經濟部

經濟部104年度台日技術交流計畫

邀請日本專家來台指導「人工養灘之規畫執行與離岸堤群佈設成效評估」成效檢討報告書

經濟部水利署第六河川局

中華民國104年11月

目　錄

壹、前言

一、計畫緣起

台灣西南海岸受海埔地開發、海岸結構物及河川輸砂量減少等影響，海岸多處早已呈現侵蝕後退之情形，近數十年來，台南、高雄海岸持續遭受海浪侵蝕而後退，自安平商港擴建後，使高雄茄萣、台南黃金海岸由南向北之漂砂，堆積於安平商港南防波堤附近海岸，而反向北方南下之漂砂被阻擋於北防波堤，並在防波堤鄰水域形成波浪繞射之掩蔽區，使防波堤側之淤砂不易再回到原處，迄今安平商港以南至喜樹段海岸已有寬達約250公尺之廣闊砂灘，然而在南段之二仁溪口南北兩岸與茄萣、崎漏段之海岸侵蝕情形卻轉趨嚴重。

1992年以後，茄萣沿海陸續興築十多座離岸堤保護海岸，海岸保護已幾乎完全依賴海堤、突堤與離岸堤等硬體結構物。由於離岸堤建構後部分海岸段固沙功效顯著，但在波浪與颱風浪連續作用下，部分海岸段呈現掏刷情形，在海岸侵淤不斷的消長變化下，離岸堤的建構工程常因地方民眾之要求而增建，形成離岸堤建構密度與長度缺乏一致性考量之情形，在新舊離岸堤層層疊疊、疏疏密密的情況下，除形成本海岸段特殊的景觀外，更影響各海岸段海岸保護的成效差異。

另一方面人工養灘工法為目前國外較成熟且運用廣泛之軟性海岸保護工法，因應上述海岸侵蝕議題，經濟部水利署第六河川局(以下簡稱六河局)於2012年起陸續辦理於台南黃

金海岸辦理人工養灘之工程，為水利署首次實施人工養灘之案例，至今完工已逾2年。鑒於國內人工養灘工程案例偏少，以及日本面臨颱風暴潮之威脅與台灣氣候條件相似，本次即透過經濟部104年度台日技術交流計畫邀請日本專家學者來台指導「人工養灘之規畫執行與離岸堤群佈設成效評估」(附件一)，由日本往昔經驗，針對台南黃金海岸人工養灘提出養灘量體、沙源、配合工法等建議，另針對高雄海岸離岸堤群提出沉陷原因防治等建議。

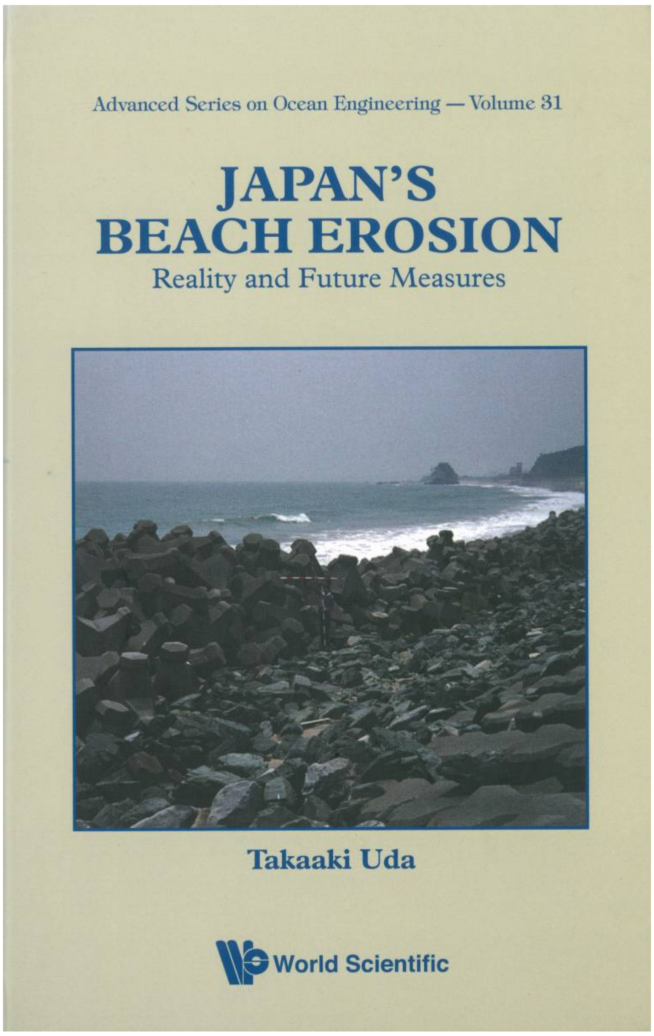
二、計畫目的

安排日本專家實地勘查高雄海岸與二仁溪、台南黃金海岸，向日方專家簡報各海岸之工程規劃及實施內容，就日本方面提供經驗分享。為擴大技術交流參與對象，於104年10月15日假水利署台中辦公室舉辦台日技術交流演講及研討會議-「日本海岸工程面臨之課題及經驗交流」2小時專題演講，邀請水利署各組室、河川局等單位派員參加，與日方專家進行經驗交流。

貳、專家名單

本次來台指導之日本專家計1人，簡介如下：

宇多高明(Uda Takaaki)，現職為財團法人土木研究中心常務理事暨海濱綜合研究室長，擁有40年以上海岸實務經驗。畢業於東京工業大學理工學研究科土木工學科。著有Japan's Beach Erosion: Reality and Future Measures (Advanced Series on Ocean Engineering – Volume 31), World Scientific Publishing Company. 渠等會同宇多夫人Uda Nobuko（自費）一同來台參與交流。



宇多高明個人簡歷

March 1949	Born in Tokyo
March 1973	Master Degree, Tokyo Institute of Technology
April 1973	Research Engineer, Coastal Eng. Division, Public Works Research Institute, Ministry of Construction
April 1980	Senior Research Engineer, ditto
December 1980 ～ November 1981	Visiting Research Engineer to Scripps Institution of Oceanography
February 1983	Dr. Eng., Tokyo Institute of Technology
April 1983	Head, Coastal Eng. Division, Public Works Research Institute, Ministry of Construction
December 1990	Lecturer of Tsukuba University
April 1993	Head, River Engineering Division, Public Works Research Institute, Ministry of Construction
April 1996	Coordinator for River Engineering, Public Works Research Institute, Ministry of Construction
Apri11997	Director of River Department，Public Works Research Institute, Ministry of Construction
April 1999	Visiting Professor of Tokyo Institute of Technology
April 2001	General Coordinator of Research, National Institute for Land, Infrastructure and Management, Ministry of Land, Traffic and Infrastructure
July 2002	Resign NILIM
August 2002	Executive Director, Public Works Research Center
October 2002	Resign of Visiting Professor of Tokyo Institute of Technology
Apri1 2007	Executive Director, Public Works Research Center & Visiting Professor, Nihon University

參、指導行程

本次臺日技術合作已於104年10月12日(星期一)至104年10月15日(星期四)，行程安排詳表1。

表1　來台服務指導日程表

日期(星期)	時間	活動事項	活動內容	地點
10月12日(一)	16:00	抵達臺灣	由六河局及成大水工所人員前往高雄小港機場接機，隨後前往水利署第六河川局辦公室拜會局長、副局長等主管人員	高雄機場 六河局
	18:00	行程及轄管組織業務職掌介紹	由六河局說明台灣海岸概況及權責分工、台南高雄海岸防護情形	六河局 會議室
	19:00	歡迎宴	由六河局蔡局長宗憲設宴、成功大學水工試驗所人員陪同接待	岡山
	20:00	住宿	高雄蓮潭國際會館	高雄
10月13日(二)	8:30	路程	高雄蓮潭國際會館→第六河川局	高雄
	9:00	高雄離岸堤群現況簡報(附件二)	高雄市政府水利局、成大水利系、成大水工所等單位與會討論，由六河局說明高雄海岸離岸堤群施設情形，沉陷原因之初步探討	六河局 會議室
	11:00	赴高雄海岸現場現勘	茄萣地區	高雄
	12:00	午餐		茄萣
	14:00	現勘建議及介紹日本離岸堤施作案例及其實務執行之經驗(附件二)	宇多先生簡報說明台湾の台南黄金海岸周辺の海浜変形、日本神奈川県の海岸（茅ヶ崎中と二宮海岸）	海科中心
	18:30	晚餐		台南
	20:00	住宿		台南 大億麗緻

表1　(續)來台服務指導日程表

日期(星期)	時間	活動事項	活動內容	地點
10月14日(三)	8:30	路程	台南大億麗緻→台南市水利局安平水資源回收中心	台南
	9:00	台南黃金海岸人工養灘現況簡報(附件二)	臺南市政府水利局、成大水利系、成大水工所等單位與會討論，由六河局說明黃金海岸侵蝕原因、人工養灘施作情形	台南市水利局安平水資源回收中心會議室
	11:00	黃金海岸現場現勘	鯤鯓、喜樹、灣裡	台南
	12:00	午餐		安平
	14:00	現勘建議及介紹日本人工養灘案例及其實務執行之經驗(附件二)	宇多先生簡報敦賀湾東岸の横浜地区における海岸人工化過程、Tahiti Moorea島の海岸踏查等案例	成功大學水工試驗所會議室
	17:00	路程		成功大學水工試驗所→台中
	19:00	晚餐		台中
	20:00	住宿	長榮桂冠酒店	台中
10月15日(四)	8:30	路程	長榮桂冠酒店→台中水利署	台中
	9:00	日本經驗專題演講及經驗交流座談會	於水利署台中辦公區辦理專題演講：「日本海岸工程面臨之課題及經驗交流座談會」(附件二)	
	11:00	赴台中高鐵	台中高鐵-桃園國際機場	台中高鐵-桃園
	14:30	返回日本	桃園機場	桃園

肆、計畫執行情形

指導行程內容說明如下，相關相片紀錄如附件三：

一、民國102年10月12日（星期一）

日本來台服務指導專家宇多高明博士於104年10月12日，搭乘中華航空班機 CI103下午4點20分抵達高雄小港國際機場。之後隨即前往位於高雄市岡山區的水利署第六河川局進行此次服務指導的區域相關簡介。

二、民國102年10月13日（星期二）

上午9點於水利署第六河川局進行高雄離岸堤群現況簡報。10點前往高雄茄萣海岸進行離岸堤及海岸侵淤狀況之現地勘查。下午2點赴國家實驗研究院海科中心，針對上午現勘提出建議及分享日本離岸堤施作案例及其實務執行之經驗。

三、民國102年10月14日（星期三）

上午10點於台南市政府水利局安平水資源回收中心會議室進行台南黃金海岸人工養灘現況簡報。10點出發前往台南黃金海岸及安平商港區段等處進行現地勘查。下午2點於國立成功大學水工試驗所針對上午黃金海岸至安平商港之海岸侵蝕及海岸漂砂造成海岸線變遷情形提出建議。會議中並介紹日本人工養灘案例及其實務執行之經驗。

四、民國102年10月15日（星期四）

上午9:00赴水利署台中辦公區進行拜會，由陳副總工程司弘凷接見，隨後並以「日本海岸工程面臨之課題及經驗交流」為題進行2小時演講。會中除了針對前二日於高雄及台南黃金海岸的現勘建議作說明之外，並針對日本海岸工程面臨之課題及經驗進行交流座談會。會後搭乘高鐵北上桃園機場於下午2:40中華航空CI018班機返回日本,完成此次邀訪行程。

伍、成效檢討

海岸水文與漂沙等動力現象變幻難測，其所引致之海岸侵淤亦複雜多變，因此在研擬防治措施時面臨相當的困難。往往除了要具備學理的基礎知識以外，現地實務亦是相當重要的經驗。本此邀訪之日本研究者宇多高明先生即是在海岸工程領域兼具學理與數十年實務經驗之人才。透過宇多先生此次的來台指導期間，對日本及六河局轄區的海岸現況、政府組織分工、所面臨的問題與未來改善的方向，作廣泛的意見交流。

1. 日本海岸侵蝕原因有河川供給土砂量減少、構造物遮蔽、沿岸漂砂受阻礙、疏浚抽砂利用等，平均每8.5公里海岸線就設有一個港口，而港口、防風林與海岸侵蝕防護皆屬不同主管機關，與台灣現況相同。

2. 日本海岸侵蝕防護之規劃設計施工等階段由地方政府(都道府縣等單位）執行，經費不足時則向中央部會請求補助，與台灣目前由中央單位執行之作法稍有差異。

3. 水利署為水利主管機關，職掌水資源、河川、海岸、排水治理等相關工作，而海岸經費相較於其他項目而言，整體比例較為偏低。日本海岸環境與台灣相似，政府組織結構類似，中央部會挹注於海岸經費的比例也是相對偏低。

4. 現地的勘查過程，宇多高明先生多次透過海岸植物生長狀

況，植地分布範圍與海灘上的底質粗細等現象，即可說明其與波浪入射方向、強度等現地水文的現象，提供從事海岸工作者，利用現地觀察掌握環境特性的方法與經驗。

5.現勘後的討論會中，除討論勘查的海岸環境，並藉由日本、美國及歐洲等案例說明，作為國內海岸管理與防治的參考。當中正面、負面案例皆有介紹。

6.現勘與討論會後，宇多先生對六河局轄區治理的具體建議包括：

(1)茄萣地區及台南黃金海岸之灘料仍持續往北輸送至安平商港南防波堤堆積，自商港防波堤擴建完工之前，便一直持續至今仍未停止，除非移除安平商港防波堤，才有辦法讓此區域的漂沙恢復到夏侵冬淤的動態平衡。未來於此區域養灘工程的取沙區仍應以安平商港南防波堤以南之區域為主。

(2)黃金海岸配合養灘施作之8隻突堤群，雖景觀上無法像自然沙灘那麼地融為一體，但是考量固沙效果的話是必要之惡。如放任突堤自然沉陷至高潮線以下，於視覺上較美觀，也會增加民眾親水的意願，但是便無法達到其固沙的效果，灘料將會逐漸流失，養灘工作就會等於白做工。於海岸治理工程中，景觀與成效常為天秤的兩端，需要有所取捨。

(3)港區防波堤移除才能恢復區域的動態平衡，無法移除防波堤的前提下，僅能以現有資源考量。興達港浚砂可考量補充至興達港北側海岸崎漏離岸堤群後方，預期可藉由往北的沿岸優勢輸砂，逐步往崎漏、茄萣及二仁溪口方向輸送。

(4)現有海岸拋放的塊石，可考慮拋放礫石粒徑約2～3cm，其粒徑較現地粗，不致於被輸送到離岸較遠深水區，同時其會隨著波浪的作用在近岸區，形成自然的岸灘坡度。此方法在日本多處海岸已有成功案例，值得參考。

(5)日本離岸堤同樣面臨沉陷的問題，有比較成功的作法是將離岸堤同樣視為海堤，在離岸堤臨外海測新增基腳保護工以加強保護碎波之沖刷，可減緩其沉陷的速度。

(6)黃金海岸的養灘拋砂地點，施作於船屋附近，因屬一凹岸地形，像是波浪遮蔽區，在此處養灘是很聰明的作法。此結果與六河局監測養灘成效之結果是相當吻合的。

(7)以台南黃金海岸養灘工程而言，可感覺出來六河局對養灘工程的用心規劃及施工，經過縝密的研究、數值模擬、水工模型試驗後才付諸實行，防護效果以及經濟效益都是個很成功的案例。

(8)宇多高明先生於回國1個月後，已完成5篇有關二仁溪口南北岸(茄萣、黃金海岸)之調查報告，詳情可參閱附件四內容。

附　件

附件一　104年6月2日經濟部國際合作處核定函

經濟部國際合作處　函

機關地址：
承辦人：陳祈典
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電子信箱：ctchen@moea.gov.tw

受文者：經濟部水利署

發文日期：中華民國104年06月02日
發文字號：經國處字第10403045560號
速別：速件
密等及解密條件或保密期限：
附件：如文

裝

主旨：有關貴署擬在104年度臺日技術合作計畫項下申請日方派遣「人工養灘之規畫執行與離岸堤群佈設成效評估」專家來臺指導一案，請　惠依說明事項配合辦理。

說明：

一、依據駐日本代表處經濟組104年5月28日日經組字第1040000731號函辦理。

訂

二、本案業經駐日本代表處經濟組洽妥日方派遣一般財團法人土木研究中心常務理事暨海濱綜合研究室長宇多高明(Uda Takaaki)於本(104)年10月12日至10月15日來臺指導，渠將偕同夫人Uda Nobuko一同前來，並自行負擔相關機票與住宿費用。

線

三、旨述專家來臺指導所需各項費用將依院頒「各機關聘請國外顧問、專家及學者來臺工作期間支付費用最高標準表」之教授級支付，包含商務艙來回機票(以本國籍航空公司為主，由本部直接撥付駐日本代表處代購)，報酬(含生活費)每日新台幣8,175元(需扣18%所得稅)及事前準備費新台幣12,000元(需扣18%所得稅)，惟請貴署先行墊付報酬及事前準備費，並向國稅局報繳稅款，於專家完成指導離臺後2週內檢據向本部申請核銷歸墊，核銷時各項單據憑證均需經申請單位首長及會計主管核章，並依規定於專家指導完成2個月內提出相關指導成效檢討之書面報告書1份暨其電子檔送本處核備。

四、請依規定辦理專家之國際技術合作人員綜合保險(保額

比照公務人員因公赴國外出差綜合保險標準辦理)，其
保險費及內陸交通費由貴署負擔。

五、檢附上述專家中、英文簡歷及護照影本1份，請 卓參。

正本：經濟部水利署
副本：經濟部會計處、駐日本代表處經濟組、外交部亞東關係協會

附件二　日本專家簡報

2015年10月13日　台湾の台南黄金海岸周辺の海浜変形

台湾の台南黄金海岸周辺の海浜変形

一般財団法人土木研究センター
常務理事・なぎさ総合研究室長
工博　宇多高明
Dr. Takaaki Uda

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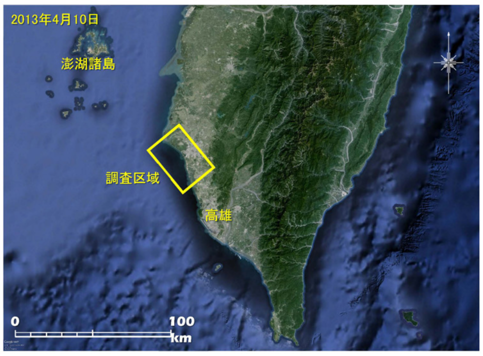

図-1　台湾南部の衛星画像

2

図-2　区域A，Bの位置

3

図-3(a)　区域Aの衛星画像（2003年2月20日）

4

図-3(b) 区域Aの衛星画像（2008年1月3日）

5

図-3(c)　区域Aの衛星画像（2012年3月1日）

6

図-3(d)区域Aの衛星画像（2013年11月16日）

7

図-3(e)　区域Aの衛星画像（2015年2月25日）

8

2015年10月13日　台湾の台南黄金海岸周辺の海浜変形

- 二仁渓の河口部では，2003～2008年に河口砂州が一挙に消失し，砂州が上流へと遡り始めた．
- その後，2012年までに河口左岸に2基の離岸堤が造られ，養浜も行われた（要確認）．養浜は2013年まで継続されたが河口部の水深は大きいままである．
- 河口の南側に設置された2基の離岸堤背後の舌状砂州の規模は2013年から2015年に減少したが，この時同時に河口左岸側に砂州が形成されていることから，河口の南側隣接部の砂が河口へと逆流したことが分かる．

9

図-4(a)　区域Bの衛星画像（2003年2月20日）

10

図-4(b)　区域Bの衛星画像（2008年1月3日）

11

図-4(c)　区域Bの衛星画像（2012年3月1日）

12

図-4(d)　区域Bの衛星画像（2013年11月16日）

13

図-4(e)　区域Bの衛星画像（2015年2月25日）

14

ま と め

- 西部濱海公路前面の海岸では多数の離岸堤が設置され，その後養浜が行われた結果，一時的に前浜が復元された．しかしその後砂が北向き沿岸漂砂により運ばれ，海浜南部から徐々に砂浜が削られた．
- 同時に，二仁渓の河口部では2003～2008年に河口砂州が一挙に消失し，砂州が上流へと遡ったことから，二仁渓の河口部も含めて水深が増大したことは間違いない．
- 台湾南西部，台南黄金海岸周辺ではその地形的特徴から北側および南西側からの波が卓越すると考えられるが，このような波浪条件の下で．安平商港の防波堤による波の遮蔽域へと砂が運ばれたことが侵食の原因と推定できる．
- 西部濱海公路前面の海浜には離岸堤が設置されていたものの透過性であるため徐々に北向きに砂が運び去られた．

15

2015年10月13日神奈川県の海岸（茅ヶ崎中と二宮海岸）

2015年11月15日　「山川海の連続性を考える県民会議」

神奈川県の海岸（茅ヶ崎中と二宮海岸）

一般財団法人土木研究センター
常務理事・なぎさ総合研究室長・日本大学客員教授
工博　宇多高明
Dr. Takaaki Uda

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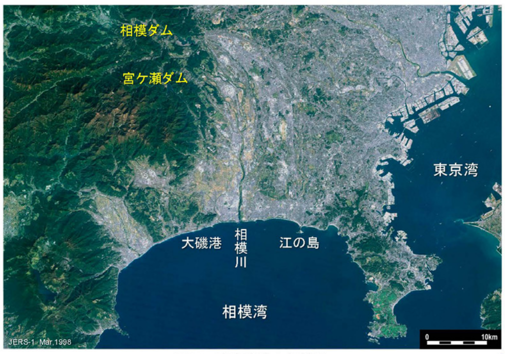


図-1　湘南海岸と相模川

2

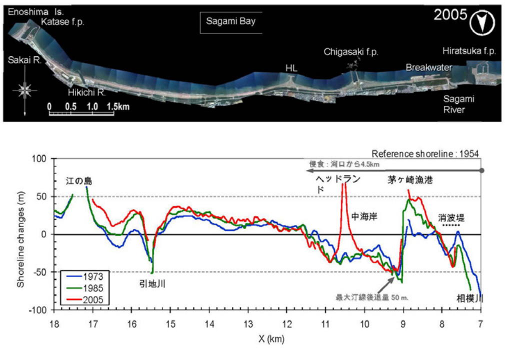


図-2　湘南海岸の汀線変化（1954年基準）

3

図-3　茅ヶ崎中海岸（1982年）

4

図-4　茅ヶ崎中海岸（2005年8月12日）

5

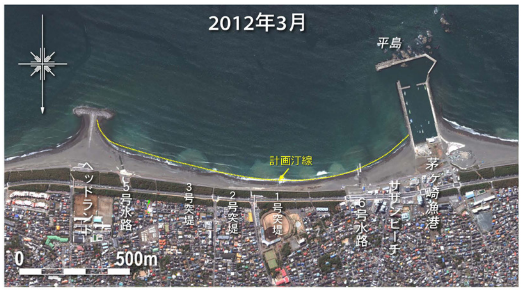


図-5 茅ヶ崎中海岸の空中写真（2012年3月）

6

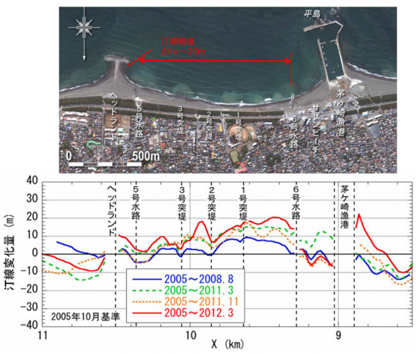


図-6　茅ヶ崎中海岸の汀線変化（2005年基準）

7

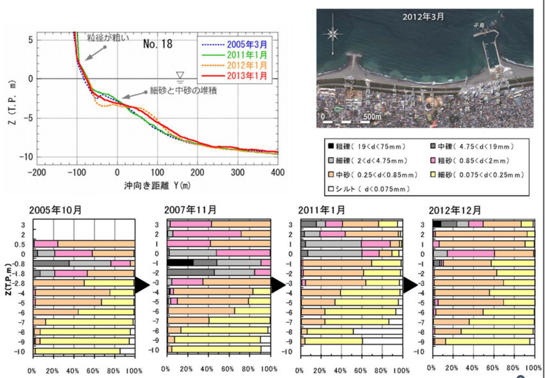


図-7　海岸中央部の縦断形変化と底質の水深方向分布の変化（No. 18）

8

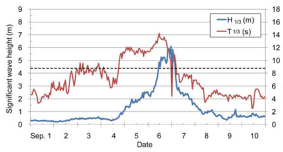
2015年10月13日神奈川県の海岸（茅ヶ崎中と二宮海岸）

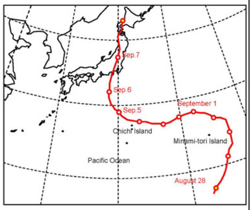
図-8　茅ヶ崎中海岸（2005年8月12日）

9

図-9　茅ヶ崎中海岸の姿（2010年10月）

10





2007年台風9号：$H_{1/3}$=6.1m, $T_{1/3}$=10.1s, S10E(平塚)，$H_{1/3}$＞4.5m → 17h (観測史上最長)

図-10 2007年台風9号来襲時の波浪

11

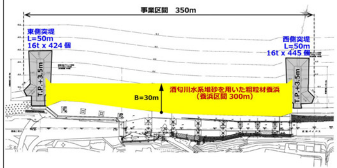
図-11 金波・銀波橋前面の被災状況(2007年9月4日)

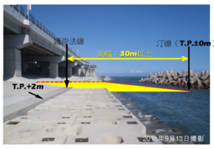
12

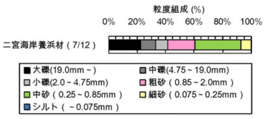
図-12 金波・銀波橋前面の被災状況（2007年9月9日）

13

酒匂川水系堆砂を用いた粗粒材養浜（計8万m³）と突堤2基により，海水浴場として利用されていた2007年（平成19年）台風9号襲来前と同程度の浜幅30mの砂浜復元.







酒匂川水系から調達する養浜材の例：二宮海岸養浜材2011年7月12日

図-13　突堤2基の間での養浜

14

図-14 金波・銀波橋付近の養浜前の状況（2012年7月17日）

15

図-15 東突堤の付け根から試験養浜区間を望む（2013年11月24日）

16

2015年10月13日神奈川県の海岸（茅ヶ崎中と二宮海岸）

図-16 粗粒材養浜により広がった前浜と砂礫に埋まった消波工（2013年11月24日）

17

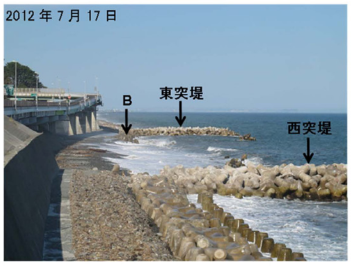


図-17 養浜開始時の試験区間の状況（2012年7月17日）

18

図-18 海浜中央部から東突堤を望む（2013年11月24日）

19

図-19 被災前の銀波橋直下の海浜状況（2006年12月1日，神奈川県撮影）

20

図-20 西突堤の付け根から東側を望む海岸状況（2012年7月17日）

21

図-21 西突堤の付け根から東側を望む海岸状況（2013年11月24日）

22

図-22 二宮海岸における破壊された鉄線篭(2012年5月2日)
海岸が汚らしくかつ危険。

23

図-23 侵食されて露出した場所打ちコンクリート杭（2014年5月2日）
フィルターユニットは場所打ちコンクリート杭の頭部に並べられていたが、
高波浪の作用により落下した。

24

2015年10月13日神奈川県の海岸（茅ヶ崎中と二宮海岸）

図-25　西湘バイパスの国管理区間前面での盛り土養浜（2014年5月2日）
土砂が流出し、高い浜崖が形成されている。

25

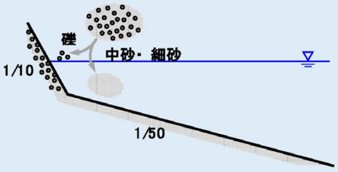
図-26　試験突堤間に形成された砂浜（2014年5月2日）

26

まとめ

（1）浜を復元するには養浜を行うことである.
（2）養浜では，使用する土砂の粒度組成と，養浜を行う予定の海浜の元々の粒度組成について十分な理解が必要.
（3）実際に，茅ヶ崎中海岸や二宮海岸で粗粒材養浜が成功した.

養浜（ 礫 ＆ 中砂・ 細砂）



礫と 砂を 投入した場合の土砂移動の模式図

27

2015年10月14日　敦賀湾東岸の横浜地区における海岸人工化過程

敦賀湾東岸の横浜地区における海岸人工化過程

一般財団法人土木研究センター
常務理事・なぎさ総合研究室長
宇多高明
Dr. Takaaki Uda

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はじめに

- 多くのポケットビーチでは漁港や海岸構造物の整備が過剰なまでに行われ，気が付いたときには人工構造物で囲まれ，構造物ばかり目立つ姿に変貌した場所が多い.
- 自然環境が重視される時代になっても，もはや様々な工夫を行うことが難しい状況まで人工化が進み，新たな空間の創出が困難な姿に近づいている.
- 人工化が進んだ敦賀湾東岸に位置する横浜海岸と，その北側に位置する大比田海岸を例として考察
- 2015年5月27日に現地踏査を行い，その上で空中写真および衛星画像を判読し海岸の人工化過程について考察.

2

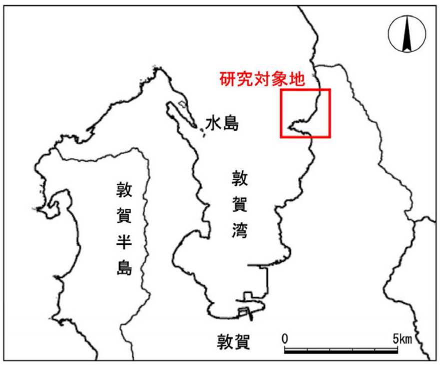


図-1　敦賀湾東岸の調査対象地の位置

3

図-2　横浜海岸と大比田海岸の位置

4

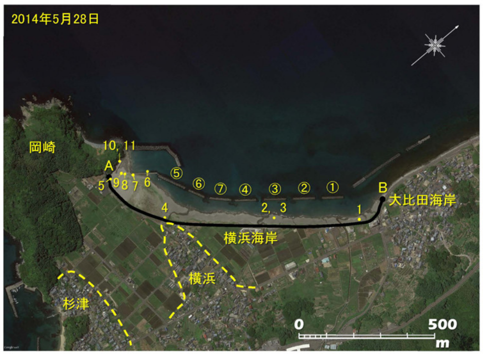


図-3　調査区域の衛星画像と離岸堤の設置順序

5

写真-1　横浜海岸北部の離岸堤背後に蛇行して流入する小河川（地点1）

6

写真-2　河川の蛇行状況（地点2）

7

写真-3　河川の蛇行状況（地点3）

8

2015年10月14日　敦賀湾東岸の横浜地区における海岸人工化過程

写真-4　漁港東側の平坦な海浜地（地点4）　9

写真-5　剣神社前の護岸と平坦な海浜地の関係（地点5）　10

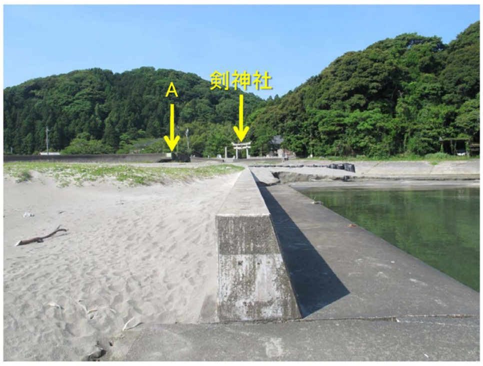


写真-6　防砂突堤の先端部から付け根方向を望む（地点6）　11

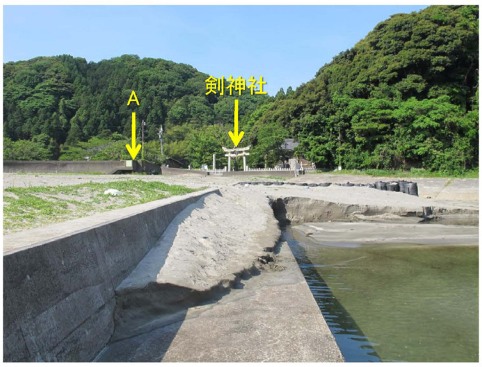


写真-7　飛砂により平坦地から泊地へと落ち込んだ浚渫土砂（地点7）　12

写真-8　泊地内で細長く伸びた砂州（地点8）　13

写真-9　泊地へと流入する流路の閉塞防止のため並べられた大型土嚢（地点9）　14

写真-10　荒廃が進んだ船小屋（地点10）　15

写真-11　斜路と泊地の間に伸びた砂州（地点11）　16

2015年10月14日　敦賀湾東岸の横浜地区における海岸人工化過程

1963

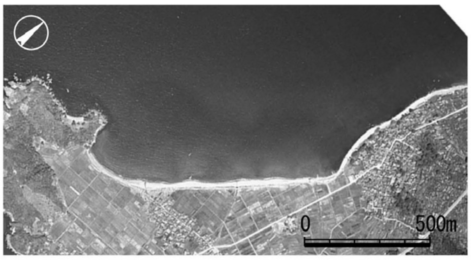


図-4　空中写真の比較（1963年）

17

1975

図-4　空中写真の比較（1975年）

18

1985

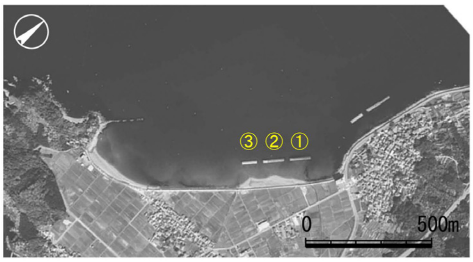


図-4　空中写真の比較（1985年）

19

1990

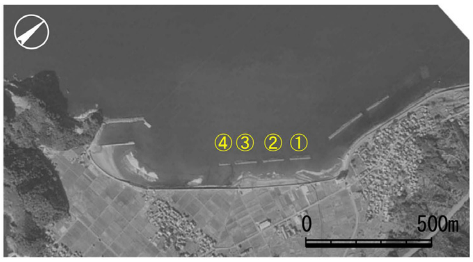


図-4　空中写真の比較（1990年）

20

1995

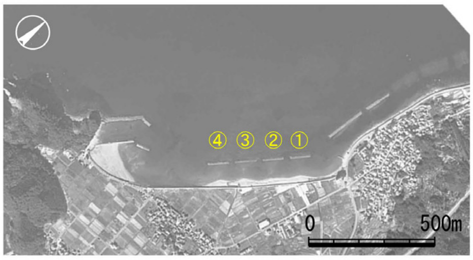


図-4　空中写真の比較（1995年）

21

1997

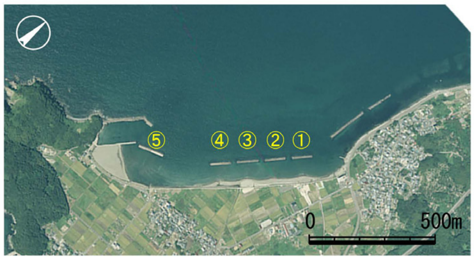


図-4　空中写真の比較（1997年）

22

2001

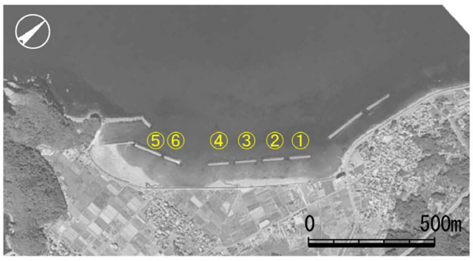


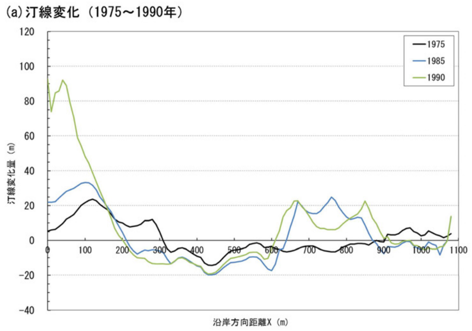
図-4　空中写真の比較（2001年）

23

2004

図-4　空中写真の比較（2004年）

24



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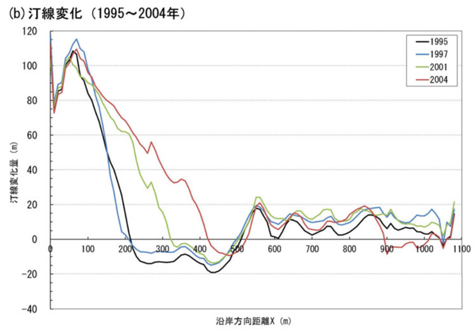

図-5　1963年基準での汀線変化（1975～1990年と1995～2004年）

26

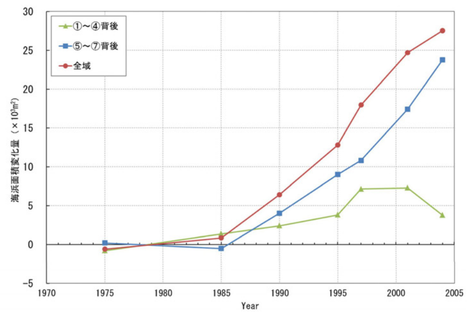

図-6　海浜面積変化量の経年変化

27

図-7　南西端の漁港周辺の衛星画像（2004年1月4日）

28

図-7　南西端の漁港周辺の衛星画像（2010年12月5日）

29

図-7　南西端の漁港周辺の衛星画像（2011年2月23日）

30

図-7　南西端の漁港周辺の衛星画像（2012年8月22日）

31

図-7　南西端の漁港周辺の衛星画像（2014年4月23日）

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2015年10月14日　敦賀湾東岸の横浜地区における海岸人工化過程

図-7　南西端の漁港周辺の衛星画像（2015年3月31日）

33

まとめ

- 横浜地区の漁港は，当地で卓越する南向きの沿岸漂砂が岬により阻止され堆積するという，維持が難しい場所に立地され，そのことが漁港としての存立に大きな影響を及ぼした．
- 堆砂が著しいため漁港維持のため浚渫が繰り返されてきた．しかも，北東側の大比田海岸方面からの漂砂供給量は現況では小さいと考えられるので，当漁港の泊地での堆砂の除去は，横浜海岸の離岸堤周辺の海底地盤高の低下をもたらしている．
- 生態系保全などの環境問題への対応のために，グリーンインフラが国際的にも声高く言われる時代に，水平線も見えないほどコンクリートブロックが山積された海水浴場と，浚渫を繰り返し行っても使用に耐えない漁港，および繰り返される浚渫の影響が周辺海岸に及びつつあるのが現状．
- 現在，既に横浜地区の泊地はほとんど使用されず，漁船は岡崎の南側の泊地に移動している状況を考慮すれば，自然現象としての漂砂とのマッチングが十分でない計画は最終的に失敗に至る．

34

2015年10月14日　Ocean Beach, San Diegoの現地踏査

Ocean Beach, San Diegoの現地踏査

一般財団法人土木研究センター
常務理事・なぎさ総合研究室長
宇多高明
Dr. Takaaki Uda

1

は じ め に

2015年5月15日，Pacific Oceanを西に望むSan DiegoのOcean Beachの現地踏査を行った．Ocean BeachはMission Bayの南側に位置する海岸で，磯と海浜があるきれいなビーチである．2015年5月Coastal SedimentがMission Bayで開催された際，立ち寄った．

2

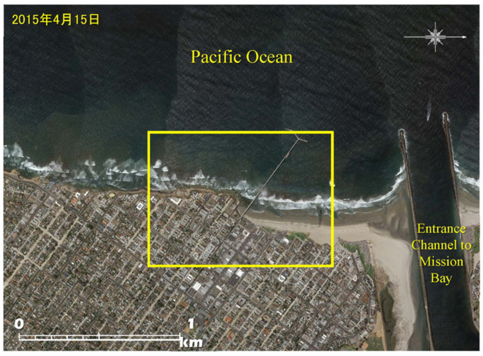

図-1　Ocean Beachの衛星画像

3

図-2　踏査地域の拡大衛星画像と写真撮影地点

4

2015年10月14日　Ocean Beach, San Diegoの現地踏査

写真-1 Ocean Beach Pier.
Californiaでは各地にこのようなpierがあり多くの人々が集まる．Pierには自由に上れ，釣りなどを行うことができる．

5

写真-2 Pierから北側海浜を望む
海岸線に沿って遊歩道が伸び，その前面に数十m幅の前浜が広がる．背後地は駐車場となっていたが，駐車場と海浜とはこの遊歩道によりきれいに分けられていた．沖合は緩勾配の海浜でわが国のように過剰に離岸堤などが並べられず自然海浜のままであった．

6

写真-3 遊歩道と護岸
遊歩道はコンクリート製で海浜利用者は裸足で歩ける．護岸と遊歩道の比高は0.6m程度で護岸の天端がよい腰掛になっていた．海浜には轍が残されていたが，これらはlifesaverや海浜のcleaningのための車両の通った跡である．

7

写真-4 護岸に沿って並べられたtrash can
海浜をきれいに保つために，海浜へのゴミ捨てが禁じられており，随所にtrash canが並べられていた．

8

写真-5 遊歩道の北端部
左端に半分見える施設はlife saverの監視小屋である．背後の芝を張った公園と青い空とがあいまって良好な環境を造り出している．

9

写真-6 Ocean Beach Pierから南側海岸を望む
Pierの南側はPoint Lomaへと続く岩石海岸が伸びる．写真の中央左には護岸があるが大部分の場所では防護施設は設置されていない．

10

写真-7 Sea cliff上部の家屋の崩落を防止するために
property ownerが設置した土砂崩落防止施設
米国では崖地に住むのは個人の選択であり，公共機関が防護施設を設置する習慣はない．

11

写真-8 海食台背後の護岸とその背後の崩落しつつある崖地

12

2015年10月14日　Ocean Beach, San Diegoの現地踏査

写真-9　岩石海岸の間に残されていた小規模なcove

13

写真-10 小規模なcoveで休む人

14

写真-11　崖地上部のocean viewの家屋

15

写真-12 Ocean viewの立派な家屋

16

まとめ

護岸や離岸堤などにより過剰なまでに覆われた日本の海岸と，San Diegoの自然がよく残され，控えめに護岸が造られ，多くの人々が遊ぶOcean Beachとはよい対比を示す．いずれが正しい道か？

17

2015年10月14日　Tahiti Moorea島の海岸踏査

Tahiti Moorea島の海岸踏査

一般財団法人土木研究センター
常務理事・なぎさ総合研究室長
工博　宇多高明
Dr. Takaaki Uda

1

はじめに

2015年7月27日から8月2日の間，TahitiのMoorea島を訪れた．Moorea島はTahiti島の西17kmに位置する．成田からTahitiのPapeete国際空港まで直行便で飛び，空港の東5.3kmにあるPapeete港から西隣りにあるMoorea島へとフェリーで渡った．Moorea島の周囲にはfringing reef(裾礁)がよく発達しており，このreefが太平洋からの高波に対して防波堤の役割を果たしている．Papeete港から西向きに進んだフェリーはMoorea島東岸にあるreef gapを通過して港に接岸した．Moorea島はほぼハート形に近い形状を有している．現地踏査ではMoorea島を左回りに回りつつ海岸状況を調べた．

2

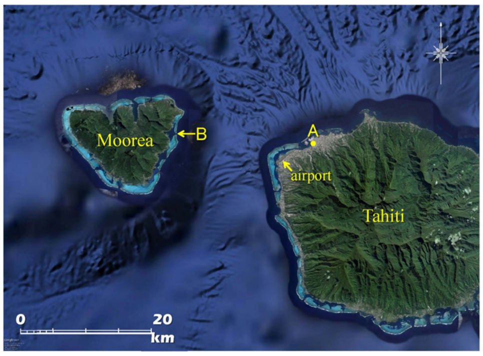

Fig. 1. Tahiti島とその西に17km離れたMoorea島の衛星画像

3

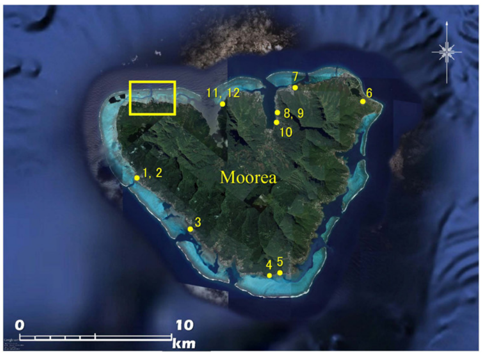

Fig. 2. Moorea島の拡大画像と海岸踏査地点番号

4

写真-1 流入河川の河口を北向きに望む（西岸の地点1）
高さ0.5m程度の石積み護岸が設置されていたが，背後の土砂の一部が流出していた．

5

写真-2 流入河川の河口を南向きに望む（西岸の地点2）

6

写真-3 汀線付近に生育するmangrove（西岸の地点3）
汀線付近はmangroveの生育に適した泥質であった．

7

写真-4 海岸道路を守る護岸（南端の地点4）

8

2015年10月14日　Tahiti Moorea島の海岸踏査

写真-5 海岸道路を守る高さ約1.5mの石積み護岸（南端の地点5）

9

写真-6 台地上から望むHotel Sofitel MooreaのLa Ora Beach Resort（北東端の地点6）

10

写真-7 Cook's Bayの入口近くにある砂浜（北岸の地点7）

11

写真-8 Cook's Bay内へと回り込んで湾奥を望む（北岸の地点8）

12

写真-9 Cook's Bay内に停泊するヨット（北岸の地点9）

13

写真-10 湾奥のPao Pao方面を望む（北岸の地点10）

14

写真-11 Opunohu Bayの湾口にある砂浜（北岸の地点11）

15

写真-12 Opunohu Bay内に停泊する大型の観光船（北岸の地点12）

16

2015年10月14日　Tahiti Moorea島の海岸踏査

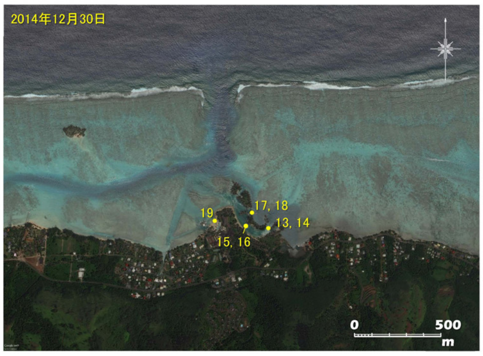

Fig. 3. Intercontinental Hotel Resort付近の拡大衛星画像　17

写真-13 滞在した海上cottage (overwater hotel)を沖合の桟橋上から早朝に望む　18

写真-14 海上cottage (overwater hotel)を沖合の桟橋上から夕刻に望む　19

写真-15 滞在した海上cottage (overwater hotel)を西側から早朝に撮影　20

写真-16 滞在した海上cottage (overwater hotel)を西側から夕刻に撮影　21

写真-17 lagoonに突き出た海上cottage (overwater hotel)　22

写真-18 lagoonに突き出た海上cottage (overwater hotel)　鏡のように静かな海.　23

写真-19 resort内の砂浜　24

2015年10月14日　Tahiti Moorea島の海岸踏査

まとめ

Tahitiでは海岸線付近のみならず，海面上にまでcottageが建てられており，多くのtouristsがcoral reefの自然を堪能していた．海岸線に沿っては小規模な護岸があるのみで海の視界を妨げるような堤防などの施設は全くなかった．このためtouristsは海と陸との断絶を感じることなく利用できていた．またこれが自然の資産として多くの観光客を集める要因になっていた．

この状況は高い堤防・護岸で囲まれたわが国の海岸とよい対比をなしていた．わが国は中緯度帯にあるため津波や高潮など災害の危険度が高いので防護レベルが高まることはやむを得ない面もあるが，海辺が高いコンクリート壁により囲まれ，海と陸の連続性が絶たれた姿となれば海岸への人々の関心をなくすことに繋がると考えられることから，調和のとれた海岸の姿について再考する必要がある．

25

2015年10月14日　駿河海岸の現地踏査

駿河海岸の現地踏査

一般財団法人土木研究センター
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1

はじめに

- 駿河海岸は，大井川河口の両翼に広がる長さ18 kmの砂礫海岸で，大井川扇状地の外縁をなす
- 大井川河口北側区域に注目
- 大井川からの流出砂礫は大井川港の南防波堤により阻止
- 北側地区では北向きの沿岸漂砂が卓越しているため侵食が進む
- 駿河海岸北部では多数の離岸堤と消波堤が設置され，さらに養浜も行われてきたが，侵食以前の自然海浜の姿は失われたままである．
- この状況を2015年8月20日の現地踏査により調査
- 宇多（1997）による駿河海岸の縦断形変化比較によれば当海岸での波による地形変化の限界水深hcはほぼ-8mにある
- また大井川港の南防波堤から北に5.6km離れたNo.20地点（図-1のA）を通過する沿岸漂砂量は1970～1982年の平均で8×104 m3/yrと推定
- さらに海岸の北端部の汀線突出部沖には深い海底谷が迫る．

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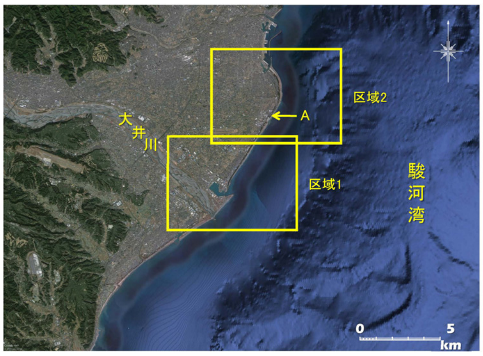

図-1　大井川と駿河海岸の衛星画像

3

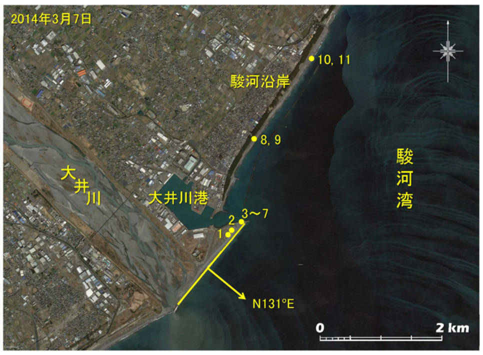

図-2　南部の区域1の衛星画像

4

2015年10月14日　駿河海岸の現地踏査

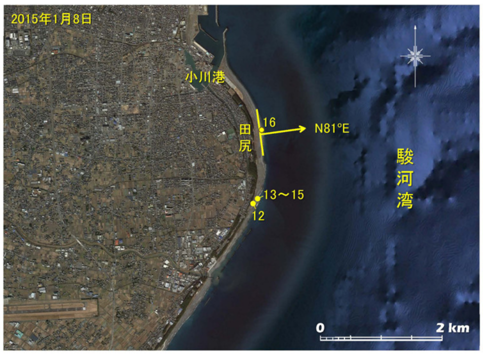

図-3　北部の区域2の衛星画像

5

写真-1　大井川河口を背にして南防波堤を望む
高い礫バームが南防波堤まで直線状に伸びる．

6

写真-2　掘削されてできた平坦面を海側から塞いで堆積した砂礫
砂礫の堆積域の陸側端には安息勾配の急斜面が形成

7

写真-3　南防波堤先端の天端を埋めた砂礫

8

写真-4　南防波堤の天端周辺での砂礫の勾配1/4

9

写真-5　南防波堤の天端を埋める礫

10

写真-6　南防波堤の内側に形成されていた砂州
ここに堆積した砂礫の一部は防波堤の天端を越えたもの，また一部は南防波堤の先端を回り込んで波により押し込まれたもの．いずれにしても南防波堤の南側の砂礫は満砂状態まで堆積が進んでいる．

11

写真-7　防波堤内側から防波堤先端方向を望む
防波堤先端での砕波は，そこに砂州が形成され水深が小さくなっていることを示す．

12

2015年10月14日　駿河海岸の現地踏査

写真-12　現地試験の行われていた幅広突堤背後での堆砂状況

17

写真-13　幅広突堤の天端背後

18

写真-14　幅広突堤の背後地にできた浜崖

19

写真-15　幅広突堤上での礫の堆積状況

20

写真-8　盛り土養浜区間に残された平坦面と浜崖

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写真-9　波の侵食作用で削り取られた盛り土

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写真-10　有脚式離岸堤周辺の海浜状況（南向き）

15

写真-11　有脚式離岸堤周辺の海浜状況（北向き）

16

2015年10月14日　駿河海岸の現地踏査

写真-16　田尻地区に形成されているきれいな天然バーム

21

まとめ

1. 大井川の北側に隣接する駿河海岸では大井川起源の砂礫が供給されてきたが，大井川港の建設に伴い北向きの沿岸漂砂が阻止され，侵食域が北側へと広がった．対策として離岸堤や消波堤も設置され，さらに養浜も行われてきたが砂浜の回復は進んでいない．．
2. 大井川港は大井川に隣接して立地しているため，現在でも大井川からの流下土砂は南防波堤により阻止されている．急流河川から粒径の大きな砂礫が供給されているが，粒径が大きいため砂礫は水深6m付近から勾配1/5程度と急な勾配をなして堆積している．このため沿岸漂砂は航路を横切れず，南防波堤の内側に沿って港内へと運ばれている．また一部の砂礫は防波堤の天端を乗り越えて航路へと落ち込んでいる．
3. 養浜手法として南防波堤の南側海岸から砂礫を採取し，それを駿河海岸の消波堤と堤防の間に平坦面を造りながら敷き均すという手法で養浜が行われてきたが，消波堤の背後には人工的な平坦面が形成される一方，その海側端にはほぼ連続的に浜崖が形成され，海浜へのアクセスが絶たれ，自然海浜の復元とは程遠い姿となっている．これを考えると，むしろある区間を区切ってそこから連続的に注入する養浜方法にする必要があると考えられる

22

BEACH EROSION ARISING FROM ANTHROPOGENIC FACTORS

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Contents

Introduction

1. Beach erosion has become a serious problem in Japan and natural sandy beaches have been rapidly disappearing, resulting in an artificial coastline excessively protected by seawalls and concrete armour units.
2. When investigating the issue of beach erosion, we soon arrive at a very important conclusion: almost all beach erosion originates from **anthropogenic factors** as a consequence that Japan has extensively altered its land during the last 20 to 30 years.
3. In Japan, coastal work is carried out by four sectors. Port construction is carried out by the Fisheries Agency and the Port Department.
4. Other coastal works are carried out by the River Department, and protective works involving planting coastal forests and the protection of farmland are overseen by the Ministry of Agriculture.

2

Introduction (continue)

5. These works have been carried out independently within their respective areas of jurisdiction.
6. For example, when a long port breakwater is extended, sand is accumulated in the wave-shelter zone of the breakwater, resulting in beach erosion on the surrounding coast.
7. The construction work at the port is carried out by the port or fishing port authority, with little connection to the works aiming to protect the surrounding coastline.
8. Overall measures to solve problems are difficult to adopt because of the **sector-by-sector administrative system**.
9. In this study, the factors that hinder the solution of coastal problems are investigated.

3

Types of Beach Erosion

Four main causes of beach erosion in Japan:
(a) Obstruction of longshore sand transport
(b) Beach changes associated with the formation of wave-shelter zones
(c) Decreased fluvial sediment supply
(d) Offshore sand mining or dredging

- **2,532** large dams have been constructed in Japan.
- **Sand mining** in river channels was prohibited in Japan in 1967 owing to excessive riverbed degradation. However, sand mining of the seabed still continues at many places, particularly in western Japan.
- In this study, beach erosion triggered by the extension of a port breakwater and beach erosion due to the decrease in fluvial sediment supply from rivers caused by excess riverbed mining and the construction of dams are investigated using four examples.

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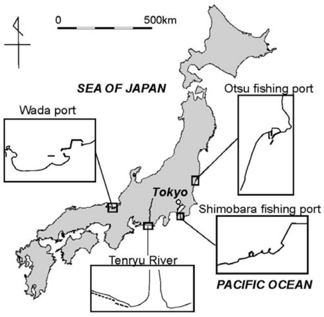

Figure 1. Location of study areas

5

Beach Erosion Associated with Formation of Wave-shelter Zone upon Construction of Offshore Breakwater
(1) Otsu fishing port

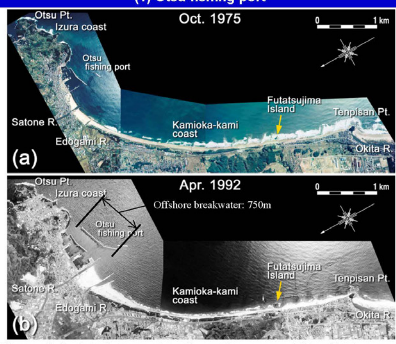

Figure 2. Aerial photographs of coastline around Otsu fishing port.

6

- **On the coast south of fishing port, the shoreline greatly retreated and it was protected heavily by concrete armour units. Note the scale. A man is standing in the center of the concrete blocks.**

Figure 3. Shoreline of eroded coast (June 19, 2004).

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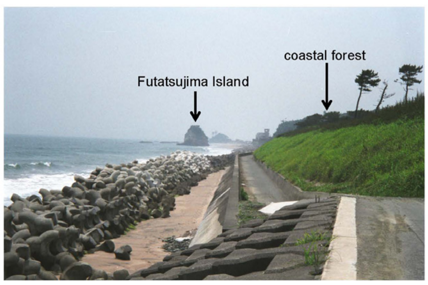


- **The southern side is also protected by seawall and concrete armour units. The construction had been carried out to protect the coastal forest behind the coastline as a recovery work by the management office of coastal forest.**

Figure 4. Kamiokakami coast south of fishing port (June 19, 2004).

8

• Near the southern end of the coastline, beach erosion is still severe, and the stairs to the beach were damaged due to scouring.

Figure 5. Damaged stairs (July 9, 2009). 9

• The yellow line shows the previous ground level before erosion. The stairs were tilted.

Figure 6. Damaged stairs looking the front (July 9, 2009). 10

•The decrease in ground level reached 1.2 m.

Figure 7. Exposed seawall (July 9, 2009). 11

Beach Erosion Associated with Formation of Wave-shelter Zone upon Construction of Offshore Breakwater
(2) Shimobara fishing port

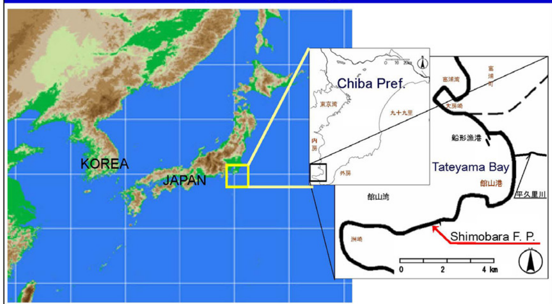


Figure 8. 12

Figure 9. Aerial photographs of Shimobara fishing port between 1997 and 2007. 13

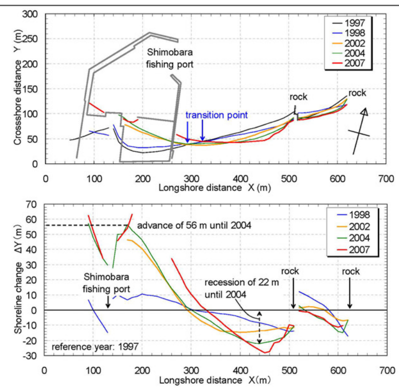
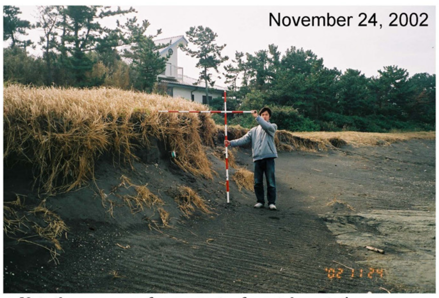


Figure 10. Shoreline configuration and changes. 14

• A sand dune was eroded and rocks, which were raised during the Kanto Earthquake in 1923, were exposed.

Figure 11. Nearby coast east of Shimobara fishing port (November 24, 2004). 15



• Note the exposure of many roots of coastal vegetations, implying the disappearance of a sand dune covered by vegetations.

Figure 12. Scarp with 1.6 m height formed in erosion zone (November 24, 2002) 16

• Sand was transported by longshore sand transport from outside to inside the wave shelter zone.

Figure 13. Sand accumulation and berm formation immediately east of the fishing port (November 24, 2002)

17

• A berm was formed owing to successive sand deposition at this site.

Figure 14. Seawall of Shimobara fishing port (November 24, 2002).

18

Figure 15. Wave overtopping to the corner of the seawall (November 24, 2002).

19

• The same location as that in Figure 15.

Figure 16. Markedly advanced shoreline owing to wave-sheltering effect of extended breakwater (July 26, 2004).

20

Beach Erosion Associated with Formation of Wave-shelter Zone upon Construction of Offshore Breakwater
(3) Wada Port

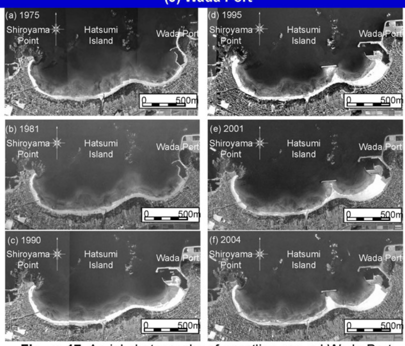


Figure 17. Aerial photographs of coastline around Wada Port.

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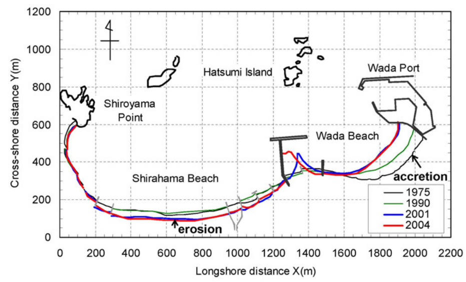
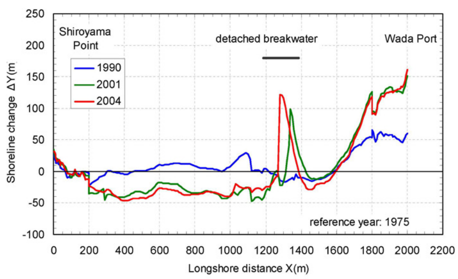


•The main cause is the extension of the breakwater of Wada Port, with an additional effect resulting from the construction of the detached breakwater.
•Because a groin was extended behind the detached breakwater, longshore sand transport, which moved freely eastward or westward without such a facility, was completely disrupted, resulting in the formation of two isolated pocket beaches.

Figure 18. Shoreline configuration and changes.

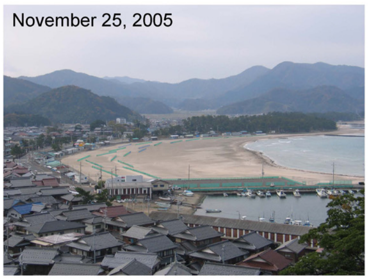
22



•This example clearly shows that when a breakwater is extended at one side of a pocket beach, the entire beach is affected.

Figure 19. Shoreline configuration and changes.

23



• Note that a very wide beach was formed thanks to the wave-sheltering effect!
• But it automatically means severe erosion on the west coast.

Figure 20. Oblique view of nearby coast of Wada Port.

24

Beach Erosion due to Decreased Fluvial Sediment Supply

Example: Tenryu River & Enshu-nada coast

- **Erosion triggered by decreased fluvial sand supply due to the construction of dams and excess riverbed mining.**

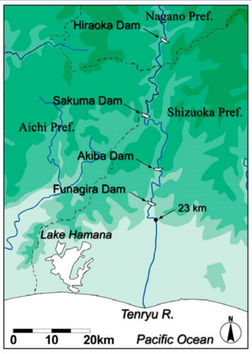


Figure 21.

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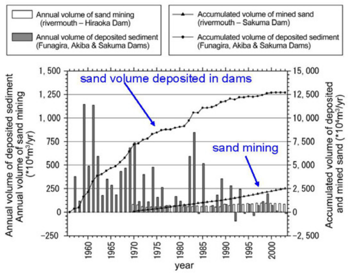
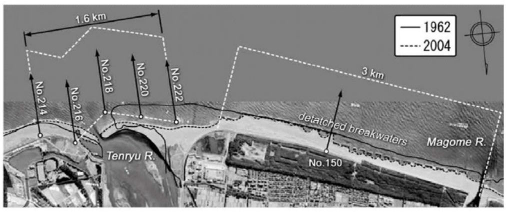


- The total amount of sand mined since 1970 → at least 25 million m^3
- Sand deposited upstream in dams → 125 million m^3
- 150 million m^3 of sand has been prevented from reaching the Enshu-nada coast.
- Cut ratio of sediment transport → Approximately 90% of the annual sand supply of the river was cut.

Figure 22. Sand accumulation in reservoirs of major dams and sand mining in Tenryu River watershed.

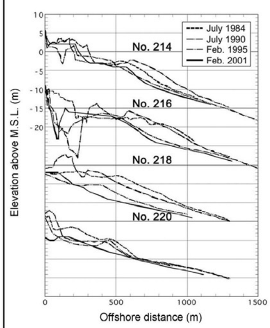
26



- Solid line: shoreline in 1962 & broken line: Shoreline in 2004
- The shoreline receded due to reduced sediment discharge from the river.
- Now detached breakwaters built west of the river mouth block continuous sand supply to west coast.

Figure 23. Shoreline recession at Tenryu River mouth and alignment of survey lines.

27



- **A 500-m-wide terrace offshore of the mouth in 1984 had entirely disappeared by 2004, as shown in the profile changes along transect No. 218.**
- **The seabed depth at the outer edge of the terrace increased by a maximum of about 5 m.**
- **Severe shoreline recession and the disappearance of the terrace, which was a reservoir of sand for longshore sand transport, thus occurred.**

Figure 24. Change in longitudinal profiles along four survey lines across the bar of the river mouth.

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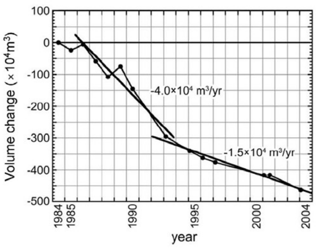

- Examined volume of sand removed from the terrace in a rectangular area 1.6 km long and 1 km long
- Rate of decrease in the total sand volume: 400 × 10^3 m^3/yr between 1986 and 1993, After 1993, 150 × 10^3 m^3/yr.
- The total decrease in volume: 4.6 million m^3 between 1984 and 2004
- Mean rate of decrease: 230 × 10^3 m^3/yr

Figure 25. Changes in sand volume offshore of the river mouth.

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- **As a measure, 22 detached breakwaters have been constructed.**
- **These breakwaters protruded from the shoreline, and the flow of sand toward the west coast has become hindered.**
- **Even though sand supply from the river is artificially increased by sand bypassing, it is difficult for such sand to be transported.**

Figure 26. Oblique aerial photograph of Hamamatsu-goto coast taken in January 2005.

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- **Five detached breakwaters had been constructed to protect the hinterland, but eastward longshore sand transport was obstructed by these structures, causing downcoast erosion.**

Figure 27. Aerial photograph of Ryuyo coast located east of Tenryu River mouth, looking east.

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Figure 28. High seawall and concrete armour units placed along shoreline

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Legal Issues Related to Beach Erosion

Example of Otsu fishing port

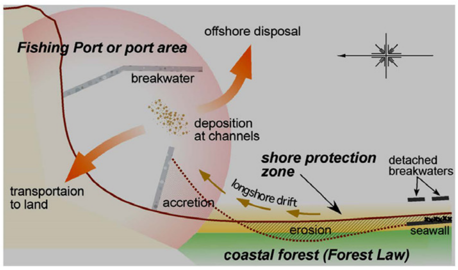

Figure 29. Coastal management areas and related laws in Japan.

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Legal Issues Related to Beach Erosion

Example of Otsu fishing port

•The construction of fishing ports, the management of coastal forests, and shore protection works are independently carried out by different agencies.

•Each work is planned so as to achieve the maximum economic rationality without consideration of the degradation of the environment in the surrounding area; this is **local optimization**.

•The optimal adjustment of the flow of sand through cooperative work among various management offices has been postponed. There is no common principle for the sound maintenance of national land.

•Thus, fundamental measures were difficult to adopt and stopgap measures were selected instead, which rapidly produced an artificial coastline.

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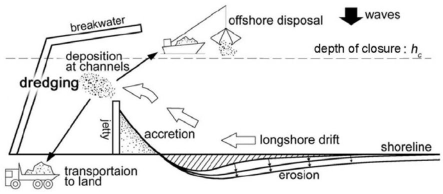
Legal Issues Related to Beach Erosion



- **Dredging** is conducted to maintain a sufficient channel depth, and dredged materials have been **disposed of offshore** or transported to land on the basis of **standards** designated by the Fishing Port Act or Port Law.
- When an offshore breakwater or a jetty preventing sand deposition inside the port is shallower than the **depth of closure**, h_c, of sand movement by waves, sand is again transported by longshore sand transport inside the port after dredging, meaning that successive dredging decreases the volume of sand on nearby beaches.

Figure 30. Sand deposition inside port and erosion triggered by dredging.

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Discussion

- When an offshore breakwater is constructed on a straight coast, forming a wave-shelter zone behind the breakwater, longshore sand transport from outside to inside the wave-shelter zone is induced.
- The stable shoreline configuration can be practically predicted using the Hsu and Evans (1989)' method, for example. Nevertheless, this is exactly what occurred between 1998 and 2007 at Shimobara fishing port.
- The natural coast, which had long been used for swimming, was altered to an artificial coastline, losing its value for recreational use.
- Although the **natural** shoreline changes are generally **reversible**, as seasonal beach rotation (Short and Masselink, 1999), the shoreline changes associated with the formation of wave-shelter zone caused by the construction of port breakwater described in this study were **irreversible**.
- Dredging conducted on the basis of general standards, with dredged sand disposed of independently by individual management authorities, results in beach erosion on the nearby coasts.
- The numbers of fishing ports and commercial ports in Japan are **2,931** and **1,079**.

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Discussion (continue)

- This means that, on average, there is **one port per 8.5 km** nationwide, since the total length of coastline in Japan is 34,000 km.
- Many of the ports that are constructed on sandy beaches have the same problems as those discussed in this paper.
- Therefore, beach erosion and accretion associated with the formation of wave-shelter zone can be seen elsewhere in Japan.
- Thus, natural beaches in Japan have been disappearing rapidly; the natural sandy beach is becoming an **'endangered geomorphology'** in Japan.
- New measures based on **comprehensive sediment management** must be taken instead of **local optimization** using hard structures.

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Conclusions

- Coastal problems in Japan are not simply due to problems in coastal engineering but are mainly a result of the social system in Japan, including the legal system.
- It is very difficult to change this situation through only administrative efforts because it is deeply related to the mindset past administrations. Through the collaboration of specialists, engineers, and NPOs, a flexible social system that can be modified efficiently must be developed.
- The mutual exchange of information must be enhanced. Instead of each coastal management office narrowly pursuing its set of responsibilities, the long-term planning of coastal works including **set-back of the coastline**, if necessary, is strongly required, as well as a necessity of **recycling sand dredged** from inside ports as a material for beach nourishment.

For detail, please read the book coming soon.

Uda, T.: Japan's Beach Erosion: Reality and Future Measures, World Scientific Publishing Co., Ltd.

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附件三、來台指導期間相關照片

104年10月12日(星期一)

水利署第六河川局進行此次服務指導的區域相關簡介

104年10月13日(星期二)

水利署第六河川局進行高雄離岸堤群現況簡報

前往高雄茄萣、彌陀及蚵仔寮海岸進行離岸堤及海岸侵蝕及汙積狀況之現地勘查


13/10/2015 12:02

13/10/2015 12:05

13/10/2015 12:28

13/10/2015 12:27

13/10/2015 12:55

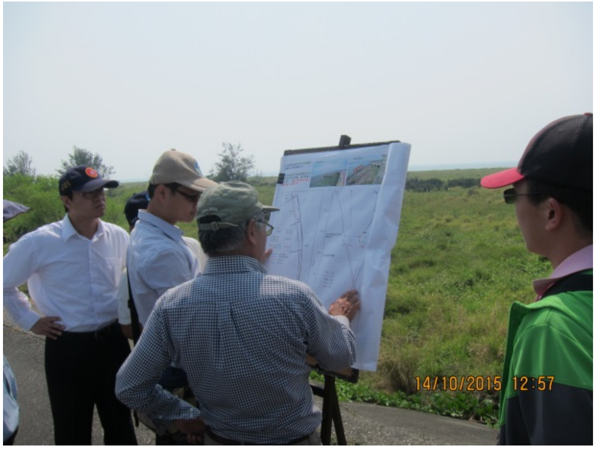
13/10/2015 13:00

國家實驗研究院海科中心，針對上午現勘提出建議及介紹日本離岸堤施作案例及其實務執行之經驗

104年10月14日(星期三)

台南市水利局安平水資源回收中心會議室進行台南黃金海岸人工養灘現況簡報

台南黃金海岸及安平商港區段的四個點進行現地勘查



國立成功大學水工試驗所針對上午黃金海岸至安平商港之海岸侵蝕及海岸漂砂造成海岸線變遷情形提出建議

104年10月15日(星期四)

水利署台中辦公處進行拜會。會中除了針對前二日於高雄及台南黃金海岸的現勘建議之外，並針對日本海岸工程面臨之課題及經驗進行交流座談會

附件四　宇多先生現勘後提供之勘查報告五份

一、FIELD OBSERVATION OF GOLDEN BEACH IN TAIWAN

FIELD OBSERVATION OF GOLDEN BEACH IN TAIWAN

Takaaki Uda

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uda@pwrc.or.jp

INTRODUCTION

Golden Beach located in Tainan has been eroded in recent years, and effective measures are required. Figure 1 shows the location map of the study area. In the central part of the study area, the Erren River flows into the sea, and Anping Harbor is located 6 km north of the river mouth. Golden Beach is located immediately north of the Erren River mouth. The number in Fig. 1 shows the site location where photographs were taken during the field observation. Field observation was carried out on October 13 and 14, 2015 from the southernmost site No. 1 to the vicinity of Anping Harbor (No. 16), as shown in Fig. 1.

RESULTS

(1) South of Erren River mouth

The south end of the study area is separated by the breakwater of Singda Port, which obstructs northward longshore sand transport, resulting in erosion north of the breakwater. Photo 1 shows the condition of the eroded coast, where concrete seawall extended straight along the coastline, and there was no foreshore in front of the seawall, and the coastline was protected by concrete armor units and large boulders against wave overtopping. In the offshore zone, detached breakwaters have been constructed. In this area, northward longshore sand transport, which was induced by the construction of the Anping Harbor breakwater, prevails and there is a fishing port breakwater upcoast, which blocks the sand supply from the upcoast. Thus, the sand volume in this area is gradually decreasing with the beach being eroded. Because the seawall and concrete armor units had only passively effected, their effect is limited to maintain the present shoreline. Even though detached breakwaters had been constructed, the recovery of sandy beach is impossible, because sand supply from the upcoast is entirely blocked by the fishing port breakwater. To recover sandy beach, beach nourishment using material with sand and gravel is needed, because the beach slope at this site has already steepened.

Photo 2 shows a scene of the beach between the detached breakwaters at site No. 2. Note that the backshore is widely covered with the vegetation zone. Coastal vegetation can grow only when the backshore is stable even in storm wave conditions, and thus the location shown in Photo 2 is found to be stable. The reason is such that detached breakwaters were constructed on both sides of this area. The sandy beach shown in Photo 2 was formed owing to the depositional effect of sand by these detached breakwaters, and sand was deposited even without beach nourishment. However, such sand is still gradually moving northward by northward longshore sand transport, implying that the sand volume in this area gradually decreases, resulting in the shoreline recession.

Immediately south of the Erren River, coastal road extends along the coastline and the area inland of this road is crowded with houses, as shown in Photo 3. To protect the densely-populated area, a super dike with a concrete pavement on top of the coastal dike has been constructed. Beyond this coastal dike, a straight walkway extended along the seaward part of the coastal dike with a fence, as shown in Photo 4. However, seaward of this fence, there was no sandy beach and the coastline was entirely covered with large boulders and concrete armor units, as shown in Photo 5. On the south side of the location shown in Photo 5, the seawall was directly exposed to sea waves. Under such a condition, normally wave overtopping over the seawall becomes severe. Such condition can be observed by the presence of dead trees on the bank, as shown by arrow A in Photo 6. Similarly, if we walk along the coastline and watch the vegetation, we can get the information of the severity of the wave overtopping over the seawall.

On the other hand, a wide sandy beach extended behind the detached breakwater located on the left side of the Erren River, as shown in Photo 5. The cuspate foreland behind the detached breakwaters was once formed owing to the depositional effect of the detached breakwater, but now the sand volume of the cuspate foreland is gradually decreasing owing to the discharge of sand by northward longshore sand transport.

(2) North of Erren River mouth

Although once there was a sandy beach immediately north of the Erren River, the beach was rapidly eroded owing to the discharge of sand by northward longshore sand transport. At present, no sandy foreshore exist in front of the seawall, as shown in Photo 7. Concrete blocks were placed along the shoreline with many drift woods. Photos 8 and 9 show the coastal condition immediately north of the river mouth. A coastal dike extends and the coastal vegetation grows along the landward side of the dike. When we carefully watch the front of the vegetation, as shown by arrow B in Photo 9, dead trees can be identified. This means that the elevation of the concrete armor units in front of the vegetation is low enough to permit the wave overtopping. Photo 10 shows the detailed condition of the area, as shown by arrow C in Photo 9, where dead trees can be observed. In this area, the elevation of the area in front of the sloping revetment of the dike is supposed to be low and no vegetation grow, in contrast to the site No. 9, as shown in Photo 9. It is realized from this that the wave overtopping is severe at this site. The condition of trees grown in the backyard of the coastline becomes good index to judge the extent of the wave overtopping over the seawall.

On Golden Beach, there was a beautiful sandy beach composed of fine sand in front of the seawall in 2008, but the sandy beach was severely eroded, and only a narrow foreshore is left at present. Figure 2 show the sequence of beach erosion on Golden Beach: (a) January 3, 2008, (b) June 30, 2009, (c) March 1, 2012, (d) January 28, 2014, and (e) June 11, 2015. Although a natural sandy beach extended in January 3, 2008, beach was rapidly eroded, and the shoreline was protected by groins. Photo 11 shows the coastal dike constructed at Golden Beach and a narrow foreshore in front of the dike. Up to now, six groins have been constructed to control northward longshore sand transport. Photo 12 shows the groin at the downdrift (north) end of the beach. The bamboos placed on the foreshore are tool for aquaculture of the oysters. Photo 13 shows the enlarged view of the groin at north end of the beach. The concrete blocks composed of the groin subsided up to such a level that the crown of the groin is invisible, as shown in arrow D. Longshore sand transport is the largest near the shoreline so that this shows that large part of longshore sand transport can pass this groin. Photo 14 shows the downcoast of the same groin. There is a difference in the shoreline position between both sides of the groin, and the shoreline on the north side retreats, suggesting that this groin has still an ability blocking part of the longshore sand transport, although the effect of blocking longshore sand transport is low.

Photo 15 shows the eroded location downcoast of these groins. A scarp was formed by the successive shoreline recession and large boulders were placed along the severely eroded area. Thus, northward longshore sand transport is assumed to still dominate downcoast of these groins, but the shoreline orientation approaches almost a constant in further downcoast area. Therefore, if a groin is constructed at an appropreate location, downcoast erosion will be avoided, and the upcoast (Golden Beach's) shoreline will be stabilized.

Finally, Photo 16 shows the accretion area immediately south of Anping Harbor. A large amount fine sand was deposited in this area because the port breakwater blocked northward longshore sand transport. In this accretion area, the shoreline has gradually advanced with maintaining the same berm height so that a very flat lowland was formed immediately south of the fishing port.

CONCLUDING REMARKS

(1) South of the Erren River, many detached breakwaters have already been constructed. These breakwaters once succeeded in blocking northward longshore sand transport. However, deposited sand was gradually transported northward, while losing part of cuspate foreland behind the detached breakwaters. In this area, beach nourishment using coarse material containing sand and gravel is supposed to be effective to recover sandy beach.

(2) Immediately north of the Erren River, the shoreline has a convex form so that wave action in this area is strong, and the coastline is protected by the seawall and groins together with concrete armor units. It is considered to be difficult to recover sandy beach in this area.

(3) The foreshore width is narrow on Golden Beach because of successive erosion. In this area, the shoreline has a concave shape and groins have already constructed as well as the beach nourishment. Without structures such as groins or detached breakwaters, nourishment fine sand should be discharged again, because the wave-sheltering effect continues eternally. It is recommended that additional groin(s) is (are) constructed downcoast (north) of Golden Beach for the entire shoreline between Golden Beach and Anping Harbor to be stable, and then beach nourishment using sand deposited immediately south of Anping Harbor is considered.

(4) In this case, we need numerical simulation using the mathematical model such as the contour-line-change model or the BG model (a three-dimensional model for predicting beach changes based on Bagnold's concept) to determine the location, length, and the point depth of the groin(s).

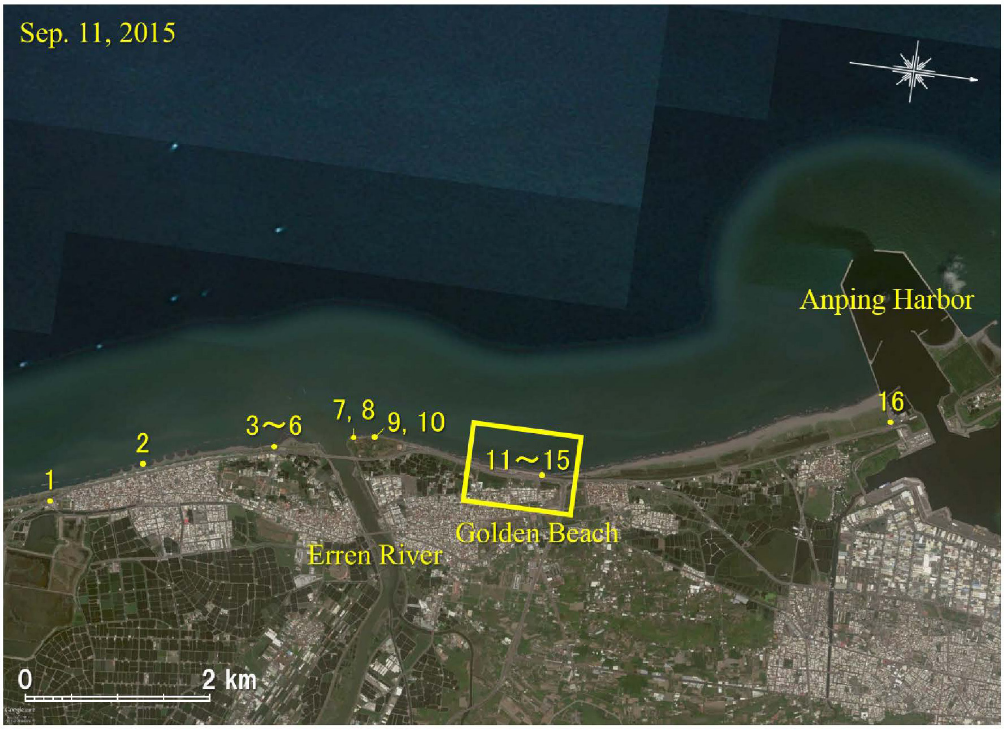

Fig. 1. Location map of Erren River, Golden Beach and Anping Harbor.


(a) Jan. 3, 2008
Golden Beach
0
200 m


(b) June 30, 2009
Golden Beach
0
200 m


(c) Mar. 1, 2012
Golden Beach
0
200 m


(d) Jan. 28, 2014
Golden Beach
0
200 m

Fig. 2. Sequence of shoreline changes on Golden Beach.

Photo 1. Southern coast covered with hard structures.

Photo 2. Cuspate foreland formed by depositional effect of detached breakwaters.

Photo 3. Super dike with concrete crown to protect coastal road and houses.

Photo 4. Walkway along coastal dike.

Photo 5. Large boulders and concrete blocks to protect coastline.

Photo 6. Coastal dike with gentle slope and vegetation.

Photo 7. Protected coastline at Erren River mouth.

Photo 8. Coastal condition immediately north of the river mouth (Site 8).

Photo 9. Coastal condition immediately north of the river mouth (Site 9).


Photo 10. Detailed condition of the area, as shown by arrow C in Photo 9.

Photo 11. Coastal dike constructed at Golden Beach.

Photo 12. Groin at downdrift (north) end of beach.

Photo 13. Enlarged view of groin at north end of beach.

Photo 14. Immediately downcoast of groin.

Photo 15. Eroded area downcoast of groins.

Photo 16. Accreted area immediately south of Anping Harbor.

二、SHORELINE CHANGES IN VICINITY OF ERREN RIVER MOUTH

SHORELINE CHANGES IN VICINITY OF ERREN RIVER MOUTH

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INTRODUCTION

South of Golden Beach is located the Erren River mouth, as shown in Fig. 1. In the vicinity of this river mouth, the satellite images have been taken since 2003. Here, the shoreline changes were investigated using these satellite images, selecting the Erren River mouth (Area I) and immediately south area (Area II) of the river mouth as the study areas. In both areas, five images taken on February 20, 2003, January 3, 2008, March 1, 2012, November 16, 2013, and February 25, 2015 were used. Figures 2 and 3 show the images of Area I of the Erren River mouth and Area II immediately south of the river. In both cases, the initial shoreline on February 20, 2003 is shown by the solid line in Figs. 2(e) and 3(e) taken on February 25, 2015 to compare the overall shoreline changes.

RESULTS

(1) Shoreline Changes in Area I

On February 20, 2003, large river mouth bars existed on both sides of the mouth, as shown in Fig. 2(a). Note the protruded shoreline on both sides as designated by arrows A and B. These protrusions are generally formed by the shoreward sand transport, where part of sand composed of a sand bar offshore of the river mouth is transported landward, and emerges from the seabed, resulting in increase in volume of sand of the foreshore. This phenomena occur, only if a large amount of sand is deposited offshore of the river mouth. In addition, a white-capped breaking waves can be seen in the offshore area, where the water depth is very shallow. On the left side of the river, a sand spit is growing, while enclosing previous sand spit, Similarly, a sand spit was formed on the right side of the opening of the river mouth. All these clearly show that the water depth at the mouth was shallow, and sand supplied from the river was transported northward.

By January 3, 2008, southern half of the offshore bar disappeared, as shown in Fig. 2(b), and the river mouth bar on the left bank of the river entirely disappeared as well. On the right bank of the river mouth bar, which was located offshore of the Erren River bridge on February 20, 2003, retreated by 135 m, and crossed the bridge. Thus, it is clear that the Erren River mouth area was severely eroded up to 2008.

By March 1, 2012, the river mouth bar on the right bank further retreated upstream of the bridge. South of the river mouth, two detached breakwaters have been constructed and a large cuspate foreland was formed behind the breakwaters. Because the water depth at the mouth of the river was supposed to be increased, sand deposited behind the breakwaters is assumed to be transported from the southern coast.

Up to November 16, 2013, the tip of the sand spit on the right bank attached to the upstream bank owing to further sand transport along the right river bank. In contrast, not only the size of the cuspate foreland behind the detached breakwaters markedly increased but also the size of the river mouth bar on the left bank increased, implying a large amount of sand was supplied from the south coast, instead of the river. For the fluvial sand supply to be transported to the river mouth, the river bed is assumed to be too deep.

On February 25, 2015, on the left river bank a river mouth bar developed, as shown in Fig. 2(e), and a sand spit formed, inplying that further sand sppply from the south coast occurred. In this figure, the initial shoreline on February 20, 2003 is also shown. When comparing the shorelines in 2003 and 2015, it is seen that the river mouth bar retreated in the upstream direction of the river along with the formation of a cuspate foreland behind the detached breakwaters. The former result suggests that the water depth of the river mouth increased owing to the dischage of sand by northward longshore sand transport.

(2) Shoreline changes in Area II

The satellite image taken on February 20, 2003 is shown in Fig. 3(a). At this stage, 16 detached breakwaters had already been constructed along the shoreline. Here, all these detached breakwaters are numbered 1 through 16, as shown in Fig. 3(a). Although the length of the detached breakwaters is 80 m, the offshore distance of the detached breakwater from the coastline increases from 100 m between No. 1 and No. 9, and then the distance increases northward with a maximum distance of 170 m between No. 13 and No. 16. At this stage, a cuspate foreland (tombolo) well developed between No. 1 and No. 9, but further north, no cuspate forelands developed except that behind No. 12.

On January 3, 2008, the size of the cusparte foreland behind detached breakwater Nos. 1−3 decreased compared with those in February 20, 2013. In constrast, sand was deposited north of No. 10, particularly between Nos. 13−15, a large amount of sand was deposited to form a wide foreshore. Up to March 1, 2012, the size of the cuspate foreland behind the detached breakwaters No. 1−5 decreased, whereas a large amount of sand was further deposited to form a large cuspate foreland behind Nos. 15 and 16. Up to November 16, the size of the cuspate foreland behind Nos. 1−5 decreased with the discharge of sand, and also the shoreline behind Nos. 13−16 started to retreat. In this area, instead of the formation of a cuspate foreland behind each detached breakwater, overall shoreline advanced behind four detached breakwaters.

Finally, on February 25, 2015, the cuspate foreland behind No. 1−4 was severely eroded, and the cuspate foreland behind Nos. 13−16 was also eroded. Thus, in Area II, sand was deposited behind the detached breakwaters at first, but erosion started from the southern part of the beach, whereas in the northern area the shoreline advanced behind the detached breakwaters, implying that sand has been gradually transported northward, even though the shoreline was protected by detached breakwaters.

CONCLUDING REMARKS

In Area I around the Erren River mouth, beach erosion occurred between 2003 and 2015, and a large amount sand discharged from this area. Although a large river mouth bar had been formed before February 20, 2003, it was eroded away up to February 25, 2015, resulting in exposure of both banks to waves. The cause is assumed to be imballance of longshore sand transport, i.e., sand supply from the south coast decreased, whereas northward longshore sand transport prevailed in this area under the condition that the fluvial sand supply from the Erren River had decreased. In Area II immediately south of the river, where detached breawaters had already constructed, at first sand was deposited behind the detached breakwaters but such sand was gradually transported away by northward sand transport, resulting that once-formed cuspate forelands behind the detached breakwaters disappeared because of the permeable structure.

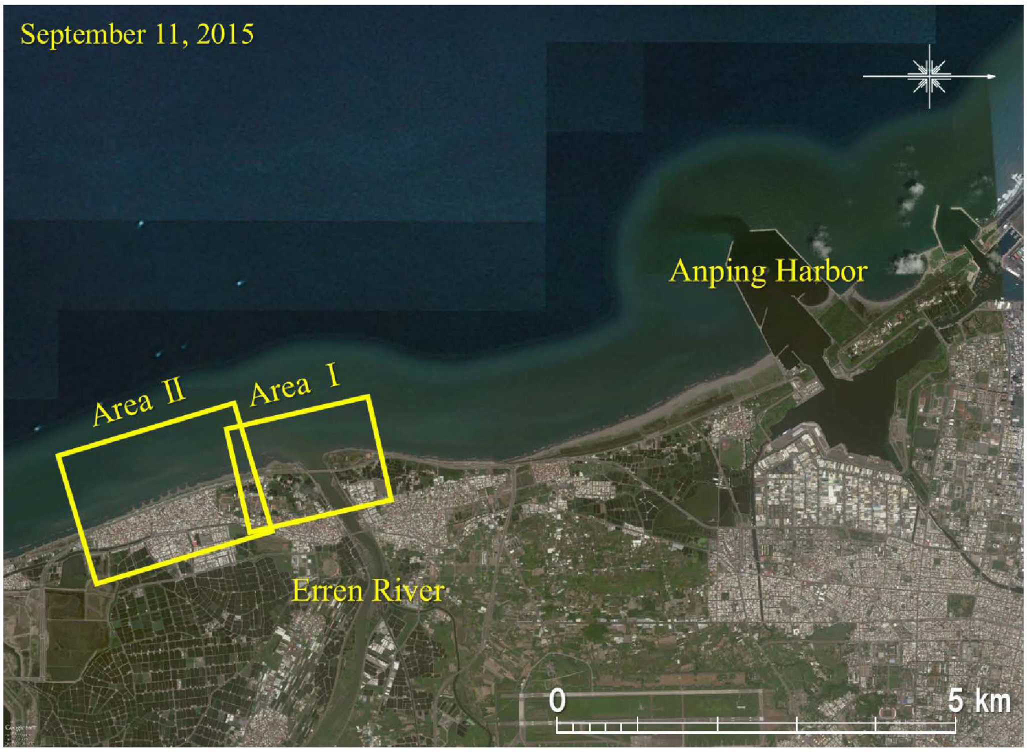
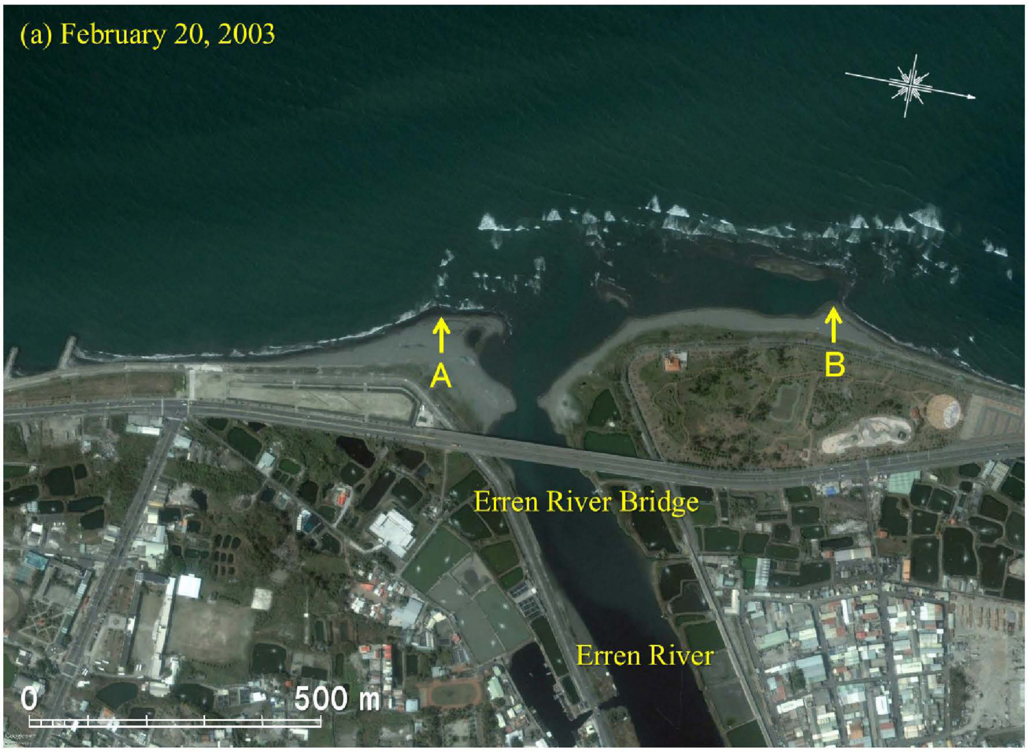


Fig. 1. Location of study areas.


(a) February 20, 2003
A
B
Erren River Bridge
Erren River
0
500 m

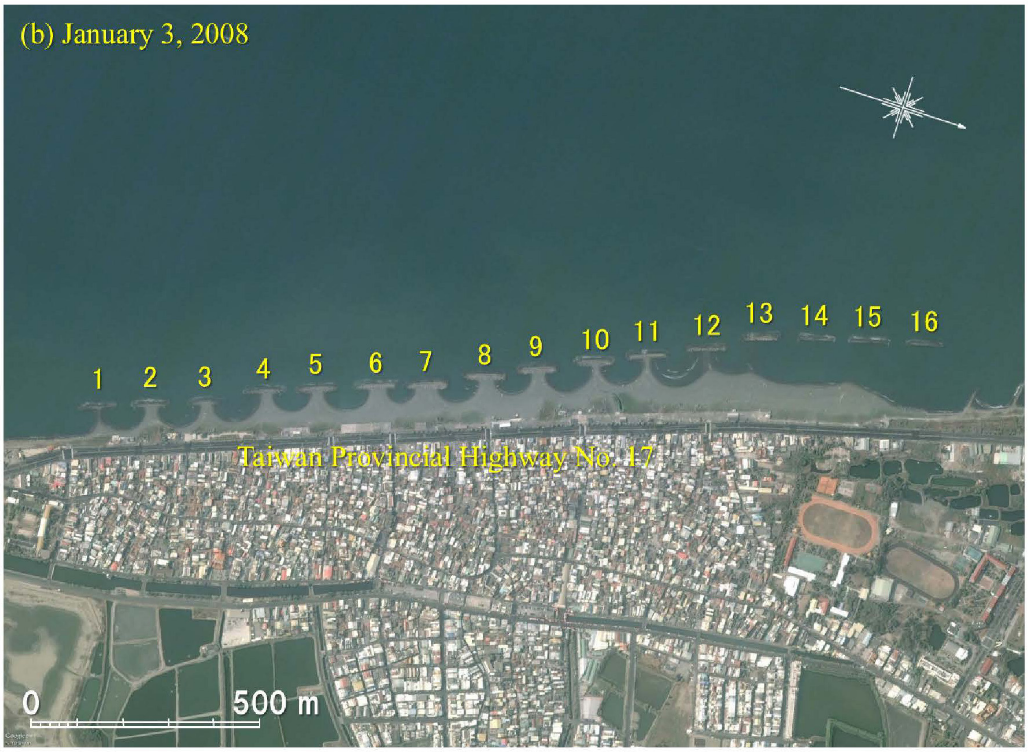

(b) January 3, 2008
Erren River Bridge
Erren River
0
500 m


(c) March 1, 2012
Erren River Bridge
Erren River
0
500 m


(d) November 16, 2013
Erren River Bridge
Erren River
0
500 m

Fig. 2. Satellite images of Area I around Erren River mouth.


(a) February 20, 2003
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Taiwan Provincial Highway No. 17
0
500 m


(b) January 3, 2008
1
2
3
4
5
6
7
8
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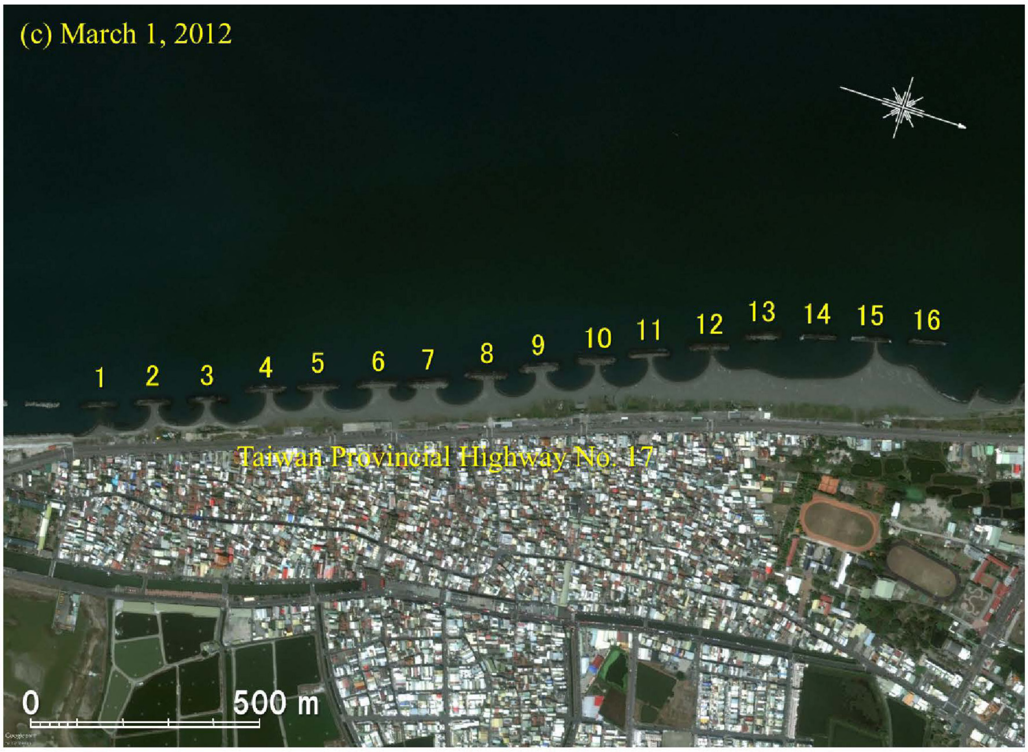
10
11
12
13
14
15
16
Taiwan Provincial Highway No. 17
0
500 m


(c) March 1, 2012
1
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Taiwan Provincial Highway No. 17
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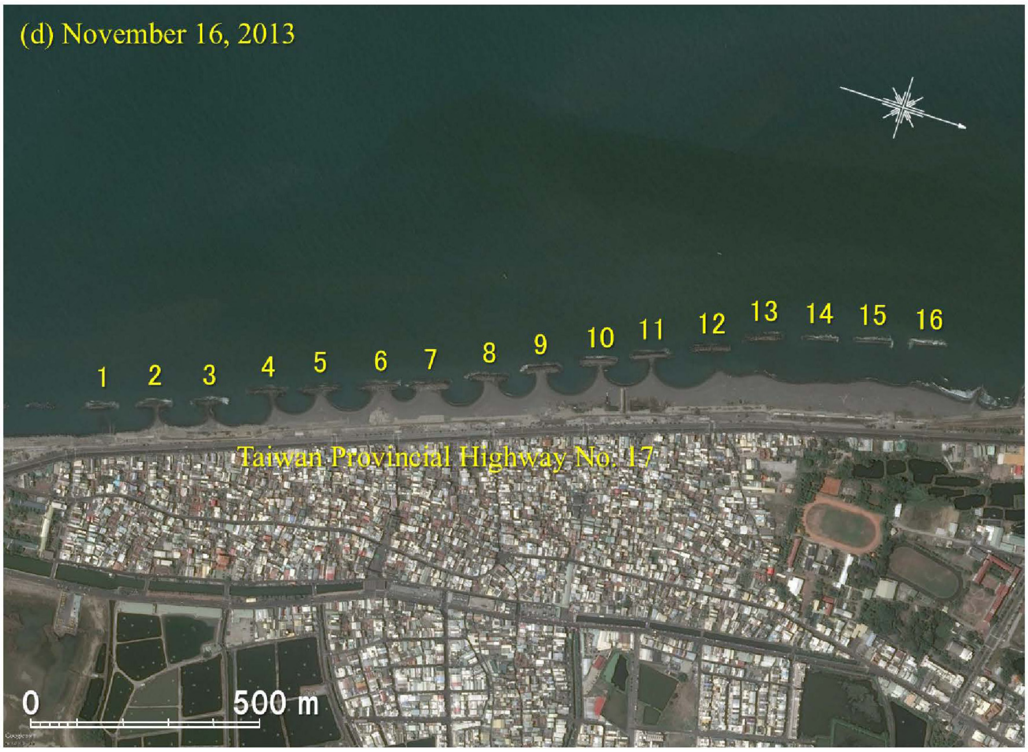
500 m


(d) November 16, 2013
1
2
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16
Taiwan Provincial Highway No. 17
0
500 m

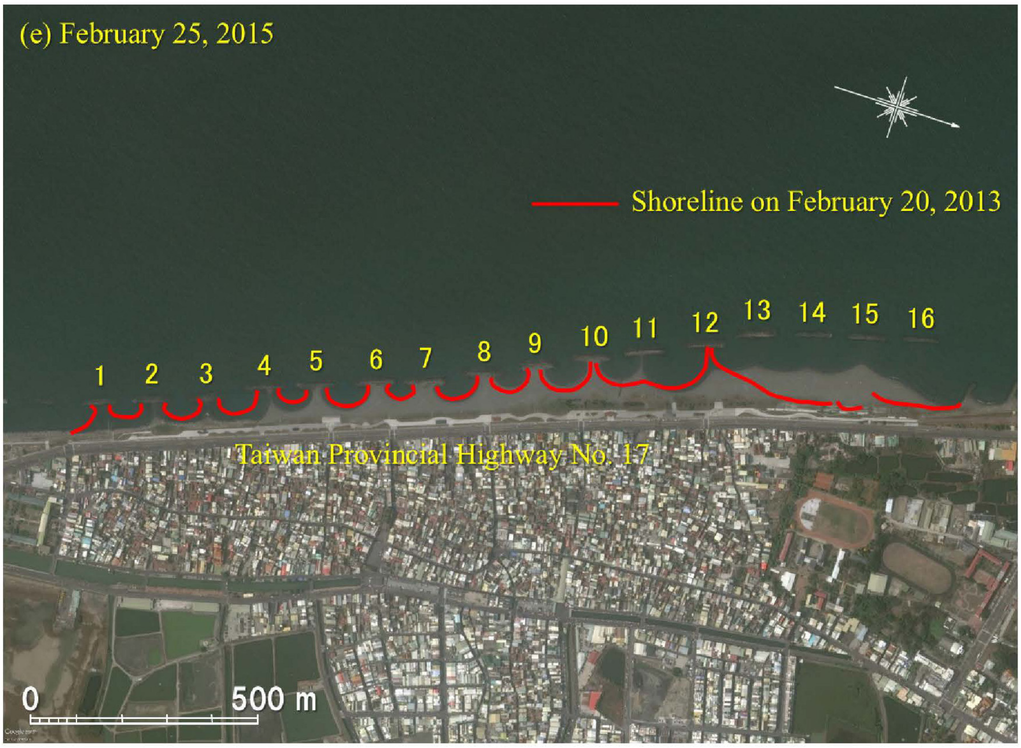

Fig. 3. Satellite images of Area II immediately south of Erren River mouth.

三、TOPOGRAPHIC CHANGES AND ESTIMATION OF LONGSHORE SAND TRANSPORT ON GOLDEN BEACH IN TAINAN

TOPOGRAPHIC CHANGES AND ESTIMATION OF LONGSHORE SAND TRANSPORT ON GOLDEN BEACH IN TAINAN

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BATHYMETRY AND PROFILE CHANGES IN STUDY AREA

The bathymetry in the study area between the Erren River mouth and Anping Harbor 6 km north of the river mouth is shown in Fig. 1, together with four transects along which profile changes were measured. The bathymetry was measured in November 2010. Transects S1 and S2 are located in the accretion zone south of Anping Harbor, whereas transects S3 and S4 are located in the eroded zone near the Erren River. Northward longshore sand transport, which was induced by the wave-sheltering effect of the Anping Harbor breakwater, was entirely blocked by the south breakwater of Anping Harbor, and a large amount of sand was deposited. A wide foreshore was formed south of the breakwater and a lowland with an elevation of 2.2 m above the mean sea level (MSL) extends, which is later shown from the profile changes along transect S1, because the shoreline has successively advanced in this area. Between the Erren River mouth and X = 2 km, there is no foreshore, and the area with no foreshore exactly coincides with the location where the seawall is exposed to waves.

The depth contours between the shoreline and -6 m advance with the greater displacement in the deeper contours, together with the shoreline advance north of X = 2 km. However, immediately south of Anping Harbor, a deep longshore channel is formed owing to the development of northward longshore currents with the development of longshore bars. In contrast, parallel contours extend along transects S3 and S4 with a steep slope near the shoreline, because a large amount of sand was transported away from this area. Along transect S3, no longshore sand bars develop, resulting in the exposure of the seawall to waves.

At the Erren River mouth, a deep channel of 4 m depth is formed and offshore of the river mouth a flat terrace of asymmetrical shape is formed, i.e., on the south side of the terrace the contours of -3 and -4 m smoothly extend alongshore, whereas on the north side a concave contours are formed owing to the development of oblique rip currents.

Figures 2–5 show the profile changes along transects S1–S4, and in each figure four profiles measured in October 2002, June 2009, May 2010 and December 2010 are shown. Along transect S1, a large amount of sand was deposited to form an upward convex profile near the shoreline with a foreshore width of 317 m. This clearly shows the deposition of sand which was transported by northward longshore sand transport. Although significantly large profile changes can be seen in offshore area, the profile changes almost converge approximately -6 m, implying that the depth of closure of this coast is approximately equal to -6 m. Along transect S2, the foreshore width becomes 172 m, which is smaller by 145 m compared with that along transect S1, because the transect is far from the Anping Harbor breakwater. In offshore zone, a large bar and trough develop, implying that fine sand is deposited in the offshore zone, which in turn suggests the difficulty of controlling sand movement by using structures.

Along transect S3, far from the Anping Harbor breakwater, the profile immediately offshore of the shoreline is concave and the seabed is very deep, which is a typical characteristics of the eroded beach. In this area, also the depth of closure is approximately is given by -6 m. Along transect S4 immediately north of the Erren River mouth, although a very flat offshore terrace existed in October 2002, this offshore terrace was eroded over time and a concave profile was formed by November 2010, and thus this transect has been eroded similarly to that along transect S3, even it is located next to the Erren River mouth.

ESTIMATION OF LONGSHORE SAND TRANSPORT RATE

When longshore sand transport is blocked by a structure, sand is deposited upcoast of the structure, resulting in the shoreline advance, whereas on the downcoast the shoreline retreats and a concave profile is formed due to the successive erosion. In this case, the change in shoreline position Δy and the change in the cross-sectional area ΔA can be determined from the profile changes. If we consider the correlation between ΔA and Δy, generally a linear relationship is obtained between them, and this regression coefficient between them is called 'the characteristic height of beach changes', h, and it can be used as a constant for transforming the change in foreshore area of the beach into the change in volume of sand of the beach.

This value can be determined from the temporal changes in profile along a transect, as shown in Figs. 2–5. Similarly, it can be determined from the comparison of two profiles measured at the same time along different transects. For example, transects S1 and S3 are selected in accreted and eroded areas, respectively. Two profiles along transects S1 and S3 are first superimposed, and then the shoreline changes and the change in cross-sectional area can be obtained from these superimposed two profiles, as schematically shown in Fig. 6. Finally, a relationship between between ΔA and Δy is calculated, as shown in Fig. 7. In the present case, we obtain the relationship

$$\Delta A = 9.2\Delta y. \quad (1)$$

Finally, the characteristic height of beach changes, *h*, becomes 9.2 m. This value is close to the sum of the berm height (h_R) 2.2 m and the depth of closure (h_c) 6 m (in fact, slightly larger value will be expected).

In addition to this, the increase in foreshore area south of Anping Harbor, which can be calculated from the shoreline change (later shown), is approximately given by 2.2×10^5 m^2. When multiplying this value by the characteristic height of beach changes (9.2 m), the entire volume of sand deposited in the south part of Anping Harbor can be calculated to be 2.0×10^6 m^3. Since the construction of the Anping Harbor breakwaters began in 1999, and 16 years have passed since then, the annual rate of the deposition of sand becomes approximately 12.5×10^4 m^3/yr. This volume of sand is considered to be supplied from the south coast by longshore sand transport.

CONCLUDING REMARKS

In the study area, northward longshore sand transport, which was induced by the wave-sheltering effect of Anping Harbor, prevails, and the rate of transport is estimated to be approximately 12.5×10^4 m^3/yr. Furthermore, the depth of closure h_c and the berm height h_R are approximately -6 m and 2.2 m in the study area, and the characteristic height of beach changes, *h*, is estimated to be 9.2 m. These values are important in designing the shape of the groin: the crown height, length and point depth of the groins: if the crown height of the groin is lower than h_R, part of longshore sand transport may pass through the groin, and if the point depth of the groin is shallower than h_c, part of sand will be transported downcoast, while turning around the tip of the groin. Also these characteristic values are important in predicting the beach changes using the numerical models.

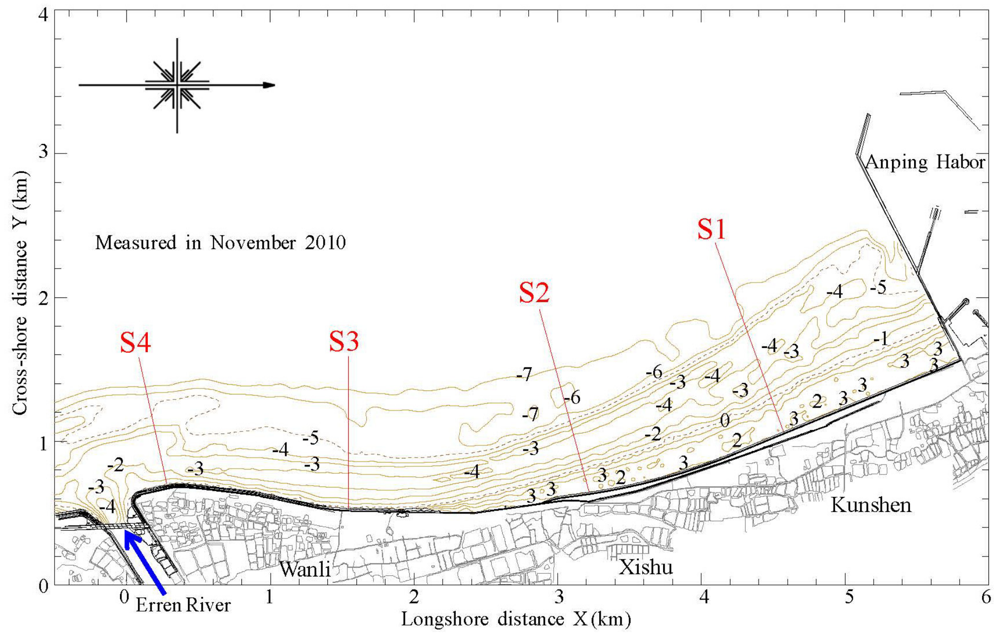

Fig. 1. Bathymetry between Erren River mouth and Anping Harbor.

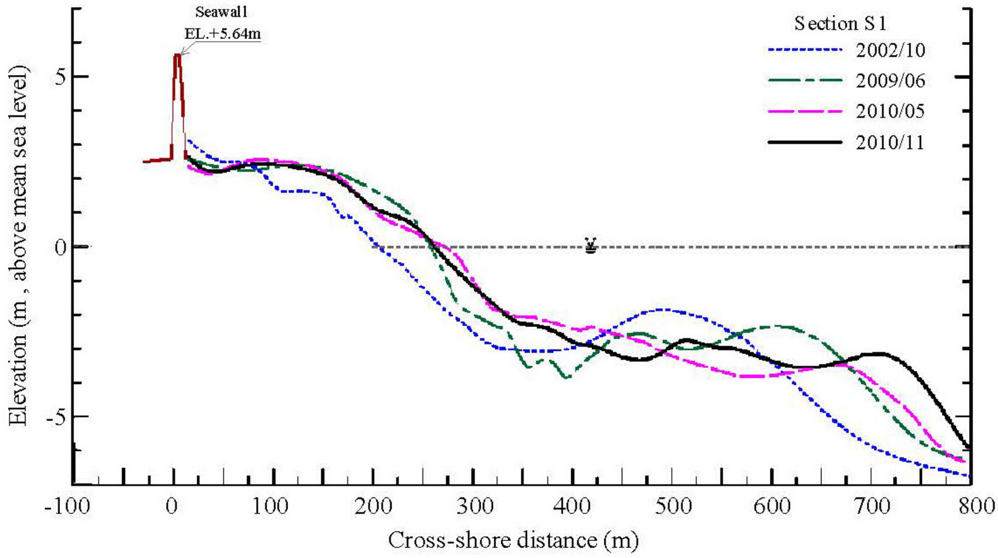

Fig. 2. Beach profile changes along transect S1.

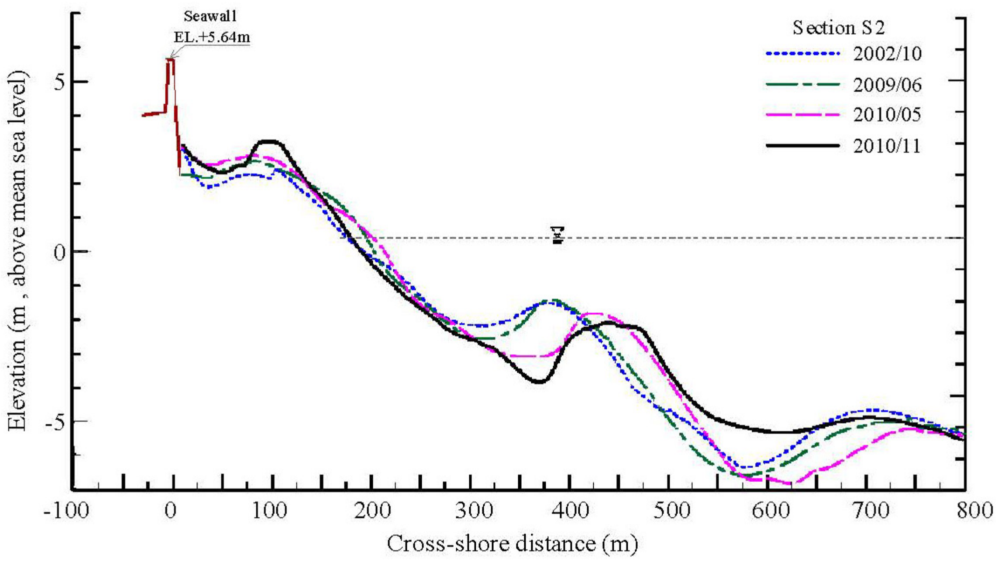

Fig. 3. Beach profile changes along transect S2.

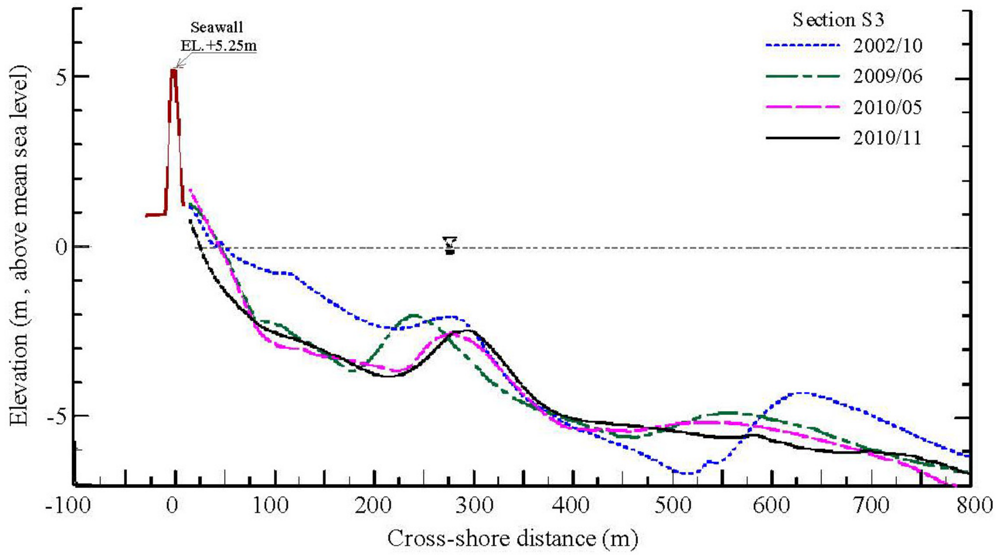

Fig. 4. Beach profile changes along transect S3.

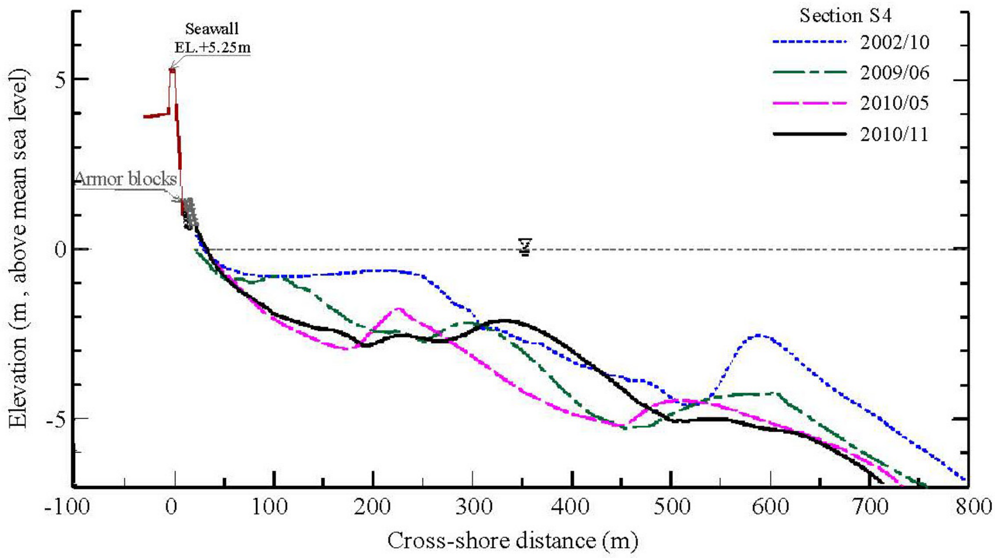

Fig. 5. Beach profile changes along transect S4.

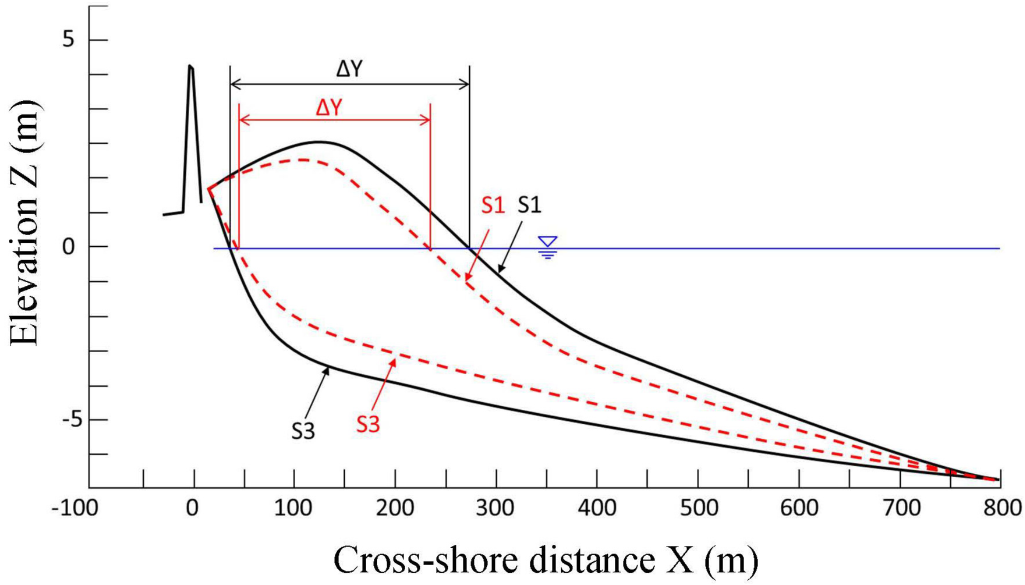

Fig. 6. Schematic diagram showing beach profile changes.

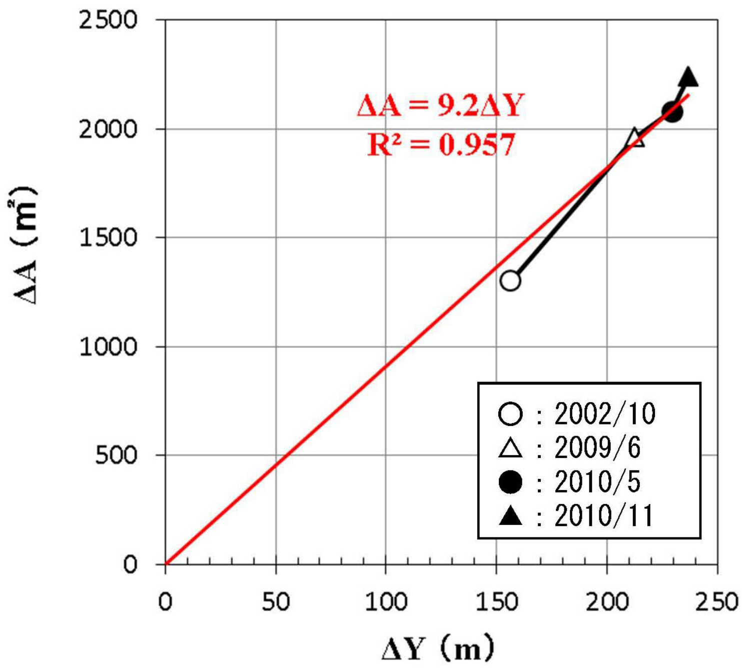

Fig. 7. Relationship between ΔA and Δy.

四、DAMAGES ON GOLDEN BEACH IN TAINAN

DAMAGES ON GOLDEN BEACH IN TAINAN

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The shoreline on Golden Beach has retreated in recent years, and the seawall constructed far from the shoreline was severely damaged. This situation is clearly seen in site photographs. Figure 1 shows the photograph of the foreshore, seawall and walkway along the shoreline on Golden Beach, taken on June 6, 2002 before the erosion. A wide foreshore extended in 2002. Note that a vegetation zone extended in front of the seawall, implying that the backshore was stable against waves, because the ground elevation of the backshore was significantly high. Because of the existence of a wide foreshore with a high elevation, the seawall was supposed to be stable.

Figures 2 and 3 show the damaged seawall on Golden Beach on January 26, 2011, looking the south and north, respectively. The plane walkway fell down owing to the successive erosion, and concrete blocks were placed in front of the damaged seawall in Fig. 2, as well as the installation of groins. Also Fig. 3 shows the damaged walkway along the seawall, showing the discharge of sand underneath the walkway indirectly caused by the lowering of the elevation of the foreshore.

By September 1, 2012, all sandy beach disappered with the exposure of gravel bed, as shown in Fig. 4. These beach changes were triggered by northward longshore sand transport induced by the wave-sheltering effect of the construction of the Anping Harbor breakwater. Sand volume has decreased by the imbalance in longshore sand transport, i.e., the outflow of sand from the area was larger than the inflow of sand. Therefore, even if a large amount of sand is to be nourished, the recovery of the previous wide sand beach is difficult, unless some structures which prevent sand from discharging northward from the site are installed.

Fig. 1. Wide sandy beach before erosion on Golden Beach (June 6, 2002).


Fig. 2. Collapsed seawall and concrete armor units (January 26, 2011).

Fig. 3. Damaged walkway (January 26, 2011).

Fig. 4. Severely eroded beach with exposure of gravel bed (September 1, 2012).

五、SHORELINE AND TOPOGRAPHIC CHANGES ON GOLDEN BEACH

SHORELINE AND TOPOGRAPHIC CHANGES ON GOLDEN BEACH

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INTRODUCTION

The construction of the south and north breakwaters of Anping Harbor located 4 km north of Golden Beach started in 1999 and completed by 2004. In 1985, before the construction of Anping Harbor, a sandy beach of the width ranging between 100 and 160 m extended between the Erren River mouth and a location, where Anping Harbor was to be constructed later. However, after the construction of Anping Harbor, the shoreline in the same area retreated by 120−160 m due to the erosion. In this study, the shoreline changes determined from aerial photographs and topographic changes determined from the bathymetric survey data were investigated. As the tidal range in Anping Harbor, the mean tide level is +0.356 m and the tidal range is 1.07 m. For wave conditions near the Erren River mouth, the significant wave height is less than 0.98 m (wave period 4-8 s) with the predominant direction of waves of SW in summer, whereas the significant wave height is less than 0.85 m (wave period 5-8.5 s) in winter.

GENERAL FEATURES

The previous report (Golden Beach 3) showed that the depth of closure h_c and the berm height h_R are approximately 2.2 and -6 m in the study area. At present, the length of the south breakwater measured off the coast is 1.9 km and the point depth is 13 m below MSL, which is much greater than the depth of closure h_c of approximately 6 m below MSL, and therefore longshore sand transport is completely blocked by the port breakwaters. Also the wave direction at Golden Beach seasonally varies from the SW and the NW so that the wave direction alternately changes in this area, implying that sand transported on the south side of Anpin Harbor during the summer season was difficult to escape from the wave-shelter zone of Anpin Harbor in winter, causing marked sand deposition in the adjacent area of the port.

SHORELINE CHANGES

Figure 1 shows the shoreline changes between 1985 before the construction of Anping Harbor and 2014, 11 years after its completion. The shoreline gradually advanced in the area between X = 2.8 km and Anping Harbor between 1985 and 2014, whereas the shoreline between the Erren River mouth and X = 2.8 km retreated with a maximum shoreline recession of 140 m. Note that there is a nodal point at X = 2.8 km, slightly north of Golden Beach, in this shoreline change. This means that northward longshore sand transport, which occurs in the depth zone between the berm height (+2.2 m) and the depth of closure (approximately -6 m), only pass through this nodal point at X = 2.8 km, causing the erosion upcoast and accretion downcoast.

BATHYMETRIC CHANGES BETWEEN 2002 AND 2015

Figure 2 shows the bathymetric changes between October 2002 and October 2015, the red and blue colors correspond to erosion and accretion of the beach. A large amount of sand was deposited north of the nodal point at X = 2.8 km. Offshore of this deposition zone a slender erosion zone with depths ranging -3 or -5 m extends northward until the attachement to the south breakwater of Anping Harbor. However, further offshore of this slender erosion zone, a large amount of sand was deposited and the deposition zone expanded close to the tip of Anping Harbor. This is mainly due to the fact that in this area fine material has been transported northward, while forming a bar and trough and was finally deposited offshore because of small equilibrium slope of sand.

In the south part of the study area, severe erosion occurred, particularly offshore the Erren River mouth. Eroded sand was entirely transported northward to deposit south of Anping Harbor. Even though eight groins were constructed in front of Golden Beach together with beach nourishment, beach was eroded. Note that erosion is severe immediately downcoast of the groins (between X = 2.2 and 2.8 km), indicating that the optimum location of groins must be carefully selected.

COMPARISON OF BATHYMETRIES IN 2010 AND 2015

Figures 3 and 4 show the bathymetries measured in 2010 and 2015. Overall features of the bathymetry do not change in five years, but some changes are noted. First, many groins were constructed between the Erren River mouth and Golden Beach as a measure against beach erosion, with 13 shorter groins near the river mouth and 8 longer groins in front of Golden Beach. When we investigate the bathymetry and bathymetric changes in the vicinity of Golden Beach using Figs. 2−4, it is seen that sand was locally deposited immediately upcoast of Golden Beach (south of long groins). However, beach was locally eroded with shoreline recession downcoast of Golden Beach, implying that the present measure using groins is not necessary effective.

Immediately south of Anping Harbor, the offshore contour of -5 m markedly advanced with further development of bar and trough topography. This clearly explains that large-scale beach changes are still occurring in this area.

CONCLUSIONS

Large-scale beach changes are still occuring in the study area, even though a measure using groins has been carried out. To solve the issue, further improvement is required. Present situation was analyzed as mentioned above, but to find out the appropreate solution, it is better to predict beach changes using the contour-line change model (Uda, 2010) or the BG model (a model for predicting three-dimensional beach changes based on Bagnold's concept)(Serizawa *et al.*, 2006), including the investigation of the effectiveness of beach nourishment with several structures.

REFERENCES

Serizawa, M., Uda, T., San-nami, T. and Furuike, K. 2006. Three-dimensional model for predicting beach changes based on Bagnold's concept, Proc. 30th ICCE, pp. 3155-3167.

Uda, T. 2010. *Japan's Beach Erosion - Reality and Future Measures*, World Scientific, p. 418.

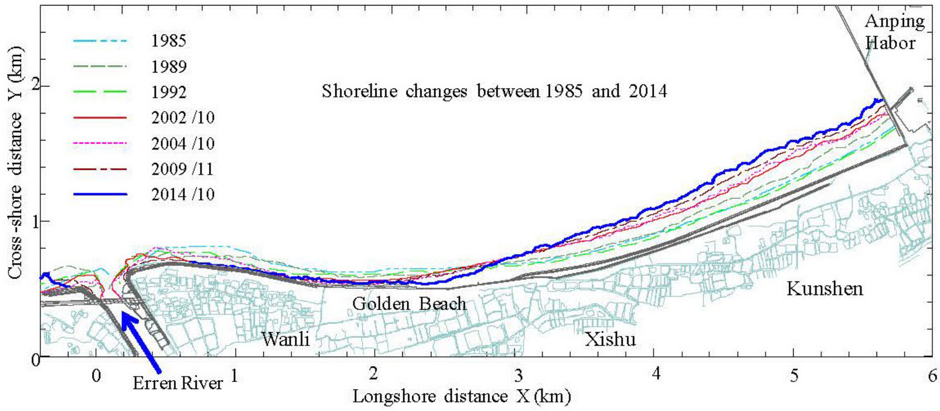

1985
1989
1992
2002 /10
2004 /10
2009 /11
2014 /10
Shoreline changes between 1985 and 2014
Anping Habor
Cross-shore distance Y (km)
Longshore distance X (km)
Golden Beach
Wanli
Xishu
Kunshen
Erren River

Fig. 1.

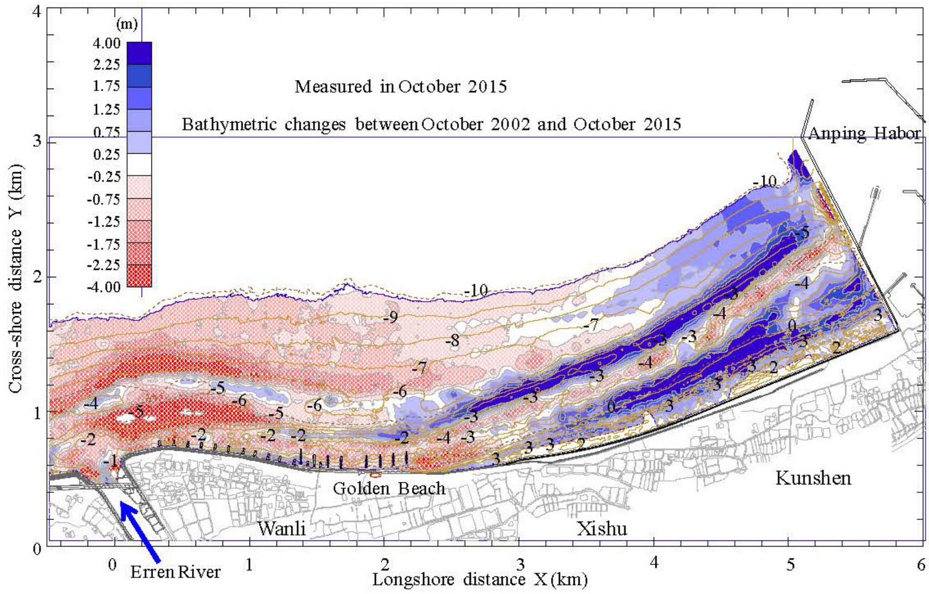
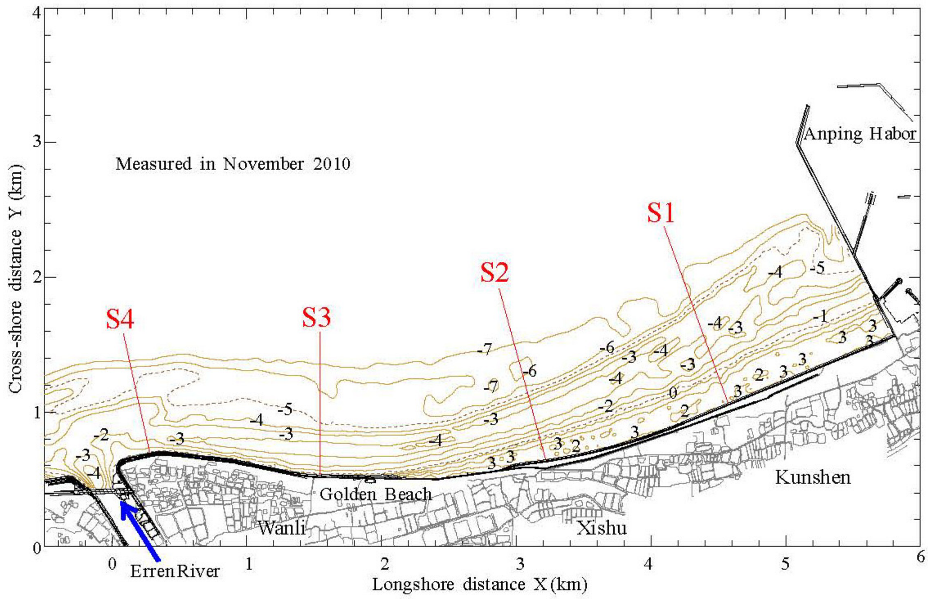
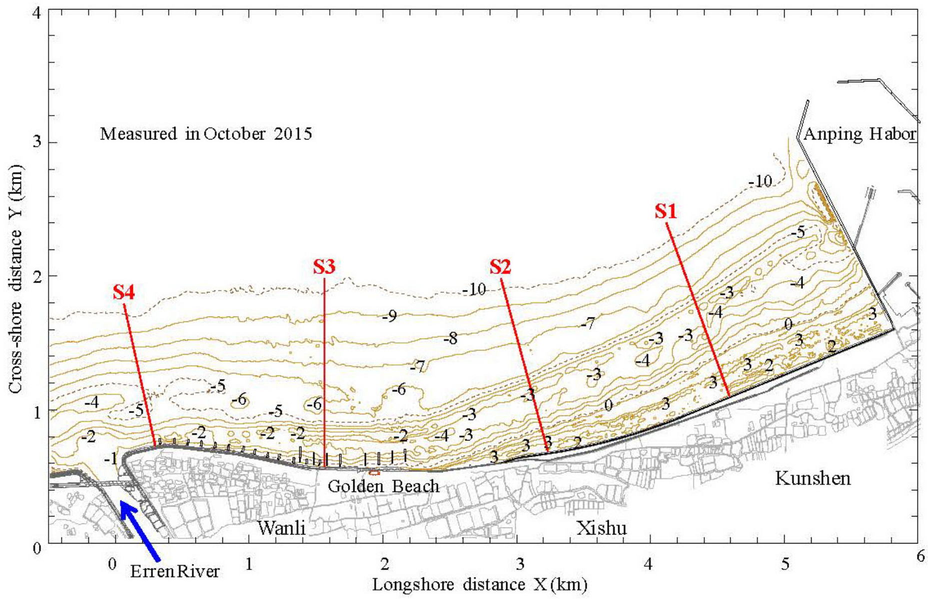

(m)
Measured in October 2015
Bathymetric changes between October 2002 and October 2015
Anping Habor
Cross-shore distance Y (km)
Longshore distance X (km)
Golden Beach
Wanli
Xishu
Kunshen
Erren River

Fig. 2.



Measured in November 2010
Anping Habor
S1
S2
S3
S4
Golden Beach
Wanli
Xishu
Kunshen
ErrenRiver
Cross-shore distance Y (km)
Longshore distance X (km)

Fig. 3.



Measured in October 2015
Anping Habor
S1
S2
S3
S4
Golden Beach
Wanli
Xishu
Kunshen
ErrenRiver
Cross-shore distance Y (km)
Longshore distance X (km)

Fig. 4.