteza, Antonio Hospitaler
S9-27

Focus on specific megaprojects

Railway Megaprojects: a Semi-probabilistic Approach to Windblown Sand Action
Lorenzo Raffaele, Luca Bruno
S10-1
The realisation of the 6.2km long Padma Multipurpose Road and Rail Bridge in Bangladesh
V. Jones, R. Halliday, M. King, Shafiqul Islam
S10-9
Megastructures for a Long Marine Bridge in Kuwait
Mohamed Akraa, Georges Mauris, Aurelie Vivier, Trinh Duong, Delphine Challant, Elodie Faivre, Serge Montens, Jean-Charles Vollery
S10-19
Additive Construction of Martian Habitats
Peter Carrato, Anne Ellis, Monserrate Román, Tony Kim
S10-29
The New Large Space Frame - TAMA-SUDARE
Junichi Sasaki, Tatsuya Yamada
S10-37

Innovative buildings

Construction of the Great Mosque of Algiers – A Megastructure Developing a New City District
Jan Akkermann, Alexander Hewener, Eric Fischer
S11-1
Multihalle Mannheim – a Contribution to the Discussion about Maintenance Ideas and Visions

for Future Utilization
Eberhard Möller, Joachim Fischer
S11-11
Post Fracture Design of the NGI Sculpture Court Structural Glass Roof
Jorge Hidalgo, Matt King
S11-21
The Construction of a New Icon in Düsseldorf
Ingo Müllers, Ralf Tesch, Michael Stahl, Guido Hulbert
S11-29
Resource Efficient Multifunctional Commercial Buildings
Richard Stroetmann, Lukas Hüttig
S11-37

Innovative cable structures

New Cable Stayed Bridge Across Storstrømmen
Barbara MacAulay, Erik Stoklund Larsen
S12-1
The Longest Axially Supported Cable-stayed Bridge in India: Chambal River Bridge
Erica Calatozzo, Serge Montens, Mathieu Muls, Jean-Charles Vollery
S12-9
High Rigidity Suspension Bridges
Marco Novarin, Julien Erdogan, Nicolas Fabry, Michal Ambor, Sebastien Petit
S12-17
Cable Stays – Asset Protection and Enhancement
Andreas Schwarz, Philipp Egger, Rachid Annan
S12-25
Analytical Study on Safety Level of Stay Cables of Cable-stayed Bridge and Extradosed Bridge under Fatigue and Ultimate Limit States
Khawaja Ali, Hiroshi Katsuchi, Hitoshi Yamada, Haeyoung Kim
S12-33
Exploration of Long-span Cable Truss Structures
Namhee-Kim Hong, Hyun-Moo Koh, Sung-Gul Hong
S12-41
Crossing the Ganges: The World's Longest Extradosed Bridge
Brook R. Robazza, Morgan T. Trowland
S12-49
Design of Multi-Span Extradose Bridges in India: Two Case Studies
Morgan Trowland , Brook Robazza
S12-57
Msikaba and Mtentu River Bridges – Large Scale Infrastructure in Rural South Africa

Nick Fuchs, Stuart Withycombe, John Anderson
S12-65
Design & Construction of Iconic Signature Bridge in Delhi
Venkat Haggade, Shishir Bansal
S12-73

Innovative designs

Innovation Design for New Style Truss Bridge in China
Gongyi Xu, Zhangong Fu, Xiaolin Liu
S13-1
Innovative Idea and Practice of Combined-Type Bridge Building
Shi Dong Luo
S13-9
Reliability of Inflatable Bridge Structures: Challenge and First Results for a New Eurocode
Jean-Christophe Thomas, Franck Schoefs
S13-19
Bridging the Gap between 1st World Innovation and 3rd World Implementation
Christiaan J. Jurgens, Jan A. Wium, Jean-Claude Labuschagne
S13-27
One Single Model: a New Parametric Approach to Megastructures
Massimo Maffeis, Andrea Biasi, Fabio Ceccato, Enrico Mazzarolo, Luca Michelini
S13-35
Innovative bionic design of flat slabs
Martina Schnellenbach-Held, Julian Mueller
S13-43
Innovative Developments of Steel and Concrete Composite Plates for two Recent Bridges in France, St Lazare Bridge and Viaduct of Guerville
Didier Guth, Claude Remy, Boris Fabre, Régis Boutes
S13-51
Lakeside Office Development on Dolomitic Ground
Kim Timm, Michael Sykes
S13-59
Optimization-driven Conceptual Design of Long Span Bridges
Helen Fairclough, Matthew Gilbert, Andrew Tyas, Aleksey Pichugin
S13-67
Hybrid Analytical Modeling of Bridge Structures: An Innovative Approach
Afshin Hatami, Rakesh Pathak
S13-75

Maintenance and management

A Life-cycle Analysis Approach applied to the Strengthening of the Jarama Steel Bridge

André Orcesi, Adélaïde Feraille, Sylvain Chataigner
S14-1
Presentation of the French Project DéCoF-Ré
Véronique Bouteiller, Lucas Bourreau, Laurent Gaillet, Franck Schoefs, Benoit Thauvin, Julien Schneider
S14-11
Scanning of Existing Structures – an Entry into BIM
Maximilian Garsch, Thomas Hertle, Andreas Wehner, Julian Pimpi, Norbert Gebbeken
S14-17
Added Value of Chloride Measurement on Wharves from SHM: a Case Study of iMareco2 Project
Franck Schoefs, Mestapha Oumouni, Yann Lecieux, Cyril Lupi, Michel Roche, Dominique Leduc, Virginie Gaillard, Dominique Follut, Pascal Lijour and Marc Labegorre
S14-25
Condition Assessment and Maintenance Strategies for Bridges at Individual and Network Level
Ye Xia, Peng Wang, Bin Kang, Yonghai He
S14-33

Marine structures

Lifecycle Assessment of Different Constructive Solutions in Aggressive Maritime Environments: Application to the Viaduct of the Oil Terminal of the Port of Leixões
Carlos Miguel Gomes de Sá, José Campos e Matos
S15-1
Case Study Analysis of Wharf Repair Projects
Xavier Hallopeau, Nick Critchley, Olivier Lesieutre
S15-9
Large Scale Locks (9,000 tons) in Lanaye, Ivoz-Ramet and Ampsin (Belgium)
Michaël Bonivers, Yannis Goblet, David Monfort
S15-19
Statistical Characterisation of Chloride Ingress Parameters from Normal and Accelerated Tests
Thanh-Binh Tran, Emilio Bastidas-Arteaga, Franck Schoefs
S15-27
Cost-Effective Climate Change Adaptation for Reinforced Concrete Structures Subjected to Chloride Ingress
Emilio Bastidas-Arteaga, Mark G Stewart
S15-35
Very Large steel-concrete Composite Offshore Pontoon-type Structure: Concept and Analysis
Xiao-Qiang Wang, Mu-Xuan Tao
S15-43

Durability Design of the Concrete Caissons for the Artificial Peninsula of Monaco Territory
Christian Crémona, Matthieu Jeusset, Christophe Vallée, Dominique Voltz, Basma Zouhny
S15-51
FLOATGEN – Design and Construction of the First Floating Wind Turbine in France
Nicolas Jestin, Perceval Modiano, Régis Bigard, Christian Cremona, Bertrand Dumas
S15-59

Metro projects

Extension of Line 1 of Lille City Metro
Aurélie Vivier, Marc Chojnacki, Charles Henry Descamps, Hervé Laproye, Julien Texier, Olivia Geneau
S16-1
New Metro Infrastructures Projects: From Design to Long-term Reliable Operation
Bertrand Collin, Floriane Galléa, Pierre Carreaud, Hervé Lançon, Mickaël De Mengin
S16-9
Structural challenges of Transit Oriented Developments above or in proximity to existing underground Metro Stations and Tunnels
Evangelos Astreinidis, Christos Tsatsanifos, Paraskevas Patsioras, Petros Chronopoulos
S16-17
Sydney Metro Cable Stayed Bridge, a Meeting of Precast Segmental Concrete and Cable Stayed Construction Technology
John Anderson, David Jefferson, Derik Hanekom
S16-25
The Railway Station Project under the CNIT in La Défense, Paris: Answers to Complex Constraints
Michel Pré
S16-33

Novelty in construction

Erection Engineering of the Skytrain Cable Stayed Bridge
Sameer Khan, George Kapos, Omar Nabeel, Marcin Tykocki
S17-1
Span by Span Segmental Construction: OPS Impact in the LG50-S Laguna Case
Pedro Pacheco, André Resende, Alberto Torres, Hugo Coelho
S17-9
Stiffening Deck Erection Work for New Millennium Bridge, Multiple Span Suspension Bridge
Jungin Kim, Jinhyuk Choi, Sangseung Lee, Junho Lee
S17-17
Numerical Analysis of Wired Connections of the Reinforcement Bars of Steel Cages: the Slashtying Technique
Konstantinos N. Kalfas, Alfredo Camara, Brett Mckinley

S17-25
New Accelerated Prefab Bridge Scheme – the NRW Bridge Modules
Abdalla Fakhouri, Katrin Baumann, Markus Gabler
S17-33
Motsa Bridge, Israel - Design and Construction Engineering Challenges
Jacques Combault, Jindrich Potucek
S17-41
Structural Development of Tensile Type Bolted Connections for Temporary Emergency Bridge Focusing on Rapid Election
Yuma Sugimoto, Takashi Tamaguchi, Yuki Mineyama
S17-49
Suspensions Bridge Construction with Cohestrand® – Installation in Jungle Conditions
María Teresa Sánchez Sánchez, Nicolas Fabry
S17-57
Volgograd Arena Stadium Roof Lifting, Volgograd, Russia
Lucie Waechter, Giulio Maria Scotto, Gökce Kizildere
S17-65
Building Bridges using Thin-walled Pre-fabricated Elements
Johann Kollegger, Stephan Fasching
S17-73

"Nouvelle Route du Littoral" viaduct

The Challenges of a Cyclonic Region for the Construction of a Viaduct with a Launching Girder
Julia Revuz, Antoine Simon, Thierry Duclos, Romain Leonard, Olivier Flamand
S18-1
The High-performance, Height-adjustable, Load-measuring Bearings of the New Route du Littoral Offshore Viaduct in La Réunion
Adel Yousfi, Thomas Spuler, Colm O'Suilleabhain
S18-9
A Particular Studies Management for an Unusual Bridge Project at Sea at la Réunion Island
Romain Léonard, Thierry Duclos, Gilles Causse, David Compte
S18-17
Zourite, a Kraken for Maritime Works
Olivier Jestin, David Compte
S18-25
A New Pier Head Connection for an Uncommon Bridge
Laurent Bailly, Brahim Djessas, Antoine Simon
S18-33

"Queensferry" and "Bosphorus" bridges

Cable Stays – Queensferry Crossing

Simon Ruas, Rachid Annan
S19-1
The Extraordinary Noise-reduced Modular Expansion Joints of the Queensferry Bridge
Arno Leegwater, Niculin Meng, Max Brüninghold
S19-9
The Third Bosphorus Bridge – Erection Sequences of the Main Span
V. de Ville de Goyet, A. Propson, C. Peigneux, Y. Duchene
S19-17
The Third Bosphorus Bridge: an Important Milestone on Long-span Cable Technology Development
Julien-Erdem Erdogan, Matthieu Guesdon
S19-25

Railway bridges

Engineering structures for the CNM HSL
Yi Zhang, Dominique Regallet, Philippe Gillet, Etienne de Boissieu
S20-1
The Vidourle Viaduct
Yi Zhang, Dominique Regallet, Sylvain Boireau, Christian Charpin
S20-11
Numerical Analysis of Large Amplitude Nonlinear Vibration of High-Speed Train PRC Bridges and Design of Tuned Mass Dampers
Atta E Mustafa,Tsukasa Mizutani, Tomonori Nagayama, Su Di
S20-19
Design of High-Speed Railway Bridges with Earthquakes
Yinghong Cao, Todd Ude
S20-27
Feasibility Study for Large Span Railway Suspension Bridge in China
Heqiang Tang, Gongyi Xu, Hanshun Liu
S20-35
Superstructures of the CEVA Railway Stations
Bernard Adam, Philippe Menétrey
S20-43
Recalculation of the Railway Bridge Buggenum
Sander van Alphen, Bert Hesselink
S20-51
Running Safety of a High-Speed Train Through a Multi-Span Bridge under a Non-Uniform Moderate Earthquake
Dong-Ho Choi, Di Mu
S20-59

Train-Bridge Dynamic Analysis Theory for Super Major Bridges and Its Engineering Applications
Mang-mang Gao, Xiao-guang Liu
S20-67
Train Structure Interaction during Ship Impact for the New Storstrøm Bridge
Alexander R. Stäblein
S20-75
Design of the Colne Valley Viaduct, a 3.4km-long HSR Viaduct in a Highly Sensitive Area
Héctor Beade-Pereda, Martin Knight, David Smith, Tomás García
S20-83
Preventive Maintenance on Superstructure and Pier of Aged Short-Span Steel Railway Structures
Weiwei Lin, Nozomu Taniguchi, Teruhiko Yoda
S20-91
Design Key Parameters for Simply-Supported Beam of High-Speed Railway in China
Zhuo Chen, Zai-tian Ke, Mang-mang Gao
S20-99

Retrofitting and repair

Diagnosis and Restoration of Four Historical Eiffel-Type Rail Viaducts
Cédric Lamarsaude, Renaud Leconte, Christophe Raulet, Claire Defargues
S21-1
Widening of the 400 m Span Cable-stayed Bridge over the Rande Strait in Spain
Álvaro Serrano-Corral, Miguel Rupérez-Astarloa
S21-9
Stay Cable Replacement and Preservation of the Pertuiset Bridge for Strengthening
Nicolas Kaczkowski, Vanessa Buchin-Roulié, Oussama Bouchhima, Nicolas Travers
S21-17
The Design of Strengthening and Refurbishment Works to the M4 River Usk Bridge, Wales
Tony Harris, Richard Owen, Jason Hibbert
S21-25
Development and Application of FASSTbridge Solution to Jarama bridge (Fast and effective Solution for Steel bridges lifetime extension)
Sylvain Chataigner, Karim Benzarti, Gilles Foret, Jean François Caron, Marc Quiertant, Maria Zalbide, David Garcia, Inigo Calderon, Ignacio Pinero, Gianluca Gemignani Collanti Concorde, Vottorio Veneto, Veit Birtel, Frank Lehmann, Mazen Wahbeh,
S21-35
Rami Boundouki, Elena Martin, Luis Sopena, Mark Weidemueller, Michael Fischer, Concepcion Iborra
Strengthening an Existing Low-Rise for Conversion to a New Hip Hotel with a Rooftop

Swimming Pool, Bangkok
Samard Buddee
S21-45
Punching Shear Strength of Concrete Slabs by Overlay of UHPC with Textile Reinforcement
Sung-Gul Hong, Hyun-Soo Youm, Namhee K. Hong
S21-53
Reinforcement of Felix Houphouët-Boigny bridge in Abidjan
Ludovic Picard, Nicolas Descamps, Emmanuel Simon, Frédéric Menuel, Hamadi Gabouge, Amandine Chambosse
S21-61
Application of Finite Element Methods to Masonry Bridges
Steve Rhodes, Philip Icke, Paul Lyons
S21-71
Strengthening of Two Major Highway Viaducts in Germany
Balthasar Novák, Jochen Reinhard, Eberhard Pelke, Vazul Boros, Carolin Roth
S21-79
Rehabilitation of Flon Arch Bridge
Claude Broquet, Guillaume Fargier, Philippe Menétrey
S21-87
Prolife: Strengthening a Steel Railway Bridge with Deck Sections
Arjen Steenbrink, Mark van der Burg, Bert Hesselink
S21-95
Staged Structural Assessment of a Large Concrete Box-girder Bridge
Timo de Goede, Rob Vergoossen, Henryk Nosewicz, Henk Sliedrecht
S21-103
Widening and Upgrading of the 77-years old Y-Bridge in Ho-Chi-Minh City
Elie Attie, Vanessa Buchin-Roulie, Nicolas Kaczkowski, Umut Aldatmaz, Michal Ambor Alain Granet, Hoang Thang Tran
S21-111

Risk management

Influence of the Design Review Process on the Structural Design Engineer due to Human Factors
Eric Brehm, Robert Hertle
S22-1
A Systematic Review for the Implementation of Risk Management within Construction of Mega Housing Projects
Mohamed Nabawy, Charles Egbu, Maged Morcos
S22-11
Communication: Megaprojects' Biggest Risk that No-one is Talking about

Christiaan J. Jurgens, Richard N. Matchett
S22-21
Multi-hazard Risk Assessment of Bridges Considering Climate Change
Omid Khandel, Mohamed Soliman
S22-29
Risk Analysis of Vehicle on Bridge Deck During Strong Side Wind
Se-Jin Kim, Ho-Kyung Kim, Won-Suk Park
S22-37
Seismic Probabilistic Risk Assessment of Weir Structures considering the Earthquake Hazard in the Korean Peninsula
Byounghan Choi, Jahangir Alam, Dookie Kim
S22-43

Seismic design and retrofitting

Seismic Assessment and Retrofit of the Caronte Viaduct (A55 Highway, Martigues)
Denis Davi
S23-1
Earthquake Countermeasures of Power Poles in Service on Railway Viaducts
Daisuke Tsukishima, Kiyotaka Sugita
S23-7
Contributions of Higher Modes of Tall Piers under Seismic Excitation
Xu Chen, Jian-zhong Li
S23-15
Seismic Performance of Composite Inverted Pendulum Light Railway Station
Liyan Xu, Xin Nie, Liangdong Zhuang
S23-23
Investigation of Bearings Unseating of Cable-stayed Bridges under Earthquakes
Yong-xing Li, Wen-jing Xu, Jiang Yi, Jian-zhong Li
S23-31
Innovative Ways of Dealing with Existing Problems: How to reliably Assess the Cause of Damage of Masonry Structures in an Area with Man-induced Earthquakes?
Karel Terwel, Roel Schipper
S23-39
Difficulties on Earthquake Design due to Standards Limits on an Extensive Offshore Bridge, Sheikh Jaber Al-Ahmad Al-Sabah Causeway in Kuwait
Aurélie Vivier, Georges Mauris, Mohamed Akraa, Serge Montens
S23-47
Experimental Study on Seismic Behaviour of Precast Piers with Combined Grouted Sleeve Splice and Grouted Central Tenon
Zhao Liu, Gan Lu, Weiding Zhuo

S23-57
Optimum Deck and Tower Configurations for the Transverse Seismic Response of Cablestayed Bridges
Alfredo Camara, Eleftheria Efthymiou
S23-65
Modelling of Structural Damping in Time History Analyses of Seismic Response of Chacao Bridge
Lars Halvor Kaasa, Kristin Nessa, Jarle Rønvik, Svein Erik Jakobsen, Aymen Cheikh Mhamed
S23-73
Influence of Phase Polarity of Bidirectional Seismic Ground Motion on Dynamic Response of Asymmetric Bridges
Akira Igarashi, Subaru Gigyu
S23-83
Effect of Accelerogram Trajectory of Bi-directional Spectrum-Compatible Waves on Nonlinear Seismic Response of Structural Model
Kazuma Inoue, Kazuaki Watanabe, Akira Igarashi
S23-91
Effect of the Valley Slope on the Seismic Response of Deepwater Rigid-frame Bridge
Jiarui Zhang, Kai Wei, Haifeng He
S23-101
Modelling the Seismic Out-of-plane Behaviour of Rammed Earth Components
Reza Allahvirdizadeh, Daniel V. Oliveira, Rui A. Silva
S23-109
Reproduction of Long-span Bridge Seismic Responses Involving Tower-girder Pounding and Tower Link Failure Estimation for Large Earthquakes
Tomoaki Takeda, Tsukasa Mizutani, Tomonori Nagayama, Yozo Fujino
S23-117
An Experimental Study on Seismic Performance of Concrete-Filled Steel Piers
Shinya Kanda, Takuro Matsubara, Hitoshi Tajima , Yoshiaki Okui, Kenichi Shiji, Seiji Okada
S23-125
Investigation on Phase Lag of Bidirectional Model in Nonlinear Seismic Analysis
Yanyan Liu, Akira Igarashi
S23-133
Lessons Learnt from the 14th November Kaikōura Earthquake and Next Generation of Resilient Solutions for Bridges
Brandon McHaffie, Ana Sarkis, Royce Liu, Alessandro Palermo
S23-141
Shake Table Studies of Seismic Damage of a Kilometre-scale cable-stayed Bridge
Wei Guo, Jianzhong Li, Zhongguo Guan

S23-149
Numerical Seismic Assessment of Masonry Made of Compressed Earth Blocks
Riccardo Nitiffi, Maura Imbimbo, Ernesto Grande, Daniel V. Oliveira
S23-157

Structural Health Monitoring

Design and Sustainable Management of Liquid Wastewater Treatment Network using the GIS Tool and the Space-based Database (Geo-LD)
Abdessalam Hijab, Hafida Boulekbache
S24-1
Measurements and simulation of temperature in a portal frame bridge
Erik Gottsäter, Oskar Larsson Ivanov, Miklós Molnár, Mario Plos
S24-9
Use of low-cost GNSS receivers for Structural Health Monitoring
Nicolas Manzini, André Orcesi, Antoine Clément, Miguel Ortiz, John Dumoulin
S24-17
Prediction of Breakage Position and Remaining Fatigue Life of Corroded Bridge Wires using 3D Scanner
Kazuhiro Miyachi, Shunichi Nakamura
S24-27
Forces in Temporary Piers in Bridge Built using Balanced Cantilever Method
Jakub Jan Jarosz
S24-35
An Adaptive NDT Inspection Strategy to Assess the Spatial Variability of Concrete Structures
Mestapha Oumouni, Franck Schoefs
S24-43
New Spatial Correlation Assessment Procedure: Application to Île-de-Ré Bridge Data
Romain Clerc, Franck Schoefs, Mestapha Oumouni
S24-51
Uncertainty Assessment and Decision from Concrete Electrical Resistivity Measurements on a Coastal Large Bridge
Lucas Bourreau, Véronique Bouteiller, Franck Schoefs, Laurent Gaillet, Benoit Thauvin, Julien Schneider, Samuel Naar
S24-59
Effect of Steel Reinforcement on Electrical Measurements on Concrete
Marie Antoinette Alhajj, Géraldine Villain, Sérgio Palma-Lopes
S24-65
Better Understanding of Tide's Influence on Half-cell Potential Measurements for Reinforced Concrete in Marine Environment
Lucas Bourreau, Véronique Bouteiller, Franck Schoefs, Laurent Gaillet, Benoit Thauvin,

Julien Schneider
S24-73
Compatible Deformation in the Condition Assessment of Beam Structures
Jun Lei, Dong Xu, Jose Turmo
S24-79
Improving the Reliability of On-site Concrete Strength Estimation with Non-destructive Techniques
Denys Breysse, Jean-Paul Balayssac, Xavier Romao, Maitham Alwash
S24-87
Monitoring Cracks on Concrete Surfaces using Multi-temporal Images
Bruno O. Santos, Jónatas Valença, Eduardo Júlio
S24-95
Long Term Monitoring of Millau Viaduct
Antoine Clement, Hervé Lançon, Emmanuel Cachot, Claude Servant
S24-103
Structural System Identification of Shear Stiffnesses in Beams by Observability Techniques
Jose A. Lozano-Galant, Seyyed Behrad Emadi, Gonzalo Ramos, Jose Turmo
S24-111
Potentials of Autonomous UAS and Automated Image Analysis for Structural Health Monitoring
Jens Kersten, Volker Rodehorst, Norman Hallermann, Paul Debus, Guido Morgenthal
S24-119
Lessons Learnt from Full-Scale Tests of Bridges in Croatia and Sweden
Ivan Duvnjak, Marko Bartolac, Jonny Nilimaa, Gabriel Sas, Thomas Blanksvärd, Björn Täljste, Lennart Elfgren
S24-127

Special session on Forensic engineering

A multilevel Approach for the Structural Vulnerability Assessment of Historical Water Tunnels. The Case of the Apulian Aqueduct
Fabrizio Palmisano, Pasquale Perilli, Luciano Venditti, Gianluca Casamassima, Gerardo Ventafridda
S25-1
A Numerical Study on Prediction of Collapse Pressure of UOE Pipes
Jiwoon Yi, Soo-Chang Kang, Jinkyo F. Choo, Do Been Kim, Wonsuk Park, Hyun-Moo Koh
S25-9
Merrison Revolutionised Design after 1970 UK Box Girder Collapses
Jonathan G M Wood
S25-17
Seismic analysis of the San Sebastian Basilica (Philippines)

Nicole O'Hearne, Nuno Mendes, Paulo B. Lourenço
S25-25
Knowledge Model for Forensics in Civil Engineering
Denys Breysse, Franck Taillandier, Cedric Baudrit
S25-33

Special session on Innovations towards improved seismic resilience and upgrade of existing structures

Experimental Studies of Seismic Performance of Precast Concrete Columns with High-strength and Conventional Steel Rebar
Weiding Zhuo, Zhao Liu, Teng Tong
S26-1
Seismic Upgrade of a Reinforced Concrete Building using Friction-Pendulum Isolators
Christos Giarlelis, Dimitrios Koufalis, Panagiotis Antoniadis, Costis Repapis
S26-9
Seismic Retrofit of Industrial Building using Damping Devices
Devis Sonda, Marco Cossu, Andrea Pollini
S26-17
Seismic Performance of Precast Segmental Bridge Piers with High-strength Bars based on Cyclic Loading Test and Numerical Simulation
Teng Tong, Weiding Zhuo, Zhao Liu
S26-25
Evaluation of Response Modification factors in moment resisting frame buildings considering Soil Structure Interaction
Farheen Kanwal, Ahmed Munir
S26-33
Implementing Resilience in Practice: Design for All in Anticipation of Earthquake Disaster
Jon Moseley, Stephanos Dritsos
S26-41
Simple Strengthening Techniques for Non-engineered Buildings against Seismic Actions
Marina Traykova, Christos Giarlelis, Andreas Lampropoulos, Stephanos Dritsos, Jon Moseley
S26-49
Seismic Upgrading of Reinforced Concrete Columns by FRP Jacketing
Efstathia Liakopoulou, Sotiria Athanasopoulou, Stephanos E. Dritsos
S26-57
Fibre Reinforced Geopolymer versus Conventional Reinforced Concrete layers for the structural strengthening of RC beams
Mohammed Haloob Al-Majidi, Andreas Lampropoulos, Andrew Cundy, Ourania Tsioulou, Salam Alrekabi

S26-65
Structural upgrade of deficient Unreinforced Masonry structures using Ultra High Performance Fibre Reinforced Concrete
Andreas Lampropoulos, Ahmad Tasji, Ourania Tsioulou
S26-75

Special session on Structural health monitoring

Structural Health Monitoring of Existing Bridges using Bridge Weigh-in-motion Measurements – Value of Information Analysis
Dominik Skokandić, Ana Mandić Ivanković, Aleš Žnidarič
S27-1
Condition Assessment of Timber Structures – Quantifying the Value of Information
Mislav Stepinac, Vlatka Rajčić, Daniel Honfi
S27-9
Value of Information in the Maintenance of a Tendon supported Large Span Roof
Mariusz Maślak, Michał Pazdanowski, Tomasz Howiacki
S27-19
Optimizing Monitoring – Implementation of Draft Guideline and Case Study of Roof Exposed to Snow Loads
Dimitris Diamantidis, Miroslav Sýkora
S27-27
Failure Probability for Extreme Load Cases evaluated by FE-calculations – A Case Study for the Rockfall Protection Gallery Rieinertobel
Yusuke Kurihashi, Masato Komuro, Matthias Schubert, Rocco Custer, Kristian Schellenberg
S27-35
Rating of Prognostic Performance Indicators through the Indicator Readiness Level
Maria Pina Limongelli, André Orcesi, Anja Vidovic
S27-43
Bridge quality control using Bayesian net
Dušan Isailović, Rade Hajdin, Jose Campos e Matos
S27-51
An Overview of the European Situation on Quality Control of Existing Bridges
COST Action TU1406
José C. Matos, Joan R. Casas
S27-59

Special structures

Ultra High-rise Building with High Seismic Performance using High Efficiency Hybrid Vibration Control System: [Tokyo Garden Terrace Kioicho] Kioi Tower
Yuichi Koitabashi, Seiya Kimura
S28-1

Modern Wind Turbines - Challenges and New Design Technologies for Tower Structures
Marion Rauch
S28-9
Reconstructing the Iron Age in 21st Century Style
Elana Rautenbach, Kim Timm
S28-17
Ashalim Solar Tower
Jean-Bernard Datry, Audrey Zonco, François Prongue, Thomas Dum, Gilles Oudin
S28-25
Success of Dam Engineering Industry Projects in Australia: Literature Review and Theoretical Framework
Pouya Amirsayafi, Xiaohua Jin, Sepani Senaratne
S28-33
Design Redundancy Analysis and Optimization for Steel Frame Structure
Xin Zhao, Jianzhe Zhao
S28-43
The First Engineered Pedestrian Bridge using Small Diameter Indonesian Teak Woods: From Design to Project
Ali Awaludin,Bambang Supriadi, Maris Setyo Nugroho, BuanAnshari, Zakiah Ahmad
S28-49
Pont de l'Espace Grotte in Lourdes, Movable Footbridge upon the Gave de Pau (France)
Christophe Peigneux, Vincent Servais
S28-57
Numerical Analysis and Theoretical Studies on Progressive Collapse of Suspend Dome Structures
Zhenyu Xu, Xianzhong Zhao, Shen Yan
S28-65
5/6 Arches: a Megastructure becoming a land marking Monument
Silvia Geyer, Claudio Pin, Daniela Lombardini
S28-73
Glass Sails of the Fondation Louis Vuitton: Approach to Robustness
Matt King, Jorge Hidalgo, Africa Garcia
S28-81
AQUATIS – Museum and Aquarium in Lausanne above a Car Park with Metro Connection
Verena Pierret, Michel Porcelli, Marco Bosso
S28-89
Comparative Study of Quasi-static and Dynamic Behaviours of a Reduced Model of ASM4 Rockfall Barriers
Romain Boulaud, Cyril Douthe

S28-97
Roof of the Lille Stadium: Instability Phenomenon in Cover-plates of Tensed-plate
Vincent de Ville de Goyet, Sébastien Seret, Arnaud Propson, Charles Havelange
S28-107
Lightweight Megastructure: Design and Construction of a 100m Span Dome in Manila
Catherine Poirriez, Yacine Bouzida
S28-115
Building Complex Shapes with Simple Tools: Fast Track Design of “the Future of Us” Gridshell in Singapore
Catherine Poirriez, Yacine Bouzida
S28-123
Technical Issues on Construction of Cable-stayed Bridge using UHPC
Jihoon Lim, Minjae Lee, Jun-ho Lee, Jungin Kim, Jahgeol Yoon
S28-131

Steel structures and technologies

Complementary Zinc Coatings
Martin Gagné, Frank E. Goodwin, Martin van Leeuwen
S29-1
Welded Connections in Innovative High Strength Steel Constructions
Jennifer Spiegler, Ulrike Kuhlmann
S29-7
Buckling of Curved Webs in Steel Box Girders
Gilles Van Staen, Hans De Backer, Philippe Van Bogaert
S29-15
An Innovative Fabrication Process from Rolled Helicoidal Steel Strips
Nicolas Leduc, Jean-François Caron, Cyril Douthe, Bernard Vaudeville, Simon Aubry
S29-23
Experimental Investigation of Shear Behavior of Cantilevered Non-Prismatic Box Girder with Corrugated Steel Webs
Siqi Yuan, Zhao Liu, Chao Wang, Zhiqi He
S29-31
Elastic Torsional Rigidity of Multi-cell Box Girders with Corrugated Steel Webs
Jun He, Chuanxi Li, Chao Tan, Xiaodong Dai, Sihao Wang, Yuqing Liu
S29-41
Newest High Performance Heavy Plates for Steel Bridges and Structures
Cécile Merlin-Manuelli, Tobias Lehnert
S29-49
Welds for High-Strength Steels – Development of New Design Rules
Richard Stroetmann, Thoralf Kästner, Lars Werner

S29-57
Performance Enhancement of High-Strength Bolted Frictional Girder Connections Focused on Bearing Bolt Hole Deformation
Hitoshi Moriyama, Takashi Yamaguchi, Hiroki Sugiyama
S29-65
Low Temperature Behaviour of High-Strength Structural Bolting Assemblies of Large Diameters
Christoph Lorenz, Natalie Stranghöner, Sandro Citarelli, Markus Feldmann, Victoria Brinnel, Sebastian Münstermann
S29-73
Fatigue and Corrosion as a Threat for Steel Heritage Bridges
Martin Macho, Pavel Ryjáček, José Campos e Matos
S29-81

Tall buildings

TMD Systems for Increase of Damping within High-Rise Buildings
Peter Huber, Luca Paroli
S30-1
Innovative Prefabricated Robustness Solutions for Story High Buildings
Thomas Cornelius, Guangli Du
S30-9
Occitanie Tower, a City in the Tower: For an Interactive Structural Design with the Architecture and Multifunctionality of the Tower
Youssef Jaradeh
S30-17
New Paris Law Court, a Major Civil Engineering Structure in the City
Iari Agez , Audrey Zonco, Hermann Fagninou, Jean-Bernard Datry
S30-25
Simplified Procedure for Estimating Modified Response Modification Factor of a Complex High-Rise Building
Ahmed Munir, Farheen Kanwal
S30-33

The Mega-floating city

The Mega-Floating City Green Float—Part I: Concept and Technological Innovations
Masaki Takeuchi, Shuhei Ono, Masanobu Hasebe
S31-1
The Mega-Floating City Green Float—Part II: Construction Planning
Shuhei Ono, Masaki Takeuchi, Masanobu Hasebe
S31-9
The Mega-Floating City Green Float—Part III: Verification by Experiments and Analysis

Masanobu Hasebe, Masaki Takeuchi, Shuhei Ono
S31-17

Timber construction

Hybrid CLT-Based Modular Construction Systems for Prefabricated Buildings
Cristiano Loss, Thomas Tannert
S32-1
Feasibility Study of Mass-Timber Cores for the UBC Brock Commons Tallwood Building
Thomas Connolly, Cristiano Loss, Asif Iqbal, Thomas Tannert
S32-9
A Review of Structural Robustness with Focus on Timber Buildings
Johannes A. J. Huber, Mats Ekevad, Ulf Arne Girhammar, Sven Berg
S32-17
Seismic Design and Off-Site Construction of College Buildings for 500 Students with Timber Frame 3D Modules in Clisson (near Nantes, France)
Rémi Thépaut, Patrice Sébille
S32-27
Possibilities of Bamboo Construction: From Vernacular Techniques to Industrialized Solutions
Hélder S. Sousa, Bhavna Sharma
S32-35

Tunnels

The Long Traffic Tunnels of Tomorrow
Silvino Pompeu-Santos
S33-1
The Submerged Floating Tube Bridge as an alternative for a crossing: pros and cons
Mathias Eidem, Arianna Minoretti, Xu Xiang, Tale Aasland
S33-9
Combining Bored Tunnels: Optimal Construction Order of Multiple Independent Shield-Driven Tunnels
Hans De Backer, Amelie Outtier, Bart De Pauw, Ken Schotte, Ahsan Naseem
S33-17

Wind effects on structures

Wind Engineering Challenges of Modern Footbridges
Anna Bagnara, Stefano Cammelli, Eva Berbekar
S34-1
Nonlinear Flutter Collapse Analysis of the Tacoma Narrows Bridge with a New Nonlinear Aerodynamic Force Model
Rui Zhou, Yongxin Yang, Yaojun Ge
S34-9
Aerodynamic and Aeroelastic Design of Long Span Bridges: Recommendations for Chile

Matias Caram, Matias A. Valenzuela
S34-17
Re-Evaluation of Aerodynamic Stability of Suspension Bridges in Seto-Ohashi Bridges
Akira Machida, Masahiro Takeguchi, Taku Hanai, Hiroshi Katsuchi
S34-25
Quantification of the Influence of Aerodynamic Model Assumptions for Dynamic Analyses of Bridges
Igor Kavrakov, Guido Morgenthal, Ahsan Kareem
S34-33
Wind Loading of Legacy Infrastructure: Recent Experience from France
Graham Knapp, Christian Barré
S34-43
Investigation of Long-Span Bridge Stability in Wind Tunnel
Sergei Solovev, Viktor Sokolov, Artem Novikov
S34-51
Wind Performance Analysis Method Based on a Simplified Model for Tall Buildings with Viscous Outrigger
Xin Zhao, Jiayue Li
S34-59
Multi-Modal Flutter Analysis of a Long Floating Bridge
Martin N. Svendsen, Stian Moe Johannesen
S34-63
Super-long span bridge aerodynamics: first results of the numerical benchmark tests from TG10
Ketil Aas-Jakobsen, Andrew Allsop, Igor Kavrakov, Allan Larsen, Ole Øiseth, Giorgio Diana, Tommaso Argentini, Simone Omarini, Daniele Rocchi, Martin Svendsen, Guy Larose, Stoyan Stoyanoff, Ho-Kyung Kim, Teng Wu, Michael Andersen, Hiroshi Katsuchi
S34-71