



密不可分的理工領域 – 從土木工程的角度來看

Wen-Chao Huang (黃文昭)

Associate Professor

Department of Civil Engineering, NCU

Interdisciplinary Program, College of Engineering, NCU

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國立中央大學土木工程學系
Department of Civil Engineering



國立中央大學理學院學士班
JOINT SCIENCE PROGRAM, COLLEGE OF SCIENCE, NCU

國立中央大學

工學院學士班
Interdisciplinary Program, College of Engineering

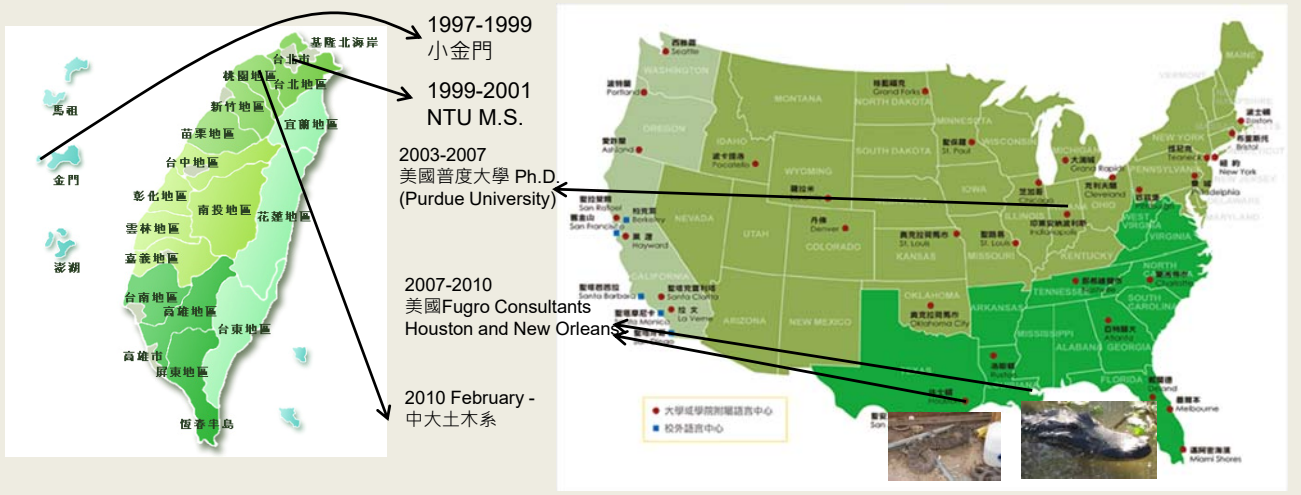


大綱

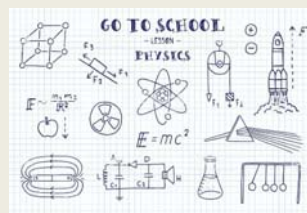
- 自我介紹
- 理學院學士班 vs. 工學院學士班
- 堤防破壞機制與風險評估
- 山崩機制與實驗分析
- MICP工法 (酵素結晶工法)
- 生醫、光電與工學院學士班
- 結論

自我介紹

- 中央大學土木工程系 (2010年~)
- 中央大學工學院學士班 (2018年~)
- 主要研究領域：大地工程與地質災害相關研究
 - 大地工程：隧道、堤防、基礎工程、邊坡穩定
 - 地質災害：斷層錯動、山崩



理學院學士班 vs. 工學院學士班



數學

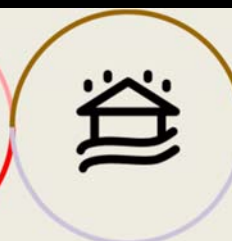
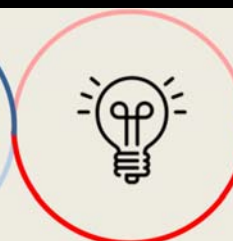
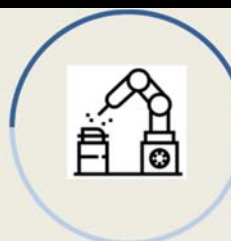
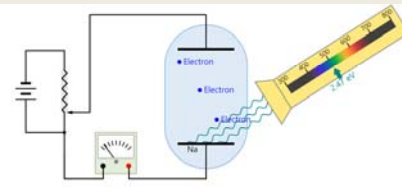
物理

化學

光電

生命科學

生醫



智慧機械

能源材料

永續防災

綠色科技

人工智慧 智能控制

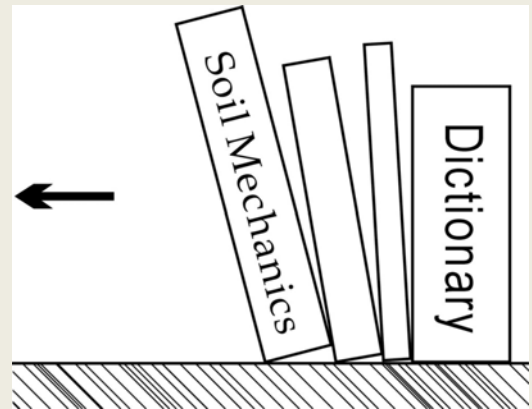
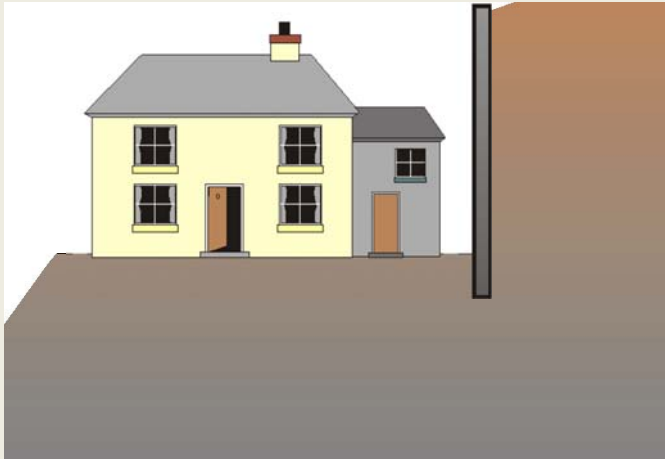
能源轉換 材料設計

永續設計 防災救災

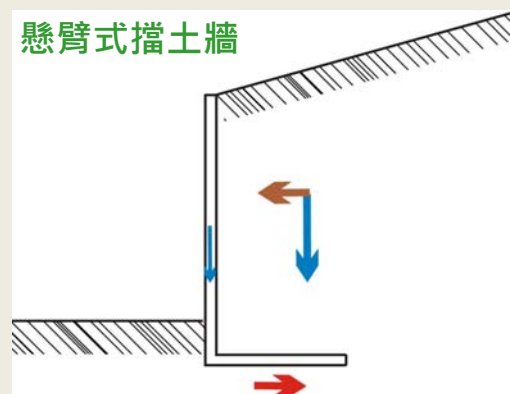
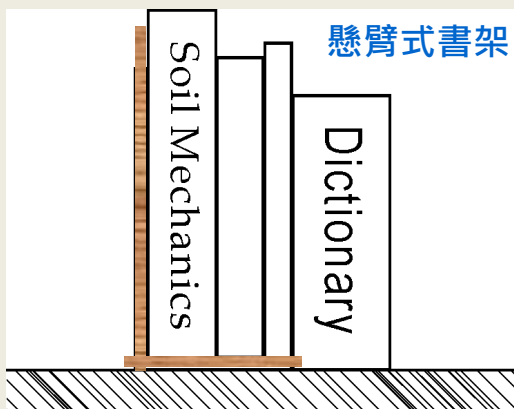
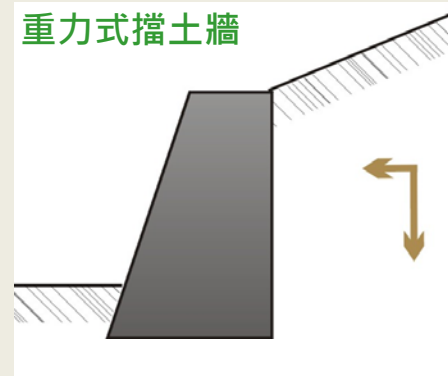
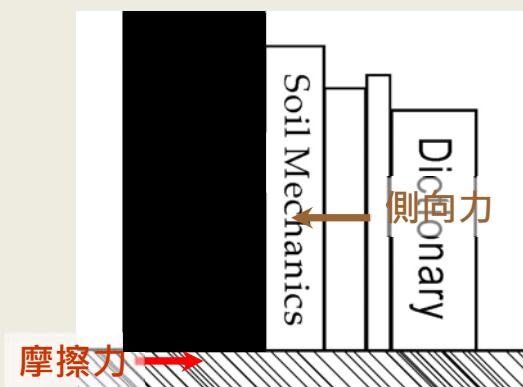
循環經濟 再生能源

案例一：土木工程之擋土牆

- 培養想像力及創造力
 - 擋土牆功用為：用來擋住土石坍塌的牆、穩定住土石邊坡阻止坍塌、創造了更多空間以供建屋築路
 - 想像書本...
- 靜力平衡、動力學(地震) – 物理、數學



土木工程之擋土牆



Levee Rehabilitation Introduction in New Orleans, Louisiana, United States

案例二

Wen-Chao Huang, Associate Professor, National Central University, Taiwan
Byron Porter, Laboratory Director, FFEB J.V., New Orleans, LA, United States
Blake Cotton, Office Manager, Fugro Consultants, New Orleans, LA, United States
Jeong-Yun Won, Project Engineer, Fugro Consultants, Houston, TX, United States

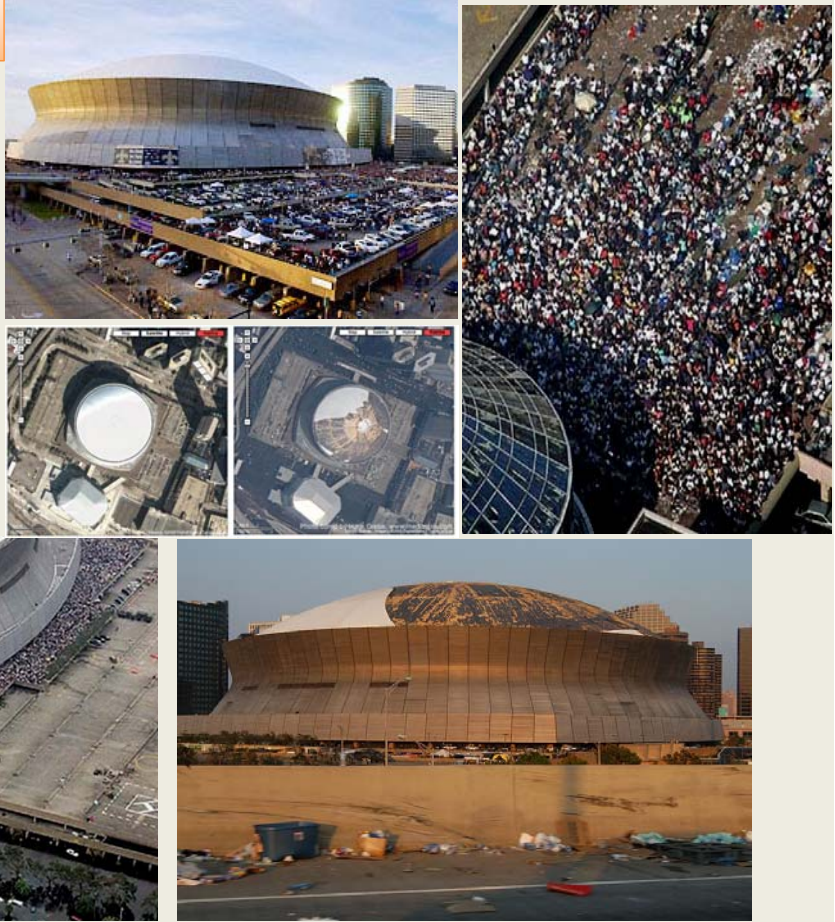
Disaster Overview

- Hurricane Katrina started as a tropical storm in August 2005
- Intensifies from Category 3 to Category 5 hurricane in Gulf of Mexico within 9 hours
- Make landfall on August 29th 2005 as a Category 3 hurricane near the coast of state of Louisiana
- City of New Orleans ordered mandatory evacuation in the fear that storm surge might top most of levees in NOLA, causing major flooding



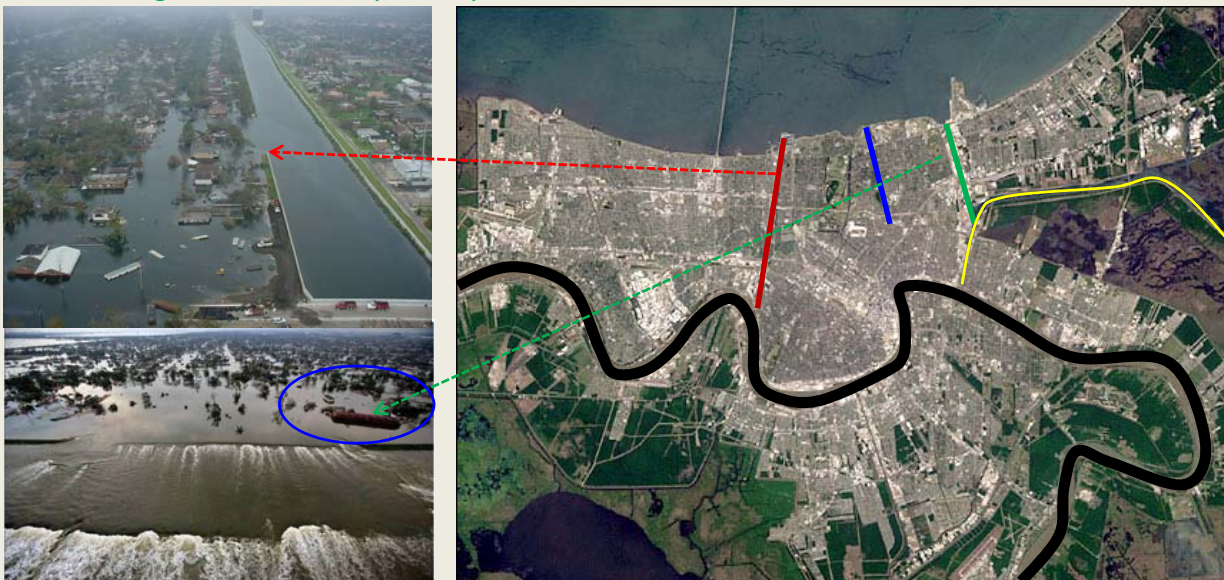
Disaster Overview

- For those who cannot leave NOLA, superdome was used as temporary shelter for the residents...
- 1800+ deaths overall
- 80+ Billion USD damage



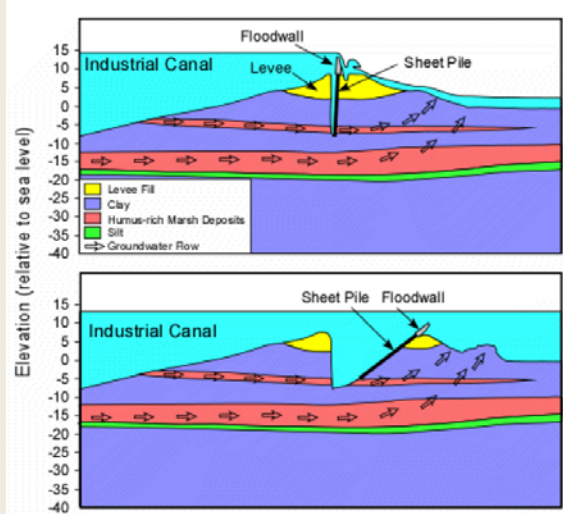
Failure of Levees

- Most damage (lost of lives and properties) due to breach of levees/floodwalls
- City is mostly protected by levee system due to its low sea level
- Major levees breached in the city
- Breach of levees for 17th street canal, London Ave. canal, Inner Harbor Navigation Canal (IHNC)



Failure of Levees

Added pressure in the canal forces water through the permeable layers to the toe of levee



(ILIT, 2006)



Sheet pile walls and floodwall collapse

(Flood Side)

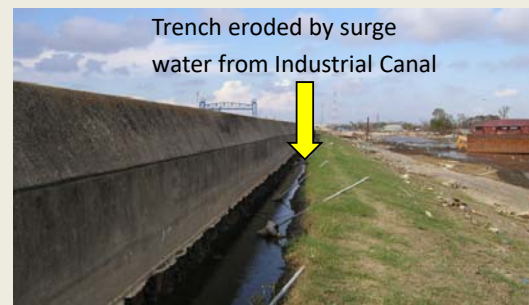
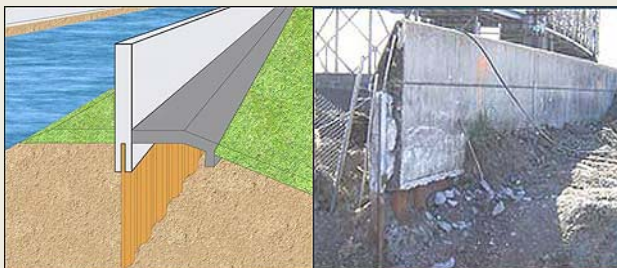
(Protected Side)



(USACE)

Disaster Overview

- Some canals are used to drain water to Lake Pontchartrain during hurricane season, some for cargo shipping
- Failure of levee might be due to
 - surge water overtopped the levee and erode the levee from protected side
 - soil condition underneath (ILIT suggested possible piping of the soil underneath)



(U.S. Army Corps of Engineers)



Geotechnical Studies Conducted for Levees in NOLA

The geotechnical study was awarded to a joint venture company at \$100 million

- Provide **100-year level** of protection by June 2011 (風險分析相關)
- For 350 miles of federal levees – over 200 miles of levees were repaired
- Design of pump stations
- Design of flood wall and flood gates
- Satisfy hurricane and storm damage risk reduction system (HSDRRS) – rebuild of levees, pump stations, floodwalls, surge barrier
- Hurricane Gustav spared NOLA



Geotechnical Studies Conducted for Levees in NOLA

Major Tasks in JV Company

■ Field Work

- ✓ Drilling and Sampling
- ✓ Field Testing (CPT, Pressuremeter...)
- ✓ Field Instrumentation

■ Laboratory Testing

- ✓ Soil Classification and the basic physical properties
- ✓ Strength Testing
- ✓ Compressibility Testing

■ Engineering Design

- ✓ Slope Stability/Seepage Analyses
- ✓ Settlement Analyses
- ✓ Pile Capacity Analyses
- ✓ Retaining Walls (T-Wall, Sheetpile Wall) Design

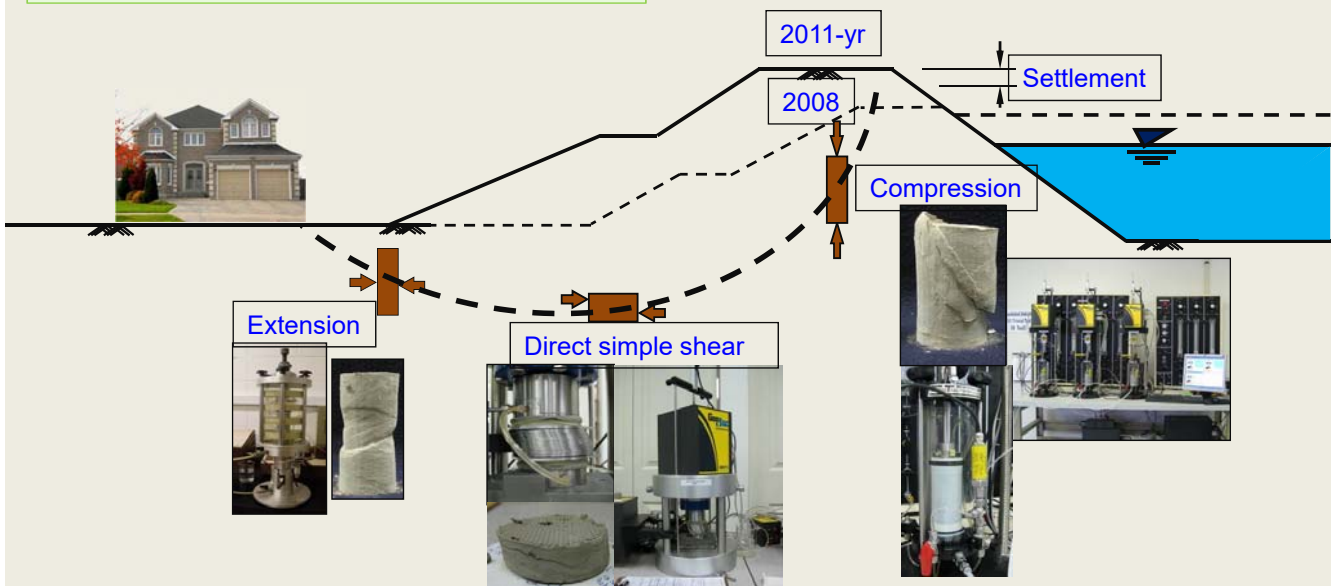


Typical Soil Samples in NOLA



Some Clays with Extremely High Atterberg Limits - ??

Engineering Analysis

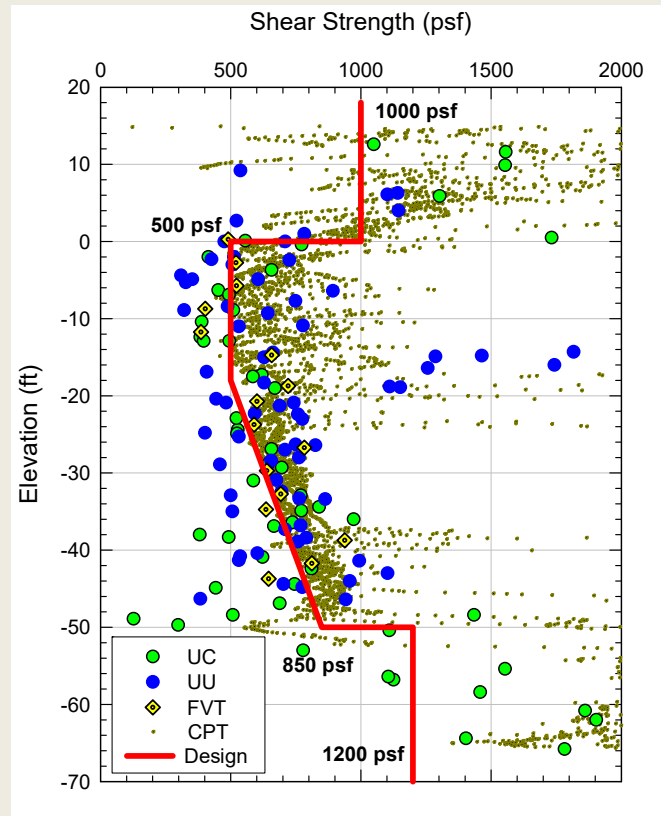


- Analysis method - Spencer's general limit equilibrium method
- Analysis software - UTEXAS & **SLOPE/W**
- Analysis conditions (water level): top of the levee, still water level, lower water level
- Additional Levees (or berms) are added to increase required slope stability

Engineering Property Interpretation

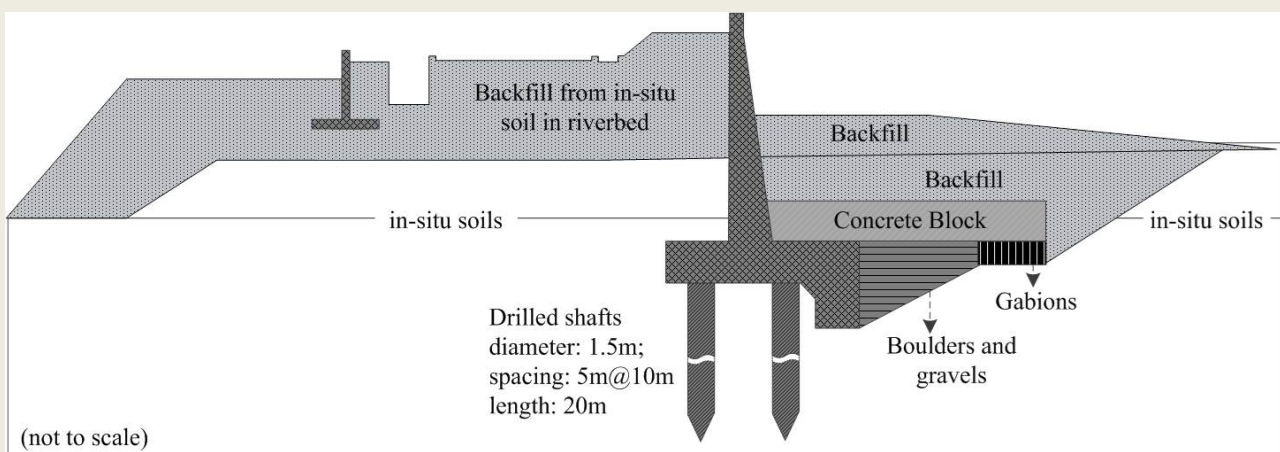
With more than:
 20,000 (UC+UU)
 3,000+ (Consolidation Tests)
 Numerous CPT-related data
 Other Field Test Data

How do we choose a representative soil profile?
 - No such Profile
 - The doubt of using UC/UU was raised (C.C. Ladd et. Al)
 - Field Test Data may be more representative
 - Use of Spatial Variability



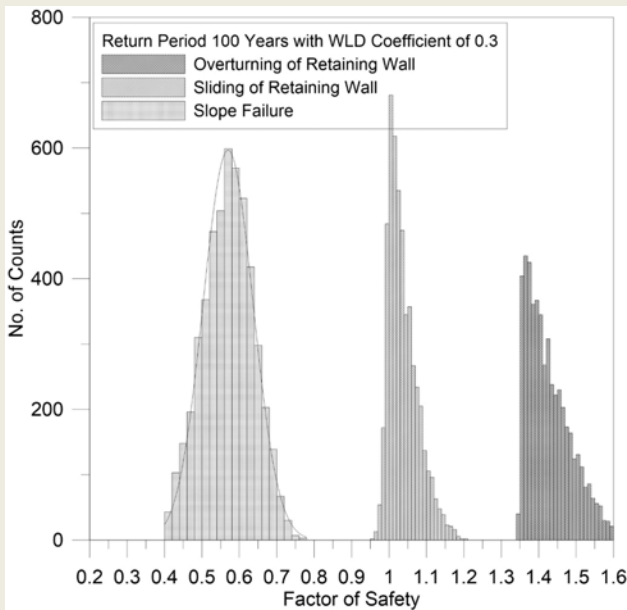
Stability of Chiuliao 1st Levee (台灣南部舊寮一號堤防風險分析)

- Updated design cross section of Chiuliao 1st Levee
 - thickened backfill
 - pile rows

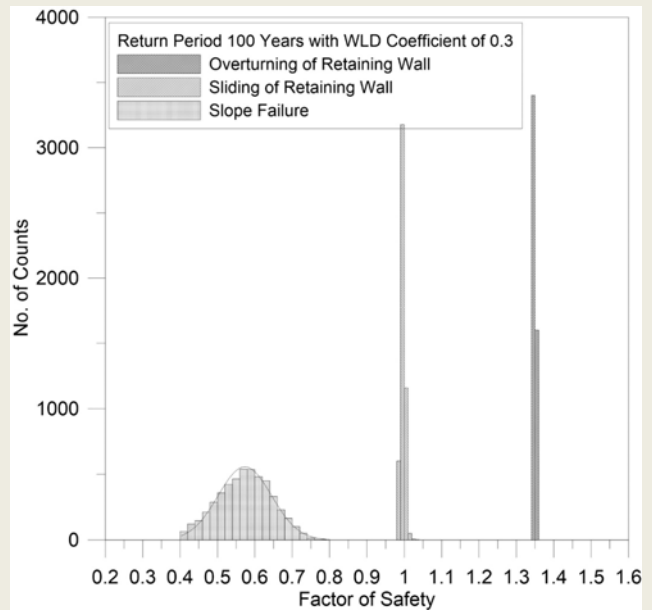


Reliability analysis of Chiuliao 1st levee

Various in-situ friction angle

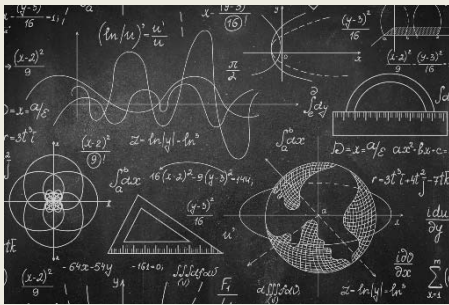


Constant in-situ friction angle

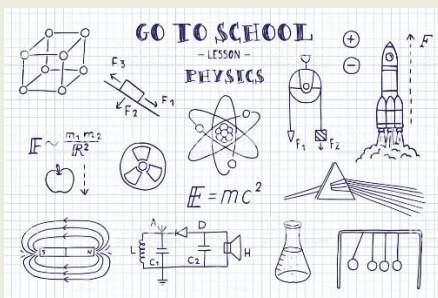


- The sliding and overturning failure is sensitive to the change of in-situ friction angles
- Reliability analyses continue.

理學 vs. 工學



數學 – 機率分析、隨機場模擬



物理 (靜力學、動力學部分)

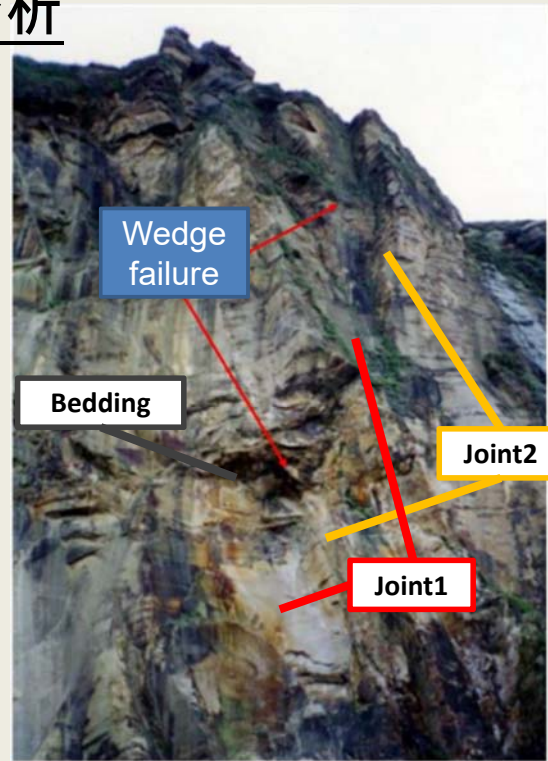


土木工程
永續防災

永續設計 防災救災

案例三：楔型岩坡穩定分析

- 一般認知上，自由的楔型岩塊由兩條不連續面以及自由坡面所構成
- 前人研究中多針對完整楔型岩塊；而完整楔型岩塊穩定性與否，可利用極限平衡法進行分析
- 台灣地區觀察到的楔型破壞，較多都由三組不連續面切割成，且破壞型式並非完全為完整岩塊楔形滑動，而是漸進式複合破壞的跡象

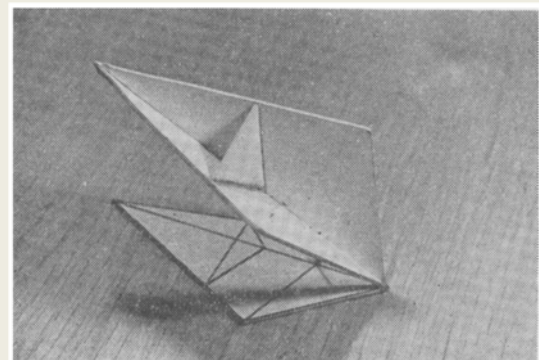


台二線信義橋附近(90.2k) (86.3.10)

(黃鎮臺、夏龍源，1990)

文獻回顧

- Hoek等人(1973)針對岩坡上楔型塊體之穩定性進行分析
 - 立體投影法
 - 極限平衡分析
 - 建立立體模型

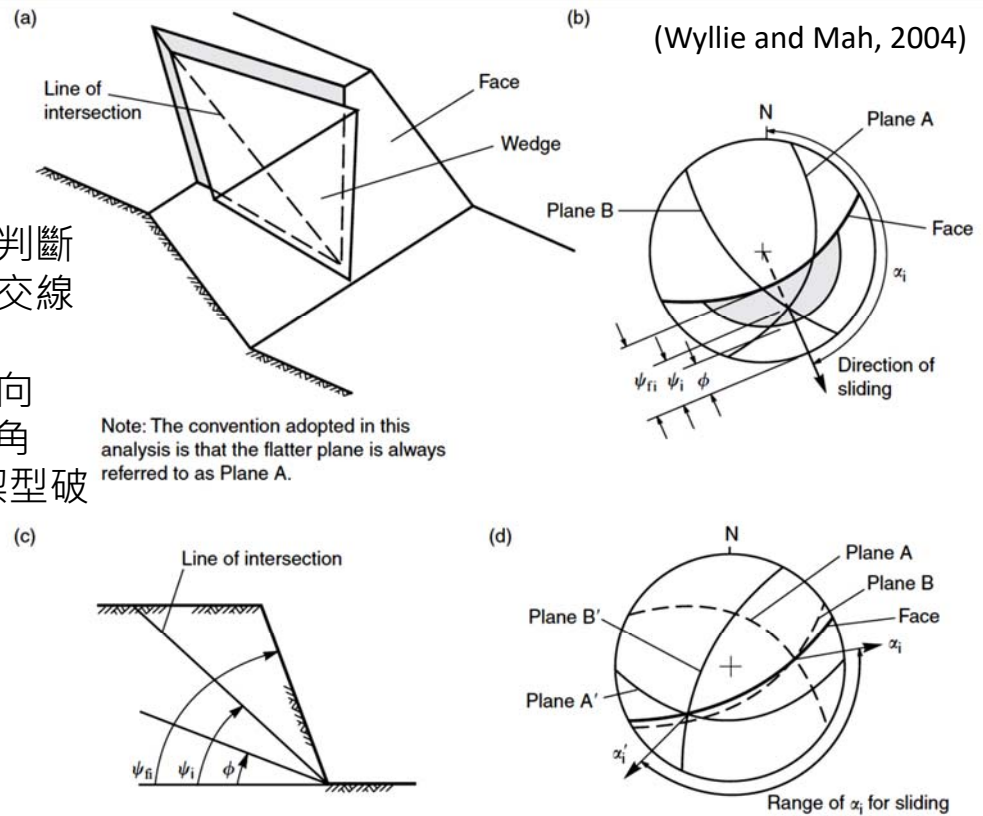


楔形破壞模型構想圖(Hoek et al., 1973)

TABLE 1. *Geometry and properties of planes*

Plane	Dip in degrees	Dip direction in degrees east of north	Strike (dip direction - 90°)	Location and properties
Plane A	45	105	15	Cohesion $c_A = 500 \text{ lb/ft}^2$, Friction angle $\phi_A = 20^\circ$. Cohesion $c_B = 1000 \text{ lb/ft}^2$, Friction angle $\phi_B = 30^\circ$.
Plane B	70	235	145	
Slope face	65	185	95	Intersection of plane A and slope crest 100 ft vertically above toe of wedge.
Upper slope	12	195	105	
External force	30	355	265	Magnitude T to be determined. 40 ft along trace of plane A.
Tension crack	70	165	75	

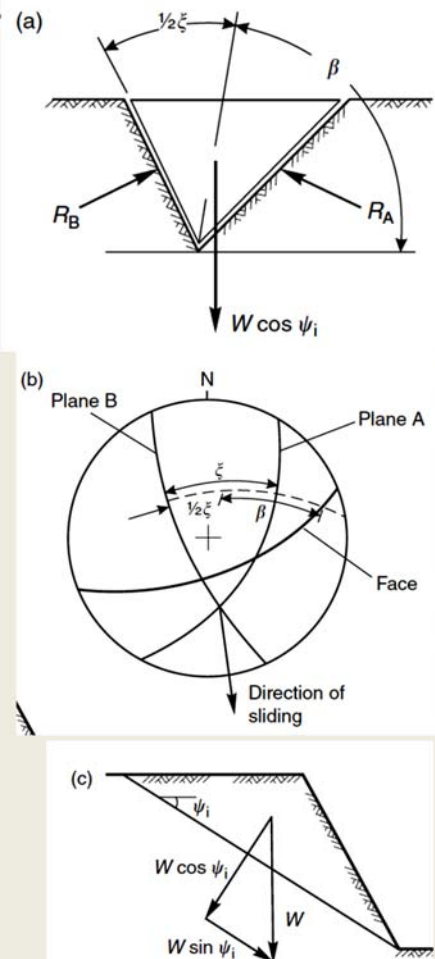
- 以立體投影法判斷楔型塊體沿兩交線滑動之可能性
- 弱面交線之線向 (Trend) 與傾伏角 (Plunge) 影響楔型破壞之可能性



Note: The convention adopted in this analysis is that the flatter plane is always referred to as Plane A.

Figure 7.3 Geometric conditions for wedge failure: (a) pictorial view of wedge failure; (b) stereoplot showing the orientation of the line of intersection, and the range of the plunge of the line of intersection ψ_i where failure is feasible; (c) view of slope at right angles to the line of intersection; (d) stereonet showing the range in the trend of the line of intersection α_i where wedge failure is feasible.

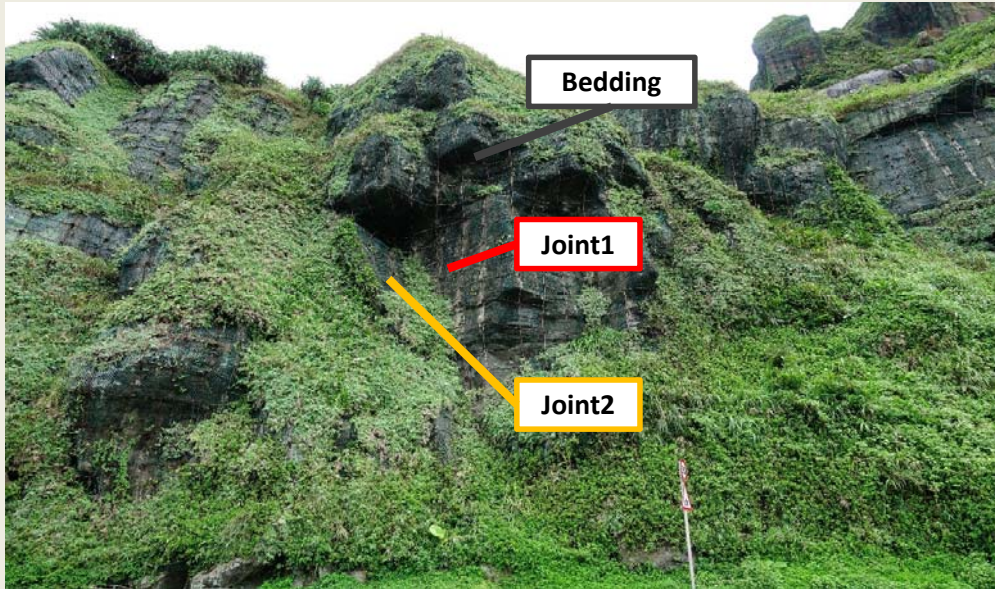
- 楔型滑動之極限平衡分析
 - 考慮條件：兩弱面位態(面角與對稱角)、兩弱面摩擦角與凝聚力、交線傾伏角、水壓力作用與否
 - 例子：最簡化狀況下 (兩弱面摩擦角相同、無凝聚力、無水壓力作用) → 安全係數與楔型塊體尺寸無關



$$FS = \frac{\sin \beta}{\sin(\xi/2)} \cdot \frac{\tan \phi}{\tan \psi_i}$$

野外調查

- 台二線80~90k (南雅里)
 - 桂竹林層(青灰色至白灰色厚層砂岩)，層面向陸地側傾
 - 現場已掛網保護
 - 弱面分佈

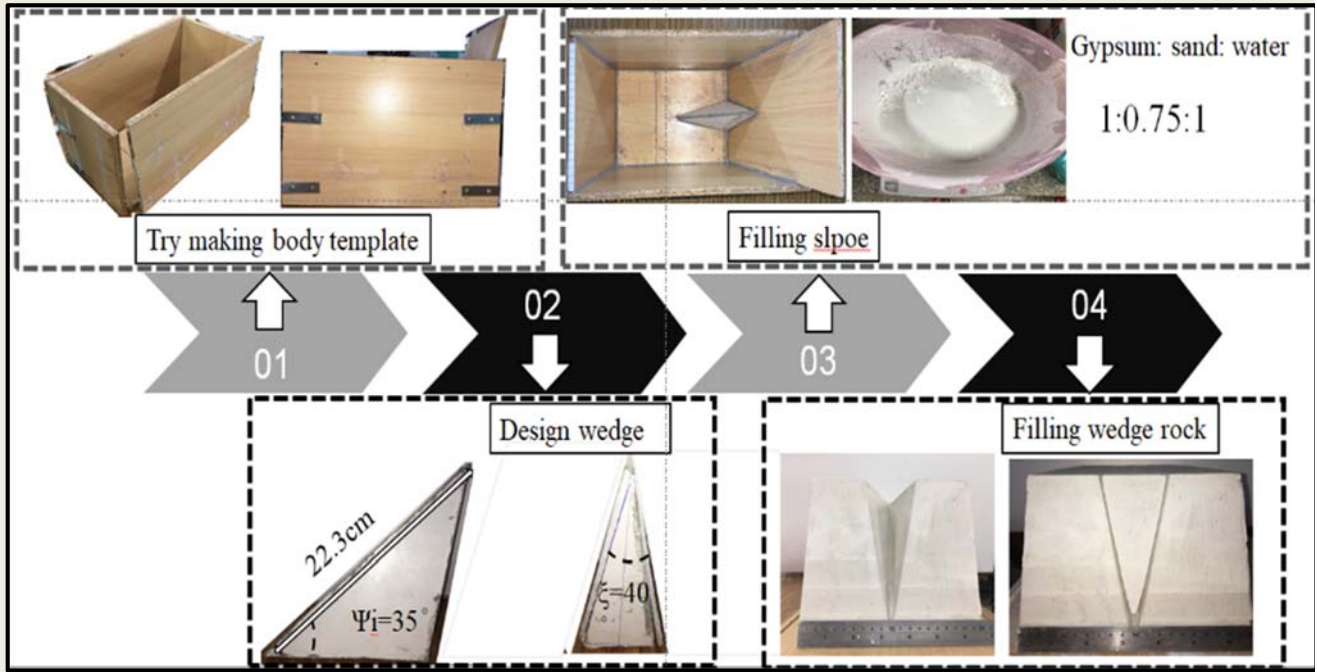


研究動機

- 目前對於楔型破壞之機制與其受影響之因素尚未了解
- 前面二例中→順向斜交與逆向斜交坡對破壞機制之影響
- 了解岩石邊坡受多組節理影響下之破壞特性
 - 單一楔型塊體之分析
 - 受多組節理切割楔型岩坡破壞特性
- 岩石邊坡受多組節理以及尺度之關係

實驗規畫 – 物理試驗材料

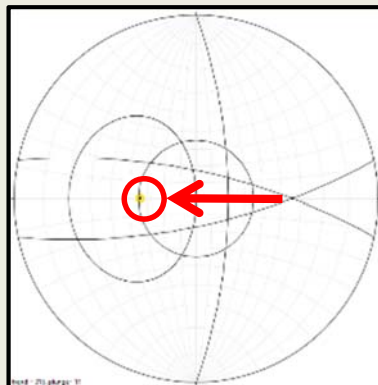
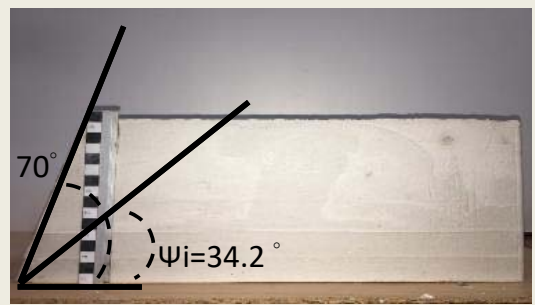
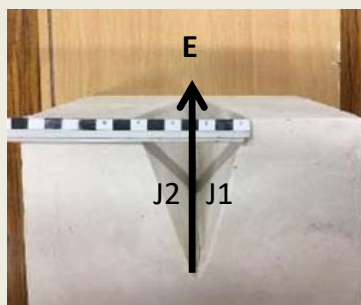
- 楔形岩坡製作：人造石膏試體 (石膏：石英細砂：水=1:0.75:1) → 單壓強度~4MPa



單一楔形塊體 – 室內1g試驗結果

石膏製楔型塊體

基本參數	數值
坡面位態	360/70°E
J1位態	78/73°S
J2位態	282/73°N
ξ	41.4°
Ψ_i	34.2°
Φ	30-35°



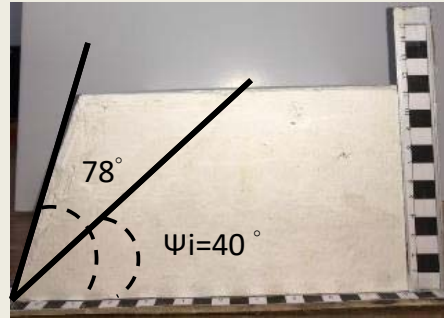
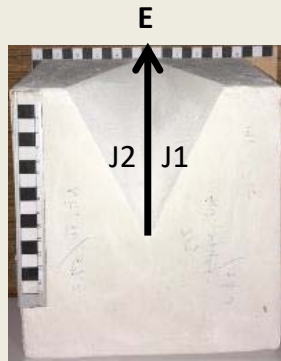
$$FS = \frac{\sin(\beta)}{\sin(0.5\xi)} \cdot \frac{\tan(\varphi)}{\tan(\psi_i)}$$

$FS_{\Phi_{30}}=2.4$

單一楔形塊體 – 室內1g試驗結果

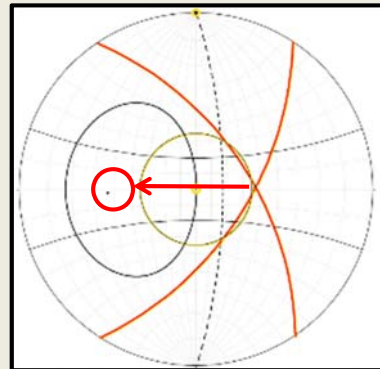
石膏製楔型塊體

基本參數	數值
坡面位態	360/78°E
J1位態	33/58°S
J2位態	326/58°N
ξ	90°
ψ_i	40°
ϕ	30-35°



$$FS = \frac{\sin(\beta)}{\sin(0.5\xi)} \cdot \frac{\tan(\varphi)}{\tan(\psi_i)}$$

FS_{φ₃₀} = 0.973



單一楔形塊體 – 室內1g試驗結果

穩定

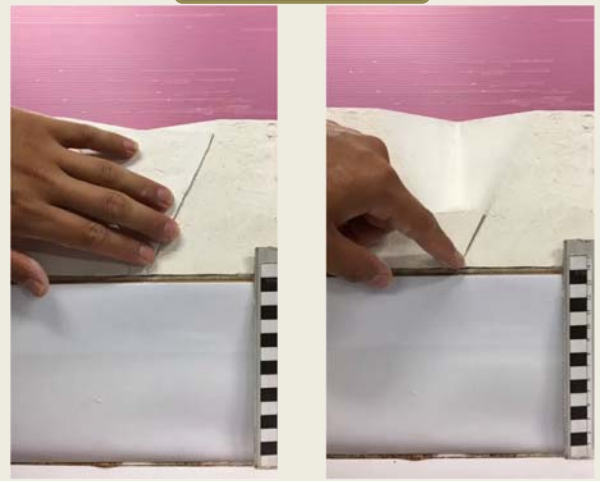
$\xi=41.4^\circ$
 $\psi_i=34.2^\circ$



FS=2.4

不穩定

$\xi=90^\circ$
 $\psi_i=40^\circ$



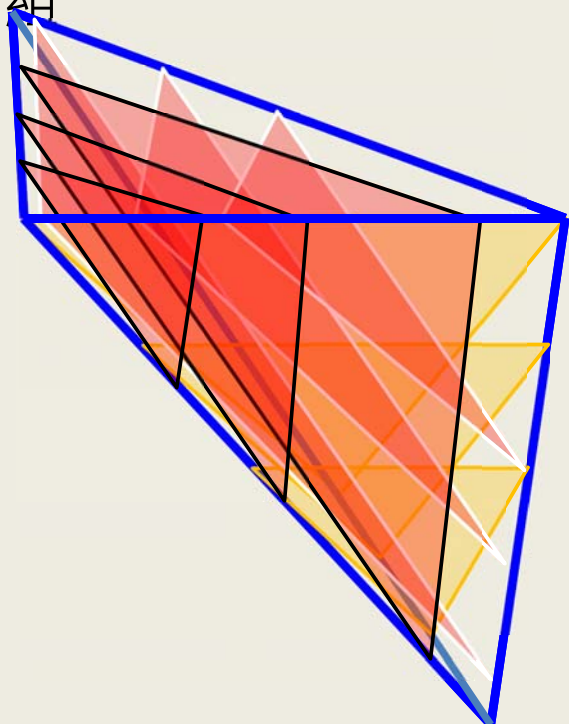
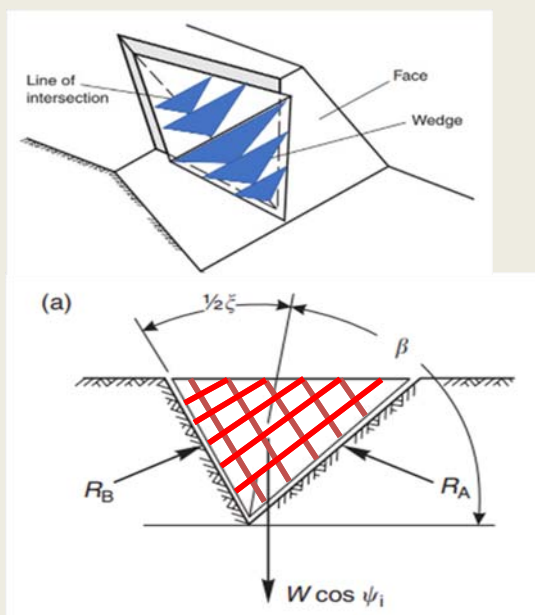
FS=0.973

實驗規畫 – 複合楔形塊體

- 單一楔形塊體由兩弱面及坡面、坡頂面構成
- 兩弱面(J1/J2)與層面(J3)切割單一楔形塊體成為數量、大小不一之岩楔單元
- 層面(J3)與坡面傾向一致及相反 → 順向斜交及逆向斜交
- 固定參數
 - 兩弱面(J1/J2)摩擦角 ϕ ：30度
 - 對稱角 β ：90度
 - 坡面角度：~70-80度
 - 坡頂面角度：水平
- 變數
 - 面角 ξ ：90/120度
 - 交線傾伏角 ψ ：30/40度

實驗規畫 – 複合楔形塊體

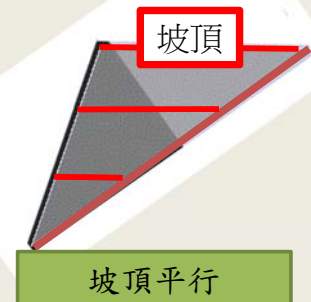
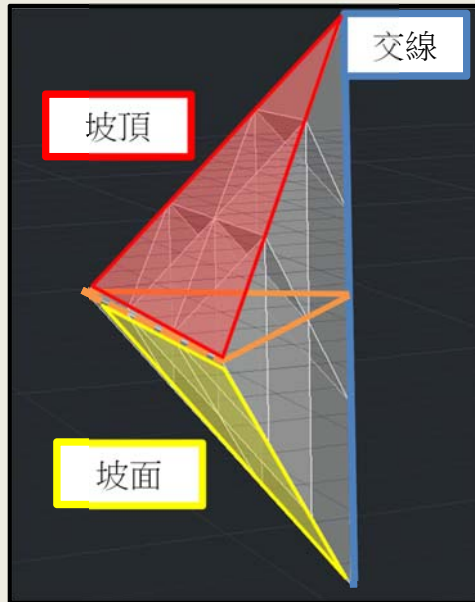
單一楔形岩塊加入弱面組



實驗規畫 – 複合楔形塊體

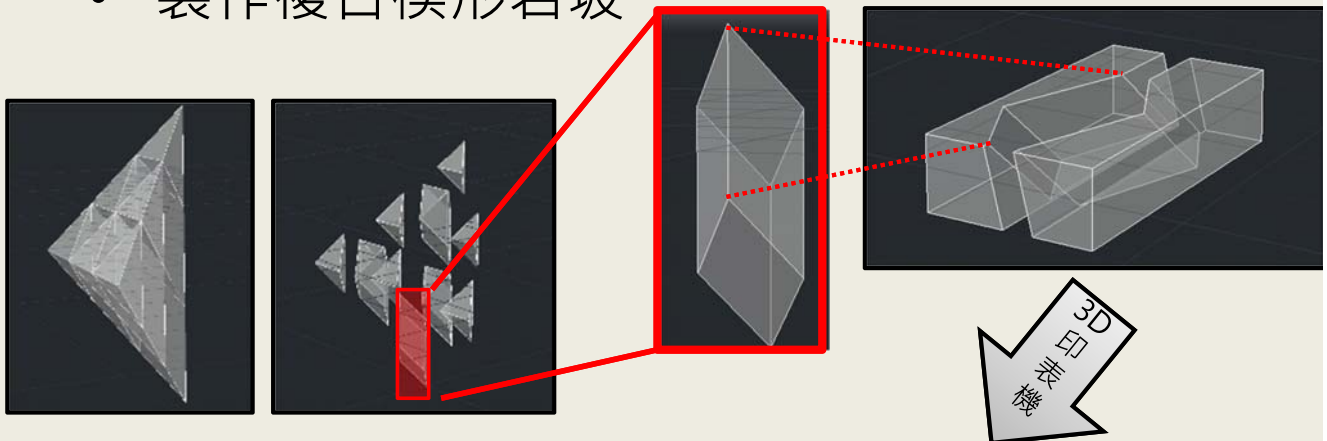
弱面配置示意

弱面組J3(層面)與交線相對位置

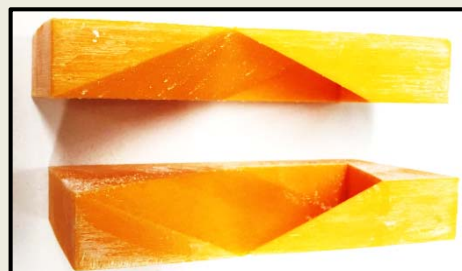


實驗規畫 – 複合楔形塊體

- 製作複合楔形岩坡

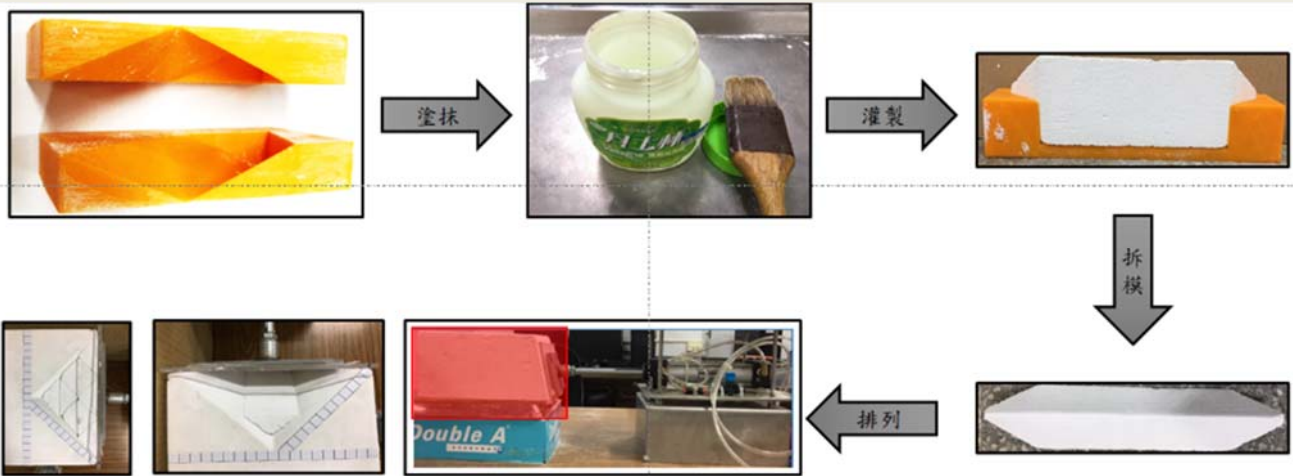


- 製作組成單一楔形岩塊之各岩楔小單元



實驗規畫 – 複合楔形塊體

- 製作複合楔形岩坡



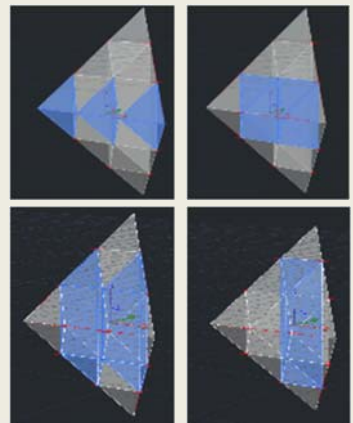
- 岩楔小單元組成大型單一楔形塊體，並放置於原坡體空間內，試驗前以氣壓式擋板固定，並於實驗開始時解開擋板
- 俯視、側視均以錄影方式記錄岩楔運動過程

複合楔形塊體(試驗1) – 試驗結果

岩楔小單元塊體運動情形

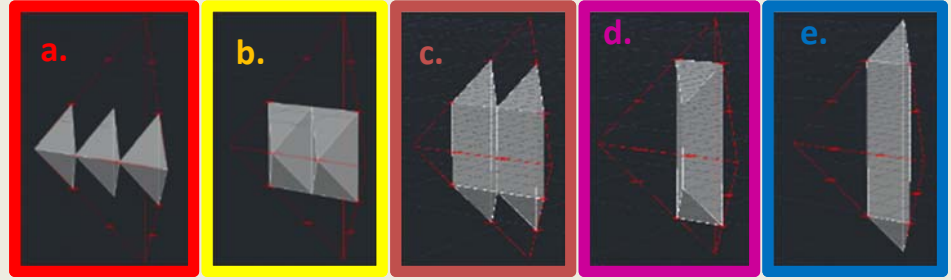
ξ	90°
ψ_i	40°
β	90°
FS	0.97

1.過程:上部第一層塊體，沿第二層微下滑；第二層塊體沿第三層頂部，帶動上部塊體向下滑動。
2.運動方式分類:平面滑動。

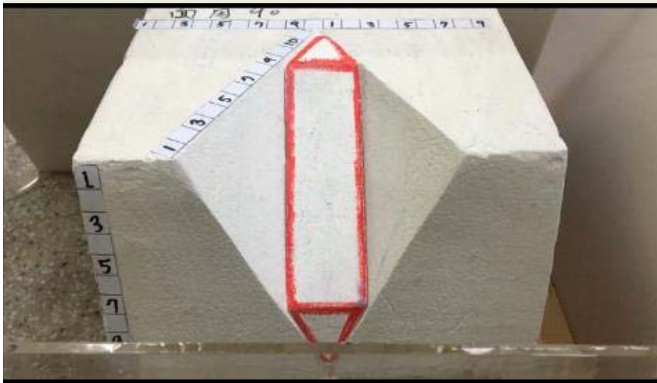


複合楔形塊體(試驗1) – 試驗結果

坡面產狀及坡趾
之小岩楔停留狀況



塊體崩落率
≈74.1%



複合楔形塊體(試驗2) – 試驗結果

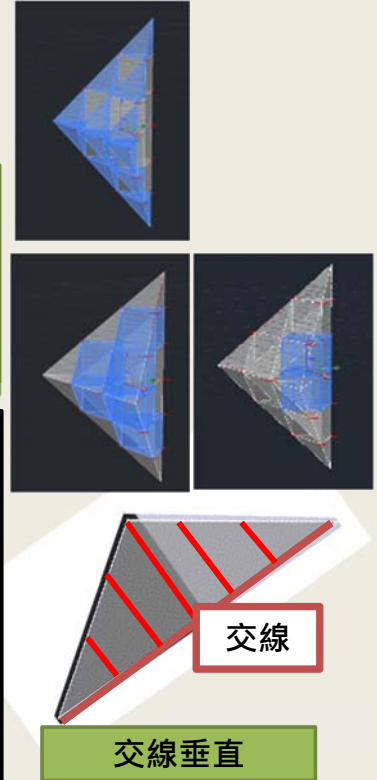
1G	$\xi=90^\circ$	$\Psi_i=40^\circ$	$FS_{\xi 90^\circ}=0.97$	交線平行	交線垂直
		$\Psi_i=30^\circ$	$FS_{\xi 90^\circ}=1.41$	交線平行	交線垂直
	$\xi=120^\circ$	$\Psi_i=40^\circ$	$FS_{\xi 120^\circ}=0.79$	交線平行	交線垂直
		$\Psi_i=30^\circ$	$FS_{\xi 120^\circ}=1.15$	交線平行	交線垂直

複合楔形塊體(試驗2) – 試驗結果

岩楔小單元塊體運動情形

ξ	90°
Ψ_i	40°
β	90°
FS	0.97

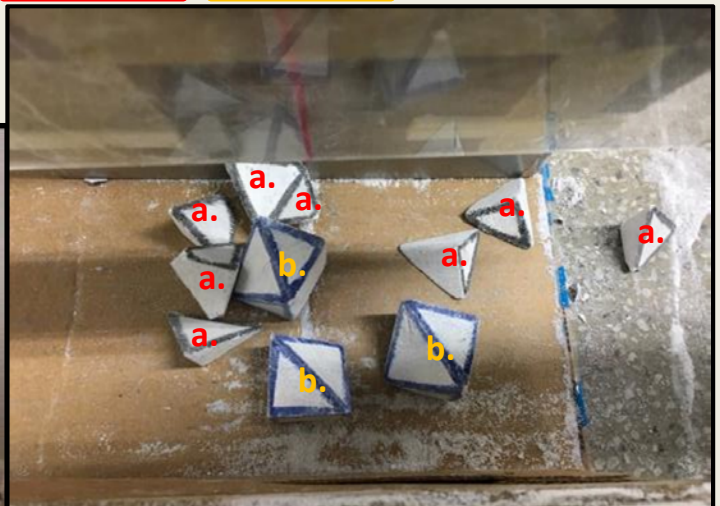
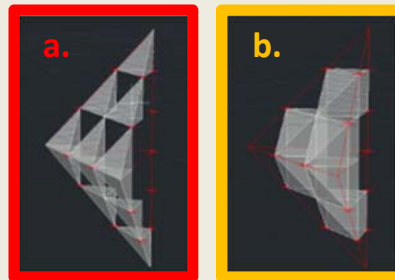
- 1.過程:坡面坡趾部分楔型塊體滑動後翻落, 接續內部較大塊體翻落和滑出; 坡頂部小型楔形塊體滑動後翻落。
- 2.運動方式分類:翻落+楔形滑動。



複合楔形塊體(試驗2) – 試驗結果

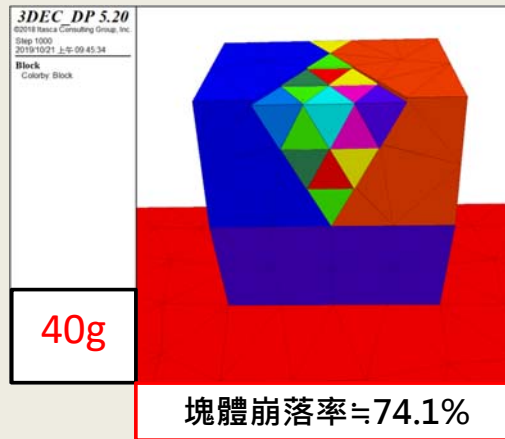
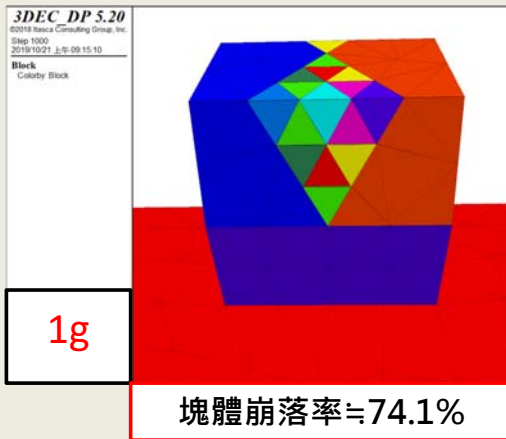
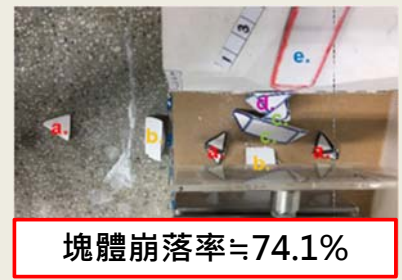
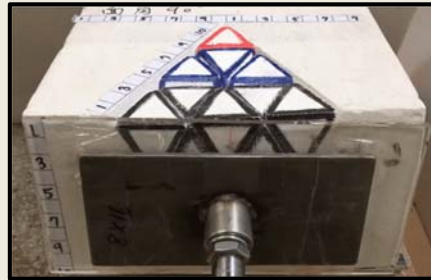
坡面產狀及坡趾之小岩楔停留狀況

塊體崩落率
≈42.6%



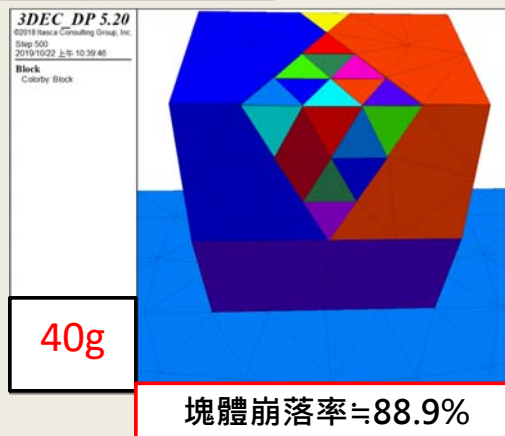
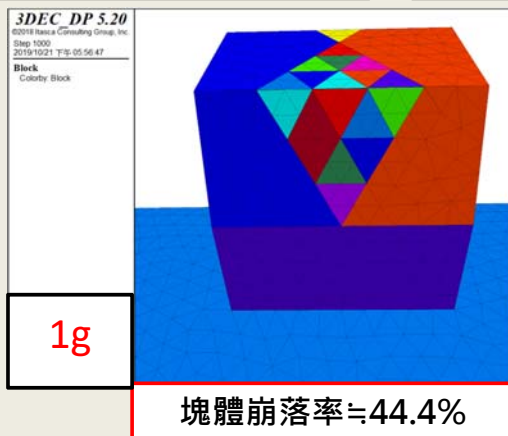
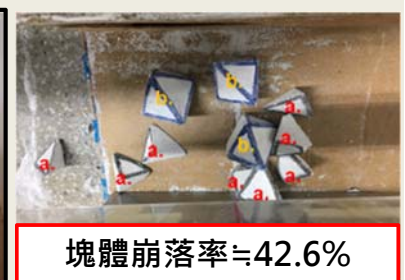
複合楔形塊體(試驗1) – 3DEC數值模擬

- 1g物理試驗 vs 數值模擬1g&40g

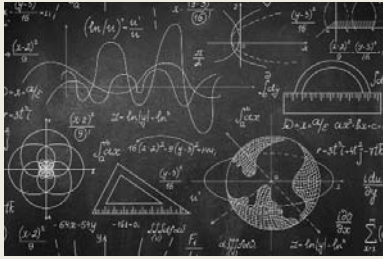


複合楔形塊體(試驗2) – 3DEC數值模擬

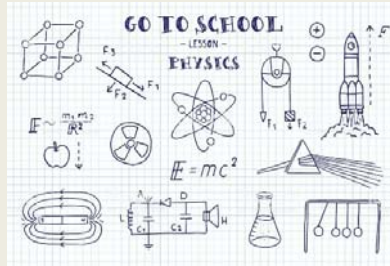
- 1g物理試驗 vs 數值模擬1g&40g



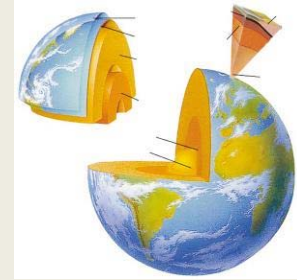
理學 vs. 工學 vs. 地球科學



數學 – 三維幾何平面相交、落石塊體尺寸、程式設計、邏輯概念



物理 (靜力學、動力學)



地球科學 (野外地質調查、岩性分類)

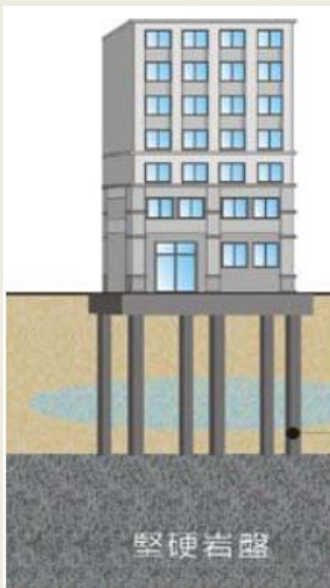


土木工程
永續防災

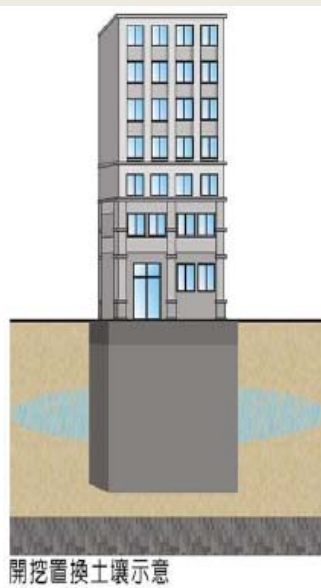
永續設計 防災救災

案例四：土壤液化問題 – 飽和土壤受地震力反覆作用而損失強度

- Mitigation of soil liquefaction (降低土壤液化潛能)



Pile foundation



開挖置換土壤示意

Replacement method

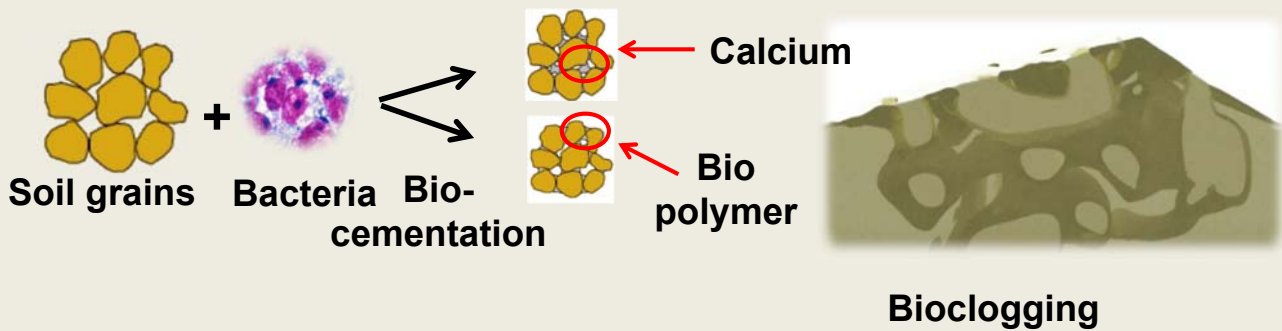


Dynamic compaction

REE

1. Introduction

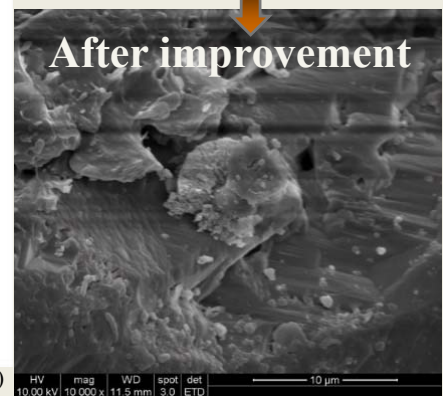
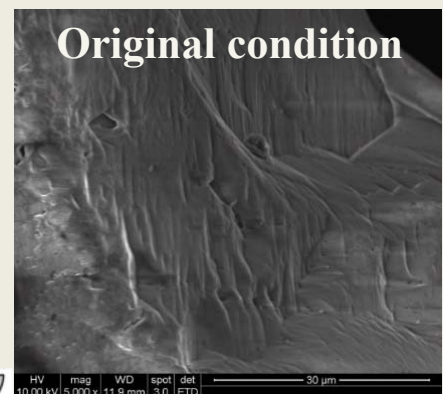
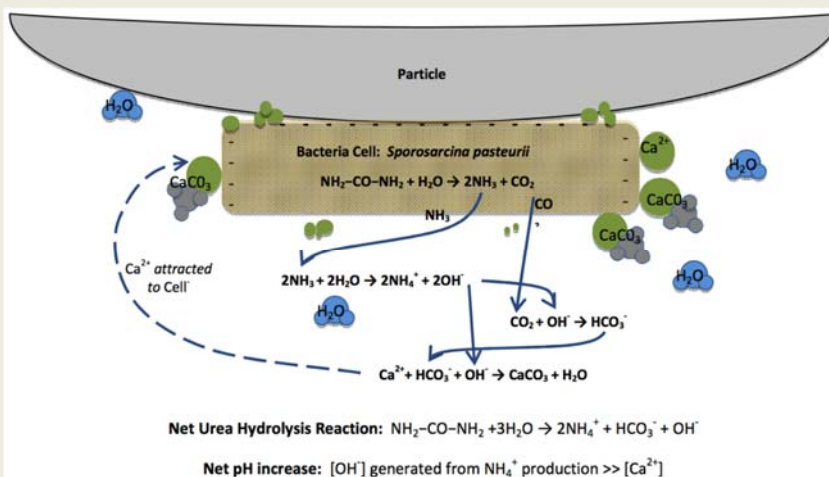
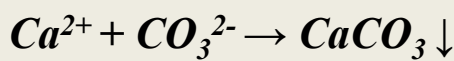
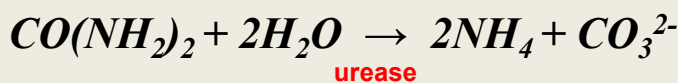
- Microbial Induce Calcium Precipitation (MICP) – 碳酸鈣沉澱技術
- MICP工法係將非連續性孔隙間之游離性離子材料進行安定化並與母材料粒子間進行架橋黏結作用，以達到諸如提升剪力強度、降低滲透係數與壓縮係數等關注參數之目的 (水利署河川海岸組 郭義浩)



中大土木系 洪汶宜教授提供

2. Literature Review

- MICP process (DeJong et al., 2012)



Source: DeJong et al. (2012)

中大土木系 洪汶宜教授提供

2. Literature Review

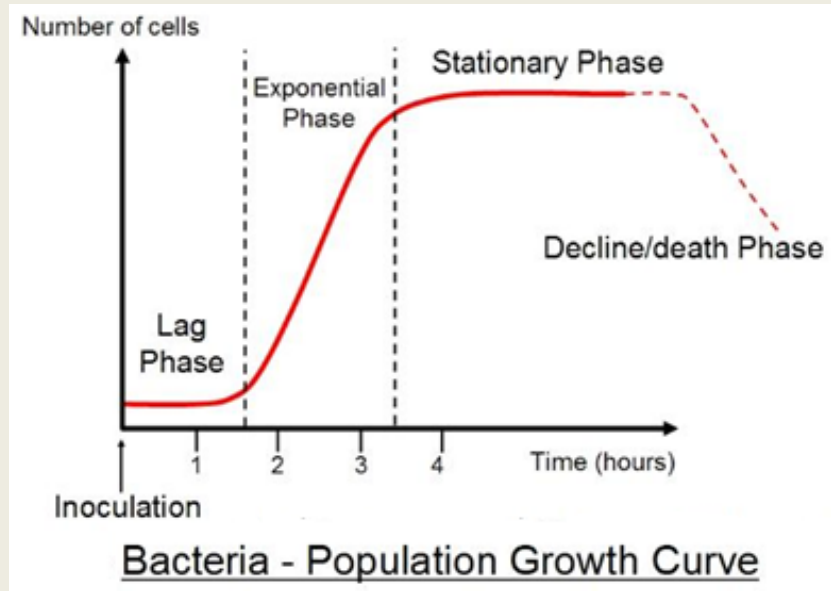
- Bacteria (Raina et al., 2016)

1. Growth environment

- ① Temperature : 4~40 °C
- ② pH : 6~8

2. Advantages

- ① High biological reproduction speed rate
- ② Large specific area



中大土木系 洪汶宜教授提供

理學 vs. 工學



化學 (微生物在土壤環境中產生化學反應，化合物與土壤)

生科 (微生物培養、適合生存環境研究、土壤環境中生存)



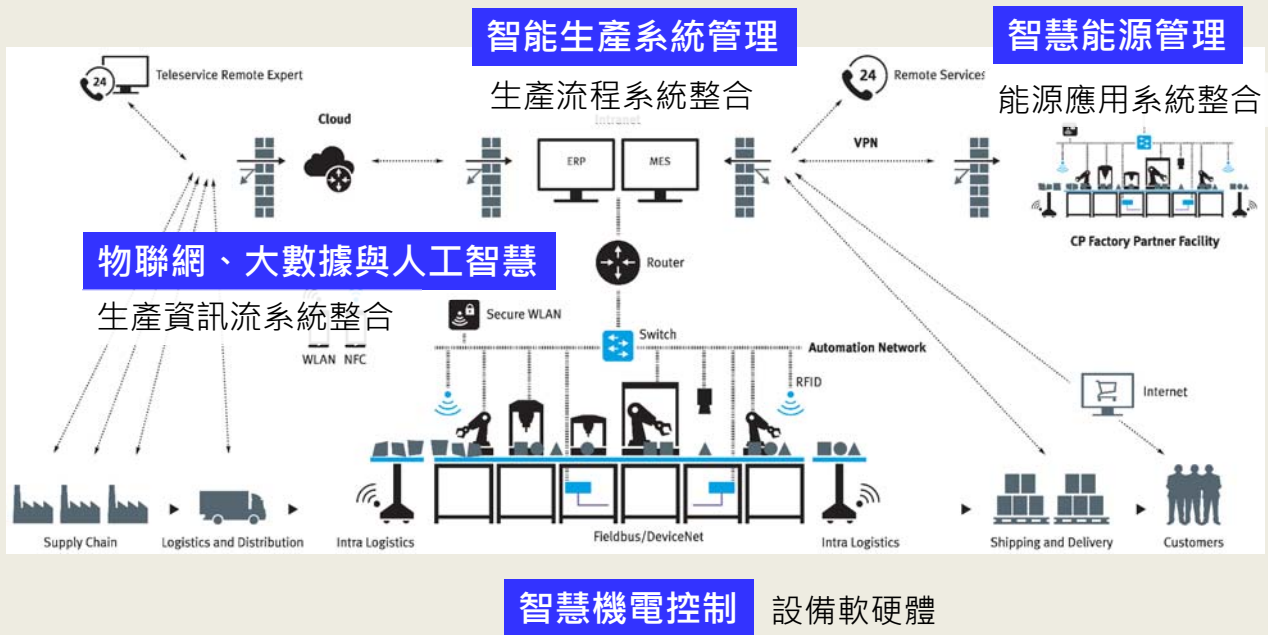
土木工程
永續防災

永續設計 防災救災

智慧機械 – 背景



結合網路與人工智慧發展新一代的 **智慧自動化生產技術**



節錄自工學院學士班簡報資料

智慧機械 – 學習與發展



課程領域

- 機械工程基本課程
- 機電控制
- 能源工程
- 資訊工程
- 企業與資訊管理

技術領域

- 智慧機電控制
- 智慧節能管理
- 物聯網、大數據與人工智慧
- 智能生產系統管理

畢業出路

- 進修: 機械、光電、能源、電機、資工、管理等領域研究所
- 證照: 製造、管理等相關領域
- 就業: 機械設備產業、民生、電子資訊產業、新興高科技產業、教育研究機構。

節錄自工學院學士班簡報資料

能源材料 – 背景



新能源的核心和基礎 – 能源材料

- 實現新能源的轉換和利用
- 發展新能源技術

- 太陽能電池
- 新世代儲能元件
- 氫能
- 熱能管理
- 微電能



節錄自工學院學士班簡報資料

能源材料 – 學習與發展



課程領域

- 材料組成與微結構
- 製程與設備
- 材料性質
- 材料在能源技術的性能表現

技術領域

- 新能源材料設計與開發
- 能源技術安全性與環境永續
- 能源材料規模生產的製程與加工技術
- 能源材料的使用壽命與可靠度評估

畢業出路

- 進修：材料、電子、奈米、半導體、光電、能源、觸媒、生醫材料等領域研究所
- 證照：材料、空污防制、化學技術士等
- 就業：半導體、光電、電子零件、鋼鐵、化學/檢驗、學術研究機構。



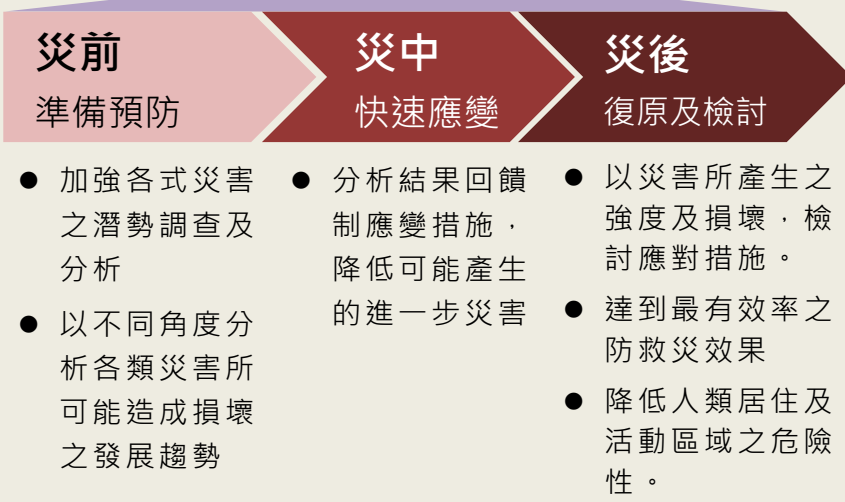
節錄自工學院學士班簡報資料

永續防災 – 背景



需要將傳統防災的系統再納入**永續的創新觀念**，
才能使得人類與自然災害和平共存

永續設計 永續維護



節錄自工學院學士班簡報資料

永續防災 – 學習與發展



節錄自工學院學士班簡報資料

綠色科技 – 背景



綠色科技

- 提供潔淨能源
- 改良產品設計
- 再生利用資源

資源



製造

- 生產系統多元化
- 創新綠色製程
- 再生能源使用
- 模組化

回收

- 可回收的設計
- 可重覆使用的設計

廢棄物

- 消除廢棄物
- 避免污染自然環境

使用與消費

- 創新產品和商業模式
- 提高資源使用效率



節錄自工學院學士班簡報資料

綠色科技 – 學習與發展



課程領域

- 化學工程
- 材料科學
- 能源工程
- 環境工程
- 經濟學

技術領域

- 綠色環保製程領域
- 能源材料的開發
- 程序設計與優化
- 環境風險經濟評估

畢業出路

- 進修: 化學工程、材料工程、工業工程、生醫工程、環境工程、等研究所
- 證照: 化工技師、環工等技師。
- 就業: 半導體、顯示器、印刷電路板、生化及醫藥工業、石化塑膠、化纖工業、環境工程、能源工業。

節錄自工學院學士班簡報資料

結論

- 理學院學士班六大領域與工學院四大領域息息相關 – 理學院 (理論學科深入研究、基礎應用) ; 工學院(理論學科應用、與民生相關之設計分析) → 跨領域學習非常重要!
- 堤防穩定性分析 – 極端氣候(地球科學)、風險評估(數學、統計應用)、穩定性設計及分析(物理、力學分析)、混凝土材料(化學)
- 山崩機制分析 – 地質調查(地球科學)、弱面位態分析(數學、立體投影分析)、穩定性分析(物理、力學分析)

結論

- MICP增加土壤剪力強度、填補混凝土縫隙 – 化學、生命科學、土壤力學
- 智慧機械、能源材料、永續防災、綠色科技 – 與理學院各領域，均有相當密切之關係

