出國報告(出國類別：其他)

參加「國際道路協會第 1 屆亞洲區域研討及展覽會（International Road Federation 1st IRF Asia Regional Congress & Exhibition）暨發表論文」出國報告

服務機關：交通部公路總局材料試驗所
姓名職稱：黃三哲　所　　長
　　　　　邱瑞昌　幫工程司
派赴國家：印尼
出國期間：103 年 11 月 16 日至 11 月 20 日
報告日期：103 年 12 月 27 日

摘 要

第 1 屆亞洲區域研討及展覽會（1st IRF Asia Regional Congress & Exhibition）是由國際道路協會（International Road Federation）所舉辦之盛大會議，會議時程為印尼時間 103 年 11 月 17 日至 11 月 19 日，為期 3 天，於印尼峇里島 Bali Nusa Dua Convention Center 2 舉辦。

本次會議主題為“構建横貫亞洲公路”（Building the Trans-Asian Highway），會中將依據亞太地區的公路運輸需求，分享成熟的和創新的解決方案，讓世界各地最新的技術和最佳的做法能夠被應用，或經適當調整滿足本地區的特定需求。

本局自 96 年起逐年辦理省道路面平整度檢測，103 年整理歷年檢測結果彙整編撰成「臺灣路面平整度改善與未來之展望」“The Improvement of Pavement and Its Future Prospects in Taiwan”論文，投稿至國際道路協會第 1 屆亞洲區域研討及展覽會，榮獲同意刊登，受邀於該研討會中發表，並與各國專家學者交換研究心得，由研討會各活動所蒐集之資訊，可作為本局未來研究發展之重要參考依據，以提升專業素質及能力。此行除獲得豐富新知識，拓展國際視野，並有利本局未來工作之推展。

關鍵字：國際道路協會，IRF，國際研討會，路面平整度，IRI，公路養護，資產管理，道路材料

目　次

壹、 前言與目的

國際道路協會（International Road Federation）為全世界道路界標竿機構，其主辦之國際研討會與會者皆是各國在公路行業及學科上具影響力的決策者和專業人士。該會訂於 2014 年 11 月 17～19 日，於印尼峇里島 Bali Nusa Dua Convention Center 2 舉辦第 1 屆亞洲區域研討及展覽會（1st IRF Asia Regional Congress & Exhibition），共有來自亞太地區 36 個國家的代表出席。本次會議主題為“構建橫貫亞洲公路”（Building the Trans-Asian Highway），研討議題包括道路行政管理、鋪面及材料運用、道路設計及建造、道路安全及交通運輸等 7 大主題，與本局業務息息相關。展示場有來自印尼、加拿大、美國、韓國、中國大陸及印度等各國廠商設攤，展示相關公路安全設施、道路試驗儀器、鋪面檢測設備、標線標誌產品、智慧型交通儀控方案等最先進的工業技術，提供與會人員對科技新知的瞭解。

本局整理自民國 96 年起，歷年 IRI（International Roughness Index）檢測結果彙整編撰成「臺灣路面平整度改善與未來之展望」“The Improvement of Pavement and Its Future Prospects in Taiwan”論文，作者為趙局長興華、黃所長三哲與陳課長志霖，榮獲國際道路協會第 1 屆亞洲區域研討及展覽會同意刊登，受邀於該研討會中發表，並與各國專家學者交換研究心得。本局能在研討會中發表論文，著實不易，能藉此機會提升臺灣的形象，使他國代表明瞭臺灣政府在此領域的用心。亦藉此研討會的機會學習觀摩其他國家的發展及研究，期能提供國內更精進的作為。

貳、 行程安排及參加單位人員

本次會議於 2014 年 11 月 17～19 日在印尼峇里島舉行，本局投稿之論文依大會議程於 17 日上午 10 時 30 分發表。參加人員奉公路總局核派為本局材料試驗所黃所長三哲及邱瑞昌工程司 2 人，行程安排如下表。

行 程 表			
日期	地點	預定行程及工作內容	說明
103.11.16 **(星期日)**	啟程 桃園～ 印尼峇里島	本日為前往參加會議之路程	1. 搭乘中華航空 CI0771 出國 2. 住宿: 印尼峇里島
103.11.17 **(星期一)**	印尼峇里島	1. 參加國際道路協會第 1 屆亞洲區域研討及展覽會開幕會 2. 發表論文”The Improvement of Pavement and Its Future Prospects in Taiwan” 3. 參加資產管理領域研討會	住宿: 印尼峇里島
103.11.18 **(星期二)**	印尼峇里島	1. 技術參訪：Bali Mandara Toll Road & Expressway 2. 參加道路材料領域研討會 3. 參加展覽會 4. 參加 GALA 晚宴	住宿: 印尼峇里島
103.11.19 **(星期三)**	印尼峇里島	1. 技術參訪：Ngurah Rai Airport International Airport 2. 參加道路材料領域研討會 3. 參加展覽會 4. 參加閉幕式	住宿: 印尼峇里島
103.11.20 **(星期四)**	返程 印尼峇里島 ～桃園	本日為會議結束後返國之路程	搭乘中華航空 CI0772 返國

參、 過程

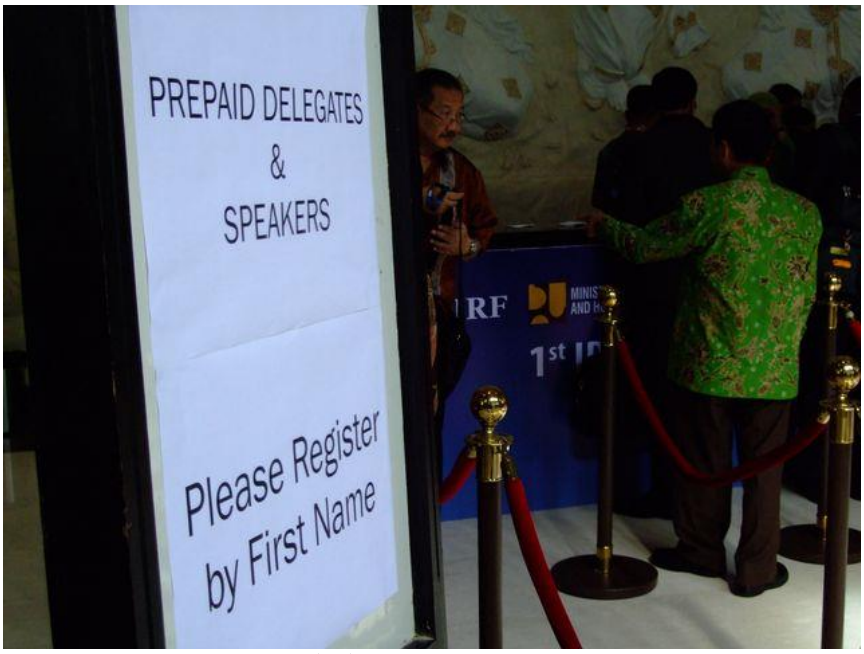
國際道路協會（IRF）於印尼峇里島 Bali Nusa Dua Convention Center 2 舉辦第 1 屆亞洲區域研討及展覽會（1st IRF Asia Regional Congress & Exhibition）。本局整理彙整歷年 IRI 檢測成果，以論文「臺灣路面平整度改善與未來之展望」“The Improvement of Pavement and Its Future Prospects in Taiwan”為題，榮獲本次研討會同意刊登，並受邀與會發表論文，與各國專家學者討論研究本局對於 IRI 的檢測實務經驗。

本次研討會包括 7 大主題：①資產管理(Asset Management)，②鋪面與材料性能(Pavements & Materials)，③公路融資(Road Financing / PPP)，④道路設計和施工(Road Design and Construction)，⑤道路安全(Road Safety)，⑥整合移動和智能交通系統（Integrated Mobility & Intelligent Transportation Systems），⑦持續性運輸(Sustainable Transport)，50 項子題，有來自 45 個國家約 120 場專家演講及學者演講，研討會議程如附件一，會議場地共有 9 間會議室提供演講使用，依據大會統計一共有超過 700 位專業人士代表 52 個國家及 23 個地區合作組織參與此次研討會，其中臺灣與會者約有 6 位。

本局指派出席人員為材料試驗所黃所長三哲及邱瑞昌工程司 2 人，因為本次出訪人員較少，故未委託旅行社代為辦理相關交通、住宿等，所有行程均由團員自行辦理。

茲因行程緊湊，將參與本次研討會過程摘要概述於下：

11 月 16 日上午前往桃園國際機場，搭乘 9：15 華航 CI0770 班機直飛印尼峇里島，飛行時間約 5 小時 20 分鐘，於下午 14：35 分抵達目的地。順利通關後驅車至下榻飯店安置行李，隨即前往大會會場完成註冊報到及領取資料冊等相關手續。



<u>大會會場註冊報到照片</u>

大會於 11 月 17 日上午 9 時舉辦開幕典禮，包括開幕致詞、演講及峇里島傳統歡迎舞蹈表演。開幕致詞由 IRF 總裁兼 CEO，Mr. C. Patrick Sankey 向與會者致歡迎詞，IRF 總裁指出：『IRF 的戰略願景是成為全球領先的知識平台，幫助世界各國實現更安全，更乾淨無污染，更有彈性且更好連接的運輸系統。自 1959 年起，亞洲各國政府致力於提供全區域的公路網絡，以提高各國間的交通連繫，並且作為支持國家經濟增長的方法。實體與非實體障礙的去除為國際貿易提供了強大的推動力，令人鼓舞的是橫貫亞洲公路協定(Trans-Asia Highway convention)目前已涵蓋穿越 32 個國家，總長超過 141,000 公里的道路。關於推動道路安全部份，每年估計有 130 萬個交通事故的受害者，昨天(2014 年 11 月 16 日)是世界道路交通事故受害者紀念日(The World Day of Remembrance for Road Traffic Victims)[1]，提醒著我們應努力避免這些悲劇發生，研究如何防止相關交通事故已成為一個全球性的公共健康危機議題。我們必須確保道路安全，包括採用更好的數據系統，加強執法能力，並採用更全面的交通安全法律，透過縝密的規劃研究與週延的工程設計改善道路安全。』

[1] 聯合國與世界衛生組織將每年 11 月的第三個星期天，訂為 The World Day of Remembrance for Road Traffic Victims，在這一日，默哀和悼念在全球道路交通事故中喪生的人、受傷者、與及他們的家人和社區。同時，對每天處理著交通傷亡事故的可怕後果、無私勇敢的救護人員、警方、消防及醫護人員等致上敬意。

C. Patrick Sankey, IRF President & CEO[2]

開幕典禮側寫照片

[2] 照片來源 http://asiarc.irfnews.org/dailynews1/2014-AsiaRC1-Daily_News1.html

演講結束後，大會協同主辦國印尼安排當地傳統峇里島迎賓舞供各與會者觀賞，表演精彩讓大家驚呼連連，實屬大會之安排及峇里島當地對觀光推展之用心。

開幕典禮結束後，緊接著隨即開始研討會議程，本局在此次研討會投稿一篇論文，獲得大會審查後接受，安排在 Technical &Scientific Session 2.1[Pavement Management and Preservation(鋪面管理與維護)]子議題下，表訂於 11 月 17 日上午發表。

黃所長三哲代表本局論文發表側寫照片

本局發表論文「臺灣路面平整度改善與未來之展望」“The Improvement of Pavement and Its Future Prospects in Taiwan”由材料試驗所黃所長三哲負責簡報，論文內容係統計分析本局自民國 96 年起檢測省道 IRI 值之成果，由成果分析可知本局養護之省道路面平坦度逐年改善，自 96 年至 102 年有長足的進步，並進一步嘗試將 IRI 檢測成果回饋至鋪面管理系統，以 PDCA 的品質管理循環，以確保可靠度目標之達成，並進而促使路面品質持續改善。本局論文獲得與會人員一致肯定，尤其以行車速

限作為 IRI 分組評估之創新概念，更令在場人士耳目一新，黃所長進一步解釋因為臺灣地處地震帶，加上颱風暴雨侵襲，公路災害頻傳，為了在有限的預算內達成最經濟有效的道路養護工作，所以導入以行車速限為分組的概念，透過統計分析的方法，設定不同組別道路養護之 IRI 門檻值，在每一次 IRI 檢測循環完成後，重新檢視路面平整度成果並據以適當修正來年之養護門檻值，以期持續改善公路品質。另一方面，本局養護單位也能利用這套方法概估所需養護預算，讓經費作最有效運用。最後，也向與會專家學者說明，本局當然瞭解 IRI 並非道路品質唯一指標，本篇論文僅是就 IRI 檢測成果的應用提出實務經驗。

此行於會場中也遇見同樣來自臺灣的代表，並留下合影照片如上圖，由左至右分別為中華智慧型運輸系統協會孫前會長瑀、國立高雄應用科技大學土木工程系蘇博士育民、本局材料試驗所黃所長三哲及邱瑞昌工程司。

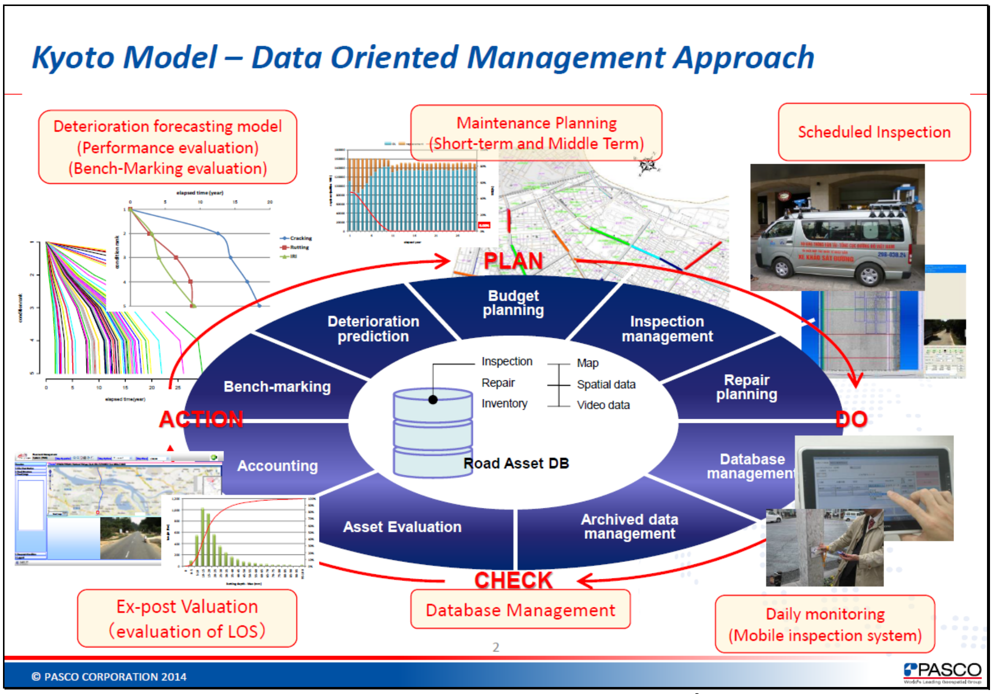
午餐時間大會提供自助式餐點供與會人員自行取用，用餐時不設桌椅，僅提供數張高桌放餐盤使用，其目的應是為了讓與會人員多一些交流，不會因為坐在固定的位置上侷限了互相認識的機會，這也是一種值得將來本局辦相關活動時，可以參考仿效的模式。

午餐時段側寫照片

11 月 17 日下午時段則參加 Japan Road Association（日本道路協會）所主持的研討會「Asset Management Technology」，本場次共有 4 位講者分別講述主題為『Japanese Policy on Road Asset Management』、『Data Oriented Road Management System -Kyoto Model』、『Asset Management of Honshu-Shikoku Bridges』及『The Introduction and the Problem of the Large-Scale Renewal of Structures on Expressways in Japan』。日本道路協會

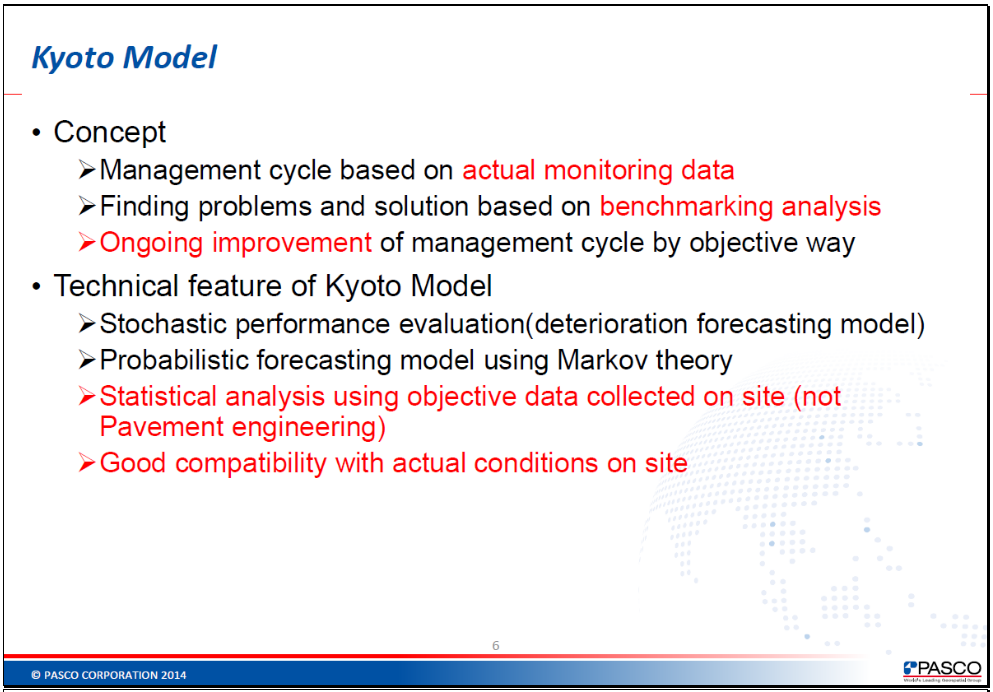
利用這次機會跟與會人員分享現階段日本的資產管理政策，並介紹「Kyoto Model」(京都模式）此種日本特有的公路鋪面資產管理系統，憑藉其高科技為導向的「Kyoto Model」管理體系，提供日本研發企業一個有用的案例研究工具。同時，日本道路協會也特別指出該協會目前在資產管理方面的努力，以實際運用在道路和橋樑的例子說明，也包括一些即將面臨的挑戰。

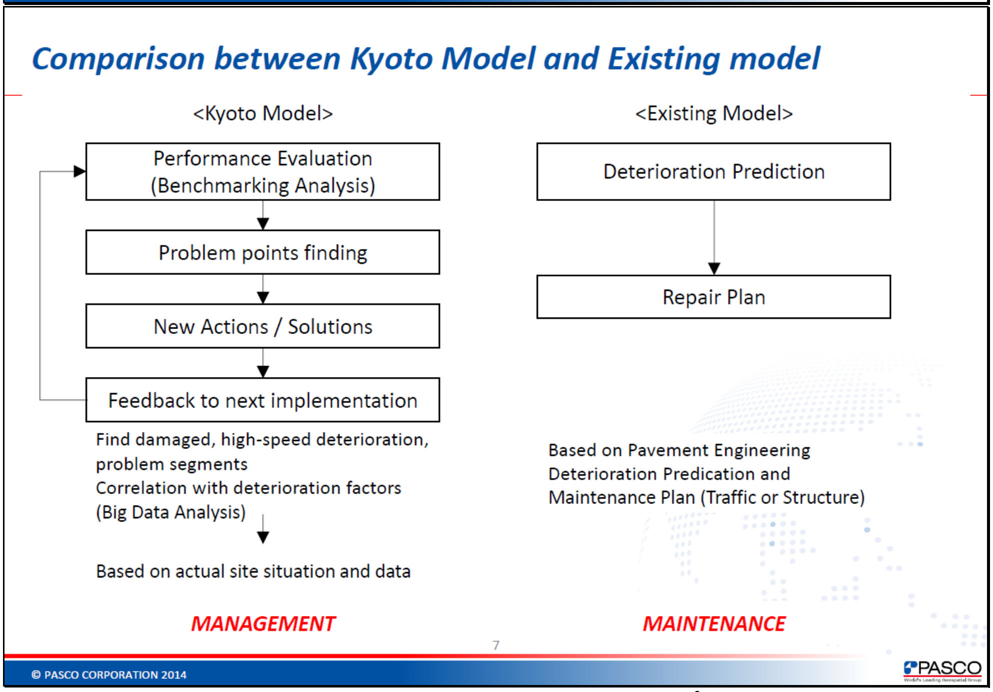
「Kyoto Model」，一種以資料導向的管理方式，由 PDCA 品質管理循環，依據經費預算擬訂維護養護計畫，運用自動檢測車定期蒐集鋪面資訊，將蒐集到的大量鋪面資訊系統化、資料庫化，檢核鋪面狀況是否如預期達成維護養護目標，評估管理成效後擬定下一循環的基準值，利用數值方法進行鋪面品質惡化預測，重新依據經費預算擬訂維護養護計畫。其概念為品質管理循環係依據自動檢測車實地蒐集所得之鋪面現況，透過標竿分析（Benchmarking Analysis）發掘問題並尋求解決方案，客觀地在管理週期間持續改進鋪面狀況。因為統計分析係由鋪面實際檢測所得海量資料（Big data)，而非僅依據鋪面工程學理理論，因此「Kyoto Model」與鋪面現況有良好的相容性。



「Kyoto Model」（京都模式）[3]

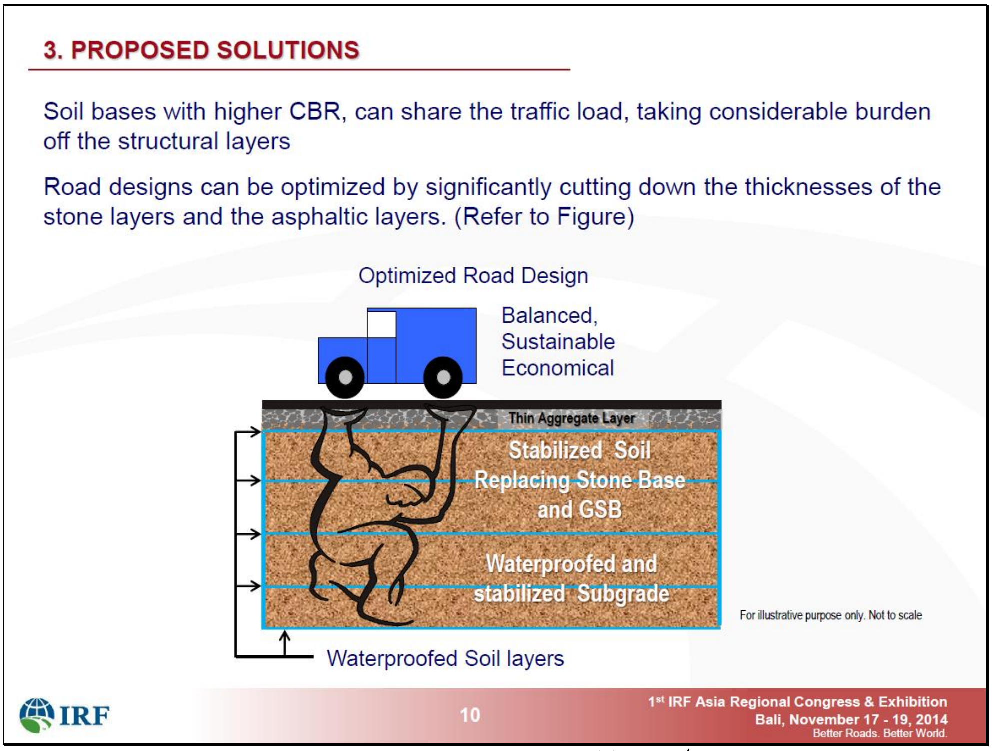
[3] *Data Oriented Road Management System - Kyoto Model*, **Kazuya AOKI**, Kyoto University / PASCO CORPORATION





「Kyoto Model」（京都模式）[3]

11 月 17 日下午還參加 APPLIED KNOWLEDGE SESSIONS：Pavement Applications 領域研討會，講題：「Nanotechnology for Soil Stabilization with Very Low Permeability」，發表人為來自印度的 Ajay RANKA 博士。其研究為利用奈米技術進行土質改良，使改良後土壤穩定且具非常低之透水性。透過土壤改良技術，即使是軟弱地質也能使用，減少消耗有限資源及對環境的破壞。



<u>利用奈米技術進行土質改良[4]</u>

土壤改良方法係使用 Ajay RANKA 博士所屬 Zydex Industries 公司，開發出來的一種奈米技術有機矽烷，其成效可以穩定土壤提高強度外，且可達到零或低度的膨脹指數，費用預估在每立方米美金 5～10 元左右。RANKA 博士指出該產品幾乎可以使用在任何土壤，只要土壤之 CBR>2，且經過改良之土壤，其透水係數可達 10^{-7}～10^{-8} cm/sec，幾乎可說是不透水層，因此可以降低水從地表滲入造成基底層破壞，而且同時路基土壤的水氣可以通過改良區揮發至大氣中，使得改良層土壤達到防水排濕的效果；如果需要更高的土壤強度，在改良同時可加入高分子聚合物（polymers）或水泥拌和，改良後土壤的強度可高達 50～100 CBR。

這樣的奈米技術的確令工程界驚喜，惟因產品是 Zydex Industries 公司專利，除宣稱的改良成效外，Ajay RANKA 博士並未透漏更多細節，目前國內也尚未有使用經驗，值得後續多加關注。

11 月 18 日 IRF 安排了第 1 個工程參觀，目的地為 Bali Mandara Toll Road & Expressway，於 2013 年亞洲太平洋經濟合作會議（Asia-Pacific Economic Cooperation，

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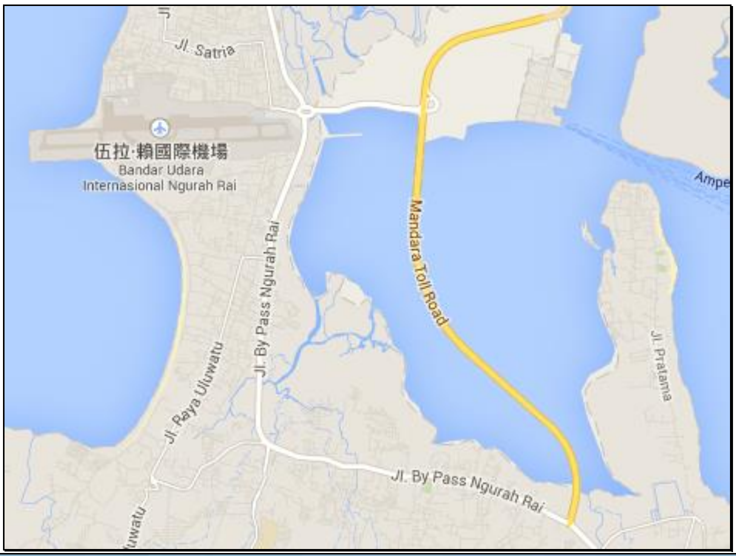
[4] *Nanotechnology for Soil Stabilization with Very Low Permeability* / **Ajay RANKA**, Zydex Industries

APEC）前夕啟用，Mandara 收費公路是一條堤道橋樑橫跨貝諾瓦灣（the Gulf of Benoa）提供峇里島首府登巴薩(Denpasar)、貝諾瓦（Benoa）、努沙杜瓦（Nusa Dua）與 Ngurah Rai 國際機場之間的快速聯絡道路。

Bali Mandara Toll Road & Expressway

如下圖所示，由於機場跑道位置限制了機場南北地區的唯一道路，為了改善交通擁堵的峇里島交通要道，造價 2.2 億美元、長度 12.7km 的 Mandara 收費公路是建在水上的堤道橋（causeway bridge），全長使用 33835 混凝土柱，原始紅樹林與停靠在貝諾瓦港的傳統船舶，讓 Mandara 收費公路有著引人注目美麗的景色。也因為是建造在海

上，公路上設有風速探測器，當風速通過限制值時，為了安全因素，將禁止摩托車進入。因為 Mandara 收費公路位於貝諾瓦灣內，而且在橋柱外圍另設有防波堤岸隔絕外海風浪，鄰近橋墩處亦填砂防護墩柱免於波浪侵害，實際車行在公路上時觀察，海面是平靜無波像一面藍色的鏡子，所以即使是建造在海上，Mandara 收費公路之橋柱尺寸相對臺灣的橋樑而言相當小，由照片可以瞭解其橋墩間跨距短，柱距非常密集。



Bali Mandara Toll Road & Expressway[5]

18 日下午參加 TS2: Pavements & Materials 領域研討會。講題：「The use of ceramic waste materials as fine aggregates in Hot Mix Asphalt (HMA)」，講者為馬來西亞籍 Salihudin

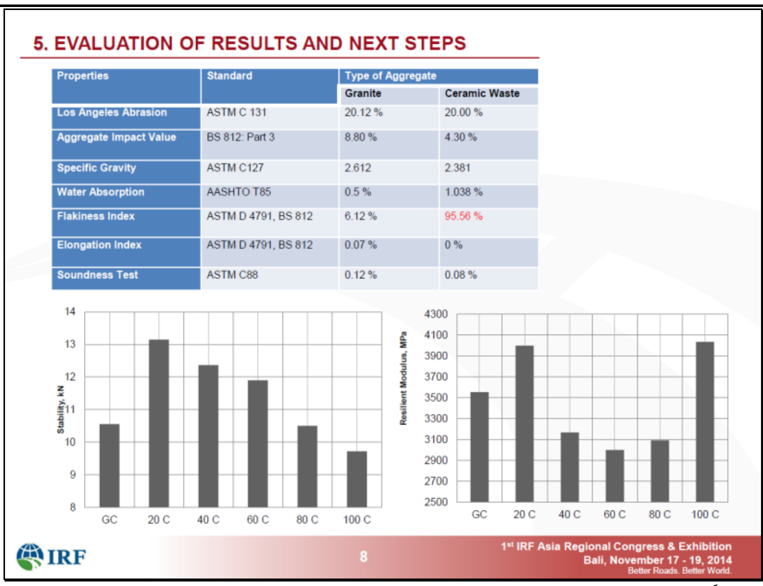
5 圖片取自 http://www.baliairport.net/bali-mandara-toll-road.html

Hassim，其研究主題是將陶瓷廢棄物經粉碎研磨後取代熱拌瀝青混凝土(HMA)的細粒料使用，目的一方面在回收利用廢棄物並減少環境負擔，另一方面也可強化 HMA 性能。方法為篩選尺寸小於 5.0mm 粉碎瓷磚取代細粒料使用，先在實驗室試驗分析其物理性質後，依陶瓷廢棄物佔細粒料的比例分別為 0%，20%，40%，60%，80%和 100%（重量百分比）分組，依馬歇爾法製作試體後評估成效，研究在 HMA 內摻入陶瓷廢棄物的可行性。。

Table 4. Replacement of ceramic waste aggregate

Sieve size (mm)	GC	20 C	40 C	60 C	80 C	100 C
14.00 10.00	100 % Granite	100 % Granite	100 % Granite	100 % Granite	100 % Granite	100 % Granite
5.00 3.35 1.18 0.425 0.150 0.075 Pan	100% Granite	20 % Ceramic waste 80% Granite	40 % Ceramic waste 60% Granite	60 % Ceramic waste 40% Granite	40 % Ceramic waste 20% Granite	100 % Ceramic waste

Note: % of aggregate weight



<u>陶瓷廢棄物使用在 HMA 之材料分組與試驗結果</u>[6]

本研究的結果指出，在 HMA 中混入粉碎陶瓷廢棄物作為細粒料初步結論是可行的。在物理性能測試方面，除了片狀指數（Flakiness index）高達 95%外，其餘物性能

[6] *The Use of Ceramic Waste Materials as Fine Aggregates in Hot Mix Asphalt (HMA)/* **Dhieyatul Husna ISMAIL, Ratnasamy MUNIANDY, Salihudin HASSIM**

滿足細粒料品質要求。另外在成效試驗方面，在不同比例的各組中，以粉碎陶瓷廢棄物取代 20%細粒料製成之馬歇爾試體表現成效最佳，其穩定值較對照樣品（混入 0%粉碎陶瓷廢棄物）增加約 0.25kN，彈性模數試驗方面則提高了約 13.5%。

然而是項研究並未顯示馬歇爾試驗的流度值是美中不足之處，流度值是代表瀝青混凝土的抵抗變形的能力，尤其在粉碎陶瓷廢棄物之片狀指數高達 95%的情形下，以粉碎陶瓷廢棄物取代細粒料在實務上是否可行，會不會產生過大變形導致車轍或路面擠壓破壞，值得就此部份再深入研究探討。

18 日晚間大會則舉辦了 Gala Dinner & IRF Awards Ceremony，與會者須自費美金 75 元晚宴費用購票進場。會中表揚了 2014 年 Global Road Achievement Awards，共有 9 個獎項：①Construction Methodology，②Design，③Environment Mitigation，④Traffic Management & ITS，⑤Program Management，⑥Project Finance，⑦Quality Management，⑧Safety，⑨Technology, Equipment & Manufacturing。得獎名單如下：

Winners of the 2014 GRAA competition:	
①Construction Methodology	Abu Dhabi Municipality & Parsons International Ltd. for “The Zayed Street Tunnel” (United Arab Emirates)
②Design	T.Y. Lin International/Moffatt & Nichol, Joint Venture for “The San Francisco-Oakland Bay Bridge New East Span” (USA)
③Environment Mitigation	Transcity Joint Venture for “Legacy Way” (Australia)
④Traffic Management & ITS	Xerox for “Merge Dynamic parking pricing” (UK)
⑤Program Management	Hubei Changjiang Road & Bridge Co. for “Ma-Wu Highway Construction Project” (China)

Winners of the 2014 GRAA competition:	
⑥Project Finance	District Department of Transportation (DDOT) for "11th Street Bridge Project" (USA)
⑦Quality Management	Delcan, a Parsons Company, for "Columbus Crossroads (I-670 / I-71 Interchange) Design-Build Project" (USA)
⑧Safety	Dubai Roads & Transport Authority for "Children Road Safety is a Shared Responsibility" (United Arab Emirates)
⑨Technology, Equipment & Manufacturing	Roadroid for "Smart phone IRI data collection" (Sweden)

2014 年 Global Road Achievement Awards 得獎人員合照[7]

[7] 照片來源：http://asiarc.irfnews.org/dailynews2/2014-AsiaRC1-Daily_News2.html

黃所長三哲也利用參加晚宴的機會，與世界各國的專家學者充分交換意見與心得，交換名片及聯絡資料，除了做好國民外交的工作外，也為將來國際技術合作埋下種子，同時留下合影照片如下：

左起蘇育民博士、古木守靖（JICA）、久保和幸（PWRI）與黃所長三哲

前排右起瞿彤斌博士、黃所長三哲與蘇育民博士

其中<u>古木守靖（FURUKI　Moriyasu）博士</u>現職為日本國際協力機構（Japan International Cooperation Agency）技術顧問，歷任建設省大宮国道所長、沖縄総合事務局次長、首都高速道路公団理事、土木学会専務理事；<u>久保和幸(Kazuyuki KUBO)博士</u>現職為獨立行政法人土木研究所（Public Works Research Institute）道路技術研究團隊上席研究員（Team Leader）。<u>瞿彤斌博士</u>為美國註冊工程師，現職為美國德克薩斯州 A&M 大學景觀建築與城市規劃系講師。

<u>古拉賴國際機場(Ngurah Rai International Airport)</u>[8]

11 月 19 日議程的第三天早上，也是最後一天，大會安排了另一個工程參觀，地點是古拉賴國際機場(Ngurah Rai International Airport)，位於峇里島首府 Denpasar 南方 13 公里，是印尼運輸量第三大之國際機場，為了應付龐大的國際觀光客出入境需求，經過整建新的國際航廈於 2013 年開幕，機場雖然僅有一條 3000m 長的跑道，每年最多可容納二千五百萬名旅客，機場一共有 18 個登機門，8 個供印尼國內航班使用，10 個供國際航班使用，經統計目前每年約有 1600 萬旅客進出古拉賴國際機場。

[8] 照片來源：http://bali-airport.com/upload/image/2014/10/dps_800_slideshow-view-from-the-top-humas-dps-9643edf72d3f4361a0e3d53d2f5fc79192ada9ebupview.jpg

<u>古拉賴國際機場參訪行程側拍</u>

11 月 19 日還參加 TS2.6: Durable Paving Materials 領域研討會。講題:「The Mechanical and Thermal Analysis of Porous Asphalt Concrete Containing Steel Slags」，講者為同樣來自臺灣的國立高雄應用科技大學蘇育民博士。多孔隙瀝青混凝土(Porous Asphalt Concrete, or PAC)具有高孔隙排水性，其優點包括環保、雨天車輛抗滑、利於排水、減少光反射、降低鋪面行車噪音等。本研究主要探討多孔隙瀝青混凝土添加爐石材料，在不同取代粗粒料的比例下，對鋪面成效及熱學性質造成的影響。

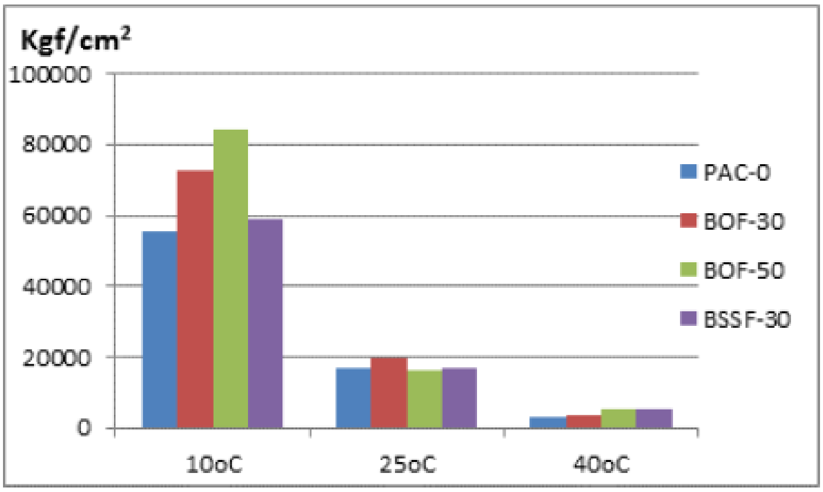
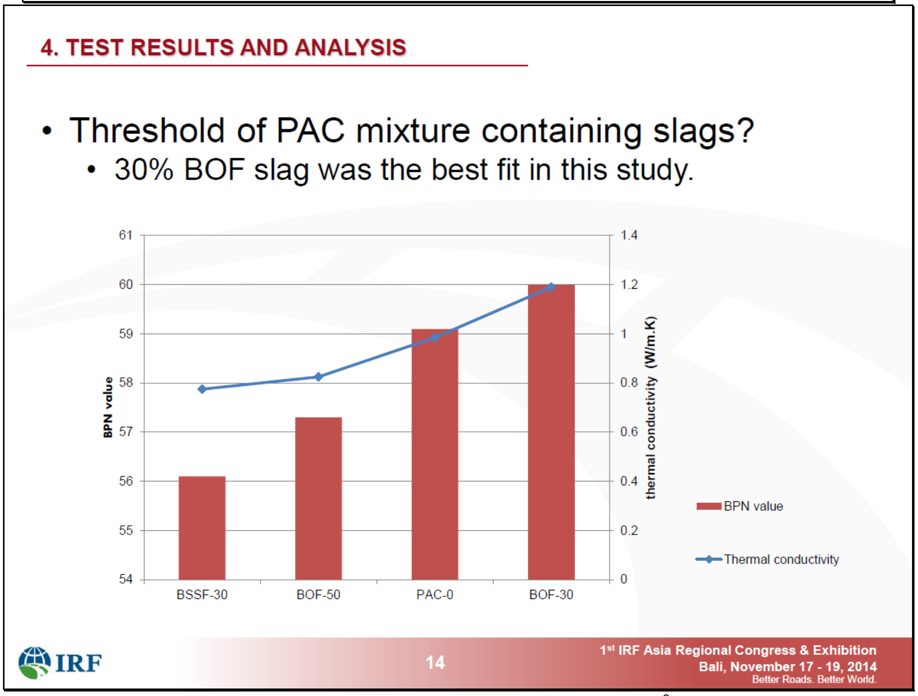


Figure 3. The resilient modulus of PAC mixtures



添加不同比例爐石之成效分析[9]

[9] *The Mechanical and Thermal Analysis of Porous Asphalt Concrete Containing Steel Slags*/ **Yu-Min SU, Dana MUTIARA, Jyh-Dong LIN**

試驗結果顯示，爐石材料較一般傳統粒料有較高的比重及吸水率，但健性及粒料磨損率則相對較低；在本研究中以轉爐石取代粗粒料 30%的多孔隙瀝青混凝土，具有最佳的成效表現，熱傳導及熱擴散係數的結果亦為所有試驗組中的最高值。本研究結果認為爐石能夠做為在設計多孔隙瀝青混凝土中取代粗粒料之材料。

雖然研究成果認為爐石能夠做為在設計多孔隙瀝青混凝土中取代粗粒料之材料，但是未經熟化穩定之爐石，遇水容易造成不均勻膨脹，導致路面破壞，這是在使用爐石作為鋪面材料時應特別值得留意的。例如臺南市的台江大道，即是因為道路基礎使用鋼鐵廠的爐石，爐石遇水產生不均勻的膨脹問題，使得台江大道變成「顛簸大道」，危及用路人的安全。

11 月 19 日下午的大會閉幕式，IRF 總裁兼 CEO，Mr. C. Patrick Sankey 提出了亞太地區的運輸挑戰在於能量的建立與強化，換而言之，透過對工程師、研究機構與實務經驗的投資，能讓亞太地區的國家達成其公路發展的目標。這也是招開本次研討會的目的，透過大型研討會提昇從業人員工作能力，並從中挑選可靠負責的專業機構合作，讓公路計畫能更有效地被執行。IRF 致力於支持公路發展，尤其是透過其豐富的專業知識平台與強力專業夥伴，帶領亞洲地區面對這些重要挑戰。

大會閉幕式合照[10]

[10] 照片來源：http://asiarc.irfnews.org/dailynews3/2014-AsiaRC1-Daily_News3.html

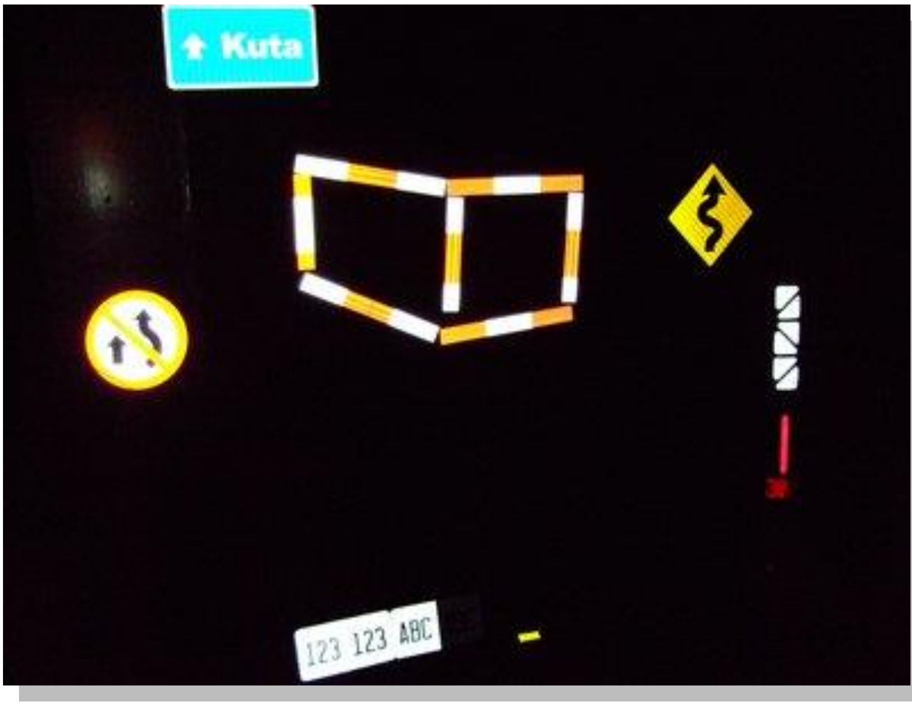
本次為期三天的第 1 屆亞洲區域研討及展覽會於下午三點正式劃下完美句點。隨即返回飯店整理此行收穫及製作出國報告，並於隔日（11 月 20 日）搭乘華航 CI0772 班機返抵臺灣。

另外展示場內有許多相關廠商設攤，茲節錄照片於下：


FORUM 8


B28
SAFEROADS
OMNI-STOP
Energy absorbing bollard
SAFEPOLE
Impact absorbing lightpole
IRONMAN HYBRID
The durability and portability of STEEL


3M


Kuta
123 123 ABC


Road Systems, Inc.
RSI
BEAT-SSCC & BEAT-BP
BEAT- SSCC
Single-Sided Crash Cushion
BEAT-BP Bridge Pier


A8
PLASTIC SAFETY SYSTEMS
RoadQuake 2F
REINVENTED
DRIVING
DOWN
DISTRACTED
DRIVING


A7
LINDSAY TRANSPORTATION SOLUTIONS


A6
TRINITY HIGHWAY INTERNATIONAL
TRINITY

肆、 心得與建議

1. 國際道路協會凝聚全球公路專家與學者，今年首度舉辦第 1 屆亞洲區域研討及展覽會，各國與會代表針對公路工程不同專業領域發表研究成果，本次有幸代表本局前往，除發表本局論文，並聽取來自不同國家的講者精采的研究成果，將最新的工程資訊或研究方向帶回國內，能夠參加此為期三天的國際公路工程會議，獲益良多並與有榮焉。

2. 本局今年投稿一篇論文，獲大會審查後接受，由於本局論文以行車速限作為 IRI 分組評估之創新概念相對特別，也吸引了一些專家學者討論內容、交換研究心得及提供建議，對本局未來業務及研究方向些得到許多助益。

3. 本次大會約有 120 場演講專題，簡報內容皆是學者多年研究精華，惟限於時間與人力，僅能針對少數主題擇要收集相關資料，作為本局未來研究發展之重要參考。建議針對此類重要之國際級大型會議，可考慮編列充足經費預算，多派人員參加與會並發表研究成果，除讓國外機構瞭解我們的研究能力外，並可蒐集帶回更充分的相關資訊，提升本局人員研究素質。

4. 主辦單位對大型國際會議之策劃統籌能力令人印象深刻，此外此次會議電子化處理作業亦是相當值得學習的，主辦單位透過電子網路處理大多數之文件與論文簡報等資料繳交，有關研討會之議程或更新事項亦即時透過電子郵件通知與會者，並公告於會議網站上，由與會者自行前往下載。相關研討會論文不提供紙本，改以電子檔存放在隨身碟內，節省印刷成本與紙張浪費，值得國內爾後主辦會議之參考。

5. 從此次實際參與 IRF 舉辦之研討會了解，IRF 著重在公路工程實務面的應用，因此除了少數純學術上的論文外，大多是當今世界各國領先的技術論文，而發表者皆為工程業界頂尖人士，實務經驗豐富，對與會者的問題多能舉實例回答，也讓我們瞭解目前國際最新應用的工程技術與科技發展現況，受益良多。

6. 透過此次研討會，瞭解目前國外的檢測車已不只有檢測路面平坦度 IRI 值，同時

透過雷射掃描鋪面狀況，分析道路的服務品質，甚至可以計算出摩擦係數，這對國內積極提昇標線抗滑值以減少兩輪車輛交通事故的我們，是一個值得關注研究的方向，因為現有的大英擺錘抗滑試驗其試驗範圍涵蓋面小，難以取得代表性數值，若改以自動檢測車以線的方式甚或以面的方式去取樣，可獲得更可觀的成果。

以上圖 iRAP (International Road Assessment Program)現場展示之自動檢測車為例，前保險桿裝有雷射測距儀與加速度規，配合車輪軸上之 DMI，投過電腦自動擷取計算鋪面平坦度 IRI 值；除此之外，車頂配有三支攝影機，可拍攝記錄鋪面現況，另搭配 GPS 全球定位系統，可與其他自動檢測系統連結，自動記錄檢測位置；車頂後側兩側則有高精度雷射測距儀，可掃描全車道鋪面，透過電腦程式描繪鋪面細部紋理，可計算車轍深度，甚或評估鋪面摩擦係數。國內目前並無相關研究與儀器，如經評估引入是項技術，應能對本局管養省道業務有所助益。

7. 橫貫 IRF 整場研討會的核心主題是如何透過最新的工程技術，最佳的管理方法，最適合的鋪面材料，來達成最重要的道路安全。正如同 IRF 所揭櫫的核心價值與

工作目標「Better Roads. Better World」，這也是主管全國公路的本局所有同仁在各自的工作崗位上努力的方向。

伍、 附件

附件一、大會議程

SUNDAY, NOVEMBER 16		
10:00 - 17:30	William Troxler Memorial Golf Tournament	
18:30 - 21:30	International Reception & IRF Fellows Reunion at Bali National Golf Club	
16:00 - 18:30	Registration & Information Desk Open	
MONDAY, NOVEMBER 17		**ROOM**
9:00 - 10:30	Opening Ceremony	Tanjung Benoa
10:30 - 11:00	Exhibition Opening	
11:00 - 12:30	● ES1: Congestion Management in Asian Cities	Pecatu 1
	● ES2: Sustainable & Resilient Road Infrastructure	Pecatu 2
	● PS1: Towards a Traffic Safety Culture (INTP)	Mengwi 1 & 2
	● PS2: Vehicle Safety Standards in Developing Economies (GRSF)	Mengwi 6
	● TS 1.1 (Mengwi 3) ● TS 2.1 (Mengwi 5) ● TS 5.2 (Mengwi 7)	Various
11:00 - 15:00	● WS1: Road Sector Reform	Mengwi 8
12:30 - 13:30	Lunch	
13:30 - 15:00	● ES3: Smart & Accessible Cities for a Connected Asia	Pecatu 1
	● PS3: Rural Road Development (Thai DRR, PMGSY)	Mengwi 6
	● PS4: Asset Management Technology (JRA)	Pecatu 2
	● SRD1: Engineering Safer Roads	Mengwi 1 & 2
	● TS 1.2 (Mengwi 3) ● TS 5.1 (Mengwi 7) ● TS 7.2 (Mengwi 5)	Various
15:00 - 15:30	Refreshments Served	
15:30 - 17:00	Building The Asian Highway Network: An Agenda for Shared Regional Prosperity	Tanjung Benoa
17:15 – 18:30	● AK1: Pavement Applications (Mengwi 7) ● AK2: Asset Management Applications (Mengwi 6)	Various
	● HS1: Infrastructure Programs in Indonesia	Pecatu 2
	● Interactive Posters	Pecatu Prefunction
	IRF Committee on ITS Meeting	Mengwi 5
	IRF Committee on Road Safety Meeting	Mengwi 8

TUESDAY, NOVEMBER 18		ROOM
9:00 - 10:30	Technical Visit 1: Bali Mandara Toll Road & Expressway	Congress Registration Area
9:00 - 10:30	UN Decade of Action for Road Safety: Asia Progress Report	Pecatu 1 & 2
10:30 - 11:00	Refreshments Served	
11:00 - 12:30	● ES4: Innovation in 21st Century Transport	Pecatu 1
	● PS5: Integrated Road Network Policy, Planning and Delivery (ARRB)	Pecatu 2
	● SRD2: Roadside Safety	Mengwi 1 & 2
	● TS 1.3 (Mengwi 3) ● TS 2.3 (Mengwi 5) ● TS 5.4 (Mengwi 7)	Various
12:30 - 13:30	Lunch	
13:30 - 15:00	● ES6: Up-skilling the Workforce in Emerging Economies	Pecatu 1
	● PS6: International Road Assessment Program (iRAP)	Mengwi 1 & 2
	● TS 3.1 (Mengwi 5) ● TS 6.2 (Mengwi 3) ● TS 7.1 (Mengwi 7)	Various
	Technical Visit 1: Bali Mandara Toll Road & Expressway	Congress Registration Area
13:30 - 17:00	● WS2: Saving Lives Through the Development of an Effective Speed Enforcement Strategy	Mengwi 8
15:00 - 15:30	Refreshments Served	
15:30 - 17:00	● ES5: Best Practices in Asset Management	Pecatu 1
	● ES7: Managing Complex Project Delivery	Pecatu 2
	● SRD3: Motorcycle Safety	Mengwi 1 & 2
	● TS 2.4 (Mengwi 3) ● TS 5.3 (Mengwi 5) ● TS 6.1 (Mengwi 7)	Various
17:15 – 18:30	● AK3: Road Safety Applications (Mengwi 7) ● AK4: ITS Applications (Mengwi 6)	Various
	● HS2: Doing Business in Indonesia	Pecatu 2
	● Interactive Posters	Pecatu Prefunction
	IRF Committee on Asset Management Meeting	Mengwi 5
	IRF Sub-Committee on Enforcement Meeting	Mengwi 8
20:00 - 22:00	Gala Dinner & IRF Awards Ceremony	Tanjung Benoa

WEDNESDAY, NOVEMBER 19		
7:00 - 8:30	IRF Asia Regional Committee Breakfast Meeting	VIP Room
9:00 - 10:30	Technical Visit 2: Ngurah Rai Airport International Airport	Congress Registration Area
9:00 - 10:30	● ES8.1: Managing Toll Demand Risk	Pecatu 1
	● PS7: Natural Asphalt Properties (IRE)	Pecatu 2
	● SRD4: Workzone Safety	Mengwi 1 & 2
	● TS 2.5 (Mengwi 3) ● TS 4.1 (Mengwi 5) ● TS 5.5 (Mengwi 7) ● TS 5.6 (Mengwi 6)	Various
9:00 - 12:30	● WS3: Performance-Based Contracts	Mengwi 8
10:30 - 11:00	Refreshments Served	
11:00 - 12:30	● ES8.2: Managing Toll Demand Risk	Pecatu 1
	● PS8: Innovations in Safe and Efficient Road Infrastructure Design (KICT)	Pecatu 2
	● SRD5: Vulnerable Road Users	Mengwi 1 & 2
	● TS 2.6 (Mengwi 3) ● TS 4.2 (Mengwi 5) ● TS 5.7 (Mengwi 7) ● TS 6.3 (Mengwi 6)	Various
12:30 - 13:30	Lunch	
13:30 - 15:00	Closing Session: Setting the Agenda to 2020	Pecatu 1 & 2

附件二、本局發表之論文全文

IRF Asia Regional Congress Paper Submission Form
November 17-19, 2014
Bali, Indonesia

PAPER TITLE (90 Characters Max)	The Improvement of Pavement and Its Future Prospects in Taiwan		
TRACK	Pavements & Materials		
AUTHOR (Capitalize Family Name)	POSITION	ORGANIZATION	COUNTRY
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KEYWORDS:

International Roughness Index（IRI）
Cumulative Percentage
Box Plot
Ride Quality

ABSTRACT:

Since 2007, the Taiwan Directorate General of Highways (DGH) has begun to use the International Roughness Index (IRI) to measure pavement roughness of all provincial highways. The annual measuring volume is about 9500 km under the calculation of a single traffic lane. The DGH has completed 7-cycle measurements till 2013, and the results have been faded back to the road maintenance management system. During these years, the pavement roughness has been considerably improved. From 2007 to 2013 the IRI mean value fell from the 4.82 m/km to 3.65 m/km, dropped significantly by 24%. Standard deviation gradually reduced from 1.57 m/km to 0.98 m/km. In 2009, we set 3 IRI targets---one for the short-term before 2009, another for the mid-term before 2011, and the other for the long-term before 2013. And, we have obtained 99-percent of our previously-set targets. With a view to more effectively utilizing the road maintenance budget, we, in 2014, classified roads into 5 groups, and set 5 different IRI targets respectively according to their different geographical areas and different designs of speeds. Using rolling management, we expect to more effectively use the test results, and achieve perfect and more efficient pavement maintenance; further, the DGH can provide the Taiwan’ s public for enjoying better road environments.

The Improvement of Pavement and Its Future Prospects in Taiwan

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1 PREFACE

There are national highways, provincial highways, city highways, county highways and country roads in Taiwan (Republic of China Highway Act 2013). In this paper, we emphatically study provincial highways used as communications between two or more counties, or municipalities (or provinces), or major political, economic and cultural centers. The total length of provincial highways is about 5,000 kilometers, and its paved area is about 90 square kilometers. Taiwan with the area of 36,000 square kilometers and with the population of 23,000,000 has the character of heavy traffic. The average daily traffic is about 11,000 passenger car unit (PCU) on provincial highways; and its maximum daily traffic is about 87,000 PCU. The peak hour volume (PHV) is at an average of 1,300 PCU; and its maximum is about 8,700 PCU (DGH website).

Since 2007, the Taiwan Directorate General of Highways (DGH) started to measure the pavement roughness of all provincial highways by employing the International Roughness Index (IRI). Basically, one testing cycle is implemented each year, by choosing a certain lane to do forward and back-ward (two-directions) tests. After the completion of tests, their analyses and statistics will be used in road maintenance and management.

2 INTRODUCTION OF TESTING INSTRUMENTS

Figure 1 is the photo of DGH’ s pavement testing car. Testing instruments are put in the right and left instrumental boxes in front of the car (just next to bumper) where 2 laser displacement sensors are set. The laser displacement sensors are used to measure the height difference between emitting point and the pavement surface. Sampling frequency is 1250Hz. Following the longitudinal sampling Resolution≦25mm regulated by ASTM E950 class 1, we take longitudial sampling resolution 11mm at the speed of 50km/hr; 22mm at the speed of 100km/hr. Two accelerometers are set in right and left instrumental boxes, establishing a reference baseline for calculating elevation changes of pavement (measuring scope, ±5g). One distance measurement instrument (DMI) is set on left rear tire, and can emit 2000 pulse signals per revolution. Because of the circumference of the above tire being 2125 mm, one signal is obtained by driving 1.1 mm. All the above obtained signals, which are transmitted to the computer server in the testing car, are further analyzed and calculated by the related software in a notebook computer. The repeatability and accuracy of the testing instruments which were approved by the Tjing Ling Industrial Research Institute, National Taiwan University, in 2013, meet the requirements of AASHTO R56.

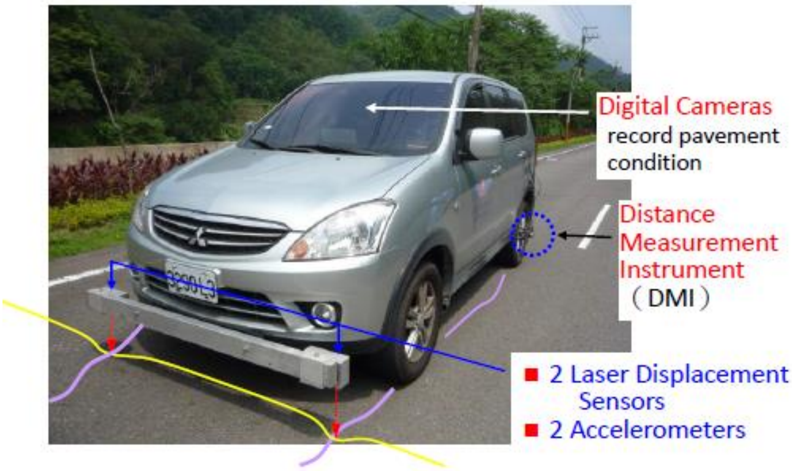

Figure 1. The photo of DGH’s pavement testing car

3 TESTING RESULTS IN THE PAST YEARS

During 2007-2013, annual measured mileage of provincial highways shown in Table 1 was about 9,500 lane kilometers. Among them, a slight increase or decrease of length resulted from completion of new roads, not-yet recovered roads because of natural disasters. The mean value of IRI (m/km), standard deviation of IRI (m/km), Max. of IRI, Min. of IRI, cumulative percentage of IRI＜5m/km and cumulative percentage of IRI＜4m/km in the past some years are statistically shown in Table 2. As shown in Table 2, the mean value of IRI gradually decreased year after year. For example, we reduced the mean value of IRI from 4.82m/km in 2007 to 3.65m/km in 2013. The reduction percentage reaches 24%. The standard deviation of IRI was changed from 1.57m/km into 0.98m/km. It means that the distribution had been gradually concentrated. The maximum of IRI has been changed from 15.46m/km into 8.37m/km. The minimum of IRI has been changed from 1.55m/km into 0.92m/km. All these evidences show that the surface of pavement has become flatter and flatter. Figure 2 shows the distribution of IRI in the past years, but too many curve lines are difficult of being read. Therefore, we only choose 4-year cumulative curves which are left-upward. This means that the percentage of flat surface of pavement is becoming high. For example, the cumulative of percentage of IRI＜5m/km has been increasingly changed from 60.1% into 90.5% year after year; similarly, the cumulative of percentage of IRI＜4m/km has been increasingly changed from 34.8% into 67.1% year after year.

Table 1. Measurement mileage of provincial highways from 2007 to 2013

Year	2007	2008	2009	2010	2011	2012	2013
Lane km	9406	9568	9124	9444	9566	9594	9627

Table 2. Statistics of IRI from 2007 to 2013

Year	2007	2008	2009	2010	2011	2012	2013
Mean Value of IRI（m/km）	4.82	4.76	4.32	4.31	4.03	4.08	3.65
Standard Deviation of IRI（m/km）	1.57	1.42	1.25	1.22	0.99	0.96	0.98
Max. of IRI（m/km）	15.46	13.75	13.10	11.45	9.92	8.33	8.37
Min. of IRI（m/km）	1.55	1.38	1.41	1.32	1.43	1.25	0.92
Cumulative Percentage of IRI＜5 m/km	60.1%	61.3%	74.7%	75.2%	84.3%	83.6%	90.5%
Cumulative Percentage of IRI＜4 m/km	34.8%	32.0%	44.9%	45.2%	52.6%	49.3%	67.1%

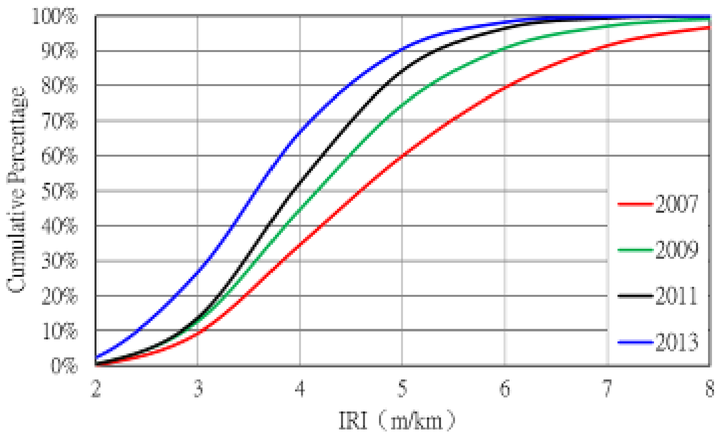

Figure 2. Cumulative distribution curves of IRI respectively in 2007, 2009, 2011 and 2013.

Figure 3 shows the distribution changes of IRI in the past years. Rectangular blocks with different colors represent different intervals of IRI. From the figure, we see each IRI interval is gradually upward year by year. For example, the part IRI<3m/km (green block) is enhanced from 9% into 27%, and the part IRI>6m/km (red block) is decreased from 21% into 2 %. Apparently, we have made good use of the statistics of IRI to more effectively maintain roads. The testing results are useful and beneficial to the mechanism of road maintenance and management.

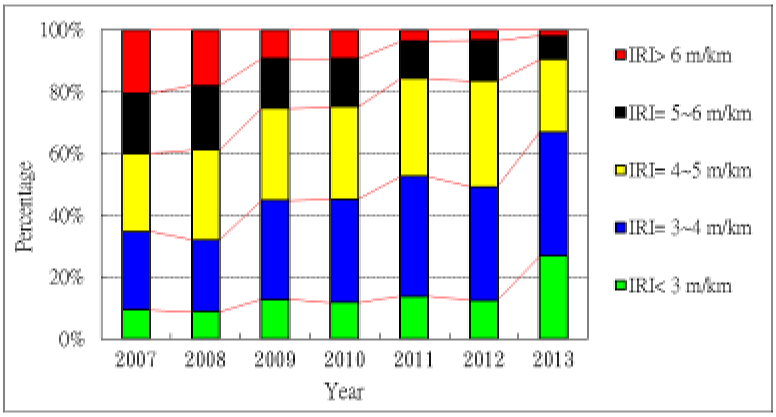

Figure 3. Distribution changes of IRI in the past years

4 DISTRIBUTIONS OF IRI IN ACCORDANCE WITH DIFFERENT SPEED LIMITS

Provincial highways are scattered over all the island of Taiwan, composed of straight expressway and roads located respectively in plains, hills, mountains. For example, there is a provincial highway just with the length of 31.4 km in Taiwan, but its elevation is changed even from 1100m into 3275m—very great difference of elevations. Therefore, different grades of roads should be maintained by different standards of maintenance. According to different speed limits, we statistically analyse so as to understand the pavement roughness on the roads with different grades. In 2013, We tested 9627 lane km on provincial highways which were further divided into 5 groups---(1) speed limit≦35km/hr（at very special mountainous areas）, (2) speed limit=40km/hr (mountainous areas), (3) speed limit=50km/hr (hilly areas), (4) speed limit≧60km/hr (plain areas), and (5) speed limits generally between 70 to 90km/hr(on most expressway). In Figure 4, the each tested length (lane km) of the above 5 groups is as follows : Speed limit≧60km/hr, 4366 lane km, 45% of total tested length; Speed limit=50km/hr, 2066 lane km, 22%; Expressway, 1153 lane km, 12%; Speed limit≦35km/hr, 1076 lane km, 11%; Speed limit=40km/hr, 966 lane km, 10%.

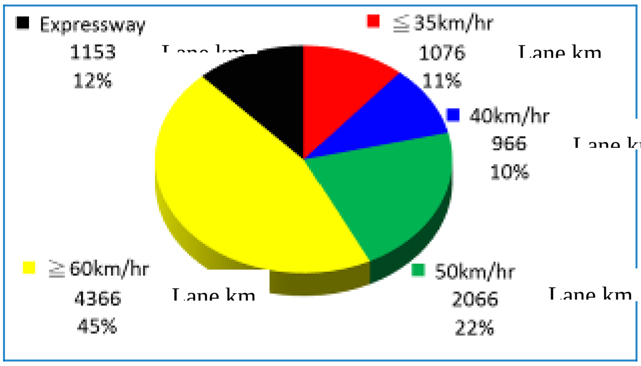

Figure 4. The each tested length (lane km) and its percentage of 5 different speed limits

The mean values, standard deviation, maximum, minimum of IRI and in 68% scope under different speed limits are shown in Table 3. The box plot of analyzed IRI data of each group are drawn as Figure 5. The substantial blue frames mean (1) the upper boundary line representing mean value + 1 standard deviation and, (2) the lower boundary line representing mean value － 1 standard deviation. Vertical lines mean maximum (up-prolonged) and minimum (down-prolonged). From the above figure and table, we understand the mean value, maximum, and minimum are becoming smaller as the speed limits are becoming higher. In other words, higher speed limits consequently make better pavement roughness. Most of the low speed limits in mountainous area, pavement implementation and maintenance are more difficult. Standard deviations are becoming smaller as the speed limits are becoming higher. And, IRI data are more concentrated, and in narrower distribution.

Table 3. IRI statistical analysis of different speed limits

Speed Limit Classification	IRI（m/km）				
	Mean Values	Standard Deviation	Max.	Min.	68% Scope
≦35km/hr	4.80	0.97	8.37	2.36	3.82～5.77
40km/hr	4.26	0.91	6.63	2.14	3.35～5.18
50km/hr	3.83	0.83	7.09	1.81	3.00～4.66
≧60km/hr	3.38	0.75	6.37	0.92	2.63～4.12
Expressway	2.80	0.71	5.24	1.13	2.09～3.51
All of The Provincial Highway	3.65	0.98	8.37	0.92	2.67～4.63

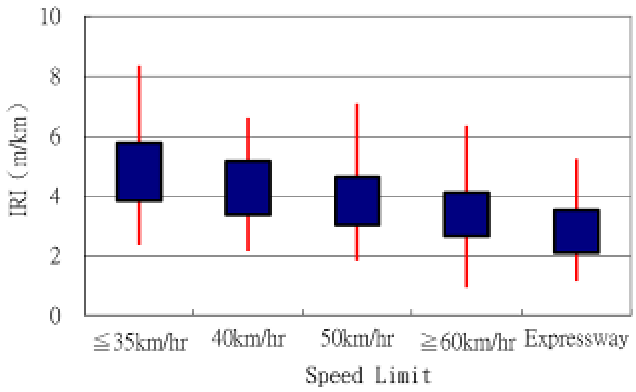

Figure 5. IRI box plot of different speed limits

5 COMPARISON OF PAVEMENT AMONG DIFFERENT COUNTRIES

We tried to do the pavement comparisons with those of other countries. After consulting the related information from many web sites, the American some state government information, including Washington (WSDOT 2013)、California (Caltrans 2011)、Florida (Florida 2010)、New Jersey (NJDOT 2008), showed the entire state roads or only particularly concentrated in a certain area; in other words, roads are not classified into different grades, so we cannot take them to do comparison with those of Taiwan's provincial highways. The only information we obtained is the pavement testing report by Virginia State in 2012 (VDOT 2012). Virginia State classified its roads into different grades to do statistics of IRI, and evaluated ride quality five grades from excellent to very poor. Their relative IRI are shown in Table 4. The IRI thresholds under the acceptable ride quality should be smaller than 2.21m/km on interstate & primary roads, and smaller than 3.47m/km on secondary roads. Because of VDOT website stating that the limits of secondary roads are 45 mph for trucks and 55mph for other vehicles, we consider doing relative and matching comparison by citing (a) Taiwan's provincial highways, including expressway, with speed limit≧70km/hr, 2863Lane Km tested in 2013, and (b) those of secondary roads in Virginia State, USA. We statistically obtain: the mean value of IRI 3.09m/km, standard deviation 0.76m/km, maximum 6.12m/km and minimum 0.92m/km. The comparison results are shown in Figure 6. Excellent Grade 1.2% and Good Grade 30.6% of Taiwan's provincial highways are little worse than Excellent Grade 2.9% and Good Grade 33.5% of Virginia's secondary roads. But, Poor Grade 4.8% of Taiwan's is better than Poor Grade 10.7% of Virginia's. If we cite IRI thresholds (IRI<3.47m/km) as Virginia's acceptable Ride Quality, 70% of Taiwan's provincial highways are acceptable, and slightly better than 66% of Virginia's secondary roads.

Table 4. Rating in ride quality on Virginia's roads

Ride Quality	IRI Rating (m/km)	
	Interstate & Primary	Secondary Roads
Excellent	<0.95	<1.50
Good	0.95～1.57	1.50～2.67
Fair	1.58～2.20	2.68～3.46
Poor	2.21～3.15	3.47～4.41
Very Poor	≧3.16	≧4.42

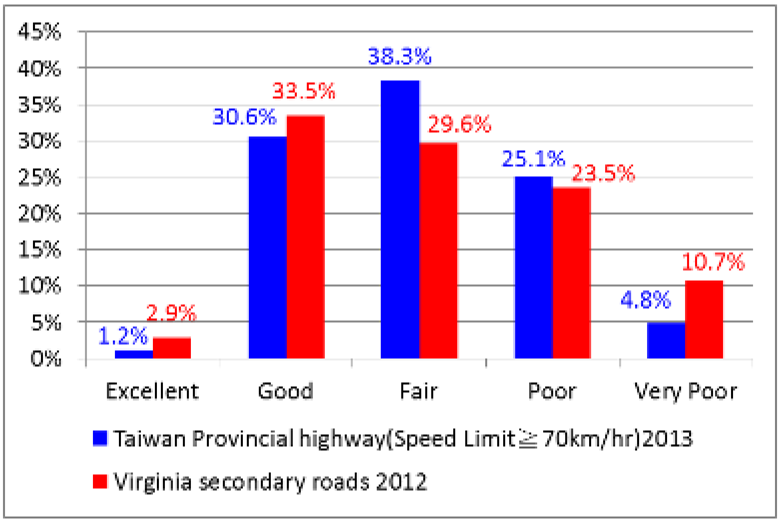

Figure 6. Comparison of ride quality of pavement between Taiwan's provincial highways and Virginia's secondary roads

Additionally, we cite the report of Irish regional road network (Kieran & Brian 2012), and do the comparison between all Taiwan's provincial highways and roads mentioned in the above Irish report. Taiwan's IRI 3.65m/km is slightly better than Irish IRI 4.2m/km. Cumulative distributions are shown as Figure 7. Taiwan's curve is more approaching S curve; and Irish curve is quadratic curve. The intersection of the two curves is at IRI 3.7 m/km. The Irish cumulative percentage on the left part of intersection is slightly higher than that of Taiwan; but, on the right part of intersection, Taiwan's cumulative percentage is much higher than that of Irish Republic. From Figure 7, we simultaneously understand that the IRI distribution of Taiwan's provincially highways is more concentrated than that of Irish Republic.

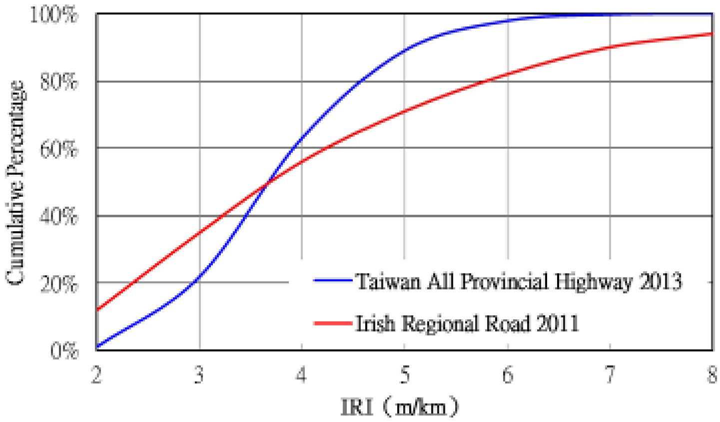

Figure 7. Comparison of IRI cumulative distribution between all Taiwan's provincial highways and Irish regional roads

6 TARGET-REACHING AND FUTURE PROSPECTS IN TAIWAN

In 2008, the second year when we observed, we found IRI mean value changed from 4.83m/km of year 2007 into 4.76m/km of year 2008; and similarly, IRI<7m/km, changed from 91.4% into 93.0%. In other words, the effect was not apparent. With a view to letting IRI testing results be applied to road maintenance system and effectively improve the pavement roughness so as to offer the public with better quality of roads, we, DGH, in 2009, set short-term, middle-term and long-term programs to improve the pavement roughness. Before the end of 2009, the short-term target of all Taiwan's provincial highways with IRI<7m/km is achieved except mountainous ones. Before the end of 2011, the middle-term target of all Taiwan's provincial highways with IRI<6m/km is achieved. Before the end of 2013, the long-term target of all Taiwan's provincial highways with IRI<5.5m/km is achieved. According our previously-set targets, we review our improvement program, excluding the statistics of mountainous roads (speed limit ≦35km/hr and speed limit=40km/hr). Through past some-year improvement, the results about the short-term target before 2009, the middle-term target before 2011 and the long-term target before 2013 are respectively shown in Table 5. Target-reaching percentages are 99.2% for short term, 98.9% for middle-term and 98.8% for long-term. Totally speaking, there was only 1% which was not achieved.

Table 5. Target-reaching situation in short-term, middle-term and long-term improvement programs of pavement roughness

Target Classification	Term Goal Achievement	The Intended Target	Total Lane km	Target-Reaching Lane km	Target-Reaching Percentages
Short-Term	The End of 2009	IRI<7m/km	7314	7254	99.2%
Middle-Term	The End of 2011	IRI<6m/km	7510	7429	98.9%
Long-Term	The End of 2013	IRI<5.5m/km	7583	7493	98.8%

During the past 4 years, the DGH has positively injected huge budget into road maintenance so as to best improve the IRI values---USD 57 million in 2009, USD 69 million in 2010, USD 121 million in 2011 and USD 95 million in 2012 as shown in Figure 8. The upper one of the Figure 8 shows the changes of IRI values from 2009 to 2013. The lower one of the figure 8 shows the budgets from 2009 to 2012. On average, annual costs of pavement roughness maintenance for Taiwan’ s provincial highways are about USD 88 million. And, it is great to obtain such good improvements. We find in the long run the injected costs can decrease the IRI values, but there is no absolute proportional relationship between injected costs and reduction degree of IRI values. This phenomenon maybe results from local typhoons and frequent earthquakes. For example, a newly constructed road may possibly completely destroyed by a typhoon, and all maintenance costs in poured become void. If we set a 2-year observation period as shown in Table 7, the average reduction of IRI values is 0.29m/km from 2009 to 2011; the reduction percentage is 6.7% (by 0.29/4.32). The average reduction of IRI values is 0.38m/km from 2011 to 2013; the reduction percentage is 9.3% (by 0.38/4.03). During the observation period, we respectively poured USD 136 million and USD 216 million. And, the IRI reduction effect per million dollars were 0.049% and 0.043% respectively. So, the both reduction effects were very close. The lower IRI values they were, the lower reduction effects we got. At present, pavement roughness of Taiwan’ s provincial highways is now faced with rapid improvement, so high IRI reduction effects were obtained. The ratio of IRI reduction value to maintenance costs will be diminished. By our continuous observation, we think the IRI values will become very stable.

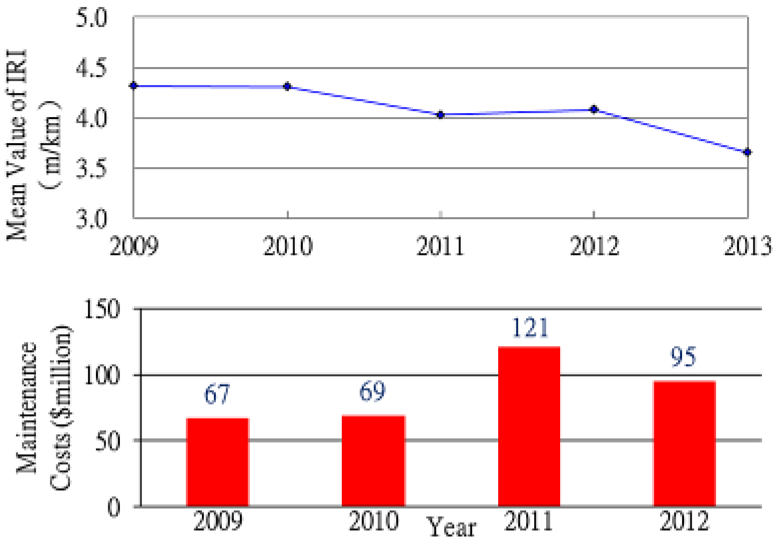

Figure 8. The changes of average IRI values of Taiwan’ s provincial highways, and their relationships with injected maintenance costs from 2009 to 2013

Table 7. The comparison between the changes of IRI values of Taiwan's provincial highways and annual injected maintenance costs from 2009 to 2013.

Year	2009	2011	2013
Mean Value of IRI（m/km）	4.32	4.03	3.65
The 2-year reduction of IRI values（m/km）		0.29	0.38
The 2-year reduction percentage of IRI		6.7%	9.3%
2-years of investment in road maintenance funding		$136 million	$216 million
Each invested $1million funding decline in the average IRI		0.049%	0.043%

The short-term and middle-term targets which we set last time have been reached. We hope the continuous improvement of pavement roughness will be obtained. In 2014, we set different targets toward different grades of roads; and simultaneously different maintenance thresholds are made so as to let targets be clear and more effective. Therefore, we in 2014 make 5-group regulations according to 5 different speed limits---speed limit≦35km、speed limit=40km、speed limit=50km、speed limit≧60km and higher speed limit applied on expressway. Using the statistical Figure 9, we approximately estimate the costs used to reach the target IRI values so that the budgets will be completely optimized. Generally speaking, mean value plus or minus some times of standard deviation is used to set maximum and minimum in quality control. Therefore, we preliminarily set (mean value) + (1 x standard deviation) as our maintenance threshold shown as in Table 8. From the view-point of normal distribution, there are 16% of Taiwan's provincial highways which IRI are higher than the thresholds which we set. So, we focus our maintenance attention on the 16% of roads, and will review the maintenance thresholds according to the final testing results in 2014.

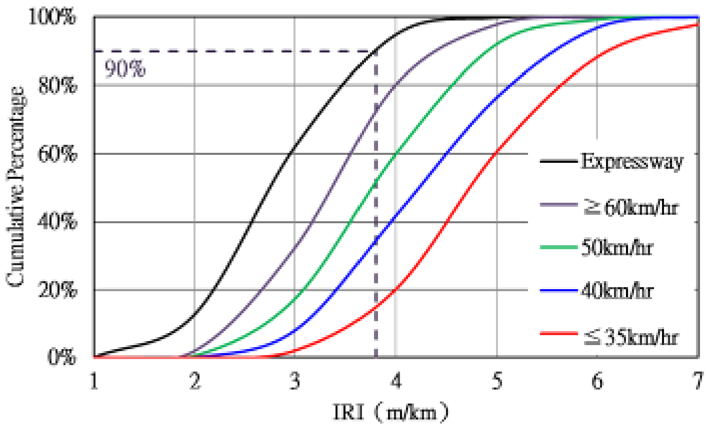

Figure 9. IRI cumulative distribution curves under different speed limits

Table 8. Suggestive standards of IRI in roads' maintenance

Speed Limit Classification	≦35km/hr	40km/hr	50km/hr	≧60km/hr	Expressway
IRI maintenance thresholds（m/km）	5.77	5.17	4.66	4.13	3.51

7 CONCLUSIONS

Since we, DGH, started to deal with testing the pavement roughness of Taiwan's provincial highways, the related operations---planning, tests-executing, review of target-reaching, road maintenance and management mechanism fed back by testing results and the executing of pavement maintenance, have been implemented during the past 7 years. From PDCA cycle, the review of target-reaching and subsequent improvements has continuously made pavement roughness of Taiwan's provincial highways better. Though the values of IRI are the same, comfortable feelings are different, resulting from different speed limits. We will set targets and review them according to different speed limits so as to let testing results be more widely used and let us be able to deliver more proper counter-proposals. Additionally, national resources will be more effectively implemented under the circumstances of our governmental tight financial situation.

IRI is not the sole factor in deciding the allocation of maintenance budgets or in enjoying maintenance superiority. As a matter of fact, there are more other factors, such as consideration of other pavements, traffic flux, population, economy and politics. Then, maintenance will be more precisely implemented. Because of the limitation of the writing length, we focus the research paper only on IRI.

Compared with those of other countries, the Taiwan's pavement roughness has been close to the international standards. We, DGH, are looking forward to endeavoring to obtain continuous improvements.

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