EFFECTS OF SLAB SIZE ON FIELD PERFORMANCE OF AIRPORT PAVEMENT INDICATED BY PAVEMENT CONDITION INDEX(PCI)

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INTRODUCTION

Joints are used in airport PCC pavement construction, with the joint spacing, or the slab size, determined during design. Federal Aviation Administration (FAA) Advisory Circular No. 150/5320-6D [1] offers a "rule-of-thumb" to determine the slab size of unreinforced PCC pavements based on the Portland Cement Association (PCA) recommendation [2]: "the joint spacing (in ft) should not greatly exceed twice the slab thickness (in inches)" and "ratio of slab length to slab width should not exceed 1.25 in unreinforced pavements." For all pavement slab thicknesses equal to or greater than 30 cm (12 in), the recommended maximum spacing for transverse and longitudinal joints is 7.62 m (25 ft). Since almost all major airports that serve heavy jet aircraft require a slab thickness greater than 30 cm (12 in), 7.62 by 7.62m (25 by 25ft) has been the most common slab size currently used at large and medium hub airports. Recently, other agencies have recommended the use of smaller slabs for new construction based on their experiences. However, justification for a change in FAA standards has not been firmly established by either theoretical research or analysis of field data.

The PCA design method states that 6.10 to 7.62m (20 by 25ft) longitudinal construction joint spacing was used (before 1973) because the "equipment was best suited to paving widths of 20 to 25 ft" (Chapter 3, [2]). However, since the 1970s, developments in paving equipment have permitted construction widths up to 15.24m (50ft), and the question of whether the standard of the 7.62 by 7.62m (25 by 25ft) size to build and rehabilitate unreinforced airport PCC pavements should still be followed arises. From a practical point of view, some airport pavement engineers have found that pavements with a slab size larger than 7.62m (25ft) usually crack earlier than pavements using smaller slabs, such as 3.81 by 3.81m (12.5 by 12.5ft). Smaller slabs have also been recognized as offering better performance by engineers in other countries, such as India [3], where 4 to 5 meter size slabs are suggested for hot weather. All runways in China were originally built as PCC pavements and most of them used 4 by 5m or 5 by 5m slabs. The sixteen years old west runway of Capital Airport, Beijing which has only two runways was surveyed in October 1996. The pavement using 4m by 5m slabs still performed well with pavement condition index [7] (PCI) = 75 and pavement structural condition index (SCI) = 91.

For reinforced concrete pavements, both the FAA and PCA design methods allow the use of larger joint spacing. AC 150/5320-6D [1] allows contraction joint spacing of up to 22.9m (75ft). The PCA method [2] suggests using joint spacing ranging from 9.1 to 21.3m (30 to 70ft), depending on slab thickness. Both methods require the use of dowels for transverse joints in the reinforced concrete pavement to avoid the loss of load transfer caused by larger joint openings associated with longer slabs.

The objective of this research is to evaluate the influence of slab size on the performance of rigid pavements by analysis of airport survey data in conjunction with numerical analysis. The theoretical analysis is not sufficient to find the optimal slab size for airport pavement design or rehabilitation because performance of the pavement cannot be directly predicted by the calculated critical response in the slabs. Environmental effects on pavement performance cannot be perfectly simulated solely by the temperature variation model employed in the analysis. The performance of the pavement is influenced by many factors which are much more complicated than any of the available simplified models. The effects of combining these factors cannot be predicted by any available theoretical model. Therefore, airport survey data, was used to verify the results obtained from theoretical analysis and to find the appropriate slab size.

Evaluation of slab size effect was conducted by statistic analyses of 24.0 million square meter (258.7 msf) PCC pavement data from 174 airports distributed in six FAA regions plus Hawaii and Japan. Among the surveyed pavements, 2.44 million square meters of pavement in seventeen airports were surveyed twice. The second survey was conducted a few years later than the first one. And 0.16 million square meters of pavement at one airport were surveyed three times. The second and third surveys were treated independently in this project, so the total surveyed pavement "area-time" was 26.8 msm (288.4 msf). The relationship between slab size and pavement performance as indicated by the PCI survey data was

investigated by different procedures, including the general effect of slab size on the measured PCI, and the effect of slab size as influenced by pavement type and age. PCI distribution curves were also employed to verify the results received by the above procedures.

NUMERICAL ANALYSIS BY FINITE ELEMENT PROGRAM JSLAB-92

JSLAB-92 [4] which was developed based on the program JSLAB [5] has been used to conduct the analysis. The mathematical model used in the program is thin plates linked by specially formulated beams and resting on a vertical, discretized spring system. A six slab pavement system with slab length and/or width from 4.57 to 7.62m (15 to 25ft) was used in the analysis and one example is given in Figure 1. The ranges of input data are: thickness from 38.1 to 48.3 cm, subgrade modulus k: from 0.136 to 1.36 MPa/cm (50 to 500 pci), relative stiffness $l=\{E\times h^3/[12\times(1-\mu^2)\times k]\}^{0.25}$ from 0.99 to 2.1 m, ratio between single load radius and relative stiffness from 0.125 to 0.264, dimensionless joint stiffness (AGG/kl) from 5.1 to 24.3, temperature gradient along the concrete slab depth from -0.33 to +0.33°C/cm (-1.5 to +1.5°F/in) , tire pressure = 1.03Mpa (150psi).

Two pavement initial states plus two types of response were investigated to evaluate the effect of slab size on the maximum bending stress at the pavement joints. The two initial states are: (1) The surface slabs keep full contact with the base or subbase layer, namely, the initial warping and curling of the slabs caused by temperature gradient and other parameters are neglected. This is the assumed initial state for calculating the critical response in AC 150/5320-6D. (2) The surface slabs are warped up or curled down by a temperature gradient so that gaps exist between the surface slabs and the base or subbase layer. This is not explicitly considered by the response prediction model in AC 150/5320-6D. However, it is implicitly considered in the damage model for thickness design. The two response types are: (1) Responses induced by load only based on the initial state one or two. (2) Total responses induced by the load and the temperature gradient.

Transverse stresses of the pavement under a B-777 gear shown in Figure 1 are given in Figure 2 where (a) presents the total transverse stresses sometime at mid-night and (b) sometime in the middle of the day. It can be seen that the sign of the transverse stresses induced by load and temperature are the same in the middle of day but they are different at mid-night. Therefore, the total stresses sometime in the early afternoon would be much higher than those at mid-night.

A 222 kN single wheel load was used to investigate the slab size effects. Results for different slab widths 4.57, 6.10 and 7.62m (15, 20 and 25ft) are listed in Table 1. Comparison among results of column 2, 3, 4 with different slab widths indicates that slab width has an insignificant effect on load induced maximum stresses (type (1)), whether based on initial states (1) or (2). But it has a significant effect on the total stresses induced by combined load and temperature gradient (Column 1 & 5, Table 1). For larger slabs, the predicted total stresses at g=-0.33°C/cm are significantly smaller, but those at g=0.33°C/cm are much larger. The Finite Element Analysis indicates significant differences between the TOTAL and LOAD INDUCED responses. Since slab cracks are caused by the total stresses rather than the stresses induced by load only, cracks would occur earlier on larger slabs than on smaller slabs. The analysis also indicates that temperature gradients in slabs have a significant effect on the total responses.

The theoretical analysis gives a strong indication that large slab size is detrimental to pavement performance. However, many aspects of pavement construction, operation, and environmental response are ignored in the model and theoretical result cannot be considered conclusive or a sufficiently accurate predictor to provide quantitative quidance for pavement design. Therefore, in this paper, the effects of PCC pavement slab size are evaluated further by statistical analysis of field measurements of PCI ([7] and [12]). An analysis was made of existing PCI data from about 26.8 million square meters of PCC runway, taxiway and apron pavements (including 2.6 msm of multiply surveyed pavements) at 174 airports located in 23 states and Japan. About 70% of the data was provided by Eckrose/Green Associates from the database they have built up during the past ten years [8]. The remainder were collected from other sources such as [9][10][11].

Pavement performance is influenced by many factors. For example, it is affected by the original design of the pavement sections. If the original design was over-conservative, the surveyed PCI measured at a particular time during the life of the pavement could be higher than that for an under-conservatively designed pavement at the same point in its life. PCI is also affected by the amount and quality of maintenance conducted since the pavement sections were put into service.

Variances due to subjective and objective measurement errors are also present in the data evaluated because the surveys were done by different people from different companies over a long period of time. However, all the surveys essentially followed FAA Advisory Circular 150/5380-6 [7] and ASTM D 5340-93 [12]. Statistical information for the above factors is not available and the following assumptions have been made:

1. All surveyed pavement sections were designed properly and the design life was twenty years for all;
2. All surveyed pavement sections were properly maintained;
3. PCC overlaid sections are treated the same as new PCC pavement and the age is counted from the time of the overlay construction;
4. All subjective effects of surveyors on the PCI results are neglected in the statistical analysis.

Errors caused by above assumptions mostly belong to "statistic error" rather than "systematic error". The statistical error can be reduced by using larger size of data. Since the size of features varies, the statistical calculation of PCI should consider the effects of feature size. The following equations are used to calculate mean value, standard deviation weighted by the feature size.

$$PCI_{AVG} = \frac{\sum_{i=1}^{n} PCI_i \times A_i}{\sum_{i=1}^{n} A_i} = \sum_{i=1}^{n} PCI_i \times \left(\frac{A_i}{\sum_{i=1}^{n} A_i}\right) \quad (1)$$

$$PCI_{STD} = \sum_{i=1}^{n} (PCI_i - PCI_{AVG})^2 \times \frac{A_i}{\sum_{i=1}^{n} A_i} \quad (2)$$

where, A_i is the area of the ith feature, PCI_i is the measured PCI value of the ith feature, $A_i / (\Sigma A_i)$ may be defined as "Weighting Factor of the Feature Size". If the sizes of all features are the same, the weighting factor will be equal to 1/n where n is the total number of the features. Then Coefficient of Variance (COV) of the PCI can be calculated by:

$$PCI_{COV} = \frac{PCI_{STD}}{PCI_{AVG}} \quad (3)$$

Prior to the analysis, the following two questions were resolved:

1. Should the collected pavement data with all ages be used ?
2. Should the collected pavement data from all sizes of airports be used ?

The mean and coefficient of variance of PCI were calculated for three groups of data: 0 to 30 year pavements from all airports(group one), older than 30 year pavements (group two) and the 0 to 30 year pavements from large, medium and small hub airports (group three).

Figure 3(a) indicates that pavements older than 30 years have average PCI values much lower than the others while Figure 3(b) indicates that their COVs are two times higher than the data in group one. This also indicates that PCIs of very old pavements have more uncertainties which might not have been considered in current design specifications. Therefore, the statistical analysis in this research uses data from pavements between 0 and 30 years old only.

Comparison between group one and group three (Figure 3) indicates that the average PCIs calculated by using the data of these two groups are close to each other. The reliability of pavement data from larger airports only and from all airports are also almost the same. Their COVs are 25.5% vs. 24.3%, 15.3% vs. 15.6, 12.2% vs. 12.2% and 18.4% vs. 18.0% respectively. The comparison leads to using pavement data from all airports rather than using data from hubs only. Figure 3 also indicates that the average PCIs of the runway are the highest and those of the aprons are the lowest. However, the COVs are just the opposite: those of the runways are the lowest and those of the aprons are the highest.

GENERAL INFORMATION OF THE SURVEYED PAVEMENTS

Data from 26.8 million square-meters of pavement (including 2.6 msm multiply surveyed pavements) from 174 airports was used in the analysis. These airports are located in 23 states (six FAA regions and Hawaii) and one airport is in

Japan. Three among them are military airports. They are Marine Corps Air Stations Futenma (OTM), Okinawa, Japan, Kaneohe Bay (KAN), Hawaii and El Toro (NZJ), California. The number of features and corresponding areas of the pavements in each state and FAA region are listed in Table 2.

Each type of pavement, runway, taxiway and apron is approximately one third of the surveyed pavements. Thirty eight percent of the surveyed pavements are older than 20 years - their design life has been exceeded, but they are still in service. The percentage of the surveyed pavements aged between 0 to 5, 6 to 10, 11 to 15, 16 to 20 and 21 to 30 years are 17%, 15%, 10%, 20% and 18% respectively. Because many features of the pavements in airport have curved edges, the size of the slab is usually calculated by the measured area of the feature divided by the number of slabs in the feature rather than directly measuring the slab. As noted, for some features, especially in the apron areas of airports, slab size and shape could be different. Therefore, an "average size" of a slab is used instead of the true size of all slabs. Fifty six percent of the total data is from slabs smaller than 46.5 m^2(500 ft^2). Most of the slabs in the 46.5 to 58.1 m^2 (500 to 625 ft^2) group are 6.10 by 7.62 m or 7.62 by 7.62 m (20 by 25ft or 25 by 25ft) - the maximum joint spacing recommended in [1] for unreinforced concrete slabs. Only 5% of the slabs are greater than 58.1 m^2 (625 ft^2).

GENERAL EFFECTS OF SLAB SIZE ON THE MEASURED PCI

Figure 4 shows the PCI of pavements grouped by three sizes: smaller than 46.5 m^2 (500 ft^2) between 46.5 and 58.1 m^2 (500 and 625 ft^2) and greater than 58.1 m^2 (625 ft^2). As indicated, higher PCIs were measured for pavements using smaller slabs. This is consistent for different types of pavements (apron, taxiway and runway). Figure 4 also indicates that slabs larger than 58.1 m^2 (625 ft^2) deteriorate much quicker than the others since the average PCIs of the large slabs are significantly lower.

EFFECTS ON PCI OF PAVEMENTS WITH DIFFERENT AGE

More detailed analyses were conducted to investigate the effects of slab size in conjunction with the pavement age. Results grouped by pavement size and age are illustrated in Figure 5. The following findings may be summarized:

1. PCIs of pavements using slabs greater than 58.1 m^2 (625 ft^2) are much lower than the others except for taxiways and runways younger than 10 years old. Since the FAA design specification [1], of which the 6C version was issued in 1978, recommends that the maximum joint spacing is 7.62m (25ft), a very limited number of pavements using slab size greater than 7.62m by 7.62m (25 by 25ft) in the past 20 years have been surveyed. For example, the areas of taxiways and runways using slabs larger than 58.1 m^2 (625 ft^2) and younger than 10 years are 0.021 and 0.015 msm respectively while the same age taxiway using slab size smaller than 46.5 m^2 and between 46.5 and 58.1 m^2 are 2.14 msm and 1.08 msm. The corresponding runway areas are 0.97 and 1.13 msm respectively. Therefore, it might not be appropriate to use the results to represent the behavior of pavements having large slabs. If these results are neglected, the performance of slabs larger than 58.1 m^2 (625 ft^2) is significantly worse than the performance of the smaller slabs accepted by the current FAA design specification [1].

2. Figure 5 indicates that the PCIs of all pavements using slabs between 46.5 to 58.1 m^2 (500 to 625 ft^2) are mostly lower than those using slabs smaller than 46.5 m^2 (500ft^2). However, the differences are not significant before the end of the design life of the pavements (the age is within 20 years). Namely, the performance of pavements using slabs no larger than 58.1 m^2 (625 ft^2) is relatively similar for "young" pavements (0 to 20 years).

3. It can been seen from Figure 5 that the slab size effects on PCIs for older pavements (between 21 to 30 years) are much greater. Namely, the larger slabs performed worse than smaller slabs for "older" pavements (20 to 30 years), and this is especially true for apron pavements.

EFFECTS EVALUATED BY PCI CUMULATIVE DISTRIBUTION CURVES

Many researchers have been interested in evaluating FAA design specification [1] to see if it provides an appropriate design which offers the designed pavement a satisfactory performance during the pavement design life. A simple procedure can be used to take advantage of collected PCI data of pavements to evaluate [1]. Following assumptions are used:

1. If the surveyed PCI value of a pavement is lower than the threshold PCI value, then consider the pavement to be in need of major structural rehabilitation.

2. Pavements aged between 16 to 23 years are used to simulate behavior of 19 and 20 years old pavements which are at end of their design service year. Using more data is for minimizing the statistical error.

Figure 6 illustrates PCI cumulative distribution curves for aprons, taxiways and runways for all surveyed pavements between 16 to 23 years old. The survey data was obtained from 174 airports ranging from large hubs to regional airfields. If a PCI value of 75 is selected, 90% of surveyed runways, 75% of surveyed taxiways and 56% of surveyed aprons would have PCI values equal to 75 or greater near the end of their design lives.

The distribution curves in Figure 6 may also be used to investigate the effects of slab size on the PCI, an indicator of pavement performance. Figure 7 presents graphical comparisons of slab size effects on PCI for different functional pavements. The slab size is divided into two groups: equal to or smaller than 37.2 m^2 (400 ft^2), and greater than 37.2 m^2 (400 ft^2). Some previously discussed findings are verified by Figure 7.

Figure 7(a) indicates that smaller slabs for apron areas performed significantly better than larger slabs. If a threshold value of 65 is assumed, the PCIs of 80% of the surveyed apron areas using smaller slabs were higher than the threshold value. Only 53% of apron pavements using larger slabs showed higher than threshold values. The difference in PCIs associated with smaller slabs for taxiways and runways does not seem as significant as for aprons.

CONCLUSIONS

1. The statistical analyses show that the pavements in the analysis sample using slab size larger than 58.1 m^2 (625 ft^2, which should be reinforced based on the recommendation of AC 150/5320-6D), performed much worse than the pavements using slab size equal to or smaller than 58.1 m^2 (625 ft^2). This is true for all functional pavement groups and age groups. Reinforcement did not significantly contribute to pavement performance.

2. Comparisons were made between pavements using average slab size smaller than 46.5 m^2 (500 ft^2), and between 46.5 to 58.1 m^2 (500 to 625 ft^2). Slabs in both groups satisfy the recommendations of AC 150/5320-6D for unreinforced pavements. The statistical analyses showed that the performance of 21 to 30 years old apron pavements using smaller slabs were significantly better than the performance of those using larger slabs. However, it was found that the difference of pavement performances in the above two groups are not significant if the pavements are younger than 20 years. This finding indicates that pavements following the joint spacing recommended by AC 150/5320-6D (slabs are not larger than 58.1m^2 (625 ft^2)) perform similarly within the 20 years design life. After twenty years of service, larger slabs deteriorate more quickly than small slabs.

3. An analysis was made of all pavements 16 to 23 years old to investigate the pavement performance near the end of the design life. This analysis indicated that the apron pavements using slab size larger than 37.2 m^2 (400 ft^2) clearly performed worse than those using smaller slabs. However, runway and taxiway pavements using larger slabs performed similarly to those using smaller slabs. This finding, in conjunction with the finding mentioned in the previous section, indicates that smaller slabs should be considered for apron areas.

4. It would probably be more desirable to use smaller slabs, including joint spacing from 3.05 to 4.57 m (10 and 15 ft), especially for apron pavements. Sufficient data for airport pavements using 4.57 by 4.57 m (15 by 15 ft) slabs currently are not available in the United States. Further studies are needed to determine the optimal spacing within the range 3.05 to 6.1m (10 to 20 ft).

5. A change in the FAA standard to smaller slab size may impact the initial cost of PCC pavements. Smaller slab size may require more passes of the paving train to place the same area of pavement than if larger slab sizes are used. Also, an increase in the linear footage of load transfer devices may be required.

6. The surveyed data indicates that apron pavements generally have lower PCIs than runway pavements when the age and slab size are the same. This could be because runway pavements often receive better routine maintenance than apron pavements. Furthermore, significant differences in the orientation of the loads on apron and taxiway/runway slabs may also play some role.

TABLES TITLES

TABLE 1 THE MAXIMUM TOTAL TRANSVERSE SRESSES FOR A 222kN SINGLE LOAD, TIRE PRESSURE p=1.03 MPa.

TABLE 2 DISTRIBUTION OF PAVEMENTS

TABLE 1 THE MAXIMUM TOTAL TRANSVERSE STRESSES FOR A 222kN SINGLE LOAD, TIRE PRESSURE p=1.03 MPa.

Width=4.57m		$\delta_{L,max}$(mm)					$\sigma_{L,max}$(MPa)				
l(m)	AGG/kl	1	2	3	4	5	1	2	3	4	5
0.99	5.1	0.07	0.64	0.35	0.41	0.53	2.17	2.43	2.45	2.62	3.25
1.26	7.3	0.02	0.65	0.40	0.44	0.69	1.95	2.15	2.20	2.29	2.68
2.10	24.3	0.29	0.87	0.80	0.87	1.42	2.00	2.08	2.12	2.09	2.18
Width=6.10m		$\delta_{L,max}$(mm)					$\sigma_{L,max}$(MPa)				
l(m)	AGG/kl	1	2	3	4	5	1	2	3	4	5
0.99	5.1	0.05	0.61	0.34	0.43	0.55	1.77	2.42	2.43	2.60	3.78
1.26	7.3	0.02	0.61	0.39	0.48	0.66	1.59	2.13	2.18	2.32	3.22
2.10	24.2	0.42	0.86	0.83	0.84	1.25	1.85	2.14	2.16	2.16	2.46
Width=7.62m		$\delta_{L,max}$(mm)					$\sigma_{L,max}$(MPa)				
l(m)	AGG/kl	1	2	3	4	5	1	2	3	4	5
0.99	5.1	0.02	0.59	0.33	0.41	0.62	1.36	2.45	2.43	2.53	4.08
1.26	7.3	-0.01	0.59	0.39	0.49	0.70	1.17	2.13	2.16	2.29	3.68
2.10	24.2	0.52	0.88	0.83	0.84	1.14	1.54	2.14	2.17	2.17	2.83

1: By a 222 kN single load and g=-0.33 °C/cm temperature gradient
2: By a 222 kN single load only. Initial shape was caused by temperature gradient g=-0.33 °C/cm.
3: By a 222 kN single load. Initial shape was flat and fully contacted to the base.
4: By a 222 kN single load only. Initial shape was caused by g=+0.33 °C/cm.
5: By a 222 kN single load and g=+0.33 °C/cm temperature gradient
l = 0.99m, h = 38.1 cm (15 in) and k = 1.36 MPa/cm(500 pci)
l = 1.26m, h = 43.2 cm (17 in) and k = 0.75 MPa/cm(275 pci)
l = 2.10m, h = 48.3 cm (19 in) and k = 0.136 MPa/cm(50 pci)
Joint simulated by interlock model, AGG=6895 MPa (100,000 lbs/in/in)[4].

TABLE 2 DISTRIBUTION OF PAVEMENTS

Region	State	Airport No. & I.D.	Number of Features	Total Area(km^2)
EA	4	4	106	2314.8
	DC	IAD	96	2080.4
	NJ	ACY	5	89.3
	NY	SCH	2	65.1
	PA	PIT	3	80.0
GL	6	98	1055	9367.9
	IN	012,2IN,4I8,BAK,CEV,EVV,FWA,HUF,I14, IND,LAF,MIE,MQJ,OKK,SER	192	1440.6
	MI	1D2,2G5,3TR,55D,5D8,76G,7D2,APN,BEH, BTL,CIU,D92,D96,D98,DET,FNT,GRR,JXN, LAN,UIZ,Y66	111	1062.1
	MN	04Y,27D,AXN,BJI,BRD,CKN,DLH,ELO, FFM,HIB,ILL,INL,MKT,ONA,OTG,RGK, RST,ULM,Y68	100	609.2
	ND	05D,20U,2D5,5N8,6D8,95D,BIS,BWP,DVL, FAR,GFK,ISN,JMS,MOT,N22,N55	238	1600.5
	SD	1D1,ABR,ATY,FSD,HON,MHE,PIR,RAP, YKN	66	742.1
	WI	ATW,AUW,C85,CMY,CWA,EAU,ENW,FLD ,GRB,ISW,JVL,LSE,MKE,MSN,OSH,RAC, RHI,STE	348	3913.4
NE	2	3	61	1243.4
	MA	BED,BOS	38	644.5
	ME	BGR	23	598.9
SO	4	52	529	6135.2
	FL	34J,40J,42J,55J,AAF,APF,BCT,BKV,BOW, COT,CTY,DAB,DED,FLL,GNV,IMM,ISM, JAX,LAL,LEE,MAI,MKY,MLB,MTH,OMN, OPF,PBI,PFN,PGD,PIE,PNS,RSW,SEF,SFB, SRQ,TLH,TPA,VNC,VPS,VRB,VRB,X14, X21,X35,X47,X51,X60,ZPH	409	4263.1
	KY	CVG,PWM	67	1279.7
	NC	RDU	35	389.7
	TN	BNA	18	202.7
SW	3	5	787	4794.2
	LA	HUM	36	320.9
	OK	TUL	198	1351.3
	TX	ADS, DFW, ELP	553	3122.0
WP	3	10	214	2453.4
	AZ	IWA,YUM	105	1383.8
	CA	NZJ	100	1045.3
	NV	4SD,BAM,EKO,ELY,LOL,MEV,WMC	9	23.3
HI	1	1	44	204.6
	HI	KAN	44	204.6
JAPAN	1	1 (FUT)	24	302.3
Summary: 23 States plus Japan, 2820 Features, 26.8 million m^2 (288.4 msf)				

FIGURE CAPTIONS

FIGURE 1 FINITE ELEMENT MESH FOR ANALYSIS

FIGURE 2 TOTAL BENDING STRESSES BY TEMPERATURE GRADIENT AND A B-777 GEAR

(a) NIGHT TIME , g = -0.33 ^{o}C/cm

(b) DAY TIME, g = 0.33 ^{o}C/cm

FIGURE 3 RESULTS BY USING DIFFERENT GROUPS OF DATA

(a) Mean Values of PCI

(b) Coefficients of Variance of PCI

FIGURE 4 PCI_{AVG} OF 0 - 30 YEARS PAVEMENTS GROUPED BY SIZE

(a) By Slab Size

(b) By Slab Size and Functions

FIGURE 5 PCI OF PAVEMENTS AFFECTED BY SIZE AND AGE

(a) Apron

(b) Taxiway

(c) Runway

FIGURE 6 DISTRIBUTION OF PCI FOR ALL PAVEMENTS AGED BETWEEN 16 TO 23 YEARS OLD (msm = million square meter)

FIGURE 7 PCI DISTRIBUTIONS GROUPED BY SLAB SIZE AND FUNCTION

(a) Apron

(b) Taxiway

(c) Runway

FIGURE 1 FINITE ELEMENT MESH FOR ANALYSIS

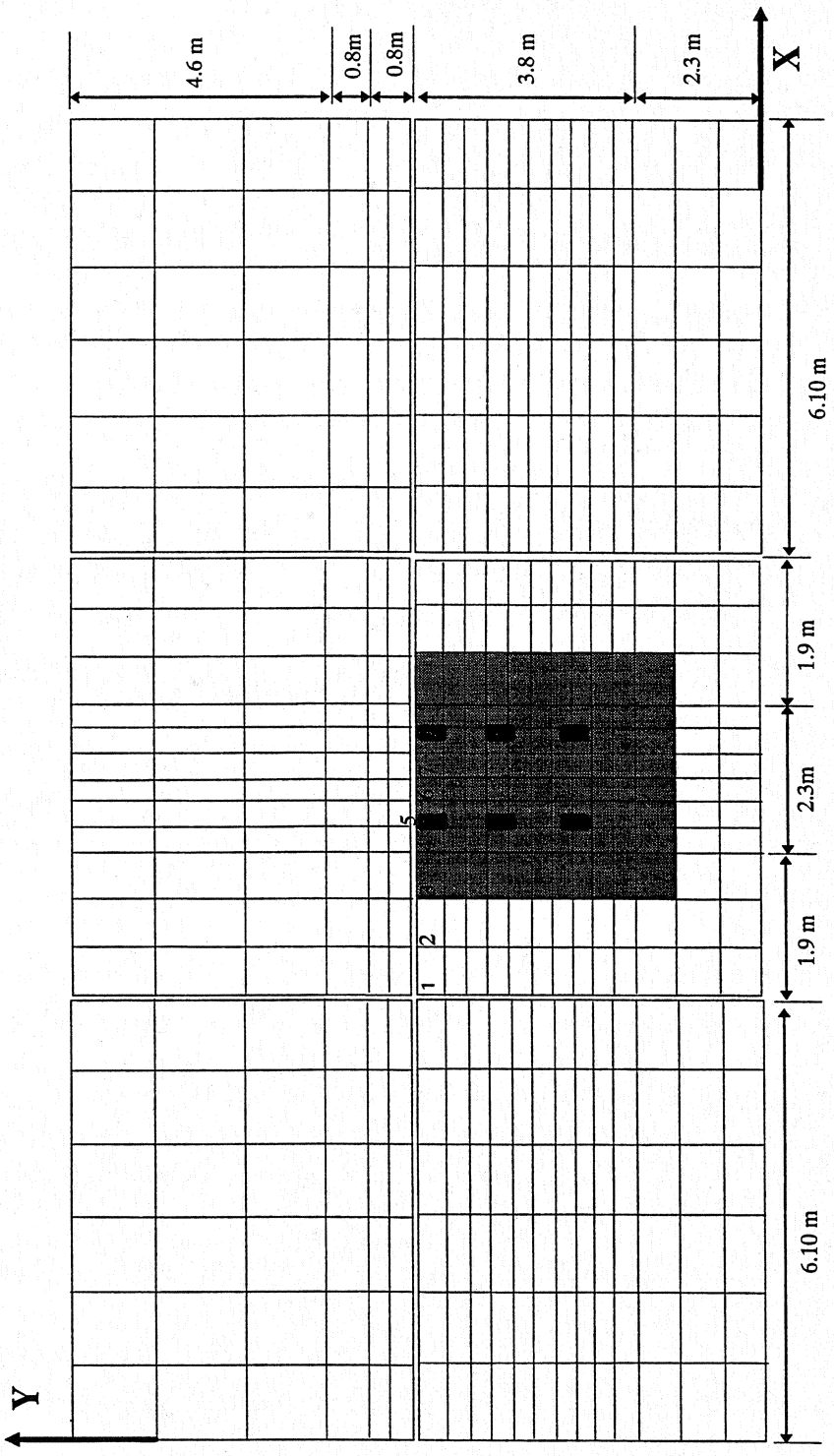
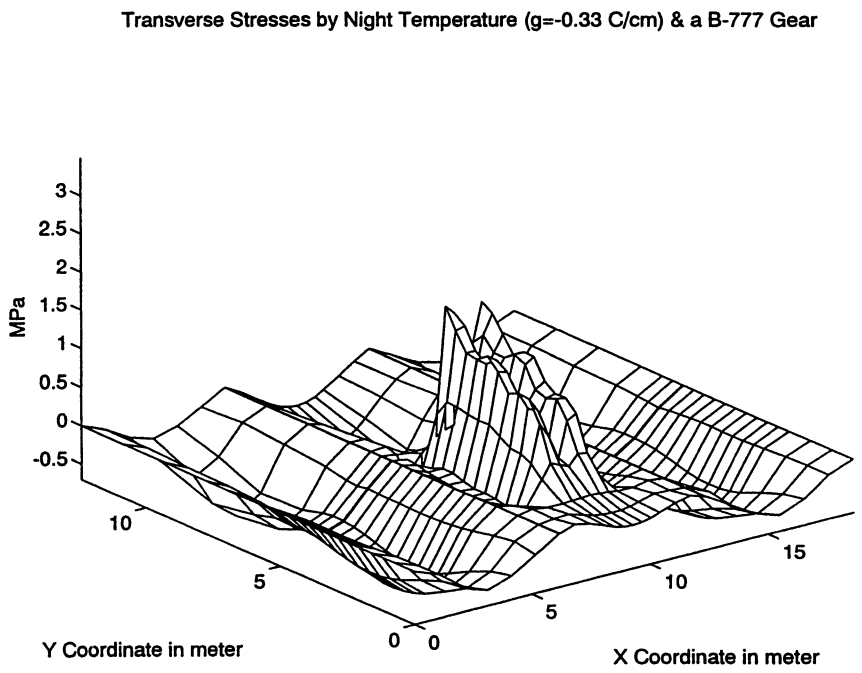


FIGURE 2 TOTAL BENDING STRESSES BY TEMPERATURE GRADIENT AND A B-777 GEAR

a) NIGHT TIME , g = -0.33 C/cm



(b) DAY TIME, g = 0.33 C/cm

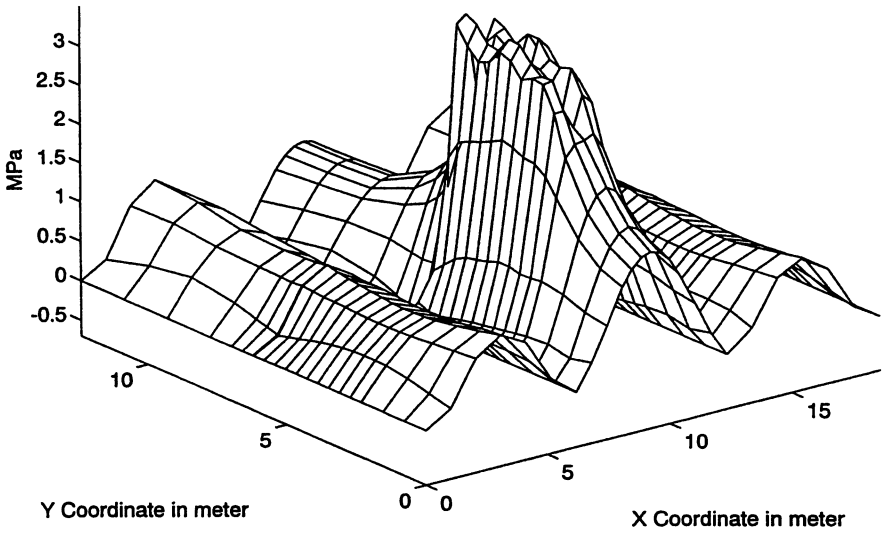
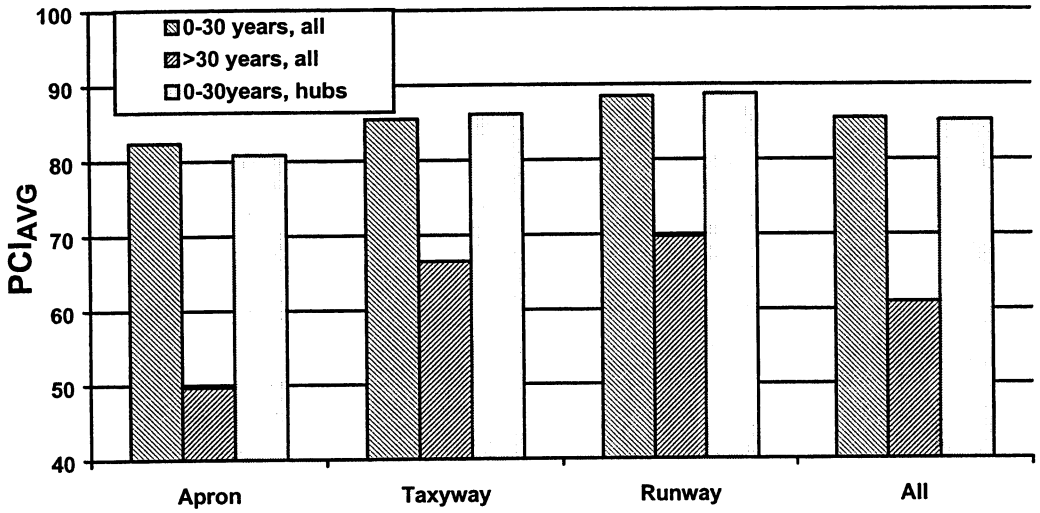
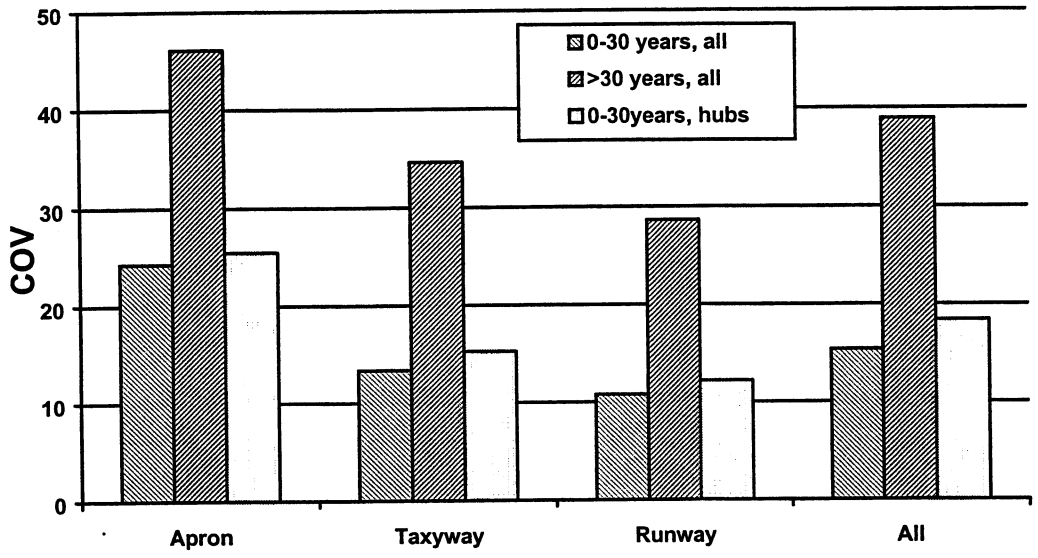


FIGURE 3 RESULTS BY USING DIFFERENT GROUPS OF DATA

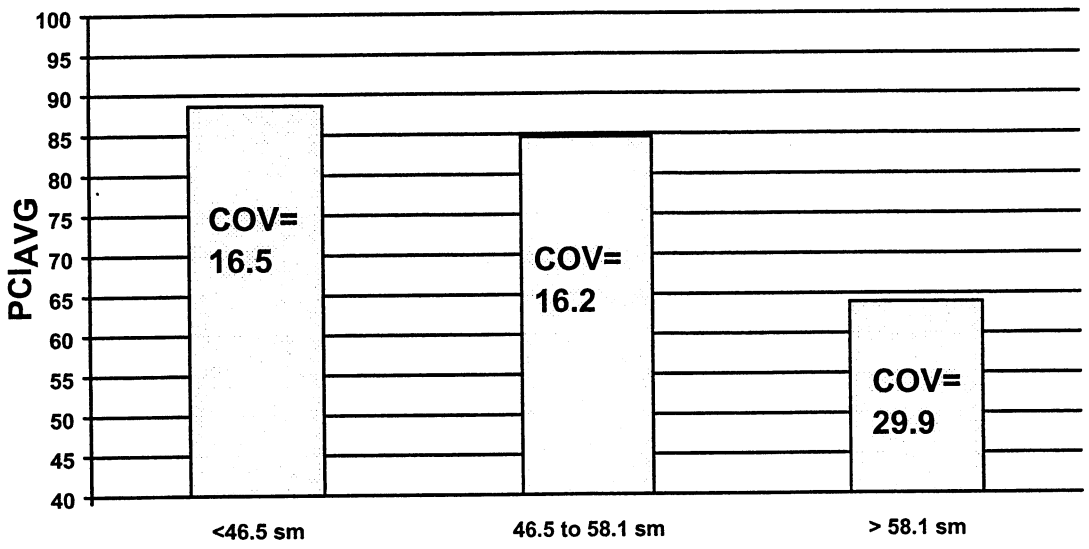


(a) Mean Values of PCI

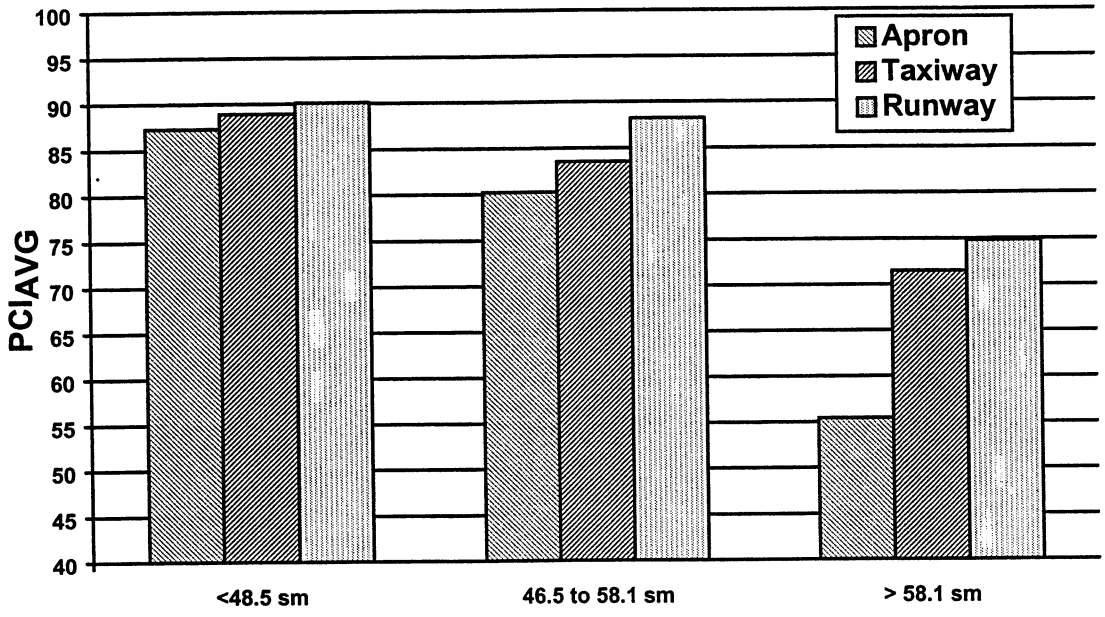


(b) Coefficients of Variance of PCI

FIGURE 4 PCI_{AVG} OF 0 - 30 YEARS PAVEMENTS GROUPED BY SIZE

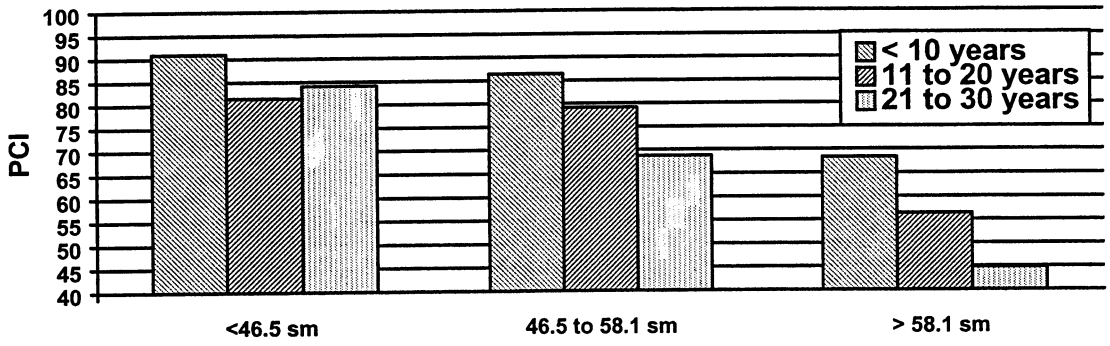


(a) By Slab Size

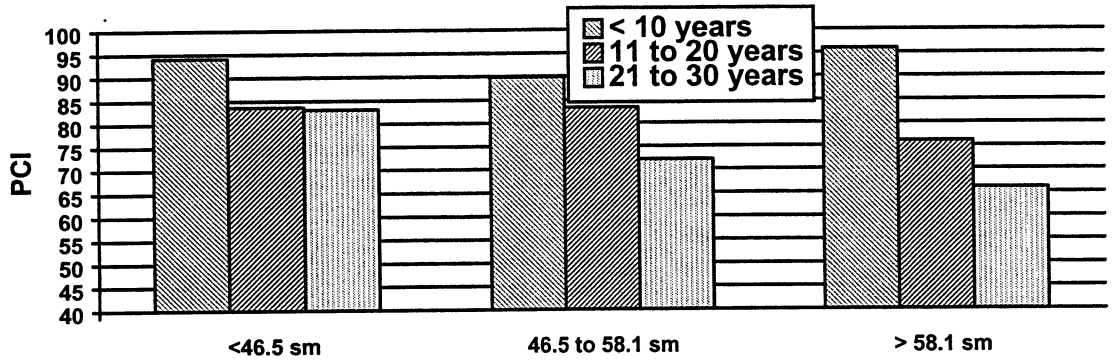


(b) By Slab Size and Functions

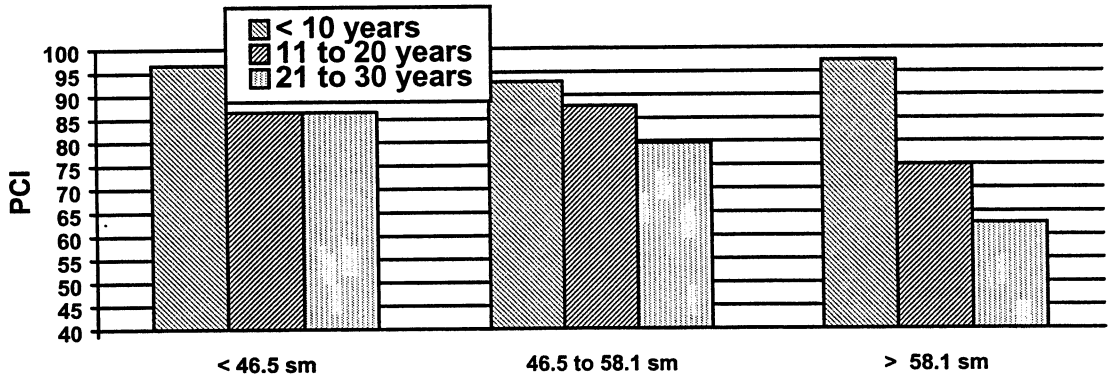
FIGURE 5 PCI OF PAVEMENTS AFFECTED BY SIZE AND AGE



(a) Apron



(b) Taxiway



(c) Runway

FIGURE 6 DISTRIBUTION OF PCI FOR ALL PAVEMENTS AGED BETWEEN 16 TO 23 YEARS OLD (msm = million square meter)

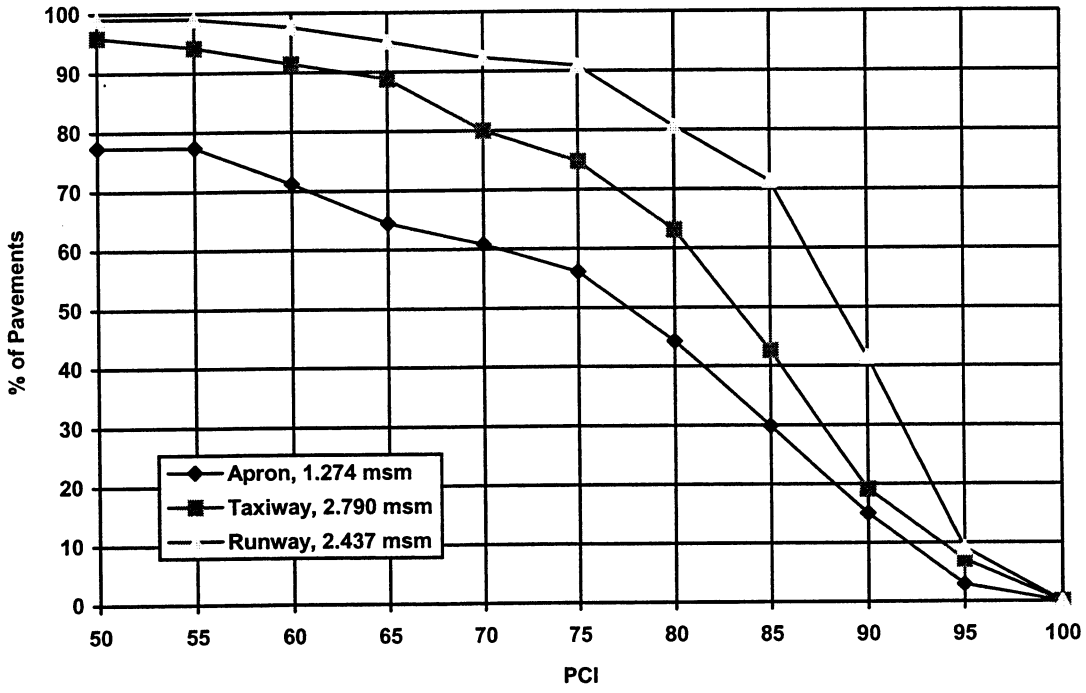
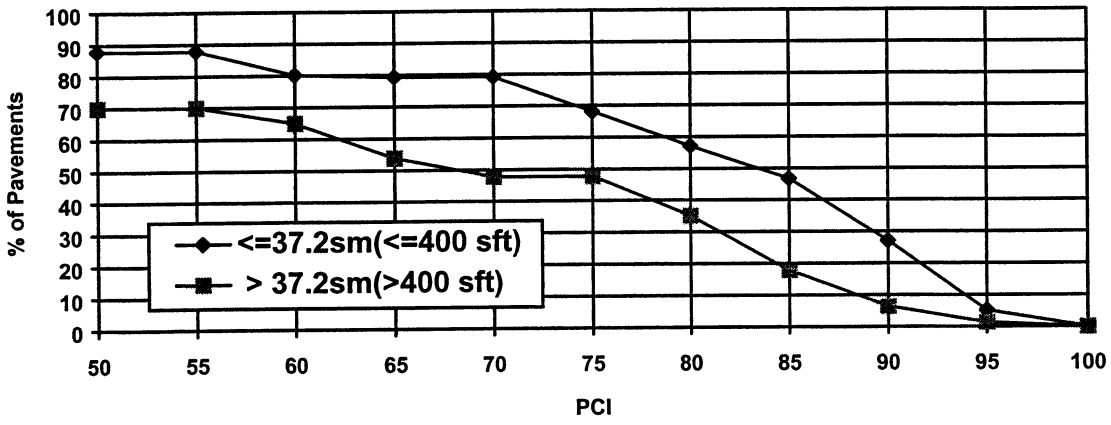
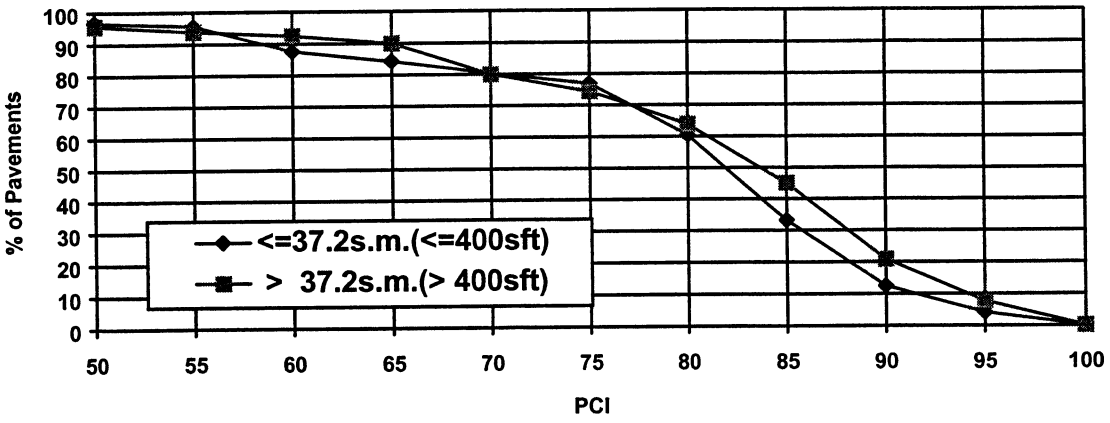


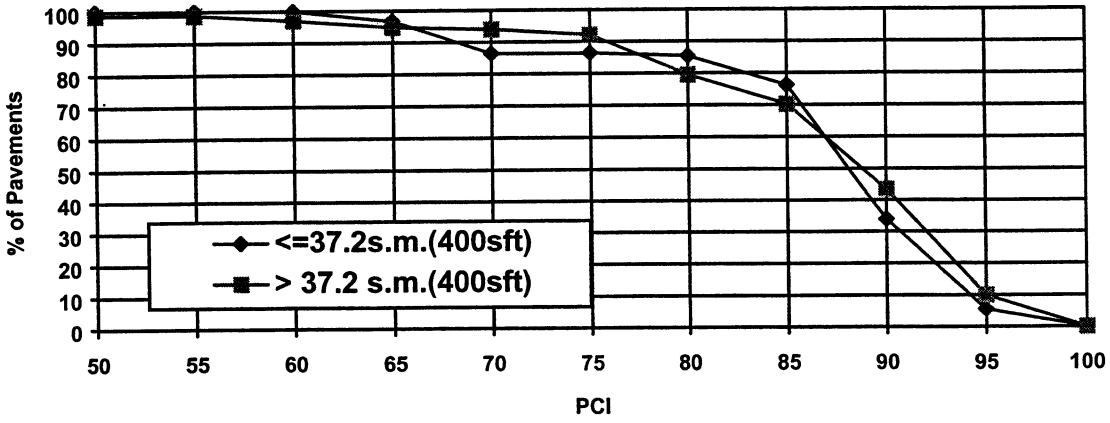
FIGURE 7 PCI DISTRIBUTIONS GROUPED BY SLAB SIZE AND FUNCTION



(a) Apron



(b) Taxiway



(c) Runway

REFERENCES

1. FAA. "Airport Pavement Design and Evaluation," Advisory Circular, AC 150/5320-6D, 1995
2. Packard, R G. "Design of Concrete Airport Pavement," Engineering Bulletin, Portland Cement Association, 1973.
3. Nanda, P.K.(Chief Editor), "Airport Pavements," The Organizing Committee, National Seminar on Airfield Pavements, India, 1995.
4. Guo, H., "Mathematical Modeling for Dowel Load Transfer Systems." A Ph.D. Thesis , Civil Engineering Department, Michigan State University, 1992.
5. Tajabji, S.D., and Colley, B.E., "Analysis of Jointed Concrete Pavements," FHWA/RD-86/041, Feb., 1986.
6. Tabaitabaie, A.M., Berenberg, E.J. & Smith, R.E., "Analysis of Load Transfer Systems for Concrete Pavements," FAA-RD-79-4, 1979.
7. FAA "Guidelines and Procedures for Maintenance of Airport Pavements," Advisory Circular, AC 150/5380-6, 12/3/1982.
8. Eckrose/Green Associates Inc. "Airport Pavement Inspection By PCI" Survey Handbook, 1996.
9. HLA, PCI & SDI "Dallas / Fort Worth International Airport Pavement Management Consulting Services, Final Report', March., 1992.
10. McQueen, R. D., "Evaluation of Runway and Taxiway Pavements at Atlantic City International Airport, Atlantic City, NJ", MRD Report, June., 1995.
11. ERES Consultants, INC., "Evaluation of the Airside Pavement at Raleigh-Durham international Airport, Morrisville, North Carolina", March., 1995.
12. ASTM D 5340 - 93 "Standard Test Method for Airport Pavement Condition Index Surveys".

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