

106-093-0267

出國報告（出國類別：出席國際會議）

# 出席第 27 屆國際海洋與極地工程研討會 出國報告

服務機關：交通部運輸研究所

姓名職稱：蔡立宏研究員兼科長、林受勳助理研究員

派赴國家：美國

出國期間：106 年 06 月 25 日至 106 年 06 月 30 日

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網 址：[www.ihmt.gov.tw](http://www.ihmt.gov.tw) (中文版 > 中心出版品)

電 話：(04)26587121

出版年月：中華民國 106 年 9 月

印 刷 者：文晁數位科技

版(刷)次冊數：初版一刷 10 冊

## 行政院及所屬各機關出國報告提要

頁數：55 含附件：無

報告名稱：出席第27屆國際海洋與極地工程研討會出國報告

主辦機關：交通部運輸研究所

出國計畫主辦機關/聯絡人/電話：

交通部運輸研究所/孟慶玉/02-23496755

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出國類別：1.考察2.進修3.研究4.實習5.其他

出國期間：106年06月25日至06月30日

出國地區：美國加州

報告日期：106年09月05日

分類號/目：HO／綜合類（交通類）

關鍵詞：國際海洋與極地工程研討會(The International Ocean and Polar Engineering Conference)、海岸工程(Coastal Engineering)、水動力學(Hydrodynamics)、計算流體動力學(CFD)、海洋氣象 (MetOcean)、再生能源(Renewable Energy)、離岸風能(Offshore Wind Energy)

內容摘要：

本報告為參加國際海洋與極地協會(ISOPE)於美國舊金山主辦之第27屆(2017) 國際海洋與極地工程研討會的彙整報告，報告內容主要包含研討會議程與論文發表，及論文研討與參觀港灣等方面。

本研討會議題涵蓋海洋與海岸工程、大地環境與工程技術、近海和極地纜線與平臺技術、自動監測與通信技術、離岸風能、海洋氣象等領域，包含世界各洲55個國家的專家學者超過1300篇摘要與733篇論文投稿及參與演講與發表。藉由參加研討與論文發表機會，可深入及充分瞭解目前國際海岸、海洋工程界之研究與研發現況與方向，可提升與本身業務相關之工程技術和學術交流，除參與論文研討外，亦就現有業務有關之離岸風電議題、海岸港灣保護與船舶繫纜方面等議題做心得分享。





## 摘要

由國際近海與極地工程協會(The International Society of Offshore and Polar Engineers, 簡稱 ISOPE)主辦之近海與極地工程國際研討會(the International Ocean and Polar Engineering Conference), 會議內容研討議題廣泛並符合目前國際趨勢, 出席者包括世界各地的國家與海洋工程領域專家學者, 發表的論文逐年增加, 本會議已成為海洋、海岸工程與能源開發界重要的國際盛會。

本年度ISOPE舉辦之第27屆國際研討會議在美國舊金山舉行, 研討會議題主要包含綠色能源、再生能源、海洋環境、流體力學、海洋工程、海岸工程、離岸風電、水下載具、船舶技術、極地工程、海洋氣象等之數值模擬、現場觀測調查、理論解析、規劃設計與安全風險評估等相關領域之研究與技術研發。同時舉辦11場主題和專題演講, 包括港池共振、離岸風電結構物、海洋、極地及能源歷史回顧、水下材料、應力方程式之應用、衝擊壓研究進展等。全球有55個國家1340篇摘要投稿733篇共4950頁論文參與此次研討會, 共進行155場次的發表研討。本次出席會議除進行本所研究成果論文發表與現場研討外, 亦就現有業務有關之離岸風電議題、港灣海岸保護以及船舶繫纜等方面議題相關技術做心得分享。

本報告內容計分四章, 第一、二章分別為參加本次研討會之目的與過程以及論文發表的情形; 第三章則是研討會心得, 包含與業務有關之論文概述與感想; 第四章提出參加本次研討會之建議; 附錄則是論文發表簡報資料與研討會主題、論文題目及作者。



# 出席第 27 屆國際海洋與極地工程研討會出國報告

## 目次

|                            |     |
|----------------------------|-----|
| 行政院及所屬各機關出國報告提要.....       | I   |
| 摘要.....                    | III |
| 目次.....                    | V   |
| 一、 目的.....                 | 1   |
| 二、 過程 .....                | 3   |
| 2.1 研討會議簡介 .....           | 3   |
| 2.2 會議主題概述 .....           | 4   |
| 2.3 論文發表 .....             | 6   |
| 2.4 當地港灣建設 .....           | 7   |
| 三、 心得.....                 | 9   |
| 3.1 海岸港灣工程 .....           | 9   |
| 3.2 離岸風電 .....             | 15  |
| 3.3 再生能源 .....             | 16  |
| 3.4 船舶繫纜 .....             | 17  |
| 四、 建議.....                 | 19  |
| 五、 附錄一 論文發表簡報資料 .....      | 21  |
| 六、 附錄二 研討會主題、論文題目及作者 ..... | 29  |



## 第一章 目的

國際海洋與極地工程研討會(The International Ocean and Polar Engineering Conference) 是由國際海洋與極地協會(The International Society of Offshore and Polar Engineers, 簡稱ISOPE)所主辦的年度性研討會議, 研討會主要研討議題包括海洋海岸港灣離岸大地工程、海洋環境、海底管線、極地工程與能源開發等所涉及學術、工程與安全風險管理等領域, 所面臨問題分析、技術研發與學術研究等, 其相關研究結果發表與研討, 以提升工程技術與學術交流為其成立宗旨, 對外發行學術期刊, ISOPE為國際海洋界知名之協會, 多年來辦理各項交流研討會議, 促進國際間各領域專家與學者之學術與工程研發技術之交流, 亦藉此機會吸收新知並作為未來研究與研發之參考。

國際海洋與極地協會創始於1989年9月15日, 屬於非營利之組織, 參加會員資格開放給對於在海洋工程及極地工程有興趣之人士, 目前主要是以海洋工程和極地工程相關領域之學者專家所組成。最初會員來自30幾個國家成員, 目前則已經有超過50個以上國家是經常性參與其會務和活動。其主辦國際研討會議的主要目的計有下列二項:

- 1.藉由國際研討會, 促進專家學者之國際合作與交流並提升研發技術與能力。
- 2.藉由高水準之論文發表, 提供最新之海洋與極地領域相關科學新知和資訊的交換, 並促進學術與產業界之交流與互動。

自1991年至2017年, 歷屆國際海洋與極地工程研討會議之舉辦國籍及城市則如下表1.1所示。參加本會議主要藉由會議期間個人論文的發表及聽取有興趣或與本身業務與研究相關議題之論文發表, 以及會議中與其他國家學者專家交流研討機會, 除可宣傳本國研究成果, 明瞭其他國的海洋領域最新研究研發現況, 認識與自己研究相關領域之學者專家, 可增加相關研究之共同研討、資料索取機會, 並可作為未來研究方向擬定之參考。

表1.1 歷屆國際海洋與極地工程研討會舉辦國家及城市

| 年度   | 屆次 | 國 家            | 城 市                       |
|------|----|----------------|---------------------------|
| 1991 | 1  | United Kingdom | Edinburgh                 |
| 1992 | 2  | USA            | San Francisco, California |
| 1993 | 3  | Singapore      | Singapore                 |
| 1994 | 4  | Japan          | Osaka                     |
| 1995 | 5  | Netherlands    | Hague                     |
| 1996 | 6  | USA            | Los Angeles, California   |
| 1997 | 7  | USA            | Honolulu, Hawaii          |
| 1998 | 8  | Canada         | Montréal                  |
| 1999 | 9  | France         | Brest                     |
| 2000 | 10 | USA            | Seattle, Washington       |
| 2001 | 11 | Norway         | Stavanger                 |
| 2002 | 12 | Japan          | Kitakyushu                |
| 2003 | 13 | USA            | Honolulu, Hawaii          |
| 2004 | 14 | France         | Toulon                    |
| 2005 | 15 | South Korea    | Seoul                     |
| 2006 | 16 | USA            | San Francisco, California |
| 2007 | 17 | Australia      | Sydney                    |
| 2008 | 18 | Canada         | Vancouver                 |
| 2009 | 19 | Japan          | Osaka                     |
| 2010 | 20 | China          | Beijing                   |
| 2011 | 21 | USA            | Maui, Hawaii              |
| 2012 | 22 | Greece         | Rhodes                    |
| 2013 | 23 | USA            | Anchorage, Alaska         |
| 2014 | 24 | South Korea    | Busan                     |
| 2015 | 25 | USA            | Big Island, Hawaii        |
| 2016 | 26 | Greece         | Rhodes                    |
| 2017 | 27 | USA            | San Francisco, California |

## 第二章 過程

### 2.1 研討會議簡介

本年度ISOPE研討會於美國加州舊金山舉辦，會議地點位於舊金山機場附近之君悅酒店 (Hyatt Regency San Francisco Airport) (圖2.1)，由於鄰近機場，所以至會場的交通可透過各種交通工具抵達，研討會於6月25日辦理報到，6月26日上午開幕緊接著是各項的專題演講與論文發表，研討會議程概要如表2.1所示。本研討會全球有55個國家超過1340篇摘要投稿733篇共4950頁論文參與，共進行155場次的發表研討以及11場主題和專題演講，10個會議室同時進行各場次發表與演講，會議場地君悅酒店之地下一樓(圖2.2)。

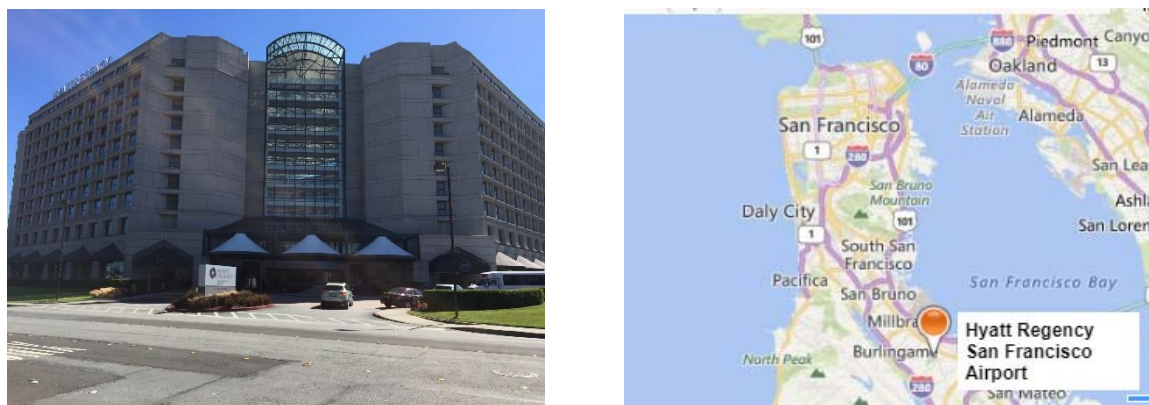


圖2.1 會議地點

表2.1 會議議程概述表

| 日期    | 議程概述表  |
|-------|--------|
| 6月25日 | 報到     |
| 6月26日 | 開幕、研討會 |
| 6月27日 | 研討會    |
| 6月28日 | 研討會、晚宴 |
| 6月29日 | 研討會    |
| 6月30日 | 結束     |



圖2.2 會議場地及與會同仁照片

## 2.2 會議主題概述

2017 年ISOPE 國際研討會之論文，本年度種類包括如：流體力學、計算流體力學、海洋工程、海岸工程、大地工程、環境工程、離岸風電、水下載具、船舶技術、極地工程及海洋氣象等之數值模擬、現場觀測調查、理論分析與技術研發之相關領域成果發表。同時舉辦特定11場主題與專題演講，包括港池共振、離岸風電結構物、海洋、極地及能源歷史回顧、水下材料、應力方程式之應用、衝擊壓研究進展等。有關會議舉辦時現場照片如圖2.3a~圖2.3c所示。

本年度年會發表之議題涵蓋範圍與本所港研中心研究相關或未來發展有關，其相關論文議題如下：

- 1.海岸工程：近岸結構物、海岸管理、海岸變遷、風暴潮、海岸波浪機制、近岸水動力。
- 2.流體動力學：海洋氣象、流體與結構物互制、浮體動力學、波浪力學、海嘯、計算流體力學。
- 3.再生能源：離岸風電結構、離岸風電基礎、離岸風能模擬、海浪、潮汐和洋流能源。
- 4.水下技術：立管、管道、電纜、海底安裝、腐蝕、觀測、無人載具、自動水下航行器。
- 5.大地工程：套管、基礎與承載重、土壤-結構-流體互制作用、土壤力學。





圖2.3a 會議發表演場



圖2.3b 針對演講主題與演講者（梅強中院士）研討



圖2.3c 會議晚宴舉辦現場照片

## 2.3 論文發表

會議中本所發表的論文為本所港研中心研究計畫「波浪與港灣構造物互制研究」之成果摘錄，發表的論文題目為「The influence of wave overtopping on the stability analysis of vertical breakwaters」(防波堤受越波影響之安定性分析)，大會安排在6月28日下午14:00的場次的第6會場發表，這一場次共有七篇論文發表，本所論文為第三篇，由本所合作單位國立成功大學水工試驗所李孟學博士進行15分鐘簡報。本文主要探討因越波產生之堤後波動對於防波堤之安定性分析之影響，以臺中港北防波堤為例，探討在極端波浪條件下，安定性分析考慮堤後波動之必要性，本篇論文發表後獲得與會學者專家的興趣與熱烈討論，學者專家所提出問題及意見綜整如下:1.本研究為何考慮越波對於防波堤之影響？2.本研究既然是考慮越波影響，其中越波量是否納入考量？且如何計算越波量？3.堤頂沒有設置波壓計如何計算越波對於防波堤之影響？4.本研究是否考慮高潮位、低潮位下的差異性？依據以上意見我們現場回復綜整如下:1.臺灣之港灣結構物必須承受夏季颱風所帶來強烈波浪的侵襲，而且隨著氣候變遷、海平面上升、極端海象頻繁，使得防波堤越波情況更常發生，因此作為本論文需考量越波之主要目的。一般計算防波堤之安定性，僅考慮堤前波浪受力，堤後僅考慮靜水壓，但本研究主要考慮越波所產生之堤後波動對於防波堤整體受力並進一步做安定性分析之影響。2.本研究以COBRAS數值模式模擬波浪入射防波堤的水理機制，對堤頂之斷面進行速度對時間積分，即可求越波量，由於本研究只考慮越波所造成之堤後波動，因此

越波量多寡並不重要，所以不納入本研究分析中。3.本研究只考慮越波所造成之堤後波動，並無計算越波衝擊堤頂之受力。4.本研究前期已針對不同潮位進行研究，分析不同潮位下會造成越波量及結構物受力之不同，本次發表之論文因考慮較極端情況，故只考慮高潮位下，越波所造成波動對於防波堤受力以及安定性之影響。有關本論文發表及研討情形如圖2.4～圖2.6。



圖2.4 論文發表現場

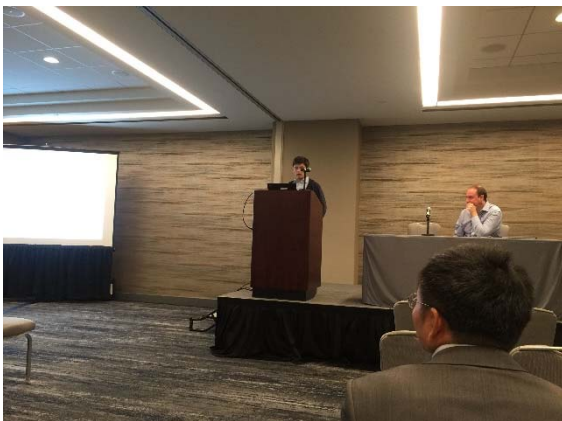


圖2.5 論文發表情形



圖2.6 研討會中討論照片

## 2.4 當地港灣建設

舊金山港（Port of San Francisco）位於美國西岸加利福尼亞州中北部岩丘半島北端，在聖法蘭西斯科灣口的西岸，在金門大橋附近，被稱為「世界三大天然港」之一，港灣面積為1,126平方公里，經1,200米寬的金門海峽通往太平洋，現在舊金山港主要以散貨裝卸和客運為主。港口區域包括近八英里的濱海帶、商業區以及碼頭，從海德街一直到印度盆地，港口所管理的地標包括漁人碼頭、39號碼頭、渡輪大樓、AT&T公園等。舊金山港港區分布奧克蘭海灣大橋(Oakland Bay Bridge)南北，從陸地往海灣建

築有幾十個突堤碼頭，多數突堤碼頭長度不長，僅能停泊1至2艘船。舊金山港由於腹地有限、交通壅擠以及環保意識抬頭，因此貨櫃裝卸擴張有限，目前負責貨運碼頭為80、92、94、96號碼頭，而28號和70號則提供船隻維修，15及17號碼頭供遠洋船舶裝卸。

漁人碼頭是美國西岸最繁忙和最知名的旅遊景點之一，從早期到今是捕魚船隊的基地，而39號碼頭原先是卸貨碼頭，漸漸發展為餐館以及各式商店林立的購物中心，在碼頭街道兩側為上下二層店鋪，每年都吸引許多遊客到此欣賞風景、品嚐美食、購買商品等。走在裡面，雖然遊客很多，由於其規劃得當，可以盡情享受其海灣與港口漁村的氣氛，因此可以發現許多建材不會使用不鏽鋼等不搭調的東西，如碼頭欄杆、座椅、地板等會使用原木材質（如圖2.7 a與圖2.7b）或漆成墨綠色，使其保有港口原始的風格。在步道上也發現豎立有潮位說明標示（如圖2.8a），以說明佈設在海中的各項監測儀器以及標尺功能（如圖2.8b），讓遊客及學生能瞭解此地的潮汐機制，包括有流向以及潮位，並說明舊金山灣像一個碗，每日海水隨潮汐漲退流進與流出兩次，每次約有港灣四分之一的水體流進與流出港灣，以上顯示當地在發展觀光同時，並兼顧海洋教育。舊金山海洋國家歷史公園（San Francisco Maritime National Historical Park）海濱由東邊海德街碼頭延伸至其西邊突出海灣的弧形防波堤所造成雙岬頭沙灘（如圖2.9a及圖2.9 b），現場沙灘寬度在靠半圓形防波堤的西南側並無沙灘，而漸往東側沙灘寬度較大，這與防波堤的設置以及當地的水理機制有關，若依岬灣理論，岬頭控制點（波浪繞射點）與波浪入射角度關係到拋物線型的沙灘形狀，西側無沙灘亦可能是底床坡度陡，再加上沒有養灘所致。



圖2.7a 舊金山港39號碼頭



圖2.7b 舊金山港39號碼頭



圖2.8a 潮汐說明立桿



圖2.8b 實際潮流方向潮位標示



圖2.9a 舊金山國家海洋歷史公園海濱



圖2.9b 舊金山國家海洋歷史公園海濱

### 第三章 心得

有關本次會議內容包含海洋領域各式主題，由於會議場次眾多，僅就參與部分會議與本所港研中心業務相關之主題作心得分享。

#### 3.1 海岸港灣工程

美國麻省理工學院(Massachusetts Institute of Technology)教授中研院梅強中院士演講主題為「Resonances in Harbors and Breakwaters」(港灣和防波堤引起的共振)(如圖 3.1a 與圖 3.1b)，演講內容分為二個部份，第一部分為長浪引起之港池共振探討，以臺灣花蓮港為例(如圖 3.2)，第二部分為移動式防波堤共振問題，以威尼斯 MOSE 計畫的 Venice Mobile Storm Gates 為例(如圖 3.3)。演說中主要以實測資料與相關理論說明引發共振之機制，及其所引起造成船舶繫泊、航行以及港灣結構物安全之影響。以臺灣 2000 年龍王颱風造成船舶擱淺案例說明，並以臺灣 1994 年提姆颱風花蓮港實測之數

據與其研究計算結果作一比較。理論方面探討非線性理論在描述波浪長波的適切性，並探討以高階三階理論去描述長波效應有無必要性，另外亦建議未來在應用至浮式結構物時理論需再作適當之修正。臺灣花蓮港以及蘇澳港均有港池共振問題，該問題影響船舶停靠安全進而也影響營運，本人會後與梅院士再針對港池共振問題作意見交換，港池共振問題由於港型已固定，因此所引起的共振週期很難再去做改變，長共振週期的能量亦難以去消滅，除非針對外廓防波堤的形狀作改變，使港灣內之水域面積與長度能夠改變，才能改變其共振機制，分散或轉移共振週期，以減少容易引起船舶斷纜之共振週期能量，如此才可減少船隻停泊於內港受長週期波浪振盪的能量，所造成船體振盪而發生斷纜與船難之風險，但對於外廓防波堤之改變，常需花費相當多的經費，主管單位須考量需經濟效益才可能去實施。



圖 3.1a 梅強中教授演講情形



圖 3.1b 梅強中教授演講情形

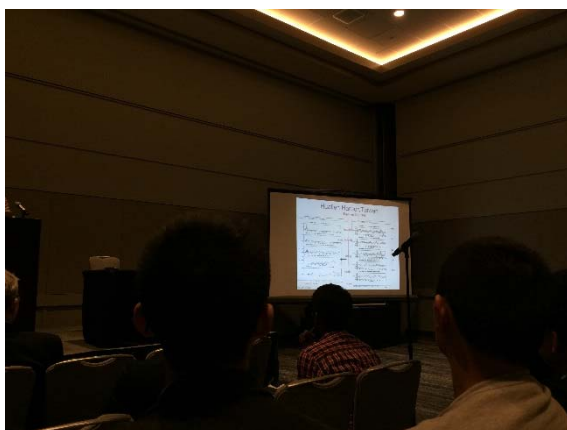


圖 3.2 花蓮港港池共振實測資料

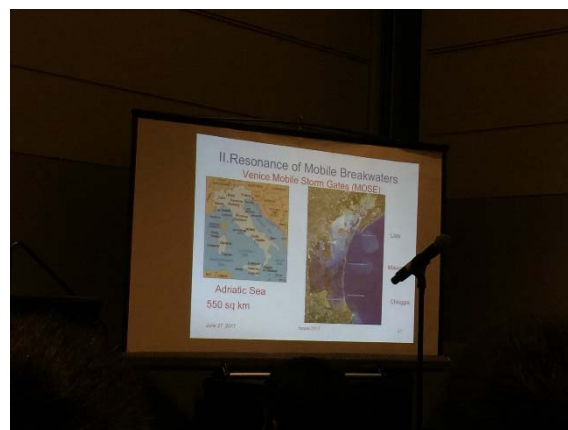


圖 3.3 移動式防波堤共振問題

有關海岸保護的論文「Investigation of wave breaking effect on Bragg reflection by series submerged breakwaters」（波浪通過系列潛堤發生碎波條件之布拉格反射），由往昔研究可知當波浪通過系列潛堤，若潛堤之間距為入射波長之半之整數倍時，此時

會發生很強的波浪反射，此現象為布拉格反射(Bragg Reflection)效應。近年很多研究欲利用此機制來達到海岸保護的目的，本人亦從事 Bragg 反射原理進行海岸保護議題的研究多年，因此對此論文倍感興趣。本研究為探討波浪通過系列潛堤後，增加考慮碎波效應條件下，分析其布拉格反射之特性(圖 3.4 及圖 3.5)。研究結果顯示潛堤個數越多，波浪通過時，其反射係數越大，而相對的透射係數愈小。當有碎波發生時，其反射係數並沒有明顯增減的趨勢，個人認為其原因為波浪碎波後，其大部分能量已消滅，加上潛堤後斜坡本來其反射的能量就不多，且斜坡上反射的波浪又受到系列潛堤的反射，因此導致最後對於堤前的反射率影響不大。系列潛堤因為潛沒水面下，不致影響自然海岸的視覺景觀，且利用的布拉格反射原理，並不和來襲的波浪作正面抵抗，其結構物受損的機會小，未來維護費用相對較低，此外，因為設置在較深水域，其由塊石堆積成的堤體，為魚蝦貝以及植物提供保護、生長、繁殖的良好環境。因此系列潛堤未來在生態保育以及海岸景觀視野上，均為正面助益的軟性海岸保護工。

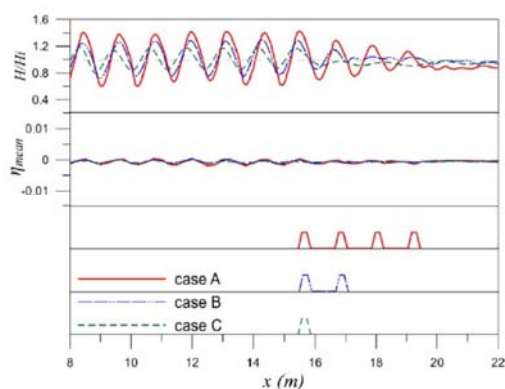


圖 3.4 波浪通過系列潛堤示意圖

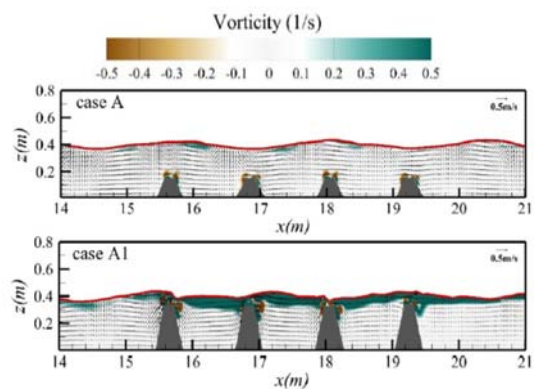


圖 3.5 波浪通過系列潛堤渦流分布

另一篇有關布拉格反射之論文「Bragg reflection of water waves by multiple composite flexible membranes」(波浪通過複合式彈性薄片之布拉格反射)，主要內容為在線性波理論基礎下，分析波浪和多個複合彈性薄片的相互作用(布置示意如圖 3.6)以及布拉格反射的特性。結果顯示多個複合式組合的彈性薄片可以增加布拉格反射的帶寬(如圖 3.7)，亦即可以使比較多的波浪條件通過時有比較大的反射發生。因此可以利用本研究的概念，根據欲保護區的波浪條件特性，以及擬消滅波浪的程度，以多層的浮式防波堤，利用其布拉格反射原理去加以設計，以達到堤後港池穩靜或海岸保護的效果。

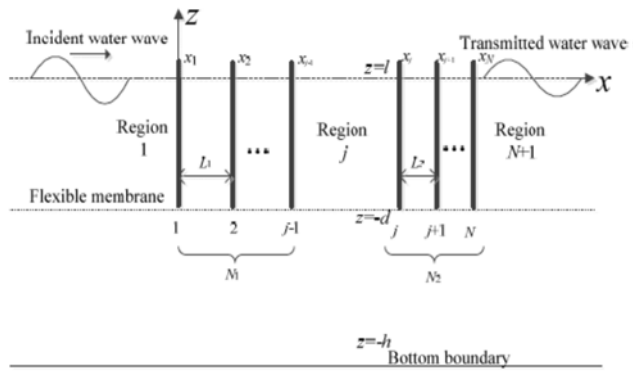


圖 3.6 複合式彈性薄片布置示意圖

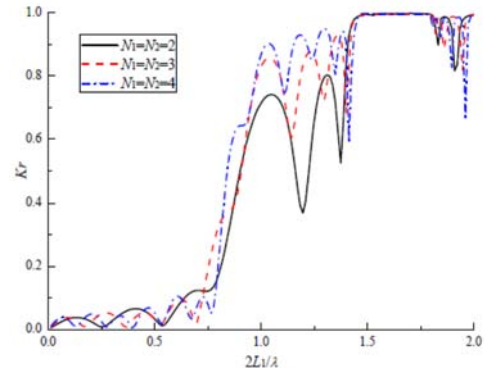


圖 3.7 不同薄片個數與週期反射率圖

有關海洋觀測的論文「The development status of an underwater multiple observation system」(水下多重觀測系統的發展狀況)中，本論文主要為在從事水下多重觀測系統(如圖 3.8)可以透過水下非接觸方式對自主水下載具 (Autonomous Underwater Vehicle, AUV) 進行充電。水下充電能夠維持長時間連續在海中觀測，有效地進行水下資源的調查。其中並說明水下充電站 (Underwater Recharging Station, URS) 的發展狀況，應用於自主水下載具電池充電，水下充電站透過非接觸式在水下為傳輸大功率的電量為電池充電。該研究並製作了實體模型加以測試分析，測試分析評估結果顯示，傳送功率和傳輸效率並不受海水條件的影響，而且如果對準在預定範圍內，則可以表現出 770W 的接收功率和 70% 的傳輸效率。本所在臺灣主要港口均建置有風波潮流觀測站，大部分測站均為底碇式觀測，需定期雇用潛水技術人員至水下海底床上更換電池，若能以本論文概念另外研發以無人載具以遙控方式為水下供電系統充電，則可以節省許多的人力與費用。

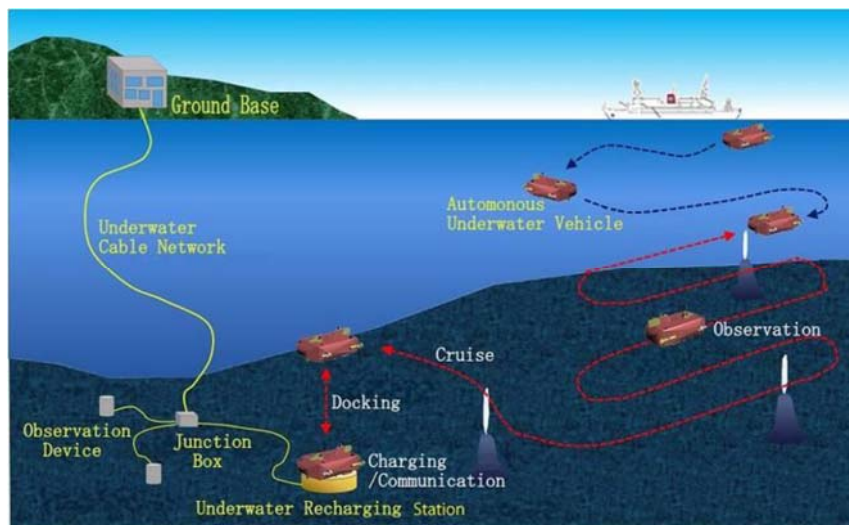


圖 3.8 水下多重觀測系統示意圖



有關防波堤保護的論文「Experimental investigation on the protections of the uncompleted breakwaters under the long-term wave conditions in the open mediterranean sea」(在開放地中海之未完工防波堤保護試驗研究),本研究透過水工模型試驗(如圖 3.9 及圖 3.10)探討地中海中未完成防波堤臨時保護工於冬季極端波浪條件下的保護效果,研究被覆層的穩定性包括陸側、海側、堤頂、堤趾以及堤心,探討不同波浪條件下防波堤臨時保護工的保護效果,本研究結果可以提供規劃、設計與施工的參考。本研究共進行六種波浪條件及五種不同臨時保護工佈置,試驗結果顯示 16 噸保護方塊僅能抵擋 1 年回歸週期波浪,如欲抵擋 10 年回歸週期波浪則應該採用 32 噸的方塊,或是兩個 16 噸組合的方塊。另外,兩層的保護方塊雖可以保護堤心,但上層會有所損害,在冬季波浪侵襲之後,需要再加以修復。本研究結果並實際應用至以色列阿什杜德港(Ashdod Port)的防波堤保護,在 2016~2017 年間亦得到預期的保護效果。本所亦從事許多港灣結構物穩定、漂沙與港池靜穩相關之水工模型試驗,未來亦可參考本研究試驗規劃方式,進行各項的分析評估研究,以使研究結果應用至實際港灣工程中能得到預期之效果。



圖 3.9 水工模型試驗情形

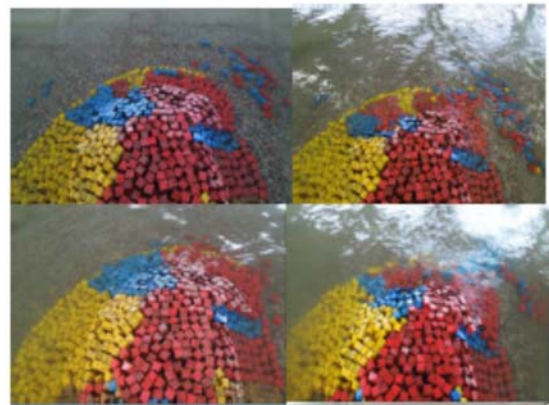


圖 3.10 堤頭保護工試驗結果

有關波浪與海流與結構物引起之海床沖刷的論文「Numerical simulation of scour pattern and scour depth prediction in front of a vertical breakwater using OpenFOAM」(應用 OpenFOAM 模式模擬垂直防波堤前沖刷之研究),本研究以新的數值方法耦合兩個模式,用以計算模擬波浪傳播和垂直防波堤前面的海床沖刷情形。OpenFOAM 模式應用於描述波流的水動力特性(圖 3.11 及圖 3.12),再將此模式應用於漂沙模式以計算模擬漂沙和沖刷(圖 3.13)現象。上述的研究並以 Xie (1981)的實驗結果加以比較驗證,顯示本研究方法的計算結果其可信度高。本研究結果顯示隨著波浪作用時間增加,防波

堤前沖刷深度逐漸加深最後趨於穩定平衡，沖刷最深的位置為波浪節點位置，而腹點位置的沖刷最小。港灣結構物如防波堤常需以較長結構物深入海中，以達到遮蔽波浪的效果，這些大型的近岸結構物與波流交互作用，其水理機制甚為複雜，常在附近發生嚴重刷深甚至有可能威脅堤體安全。本所近幾年亦從事堤頭沖刷相關議題研究，本論文的研究方法(如應用之模式、數值方法等)與結果均可作為本所未來在此相關議題研究之參考。

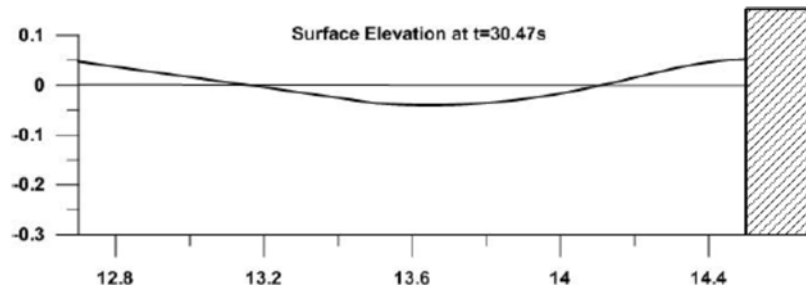


圖 3.11 數值計算表面水位分布結果

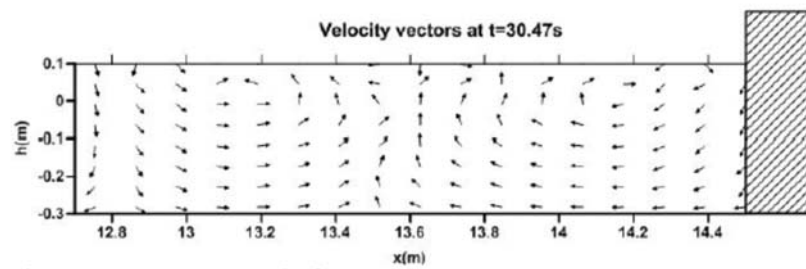


圖 3.12 數值計算流矢分布結果

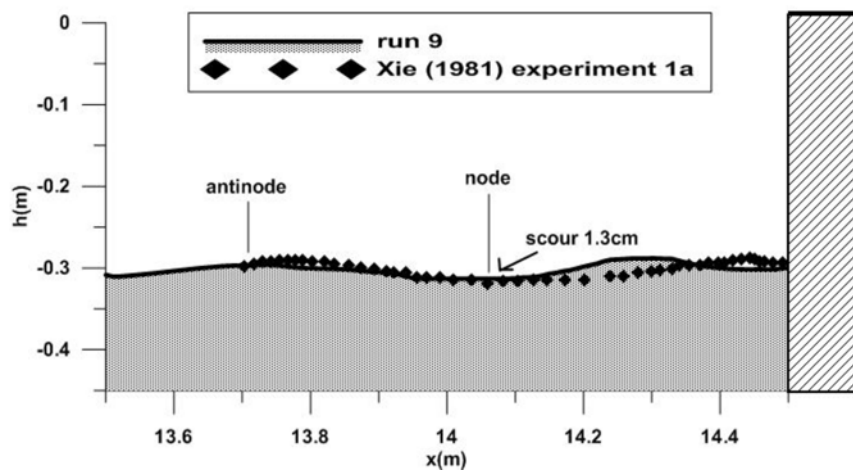


圖 3.13 沖刷數值計算與試驗結果比較

### 3.2 離岸風電

美國緬因大學 Habib Joseph Dagher 博士主講浮式離岸風電(如圖 3.14 及圖 3.15)，主要說明美國政府自 2012 年支持離岸風電設置計畫，預計於 2019 及 2020 年以前建立具有兩個 6MW 渦輪機組之離岸浮式混凝土風電，風電設置於美國東岸緬因州的外海，由於該地點之水域很深，若要以傳統樁基礎的方式去設置，是有困難甚至不可行，故該大學設計浮式離岸風電可適用於 100 公尺以上水深的海域，能抵擋來襲的巨浪及強風，因此在比較深的水域浮式比固定式離岸風電更為適用，未來臺灣發展離岸風電勢必由淺水區往深水區域建置，在經費以及安全的考量下，必須考量以浮式結構作為基礎，因此可以參考本離岸浮式混凝土風電結構的設置方式。



圖 3.14 浮式離岸風電設置地點

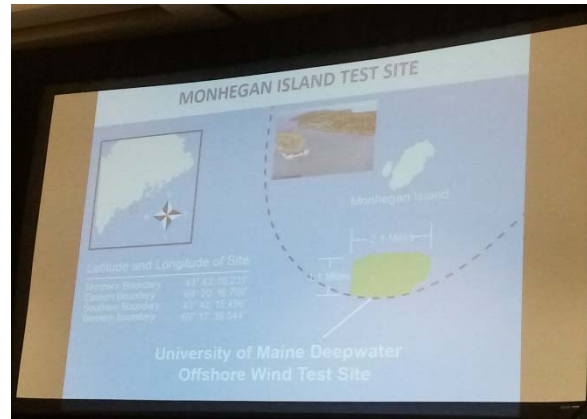


圖 3.15 浮式離岸風電示意圖

在離岸風電之構件腐蝕論文「Real offshore exposure tests of a mineral corrosion protection system」（礦物腐蝕保護之離岸暴露試驗研究），主要在北海現有的離岸風電結構上，將不同保護系統的試體安置於三個不同高度（大氣帶，飛濺區，水下區），在海上曝露約五年時間，研究試體裂化情形、腐蝕速率以及氯化物滲透和腐蝕保護能力。結果顯示礦物防腐系統適用於低於水位的海上應用，在水面以上的大氣和飛濺區域，裂化及腐蝕速率會增加(如圖 3.16 及圖 3.17)。本所未來在離岸風電計畫亦將進行金屬在飛濺區的腐蝕研究，可參考此研究方法及結果，做為未來現地規劃與試驗之參考。

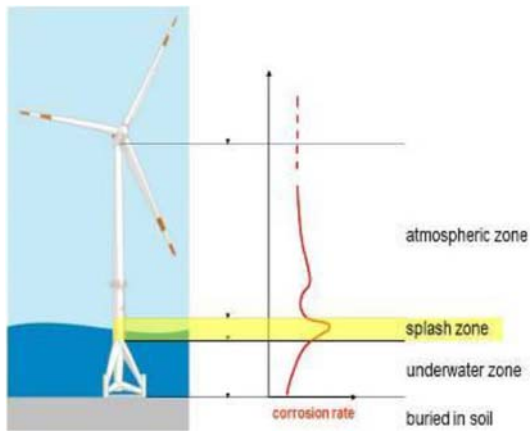


圖 3.16 離岸風電結構各位置腐蝕速率

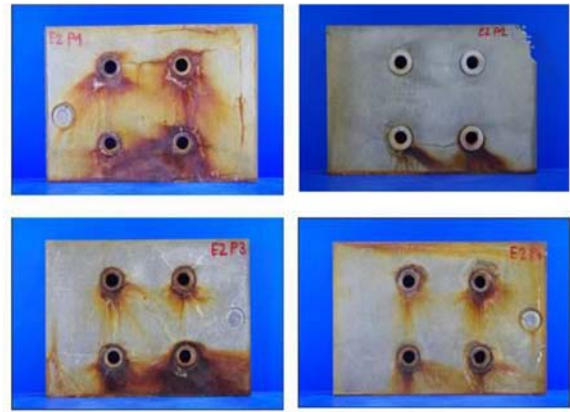


圖 3.17 噴濺區腐蝕情形

### 3.3 再生能源

在波浪發電效能之論文「Hydrodynamic performances of wave pass two buoys-type wave energy converter」(波浪通過兩個浮筒之波能轉換水動力表現分析)，主要是以數值模式去探討不同浮筒間距、不同浮筒半徑布置下，不同波高與不同波浪週期通過後，在不同時間之浮筒三維水動力之表現(如圖 3.18)，並分析其發電效能。研究結果顯示發電效能與浮筒的間距無直接關係，波浪的週期則對浮筒發電的影響較大，隨著波浪週期的增加發電量會減小，但浮筒底部改為圓弧後，因水粒子順著弧形表面流流動，其產生的動力比平底浮筒發電效率高。其論文令人能更加了解利用波浪發電，其浮筒布置方式以及浮筒底部形狀與波浪條件間其發電效能關係，未來在進行波浪發電相關研發時，可再研究更多的布置條件以及不同的浮筒形狀，找到其最佳發電參數組合，作為未來實際設計應用之參考。

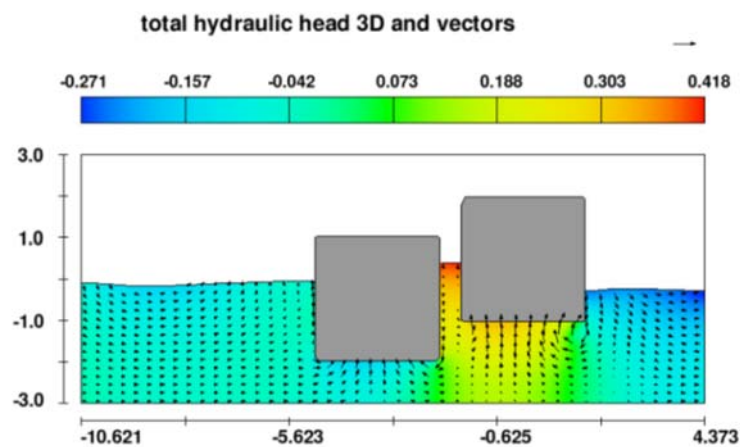


圖 3.18 波浪通過浮筒其水位及水粒子速度向量示意圖

在潮流發電上之論文「Computational modelling of hydrodynamics of a proposed tidal stream energy extraction site」（數值模擬潮流能量之水動力分析），此篇論文主要以數值模式方式，模擬計算及分析潮流發電的潛勢變化，並利用三個不同地點的潮流觀測作為模式驗證(圖 3.19)。研究結果顯示所研究之目標區為適合發展潮流發電之地點(蘇格蘭與奧可尼島間)，在陸地與島嶼間之水域，潮流經過時由於地形因素，造成流速增加(圖 3.20)，非常值得發展潮流發電。但結果亦顯示機組的設置，可能對海域生物有所影響，海底地形亦可能因此發生變化，此提醒我們，對於我國在發展離岸風電或者在近岸從事開發工程時，對其可能對生態以及水域環境造成影響和變化，均應該事前做深入之分析與研究。

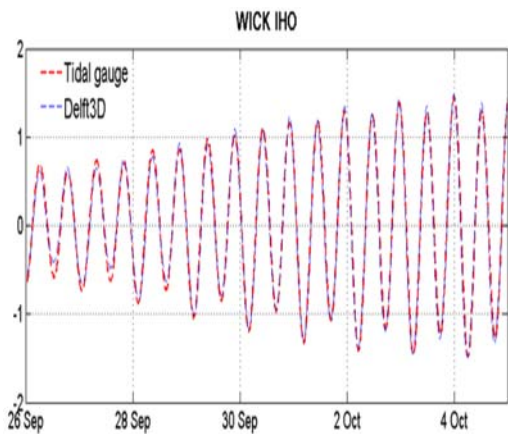


圖 3.19 數值模擬與觀測值比較

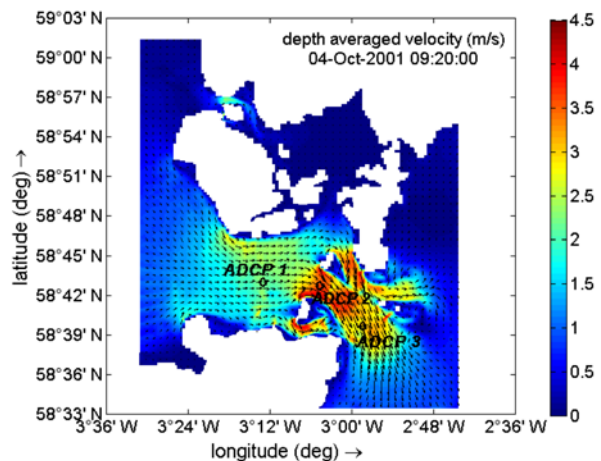


圖 3.20 水深平均之流速變化數值模擬結果

### 3.4 船舶繫纜

在船舶繫纜之論文「Numerical investigation on dynamic responses of HMPE mooring system with damaged lines」（高聚乙炔纖維纜線受損之動力分析），本篇論文主要為船舶纜繩常因使用受損或長時間使用，繫泊纜線的動態剛度降低，因而降低繫纜的強度與安全度。以往對船纜繩在不同損傷的繫泊系統分析的研究較少，因此，本論文探討 HMPE 繫泊系統受損線路的動力分析，繫纜動力分析示意如圖 3.21 所示。首先，透過實驗獲得損傷的 HMPE 繩索的動態剛度方程式，然後，在繫泊分析中採用動態剛度方程式進行不同損傷繩索的繫泊系統的偏移和張力分析(如圖 3.22)，並根據分析結果提出繫泊線檢測和評估的建議。臺灣船舶繫纜線斷纜時有所聞，且斷纜後不僅船隻本身

可能因無動力飄移而撞損、擱淺甚至沈船，更有可能因碰撞使其他船隻、港灣結構物以及碼頭裝卸設備受損。臺灣近年案例如 2015 年蘇迪勒颱風襲擊臺灣，造成臺中港多艘船舶斷纜，去(2016)年莫蘭蒂颱風襲擊臺灣，造成高雄港多艘船隻斷纜、漂移撞擊碼頭機具，損失慘重。其斷纜原因目前可能都朝向惡劣的海氣象條件所造成，其實應該還要朝船舶繫纜的方式、繫纜繩的強度以及是否因長時間使用而使強度疲勞減衰去作分析探討。本所明年度已規畫此相關研究主題，期望對於船舶繫纜的機制能更深入分析了解，並能提出有效的繫纜建議方式，最終亦將針對颱風來襲，提出船舶繫纜斷纜可能的風險預警機制。

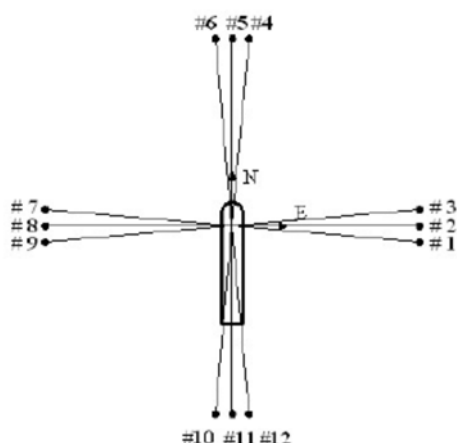


圖 3.21 船舶繫纜示意圖

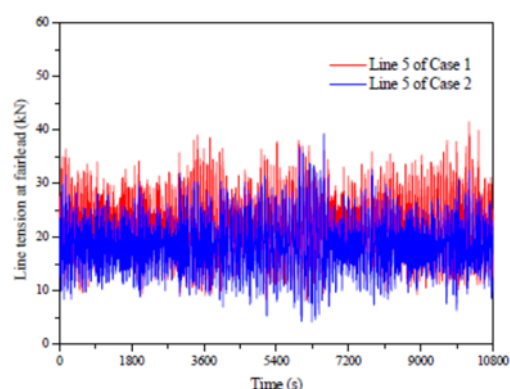


圖 3.22 不同時間之張力分析比較圖

另一篇船纜受力之論文「Effect of wind and current loads to FDPSO mooring fatigue」(風和流對FDPSO繫泊疲勞的影響分析)，本篇論文主要探討FDPSO船舶纜繩(如圖3.23)受到風，波和流作用的疲勞影響，以時域耦合分析方法計算得到在三種風與流條件的纜繩張力時間變化(如圖3.24)，並分析短期海況的疲勞負載譜，然後是根據T-N曲線和Miner線性累積計算繫纜線的疲勞損傷。結果顯示如果不考慮平均張力校正，風和流作用力對繫泊疲勞影響不大，而在一般海象條件下，由靈敏度曲線分析顯示風速和流速影響繫泊張力循環不大。因此，為了分析繫泊系統的疲勞損傷，建議考慮用約0.1的疲勞損傷的影響係數。本所明年度(107)計畫進行船舶碼頭繫纜受風與波之影響與風險評估相關研究，本論文僅考慮在一般風波流條件對纜繩的影響，未來本所的研究將會考量容易造成斷纜之颱風條件的風及波浪作用，預期其研究成果能提供相關單位作為船隻管理與安全預警之參考。

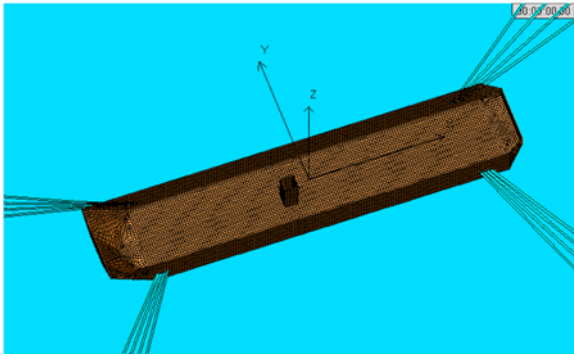


圖 3.23 船舶繫纜示意圖

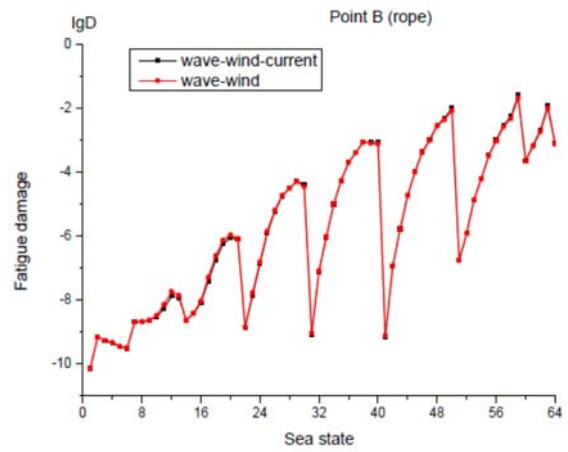


圖 3.24 風波流對纜繩疲勞損害歷程圖

## 第四章 建議

本次研討會所涵蓋的海洋相關領域文章發表，集合來自不同國家專家學者將他們近年的研究成果分享給與會人士，藉由發表會或發表結束後共同研討，並能結識新朋友甚至為以後研究留下聯繫資訊。本次研討會對於個人的業務以及資訊的取得均有正面的幫助，也提升研究視野了解各研究主題最新發展。綜合以上心得提出個人建議如下：

1. 國際研討會提供研究交流與吸收新知的機會，並能藉此平台將本所的研究成果發表並與專家學者研討，擴展研究的視野，因此，應該多鼓勵同仁參加相關性質之國際性研討會，對於個人以及本所研究業務均有實質之幫助。
2. 離岸風電目前在國際上的許多國家的學者專家均致力在進行推廣與研究，國內目前正是起步時期，建議需要進行各項的資料收集、交流與諮詢，取得各項最新研究與發展的資訊，以作為目前及未來從事離岸風電相關工程與研究之參考。
3. 港口在進行轉型或多元化發展時，在規劃上必須考慮產業、生態、景觀、永續與城市競爭力等面向，並應著重於原有設施或老舊建築的活化再利用及保留原有歷史風格，和現代化都市發展不但沒有違和感，更產生復古或文創元素加諸其中，進而達到文化、藝術、美感、開發等多元呈現；建議臺灣未來的海岸或港灣開發與利用，要多方面整體考量規劃，並能落實管理，做得更有親水性、休閒性與協調性，也才不致使觀光區只求拼經濟，卻忽略了管理與整體規劃。






The 27th International Ocean and Polar Engineering Conference  
San Francisco, California, USA

**The Influence of Wave Overtopping on the Stability Analysis of Vertical Breakwater**

Dr. Li-Hung TSAI  
Dr. Hung-Chu HSU  
Dr. Cheng-Jung HSU  
Dr. Meng-Syue LI

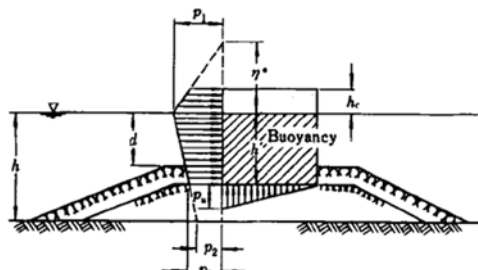


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Harbor and Marine Technology Centre

## INTRODUCTION

- Many previous wave-structure interaction studies had discussed the effect of wave overtopping but some of which in structure stability analysis assumed seaward loads were static.



- **In theory**, there are some idealized theoretical models which had been presented (e.g., Sollitt and Cross 1972; Vidal et al. 1988; Liu and Wen 1997).
- **In different laboratories**, hydraulic **physical models** had been used to study the problem (e.g., Allsop et al. 1985; Owen 1980; Franco et al. 1994; Van der Meer and Janssen 1995; Pedersen 1996; Hedges and Reis 1998; Franco 1999; Besley 1999).
- The numerical approach becomes more flexible and efficient because of the rapid growth of the computer performance.



- Lin and Liu (1998) developed COBRAS model to study wave-structure problem. In order to validate COBRAS model,
- Hsu et al. (2002) compared numerical results of elevation and pressure with laboratory measurements related to a hydraulic physical model of a composite breakwater by Sakakiyama and Liu (2001).
- Hsieh et al. (2008) used COBRAS model to investigate the wave-structure interaction of quarter-circular shape breakwater.
- Losada et al. (2008) modified COBRAS to investigate the functionality of rubble mound breakwaters with special attention focused on wave overtopping processes.
- Guaniche et al. (2009) followed to carry out an analysis of wave induced loads corresponding to a low-mound and a rubble-mound breakwater with both regular and irregular incident wave conditions. Good agreement was found between COBRAS numerical result and experimental data.
- Walkden et al. (2001) investigated the seaward loads induced by wave overtopping on a caisson breakwater. **They commented that seaward loads should be considered as failure mode of breakwater designs.**



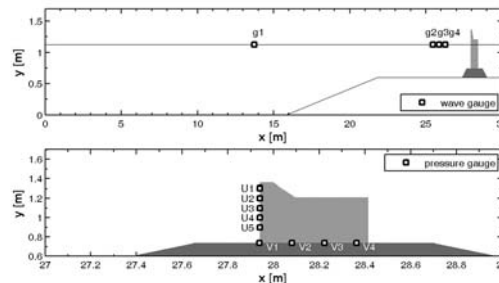
## MODEL VALITAION

- The COBRAS model (Cornell Breaking Wave and Structures) is a bidimensional numerical model that solves the Reynolds Averaged Navier Stokes (**RANS**) 2DV equations, with a three dimensional nonlinear  $k-\varepsilon$  turbulence model.
- COBRAS model features:
  - Use **VOF** (Volume of Fluid) method for tracking the free surface.
  - The **grid size can be non-uniform**: a finer grid can be defined for specific study zones representation.
  - Allows the definition of **obstacles and porous media** which are defined through continuous conic function.

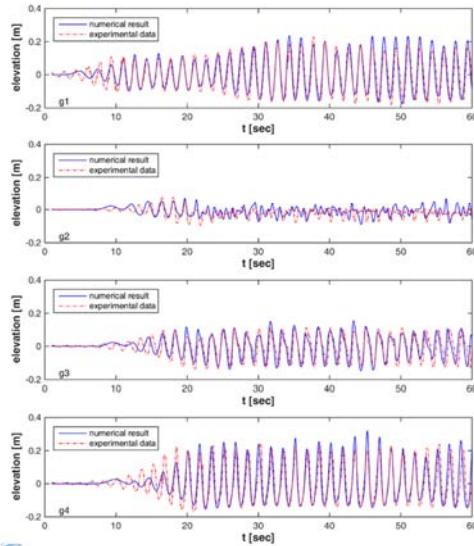


## MODEL VALITAION

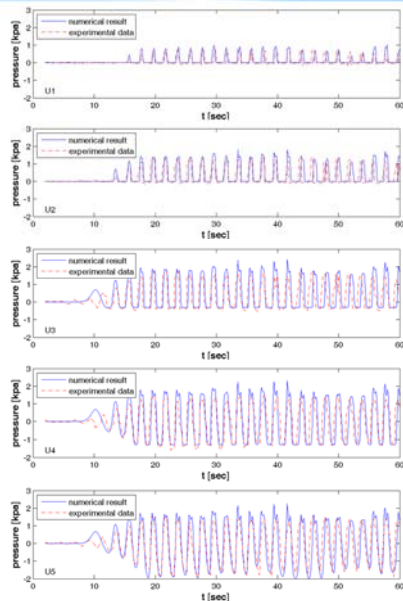
- Lee (2006) conducted a physical model testing of Taichung harbor wave-breakwater interaction in general wave condition ( $H=0.19\text{m}$  and  $T=1.67\text{s}$ ) and typhoon wave condition ( $H=0.25\text{m}$  and  $T=2\text{s}$ ).



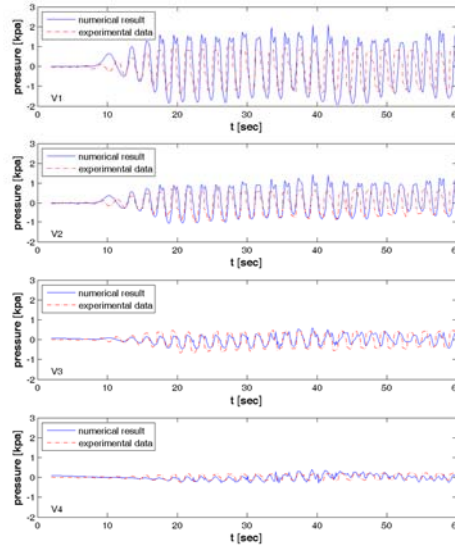
## The elevation in general wave condition



## The pressure along the front face of the caisson in typhoon wave condition

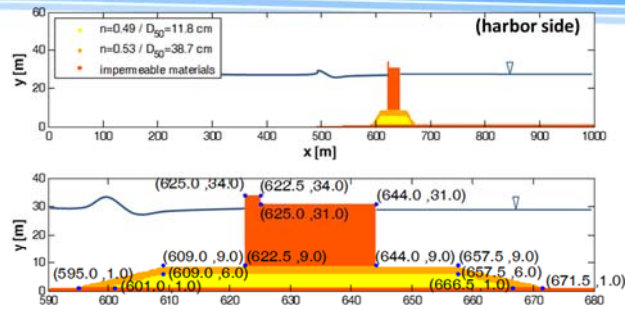


## The pressure on the bottom of the caisson in typhoon wave condition



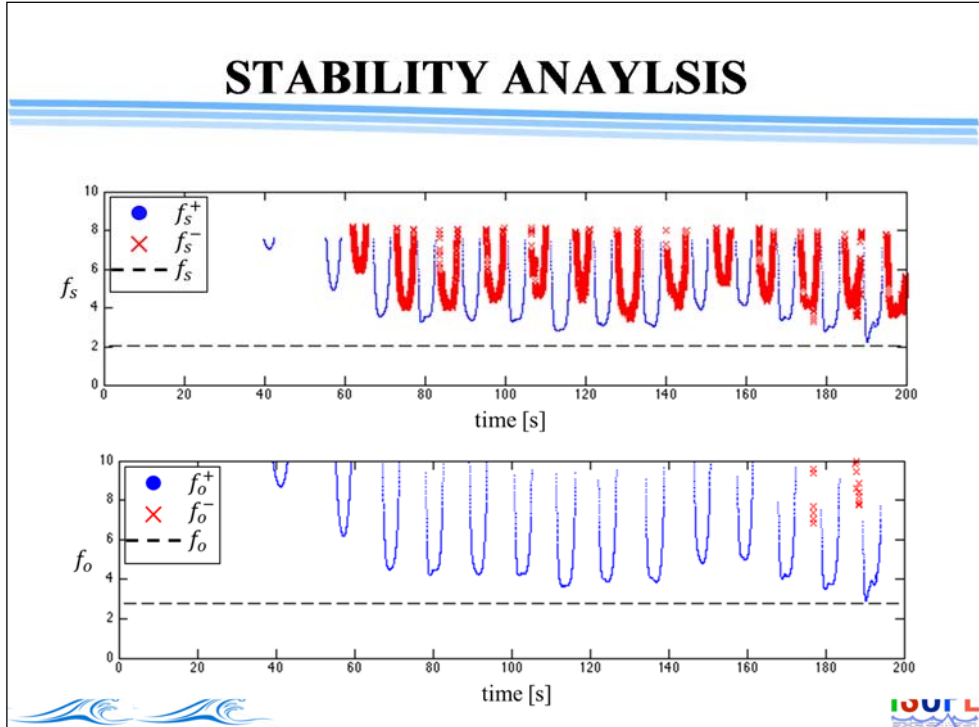
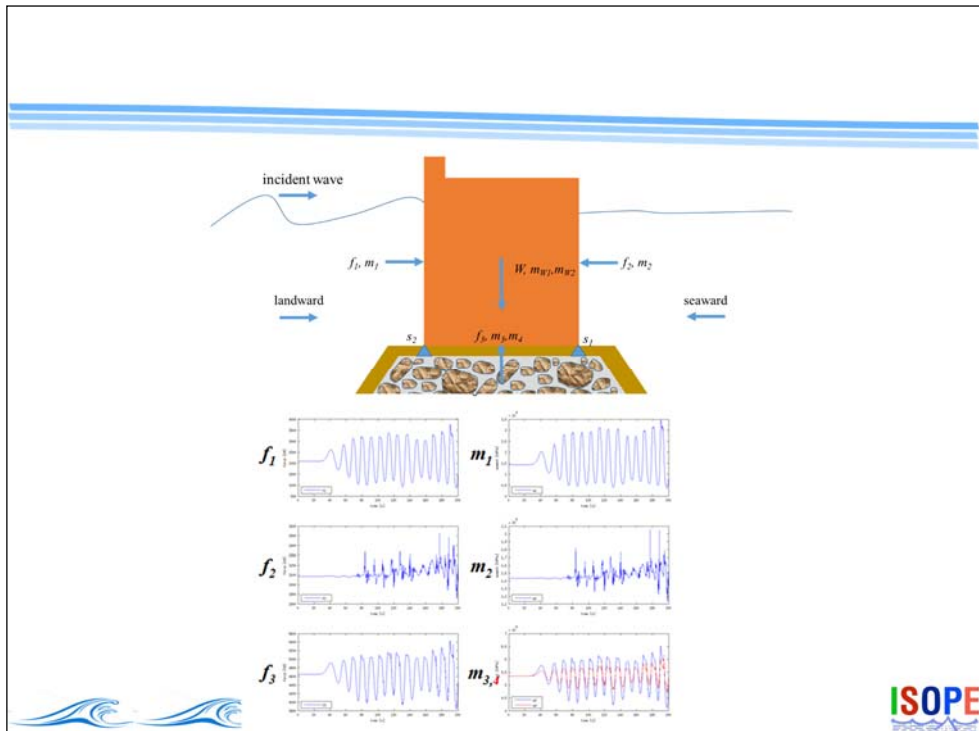
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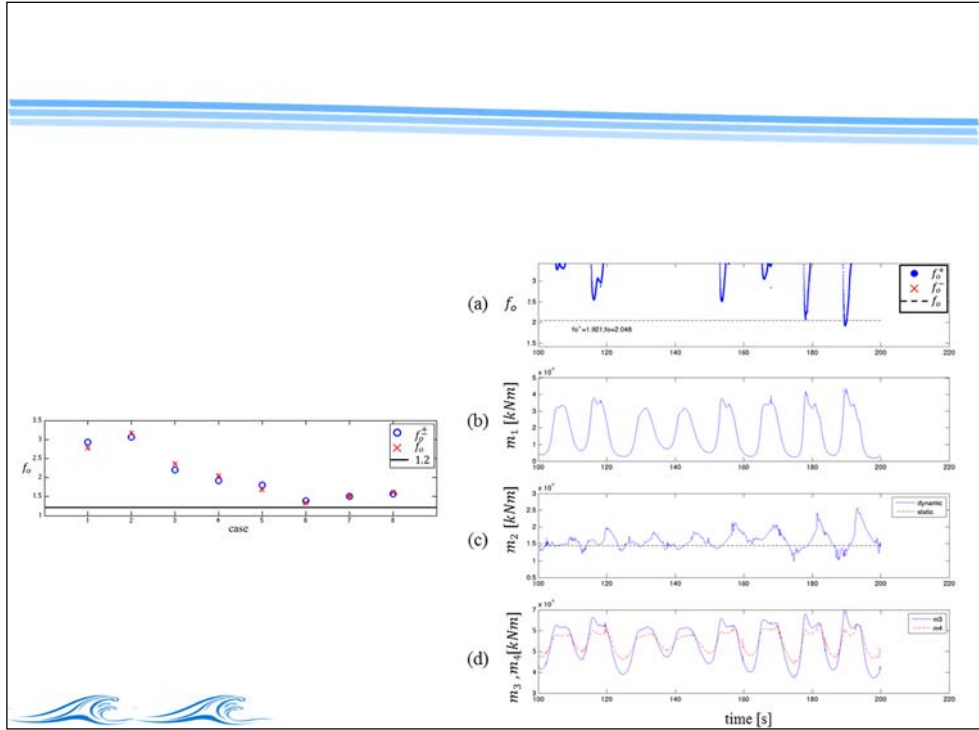
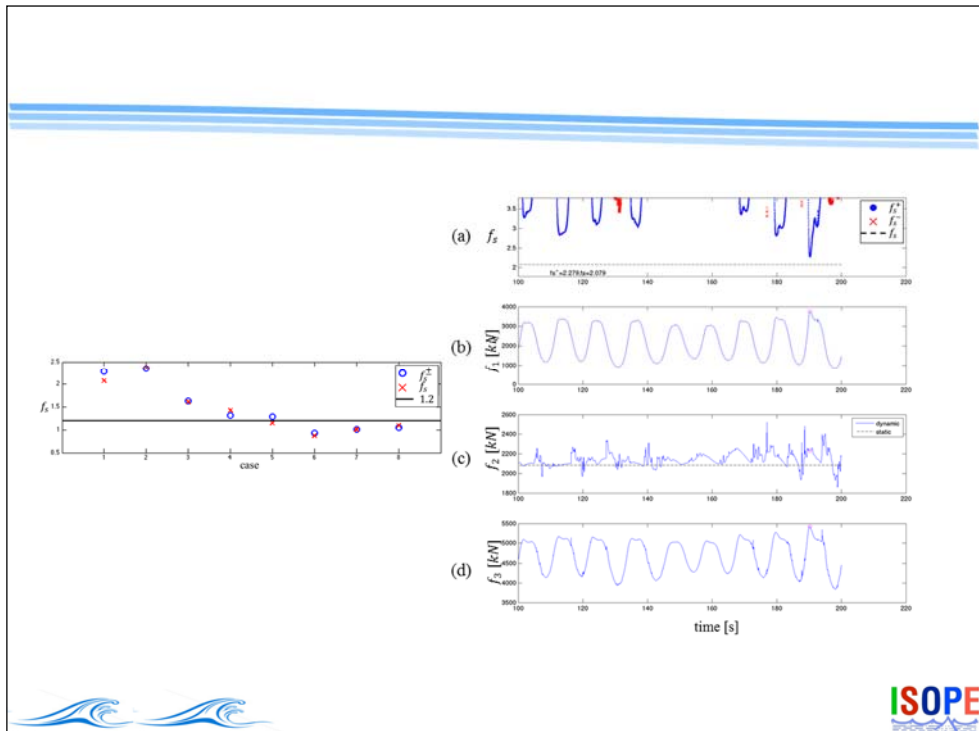
## LOAD ANALYSIS-



| case | H (m) | T (sec) | return period (year) |
|------|-------|---------|----------------------|
| 1    | 7.77  | 11.30   | 50                   |
| 2    | 8.46  | 11.70   | 100                  |
| 3    | 9.24  | 12.20   | 200                  |
| 4    | 9.45  | 12.30   | 250                  |
| 5    | 12.87 | 14.13   | 50*                  |
| 6    | 13.70 | 14.63   | 100*                 |
| 7    | 14.47 | 15.25   | 200*                 |
| 8    | 14.63 | 15.38   | 250*                 |

ISOPE





## CONCLUSION

To perform the structure stability of breakwater concerning the effect of wave overtopping, a wave-structure interaction of Taichung harbor is simulated by a numerical model.

•First, a COBRAS model of the Taichung Harbor breakwater structure is created, then the model is verified with experimental data, and reasonable agreement is shown between the two. According to the numerical result, the pressure distribution along the rear side of caisson can be calculated in dynamic, moreover, the load analysis including the force and its moment can be analyzed.

•Second, the risk of sliding is greater than that of overturning in Taichung harbor breakwater. Under the extreme wave more than 100 year-return-period, the breakwater is unstable due to sliding, but that is safe from overturning. The influence of Wave Overtopping on the Stability Analysis is dominated by the force on rear side of caisson and the phase difference on the two ends of caisson. If the impulse force happens at the moment of the minimum of the front force, the safety factor might decrease significantly and the failure of sliding might cause breakwater damage.

•The study establishes an evaluating procedure concerning wave-structure interaction on extreme wave and the influence of wave overtopping to provide ports and other authorities with an appropriate assessment and evaluating strategy of harbor stability analysis.



*Thank you for  
your listening*





## 附錄二 研討會主題、論文題目及作者

### 1.研討會主題

#### 一、VOLUME I

##### (一) FRONTIER ENERGY AND RESOURCES

1. Enhanced Oil Recovery (EOR),
2. Gas Hydrates,
3. Deep-Ocean Minerals

##### (二) RENEWABLE ENERGY (OFFSHORE WIND AND OCEAN)

1. Wave Energy Converter,
2. Ocean Energy & Resources,
3. Tidal & Current Energy,
4. Offshore Wind Structures,
5. Offshore Wind Foundations,
6. Offshore Wind Aerodynamics,
7. Offshore Floating Wind Turbine: Floating,
8. Wind Energy Simulations,
9. Offshore Wind Turbine- Design & Installation,
10. Offshore Wind – Turbine Design & Energy Storage

##### (三) OCEAN, ARCTIC ENVIRONMENT

1. Oil Spill and Carbon Capture,
2. Climate Effects & Diffusivity

##### (四) LNG, OFFSHORE MECHANICS AND OCEAN TECHNOLOGY

1. LNG,
2. Bunkering,
3. FLNG,
4. LNG Storage,
5. TLP/SPAR/VLFS/FPSO,
6. Structural Health Monitoring,
7. Jack-up & Jacket,
8. Design,
9. Float-over Installation

##### (五) ARCTIC SCIENCE & TECHNOLOGY

1. Structures in Ice Modeling,
2. Arctic Structures,
3. Ice Mechanics,

4. Ice Monitoring,
5. Safety in Arctic Operations,
6. Ships in Ice

## 二、VOLUME II

### (一) GEOTECHNICAL ENGINEERING

1. Suction Pile,
2. Anchor and Pipelines,
3. Soil-Structure-Fluid Interactions,
4. Foundation & Loads,
5. Soil Property and Mechanics,
6. Geohazard & Liquefaction

### (二) SUBSEA, PIPELINES, RISERS AND UMBILICALS

1. Flexible and Umbilical,
2. Riser Design,
3. Riser & Flow Assurance,
4. Pipeline,
5. Installation

### (三) UNDERSEA VEHICLE, COMMUNICATION, CONTROL

1. Sensors and Observation,
2. AUV and Control,
3. Robotics and Propulsion,
4. ROV,
5. Towed Vehicles and USV

## 三、VOLUME III

### (一) HYDRODYNAMICS HYDRODYNAMICS

1. MetOcean,
2. Fluid-Structure Interactions,
3. Floating Bodies,
4. Slamming/Whipping/Impact,
5. Wave Mechanics,
6. Numerical Wave Tank (NWT),
7. Dynamic Positioning (DP) & Seakeeping Control,
8. Computational Fluid Dynamics (CFD),
9. Added Resistance,
10. Internal Waves,
11. Drag & Drag Reduction,

12. Seakeeping Dynamics

**(二) TSUNAMI AND SAFETY SYMPOSIUM**

1. Tsunami

**(三) LNG SLOSHING DYNAMICS AND DESIGN**

1. Numerical & Experimental Methods,
2. Fluid-Structure Interactions,
3. Impact Assessment

**(四) FLOW-INDUCED VIBRATIONS: VIV**

1. Vortex-induced Vibrations

**(五) COASTAL HYDRODYNAMICS**

1. Nearshore Hydrodynamics,
2. Coastal Wave Mechanics,
3. Storm Surge,
4. Coastal Structures,
5. Sediment Transport,
6. Coastal Erosion,
7. Coastal Management

**四、VOLUME IV**

**(一) HIGH-PERFORMANCE MATERIALS (HPM)**

1. Advanced Steels,
2. Advances in Welding,
3. Composite Materials,
4. Fatigue and Fracture,
5. Tubulars

**(二) ARCTIC MATERIALS**

1. Arctic Materials

**(三) CRYOGENIC MATERIALS**

1. Cryogenic Materials

**(四) ASSET INTEGRITY**

1. Assessments & Analysis,
2. Inspection & Monitoring,
3. Corrosion

**(五) STRAIN-BASED DESIGN**

1. Strain Capacity and Material Properties,
2. Strain-Based Design and Assessment

**(六) MECHANICS AND HYDROELASTICITY**

1. Collision,
2. Hydroelasticity,
3. Reliability

**(七) ADVANCED SHIP TECHNOLOGY**

1. Ship Design & Production,
2. Ultimate Strength & Fatigue,
3. High-Speed Planing,
4. Sea Trial & Performance,
5. Powering

## 2.論文題目及作者

本部份僅彙整摘錄本次研討會，有關第三部分論文頁碼、題目及作者，其餘部分請參考 <http://www.iso-pe.org/publications/publications.htm> 網址。

### (一) HYDRODYNAMICS

#### Keynote

- 1 Morison Equation in Practice and Its Validity  
Jin S Chung

#### MetOcean

- 9 Metocean Extreme Estimations: the Sensitivity of Offshore Design Measures to Statistics' Uncertainties  
Rami Zughayar, Ove Tobias Gudmestad, Francesco De Leo, Giovanni Besio
- 16 Arctic Wave Observation by Drifting Type Wave Buoys in 2016  
Takuji Waseda, Adrean Webb, Kazutoshi Sato, Jun Inoue, Alison Kohout, Bill Penrose, Scott Penrose,
- 21 Sea-level Records Analysis with Improved Empirical Mode Decomposition (EMD) and Artificial Neural Networks (ANN)  
Han Soo Lee, Sooyoul Kim
- 25 Hydrodynamic Conditions for Typhoon induced Fluid Mud in Open Muddy Channels  
Qixiu Pang, Haixia Xin, Ruibo Zhang, Chenpeng Wen
- 30 Analysis of Extreme Waves with Tropical Cyclone Wave Hindcast Data  
Zhuxiao Shao, Bingchen Liang, Xinying Pan, Huijun Gao
- 34 Numerical Study on Wind Wave in Limited Wind Zone  
Yi-feng Zhang, chen-feng Zhang
- 40 Research and Realization of Telemetry and Telecontrol Systems of Intelligent Buoys  
Caiyun Xu, Runze Gan, Chunhui Zhou, Yuanzhou Zheng, Lei Zhang
- 45 Wave Hindcasting and Extreme Value Analysis for North-western Coast of Sri Lanka  
D.P.C. Laknath, H.P.G.M. Caldera, D.P.L. Ranasinghe
- 53 Characteristics of Residual Water Level Variation along China Coast and its Relation to Sea Level Change  
Hui Wang, Ke Xiu Liu, Wen Jing Fan, Jian Long Feng, Guo Song Wang, Jian Li Zhang
- 59 Directional Grouping of Rogue Waves off the West Coast of Ireland  
Brandon Strong, Frederic Dias, Jason Flanagan, Eugene Terray
- 68 Air-Sea Interaction on Wave in the Northern South China Sea During an Intense Cold Air Outbreak  
Lifang Jiang, Yi Yin, Chunxia Liu
- 74 Assessment of tropical cyclones in ECMWF reanalysis data over Northwest Pacific

## Ocean

Jiangxia Li, Shunqi Pan, Yongping Chen, Yi Pan

- 81 Berth Operability and Port Downtime Due to MetOcean in Eastern Thailand  
Wissanu Hattha, Tetsuya Hiraishi
- 89 Analysis Flow Mechanism of Cambodian South Coastal Region  
Naoyuki Inukai, Neam Kopy, Chamnab EM

## Fluid-Structure Interactions

- 96 Numerical Study of Oscillatory Dual Cylinders in Tandem Arrangement  
Xiaotong Zhang, Dixia Fan, Decheng Wan
- 104 Uncertainties in Wave Loads on Slender Pile Structures Due to Uncertainties in Modelling Waves and Associated Kinematics  
Sverre Kristian Haver, Kåre Edvardsen, Gunnar Lian
- 114 Development of a 3-D Numerical Model for Simulating Interaction of Water Waves and Offshore Structures  
Yu-Cheng Chang, Ching-Jer Huang, Chun-Yuan Lin
- 120 Numerical Investigation on Wave Elevation around a Biofouled Cage Array  
Chun-Wei Bi, Yun-Peng Zhao, Guo-Hai Dong, Tiao-Jian Xu, Hui-Min Hou
- 127 Numerical simulation of the vortex structure around the net cage in current  
Ming-Fu Tang, Tiao-Jian Xu, Guo-Hai Dong, Yun-Peng Zhao
- 133 Suction Force and Multiple Frequencies Subjected to Oscillating Cylinder on Water Surface  
Zhaobing Jiang, Mingyi Tan, Shan Ma

## Floating Bodies

- 138 Effect of Wave Interaction among Multiple Floating Bodies on Hydrodynamic Forces  
Zhengke Wang, Guanghua He, Zhigang Zhang, Chi Qi
- 144 Computation of Wave Drift Forces and Motions of DTC Ship in Oblique Waves  
Cong Liu, Jianhua Wang, Decheng Wan, Xinguo Yu
- 153 Rational Determination of Design Wave using Combined Design Load Parameters (DLP) on Semi-Submersible with Twin Pontoon Type  
Won-Hyuk Choi, Dong-Kyoon Kim, Yong-Sun Baik, Seung-Han Moon
- 161 Hydrodynamic Study of Wave Evolution Characteristics around Semi-Submersible Platform in Shallow Water with Submerged Terrain near Island  
Ke Xia, Yong Ai, Decheng Wan
- 170 Numerical study of the dynamic characteristics of an air-gun bubble generated above the solid boundary  
S. Zhang, S P. Wang, A. M. Zhang
- 175 Numerical Computations on Nonlinear Wave Forces and Run-ups on a TLP in High

## Waves

B.W. Nam, Y.J. Ha, S.Y. Hong

- 181 Numerical Green Water Assessment for an FPSO with Consideration of Nonlinear Effects from Bilge Keel, Spread Mooring and Asymmetric Risers  
Shuo Wang, Xin Wang, Wai Lok Woo
- 189 Numerical and Experimental Motion Investigations of a Light Weight Semi-Submersible in Irregular Sea  
Yanbin Bai, Haining Lv, Jim Wang, John Cheng, Yong Luo
- 196 Mooring Line Top-Tension Prediction Using NARX  
Murat Yetkin, Min-Soo Kim, Yooil Kim
- 203 Response of Moored Ship in the Waves Generated by Passing Ship  
Lilan Zhou, Ji Yang, Chang Hong, Jiangtao Qin
- 210 Time Domain Analysis of Side by Side Vessels' Motion Responses During Offshore Installation and Underway Replenishment  
Xi Chen, Ren-chuan Zhu
- 217 Research on Hydrodynamic Calculation Method of Deepwater CALM Buoy  
Zhuang Kang, Cheng Zhang, Wenchi Ni, Xiang Xu
- 225 Optimization of Separation Distance between Two Floating Bodies  
Shashikala A.P, Shankar K Varma

## **Slamming, Whipping, Impact**

- 232 Numerical Investigation on Effects of Compressibility on Water Entry Problems  
Maria Bihnam, Maiwand Said, Shiqiang Yan, Qingwei Ma
- 240 Study of 18000 TEU Container Vessel's Fatigue Strength under Influences of Springing Phenomenon  
Penghao Shan, Jiameng Wu, Shijian Cai
- 246 Wave Loading on a Flexible Offshore Structure  
Arman Ghezelbashan, Cedric D'Mello
- 252 Fully Nonlinear Simulation of Ringing of a Two Dimensional Barge in Focused Waves  
Bin-zhen Zhou, Jiang-Hui Qi, Peng Jin, Liang Zhang
- 259 Vertical water entry of a cone under the condition of free fall motion  
Jian Hu, Qian-Qi Han, Shi-Li Sun
- 263 FSI Analysis of Solitary Wave Interacting with Horizontal Flexible Plate by MPS-FEM Method  
Chengping Rao, Youlin Zhang, Decheng Wan
- 273 The Dynamic Response of the Large Containership's Bow Structure under Slamming Pressures  
Bin Yang, De-yu Wang

- 280 A Method to Measure Wave Impact Force and Its Validation  
Yinghao Guo, Longfei Xiao, Yufeng Kou, Guocheng Zhao
- 289 Numerical Simulation of Water Ditching by an Airplane Using a Two-Phase Solver  
Bin Wu, Min Yu, Tingqiu Li, Zhou Jiahang
- 295 Numerical Simulation of Water Entry of Twin Wedges Using a CIP-based Method  
Zijun Hu, Xizeng Zhao, Du Cheng, Dake Zhang
- 301 Numerical Simulation of Free Surface Impact on a Vertical Cylinder Using UMTHINC  
Mohamed M. Kamra, Changong Hu
- 308 Aeration Effects on Hydrodynamic Loads of Circular Cylinder's High-speed Water Entry  
Yao HONG, Benlong WANG, Hua Liu
- 313 Nonlinear Analysis of Green Water Impact on Forward-speed Wigley Hull  
Guanghua He, Zihao Zhang, Naiwen Tian, Zhengke Wang
- 320 A method to predict slamming pressure based on the relative motion of ship and waves  
Hui Li, Qiang Huang, Kaihong Zhang, Yakang Peng, Huilong Reng

### **Wave Mechanics**

- 329 Numerical Simulation of Freak Waves in Random Wave Field  
Lei Wang, Jinxuan Li, Shuxue Liu
- 335 A Pseudo-Spectral Method for Extreme Storm Waves  
Nicole Beisiegel, Frédéric Dias
- 340 Focused Waves on Depth-Varying Currents: the Role of Vorticity  
Magnus Beyer, Chris Swan, Marios Christou
- 348 Water Wave Problems in a Sloping Seabed Environment  
Aichun Feng, Allan Ross Magee
- 356 Numerical investigation of shear stress under plunging breaker on a sloping beach  
Lian Tang, Onyx W.H Wai
- 360 A flux-limiter weighted high-resolution conservation algorithm  
Fang Li, Tingqiu Li, Qiu Jin, William Geraint Price, Pandeli Temarel, Dominic A Hudson
- 367 Assessment of the capability of the Nonlinear Schrodinger equation and the High-order spectral method to simulate propagation of random waves  
Weida Xia, Yuxiang Ma, Guohai Dong, Xiaozhou Ma
- 373 Numerical Simulation of Solitary-Wave Scattering and Damping in Fragmented Sea Ice  
Philippe Guyenne, Emilian I. Părău
- 381 Experimental Study on the Evolution of the Peregrine-type Surface Gravity Waves in



- Finite Water Depth  
Yuxiang Ma, Yongbo Song, Bo Liao, Xiaozhou Ma, Guohai Dong
- 386 Computation of Axisymmetric Gravity Currents  
Yosuke Sawano, Hiroya Tsugawa, Nobuhiro Baba
- 391 Numerical Investigation of Crest-Height Statistics in Deep Water  
Demetris Hadjigeorgiou, Chris Swan, Marios Christou
- 399 Numerical simulation of wave motion over fringing reefs using a shock-capturing Boussinesq model  
Kezhao Fang, Dongbin He, Zhongbo Liu, Jiawen Sun
- 406 Numerical Investigation of a Novel Wave Absorbing Method by Gap Resonance  
Zhiwei Song, Lin Lu, Rui Gao, Lizhi Tang, Zhongbing Zhou, Chunyang Liu
- 412 Stream Function Wave Embedment into Linear Irregular Seas: A New Method Based on the Hilbert Transform  
Fabio Pierella, Roy Stenbro, Luca Oggiano, Jacobus de Vaal, Tor Anders Nygaard
- 420 Experiments on Spontaneous Modulation Instability in Hydrodynamics  
Amin Chabchoub, Goëry Genty, John M. Dudley, Bertrand Kibler, Takuji Waseda
- 425 Investigation On the Gravity Collapse in Density Stratified Fluid  
Gang Wei, Hui Du, Junnan Xu
- 433 A Depth-integrated Non-Hydrostatic Model for Cross-shore Wave Motion  
Jiawen Sun, Yonghai Yu, Jing Yin, Dongbin He

#### **Numerical Wave Tank (NWT)**

- 440 On Differences of Rogue Waves Modeled by Three Approaches in Numerical Wave Tank  
Jinghua Wang, Q.W. Ma, S. Yan
- 448 Development of an Efficient Two-phase 3D Numerical Wave Flume  
Charalambos Frantzis, Dimokratis G. E. Grigoriadis
- 455 Numerical Wave Flume Based on Second Order Wavemaker Theory  
Haochen Zhang, Shuxue Liu, Jinxuan Li, Xiaohuan Tian
- 461 Application of ALE to nonlinear wave diffraction by a non-wall-sided structure  
Jie Zhang, Masashi Kashiwagi
- 469 Numerical Investigation of Irregular Breaking Waves for Extreme Wave Spectra using CFD  
Ankit Aggarwal, Mayilvahanan Alagan Chella, Hans Bihs, Csaba Pakzodi, Petter Andreas Berthelsen, Øivind A. Arntsen
- 476 Numerical study of wave interaction with the vertical cylinder using 3D viscous numerical wave tank  
Aditya Gokodkani, Sriram V

## **Dynamic Positioning (DP) and Seakeeping Control**

- 483 Backstepping-based adaptive control for dynamic positioning using orthogonal neural network  
Linfeng Lu, Haixiang Xu, Wenzhao Yu, Hui Feng
- 489 Research on Nonlinear Model Predictive Control for Dynamic Positioning Vessel  
Qing Wen, Haixiang Xu, Wenzhao Yu, Hui Feng
- 494 Weather Stand-by Assessment in Offshore Operations Using Motion Limit Criteria  
Michele Drago, Andrea Del Guzzo, Luigino Vitali, Roberto Bruschi
- 502 Hydrodynamic Forces in Low speed and Station-Keeping Model Test of DP Vessels  
Qiaosheng Zhao, Qiang Sun, Naxin Wei, Xijian Wang
- 507 Development of Simple Dynamic Positioning System - Algorithm and User Interface  
-

## **Nobukazu Wakabayashi, Takayuki Watanabe, Misako Urakami, Daisuke Terada**

- 513 Deterministic Predictions of Vessel Responses Based on Past Measurements  
Ulrik Dam Nielsen, Jørgen Juncher Jensen
- 520 DP Drillship Stationkeeping in Ice - Comparison between Numerical Simulations and Ice Basin Tests  
Mohamed Sayed, Shameem Islam, David Watson, Ivana Kubat, Robert Gash, Brian Wright
- 529 Development of Track Control System utilizing Heading Control System for Ocean Observation Sailing  
Takayuki Watanabe, Nobukazu Wakabayashi, Misako Urakami, Daisuke Terada
- 537 Feature Recognition for Initial Pose Estimation to Enhance Vision-based UAV Relative Navigation  
Haiwen Yuan, Changshi Xiao, Fan Zhang, Chen Shi, Huixian Ye, Supu Xiu, Chunhui Zhou, Qiliang Li
- 544 A Technology for Measuring the Fender Motion Based on the Sensor JY901  
Dongmei Yang, Zhiqun Guo, Honqing Chen
- 549 Simulation Study on Course Adaptive Control for Ship Navigating in Continuous Curved Channel  
Yanmin Xu, Junchao Zhao, Hongbing Zou, Chunming Zou, Hongxu Guan
- 556 Dynamic Speed Control Model for Very Large Ship in Restricted Waters  
Huanhuan Li, Jingxian Liu, Ryan Wen Liu
- 563 Numerical Study on Squat of KVLCC2 in Infinite and Shallow Water  
Fangfan Hu, Jiangtao Qin, Lilan Zhou, Keqiang Chen

## **CFD**

- 570 On the coupling of Incompressible SPH with a Finite Element potential flow solver for nonlinear free surface flows

- Georgios Fourtakas, Peter K. Stansby, Benedict D. Rogers, Steven J. Lind, Shiqiang Yan, Qingwei W. Ma
- 578 Improved SPH for simulating violent flow and two bodies interaction  
Xing Zheng, Xi-peng Lv, Qing-Wei Ma, Wen-yang Duan
- 584 Experimental Validation of SPH for Wave Generation and Propagation in Large Wave Tank  
Andi Trimulyono, Hirotada Hashimoto, Kouki Kawamura
- 591 Modelling of Extreme Wave Impact on a Fixed Platform  
Min Luo, Chan Ghee Koh
- 596 SPH Modelling of the Impact of a Flat Plate upon an Aerated Water Surface  
Hassan Sdiq, David I. Graham, Jason Hughes
- 604 Numerical study of a buoyant round jet in a stagnant environment  
Yen-Lung Chen, Shih-Chun Hsiao, Yu Hsiao
- 609 Geometric Modeling over a Background Cartesian Grid Using Radial Basis Functions  
Shaoshan Zhou, Tingqiu Li, Qiu Jin, William Geraint Price, Pandeli Temarel, Dominic A Hudson
- 615 Investigation of Bubble Dynamics near Free Surface in Compressible Fluid  
Wei Xiao, Tongshun Yu, Yingyu Chen, Xujie Wang
- 622 Modeling of 2D Irregular Waves on a Sloped Bottom Using a Fully Nonlinear Navier-Stokes/VOF Formulation  
Luca Oggiano, Fabio Pierella, Jacobus de Vaal, Tor Anders Nygaard, Roy Stenbro, Emile Arens
- 630 Numerical Simulation of Floating Body under Heave Oscillations Using 2D IMLPG\_R  
Rijas A S, Sriram V
- 637 Coupling of Viscous and Potential Flow Models with Free Surface: Implementation and Application to Floating Structures  
Xin Lu, Dominic Denver John Chandar, Chen Yu, Jing Lou
- 646 Coupled Mooring Analysis of a CALM Buoy by a CFD Approach  
Haoyuan Gu, Hamn-Ching Chen, Linyue Zhao
- 654 A Hybrid Approach Coupling MLPG-R with QALE-FEM for Modelling Fully Nonlinear Water Waves  
Shiqiang Yan, Qingwei Ma
- 662 Validation of an Open-source CFD Tool to Support Efficient Design of Offshore Gravity-based Structures Exposed to Extreme Waves  
Hossein Babaei, Scott Baker, Andrew Cornett
- 670 Using CFD to Assess the Hydrodynamic Loads on Non-Standard Jack-up Leg Shapes  
Zana Sulaiman, Andries Hofman, Cees Wallenburg
- 678 Modelling Wave Interaction with Deformable Structures based on a Multi-region

#### Approach within OpenFOAM

P. J. Martínez Ferrer, L. Qian, Z. H. Ma, D. M. Causon, C. G. Mingham

- 686 A Two-Phase Incompressible-Compressible (Water-Air) Smoothed Particle Hydrodynamics (ICSPH) Method Applied to Focused Wave Slam on Decks  
Steven J. Lind, Qinghe Fang, Peter K. Stansby, Benedict D. Rogers, Georgios Fourtakas
- 693 CFD Study of VIM of a Paired-Column Semi-Submersible Platform  
Weiwen Zhao, Decheng Wan
- 701 Numerical Simulation of a Damaged Ship Flooding with a Three-Dimensional SPH Method  
F.R. Ming, H. Cheng, A M. Zhang
- 706 Wave-Resistance Computation via CFD and IGA-BEM Solvers: A Comparative Study  
Xinning Wang, Sotirios P. Chouliaras, Panagiotis D. Kaklis, Alexandros A.-I. Ginnis, Constantinos G. Politis, Konstantinos V. Kostas
- 713 A Hybrid Solver Based on Efficient BEM-potential and LBM-NS Models: Recent LBM Developments and Applications to Naval Hydrodynamics  
C.M. O'Reilly, S.T. Grilli, J.C. Harris, A. Mivehchi, C.F. Janssen, J.M. Dahl
- 721 A hybrid solver based on efficient BEM-potential and LBM-NS models: recent BEM developments and applications to naval hydrodynamics  
Amin Mivehchi, Jeffrey C. Harris, Stéphan T. Grilli, Jason M. Dahl, Chris M. O'Reilly, Konstantin Kuznetsov, Christian F. Janssen
- 729 Experimental and Numerical Simulation on the Whole Water Exit of a Spheroid  
Qigang Wu, Baoyu Ni, Xiaolong Bai, Yanzhuo Xue

#### **Added Resistance**

- 737 Wave Added Resistance and Propulsive Performance of a Cruise Ship in Waves  
Petri Valanto, YongPyo Hong
- 746 Numerical and Experimental Study on the Estimation of Added Resistance of an LNG Carrier in Waves  
Taeyoung Kim, Seonoh Yoo, Semyun Oh, Hyun Joe Kim, Dongyeon Lee, Booki Kim
- 753 Numerical Investigation on Added Resistance with Wave Steepness for KVLCC2 in Short and Long Waves  
Mingyu Kim, Olgun Hizir, Osman Turan, Atilla Incecik
- 761 Mesh Sensitivity Analysis for the Numerical Simulation of a Damaged Ship Model  
Ivana Martic, Nastia Degiuli, Andrea Farkas, Josip Bašić
- 767 Hydrodynamic Analysis and Model Test Study of Wind Turbine Installation Vessel  
Zhuang Kang, Xiang Xu, Wenchi Ni, Cheng Zhang

## **Internal Waves**

- 775 Lattice Boltzmann based internal wave-maker  
Kai Wang, Yang Yu, Liuming Yang, Guoxiang Hou, Sheng Xu, Shihua Xu
- 782 Influences and Countermeasures of Internal Solitary Waves on Deepwater Drilling in the South China Sea  
Liangbin Xu, Jianliang Zhou, Chaowei Li, Leixiang Sheng, Yu Wang, Xining Hao
- 792 Modelling Wave Trains from Internal Solitary Waves in South China Sea  
Xu Wang, Jifu Zhou, Dalin Tan
- 796 Numerical study on flow evolution of mode-2 internal solitary waves propagating over variable topography  
Ming-Hung Cheng, Chih-Min Hsieh, Robert R. Hwang, Wen-Chang Yang, Shih-Feng Su
- 804 An experimental study of internal solitary wave forces on a semi-submersible  
Min Chen, Ke Chen, Yun-Xiang You, Chen Chen
- 810 Wave Simulation Using an InternalWave-Maker in a CIP-based Model  
Zhouteng Ye, Mengyu Li, Xizeng Zhao
- 817 Experiments on Internal Waves Generated by a Self-Propelled Model in a Stratified Fluid  
Hongwei Wang, Ke Chen, Yunxiang You, Xinshu Zhang, Minhua Shu

## **Drag and Drag Reduction**

- 823 The EFD and CFD Study of Rudder-Bulb-Fin System in Ship and Propeller Wake Field of KVLCC2 Tanker in Calm Water  
Tho Quang Truong, Ping-Chen Wu, Kaoru Aoyagi, Kenta Koike, Yu Akiyama, Yasuyuki Toda
- 831 The ship wall-pressure distribution characteristics on gas film drag reduction  
Shengqiang He, Jiamei Wang, Shunhuai Chen, Aokui Xiong, Lizheng Wang, Hao Wang
- 835 Model Test Research of Low-speed Vessel on Gas Film Drag Reduction  
Lizheng Wang, Shengqiang He, Jiamei Wang, Shunhuai Chen, Yan Jin, Qiong Li
- 839 Numerical Simulation on Drag Reduction of River-sea Bulk Cargo by Gas Film  
Fan Yang, Lizheng Wang, Jiamei Wang, Shunhuai Chen, Liang Luo, Min Wang
- 844 In-Service Performance Evaluation of Low Frictional AF Marine Coating  
Inwon Lee, Hyun Park
- 851 Numerical investigation of shark skin inspired riblet drag reduction structure  
Yansheng Zhang, Osman Turana
- 858 Drag Calculation of Macroscopic Objects with Riblet Microstructure  
Wei Chen, Hao Zhang, Lei Wang, Wenjun Leng, Guoxiang Hou

## **Seakeeping Dynamics**

- 865 Hydrodynamic Performance of Tandem Oscillating Foils in Waves  
Huimei Xie, Dongjiao Wang, Zijun Lin, Shouqiang Qiu, Jiawei Ye
- 871 Numerical Calculation on Propeller-induced Pressure Fluctuation of a River-to-sea Ship  
Weiguo Wu, Jiezheng Wei, Yongshui Lin, Shengjie Qin, Tao Yang
- 877 An Innovative Force Sensor to Evaluate the Drag of Small Outboard Motor Watercrafts  
Giuseppe Conte, David Scaradozzi, Daniele Mannocchi, Anna Maria Perdon
- 884 Stability Analysis of Randomly Excited Ship Parametric Roll Resonance  
Xiao Zhang, Hezhen Yang, Zhiqiang Xie, Du Shen, Chunxu Wang
- 889 Numerical Study of the Characteristics of Strongly Stratified Flows Past a Cylinder  
Mingchang Niu, Yong Ding, Weizhuang Ma, Yuce Xi
- 895 Hydrodynamic and Wave Performance around a Ship Hull on the Free Surface under Stokes Waves  
Shengtao Chen
- 901 An Improved Method to Calculate Inertial Forces and Dynamic Loads of Whole Ship  
Zhe Cheng, Shaoxiong Zhang, Zekun Bian
- 909 Effects of Nonuniform Heading Distribution and Variant Speeds on EDW  
Yachong Liu, Jiameng Wu, Wenbo Zhu
- 916 Analysis of the Coupled Horizontal and Torsional Loads of an Ultra Large Containership  
Yuwen Liu, Hui Li, Kaihong Zhang, Baoli Deng, Yakang Peng

## **TSUNAMI AND SAFETY SYMPOSIUM**

- 924 FPGA Based Solution for Fast Tsunami Wave Propagation Modeling  
Mikhail M. Lavrentiev, Alexey A. Romanenko, Konstantin K. Oblaukhov, Andrey G. Marchuk, Konstantin F. Lysakov, Mikhail Yu. Shadrin
- 930 Tsunami detection by High Frequency Radar using a Time-Correlation Algorithm: performance analysis based on data from a HF radar in British Columbia  
Charles-Antoine Guérin, Stéphan T. Grilli, Patrick Moran, Annette Grilli, Tania Insua
- 937 An Empirical Formula of Evaluation of Wave Amplitude for Trans-ocean Tsunamis  
Hua Liu, Wei Wu, Zhicheng Zhang
- 942 Tsunami Run-up Modeling with Adaptive Mesh Refinement: Monai Valley Benchmark Test  
Han Soo Lee
- 946 A Study on Characteristics of Local Pressure on Coastal Dikes Induced by Tsunami Overflow  
Takahide Honda, Teppei Omata, Chathura Deshapriya Manawasekara, Yukinobu Oda,

- Kazunori Ito
- 953 Experimental Study on Reduction of Tsunami Wave Force Acting on Land Structures Due to Protective Barriers  
Tsuyoshi Ikeya, Kazuki Suzuki, Seiya Suenaga, Nobuyuki Iwamae, Takako Fukuyama, Yoshinobu Akiyama, Tomokazu Tateno
- 960 Nearshore FSO Response under Rapidly Varying Landslide Tsunami Hydrodynamic Loads  
Dale Kerper, Shubhra Misra, Hans Fabricius Hansen, Fengyan Shi, Pramod Rao, James T. Kirby, Ed Willey, David B. Ervin
- 968 Nonlinear Finite Element Analysis of RC Walls Subjected to Tsunami and Debris Impact  
Atsushi Shibayama, Yoshinori Miyagawa, Naoto Kihara, Hideki Kaida
- 976 Effect of Scour Protections against Tsunami Overflow at a Landward Toe of Coastal Dikes  
Naoki Takegawa, Yutaka Sawada, Toshinori Kawabata
- 981 Investigation of the artificial underwater object's protection properties using numerical modeling  
Kensaku Hayashi, Alexander P. Vazhenin, Andrey G. Marchuk
- 989 Strong Motion Prediction during a Scenario Earthquake along the Coast of Sea of Japan  
Masaki Yamauchi, Yoshiya Hata, Akira Murata, Yasuko Kuwata, Maki Koyama, Tadayoshi Nakashima, Masakatsu Miyajima

## **LNG SLOSHING DYNAMICS AND DESIGN**

### **Numerical and Experimental Methods**

- 995 A time domain model to evaluate the liquid cargo motion influence on the ship motion influence on the ship motion  
Daniel Prata Vieira, Edgard Borges Malta, Carlos Hakio Fucatu, Kazuo Nishimoto
- 1002 Numerical Study of Sloshing in a Swaying Tank with a Submerged Horizontal Perforated Plate  
Heng Jin, Yong Liu, Hua-jun Li
- 1009 MPS Simulation of Sloshing Flows in a Tuned Liquid Damper  
Xiao Wen, Xiang Chen, Decheng Wan
- 1017 Numerical Modelling of Nonlinear Sloshing in Tuned Liquid Damper (TLD)  
Saravanan Gurusamy, Deepak Kumar
- 1025 Numerical Prediction of Wave Impact on a Cylinder Body Mounted in a Sloshing Tank  
Il-Ryong Park, Je-In Kim, Sa-Young Hong, Bo-Woo Nam
- 1032 Effects of the Arrangement of Vertical Baffles on Liquid Sloshing by MPS Method

- Xiang Chen, Youlin Zhang, Decheng Wan
- 1040 Application of the Lie-group scheme in Euclidean space solving nonlinear sloshing behaviors  
Shin-Ping Soon, Chao-Feng Shih, Yung-Wei Chen, Yu-Chen Liu
- 1048 Experiment of natural gas liquefaction process with double mixed refrigerant under sloshing conditions  
Jianlu Zhu, Yuxing Li, Wuchang Wang, Xueyu Chang, Hui Han, Chengzhong Sun, Longfei Dong, Jie Chen, Weiping Zeng
- 1054 Investigation of the Motion Accuracy Influence on Sloshing Model Test Results  
J. Neugebauer, S. Liu, R. Potthoff, O. el Moctar
- 1062 A Study on Sloshing Behavior for Moss Type LNG Tank based on SPH Numerical Simulation and Large- Scale Model Experiment  
Chong Ma, Masayoshi Oka, Takahiro Ando Naoya Matsubara
- 1070 Experimental Study of Slosh-Induced Loads on LNG Fuel Tank of Container Ship  
Jieung Kim, Sang-Yeob Kim, Yonghwan Kim, Kwang-Min Lee, Young-Jae Sung

#### **Fluid-Structure Interactions**

- 1077 Sloshing Flows in an Elastic Tank with High Filling Liquid by MPS-FEM Coupled Method  
Youlin Zhang, Xiang Chen, Decheng Wan
- 1085 Fluid Structure Interaction Analysis of Composite Structures exposed to Sloshing  
André Baeten
- 1093 Numerical Studies on Sloshing Loads using Sloshing Coupled Ship Motion Algorithm  
Jai Ram Saripilli, Debabrata Sen
- 1103 Anti-Slosh Performance of Inflatable Components in Relation to Shape Retention and Load Transfer  
Erik Jeroen Eenkhoorn
- 1112 A Study on Effect of Liquid Motion in a Fully-filled 3D Tank on Load on the Tank  
Yusong Cao, Fuwei Zhang

#### **Impact Assessment**

- 1122 Sloshing Load Assessments for Mid-scale Single Row Floating LNG Solution  
Chang Seop Kwon, Hyun Joe Kim, Jong Jin Park, Yong Ho Choi, Min Sung Chun, Dong Hoon Yoo, Dong Hyun Choi, Dong Yeon Lee, Booki Kim
- 1130 Comparison of Impact Pressure on 2D and 3D Tanks under Harmonic Excitation  
Sang-Yeob Kim, Yonghwan Kim
- 1137 Analysis of Sloshing Impact Pressures Using Different Extreme Statistical Theories  
Ekin Ceyda Cetin, Sangyeob Kim, Yonghwan Kim



- 1143 Anti-Slosh Inflatable Component Case Study  
Erik Jeroen Eenkhoorn

#### **FLOW-INDUCED VIBRATIONS: VIV**

- 1151 Vortex Induced Vibration of Riser with Low Span to Diameter Ratio Buoyancy Modules  
Dixia Fan, Michael S. Triantafyllou
- 1160 Vortex Shedding Behavior of a Horizontal Circular Cylinder near the Free Surface with Different Submerged Depths  
Qian Li, Q.W. Ma, S. Yan
- 1165 CFD Simulations of Flows around Finite Stubby Circular Cylinder with Free End  
Jiawei He, Weiwen Zhao, Decheng Wan
- 1171 Investigation of Pipe-Soil Interaction on the Fatigue Life Extension of Subsea Pipeline Free Spans  
Yusha Han, Ed Clukey, Naveen Ravirala, Paul Jukes
- 1176 Large-eddy Simulation of Turbulence Characteristics of Oscillatory Flow Over 3-D Vortex Ripples  
Iason A. Chalmoukis, Athanassios A. Dimas
- 1184 VIM Induced Fatigue Damages on Steel Catenary Risers of a Semi-Submersible FPS in South China Sea  
Tie Ren, Tiebing Shan, Zhiping Shen, Pu Wang, Shixiao Fu
- 1190 Interaction between Two Vibrating Cylinders Immersed in Fluid  
Zhonglu Lin, Dongfang Liang, Ming Zhao
- 1198 Drag Coefficient Enhancement of Dual Cylinders in Oscillatory Flow  
Dixia Fan, Xiaotong Zhang, Michael S. Triantafyllou
- 1206 Experimental Investigation on the Vortex-Induced Vibrations in Yawed Flexible Cylinders  
Daniel Prata Vieira, Aline Massabni Momenti, Maria Eduarda F. Chame, André Luis Condino Fugarra
- 1213 Modal Vibrations of Side-by-side and Tandem Vertical Riser Pipes Experiencing a Stepped Current  
Di Deng, Bowen Fu, Decheng Wan
- 1221 Numerical Simulation of Vortex-induced Motion of a Deep Draft Semi-Submersible Platform  
Zhenghao Liu, Weiwen Zhao, Decheng Wan
- 1228 Spanwise force correlation of rotating square cylinders in three-dimensional cross-flow  
J.-B. Frigo, C. Béguin, A. Hay, S. Etienne, D. Pelletier

- 1237 Parametric Study of VIV Fatigue Analysis for SCR  
Sung-Je Lee, Jeong-Dae Lee, Seock-Hee Jun, Kwang-Kyu Yoo, Young-Seok Joo, Sung-Kon Han, Sung-Gun Park
- 1244 Coupled Simulation of CFD and Nonlinear Cable Dynamics for Vortex-Induced Vibration of a Very Long Cable System  
Euntaek Lee, Hyung Taek Ahn
- 1251 Three Dimensional Numerical Simulation of Vortex Induced Vibration for an 800-m-Long Drilling Riser  
Jiasong Wang, Ke Lin, Jianliang Zhou, Liangbin Xu, Leixiang Sheng
- 1257 Three-dimensional Dynamics of Vortex-induced Vibration on a Fluid-conveying Pipe in the Subcritical Regime  
Jinlong Duan, Ke Chen, Yunxiang You, Wei Li, Renfeng Wang
- 1264 Vortex-Induced Vibrations of a Flexible Cylinder Experiencing an Oscillatory Flow  
Bowen Fu, Decheng Wan, Zhiqiang Hu
- 1271 Passive Vibration Control of Pipe-in-pipe (PIP) Systems Subjected to Vortex Induced Vibration (VIV)  
Hamid Matin Nikoo, Kaiming Bi, Hong Hao
- 1277 Experimental Study of Vibrations for a Hydrofoil  
Renfeng Wang, Ke Chen, Yunxiang You, Tianqun Hu, Xinshu Zhang
- 1283 The Study on the Arrangement of VIV Suppression Device on Top Tension Riser in Soliton Current  
Xiaoliang Qi, Gang Xu, Chongyao Zhou, Kevin Huang, Yongtian Kang
- 1290 An effective time-domain approach for prediction of vortex-induced vibrations in a 2D plane  
Wei Lin, Cheng Su
- 1298 Consideration of HVIV Response of SLWRs  
Craig Dillon-Gibbons, Andrew Kilner, Marcollo Hayden

## **COASTAL HYDRODYNAMICS**

### **Nearshore Hydrodynamics**

- 1307 Computational Modelling of Hydrodynamics of a Proposed Tidal Stream Energy Extraction Site  
Harshinie Karunarathna, Antonia Chatzirodou, Dominic E. Reeve
- 1313 The Numerical Investigation of Flow Field of Eastern Coast in Taiwan  
Chih-Chung Wen, Yong-Jun Lin, Hui-Ming Fang, Sung-Shan Hsiao, Li-Hung Tsai, Tsung-Lin Lee, Shu-Huei Jhang

### **Coastal Wave Mechanics**

- 1318 Parallel Three-Dimensional Non-Hydrostatic Model for Predicting Water Wave

## Motions

Congfang Ai, Sheng Jin

- 1323 A Flexible 2D Nonlinear Approach for Nonlinear Wave Propagation, Breaking and Run up  
Andrea G Filippini, Maria Kazolea, Mario Ricchiuto
- 1332 An Efficiency Test on Generation of Transformed Multi-directional Waves in Experimental Basin  
Katsuya Hirayama, Yasuhiro Aida, Akinori Nakamura
- 1336 Experimental Study on the Wave Attenuation Characteristics over Muddy Bed and Fluid Mud  
Mingxiao Xie, Zhiwen Yang, Xin Li, Mengguo Li
- 1341 Experimental Study on Wave Propagation and Deformation over Steep Reef in Large Scale Wave Flume  
Songgui Chen, Hanbao Chen, Huaqin Zhang, Jinhai Zheng
- 1347 A Method for Approximating Surface Elevation from a Shore Mounted X-Band Radar with a Low Grazing Angle  
Charles E. Greenwood, James Morrison, Angus Murray, Arne Vogler
- 1355 Improvement in Estimation Stability and Accuracy of Wave Directional Spectrum by a Bayesian Method for Swell Observation  
Takashi Fujiki, Noriaki Hashimoto, Koji Kawaguchi
- 1363 Applied Extended Wind Wave Model for the Effect of Porous Bottoms and Reefs  
Yuan-Jyh Lan, Tai-Wen Hsu, Yi-Shiang Lin
- 1371 Investigation of Wave Breaking Effect on Bragg Reflection by Series Submerged Breakwaters  
Ying-Chi Chen, Ching-Piao Tsai, Wen-Hung Chang, Chun-Han Ko
- 1377 Bragg Reflection of Water Waves by Multiple Composite Flexible Membranes  
Wei-Wei Ding, Zao-Jian Zou, Jing-Ping Wu

## Storm Surge

- 1384 Analysis of Ship Mooring Force Influence Factors in Three Gorges Ship Lock and Experimental Research  
Chen Zhang, Lizheng Wang, Shunhuai Chen, Wei Zhang
- 1390 Wave Height to Depth Measures During Extreme Runup  
James G. Herterich, Frédéric Dias
- 1395 Simulation of storm surge in northeast coast of the US; a closer look at the wind forcing  
Marissa J. Torres, M. Reza Hashemi, Scott Hayward, Isaac Ginis, Malcolm Spaulding

## **Coastal Structures**

- 1403 Numerical Simulation of Wave Overtopping Over Low-Crested Breakwaters Using the Immersed Boundary Method  
Theofano I. Koutrouveli, Athanassios A. Dimas
- 1411 Real Sea Waves Interaction with an Array of Cylinders in Tandem  
Xinran Ji, Jinxuan Li, Shuxue Liu, Haochen Zhang
- 1415 The Influence of Wave Overtopping on the Stability Analysis of Vertical Breakwaters  
Li-Hung Tsai, Hung-Chu Hsu, Cheng-Jung Hsu, Meng-Syue Li
- 1421 The Reflection Performance of Two Horizontal Plates before Vertical Wall  
Zhenglin Tian, Zhaochen Sun, Shuxiu Liang
- 1427 The Experimental Investigation on the Protections of the Uncompleted Breakwaters under the Long- Term Wave Conditions in the Open Mediterranean Sea  
Sheng Peng, Youde Feng, Xiandao Feng
- 1434 An Experimental Study on Sand Dune Cover Over a Coastal Structure  
Badreyah Almarshed, Jens Figlus
- 1440 Numerical Investigation of Floating Breakwater Coupled with Mooring System Using Openfoam  
Zhe Ma, Xianyun Zhang, Dongsheng Qiao, Jiawen Sun, Gangjun Zhai
- 1446 The 3-D Numerical Simulation of Wave Impact on a Horizontal plate  
Dongxu Wang, Jinsong Gui, Jiawen Sun, Zhe Ma
- 1452 Dynamic Simulation of a Kelp Raft Culture System under Current  
Wenwan Cheng, Zhaochen Sun, Shuxiu Liang
- 1459 Method to Estimate the Aging of Large Rubber Marine Fender  
Hitoshi Akiyama, Teruya Shiomi, Atsuo Omura, Shuji Yamamoto, Shigeru Ueda, Toshiro Kamada
- 1467 An Experimental Study of the Hydrodynamic Performance on the Anti-rolling Type Floating Breakwater  
Zhiwen Yang, Mingxiao Xie, Zhiqiang Hou, Xinran Ji, Weijun Guo, Fang He

## **Sediment Transport, Coastal Erosion**

- 1473 Large-Eddy Simulation of Oscillatory Flow, Sediment Transport and Morphodynamics over Ripples  
Georgios A. Leftheriotis, Athanassios A. Dimas
- 1480 Ridge-Runnel and Swash Dynamics Field Experiment on a Steep Meso-Tidal Engineered Beach: Numerical Model Simulation of Ridge Accretion  
Jens Figlus, Youn-Kyung Song, Patricia Chardón-Maldonado, Jack A. Puleo
- 1488 Numerical Modelling of Arctic Coastal Erosion due to Breaking Waves Impact Using REEF3D  
Nadem Ahmad, Hans Bihs, Mayilvahanan Alagan Chella, Øivind A. Arntsen, Ankit

- Aggarwal
- 1496 Experimental Study of the Influence of Wave Breaking Over a Sloping Beach on the Flow Upstream of the Surf Zone  
Konstantina A. Galani, Athanassios A. Dimas
- 1503 Physical and Numerical Modelling of Trench Infill  
David Todd, Syed A. Ali, Richard J. S. Whitehouse, Michiel A. F. Knaapen
- 1511 Design and Operation of Sonde Arrays to Measure Fluid Mud in the Marine Environment  
Charles Roger Bostater Jr., Tyler Rotkiske, Taylor Oney, Emem Obot
- 1515 Tropical Cyclone-Induced Coastal Hazards, Impacts and Causes on the Coast of China  
Zai-Jin You
- 1519 Analysis of Coastal Erosion in Khlong Wan Coast  
Kornvisith Silaram, Yoshimichi Yamamoto, Nunthawath Charusrojthanadech
- 1527 Experimental Study on the Erosion of the Breakwater - A Case Study of Mai-Liao Harbor  
Wei-Chun Hu, Chi-Fang Chan, Chao-Lung Ting, Chung-Pan Lee, I-Fan Tseng, Yung-Fang Chiu, Pei-Yu Lee, Wei-Lun Li
- 1532 Numerical simulation of scour pattern and scour depth prediction in front of a vertical breakwater using OpenFOAM  
Nikolaos Karagiannis, Theofanis Karambas, Christopher Koutitas
- 1540 Prediction of Gravel Beach Storm Profiles under Bimodal Sea-states  
Andrea Polidoro, Tim Pullen, Jack Eade, Belen Blanco, Travis Mason

### **Coastal Management**

- 1548 A Monitoring and Modeling Study for Kikiaola Harbor in Hawaii, USA  
Lihwa Lin, Zeki Demirbilek, Thomas D. Smith
- 1556 Investigation on coastline evolution using long-term observations and numerical modelling  
Elvira Armenio, Francesca De Serio, Michele Mossa, Biagio Nobile, Antonio F. Petrillo
- 1565 Effect of Jetties in Coastal Change at Chumphon Estuary  
Atsanupong Promngam, Nunthawath Charusrojthanadech, Komsan Maleesee, Yoshimichi Yamamoto