表 2-1 極限強度受參數調整影響比較表【6】

Influence of parameters on the computed ultimate load P_u

Slenderness			
a/d	0.8	1.5 (+ 88%)	2.3 (+188%)
P_u (kN)	975	853 (−13%)	822 (−16%)
Concrete compressive strength			
f_{cc} (MPa)	21.0	29.5 (+40%)	38.0 (+81%)
P_u (kN)	975	1190 (+22%)	1404 (+44%)
Concrete tensile strength			
f_{ct} (MPa)	2.0	2.5 (+25%)	3.0 (+50%)
P_u (kN)	975	961 (−1%)	982 (+1%)
$P_{crack\text{-}through}$ (kN)	770	893 (+16%)	975 (+27%)
Fracture energy			
G_f (N/m)	98	123 (+26%)	145 (+48%)
P_u (kN)	975	955 (−2%)	959 (−2%)

表 2-2 DIANA 之資料庫表【11】

Analysis Type	Material Model	Element Library
(1) Linear static	(1) Elastic	(1) Truss
(2) Nonlinear	(2) Plasticity	(2) Beam
(3) Dynamic	(3) Viscoplasticity	(3) Plane Stress
(4) Euler stability	(4) Cracking	(4) Plane Strain
(5) Potential flow	(5) Viscoelasticity	(5) Axisymmetric
(6) Coupled flow-stress	(6) Fraction	(6) Plate Bending
	(7) Soil Specials	(7) Flat Shell
(7) Phased	(8) Shrinkage Strains	(8) Curved Shell
(8) Parameter estimation	(9) Hyperelasticity	(9) Solid
	(10) Interface Non-linearity	(10) Interface
(9) Lattice	(11) User-supplied Material Model	(11) Spring
(10) Nonlinear dynamic		(12) Point Mass
		(13) Embedded Reinforcement
		(14) Flow

表 2-3 彈塑性分析比較表

相同點	相異點
Deformation compatibility Equilibrium condition	Stress- strain relation of material Loading unloading property

表 2-4 破壞準則之特性及演進表

破壞準則	參數	偏差面	經線
Maximum-tensile-stress(1876)	1	triangle	straight
Tersa(1864)	1	hexagon	straight
Von Mises(1913)	1	circle	straight
Mohr-Coulomb(1900)	2	hexagon	straight
Drucker-Prager(1952)	2	circle	straight
Bresler-Pister(1958)	3	circle	parabola
Reimann(1965)	4	approximate triangle	parabola
Willam-Warnke-3(1975)	3	approximate triangle	straight
Chen-Chen(1975)	3	circle	straight+curve
Willam-Warnke-5(1975)	5	triangle→circle	parabola
Ottosen(1977)	4	triangle→circle	curve
Hsieh-Ting-Chen(1979)	4	approximate triangle	curve
Lade,P.V.(1982)	3	triangle→circle	curve
Faruque et al.(1986)	4	triangle→circle	curve
Boswell et al.(1987)	8	triangle→circle	parabola
De Boer,R et al.(1989)	4	triangle→circle	curve

表 3-1 沉箱頂版設計基本材料參數表

	常時	施工與地震時
養護28天後混凝土之抗壓強度	$f_c' = 210\ ^{kg}/_{cm^2}$	$f_c' = 210\ ^{kg}/_{cm^2}$
	$f_y = 2100\ ^{kg}/_{cm^2}$	$f_y = 2793\ ^{kg}/_{cm^2}$
混凝土外緣壓應力	$f_c = 84\ ^{kg}/_{cm^2}$	$f_c = 111.72\ ^{kg}/_{cm^2}$
無鋼筋混凝土最外緣拉應力	$f_t = 6.09\ ^{kg}/_{cm^2}$	$f_t = 8.094\ ^{kg}/_{cm^2}$
	$V_c = 3.65\ ^{kg}/_{cm^2}$	$V_c = 4.856\ ^{kg}/_{cm^2}$
	$V_c' = 6.956\ ^{kg}/_{cm^2}$	$V_c' = 9.25\ ^{kg}/_{cm^2}$

表 3-2 模型尺寸表

Converge ansys of model size describe	
Column radius (m)	1
Plate radius (m)	3.6
Plate thick (m)	3
Support wide (m)	0.9

表 3-3 混凝土材料參數表

Concrete material property	
Elastic modulus E_c (MPa)	
Poisson ratio	0.2
Compression strength f_c (MPa)	21
Tension strength f_t (MPa)	2.1
Compression behavior	Parabola
Tension behavior	Hordyk

(Parabola、Hordyk 見附錄一)

表 3-4 鋼筋材料參數表

Reinforcement material property	
Elastic modulus E_s (MPa)	2e+05
Poisson ratio	0.2
Yield strength f_y (MPa)	270
Stress-strain	Von Mises

表 3-5 切割(Mesh)元素表

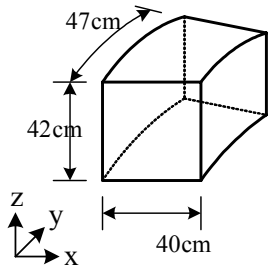
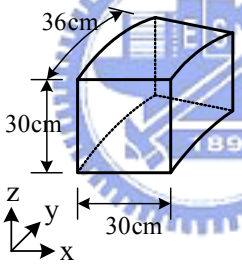
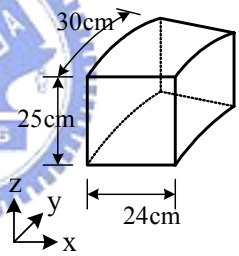
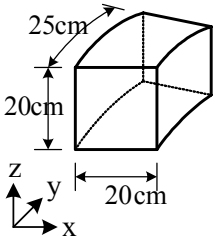
No.	No.1	No.2	No.3	No.4
Solid size				
Total element	666	1616	2784	5155
Total node	2731	6169	10479	18562

表 3-6 收斂誤差百分比

Converge of mesh element size			
No.	Element	Ultimate load	Error percent(%)
No.1	666	1750.3	9.5
No.2	1616	1916.2	3.8
No.3	2784	1846.7	0.1
No.4	5155	1844.8	

表 3-7 迭代步伐型式表

Step A	基本位移量		加乘係數		每步位移量	累積位移量	Step B	基本位移量		加乘係數		每步位移量	累積位移量
1	0.5	×	0.18	=	0.09×(step)1	= 0.09	1	0.5	×	0.2	=	0.1 ×(step)1	= 0.1
2	0.5		0.18		0.09×(step)2	0.18	2	0.5		0.2		0.1 ×(step)2	0.2
3	0.5		0.18		0.09×(step)3	0.27	3	0.5		0.2		0.1 ×(step)3	0.3
4	0.5		0.18		0.09×(step)4	0.36	4	0.5		0.2		0.1 ×(step)4	0.4
⋮	⋮		⋮		⋮	⋮	⋮	⋮		⋮		⋮	⋮
41	0.5		0.18		0.09×(step)41	3.69	33	0.5		0.2		0.1 ×(step)33	3.3
⋮	⋮		⋮		⋮	⋮	⋮	⋮		⋮		⋮	⋮
50	0.5		0.18		0.09×(step)50	4.5	50	0.5		0.2		0.1 ×(step)50	5
Step C	基本位移量		加乘係數		每步位移量	累積位移量	Step D	基本位移量		加乘係數		每步位移量	累積位移量
1	0.5	×	0.4	=	0.2×(step)1	= 0.2	1	0.5	×	0.6	=	0.3×(step)1	= 0.3
2	0.5		0.4		0.2×(step)2	0.4	2	0.5		0.6		0.3×(step)2	0.6
3	0.5		0.4		0.2×(step)3	0.6	3	0.5		0.6		0.3×(step)3	0.9
4	0.5		0.4		0.2×(step)4	0.8	4	0.5		0.6		0.3×(step)4	1.2
⋮	⋮		⋮		⋮	⋮	⋮	⋮		⋮		⋮	⋮
21	0.5		0.4		0.2×(step)21	4.2	14	0.5		0.6		0.3×(step)14	4.2
⋮	⋮		⋮		⋮	⋮	⋮	⋮		⋮		⋮	⋮
50	0.5		0.4		0.2×(step)50	10	50	0.5		0.6		0.3×(step)50	15
Step E	基本位移量		加乘係數		每步位移量	累積位移量	Step F	基本位移量		加乘係數		每步位移量	累積位移量
1	0.5	×	0.8	=	0.4×(step)1	= 0.4	1	0.5	×	1	=	0.5×(step)1	= 0.5
2	0.5		0.8		0.4×(step)2	0.8	2	0.5		1		0.5×(step)2	1
3	0.5		0.8		0.4×(step)3	1.2	3	0.5		1		0.5×(step)3	1.5
4	0.5		0.8		0.4×(step)4	1.6	4	0.5		1		0.5×(step)4	2
⋮	⋮		⋮		⋮	⋮	⋮	⋮		⋮		⋮	⋮
11	0.5		0.8		0.4×(step)11	4.4	9	0.5		1		0.5×(step)9	4.5
⋮	⋮		⋮		⋮	⋮	⋮	⋮		⋮		⋮	⋮
50	0.5		0.8		0.4×(step)50	20	50	0.5		1		0.5×(step)50	25

表 3-8 位移增量收斂誤差百分比

Type	Increment Displacement (mm)	Ultimate load (Ton)	Error percent(%)
A	0.09	1582.66	1.4
B	0.1	1559.39	3.1
C	0.2	1607.48	5.1
D	0.3	1688.29	4.4
E	0.4	1763.21	3.7
F	0.5	1827.74	

表 4-1　¼之沉箱頂版分析表

type	Column Radius (m)	Shear span a (m)	Plate depth d (m)	$\frac{a}{d}$	Concrete f_c (MPa)	Concrete f_t (MPa)	Steel of f_y (MPa)	Ultimate load P_u (ton)
1	1	2.15	2.9	0.74	21	2.1	270	1333.4
2	1.25	1.9	2.9	0.66	21	2.1	270	1495.1
3	1.5	1.65	2.9	0.57	21	2.1	270	1877.9
4	1.75	1.4	2.9	0.48	21	2.1	270	1993.2
5	2	1.15	2.9	0.39	21	2.1	270	2479.8

表 4-2 內插後混凝土之勁度比較表

Interpolation method	Stiffness of concrete E	decrease %
First yield stage	25000	100
Second yield stage	8743	35

(E單位:MPa)

表 4-3 誤差比較表

Radius 1m	Integer ratio	Boundary coundition	Step converge	Displacement control	Ultimate load P_u (ton)	Error %
Caisson plate	$\frac{1}{4}$	xyz surface	50	vertical distribute	1333.4 ↓×2	0.33
Caisson plate	$\frac{1}{4}\times 2$				2666.8	
Caisson plate	$\frac{1}{2}$	xz surface	50	vertical distribute	2675.6	

表 4-4 柱墩直徑 2 m 之梯形轉角位移量表

Analysis type	Total step converge	Column diameter	Displacement corner ratio	Step of increment displacement
1/2 Caisson plate	50	2000mm	θ=0.129°	6.75MM 2.25MM
1/2 Caisson plate	50	2000mm	θ=0.258°	9MM 0MM
1/2 Caisson plate	50	2000mm	θ=0.386°	11.25MM -2.25MM
1/2 Caisson plate	50	2000mm	θ=0.516°	13.5MM -4.5MM
1/2 Caisson plate	50	2000mm	θ=0.645°	15.75MM -6.75MM
1/2 Caisson plate	50	2000mm	θ=0.774°	18MM -9MM
1/2 Caisson plate	50	2000mm	θ=0.902°	20.25MM -11.25MM

表 4-5 柱墩直徑 4 m 之梯形轉角位移增量表

Analysis type	Total step converge	Column diameter	Displacement corner ratio	Step of increment displacement
1/2 Caisson plate	50	4000mm	θ=0.065°	6.75MM 2.25MM
1/2 Caisson plate	50	4000mm	θ=0.129°	9MM 0MM
1/2 Caisson plate	50	4000mm	θ=0.193°	11.25MM -2.25MM
1/2 Caisson plate	50	4000mm	θ=0.258°	13.5MM -4.5MM
1/2 Caisson plate	50	4000mm	θ=0.332°	15.75MM -6.75MM
1/2 Caisson plate	50	4000mm	θ=0.387°	18MM -9MM
1/2 Caisson plate	50	4000mm	θ=0.451°	20.25MM -11.25MM

表 4-6 程式分析之極限載重比較表

Load tyep	Pier column diameter 2M			Pier column diameter 4M		
displacement	P_u (Ton)	M_u (Ton-M)	$\frac{M_u}{P_u}$ (CM)	P_u (Ton)	M_u (Ton-M)	$\frac{M_u}{P_u}$ (CM)
6.75MM 2.25MM	7006	1022	14.6	12412	5070	40.8
9MM 0MM	5922	1618	27.3	11234	9186	81.8
11.25MM -2.25MM	5342	1854	34.7	10682	11158	104.5
13.5MM -4.5MM	4494	1684	37.4	10486	11712	111.7
15.75MM -6.75MM	4426	1750	39.5	10248	12870	125.6
18MM -9MM	4096	1634	39.9	9442	11080	117.4
20.25MM -11.25MM	3936	1610	40.9	9452	11240	118.9
Avg. strength	4084	1718		10464	11446	
Avg. e ($\frac{M_u}{P_u}$) -increment			3.14			10.25

表 4-7 各式極限載重表

Circular for Pier diameter Cd (m)	Caisson plate design of Ultimate load $P_{u(caisson\ design)}$ (ton)	ACI code punching shear design of Ultimate load $P_{u(punching)}$ (ton)	ACI code strut-and-tie design of Ultimate load $P_{u(strut\text{-}tie)}$ (ton)	DIANA analysis of Ultimate load $P_{u(DIANA)}$ (ton)
2	1525.3	4295.6	4246.7	5333.6
2.5	2025.3	4733.9	5112.7	5980.4
3	2725.3	5172.2	6385.3	7511.6
3.5	3525.3	5610.5	7775.3	7972.8
4	4825.1	6028.9	9249.7	9919.2

表 4-8 極限載重比較表

Pier diameter	2	2.5	3	3.5	4
$\frac{P_{u\ (punching\ shear)}}{P_{u\ (caisson\ design)}}$	2.82	2.34	1.89	1.59	1.25
$\frac{P_{u\ (strut\text{-}and\text{-}tie)}}{P_{u\ (caisson\ design)}}$	2.78	2.52	2.34	2.21	1.92
$\frac{P_{u\ (DIANA)}}{P_{u\ (caisson\ design)}}$	3.49	2.95	2.75	2.26	2.05
average	3.03	2.60	2.33	2.02	1.74