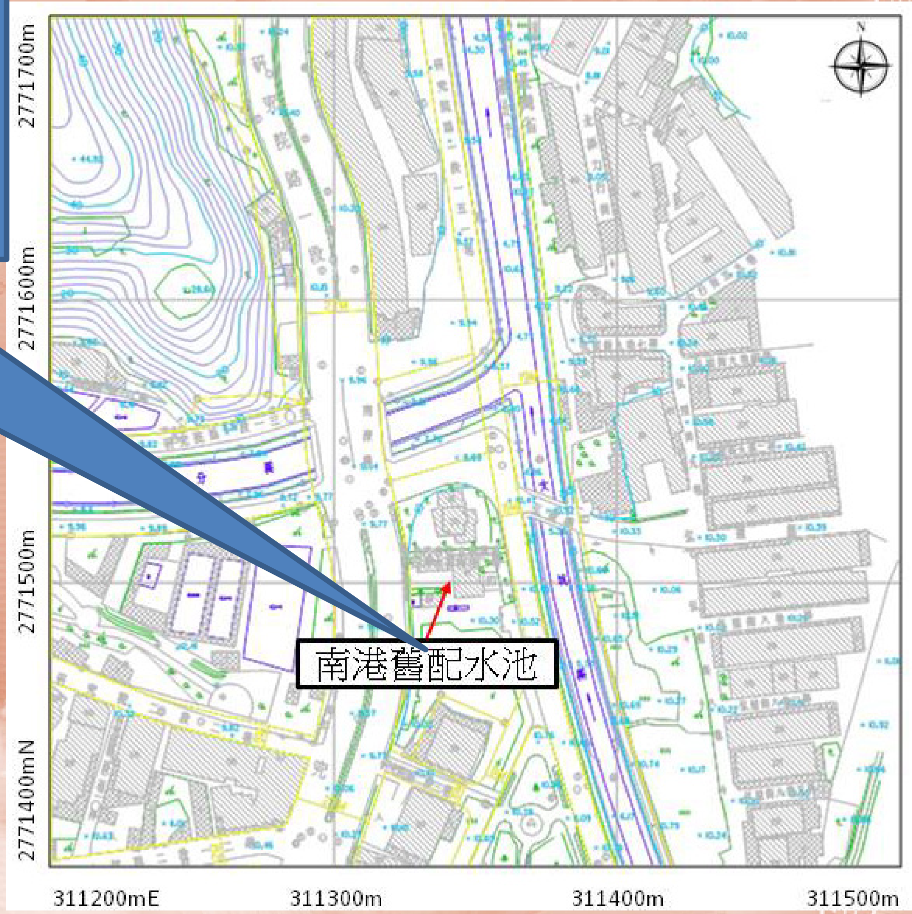
Seismic Evaluation and Retrofit of Existing Distribution Reservoirs in Taipei City

水管橋與配水池耐震安全評估
及補強改善設計委託技術服務

- By Professional Engineer
- Chen Hsiang, Mike, Lu
- From Sinotech Engineering Consultants

Nangang distribution reservoir - Location

This paper presents the main results of the seismic safety assessment for the Nangang distribution reservoir in Taipei city.



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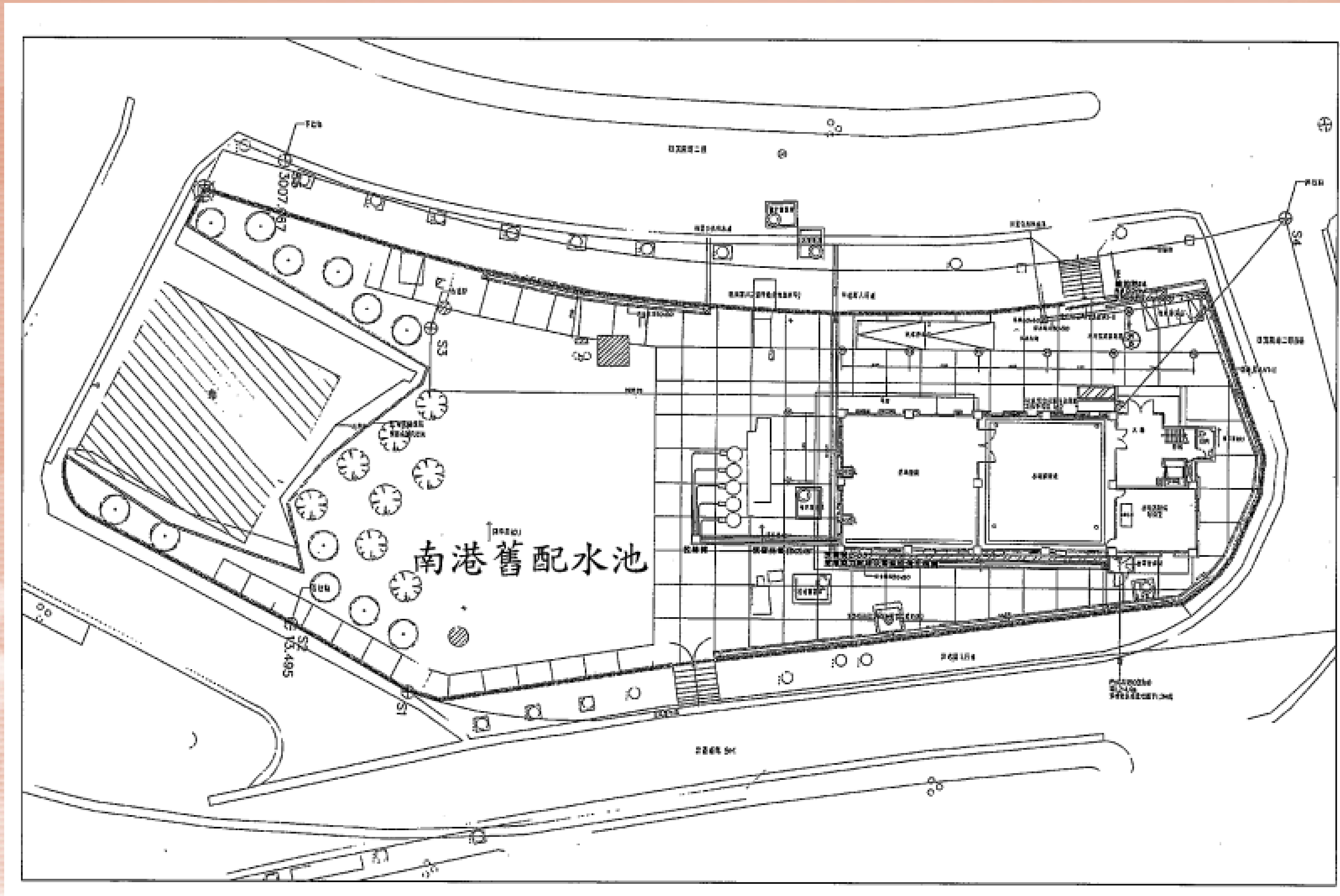

水管橋與配水池耐震安全及補強改善

Structure Data	
Item	**Details**
GPS (N)	North Latitude 25.048587
GPS (E)	East Longitude 121.616180
Structure Type	Reinforced Concrete
Length	34.02m
Width	27m
Depth(m)	5
Tank Area (m^2)	883
Tank Capacity(ton)	5000
Design Year	1980
Construction Finished Year	1988

Nangang Distribution Reservoir Damage Photos

Corrosion of imbeded reinforcement

Concrete Spalling

Buckled Reinforcement

Guide wall cracks

Efflorescence: migration of a salt to the surface of a porous material, where it forms a coating

Corrosion of imbeded reinforcement

Floor cracks

Column Capital

Earthquake Coefficient

- DesignYear 1980
  - Kh=0.16
- Current Code:
  - Kh=0.24 for concrete structure
  - Kh=0.18 for earthquake soil pressure

水管橋與配水池耐震安全評估
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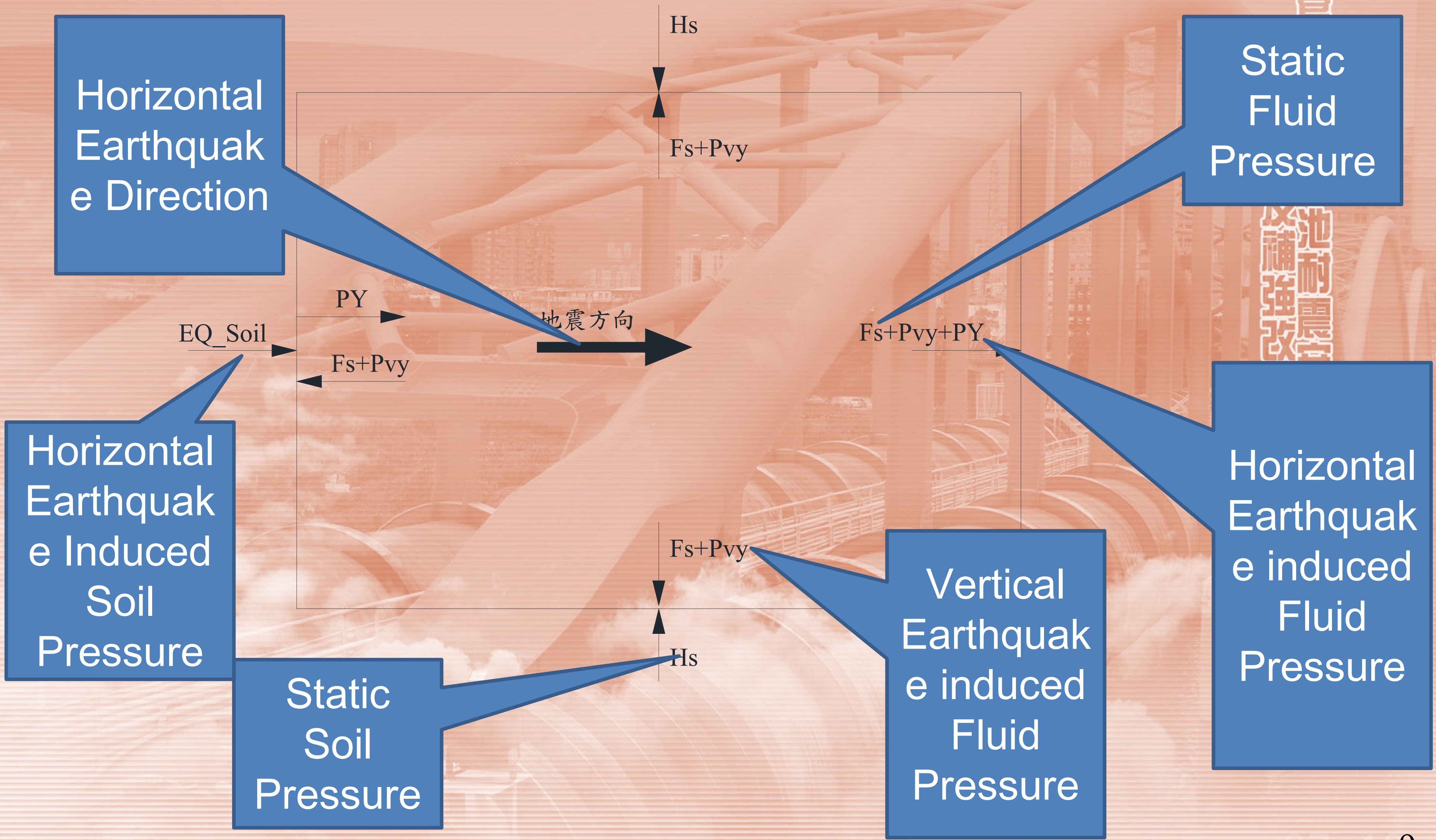
Distribution Reservoir SEISMIC ASSESSMENT

- Code

  Seismic Design of Potable Water Tank Structure” [2] drafted by the National Center for Research on Earthquake Engineering (NCREE) of Taiwan in 2016.

Distribution Reservoir Analysis Loading Combination



Existing Structure Details

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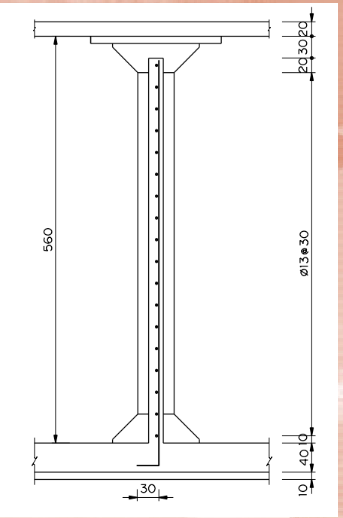
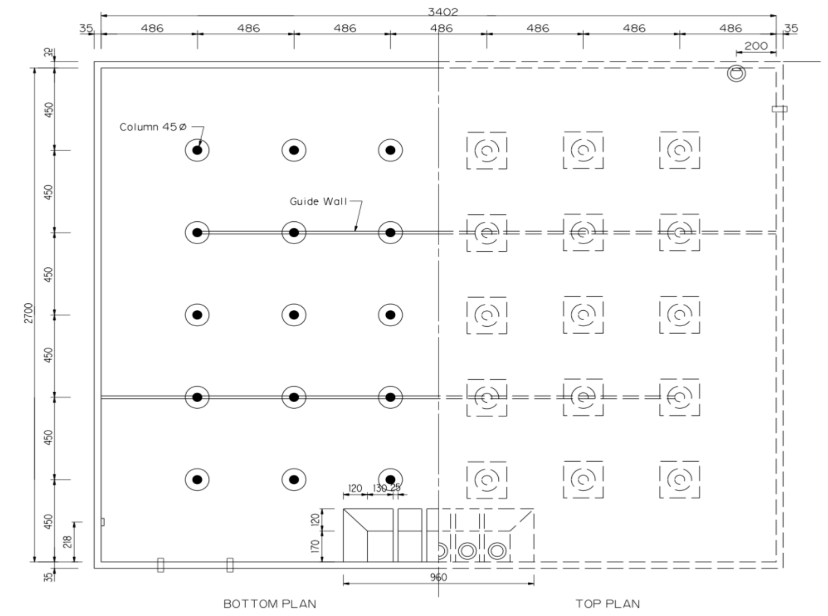
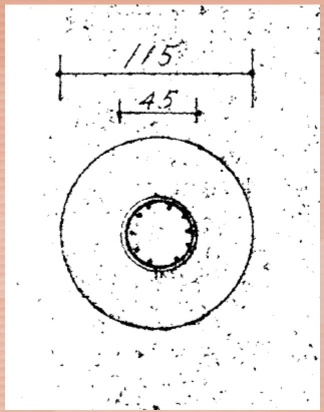




Existing Structure Details

X 向: $d_{max} = \frac{L}{2} C_c I = 34.02 / 2 * 0.021 * 1.5 = 0.52$ m

Y 向: $d_{max} = \frac{L}{2} C_c I = 9 / 2 * 0.158 * 1.5 = 1.07$ m



Free board is only 30cm+-

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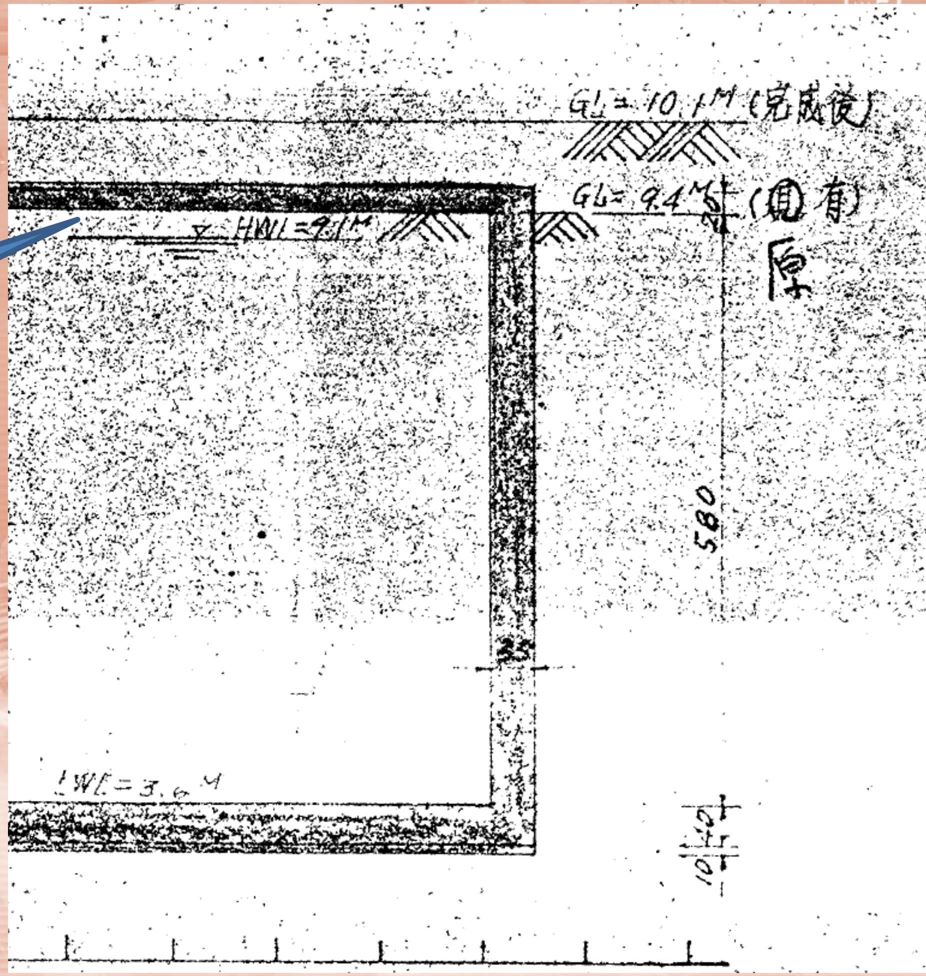
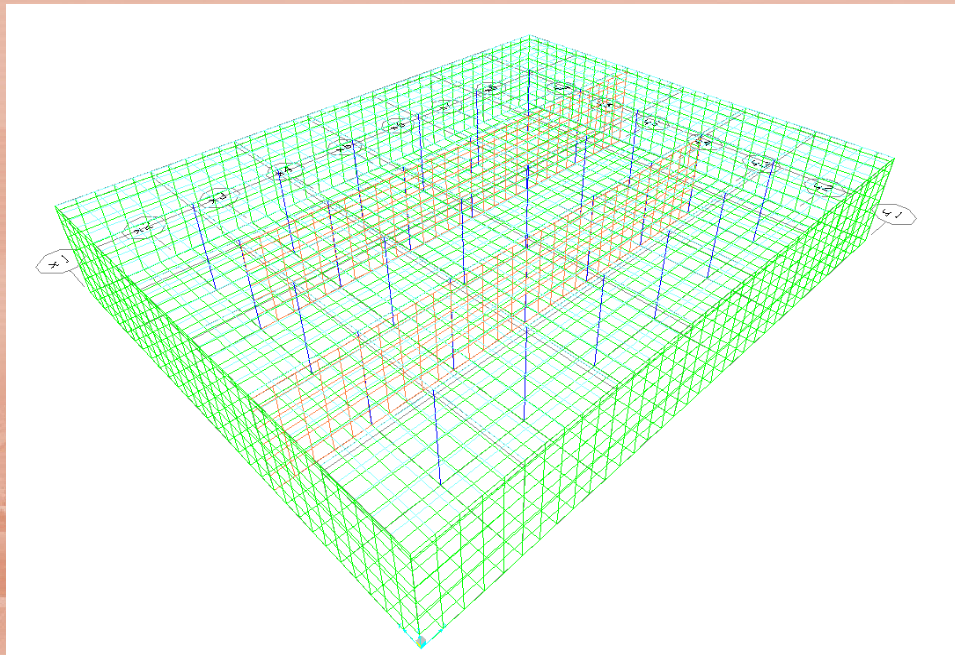


Sap 2000 Analysis Model



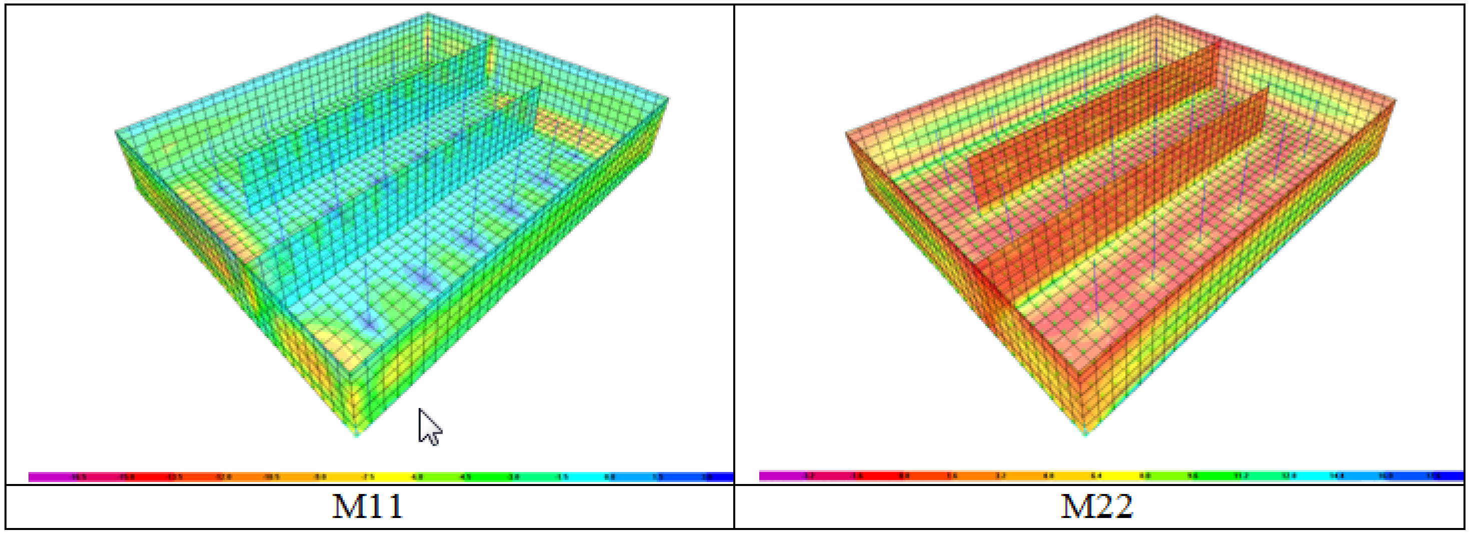


Figure 6. Moment Contours of Nangang Distribution Reservoir (roof slab removed for clarity)

Shear failure location of column

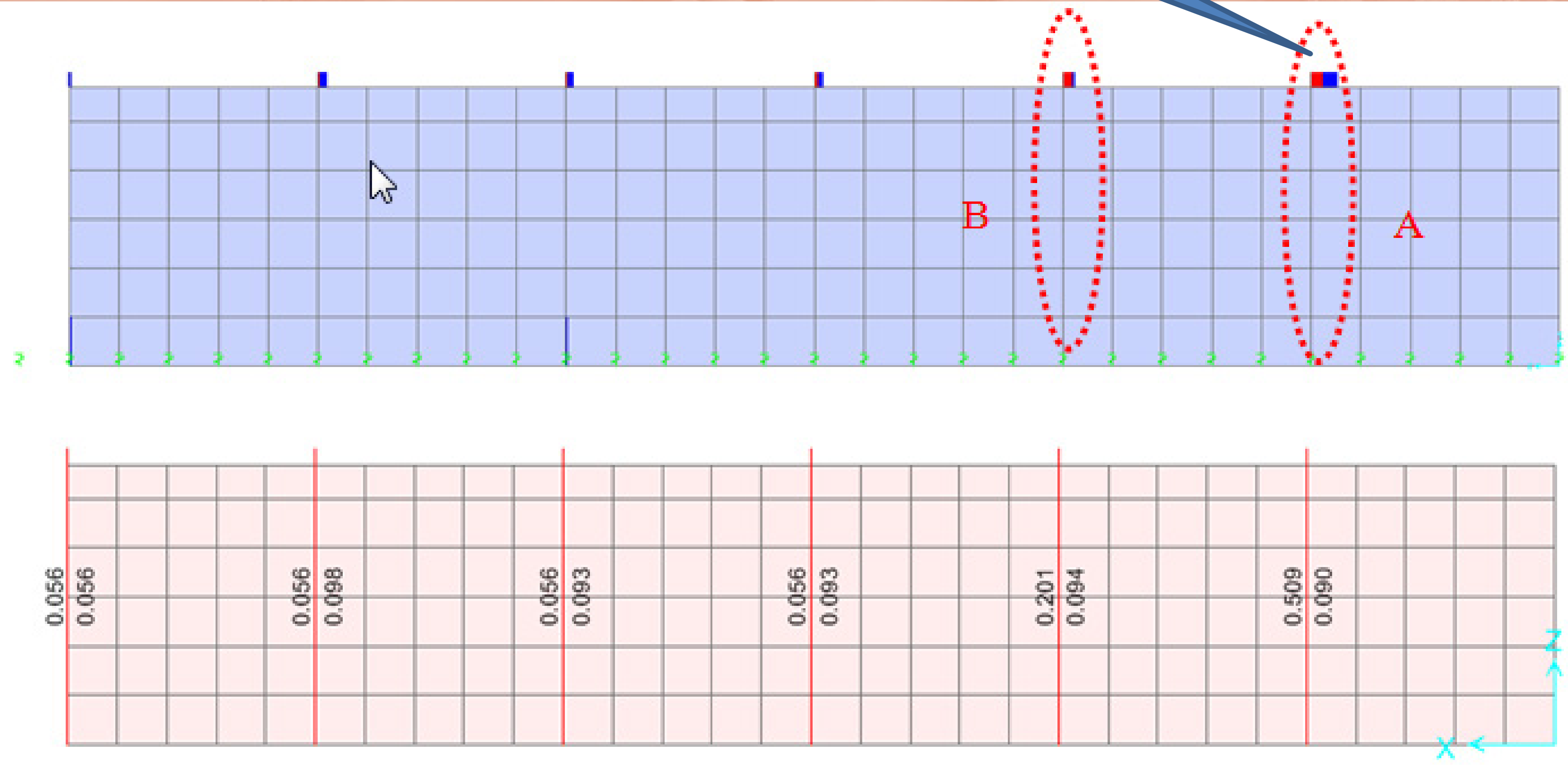


Figure 7. Shear Demand and Capacity of Columns

The simplified Westergaard's formula l

$$P = \frac{7}{12} k_h \gamma_w H_L{}^2$$

where P= total hydrodynamic force, k_h =0.4S_{DS} and H_L=water depth.

$$M_{comb} = \sqrt{M_{imp}^2 + M_{conv}^2}$$

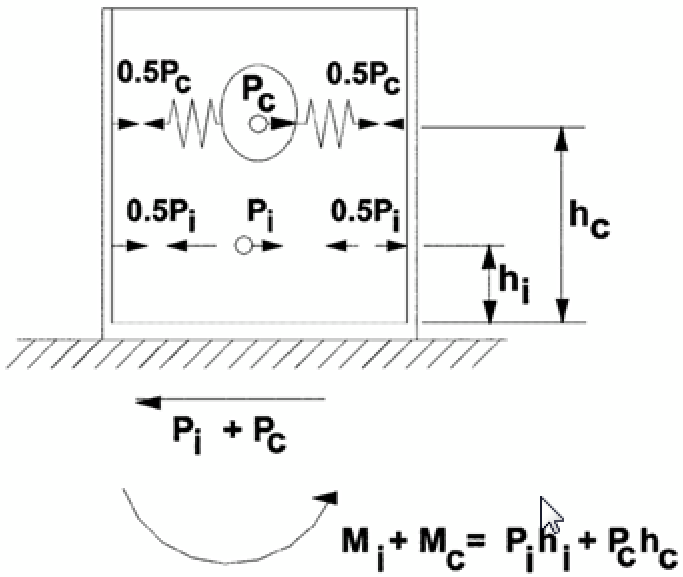
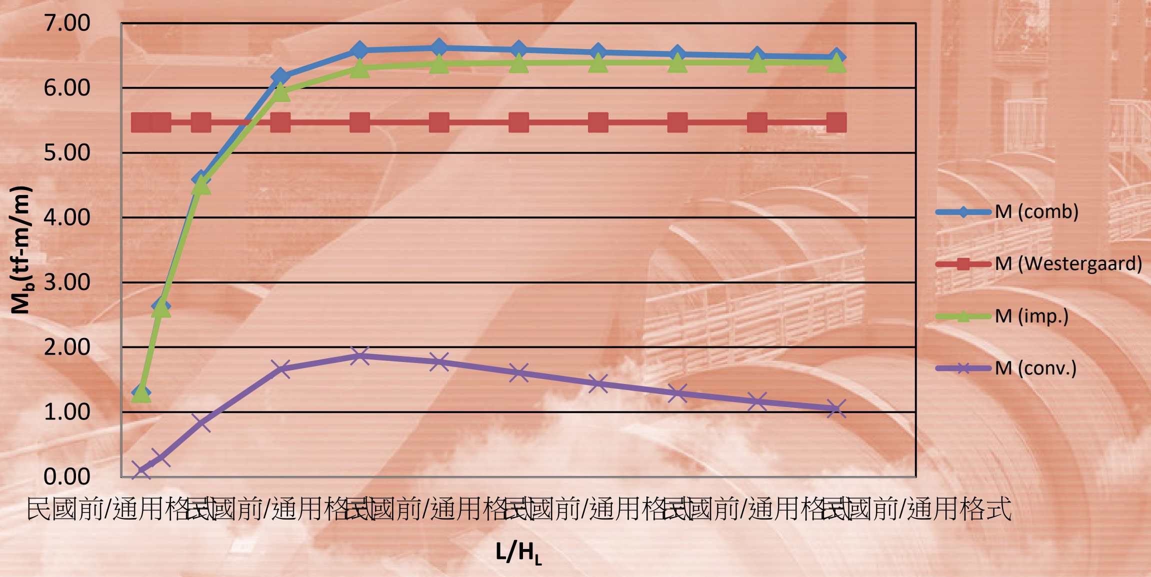
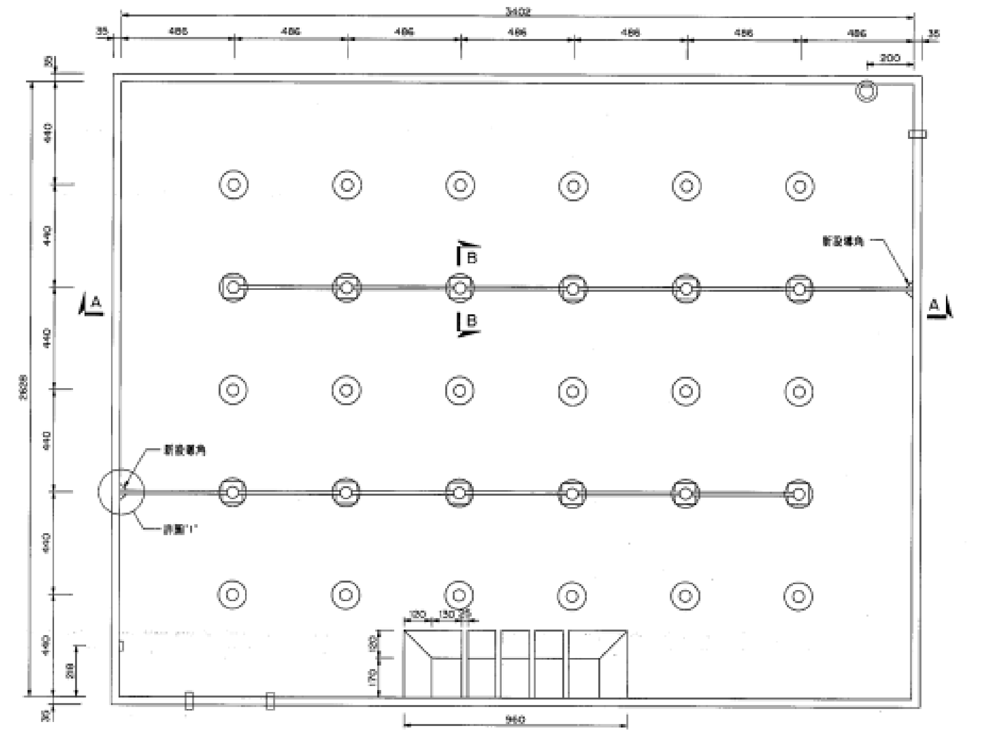


Figure 12. Dynamic Model of Liquid-Containing Tank [Fig. R9.1 ACI 350.3]

TABLE I. Forces for Different L/H_L Ratios Calculated by Housner's Approach

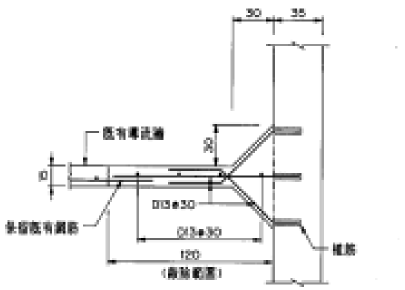
L (m)	H_L (m)	L/H_L	P_i (tf/m)	P_c (tf/m)	M_{imp}(tf-m/m)	M_{conv}(tf-m/m)	M_{comb} (tf-m/m)
1.25	5.0	0.25	2.46	0.49	0.49	0.49	0.49
2.5	5.0	0.5	4.94	0.98	0.98	0.98	0.98
5.0	5.0	1.0	8.64	1.94	1.94	1.94	1.94
10.0	5.0	2.0	11.59	3.31	3.31	3.31	3.31
15.0	5.0	3.0	12.31	3.60	3.60	3.60	3.60
20.0	5.0	4.0	12.44	3.40	3.40	3.40	3.40
25.0	5.0	5.0	12.46	3.06	3.06	3.06	3.06
30.0	5.0	6.0	12.47	2.74	2.74	2.74	2.74
35.0	5.0	7.0	12.47	2.45	2.45	2.45	2.45
40.0	5.0	8.0	12.47	2.21	2.21	2.21	2.21
45.0	5.0	9.0	12.47	2.01	2.01	2.01	2.01





平面圖

1:100



詳 圖 "1"

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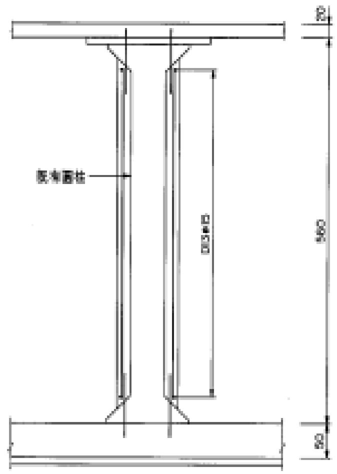

剖 面 B - B

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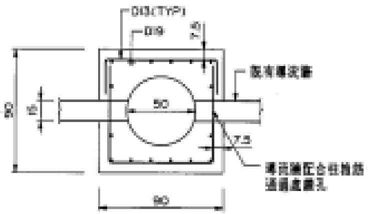

剖 面 C - C

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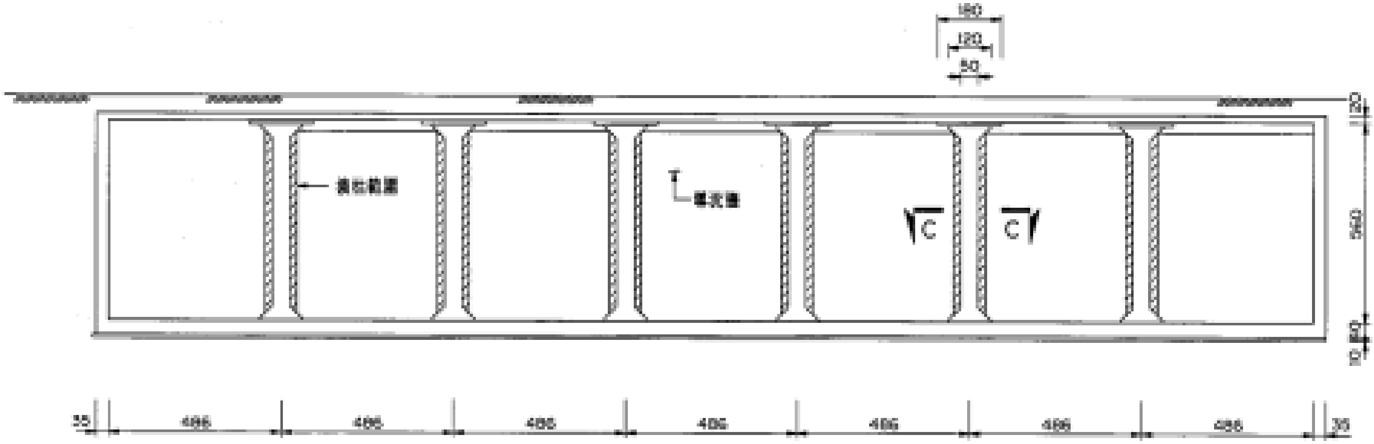

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評估

REMARK

- From the results of comparison study, it was indicated that the simplified Westergaard formula produces higher hydrodynamic force than the Housner's approach does when the ratio of the tank length to the water depth is relatively small (<2.0).
- Therefore, larger tanks in Taipei city designed during 1980s~1990s like the Nangang distribution reservoir, the hydrodynamic force calculated by using the simplified Westergaard formula in design was probably under-estimated, which may fail to meet the requirements of the new design code.


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Taipei Water Department
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