台灣 V_{S30} 推估方法回顧與精進建議

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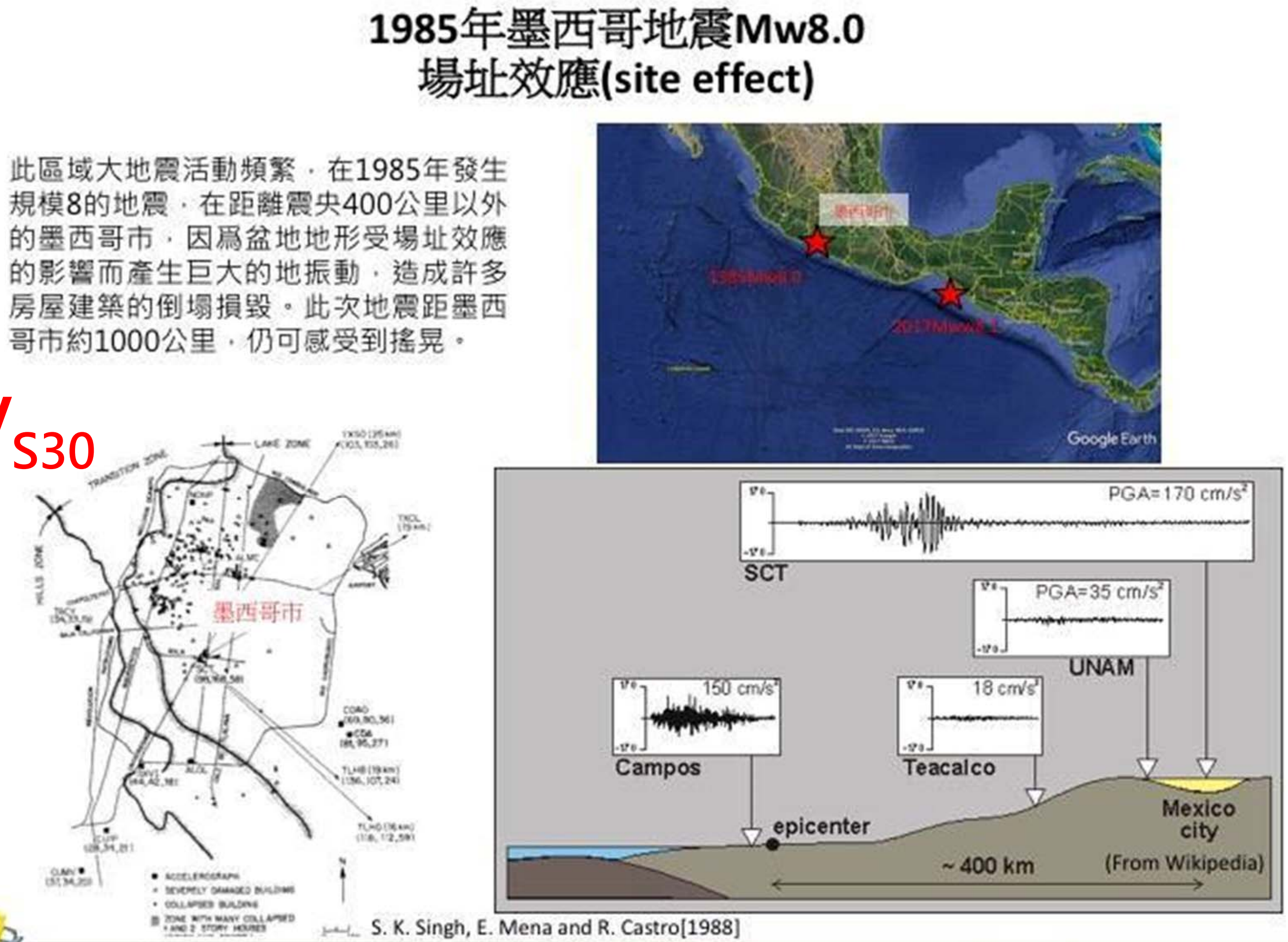
地震災害鏈風險評估及管理研究中心研討會　　2019年3月5日

場址效應

- 場址分類
  - 定性
  - 定量：V_{S30}



台灣地震科學中心的貼文
https://www.facebook.com/groups/tectw/permalink/1638599559491667/

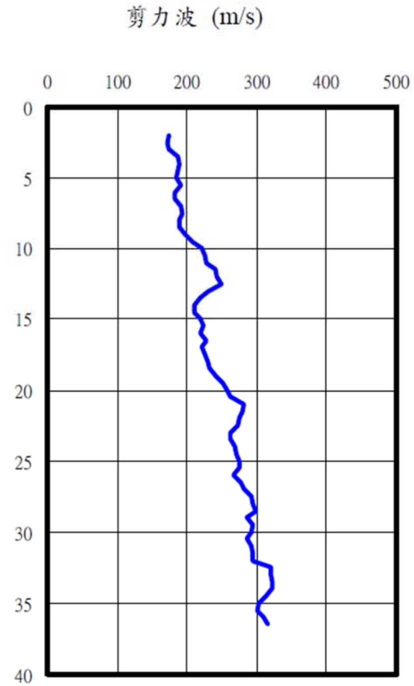
什麼是 V_{S30}？

若某 30 公尺深之地層剖面包含了 N 個土壤或岩石層，則該場址之 V_{S30} 可由下式計算：

$$V_{S30} = \frac{30}{\sum_{i=1}^{n} \frac{d_i}{V_{si}}} \qquad (1.1)$$

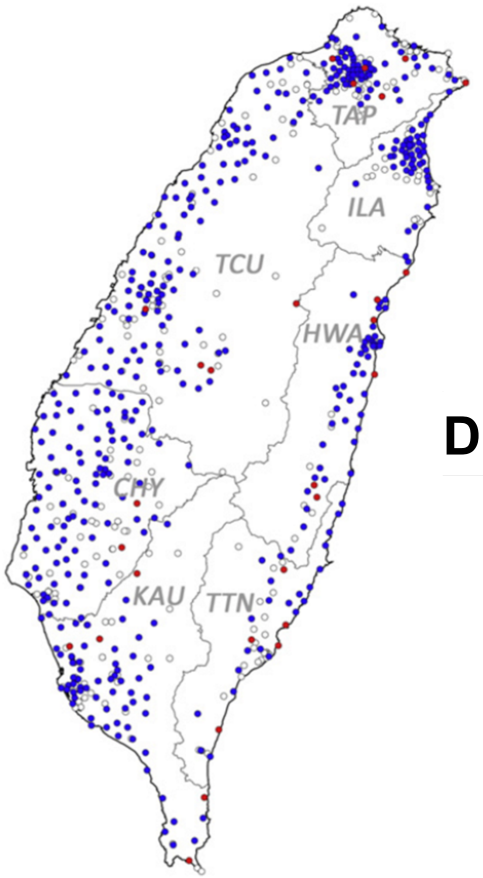
其中， d_i 表示第 i 層土壤或岩石層之厚度，V_{S30} 則代表第 i 層土壤或岩石層之剪力波速度。

- 耐震設計規範
- 地震災損
- 強地動預估式
- 特定場址耐震設計...



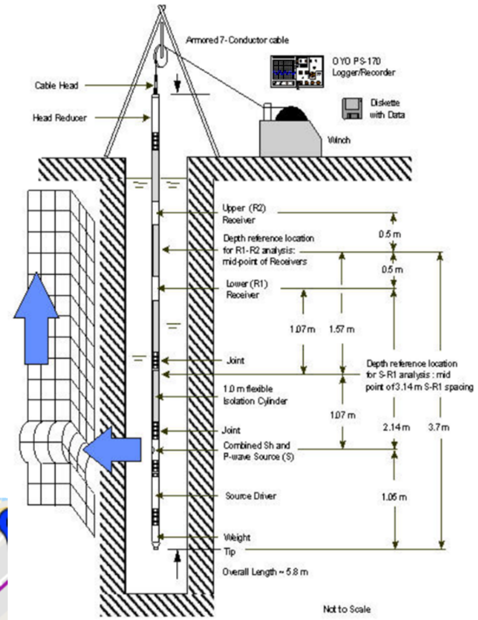
PS Logger
CHY049

強震測站場址工程地質資料庫
(PS Logger)



NCREE

Drilled free-field TSMIP stations

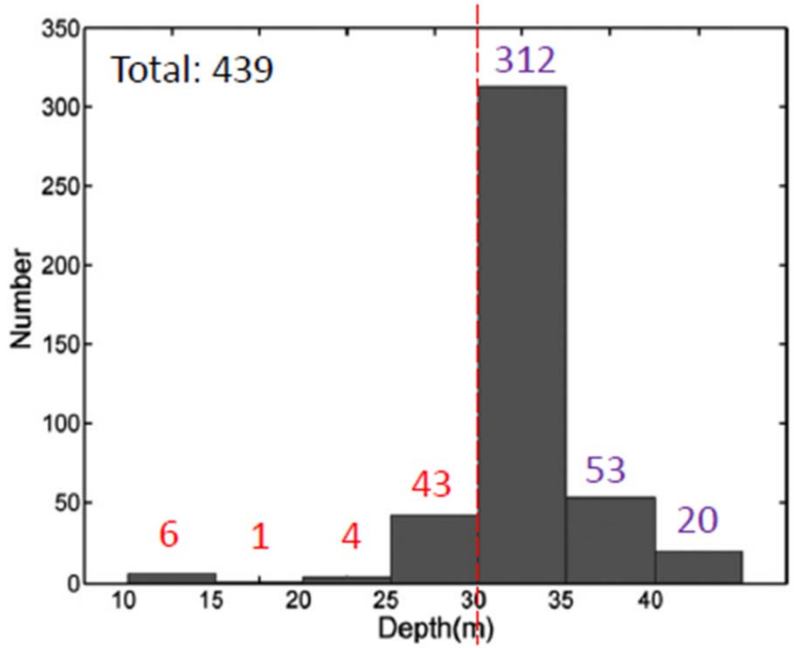


TCU001
TCU002
TCU003
TCU004
... 還有 106 個

兩個問題

$$V_{S30} = \frac{30}{\sum_{i=1}^{n} \frac{d_i}{V_{s\,i}}}$$

- Q1: 如果波速量測未及30公尺?
- Q2: 如果沒有波速量測資料?



Kuo et al. (2011) in Soil Dynamics and Earthquake Engineering

Q1: 如果波速量測未及30公尺?

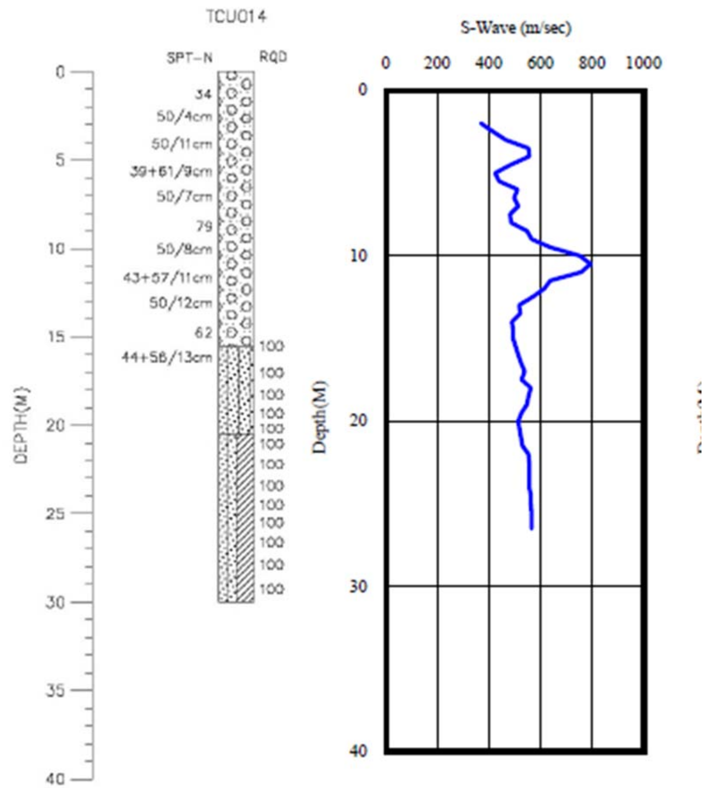
Coefficients of the Equation $\log \overline{V}_s(30) = a + b \log \overline{V}_s(d)$

d	a	b	σ
10	4.2062E − 02	1.0292E + 00	7.1260E − 02
11	2.2140E − 02	1.0341E + 00	6.4722E − 02
12	1.2571E − 02	1.0352E + 00	5.9353E − 02
13	1.4186E − 02	1.0318E + 00	5.4754E − 02
14	1.2300E − 02	1.0297E + 00	5.0086E − 02
15	1.3795E − 02	1.0263E + 00	4.5925E − 02
16	1.3893E − 02	1.0237E + 00	4.2219E − 02

$$\log \overline{V}_s(30) = a + b \log \overline{V}_s(d)$$

d	a	b	σ
21	2.5311E − 02	1.0072E + 00	2.7001E − 02
22	2.6900E − 02	1.0044E + 00	2.4087E − 02
23	2.2207E − 02	1.0042E + 00	2.0826E − 02
24	1.6891E − 02	1.0043E + 00	1.7676E − 02
25	1.1483E − 02	1.0045E + 00	1.4691E − 02
26	6.5646E − 03	1.0045E + 00	1.1452E − 02
27	2.5190E − 03	1.0043E + 00	8.3871E − 03
28	7.7322E − 04	1.0031E + 00	5.5264E − 03
29	4.3143E − 04	1.0015E + 00	2.7355E − 03

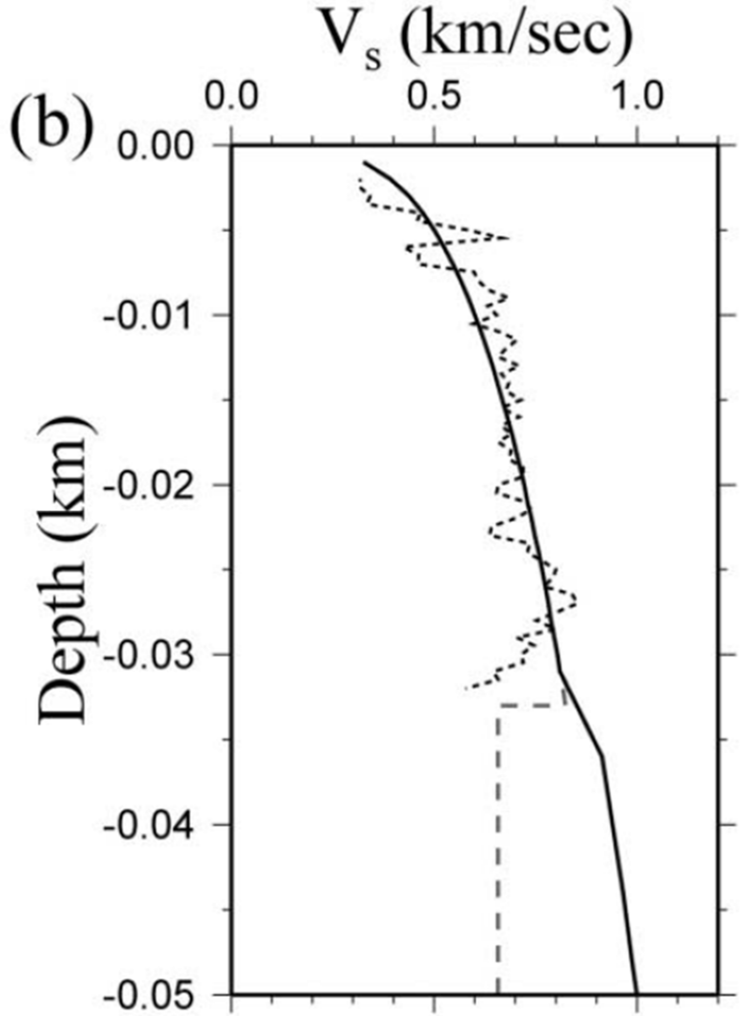
σ is the standard deviation of the residuals about the fitted line; velocities in meters per second.



Boore (2004) BSSA

Q1: 如果波速量測未及30公尺?

$$\beta(z) = \frac{\partial z}{\partial S_{tt}(z)} = c \cdot z^d$$



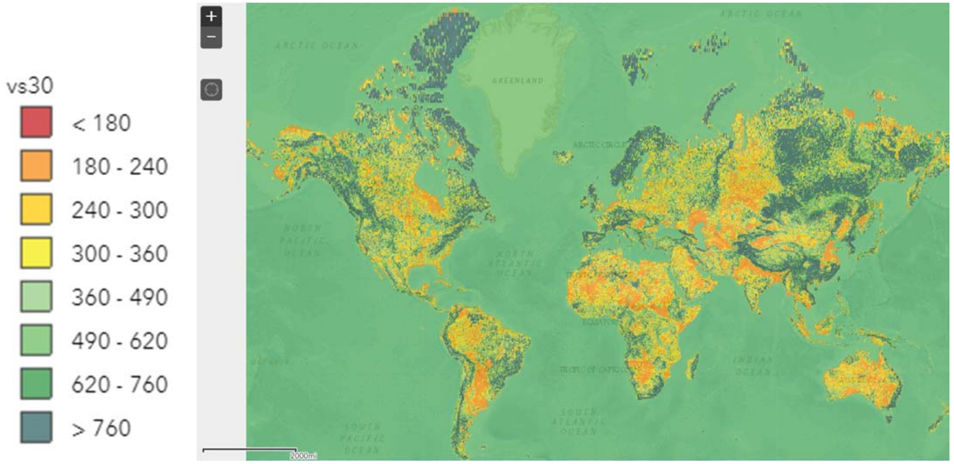
Boore (2004) BSSA

Q2: 如果沒有波速量測資料?

表 1.4 以不同地質條件推估 V_{s30} 之相關研究列表

地質條件	相關研究
地形單元	Holzer *et al*., 2005; Matsuoka *et al*., 2005
土壤厚度	Holzer *et al*., 2005
高程	Matsuoka *et al*., 2005; Chiou and Wen, 2006
坡度	Matsuoka *et al*., 2005; Wald and Allen, 2007
與山丘的距離	Matsuoka *et al*., 2005

蔡璧嬬 (2007)

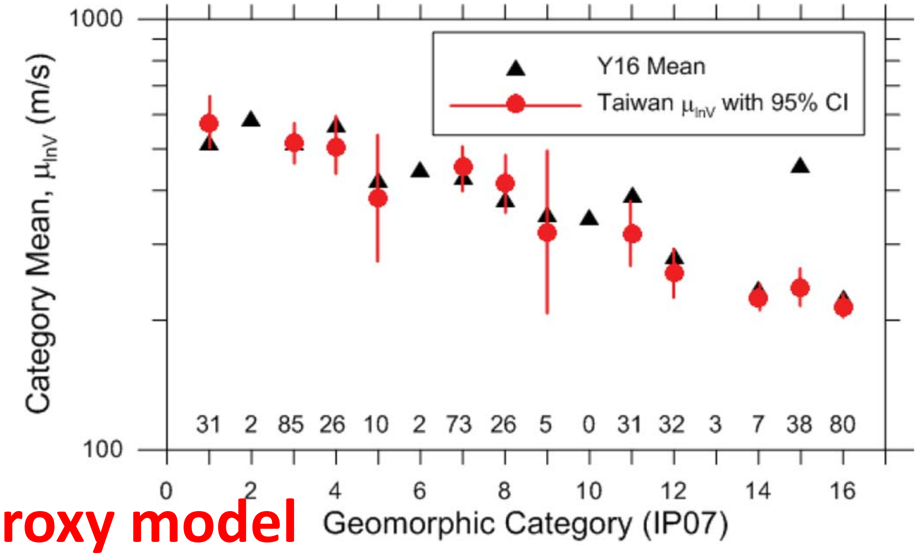


Allen (2009)

Q2: 如果沒有波速量測資料?

Terrain-based Proxy Model

(16 Terrains; Yong, 2016)



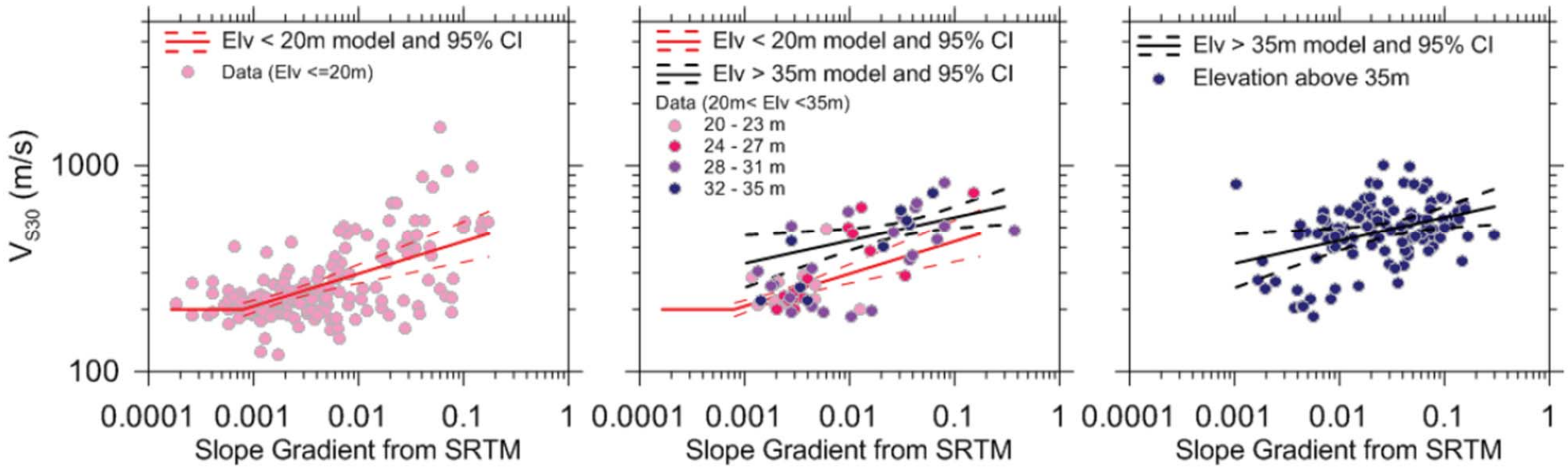
Geology

(1)全新世**+**全或更

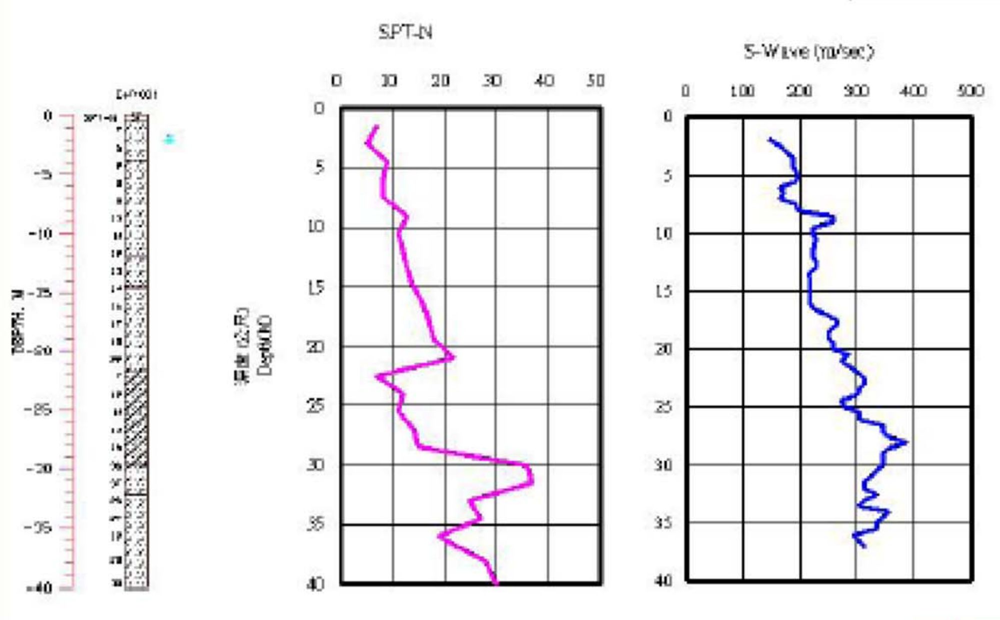
(2)更新世

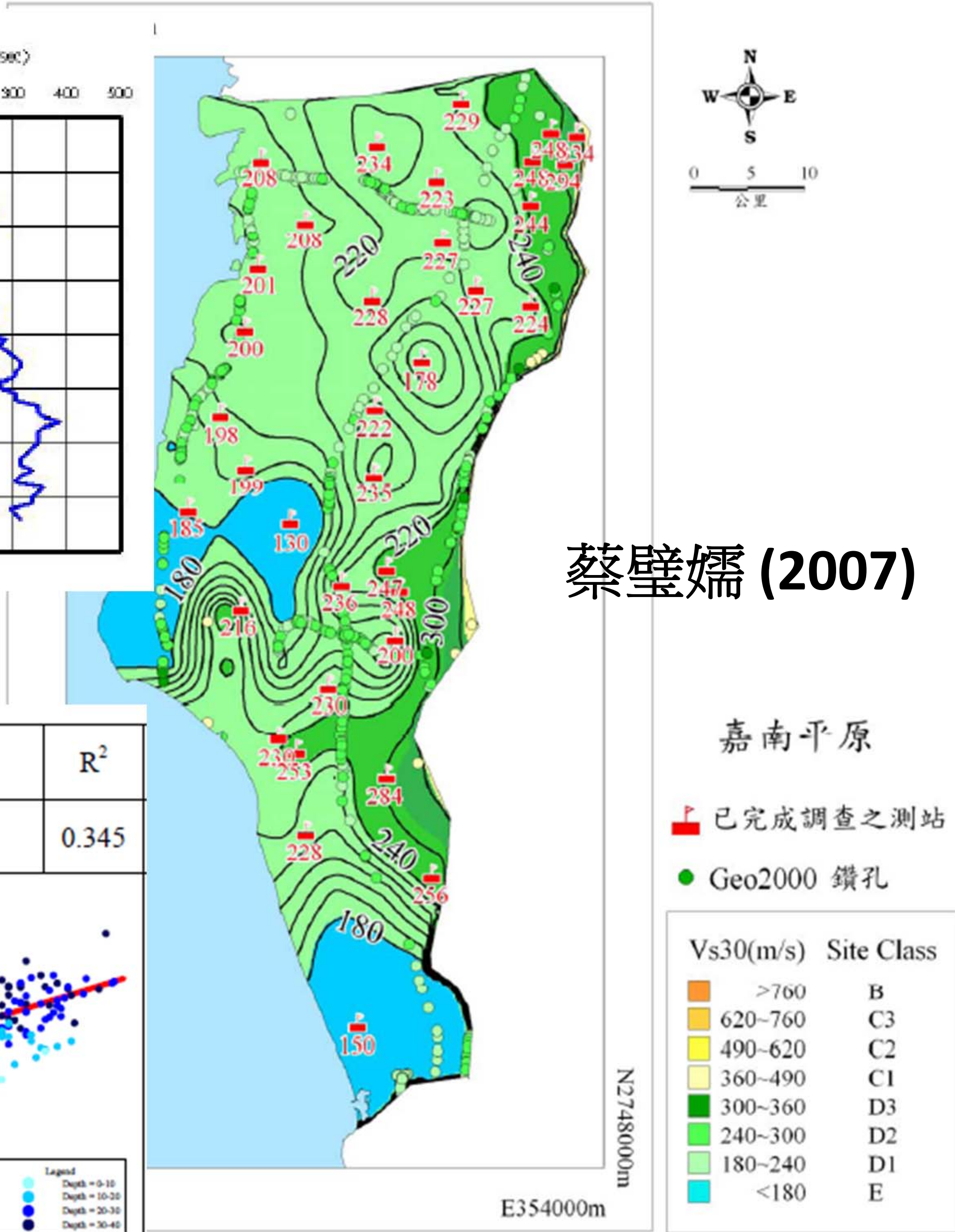
(3)早於更新世

Geology-Slope-Elevation-based Proxy model

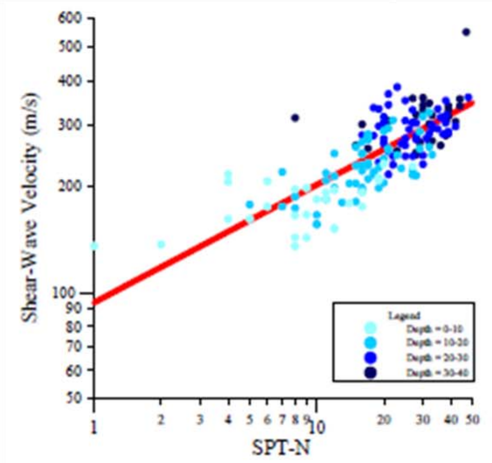
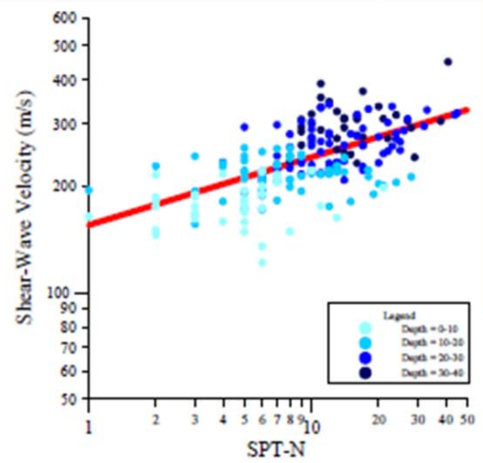


Kwok, O. L. A., J. P. Stewart, D. Y. Kwak, and P. L. Sun (2018). ***Earthquake Spectra.***





蔡璧嫣 (2007)

粗顆粒	R^2	細顆粒	R^2
$V_s=93.677\times N^{0.334}$	0.536	$V_s=155.363\times N^{0.192}$	0.345
			

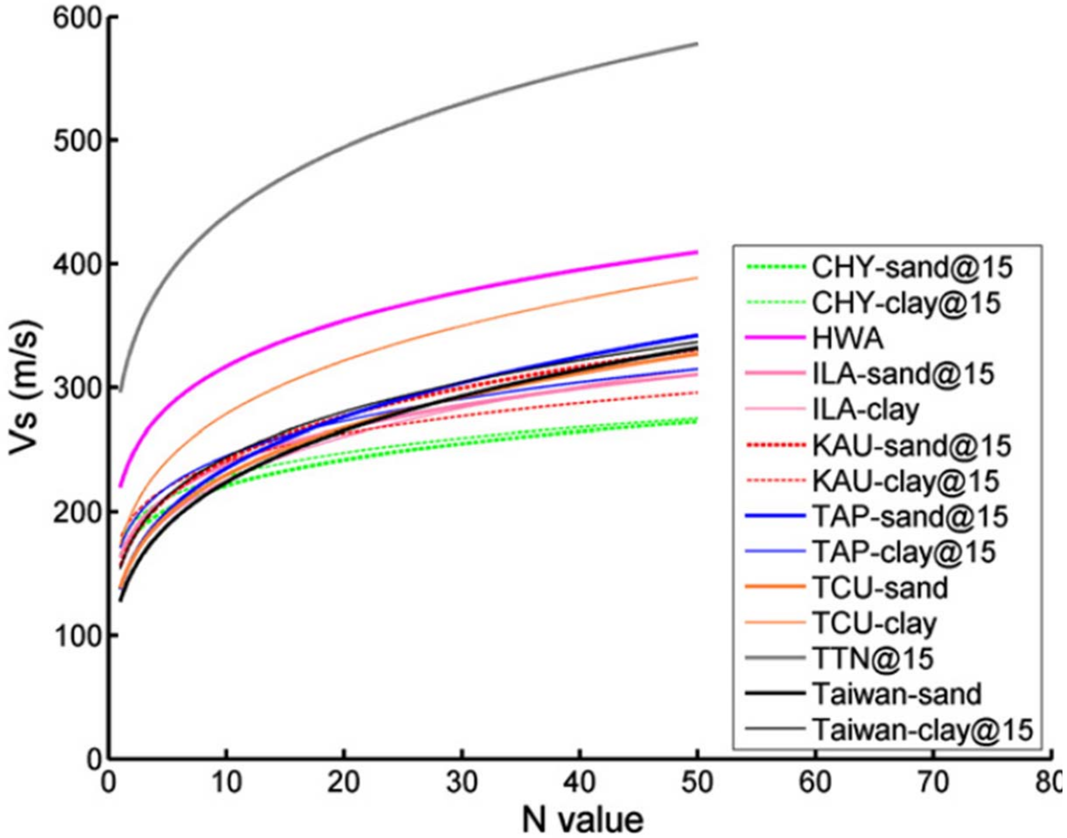
Lee and Tsai (2008)

Q2: 如果沒有波速量測資料?

Table 3

Evaluated empirical S-wave velocity equations in seven regions and the whole of Taiwan. The σ column shows the standard deviations of the calculated S-wave velocities.

Region	Empirical Vs equation
CHY	$Vs = 114.29\ N^{0.130} D^{0.133}$
	$Vs = 114.02\ N^{0.115} D^{0.159}$
HWA	$Vs = 219.79\ N^{0.159}$
ILA	$Vs = 142.23\ N^{0.165} D^{0.05}$
	$Vs = 139.64\ N^{0.208}$
KAU	$Vs = 112.46\ N^{0.194} D^{0.118}$
	$Vs = 131.52\ N^{0.129} D^{0.113}$
TAP	$Vs = 99.08\ N^{0.233} D^{0.121}$
	$Vs = 118.03\ N^{0.156} D^{0.137}$
TCU	$Vs = 138.36\ N^{0.220}$
	$Vs = 172.98\ N^{0.207}$
TTN	$Vs = 233.35\ N^{0.171} D^{0.088}$
Taiwan	$Vs = 127.35\ N^{0.245}$
	$Vs = 129.12\ N^{0.200} D^{0.065}$



Kuo et al. (2012). *Engineering Geology*, 129-130, 68-75.

其它：微地動單站頻譜比...

- 接收函數法：自由場強震站地震紀錄分析淺部速度構造(林哲民等，2017)

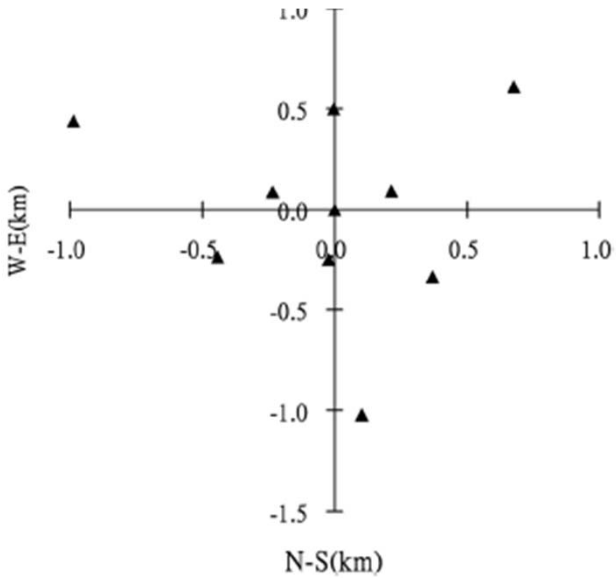


Fig. 2. Array configuration of XL-array at the Lugang site.

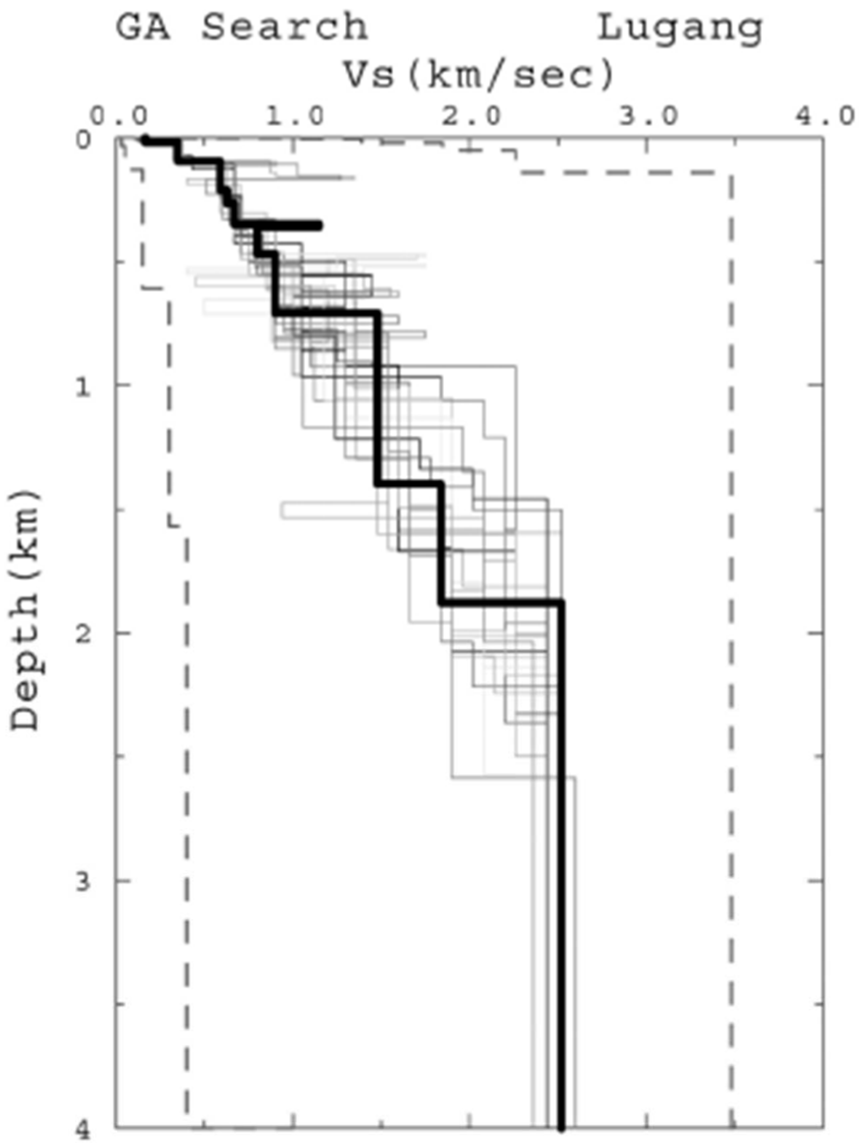
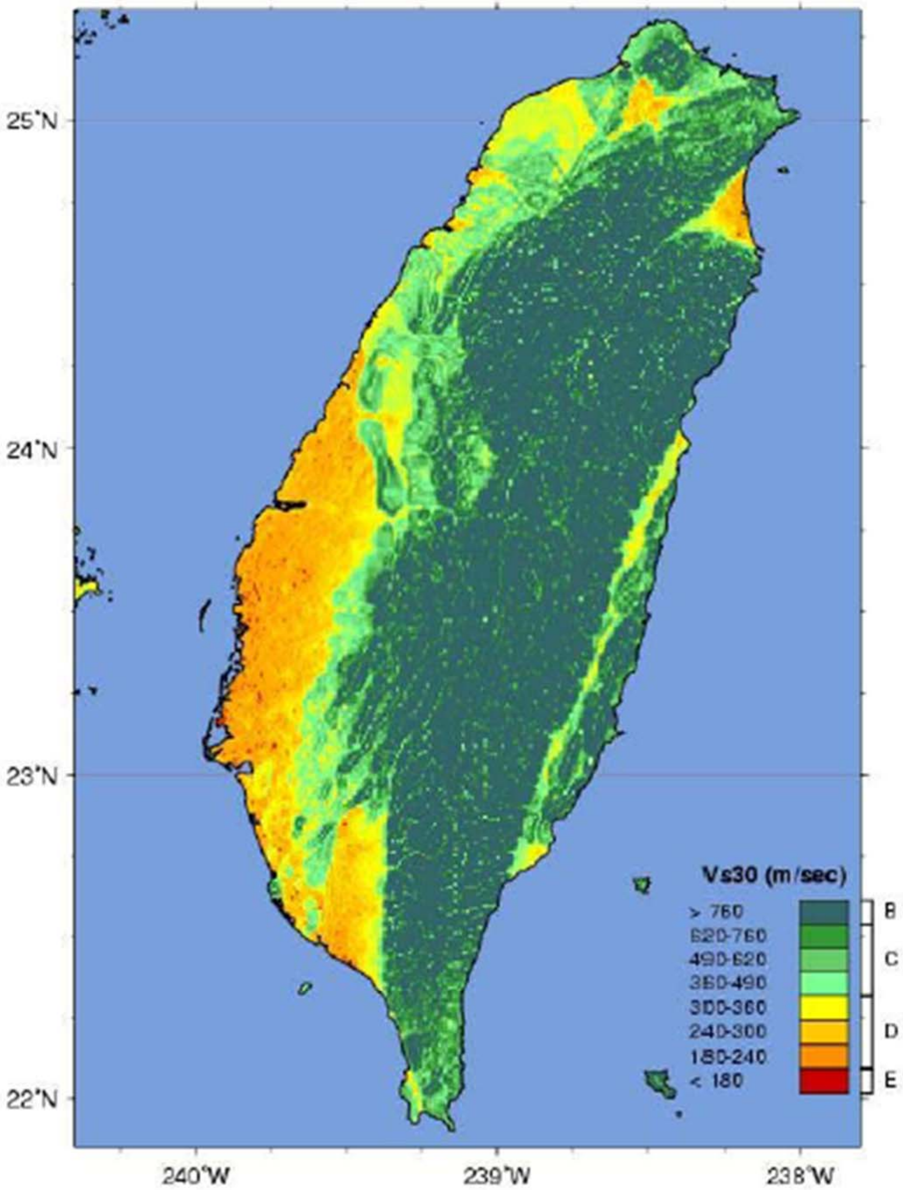


Fig. 5. Best twenty results and the searching ranges (dashed lines) of GA searches for the initial model of inversion for the Lugang site. The bold line indicates the final model with the lowest misfit.

Lin et al. (2009) TAO



以地形斜率估算的全臺 Vs30 分布圖（Allen and Wald，2007）。

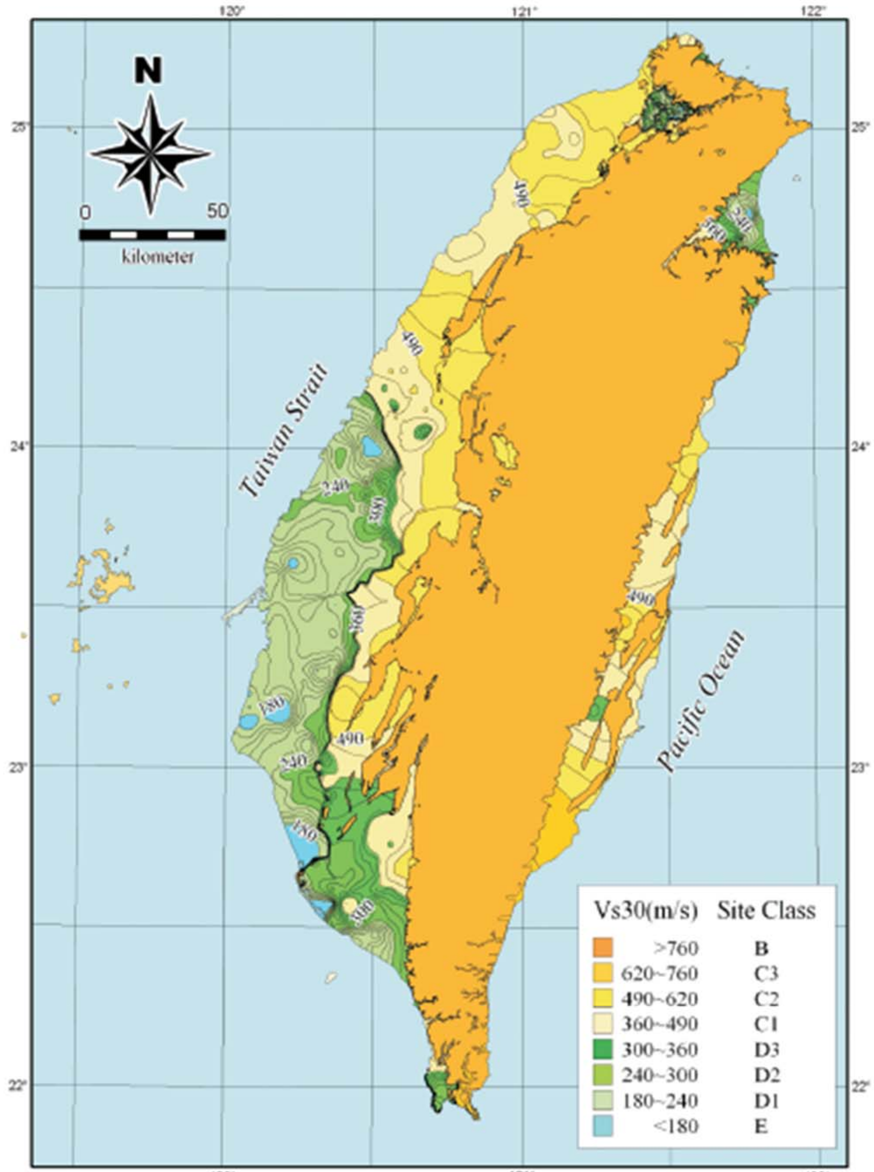


Fig. 10. Vs30 map of Taiwan.

(Lee and Tsai, 2008)

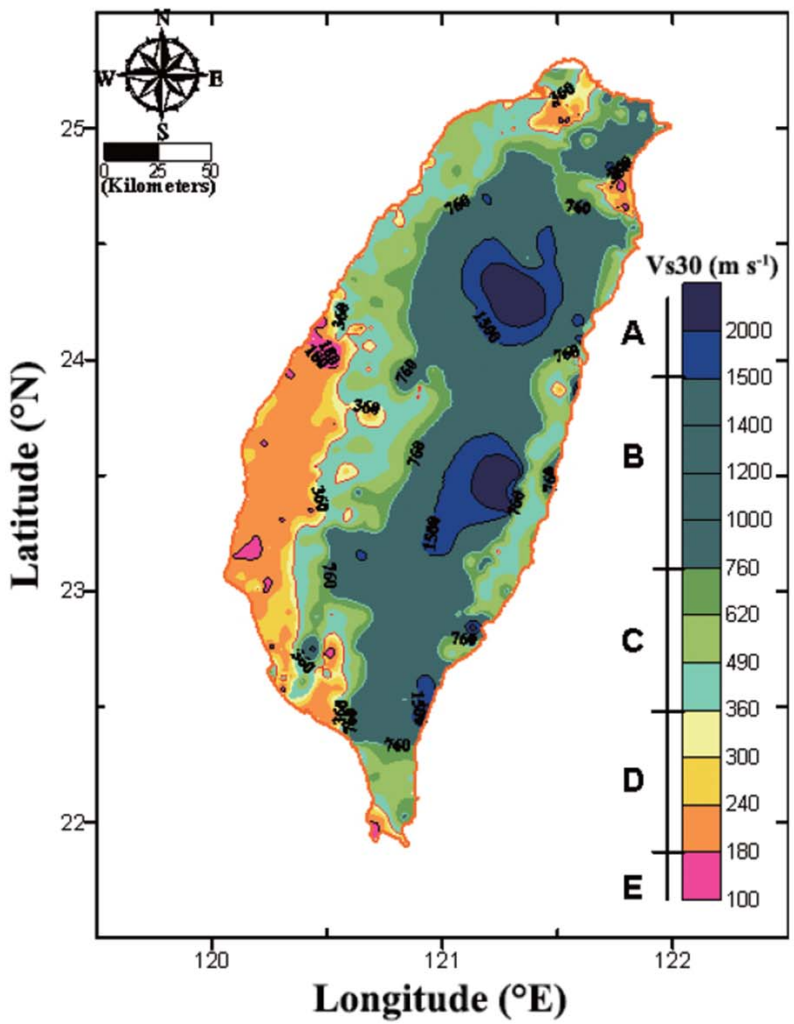
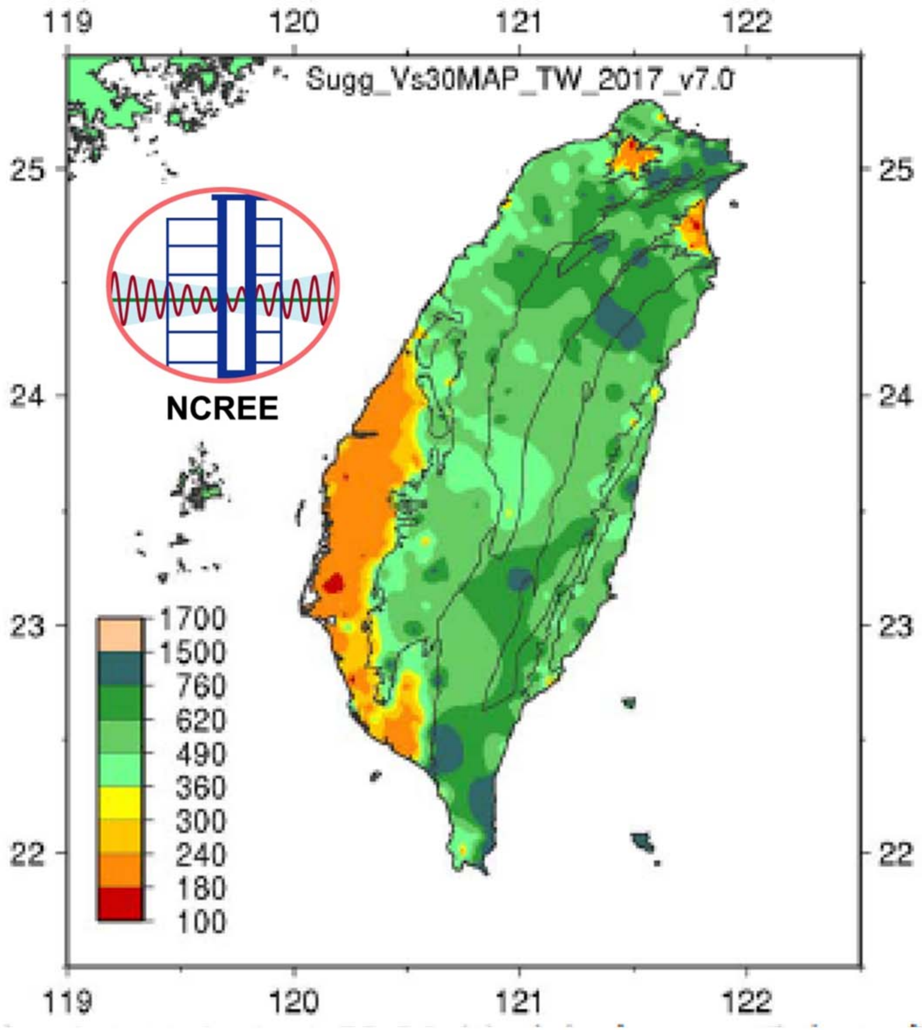


Fig. 12. The refined Vs30 contour map based on combined measured and estimated data.

(Liu and Tsai, 2015)



Kwok et al. (2018). *Earthquake Spectra*

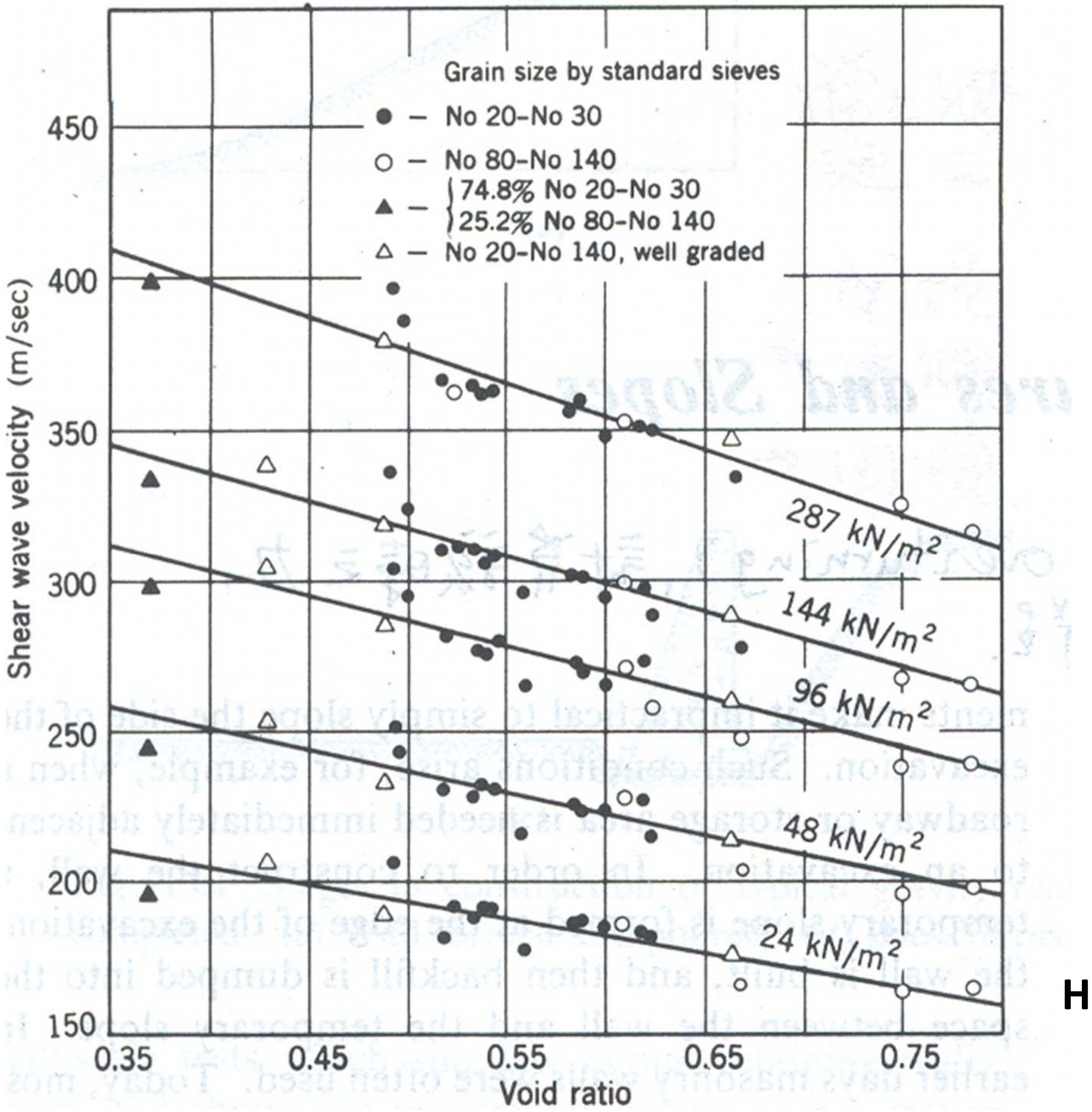
+

林哲民等人(2017) Vs > 600m/s 與離島

精進?

- 是否需要大費周章?
  - 特定場址危害度評估應該自行調查與量測
  - 對地震災損預估是否敏感?
  - 對建築規範選擇地盤分類是否敏感?
    - V_{S30}>270 *m*/*s* 者，第一類地盤(堅實地盤)；
    - 180 *m*/*s* <V_{S30}< 270 *m*/*s* 者，為第二類地盤(普通地盤)；
    - V_{S30}<180 *m*/*s* 者，為第三類地盤(軟弱地盤)。

如何精進?
Vs, e, and σ_v



Hardin and Richart (1963)

Lambe and Whitman, 1979, Soil mechanics, John Wiley, New York.

Engineering Geology 119 (2011) 1–17

Contents lists available at ScienceDirect

Engineering Geology

journal homepage: www.elsevier.com/locate/enggeo

土壤深度之影響

Empirical correlations of shear wave velocity (V_s) and penetration resistance (SPT-N) for different soils in an earthquake-prone area (Erbaa-Turkey)

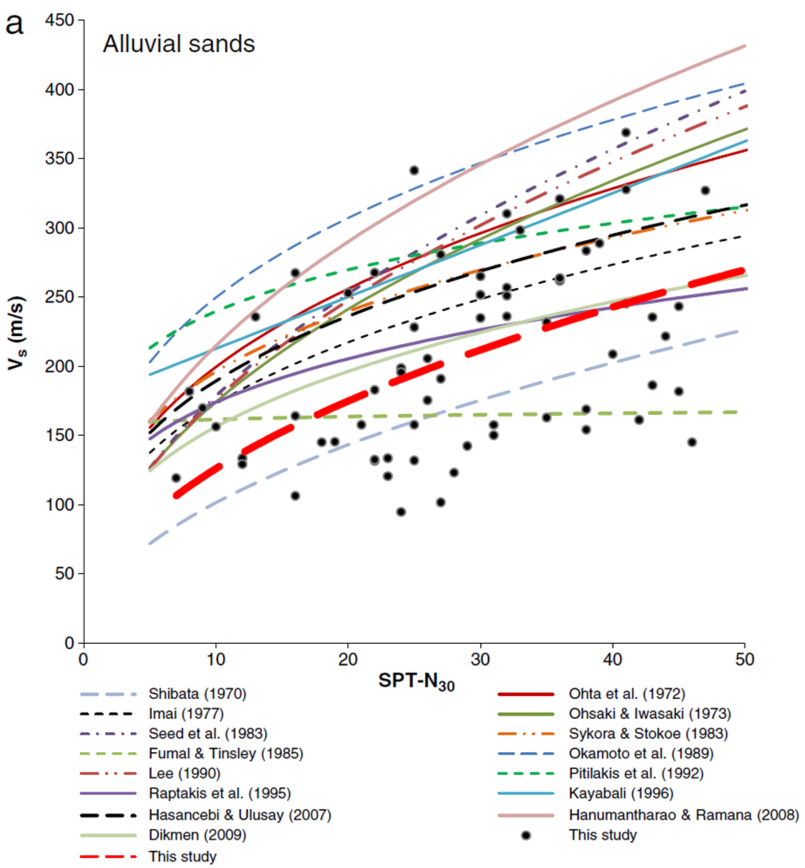
Muge K. Akin [a,*], Steven L. Kramer [b], Tamer Topal [c]

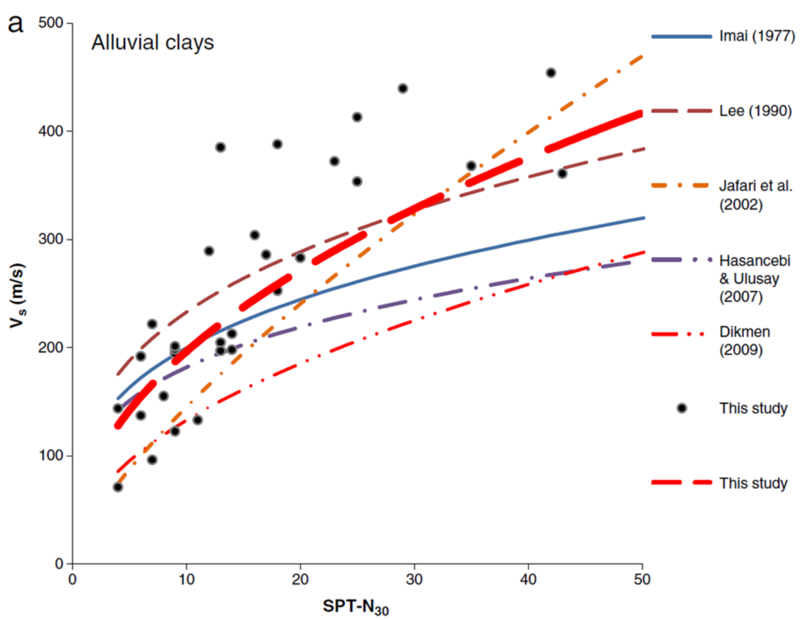
[a] Dept. of Geological Engineering, Yuzuncu Yil University, Van, Turkey
[b] Dept.of Civil and Environmental Engineering, University of Washington, Seattle, USA
[c] Dept. of Geological Engineering, Middle East Technical University, Ankara, Turkey

$$V_s = a{\cdot}N^b \qquad V_s = c{\cdot}N^d{\cdot}z^e$$

Table 2
The results of regres

Soil type	Model 1			Model 2			
	a	b	$\sigma_{\ln Vs}$	c	d	e	$\sigma_{\ln Vs}$
Alluvial sand	4.0280	0.4405	0.3231	4.0852	0.1091	0.4257	0.1940
Alluvial clay	4.7037	0.2629	0.1564	4.8023	0.1007	0.2161	0.0916
All alluvial soils	4.2052	0.4671	0.2905	4.3576	0.1162	0.3505	0.1883
Pliocene sand	3.7432	0.4740	0.3037	3.6519	0.1756	0.4815	0.1421
Pliocene clay	4.9479	0.1941	0.1512	4.9457	0.0490	0.2317	0.0934
All Pliocene soils	3.6542	0.5440	0.1344	3.9523	0.3588	0.1772	0.0656





有效覆土應力之影響(地下水位)

Soil Dynamics and Earthquake Engineering 30 (2010) 1026–1035

Contents lists available at ScienceDirect

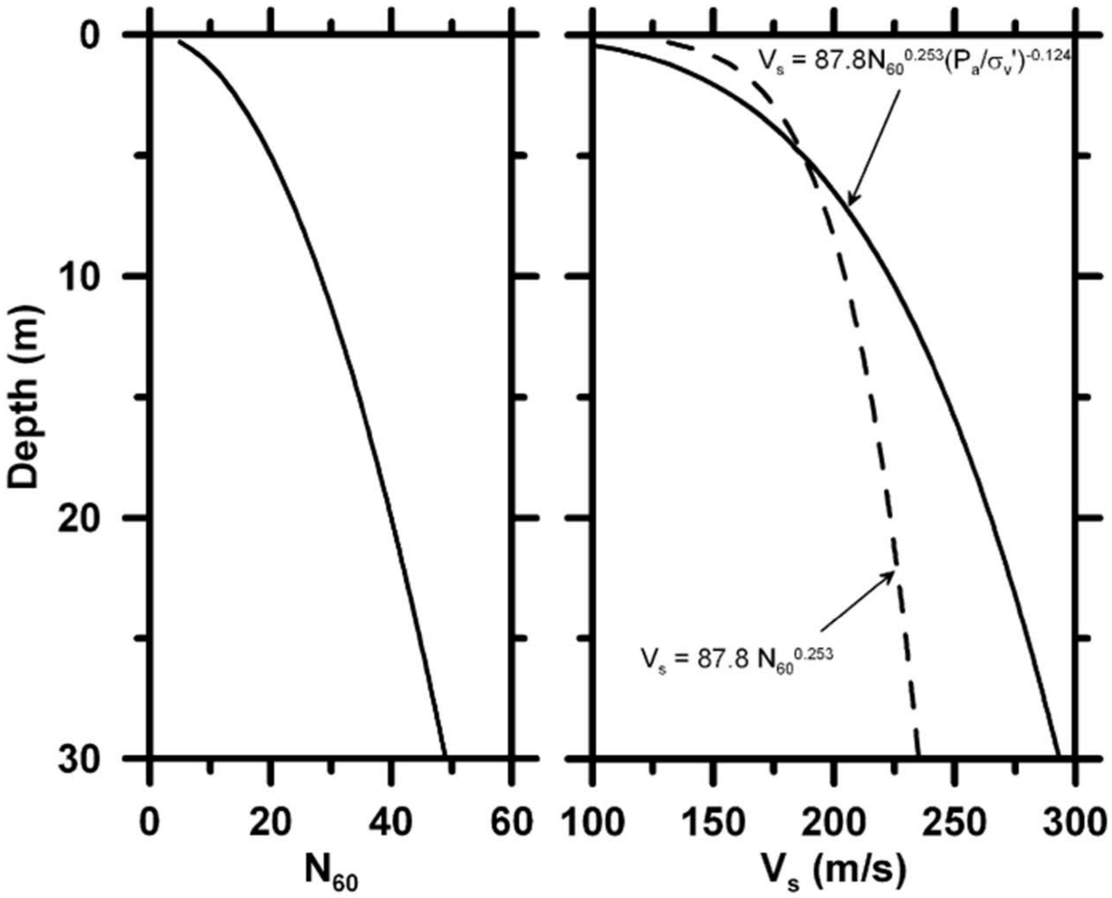
Soil Dynamics and Earthquake Engineering

journal homepage: www.elsevier.com/locate/soildyn

Shear wave velocity as function of standard penetration test resistance and vertical effective stress at California bridge sites

Scott J. Brandenberg[a,*], Naresh Bellana[a], Thomas Shantz[b]

[a] 5731 Boelter Hall, Department of Civil and Environmental Engineering, University of California, Los Angeles, CA 90095-1593, USA
[b] Caltrans Division of Research and Innovation, California Department of Transportation, 5900 Folsom Blvd., Sacramento, CA 95819, USA



$$(N_1)_{60} = \left(\frac{P_a}{\sigma'_v}\right)^n N_{60}$$

$$V_{s1} = \left(\frac{P_a}{\sigma'_v}\right)^m V_s$$

$$V_s = 87.8N_{60}^{0.253}\left(\frac{P_a}{\sigma'_v}\right)^{0.253n-m}$$

$n=0.5$ and $m=0.25$ such that $0.253n-m=-0.124$,

Shear-Wave Velocity to Evaluate In-Situ State of Ottawa Sand

Vs, e, and σ_v

By P. K. Robertson,[1] Member, ASCE, S. Sasitharan,[2] J. C. Cunning,[3] and D. C. Sego,[4] Member, ASCE

J. Geotech. Engrg., 1995, 121(3): 262-273

For Ottawa sand, based on the results of this study, the relationship between shear-wave velocity (V_s), void ratio (e), and mean effective stress during consolidation (p'_c) can be expressed as

$$V_s = (381 - 259e)\left(\frac{p'_c}{P_a}\right)^{0.26} \text{ m/s}$$

Clean, un-cemented, freshly deposited sand

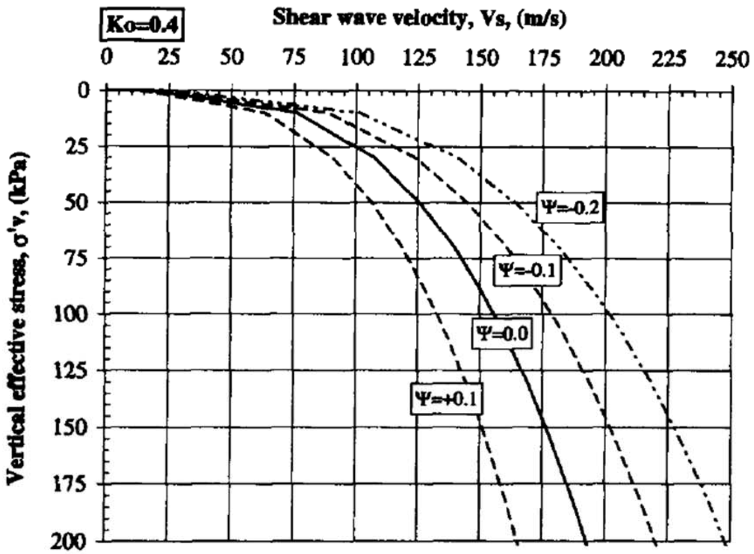
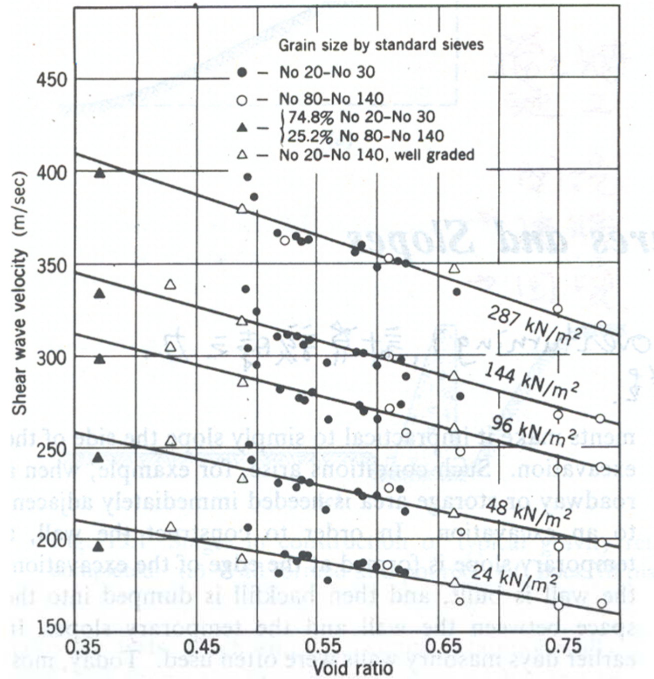


FIG. 9. Profiles of State Parameter (ψ) in Terms of Shear-Wave Velocity and Vertical Effective Stress for K_o = 0.4



$$\psi = \left(\frac{A}{B} - \Gamma\right) - \left(\frac{V_s(P_a)^{na+nb}}{B(\sigma'_a)^{na}(\sigma'_p)^{nb}} - \lambda_{\log} p'_{ss}\right)$$

For Ottawa sand, (14) can be used to evaluate state parameter (ψ) using the following constants: A = 381 (m/s); B = 259 (m/s); na = 0.13 (dimensionless); nb = 0.13 (dimensionless); $\lambda_{\log}$ = 0.0745 [1/$_{\log}$(kPa)]; and Γ = 0.926 (dimensionless).

SOILS AND FOUNDATIONS Vol. 37, No. 4, 105-113, Dec. 1997
Japanese Geotechnical Society

SPT *N*-VALUE AND S-WAVE VELOCITY FOR GRAVELLY SOILS WITH DIFFERENT GRAIN SIZE DISTRIBUTION

TAKEJI KOKUSHO[i] and YASUO YOSHIDA[ii]

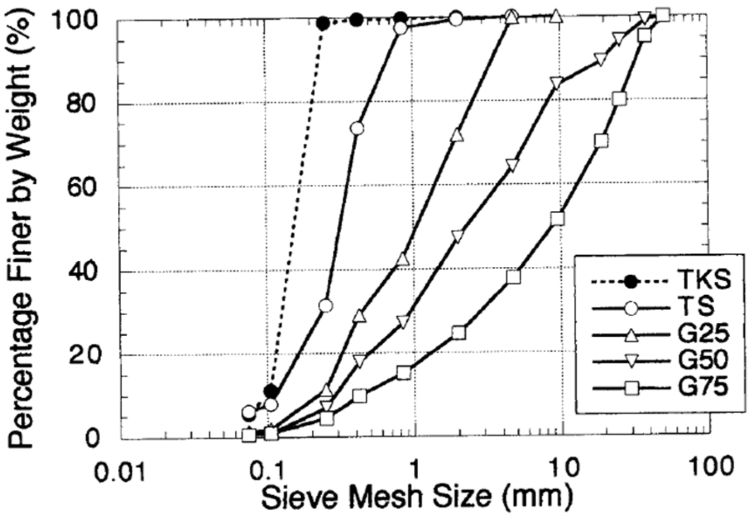


Fig. 2. Grain size distribution of five types of soil tested

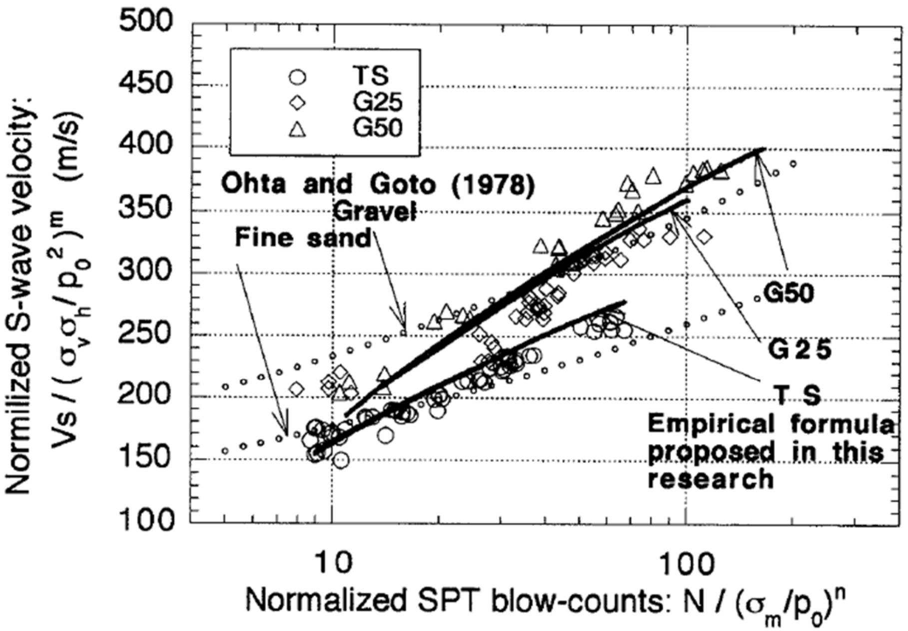


Fig. 18. Normalized S-wave velocity versus normalized *N*-value relationships compared with empirical formulae proposed in this research and previous research

先測試

- PS-Logger測站砂土層之V_{S30}
  - 與N值及深度相關性高?
  - 或是與有效覆土應力及孔隙比相關性高?

感謝

- 國震中心(郭俊翔博士)的報告
- 楊佩欣、高嘉謙同學資料提供
- 李錫堤老師、馬國鳳老師的討論

國家地震工程研究中心
NATIONAL CENTER FOR RESEARCH ON EARTHQUAKE ENGINEERING

臺灣強震測站場址資料庫

郭俊翔 林哲民 [illegible] 溫國樑 謝宏灝