出國報告（出國類別：考察）

橋梁耐震、檢測及公路防災技術交流考察報告

服務機關：交通部高速公路局
姓名職稱：王吉杉組長、張勝緯分局長
派赴國家：美國
出國期間：113 年 9 月 26 日至 113 年 10 月 3 日
報告日期：113 年 12 月 25 日

摘要

報告名稱：橋梁耐震、檢測及公路防災技術交流考察報告

主辦機關：交通部高速公路局

連絡人/電話：王吉杉/02-29094929、張勝緯/04-25583058

出國人員：王吉杉、張勝緯

出國類別：考察

出國地點：美國

出國期間：113 年 9 月 26 日至 113 年 10 月 3 日

分類號/目：H0/綜合類（交通）

關鍵詞：美國加州運輸署（California Department of Transportation, CADOT 簡稱 Caltrans）、橋梁檢測（Bridge Inspection）、橋梁檢測國家標準（National Bridge Inspection Standards, NBIS）

內容摘要：交通部高速公路局自民國 91 年起即與加州運輸署簽訂雙邊合作協議，除雙方人員交流互訪外，亦曾辦理「臺美公路與橋梁工程研討會」由雙方交通部層級官員共同與會進行交流，對於本國公路與橋梁工程技術提昇、臺灣國際能見度提昇，均有莫大助益。2022 年第三季以來，新冠疫情趨緩，國際交流逐漸活絡，爰在臺美雙邊既有合作協議架構下重啟技術交流，並進行第五次雙邊合作協議換約之討論。本次考察，包括輕質混凝土橋面版改建、加州 57 號及 60 號共線公路常態性交通壅塞改善計畫、第 6 街橋梁改建、長堤跨港大橋檢測設施及其橋梁維護設計理念、第 7 區交通控制中心等，均納入考察範圍。本次考察，特別感謝加州運輸署橋梁檢測南區辦公室趙青主任協助安排行程。

目錄

壹、目的

交通部高速公路局自民國 91 年起即與加州運輸署簽訂雙邊合作協議（Agreement on The Mutual Collaboration between California Department of Transportation and Taiwan Area National Freeway Bureau, Republic of China），雙邊合作協議每期 5 年，迄今已 5 次換約。合作協議有效期間，除雙方人員交流互訪外，亦曾參與「臺美公路與橋梁工程研討會」由雙方交通部層級官員共同與會進行交流，對於本國公路與橋梁工程技術提昇、臺灣國際能見度提昇，均有莫大助益。

雙邊雖然由橋梁工程技術合作為起始，在多年的合作基礎上，已逐步開拓在設施防災、鋪面管理、關鍵基礎設施防護等面向，期由多面向的參訪、研討擴大交流，鞏固雙邊合作交流。

貳、考察行程

本次考察，雖然事前已預排相關參訪行程，但須配合加州運輸署當地工程進度、事件與接待官員行程，實際行程調整如下表。

日期	星期	行程概述
臺灣時間 9/26	四	臺北飛洛杉磯
美國時間 9/26	四	上午抵達洛杉磯及加州運輸署南加州辦公室參訪
美國時間 9/27	五	Rio Houdo Busway Bridge 輕質混凝土橋面版改建工程、加州 57 號及 60 號共線公路常態性交通壅塞改善計畫改建
美國時間 9/28	六	資料整理
美國時間 9/29	日	資料整理
美國時間 9/30	一	參訪第六街高架橋(Sixth Street Viaduct)、長灘國際門戶大橋(New Gerald Desmond Bridge，最後命名為 Long Beach International Gateway)
美國時間 10/1	二	參訪洛杉磯區交控中心（LARTMC）、再次參訪加州運輸署南加州辦公室－橋面板劣化補強交流座談
美國時間 10/2	三	洛杉磯飛臺北
臺灣時間 10/3	四	返抵臺灣

參、考察紀要

一、 加州運輸署業務參訪

加州面積 423,970 平方公里，約為臺灣 12 倍大，倘將加州視為單一經濟體，則為世界第 5 大經濟體[1]。州政府位於加州中北部的沙加緬度郡(Sacramento County)，加州運輸署[2]（California Department of Transportation，簡稱 Caltrans）總部亦位於沙加緬度郡負責全加州鐵路、捷運、公路、航空、大眾運輸、運輸規劃與管理、運輸基礎設施維護等工作，員工人數超過 20,000 人，以職場招募為主，與國內須通過公職考試之遴才方式不同，除白人外，西班牙裔、拉丁美裔約佔 35%、亞洲裔約佔 8%，其中近 6000 人具備 PE(Professional Engineer)或 SE(Structure Engineer)資格，自辦檢測與設計的工程占相當大的比例。

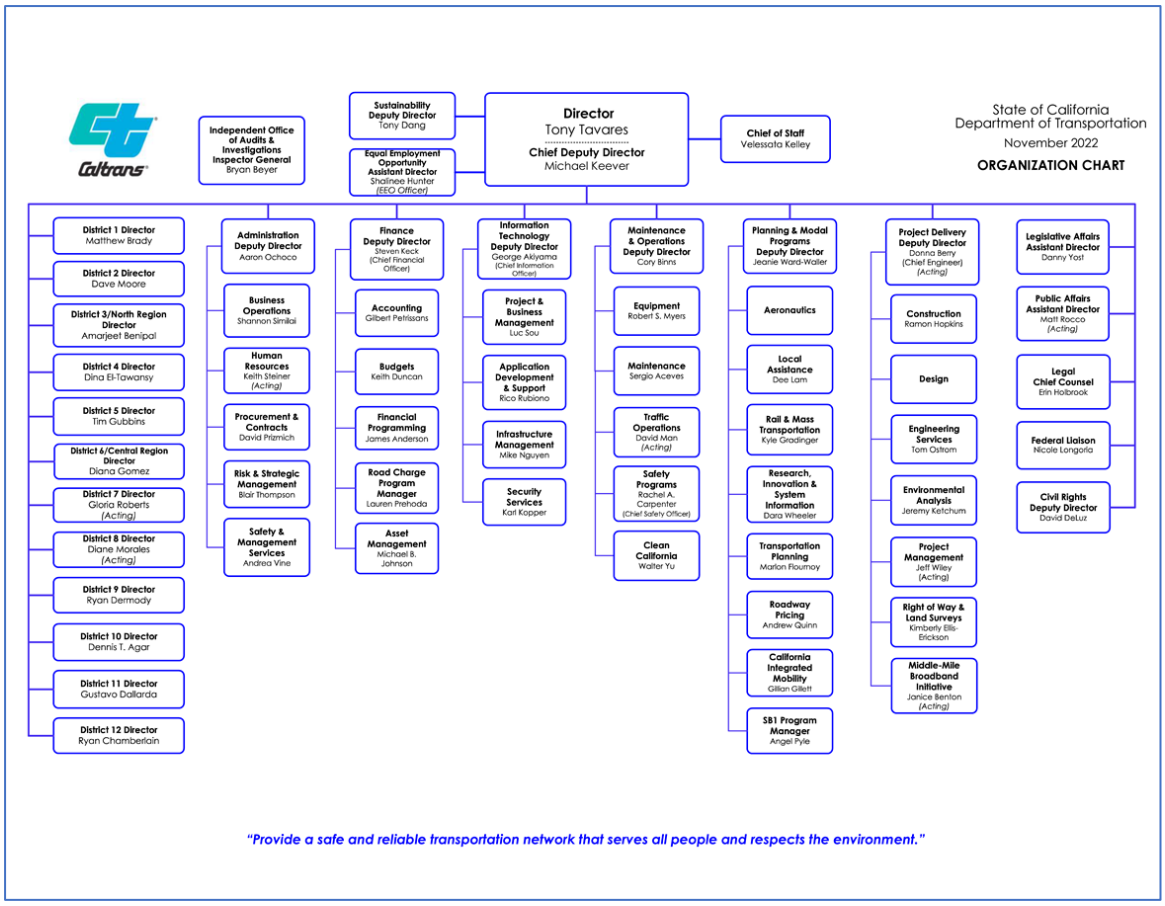
為有效管理各地運輸事務，又將全加州劃分為 12 個分區（或稱分署），各個分區置有 Director，與橋梁檢測有關業務，主要歸營運與維修部門主管，該部門管理近 24,364 公里長公路維護、1,416 平方公里路權管理與 13,063 座州際公路橋梁，另外透過辦理橋梁檢測作業、提供檢測缺失之維修建議與郡、市政府辦理橋梁維修或新建(改善)工程時針對結構部分協助辦理品質管理，協助郡、市政府管理 12,200 多座橋梁。

結構維護與調查部門（Structure Maintenance and Investigations）為署本部署內單位，又分為六個辦公室，包括 1.北加州結構調查辦公室（Office of Structure Investigations-North）；2.南加州結構調查辦公室（Office of Structure Investigations-South）；3.結構設計與分析辦公室（Office of Structural Design and Analysis）；4.橋梁資產管理辦公室（Office of Bridge Asset Management）；5.特殊檢查辦公室（Office of Specialty Inspections）；6.收費橋梁檢查辦公室（Office of Structure Investigations-Toll Bridges）等 6 個辦公室，本次考察係由南加州調查辦公室安排行程及接待，故參訪區域以其轄區內橋梁為主。加州運輸署組織

[1] 網頁瀏覽：外交部領事事務局，https://www.boca.gov.tw/sp-foof-countrycp-03-107-79acc-04-1.html，瀏覽日：20221127。

[2] 美國為聯邦制國家，U.S. Department of Transportation 為國家層級，一般譯為美國交通部；至於 California Department of Transportation 為州政府層級，類比省的層級，有譯為加州運輸「部」、加州交通「廳」、亦有譯為加州運輸「署」者。參考之前同性質出國報告，本文將 California Department of Transportation 譯作加州運輸署。

架構如圖一。



圖一 加州運輸署組織架構圖

美國政府體制採聯邦制度，中央政府掌管政策制定與財源分配，但因各州政府轄區特性、財政與組織差異很大，自主性相當高，在橋梁管理政策上除訂定規範要求遵循外，會透過補助款引導或要求州政府，聯邦政府亦派駐有 2 位橋梁工程師長駐在加州，檢視 Caltrans 的橋梁檢測結果，如橋梁檢查結果經過聯邦人員檢視後認為品質不佳、未獲審核通過，聯邦政府將會扣減對加州政府之補助款。

在南加州結構調查辦公室橋梁檢測業務大多由其職員辦理，管理類似顧問公司方式，專職橋梁檢測工作，極少工務行政業務，所有工時、業務支出需與負責計畫內容符合，方可支應經費，在待遇方面，工程師月薪約 1 萬美金，且享有各類保險、休假等福利。每一位負責橋梁檢測之資深工程師（Senior Engineer）轄管 6 位工程師，實際橋梁檢測業務一般由工程師執行，資深工程師負責橋梁檢測成果之審核，但複雜橋梁之檢查，資深工程師也會參與。部

分橋梁檢測業務也會委託顧問公司辦理，委外辦理檢測之橋梁，加州運輸署也與本局一樣負責 QA，採抽委外數量 5%之橋梁自辦橋檢，將結果與顧問公司檢查結果作比對。

橋梁檢測在工作分配上，會依據橋梁可近性、結構複雜程度、構件多寡、橋梁檢測所需時間給予綜合評值，再平均分配給工程師執行，以求每位工程師之工作量相當。一般作業是二週實地檢查、二週寫報告，每座橋梁檢查報告最慢三個月要提交，資深工程師會管控進度，確保按時交報告。

Caltrans 是由工程師所建立、運作的組織，擁有大量的專業工程師，自辦大量的檢測、維修與新改建工程設計與監造作業，建立完整而齊全的作業規範，以供遵循。為了確保執行成果的正確性與可靠性，對於委外辦理作業的品管也有一定的文件與程序可以遵循。然而對於日益增加的統包工程或州政府補助部分預算由郡、市政府自辦設計、監造工程，Caltrans 亦被要求協助辦理品管作業，對於各項成果檢覈的內容、頻率則還在試辦、制定文件與程序中。

二、Rio Houdo Busway Bridge 輕質混凝土橋面版改建工程

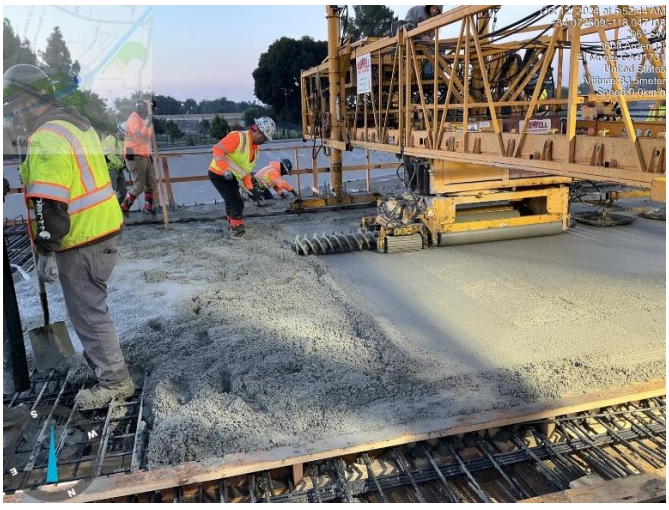
Rio Houdo Busway Bridge 是一座橋齡超過百年的公車專用橋(如圖二)，由於基礎為木樁，上部結構使用鋼梁及輕質混凝土橋面版的剛性鋪面，因橋面版劣化嚴重而進行輕質混凝土的橋面版更新工程。

圖二 Rio Houdo Busway Bridge

Houdo 河上游為 Peck Road Park Lake，參訪時正值當地的非汛期，工程司表示許多城市內許多河川因防災考量改建為 3 面光的構造，對於本座跨河橋的基礎型式採用壁式橋墩，在迎水面造型利於減緩壅高及對水流的干擾，而河床面的構造對於國內跨河橋梁基礎沖刷的防治也有相當大的助益。但對於國人講求環境保護與生態保育多樣性的情境下，除了小斷面的區域排水外並不多見，防災與生態保育的權重衡量，並非放諸四海都可以適用的。

由於該橋的基礎使用木樁，無法增加承重，在橋面劣化改善的方案上須進行諸多評估，由於劣化較為嚴重，無法僅進行裂縫灌注搭配局部修復，也無法使用 Deck on Deck 橋面板增厚的工法，最終採取改建橋面版的方案，而材料則使用加州已經相當成熟的輕質混凝土。

加州橋梁之橋面版完成澆置後會進行掃紋，即採剛性路面方式服務用路人，與國內在橋面版上加鋪 5 公分的瀝青混凝土面層不同，工程司表示加鋪面層無法檢測橋面版上方面層的狀況，加上加州居民對於行車舒適性與維護費用提高可能增加稅金的衡量，普遍選擇接受舒適度不佳的剛性鋪面。輕質混凝土施工如圖三。



圖三 橋面版澆置施工

三、 州公路 57/60 匯流交通壅塞改善計畫（57/60 Freeway Confluence Construction）

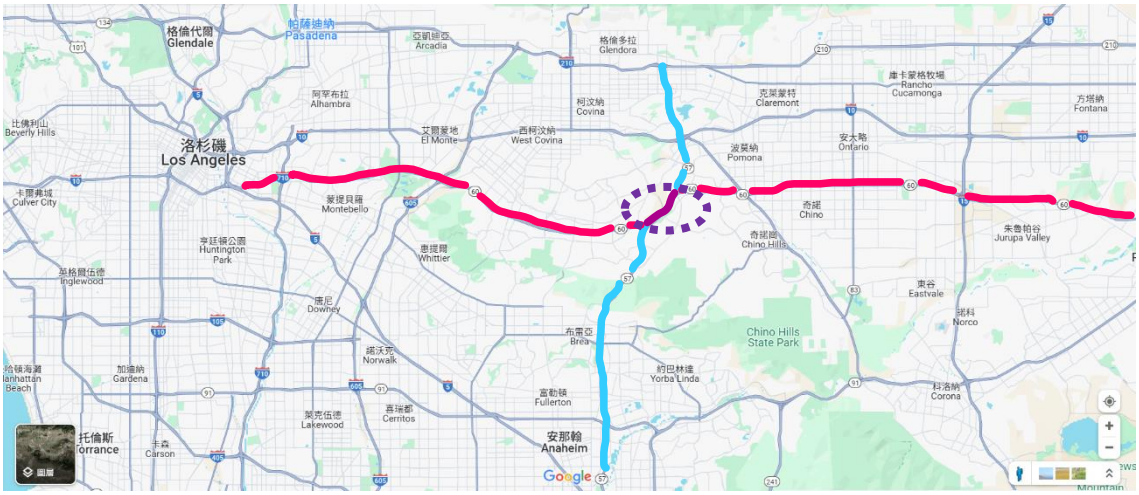
鑽石吧市和工業市之間的 57 號國道 (SR-57) 和 60 號國道 (SR-60) 交匯處是全國交通擁堵和事故最嚴重的高速公路路段之一(如圖四)。這個兩英里長的區域也是全國最繁忙的卡車貨運路線之一。 57/60 共線路段每日交通量超過 350,000 輛次，與台灣國道最大交通量路段日交通量 20 萬輛次相比約 1.75 倍之高，其中包括估計 26,000 輛貨運卡車。根據美國運輸研究所的數據，這是加州問題最嚴重的卡車瓶頸，在全國排名第七。這是重要的區域間高速公路和貨運走廊，對南加州的港口、聯運設施、倉儲、製造業和出口依賴型產業至關重要。

兩條交通量很大的州公路在進入谷地地形後，受限於現地條件，能開闢的車道數無法滿足各州到原先的車道數，形成較多車道數交通匯集到共線路段，車道數減少導致交通壅塞，雖然已經透過個別州公路在匯入共線路段前縮減車道，以符合交流道匝道匯入共線主線時可達車道平衡，但各州公路在進入交流道前因車道數縮減，造成在改善區段外的上游區也有壅塞的情形。各斷面車道數如圖五。

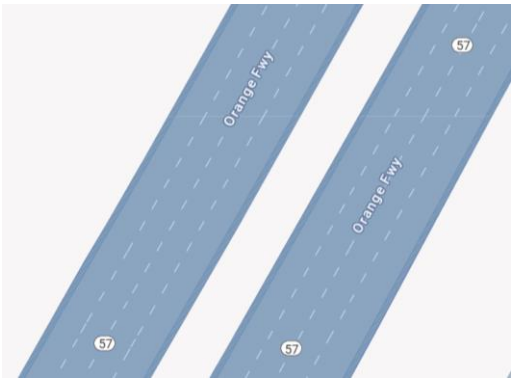
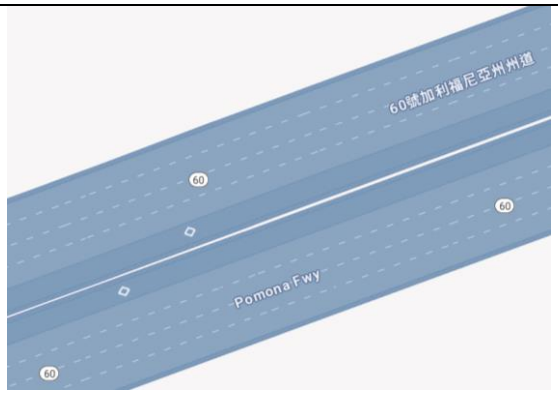
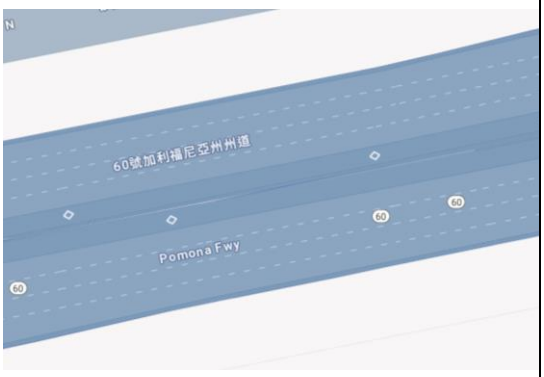
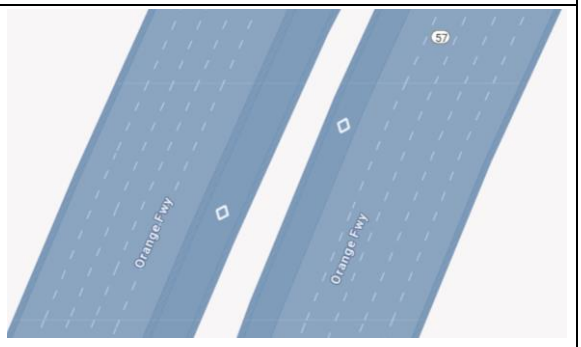
另外，各州公路的重車比偏高，本就容易因重車車速較慢造成該車道或相鄰車道的車速降低；還有需於共線路段轉換到不同州公路的車流交織，特別是行駛於外側的重車，需橫越數個車道才能順利轉換至另 1 個州公路，此種車流型態對車速、事故的影響會更大。

為了改善擁擠和危險的 57/60 共線交匯處，受限於地形限制主線車道數增加不足以滿足 2 州公路匯入的車道數需求。因此該計畫除在主線增加車道數外，主要採取轉換州公路車輛的提前分流、新增匝道與立體交叉橋梁來重新調整動線；此外也針對改善路段內影響地區道路的交流道跨越橋進行一併車道調整與改善，以降低危險的車道交織，從而提高通勤安全並減緩交通壅塞。改善計畫車道及匝道配置意象如圖六~圖九。

改善計畫於 2023 年 7 月啟動，目前正在進行中，預計於 2028 年 7 月竣工，期望在舉辦 2028 洛杉磯奧運時發揮其運輸的功能。



圖四 57/60 Freeway Confluence Construction 位置圖

	
斷面 A(雙向各 4 車道)	斷面 B(雙向各 5 車道)
	
斷面 C(雙向各 5 車道)	斷面 D(雙向各 6 車道)
	
斷面 E(5+3 匯入 8 車道)	斷面 F(5+3 匯入 8 車道)

圖五 各斷面車道數

圖六 新增東出 SR-60 Grand Avenue 匝道橋，避開地方號誌回堵

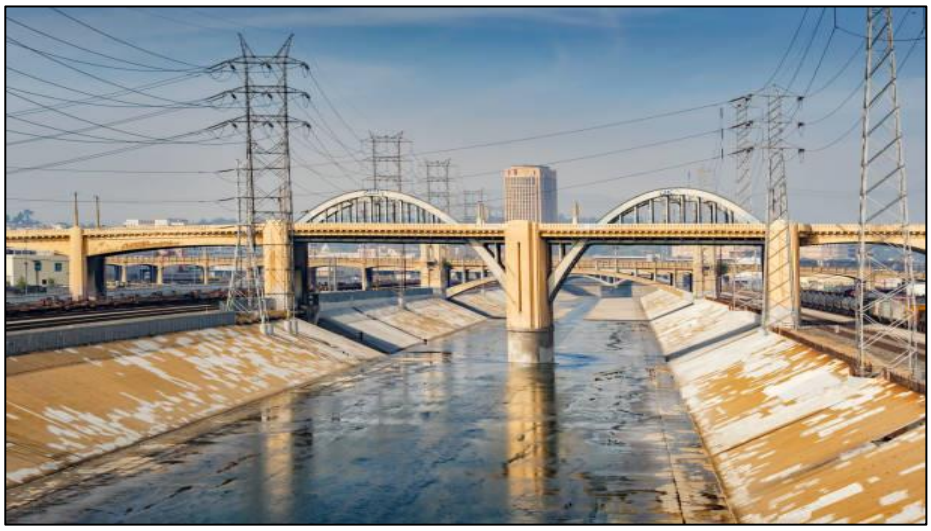
圖七 改建 Grand Avenue 橋調整車道配置，增設東入環道及拓寬調整原東出匝道並增設提前分流之東出匝道

圖八 增設北側系統交流道主線車道，供東行 SR-60 通行(跨 Diamond Bar Blvd.)

圖九 增設北側系統交流道主線車道，供東行 SR-60 通行(跨 Prospectors Road)

四、 參觀 Sixth Street Viaduct

第六街高架橋(Sixth Street Viaduct)位於洛杉磯市區，是一座連接洛杉磯市中心藝術區和博伊爾高地 (Boyle Heights)的橋梁，跨越洛杉磯河、聖安娜高速公(US 101) 、金州高速公路(I-5)、幾條當地街道，以及多條鐵路。第一代橋梁(如圖十)於1932年啟用，橋長1100公尺，寬度14公尺，由鋼筋混凝土西段、河上中央鋼拱段、鋼筋混凝土東段三個獨立結構組成，第一代橋梁通車後20年即因混凝土發生鹼骨材反應，導致混凝土產生幾條大裂縫並削弱結構的強度，洛杉磯市政府雖然進行了多次修復補強工程，始終無法徹底改善。2007年加州運輸署公布州政府所轄1,620座一般結構缺失橋梁以及228急迫需要改建橋梁均未含第六街高架橋，但加州運輸署仍建議洛杉磯市政府優先將第六街高架橋改善或重置新建。同年，2007年洛杉磯市工程局發布報告指出，第六街高架橋在未來50年內遭遇地震倒塌之機率為70%，較可接受之標準，橋梁倒塌機率為2%或超過50年，高出甚多。第一代橋梁最終在2016年拆除。



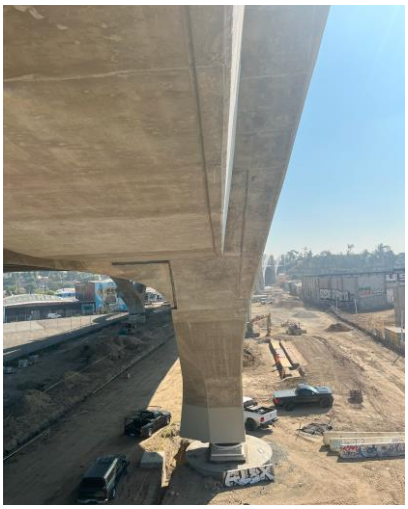
圖十 第一代 Sixth Street Viaduct

第二代橋梁由洛杉磯建築師Michael Maltzan設計，HNTB 設計建造團隊於2022年建造完成，總工程經費5.88億美元，號稱洛杉磯史上規模最大的橋梁興建計畫，完工之後，除了4線道的汽車道之外，設有自行車道與寬敞的人行道。新橋設計概念為「光之彩帶」(如圖十一)，為10對傾斜式RC拱肋加上網狀鋼索構成之網狀吊索系統繫桿拱橋(network tied arch bridge)，

彷彿一條優美的彩帶伸展在洛杉磯市區橋上，吸引眾人目光，水泥風格與橋下經常出現在電影場景的洛杉磯河相互輝映。站在橋上抬頭可以欣賞洛杉磯聞名的天際線，附近是鐵路貨櫃行經的路線和點綴著街頭塗鴉的倉庫。這座橋已成為洛杉磯市的新地標。

圖十一 第二代 Sixth Street Viaduct

這座橋為了形塑優美的彩帶線形，在橋梁主構件外側以假柱假拱的方式向外極致延伸，因此會出現墩柱支承貌似偏心的假象(如圖十二)，或是RC拱肋外斜翻飛的效果，也是本座橋的最大特色；另外這座橋梁對於行人及自行車有非常友善的設計，自行車及行人專用道可由主線再岔出，在橋梁外側及下方穿梭迴繞(如圖十三)，亦可作為橋檢人員目視檢測的通道。

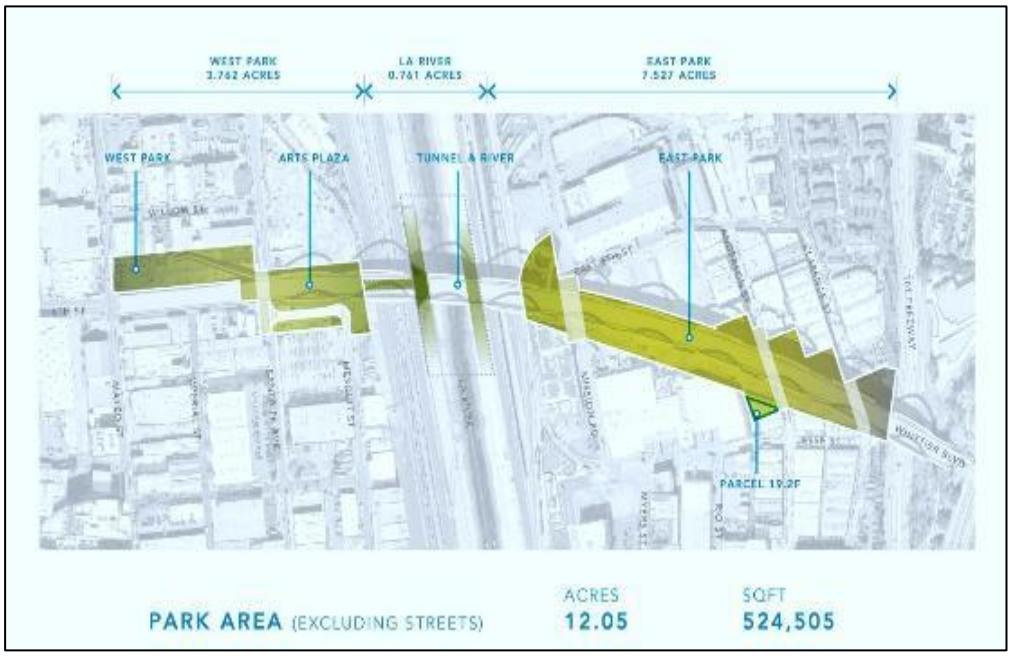


圖十二 支承外假柱及假拱

圖十三 橋下人行自行車道穿梭

這座橋具有高度親民特性，但也伴隨衍生出一些社會問題，該橋曾在五天內四度遭暫時關閉，原因是「非法活動和公共安全問題」，所謂「非法活動和公共安全問題」，包括非法賽車、塗鴉，還有不少民眾在橋上表演各式駕駛特技，包含飄移、逆向追撞；甚至有人在橋拱上危險「跑酷」（Parkour）、進行網絡直播，五花八門的行徑嚴重影響交通安全。

參訪當日，橋下尚在施作近三千萬美元的第六街公園(如圖十四)，未來橋下將提供公眾12英畝的優質開放空間，該公園由設計師瓊斯(Hargreaves Jones)負責操刀，以城市公園為設計主題，將會有兩座狗公園、一座滑板公園、一座表演藝術廣場、足球場、大型兒童遊樂場、食物餐車廣場和午餐區、風景優美的歷史鐵路通行區。藝術廣場則是當地藝術家展示作品及社區聚會場所。



圖十四 第六街公園配置圖

五、 參觀 New Gerald Desmond Bridge

傑拉爾德・德斯蒙德大橋(Gerald Desmond Bridge，如圖十五)位於洛杉磯郡長灘市的長灘港(Port of Long Beach)港口，這座橋以長灘市前市檢察官 Gerald Desmond 命名，1968 年完工通車，橋梁長度約 2.4 公里，主跨度 161 公尺(鋼拱橋)，橋下淨高 47 公尺，由長灘橫跨 Back Channel 到終點島（Terminal Island），橋面共規劃 5 車道(上橋 3 車道，下橋 2 車道)。長灘港為美國主要貿易商港，全美 15%海運進口貨物行經 Gerald Desmond Bridge，近年來因為長灘港貨運船隻趨於大型化，導致現有橋梁淨高不足，且橋梁車道數不足以容納大增之交通量，而交通量增加造成橋梁承受載重增加 2 倍以上，也使橋梁結構不堪負荷，導致橋梁結構受損。另外，既有橋梁無路肩，影響緊急救災效率，橋上如有事故發生，必須封閉車道進行處理，嚴重影響交通。2007 年 Caltrans 針對該橋結構評等僅有 43 分。

圖十五 傑拉爾德・德斯蒙德大橋(Gerald Desmond Bridge)

基於以上幾項因素，長灘港務局及 Caltrans 於 2008 年提出既有橋梁旁新建 New Gerald Desmond Bridge 計畫，並獲得美國聯邦政府同意負擔大部分經費，有別於一般州公路由 Caltran 自辦設計、監造、施工、維護的模式，本計畫屬於特殊性橋梁，技術性及施工難度高，所以採統包(Design-Build)方式招標，以節省時間、提高效率，於 2013 年 1 月開工， 2020 年 8 月完工通車，總建造經費約 15 億美元。

新橋配置雙向各三車道，橋寬約 50.6 公尺，橋下淨高 62.5 公尺，適合大型巴拿馬貨輪通過，橋面增設路肩供緊急救援使用，並設置行人及腳踏車通道，徹底解決舊橋所遭遇的問題。新橋完工通車後，舊橋拆除工作於 2022 年 7 月開始, 2023 年 8 月完成。2021 年州政府正式將該橋命名為長灘國際門戶大橋(Long Beach International Gateway Bridge)，如圖十六。

新橋總長 2682 公尺,主要包含以下 3 部分：

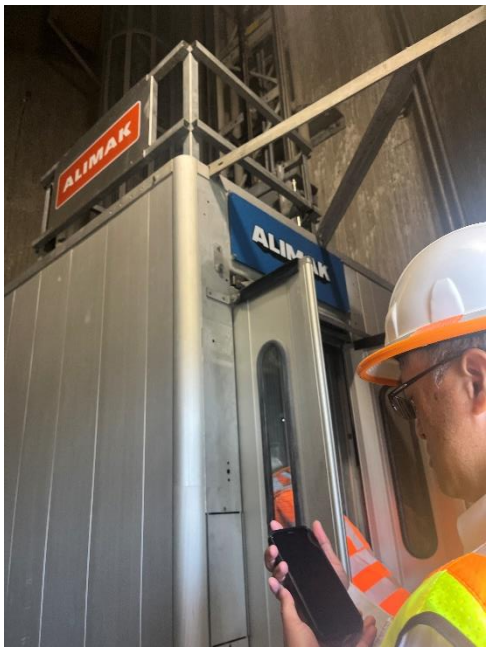
(1) 主橋:加州第一座雙塔對稱斜張橋,橋面材質為 RC+鋼材,長 610 公尺，計有 3 跨，其中主跨跨度 305 公尺,兩側邊跨各 152.5 公尺。包含 2 座橋塔，每座橋塔各有 40 根鋼纜與主梁銜接。橋塔高 157 公尺,為全美橋塔高度第二高之斜張橋。橋下淨高 62.5 公尺，更為全美橋下淨高最高之斜張橋。
(2) 西引道橋：場鑄預力箱型梁橋，採支撐先進(Movable Scaffolding System)工法施工，長 853 公尺，計有 14 跨。
(3) 東引道橋：場鑄預力箱型梁橋，採支撐先進(Movable Scaffolding System)。

由於靠近活躍地震帶,安全性和生命週期為設計團隊關注重點，本橋梁設計服務年限 100 年，設計標準可以確保遭遇 1000 年重現期地震時整座橋梁維持彈性功能,橋樑主跨兩端設置大伸縮量之活動伸縮縫,每個橋塔則設置 8 個(橋上橋下各 4 個,如圖十七)液壓阻尼器(fluid viscous damper)。

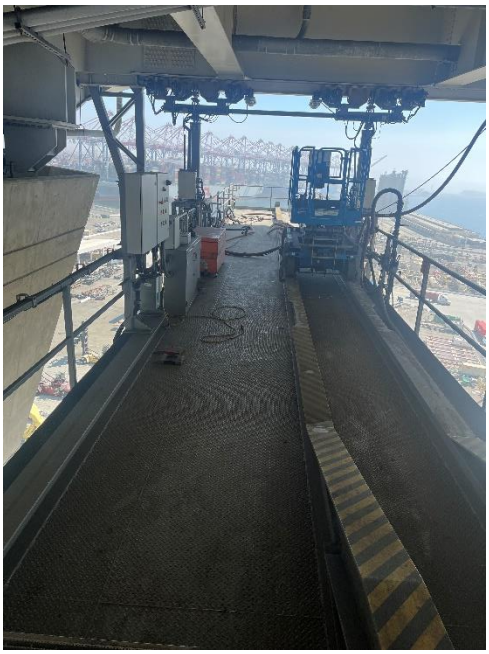
整座橋設計 90 支墩柱，共 350 根基樁，樁長介於 31～53 公尺，樁徑 1.5~2.5 公尺，各墩柱下方大多配置 4 根基樁，2 座橋塔則各配置 12 根基樁。斜張橋也為未來養護作業導入友善設計,橋墩內設有垂直重型升降梯（如圖十八）,橋面下方東西行線各設置 1 台油壓移動式維修平台（如圖十九），主橋(鋼橋)與引橋(預力箱型梁橋)交接處如圖二十。

圖十六 長灘國際門戶大橋(Long Beach International Gateway bridge)

圖十七　橋面 4 個液壓阻尼器



圖十八橋墩內垂直升降梯



圖十九 油壓移動式維修平台

圖二十 Long Beach International Gateway Bridge
主橋與引橋交接處

六、 參訪洛杉磯區交控中心（LARTMC）

Los Angeles Regional Transportation Management Center 簡稱 LARTMC,該中心是加州運輸署 12 個分區交控中心的第 7 區(如圖二十一),本次參訪 LARTMC 為我方歷年參訪團首次,主要想了解加州運輸署交控中心的組織,運作模式,以及在協助橋梁維運上所扮演的角色。

圖二十一　Los Angeles Regional Transportation Management Center

LARTMC 對於我們的到訪相當重視,由 Mumu,Renee,Hung 3 位主管及同仁帶領我們參觀該中心建築設施,以及介紹交控中心值班席運作情形,以下為參訪過程獲得的資訊：

(1) Caltrans 有 12 個分區交控中心,其中第 3、7、8、11、12 等 5 個分區是全年 24 小時運作，且設有州公路警察客服中心，第 1、4、6、10 等 4 個分區也是全年 24 小時運作，但未設有州公路警察客服中心，第 2、5、9 區則只在週一~週五每天運作 16 小時，每個分區皆為獨立運作,各分區資訊系統不同,資料亦未相互介接備援。

(2) LARTMC 除了服務居住在大洛杉磯的 960 萬居民外,也服務每天在大落磯地區活動的 2000 萬民眾,民眾可以透過 20 個左右的交通網站,或是電視台（視頻）即時路況顯示,取得由數百處 VD 所監測出之 840 公里主線壅塞資訊,以及 109 處 CMS 所顯示之即時事件及旅行時間資訊。

(3) LARTMC 交控系統無論在運作邏輯架構或設備種類,均與我國道交控系統大致相近,惟各項設備設置密度大多低於我國道,例如僅有少數入口匝道設置匝道儀控,CCTV 係採用槍型,與我國到採用球型不同,另外,出口匝道尚無防逆向及回堵偵測等系統,其中緊急電話（ET）因 3C 產品普及,也將慢慢淘汰。

(4) Caltrans 配有拖吊車,用路人車輛故障時,拖吊車可免費協助用路人將故障車脫離州公路,再由用路人自行處理後續送廠維修事宜,可減少故障車佔用車道時間,降低交通衝擊。

(5) Caltrans 所轄公路均以免收費為原則,以 LARTMC 所轄第 7 分區來說,部份公路對於共享運具（Carpool）於左道設有高乘載車道（HOV）,車上乘客 2 人以上即可免費行駛,僅部分進入洛杉磯市區公路設有收費車道(Express lanes,如圖二十二),收費車道另由 Metro 經營及維護,有些 Carpool lane 可能開著開著就變成 Express lane,如果沒有加入 FarTrak 收費系統,就要轉出來一般車道;在另一分區（Orange County）則有幾條地方道路轉接主要高速公路的全車道收費公路（Toll road,如圖二十三）,HOV 車道(或收費車道)與一般車道間，以雙黃實線間之距離作區隔。

(6) 大洛杉磯地區尖峰時段壅塞問題相當嚴重,且 2008 年將迎來洛杉磯奧運,但對於重現性壅塞路段, LARTMC 並無開放路肩機制,亦尚未與地方政府合作適應性號誌,州公路及高速公路路肩雖有 3 公尺以上寬度,但很多排水系統格柵設於路肩中央,要開放路肩有其難度。

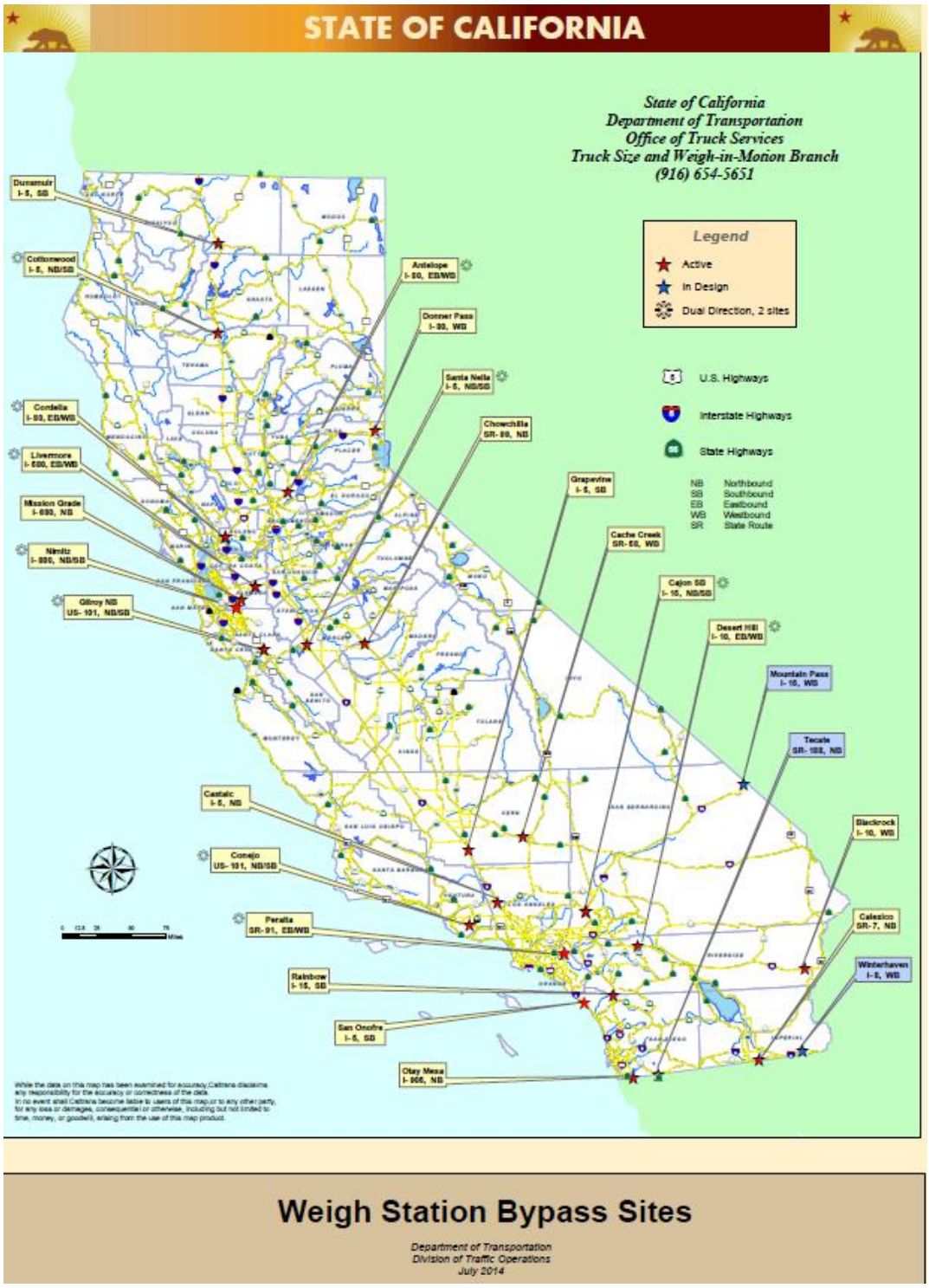
(7) Caltrans 設有 145 處動態地磅（Weigh-in-motion）,所有 wim 感測器都是埋入混凝土路面中,設置於主線的 wim,只作為交通調查使用,另有 20 多處 wim 配合路側（bypass）執法地點進行超載車預篩,篩選式 wim 配置地點如圖二十四。

(8) LARTMC 在未來 30 年,除了作為 ITS 中心外,也作為政府聯合作戰緊急應變中心,因此該棟建築採用高科技建築技術及先進設備,在大樓基礎採用隔減震支承之抗震結構系統（如圖二十五）。

圖二十二　收費車道

圖二十三　收費公路

圖二十五 LARTMC 大樓基礎抗震系統



圖二十四　Weigh Station Bypass Sites配置圖

七、 橋面板劣化補強交流座談

回國前最後 1 個行程，再次拜訪了 Caltrans 第 7 區辦公室,這次訪美行程因為時間較短,加上過去幾次局內同仁拜訪 CalTrans,多以觀摩橋梁檢測機制 & 現場實務及新建橋梁為參訪重點,所以這次觀摩重點除仍保留新建橋梁外,另外將觀摩重點放在橋梁維修工法及材料上。

這次的交流座談由趙青主任和 Tony(資深 PE)與會,以下是這次座談所獲得的寶貴經驗和資訊：

(1) Caltrans 所轄的橋梁皆為混凝土路面,未鋪 AC,因此橋面出現裂縫等劣化現象時,通常在早期即能透過目視檢測發現,並及時採取標準化的工法及材料進行修復,像這次參訪的第一座橋梁需拆除重置橋面板的案例不多。

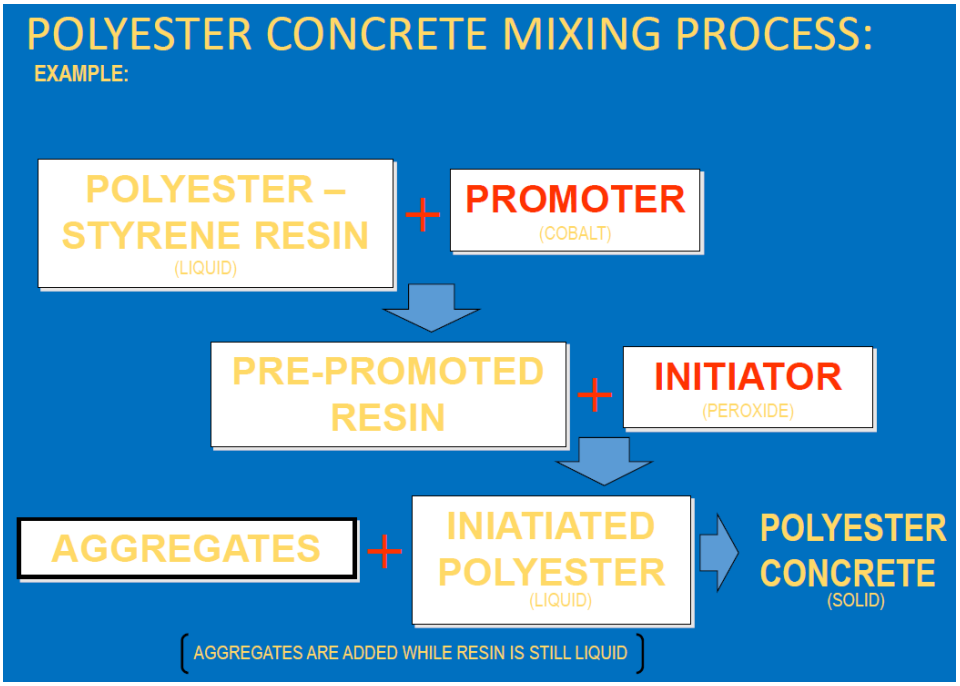
(2) 前面所稱標準化的修復工法是採用微刨回鋪或直接加鋪的方式,採用的回鋪(加鋪)材料是一種聚酯混凝土(PPC,聚酯樹酯黏合劑＋骨材),再回鋪(加鋪)之前要先清潔乾燥橋面及均勻塗佈甲基丙烯酸樹酯底漆,回鋪(加鋪)厚度至少 3/4 英吋,通常介於 1~1.5 英吋較佳；聚酯混凝土拌合程序如圖二十六。

(3) 聚酯樹酯黏合劑之於 PPC,類似波特蘭水泥在 PCC 中的結合性,那為什麼選擇 PPC 而不選擇 PCC 呢？原因包括：不滲透氯離子;防滑磨損表面;耐磨性是 PCC 的 10 倍; 施工後 4 小時即可恢復服務通車；聚酯混凝土專用拌合卡車如圖二十七，有容量 300~500 加侖的聚酯樹酯黏合劑桶及級配料倉；料倉出口輸送帶如圖二十八。

(4) 聚酯混凝土有高強度,低滲透性的特性,因此回鋪(加鋪)不需加錨錠鋼筋或鋼絲網,也不需再做防水層,Caltrans 長期追蹤採此工法補強之橋梁,修復後橋梁結構狀態及防水功能均維持良好；聚酯混凝土鋪裝機如圖二十九，一次鋪築最大寬度至少要有 3.6 公尺，不可使用固定厚度雪橇。

(5) 回鋪（加鋪）聚酯混凝土後須進行掃紋，紋深介於 1/8~3/16 英吋，採取縱向(平行車行方向)掃紋，Caltrans 所有鋼性路面皆採縱向掃紋，據表示主要可以降低噪音，抗滑及摩擦功能亦佳,有關本修復工法之

施工及材料規範詳附錄一。



圖二十六 聚酯混凝土拌合程序

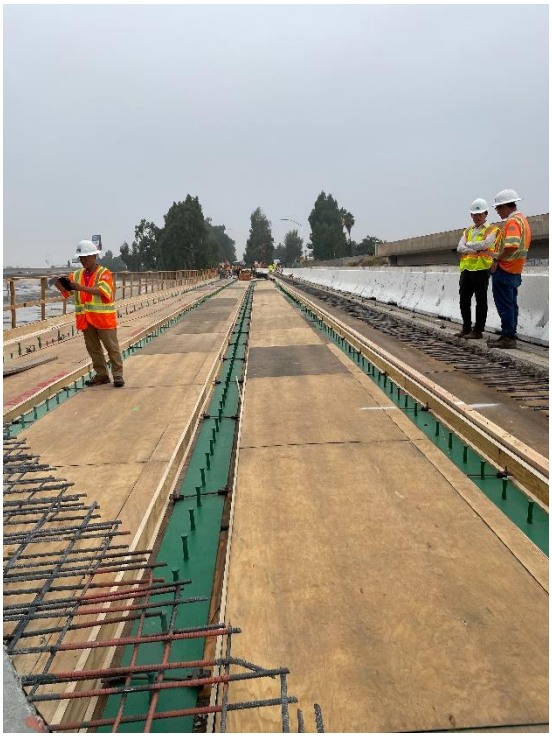
圖二十八 料倉出口輸送帶

圖二十七 聚酯混凝土專用拌合車

圖二十九 聚酯混凝土鋪裝機

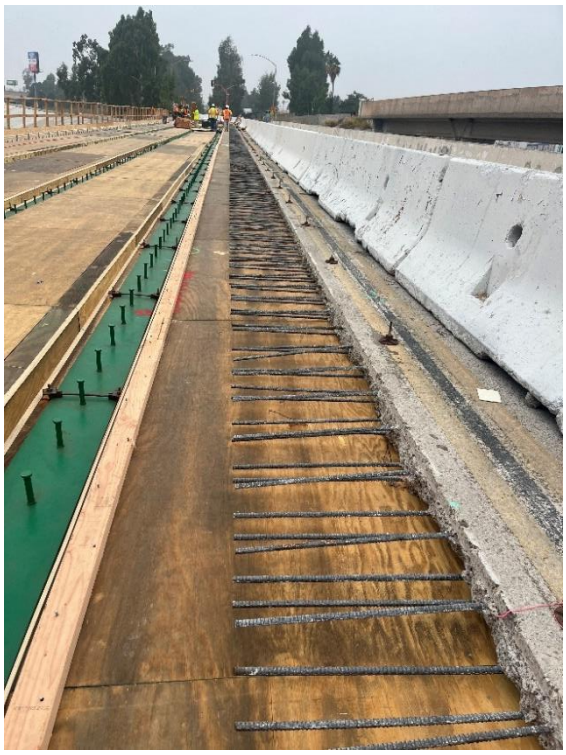
肆、參訪照片

橋面板嚴重裂化(Rio Houdo Busway Bridge)



橋面板拆除後鋪底模及鋼筋綁紮(Rio Houdo Busway Bridge)

伸縮縫處既有搭接長度鋼筋保留完好(Rio Houdo Busway Bridge)

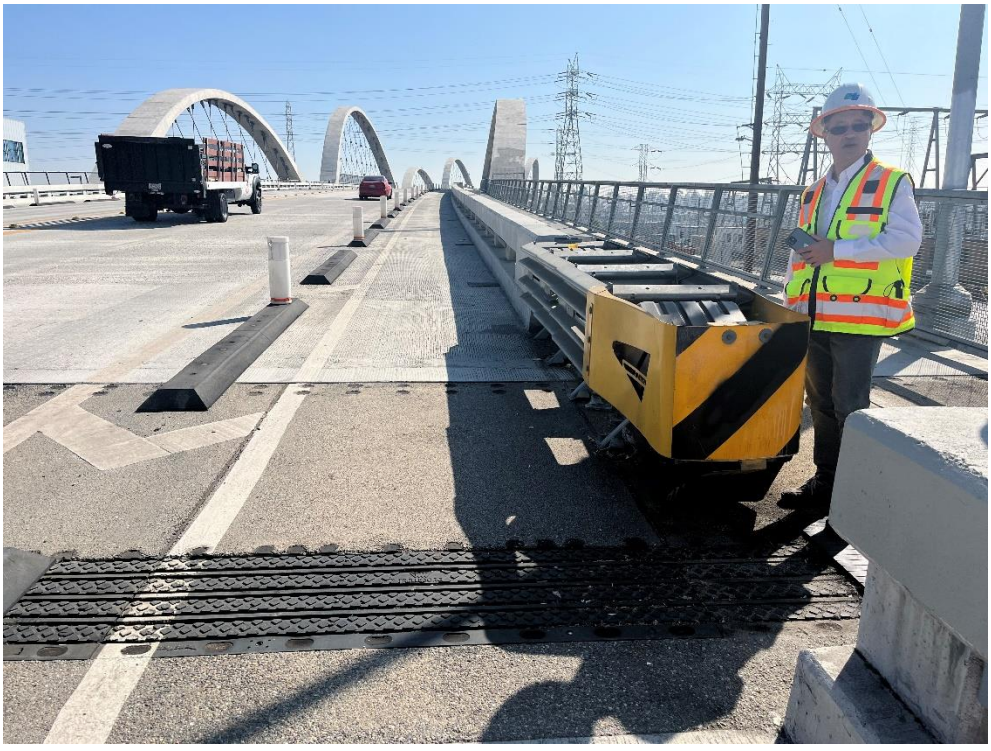


既有橋面板鋼筋及鋼梁剪力釘保留完好(Rio Houdo Busway Bridge)

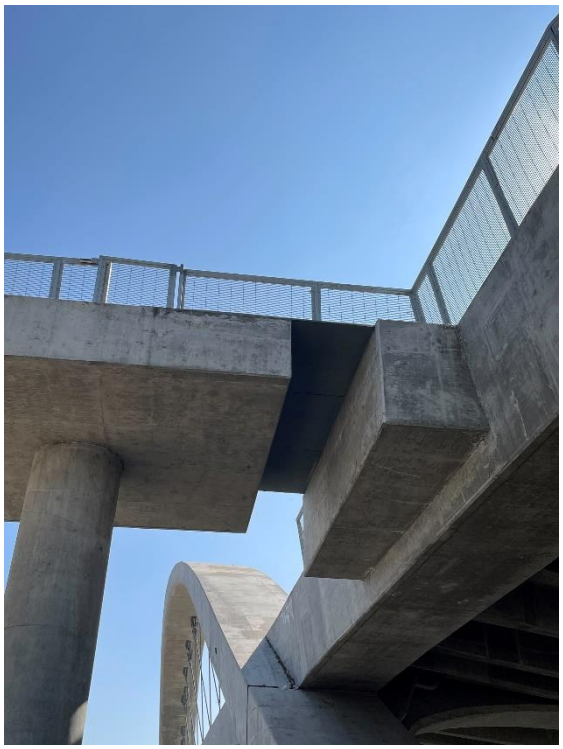
輕質混凝土澆置 (Rio Houdo Busway Bridge)

Grand Avenue 東入環道施工(57/60 Freeway Confluence Construction)

光之彩帶展開及人行自行車道迴繞(Sixth Street Viaduct)



自行車道橡膠路緣凸塊、人行道護欄及緩撞設施(Sixth Street Viaduct)



人行自行車道與主橋銜接處伸縮縫(Sixth Street Viaduct)

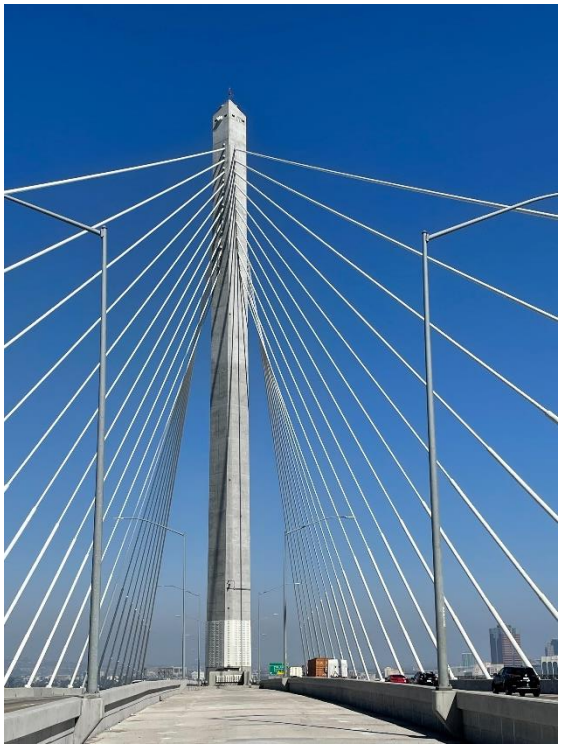
橋面違規特技騎車烙痕(Sixth Street Viaduct)

遠眺長灘國際門戶大橋(左側柱狀物為鑽油井遺留鋼管)

東行側維修平台上遠眺長灘港

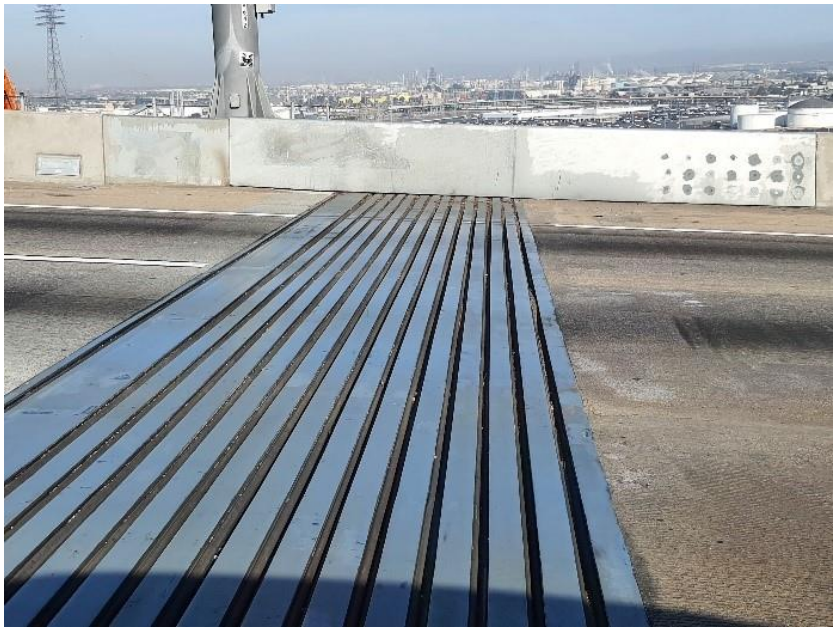
西行側油壓移動式維修平台

鋼床板橋面及自行車道(長灘國際門戶大橋)



中央分隔帶觀看橋塔(長灘國際門戶大橋)

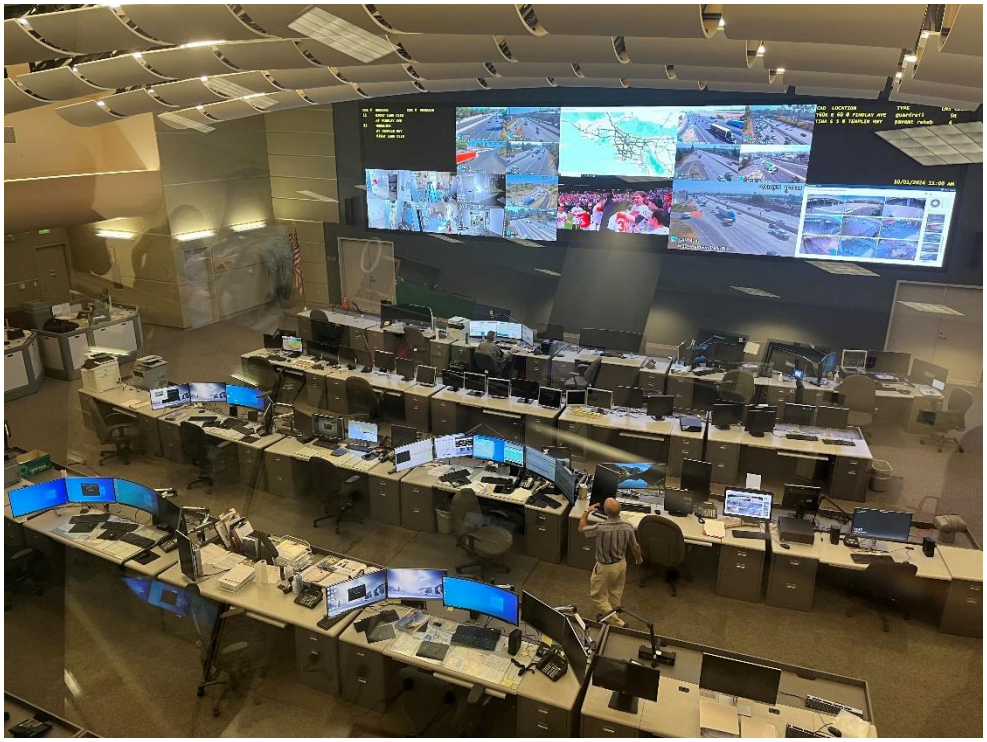
東西向移動式維修平台各自分離(長灘國際門戶大橋)



主橋及引橋銜接處大型模組伸縮縫(長灘國際門戶大橋)

升降梯頂到維修平台之護籠爬梯(長灘國際門戶大橋)

參訪洛杉磯區交控中心（LARTMC）



交控中心內部配置及值班席運作情形（LARTMC）

移動式號誌及緩撞設施

伍、 心得

(一) 加州公路系統不管是橋梁或路堤，路面結構幾乎都是剛性路面，路面結構強度及耐久性均較柔性路面佳，且加州剛性路面均採直向掃紋，據其表示可降低噪音及紋路磨損速度，與我國道剛性路面採橫向掃橫紋之方式不同，因此可以減少路面刨除整修頻率。即使少部分道路為柔性路面，Caltrans 仍然採取低度養護策略，因此柔性路面道路常見車轍及老化龜裂情形(如照片一)。

照片一 路面車轍及老化龜裂

(二) 由於路面結構採低度養護，剛性路面普遍非十分平整，跳動情形較我國道剛性路面明顯，柔性路面道路亦常見車轍及老化龜裂情形，Caltrans 很少接到用路人抱怨或陳情，應與加州公路基本上不收費，因此維護經費有限，且民眾亦不希望加稅，基此，用路人多能理解與包容。

(三) Caltrans 組織龐大，員工人數超過 20,000 人，橋梁工程幾乎都採自辦設計、自辦監造、自辦施工、自辦橋檢，僅有極少數聯邦政府補助經費(例如：Sixth Street Viaduct)或特殊結構橋梁(例如： New Gerald Desmond Bridge)等大型計劃會委託顧問公司設計及發包民間營造公司施工，此類案件 Caltrans 仍會扮演 QA 的角色，與本局員工人數有

限，橋梁工程大多委外設計、監造、發包施工之機制大為不同。

(四) Caltrans 人員分工明確，設計、監造、施工、橋檢各自有獨立部門，因此第一線員工在自己的工作職掌上非常專業，但對於其他單位業務較無涉略，偏向專才培養，與本局新建工程委外設計、監造、施工，第一線員工主要負責工程履約管理，維護工程則大多從設計發包監造履約管理一手包辦，職掌業務較為繁雜，偏向管理及通才培養的方向有所不同。

(五) Caltrans 因為自辦設計、監造、施工，因此橋梁或道路工程設施的設計型式、工法、材料等皆趨向於單一化、標準化，例如橋梁大多為預力混凝土箱型梁橋型式且無帽梁(如照片二)，墩柱多採圓柱且無帽梁，又如邊坡保護多採土釘(soil nail)+外覆鋼筋混凝土牆，隔音牆則幾乎都採混凝土空心磚型式(如照片三)。

(六) Caltrans 橋梁橋面皆採剛性路面，結構強度高、生命週期長，如有劣化情形，通常可經由目視檢測及早發現並進行微刨回鋪聚酯混凝土的標準改善方式，很少整座橋面板敲除重做；因我國道橋面板有加鋪柔性路面，所以在橋面板裂化檢測及維修工法上，有較大差異。

(七) Caltrans 通常在橋梁橋面板有嚴重受損時才會啟動橋面板敲除重作工程，重新澆置材料時皆採用輕質混凝土，我國道橋梁近幾年也開始採用輕質混凝土，雙方之發展方向一致。

(八) Caltrans 特殊橋梁從設計、興建到完工階段，特別重視民眾參與及族群公平，包括橋梁外型、意象、功能、橋下空間運用，例如 Sixth Street Viaduct「光之彩帶」意象、人行及自行車道設計、橋下空間公園化…等；又如 New Gerald Desmond Bridge 採雙塔斜張橋、人行及自行車道設計、公開命名「長灘國際門戶大橋」(Long Beach International Gateway Long Beach International Gateway)。

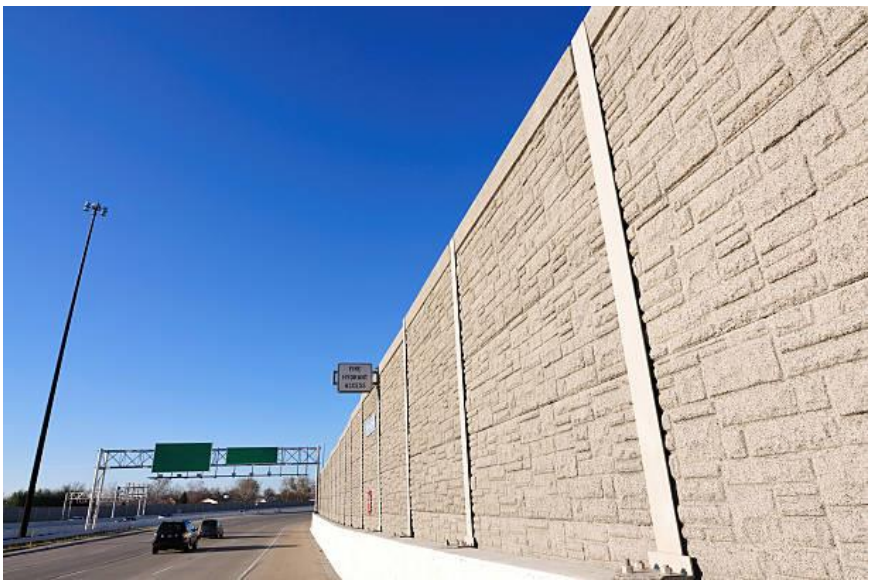
(九) Caltrans 有多達 12 個分區交控中心，皆為獨立運作，各分區交控系統未介接，所以交通資料訊息沒有即時連結交換，交控中心間亦未互為備援，與我國道 4 個交控中心同步運作，互為備援之機制不同。

(十) Caltrans 高速公路及州公路以不收費為原則、收費為例外，與我國道採收費為原則、不收費為例外之機制有很大差異，以第七分區(LARTMC)來說，有提供共享汽車(乘坐 2 人以上)的免收費高乘載車道(HOV)，僅少數提供快速進入市區的收費車道(Toll Lane)。

(十一) Caltrans 因應重車管理建置了接近 145 處動態地磅,大多為主線 WIM,主要作為搜集交通資訊之用,其中含 20 多處篩選式動態地磅,作為州公路警察執法之用,與我國道之重車管理機制機制雷同

(十二) 加州州公路入口匝道很少設置 RMS,即使主線壅塞嚴重,入口匝道車流仍維持放行,與我國道主要提供長途車輛使用,必須維持主線通暢,所以每個入口匝道都設置 RMS 管控入口車流之理念有所不同。

(十三) 參訪過程中，發現加州和我國面對違法公民行為時，在處罰額度上有極大的差異，例如無障礙車位違停，加州處罰額度 250 美元(約新台幣 7,750 元，如照片四)，我國則只罰新台幣 600~1,200 元；又如亂倒垃圾，加州處罰額度 1,000 美元(約新台幣 31,000 元，如照片五)，我國則只罰新台幣 1,200~6,000 元。綜觀加州薪資約為我國 2~2.5 倍，罰款額度卻為我國 5 倍以上，或許也是美國人較為守法的 1 項重要因素。



照片三　空心磚隔音牆

照片二　混凝土箱型梁橋

照片四　無障礙車位告示牌

照片五　禁倒垃圾告示牌

陸、建議

(一) Caltrans 有 2 萬多個員工，自辦設計、監造、施工、橋檢、維護，人員分工明確，各司其職，師徒制扮演經驗傳承的重要角色，但因人事成本很高，過去亦曾檢討組織瘦身、業務委外可行性，但因工會擔心因此影響員工工作權而反對，最終 Caltrans 還是維持目前的組織架構及運作機制；我國政府組織朝向人事精簡化、員額總量管制化的方向發展，以及民間能做的政府盡量不與其爭利，在這樣的原則下，本局目前正式員工僅約千人規模，未來亦不可能大幅增加人力，因此不可能學習 Caltrans 建構龐大組織架構及員工專才化，而是維持目前管理及通才化的方向。

(二) 雖然本局只能繼續朝管理及通才化培養人力，但因長期委外設計、監造、施工、橋檢的結果，本局新進同仁專業技術能力有弱化的趨勢，即使工作可以完全委外，責任仍然無法完全委外，所以本局同仁仍應具備基本的專業智能，否則對於工程設計規範、材料、施工流程、抽查(驗)重點基本認知不足，又如何能督導顧問公司落實設計及監造職責？建議應該要建立常設訓練單位，對於新進同仁及久任同仁，分別施以基礎訓練及進階訓練課程，培養及維持本局同仁一定的專業技術能力水平。

(三) 本局目前在兩個新建分局各設有材料試驗所，但在目前國內材料試驗 TAF 化，即使成功申請 TAF，亦因廠商會質疑球員兼裁判，材料試驗所很難發揮其材料試驗的功能，建議可轉型為本局常設訓練單位，賦予承辦全局工程同仁基礎訓練及進階訓練的任務，也為新工、養護單位間營造出工程人員相互流動的有利條件。

(四) 基礎訓練可包括混凝土、AC、土方級配等材料，從料源管制→驗廠→配比設計→駐廠檢試驗→現場施工檢驗，一系列完整的課程，基礎訓練亦可就鋼筋綁紮、模板組立、混凝土澆置施工流程、抽查(驗)重點等納入訓練課程；至於進階訓練可安排常見的專業工程，例如：基樁、地錨、預力梁施工及預力、鋼樑製造及吊裝、地盤改良…等，或是國道少見的工法(遇案)，例如：管幕工法、砂腸袋、中空版梁、

連續壁…等，訓練課程從規範規定→現場首件檢查→抽查記錄填寫→測驗。

(五) 加州公路多為剛性路面，皆採縱向掃紋，據表示可減少磨損速率及降低噪音，本局剛性路面皆採橫向掃紋，建議本局未來有新建鋼性路面或剛性路面重建，可試辦縱向掃紋，倘成效良再予推廣。

(六) 加州橋梁皆為剛性路面，便於橋面板目視檢測劣化情形，並逐年追蹤管控劣化情形，通常劣化達到一定程度，Caltrans 即會著手辦理橋面板淺刨回鋪修復方式，據表示回鋪材料聚酯混凝土具有高強度、低滲透性之特性，經其蒐集追蹤多年多處修復案例，修復後路面結構及防水功能均維持良好,已成為加洲橋面板結構修復之標準工法,因此材料及施工規範完備，相關材料及施工廠商也已形成完整產業鏈;目前，國內橋梁也有橋面板中度劣化之情形，建議可請顧問公司評估試辦此工法及材料之可行性,惟因本局橋梁橋面板上方尚有 5~7 公分 AC，因此刨鋪厚度及回鋪聚酯混凝土後是否尚需 AC 面層？亦可請顧問公司一併評估考量。

(七) 加州橋梁橋面板有嚴重裂化致需敲除時,係採取鋼梁或預力梁保留,僅打除橋面板結構，但保留既有橋面板搭接長度鋼筋完好(不可重機械打除)，重新綁紮鋼筋後以輕質混凝土澆置，可降低橋梁淨載重，目前本局也開始導入這項工法，惟我國道(尤其國 1)車流量太大，此工法需多次交維，且每階段交維時間冗長，影響國道運轉甚鉅，建議新工可多採用，既有橋面板劣化情形若非太嚴重，則可嘗試淺刨回鋪工法即可。

(八) 加州特殊橋梁從設計、興建到完工階段，特別重視民眾參與及族群公平，包括橋梁外型、意象、功能、橋下空間運用。建議未來本局若有新建殊橋梁，從設計、興建到完工階段可擴大民眾參與程度，建立一般民眾對於重大建設的認同感，以及凝聚附近居民對於新地標的光榮感。

(九) 加州特殊橋梁設計階段即導入友善設計，例如：友善民眾(設置人行道、自行車道、觀景台、橋下公園)、友善橋檢及橋維人員(橋塔內部升降梯、橋跨間移動式油壓施工平台車),此項理念與本局政策一致，

只是落實程度上 Caltrans 更為周延、徹底，值得本局學習。

(十) 首次參訪加州運輸署 12 個分區交控中心的第 7 區 LARTMC，並參觀交控中心運作情形，其各類資蒐、資顯系統與本局交控系統大致雷同，但本局在設備種類、設備密度、設備等級、反應計畫、資料應用各方面，均有過之而無不及，例如 LARTMC 並無隧道 IID、防逆向偵測系統、出口壅塞 QLD 等系統，也無完整 RMS 管制機制，CCTV 採槍型(我國道為球型)…等；此外，加州主要公路雍塞程度不亞於我國道，但並未介入太多應變措施，例如路肩大於 3 公尺，卻因路面條件不佳(排水暗溝格柵設於路肩中央)，尚無規劃開放路肩措施。即便如此，LARTMC 還是有值得我們學習的地方，例如加州政府將交控中心定位為政府聯合作戰緊急應變中心,因此交控中心建築採用高科技建築技術及先進設備,並且與州公路警察合署辦公，事故災害處理更具及時性和機動性。

(十一) 面對 2028 洛杉磯奧運，屆時將有世界各地蜂擁而至的大量人流與車流，LARTMC 接待人員擔憂洛杉磯各公路系統難以負荷，目前已著手進行一些道路設施改善、增加道路容量(例如：州公路 57/60 匯流交通壅塞改善計畫)。訪談交流過程中，LARTMC 人員對於本局交通管理策略、交控系統運作機制、交通雍塞應變機制(例如：開放路肩、匝道儀控…)等均深感興趣，高度表達參訪本局之意願。

附　　錄

5. For slab bridges, perform removal activities within a span along a front parallel with the primary reinforcing steel.

Temporary support shoring, temporary bracing, and protective covers must not encroach within 8 feet horizontally or 15 feet vertically of traffic lanes or shoulders open to traffic.

Temporary support shoring, temporary bracing, and protective covers over railroad property must (1) conform to guidelines of the railroad company involved and (2) provide the minimum clearances specified for railroad traffic.

60-2.02C(2) Protective Covers

Provide protective covers for removal work over traffic or railroad property. Protective covers must:

1. Be constructed before starting removal activities.
2. Prevent any materials, equipment, or debris from falling onto traffic or railroad property.
3. Be supported using shoring, falsework, or the existing structure.
4. Provide the openings specified in section 12-4. If no openings are specified for removal work, provide a vertical opening of 15 feet and a horizontal opening of 32 feet for traffic.
5. Be cleaned of debris and fines before being removed.

At locations where only bridge railing is removed, protective covers must extend from the face of the exterior girder or at least 2 feet inside of the railing to be removed to at least 4 feet beyond the outside face of the railing.

At locations where entire girders are removed, protective covers must extend at least 10 feet beyond the outside face of the bridge railing.

A separate protective cover is not required during removal of bridge segments if portions of the bridge satisfy the requirements for protective covers.

60-2.02C(3) Preliminary Work

Preliminary work is limited to activities that (1) will not reduce the structural strength or stability of the bridge or bridge elements to a hazardous level as determined by the Engineer or (2) do not cause debris or any other material to fall onto the roadway.

You may perform preliminary work if you use protective covers. Protective covers must:

1. Support all loads
2. Prevent dust and fine material from falling onto the traveled way
3. Extend at least 4 feet beyond the limit of the work being performed

Bottom slabs of box girders may be considered as protective covers for preliminary work performed on top slabs inside the limits of the exterior girders.

Use temporary support shoring and bracing during preliminary work if needed to ensure the stability of the bridge.

60-2.02D Payment

Not Used

60-2.03–60-2.10 RESERVED

60-3 STRUCTURE REHABILITATION

60-3.01 GENERAL

60-3.01A General

Section 60-3.01 includes general specifications for rehabilitating structures.

If you are unable to complete bridge reconstruction activities before the bridge is to be opened to traffic, furnish and maintain temporary decking under section 48-4 until that portion of the work is complete.

Where shown, (1) repair and prepare surfaces and (2) apply deck treatments and overlays to approach slabs as specified for concrete bridge deck surfaces.

60-3.01B Materials

Not Used

60-3.01C Construction

Not Used

60-3.01D Payment

Not Used

60-3.02 BRIDGE DECK REPAIR AND PREPARATION

60-3.02A General

60-3.02A(1) Summary

Section 60-3.02 includes specifications for (1) repairing concrete deck surfaces and (2) preparing concrete deck surfaces to receive an overlay or a deck treatment.

60-3.02A(2) Definitions

Reserved

60-3.02A(3) Submittals

Submit a work plan for chip seal removal. Include:

1. Description of equipment for chip seal removal
2. Procedure for residual chip seal removal from the deck after grinding or micro milling operations
3. Procedure for chip seal removal next to bridge rails, undulations, or drains

60-3.02A(4) Quality Assurance

Reserved

60-3.02B Materials

60-3.02B(1) General

Reserved

60-3.02B(2) Rapid Setting Concrete

Rapid setting concrete must comply with the specifications for bonding materials in section 51-1.02C.

You may extend rapid setting concrete using a clean, uniform, and rounded aggregate filler with a moisture content of no more than 0.5 percent. Aggregate gradation must comply with the requirements shown in the following table:

Sieve size	Percentage passing
1/2"	100
No. 16	0–5

The amount of aggregate filler must comply with the manufacturer's instructions. Concrete strengths for extended concrete must be at least as specified for magnesium phosphate concrete.

Combine components of dual-component magnesium phosphate by mixing only complete units supplied by the manufacturer. Do not add water to dual-component magnesium phosphate.

60-3.02C Construction

60-3.02C(1) General

Protect existing drain inlets, joint seals, joint seal assemblies, and other facilities to be incorporated into the new work from damage.

Before starting deck rehabilitation activities, complete the removal of any traffic stripes, pavement markings, and pavement markers.

Coarse aggregate remaining above the removal depth must be firmly embedded.

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High-pressure water jet equipment must (1) have rotating or oscillating jets and (2) be rated at 30,000 psi minimum.

Dust must not be blown into the air while blowing the deck.

Cold milling equipment must:

1. Have a minimum concrete removal depth of 1/4 inch
2. Provide a surface relief of at most 1/4 inch
3. Provide a 5/32-inch grade tolerance

Cold milling equipment must have:

1. 3 or 4 riding tracks
2. Automatic grade control system with electronic averaging with 3 sensors on each side
3. Conveyer system that leaves no debris on the bridge
4. Drum that operates in an up-milling direction
5. Bullet tooth tools with tungsten carbide steel cutting tips
6. Maximum tool spacing of 1/4 inch
7. Maximum operating weight of 66,000 lb
8. Maximum track unit weight of 6,000 lb/ft
9. New tooth tools at the start of the work

Micro milling equipment must:

1. Have a minimum concrete removal depth of 0.04 inch
2. Provide a surface relief of at most 0.045 inch
3. Provide a 5/32-inch grade tolerance
4. Produce consistent depth of texture in the finished surface

Micro milling equipment must have:

1. 3 or 4 riding tracks
2. Automatic grade control system with electronic averaging and 3 sensors on each side
3. Conveyer system that leaves no debris on the bridge
4. Drum that operates in an up-milling direction
5. Bullet tooth tools with polycrystalline diamond enhanced cutting tips
6. Maximum tool spacing of 0.20 inch
7. Maximum operating weight of 66,000 lb
8. Maximum track unit weight of 6,000 lb/ft
9. New tooth tools at the start of the work

Produce the finished surface using 2 passes of the micro milling equipment.

Provide personnel on each side of the milling drum to monitor milling activities. Maintain constant radio communication with the operator during milling activities.

60-3.02C(2) Removing Concrete Deck Surface

Remove the concrete deck surface to the depth described.

Before removing concrete, clean the deck surface by vacuuming, then blow the deck clean with high-pressure air.

Remove the deck surface by micro milling or high-pressure water jetting.

60-3.02C(3) Removing Asphalt Concrete Surfacing

Where shown, remove asphalt concrete surfacing and reinforced concrete expansion dams from concrete bridges and approaches.

Before removing asphalt concrete surfacing, verify the depth of the surfacing at the supports and midspans of each structure (1) in each shoulder, (2) in the traveled way, and (3) at the roadway crown, if a crown is present.

Remove asphalt concrete surfacing by cold milling under the following conditions:

1. If a membrane seal is shown:
   1.1. Remove the seal by cold milling
   1.2. Do not remove more than 1/2 inch of the existing concrete slab
2. If a membrane seal is not shown:
   2.1. Remove asphalt concrete surfacing until a 1/2-inch minimum of surfacing remains on top of existing concrete slab
   2.2. Use other authorized means to remove the remaining asphalt concrete without damage to the concrete slab

Where a portion of the asphalt concrete surfacing is to remain, saw cut a 2-inch-deep true line along the edge to remain in place before removing asphalt concrete. Remove the asphalt concrete without damaging the surfacing to remain in place.

60-3.02C(4) Removing Seals

Where shown, remove bituminous chip seals, bituminous slurry seals, and polymer chip seals entirely from bridge decks by grinding or micro milling. Remove no more than 1/4 inch of concrete deck surface.

Grinding must comply with section 42-3.

Any residual chip seals and other foreign materials remaining in the bridge deck after the grinding or micro milling operation must be removed by other authorized means.

60-3.02C(5) Removing Unsound Concrete

Where shown, remove unsound portions of bridge decks, curbs, and railings.

Unsound concrete is concrete that emits a dead or hollow sound when chained or tapped with a metal tool. The Engineer determines the soundness of concrete.

Equipment and tools that in the Engineer's opinion remove excess quantities of sound concrete are not allowed.

For bridges over railroads, stop removal activities when trains pass under the bridge.

Reinforcing steel exposed after removing unsound concrete must be restored to position and blocked and tied under section 52.

Replace or repair reinforcing steel damaged and rendered useless during removal.

60-3.02C(6) Rapid Setting Concrete Patch

Before placing rapid setting concrete patches, abrasive blast clean the contact surfaces of existing concrete and reinforcing steel. Remove at least 1/8 inch of concrete and all foreign material. Immediately before placing new concrete, clean surfaces by vacuuming and (1) pressure jetting or (2) other authorized means to remove debris.

The surface temperature of the existing concrete must be at least 40 degrees F during placement of the rapid setting concrete. Contact surfaces to receive magnesium phosphate concrete must be dry. Contact surfaces to receive modified high-alumina concrete or portland-cement-based concrete may be damp but not saturated.

Magnesium phosphate concrete must not be mixed in containers or worked with tools containing zinc, cadmium, aluminum, or copper. Modified high-alumina-based concrete must not be mixed in containers or worked with tools containing aluminum. Do not retemper concrete. Finishing tools cleaned with water must be thoroughly dried before working concrete.

The Engineer may require that you use a flow-controlled modified concrete on slopes greater than 5 percent.

Cure modified high-alumina-based concrete and portland-cement based concrete using the curing compound method. Do not cure magnesium phosphate concrete.

60-3.02C(7) Prepare Concrete Deck Surface

Prepare concrete bridge decks (1) after the removal of any unsound concrete and placement of any rapid setting concrete patches and (2) before applying deck treatments or placing deck overlays.

Perform the following activities in the order listed:

1. Abrasive blast the deck surface with steel shot. Steel shot must comply with SSPC-AB 3. Recycled steel shot must comply with SSPC-AB 2.
2. Clean the deck surface by vacuuming.
3. Blow the deck surface clean using high-pressure oil-free air.

The deck surface must be dry when abrasive blasting is performed. Remove all laitance, surface contaminants, and foreign material from the deck surface.

If the deck surface becomes contaminated or you allow traffic on the clean deck before placing the deck treatment or overlay, abrasive blast clean the contaminated area, clean the deck by vacuuming, and blow the deck surface clean using high-pressure oil-free air.

60-3.02C(8) Remove Polyester Concrete Overlay

Remove polyester concrete overlay by micro milling.

Before removing the overlay, verify the depth of polyester concrete at supports and midspan of each structure:

1. In each shoulder
2. In the traveled way
3. At the roadway crown, if a crown is present

Remove no more than 1/8 inch of the underlying concrete surface.

Remove residual polyester concrete remaining on the surface after micro milling by other authorized means. Do not damage the underlying concrete.

60-3.02C(9)–60-3.02C(15) Reserved

60-3.02D Payment

The payment quantity for rapid setting concrete (patch) is the volume determined from scale weights divided by a plastic density of 135 lb/cu ft.

If rapid setting concrete is used to fill voids from the removal of unsound concrete, the payment quantity for remove unsound concrete is the same as the payment quantity for rapid setting concrete (patch). No deduction is made for concrete used to fill spalls that existed before the work began.

60-3.03 BRIDGE DECK TREATMENT

60-3.03A General

60-3.03A(1) General

Section 60-3.03 includes specifications for treating bridge decks.

60-3.03A(2) Materials

Not Used

60-3.03A(3) Construction

Not Used

60-3.03A(4) Payment

Not Used

60-3.03B Methacrylate Resin Bridge Deck Treatment

60-3.03B(1) General

60-3.03B(1)(a) Summary

Section 60-3.03B includes specifications for treating bridge decks with a high-molecular-weight methacrylate resin.

60-3.03B(1)(b) Definitions

Reserved

60-3.03B(1)(c) Submittals

Submit a work plan for applying the methacrylate resin treatment. Include in the plan:

1. Schedule of work for the test area and for each bridge
2. Procedure for storing and handling resin components and absorbent material
3. Description of equipment for applying resin
4. Range of gel time and final cure time for resin
5. Description of absorbent material to be used
6. Description of equipment for applying and removing excess sand and absorbent material
7. Procedure for removing resin from the deck and equipment to be used
8. Procedure for avoiding spills or discharges of methacrylate, including materials and equipment
9. Procedure for cleaning up spills or discharges of methacrylate, including materials and equipment
10. Procedure for preventing resin from dripping from the structures
11. Procedure for disposing of excess resin and containers

Submit an SDS for each resin component and diatomaceous earth shipment before use.

Submit test samples of methacrylate resin components at least 15 days before use.

60-3.03B(1)(d) Quality Assurance

Complete a test area before starting deck treatment activities. Notify the Engineer at least 15 days before treating the test area.

The test area must be:

1. At least 500 sq ft
2. Located within the project limits outside the traveled way at an authorized location
3. Constructed (1) using the same materials, equipment, and construction methods to be used in the work and (2) under conditions similar to those anticipated when the work will be performed

The completed test area must demonstrate (1) compliance with these specifications and (2) work will be completed within the time allowed.

The Engineer performs friction testing of the treated test area under California Test 342. After completion of the test area, allow 10 days for the Engineer to perform the testing.

Do not perform deck treatment activities until the test area is authorized. The authorized test area is the standard of comparison in determining the acceptability of treated deck surfaces.

The Engineer may perform testing under California Test 342 to verify the coefficient of friction of the treated deck surfaces. The coefficient of friction of the treated surface must be at least 0.35 when tested under California Test 342.

60-3.03B(2) Materials

High-molecular-weight methacrylate resin consists of resin, promoter, and initiator.

High-molecular-weight methacrylate resin must be low odor and comply with the requirements shown in the following table:

Quality characteristic	Test method	Requirement
Volatile content[a] (max, %)	ASTM D2369	30
Viscosity[a] (max, cP, Brookfield RV with UL adaptor, 50 RPM, at 25 °C)	ASTM D2196	25
Specific gravity[a] (min, at 25 °C)	ASTM D1475	0.90
Flash point[a] (min, °C)	ASTM D3278	82
Vapor pressure[a] (max, mm Hg, at 25 °C)	ASTM D323	1.0
Tack-free time (max, minutes) except Sample 50 ± 5 g Test 2 ± 0.05 g in 55 ± 5 mm diameter disposable aluminum weighing dish	ASTM C679	400
PCC-saturated surface-dry bond strength (min, psi, at 24 hours and 70 ± 2 °F)	California Test 551	500

[a]Perform test before adding the initiator.

Sand for the abrasive sand finish must be a commercial-quality, dry-blast sand. The size of the sand must be such that not less than 95 percent passes the no. 8 sieve and not less than 95 percent is retained on the no. 20 sieve when tested under California Test 205.

Absorbent material must be diatomaceous earth, abrasive blast dust, or an authorized substitute recommended by the resin supplier.

60-3.03B(3) Construction

Notify the Engineer at least 15 days before delivery of methacrylate resin components in containers larger than 55 gallons to the job site.

The Engineer determines the exact methacrylate resin application rate at time of placement.

High-molecular-weight methacrylate resin applied by machine must be (1) combined in volumetric streams of promoted resin to initiated resin by static in-line mixers and (2) applied without atomization.

You may apply resin manually. Mix at most 5 gallons of resin at a time.

The deck must be dry before applying resin. The concrete surface must be from 50 to 100 degrees F. Relative humidity must be not more than 85 percent during the work shift.

Thoroughly mix all resin components. Apply resin to the deck within 5 minutes of mixing at an approximate application rate of 90 sq ft/gal. Resin that thickens during application is rejected.

Uniformly spread the resin. Completely cover surfaces to be treated and fill all cracks. Redistribute excess resin using squeegees or brooms within 10 minutes of application. For textured or grooved deck surfaces, remove excess resin from the texture indentations.

Apply the abrasive sand finish no sooner than 20 minutes after applying the resin. The sand application rate must be at least 2 lb/sq yd or until saturation as determined by the Engineer. Apply absorbent material before opening the lane to traffic. Remove excess sand and absorbent material by vacuuming or power sweeping.

Traffic or equipment is not allowed on the treated surface until you have verified that the following requirements have been met and the opening of the treated surface to traffic and equipment is authorized:

1. Treated deck surface is tack free and not oily
2. Sand cover adheres and resists brushing by hand
3. Excess sand and absorbent material has been removed
4. No material will be tracked beyond the limits of treatment by traffic

Remove resin from the deck surface if the Engineer determines (1) the conditions listed above have not been met and (2) the allowable lane closure time will be exceeded.

60-3.03B(4) Payment

The payment quantity for furnish bridge deck treatment material is the volume of mixed high-molecular-weight methacrylate resin placed.

60-3.03C–60-3.03J Reserved

60-3.04 DECK OVERLAYS

60-3.04A General

60-3.04A(1) General

Section 60-3.04 includes specifications for overlaying concrete bridge decks.

60-3.04A(2) Materials

Not Used

60-3.04A(3) Construction

Not Used

60-3.04A(4) Payment

Not Used

60-3.04B Polyester Concrete Overlays

60-3.04B(1) General

60-3.04B(1)(a) Summary

Section 60-3.04B includes specifications for placing polyester concrete overlays on concrete bridge decks.

Placing polyester concrete overlay includes placing a prime coat of methacrylate resin to the bridge deck before placing the polyester concrete overlay.

Furnishing polyester concrete includes furnishing and placing the trial overlay and concrete base for the trial overlay.

60-3.04B(1)(b) Definitions

Reserved

60-3.04B(1)(c) Submittals

Submit a work plan for the placement of the deck overlay. Include the following in the work plan:

1. Schedule of overlay work for each bridge and a schedule of work for any trial overlays
2. Method for storage and handling of methacrylate resin and polyester concrete components
3. Description of equipment for applying methacrylate resin
4. Description of equipment for measuring, mixing, placing, and finishing the polyester concrete overlay
5. Method for isolating expansion joints and drainage
6. Cure time for polyester concrete
7. Description of equipment for applying sand
8. Method for avoiding spills or discharges of methacrylate and polyester concrete, including materials and equipment
9. Method for cleaning up spills or discharge of methacrylate and polyester concrete, including materials and equipment
10. Procedure for preventing resin from dripping from the structures
11. Method for disposal of excess methacrylate resin, polyester concrete, and containers

For each shipment of methacrylate and polyester concrete, submit an SDS for each component.

Submit test samples of methacrylate resins, polyester resins, and aggregates with a certificate of compliance and manufacturer's test results at least 15 days before use.

Submit aggregate and resin volumes recorded from the volumetric mixer at the end of each work shift.

60-3.04B(1)(d) Quality Assurance

Complete a trial polyester concrete overlay before starting overlay activities. Notify the Engineer at least 15 days before constructing the trial overlay.

The trial overlay must be:

1. At least 12 by 12 feet and the same thickness as the overlay shown
2. Constructed on a prepared concrete base within the project limits at an authorized location
3. Constructed (1) using the same materials, equipment, and construction methods to be used in the work and (2) under conditions similar to those anticipated when the work will be performed

Use the trial overlay to determine the initial polyester-concrete set time.

The Engineer performs friction testing of the trial overlay under California Test 342. After completion of the trial overlay, allow 10 days for the Engineer to perform the testing.

The completed trial overlay must demonstrate (1) compliance with these specifications and (2) that the work will be completed within the time allowed.

Do not perform overlay activities until the trial overlay is authorized. The authorized trial overlay is the standard of comparison in determining the acceptability of the overlay.

The Engineer may perform testing under California Test 342 to verify the coefficient of friction of the overlay surfaces.

Dispose of the trial overlay and concrete base after acceptance of all polyester concrete overlay surfaces.

Place polyester concrete overlay on:

1. Portland cement concrete no sooner than 28 days after concrete placement
2. Portland cement based RSC no sooner than 14 days after concrete placement and your test results for prequalification of RSC show that the concrete attained at least 3,500 psi compressive strength
3. RSC using hydraulic cement other than portland cement or portland limestone cement no sooner than 3 days after concrete placement and your test results for prequalification of RSC show that the concrete attained at least 3,500 psi compressive strength
4. Magnesium phosphate based rapid setting concrete patch material no sooner than 3 days after final set
5. Modified high-alumina-based rapid setting concrete patch material no sooner than 30 minutes after final set

60-3.04B(2) Materials

Polyester concrete consists of polyester resin binder and aggregate.

Polyester resin binder must:

1. Be an unsaturated isophthalic polyester-styrene copolymer
2. Contain not less than 1 percent by weight gamma-methacryloxypropyltrimethoxysilane, an organosilane ester silane coupler
3. Be used with a promoter compatible with suitable methyl ethyl ketone peroxide and cumene hydroperoxide initiators
4. Comply with the requirements shown in the following table:

Quality characteristic	Test method	Requirement
Viscosity[a] (cP, RV, no. 1 spindle, 20 RPM, at 25 °C)	ASTM D2196	75–200
Specific gravity[a] (at 25 °C)	ASTM D1475	1.05–1.10
Elongation (min, %) Type I specimen, 0.25 ± 0.03 inch thick Rate = 0.45 in/min Sample Conditioning: 18/25/50+5/70	ASTM D638 ASTM D618	35
Tensile strength (min, psi) Type I specimen, 0.25 ± 0.03 inch thick Rate = 0.45 in/min Sample conditioning: 18/25/50+5/70	ASTM D638 ASTM D618	2,500
Styrene content[a] (%, by weight)	ASTM D2369	40–50
PCC saturated surface-dry bond strength (min, psi, at 24 hours and 70 ± 2 °F)	California Test 551	500
Static volatile emission[a] (max, g/sq m loss)	SCAQMD Method 309-91	60

[a]Test must be performed before adding initiator.

Aggregate for polyester concrete must:

1. Comply with sections 90-1.02C(1), 90-1.02C(2), and 90-1.02C(3), except fine aggregate must consist of natural sand
2. Have not more than 45 percent crushed particles retained on the no. 8 sieve when tested under California Test 205
3. Have a weighted-average aggregate absorption of not more than 1 percent when tested under California Tests 206 and 207
4. At the time of mixing with resin, have a moisture content of not more than one half of the weighted-average aggregate absorption when tested under California Test 226
5. Comply with the percentage passing limits for one of the aggregate gradations shown in the following table:

Aggregate Gradation

Sieve size	Percentage passing	
	3/8 inch maximum	No. 4 maximum
1/2"	100	100
3/8"	83–100	100
No. 4	65–82	62–85
No. 8	45–64	45–67
No. 16	27–48	29–50
No. 30	12–30	16–36
No. 50	6–17	5–20
No. 100	0–7	0–7
No. 200	0–3	0–3

High-molecular-weight methacrylate for the resin prime coat must comply with section 60-3.03B except:

1. Methacrylate resin must be free of wax
2. Tack-free time requirements do not apply
3. Friction testing is not required for the resin prime coat

Sand for abrasive sand finish must:

1. Be commercial-quality blast sand
2. Be graded such that not less than 95 percent passes the no. 8 sieve and not less than 95 percent is retained on the no. 20 sieve when tested under California Test 205
3. Have an average absorption of not more than 1 percent when tested under California Test 207

60-3.04B(3) Construction

60-3.04B(3)(a) General

Notify the Engineer at least 15 days before delivery of methacrylate resin components in containers larger than 55 gallons to the job site.

The Engineer provides the final grade and cross slope before the start of overlay work.

Complete the construction of approach slabs before placing polyester overlay.

New concrete deck surfaces must comply with section 51-1.03F(5) before starting overlay work.

60-3.04B(3)(b) Placing Methacrylate Resin

The Engineer determines the exact percentage of polyester resin binder at the time of placing.

The deck must be dry before placing the methacrylate prime coat. The concrete surface must be from 50 to 100 degrees F and the relative humidity must be not more than 85 percent.

Clean the deck by vacuuming, then blow the deck clean with high-pressure oil-free air. Dust must not be blown into the air while blowing the deck.

Thoroughly mix all components of the methacrylate resin. Apply the resin to the deck surface within 5 minutes of mixing. Apply the resin uniformly and spread to completely cover surfaces to be overlaid.

Apply methacrylate resin at an approximate rate of 55 sq ft/gal.

60-3.04B(3)(c) Placing Polyester Concrete

Use a continuous mixer to mix polyester concrete. The continuous mixer must:

1. Employ an auger screw device with a discharge chute
2. Be equipped with an automatic metering device that measures and records aggregate and resin volumes
3. Have a visible readout gage that displays volumes of aggregate and resin being recorded
4. Be certified under California Test 109 before use
5. Produce a satisfactory mix consistently during a demonstration

Record polyester concrete volumes at least every 5 minutes, including time and date.

Finishing equipment for polyester concrete must:

1. Have grade control capabilities resulting in a roadway surface that meets the smoothness requirements of section 51-1.01D(3)(b)(ii) and is capable of adjusting for a variable thickness overlay along and across the existing deck surface. The use of fixed height skid-supported strike off equipment is not allowed.
2. Be used to consolidate the polyester concrete.
3. Have a 12-foot minimum paving width.
4. Be self-propelled and equipped with automatic screed controls and sensing devices that control the thickness, longitudinal grade, and transverse screed slope. Advancing the finishing equipment with winches or a pulling device is not allowed.

Place polyester concrete:

1. Immediately after applying the methacrylate prime coat
2. Before gelling occurs
3. Within 15 minutes of adding the initiator

The weight of resin binder must be approximately 12 percent of the weight of the aggregate. Polyester concrete must have an initial set time from 30 to 120 minutes when tested using an initial-setting-time Gillmore needle under ASTM C266.

Consolidate and finish the overlay to the required grade and cross section using finishing equipment. Polyester concrete must be consolidated to a relative compaction of not less than 97 percent when tested under California Test 552.

Texture the polyester concrete surface before gelling occurs by longitudinal tining under 51-1.03F(5)(b)(iii), except do not perform initial texturing.

Apply a sand finish of not less than 0.8 lb/sq yd before gelling occurs.

Protect the overlay from moisture and do not allow traffic or equipment on the overlay (1) for a minimum of 4-hour cure time after final finishing and (2) until each rebound test result for the final finish shows a reading of at least 28 when tested under ASTM C805. The cure time must be extended if ordered. The rebound test may not be used to reduce the 4-hour cure time of the overlay.

Completed polyester concrete deck surfaces must have a uniform surface texture with a coefficient of friction of at least 0.35 when tested under California Test 342 and a surface smoothness complying with section 51-1.01D(3)(b)(ii).

Taper the polyester concrete overlay edges if the overlay (1) is not completed within the allowable lane closure time and (2) is more than 1/2 inch higher in elevation than the adjacent pavement. Taper the edges that are longitudinal to the direction of traffic at a 4:1 (horizontal:vertical) slope.

Tapers may remain and be overlaid with polyester concrete overlay.

60-3.04B(4) Payment

The payment quantity for furnish polyester concrete overlay is the volume determined using:

1. Quantity of resin binder used
2. Percentage by weight of resin binder in the polyester concrete
3. Unit weight of 135 lb/cu ft

60-3.04C Polyester Concrete Expansion Dams

60-3.04C(1) General

60-3.04C(1)(a) Summary

Section 60-3.04C includes specifications for constructing polyester concrete expansion dams.

Polyester concrete expansion dams must comply with the specifications for polyester concrete overlays in section 60-3.04B, except a trial overlay is not required.

Reinforcement must comply with section 52.

60-3.04C(1)(b) Definitions

Reserved

60-3.04C(1)(c) Submittals

Reserved

60-3.04C(1)(d) Quality Assurance

Reserved

60-3.04C(2) Materials

Not Used

60-3.04C(3) Construction

For new asphalt concrete overlays, place the asphalt concrete overlay before starting polyester concrete activities. Saw cut and remove asphalt concrete at expansion dam locations.

For existing asphalt concrete overlays, remove expansion dams and asphalt concrete to the limits shown. Removing expansion dams must comply with section 60-2.02, except a bridge removal work plan is not required.

Where a portion of the asphalt concrete overlay is to remain, saw cut a 2-inch-deep true line along the edge to remain in place before removing the asphalt concrete. Do not damage the existing surfacing to remain in place.

Prepare the deck surface under section 60-3.02C(7).

You may use a mechanical mixer to mix the polyester concrete for expansion dams. The mixer capacity must not exceed 9 cu ft unless authorized. Initiate the resin and thoroughly blend it immediately before mixing it with the aggregate. Mix the polyester concrete for at least 2 minutes before placing.

The application rate of methacrylate resin must be approximately 100 sq ft/gal.

You may place and finish expansion dams using hand methods.

Protect expansion dams from moisture, traffic, and equipment for at least 4 hours after finishing.

For expansion dams over 6 feet long, install 1/4-inch-wide joint material at 6-foot intervals across the width of the expansion dam. Joint material must be either expanded polyurethane or expanded polyethylene.

60-3.04C(4) Payment

The payment quantity for polyester concrete expansion dam is the volume determined from the dimensions shown.

60-3.04D Concrete Overlays

60-3.04D(1) General

Section 60-3.04D includes specifications for overlaying bridge decks with concrete.

Constructing concrete overlays must comply with section 51.

60-3.04D(2) Materials

Not Used

60-3.04D(3) Construction

Not Used

60-3.04D(4) Payment

Not Used

60-3.04E Multilayer Polymer Overlays

Reserved

60-3.04F–60-3.04M Reserved

60-3.05 REPAIRING STRUCTURES

60-3.05A General

60-3.05A(1) General

Section 60-3.05 includes specifications for repairing structures.

60-3.05A(2) Materials

Not Used

60-3.05A(3) Construction

Not Used

60-3.05A(4) Payment

Not Used

60-3.05B Repairing Spalled Surface Areas

60-3.05B(1) General

60-3.05B(1)(a) Summary

Section 60-3.05B includes specifications for repairing spalled concrete surfaces except on bridge decks.

60-3.05B(1)(b) Definitions

Reserved

60-3.05B(1)(c) Submittals

For alternative filler material, submit a test sample of at least 1 complete unit of all materials for repairing the concrete surfaces. Allow 45 days for testing.

For a contract with less than 60 original working days, submit certificates of compliance for the filler material and bonding agents.

60-3.05B(1)(d) Quality Assurance

Reserved

60-3.05B(2) Materials

Mortar must comply with section 51-1.02F.

Shotcrete must comply with section 53.

Alternative filler materials and bonding agents must comply with the requirements shown in the following table:

Quality characteristic	Test method	Requirement
Abrasion resistance (max, grams, at 28 days)	California Test 550	25
Modulus of elasticity (psi, at 28 days)	California Test 551	1.5×10^6–3.5×10^6
Water soluble chlorides (max, mg/kg)	California Test 422	500
Water soluble sulfates (max, mg/kg)	California Test 417	2,500

For a contract with less than 60 original working days, alternative materials must be authorized before use.

60-3.05B(3) Construction

Remove unsound concrete under section 60-3.02C(5).

Clean concrete surfaces and existing reinforcing steel by abrasive blasting before placing filler material. Place reinforcing steel where shown.

Fill spalled surface areas under section 51-1.03F(2) or you may use an authorized alternative filler material and bonding agent.

If using an alternative filler material, apply a bonding epoxy before placing the filler material. Place the filler material under the manufacturer's instructions.

If using shotcrete, you may apply the shotcrete using a dry-mix process with a hydration liquid applied immediately after placing the shotcrete.

The final surface finish of the patched concrete surface must comply with section 51-1.03F.

Patched concrete must emit a ringing sound similar to adjacent sound concrete when struck with a metal tool 14 days after placement.

Removing and patching spalled concrete more than 4 inches deep is change order work.

60-3.05B(4) Payment

The payment quantity for repair spalled surface area is the area measured of the completed repaired surface. Measured areas are recorded daily by the Engineer and agreed upon by you.

60-3.05C Epoxy Crack Injection

60-3.05C(1) General

60-3.05C(1)(a) Summary

Section 60-3.05C includes specifications for filling cracks in concrete structures with pressure-injected epoxy.

60-3.05C(1)(b) Definitions

Reserved

60-3.05C(1)(c) Submittals

Reserved

60-3.05C(1)(d) Quality Assurance

Before starting injection activities and at hourly intervals when requested, take a 3-ounce sample of mixed epoxy from the injection gun. If samples show improper proportioning or mixing, stop injection activities and correct deficiencies.

60-3.05C(2) Materials

Epoxy must comply with the specifications for epoxy resin adhesive for injection grouting of concrete pavement. Multiple formulations may be required for cracks of varying widths.

60-3.05C(3) Construction

The Engineer selects cracks having widths from 8 to 250 mils for injection and filling.

Clean cracks of material that would impair bonding of epoxy using oil-free compressed air. Remove any remaining material by flushing with water under pressure. After flushing, blow cracks clean with oil-free compressed air.

Insert injection ports into cracks. Space the ports not more than a distance equal to the thickness of the concrete being injected. Spacing at ends of cracks must be equal to half the concrete thickness. Adjust port spacing to ensure epoxy substantially fills the cracks.

Seal the crack surfaces between ports with tape or other temporary sealant capable of retaining epoxy in cracks during pressure injection and until epoxy has hardened.

Concrete temperature must be from 50 to 90 degrees F during injection activities.

Pressure inject epoxy adhesive into cracks through injection ports. Use the lowest practical pumping pressure. Injection equipment must maintain epoxy proportion and mix consistency. Fill cracks completely. Do not allow epoxy to run down the face of the concrete from the head of the injection gun.

Start injection at the 1st port at the end of a crack. Pump epoxy into the port until epoxy runs substantially from the adjacent port. Seal the 1st port and start injection from the next port. Continue in this manner until the crack is filled. For slanting or vertical cracks, start injecting at the lower end of the crack. Where vertical and horizontal cracks intersect, inject the vertical crack below the intersection first.

Seal ports by removing the fitting, filling the void with epoxy, and covering the void with tape or surface sealant. Leave the sealing tape and temporary surface sealant in place until the epoxy has hardened.

Clean excess epoxy from concrete surfaces exposed to public view after removing sealant.

60-3.05C(4) Payment

For cracks extending around corners of members, the payment quantity for inject crack epoxy is the crack length measured on both faces, including the crack length shown to be filled on the opposite side of a member that is completely filled after injection from only 1 side.

60-3.05D Heat-Straighten Steel Girders

Reserved

60-3.05E Galvanic Anodes

Reserved

60-3.05F Replace Bearings

60-3.05F(1) General

Section 60-3.05F includes specifications for replacing bearing pads or steel rocker bearings with elastomeric bearing pads.

Elastomeric bearing pads must comply with section 51-3.02.