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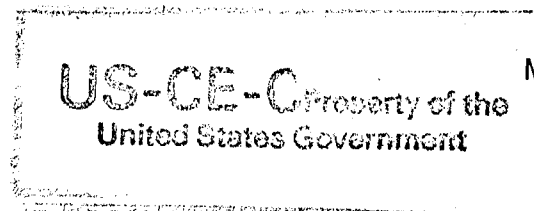
Airfield Pavement Failure Evaluation, Yap International Airport, Yap Island, Federated States of Micronesia

by Steve L. Webster, Gary L. Anderton



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U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-619

Final report

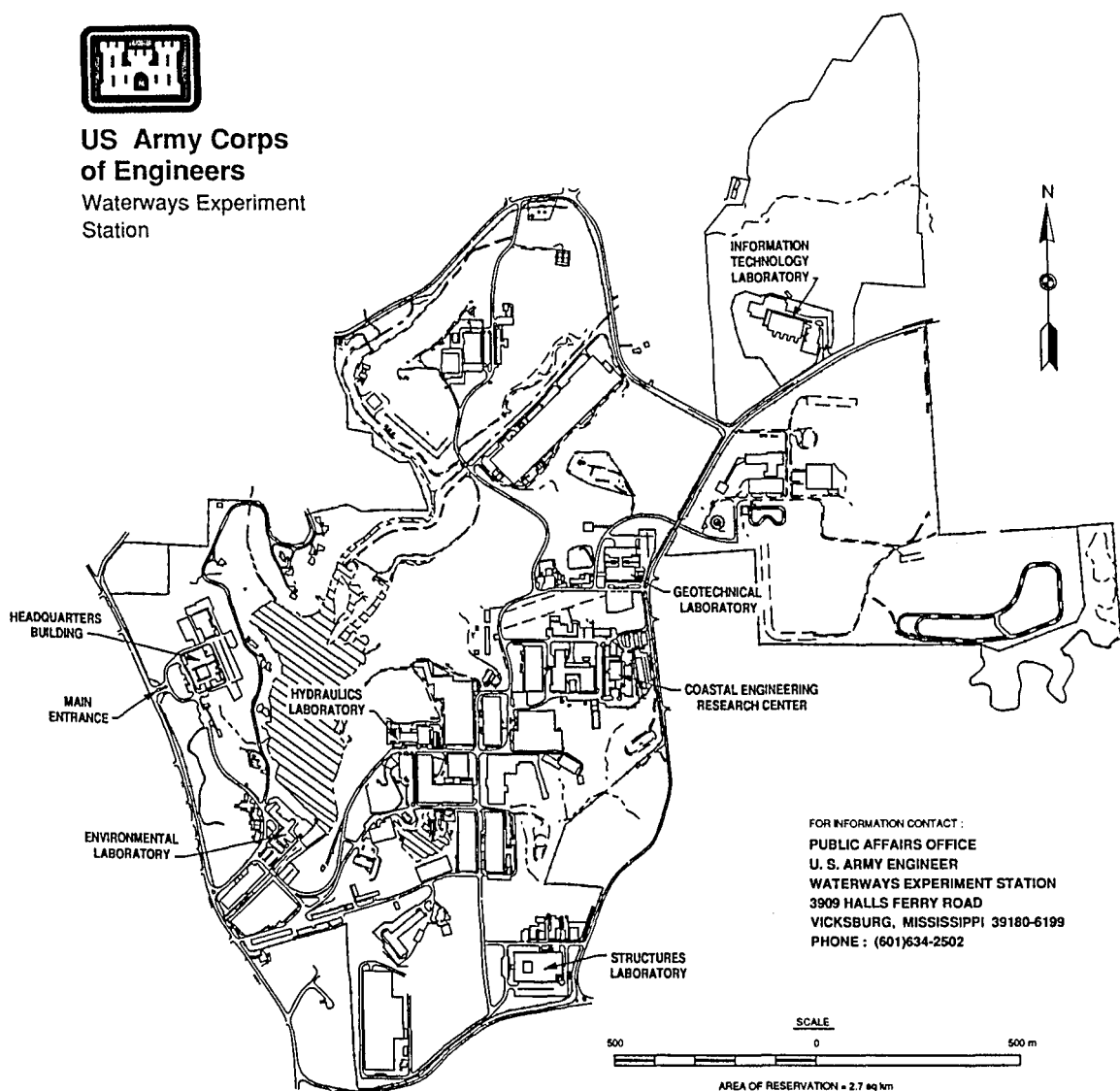
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Preface

The investigation reported herein was authorized by U.S. Army Corps of Engineers, Pacific Ocean Division (POD), Fort Shafter, Hawaii, in MIPR No. E96940003 dated 2 November 1993. The Technical Monitor was Mr. Raymond Kong, FM&S Division.

The pavement investigation at Yap International Airport was performed by an evaluation team consisting of U.S. Army Engineer Waterways Experiment Station (WES) and POD personnel during the period 21 to 29 January 1994. The WES team consisted of Messrs. S. L. Webster, G. L. Anderton, T. P. Williams, and R. Felix, Jr., Pavement Systems Division (PSD), Geotechnical Laboratory (GL). The POD team consisted of Messrs. R. Kong and T. Lichte, FM&S. PSD personnel engaged in the laboratory evaluations at WES included Messrs. B. Burke, J. Duncan, R. Felix, H. McKnight, and J. Simmons. Laboratory tests conducted by the Soil Research Center (SRC) at WES were coordinated by Mr. P. Griffing and conducted by Messrs. C. Carter, L. Dunbar, and Ms. A. Thomas. Direct supervision was provided by Dr. G. M. Hammitt II, Chief, PSD, Dr. A. J. Bush, III, Chief, Criteria Development and Applications Branch, PSD, and Mr. T. W. Vollar, Chief, Materials Research and Construction Technology Branch, PSD. This report was prepared by Messrs. Webster and Anderton. The work was performed under the general supervision of Dr. W. F. Marcuson III, Director, GL, WES.

Director of WES during the conduct of the evaluation and preparation of this report was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
degreés (angle)	0.01745329	radians
feet	0.3048	meters
inches	2.54	centimeters
pounds (force)	4.448222	newtons
pounds (force) per square inch	6.894757	pascals
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per cubic inch	27.6799	grams per cubic centimeter
square feet	0.09290304	square meters
cubic feet	0.028317	cubic meters

1 Introduction

Background

This report gives the findings of a pavement investigation and evaluation of the runway, taxiway, and apron pavements at Yap International Airport, Yap Island, Federated States of Micronesia. This investigation was performed under MIPR No. E9640003, dated 2 November 1993, from U.S. Army Corps of Engineers, Pacific Ocean Division (POD), Fort Shafter, HI, to U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. The fieldwork was performed by WES and POD personnel during the period 21 to 29 January, 1994.

The POD was contacted by the Governor of the State of Yap through the National Government of the Federated States of Micronesia and requested to investigate pavement failures at the Yap International Airport. The airfield was constructed in 1983 and many cracks were already showing up in the pavement surfaces in 1990. The Yap Government was concerned that the cracks represented latent construction defects. Also, since 1990, the number of areas in the taxiway and runway requiring temporary concrete patch repairs had increased at an alarming rate.

Objective and Scope

The objectives of this study were to determine the causes of the pavement failures and to recommend repair necessary to sustain the current traffic utilizing the airport. The objectives were accomplished by performing field tests on the airfield pavements and laboratory tests at WES on the pavement materials. The field testing included a pavement condition survey, dynamic cone penetrometer (DCP) tests to determine California Bearing Ratio (CBR) strength values for the base and select fill materials, in situ moisture content, and drainage investigation. The laboratory testing included gradation and asphalt content tests on the asphalt concrete. In addition, sieve analysis, Los Angeles Abrasion, atterburg limits, and soaked CBR-moisture-density compaction tests were conducted on the base and select fill materials. Three test pits (two located in failed areas and one in a non-failed area) were excavated in the runway during the field investigation.

This report gives a summary of the results of the tests performed, conclusions as to why the pavement failed, and recommendations for short and long term repair.

2 Design

The US Department of the Navy, Naval Facilities Engineering Command, Pacific Division, Makalapa, Hawaii, had Lyon Associates, Inc., Hawaii complete the design plans for the airfield. The pavement design procedure used conformed with FAA Advisory Circular AC 150/5320-6C. The design life was 20 years. The design traffic was 1200 annual departures with the B-727-200 as the critical aircraft at a gross weight of 190,500-lb. The airfield consisted of both cut and fill sections. The pavement design for the critical traffic areas was 4-in. AC surfacing over 17-in. of crushed schist base course. In cut sections, the design subgrade CBR was 12. In fill areas, 43-in. of select fill (CBR 12) was placed over a design subgrade of CBR 3. The same pavement design was used for the runway, taxiway, and apron. The overruns at the end of the runway consisted of 2-in. of AC surfacing over 8.5-in. of crushed Schist base on cut sections with an additional 20-in. of select fill over fill sections. Figure 1 shows the airfield pavement layout at Yap International Airport.

3 Field Testing

The field investigation of the airfield pavements involved (a) a pavement condition survey of the pavement features, (b) drainage investigation, (c) in situ water contents measured in excavated test pits, and (d) dynamic cone penetrometer (DCP) tests at selected locations on the runway, taxiway, and apron .

Pavement Condition Survey

A pavement condition survey is a visual inspection of the airfield pavements to determine the present surface condition. The condition survey consists of inspecting the pavement surface for various types of distresses, determining the severity of each distress, and measuring the quantity of each distress. The result of the condition survey is the Pavement Condition Index (PCI) of each pavement feature. The PCI is a numerical indicator based on a scale from 0 to 100 and is determined by measuring pavement surface distress that reflects the surface condition of the pavement. Pavement condition ratings (from excellent to failed) are assigned to different levels of PCI values. Knowledge of the condition survey procedures discussed in TM 5-826-6/ AFM 93-5 (Headquarters, Departments of the Army and the Air Force 1989) is required for the use and understanding of the condition survey results.

Test Procedure

The pavement facilities were subdivided into features based on type of construction, usage, and general level of distress. Figure 2 shows the various feature identifications and locations. Each feature was then subdivided into sample units. The AC sample units measured 5,000-sq ft. Each PCC refueling pad, containing 20 slabs each, was counted as a sample unit. The PCI and estimated distress quantities were then determined for each feature. The information was based on inspection of a selected number of sample units within each feature. The statistical sampling technique was used to determine the number of sample units to be inspected to provide a 95 percent confidence level. Sample units were chosen randomly on the runway, taxiway, and apron. All slabs in each refueling pad were inspected. After the sample units were inspected, the mean PCI of all sample units within a feature was calculated and the feature was rated as to its condition: excellent, very good, good, fair, poor, very poor, or failed. These ratings and their respective PCI

value are shown in Figure 3. The pavement condition summary is shown in Figure 4.

Analysis of PCI Data

The results from the Micro PAVER computer program identifying the feature, inspection date, PCI, rating, distress quantity, and distress mechanism are presented in Appendix A. The major distress types found on the AC pavements were alligator cracking, rutting, depressions, weathering, and longitudinal and transverse cracking. The patching consisted of 10-in.-thick PCC patches (with wire fabric plus some reinforcement) in the wheel paths. The depressions usually were located in areas between the PCC patches. The PCC patches were screeded level to the original pavement surface. This patching procedure left the patch at a higher elevation than the trough in wheel paths leading to and after the patch. In areas where the rutting was 3/4 to 1 in. deep, the PCC patch resulted in a 3/4 to 1 in. bump that was strongly noticeable in the B-727-200 aircraft. The only distress type observed on the PCC fuel pads was linear cracking. Photos 1 through 10 show various types of distresses observed during the survey. The PCI of features RC2, RC3, RC4, RC5, RC6, and TW ranged between 13 and 36 indicating that the pavement in these areas had deteriorated to a level where normal maintenance, or rehabilitation with an overlay, could not be expected to ensure reliable long-term performance under the current aircraft loadings.

Drainage Investigation

Drainage of the airfield pavements is important because the average rainfall is 120-in. a year on Yap Island. The POD personnel conducted a survey of all surface drainage. Figure 5 shows a layout of the trench subdrain system found along the edges of the runway, taxiway, and apron pavements. The trench drain contained a 6-in.-dia. drainage pipe which was connected to manholes at 1000-ft intervals. Lateral 6-in.-dia. outlet pipes extended from the manholes to either "V" or concrete ditches located outside the edge of the safety area. Inspection of the south-side manhole at Sta 37+00 found it to be full of water (3-ft-deep). The opening to the lateral drain was found to be buried at the "V" ditch. When the outlet was found and unplugged, water poured out of the lateral outlet for more than 24 hours (Photo 11 & 12). This clogged drain was located in the area where the runway pavement was in the worst condition. The two inspection/cleanout caps found along the taxiway could not be opened for inspection.

The entire runway was grooved with saw cuts on a 2-in. spacing perpendicular to traffic (Photos 4 & 13). This was effective in providing good skid resistance and lateral surface drainage.

In Situ Water Content Measurements

Three test pits were excavated in the runway pavements in order to obtain samples for laboratory testing, measurement of in situ water contents, and additional DCP data. Figure 6 shows the test Pit locations. Two test pits were located in failed pavement areas (Pit 1 at Sta 34+25 and Pit 2 at Sta 39+60) and one in a non-failed area (Pit 3 at Sta 10+00). All test pits were located in the wheel paths off of the runway centerline. The failed areas contained severe alligator cracking and rutting with loose pieces of pavement beginning to dislodge from the runway. The pavement at the Pit 3 location was in good condition with no surface defects and less than 1/4-in of rutting. Samples for oven-dried water content measurements were taken from the top 6-in. and bottom 11-in. of the base and from the top 10-in. of the select fill material at all three pit locations. Table 1 shows the results of the water content measurements. The water content ranged from 5.7 to 8.6 percent in the base material for the failed areas (Pits 1 and 2) and was over 8 percent in the select fill. In the non-failed area (Pit 3) the base water content was only 4 percent and select fill was 5.6 percent. Results of the water content measurements indicated that the strength of the base material was dependent on water content and that pavement failure resulted when the water content of the base increased to approximately 5.6 percent or more.

Table 1
Summary of Water Content and CBR Data from Test Pits

Test Pit No.	Location	Material	Depth from Surface, in.	Water Content, %	CBR %
1	STA 34+25	AC	0-4		
		Base	4-10	8.6	15
		Base	10-21	5.6	48
		Select Fill	21-31	8.8	19
2	STA 39+60	AC	0-4		
		Base	4-10	5.7	45
		Base	10-21	6.0	54
		Select Fill	21-31	8.1	22
3	STA 10+00	AC	0-4		
		Base	4-10	4.0	100
		Base	10-21	4.1	100
		Select Fill	21-31	5.6	44

Dynamic Cone Penetrometer (DCP)

The DCP is a soil test device used for evaluating the load carrying capability of roads and airfields (Figure 7). The dual mass DCP consists of a 5/8-in.-dia. steel rod with a steel cone attached to one end which is driven into the pavement or subgrade by means of a sliding dual mass hammer. The angle of the cone is 60 degrees and the diameter of the base of the cone is 0.790-in. The DCP is driven into the soil by dropping either a 17.6-lb or 10.1-lb hammer from a height of 22.6-in. The heavy hammer is converted to the lighter hammer by removing a hexagonal set screw and removing an outer steel sleeve. The lighter hammer is more suitable for use and yields better test results in weaker soils. The heavy hammer is used on high strength soils which are difficult to penetrate with the light hammer. The cone penetration caused by one blow of the heavy hammer is essentially twice that caused by one blow of the lighter hammer. The depth of penetration is measured at selected penetration or hammer drop intervals and the soil strength is reported in terms of DCP index. The DCP test penetrates soils to depths of 39-in. Final test results are reported as DCP index or California Bearing Ratio (CBR) values for each test depth resulting in a soil-strength-with-depth profile for each test location.

DCP Test Procedure

For this investigation, the CBR values of the base and select fill pavement materials were determined based on a correlation and DCP test procedure recommended by Webster, Grau, and Williams (1992). First, a 1-in.-dia. hole was drilled through the 4-in.-thick AC. The cone of the DCP was then placed on top or near the top of the base and the hammer was then dropped repeatedly to drive the cone through the underlying pavement layers. For this investigation, the heavy hammer was used in all tests. DCP tests were conducted at selected locations on the runway, taxiway, and apron. In addition, DCP tests were conducted at the 3 test pit locations (2 in failed pavement areas and 1 in a non-failed area).

DCP Test Results

The DCP test results tests are presented in Appendix B. Each data sheet shows a tabulation of hammer blows and accumulative cone penetration. The test results are also plotted in terms of CBR versus depth for each test location. Below each plot is a cross section of the pavement at the test location showing the rated CBR value within the various materials. Table 1 shows the results of the DCP tests (in terms of CBR) and water content measurements for the three test pits. Test Pits 1 and 2 were likely in the zone of influence of the clogged edge drain at Sta 37+00. The select fill water content was higher (over 8 percent) and CBR values lower ($\text{CBR} < 25$) at both of these locations compared with the non-failed pavement at Pit 3, which had a base water content of 4 percent ($\text{CBR} 100$) and select fill water content of 5.6 percent ($\text{CBR} > 40$). Figure 8 shows relationship of water content versus CBR for the base and select fill materials based on the DCP and field water content

measurements. For a water content of 4 percent, CBR values were 100. As the water content increased to 8-9 percent, the CBR dropped to approximately 12-20 percent. These test results indicated that the cause of the pavement failures was due to loss of strength in the base course due to an increase in water content.

Field Pavement Evaluation

The original pavement design conformed with FAA Advisory Circular AC 150/5320-6C. The design life was 20 years. The design traffic was 1200 annual departures with the B-727-200 as the critical aircraft at a gross weight of 190,500-lb. The airfield consisted of both cut and fill sections. The pavement design for the critical traffic areas was 4-in. AC surfacing over 17-in. of crushed schist base course. In cut sections, the design subgrade CBR was 12. In fill areas, 43-in. of select fill (CBR 12) was placed over a design subgrade of CBR 3. The same pavement design was used for the runway, taxiway, and apron. For pavement evaluation purposes, traffic of 1200 annual departures with the B-727-200 as the critical aircraft at a gross weight of 190,500-lb is still valid. Current traffic consists of eight departures per week with the B-727-200 aircraft and small amounts of other light aircraft.

Based on thickness and water content measurements from the three test pits and DCP data, the pavements were found to consist of 4-in. AC surfacing over 17-in. of crushed schist base course over crushed schist select fill or subgrade. These thicknesses meet the FAA design requirements for the B-727-200 aircraft. However, the FAA pavement thickness requirements are based on a CBR value of 80 for the base course. Based on the CBR values from the DCP test data, the base course CBR values ranged from 100 to 12. Base course CBR values of less than 80 were found at many locations along the runway, taxiway, and apron. Based on the low CBR values found in the base course at many locations, the pavements are considered structurally inadequate to withstand the current traffic of the B-727-200 aircraft. The poor condition of the pavements is supported by the PCI ratings which show portions of the runway in very poor condition with a PCI rating of only 13.

4 Laboratory Testing at WES

Asphalt Concrete

Samples of the 4-in.-thick asphalt concrete (AC) surfacing were obtained from the Pit 1 Area (Station 34+25) and from the Pit 3 Area (Station 10+00) of the runway. These samples were packaged separately and shipped to WES to be tested in the Pavement Systems Division Laboratory. The Pit 1 Area of the runway had severe rutting and severe alligator cracking in the AC with at least one sand slurry seal coat on the surface (Photo 1). The Pit 3 Area of the runway contained no significant distresses and appeared to be very sound (Photo 3). Samples of the pavement sublayers were taken from these two test pits and an additional test pit. The locations of these three test pits are shown in Figure 6.

When sampling the Pit 1 Area, the AC was noted to be deteriorated to the point where some small AC chunks could be removed by hand. Other AC samples were easily removed with hand tools. The AC surfacing in the severely deteriorated Pit 1 Area consisted of approximately 2-in.-thick intact AC material with numerous fatigue cracks over a 2-in. thickness of loose asphalt coated aggregates with much of the asphalt cement stripped away. The deteriorated condition of the AC surfacing in this area was likely caused by the progression of a weakening base course, repeated wheel loads, increasing fatigue cracking, and rain water infiltration. At this location, as the condition of the AC worsened, the rate of deterioration increased as the increased cracking allowed more water to infiltrate and the base to weaken even more. The repeated shearing action in these areas from routine wheel loads in wet conditions is the cause of the stripping action on the bottom of the AC layer. The slurry seal coat had infiltrated the AC material through the numerous cracks and this contamination combined with the deteriorated condition of the AC samples prevented any testing of physical properties in the laboratory.

The AC samples from the Pit 3 Area were intact and the AC appeared to be in good condition. Laboratory tests conducted on the Pit 3 AC samples included a measure of in-place density and voids, recompact density, gyratory testing machine analysis, asphalt extraction to determine asphalt content, and a sieve analysis on the mineral aggregates in the AC mixture. A summary of these test results are presented in Table 2.

In general, the test results of the asphalt concrete samples indicate a good quality asphalt mixture at Yap International Airport. The percent laboratory compaction value of 97.9 percent indicates sufficient density in the asphalt concrete layer was obtained during construction. A gyratory stability index (GSI) of 1.03 indicates a good quality aggregate in the AC mixture. The 3.0 percent voids in-place value is in the lower end of the desired 3.0 to 5.0 percent range, indicating that the 6.5 percent asphalt cement content is very close to the maximum amount of asphalt cement for this particular mixture before oversaturation and instability occur. From a durability standpoint, asphalt contents in this range are desirable. The results of the sieve analysis indicate a well-proportioned aggregate gradation with no significant variations from the current FAA standard.

Table 2 Pit 3 Asphalt Concrete Physical Properties			
In-Place Field Density (pcf) - 141.8	Sieve Analysis		
Recompacted Density (pcf) ^a - 144.9	Sieve	FAA Spec. P-401 Limits	Pit 3 Sample
Percent Laboratory Compaction ^b - 97.9	3/4-in.	100	100
In-Place Voids (%) - 3.0	1/2-in.	79-99	91.0
Gyratory Stability Index ^c - 1.03	3/8-in.	68-88	84.7
Percent Asphalt Cement - 6.5 %	No. 4	48-68	63.7
^a Recompacted in Gyratory Testing Machine using standard air-field compaction effort (200 psi, 30 rev, 1 degree) after oven heating and breaking down hardened field samples. ^b Theoretical measure of field density quality calculated by dividing field density by recompacked density. ^c Derived from Gyratory Testing Machine during recompaction; WES experience indicates that mixes with GSI values above 1.1 have a high potential for instability problems including rutting in the AC mixture.	No. 8	33-53	54.3
	No. 30	20-40	41.1
	No. 50	14-30	28.5
	No. 50	9-21	16.3
	No. 100	6-16	9.7
	No. 200	3-6	7.1

Pavement Sublayers

Samples of the runway pavement sublayers were taken from each of the three test pits. Photo 14 shows base material being removed from Pit 3. The location of each sublayer was identified during the previous DCP tests by substantial changes in CBR strength. The sublayers were separated into three distinct regions and labeled, from top to bottom as "top of base" which ranged from 4- to 10-in. below the surface, "bottom of base" located 10- to 21-in. below the surface, and "select fill" located 21- to 43-in. below the surface. These pavement sublayer locations differ from the design section in that the strength of the designed base course layer was found to be significantly higher in the top half of the designed base course thickness when compared to the

bottom half. Also, there was no discernible difference between the CBR strength of the bottom half of the designed base course thickness and the entire thickness of the designed subbase course. The cross-sections of the designed layers and the WES sample layers are comparatively illustrated in Figure 9.

One cubic foot samples were taken from each of the three pavement sublayers in each of the three test pits, resulting in nine separate samples. Laboratory tests on these samples included washed sieve analyses of each sample, one Los Angeles Abrasion test on combined bottom of base materials, Atterburg Limits on each sample, and moisture-density tests on combined top and bottom of base course samples. The results of these tests are presented and discussed in the following paragraphs.

Sieve Analyses. The results of the sieve analyses are given in Tables 3-4 and in Figures 10-13. The results of the base course sieve analyses indicate that there is a lack of top-sized material and too many fine aggregates throughout the base course layers when compared to the specified FAA gradation requirements. The existing grading undoubtedly has a reduced permeability and holds subsurface water longer than the designed gradation. This difference is critical in the presence of plastic fines and high moisture contents, such as the case at Yap Airport.

Another item of interest in the base course sieve analyses is the notable differences between the top and bottom layers for the Pit 1 and 2 samples, while there is no significant differences between the top and bottom samples in Pit 3. Since the Pit 3 area was structurally sound when sampled and Pits 1 and 2 had significant structural failures, the reduced amount of larger aggregates in the bottom of the base may have either caused or become the result of the structural failure. Degradation of the larger aggregates under routine wheel loads and in the presence of high moisture contents is a likely scenario in these areas.

The results of the select fill sieve analyses are given in Table 4 and are graphically represented in Figure 13. The gradation of the Pit 1 sample differs from those of Pits 2 and 3, as the Pit 1 material is substantially coarser than the other two samples. The significance and possible reason for this difference is unknown. This variance is not suspected as a significant contributor to the current runway pavement failures at Yap Airport.

Los Angeles Abrasion. The relatively large top-size aggregates in the base course samples require a relatively large sample size to conduct the Los Angeles Abrasion test (ASTM C 131). Since the amount of field sampled materials was limited, a single abrasion test was conducted on a combined sample of materials representing the "bottom of base" materials from Pits 1, 2 and 3. This abrasion test is conducted to indicate the durability of a given aggregate sample in terms of resistance to mechanically-induced degradation. The maximum percent wear prescribed by the FAA specification P-209 "Crushed Aggregate Base Course" is 45 percent. The results of the test on the combined base course sample was 18.61 percent wear, well below the 45 percent maximum requirement.

Atterburg Limits. Tests of Atterburg Limits (ASTM D 4318) were conducted on samples representing the top of base, bottom of base, and select fill for each of the three test pits. Atterburg Limits were conducted on the materials passing the No. 40 sieve, and the determinations of the liquid limit (LL), plastic limit (PL), and plasticity index (PI) are reported in Figures 10-13.

The most significant test results from the Atterburg Limits evaluation are the liquid limit (LL) and the plasticity index (PI). The LL values of the base course materials from all three test pits ranged from 27 to 30, exceeding the FAA specified (P-209) maximum of 25. The PI values of the base course materials ranged from 7 to 9, once again well above the FAA specified (P-209) maximum of 4. These test results indicate the presence of excessively plastic fines. Since the sieve analyses indicate an excess in the amount of fines in the base and the presence of high moisture contents in the base has also been proven, a significant loss in base course strength is to be expected.

Table 3
Sieve Analysis of Base Course Samples

Sieve	Percent Passing						
	FAA Spec. P-209 Limits	Pit 1		Pit 2		Pit 3	
		Top	Bottom	Top	Bottom	Top	Bottom
2 in.	100	100	100	100	100	100	100
1 1/2 in.	95-100	84.1	94.0	91.7	95.6	92.2	92.3
1 in.	70-95	76.7	83.2	78.9	89.7	78.9	73.1
3/4 in.	55-85	68.9	75.0	65.1	70.3	67.6	67.2
1/2 in.		59.3	63.6	55.3	63.6	57.3	57.4
3/8 in.		54.5	57.4	50.3	53.3	52.3	53.0
No. 4	30-60	44.4	45.9	40.0	42.2	41.8	41.3
No. 8		36.9	37.8	32.7	34.8	33.4	33.4
No. 10		34.9	35.6	30.7	32.8	31.2	31.1
No. 16		30.6	30.8	26.1	28.4	25.6	26.3
No. 20		28.3	28.3	23.7	26.1	23.0	23.8
No. 30	12-30	25.7	25.4	21.0	23.5	20.0	21.0
No. 40		23.6	23.0	18.8	21.3	17.6	18.7
No. 50		21.9	21.1	17.1	19.6	15.7	16.9
No. 60		20.7	19.8	16.0	18.3	14.4	15.6
No. 80		19.6	18.8	15.1	17.4	13.4	14.7
No. 100		18.7	17.9	14.3	16.6	12.6	13.9
No. 200	0-8	16.5	15.8	12.5	14.6	10.8	12.0

Table 4 Sieve Analysis of Select Fill Samples			
Sieve	Percent Passing		
	Pit 1	Pit 2	Pit 3
2 1/2 in.	100	100	100
2 in.	81.0	90.7	100
1 1/2 in.	71.3	87.4	94.8
1 in.	63.4	82.0	83.0
3/4 in.	57.5	74.7	76.3
1/2 in.	51.0	65.3	69.4
3/8 in.	46.9	60.7	64.8
No. 4	37.3	48.3	52.1
No. 8	30.7	40.3	43.1
No. 10	28.7	37.9	40.4
No. 16	24.3	32.3	34.5
No. 20	21.9	29.2	31.3
No. 30	19.0	25.6	27.6
No. 40	16.4	22.4	24.7
No. 50	14.3	19.8	22.5
No. 60	12.6	17.9	21.1
No. 80	11.5	16.6	19.9
No. 100	10.5	15.4	19.0
No. 200	7.8	12.3	16.8

Laboratory Compaction and CBR Data. Laboratory compaction and CBR data, determined for the combined base material taken from Pits 1-3 for a CE 55-blow compactive effort (MIL-STD-621A, Method 101), are shown in Figure 14. Both the unsoaked and soaked conditions are shown in Figure 14. Optimum water content was 4.2 percent and maximum dry density was 153.8 lb/cu ft. The water contents after soaking ranged from 7.4 - 8.4 percent. Based on the laboratory compaction tests the soaked design CBR was 15 for the base material. This design CBR agrees with the field DCP data (Table 1) which measured a 15 CBR for the top of the base in Pit 1 which had a water content of 8.6 percent.

PCC Patching of Test Pits. The standard airfield patching procedure was used to patch Pits 1-3. The AC surface and 10 in. of base were removed and the bottom of the base was compacted as shown in Photo 15. A 4-in.-thick layer of dredged coral material was then placed and compacted. Next, 10-in. of PCC was placed with wire/rebar reinforcement as shown in Photos 16 and 17. The completed PCC patch for Pit 1 is shown in Photo 18.

5 Conclusions and Recommendations

Conclusions

Based on the field and laboratory tests conducted, it is concluded that:

- a.* The pavements are structurally inadequate to withstand the current traffic of the B-727-200 aircraft. The pavement thickness requirements for the AC surface, base course, and select fill meet FAA design requirements; however, the base course CBR values are less than the FAA requirement of 80 at many locations along the runway, taxiway, and apron. Based on the field DCP data and the laboratory CBR data on the base course material, the base course is structurally inadequate to withstand the traffic of the B-727-200 aircraft. The poor condition of the pavements is supported by the PCI ratings which show portions of the runway in very poor condition with a PCI rating of only 13.
- b.* The immediate cause of the poor condition of the pavements and the increasing failures is due to water in the base course. The base course material doesn't meet FAA specifications for Item P-209, Crushed Aggregate Base Course. The base course has too many fines (10.8-16.5 percent passing No. 200 sieve versus 0-8 percent allowed by Item P-209). Also, the fines are plastic with PI values ranging from 7-9 versus the maximum allowed of 4. When water enters the base course, the CBR strength decreases from 100 CBR at a 4 percent water content to approximately 15 CBR at a water content of 7.5 percent or more.
- c.* The clogged edge drain at Sta 37+00 probably accelerated the pavement failures by offering a ready supply of water to the base and select fill material.

Recommendations

Based on the results of this investigation, it is recommended that:

Short Term

- a. The drainage system be checked and maintained on a regular basis.
- b. The surface cracks be sealed and kept sealed based on a regular inspection and maintenance schedule. The current sealing procedure using emulsified asphalt and sand is an adequate maintenance procedure.
- c. The current repair procedure for failed areas using PCC patches with wire/rebar reinforcement should be modified. The current procedure of screeding the surface to match the original pavement surface creates a bump in the rutted pavement that is strongly felt in the aircraft as it travels over the patch. If possible, the final surface of the patch should match the existing ruts in the wheel paths. Under the current patching procedure, the rutted area between two patches may pond water.

Long Term

The long term repair of the airfield pavements should involve rehabilitation of the 50-ft-wide center portion of the entire 6000 ft length of the runway, entire taxiway and apron (except PCC fuel pads), and repair of failed areas in the overruns.

Design. Assume the select fill CBR is 12 (original design) and the base CBR is 15 (based on field and laboratory tests). Assume the existing pavement is to be strengthened in the critical areas to accommodate the B-727-200 aircraft weighing 190,500-lb. and an annual departure level of 1200. The flexible pavement required (referring to Figure 3-4 of FAA Advisory Circular AC 150/5320-6C) for these conditions is:

Bituminous Surface	4 inches
Base	<u>15 inches</u>
Total pavement thickness	19 inches

Rehabilitation. The rehabilitation could be accomplished by a variety of methods based on materials available and costs. Methods believed worth considering are (Figures 15 & 16):

- a. *Runway:* Repair the 50-ft-wide center portion for the full runway length and then add a 3-in.-thick overlay to the entire runway surface. Figure 15 shows cross section view for this rehabilitation. Table 3-3

of FAA AC 150/5320-6C was used to reduce the base thickness by 1-in. based on 3-in. of bituminous surface course with an equivalency factor of 1.4. The rehabilitated base course could be:

- (1) Use 11-in. of new base material meeting FAA Item P-209.
 - (2) Use 11-in. of existing base after it has been removed, washed to remove plastic fines in order to meet Item P-209 requirements, and reinstalled.
 - (3) Use 11-in. of existing base after it has been removed, modified by adding portland cement at a central plant (up to a maximum of 4 percent) to reduce the PI to meet Item P-209, and reinstalled.
(Note: This will require some lab testing)
 - (4) Use 8-in. of new AC base plus 4-in. of AC surface.
- b. *Taxiway and Apron:* Remove all the existing AC surface and 15-in. of base, reinstall a 15-in.-thick rehabilitated base using one of the methods above, and install 4-in. of new AC wearing surface. If full-depth AC is used, remove all the existing AC surface and 11-in. of base and place 11-in. of new AC pavement base plus 4-in. of AC surface. The final surface should tie in with the fuel pad and runway surface. A full PCC rigid pavement design and repair for the taxiway and apron should also be considered.
- c. *Runway overruns:* Repair failed areas and overlay with 2-in. AC.
- d. *Drainage outlets:* Check all drainage outlets and add a concrete drop basin around those that can potentially clog with grass and roots. The drainage system should be checked and maintained on a regular basis.

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Webster, Steve L., Grau, Richard H., Williams, Thomas P. (1992). "Description and application of dual mass dynamic cone penetrometer," Instruction Report GL-92-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

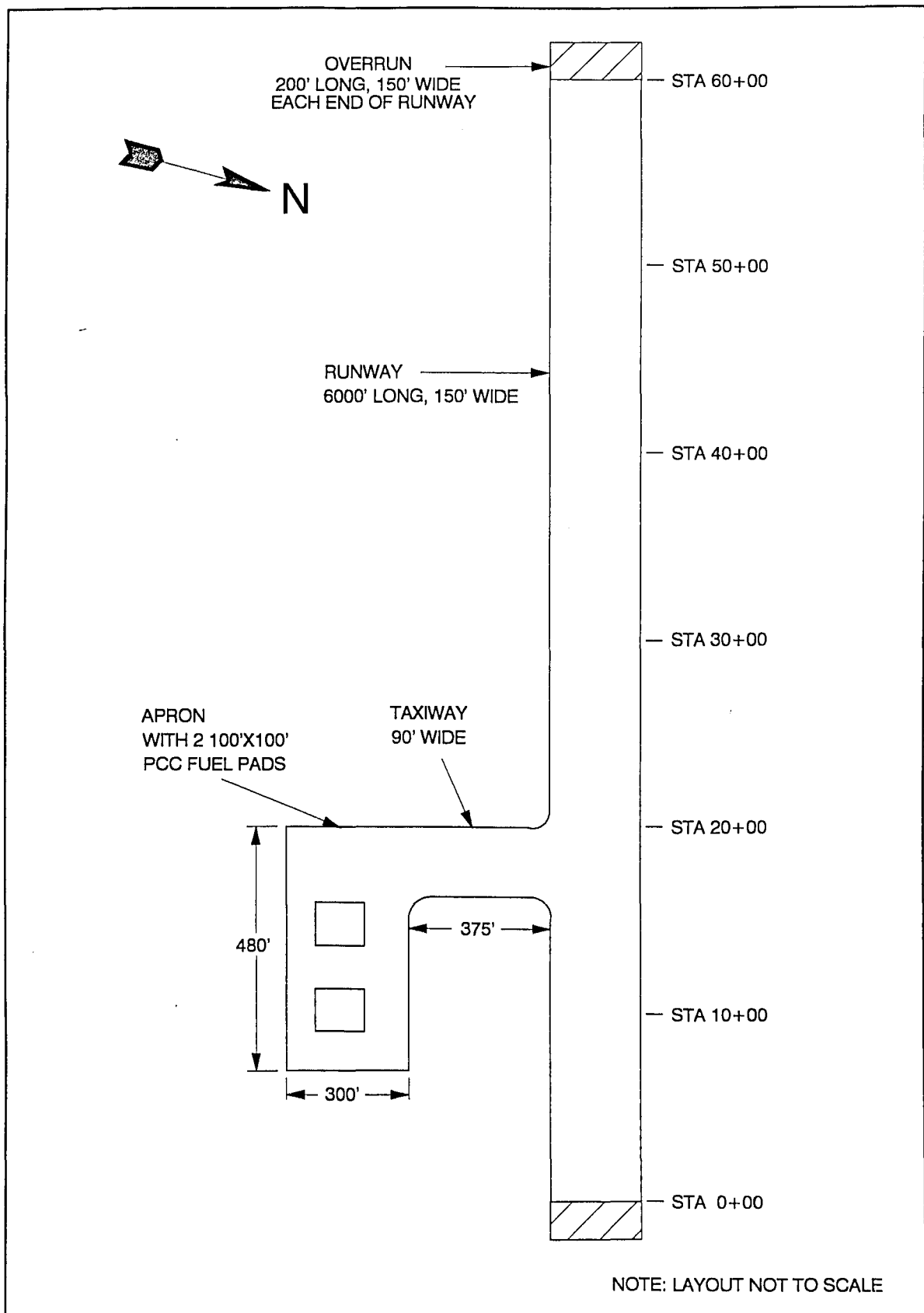


Figure 1. Layout of pavements at Yap International Airport

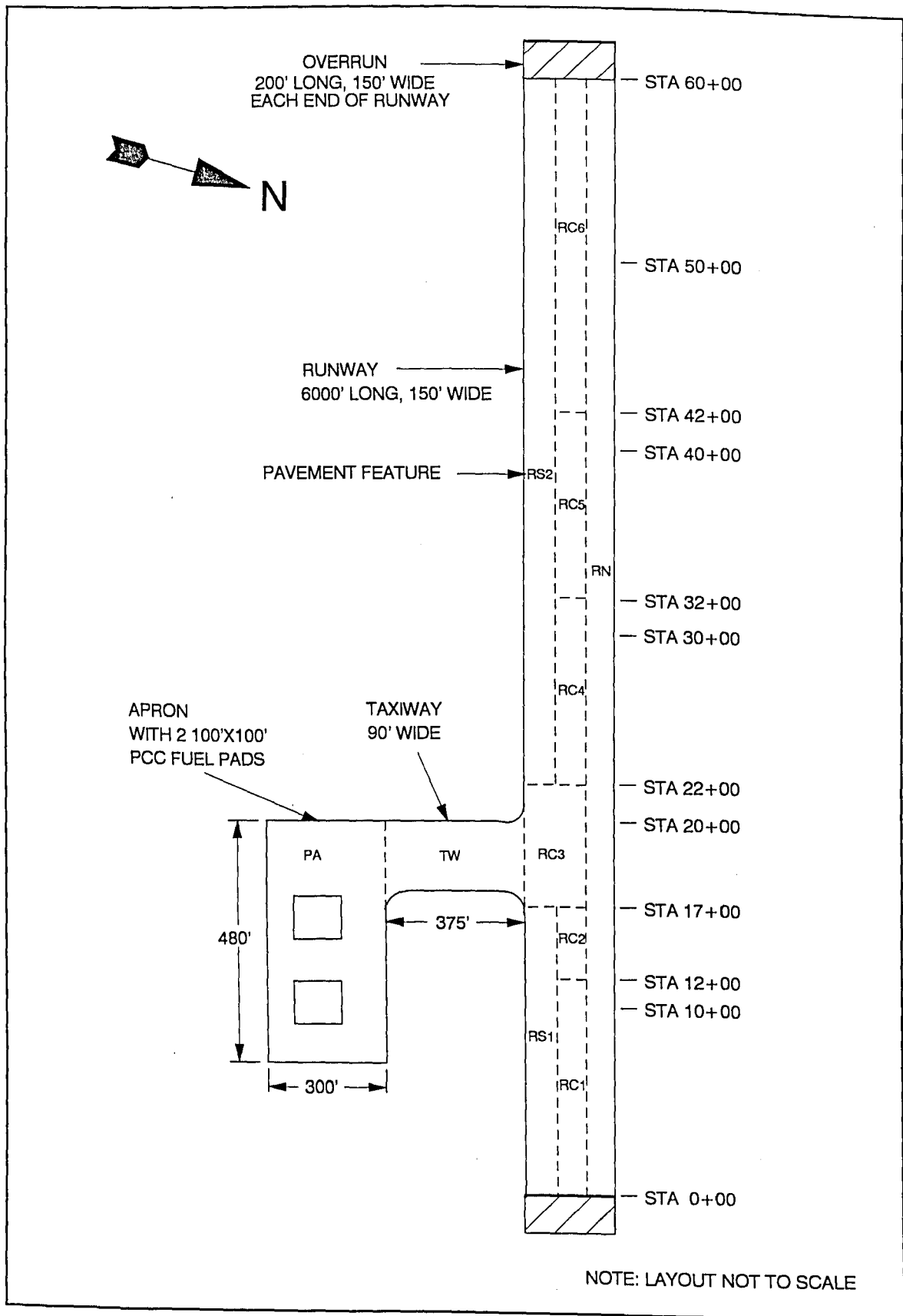


Figure 2. Pavement feature identification

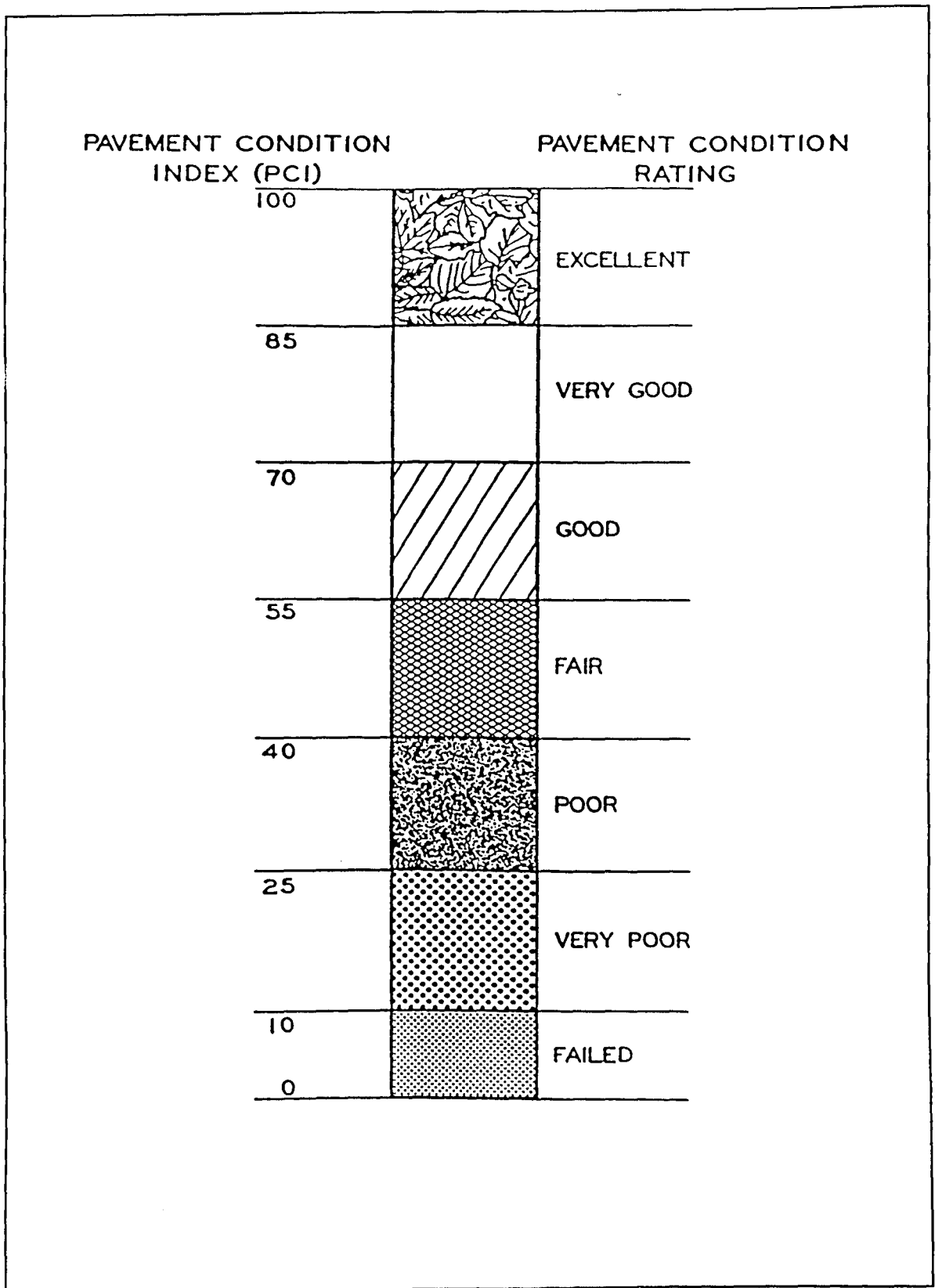


Figure 3. Scale of pavement condition rating

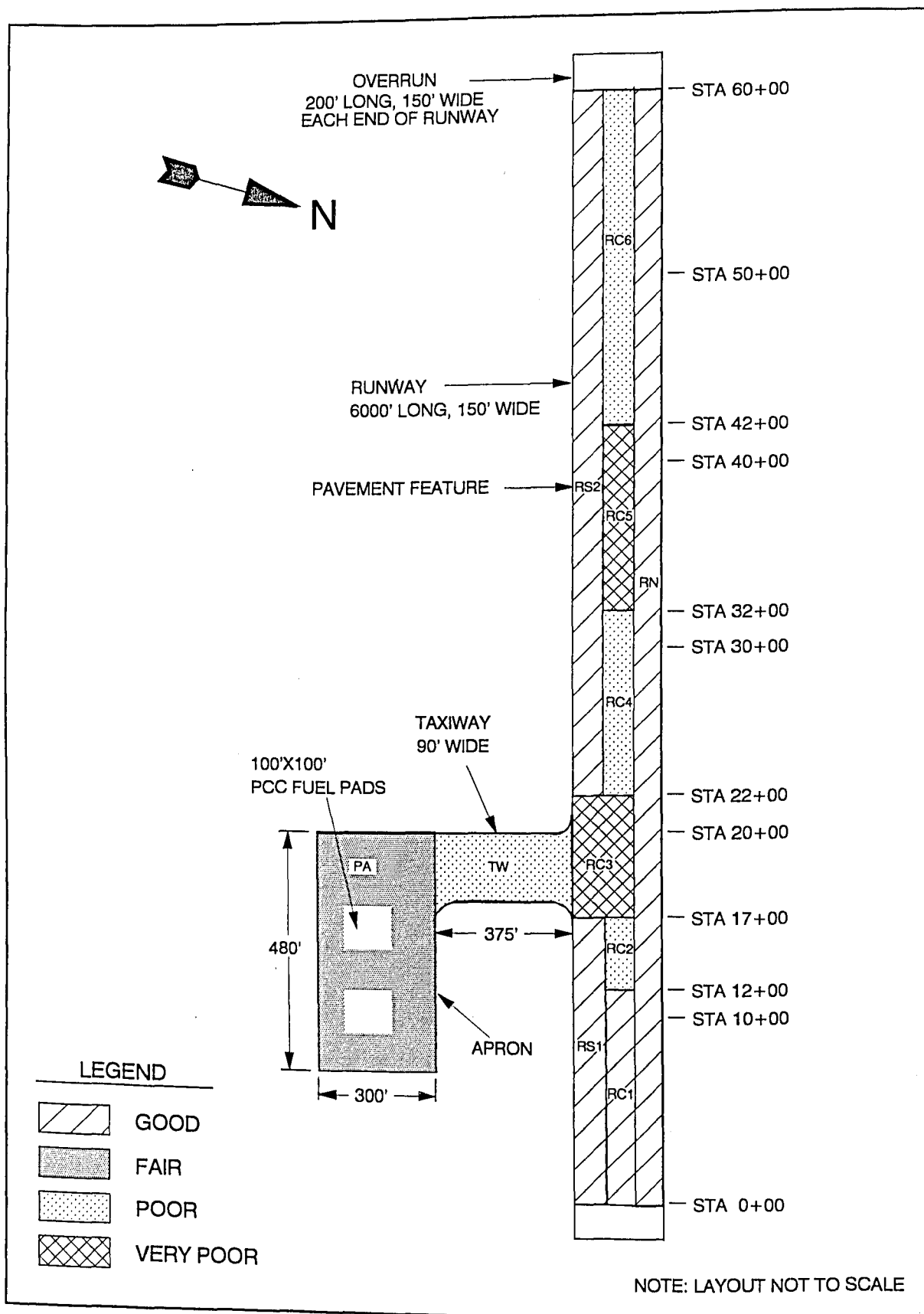


Figure 4. Pavement condition summary

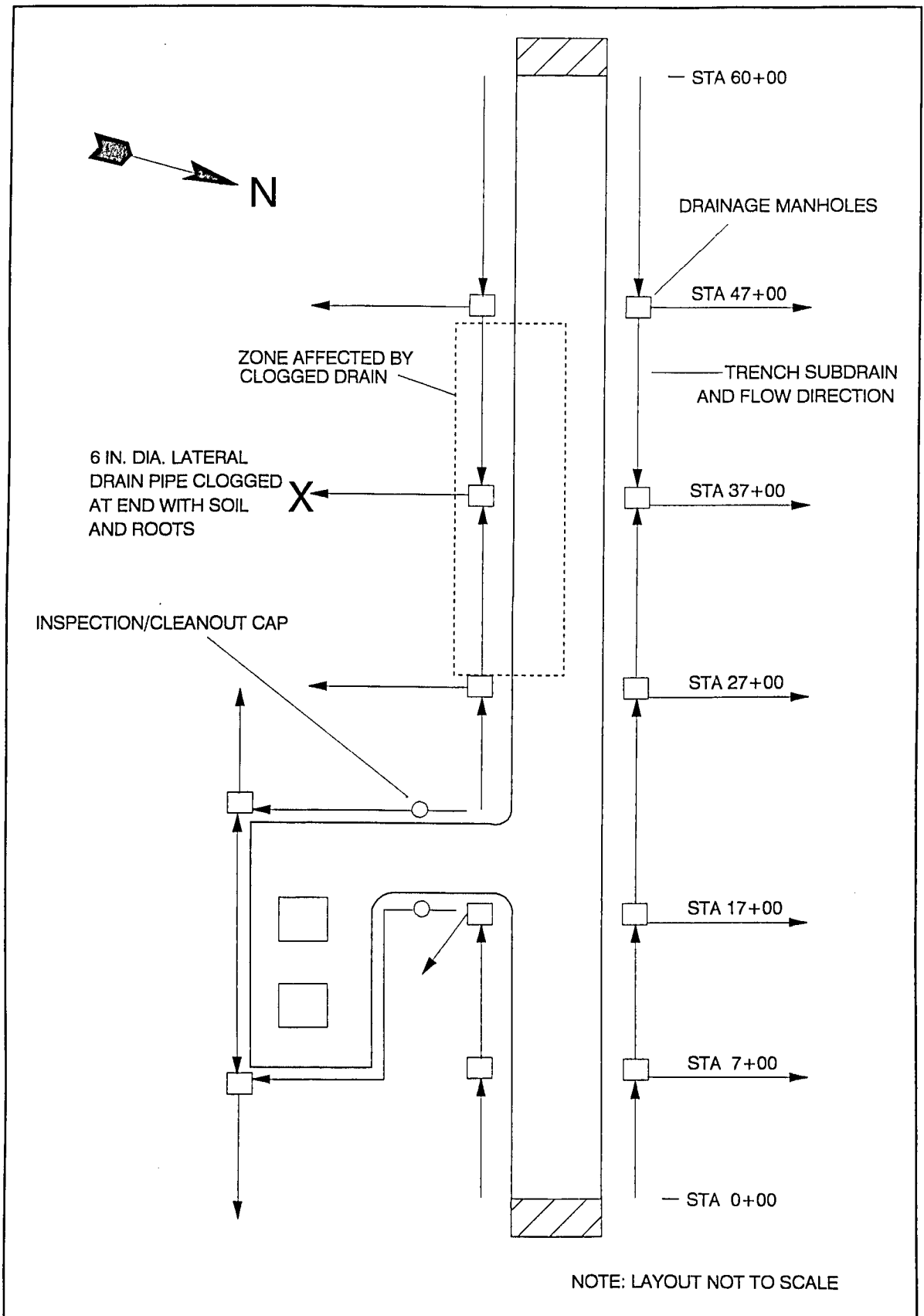


Figure 5. Layout of trench subdrain system

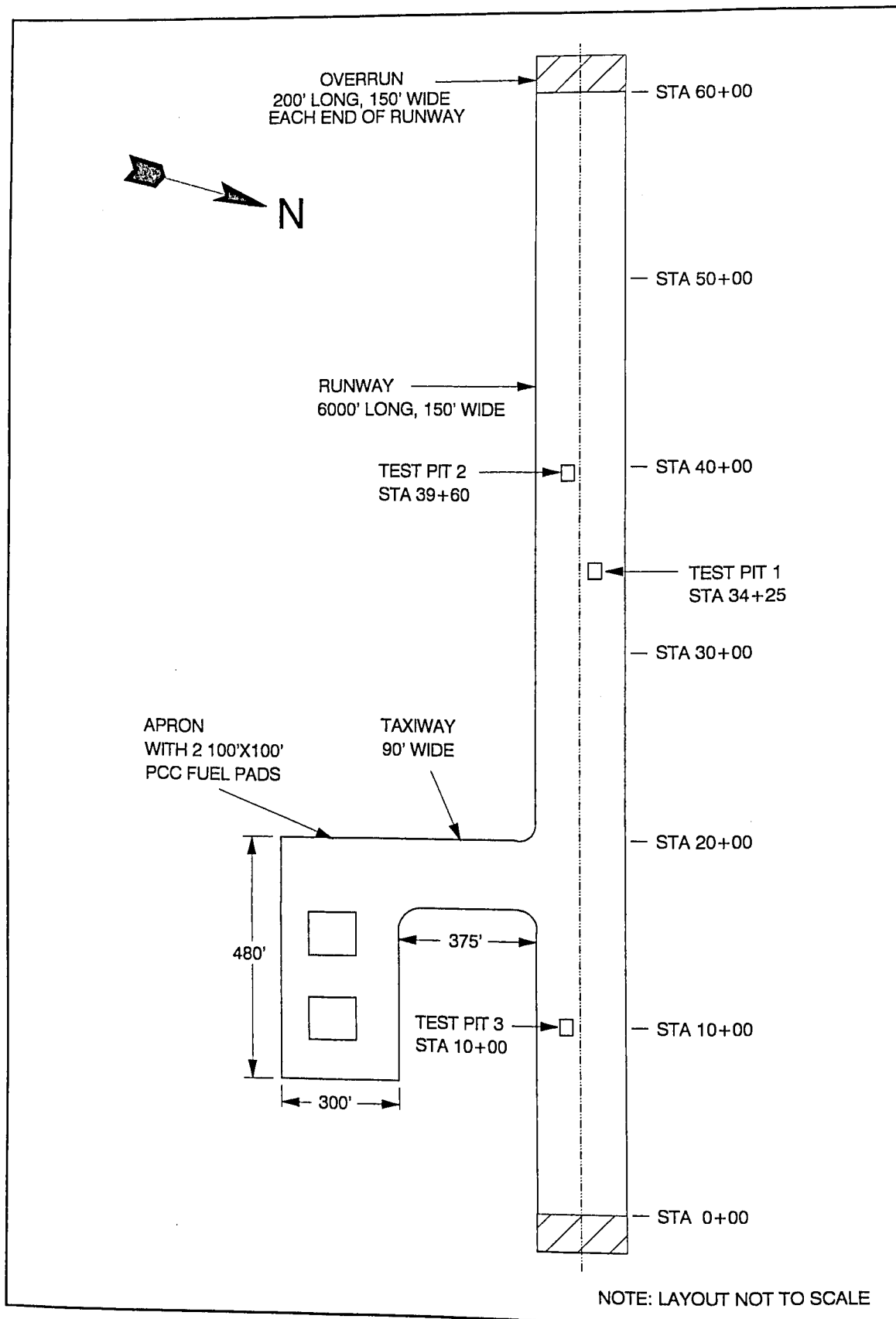
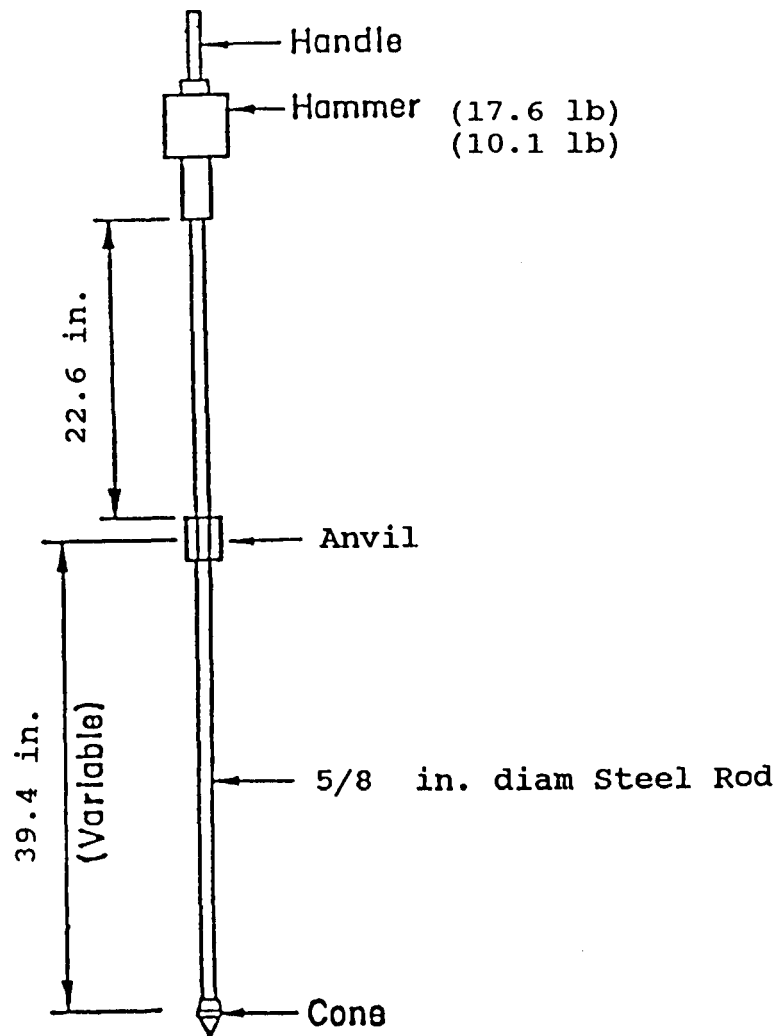


Figure 6. Test pit locations



THE CONE

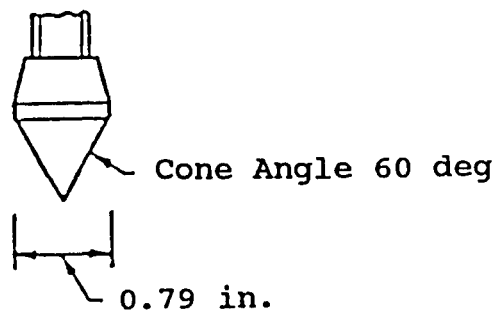


Figure 7. Dynamic Cone Penetrometer (DCP)

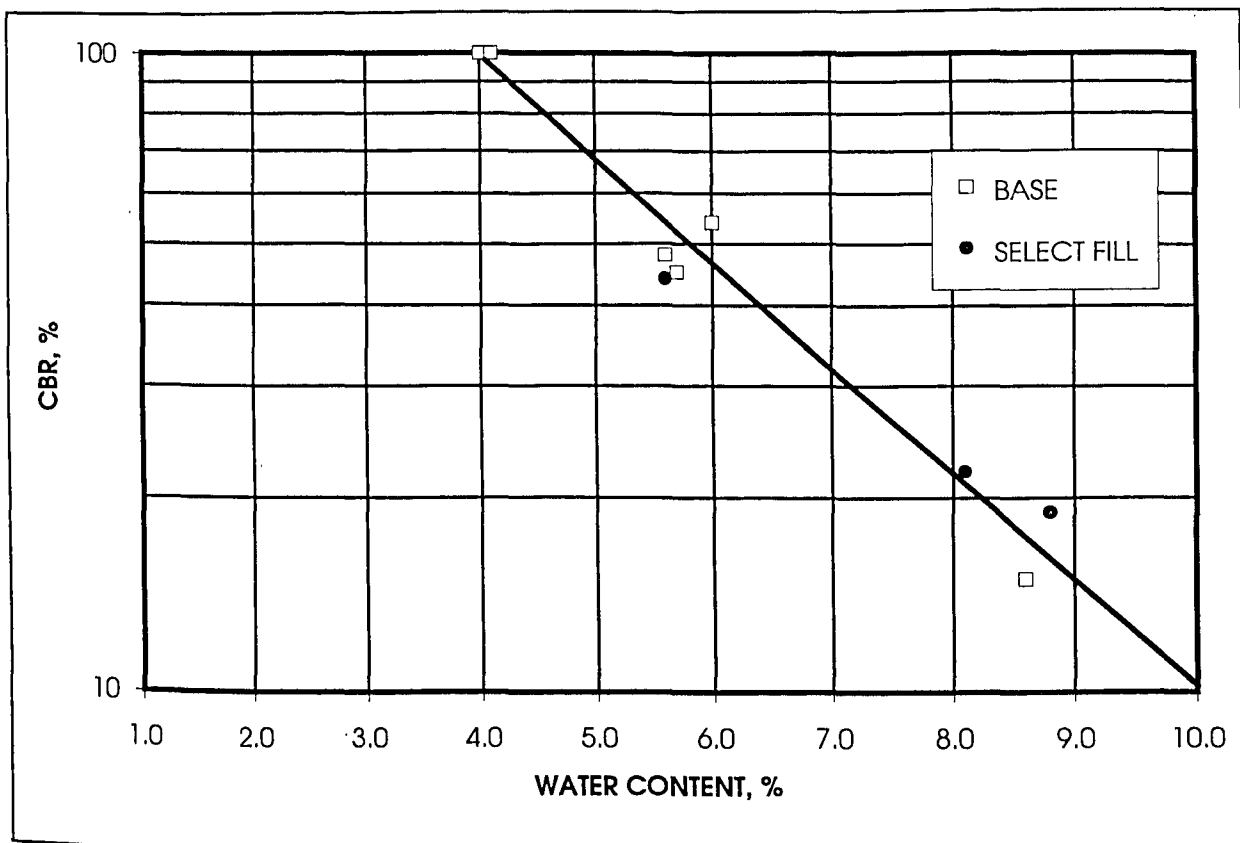


Figure 8. CBR versus water content, from test pit data

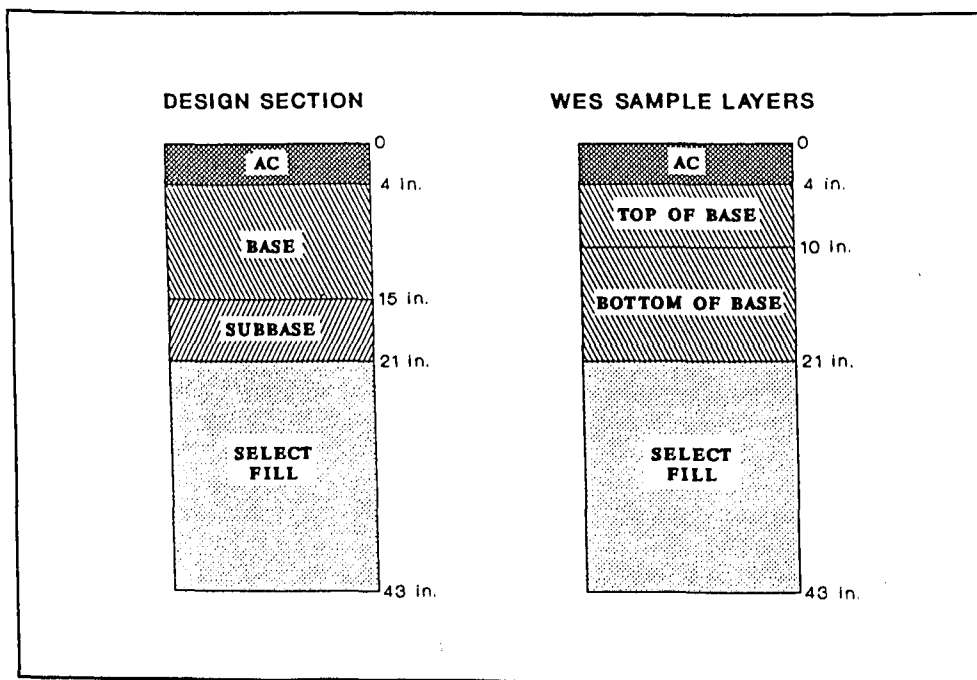


Figure 9. Cross sections of runway pavement layers

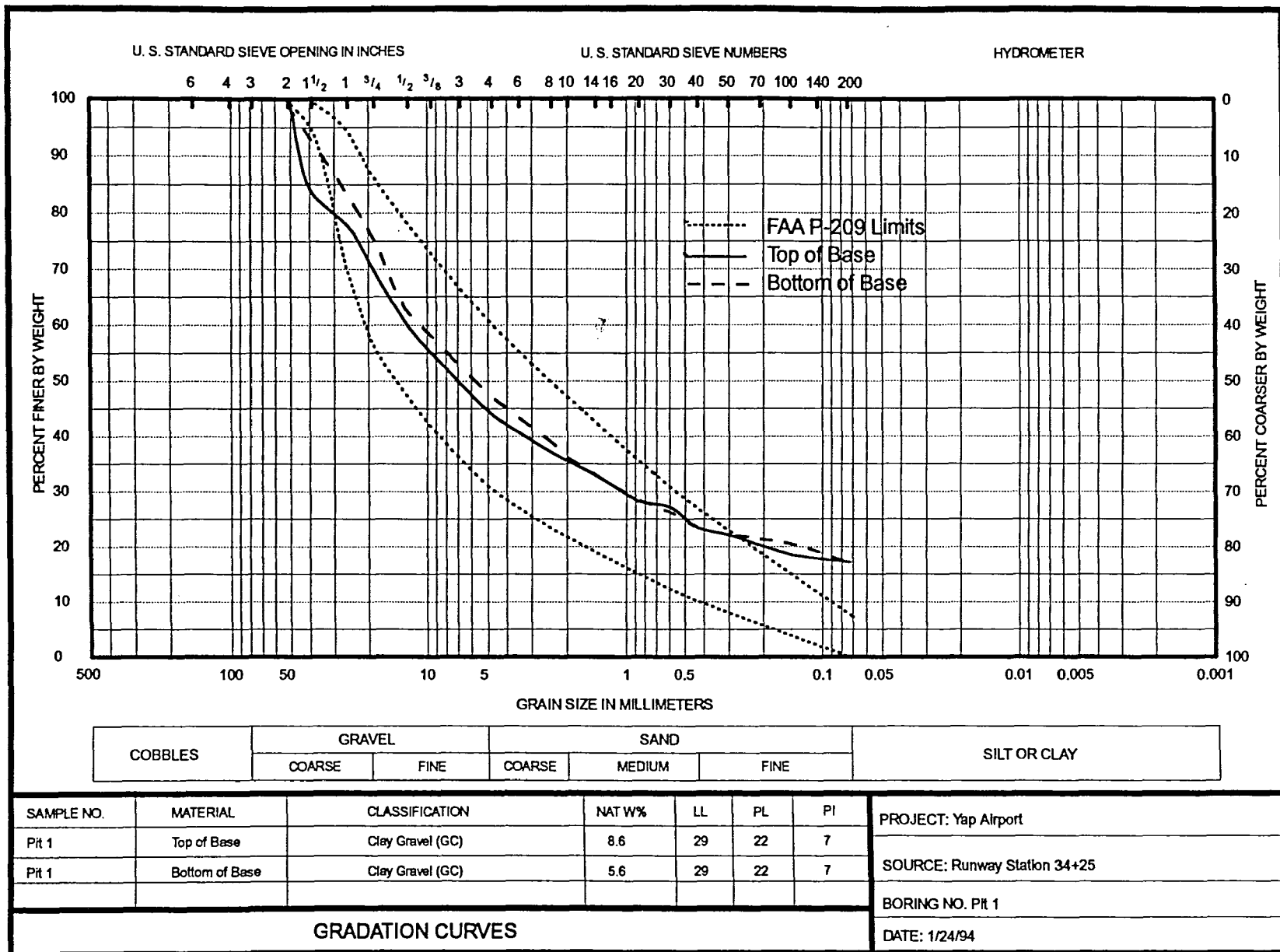


Figure 10. Gradation curves for base course from Pit 1

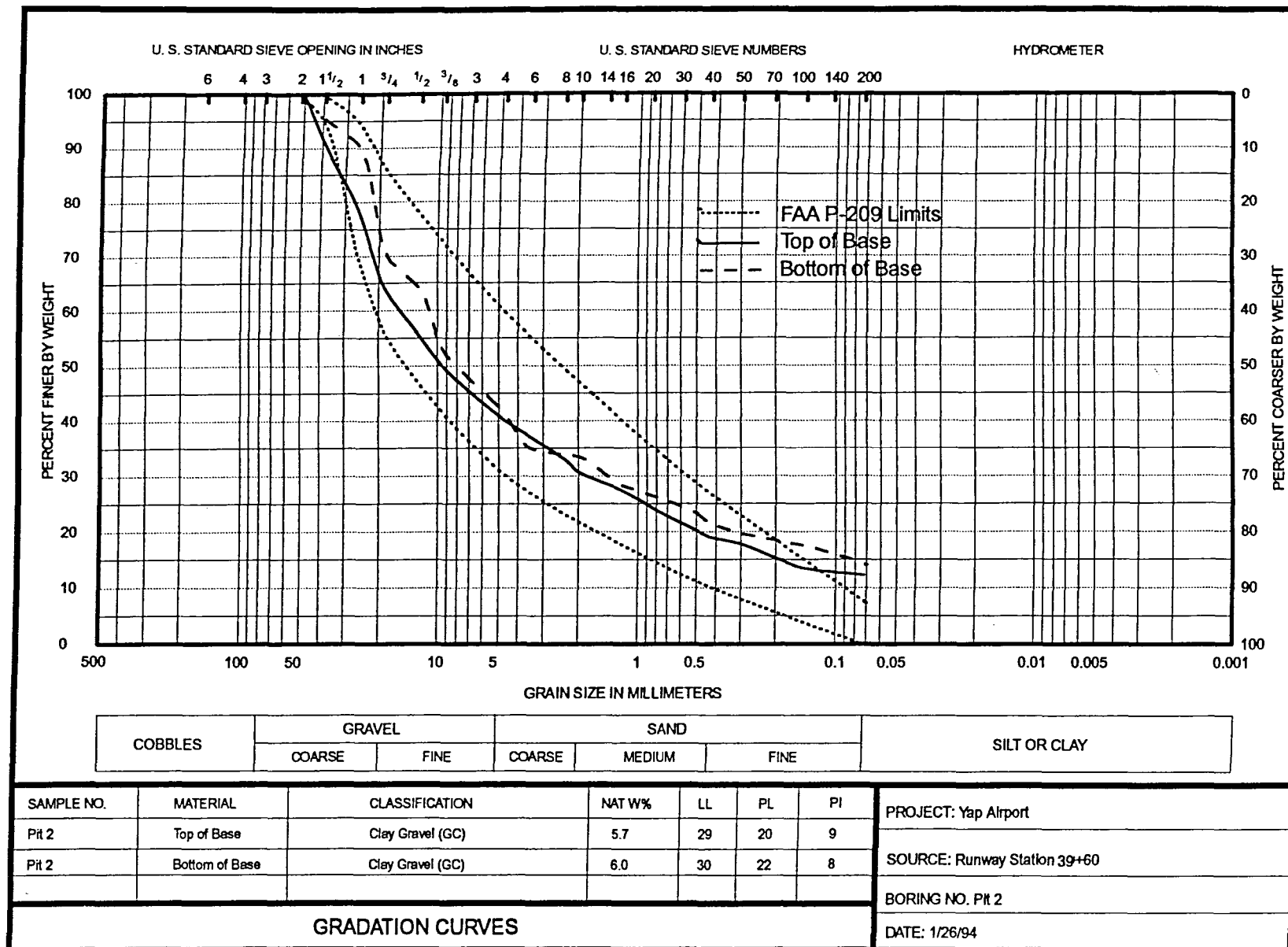


Figure 11. Gradation curves for base course from Pit 2

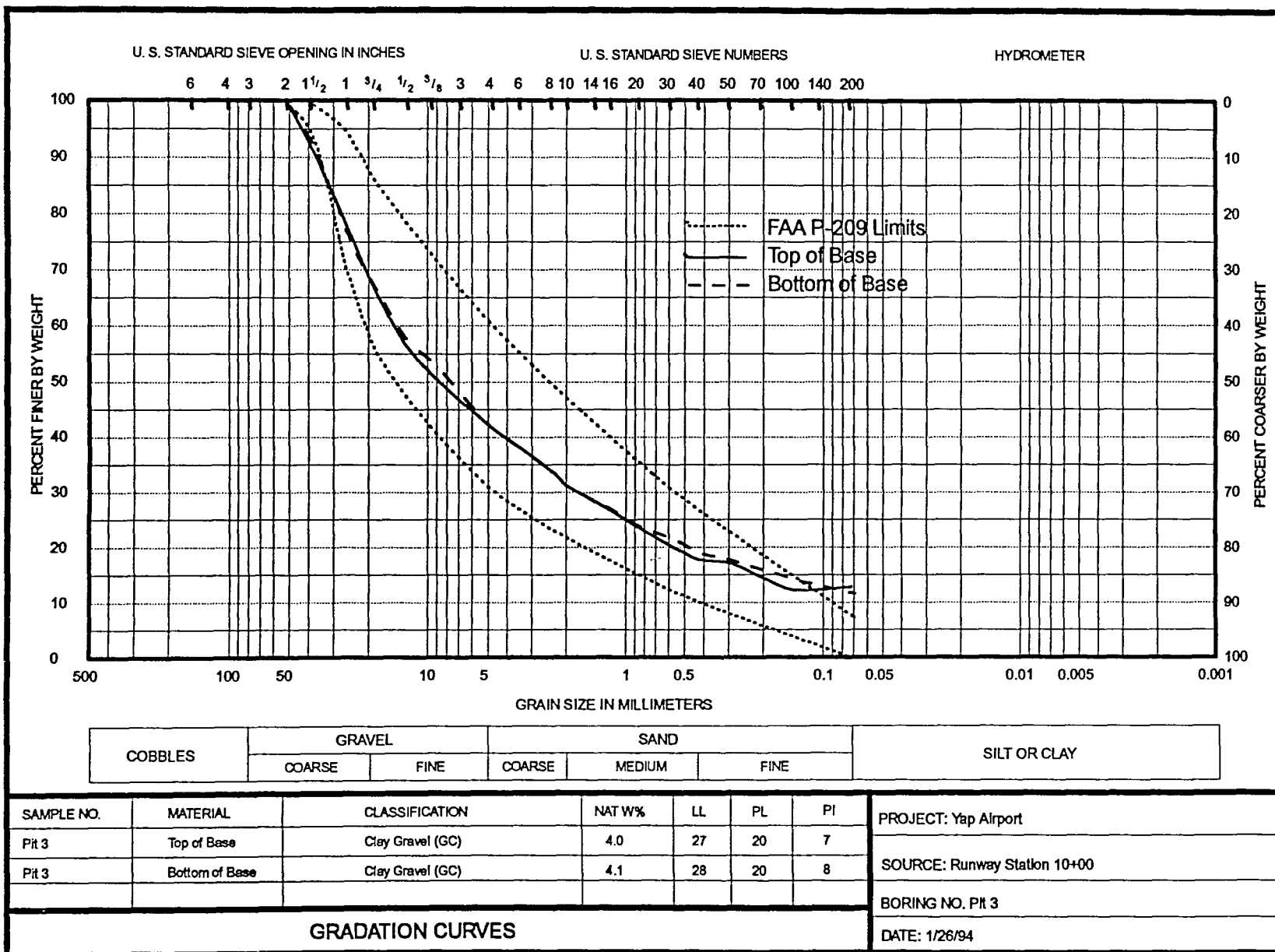


Figure 12. Gradation curves for base course from Pit 3

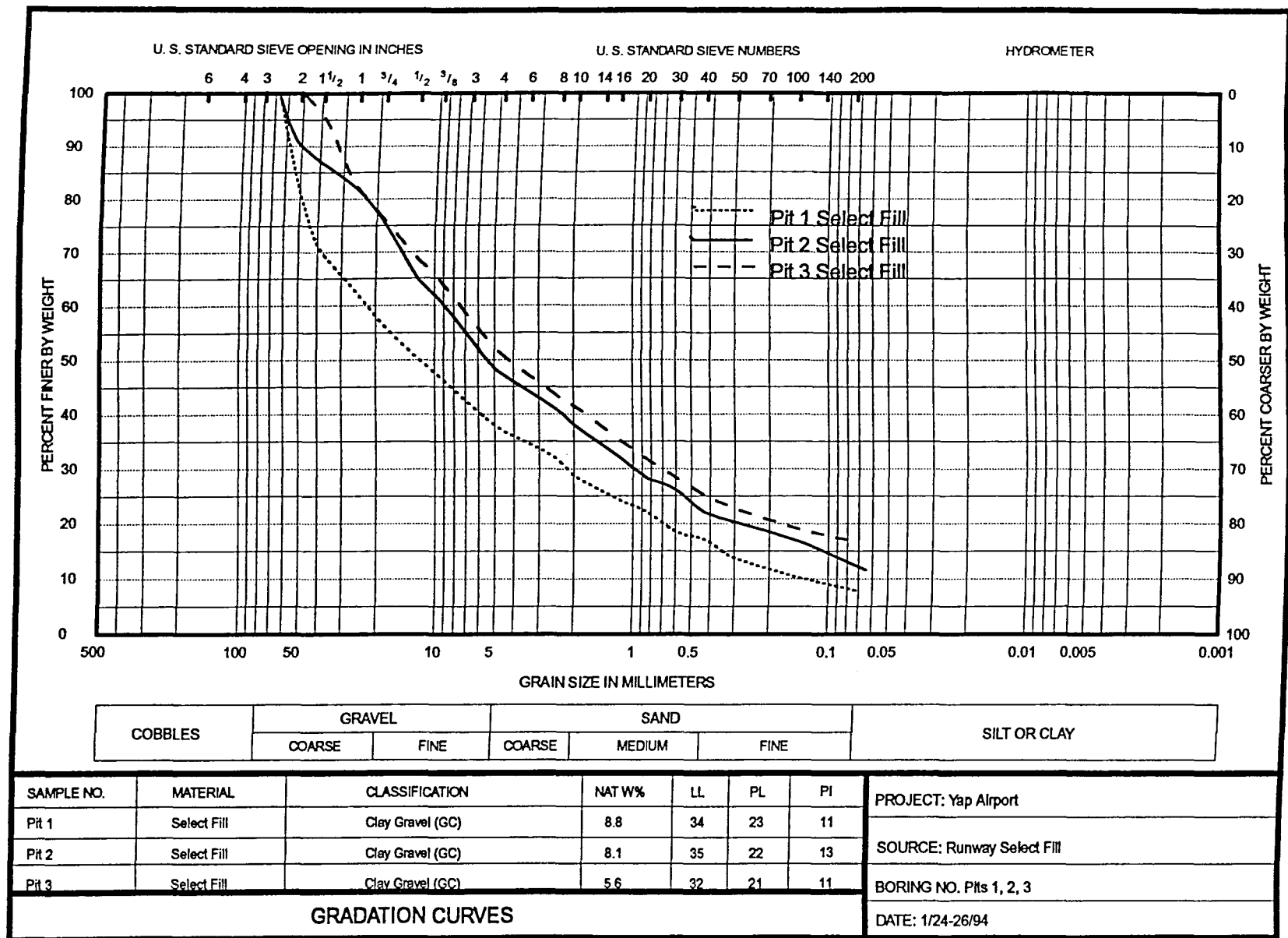


Figure 13. Gradation curves for select fill material from Pits 1-3

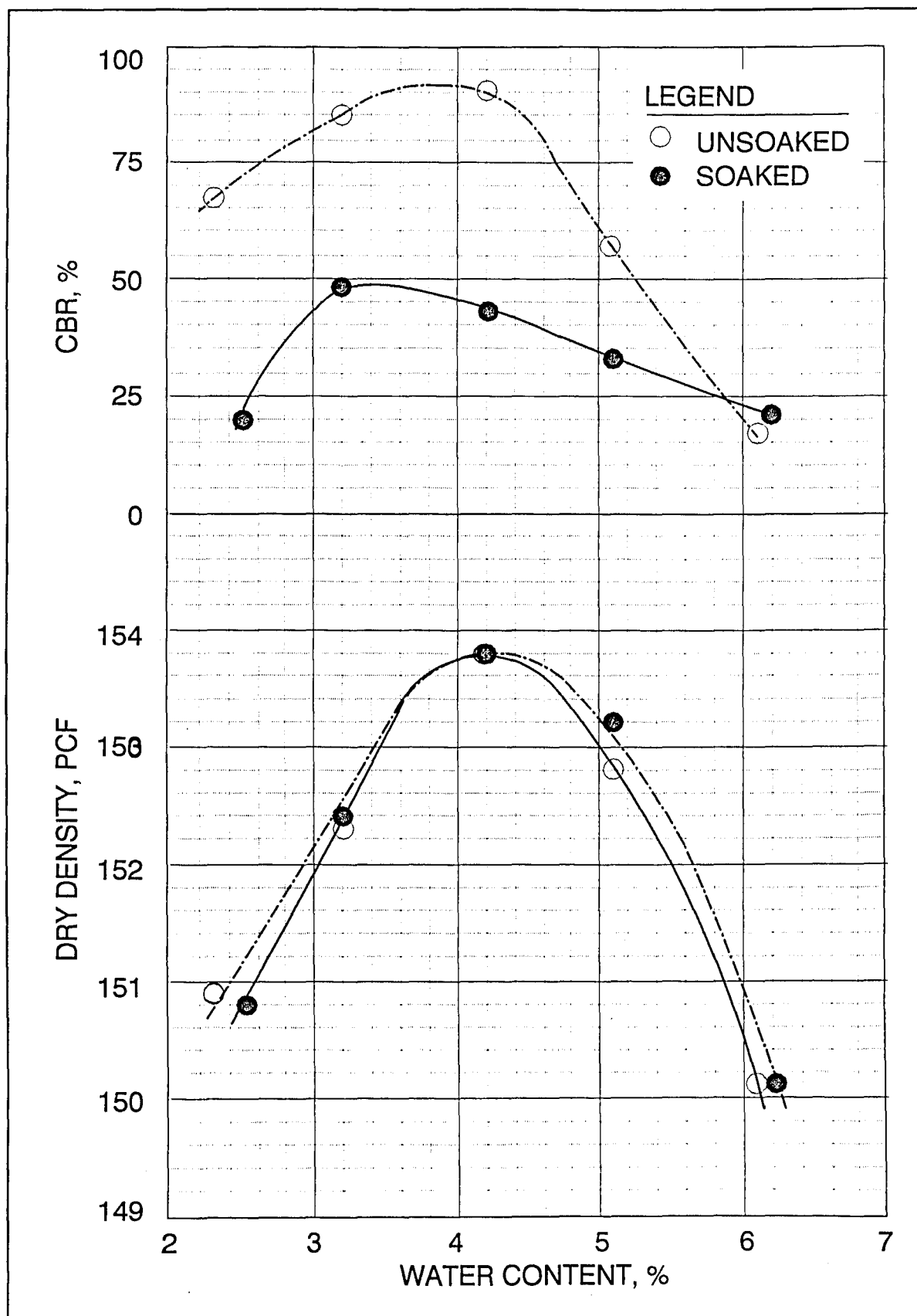


Figure 14. CBR, density, and water content data for base material from Pits 1-3

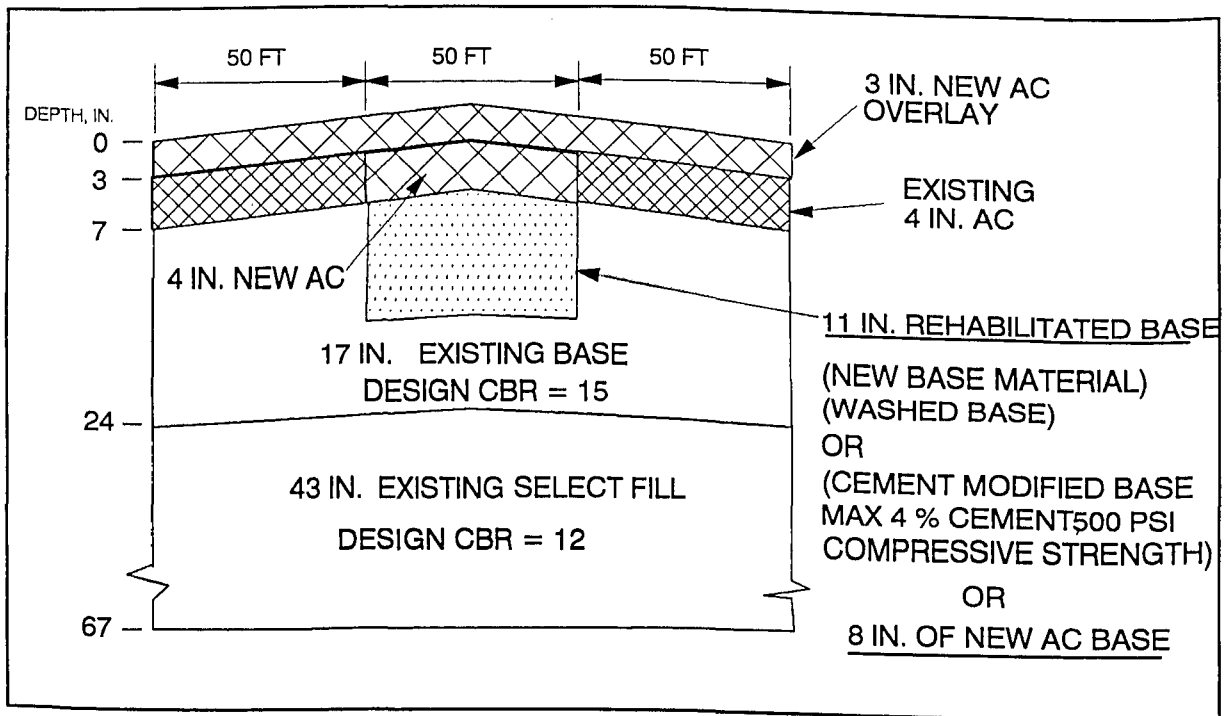


Figure 15. Recommended repair for runway

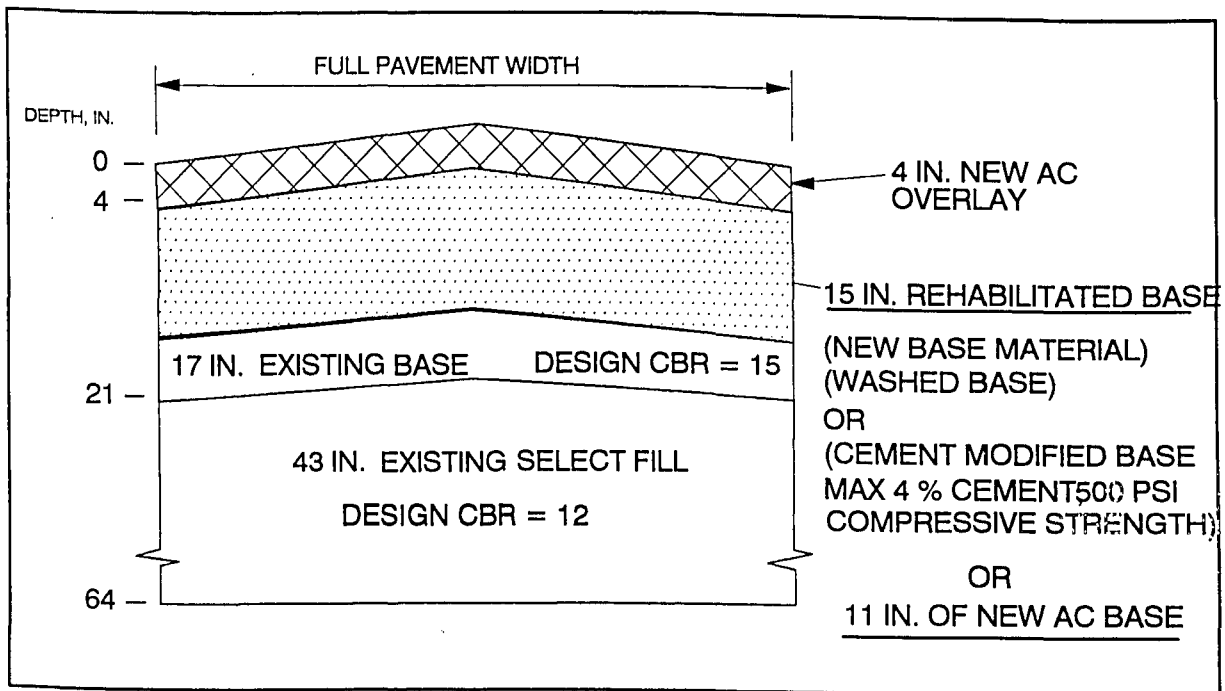


Figure 16. Recommended repair for taxiway and apron



Photo 1. High severity alligator cracking and rutting at Pit 1 location



Photo 2. High severity alligator cracking and rutting at Pit 2 location



Photo 3. Pavement condition at Pit 3 location



Photo 4. Low severity raveling/weathering typical for all Yap airfield pavements



Photo 5. Concrete patches with liquid asphalt/sand seal on taxiway

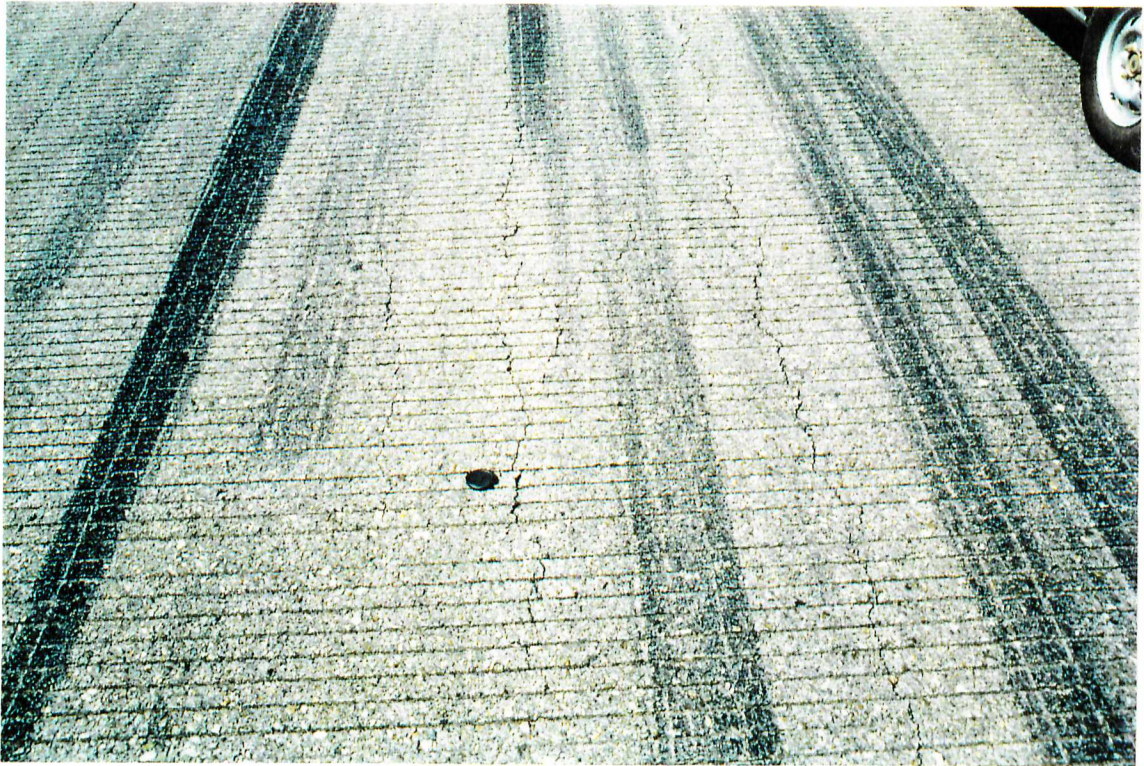


Photo 6. Low severity alligator cracking on runway

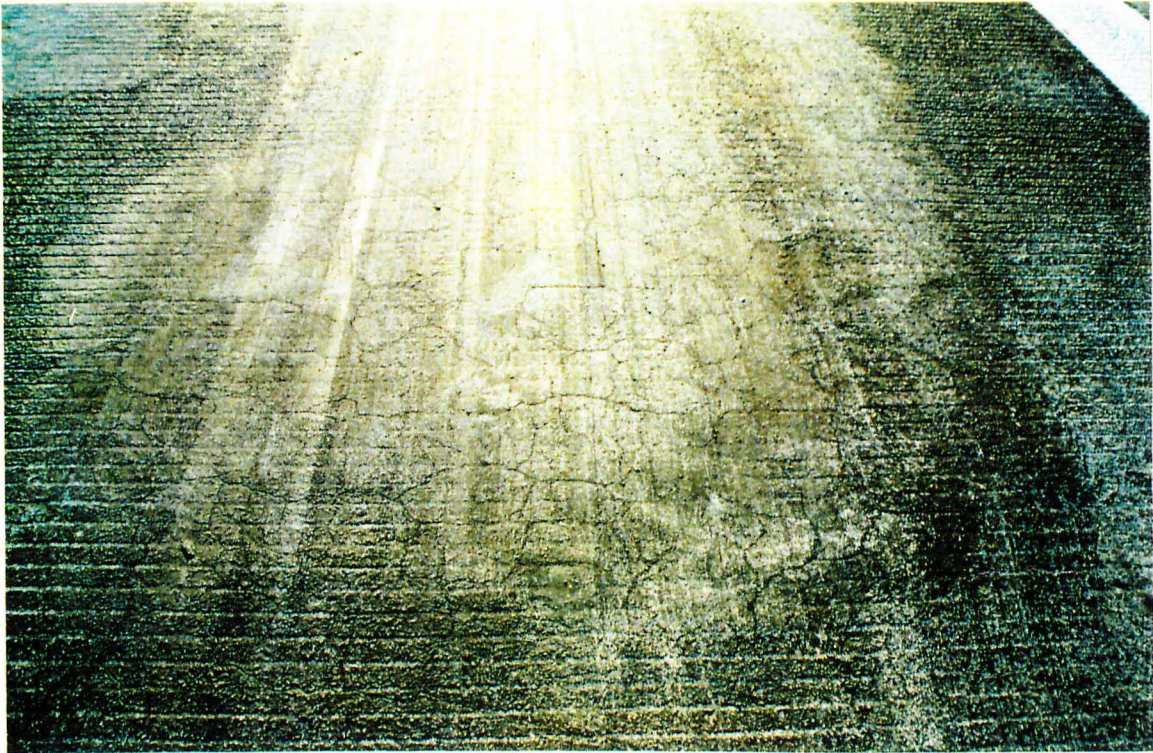


Photo 7. Medium severity alligator cracking with liquid asphalt seal on runway



Photo 8. Medium severity depression at end of PCC patch on runway



Photo 9. Medium severity patch at apron fuel pad



Photo 10. Failure on West overrun (airplane got stuck turning around)



Photo 11. Water flowing from unplugged drain at runway Sta 37+00



Photo 12. Closeup of unplugged drain at Sta 37+00



Photo 13. Pavement grooving for lateral drainage of runway surface



Photo 14. Base course material from Pit 3



Photo 15. Compacting base in bottom of Pit 1



Photo 16. Placing concrete in Pit 1 repair



Photo 17. Wire/rebar reinforcement in Pit 1 repair



Photo 18. Completed PCC patch at Pit 1

Appendix A

Pavement Condition Survey Results

INSPECTION REPORT

```

=====
Network ID      - USWES
Branch Name     - RUNWAY
Branch Number   - RC-1
Section Number  - 1      Family - DEFAULT
Section Length  - 1200.00 LF
Section Width   - 50.00 LF
Section Area    - 60000.00 SF
=====
  
```

```

Inspection Date: JAN/25/1994
Riding Quality :      Safety:      Drainage Cond.:
Shoulder Cond. :      Overall Cond.:      F.O.D.:
=====
  
```

```

-----
PCI OF SECTION = 68                                RATING = GOOD
  
```

```

TOTAL NUMBER OF SAMPLE UNITS = 12
NUMBER OF RANDOM SAMPLE UNITS SURVEYED = 5
NUMBER OF ADDITIONAL SAMPLE UNITS SURVEYED = 0
RECOMMENDED MINIMUM OF 5 RANDOM SAMPLE UNITS TO BE SURVEYED.
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED = 1.0%
  
```

*** EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION ***

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
48 L & T CR	LOW	5316.00 (LF)	8.86	21.7
52 WEATH/RAVEL	LOW	60000.00 (SF)	100.00	26.4

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

	RELATED DISTRESSES =	PERCENT DEDUCT VALUES.
LOAD	.00	PERCENT DEDUCT VALUES.
CLIMATE/DURABILITY	100.00	PERCENT DEDUCT VALUES.
OTHER	.00	PERCENT DEDUCT VALUES.

INSPECTION REPORT

```

=====
Network ID      - USWES
Branch Name     - RUNWAY
Branch Number   - RC-2
Section Number  - 1      Family - DEFAULT
Section Length  - 500.00 LF
Section Width   - 50.00 LF
Section Area    - 25000.00 SF
=====
  
```

```

Inspection Date: JAN/25/1994
Riding Quality :      Safety:      Drainage Cond.:
Shoulder Cond. :      Overall Cond.:      F.O.D.:
-----
  
```

```

-----
PCI OF SECTION = 27                                RATING = POOR
  
```

```

TOTAL NUMBER OF SAMPLE UNITS = 5
NUMBER OF RANDOM SAMPLE UNITS SURVEYED = 5
NUMBER OF ADDITIONAL SAMPLE UNITS SURVEYED = 0
RECOMMEND EVERY SAMPLE UNIT BE SURVEYED.
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED = 16.8%
  
```

*** EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION ***

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
41 ALLIGATOR CR	LOW	5800.00 (SF)	23.20	52.6
48 L & T CR	LOW	4820.00 (LF)	19.28	32.3
52 WEATH/RAVEL	LOW	25000.00 (SF)	100.00	26.4
53 RUTTING	LOW	4000.00 (SF)	16.00	32.1
53 RUTTING	MEDIUM	1600.00 (SF)	6.40	38.7

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

LOAD	RELATED DISTRESSES =	67.76 PERCENT DEDUCT VALUES.
CLIMATE/DURABILITY	RELATED DISTRESSES =	32.24 PERCENT DEDUCT VALUES.
OTHER	RELATED DISTRESSES =	.00 PERCENT DEDUCT VALUES.

INSPECTION REPORT

```

=====
Network ID      - USWES
Branch Name     - RUNWAY
Branch Number   - RC-3
Section Number  - 1      Family - DEFAULT
Section Length  - 500.00 LF
Section Width   - 100.00 LF
Section Area    - 50000.00 SF
=====
  
```

```

Inspection Date: JAN/25/1994
Riding Quality :      Safety:      Drainage Cond.:
Shoulder Cond. :      Overall Cond.:      F.O.D.:
=====
  
```

```

-----
PCI OF SECTION = 14                                RATING = V. POOR
  
```

```

TOTAL NUMBER OF SAMPLE UNITS = 10
NUMBER OF RANDOM SAMPLE UNITS SURVEYED = 7
NUMBER OF ADDITIONAL SAMPLE UNITS SURVEYED = 0
RECOMMENDED MINIMUM OF 5 RANDOM SAMPLE UNITS TO BE SURVEYED.
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED = 3.7%
  
```

*** EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION ***

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
41 ALLIGATOR CR	LOW	28000.00 (SF)	56.00	64.4
48 L & T CR	LOW	2264.29 (LF)	4.53	13.7
52 WEATH/RAVEL	LOW	50000.00 (SF)	100.00	26.4
53 RUTTING	LOW	5714.29 (SF)	11.43	29.4
53 RUTTING	MEDIUM	6271.43 (SF)	12.54	45.5

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

	RELATED DISTRESSES =	PERCENT DEDUCT VALUES.
LOAD	77.65	PERCENT DEDUCT VALUES.
CLIMATE/DURABILITY	22.35	PERCENT DEDUCT VALUES.
OTHER	.00	PERCENT DEDUCT VALUES.

INSPECTION REPORT

```

=====
Network ID      - USWES
Branch Name     - RUNWAY
Branch Number   - RC-4
Section Number  - 1      Family - DEFAULT
Section Length  - 1000.00 LF
Section Width   - 50.00 LF
Section Area    - 50000.00 SF
=====
  
```

```

Inspection Date: JAN/25/1994
Riding Quality :      Safety:      Drainage Cond.:
Shoulder Cond. :      Overall Cond.:      F.O.D.:
  
```

```

-----
PCI OF SECTION = 27                                RATING = POOR
  
```

```

TOTAL NUMBER OF SAMPLE UNITS = 10
NUMBER OF RANDOM SAMPLE UNITS SURVEYED = 5
NUMBER OF ADDITIONAL SAMPLE UNITS SURVEYED = 0
RECOMMENDED MINIMUM OF 5 RANDOM SAMPLE UNITS TO BE SURVEYED.
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED = 5.5%
  
```

*** EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION ***

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
41 ALLIGATOR CR	LOW	17600.00 (SF)	35.20	57.8
48 L & T CR	LOW	1850.00 (LF)	3.70	11.8
52 WEATH/RAVEL	LOW	50000.00 (SF)	100.00	26.4
53 RUTTING	LOW	6400.00 (SF)	12.80	30.3

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

LOAD	RELATED DISTRESSES =	69.78 PERCENT DEDUCT VALUES.
CLIMATE/DURABILITY	RELATED DISTRESSES =	30.22 PERCENT DEDUCT VALUES.
OTHER	RELATED DISTRESSES =	.00 PERCENT DEDUCT VALUES.

INSPECTION REPORT

```

=====
Network ID      - USWES
Branch Name     - RUNWAY
Branch Number   - RC-5
Section Number  - 1      Family - DEFAULT
Section Length  - 1000.00 LF
Section Width   - 50.00 LF
Section Area    - 50000.00 SF
=====
  
```

```

Inspection Date: JAN/25/1994
Riding Quality :      Safety:      Drainage Cond.:
Shoulder Cond. :      Overall Cond.:      F.O.D.:
=====
  
```

PCI OF SECTION = 14

RATING = V. POOR

```

TOTAL NUMBER OF SAMPLE UNITS = 10
NUMBER OF RANDOM SAMPLE UNITS SURVEYED = 5
NUMBER OF ADDITIONAL SAMPLE UNITS SURVEYED = 0
RECOMMENDED MINIMUM OF 6 RANDOM SAMPLE UNITS TO BE SURVEYED.
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED = 5.7%
  
```

*** EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION ***

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
41 ALLIGATOR CR	LOW	8140.00 (SF)	16.28	48.5
41 ALLIGATOR CR	MEDIUM	810.00 (SF)	1.62	34.1
45 DEPRESSION	MEDIUM	1040.00 (SF)	2.08	22.2
48 L & T CR	LOW	7290.00 (LF)	14.58	28.5
50 PATCHING	LOW	1388.00 (SF)	2.78	6.9
52 WEATH/RAVEL	LOW	50000.00 (SF)	100.00	26.4
53 RUTTING	MEDIUM	14612.00 (SF)	29.22	55.9

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

```

LOAD          RELATED DISTRESSES = 62.29 PERCENT DEDUCT VALUES.
CLIMATE/DURABILITY RELATED DISTRESSES = 27.75 PERCENT DEDUCT VALUES.
OTHER         RELATED DISTRESSES = 9.96 PERCENT DEDUCT VALUES.
  
```

INSPECTION REPORT

```

=====
Network ID      - USWES
Branch Name     - RUNWAY
Branch Number   - RC-6
Section Number  - 1      Family - DEFAULT
Section Length  - 1800.00 LF
Section Width   - 50.00 LF
Section Area    - 90000.00 SF
=====
  
```

```

=====
Inspection Date: JAN/25/1994
Riding Quality :          Safety:          Drainage Cond.:
Shoulder Cond. :          Overall Cond.:      F.O.D.:
=====
  
```

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-----
PCI OF SECTION = 35                                RATING = POOR
  
```

```

TOTAL NUMBER OF SAMPLE UNITS = 18
NUMBER OF RANDOM SAMPLE UNITS SURVEYED = 5
NUMBER OF ADDITIONAL SAMPLE UNITS SURVEYED = 0
RECOMMENDED MINIMUM OF 15 RANDOM SAMPLE UNITS TO BE SURVEYED.
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED = 14.6%
  
```

*** EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION ***

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
41 ALLIGATOR CR	LOW	13536.00 (SF)	15.04	47.6
45 DEPRESSION	LOW	86.40 (SF)	.10	.3
48 L & T CR	LOW	7236.00 (LF)	8.04	20.4
52 WEATH/RAVEL	LOW	90000.00 (SF)	100.00	26.4
53 RUTTING	LOW	8640.00 (SF)	9.60	28.0
53 RUTTING	MEDIUM	2880.00 (SF)	3.20	32.7

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

```

LOAD          RELATED DISTRESSES = 69.73 PERCENT DEDUCT VALUES.
CLIMATE/DURABILITY RELATED DISTRESSES = 30.08 PERCENT DEDUCT VALUES.
OTHER         RELATED DISTRESSES = .19 PERCENT DEDUCT VALUES.
  
```

INSPECTION REPORT

```

=====
Network ID      - USWES
Branch Name     - RUNWAY
Branch Number   - RN-1
Section Number  - 1      Family - DEFAULT
Section Length  - 6000.00 LF
Section Width   - 50.00 LF
Section Area    - 300000.00 SF
=====
  
```

```

-----
Inspection Date: JAN/25/1994
Riding Quality :          Safety:      Drainage Cond.:
Shoulder Cond. :          Overall Cond.:      F.O.D.:
-----
  
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-----
PCI OF SECTION = 65                                RATING = GOOD
  
```

```

TOTAL NUMBER OF SAMPLE UNITS = 60
NUMBER OF RANDOM SAMPLE UNITS SURVEYED = 10
NUMBER OF ADDITIONAL SAMPLE UNITS SURVEYED = 0
RECOMMENDED MINIMUM OF 5 RANDOM SAMPLE UNITS TO BE SURVEYED.
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED = 5.0%
  
```

*** EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION ***

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
48 L & T CR	LOW	33840.00 (LF)	11.28	24.9
52 WEATH/RAVEL	LOW	300000.00 (SF)	100.00	26.4

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

LOAD	RELATED DISTRESSES =	.00 PERCENT DEDUCT VALUES.
CLIMATE/DURABILITY	RELATED DISTRESSES =	100.00 PERCENT DEDUCT VALUES.
OTHER	RELATED DISTRESSES =	.00 PERCENT DEDUCT VALUES.

INSPECTION REPORT

```

=====
Network ID      - USWES
Branch Name     - RUNWAY
Branch Number   - RS-1
Section Number  - 1      Family - DEFAULT
Section Length  - 1700.00 LF
Section Width   - 50.00 LF
Section Area    - 85000.00 SF
=====
  
```

Inspection Date: JAN/25/1994

Riding Quality : Safety: Drainage Cond.:
 Shoulder Cond. : Overall Cond.: F.O.D.:

 PCI OF SECTION = 68

RATING = GOOD

TOTAL NUMBER OF SAMPLE UNITS = 17
 NUMBER OF RANDOM SAMPLE UNITS SURVEYED = 8
 NUMBER OF ADDITIONAL SAMPLE UNITS SURVEYED = 0
 RECOMMENDED MINIMUM OF 5 RANDOM SAMPLE UNITS TO BE SURVEYED.
 STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED = .0%

*** EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION ***

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
48 L & T CR	LOW	5960.63 (LF)	7.01	18.7
52 WEATH/RAVEL	LOW	85000.00 (SF)	100.00	26.4

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

LOAD	RELATED DISTRESSES =	.00 PERCENT DEDUCT VALUES.
CLIMATE/DURABILITY	RELATED DISTRESSES =	100.00 PERCENT DEDUCT VALUES.
OTHER	RELATED DISTRESSES =	.00 PERCENT DEDUCT VALUES.

INSPECTION REPORT

```

=====
Network ID      - USWES
Branch Name     - RUNWAY
Branch Number   - RS-2
Section Number  - 1      Family - DEFAULT
Section Length  - 4000.00 LF
Section Width   - 50.00 LF
Section Area    - 200000.00 SF
=====
  
```

```

Inspection Date: JAN/25/1994
Riding Quality :      Safety:      Drainage Cond.:
Shoulder Cond. :      Overall Cond.:      F.O.D.:
=====
  
```

```

-----
PCI OF SECTION = 69                                RATING = GOOD
  
```

```

TOTAL NUMBER OF SAMPLE UNITS = 40
NUMBER OF RANDOM SAMPLE UNITS SURVEYED = 9
NUMBER OF ADDITIONAL SAMPLE UNITS SURVEYED = 0
RECOMMENDED MINIMUM OF 5 RANDOM SAMPLE UNITS TO BE SURVEYED.
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED = .0%
  
```

*** EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION ***

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
48 L & T CR	LOW	10555.56 (LF)	5.28	15.4
52 WEATH/RAVEL	LOW	200000.00 (SF)	100.00	26.4

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

```

LOAD RELATED DISTRESSES = .00 PERCENT DEDUCT VALUES.
CLIMATE/DURABILITY RELATED DISTRESSES = 100.00 PERCENT DEDUCT VALUES.
OTHER RELATED DISTRESSES = .00 PERCENT DEDUCT VALUES.
  
```

INSPECTION REPORT

```

=====
Network ID      - USWES
Branch Name     - TAXIWAY
Branch Number   - TW
Section Number  - 1      Family - DEFAULT
Section Length  - 375.00 LF
Section Width   - 90.00 LF
Section Area    - 33750.00 SF
=====
  
```

```

=====
Inspection Date: JAN/25/1994
Riding Quality :      Safety:      Drainage Cond.:
Shoulder Cond. :      Overall Cond.:      F.O.D.:
=====
  
```

```

-----
PCI OF SECTION = 24                                RATING = V. POOR
  
```

```

TOTAL NUMBER OF SAMPLE UNITS = 6
NUMBER OF RANDOM SAMPLE UNITS SURVEYED = 5
NUMBER OF ADDITIONAL SAMPLE UNITS SURVEYED = 0
RECOMMEND EVERY SAMPLE UNIT BE SURVEYED.
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED = 16.6%
  
```

*** EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION ***

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
41 ALLIGATOR CR	LOW	17145.00 (SF)	50.80	62.9
45 DEPRESSION	LOW	446.85 (SF)	1.32	8.4
48 L & T CR	LOW	168.75 (LF)	.50	4.1
50 PATCHING	LOW	1850.85 (SF)	5.48	10.5
52 WEATH/RAVEL	LOW	33750.00 (SF)	100.00	26.4
53 RUTTING	MEDIUM	2149.20 (SF)	6.37	38.6

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

```

LOAD          RELATED DISTRESSES = 67.36 PERCENT DEDUCT VALUES.
CLIMATE/DURABILITY RELATED DISTRESSES = 27.10 PERCENT DEDUCT VALUES.
OTHER         RELATED DISTRESSES = 5.54 PERCENT DEDUCT VALUES.
  
```

INSPECTION REPORT

```

=====
Network ID      - USWES
Branch Name     - FUEL PADS           Slab Length    -      25.00 LF
Branch Number   - FP                 Slab Width     -      20.00 LF
Section Number  - 1                  Family - DEFAULT Number of Slabs -      40
=====
  
```

```

Inspection Date: JAN/25/1994
Riding Quality :                      Safety:      Drainage Cond.:
Shoulder Cond. :                      Overall Cond.: F.O.D.:
-----
  
```

```

-----
PCI OF SECTION = 80                                RATING = V. GOOD
  
```

```

TOTAL NUMBER OF SAMPLE UNITS =      2
NUMBER OF RANDOM SAMPLE UNITS SURVEYED      =      2
NUMBER OF ADDITIONAL SAMPLE UNITS SURVEYED =      0
RECOMMEND EVERY SAMPLE UNIT BE SURVEYED.
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED =      .0%
  
```

*** EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION ***

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
63 LINEAR CR	LOW	18 (SLABS)	45.00	19.7

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

Mechanism	Related Distresses	Percent Deduct Values
LOAD	RELATED DISTRESSES = 100.00	PERCENT DEDUCT VALUES.
CLIMATE/DURABILITY	RELATED DISTRESSES = .00	PERCENT DEDUCT VALUES.
OTHER	RELATED DISTRESSES = .00	PERCENT DEDUCT VALUES.

INSPECTION REPORT

```

=====
Network ID      - USWES
Branch Name     - PARKING APRON
Branch Number   - PA
Section Number  - 1      Family - DEFAULT
Section Length  - 480.00 LF
Section Width   - 300.00 LF
Section Area    - 144000.00 SF
=====
  
```

```

Inspection Date: JAN/25/1994
Riding Quality :      Safety:      Drainage Cond.:
Shoulder Cond. :      Overall Cond.:      F.O.D.:
=====
  
```

```

-----
PCI OF SECTION = 49                                RATING = FAIR
  
```

```

TOTAL NUMBER OF SAMPLE UNITS = 5
NUMBER OF RANDOM SAMPLE UNITS SURVEYED = 5
NUMBER OF ADDITIONAL SAMPLE UNITS SURVEYED = 0
RECOMMEND EVERY SAMPLE UNIT BE SURVEYED.
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED = 13.1%
  
```

*** EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION ***

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
41 ALLIGATOR CR	LOW	23961.60 (SF)	16.64	48.8
48 L & T CR	LOW	15696.00 (LF)	10.90	24.4
50 PATCHING	LOW	460.80 (SF)	.32	2.1
52 WEATH/RAVEL	LOW	144000.00 (SF)	100.00	26.4

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

```

LOAD          RELATED DISTRESSES = 47.94 PERCENT DEDUCT VALUES.
CLIMATE/DURABILITY RELATED DISTRESSES = 52.06 PERCENT DEDUCT VALUES.
OTHER         RELATED DISTRESSES = .00 PERCENT DEDUCT VALUES.
  
```

Appendix B

DCP Test Results

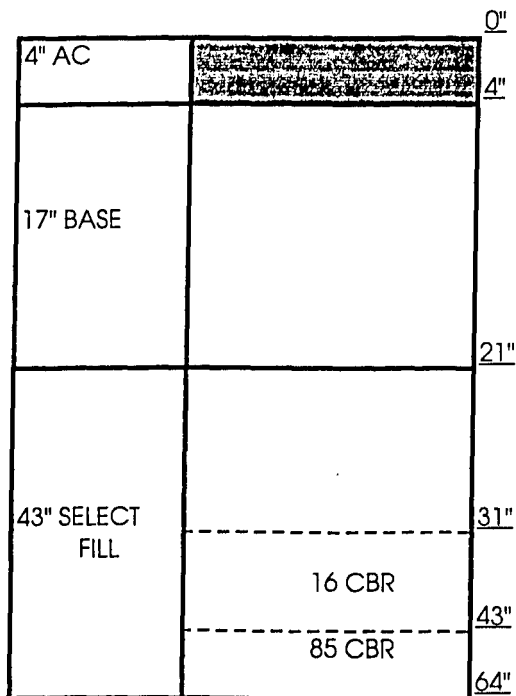
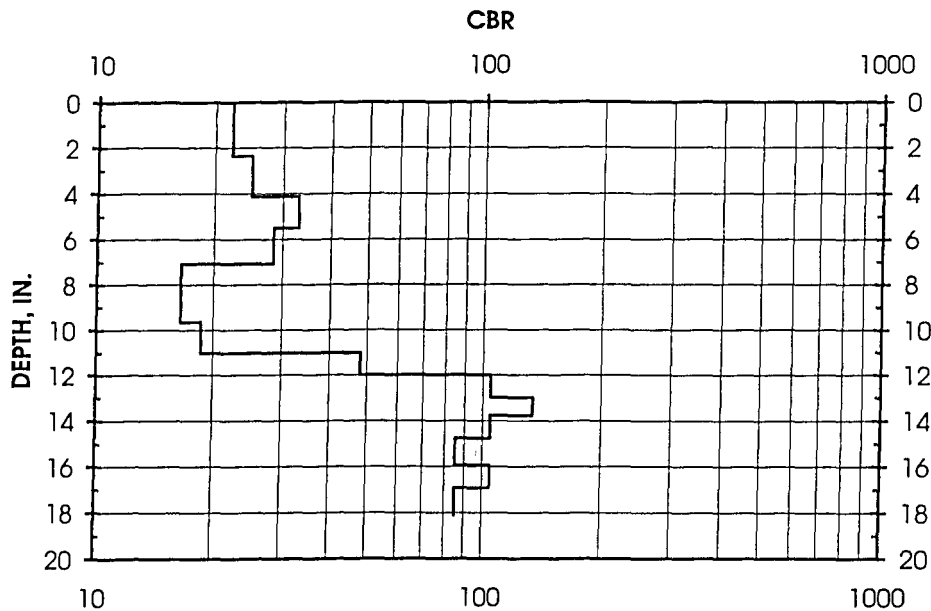
[illegible]

DCP DATA	
Project: YAP AIRFIELD	Date: Jan-94
Location: STA 34+25, 31"depth=0	Soil Type(s): CHRUSHED SCHIST SELECT FILL

Test 5: 7' N OF CL
Hammer: 1

No. of Blows	Accumulative Penetration
0	0
6	60
5	105
5	140
5	180
5	245
3	280
5	305
10	330
10	350
10	375
10	405
10	430
10	460

TEST RUN IN BOTTOM OF PIT 1, 0 = 31" DEPTH



DCP DATA

Project: YAP AIRFIELD

Date: Jan-94

Location: STA 39+60, PIT 2

Soil Type(s): CRUSHED SCHIST BASE AND SELECT FILL

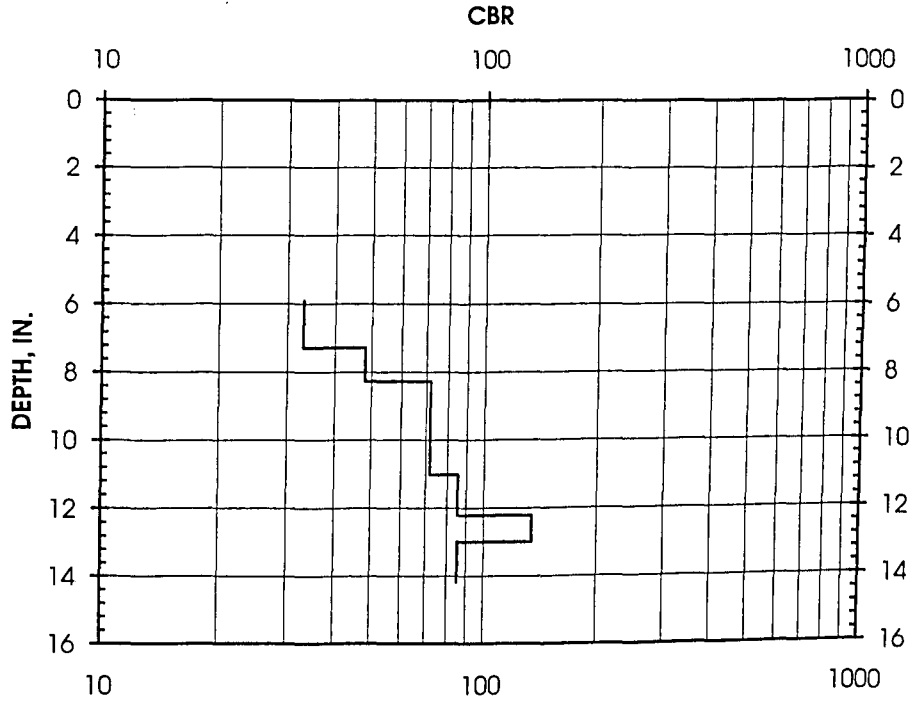
Test 6: 7' S OF CL

Note: Test run thru hole drilled in AC, 0 Depth = AC Surface

Hammer:

1

No. of Blows	Accumulative Penetration
0	150
5	185
5	210
10	245
10	280
10	310
10	330
10	360



4" AC		0"
17" BASE	? CBR	4"
	33 CBR	6"
		8"
	72 CBR	11"
	85 CBR	14"
43" SELECT FILL		21"
		64"

DCP DATA	
Project: YAP AIRFIELD	Date: Jan-94
Location: STA 39+60, PIT 2	Soil Type(s): CRUSHED SCHIST BASE AND SELECT FILL
Test 7: 7' S OF CL	Note: Test run thru hole drilled in AC, 0 Depth = AC Surface
Hammer: 1	

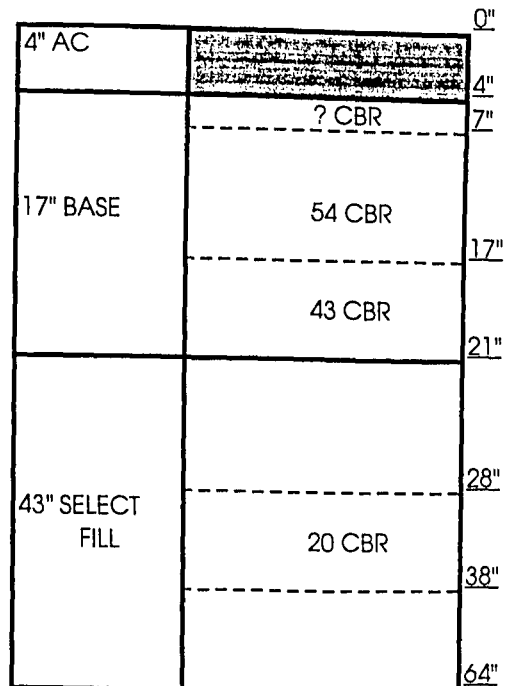
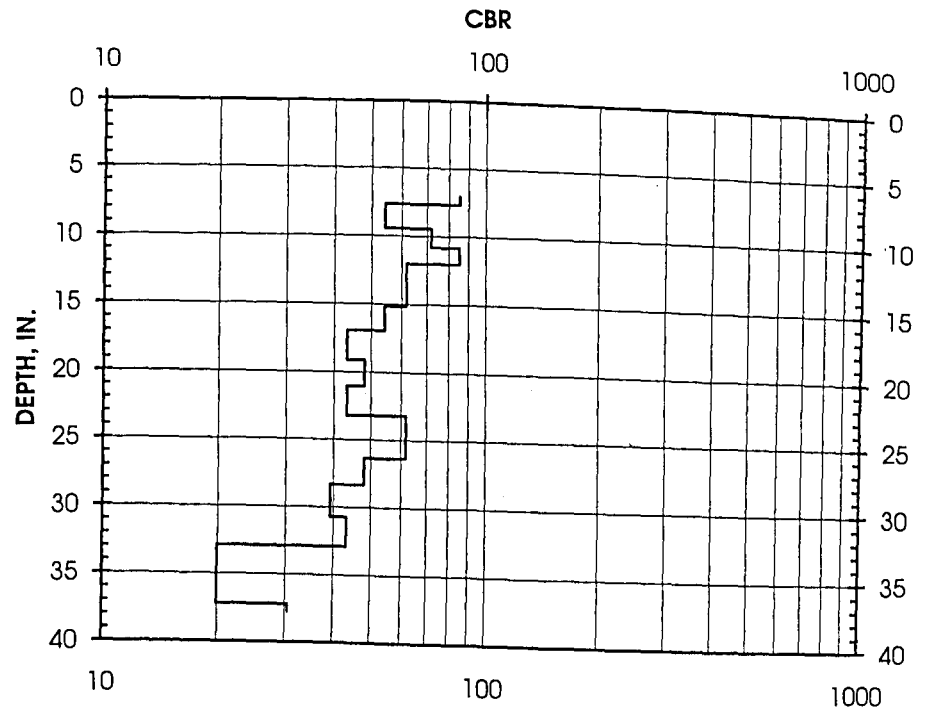
Date: Jan-94

Soil Type(s): CRUSHED SCHIST BASE AND SELECT FILL
Note: Test run thru hole drilled in AC - 25

Note: Test run thru hole drilled in AC, 0 Depth = AC Surface

No. of Blows	Accumulative Penetration
--------------	--------------------------

0	180
5	195
10	240
10	275
10	305
10	345
10	385
10	430
10	485
10	535
10	590
10	630
10	670
10	720
10	780
10	835
5	890
5	945
2	960



DCP DATA		Date: Jan-94	
Project: YAP AIRFIELD		Soil Type(s): CHRUSHED SCHIST SELECT FILL	
Location: Sta 39+50 PIT #2 0=27"			
Test 9: 2' S OF CL			
Hammer: 1			
No. of Blows	Accumulative Penetration		
0	15		
3	60		
3	80		
3	110		
3	140		
3	160		
3	185		
3	205		
3	225		
3	245		
3	270		
3	295		
3	320		
3	340		
3	360		
3	380		
3	400		
3	415		
3	435		
3	470		
3	500		
3	525		
3	545		
3	575		
6	635		
5	670		
5	700		
5	710		
5	720		
10	745		

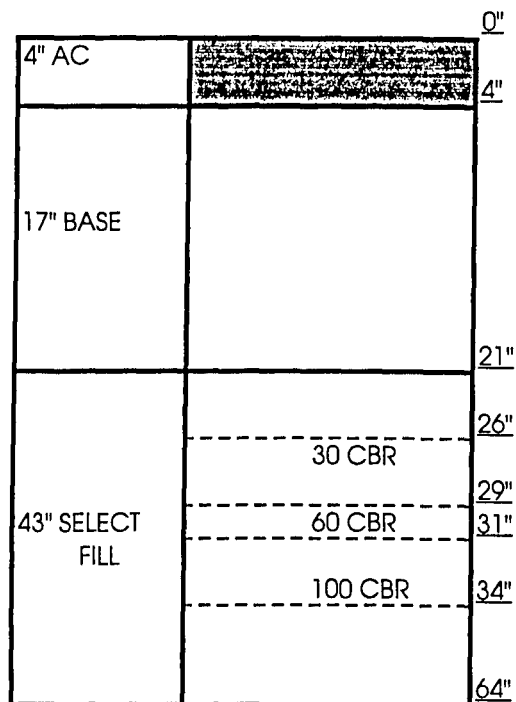
TEST RUN IN BOTTOM OF PIT 2, 0 = 27"

Layer	Depth (inches)	CBR
4" AC	0" - 4"	
17" BASE	4" - 21"	
43" SELECT FILL	21" - 27"	22 CBR
	27" - 33"	27 CBR
	33" - 44"	19 CBR
	44" - 52"	40 CBR
	52" - 64"	

[illegible]

[illegible]

No. of Blows	Accumulative Penetration
0	20
14	125
5	150
10	190
15	225
10	250
15	290
10	310



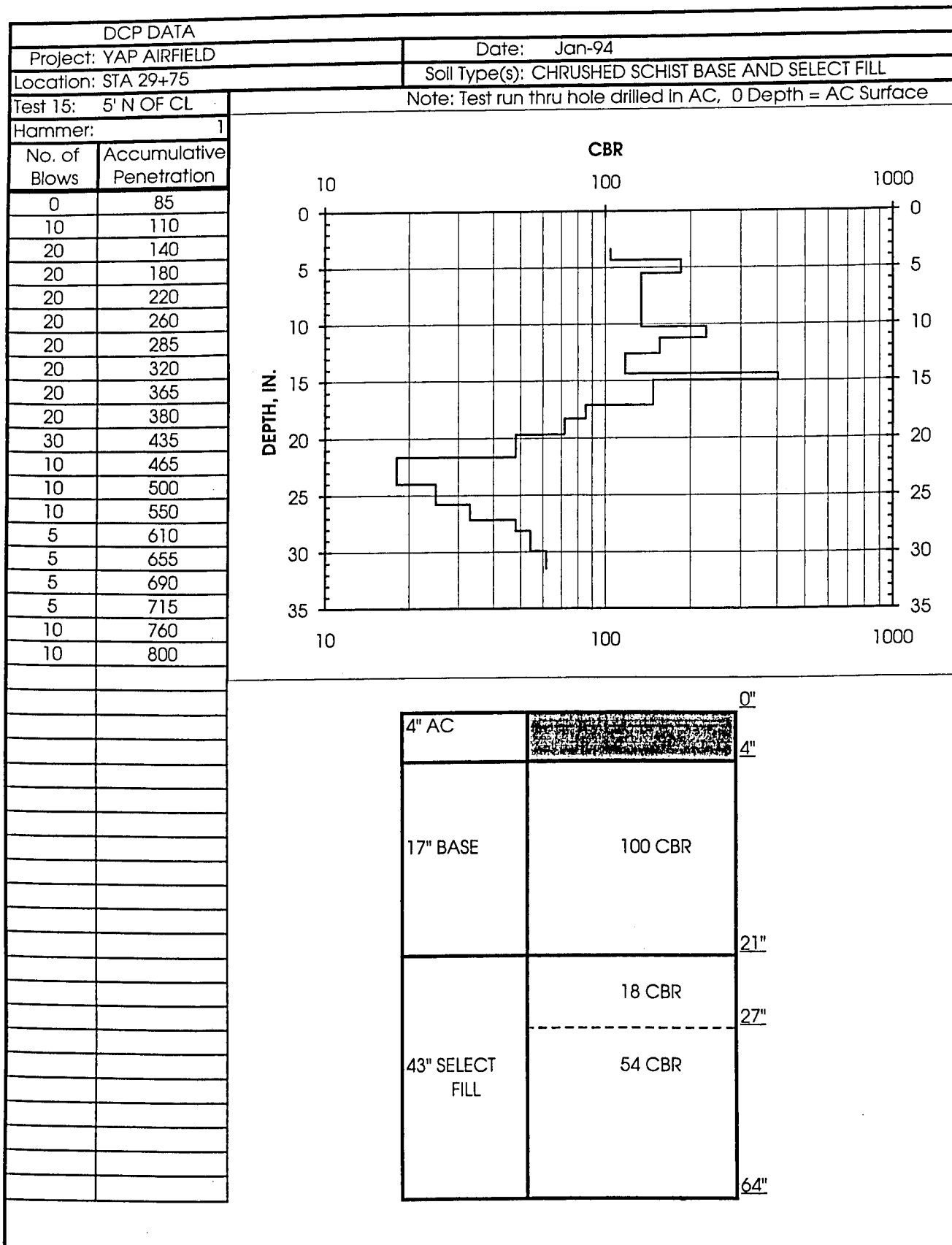
DCP DATA

Project: YAP AIRFIELD	Date: Jan-94
Location: STA 15+00, SEALED AREA	Soil Type(s): CRUSHED SCHIST BASE AND SELECT FILL
Test 12: 7' N OF CL	Note: Test run thru hole drilled in AC, 0 Depth = AC Surface
Hammer: 1	

No. of Blows	Accumulative Penetration
0	70
20	100
20	130
20	165
20	195
20	225
20	250
20	270
20	300
20	320
20	345
20	370
20	400
20	430
13	460
10	495
10	540
5	565
5	590
5	625
5	655
5	680
10	700
10	720
10	740
10	765
10	785
10	805
10	820
10	835

Depth (in)	CBR
0	100
1	100
2	100
3	100
4	100
5	100
6	100
7	100
8	100
9	100
10	100
11	100
12	100
13	100
14	100
15	100
16	100
17	100
18	100
19	100
20	100
21	100
22	100
23	100
24	100
25	100
26	100
27	100
28	100
29	100
30	100
31	100
32	100
33	100
34	100
35	100

Layer	Thickness (in)	CBR
4" AC	4"	100
17" BASE	17"	60
43" SELECT FILL	43"	33



DCP DATA		Date: Jan-94	
Project: YAP AIRFIELD		Soil Type(s): CHRUSHED SCHIST BASE AND SELECT FILL	
Location: STA 29+75		Note: Test run thru hole drilled in AC, 0 Depth = AC Surface	
Test 16: 68'S OF CL			
Hammer: 1			
No. of Blows	Accumulative Penetration		
0	75		
10	105		
10	120		
10	145		
10	160		
10	185		
10	200		
10	210		
10	235		
10	255		
10	280		
10	300		
10	325		
10	355		
10	385		
10	405		
10	435		
10	460		
10	485		
10	520		
5	540		
5	565		
5	585		
5	630		
5	650		
5	675		
5	685		
2	690		

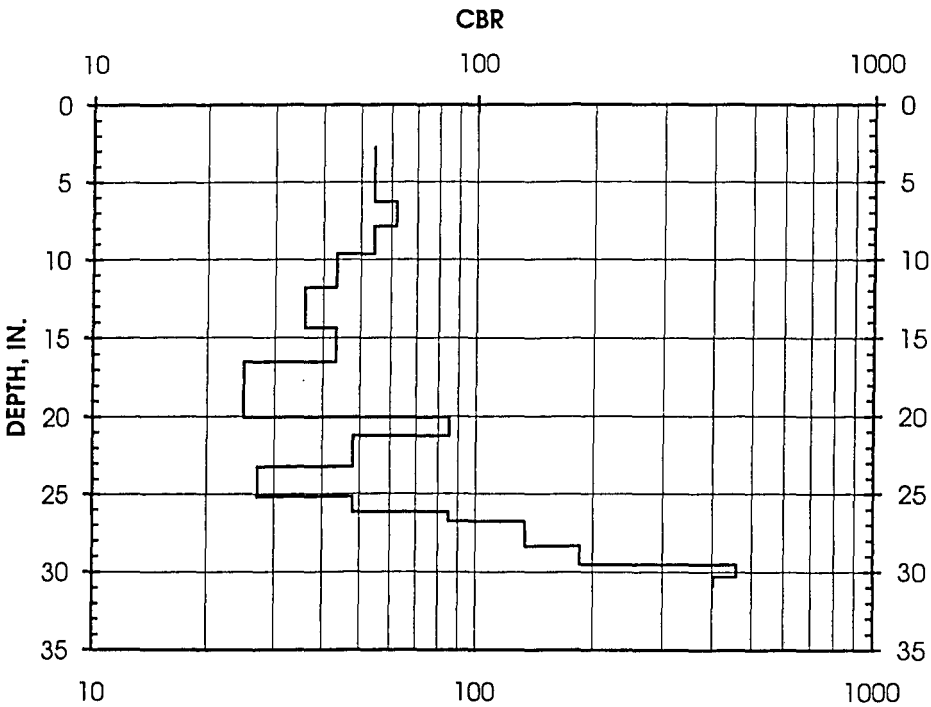
CBR

DEPTH, IN.

Depth (in)	Material	CBR
0" - 4"	4" AC	
4" - 19"	17" BASE	100 CBR
19" - 21"		62 CBR
21" - 25"		25 CBR
25" - 27"		48 CBR
27" - 64"	43" SELECT FILL	100 CBR

[illegible]

Test 19: 60' N OF CL	
Hammer	1

[illegible]

4" AC		
17" BASE	54 CBR	10"
	36 CBR	17"
	25 CBR	21"
43" SELECT FILL	48 CBR	23"
	27 CBR	25"
	48 CBR	27"
	100 CBR	31"
		64"

DCP DATA

Project: YAP AIRFIELD

Date: Jan-94

Location: STA 37+00 At Clogged Drain

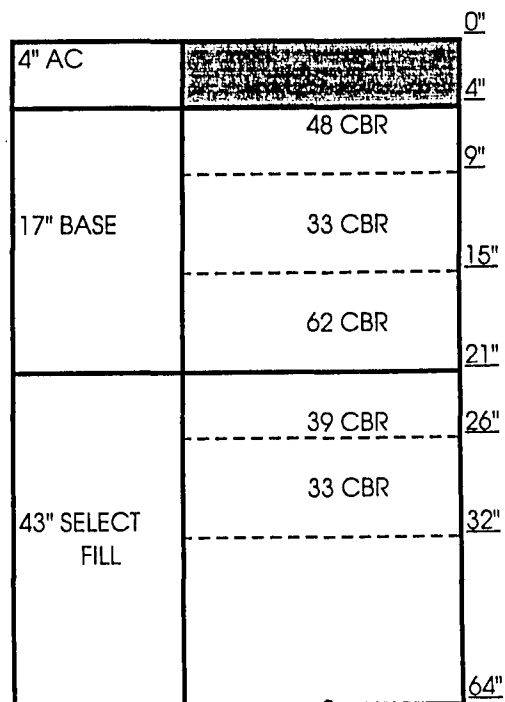
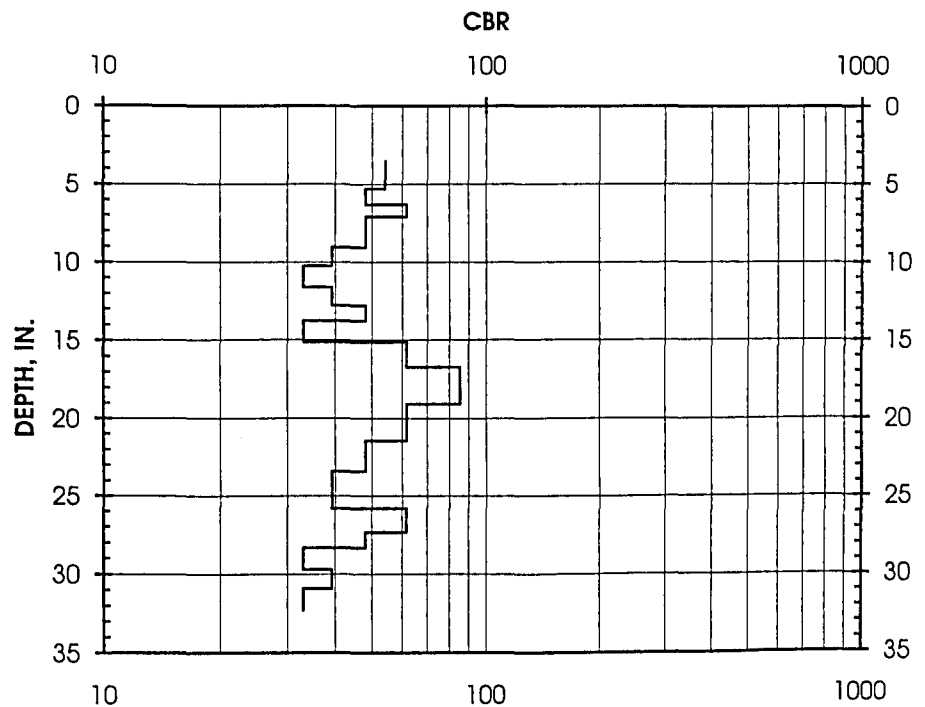
Soll Type(s): CHRUSHED SCHIST BASE AND SELECT FILL

Test 20: 65' S OF CL

Note: Test run thru hole drilled in AC, 0 Depth = AC Surface

Hammer: 1

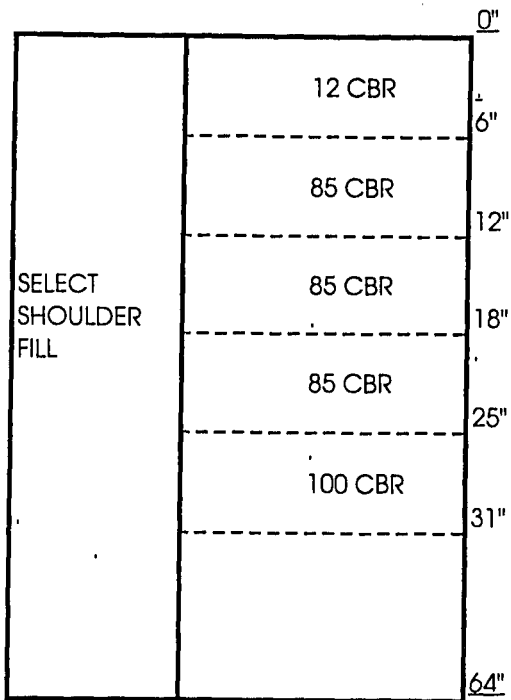
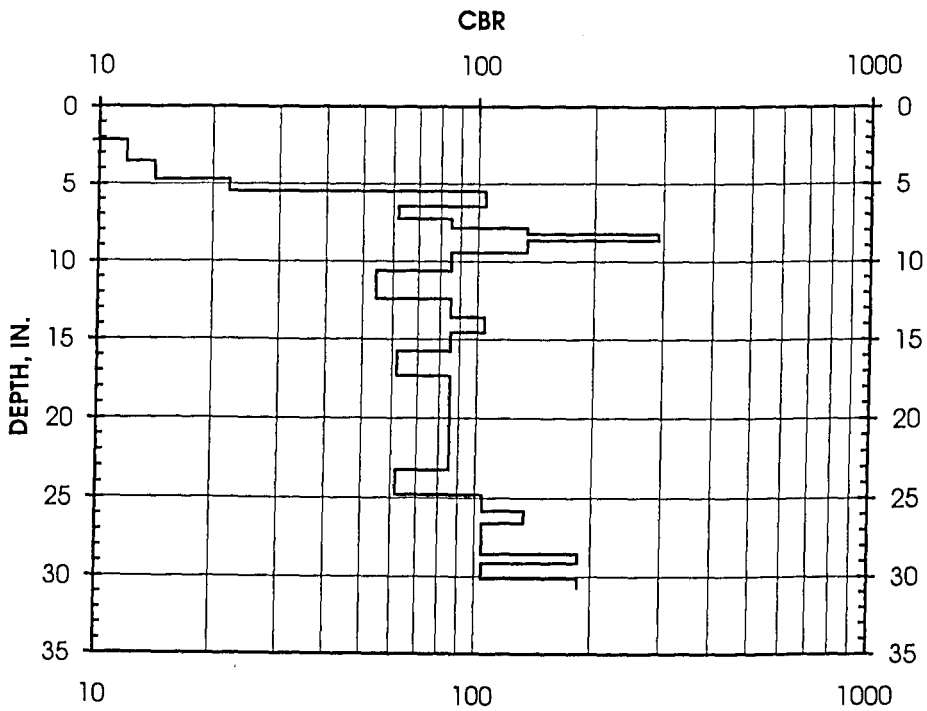
No. of Blows	Accumulative Penetration
0	90
10	135
5	160
5	180
5	205
5	230
5	260
5	295
5	325
5	350
5	385
10	425
10	455
10	485
5	505
10	545
5	570
5	595
5	625
5	655
5	675
5	695
5	720
5	755
5	785
5	820



[illegible]

DCP DATA	
Project: YAP AIRFIELD	Date: Jan-94
Location: STA 37+00 (SHOULDER)	Soil Type(s): CHRUSHED SCHIST SELECT FILL SHOULDER
Test 25: 10' OFF OF S RUNWAY EDGE, IN SHOULDER AREA	

Hammer: 1

[illegible]

DCP DATA

Project: YAP AIRFIELD

Date: Jan-94

Location: Taxiway STA 0+50 CL

Soil Type(s): CHRUSHED SCHIST BASE AND SELECT FILL

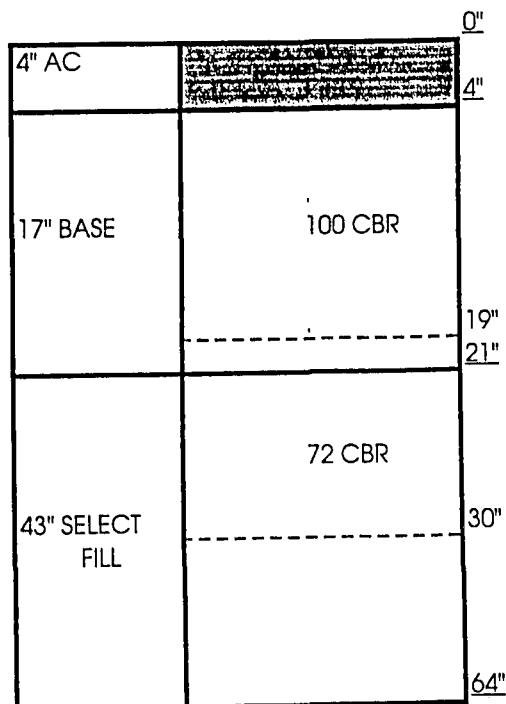
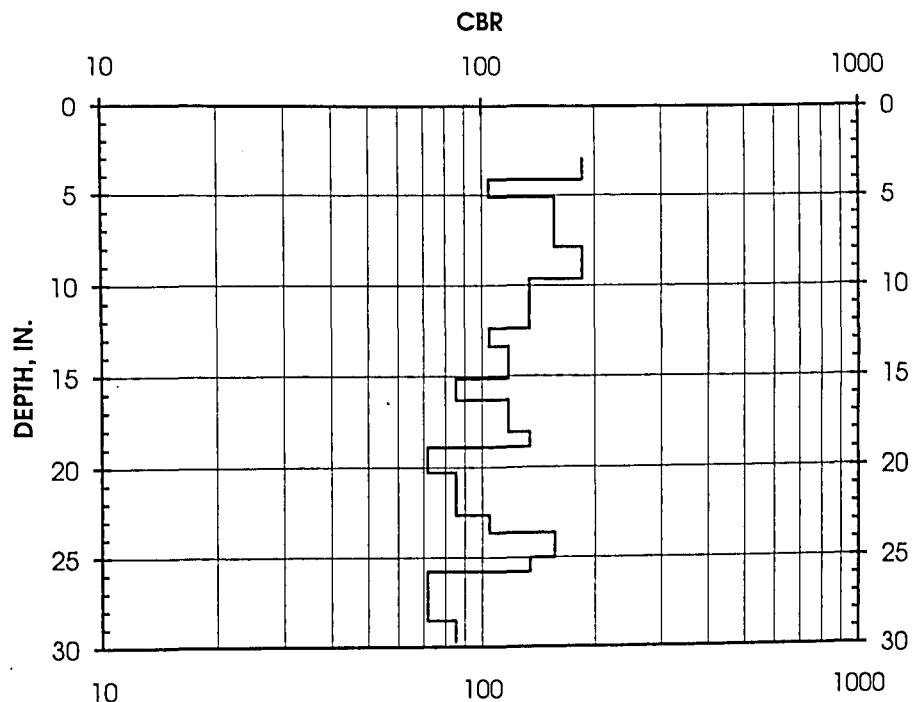
Test 26: 50' Off RW Edge In TW CL

Note: Test run thru hole drilled in AC, 0 Depth = AC Surface

Hammer:

7

No. of Blows	Accumulative Penetration
0	75
20	105
10	130
20	165
20	200
30	245
20	285
15	315
10	340
20	385
10	415
20	460
10	480
10	515
10	545
10	575
10	600
20	635
10	655
10	690
10	725
10	755



DCP DATA

Project: YAP AIRFIELD

Date: Jan-94

Location: Taxiway STA 2+00

Soil Type(s): CHRUSHED SCHIST BASE AND SELECT FILL

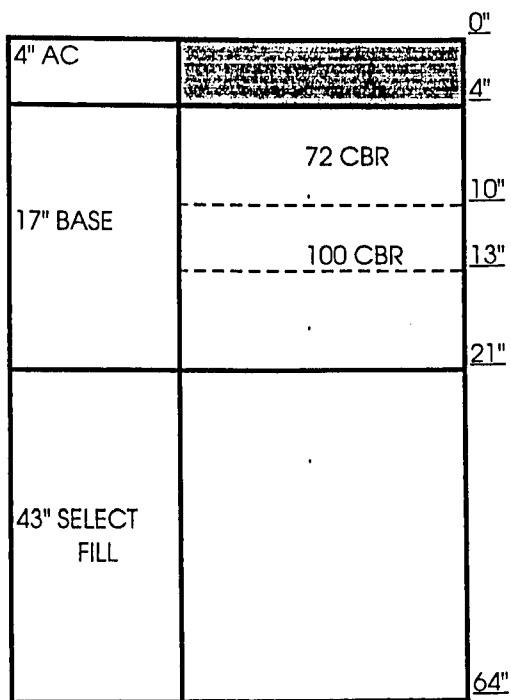
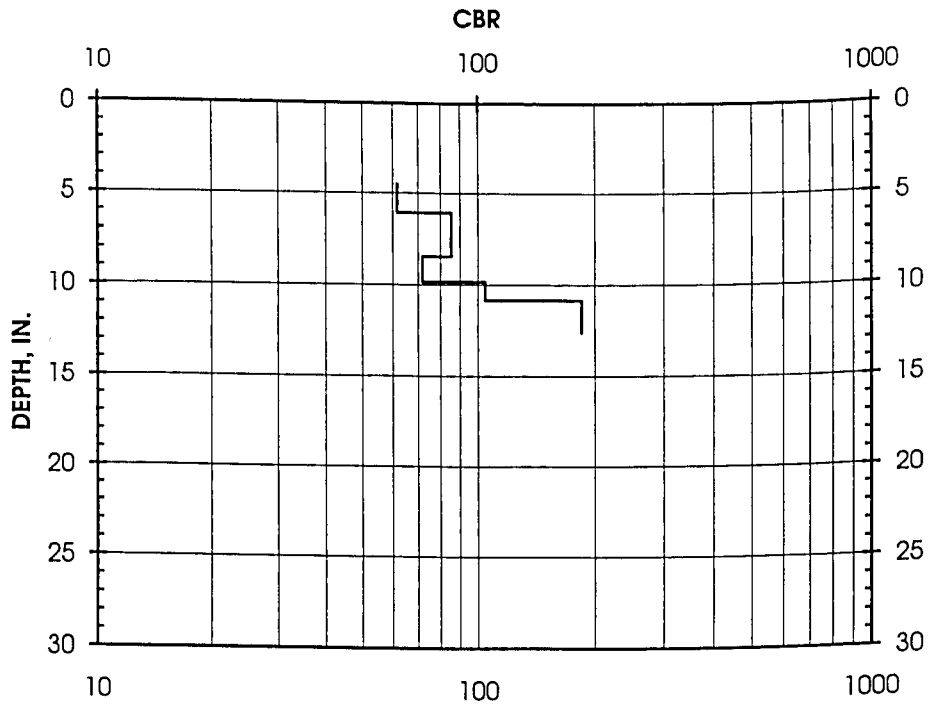
Test 27: 7'WOF CL

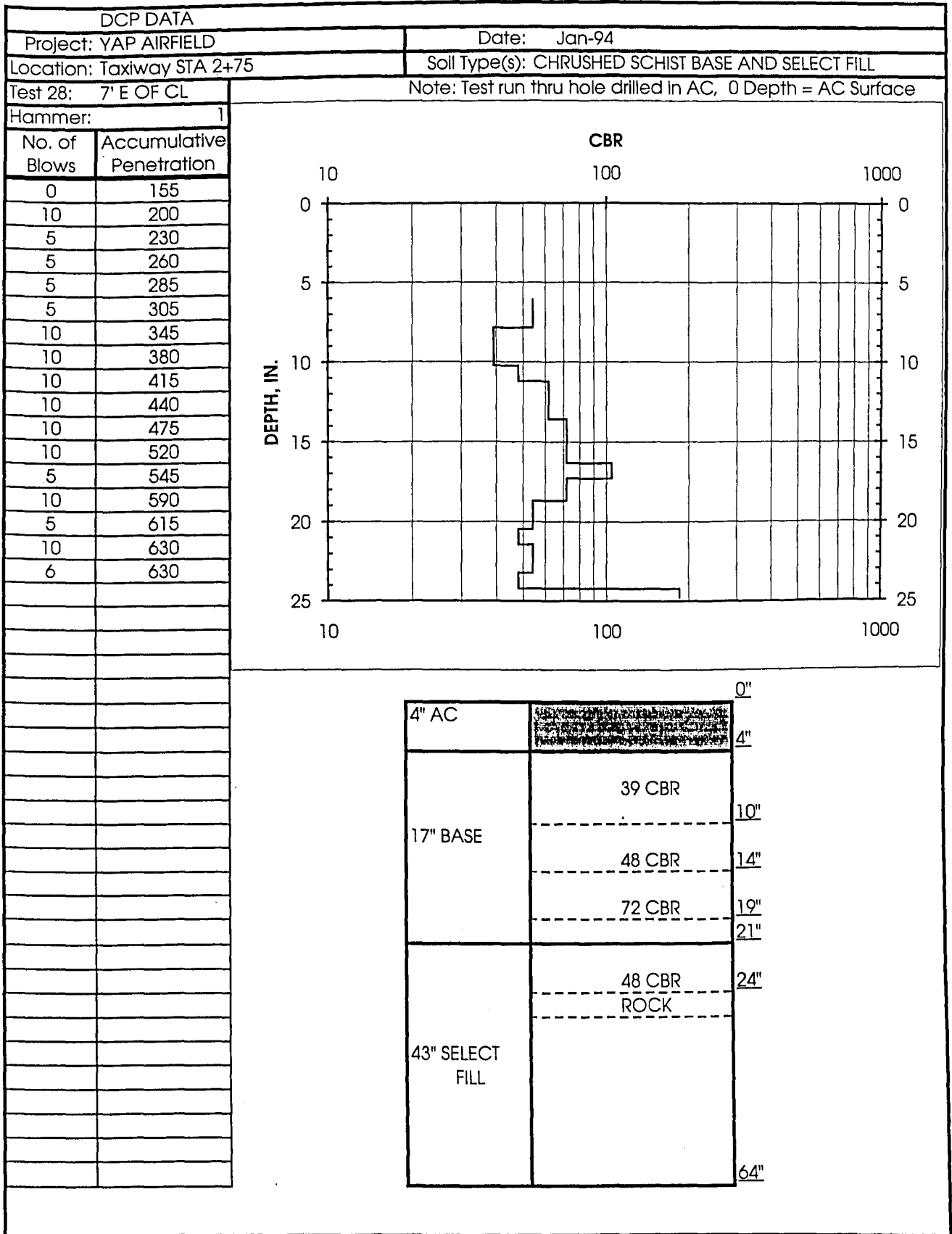
Note: Test run thru hole drilled in AC, 0 Depth = AC Surface

Hammer:

1

No. of Blows	Accumulative Penetration
0	115
10	155
10	185
10	215
10	250
10	275
10	290
10	305
10	320





[illegible]

DCP DATA

Project: YAP AIRFIELD

Date: Jan-94

Location: Parking Apron

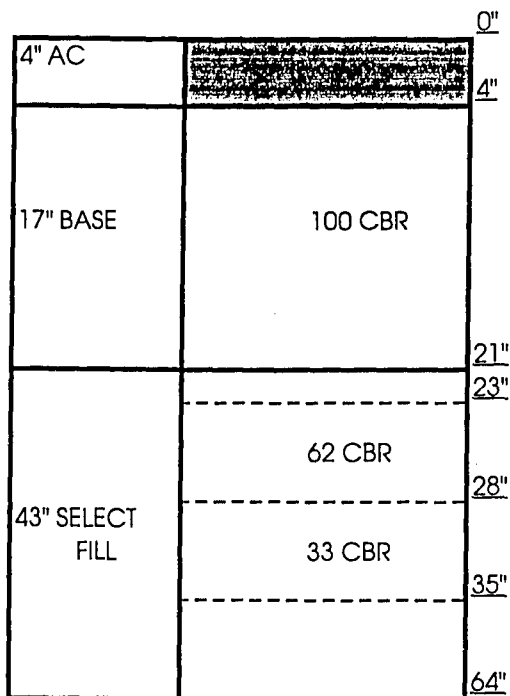
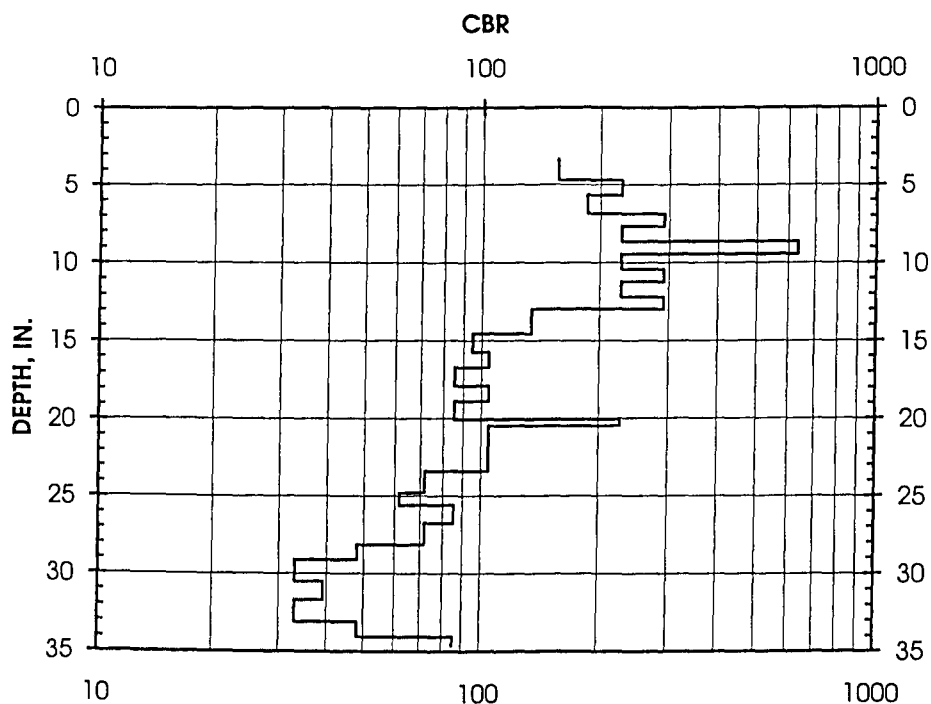
Soil Type(s): CHRUSHED SCHIST BASE AND SELECT FILL

Test 31: S W Corner

Note: Test run thru hole drilled in AC, 0 Depth = AC Surface

Hammer:

1

[illegible]

REPORT DOCUMENTATION PAGE

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13. ABSTRACT (Maximum 200 words) An airfield pavement investigation was performed in January 1994 at Yap International Airport, Yap Island, Federated States of Micronesia, to determine the causes of premature pavement failures. Field testing included a pavement condition survey, dynamic cone penetrometer (DCP) tests, in situ water content measurements, and a drainage investigation. Laboratory testing included gradation and asphalt content tests on the asphalt concrete, and sieve analysis, Los Angeles Abrasion, Atterburg limits, and soaked CBR-moisture-density compaction test on the select fill materials. Results of the evaluation found the pavements structurally inadequate to withstand the current traffic of the B-727-200. The cause of the poor condition of the pavements and the increasing failures are due to water in the base course. The base course material does not meet Federal Aviation Administration specifications because of too many fines passing No. 200 sieve and the plasticity index of the fines being too high. When water enters the base course, the California Bearing Ratio strength decreases from approximately 100 to 15. A clogged edge drain at Sta 37+00 probably accelerated the pavement failures by offering a ready supply of water to the base and select fill material. Recommendations for both short and long term repair of the airfield pavements are presented.				
14. SUBJECT TERMS See reverse.			15. NUMBER OF PAGES 93	
			16. PRICE CODE	
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14. (Concluded).

Airport traffic
Dynamic cone penetrometer
Gradation
Moisture content

Pavement condition survey
Pavement failure
Yap International Airport