TABLE 12.6 EQUIVALENT STRESSES FOR SLABS WITHOUT CONCRETE SHOULDERS

Slab thickness (in.)	k of Subgrade–subbase (pci)						
	50	100	150	200	300	500	700
4	825/679	726/585	671/542	634/516	584/486	523/457	484/443
4.5	699/586	616/500	571/460	540/435	498/406	448/378	417/363
5	602/516	531/436	493/399	467/376	432/349	390/321	363/307
5.5	526/461	464/387	431/353	409/331	379/305	343/278	320/264
6	465/416	411/348	382/316	362/296	336/271	304/246	285/232
6.5	417/380	367/317	341/286	324/267	300/244	273/220	256/207
7	375/349	331/290	307/262	292/244	271/222	246/199	231/186
7.5	340/323	300/268	279/241	265/224	246/203	224/181	210/169
8	311/300	274/249	255/223	242/208	225/188	205/167	192/155
8.5	285/281	252/232	234/208	222/193	206/174	188/154	177/143
9	264/264	232/218	216/195	205/181	190/163	174/144	163/133
9.5	245/248	215/205	200/183	190/170	176/153	161/134	151/124
10	228/235	200/193	186/173	177/160	164/144	150/126	141/117
10.5	213/222	187/183	174/164	165/151	153/136	140/119	132/110
11	200/211	175/174	163/155	154/143	144/129	131/113	123/104
11.5	188/201	165/165	153/148	145/136	135/122	123/107	116/98
12	177/192	155/158	144/141	137/130	127/116	116/102	109/93
12.5	168/183	147/151	136/135	129/124	120/111	109/97	103/89
13	159/176	139/144	129/129	122/119	113/106	103/93	97/85
13.5	152/168	132/138	122/123	116/114	107/102	98/89	92/81
14	144/162	125/133	116/118	110/109	102/98	93/85	88/78

Note. Number at left is for single axle and number at right is for tandem axle (single/tandem); 1 in. = 25.4 mm, 1 pci = 271.3 kN/m^3.

Source. After PCA (1984).

Example 12.2

The sensitivity analysis presented in Table 5.13 shows an average edge stress of about 283 psi (1.95 MPa) under a 36-kip (160-kN) tandem-axle load when h = 8 in. (203 mm) and k = 100 pci (27.1 MN/m^3). Assuming a concrete modulus of rupture of 500 psi (4.5 MPa) and using the PCA fatigue equation, or Eq. 5.36, determine the allowable number of load repetitions. Compare the result with that obtained from Table 12.6 and Figure 12.12.

Solution: Because only a small portion of wheel loads is applied at the pavement edge, the edge stress must be multiplied by an adjustment factor of 0.894, so the actual stress is $\sigma = 0.894 \times 283 = 253$ psi (1.75 MPa). With $\sigma/S_c = 253/500 = 0.506$, from Eq. 5.36*b*, $N_f = [4.2577/(0.506 - 0.43250)]^{3.268} = 5.8 \times 10^5$.

From Table 12.6, the equivalent stress for a tandem-axle load with a k value of 100 pci (27.1 MN/m^3) and a slab thickness of 8 in. (203 mm) is 249 psi (1.72 MPa), which is slightly smaller than the 253 psi (1.75 MPa) obtained in the sensitivity analysis. This is as expected because the dual and tandem spacings as well as the tire contact pressure assumed by PCA is not known and may be quite

TABLE 12.11 EROSION FACTORS FOR SLABS WITH AGGREGATE INTERLOCK JOINTS AND CONCRETE SHOULDERS

Slab thickness (in.)	k of Subgrade–subbase (pci)					
	50	100	200	300	500	700
4	3.46/3.49	3.42/3.39	3.38/3.32	3.36/3.29	3.32/3.26	3.28/3.24
4.5	3.32/3.39	3.28/3.28	3.24/3.19	3.22/3.16	3.19/3.12	3.15/3.09
5	3.20/3.30	3.16/3.18	3.12/3.09	3.10/3.05	3.07/3.00	3.04/2.97
5.5	3.10/3.22	3.05/3.10	3.01/3.00	2.99/2.95	2.96/2.90	2.93/2.86
6	3.00/3.15	2.95/3.02	2.90/2.92	2.88/2.87	2.86/2.81	2.83/2.77
6.5	2.91/3.08	2.86/2.96	2.81/2.85	2.79/2.79	2.76/2.73	2.74/2.68
7	2.83/3.02	2.77/2.90	2.73/2.78	2.70/2.72	2.68/2.66	2.65/2.61
7.5	2.76/2.97	2.70/2.84	2.65/2.72	2.62/2.66	2.60/2.59	2.57/2.54
8	2.69/2.92	2.63/2.79	2.57/2.67	2.55/2.61	2.52/2.53	2.50/2.48
8.5	2.63/2.88	2.56/2.74	2.51/2.62	2.48/2.55	2.45/2.48	2.43/2.43
9	2.57/2.83	2.50/2.70	2.44/2.57	2.42/2.51	2.39/2.43	2.36/2.38
9.5	2.51/2.79	2.44/2.65	2.38/2.53	2.36/2.46	2.33/2.38	2.30/2.33
10	2.46/2.75	2.39/2.61	2.33/2.49	2.30/2.42	2.27/2.34	2.24/2.28
10.5	2.41/2.72	2.33/2.58	2.27/2.45	2.24/2.38	2.21/2.30	2.19/2.24
11	2.36/2.68	2.28/2.54	2.22/2.41	2.19/2.34	2.16/2.26	2.14/2.20
11.5	2.32/2.65	2.24/2.51	2.17/2.38	2.14/2.31	2.11/2.22	2.09/2.16
12	2.28/2.62	2.19/2.48	2.13/2.34	2.10/2.27	2.06/2.19	2.04/2.13
12.5	2.24/2.59	2.15/2.45	2.09/2.31	2.05/2.24	2.02/2.15	1.99/2.10
13	2.20/2.56	2.11/2.42	2.04/2.28	2.01/2.21	1.98/2.12	1.95/2.06
13.5	2.16/2.53	2.08/2.39	2.00/2.25	1.97/2.18	1.93/2.09	1.91/2.03
14	2.13/2.51	2.04/2.36	1.97/2.23	1.93/2.15	1.89/2.06	1.87/2.00

Note. Number at left is for single axle and number at right is for tandem axle (single/tandem); 1 in. = 25.4 mm, 1 pci = 271.3 kN/m^3.

Source. After PCA (1984).

Explanation of Worksheet

1. Single-axle loads are incremented at 2-kip (8.9-kN) intervals, and tandem-axle loads are incremented at 4-kip (17.8-kN) intervals. The largest load in the single- or tandem-load group should be entered first. If the allowable number of repetitions for a given load is unlimited, it is not necessary to compute the damage for the remaining loads in the same group.
2. The axle loads in column 1 are multiplied by a load safety factor of 1.2.
3. The predicted or expected repetitions are obtained from Table 12.5. To be on the conservative side, the upper limit of the load in the range is used to represent the range. For example, all axle loads between 28 and 30 kip (125 and 134 kN) are considered as 30 kip (134 kN). With an annual growth rate of 4% and a design period of 20 years, from Table 6.12, growth factor $G = 1.5$. Design ADT = 12,900 × 1.5 = 19,350, or 9675 in one direction. ADTT = 19,350 × 0.19 = 3680, or 1840 in one direction. For an ADT of 9675 in one direction, from Figure 6.8, lane distribution factor $L = 0.81$. Therefore, the total number of trucks on the design lane during the design period is 1840 ×

Calculation of Pavement Thickness

Project Design 1A, four-lane Interstate, rural

Trial thickness 9.5 in.
Subbase-subgrade k 130 pci
Modulus of rupture, MR 650 psi
Load safety factor, LSF 1.2

Doweled joints: yes ✓ no ___
Concrete shoulder: yes ___ no ✓
Design period 20 years

4 in. untreated subbase

Axle load, kips	Multiplied by LSF 1.2	Expected repetitions	Fatigue analysis: Allowable repetitions	Fatigue analysis: Fatigue, percent	Erosion analysis: Allowable repetitions	Erosion analysis: Damage, percent
1	2	3	4	5	6	7

8. Equivalent stress 206
9. Stress ratio factor 0.317
10. Erosion factor 2.59

Single Axles

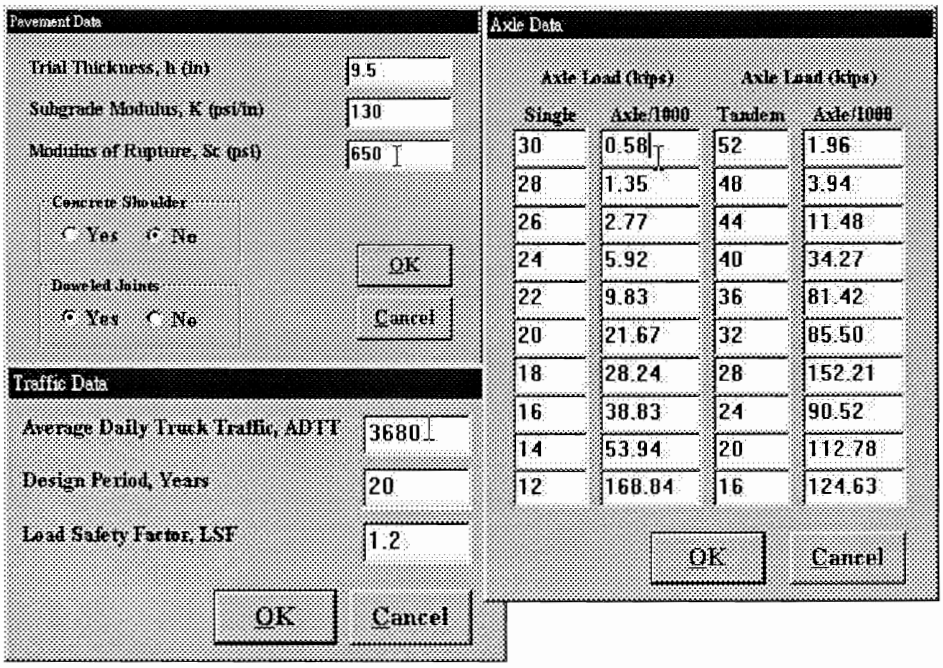
30	36.0	6,310	27,000	23.3	1,500,000	2.4
28	33.6	14,690	77,000	19.1	2,200,000	0.7
26	31.2	30,140	230,000	13.1	3,500,000	0.9
24	28.8	64,410	1,200,000	5.4	5,900,000	1.1
22	26.4	106,900	Unlimited	0	14,000,000	0.8
20	24.0	235,800	"	0	23,000,000	1.0
18	21.6	307,200	"	0	64,000,000	0.5
16	19.2	422,500			Unlimited	0
14	16.8	586,900			"	0
12	14.4	1,837,000			"	0

11. Equivalent stress 192
12. Stress ratio factor 0.295
13. Erosion factor 2.39

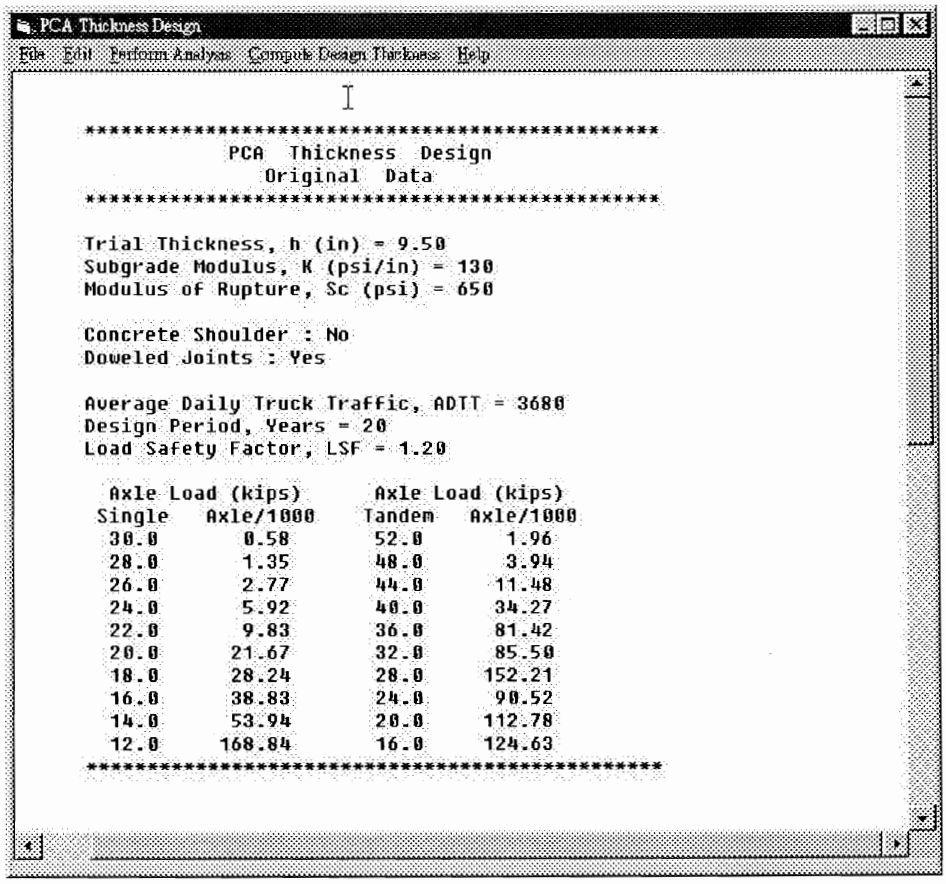
Tandem Axles

52	62.4	21,320	1,100,000	1.9	920,000	2.3
48	57.6	42,870	Unlimited	0	1,500,000	2.9
44	52.8	124,900	"	0	2,500,000	5.0
40	48.0	372,900	"	0	4,600,000	8.1
36	43.2	885,800			9,500,000	9.3
32	38.4	930,200			24,000,000	3.9
28	33.6	1,656,000			92,000,000	1.8
24	28.8	984,900			Unlimited	0
20	24.0	1,227,000			"	0
16	19.2	1,356,000				
			Total	62.8	Total	38.9

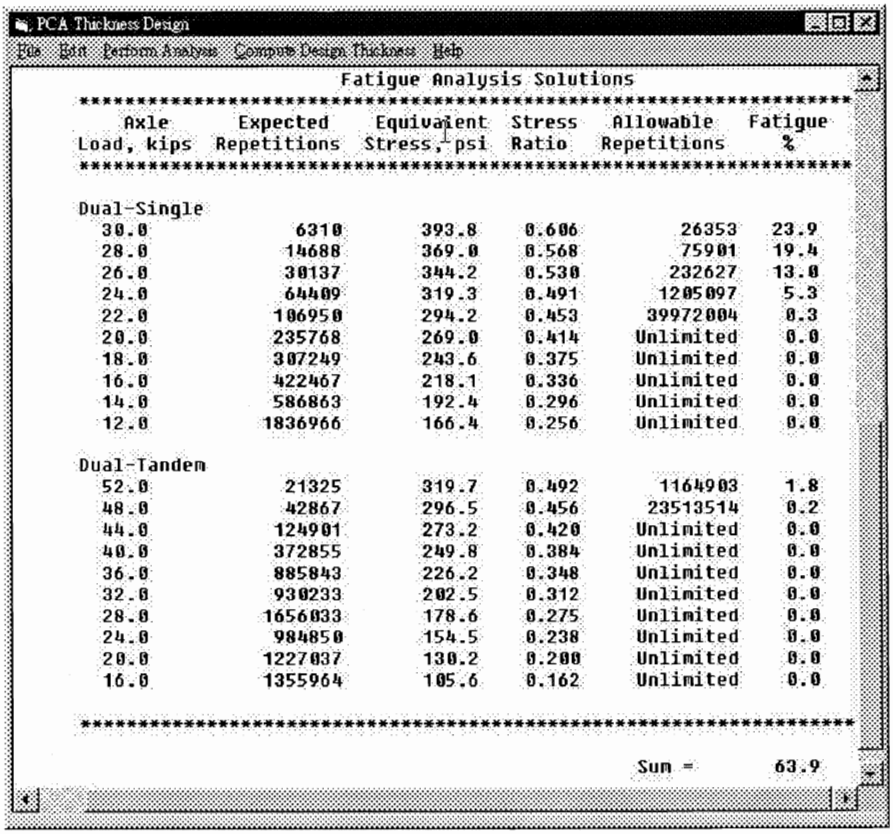
Figure 12.15 Worksheet for sample problem (1 in. = 25.4 mm, 1 psi = 6.9 kPa, 1 pci = 271.3 kN/m^3). (After PCA (1984).)



圖一　PCAWIN 基本資料輸入視窗圖例



圖二　PCAWIN 疲勞損壞分析結果輸出圖例一



PCA Thickness Design

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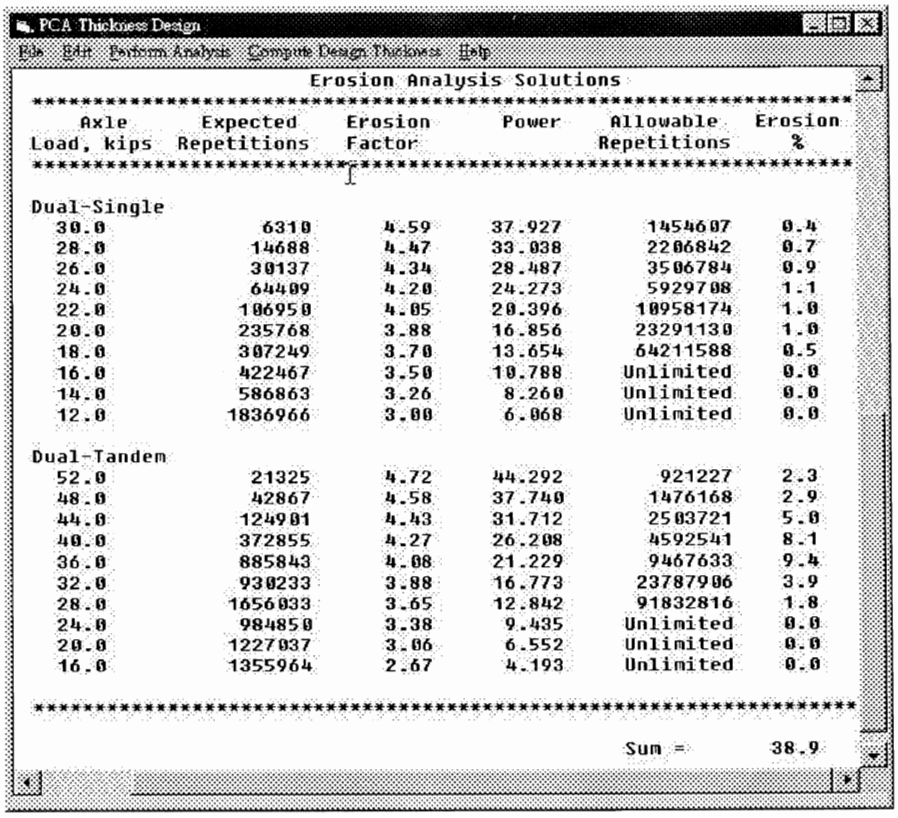
Fatigue Analysis Solutions

Axle Load, kips	Expected Repetitions	Equivalent Stress, psi	Stress Ratio	Allowable Repetitions	Fatigue %
Dual-Single					
30.0	6310	393.8	0.606	26353	23.9
28.0	14688	369.0	0.568	75901	19.4
26.0	30137	344.2	0.530	232627	13.0
24.0	64409	319.3	0.491	1205097	5.3
22.0	106950	294.2	0.453	39972004	0.3
20.0	235768	269.0	0.414	Unlimited	0.0
18.0	307249	243.6	0.375	Unlimited	0.0
16.0	422467	218.1	0.336	Unlimited	0.0
14.0	586863	192.4	0.296	Unlimited	0.0
12.0	1836966	166.4	0.256	Unlimited	0.0
Dual-Tandem					
52.0	21325	319.7	0.492	1164903	1.8
48.0	42867	296.5	0.456	23513514	0.2
44.0	124901	273.2	0.420	Unlimited	0.0
40.0	372855	249.8	0.384	Unlimited	0.0
36.0	885843	226.2	0.348	Unlimited	0.0
32.0	930233	202.5	0.312	Unlimited	0.0
28.0	1656033	178.6	0.275	Unlimited	0.0
24.0	984850	154.5	0.238	Unlimited	0.0
20.0	1227037	130.2	0.200	Unlimited	0.0
16.0	1355964	105.6	0.162	Unlimited	0.0
			Sum =		63.9

圖三　PCAWIN 疲勞損壞分析結果輸出圖例二



PCA Thickness Design

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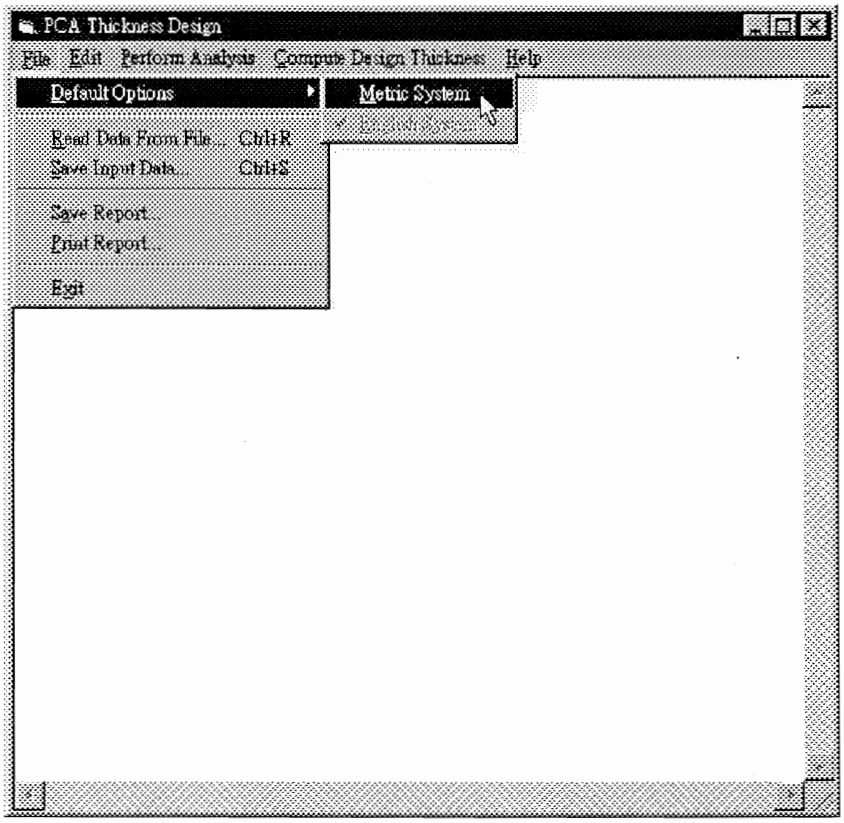
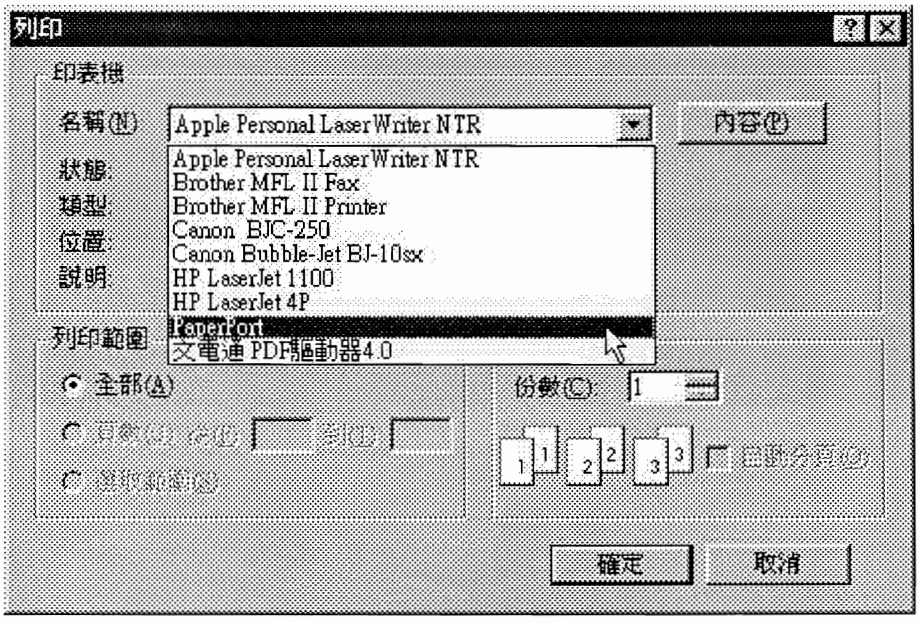
Erosion Analysis Solutions

Axle Load, kips	Expected Repetitions	Erosion Factor	Power	Allowable Repetitions	Erosion %
Dual-Single					
30.0	6310	4.59	37.927	1454607	0.4
28.0	14688	4.47	33.038	2206842	0.7
26.0	30137	4.34	28.487	3506784	0.9
24.0	64409	4.20	24.273	5929708	1.1
22.0	106950	4.05	20.396	10958174	1.0
20.0	235768	3.88	16.856	23291130	1.0
18.0	307249	3.70	13.654	64211588	0.5
16.0	422467	3.50	10.788	Unlimited	0.0
14.0	586863	3.26	8.260	Unlimited	0.0
12.0	1836966	3.00	6.068	Unlimited	0.0
Dual-Tandem					
52.0	21325	4.72	44.292	921227	2.3
48.0	42867	4.58	37.740	1476168	2.9
44.0	124901	4.43	31.712	2503721	5.0
40.0	372855	4.27	26.208	4592541	8.1
36.0	885843	4.08	21.229	9467633	9.4
32.0	930233	3.88	16.773	23787906	3.9
28.0	1656033	3.65	12.842	91832816	1.8
24.0	984850	3.38	9.435	Unlimited	0.0
20.0	1227037	3.06	6.552	Unlimited	0.0
16.0	1355964	2.67	4.193	Unlimited	0.0
			Sum =		38.9

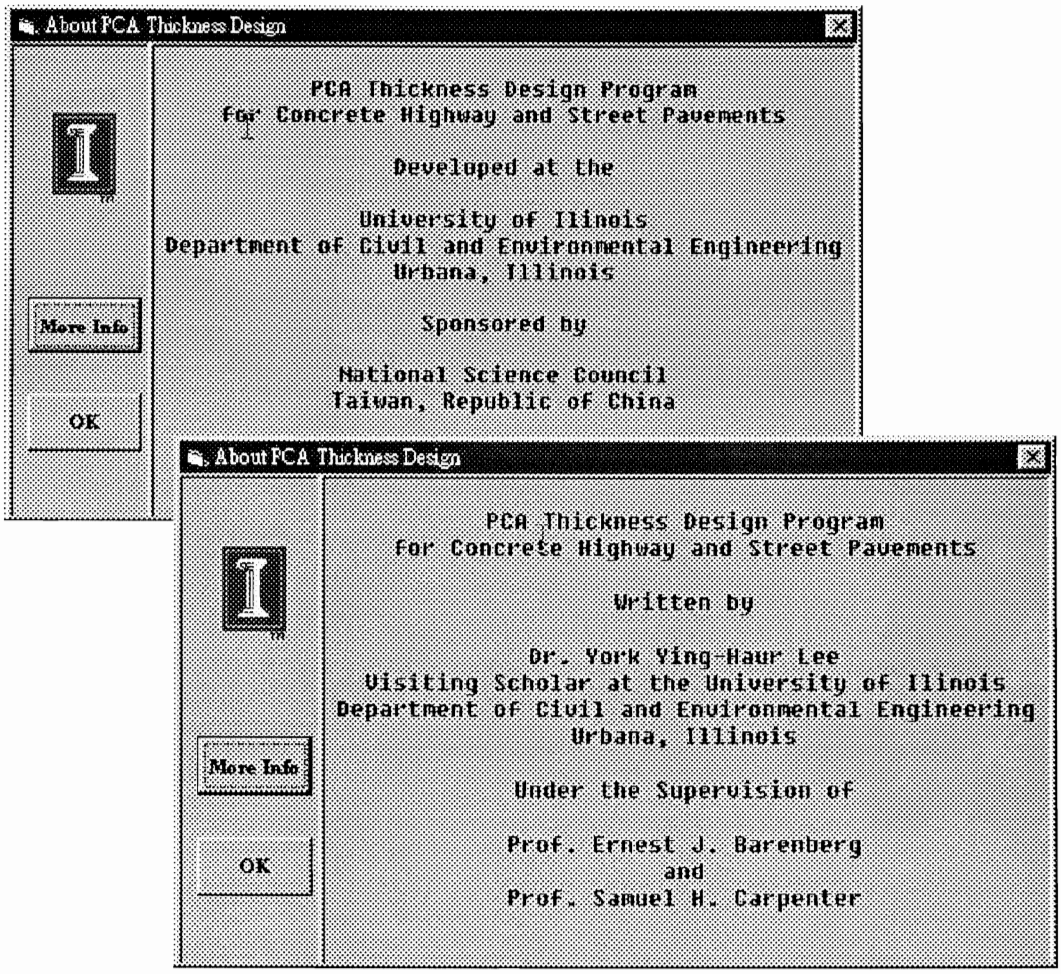
圖四　PCAWIN 侵蝕分析結果輸出圖例



圖五　PCAWIN 基本設定與檔案管理視窗圖例



圖六　PCAWIN 列印功能之印表機選擇視窗圖例



圖七　PCAWIN 程式說明視窗圖例