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CONDITION SURVEYS OF PAVEMENTS SUBJECTED TO CHANNELIZED TRAFFIC, DAVIS-MONTHAN AIR FORCE BASE, TUCSON, ARIZONA

Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

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Preface

The purpose of this report is to present the results of a condition survey performed on taxiway 14, Davis-Monthan Air Force Base, in accordance with addendum 6 to Instructions and Outline, "Condition Survey for Existing Pavements." This report has been prepared for inclusion in a series of reports entitled Condition Surveys of Pavements Subjected to Channelized Traffic prepared in connection with research studies of flexible pavements.

The field work at Davis-Monthan Air Force Base was accomplished by a Waterways Experiment Station field party during June and July 1955. The party was composed of Messrs. P. J. Vedros and C. L. Rone, soils and pavement engineers, and Messrs. W. J. Harper, R. A. Andress, L. L. Steen, J. W. Loviza, D. M. Pennington, and C. L. Tisdell, soils technicians. This report was prepared by Mr. Rone. The investigation was performed under the general supervision of Messrs. W. J. Turnbull, C. R. Foster, O. B. Ray, and J. F. Redus.

Acknowledgment is made to the officers and men of Davis-Monthan Air Force Base and personnel of the Los Angeles District, Corps of Engineers, for their assistance and cooperation in the field studies.

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CONDITION SURVEYS OF PAVEMENTS SUBJECTED TO CHANNELIZED TRAFFIC

DAVIS-MONTHAN AIR FORCE BASE, TUCSON, ARIZONA

Introduction

1. This report presents the results of field and laboratory investigations conducted to obtain data regarding pavement conditions at Davis-Monthan Air Force Base. These investigations are part of a series of studies to determine the effect of channelized traffic on the various elements of flexible pavements. Davis-Monthan AFB was included in these investigations because taxiway 14 had shown signs of distress along the channelized traffic lane.

Previous investigations

2. Several previous investigations have been made of the Davis-Monthan pavements and the results published. The first investigation was reported by the Los Angeles District, CE, in Airfield Pavement Evaluation, Davis-Monthan Field, Tucson, Arizona, dated May 1944. The facilities built or reconstructed between 1944 and 1947 were also evaluated by the Los Angeles District and the results were published in a report entitled Airfield Pavement Evaluation, Addendum No. 1, Davis-Monthan Field, Tucson, Arizona, dated November 1947. The South Pacific Division Laboratory, Sausalito, California, performed tests on typical subgrade material for use in the design of improvements at the base and published the results in Report of Soil Tests on Disturbed Subgrade Sample, Davis-Monthan Air Force Base, dated March 1951. Results of tests performed by the South Pacific Division Laboratory on samples of base course, granular imported borrow, and select borrow materials from two locations on runway 6 and one location on taxiway 14 are published in Report of Soil Test on Samples from Completed Construction, Davis-Monthan Air Force Base, dated May 1952. Results of tests performed on disturbed and undisturbed materials from runway 6 and taxiway 14 were published by the South Pacific Division Laboratory in Report of Soil Tests, Pavement Evaluation,

Davis-Monthan Air Force Base, Tucson, Arizona, dated September 1952. A complete re-evaluation of facilities constructed prior to 1952 was made by the Waterways Experiment Station and the results were reported in Airfield Pavement Evaluation; Davis-Monthan Air Force Base, Tucson, Arizona, Technical Memorandum 3-344, Report 4, dated December 1953. The first report of distressed pavement on taxiway 14 was made by the Los Angeles District in Distressed Pavement Report, Davis-Monthan Air Force Base, Tucson, Arizona, dated December 1954. Pertinent data have been extracted from these reports and included herein.

Description of site and facilities

3. Davis-Monthan Air Force Base is located in Pima County approximately 2 miles east of Tucson, Arizona, on the Mexican Plateau which is surrounded by the Tucson Mountains on the northwest, Cat Mountains on the west, Torque Verde Mountains on the east, and the Santa Catalina Mountains on the northeast. The field is located physiographically in the Open Basin section of the Basin and Range province. The natural material at the base consists of sediments derived mainly from granitic and gneissic detritus. The sediments consist mainly of sand, gravel, and clay in various proportions with an appreciable filling of lime carbonate. The natural soil is usually classified as SC by the Unified Soil Classification System. The water table at the base is approximately 200 ft below the ground surface. The elevation of the field is about 2600 ft above mean sea level. The climate in the area is generally arid, summers being long and hot and winters short and cool. The average annual rainfall is approximately 12 in. Maximum and minimum temperatures reported are 111 and 15 F, respectively. Although freezing temperatures have been recorded, they are not of sufficient duration to cause detrimental frost action.

4. At the time of this investigation, the air base consisted of five facilities listed as runways with the necessary connecting taxiways, parking aprons, and warm-up aprons as shown on plate 1. Runways 1 through 3 were closed to all landings and take-offs but were being used for taxiing and parking of aircraft. Runway 5 was being used for parking of obsolete aircraft. All landings and take-offs were being made on runway 6, which is 200 ft wide and 11,500 ft long.

Construction history

5. Plate 1 includes a layout of all facilities, and typical sections of the various types of construction used together with construction dates for the facilities built between 1951 and 1955. The construction history for pavements built prior to 1951 is discussed in WES Technical Memorandum 3-344, Report 4, and will not be repeated in this report. Four phases of construction have been completed since 1951, as follows:

a. First phase, July 1951-December 1952. Flexible pavement was used in the first phase of construction on runway 6, taxiways 14 through 18, and warm-up aprons near each end of runway 6. Rigid pavement was used for the refueling stands.

b. Second phase, April 1953-July 1954. The portion of parking apron 1 adjacent to taxiway 14 was constructed of portland-cement concrete during this phase.

c. Third phase, May-November 1953. The flexible pavement facilities constructed during this phase were the extension to taxiway 14 near the alert aprons, taxiway 15A, the alert taxiway, and the alert aprons. Tar-rubber binding material (Surfa-aero-sealz and Flintbinder C-2) was used in the wearing course on alert aprons 1 and 2 and taxiway 14 between the alert aprons (detail "A," plate 1).

d. Fourth phase, 1954-1955. During this phase the southeast end of parking apron 1, the calibration hardstand, parking apron 3, the overlay on parking apron 2, and the extension of taxiway 14 adjacent to alert apron 2 were constructed of portland-cement-concrete pavement. At the time of this investigation, 25-ft-wide flexible pavement shoulders were being added to taxiways 10, 14, 15, 16, 17, and 18 but this new construction is not discussed in this report since it was incomplete.

Traffic data

6. Traffic data for the pavements constructed prior to 1951 are discussed in WES Technical Memorandum 3-344, Report 4, and will not be discussed in this report. No traffic data are available for the aircraft using the facilities between March 1952 and January 1953. After completion of the first phase of construction in December 1952 the field was converted to a jet bomber (B-47) base, and limited traffic records for 10 months since that time are available. These records indicate that during the 10 months runway 6 received approximately 200 cycles (one

landing and one take-off) of KC-97 (175,000-lb gross load) traffic per month and approximately 350 cycles of B-47 (180,000-lb gross load) traffic per month. A study of the lateral distribution of channelized traffic on taxiways indicated about 75 per cent of the B-47 traffic occurred in a lane 7.5 ft wide. Tire contact width for the B-47 tires averages 13.2 in. Since runway 6 is the only runway used for landings and take-offs and taxiway 14 is used by all aircraft using runway 6, the number of cycles of B-47 traffic on runway 6 can be converted to coverages of the central 7.5 ft of taxiway 14 as follows:

$$\text{Coverages} = \text{cycles}\ \frac{\text{percentage of traffic x No. tires x tire contact width}}{\text{width of traffic lane}}$$

Substituting the figures mentioned above in this equation,

$$\text{Coverages} = \text{cycles}\ \frac{(75\%\ \text{of}\ 4 \times 13.2)}{7.5 \times 12} = \text{cycles} \times 0.44\ .$$

Assuming the 10 months for which traffic records are available to be normal operating months, the 350 cycles of operations per month would indicate the taxiway had received approximately 10,500 cycles of operation between January 1953 and July 1955. Applying the above formula to the indicated cycles of operation gives 4600 coverages of B-47 traffic that have been applied to the center 7.5-ft lane on taxiway 14.

Description of Survey

Test locations

7. Field testing and sampling were performed in test pits at five locations (plate 1) along taxiway 14. The following tabulation lists the test locations and the reasons for their selection.

Pit No.	Location on Taxiway 14	Reason for Selection
1	On center line, 717 ft southwest of center line of taxiway 15	In channelized traffic lane; satisfactory area

(Continued)

Pit No.	Location on Taxiway 14	Reason for Selection
2	10 ft southwest of center line, 717 ft southeast of center line of taxiway 15	In area of little or no traffic, adjacent to area represented by test pit 1
3	12 ft southwest of center line; sta 58+36	In area of little or no traffic, adjacent to area represented by test pit 4
4	Center line; sta 58+36	In channelized traffic lane; area slightly deformed but pavement not cracked
5 (trench)	Sta 54+96; test trench extended across traveled lane into untraveled area	Area in channelized traffic lane badly rutted; area outside channelized traffic lane satisfactory

In-place testing and sampling

8. CBR (IU),* density, and moisture-content values were determined at the surface of the base course, surface of subbase, and surface of the subgrade, and density and moisture content were measured at approximately 1-ft intervals below the surface of the subgrade to a depth about 55 in. below the pavement surface. In-place tests were performed in the traveled lane and outside the traveled lane in test trench 5. A profile of test trench 5 is shown on plate 2. Detailed results of the in-place tests are summarized in table 1. Disturbed samples of base course, subbase, and subgrade, and cores and chunk samples of the pavement were obtained for laboratory testing. In addition to obtaining cores and chunk samples from test pit locations, cores for laboratory testing were obtained from the B-47 lane in an area of rich pavement at sta 33+00 on taxiway 14. Three cores of each type of tar-rubber pavement used on the alert aprons were taken for inspection purposes.

Laboratory testing

9. Pavement. The pavement at all test locations consisted of a wearing course and a binder course. The pavement was approximately 4 in. thick at all locations tested except test trench 5, where the pavement was about 3-1/4 in. thick in the traveled lane and about 5-1/4 in. thick outside the traveled lane (plate 2). The cored specimens were

* In-place unsoaked.

separated along the interfaces between the layers and tested for unit weight, Marshall stability, and flow; and the voids relationships were computed. Each layer of the cores was subjected to extraction tests to determine the percentage of asphalt. Gradation and specific gravity of the extracted aggregate were determined. Penetration, ductility, and specific gravity of specimens of recovered asphalt were determined. Chunk samples from test pit 1 were heated and recompacted at two compaction efforts, 50 and 75 blows. The recompacted specimens were then tested for unit weight, Marshall stability, and flow, and the voids relationships were computed. The results of the pavement tests are given in table 2. Gradations of the aggregates are shown in table 2 and on plates 3 and 4.

10. Base course. The base course was a crushed gravel containing appreciable amounts of sand and clay. Gradation and Atterberg limits of samples from test pit 1 and test trench 5 were determined and are shown on plate 5. Moisture-density-CBR relationships for the remolded soaked and unsoaked conditions at three compaction efforts were determined on samples from test pit 1 and are shown on plate 6. Specific gravity of the material from test pit 1 was determined. The results of the laboratory tests are summarized in table 3.

11. Subbase. The subbase material was a pit-run gravel containing varying amounts of sand and clay. Gradation and Atterberg limits values of samples from test pit 1 and test trench 5 were obtained and are shown on plate 7. Moisture-density-CBR relationships for the remolded soaked and unsoaked conditions at three compaction efforts were determined on samples from test pit 1 and are shown on plate 8. Specific gravity of material from test pit 1 was determined. The results of laboratory tests are shown in table 3.

12. Subgrade. The subgrade material at all locations tested was a clayey sand. Gradation and Atterberg limits of samples from test trench 5 were determined and are shown on plate 9 together with results for similar material from test pit 2 of the 1952 evaluation by WES. Other laboratory test data for samples from test pit 2 (1952) are used for analytical purposes. Moisture-density-CBR relationships from the

1952 evaluation are shown on plate 10. The results of laboratory tests are summarized in table 3.

Observations of pavement conditions

13. Surface conditions of the pavements on taxiway 14 were observed by WES personnel in June 1954, the beginning of the second summer of use. Minor deformation was noted along the center line over an area about 7 ft wide where, in addition to slight pavement rutting, the surface was bleeding, tire printing was pronounced, and excess asphalt was being picked up by plane tires. The most serious condition existed in one small area of taxiway 14 near the intersection with ladder taxiway 16 where slight rutting had occurred. There was no evidence of base course or subgrade distress in 1954.

14. In addition to conducting the in-place tests in 1955, the surface conditions of all the pavements were observed by WES personnel. Porpoising of B-47 planes on take-off had been reported by the Air Force but no surface irregularities that would cause this were located by visual inspection. Rectangular cracking with no apparent deformation (fig. 1) had occurred in an area about 3000 ft long on each end of the runway. A few rich areas were observed in the runway pavement and bleeding was occurring in those areas. An area about 150 ft long on the southeast

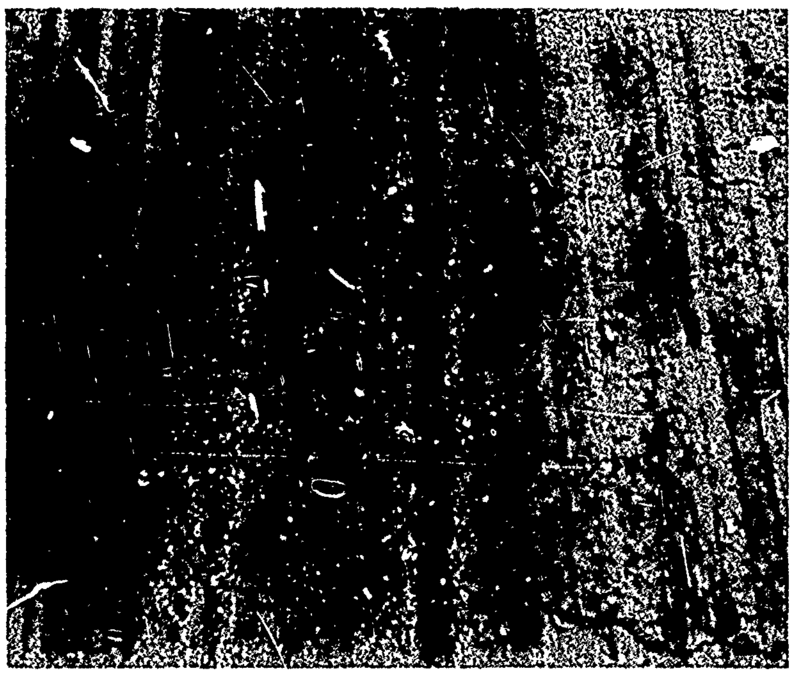

Fig. 1. Typical cracking on the ends of runway 6

end of the runway had been badly eroded by jet blast -- generally to a depth of about 1 in. Effects of jet blast were noted also on the northwest end of the runway but were not as severe as those on the southeast end. There was evidence of fuel spillage at various places on the warm-up aprons. Planes seldom stop in exactly the same position on warm-up aprons; therefore, repetitions of spillage on the same spot seldom occur. No pavement deterioration has occurred in these areas. The northwest warm-up apron showed tire printing due to rich asphaltic concrete. The entire length of taxiway 14 showed slight loss in grade in the traffic lanes as a result of channelized traffic of both B-47 and KC-97 planes. The loss in grade was generally less than 1/2 in. except in the most severe area of distress at test trench 5 where a loss in grade of about 2-1/2 in. and longitudinal cracking had occurred. The area represented by test trench 5 was about 100 ft long. The pavements completed prior to 1951 (runways 1 through 4) used for parking and taxiing of aircraft were showing distress due to overloading and fuel spillage. Effects of jet blast were noted along runway 1 in areas that were being used for parking and maintenance of aircraft. No distress was noted in the rigid pavements constructed since 1951. No cracks were noted in the northwest half of the alert aprons where Flintbinder C-2 had been used in the wearing course, but shrinkage cracks were observed in the southeast half of each alert apron and on taxiway 14 near these aprons where Surfa-aero-sealz had been used. The cracks appeared in the center of the construction lanes as well as along the construction joints (figs. 2 and 3). Cores taken in the cracked area of the alert aprons showed the cracks extending only through the wearing course where Surfa-aero-sealz was used.

15. The pavements were again inspected in October 1955 after the hot weather was over. A seal coat consisting of a fairly large amount of RC-2 and finely crushed aggregate had just been placed on taxiway 14 and runway 6. The seal was soft and bleeding. Tires were picking up the asphalt, spillage was damaging the seal, and blast was eroding the seal and the softened original pavement. The seal coat appeared entirely unsatisfactory from an operational standpoint. From the observations made over the 1-1/2-yr period from mid-1954 to late 1955. the slight pavement rutting observed in June 1954 apparently did not progress during

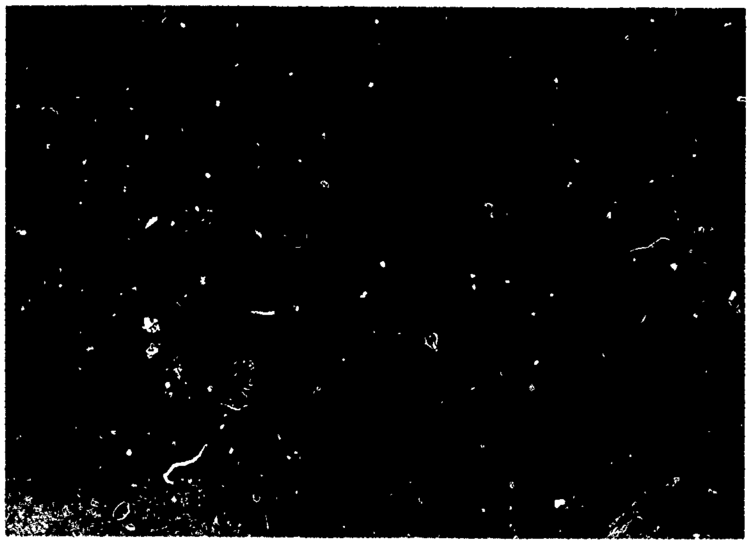

Fig. 2. Shrinkage cracks in center of construction lane in the Surfa-aero-sealz pavement on the alert aprons

Fig. 3. Cracking along the construction joints in the Surfa-aero-sealz pavement on the alert aprons

the summers of 1954 and 1955. One small area of severe distress (test trench 5) developed in the summer of 1955, but this was considered an unusual condition covering a relatively small area; it will be discussed later. Observations made in October 1955 revealed little progression of the cracking in the pavements containing Surfa-aero-sealz tar-rubber, but did show that one or two longitudinal cracks had appeared in the portion paved with Flintbinder C-2.

Analysis of Data

16. In this analysis, "traveled areas" are those used by the B-47 planes. A plot of CBR versus depth is presented on plate 11 for use in

analyzing data from the base, subbase, and subgrade. Plate 11 also includes the design curve in use for 100,000-lb assembly loads at the time these pavements were designed and, for comparison, a design curve prepared at a later date for channelized traffic areas. Plots of density versus depth showing in-place data and design requirements are presented on plate 12.

Pavement

17. The flexible pavement consists of hot-mix asphaltic concrete placed in two courses (1-1/2-in.-thick wearing and 2-1/2-in.-thick binder). Crushed granite aggregate was used in the wearing and binder courses. Comparison of the gradations shown on plates 3 and 4 indicates that the binder course aggregates are generally more coarsely graded than those in the wearing course. A complete summary of laboratory tests performed on the individual layers of the asphaltic concrete is given in table 2; for analytical purposes, data from field cores and laboratory specimens recompacted with 75 blows are shown in the following tabulation:

Pit	Asphalt Content %	Marshall Stability lb	Flow 1/100 in.	In-place Density Lb/cu ft	In-place Density % 75-blow Recomp	Voids Total Mix, %	Voids Filled with Asphalt, %
				Wearing Course			
				Cores			
1	6.7	1701	14	147.6	100.3	---*	----*
2	8.1	1573	13	146.2	99.4	---*	----*
3	6.8	1956	13	147.5	100.3	1.0	94.0
4	7.0	1942	15	146.7	99.7	1.3	92.5
5T**	6.8	1574	23	147.5	100.3	0.9	94.5
5U**	6.0	2222	13	147.6	100.3	1.9	87.9
				75-blow Recompaction			
1	6.3	2380	16	147.1	-----	1.9	88.3

(Continued)

* Asphalt flushed from the wearing course; voids relationships not applicable.

** T indicates portion of test trench in traveled lane; U indicates portion of test trench in untraveled area.

Pit	Asphalt Content %	Marshall Stability lb	Flow 1/100 in.	In-place Density Lb/ cu ft	In-place Density % 75-blow Recomp	Voids Total Mix, %	Voids Filled with Asphalt, %
				Binder Course			
				Cores			
1	5.6	1693	18	148.9	100.7	1.6	89.0
2	5.6	1227	17	147.8	100.0	2.4	84.3
3	5.0	1273	15	149.3	101.0	2.2	84.1
4	5.5	1715	20	149.7	101.3	1.2	91.4
5T	6.1	905	33	147.2	99.6	1.0	93.3
5U	5.4	1379	19	148.6	100.5	2.1	85.6
				75-blow Recompaction			
1	6.0	2605	14	147.8	-----	1.7	89.0

Analysis of the above data indicates that conditions are generally the same in the wearing course in both the traveled (pits 1, 4, and 5T) and untraveled (pits 2, 3, and 5U) areas. The data for the binder course showed about the same conditions in traveled and untraveled areas except for voids in the total mix and voids filled with asphalt. In the traveled areas voids averaged about 1.3% and voids filled averaged 91.2%; in the untraveled areas voids averaged 2.2% and voids filled 84.7%. Laboratory tests performed on the cored specimens indicated that at all locations tested, except the binder course in the traveled area of trench 5, the stability of the asphaltic concrete was above the 1000 lb required for high-pressure tires at the time of the design of these pavements. Flow values for the wearing course were all below the maximum allowable of 16 except for the traveled area of test trench 5; those for the binder course were higher than 16 except at test pit 3. Voids in the total mix were well below the minimum allowable of 3% for wearing courses and 5% for binder courses in both traveled and untraveled areas. Conversely, the voids filled with asphalt were well above the maximum allowable in all cases. Observation of the sawed face of the asphaltic concrete at test trench 5 indicated that the major part of the loss in grade at that location was due to movement in the binder course (plate 2). The movement in the binder course is believed to be partially due to low shear resistance between the binder course and the base course. About 1/8 in. of fine material had cemented together forming a hard, slick surface on the base course. Engineers at the field stated that this probably resulted from slush rolling. The prime did not penetrate this hard surface and, therefore, provided little bond to the base course. The stability of the rich binder course was not sufficient to resist movement when the temperature of the pavement became high during the summer months. No plastic flow was apparent in the wearing course.

18. Results of penetration and softening point tests made in 1954 and 1955, taken from the distressed pavement report previously referenced and table 2 of this report, are summarized below. Information was not available, but it is presumed that the penetration of the original asphalt was in the range of 85 to 100; no assumption can be made concerning its softening point.

	Wearing Course		Binder Course	
Year	Penetration 1/100 cm	Softening Point, °F	Penetration 1/100 cm	Softening Point, °F
1952	85-100 (assumed)	---	85-100 (assumed)	---
1954	62	120	46	127
1955	34	136	32	132

The penetration has decreased and the softening point increased with time for both wearing and binder courses.

Base course

19. The base course material consisted of crushed gravelly sand containing clay and was classified as SW-SC using the Unified Soil Classification System. The gradations shown on plate 5 indicate the material to be reasonably well graded. In-place CBR (IU) values at all locations tested were equal to or greater than the 80% required by design criteria in 1955, as seen on plate 11. The in-place density values in the traveled area were 98 or 99% of the modified maximum AASHO density of 137.1 lb/cu ft, as shown on plate 12, and in-place values in untraveled areas ranged from 95 to 101%; this indicates an increase in base course density in the traveled lane of about 3%. An increase in density of 3% would amount to about 0.2-in. loss in grade due to base course densification.

20. Tests by the field control laboratory during construction in 1952 showed that the material ranged from nonplastic to a plastic material with a plasticity index of 6%. Tests performed by the South Pacific Division Laboratory in 1952 for evaluation purposes indicated plasticity index values ranging from 8 to 12%. Results of tests performed by WES for this investigation showed plasticity index values of 8% for test pit 1 and 5% for test trench 5. The samples tested came from different portions of taxiway 14 and do not necessarily represent the same areas. Atterberg limits tests performed by WES were in accordance with the Manual for the Evaluation of Flexible Pavements in the Zone of Interior; it is not known which procedure was used by the Los Angeles District.

21. The test results discussed above indicate that the usual base course material encountered has appreciable plasticity, and it is believed that the material from test pit 1 is typical of much of the taxiway. The results of the laboratory CBR test (plate 6) indicate that this material is sensitive to change in molding moisture, but suffers only moderate loss of strength from soaking. The in-place moisture contents ranged from 1.3 to 4.1%, averaging about 2.7%. This is well below the modified AASHO optimum of about 6.0%.

Subbase

22. The subbase material was a pit-run gravelly sand containing clay (SC) and was fairly well graded, as shown on plate 7. Laboratory CBR tests indicated the subbase material to be sensitive to molding moisture and to suffer moderately high loss of strength on soaking (plate 8). In-place CBR (IU) values at all locations tested were about equal to or in excess of design requirements for dual-wheel assembly loads of 100,000 lb in nonchannelized traffic areas, as shown on plate 11. The in-place density values ranged from 97 to 99% of modified AASHO maximum density of 128.9 lb per cu ft in the traveled areas, and from 97 to 103% in the untraveled areas, as shown on plate 12. A comparison of the in-place densities in the traveled lane with the in-place densities in the untraveled areas indicates that no increase in density can be attributed to traffic. In-place moisture content values ranged

from 0.8 to 7.1%, which is well below the modified optimum of 8.1%. Atterberg limits values of the subbase material show that the plasticity index ranged from 10 to 17%. The profile of test trench 5 (plate 2) indicates no thickness differential between the traveled and untraveled areas.

Subgrade

23. The subgrade material was clayey sand which classified as an SC. Gradation curves for typical subgrade soils (plate 9) indicate the materials to be pebbly with considerable fines. Remolded CBR values for the soaked specimens (plate 10) showed a considerable loss in strength after soaking. Plate 11 shows that in-place CBR values were about equal to or in excess of the amount required by design criteria for dual-wheel loads of 100,000 lb in nonchannelized traffic areas. In-place density values at the surface of the subgrade ranged from 75 to 84% of modified maximum AASHO density in the traveled areas and from 85 to 91% in the untraveled areas, as seen on plate 12. Average density values at 1 and 2 ft below the surface of the subgrade were 73 and 70% of modified maximum density, respectively. A comparison of the density values obtained in the traveled lane and those obtained outside the traveled lane indicates that traffic had not densified the subgrade material. From table 1 it may be seen that in-place moisture contents at the surface of the subgrade ranged from 4.9 to 8.3% in the traveled areas and from 6.3 to 13.6% in the untraveled areas; modified AASHO optimum is 8.8%. The average moisture contents at 1 and 2 ft below the surface of the subgrade were 7.6 and 8.1%, respectively (table 1). The profile of test trench 5 shown on plate 2 indicates that no loss in grade has occurred in the subgrade.

Discussion of Findings

Pavement

24. Analysis indicates that traffic has tended to decrease the voids in the binder course. The average amount of decrease in voids in this course was about 0.9% which reduced the voids very nearly to those found in the wearing course. Examinations showed the movement to have

taken place in the binder course. This indicates that the binder material reached a critical condition at a higher void content than the wearing course. The slightly coarser gradation of the binder course aggregate or slight variations in the grading of the two aggregates may account for this. No movement was noted during the first summer of usage, but movement was observed during the first hot weather of the second summer. It is possible that more than a year's traffic was required to reduce the voids to the critical condition. It is considered of particular significance that no further general movement occurred in the two ensuing summers, which is believed to result from the asphalt having hardened sufficiently by the middle of the second summer to withstand the imposed loads. This is indicated by the marked decrease in penetration values for both wearing and binder courses and the increase in softening point.

Base course and subbase

25. Observations and tests indicated that the base and subbase courses were satisfactory under the imposed loads for the existing conditions. However, this cannot be construed as a completely satisfactory condition because the densities were generally lower than the minimum required and the moisture contents were well below optimum. An increase in moisture content to about optimum would probably permit additional densification. If the moisture content increases to more than modified AASHO optimum, a rapid decrease in strength will be produced, as evidenced by the laboratory curves on plates 6 and 8. This almost surely would be critical in the base course and the subbase.

Subgrade

26. In-place moisture contents in the traveled lanes were below modified AASHO optimum, but some of the values for untraveled areas were well above optimum. In-place CBR values were well above those required by the CBR curves in all cases. The two locations with moisture contents above modified AASHO optimum (11.1 and 10.7%) had in-place density values of 111.5 and 119.4 lb per cu ft, respectively. When compared to the curves on plate 10, the in-place conditions lie to the dry side of the line of optimum moisture contents. This explains the fact that about the same CBR values were found in the areas of higher moisture content as in drier

areas. No explanation was found for the apparently high in-place CBR values as compared to laboratory values for the same conditions.

In-place CBR versus depth

27. A comparison of the in-place CBR values with the design curve for nonchannelized traffic on plate 11 shows that three points fall on the curve and the remainder are well below it. Comparison of the points with the curve for channelized traffic areas shows that three points are appreciably above the line, two fall about on the curve, and the remainder lie well below the curve. From this analysis it appears that a few areas may be approaching a critical condition, and could cause trouble if the moisture content increased. Most of the points represent conditions of ample strength; however, it should be noted that the materials are at low moisture content and that an increase in moisture content could cause a drop in strength. The points fall on or below the curve for nonchannelized traffic and, although some of the points represent channelized areas, no distress was found in the base course, subbase, or subgrade. Although the curve for channelized traffic areas indicates that some areas should have evidenced distress, it may be that the planes operate at assembly loads above 100,000 lb so infrequently that the effects of overloads are not evidenced.

In-place density versus depth

28. As has been pointed out, traffic appeared to densify the base course slightly, but construction density in the other layers appeared to be generally adequate for the traffic imposed on the material in this dry condition. A comparison of the in-place values with the design requirements on plate 12 shows that density values in the traveled lanes follow the design requirements quite closely to a depth of about 15 in. Below this the in-place values are considerably lower than required. The design requirements were exceeded in only one instance and that in an untraveled area. From the observations made it appears that the density values shown for the traveled areas are adequate for the materials at the existing low moisture contents and under the imposed traffic. An increase in moisture content to about optimum would almost certainly permit considerable additional densification.

Significant Facts and Postulates

29. The following significant facts are believed warranted from the investigation of pavement conditions on taxiway 14 at Davis-Monthan.

a. Observed movement occurred mainly in the asphaltic concrete binder course.

b. Void content of the binder course was relatively lower with respect to the minimum allowable than that of the wearing course.

c. Base and subbase layers were in a satisfactory condition at the time of the survey (July 1955), but are subject to future decreases in strength with increase in moisture content.

d. In-place density values produced by traffic were about equal to design requirements to a depth of about 15 in. but were considerably less than design requirements below 15 in. They appeared adequate for the existing low moisture contents and imposed traffic.

e. Although a few points fell on the unsafe side of the design curve in the channelized traffic area, the base course, subbase, and subgrade appeared adequate for the existing conditions and channelized traffic imposed.

30. The following postulations are also believed warranted.

a. Movement after the second summer apparently was prevented by hardening of the asphalt due to aging, as evidenced by decreased penetration and increased softening point.

b. Base and subbase materials have excessive plasticity and are considered critical.

Table 1

In-place Soil Tests

(Results of Individual Tests)

FACILITY	TEST PIT NO.	TEST LOCATION	PAVEMENT THICK IN	PAVEMENT DESCRIPTION	PAVEMENT FLEX STR PSI	BASE THICK IN	BASE LL	BASE PI	BASE DESCRIPTION	BASE DEPTH OF TEST FR SFC IN	BASE IN PLACE CBR	BASE IN PLACE MOISTURE %	BASE IN PLACE DENSITY LB/CU FT	SUBGRADE LL	SUBGRADE PI	SUBGRADE CLASSIFICATION	SUBGRADE DEPTH OF TEST FR SFC IN	SUBGRADE IN PLACE CBR	SUBGRADE IN PLACE MOISTURE %	SUBGRADE IN PLACE DENSITY LB/CU FT	REMARKS
Taxiway 14	1	Sta 7+17, ℄ of taxiway 14	4	Asphaltic concrete		8	25	8	SW-SC, clayey gravelly sand	4	122 155 140 142	2.5 3.0 --- 2.8	135.3 134.4 ----- 134.9	24	10	SC, clayey sand	31-1/2	33 37 34 33	7.9 8.2 8.3 8.1	101.6 104.7 106.0 104.0	
						9-1/2	39	17	Subbase SC, clayey gravelly sand	12	106 87 97 97	7.1 7.1 --- 7.1	127.7 120.8 ----- 120.3	--	--	SC, clayey sand	43	-- -- -- --	7.2 7.3 7.2 7.3	89.7 84.9 [illegible] [illegible]	
						10	--	--	Fill Gravel and sand	21-1/2	40 50 45 45	3.8 3.6 --- 3.7	119.7 120.7 ----- 120.2	32	16	SC, clayey sand	55	-- -- -- --	4.9 6.7 7.8 6.8	87.7 87.3 91.4 88.1	
Taxiway 14	2	Sta 7+17, 10 ft SW of ℄ of taxiway 14	4	Asphaltic concrete		6-1/2	--	--	SW-SC, clayey gravelly sand	4	84 102 90 92	3.1 2.8 --- 3.0	127.4 133.9 ----- 130.7	--	--	SC, clayey sand	31	40 34 43 39	13.6 9.6 10.1 11.1	112.4 102.6 114.6 111.5	
						20-1/2	--	--	Subbase SC, clayey gravelly sand	10-1/2	97 78 86 87	5.1 4.1 --- 4.6	129.6 125.6 ----- 127.6	--	--	SC, clayey sand	43	-- -- -- --	7.7 9.6 9.3 9.3	95.4 99.1 93.2 95.9	
														--	--	SC, clayey sand	55	-- -- -- --	9.1 8.6 7.9 8.5	85.1 91.6 87.9 88.2	
Taxiway 14	3	Sta 56+30, 12 ft SW of ℄	4	Asphaltic concrete		10	--	--	SW-SC, clayey gravelly sand	4	63 77 60 70	4.1 3.4 --- 3.8	136.5 124.3 ----- 130.4	--	--	SC, clayey sand	27	44 32 40 39	10.7 11.3 10.2 10.7	121.5 118.0 119.1 119.4	
						13	--	--	Subbase SC, clayey gravelly sand	14	34 34 21 25 29	4.0 4.5 --- --- 4.3	125.3 123.5 ----- ----- 124.4	--	--	SC, clayey sand	39	-- -- -- --	10.1 10.5 10.4 10.3	109.1 109.6 102.4 107.4	
														--	--	SC, clayey sand	51	-- -- -- --	12.6 13.5 11.2 13.1	94.8 92.0 96.7 95.0	

WES FORM NO. 778 REVISED MAR 1953   121955A

(1 of 3 sheets)

Table 1 (Continued)

Facility	Test Pit No	Test Location	Pavement Thick in.	Pavement Description	Flex Str psi	Base Thick in.	LL	PI	Base Description	Depth of Test fr Sfc in.	Base In Place CBR	Base In Place Moisture %	Base In Place Density lb/cu ft	Subgrade LL	Subgrade PI	Subgrade Classification	Depth of Test fr Sfc in.	Subgrade In Place CBR	Subgrade In Place Moisture %	Subgrade In Place Density lb/cu ft	Remarks
Taxiway 14	4	Sta 58+36 ℄	5	Asphaltic concrete		9	--	--	SW-SC, clayey gravelly sand	5	64 102 92 93	2.4 3.0 --- 2.7	139.5 129.6 ----- 134.6	--	--	SC, clayey sand	26	14 14 13 14	6.8 6.7 6.7 6.7	101.0 90.0 95.0 95.3	
									Subbase												
						12	--	--	SC, clayey gravelly sand	14	57 49 43 52	3.3 3.3 --- 3.3	124.5 120.6 ----- 120.6	--	--	SC, clayey sand	30	-- -- -- --	7.1 6.0 6.9 6.9	98.7 91.0 90.5 91.6	
														--	--	SC, clayey sand	50	-- -- -- --	6.3 5.8 5.2 6.0	93.2 93.0 91.0 92.8	
Taxiway 14	5	Sta 54+96 (trench)		*Untraveled*																	
			5-1/4	Asphaltic concrete		6	22	5	SW-SC, clayey gravelly sand	7	170 166 166+ 151	1.6 1.3 2.0 1.6	140.0 130.9 139.6 139.0	20	11	SC, clayey sand	33	42 41 35 -- 39	6.3 7.1 7.4 7.4 7.1	110.2 109.6 114.0 114.2 114.2	
									Subbase												
														--	--	SC, clayey sand	48	-- -- -- --	6.2 6.7 6.6 6.5	91.9 90.9 91.7 91.5	
						21	25	10	SW-SC, clayey gravelly sand	12	151 106 103 120	2.3 1.4 2.2 2.0	136.6 120.0 135.1 133.5								
														--	--	SC, clayey sand	56	-- -- -- --	8.1 8.4 8.2 8.2	88.1 94.0 90.0 91.0	
				Traveled																	
			3-1/4	Asphaltic concrete		6	22	5	SW-SC, clayey gravelly sand	4	166+ 166+ 166+ 166+	2.2 1.9 --- 2.1	136.2 135.0 ----- 135.6	20	11	SC, clayey sand	32	31 24 31 29	5.6 4.9 5.8 7.7 6.0	109.4 113.2 106.4 109.7 109.7	
									Subbase												
						22	25	10	SW-SC, clayey gravelly sand	10	83 93 163 166+ 126	1.6 0.8 --- --- 1.2	127.2 123.6 ----- ----- 125.4	--	--	SC, clayey sand	44	-- -- -- --	5.9 5.3 5.0 5.7	90.6 92.7 90.0 91.1	
														--	--	SC, clayey sand	56	-- -- -- --	6.8 5.6 6.1 6.2	87.6 89.0 88.2 88.5	

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(2 of 2 sheets)

Table 2

Summary of Test Results

Pavement

LOCATION		DESCRIPTION[1]					QUALITY					ASPHALT					AGGREGATE[3]						REMARKS
FACILITY	PIT NO.	TYPE AND CONDITION	COURSE	THICKNESS INCHES	TYPE OF SAMPLE	No.	UNIT WT LB PER CU FT	STABILITY LB	FLOW 1/100 IN.	PER CENT VOIDS[2] TOTAL MIX	PER CENT VOIDS[2] FILLED WITH ASPHALT	PER CENT	SP GR	DUCTILITY CM	PENETRATION 1/100 CM Pen.	Soft. Point	SP GR +#10	SP GR -#10	GRADATION PER CENT PASSING 1"	#10	#40	#200	
Taxiway No. 14	1	Traveled	Wearing	1-1/4	Core	7	147.6	1701	14	---	----	6.7							100	40.9	25.2	7.2	Pavement bleeding.
					Recomp-50 blows	4	146.4	2048	15	2.4	85.6	6.3	1.031	150+	34	136F	2.627	2.654	100	47.5	22.6	6.1	
					75 blows	4	147.1	2380	16	1.9	88.3	6.3											
			Binder	2-3/16	Core	7	148.9	1691	18	1.6	89.0	5.6							100	37.1	18.1	5.7	
					Recomp-50 blows	4	146.7	2276	16	2.5	84.6	6.0	1.027	150+	32	132F	2.631	2.651	100	34.3	10.3	5.5	
					75 blows	4	147.8	2605	14	1.7	89.0	6.0											
	2	Untraveled	Wearing	1-1/4	Core	8	146.2	1573	13	---	----	8.1							100	52.4	24.8	6.1	Pavement bleeding.
			Binder	1-15/16	Core	8	147.3	1227	17	2.4	84.3	5.6							100	39.3	19.2	5.0	
	3	Untraveled	Wearing	1-9/16	Core	8	147.5	1956	13	1.0	94.0	6.8							100	52.6	25.4	7.3	
			Binder	2-1/16	Core	8	149.3	1273	13	2.2	84.1	5.0							100	30.7	16.0	5.1	
	4	Traveled	Wearing	1-5/16	Core	8	146.7	1942	15	1.3	92.5	7.0							100	54.1	27.9	9.6	
			Binder	2-1/4	Core	8	149.7	1715	20	1.2	91.4	5.5							100	35.0	16.9	5.3	
	5	Traveled	Wearing	1-1/2	Core	8	147.5	1574	23	0.9	94.5	6.8							100	45.3	24.9	10.3	
			Binder	1-13/16	Core	8	147.2	905	33	1.0	93.3	6.1							100	40.8	27.3	11.1	
	5	Upheaval area	Wearing	1-9/16	Core	4	147.2	1412	22	0.5	97.1	7.3							100	52.4	26.7	10.9	
			Binder	1-5/8	Core	4	148.3	1224	21	0.9	94.3	6.4							100	42.5	21.4	7.5	
			Binder	1-9/16	Core	4	147.8	1541	20	1.3	91.9	6.4											
	5	Untraveled	Wearing	1-3/8	Core	8	147.6	2222	13	1.9	87.9	6.0							100	38.1	20.2	6.2	
			Binder	2-1/2	Core	8	148.6	1379	19	2.1	85.6	5.4							100	40.8	22.0	8.1	
	-	Rich area, sta 33+00 Traveled	Wearing	1-5/8	Core	15	147.0	1218	19	---	----	7.9							100	53.9	26.2	8.5	Pavement bleeding.
			Binder	2-1/16	Core	15	147.5	962	23	2.2	85.9	5.8							100	37.7	15.3	5.4	
Average		Traveled	Wearing				147.3	1739	17	1.1	93.5	6.5							100	49.4	26.0	9.0	
			Binder				148.6	1438	24	1.3	91.2	5.7							100	40.3	20.8	7.4	
		Untraveled	Wearing				147.1	1917	13	1.5	91.0	7.0							100	47.7	23.5	6.5	
			Binder				148.6	1293	17	2.2	84.7	5.1							100	36.9	19.1	6.3	

Note:

1. Cores from pits 3, 4, and 5 were badly deformed when received and measurement of thickness was difficult.
2. Asphalt flushed from the wearing course pavement in pits 1 and 2 and the rich area; voids relationships are not applicable.
3. Aggregate is described as crushed granite and gravel. The water absorption tests on the recovered aggregate from pit 1 are as follows:

Water Absorption Per Cent

	+10	-10	Blend Weighted Avg
Wearing Course	1.05	2.31	1.65
Binder Course	1.01	2.59	1.48

Summary of Test Results Pavement 121655A
WES Form No. 775
Rev Oct 1952

Table 3

SUMMARY OF TEST RESULTS

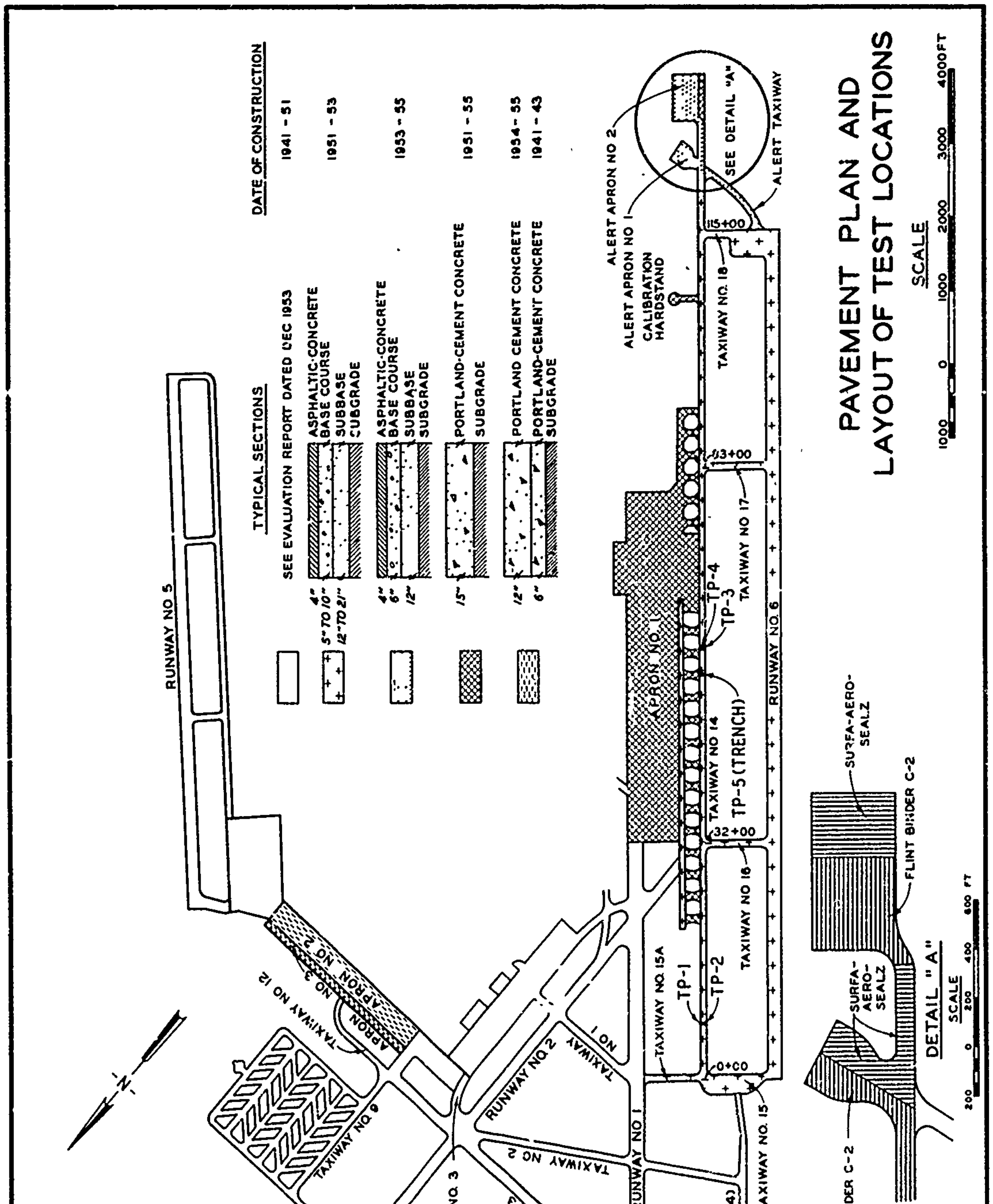
BASE COURSE, SURFACE, AND SUBGRADE

LOCATION: Facility	Pit No	DESCRIPTION: Condition	Depth from Sfc In	CLASSIFICATION: Sp Gr	LL	PI	Dept of Army Uniform	FIELD IN-PLACE: % Mod AASHO Dens	Moisture Per Cent	% Sat.	Density Lb per Cu Ft	CBR: Unsoaked In-Place (IU)	CBR: Undist Soaked (US)
													BASE COURSE
Taxiway No 1- Traveled	1	Satisfactory	4	2.70	25	8	GW-SC Gravelly sand with clay	98	2.8	30	134.9	142	---
Untraveled	2	Satisfactory	4	----	--	--	GW-SC Gravelly sand with clay	95	3.0	28	130.7	92	---
Untraveled	3	Satisfactory	4	----	--	--	GW-SC Gravelly sand with clay	95	3.8	35	130.4	79	---
Traveled	4	Slightly deformed, no crack	5	----	--	--	GW-SC Gravelly sand with clay	98	2.7	29	134.0	91	---
Traveled	5	Deformed; crack	4	----	22	5	GW-SC Gravelly sand with clay	99	2.1	23	135.6	56	---
Untraveled	5	Satisfactory	7	----	22	5	GW-SC Gravelly sand with clay	101	1.6	21	139.8	151	---
													SURFACE
Traveled	1	Satisfactory	12	2.63	39	17	SC Gravelly sand	99	7.1	66	120.3	97	---
Untraveled	2	Satisfactory	10-1/2	----	--	--	SC Clayey sand	99	4.6	43	127.6	87	---
Untraveled	3	Satisfactory	14	----	--	--	SC Clayey sand	97	4.3	39	124.4	29	---
Traveled	4	Slightly deformed, no crack	14	----	--	--	SC Clayey sand	98	3.3	39	126.6	52	---
Traveled	5	Deformed, crack	10	----	25	10	GW-SC Clayey sand	97	1.2	10	125.4	126	---
Untraveled	5	Satisfactory	12	----	25	10	GW-SC Clayey sand	103	2.0	23	133.5	120	---
													SUBGRADE
Traveled	1	Satisfactory	31-1/2	----	24	10	SC Clayey sand	80	8.1	37	104.8	33	---
Untraveled	2	Satisfactory	31	----	--	--	SC Clayey sand	85	11.1	61	111.5	36	---
Untraveled	3	Satisfactory	27	----	--	--	SC Clayey sand	91	10.7	74	119.4	39	---
Traveled	4	Slightly deformed; no crack	26	----	--	--	SC Clayey sand	75	6.7	26	98.3	14	---
Traveled	5	Deformed, crack	32	----	26	11	SC Clayey sand	84	6.0	31	109.7	20	---
Untraveled	5	Satisfactory	33	----	26	11	SC Clayey sand	87	7.1	42	114.2	39	---
E-W runway*	2	-----	11-1/2	2.65	26	11	SC Clayey sand	92.7	5.7	42	121.2	42	---

LOCATION: Facility	Pit No	LABORATORY — MOD AASHO COMP: Optimum Moisture Per Cent	% Sat.	Maximum Density Lb per Cu Ft	SOAKED CBR: Molding Moisture Per Cent	% Sat.	Molding Density Lb per Cu Ft	% Mod AASHO Dens.	Soaked Moisture Per Cent	% Sat.	Soaked Density Lb per Cu Ft	% Mod AASHO Dens.	CBR (RS)	UNSOAKED CBR: Molding Moisture Per Cent	% Sat.	Molding Density Lb per Cu Ft	% Mod AASHO Dens	CBR (RU)	REMARKS
Taxiway No 1- Traveled (Base course)	1	6.3	74	137.1	5.9	69	137.0	100	6.7	79	137.0	100	166	3.9	39	132.4	96	160	
Traveled (Surface)	1	8.1	70	120.9	8.3	80	123.9	100	9.5	91	120.9	100	101	6.2	55	126.4	98	160	
E-W runway*	2	8.8	88	131.0	8.8	68	131.0	100	9.2	93	131.0	100	46	8.8	88	131.0	100	90	

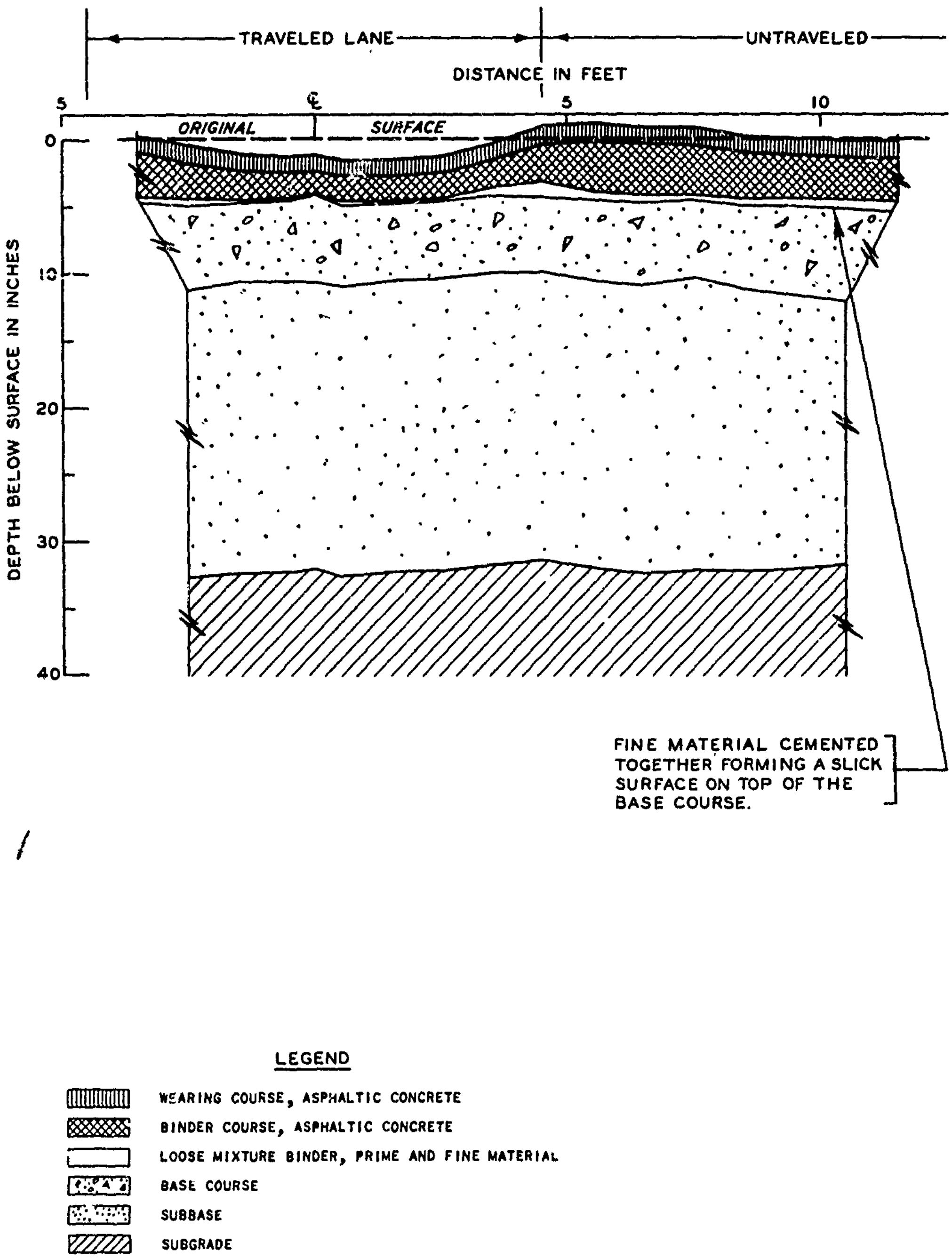
* Test pit 2 of 1952 evaluation by Waterways Experiment Station.

WES Form No. 774 1C-3553
Rev July 1952



PAVEMENT PLAN AND
LAYOUT OF TEST LOCATIONS
SCALE
1000 0 1000 2000 3000 4000 FT
TYPICAL SECTIONS
DATE OF CONSTRUCTION
SEE EVALUATION REPORT DATED DEC 1953 1941 - 51
4" 5" TO 10" 12" TO 21" ASPHALTIC-CONCRETE BASE COURSE SUBBASE SUBGRADE 1951 - 53
4" 6" 12" ASPHALTIC-CONCRETE BASE COURSE SUBBASE SUBGRADE 1953 - 55
15" PORTLAND-CEMENT CONCRETE SUBGRADE 1951 - 55
12" 6" PORTLAND CEMENT CONCRETE PORTLAND-CEMENT CONCRETE SUBGRADE 1954 - 55 1941 - 43
RUNWAY NO 5
RUNWAY NO 6
RUNWAY NO 1
RUNWAY NO 2
RUNWAY NO 3
APRON NO 1
APRON NO 2
APRON NO 3
ALERT APRON NO 1
ALERT APRON NO 2
ALERT TAXIWAY
CALIBRATION HARDSTAND
SEE DETAIL "A"
TAXIWAY NO 18
TAXIWAY NO 17
TAXIWAY NO 14
TAXIWAY NO 16
TAXIWAY NO 15A
TAXIWAY NO 15
TAXIWAY NO 13
TAXIWAY NO 10 (OLD RUNWAY NO 4)
TAXIWAY NO 12
TAXIWAY NO 9
TAXIWAY NO 3
TAXIWAY NO 2
TAXIWAY NO 1
TP-1
TP-2
TP-3
TP-4
TP-5 (TRENCH)
0+00
32+00
83+00
115+00
N
SURFA-AERO-SEALZ
FLINT BINDER C-2
DETAIL "A"
SCALE
200 0 200 400 600 FT
VICINITY MAP
DAVIS-MONTHAN AFB
TUCSON
WRIGHTSTOWN
RILLITO
KINO
AGUIRE
CRUZ
FELIX
SAN XAVIER MISSION
121955C

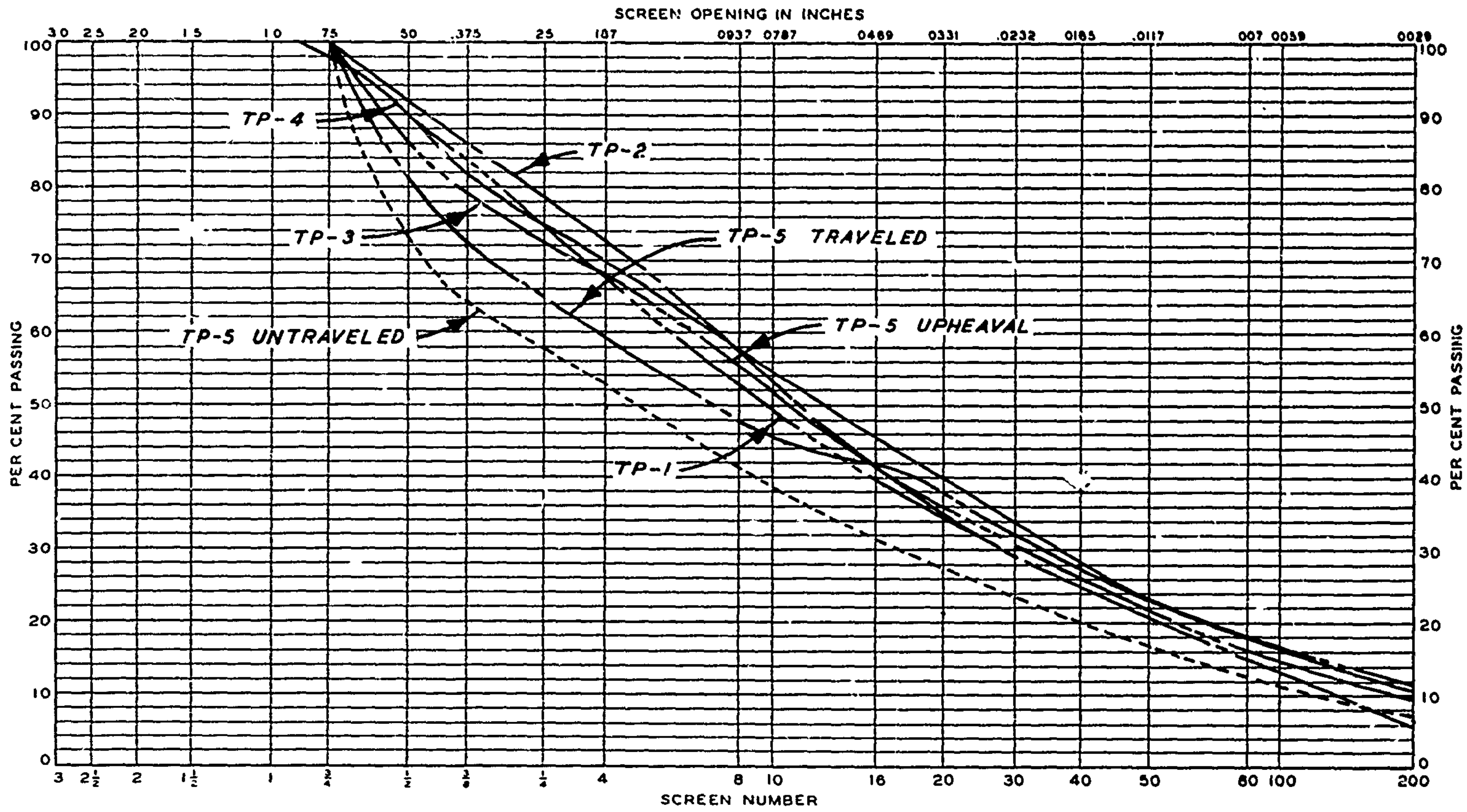
PLATE 1



PROFILE OF TEST TRENCH
TAXIWAY 14

072456-A

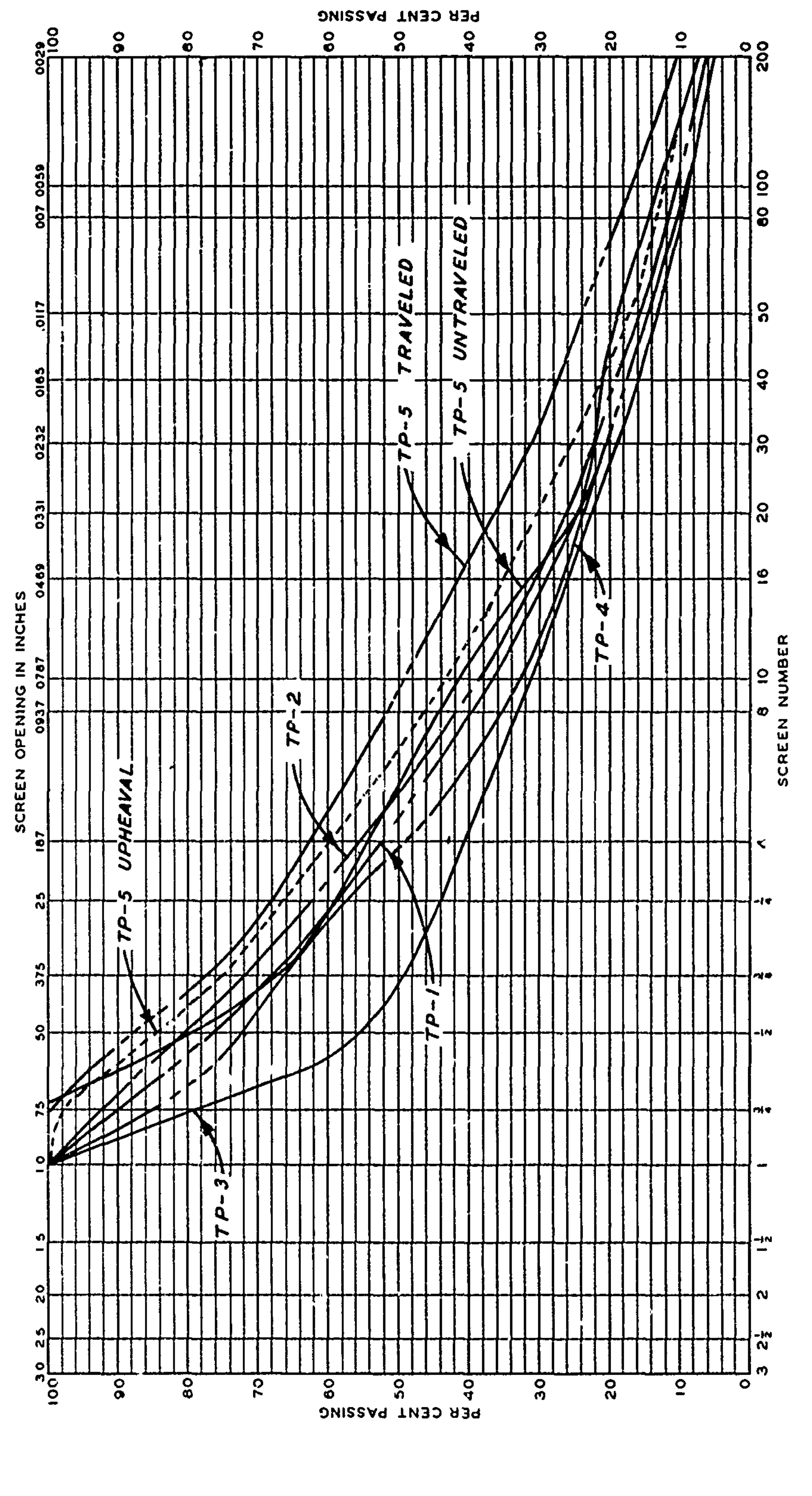
PLATE 2



GRADATION OF WEARING COURSE AGGREGATE

TAXIWAY 14

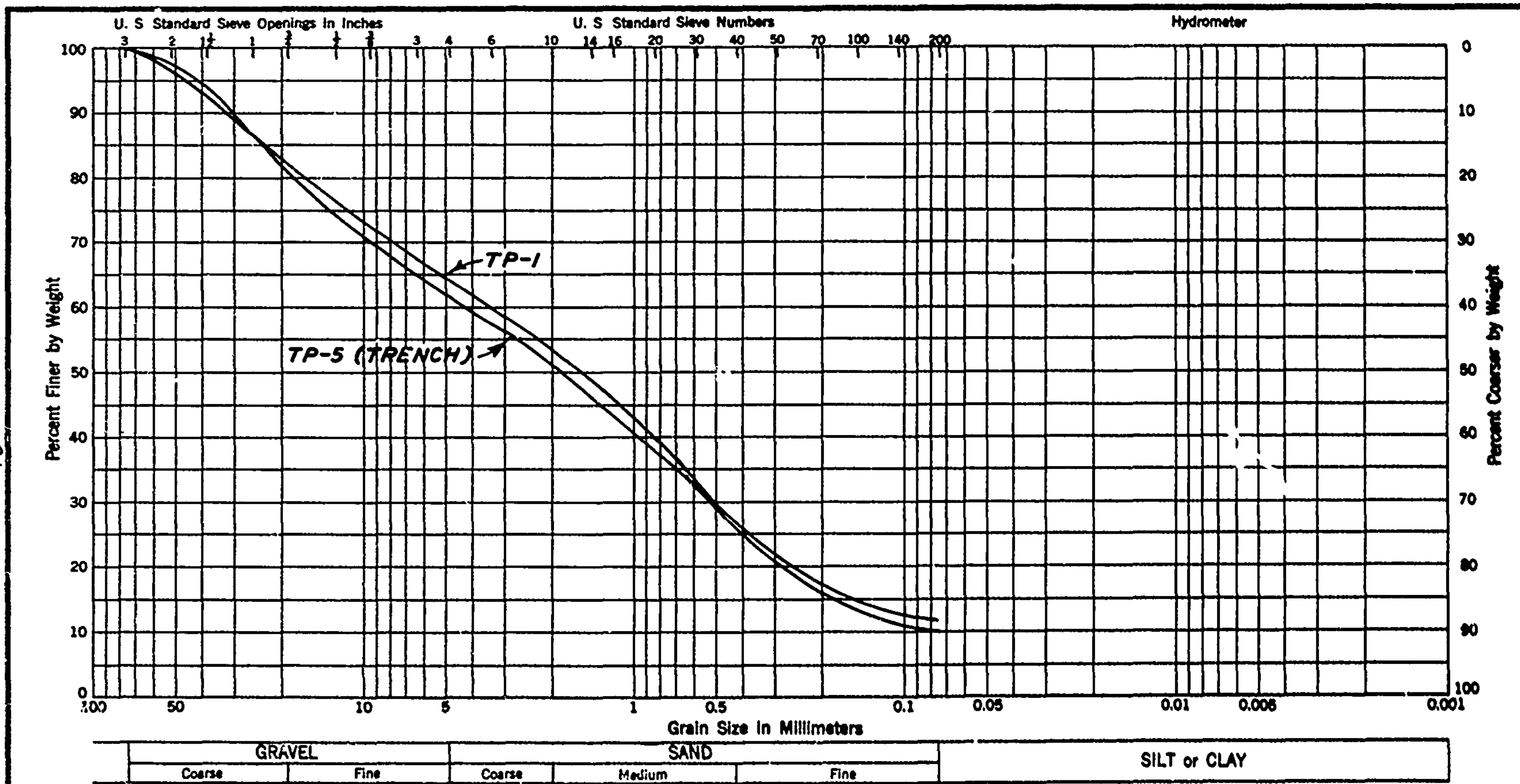
121955 F



GRADATION OF BINDER COURSE AGGREGATE

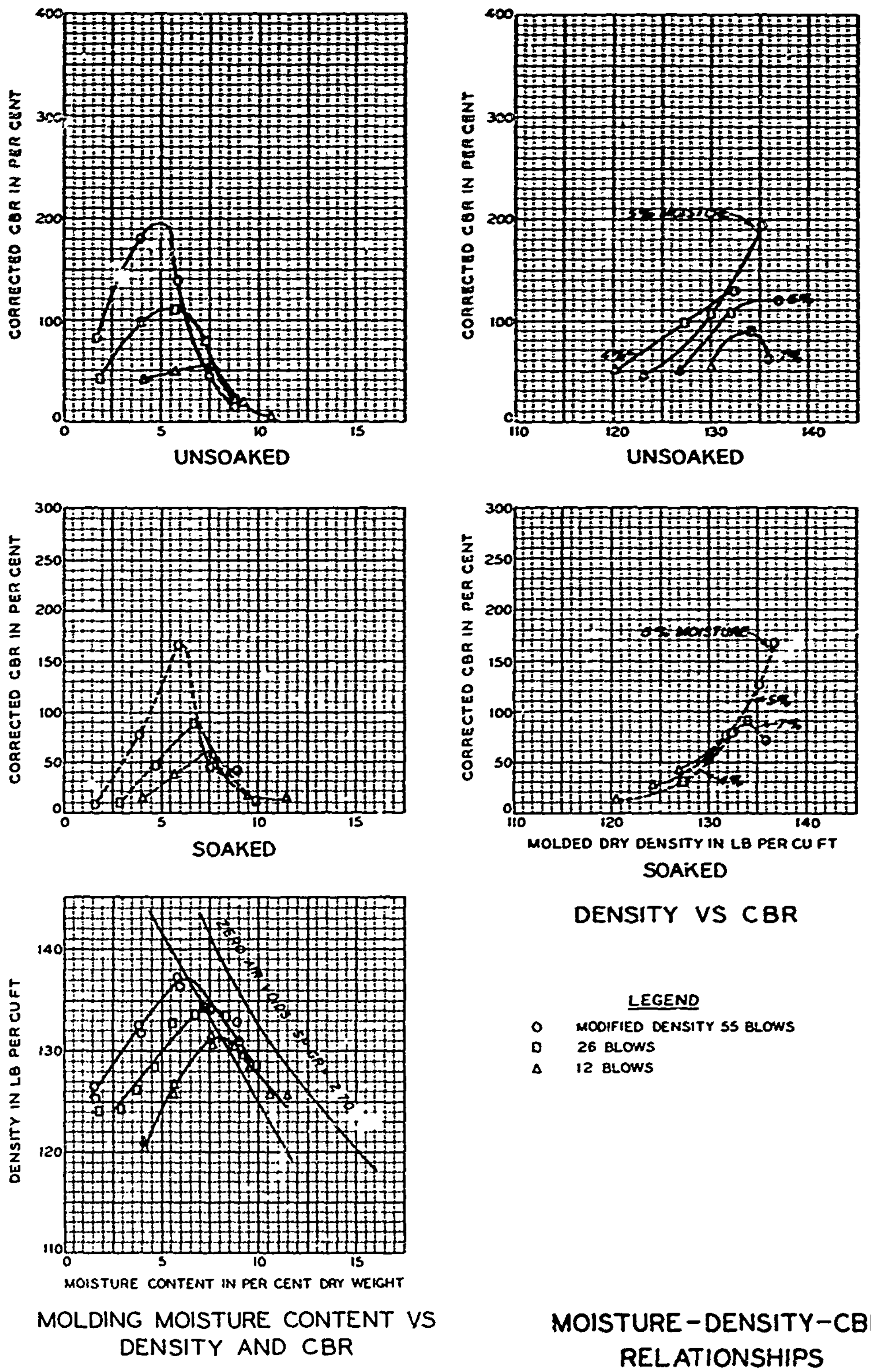
TAXIWAY 14

PLATE 4



Number	Depth	Natural Moisture	L. L.	P. L.	P. I.	Classification
TP-1			25	17	8	SW-SC; GRAVELLY SAND, WITH CLAY
TP-5			22	17	5	SW-SC; GRAVELLY SAND, WITH CLAY
12195	5H					

GRADATION CURVES OF TYPICAL BASE COURSE MATERIALS

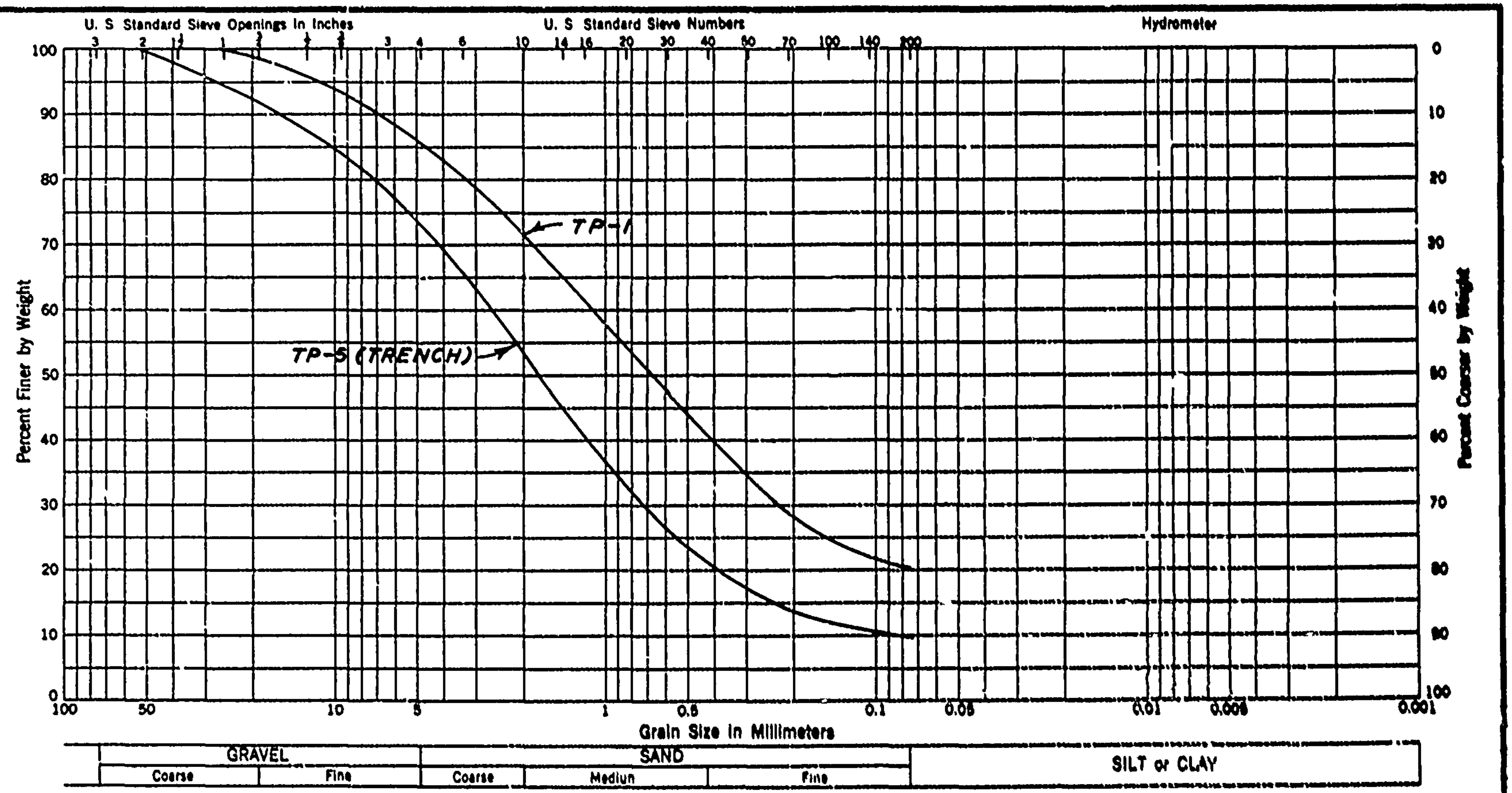


MOISTURE-DENSITY-CBR RELATIONSHIPS

BASE COURSE SW-SC
TP-1

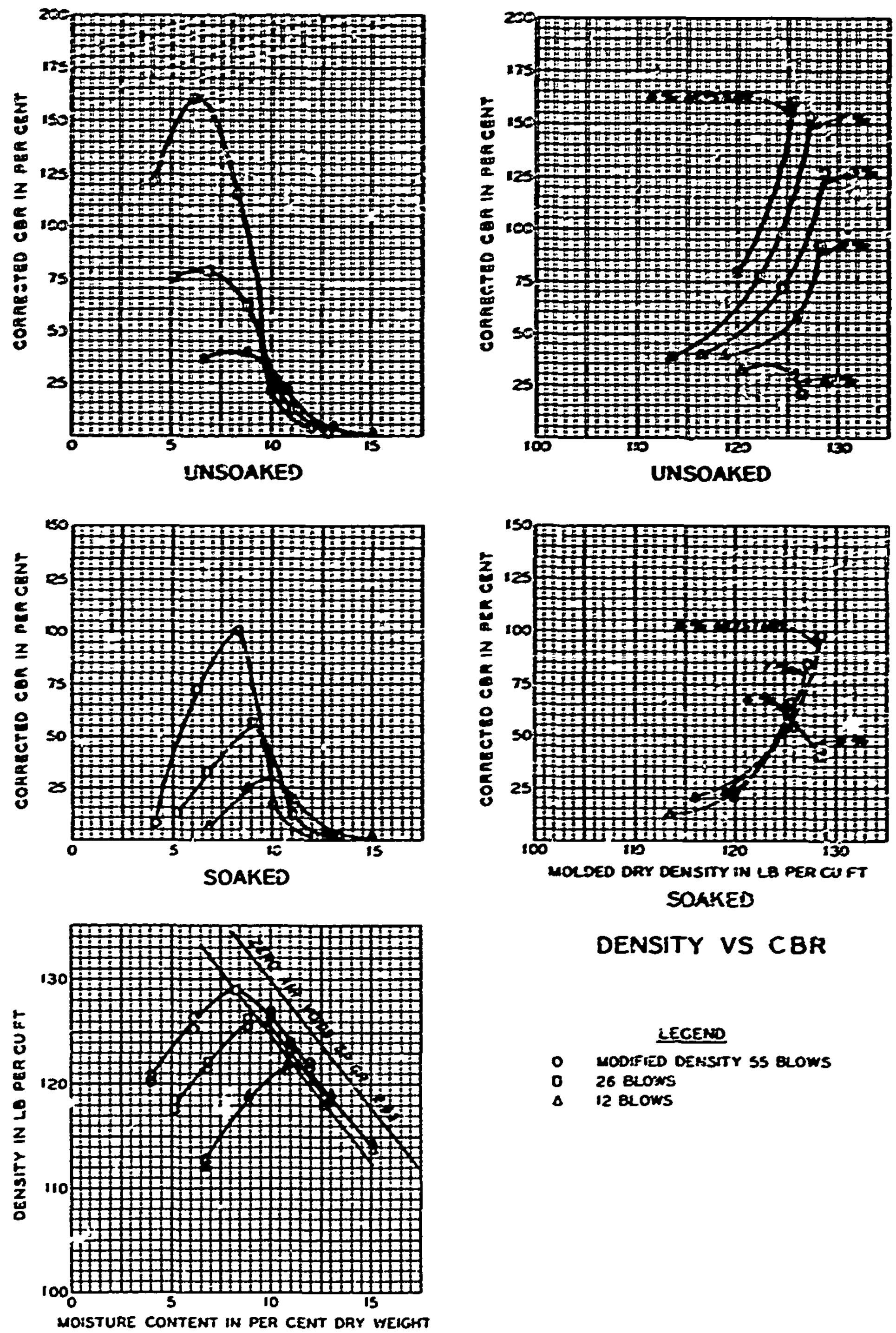
121955 J

PLATE 6



Number	Depth	Natural Moisture	L. L.	P. L.	P. I.	Classification
TP-1			39	22	17	SC - CLAYEY GRAVELLY SAND
TP-5			25	15	10	SW-SC - CLAYEY SAND
121955K						

GRADATION CURVES OF TYPICAL SUBBASE MATERIALS



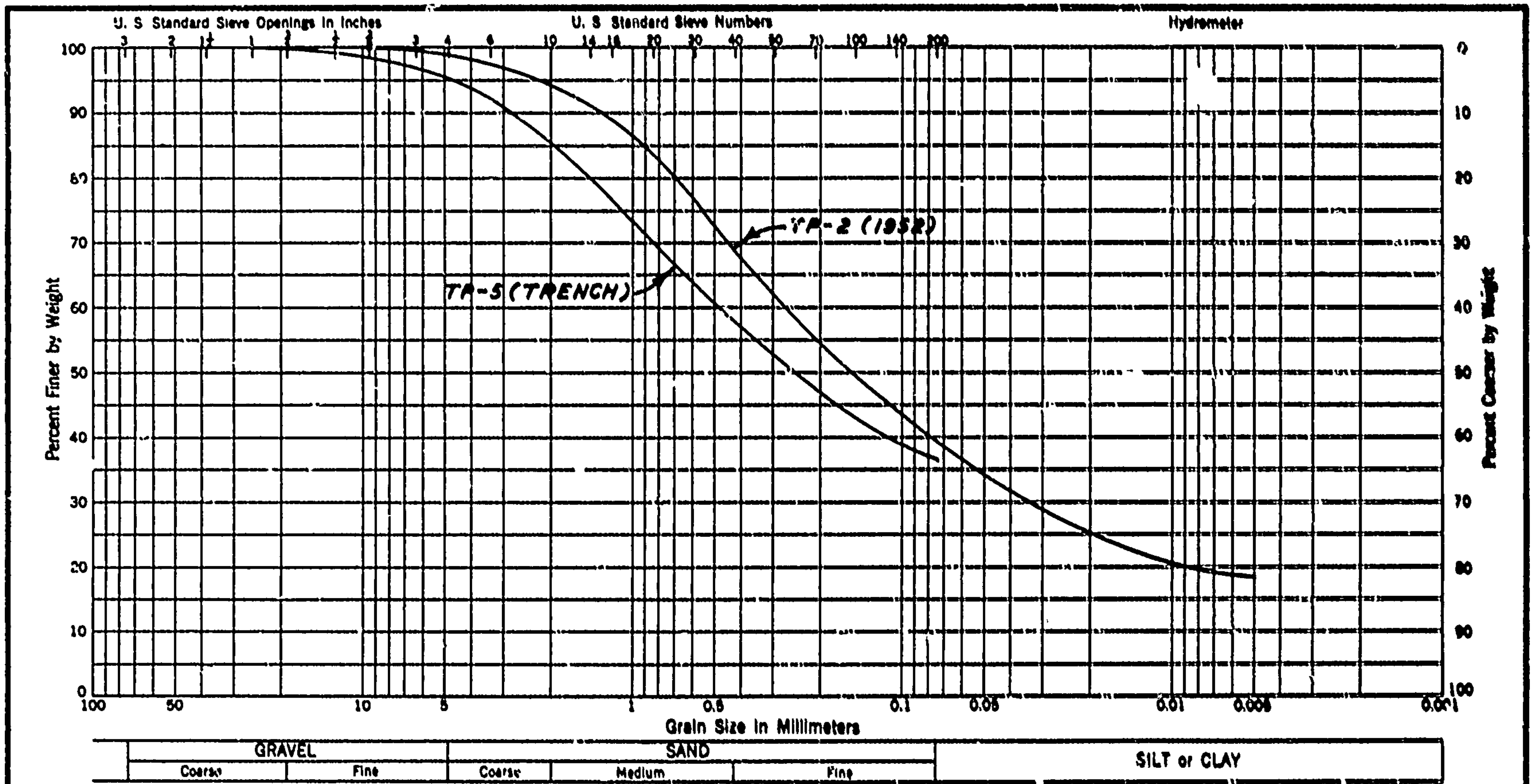
MOLDING MOISTURE CONTENT VS DENSITY AND CBR

MOISTURE-DENSITY-CBR RELATIONSHIPS

SUBBASE - SC

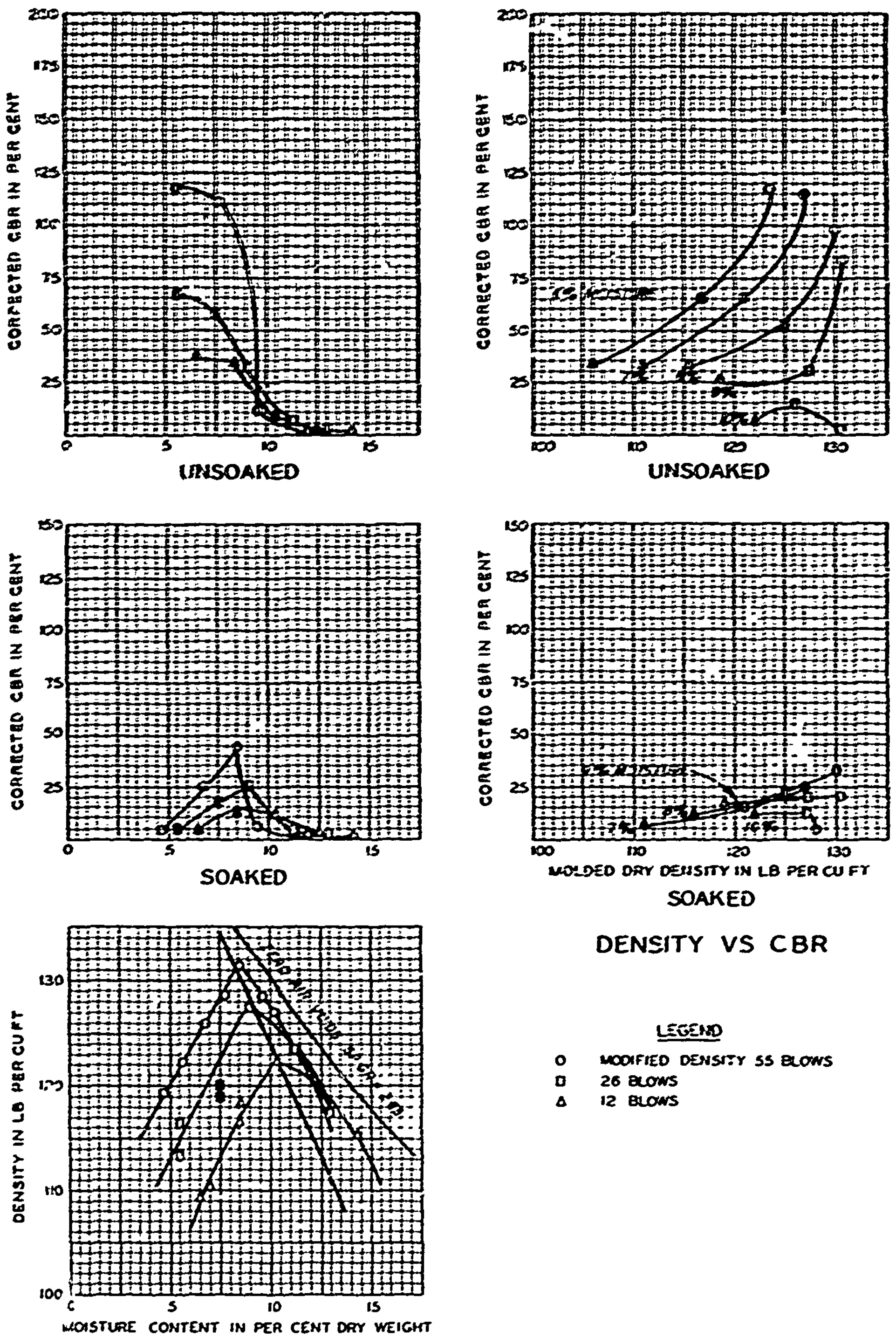
TP-1

121955 L



Number	Depth	Natural Moisture	L. L.	P. L.	P. I.	Classification
TP-2	—		26	15	11	SC - CLAYEY SAND
TP-5	32"		26	15	11	SC - CLAYEY SAND
121955M						

GRADATION CURVES OF TYPICAL SUBGRADE MATERIALS



MOLDING MOISTURE CONTENT VS DENSITY AND CBR

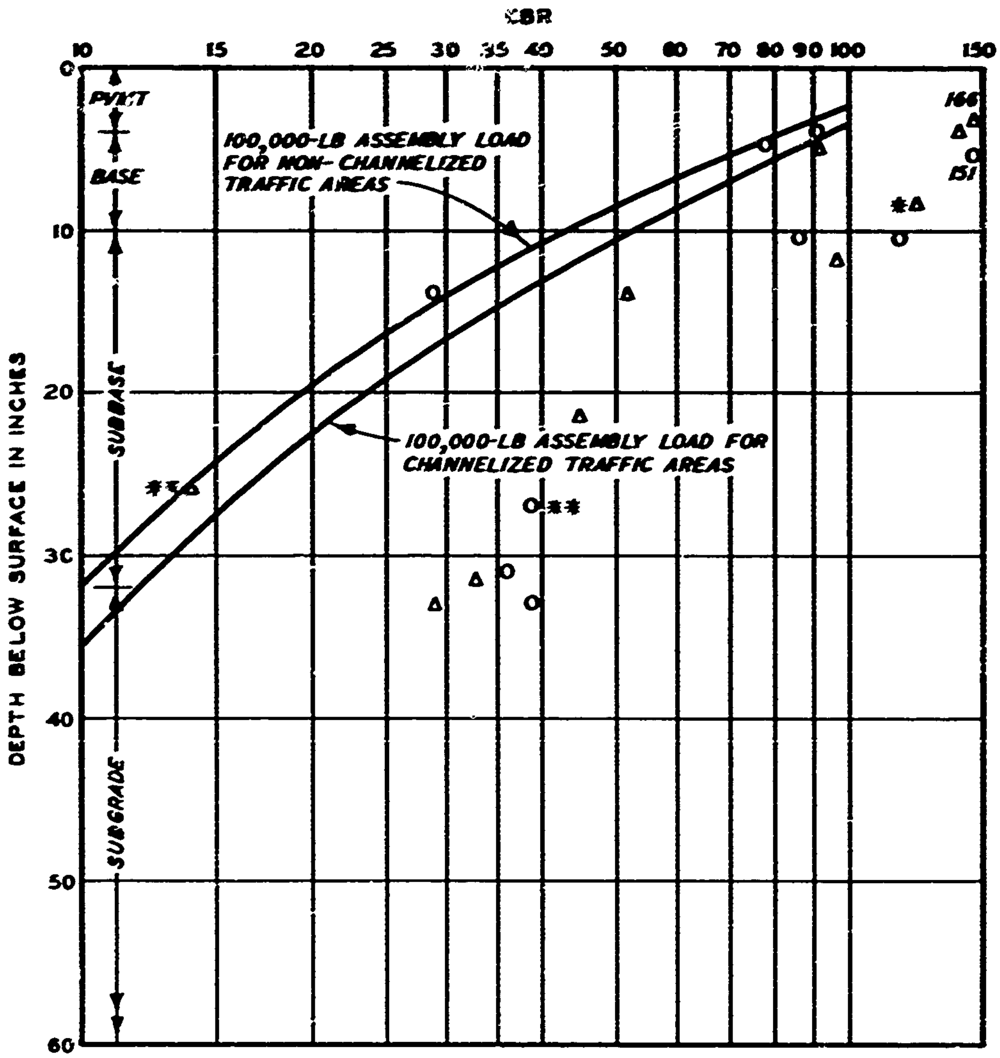
MOISTURE-DENSITY-CBR RELATIONSHIPS

SUBGRADE SC

TP-2 (1952)

031653 S

PLATE 10



LEGEND

Δ IN TRAVELED LANE

O OUTSIDE TRAVELED LANE

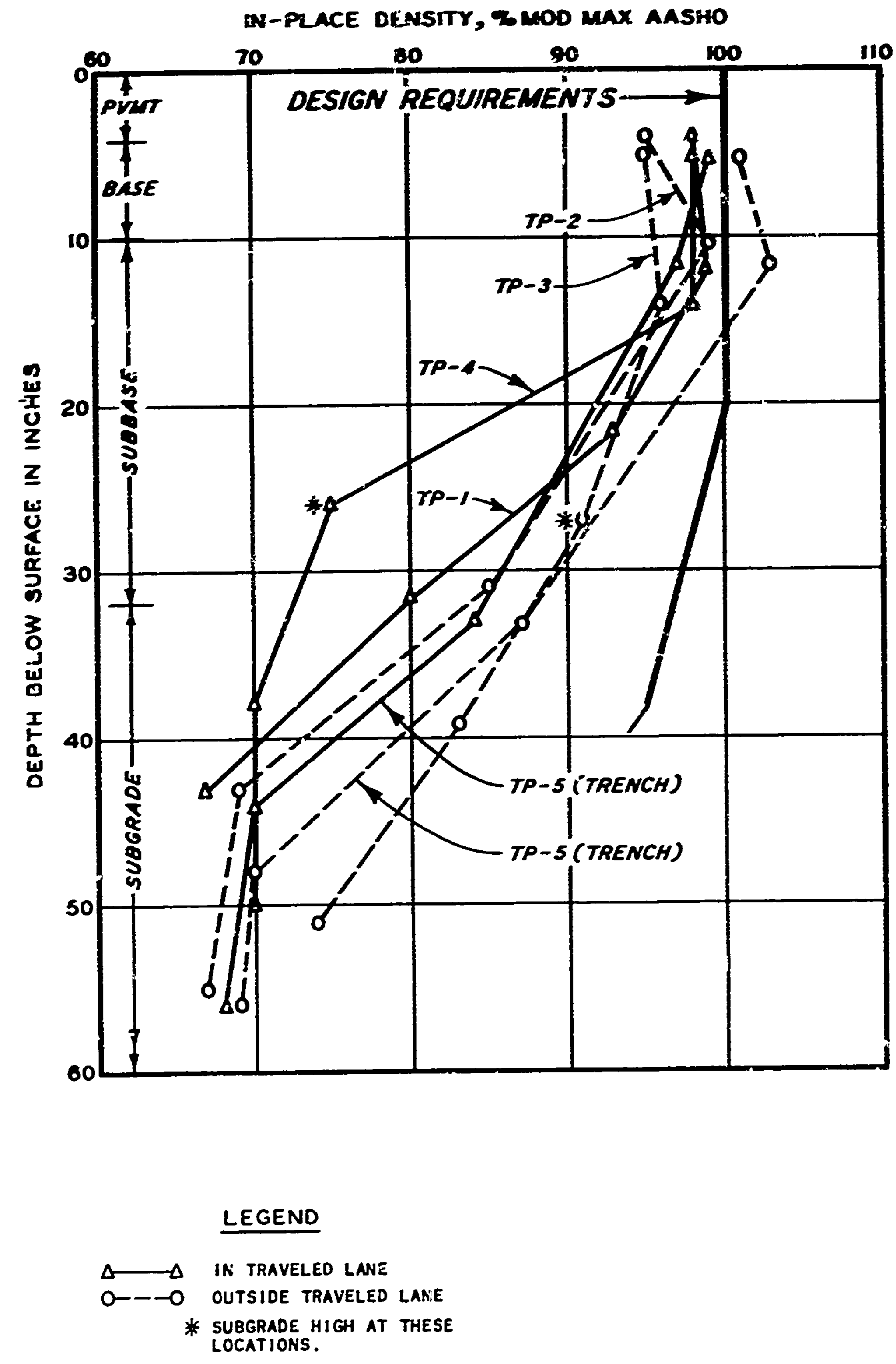
* SUBBASE HIGH AT THIS LOCATION.

** SUBGRADE HIGH AT THESE LOCATIONS.

IN-PLACE CBR VS DEPTH

TAXIWAY 14

072456-B



DENSITY VS DEPTH

TAXIWAY 14