



加勁擋土牆於 工程、防災與自然生態保護之應用

楊國鑫 博士

教授

國立臺灣大學 土木工程系



國立臺灣大學
National Taiwan University

大綱

1. 自我介紹
2. 土工合成材與加勁擋土牆簡介
3. 工程、防災與自然生態保護之應用
4. 結語



自我介紹





楊國鑫 博士

Yang, Kuo-Hsin Ph.D.

現職：

國立台灣大學 土木工程系 副教授, 2009-2016

學歷：

美國德州大學奧斯汀校區 博士, 2009

美國密西根大學安娜堡校區 碩士, 2005

國立臺灣大學 學士, 2000



專業服務：

國際地工合成材協會-土壤加勁技術委員

中華地工材料協會 理事

中華民國大地工程學會 理事

土木工程及建築國家標準技術委員會 (CNS-TC1) 委員

研究興趣：

擋土工程與邊坡穩定、地工合成材應用、大地環境與防災

研究規劃

研究主軸

水土資源保育

研究主題

大地環境與防災工程

主要研究方向

非飽和土壤
滲流與應力分析

應用於降雨入滲導致坡地崩塌與土石流誘發機制研究。



降雨導致邊坡崩塌

飽和土壤滲流與
土壤管湧破壞

應用於河堤等水工構造物與堰塞壩受洪水滲流影響之破壞機制研究。



堤防受洪水與滲流破壞

坡地治理與保育之
永續工程

應用地工合成材於坡地治理與保育，提升地工構造物對抗天然災害衝擊的穩定性。



以地工合成材加勁工法修復崩塌之道路邊坡

國際土工合成材 青年成就獎

2014 Young IGS Award

The Young Achievement Award International Geosynthetics Society

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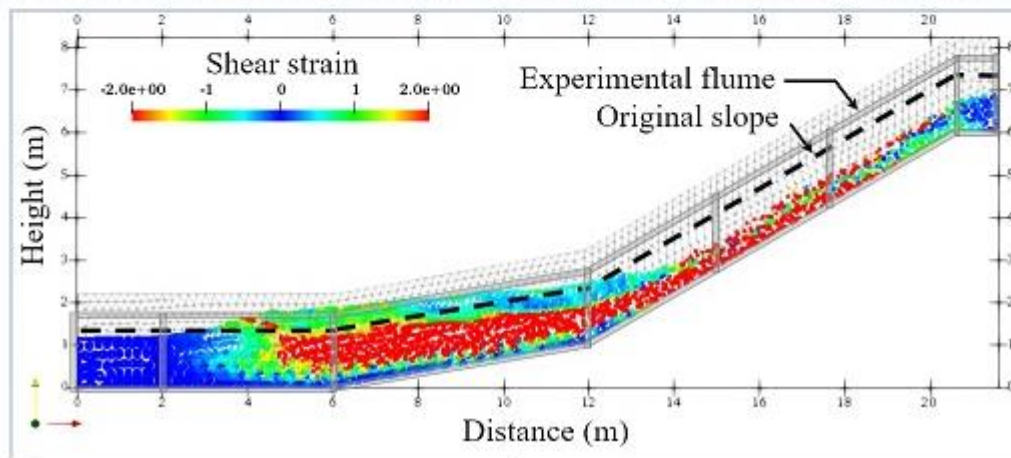


SLIDESHOW: 10 ICG Highlights and Honors

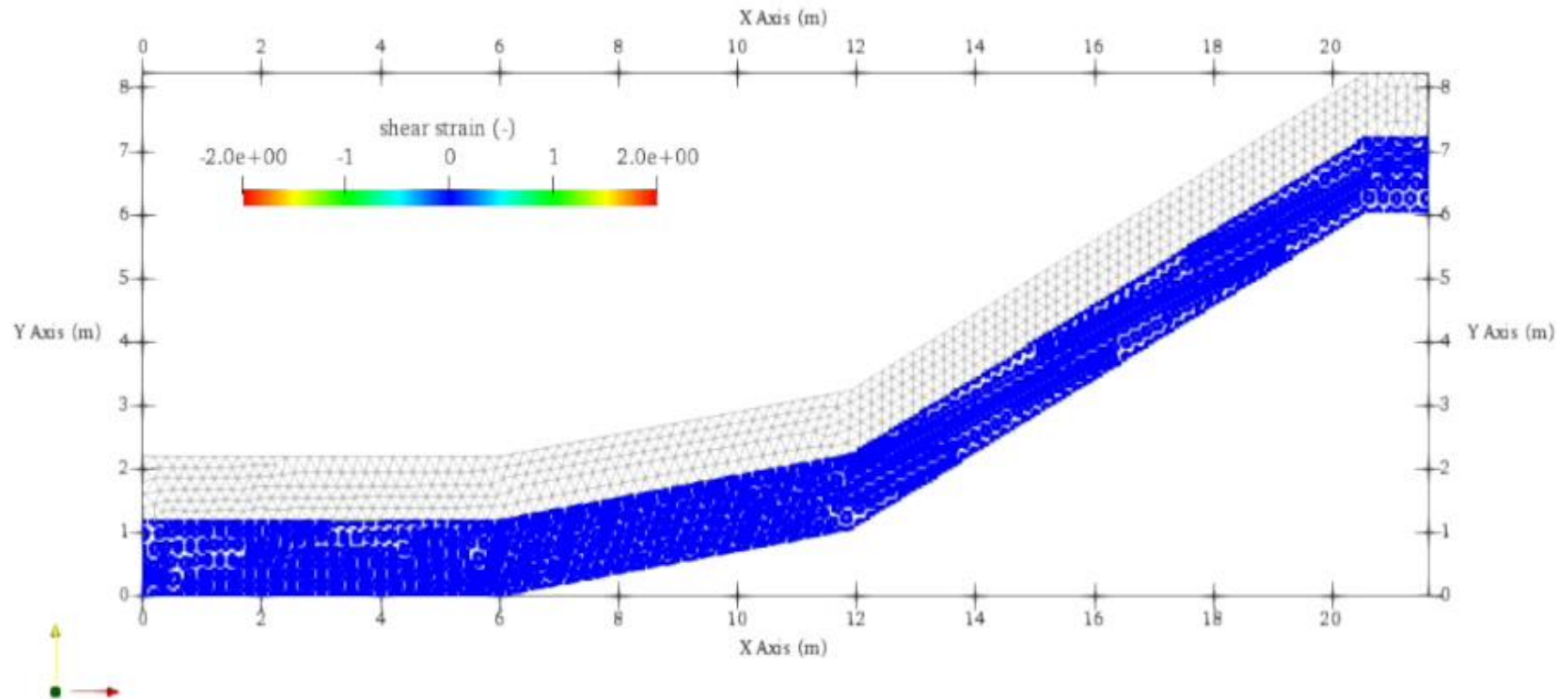
/ October 16, 2014



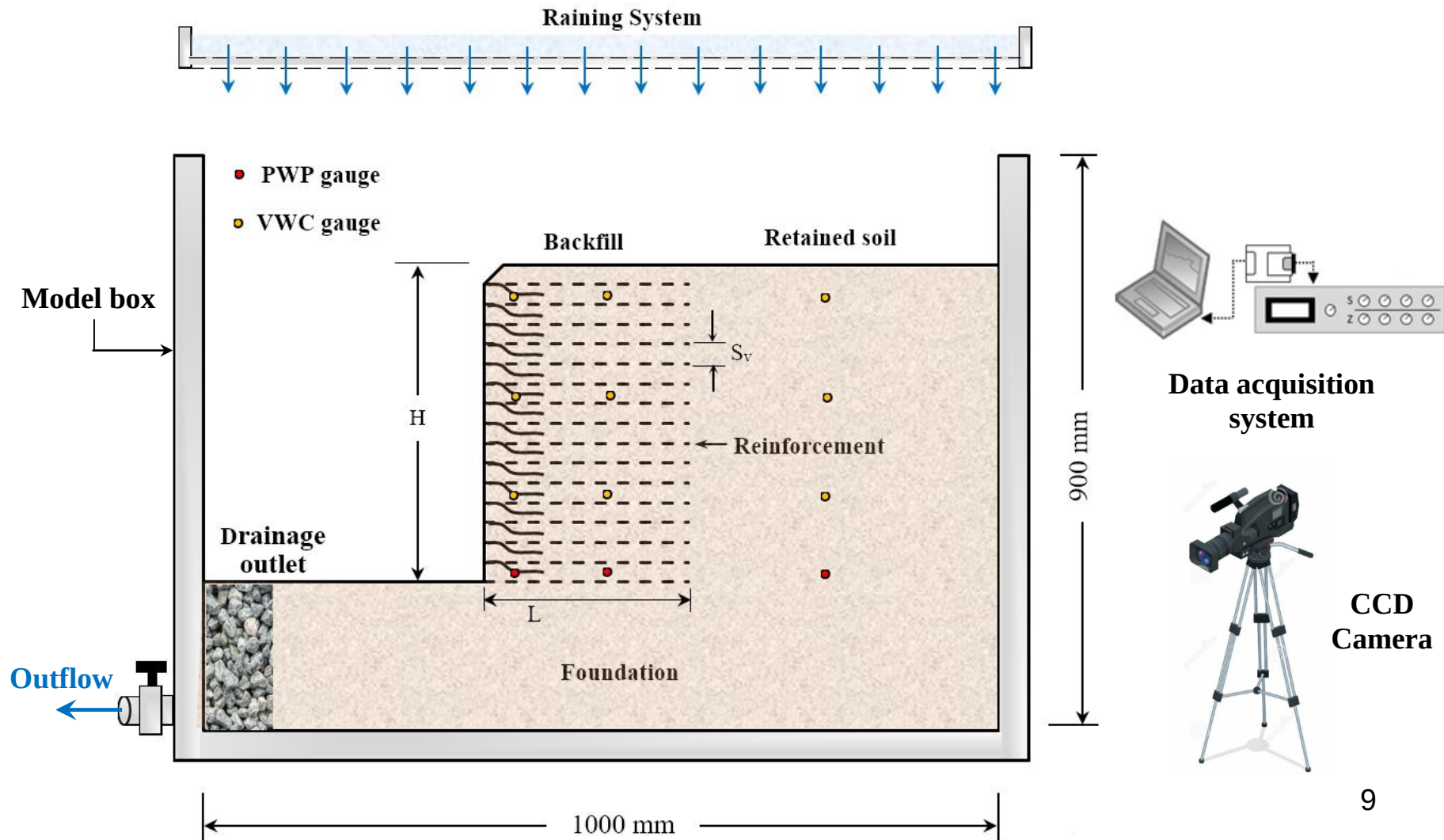
Material Point Method Analysis of Slope Post-Failure Mechanism

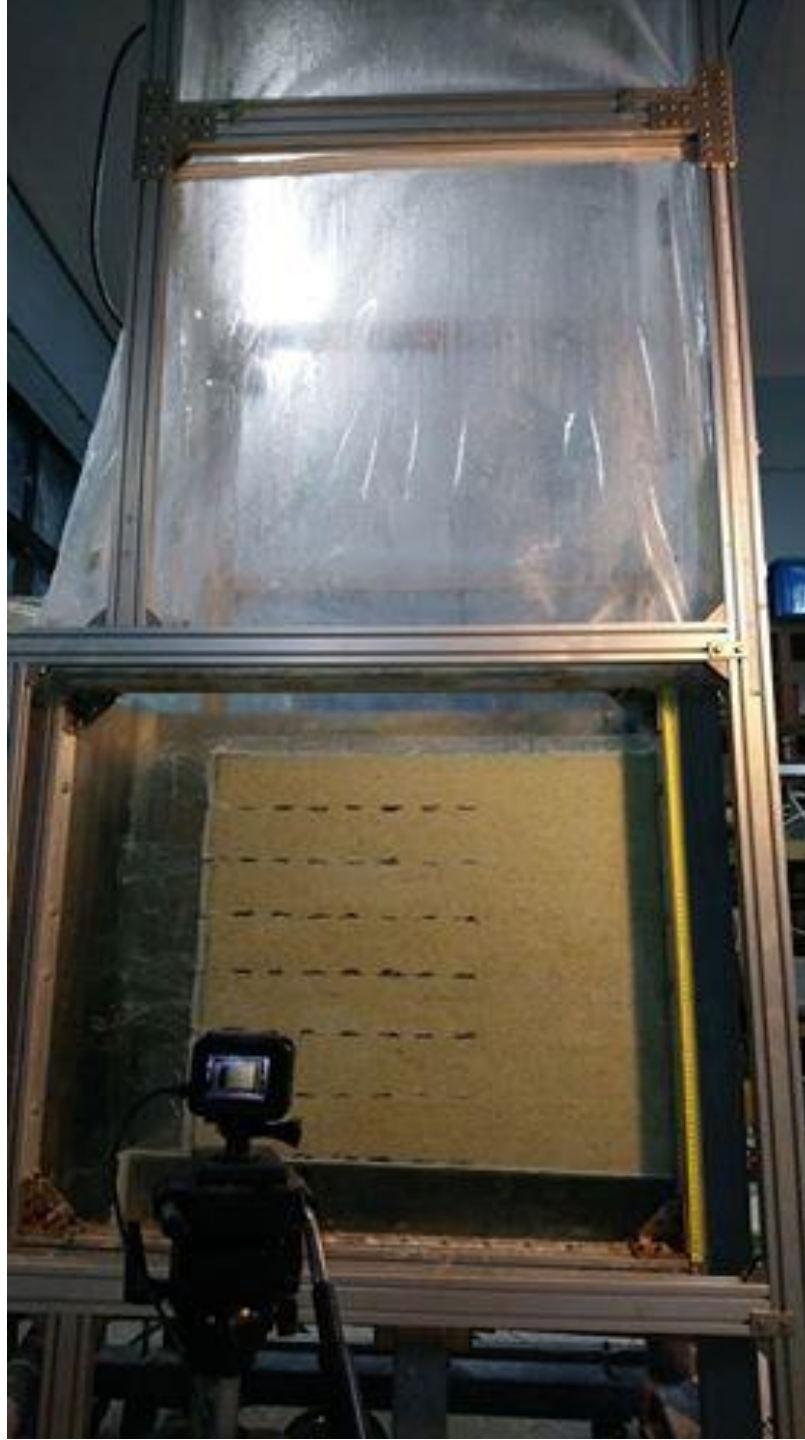


Material Point Method Analysis of Slope Post-Failure Mechanism

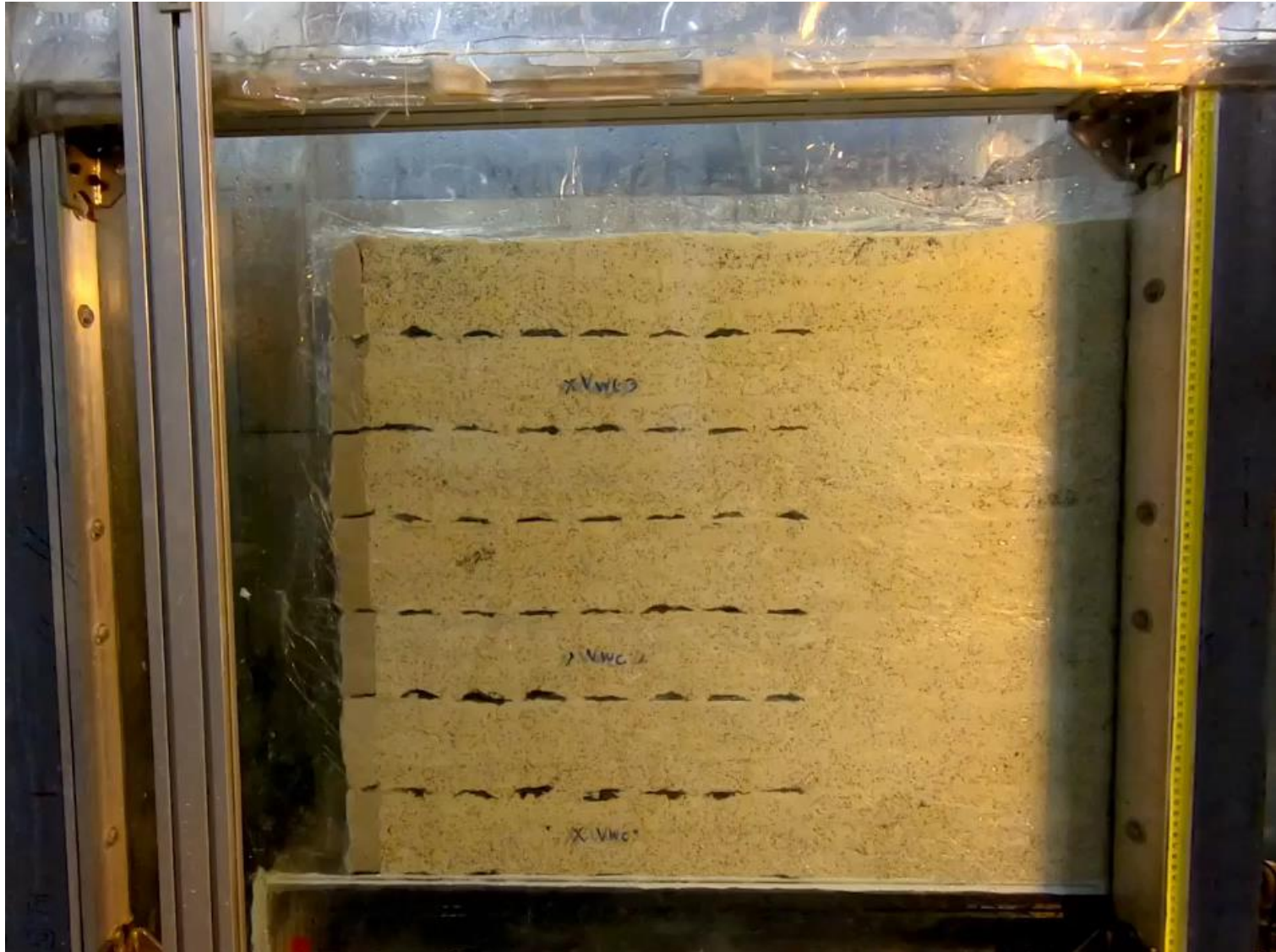


Model Test on Reinforced Wall subjected to Rainfall

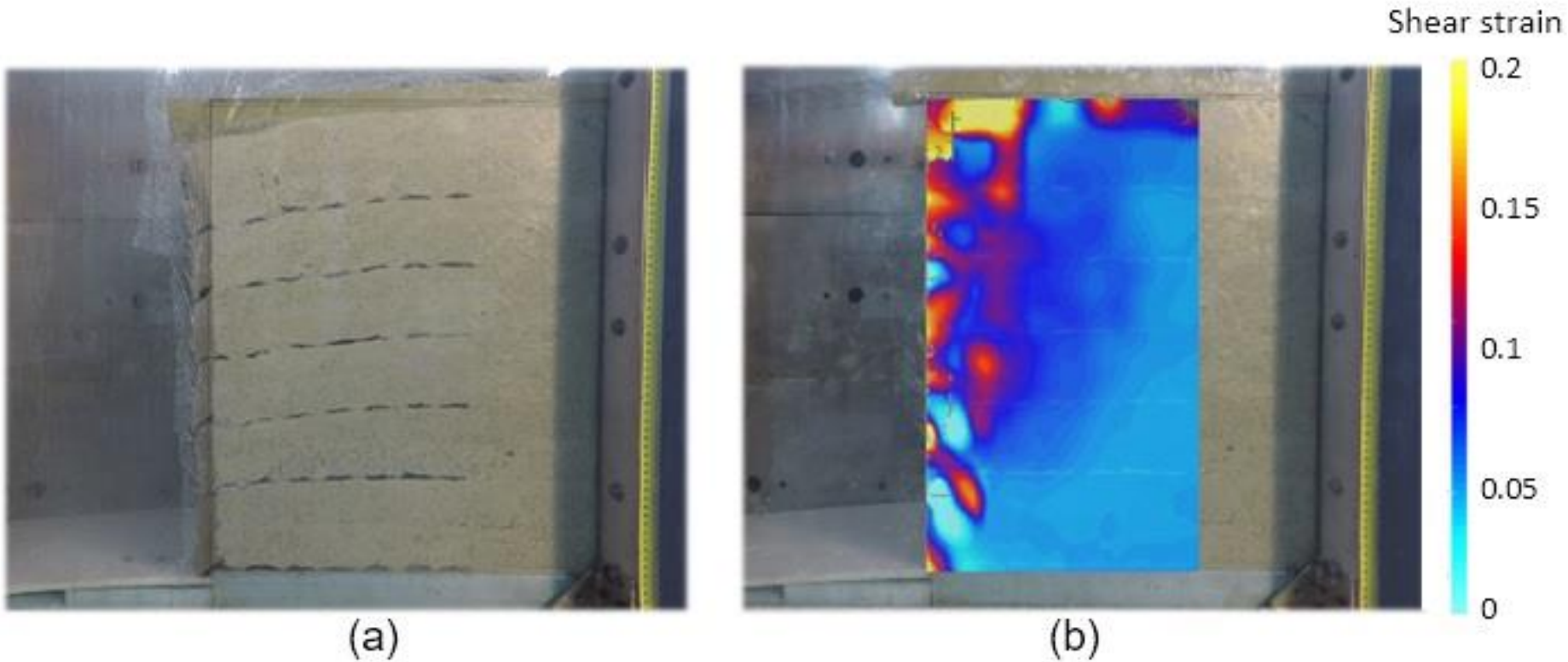




Model Test on Reinforced Wall subjected to Rainfall



Model Test on Reinforced Wall subjected to Rainfall



國際土工合成材 青年成就獎

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SLIDESHOW: 10 ICG Highlights and Honors

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Design Reinforcement Layout



Removing Facing Panel

**Construction
and
Compaction**



**Surcharge
and
Design Success !!**

工程、防災與自然生態保護之應用



定義

Geosynthetics:

Planar or 3D products manufactured from polymeric material, which are used with soil, rock or geotechnical engineering material as an integral part of a man-made project, structure, or system (ASTM D 4439)

土工合成材：

以聚合物製造之平面或立體產物用於和土、石或其它大地工程材料作為人造計畫、結構或系統之一部份

Geosynthetics:

Synthetic polymeric materials that are specifically manufactured to be used in geotechnical and geoenviromental applications



International Geosynthetic Society

The 7th European Geosynthetics Conference
www.eurogeo7.org



The International Geosynthetic Society (IGS) is a learned society dedicated to the scientific and engineering development of geotextiles, geomembranes, related products, and associated technologies. The core purpose of the IGS is to provide the understanding of and promote the appropriate use of geosynthetic technology throughout the world.

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CORPORATE MEMBERS



Search For IGS Corporate Members

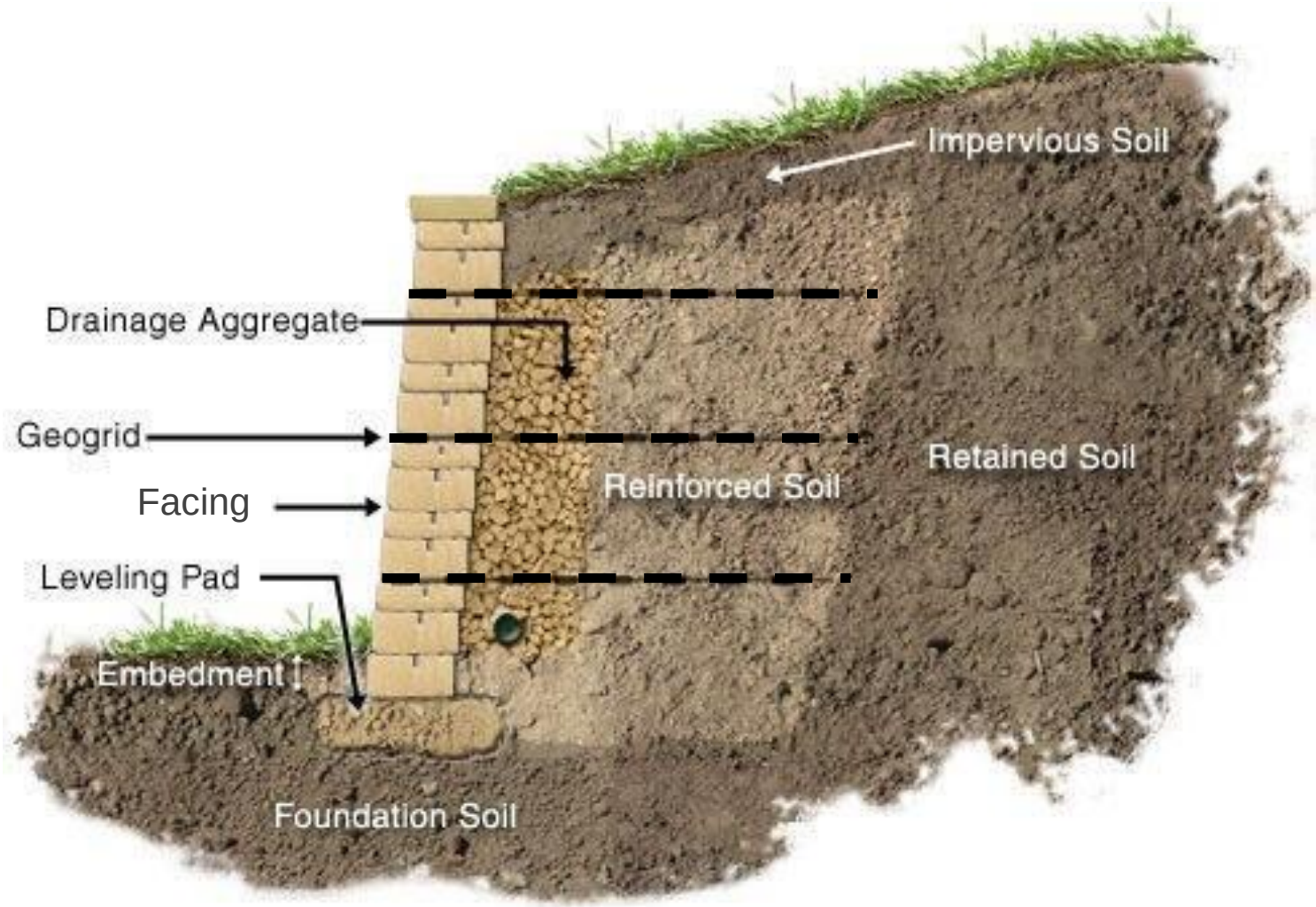
土工合成材種類

- 土工織物(Geotextile)
- 土工格網(Geogrid)
- 土工纖維(Geofiber)
- 土工網格(Geonet)
- 土工複合材(Geocomposite)
- 土工管(Geopipe)
- 土工不透水布(膜)(Geomembrane)
- 土工皂土毯(Geosynthetic Clay Liner)
- 土工抗沖蝕毯 (Erosion Control Geomat)
- 土工格巢(Geocell)
- 土工泡綿(Geofoam)
- 土工沙腸袋 (Geotube)

土工合成材功能

- 分隔 Separation
(separate two soil layers)
- 加勁 Reinforcement
(increase soil shear strength and system stability)
- 過濾 Filtration
(prevent internal erosion)
- 排水 Drainage
(decrease pore water pressure and accelerate consolidation)
- 阻水 Infiltration Barrier
(water barrier)
- 保護 Protection
(erosion control, protect other geosynthetics)

加勁擋土結構物 主要元件



主要材料

回填土



主要材料

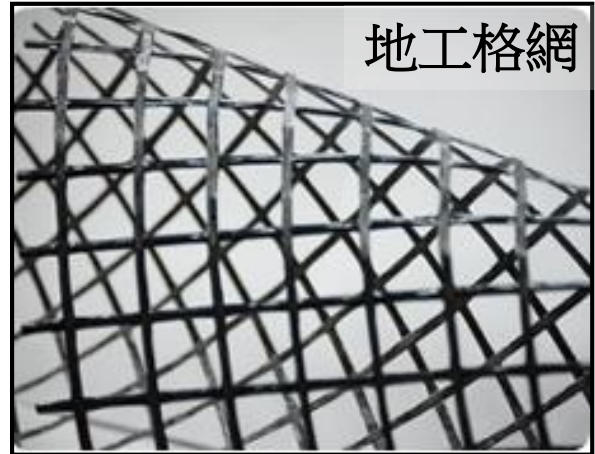
加勁材

金屬加勁材

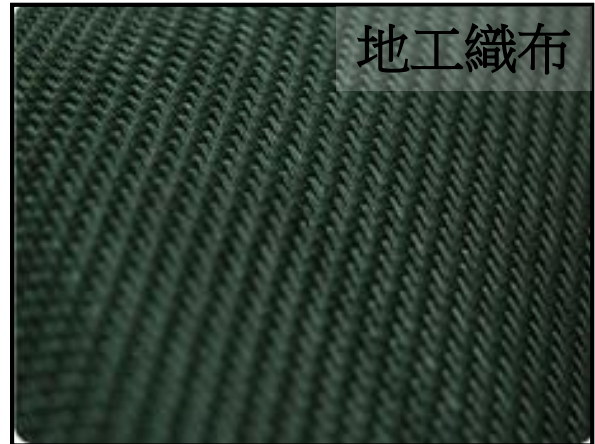


土工合成材

土工格網



土工織布



加勁結構物應用

小規模

住家



交通運輸



大規模

邊坡穩定與
生態工法



與傳統重力式擋土牆相比



傳統重力式擋土牆



加勁式擋土牆

- ❑ 美觀與生態環保
- ❑ 減少混凝土使用量，節能減碳
- ❑ 照價低
- ❑ 建造簡易且快速
- ❑ 耐震
- ❑ 屬柔性結構物，可容忍較大的變形

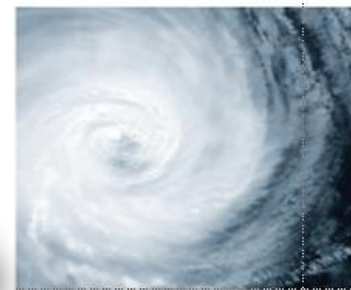
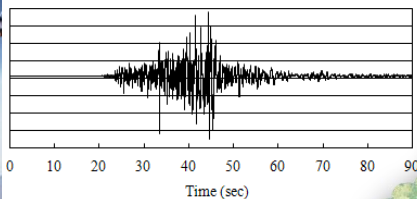
與傳統重力式擋土牆相比

比較項目	加勁擋土牆	傳統 RC 擋土牆
建造成本	約台幣 4,000~6,000(10m 高)，單價不因牆高而有變化。	約台幣 6,000~10,000(10m 高)，隨牆之高度昇高，單價上漲頗鉅。
外觀	牆面可植生，能就幾何形狀，可與環境配合，景觀較佳。	混凝土場鑄，一般變化甚少，且牆面品質不易掌握。
施工方式	施工簡易，無須打設基礎，且施工快速。	需要開挖及打設基礎，方能施工，施工速度較慢。
設計理念	內穩定：藉加勁材料與上下接觸的土壤摩擦力提供穩定的來源。	外穩定：需要牆面與基礎連結成一體提供穩定力矩，需增加滑動抵抗力。
土壓力	柔性結構，土壓力較小，且分佈略呈長方形，	呈三角形分佈，當牆高增加時，土壓力增大甚鉅。
基礎	基礎為柔性，在一般土壤情況下，不需要基樁。	基礎為剛性，承載力要求高，除非土壤特別堅硬，需樁基礎。
耐震性	提供了土壤缺乏的抗張能力，且屬柔性結構，耐震性較佳，回包式加勁材料與土壤合而為一。	牆面與被填土為獨立個體，牆面承受因地震而增加之主動土壓力，往返稜動多次後可能造成分離，甚至破壞。
容忍沈陷能力	最大容許沈陷量達 30 公分。	一般以 2.5 公分為設計準則，最大容許沈陷量為 5 公分。

台灣天然災害



震災(88年921地震)



颱風豪雨



水災(90年納莉颱風)



土石流(98年莫拉克颱風)



坡地災害(99年國道三走山)

坡地復育



邊坡破壞及山崩



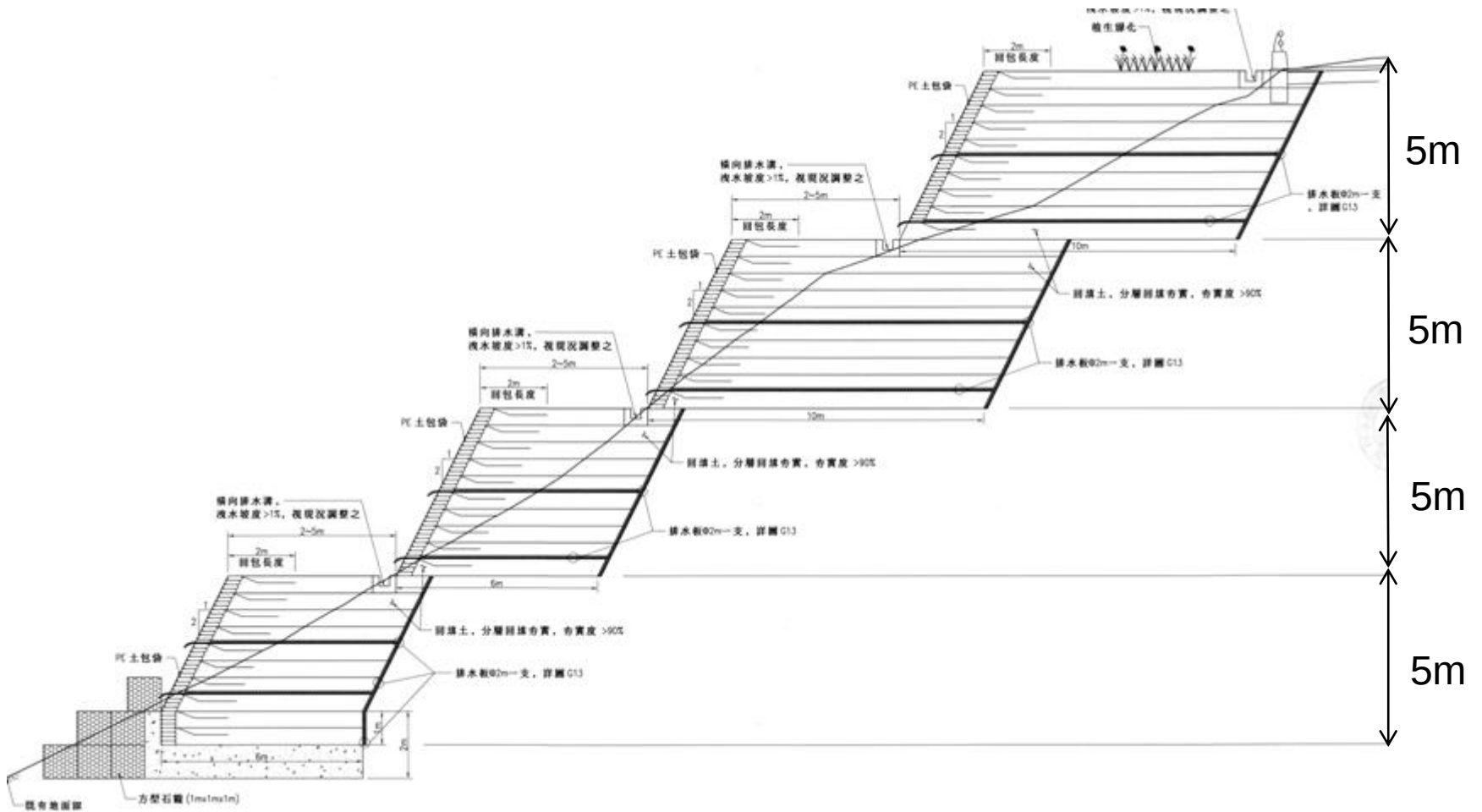
2009年莫拉克颱風

案例



土工合成材應用於修復道路及邊坡

案例



設計一個4層的加勁擋土牆以重建邊坡

案例

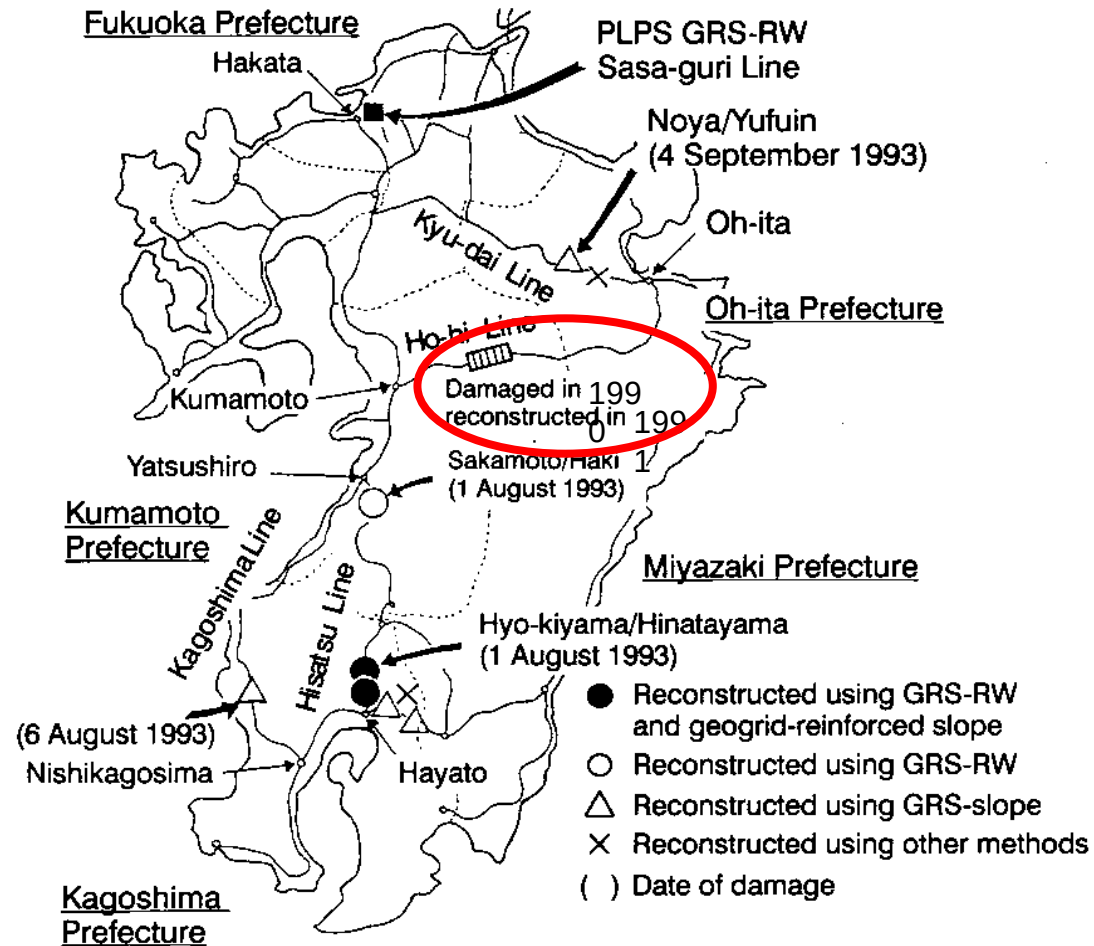


土工合成材應用於修復道路及邊坡

泥岩邊坡保護



案例



Locations of railway embankments
that failed by the 1990 and 1993 floods

Site 2

A small drain pipe crossing the embankment was clogged by flowing timbers and a natural reservoir was formed. The embankment was fully eroded by over-topping flood.

1990



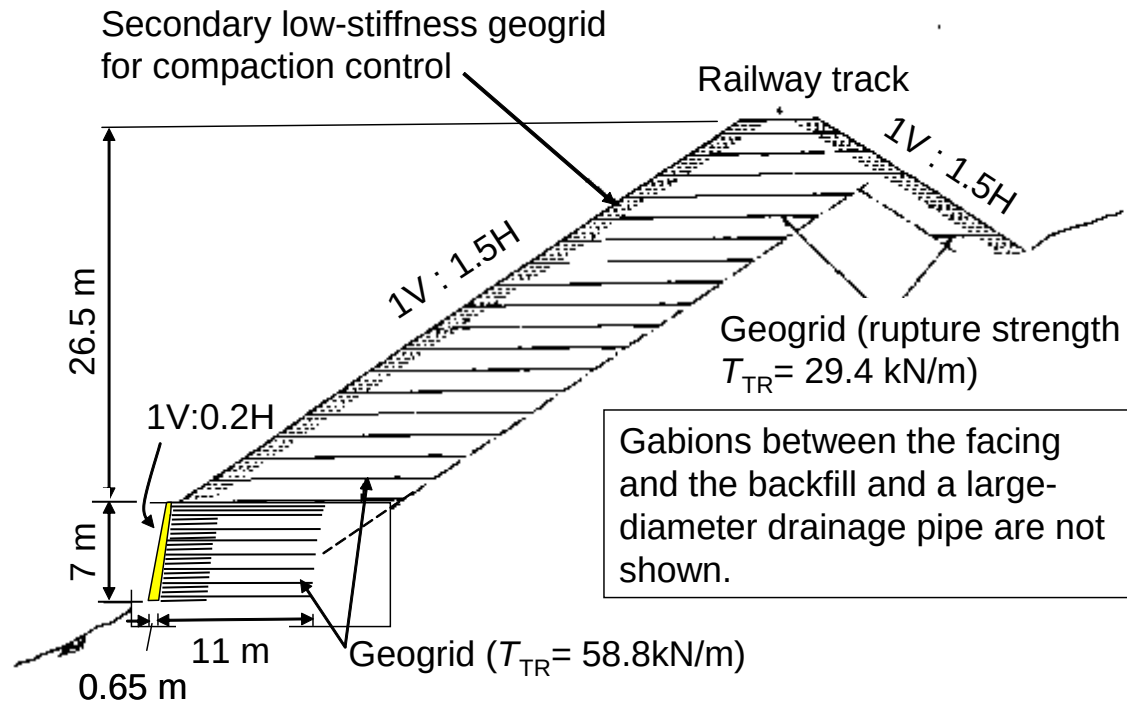
1994



GR RWs were adopted, due to:

- a) fast construction;
- b) small construction machines necessary;
- c) a high stability against heavy rainfalls and earthquakes; and
- d) low cost for construction and maintenance

Reconstruction to GR slope and GRS-RW in 1991



Site 2



A bigger overtopping flood, July 2012

Original unreinforced fill section, survived the 1990 flood but fully eroded by the July 2012 flood

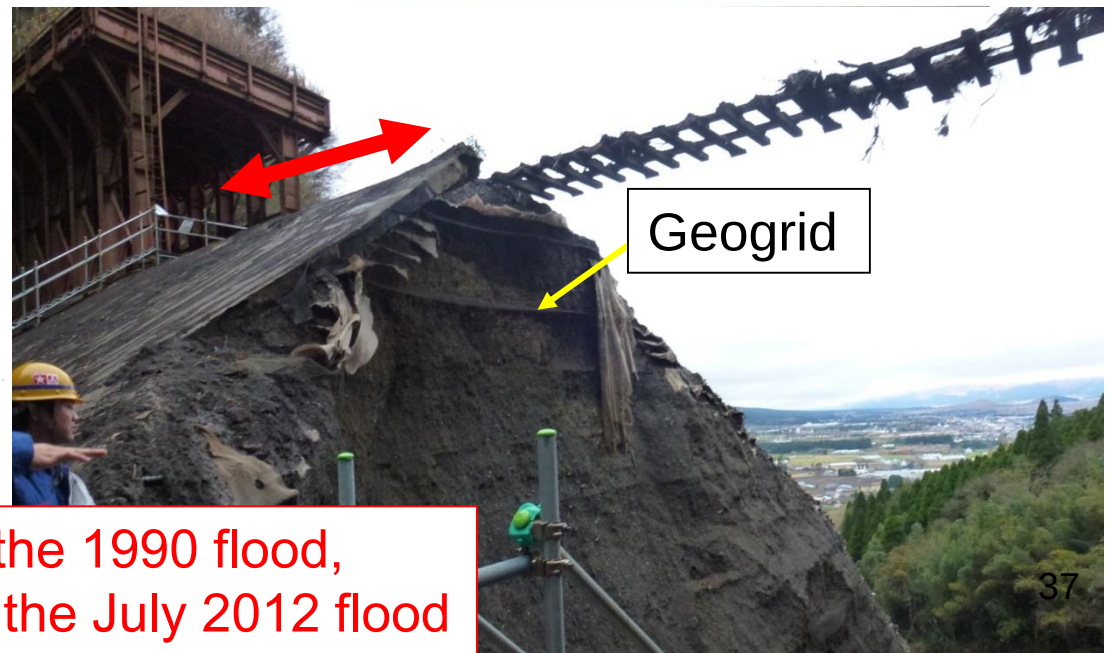
Site 2



A bigger overtopping flood, July 2012



Site 2



GRS section, fully eroded by the 1990 flood, restored in 1991 and survived the July 2012 flood

Original unreinforced fill section, survived the 1990 flood but fully eroded by the July 2012 flood (then excavated for restoration works)

GRS section, fully eroded by the 1990 flood, restored in 1991 and survived the July 2012 flood



強降雨相關研究

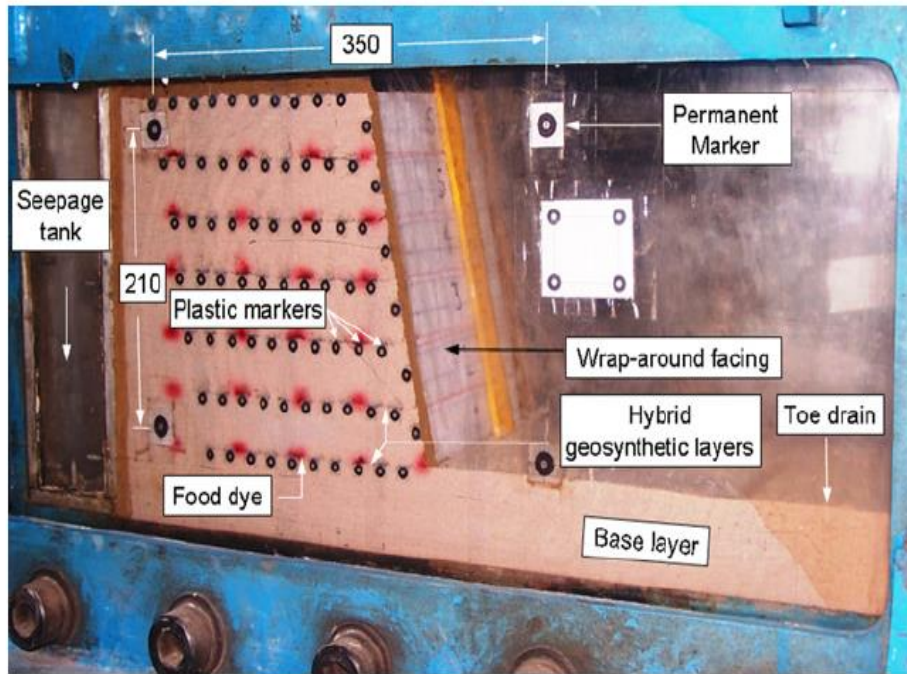
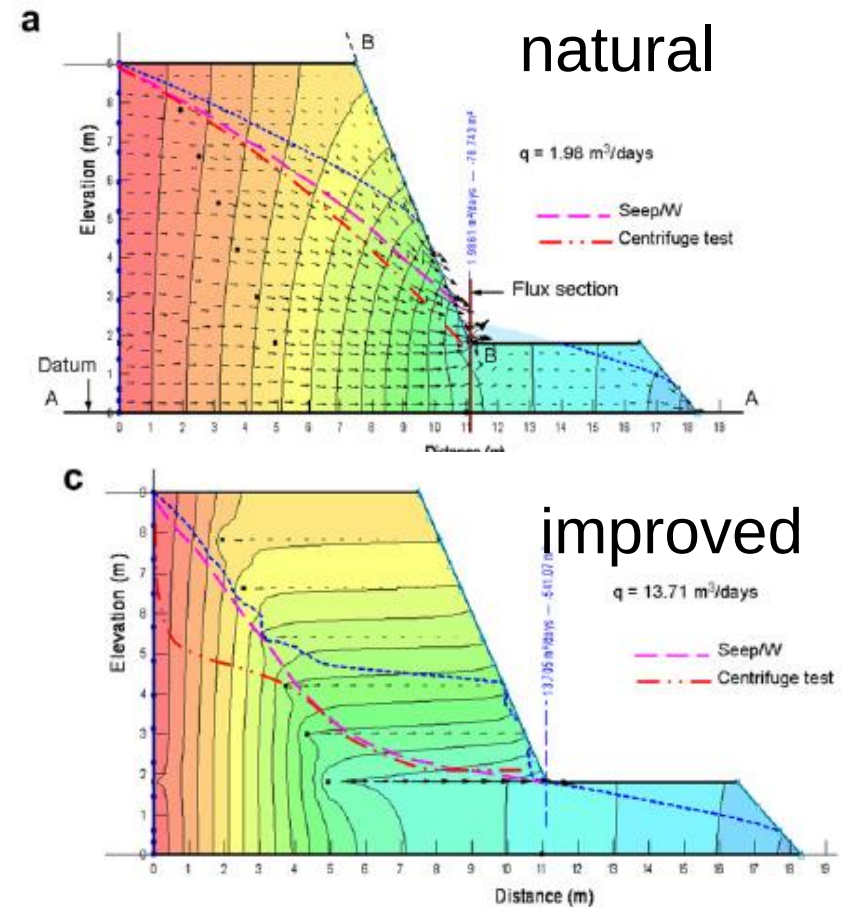


Fig. 3. Perspective view of model hybrid geosynthetic reinforced slope before centrifuge test (all dimensions are in mm).



Geosynthetics provide reinforcement and drainage functions to decrease pore water pressure and enhance system stability

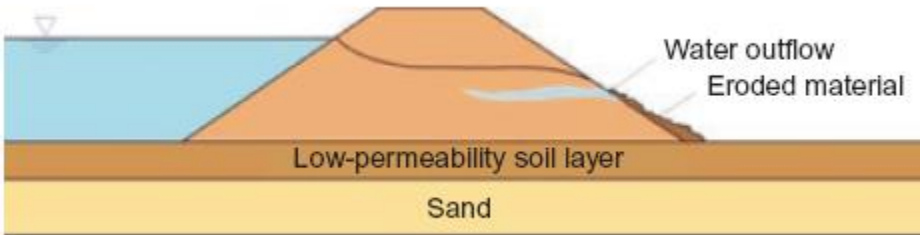
洪水



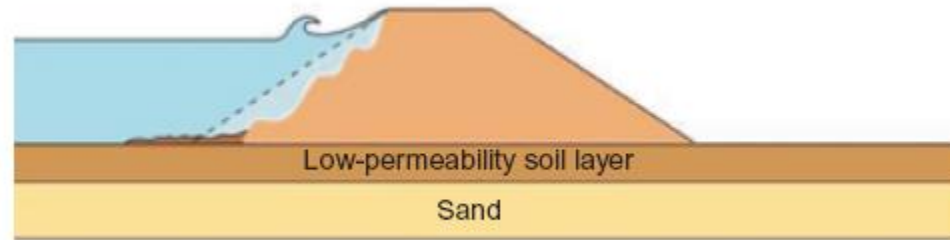
洪水災害



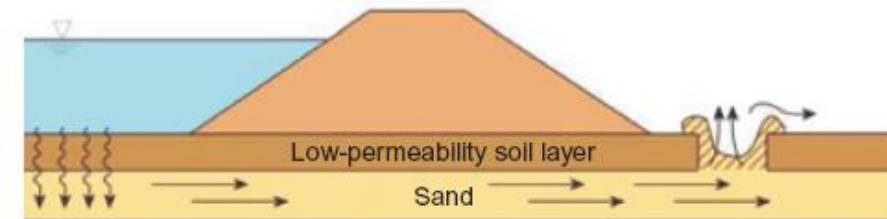
洪水災害



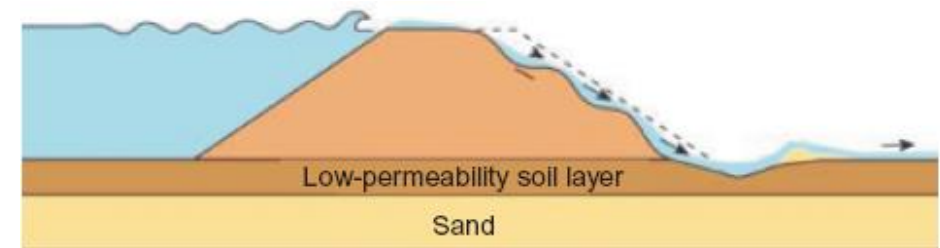
Internal erosion



Surface erosion of water-side slope
due to water wave



Seepage failure



Overtopping

颶風卡崔納 (Hurricane Katrina)

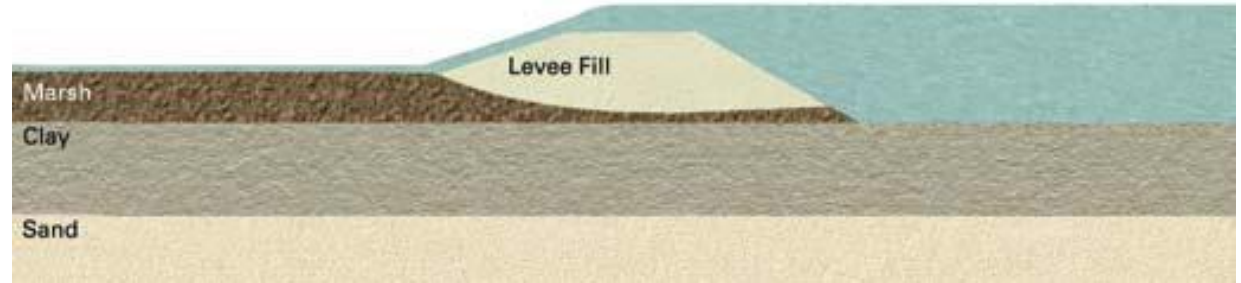
Figure 3.1 Path and Intensity History of Hurricane Katrina (August 2005)



This image is a montage of four satellite photographs taken in late August 2005, as Hurricane Katrina made its way from the Bahamas through the Gulf of Mexico, gaining strength.

溢頂 (Overtopping Failure)

- ❧ Floodwater overtop the levee



- ❧ The flood water scours some soil away



- ❧ The levee washed away



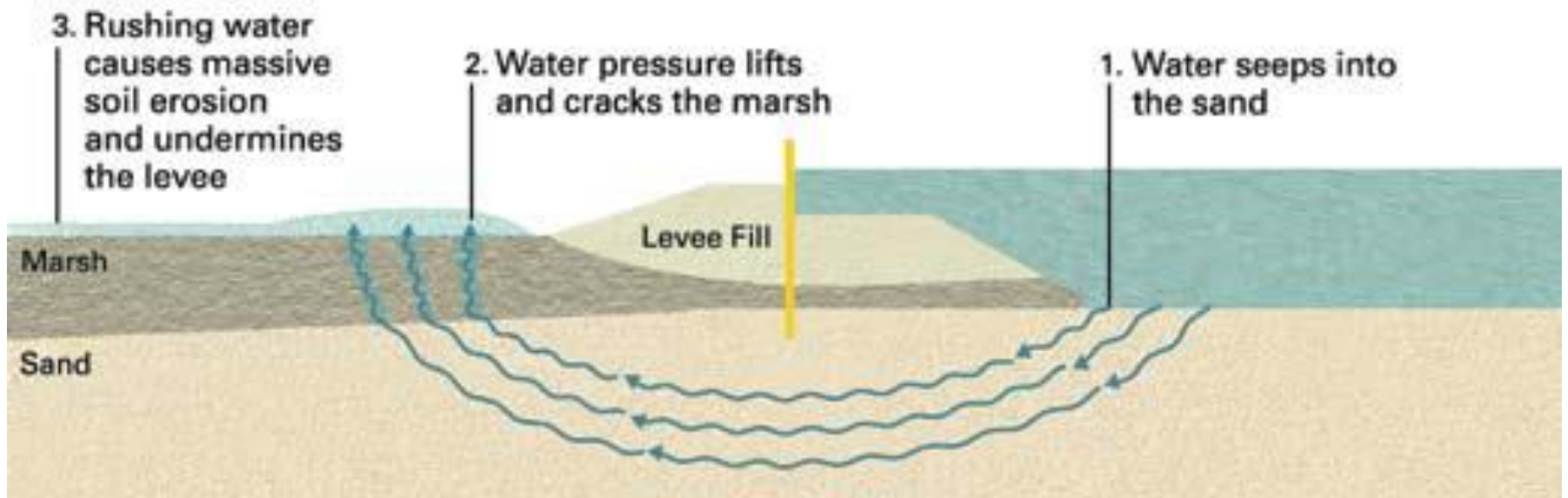
溢頂 (Overtopping Failure)

Figure 7.12 Obliterated Levee along the Mississippi River-Gulf Outlet



Many levees that were constructed with hydraulic fill severely eroded or washed away entirely. (This photo was taken after floodwaters had receded.)

滲流破壞 (Seepage Failure)



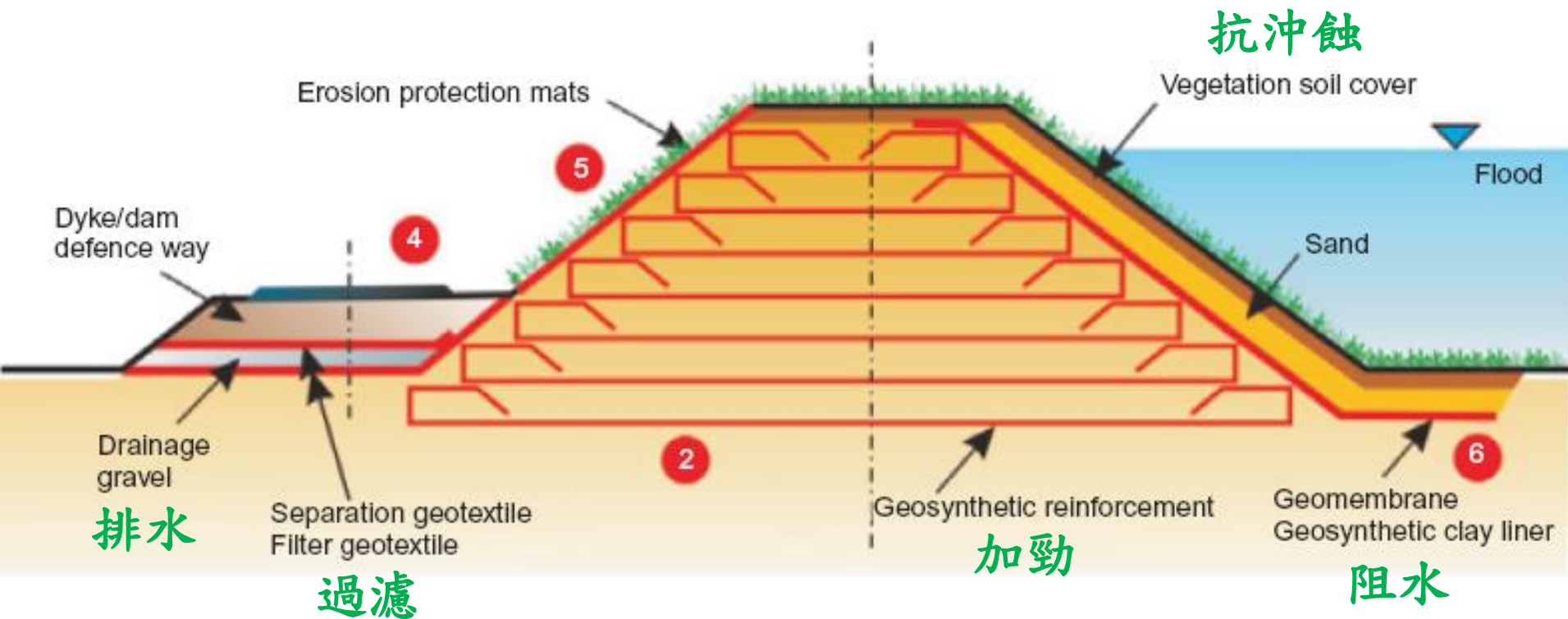
Seepage failure occurred below levees

滲流破壞 (Seepage Failure)



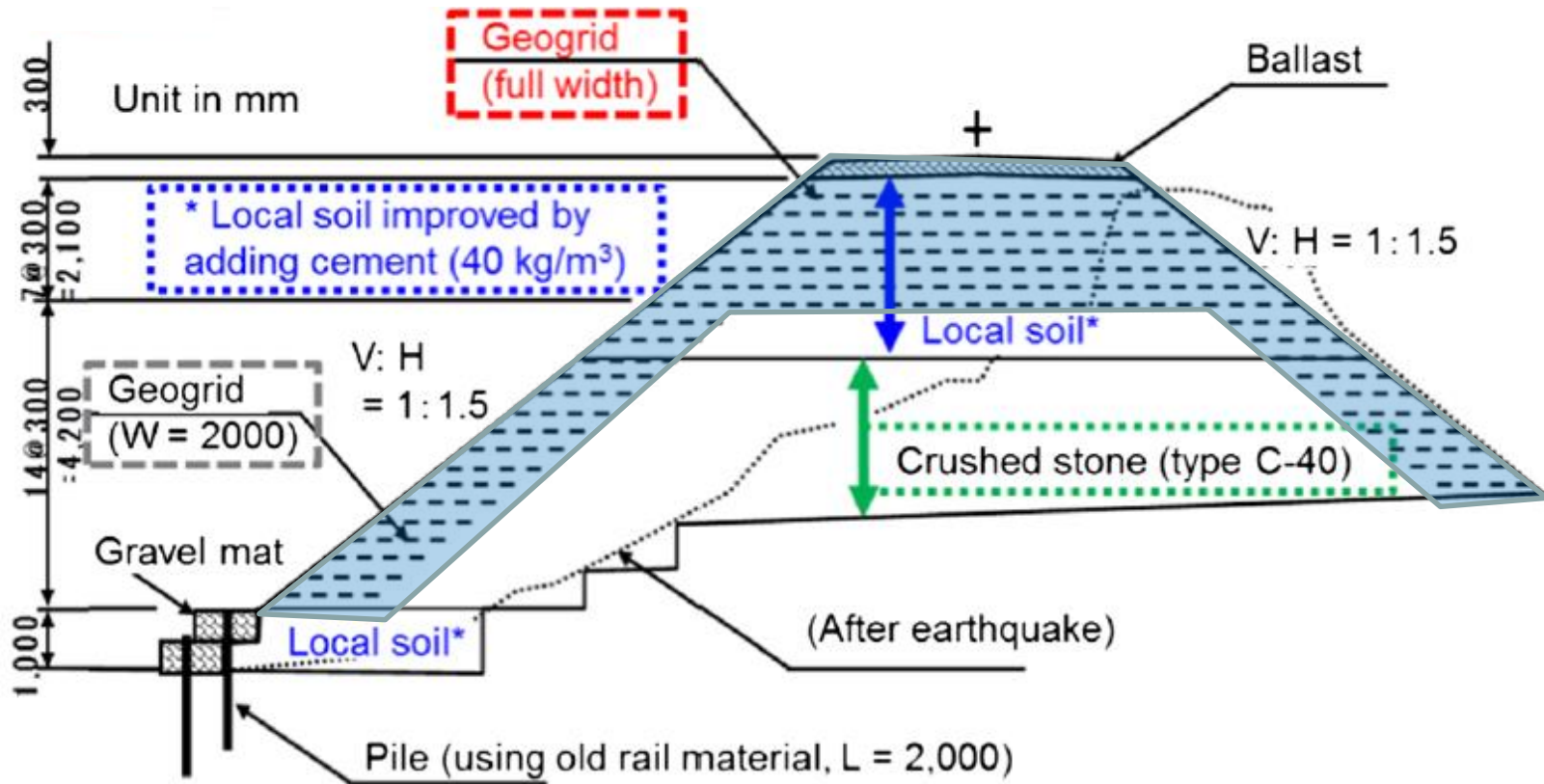
Road buried by sand caused by seepage

防洪改良設計



土工合成材應用於防洪河堤示意圖

防洪改良設計



堤防修復與既有堤防增加高度

河川護岸



河川護岸

經濟部

壹、計畫範圍



治理範圍：曾文水庫靜水池下游約150m處，至五號橋上游約15m處之右岸邊坡，全長約716m護岸。



經濟部水利署



Act to Go to

河川護岸

經濟部

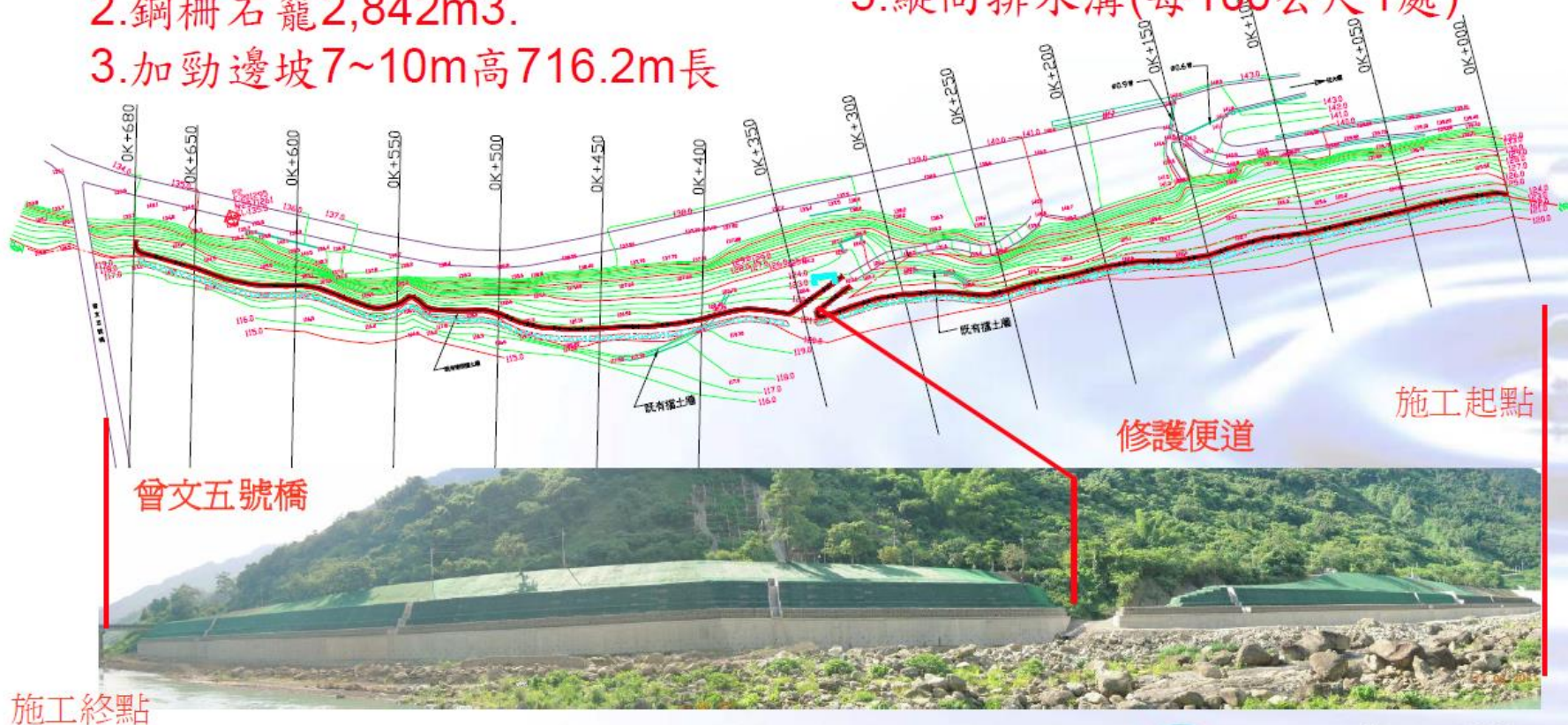
參、工程概要

• 工程主要內容:

1. 懸臂式擋土牆716.2m.
2. 鋼柵石籠2,842m³.
3. 加勁邊坡7~10m高716.2m長

4. 戕台溝637公尺

5. 縱向排水溝(每100公尺1處)



經濟部

● 設計斷面



河川護岸

經濟部

參、工程概要(續)

- 施工過程



基礎灌漿錨筋



基礎開挖



擋土牆施作



河川護岸

經濟部

參、工程概要(續)

- 施工過程



土方輾壓施作



加勁格網施設

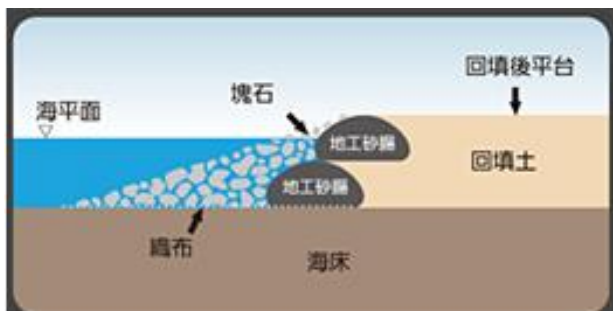


植生噴植

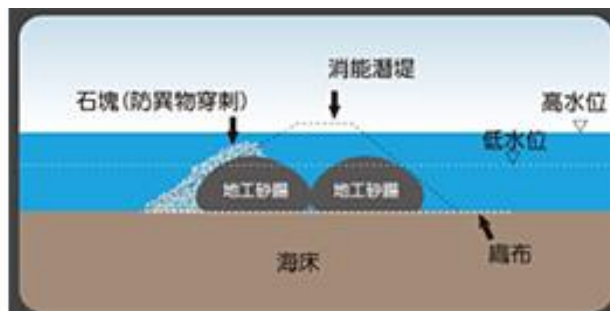
土工沙腸袋 (Geotube)

主要功用：抗沖蝕

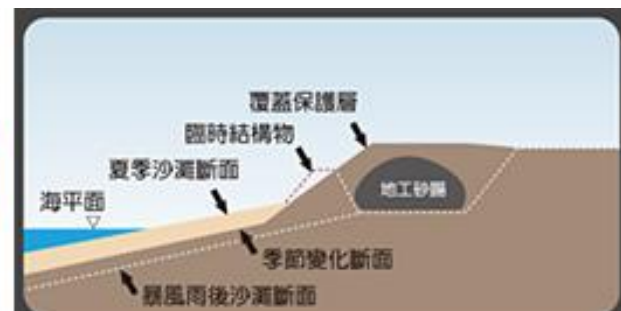




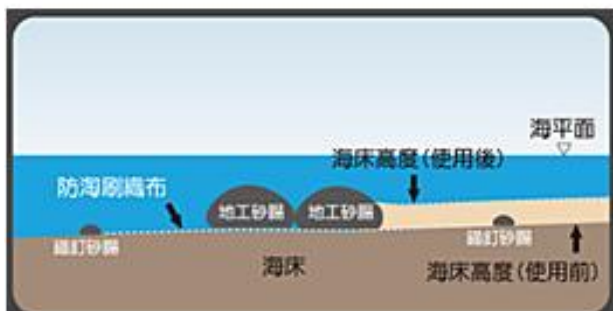
1. 海岸保護、填海造路



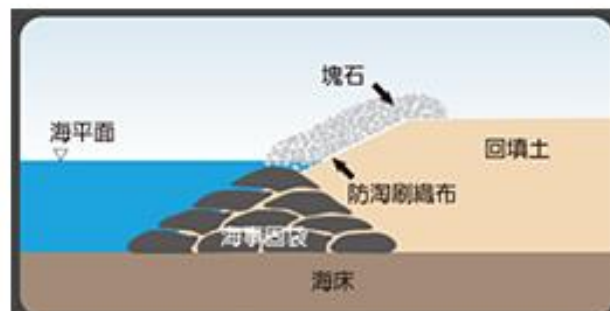
2. 離岸潛堤



3. 海岸保護



4. 海岸保護-養灘定砂



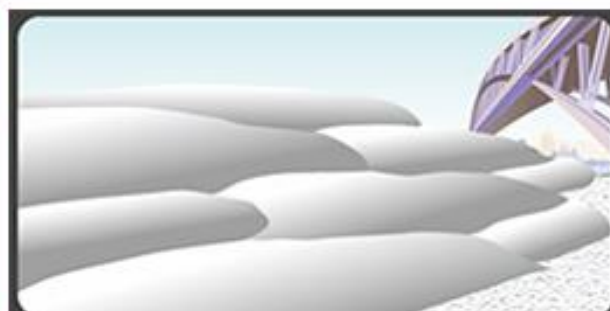
5. 填海造陸



6. 人工島



7. 海底管線保護



8. 水庫清淤淤泥固化



應用：河川丁壩護岸



應用：橋梁保護



應用：海岸保護與養灘



地震

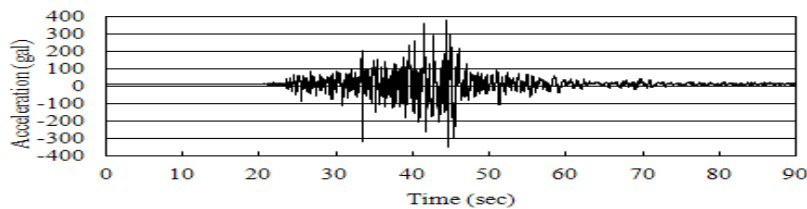


地震災害

1995 Kobe Earthquake



Gravity Wall



Gravity type wall collapsed during 1995 Kobe Earthquake compared to superior performance of MSE wall under seismic loading.



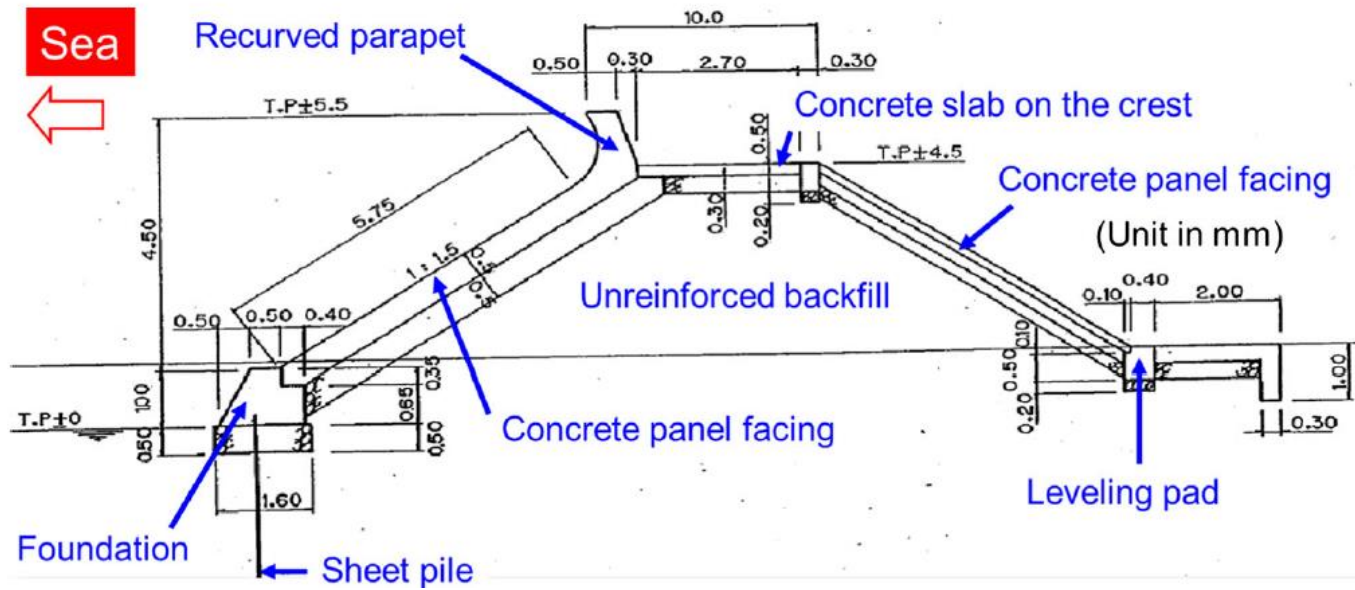
GRS Wall

海嘯災害

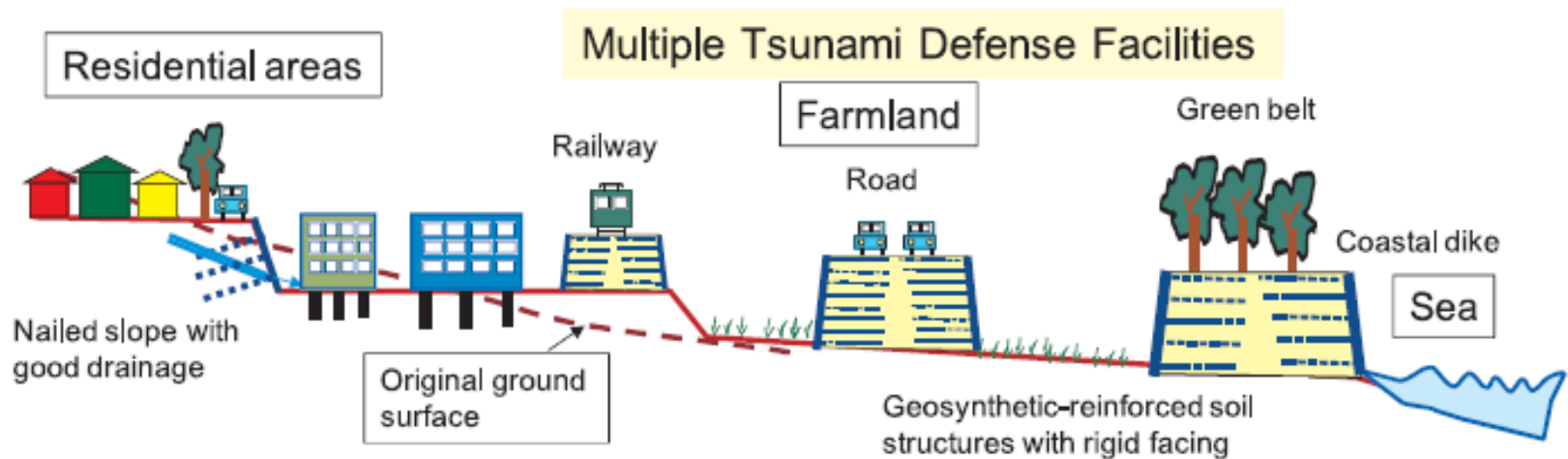


2011 Great East Japan Earthquake

傳統海堤破壞



海嘯防禦系統



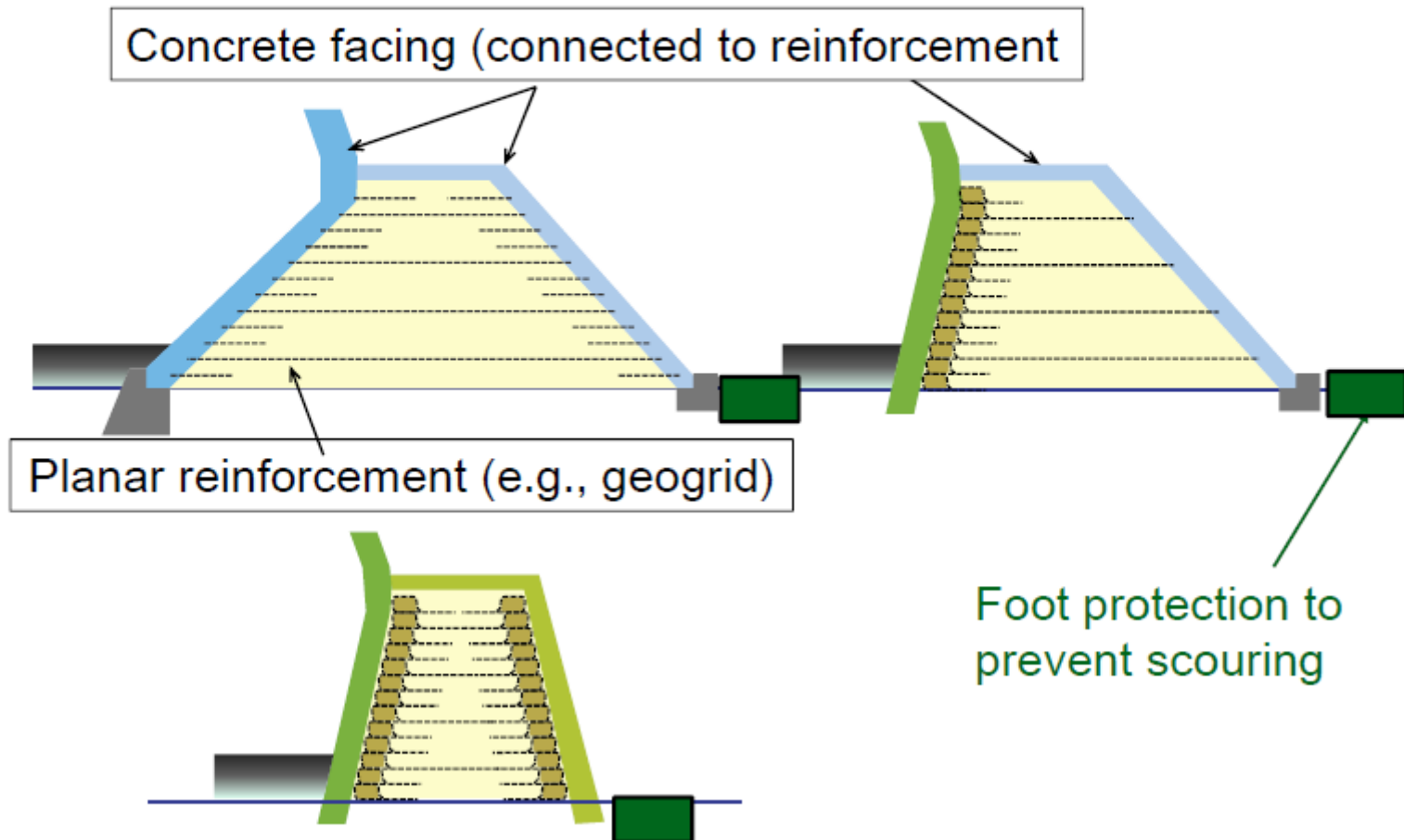
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Application of GRS structures for Tsunami Defense

Proposed by Japan Geotechnical Society

抗海嘯災害改良設計

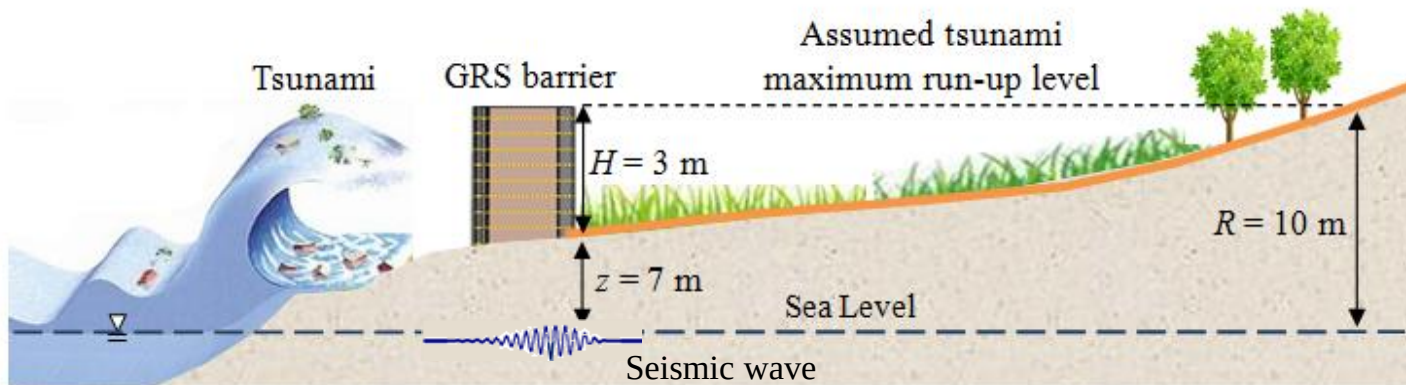
Various types of GRS coastal dike proposed as a barrier for over-flowing tsunami



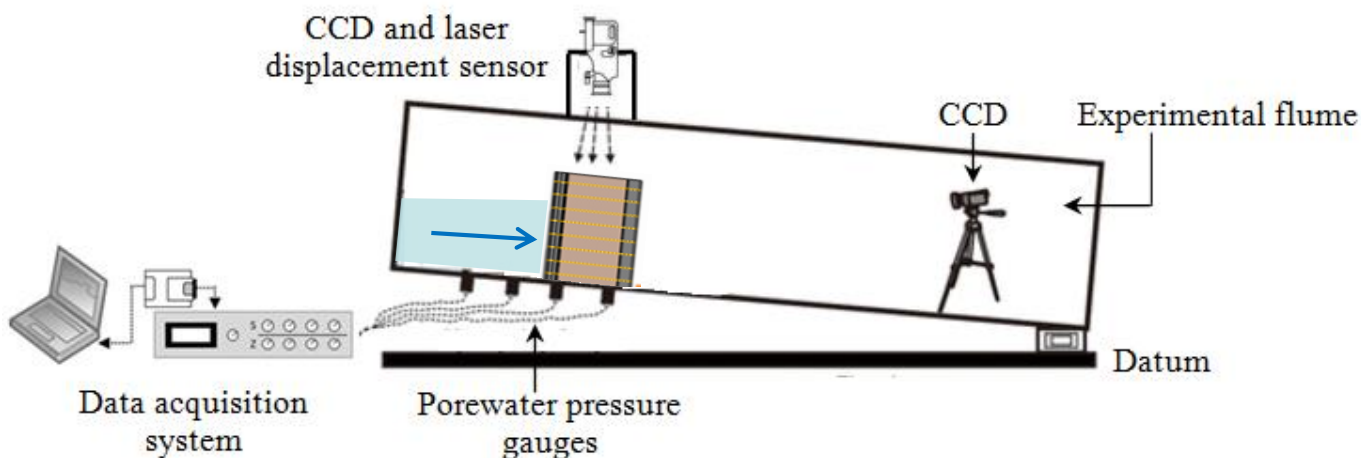
海嘯防禦系統



海嘯防禦系統相關研究



加勁擋土壁壘應用於抗海嘯之可行性分析示意圖

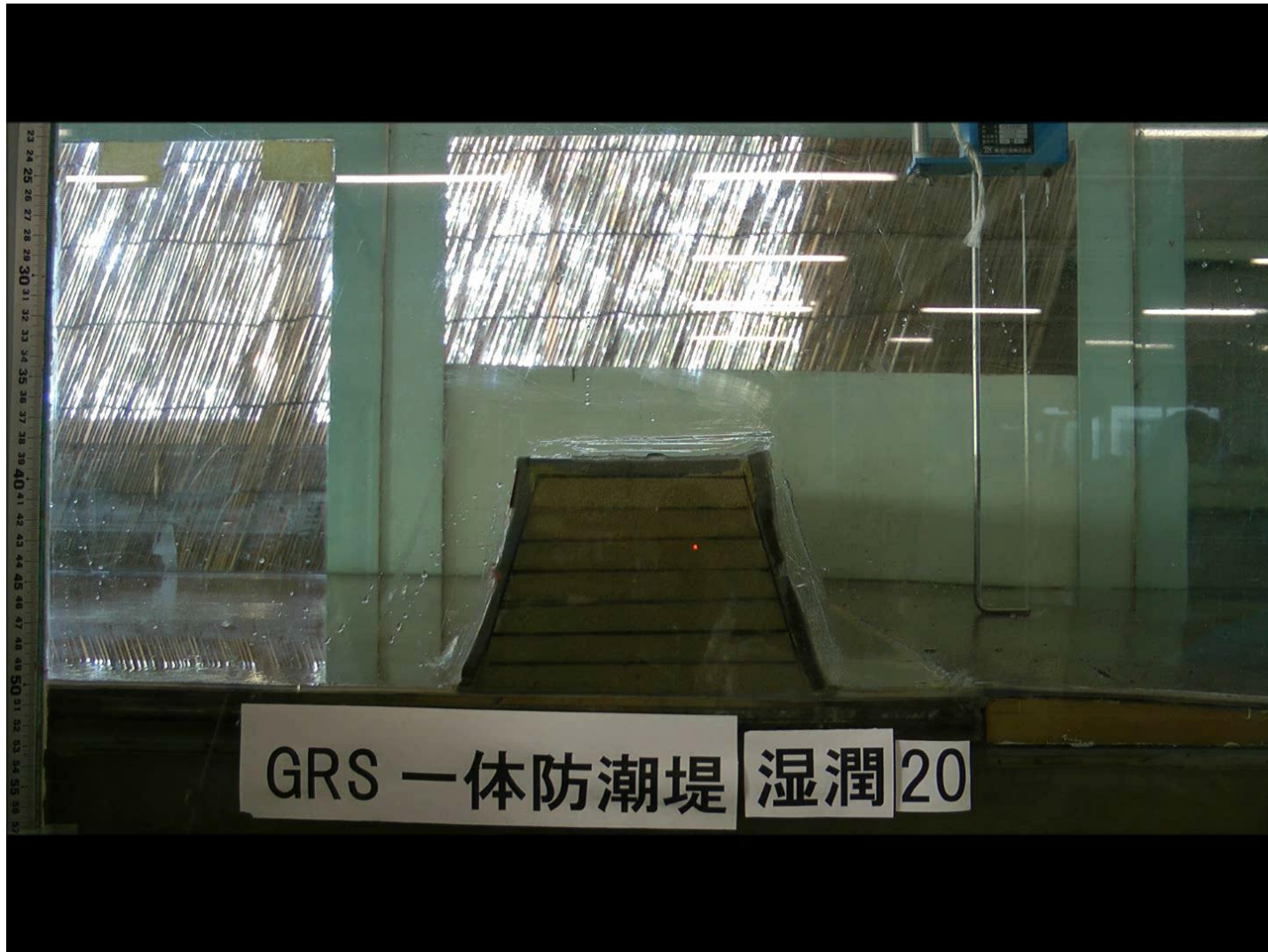


以水槽試驗探討加勁擋土構造物
受天然災害側向力作用之破壞機制與設計方法

海嘯防禦系統相關研究



海嘯防禦系統相關研究



GRS coastal dykes against overtopping Tsunami
Physical Modelling at Tokyo University of Science (by Prof. Fumio Tatsuoka)

橋梁系統

Flow-away of bridge girder by great tsunami 2011 Great East Japan Earthquake

A railway bridge (Tsuyano-gawa bridge) that lost multiple simple-supported girders by tsunami forces



Over 340 bridges collapsed by tsunami,
mostly by flow-away of girder and/or backfill

KOSA, Kenji (2011) :
Bulletin of JAEE, No.15, Oct.

橋梁系統

Collapse of a masonry RW by scouring of supporting ground and associated erosion of the backfill



橋梁系統

Both bearings & backfill are weak components for seismic & tsunami forces

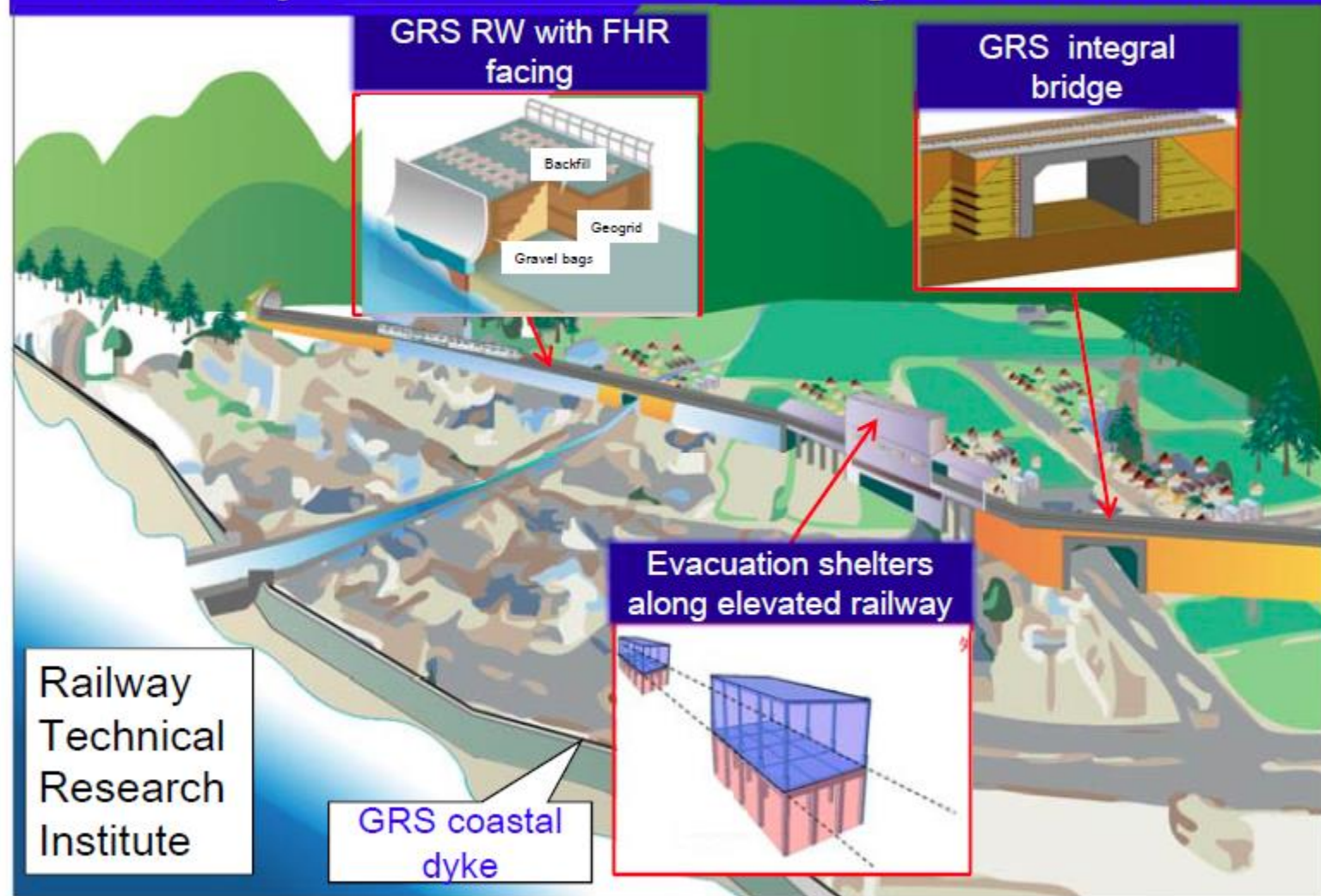


A solution by GRS integral bridge



海嘯防禦系統

Railway that can survive a great tsunami



斷層災害-斷層與地質狀況

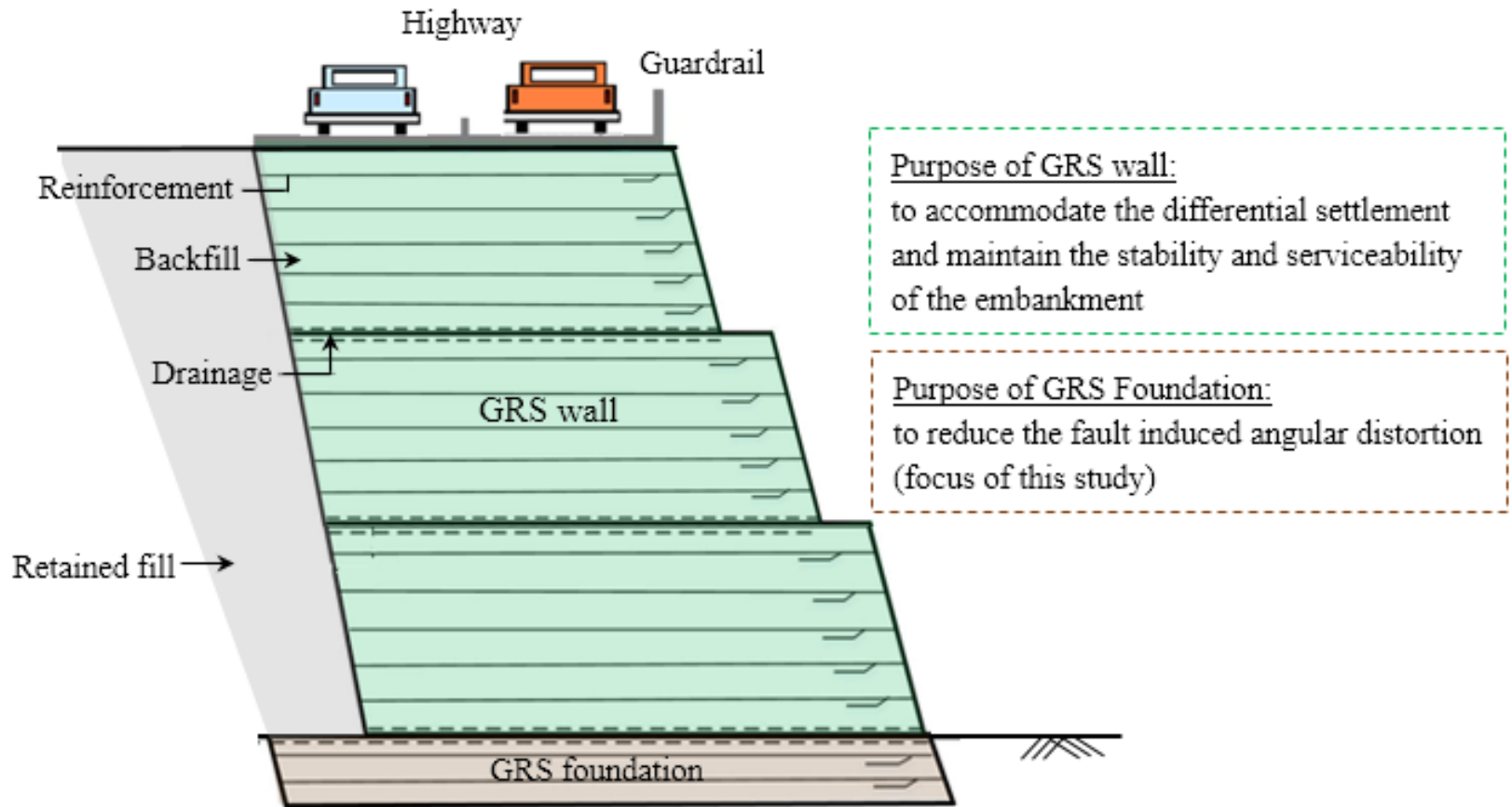


傳統重力式擋土牆破壞



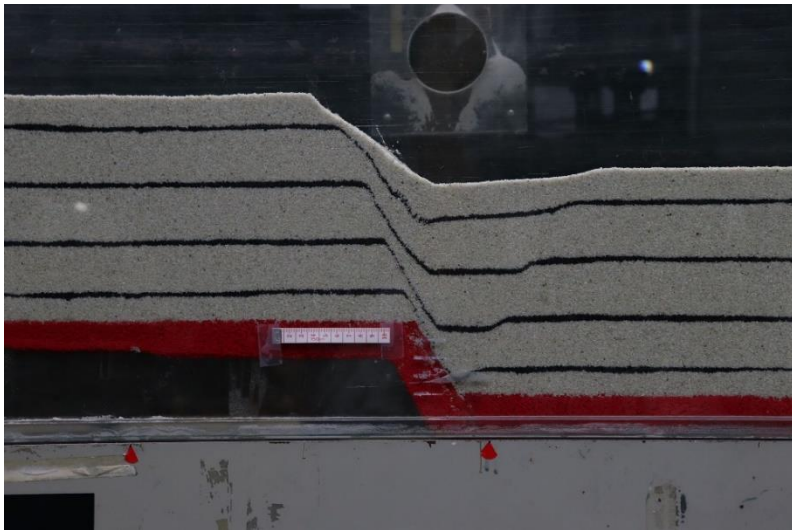
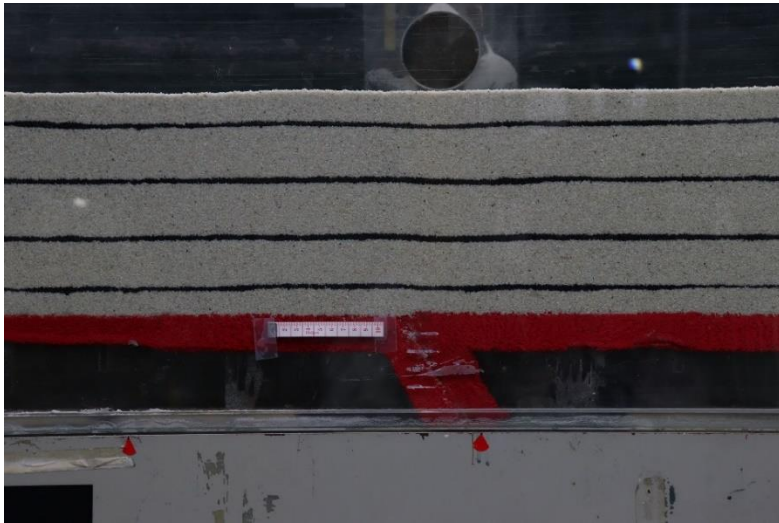
921地震災後
(烏牛欄溪)⁷⁷

抗斷層差異沉陷改良設計



加勁路堤為柔性結構物
可吸收地震波，並減少因斷層產生之角變量

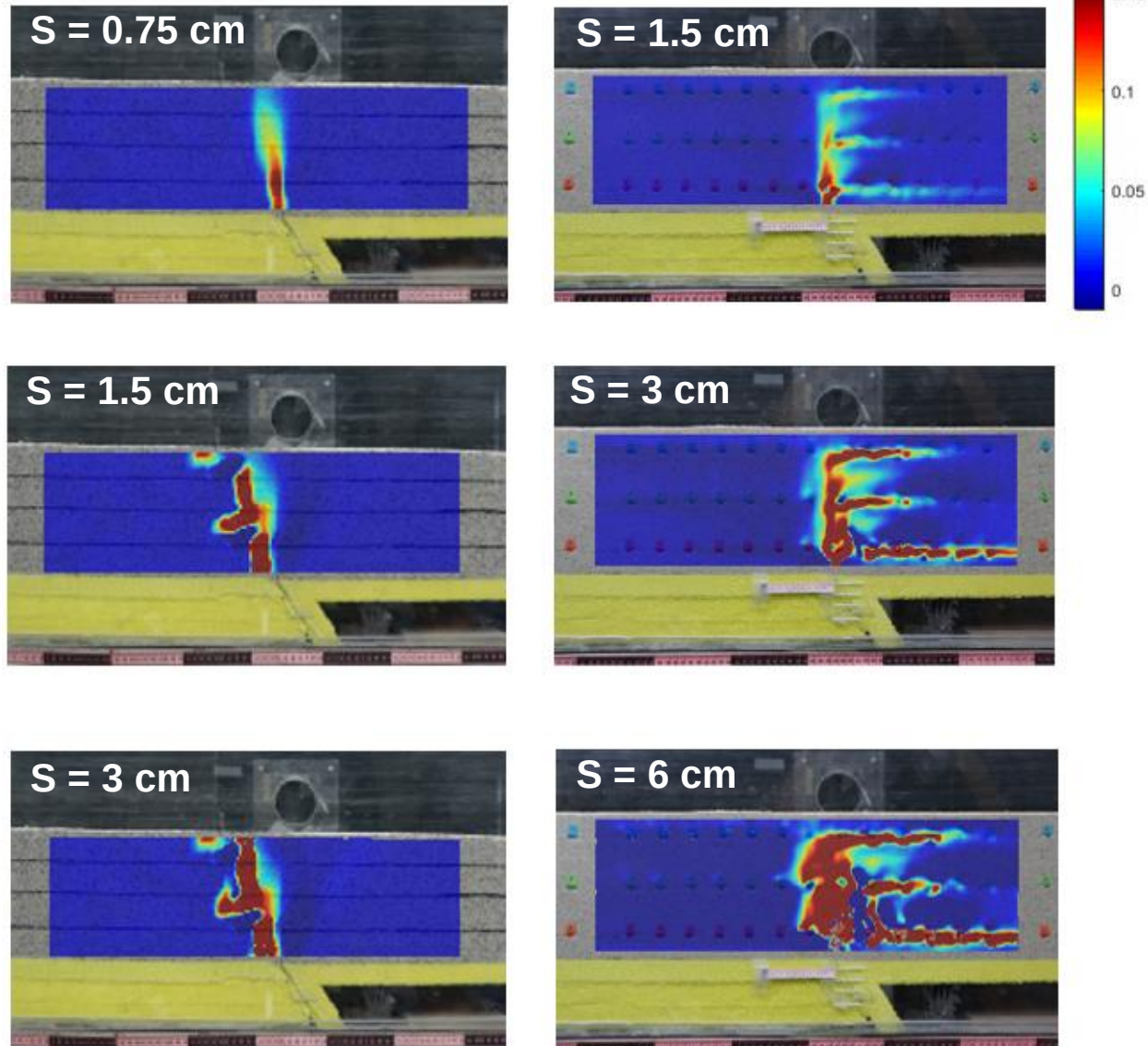
抗斷層相關研究



Unreinforced Foundation

Reinforced Foundation

抗斷層相關研究



Unreinforced Foundation Reinforced Foundation

落石



落石災害



山區落石造成道路受損與阻斷
(宜蘭臺7線)



Figure 27. Severe rockfall along an expressway; cars were crushed

衝撞擊災害相關研究

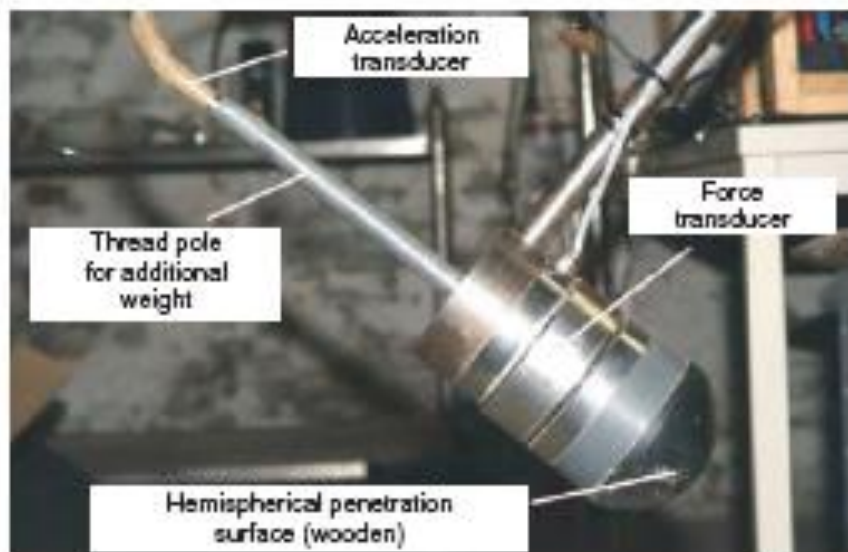


Figure 29. Pendulum simulating the rockfall



Figure 30. Construction of the 'standard' model for simulating rockfalls on barrier fill dams

落石、土石流、漂流木等

衝撞擊災害相關研究

物理模型試驗



(a)



(b)

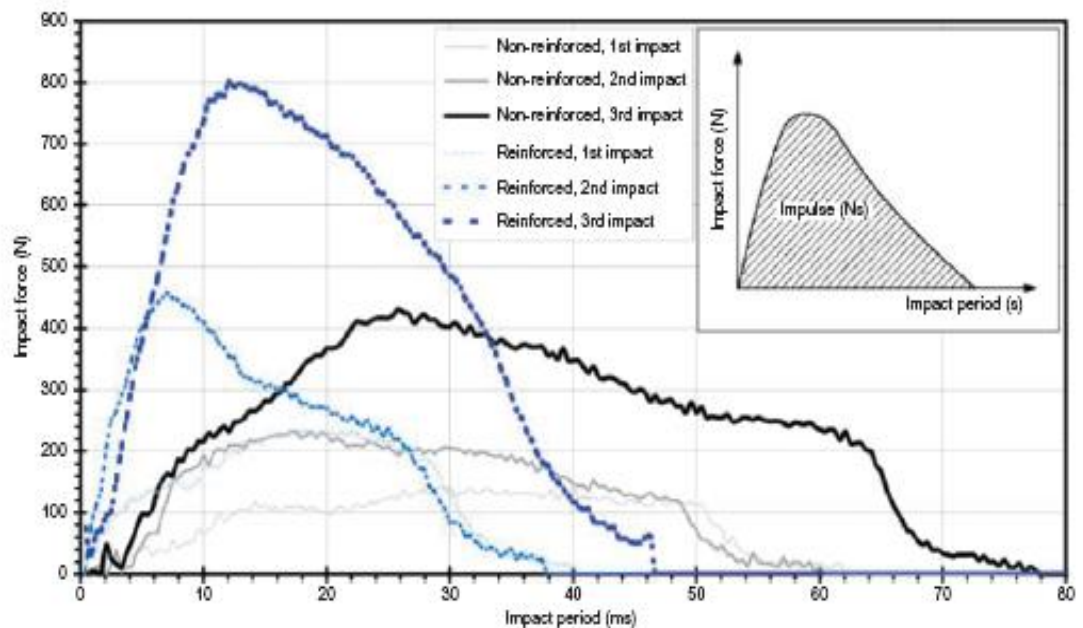
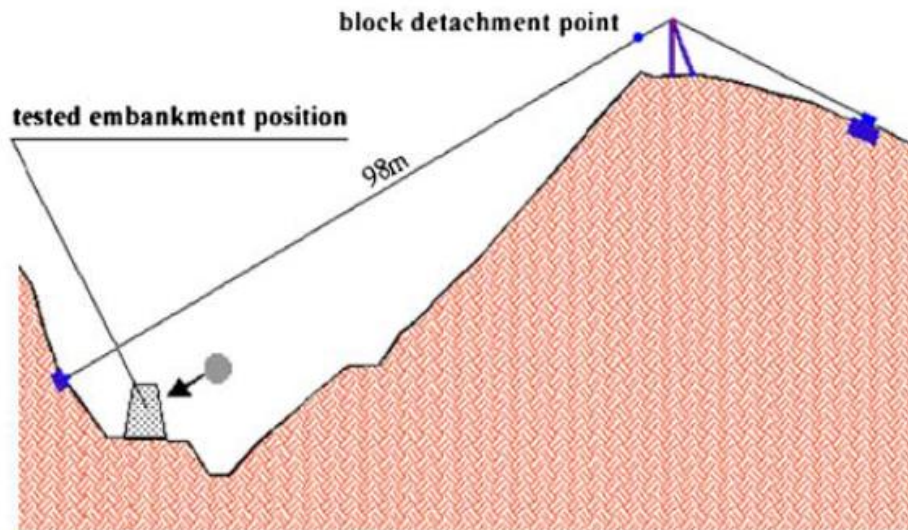


Figure 33. Example of force–time relation for the first three impacts (reinforced/non-reinforced)

相同撞擊能量下，加勁結構物

- 承受較大的衝力
- 較快速吸收所有衝擊能量

落石防災相關研究



Full scale model

落石防災相關研究



Collapse of unreinforced soil barrier

落石防災相關研究

GRS Barrier



First Impact



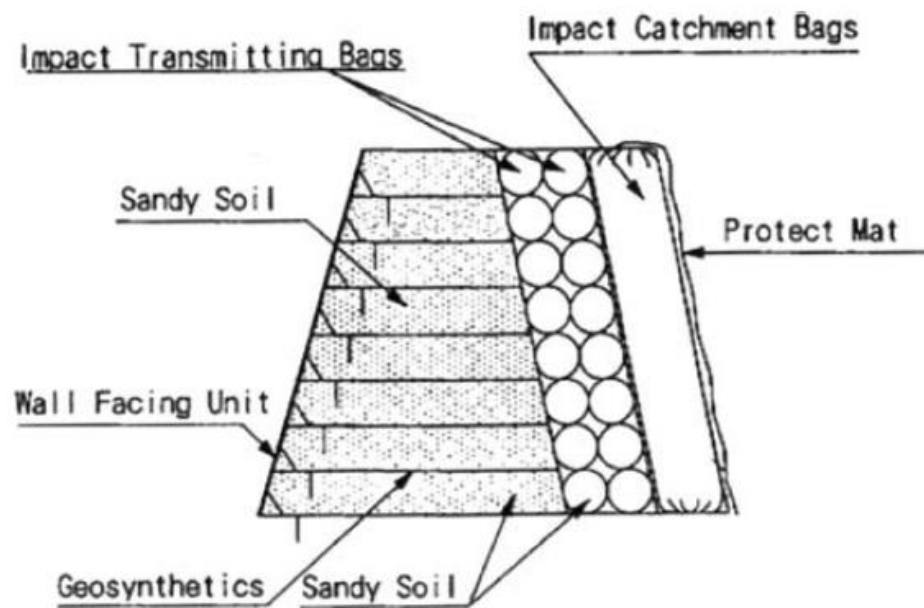
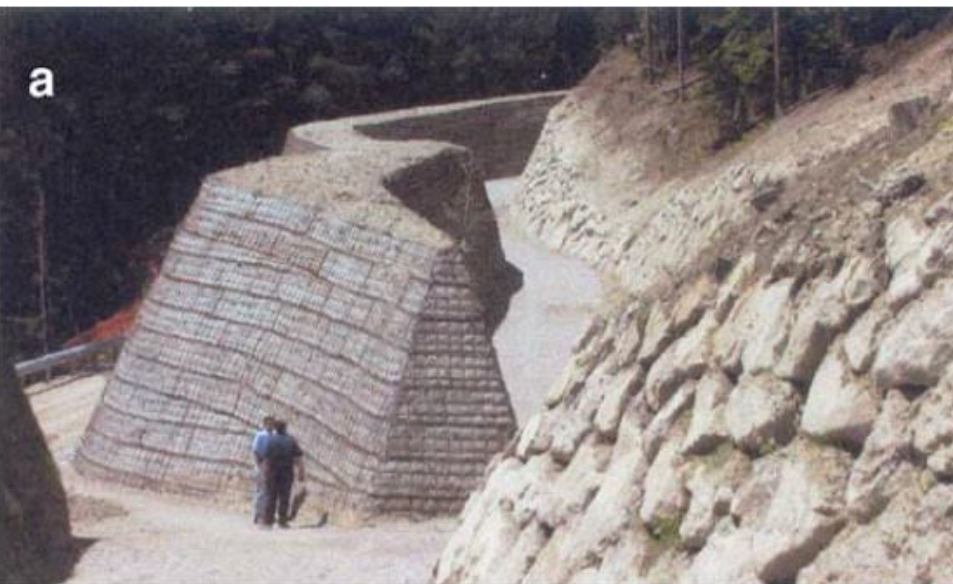
Second Impact

落石防災相關研究

Test number	Block mass [kg]	Impact energy [kJ]	Number of impacts	Soil	Maximum geogrid tensile strength [kN/m]
1	5000	2500	1	Sand and gravel $c'=9 \text{ kPa}$; $\phi'=34^\circ$; $\gamma'=21.10 \text{ kN/m}^3$	50
2	8700	4500	3	Sand and gravel $c'=9 \text{ kPa}$; $\phi'=34^\circ$; $\gamma'=21.10 \text{ kN/m}^3$	45
3	8700	4500	1	Sand and gravel $c'=9 \text{ kPa}$; $\phi'=34^\circ$; $\gamma'=21.10 \text{ kN/m}^3$	Absent

Test number	Impact energy [kJ]	Impact number	Mountain-side max displacement [m]	Valley-side max displacement [m]
1	2500	1	0.60	0.17
2	4500	1	0.95	0.80
		2	1.30	1.20
		3	Collapse	—
3	4500	1	Collapse	—

落石防災設計



防落石擋牆



加勁結構物應用於防落石擋牆
(台灣北海岸道路)

落石防災設計



Figure 88. Concrete shelter damaged by heavy rockfall

原本設計（明隧道）

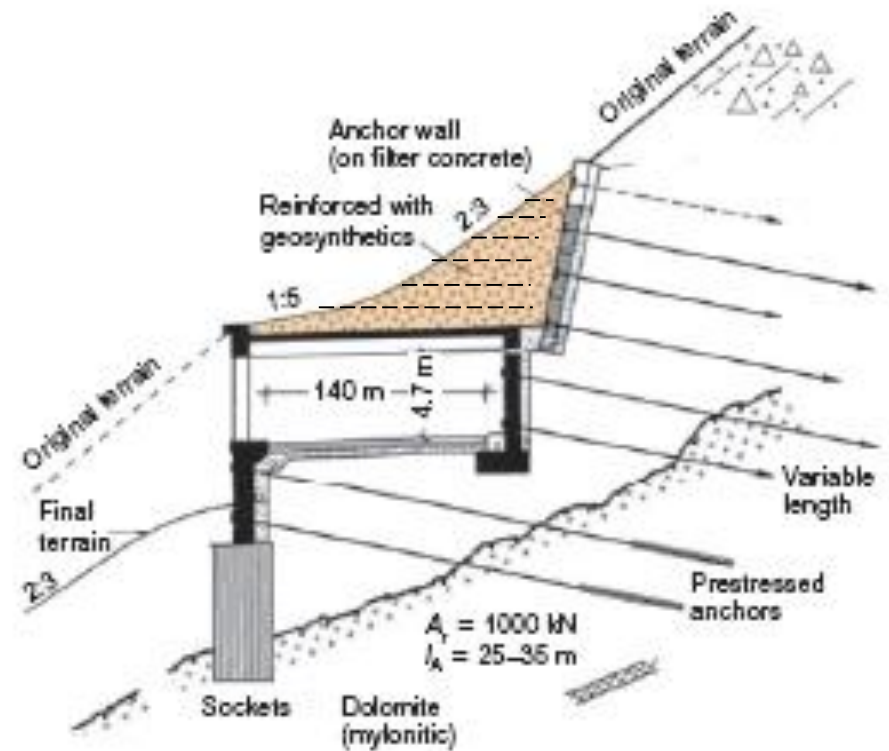


Figure 89. Reinforced concrete shelter (gallery) against rockfall, debris flow and avalanches, covered by protective fill reinforced with geosynthetics; A_t is anchor force

改良設計

土石流



土石流災害



Sever Surficial Erosion and
Debris flow in
“Fire Flame” Mountain,
Taiwan



土石流擋牆



加勁結構物應用於土石流導牆
(苗栗火焰山臺140線道路)



土石流攔沙壩

FITZSIMMONS CREEK, Whistler, British Columbia, Canada

Mitigation measures	Open check dam with geosynthetic-reinforced soil (GRS) abutments
Process type (and basis)	Debris floods
General notes	Additional information in Strouth et al. (2012), Roche (2010) and Currie (2010).
Dimensions	6.3 m tall and 13.5 m wide outlet. The smaller openings are 1.3 m wide. Horizontal steel beams are 0.85 x 0.61 m and vertical beams are about 0.3 x 0.3 m (1' x 1').
Grid design	The grid is designed to be flexible and to displace slightly upon impact. Similar to the Sea to Sky barriers, there are rubber dampers to cushion impact, and the grid is able to rotate. The components were custom designed for this barrier.
Construction	Designed by KWL, BGC and Gygax. Constructed between 2007 and 2009.



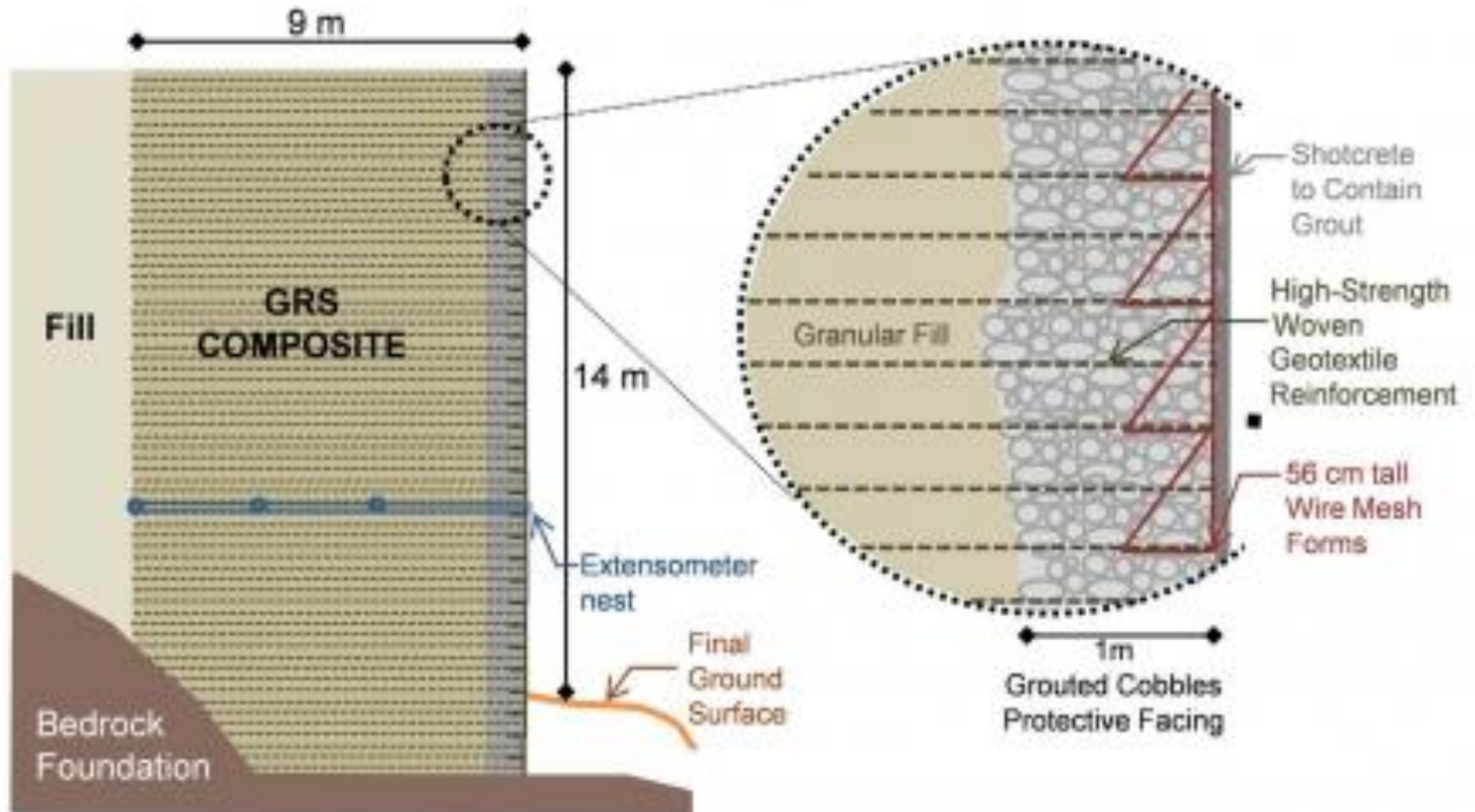
土石流攔沙壩

Looking at the GRS left abutment (from right abutment)



Site photographs by author, July 2016

土石流攔沙壩



雪崩擋牆



Figure 39. Protective fences on top of a mountain to prevent the formation of avalanches



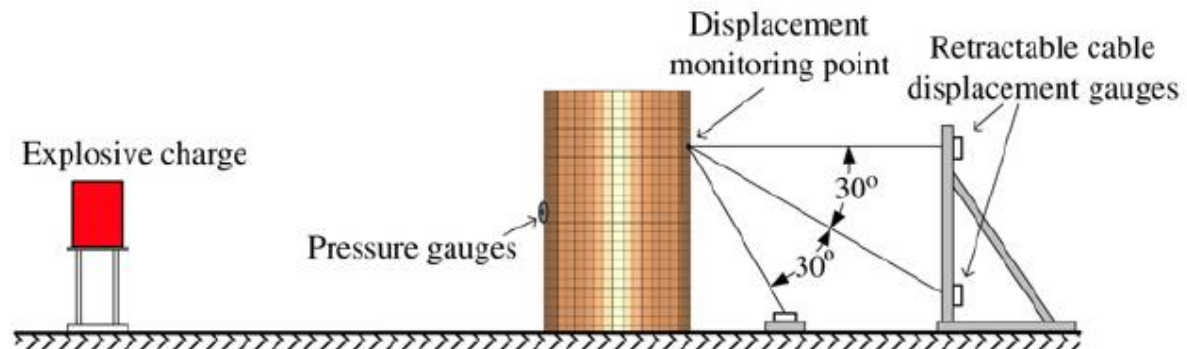
加勁結構物應用於
雪崩保護（冰島）



軍事與爆震



爆震防禦擋牆



爆震防禦擋牆



爆震防禦擋牆



生態環境保護



融合於自然生態環境



滯洪池



台中紅谷公園 (生態滯洪)

滯洪池



台中秋紅谷公園
(生態滯洪)

生態廊道



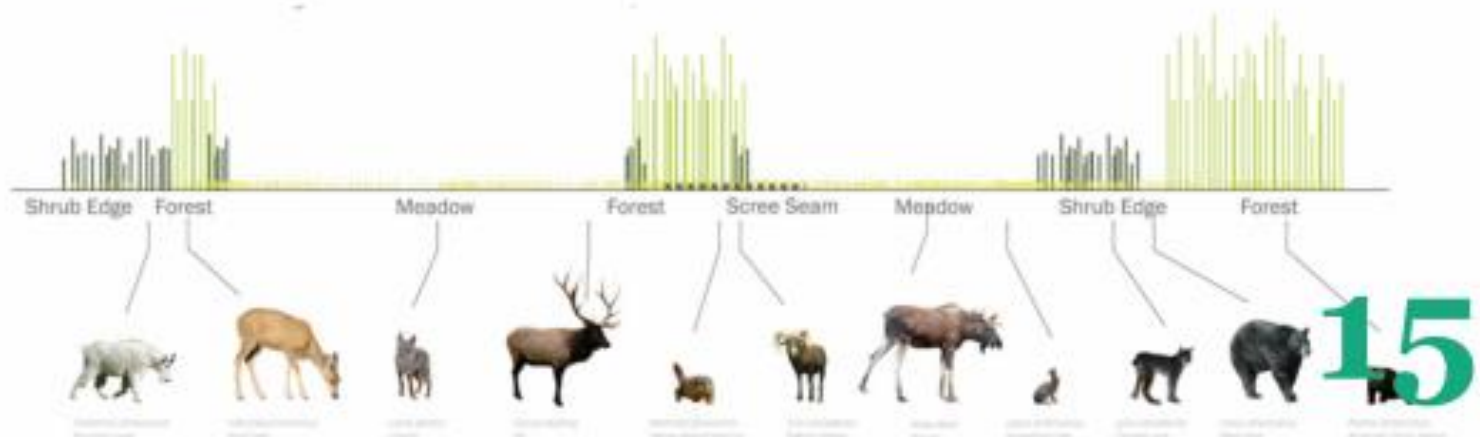
USDA Photo: Ken Hammond

members of relatively common species; others are rare, and vehicle-caused mortality is a serious threat to their recovery.

Millions upon millions of wild animals are killed on our nation's highways every year. Some scientists estimate that humans kill more wild animals with their cars than with any other instrument, including guns. Most animals are

GRS wall for
wild animal bridge

生態廊道



生態廊道



生態隔絕柵



Figure 47. Photo. Mechanically stabilized earth (MSE) wall serving as wildlife exclusion “fence” (Credit: Tony Clevenger).

廢土再利用



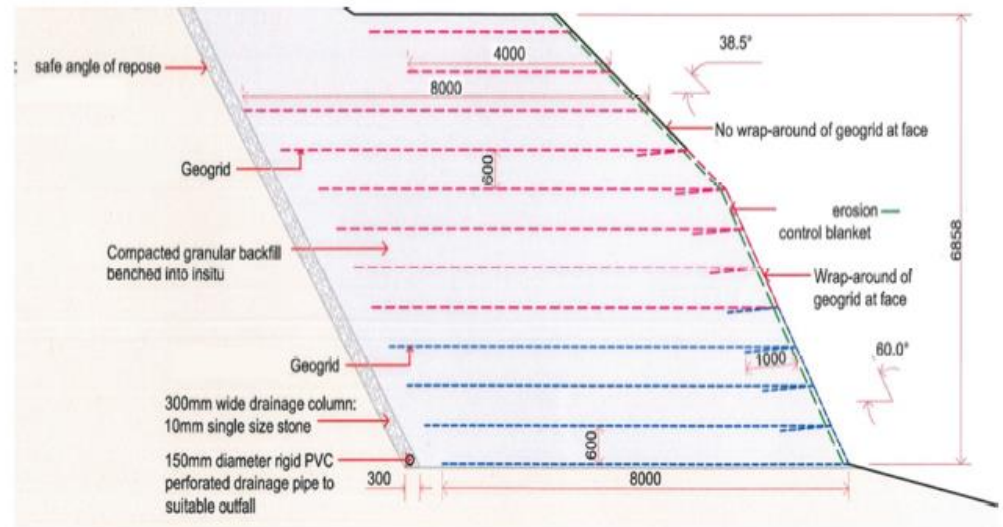
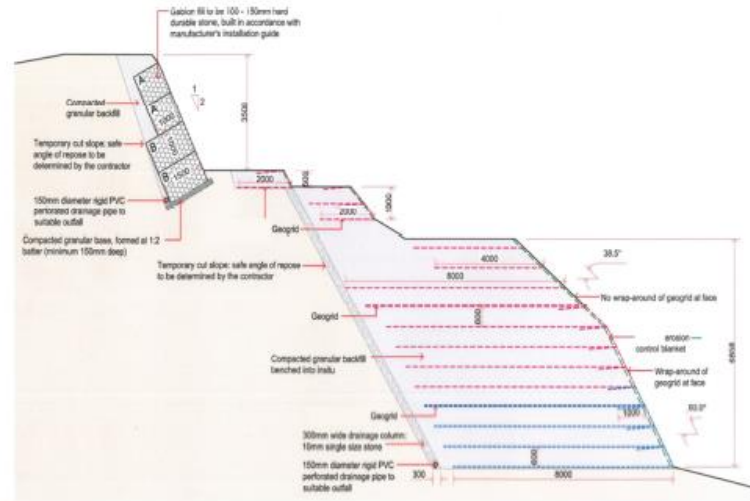
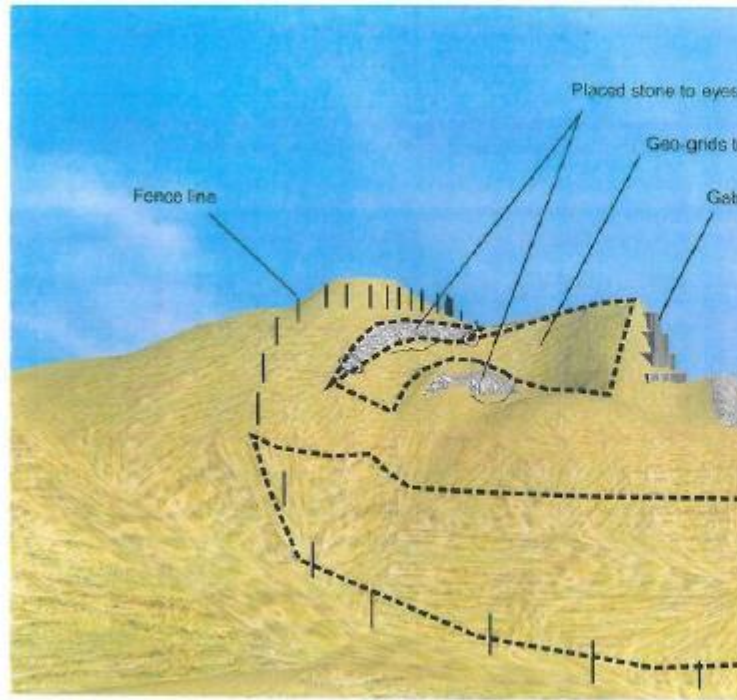
Northumberlandia 北方夫人雕像

廢土再利用



Northumberlandia 北方夫人雕像

廢土再利用





結語



結語

- 土工合成材具有分隔、加勁、過濾、排水、阻水、保護等功能，於補強土壤在工程應用上不足之處。
- 加勁擋土牆主要由土壤、加勁材、牆面與排水系統四個元素構成。
- 比起傳統重力式擋土牆，加勁結構物具多項優點。
- 加勁結構物可應用於擋土、邊坡、防災與自然生態等工程中。可有效抵抗天然災害的衝擊，提升系統的穩定性與韌性，以期減低基礎設施構造物在災害下受損或毀壞，達到永續安全的最終目標。

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加勁擋土牆於 工程、防災與自然生態保護之應用

報告完畢 謝謝聆聽

楊國鑫 博士

國立台灣大學

土木工程系 教授

kyang@ntu.edu.tw

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國立台灣大學
National Taiwan University

推廣之問題與對策



土工合成材於臺灣之應用

每年約使用3,000,000-4,000,000 m²/year
應用於災害防治與搶救

- 邊坡穩定與滑坡整治
- 河堤保護與防洪工法
- 海岸保護與護灘工法
- 水土保持



問題與對策

□ 工程師不熟悉加勁擋土構造物相關設計

安排學校課程，舉辦教育訓練，編輯設計規範

□ 加勁擋土構造物仍有破壞案例

建立專家學者審查制度

□ 廠商競爭與惡性黑函

建立依據設計需求的標準材料規格