REPORT ON SOIL INVESTIGATION AND PAVEMENT DESIGN FOR TOLEDO EXPRESS AIRPORT

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TOLEDO EXPRESS AIRPORT

It is the purpose of this report to provide a permanent record of the soil investigation and related design studies made in connection with the construction of the Toledo Express Airport. The report will be devoted to the airfield proper, being concerned with the design and construction of the runways, taxiways, and aprons, rather than buildings and utilities serving the airport. There have been reproduced in Appendixes A, B, and C reports and correspondence having to do with design and construction, including the results of soil surveys and soil tests upon which the pavement design has been based. The Appendixes are fairly complete in themselves and provide a chronological record of the developments with which the Engineering Research Institute and the author of this report were concerned.

In Appendix A are reproduced three previous reports which were presented over the period from November, 1952, to February, 1954. The first report, entitled "Preliminary Design Recommendations", presents an initial evaluation of the Oak Openings Site, outlines a suggested program to be followed in preparation of the plans and specifications, and presents the results of the first series of soil tests which were made to evaluate the capability of these soils to support the proposed runways, taxiways, and aprons. The second report presents the soil survey made by O. L. Stokstad and H. E. Barnes in April, 1953. In this report the dominant soil types at the Oak Openings Site are described, and the general characteristics which affect the runway construction and pavement design are established. An essential part of the soil survey was the mapping of the soil areas in the field, and this information was combined with the topography on a special set of supplementary plans. These supplementary plans were made available to bidders but not included in the standard plans. For record purposes the work sheets from the soil survey have been included in Appendix A as part of the soil survey report.

It may here be noted that the writer's first contact with this project was in the summer of 1952, at which time a preliminary inspection and evaluation of the Oak Openings Site was made. A brief evaluation of the characteristics of the site and suggestions for its development are given in the first letter reproduced in Appendix B. During the period from the summer of 1952 to May, 1953, there were periodic conferences on problems of airport development and, as noted above, more comprehensive design recommendations were made and the soil surveys completed prior to establishing a definite project with the Engineering Research Institute for continued investigation and design studies. Authorization for such a project was made in May, 1953, and, subsequently, assistance required by the writer was provided as part of this project.

SOIL SURVEY AND SOIL TESTS

During the summer and fall of 1953 the writer and his assistants collaborated with the Consulting Engineers in a series of design conferences and field inspections having to do with design and preparation of Plans and Specifications, as well as construction control. As a matter of fact, most of the results of soil investigation, laboratory soil tests, and subsequent analyses were presented to the Consulting Engineers through such conferences and incorporated by them in the Plans and Specifications. The second letter in Appendix B, under date of June 8, 1953, outlines the general program which was recommended for the development of the Toledo Express Airport, a program which was followed in its essential phases. Contract No. 1, for clearing and grubbing of the site, was let on June 9, and Contract No. 6, for grading, draining, and paving, was let on July 28. Prior to the completion of the

Plans and Specifications for this general contract, there was a period of concentrated activity, during which the writer and his assistants, in collaboration with the Consulting Engineers, were concentrating on completion of soil tests, grading estimates, and paving design.

Appendix C has been prepared to provide a permanent record of the soil test results on which many of the important decisions and the final pavement design were based. Most of the data and information in Appendix C has not been presented in the form of a written report prior to this final report, although there are brief references to it in the correspondence in Appendix B, and these data and pavement designs were studied and restudied many times in the design conferences referred to above.

Following the soil surveys, a greater number of more representative samples were taken from the various soil areas over that portion of the site included in the grading contract. Sufficient samples were obtained to provide material for the series of laboratory tests preliminary to design. The first tests were mechanical analyses to determine the grading of the soil and to establish those soils which could be combined in so far as design and construction problems were concerned. All of the soils were predominately medium and fine sand of quite uniform size. There was, however, a significant variation in the percentage of silt and clay, which finally led to the establishment of two main groups, which are represented by the combination of Newton and Maumee series in one group and the Plainfield and Bridgman series in the other.

The essential differences between these two groups is indicated on Figures 1, 2, and 3, in which the mechanical analyses of all samples in each group have been plotted. It can be seen that the Newton and Maumee series, shown on Figures 1 and 2, have soil fines (Pass No. 200 Sieve) averaging approximately 12 per cent. The Plainfield and Bridgman series, shown on Figure 3, have percentages of soil fines (Pass No. 200 Sieve) of about 5 per cent. Other than this, the difference in gradation is insignificant, a fact which is most apparent from Figure 4, in which the average mechanical analysis of these two groups has been shown.

Following the mechanical analysis tests the compaction characteristics of these two soil groups were studied in considerable detail. The density range under all conditions, varying from loose to maximum compaction, was determined by all current methods of compaction. The results are shown on Figures 5 and 6 for both groups of soils. Aside from density in the loose state, density was determined by vibration, both the Standard and Modified Proctor tests, and by the Cone Method, a special method developed in the Michigan Soil Mechanics Laboratory. As shown on Figure 5, there was some variation in maximum density between the various methods. The Cone Method gives the highest density of approximately 117 pounds per cubic foot. Inasmuch as the State of Ohio Department of Highways' Construction and Materials Specifications were selected for control on the Toledo Express Airport, their standard density test was selected for job control. This test procedure is commonly known as the Standard Proctor Density, and, in this series of tests, a maximum dry density of 112.9 p.c.f. and an optimum moisture content 11.1% represented standard density for the Newton-Maumee group of soils, shown on Figure 5. The maximum dry density by the same criterion for the Plainfield-Bridgman group of soils, as shown on Figure 6, was 111.1 p.c.f. and the optimum moisture content was 12.9%. Results similar to these were obtained on other test samples by the Toledo Testing Laboratory and used in compaction control during the grading of the runways. In this connection it may be noted that the maximum dry weight obtained by the Toledo Testing Laboratory and used in the control varied from 108.8 p.c.f. to 110.0 p.c.f.

One of the important decisions made as the runway design studies progressed, was the adoption of limestone screenings to be used as a subbase over the sand. This subbase served a dual purpose. When compacted, it became a stable working platform for paving operations, which eliminated the disturbance and rutting which would have resulted from trucking and other construction operations on the more or less incoherent sandy soil existing at this site. Limestone screenings were available at an old quarry within reasonable trucking distance of the airport, and there were considerable quantities which had accumulated as waste material. These screenings were selected for the subbase and the results of laboratory tests on this material are given in Figures 7 and 8. Figure 7 shows the mechanical analysis or gradation of two representative samples of these screenings. It may be noted that these materials are very well graded, in fact close to the ideal grading for maximum density. In Figure 8 the compaction tests on these materials are shown for the Standard Proctor procedure and for the Cone test. The maximum dry densities obtained for the two samples are 131.7 and 136.7 p.c.f. with optimum moisture contents of 7.3 and 9.0 per cent, respectively. These densities are especially high but consistent with the almost ideal gradation. They are indicative of material of especially high stability, an indication which was borne out both in the laboratory CBR tests and in the performance of this material under construction conditions.

The final phase of laboratory testing preparatory to pavement design was a series of California Bearing Ratio (CBR) tests. The results of the CBR tests are shown on four graphs designated as Figures 9, 10, 11, and 12. Figure 9 shows the results of three CBR tests on a representative sample of the Newton-Maumee group of soils, while Figure 10 shows the results of four similar tests on a sample representative of the Plainfield-Bridgman series. Figures 11 and 12 show the results of CBR tests on the samples of limestone screenings designated as Samples 53H931 and 932. A summary of the compaction tests and CBR tests has been made in Table I, where all of the results are presented in a form for easy comparison.

According to procedure for conducting CBR tests, controlling values are determined at penetrations of 0.1 and 0.2 inch. The critical or design value of CBR is the maximum ratio obtained when the applied pressure at 0.1 inch is divided by 1,000 or the pressure of 0.2 inch is divided by 1,500. This ratio is then expressed as a percentage and used in those terms in those pavement design methods that employ the CBR. The standard values of 1,000 p.s.i. and 1,500 p.s.i. are supposed to represent the pressure sustained by a standard material, crushed limestone, at the selected deflections. The actual pressures then sustained by other materials and the corresponding CBR values are plotted on the graphs and may be referred to the vertical scales except the CBR at 0.2 inch, which, according to the arbitrary standards, is not to scale. Otherwise, any CBR value in per cent, multiplied by 10, will indicate the load applied in p.s.i. Computation of the CBR values is illustrated on Figure 9.

The significant results of the CBR tests are the values for the sandy subgrade soil, which varied from 22.8 to 28.5 when no excess of moisture was present. These values would justify an average value of 25.0 for pavement design and certainly a minimum value of 20.0. It should be pointed out that all materials, including both sands and the limestone, showed lower CBR values at the optimum moisture contents than at moisture contents considerably lower than optimum. It was also noted in the tests, as shown on both the curves and computed values in Table I, that water squeezed out of the sample as load was being applied. Such movement of moisture in the granular materials would tend to render them less stable.

The practical significance of this latter phenomenon is that field compaction may be more effectively accomplished at moisture contents somewhat lower than optimum. This also means that under heavy rolling, sufficient to squeeze moisture out of the soil, there might be a loss of stability, even though the higher moisture content served as a lubricant during initial compaction, making the density easier to obtain up to a certain point. In so far as permanent subgrade stability is concerned these results are at least indicative of the desirability of effective drainage and a high grade line for the paved areas. In these relatively fine sands, it is thus apparent that there is sufficient reaction to moisture to decrease bearing capacity, although the actual range of pressures under the pavement would be substantially less than even the minimum pressures equivalent to the CBR values shown in Table I.

Before leaving the test results there are tests on one special sample which are the last data given in Appendix C. These tests are on the topsoil from the Maumee series and consist of a mechanical analysis and a determination of loss of ignition and organic content. This information was obtained for Mr. Stokstad and those with whom he consulted in the matter of topsoil dressing and turf development. It is included in Appendix C to provide a complete record of all tests performed.

DESIGN AND CONSTRUCTION PROBLEMS

Reference has already been made to the numerous design conferences held in Toledo, while the Consulting Engineers and representatives of the City were engaged in the final preparation of plans and specifications and letting of contracts. During this period there were made a number of decisions which, in the writer's opinion, had a most far-reaching influence on the quality of the airport paving and will determine its ultimate performance over the years. In connection with these problems the recommendations presented by the writer and his associates were given full consideration and were followed in the final plans and specifications in all of their essential features. There were, of course, the usual discussions and debates necessary to arrive at the best and most economical solution, but there were no compromises made which would jeopardize the excellence of the airport as it was finally planned and built.

Clearing and Grubbing

The first contract for clearing and grubbing of the site was let on June 9th. Much of the airport site was covered by second-growth timber and represented difficult clearing. The wooded area at the south end of the non-instrument runway was particularly heavy and presented a difficult and expensive clearing job. As part of the clearing contract all timber, brush, roots, and debris were cleared away, which, when combined with the topsoil removal, eliminated all but a negligible amount of the detrimental organic materials in the graded portion of the runway.

Grading and Drainage

The general contract for the grading, drainage, and paving, designated as Contract No. 6, was let on July 28th and was preceded by a thorough study and evaluation of soil properties and other conditions of paramount importance to the pavement design and ultimate performance of the airfield itself. The soil survey already mentioned was an important factor in the determination of final grades and quantities of cut and fill. Grade lines of the runways, taxiways, and aprons were kept at the highest possible elevation above ground water level, consistent with plans for improving the drainage of the area. The objective of these plans was to insure that all paved areas would be at least four feet above the existing ground water level.

One of the most important items from the standpoint of cost was the earth work and yardage involved in cut and fill. The Consulting Engineers made one of the most comprehensive analyses of this phase of the problem that the writer has seen made on a project of this nature. Excavation and fill were both computed by two methods; first, by the conventional cross-section method and, second, by an area-volume method which the writer recommended and which has been incorporated in the final plans. There is no particular point in going into the details of these analyses in this report beyond noting that the Consulting Engineers spared no effort in producing a final result and a final measurement of this important pay quantity as accurately as it could be anticipated under the conditions. In this respect, complete accuracy was difficult because of the variable elevation produced by clearing and removal of topsoil, and it is interesting to note that the final estimates, which were altered somewhat by changes during the construction period, are reasonably close. Another point of interest is that the methods used provided the Contractor with the grading distribution plan, which made it possible for him to program his earth moving operations much better than usual. The final excavation as estimated was 739,426 cubic yards, and the final pay quantity after the grading had been completed was reduced to 689,408 cubic yards. The estimated excavation included a shrinkage factor of 30 per cent, based upon tests made as part of the soil investigation.

The first step in the grading operation was the removal and stockpiling of the topsoil, which was estimated at 225,375 cubic yards, and which amounted in the final figure to 272,665 cubic yards. It may be noted that the over-run in topsoil removed is approximately the same as the under-run in the major excavation item. The topsoil was stockpiled and saved for top dressing the field area to provide a suitable bed for turf development. Conservation of this important resource was fully utilized, as may be noted in the quantities involved in the third pay item in grading, designated as Placing of Topsoil. The original estimate of this item was 788,958 sq. yds., while the final figure was 772,587 sq. yds. These figures would indicate that top dressing for turf development was finished substantially as planned. This is important as adequate turf development over the entire airport site is necessary if difficulties from wind erosion are to be avoided.

PAVEMENT DESIGN

Following the problems involved in grading, the last stage of design studies had to do with pavement design, which was the final objective of the comprehensive program of soil investigation and tests. As has been pointed out in several of the preliminary reports and earlier portions of this report, the granular soil at this site was one of great advantages from the standpoint of airport development. Being permeable, it was conducive to good drainage, and, as is characteristic of granular materials, it provided high internal stability with respect to load carrying capacity. Its favorable properties in this respect have already been presented in connection with discussion of soil tests and will now be emphasized as part of the paving design. The classification of the soil by the CAA design prodecure, which was the one accepted as official in pavement design, indicates its superiority as a subgrade, while the CBR tests indicate its relatively high internal stability in terms of other design methods which have been used as check tests in the pavement design.

Pavement design was predicated on the classification as an Express Airport under CAA Standards, which is implied in the name Toledo Express Airport.

In this connection reference is made to the CAA Technical Standard Order N-6, dated November 4, 1945, which is given as Table I in their pamphlet on airport paving published in May, 1948. Under this standard the pavement for the Toledo Express Airport was designed for a single wheel load of 45,000 pounds, for which the equivalent dual wheel load is 60,000 pounds. The following tabulation summarizes the pavement design, indicating factors involved in the design of both rigid and flexible pavements, and the final thicknesses established. This summary presents the various combinations of pavement components and total thickness as prepared by O. L. Stokstad and the writer to meet the range of loads and conditions involved in this project.

FLEXIBLE PAVEMENT

Single Wheel Load - 45,000 lbs.
Dual Wheel Load - 60,000 lbs.

CAA Standards

Soil Type E-2 Subgrade Class F_a or F_1

		F_1	F_a
Non Bituminous Base			
Runways	Surface	2-1/2"	2-1/2"
	Base	7-1/2"	7-1/2"
	Subbase	2-1/2"	0
	Total Thickness	12-1/2"	10"
Aprons-Taxiways	Surface	2-1/2"	2-1/2"
	Base	9-1/2"	9-1/2"
	Subbase	3"	0
	Total Thickness	15"	12"
Bituminous Base			
Runways	Surface	2"	2"
	Base	6"	6"
	Subbase	4-1/2"	0
	Total Thickness	12-1/2"	8"
Aprons-Taxiways	Surface	2-1/2"	2-1/2"
	Base	5-1/2"	5-1/2"
	Subbase	6-1/2"	0
	Total Thickness	14-1/2"	8"

U.S. Engineers Standards

Sand Subgrade - CBR Minimum - 20%
Average - 25%

Aprons-Taxiways - Required Thickness - 13-1/2"

Surface	3-1/2"
Base	6"
Subbase	4"
	13-1/2"

Runways - Reduce 1" - Total Thickness - 12-1/2"

Selected Thickness

Aprons-Taxiways - 13-1/2"
Runways - 12-1/2"

Stage Construction

Non-Instrument Runway - 8-1/2"
Non-Instrument Taxiways - 9-1/2"

CONCRETE PAVEMENT

C.A.A. Standards

Soil Type E-2 Subgrade Class R1a

	Wheel Load 45,000 lbs.	Wheel Load 60,000 lbs.
Runways		
Required Thickness	8"	9"
Reduction for Use of Steel Reinforcing	1"	1"
Net Thickness	7"	8"
Aprons-Taxiways		
Required Thickness	10"	12"
Reduction for Use of Steel Reinforcing	1"	1"
Net Thickness	9"	11"

Portland Cement Association Design

Assume Subgrade Modulus k = 300
Modulus of Rupture = 700 p.s.i.
E = 4,000,000 p.s.i., μ = 0.15

Aprons-Taxiways - Assume Factor of Safety = 1.8
Allowable Stress = 390 p.s.i.
Single Wheel Load = 45,000 lbs.
Required Thickness = 10"

Dual Wheel Load = 60,000 lbs.
Required Thickness = 9-1/2"

Runways - Factor of Safety = 1.5
Allowable Stress = 470 p.s.i.
Single Wheel Load = 45,000 lbs.
Required Thickness = 9"

Dual Wheel Load = 60,000 lbs.
Required Thickness = 8"

Selected Thickness

Aprons and Taxiways - 9" Reinforced
Runways - 8" Reinforced

Reinforcing - Ohio Department of Highways-Type"A" Mesh Fabric
Longitudinal Wire No.00 @ 6" ctrs - 64.28 lbs.per 100 sq.ft.
Transverse Wire No. 4 @ 12" ctrs - 13.99 lbs.per 100 sq.ft.
Total- 78.27 lbs.per 100 sq.ft.

DISCUSSION OF PAVEMENT DESIGN

In discussing the pavement design as outlined above, it may be emphasized that all design methods used are empirical in character and represent a norm or average of current practice. Furthermore, rather than being completely precise mathematical procedures, they permit considerable latitude for the exercise of engineering experience and judgment. This latitude becomes apparent in the above outline in several places which will be pointed out and discussed briefly.

Flexible Pavements

In the CAA method for flexible pavements the determination of soil type is fairly exacting, being dependent upon mechanical analyses and other standardized test procedures. However, the next step in selecting the subgrade class depends almost entirely upon a judgment evaluation of drainage and frost conditions. Either subgrade classes of F_a or F_1 could be justified, with the latter being the more conservative and requiring a nominal thickness of subbase as an increase in total pavement thickness. In the pavement design outline, thickness figures are given for both classes of subgrade. The maximum thickness for an F_1 subgrade may be taken as sufficient for the worst conditions of subgrade and drainage at the Oak Openings Site, while the minimum thicknesses for an F_a subgrade seem a reasonable estimate of average drainage and frost action.

From another viewpoint the selected thicknesses which correspond more closely with the greater values for an F_1 subgrade may be regarded as permitting wheel loads greater than 45,000 lbs. on which the present design was specifically based. This brings up another source of vagueness in most of the current design methods. For example, the CAA design charts make no provision for dual wheel loads and there is some question as to whether these charts can be used for a single wheel load on dual tires or are limited to a single wheel load on a single tire.

The U.S. Engineer method for flexible pavement design makes no provision for dual tires or wheels, nor does it restrict the design curves to a single tire or wheel load. All of these uncertainties must be regarded in view of two facts; first, that most of the heavier airplane wheel loads are on closely spaced dual tires, and, second, in so far as structural action on a flexible pavement is concerned, there is no significant difference in the contact area of a dual tire and a single tire at the same total load and inflation pressure.

With reference to the U.S. Engineers design of flexible pavements, the selection of the CBR value is the point of greatest latitude. The design figures originally presented to the Consulting Engineers were based on a minimum CBR of 20% for the compacted sand subgrade and a 45,000 lb. wheel load. The laboratory tests would justify an average CBR of 25% upon which the design may be based. Reference to the applicable design curves would indicate that a CBR of 25% and a wheel load of 60,000 lbs. would require approximately the same thickness as the 45,000 lb. wheel load and the CBR 20%. Thus, it may be concluded that the selected pavement thicknesses are sufficient for actual wheel loads of 60,000 lbs. under conditions fairly representative of the Toledo Airport.

Concrete Pavement

Turning to the design of the concrete pavement normally characterized as rigid pavement design, there are similar judgment factors which involve equal opportunity to introduce experience and judgment in the final answer and corresponding latitude in determination of specific values of design factors. In so far as the CAA method is concerned, the subgrade class of Rla is definite, as there is no change suggested for a wide range of drainage and frost conditions in the granular soil E-2.

There are, however, two other judgment factors of importance. In the first place, there is the question of whether the design curves are applicable to both the single wheel load of 45,000 lbs. and its equivalent dual wheel load of 60,000 lbs. Both have been shown in the design, and there is some support for the view that the selected thickness of 8" reinforced pavement on runways and 9" reinforced pavement on the aprons and taxiways is sufficient for more than the specific wheel load of 45,000 lbs. used in design.

The Portland Cement Association design has been worked out for both single wheel loads and dual wheel loads by a theoretically precise mathematical method. Without going into the validity of the assumptions on which the rigorous mathematics is based, it is pertinent to the present discussion to point out that the P.C.A. design for a dual wheel load of 60,000 lbs. requires slightly less thickness than for a single wheel load of 45,000 lbs. Further it should be stated that, in spite of the writer's implied questioning of design assumptions, this method represents the most widely used practice in the field of rigid pavement design.

Other factors permitting the most latitude or judgment in determining final pavement thickness are estimating the subgrade modulus and selecting the factor of safety for the allowable tensile stress in the concrete. With respect to subgrade modulus, the value of 300 p.s.i. (per inch, is considered conservative and particularly so considering the thorough compaction of the sand subgrade and the use of the high stability subbase of limestone screenings.

The allowable tensile stress in the concrete is determined by selection of the factor of safety which the writer reduced to the lower limit of the range recommended by P.C.A. This has been done because of the belief that the tensile stress is fictitious in the long range performance of the pavement and that the actual pavement performance will be determined by the subgrade support provided in combination with the structural continuity furnished by steel reinforcing.

Thus, in using this method of design because it has been widely accepted, the writer takes full advantage of design tolerances to decrease pavement thickness. This is done in the firm belief that the concrete pavement slab should be designed to be less rather than more rigid, so as to fully mobilize subgrade support, which must eventually carry the load in any case. This procedure is then backed up by providing the highest type subgrade possible and insisting upon an adequate amount of steel reinforcement to provide structural continuity in the slab.

Under the conditions of this project it is the writer's opinion that the concrete pavement as designed and built will provide a long period of highly efficient service and permit load applications substantially greater than those for which it was specifically designed.

The pavement sections finally selected in the design stage, after numerous conferences, included a number of combinations of crushed stone base, asphaltic base, and asphaltic surface courses and alternate reinforced concrete sections. The final subbase of limestone screenings was the only common feature of all paving alternates. The various combinations, however, provided a total thickness in accord with the design studies, with some monor variations which will be noted. Provision was made, for example, to permit stage construction on the Non-instrument runway and taxiways, with the objective of postponing construction of the full thickness of bituminous surface to some future date. Had this alternate been adopted, the temporary surfaces would have been 8-1/2 inches on the Non-instrument runway and 9-1/2 inches on the taxiway. As finally prepared there were a total of nine paving alternates on which bids were taken, varying from reinforced concrete pavement for the entire airport to a minimum of concrete with various combinations of asphaltic base and surfaces. The alternate finally selected and built was Alternate "K", which was substituted for Alternate "H".

Alternate K has been tabulated on Sheet No. 9 (Revised) of the contract plans and may be summarized as follows. Reinforced concrete 9 inches in thickness was used for part of the main apron in front of the Administration Building, and for the end connectors and warm-up pads. These areas, designated by a numerical area code on the plans as 13b, 3, 6, 9b, 11, 19, 20, and 21, make up a total of 46,864 sq. yds. of concrete pavement as built at a bid price of $5.28 per sq. yd. or $5.69 per sq. yd. including the 4-inch subbase.

The pavement for the runways and hangar aprons, designated by Code Nos. 1, 8, and 17, made up a total of 163,464 sq. yds. of flexible pavement 12-1/2 inches in thickness consisting of the following courses.

4"	Subbase - Limestone Screenings
4"	Waterbound Macadam - Crushed Stone
2"	Asphaltic Concrete B-35 - Base Course
1-1/2"	Asphaltic Concrete T-35 - Type A Leveling Course
1"	Asphaltic Concrete T-50 - Type B Surface Course
12-1/2"	Total Thickness

The balance of the airport paving, including taxiways, connectors, the north end of the Non-instrument Runway, and the remaining portion of the main apron was built of flexible types with a total thickness of 13-1/2 inches. These areas, designated by Code Nos. 2, 4, 5, 9a, 10, 12, 13a, 14, 15, 16, and 18, made up a total of 109,502 sq. yds. with the courses shown in the preceding paragraph, except for the substitution of a 3-inch, B-35, asphaltic concrete base course instead of the two inches used for 12-1/2-inch paving. For cost comparison it may be noted that the bid prices amounted to $2.83 per sq. yd. for the 12-1/2 inch pavement and $3.18 per sq. yd. for the 13-1/2 inch pavement. The cost, in dollars per sq. yd, of the component parts of these surfaces were as follows:

		TOTAL THICKNESS	
		12-1/2"	13-1/2"
4"	Subbase - Limestone Screenings	$0.411	$0.411
4"	Water Bound Macadam - Crushed Stone	0.710	0.710
	T-30 Prime Coat	0.063	0.063
2"	Asphaltic Concrete - Base Course	0.692	
3"	Asphaltic Concrete - Base Course		1.037
1-1/2"	Asphaltic Concrete T-35 Type A	0.544	0.544
1"	Asphaltic Concrete T-50 Type B Surface	0.410	0.410
	Cost per sq. yd.	$2.830	$3.175

In connection with the reinforced concrete pavement in which structural continuity is considered to be of primary importance, it is obvious that the type and spacing of joints is an important consideration. These details were covered in the contract plans on Sheet 27 and an addendum Sheet 1A, issued 7-22-53.

Longitudinal contraction joints were provided at the center of the runways, which were 150 feet in width and at intervals of 75 feet in the apron. Transverse contraction joints of the same type were provided at intervals of 60 feet in the runways and taxiways. These joints, which were standards of the Ohio Department of Highways, and designated at T.J. 1, 2, or 3, provided for accurately aligned 1" smooth dowels, lubricated on the free end and on 12" centers. The only expansion joints provided in this pavement were at intersections where there were abutting pavement slabs. These expansion joints were of a similar type and designated by the same standards, T.J. 1, 2, or 3, except that they provided a 1" opening for expansion with either wood board or preformed expansion joint filler.

The pavement was laid in single lanes, 10 or 12-1/2 feet in width depending upon the total width being a multiple of the lane width. A longitudinal hook bolt and key joint, L.J.-1, was provided between adjacent lanes throughout. The hook bolts were on 30-inch centers and a conventional trapezoidal shaped keyway was provided for load transfer at the joint. Similar hook bolt and key joints were used at all construction joints.

In addition to the airfield paving as outlined above, there were several minor items which involved paving, and were handled as extras. These included the Service Building apron and service drive, paving for the Executive Hangar as finally built and paved connectors and aprons for the Tee Hangar area. Mention is made of these miscellaneous paved areas as they represent paved areas which may be the subject of future observation and comment reflecting on the service behavior of the airfield pavement in general. However, being extras, they are not in all cases of the same section, and their construction may not be truly representative of the airfield paving, which is the subject of this report.

The aprons for the Executive Hangar, which are actually an extension of the main apron, have the same section as the runways and that portion of the main apron on which bituminous paving was used. This paving was the lighter section, 12-1/2 inches in thickness as detailed above, and was presumably put down under the same construction controls. The paving in the Tee Hangar area was 9 inches in total thickness, consisting of the 4-inch subbase of limestone screenings, 4-inch waterbound macadam base, and a 1-inch asphaltic concrete surface of Type B. The Service Building apron and drive paving was made up of the 4-inch subbase, 4-inch waterbound macadam base, a 1-1/2 inch T-35 asphaltic concrete leveling course, and a 1 inch asphaltic concrete surface, giving a total thickness of 10-1/2 inches.

There are, however, several of the factors discussed above which deserve special emphasis in the present report. In order to take full advantage of the inherent stability of the granular soil and to prevent any more than negligible settlement of the paved areas, it is necessary that these soils be thoroughly compacted. It was to determine the densities which should be obtained that the compaction characteristics of these soils were so carefully studied. It then follows that this standard density must be obtained during the grading operation, if full benefit is to be realized. For control of compaction, and, as a matter of fact, as standard for the entire paving operation, Construction and Materials Specifications of the State of Ohio Department of Highways were adopted for the Toledo Airport. With respect to compaction, the soils at the Toledo Airport fall into two categories. For fill areas the compaction requirements may be indicated as follows:

Laboratory Maximum Dry Weight p.c.f.	Minimum Field Compaction Requirements Per Cent
103.0 - 109.9	98
110.0 - 119.9	96

In addition the subgrade for a depth of 12 inches must be compacted as follows:

Laboratory Maximum Dry Weight p.c.f.	Minimum Subgrade Compaction Requirements Per Cent
103.0 - 109.9	102
110.0 - 119.9	100

With the requirement for adequate compaction of the subgrade established, consideration was given to the fact that the subgrade must be protected against disturbance of rutting during the paving operation, a common oversight on many pavement projects. In this connection the Toledo Airport was particularly fortunate in having within practicable hauling distance considerable quantities of limestone screenings which had accumulated in quarries in the vicinity as waste materials. With such material readily available, it was decided to place a subgrade mat of limestone screenings of four inches compacted thickness to serve as a working platform during the paving operations and, likewise, to provide a subbase of superior quality for both concrete pavement and flexible pavement as selected.

The third decision of importance, which was made after some discussion, was the requirement that steel reinforcement be used in the concrete pavement selected as an alternate design for the runways and taxiways and specified for the aprons and warm-up areas. In the writer's opinion, the structural continuity provided by this steel reinforcement is a most important factor in pavement performance, second only to an adequate supporting subgrade.

CONSTRUCTION PROGRAM

Following the award of the General Contract, in early August the construction program got underway. The grading was, of course, the first phase of this work and one of primary importance in so far as the success of the airport paving is concerned. Recognizing that close control of the compaction was essential, the City retained the Toledo Testing Laboratory to conduct the field testing and supervise the field compaction. In the writer's opinion, this phase of the airport construction was most effectively handled, with results which are a considerable source of satisfaction, although the writer's connection with this work became less and less frequent. Starting on August 10, 1953, and extending to July 2, 1954, the Toledo Testing Laboratory has presented daily reports while construction operations were in progress. The writer has received copies of these reports throughout this period and followed the care with which these specifications were enforced with a great deal of interest. It is felt that this engineering control of the project is a most important factor in the excellence of the final result and will be equally important in excellent pavement performance, which it is anticipated will be realized over the years.

Following compaction of the sand fill and subgrade, the subbase of limestone screenings was placed over the entire paving area and thoroughly compacted. The use of limestone screenings for a subbase worked out exceptionally well, and it provided a fine working platform for placing the asphaltic surface.

In connection with the work of the Toledo Testing Laboratory, special note has been made of the ground water observations made periodically as a part of the construction control program. These observations were reported under date of August 2, 1954, and the conclusions presented in these observations have been discussed with the Consulting Engineers.

From this report it would appear that critical areas of high water table that were located have been corrected by special drainage, with the possible exception of two areas. One of these areas is in the vicinity of Station 45 + 00 to 46 + 00 on the Non-instrument runway, and the other along the southerly edge of the apron where a low point in the surface grade approaches too close to the observed water table.

From discussion with the Consulting Engineers it is understood that this problem has been discussed with the City, and corrective measures under consideration late in the 1954 construction season have been postponed until next year. One of the factors in this postponement was the hope that the drainage improvement of the entire airport area would lower water tables in general and might clear up these critical areas. However, if after a year's observation these critical areas of high water table still remain, special drainage will be installed to lower the water to the desired depth.

CONCLUSION

In conclusion the writer wishes to express his appreciation for the opportunity presented to work with the Consulting Engineers and representatives of the City on this project. This association throughout was characterized by good understanding and cooperation and a determination on the part of all concerned to build an airport of which the City could be proud. In this connection it is the writer's opinion that the results have certainly justified the efforts of all concerned. It is believed that the performance that will be realized in the future will serve to confirm this high opinion.

Respectfully submitted,

W. S. Housel

APPENDIX A

PREVIOUS REPORTS ON AIRPORT DESIGN AND CONSTRUCTION

REPORT ON

PRELIMINARY DESIGN RECOMMENDATIONS

FOR THE

NEW TOLEDO EXPRESS AIRPORT

William S. Housel
Consulting Engineer
Ann Arbor, Michigan

November 28, 1952

PRELIMINARY DESIGN RECOMMENDATIONS FOR THE NEW TOLEDO EXPRESS AIRPORT

With the selection of the Oak Openings Site for the New Toledo Express Airport an accomplished fact, it is possible to make more definite plans for solution of the various engineering and construction problems involved in the proposed airport. In accordance with arrangements made through Stepleton, McDonnell and Barber, the writer has agreed to act as Engineering and Technical Advisor on this project. In this connection, it is understood that the consulting services desired are with reference to engineering design of those physical features of the construction having to do with soil conditions, drainage, and the structural adequacy of the paving for runways, taxiways, and aprons. Those phases of design having to do with aeronautical requirements, planning of auxiliary service facilities, and the design of buildings are not contemplated as being a part of this arrangement. Unless specifically requested to do otherwise, the writer's suggestions and recommendations will be limited by this understanding.

It is the purpose of this report to present some preliminary recommendations with respect to the planning and engineering studies which should now be undertaken in the orderly preparation and execution of plans and specifications for construction of the airport. It is recognized that upon official approval of the project, there will be considerable urgency in making rapid progress with the design in order to get the construction under way at the earliest possible date. Under the impetus of such urgency, it has happened all too frequently in the past that proper investigation and planning have been compromised to the ultimate detriment of the project, both from the standpoint of efficient progress toward completion and the adequacy of the airport as a permanent facility. For this reason, the writer would like to emphasize that a reasonable period devoted to preliminary investigation and intelligent planning is imperative and will actually save time in the long run as well as insuring the most satisfactory performance of the airport over the years.

THE "OAK OPENINGS SITE"

The "Oak Openings Site" which is described in the "Preliminary Report of Investigation" by Leigh Fisher & Associates of South Bend, Indiana, is in an area of the most favorable soil conditions to be found in the vicinity of Toledo. Its favorable features have been pointed out by the writer in a letter under date of August 1, 1952, which was included in the report referred to above. More recently, Stepleton, McDonnell and Barber have obtained representative samples of the subsoil from thirteen borings made at stations along the two runways and in the building area. The location of these borings is indicated on a preliminary runway layout which is to be submitted with a report now being prepared by Leigh Fisher & Associates.

These samples were submitted to the Soil Mechanics Laboratory at the University of Michigan and tests were made on typical samples from five of these borings. The results of these tests have been summarized in a tabulation appended to this report. All samples are predominantly medium and fine sand with a very small percentage of silt and clay. Several samples containing noticeable amounts of black topsoil were tested for organic content. One sample showed slightly more than 2 per cent loss on ignition. The other samples tested for ignition loss showed only traces of combustible organic matter.

The primary purpose of these tests was to establish the soil classification which may be related to paving design standards. In terms of the Civil

Aeronautics Administration classification there were, in the thirteen samples tested, four classified as E-1, seven as E-2, and two as E-3. In terms of the Highway Research Board Classification, which is also used by the American Association of State Highway Officials, all thirteen samples would be classified as A-3 with a group index of zero.

These tests clearly establish the soil at the Oak Openings Site as most favorable for construction purposes for the full depth of probable grading operations. It is a relatively clean granular material with good internal drainage and high stability as a supporting subgrade. Its unusual uniformity throughout the site should lend itself to consistently good compaction control during construction. With proper specifications and field control during the grading and paving operations it should not be difficult to provide a supporting subgrade for the paved areas of uniformly high quality.

PRELIMINARY DESIGN RECOMMENDATIONS

For the purposes of this report, it seems pertinent to discuss in a preliminary fashion the problems which should be anticipated in the construction of the New Toledo Express Airport and outline some tentative design recommendations. This will be done very briefly at this time, in some cases doing little more than to indicate several steps to be followed and in the sequence that they should probably be undertaken.

TOPOGRAPHIC MAP

The first engineering work to be done is the preparation of an accurate topographic map with a probable contour interval of one foot and not to exceed two feet. Such a map is essential in establishing the grade line of the runways and taxiways and the elevation of other paved areas, buildings, and miscellaneous facilities. Accurate topography is also the basis for developing the grading plan which is important in the economic use of the soil, the major material out of which the airport will be built.

DETAILED SOIL SURVEY

While considerable preliminary information on soil types is already available, a detailed soil survey is essential to proper planning. Such a survey is neither expensive nor time consuming and can be made by two experienced men in several days. Its value lies in the accurate mapping of soil types which provides area significance to the specific tests which have been made and others which will be made.

There are three general soil types or series in the proposed site and these are designated as Plainfield, Maumee, and Newton. Plainfield is a well drained sand with a low water table, while Maumee and Newton are both poorly drained, having a high water table which may be close to the surface of the ground during the wet season of the year. Both of the latter soil series are swamp or swamp border soils and would normally have a heavy black topsoil which should be properly disposed of in the grading operations.

INVESTIGATION OF DRAINAGE FEATURES

As might be anticipated from the description of the soil types, there will be a special drainage problem. All of the soils involved have good internal drainage which means simply that they are relatively permeable. The poor drainage of the Maumee and Newton series is a matter of topography and the lack of free outlet for the subsurface water which has accumulated.

Thus the first requirement in the engineering study of drainage is to make a survey of drainage outlets to insure that there will be full opportunity for disposing of the flow from subsurface drainage which may be required to control the elevation of the ground water table.

The drainage system that will be required must be worked out with the grading plans and cannot be anticipated in any detail at this time. However, the general features may be suggested. With the sandy soil, percolation rates will be high and there will probably be little, if any, surface drainage and storm sewers required. There will be few surface inlets required except possibly in the paved aprons and building area. Precipitation will percolate into the soil and be carried away where necessary by the subdrainage system.

PRELIMINARY SOIL TESTS

In addition to presently available data on soils, representative samples from typical soil areas should be obtained to establish density curves for control of compaction and to obtain more specific data on subgrade bearing capacity for pavement design.

Fairly large disturbed samples will be needed for determination in the laboratory of the density range and compaction characteristics of the soil. These samples should not be taken until the grading plan has been worked out, at which time they may be selected to represent the soil which will be used in grading the runways and other paved areas. After these data are obtained, nothing further will be required in the line of compaction tests until the actual grading of the runways. At that time, compaction control tests will be carried along with the grading for purposes of field control.

These same samples may be used to conduct certain laboratory tests which will establish the subgrade bearing capacity needed for design of the paved surfaces. These tests are preliminary and will be supplemented by confirming tests made either in the laboratory or in the field after the runways have been graded. The tests will include the C.B.R. test from which an estimate may be made of the subgrade modulus used in design of rigid pavements.

GRADING PLAN

The first phase of actual construction operations will be clearing and grading. Clearing may proceed at any time and obviously requires little, if any, engineering control. However, before any grading operations should be undertaken, a well considered grading plan should have been worked out. Here again final decisions and details of the grading plan must await the topographic map and correlation of runway grades with elevations in the building and service areas. At this time, it is only possible to outline several of the desirable objectives to be kept in mind.

In this connection, it is the writer's feeling that runways should be maintained on a relatively high grade line to minimize the need for extensive subdrainage, to decrease possible snow removal, and to provide maximum ponding volume in field areas between runways. These objectives will call for a grading plan in which the attempt to balance cut and fill along the longitudinal profile of the runway will be subordinated to the procedure of obtaining borrow for runway fill from the field area between runways. This will necessitate an area grading plan rather than conventional volume control used in grading of a strip with yardages estimated from station cross-sections.

The first step in grading will involve stripping of the topsoil in any areas where it is sufficiently heavy to be detrimental in the subgrade for pavements. Furthermore, any available topsoil is an asset which should not be wasted as it will be required in top-dressing the sandy soil where turf is to be maintained in unpaved areas. Consequently, the topsoil should be stripped and stockpiled for this purpose as an initial phase of the grading contract.

As one element in the grading plan, transverse grades should be carried from the edge of all paved areas for some distance on both sides of the runways and taxiways into the adjacent field areas. In this way, any surface runoff at times of abnormal rainfall may be carried rapidly away from the paved areas into potential ponding areas until it percolates into the subsoil and reaches the subdrainage system.

PAVEMENT DESIGN

As previously noted, the soil conditions at the site of the proposed airport are very favorable from the viewpoint of the supporting subgrade of the airfield pavements. With reasonable care in construction, the subgrade should be of uniformly high supporting capacity and there should be no limitations imposed in the design of the pavements. Some additional quantitative tests are required to furnish data for determining the actual thickness of the pavements and these should be performed in proper sequence. At this time, it is only possible to anticipate several of the problems involved.

In the first place, selection of the type of pavement should be made after the relative thickness and resulting costs have been determined. Until this is done, the writer would hesitate to recommend either the flexible or rigid type pavement. In either case, the supporting subgrade is the controlling element in design. In the rigid type pavement, such as Portland cement concrete, there will be no subbase required. With the high subgrade support provided, thickness of such a pavement should be close to the minimum required for the wheel loads to be specified.

A flexible type pavement consisting of a high quality base course and a bituminous wearing surface has been mentioned in the "Preliminary Report of Investigation" by Leigh Fisher & Associates. Such a pavement may prove to be the most economical and should unquestionably furnish an adequate pavement from the standpoint of load supporting capacity.

The main design problem involved in the flexible pavement is the selection of the base course. This would ordinarily be a well graded gravel or crushed stone base but consideration may also be given to a stabilized soil base course. The sandy soil at this site is favorable to soil stabilization with the stabilizing agents normally used consisting of Portland cement, asphaltic emulsion, asphaltic oil, or tar. While such a base course should be considered, its design and construction present some definite problems which would have to be thoroughly explored. A comprehensive laboratory investigation is needed to determine proper proportions of the stabilized mix and to demonstrate the adequacy and permanence of the stabilization. In construction, thorough mixing and complete curing must be assured and this is not always easy under field conditions. For these reasons, the more conventional types of base construction may be preferred.

In conclusion, it should be recognized that the selection of pavement type is one of the most important problems to be solved. This selection should only be made after careful study and review by all those who are concerned with the project, both in relation to the design and construction and from the long time operation and maintenance of the airport.

Respectfully submitted,

William S. Housel
Consulting Engineer
Ann Arbor, Michigan

November 28, 1952

UNIVERSITY OF MICHIGAN
SOIL MECHANICS LABORATORY
ANN ARBOR, MICHIGAN

SUMMARY OF SOIL TEST DATA FOR NEW TOLEDO EXPRESS AIRPORT

FIELD DESCRIPTION			LAB. NO.	PARTICLE SIZE DISTRIBUTION						LIQUID LIMIT	PLASTICITY INDEX	ORGANIC CONTENT % BY WEIGHT	CLASSIFICATION	
				HRB			CAA							
BORING NO.	SA.NO.	ELEV.	52 H	C.S.	F.S.	SILT & CLAY	C.S.	F.S.	SILT & CLAY				HRB	CAA
2	A	674.0	1038	4	94	2	59	39	2	-	-	-	A-3-(0)	E-1
2	B	668.0	1039	3	93	4	23	75	2	16	NP	0.55	A-3-(0)	E-2
2	C	666.0	1040	3	95	2	29	69	2	-	-	0.58	A-3-(0)	E-2
5	A	675.9	1041	8	87	5	59	36	5	18	NP	-	A-3-(0)	E-1
5	B	671.9	1042	7	90	3	51	47	2	-	-	0.58	A-3-(0)	E-1
5	C	667.9	1043	6	90	4	39	59	2	15	NP	0.57	A-3-(0)	E-2
10	A	661.1	1044	2	92	6	35	61	4	17	NP	-	A-3-(0)	E-2
10	B	656.1	1045	2	91	7	14	82	4	19	NP	-	A-3-(0)	E-3
10	C	654.1	1046	2	88	10	13	83	4	15	NP	-	A-3-(0)	E-3
11	A	657.4	1047	3	94	3	29	69	2	-	-	2.24	A-3-(0)	E-2
11	B	651.4	1048	3	95	2	21	78	1	17	NP	0.63	A-3-(0)	E-2
13	A	656.8	1049	3	95	2	40	58	2	-	-	-	A-3-(0)	E-1
13	B	651.8	1050	1	90	9	18	80	2	17	NP	-	A-3-(0)	E-2

General Notes:

1. Definition of soil fractions:

		HRB	CAA
Coarse Sand	(C.S.)	- Pass No.10, Ret. No. 40	Pass No.10, Ret. No. 60
Fine Sand	(F.S.)	- Pass No.40, Ret. No.200	Pass No.60, Ret. No.270
Silt & Clay		- Pass No.200	Pass No.270

2. HRB - Highway Research Board
   CAA - Civil Aeronautics Administration
3. Textural Classification of all samples is sand based on the tri-axial texture chart.
4. No samples contained gravel.

SOIL SURVEY

TOLEDO EXPRESS AIRPORT

LUCAS COUNTY, OHIO

BY

ENGINEERING RESEARCH INSTITUTE

UNIVERSITY OF MICHIGAN

ANN ARBOR, MICHIGAN

FOR

STEPLETON, McDONNELL & BARBER

ASSOCIATE ENGINEERS AND ARCHITECT

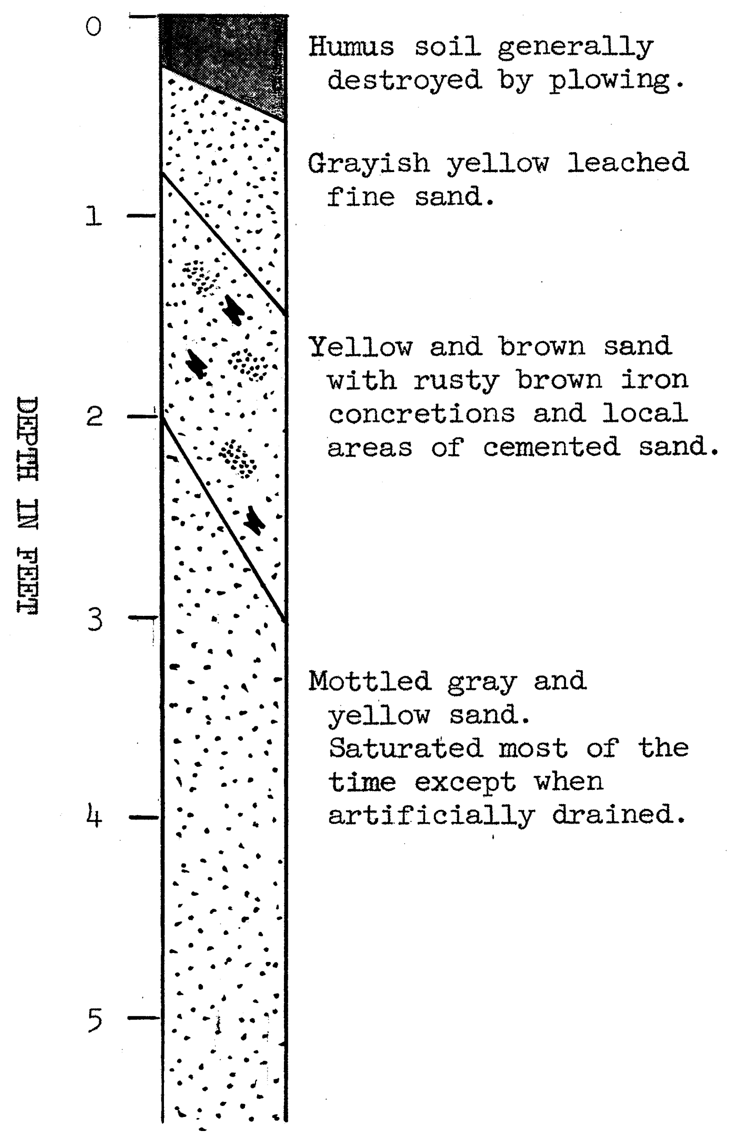
TOLEDO, OHIO

APRIL, 1953

Survey by -

O. L. Stokstad
H. E. Barnes

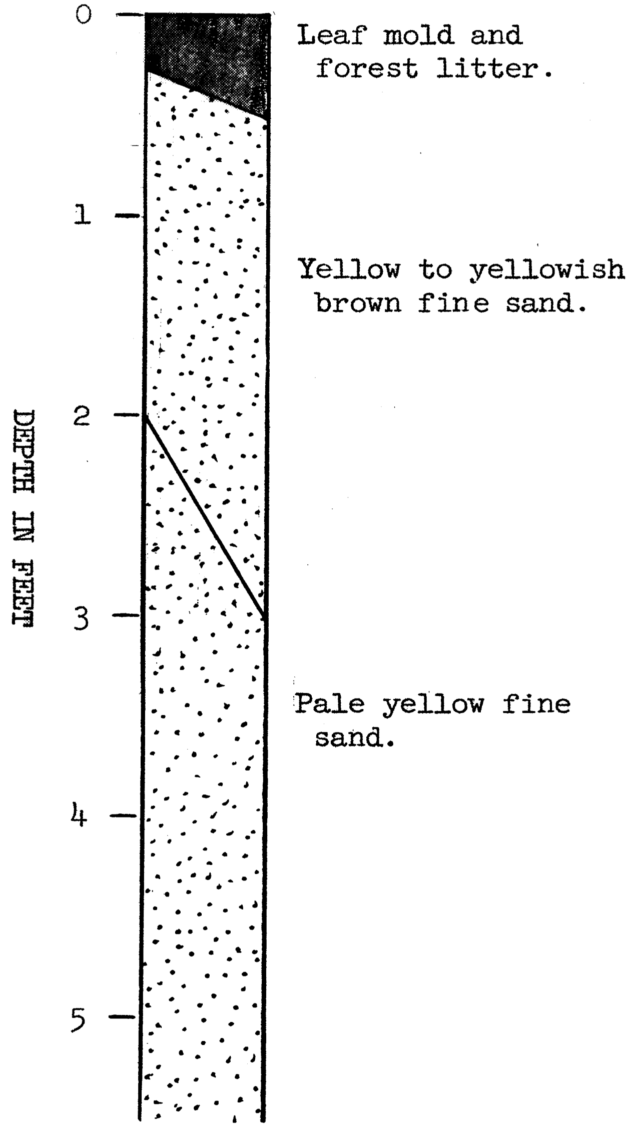
SAUGATUCK FINE SAND



Remarks

1. This soil lies slightly higher than the Newton and Maumee soils.
2. The topsoil has generally been altered by farming operations to the point where stripping may not be necessary.
3. Generally, these soils should be well rolled in all building and pavement areas.
4. Saugatuck soils are a source of underwater granular borrow.
5. Water table is an important design control.

PLAINFIELD FINE SAND



Remarks

1. This soil occurs on the better drained sand formations of the area in association with Bridgeman soils which occupy the highest ridges.

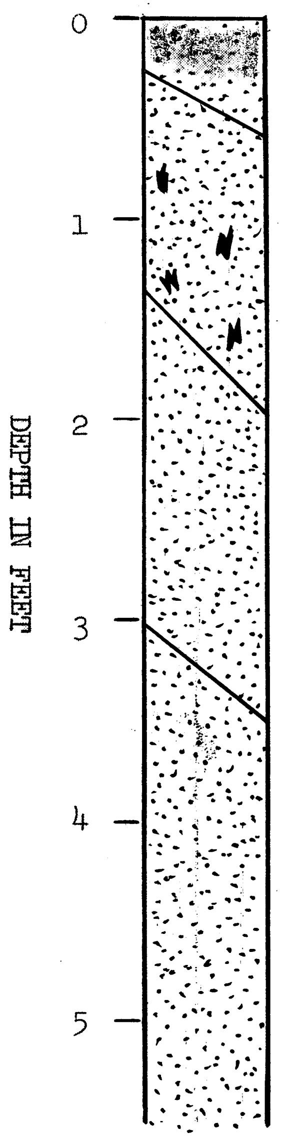
2. Plainfield soils can serve as dry borrow resources for embankment construction.

3. Check for water table in cuts of more than 4 or 5 ft. depth.

4. Plainfield soils are subject to wind erosion wherever the natural turf or forest mat is destroyed. Such areas will need the addition of topsoil before a good grass cover can be grown.

PLAINFIELD FINE SAND

NEWTON FINE SAND



Dark gray fine sand.

Mottled yellow, brown and gray fine sand. Contains iron concretions.

Yellow and gray fine sand.

Gray fine sand. Permanently saturated.

Remarks

1. This soil lies slightly higher than the Maumee soil. Water table occurred at depths of from 1.5 to 3.5 feet on 18 Apr. '53 varying with the influence of artificial drainage.

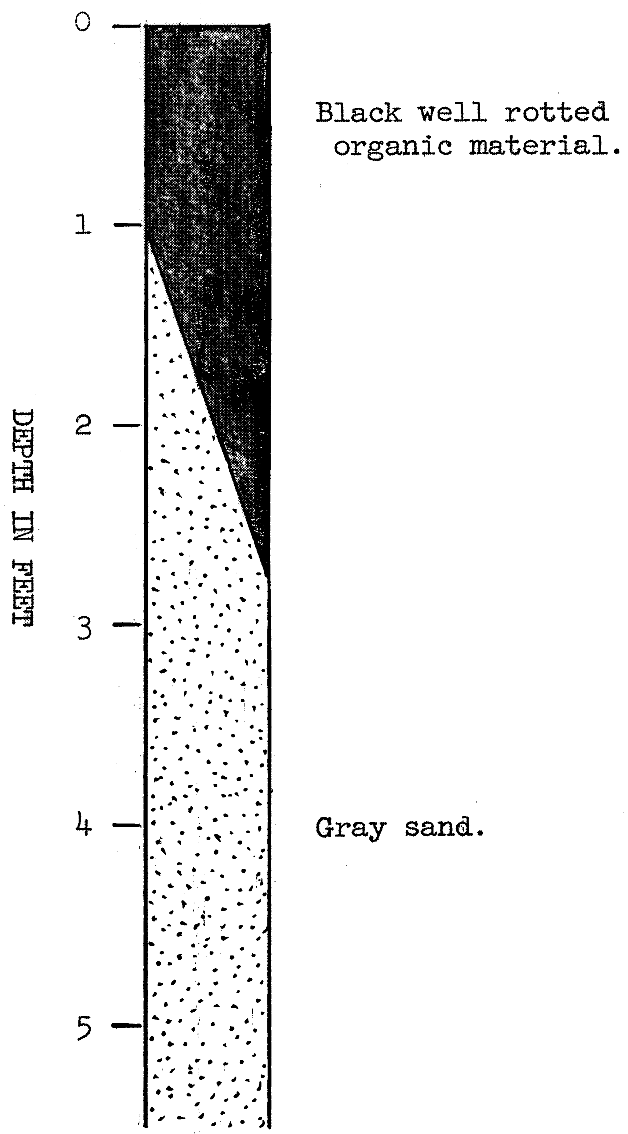
2. Generally the topsoil is not loamy enough to be worth salvaging. The leaf mold and forest litter should be removed in forested areas. In farmed area, good rolling may be sufficient in pavement areas.

3. Ditch-cut materials will make excellent fill for embankment construction.

4. Newton soils are suitable for underwater borrow.

NEWTON FINE SAND

MUCK



Remarks

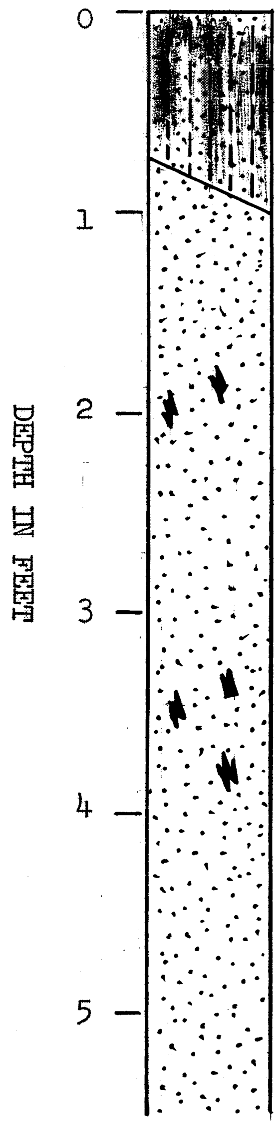
1. An area of shallow muck was encountered between stations 95 and 101 on the east-west runway. This area should be sounded at each station to a width equal to the width of pavement and shoulders.

2. All muck should be removed from pavement and building areas.

3. This material may be salvaged for the use of mulching around shrubs in a landscaping program. Generally, it does not make a good topsoil material because removed from its permanently saturated site decomposition accelerates to the point where the organic matter largely disappears within a few years.

MUCK

MAUMEE LOAMY FINE SAND



Grayish black loamy fine sand. Organic content high.

Gray fine sand streaked with yellow and orange. Occasional areas contain iron concretions.

Permanently saturated.

Remarks

1. An excellent source of topsoil which should be stripped and salvaged for use in the operation of turfing runway shoulders and building grounds.

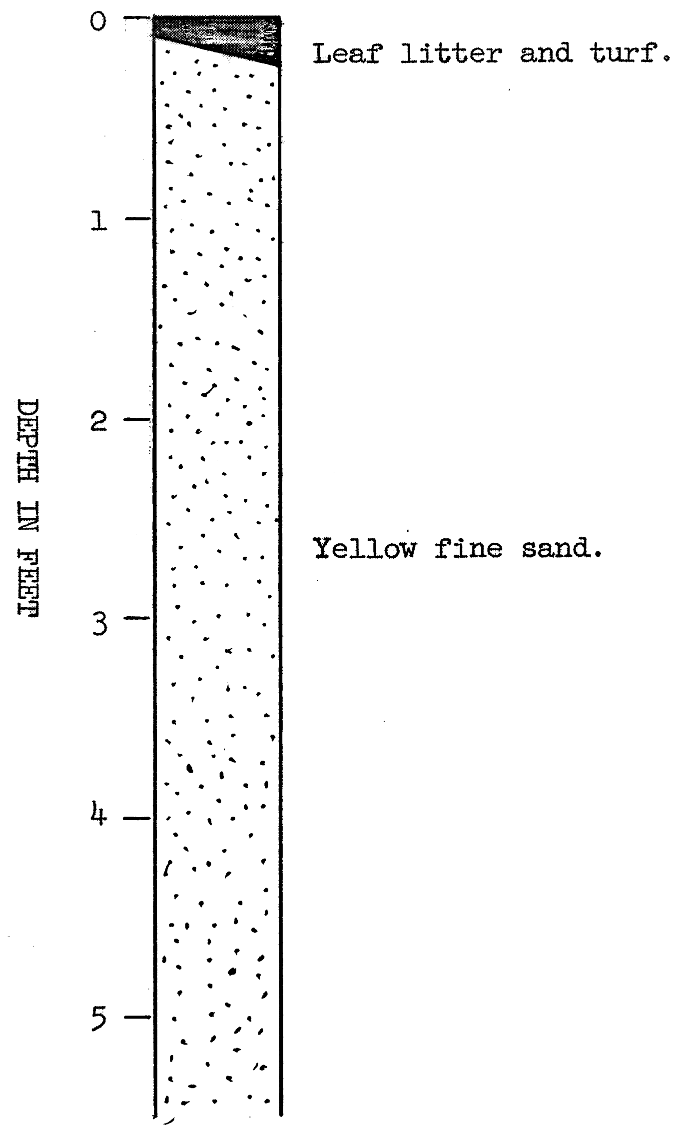
2. Generally the sand is rather soft to a depth of about 3 feet and therefore additional compaction by rolling is required in pavement or building areas.

3. The water table occurred at depths of from 0 to 2.5 feet on 18 Apr. '53 depending to some extent on the nearness to a county drain.

4. No clay was found within depths involved in runway grading.

MAUMEE LOAMY FINE SAND

BRIDGMAN FINE SAND



Remarks

1. This soil was mapped on one of the higher dune-like sand ridges of the area.
2. A good source of sand borrow.
3. The soil is subject to wind erosion wherever the vegetative cover is destroyed.
4. The loose incoherent nature of this sand makes truck hauling difficult.
5. The sand may be stabilized for construction purposes by adding other types of granular materials such as limestone fines. Avoid the use of clay in pavement areas. Turf areas should receive topsoil salvaged from the Maumee soils.

BRIDGMAN FINE SAND

SOIL SURVEY REPORT

The area involved in this survey is a deep deposit of fine sand generally poorly drained. Variation in the soils identified has resulted mainly from variations in the depth to normal water table, with the heaviest topsoil occurring in the more poorly drained positions.

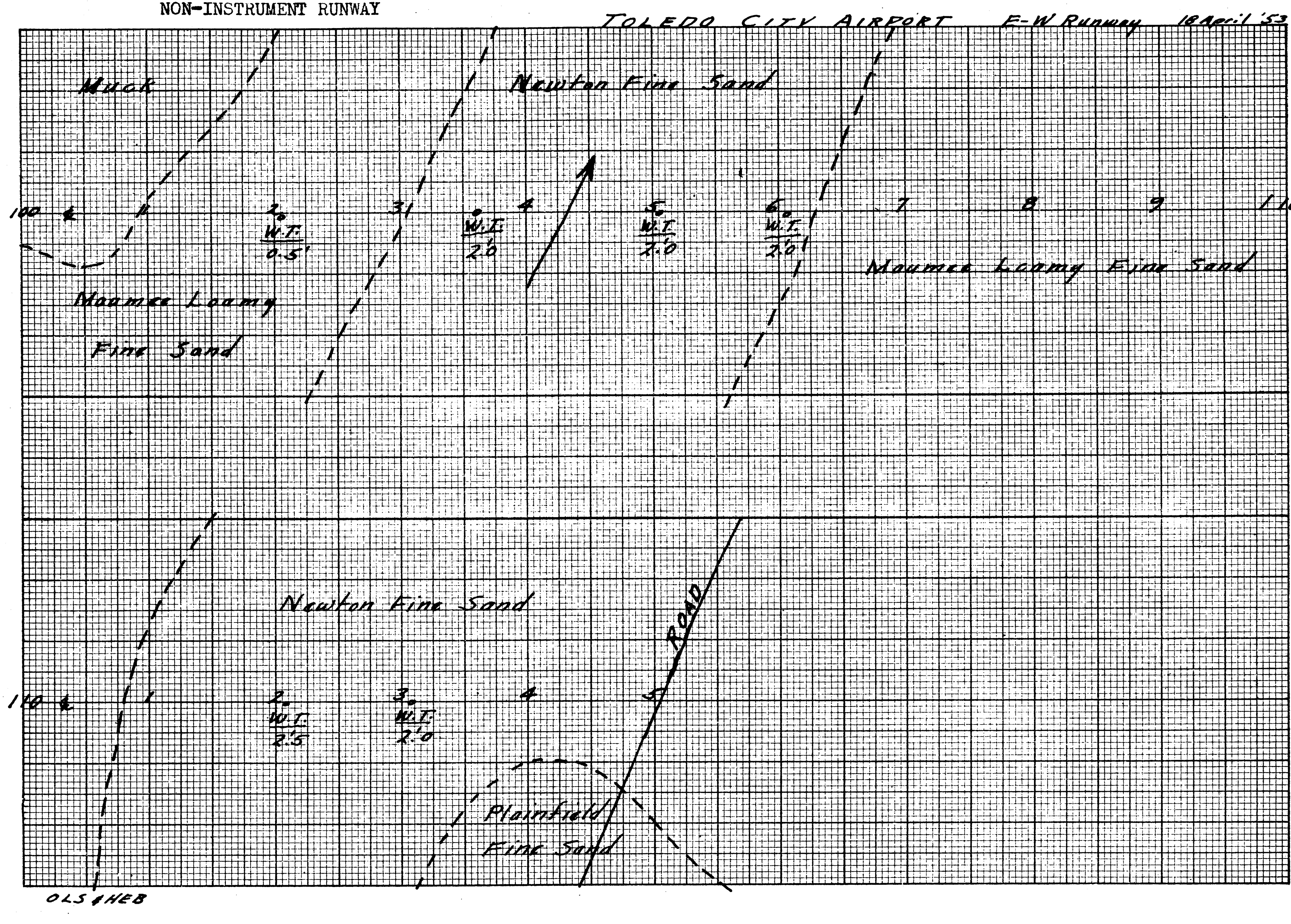
The principal control in determining the elevation of runway pavements will be the position of the ground water table during the critical season of the year. It is recommended that pavement grades be kept at least 5 feet above water table elevations. Since the soil survey was made at a time when ground water is normally at its highest level, the water table soundings as shown on the soil survey sheets may be used in design. Some changes in these water table levels should be expected as the existing drainage pattern is altered.

Most of the grading will involve shallow cut and fill in the weathered portion of the soil profile. The fluffed condition of these fine sand soils will require that foundation areas be well rolled or otherwise compacted before constructing shallow fills, base courses, pavements, floors, or footings. The soils, being of a granular nature, are easily drained and do not present special problems of pavement support such as mud pumping. They are easily drained and, when thus adequately treated, are not subject to frost heaving or spring break-up.

The extensive areas of Maumee soils will be the best sources of topsoil, which should be salvaged for use in establishing turf surfacing on runway or taxiway shoulders, building grounds, and other grading areas where the original topsoil has been destroyed.

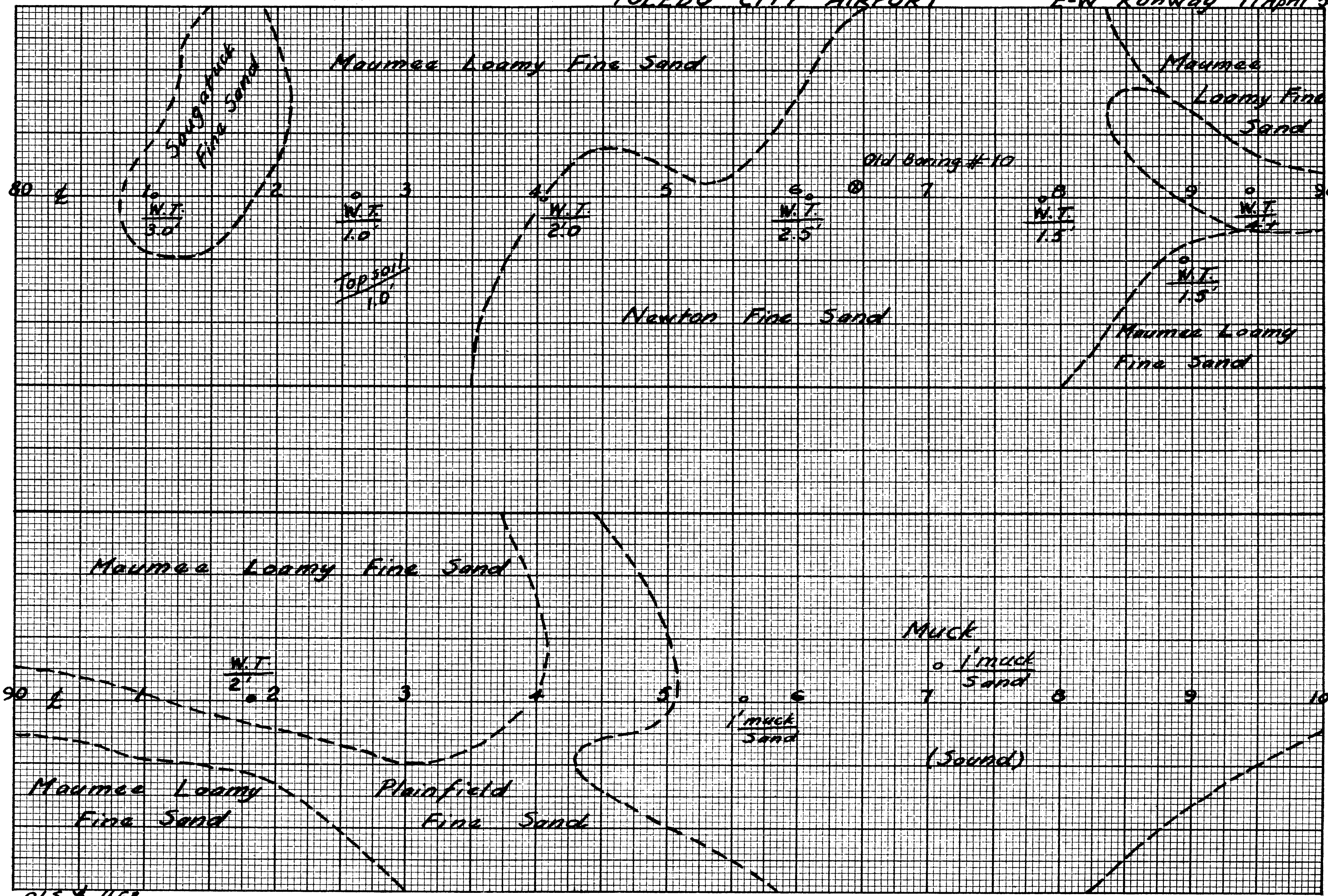
O. L. Stokstad

NON-INSTRUMENT RUNWAY



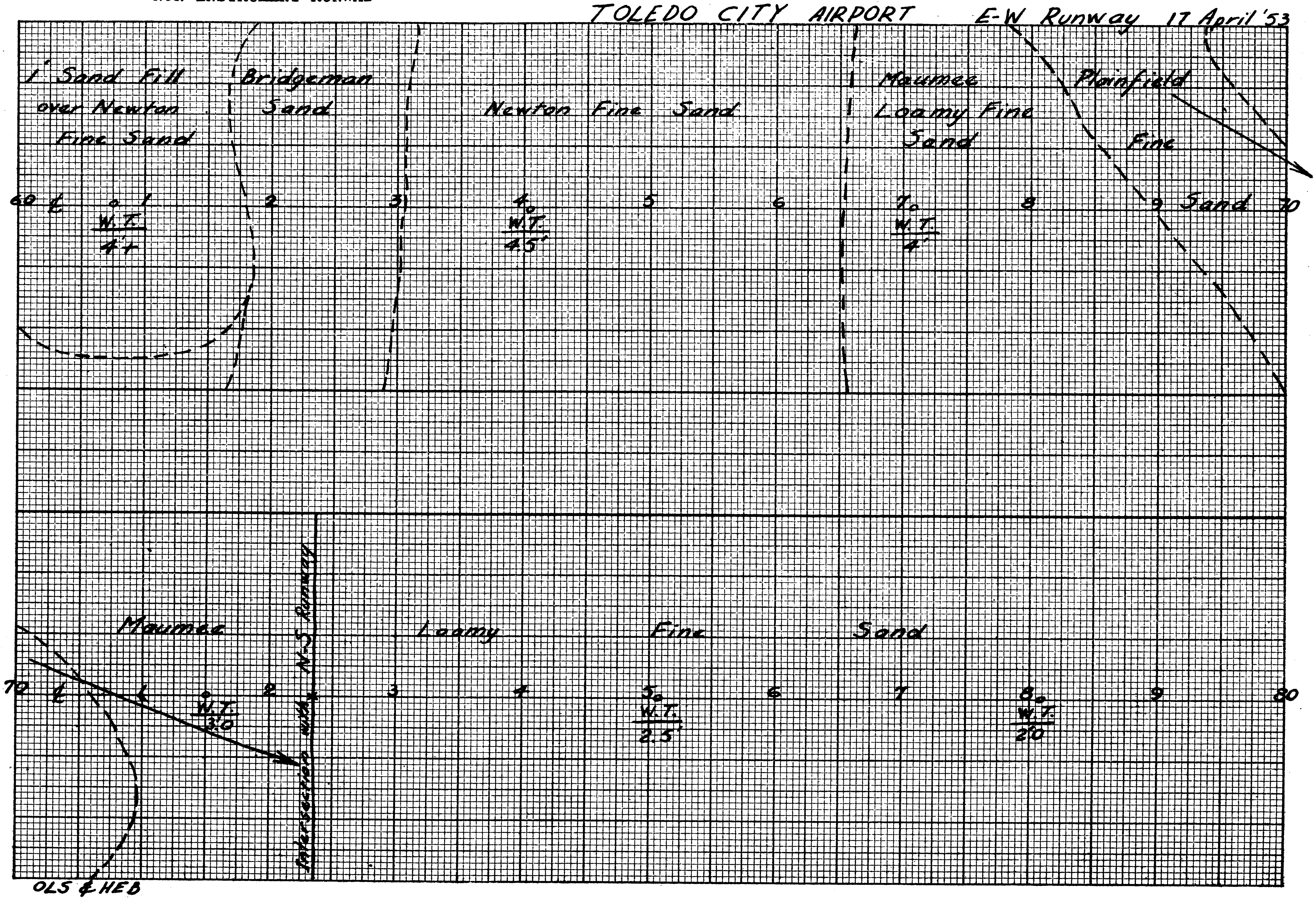
NON-INSTRUMENT RUNWAY

TOLEDO CITY AIRPORT E-W Runway 17 April '53



OLS & HEB

NON-INSTRUMENT RUNWAY



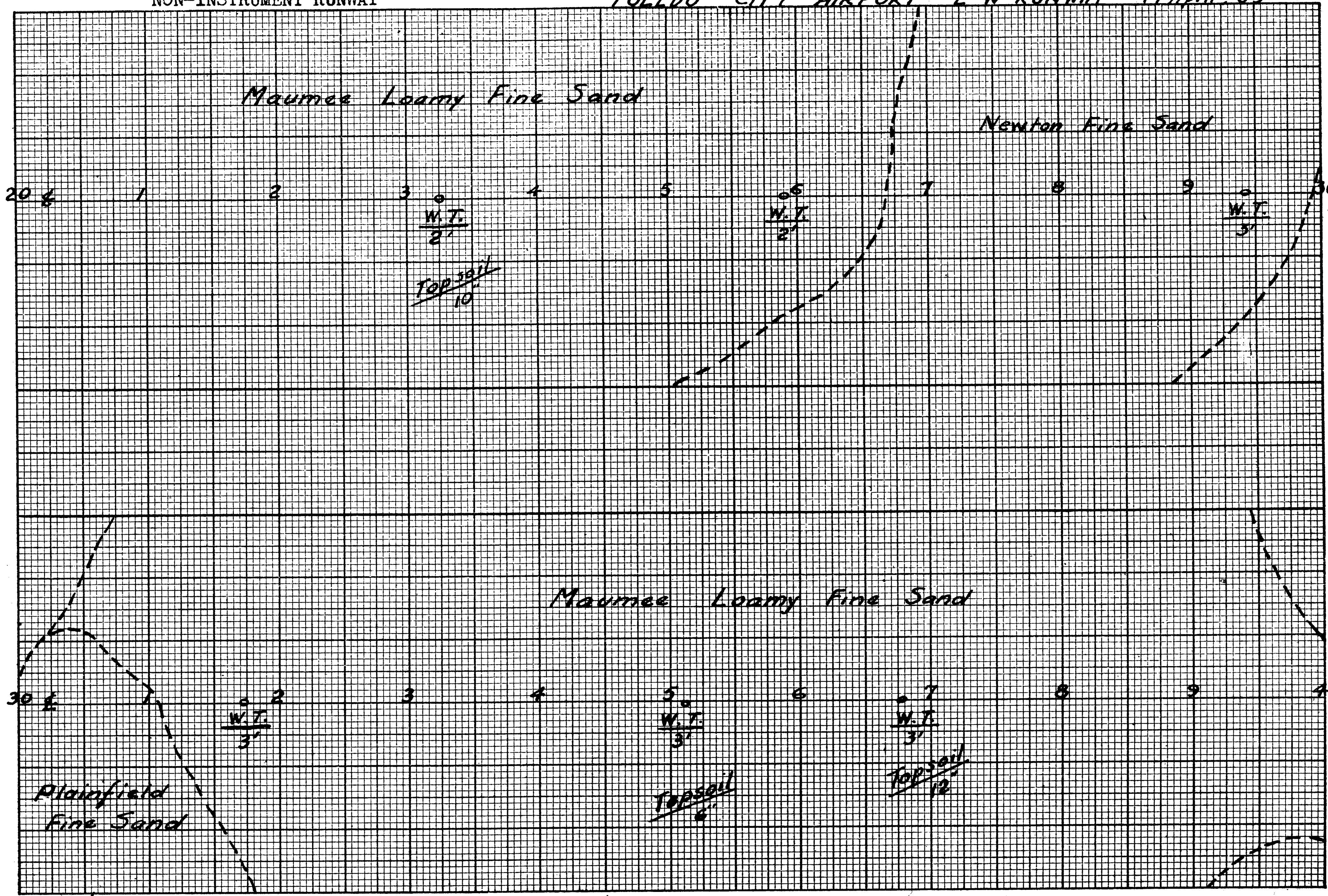
NON-INSTRUMENT RUNWAY

TOLEDO CITY AIRPORT E-W Runway 17 April '53

OLS & HEB

NON-INSTRUMENT RUNWAY

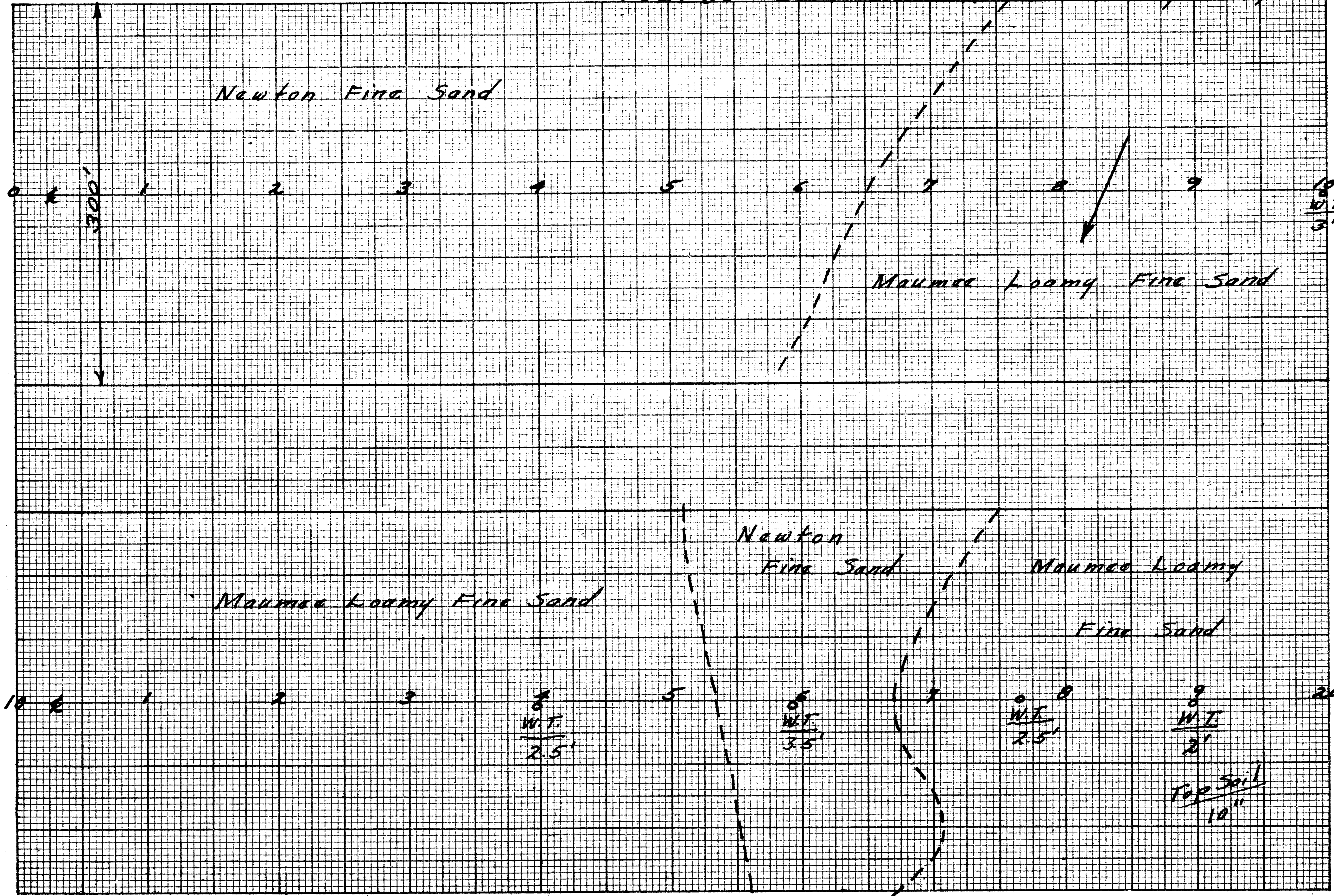
TOLEDO CITY AIRPORT E-W RUNWAY 17 April 53



OLS & HEB

NON-INSTRUMENT RUNWAY

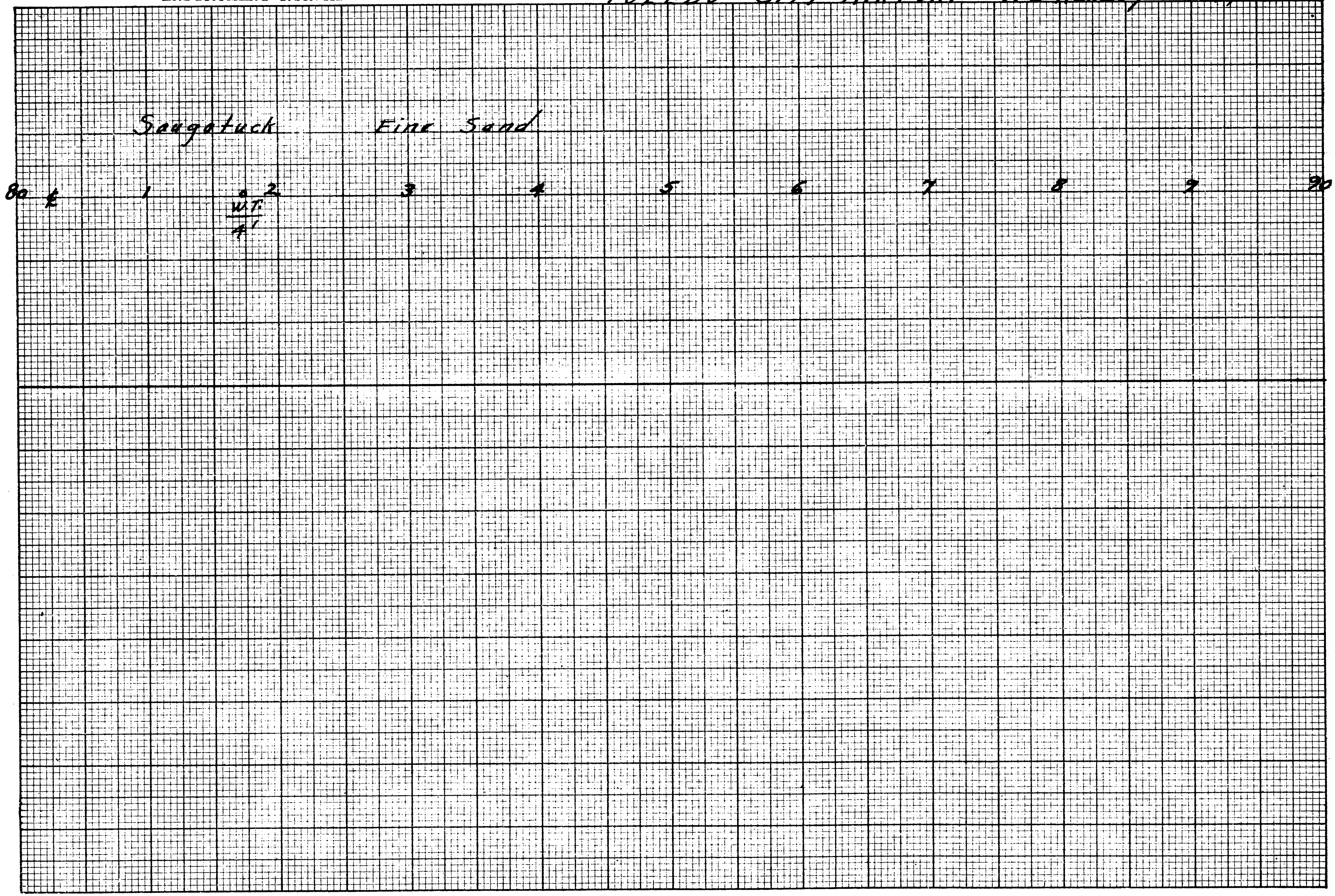
TOLEDO CITY AIRPORT / E-W Runway 17 April '53



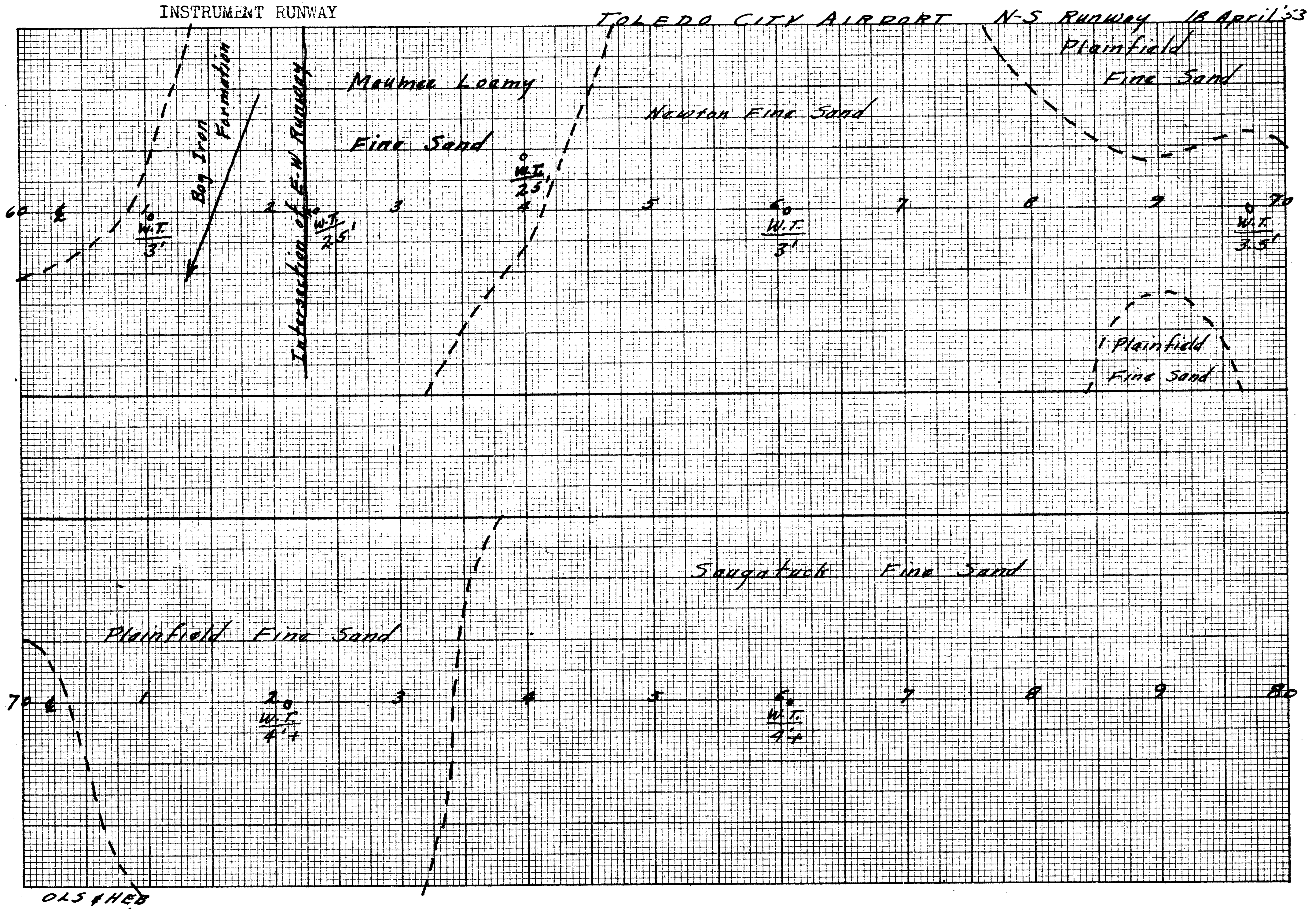
OLS / HEB

INSTRUMENT RUNWAY

TOLEDO CITY AIRPORT N-S Runway 18 April '53



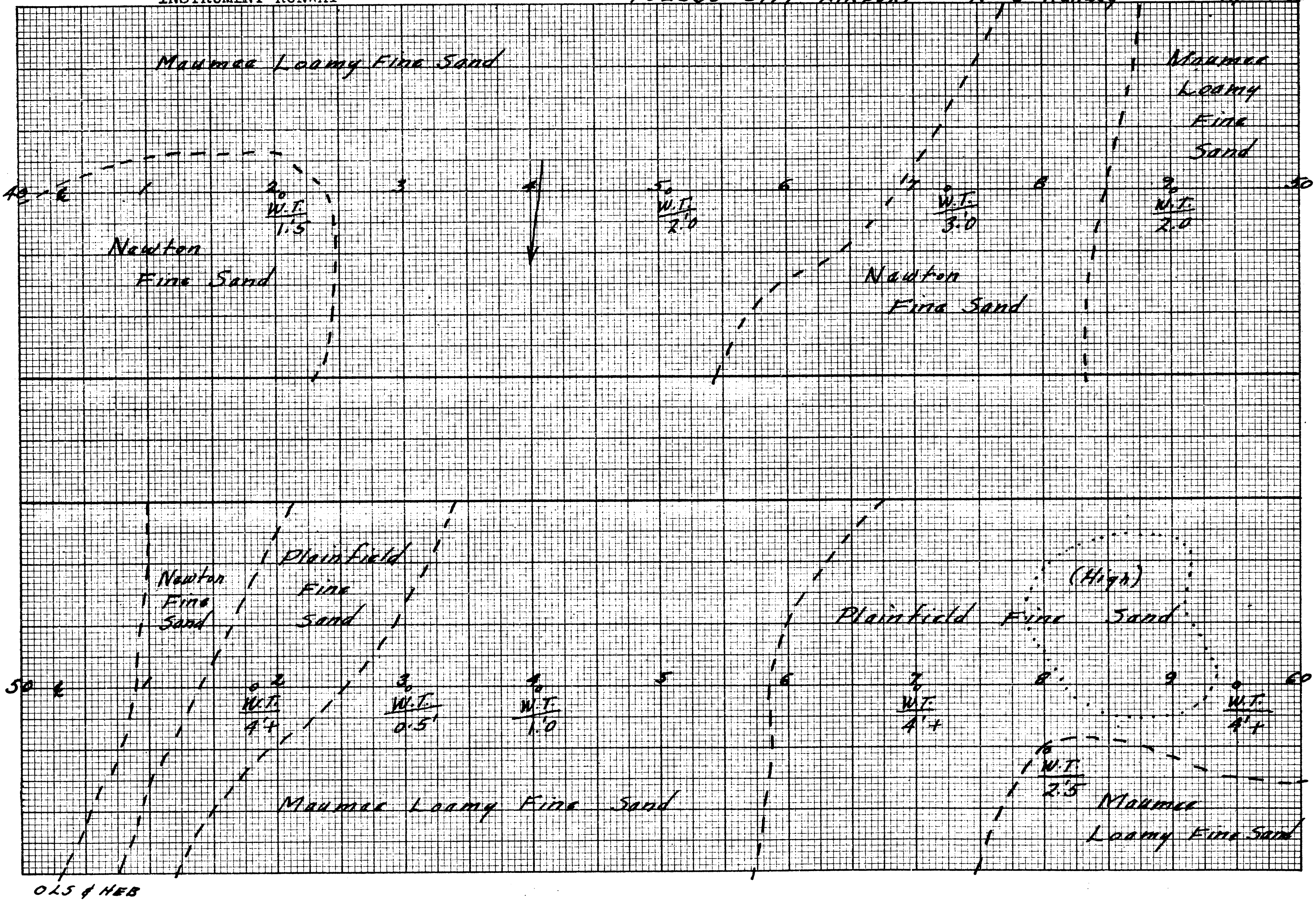
OLS & HEB


INSTRUMENT RUNWAY
TOLEDO CITY AIRPORT N-S Runway 18 April '53
Bog Iron Formation
Intersection of E-W Runway
Maumee Loamy
Fine Sand
Newton Fine Sand
Plainfield
Fine Sand
W.T. 3'
W.T. 2.5'
W.T. 2.5'
W.T. 3'
W.T. 3.5'
Plainfield
Fine Sand
Saugatuck Fine Sand
Plainfield Fine Sand
W.T. 4'
W.T. 4'
60
70
80
OLS & HEB

INSTRUMENT RUNWAY

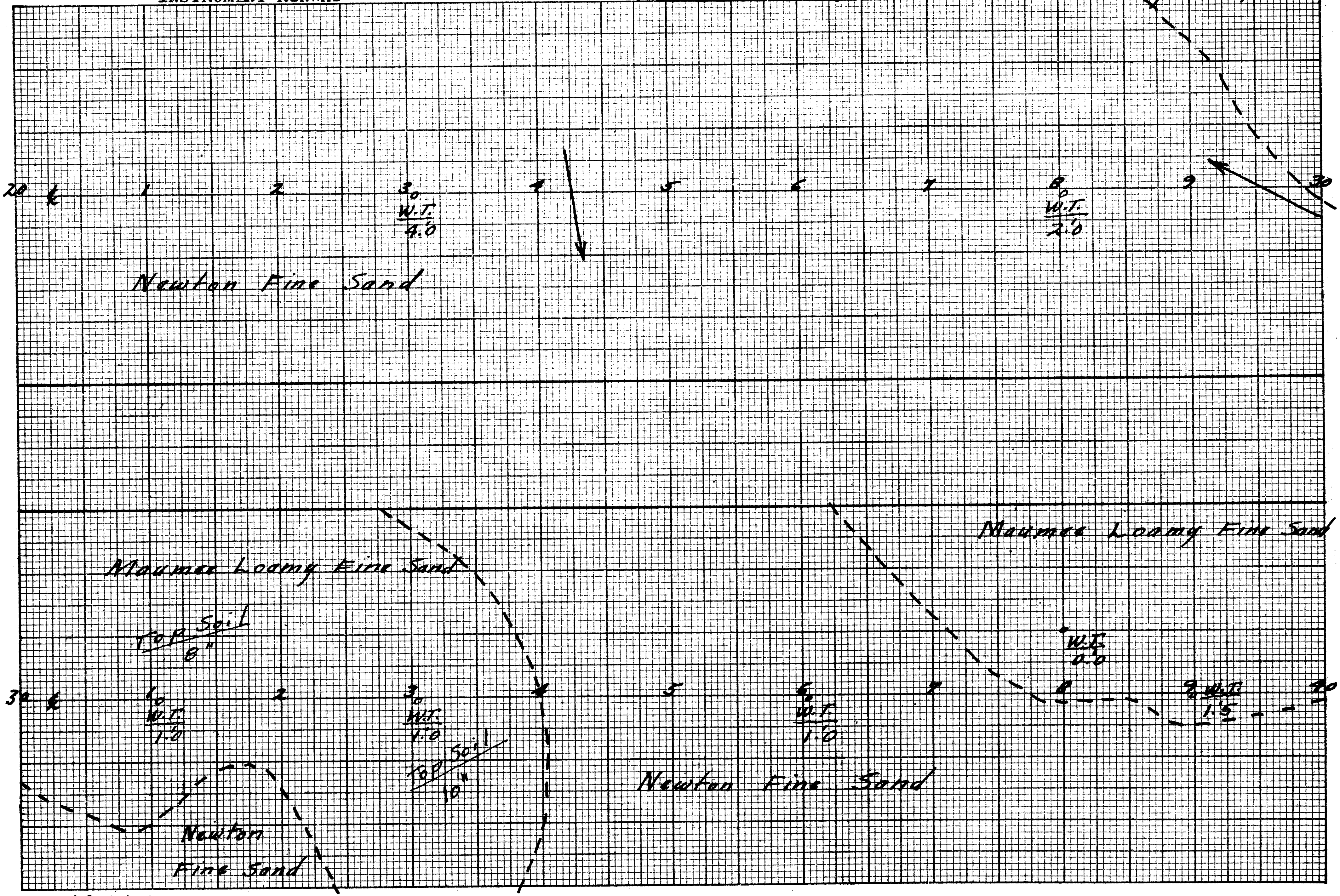
TOLEDO CITY AIRPORT — N-S Runway

18 April '53



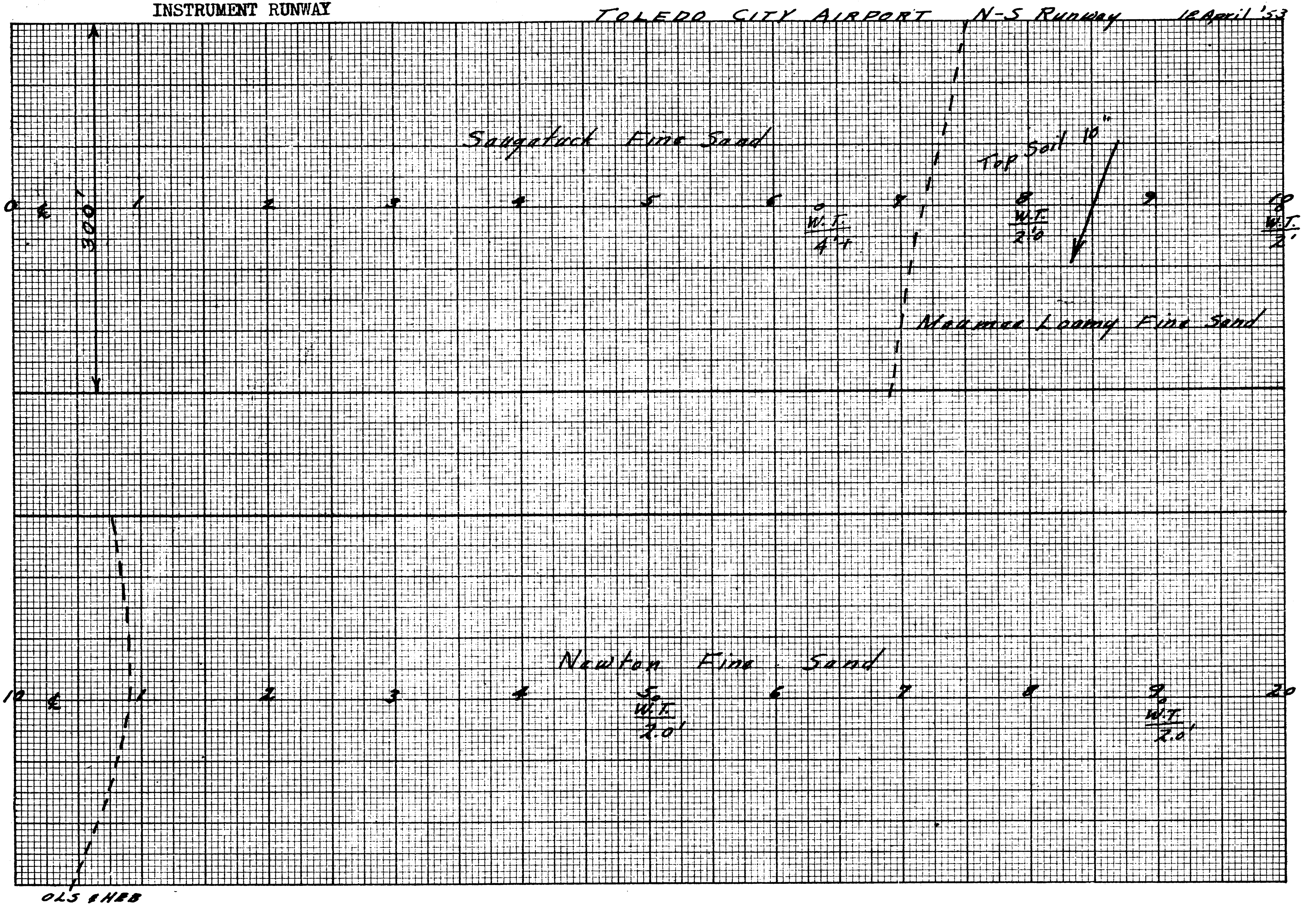
INSTRUMENT RUNWAY

TOLEDO CITY AIRPORT N-S Runway 18 April '53



OLS & HEB

INSTRUMENT RUNWAY



ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR, MICH.

February 5, 1954

Stepleton, McDonnell, Barber & Evans
Associated Engineers & Architects
Suite 201 Colton Building
Toledo 2, Ohio

Attention: Mr. Porter W. McDonnell

Dear Mr. McDonnell:

In response to your request, Saturday, January 30, 1954, was spent at the new Toledo Express Airport in conference with yourself, C. L. Piper, and Joseph Okenka regarding procedures to be followed and materials to be used in obtaining a vegetative covering on the Toledo Express Airport. This letter is a confirmation of the verbal decisions arrived at during that conference.

The review of the turfing problem became necessary when limited funds did not permit turfing procedures as suggested by Mr. J. R. Kessinger, Turf Specialist with the C.A.A. His suggestions are excellent and would serve well as a basis for contracting the work of establishing a vegetative covering. This project, on the other hand, is one on which the Toledo Airport management plans to use their airport maintenance and farm organization for a more or less gradual development of a turf cover. This procedure has certain advantages, especially in its low first cost and in the fact that it permits improvising to take advantage of climatic conditions, soil conditions, construction progress, local price variations, and farm equipment on hand.

The area on which a new turf must be established totals 400 acres, which may be divided into 3 classifications based on location and intensity of use.

1. Areas of intensive use are generally located along the north side of the east-west runway around the service area and include lawns around the airport buildings. This classification totals 61 acres. Treatment includes the use of salvaged topsoil which is being placed by the Grading Contractor. Positive control of wind erosion is a very important factor in these areas. Such erosion occurs partly as a result of natural winds and especially from "prop blast" around service and warm-up areas. Intensively used areas are recommended for the most expensive treatment planned and consist of the following:

Lime - 500 lbs. per acre

Fertilizer - 500 lbs. per acre of 5-10-5 with an additional 300 lbs. application of 10-6-4 or ammonium sulphate in the fall (in the case of a spring seeding) or in the following spring (in the case of a fall seeding). The high potash content of a 5-10-10 is not needed for grass.

Seed - 120 lbs. per acre of a mixture roughly composed of:

Rye Grass	20%
Red Top	10%
Fescue (Creeping Red & Alta)	35%
Canada Blue Grass	15%
Kentucky Blue Grass	15%
White Clover	5%

Cost - Roughly $150.00 per acre for materials. The actual work of fitting the land, fertilizing, and seeding will be done by Mr. C. L. Piper's organization.

61 acres @ $150.00 = $9,150.00

2. Areas of intermediate use intensity include ditch slopes, runway and taxiway shoulders, and overrun areas not included in the first classification. It involves the south side of the east-west runway and both sides of the north-south runway and taxiway. This classification totals 90 acres. The first 30-foot width of shoulder areas next to paved surfaces has been or will be topsoiled using stockpiled material. Treatment recommended for this classification consists of the following:

   Lime - 500 lbs. per acre

   Fertilizer - 500 lbs. per acre of 5-10-5

   Seed - A grain nurse crop consisting of rye or oats at the rate of about one bushel per acre or about one-half the amount used when planting for a good yield of grain. A grass mixture consisting of alfalfa, alsike, timothy and brome seeded at the rate of 35 lbs. per acre in the following proportions:

Smooth Brome	50%
Timothy	30%
Alsike Clover	10%
Alfalfa	10%

   Cost - Roughly $30.00 per acre for seed and fertilizer. The work of seeding and fertilizing to be done by Mr. Piper's organization.

   90 acres @ $30.00 = $2,700.00

3. Areas of minimum use intensity include mainly the graded areas beyond 500 ft. overruns at the ends of the runways and other more or less outlying or isolated locations where the topsoil has been destroyed. This classification totals 250 acres. Recommended treatment consists of the minimum required to control wind erosion until a program of fertilizing and seeding can be accomplished as

a part of the regular airport grounds maintenance program. This minimum treatment includes the following:

Lime - 500 lbs. per acre

Fertilizer - 300 lbs. per acre of 5-10-5

Seed - Rye or oats at one bushel per acre. A grass mixture consisting of sweet clover, timothy, and smooth brome at the rate of 35 lbs. per acre in the following proportions:

Sweet Clover (dwarf)	20%
Timothy	30%
Smooth Brome	50%

Cost - Roughly $20.00 per acre for seed and fertilizer. The seeding and fertilizing operation will be done by Mr. Piper's maintenance organization. 250 acres @ $20.00 = $5,000.00

In addition to the seed and fertilizer costs as listed above, there will be some reseeding costs and also some emergency mulching costs involving the use of straw or wild hay to hold some particularly troublesome spots. Also the fertilizing and seeding operations to be done by the airport maintenance organization will require the purchase of 2 spreaders for lime, fertilizer and grass seed at approximately $500.00 each. A cost estimate for this first seeding project may therefore be summarized as follows:

Intensive Treatment Areas	$9,150.00
Intermediate Treatment Areas	2,700.00
Minimum Treatment Areas	5,000.00
Emergency Mulching and Grain Planting	2,150.00
New Equipment Required	1,000.00
	$20,000.00

If actual costs should prove to be less than this estimate, it would be highly desirable to extend the planting of permanent grasses and to increase the fertilizer quantities. The recommendations listed above should not be considered as providing a completely adequate treatment but rather as an attempt to make the available funds do the best job possible in protecting the airport investment and the aricraft equipment which will be using the field.

In planning seeding operations, it will be well to remember that nature's time for grass seeding is late summer and early fall. This timing permits new grass to become well established during the moist and cool fall period. To accomplish such timing, it will be necessary in most instances to make separate operations of grain nurse crop planting and grass seeding. In order to protect newly graded areas from erosion, the grain should be planted as soon as each area can be finished by the contractor and accepted by the owner. Rye is the most commonly used nurse crop since it will grow late in the fall and start growth early in the spring, providing good protection of the ground surface through the winter. Oats have a special advantage if it can be planted before the middle of September in that it will make a good fall growth to provide ground cover and then winter kill so as to form an anchored and noncompetitive protection for new grass the following spring.

Finally, it must be remembered that the planting program as outlined above is just the beginning and that the success of the final turf will depend on an adequate turf management program which will include early seeding of permanent grasses and a long range fertilizer program to keep the grass properly fed. Specialists like Mr. Kessinger from C.A.A. can be of much assistance in planning this management program.

Respectfully submitted,

O. L. Stokstad

OLS/fsm
cc: W. S. Housel

A P P E N D I X   B

CORRESPONDENCE AND

MONTHLY PROGRESS REPORTS

August 1, 1952

Stepleton, McDonnell and Barber
Associated Engineers and Architect
414 Commerce Building
Toledo, Ohio

Subject: Proposed Toledo Airport Development in Swanton and Monclova Townships.

Gentlemen:

This will confirm my comments and discussion in conference with Mr. McDonnell on July 30, 1951, with regard to the proposed site of an airport development for the City of Toledo.

From the standpoint of soil conditions the proposed site is as favorable as any that could be found in the vicinity of Toledo. Soil series that have been mapped on the County soil map are Plainfield, Maumee, and Newton. The parent material in these series is sand which has been altered to some degree by weathering action but is still considered very favorable from the standpoint of grading operations and high internal stability and supporting capacity for the runways or other airport facilities.

The major factor of importance in the soil conditions aside from texture is that of drainage. Plainfield is a well drained sandy soil, while both Maumee and Newton are poorly drained due to the presence of a high water table. Inasmuch as the soil is sandy and permeable, the poor drainage is a matter of topography and the internal drainage characteristics of the soil are considered quite favorable. The main problem under such soil conditions is one of controlling the water table under the runways so that it will be below the depth of frost penetration at critical periods of the year. Thus the site may require some subdrainage and particularly the provision of suitable outlets to lower the ground water table. On the other hand, in the grading of the runways to provide adequate transverse slopes for surface drainage, the grade line should be established as high as practicable and this may be worked out to maintain pavement grades sufficiently above the existing water table to eliminate any detrimental frost action.

This sand in common with granular materials in general has high internal stability and with adequate compaction control could provide an ideal foundation for the runway pavements with a high subgrade bearing value. Furthermore, compaction of these materials is relatively easy and, while it must be accurately controlled, should present no particular difficulties in construction.

The writer had some discussion with Mr. McDonnell regarding possible pavement types and pavement thicknesses that would normally be required for a high type airport as presumably will be provided for the City of Toledo. In the absence of specific requirements which are yet to be determined and assuming an airport of the "Deluxe" classification of the Civil Aeronautics Administration, the thickness of concrete pavement required under current design methods would be on the order of 12 inches.

The thickness of flexible type pavements of equivalent load-carrying capacity is difficult to estimate without specific load requirements and the selection of one of a number of methods of design. For the purpose of preliminary estimates it is believed that an equivalent flexible type pavement would cost on the order of 10 per cent less than a Portland cement concrete or rigid type pavement. From the standpoint of load-carrying capacity and general pavement performance it is the writer's opinion that it is too early to express any particular preference as to the type of pavement to be provided. However, it is believed that either type of pavement would be capable of meeting all requirements and giving a high quality performance in the operation of the airport.

Yours very truly,

W. S. Housel

WSH/jm

WILLIAM S. HOUSEL
Consulting Engineer
Ann Arbor, Michigan

June 8, 1953

Stepleton, McDonnell & Barber
Associated Engineers & Architect
414 Commerce Building
Toledo, Ohio

Attention: Mr. Porter W. McDonnell

Subject: Tentative Program for the Toledo Express Airport

Gentlemen:

After our conference of Tuesday, June 3, with representatives of the City of Toledo, it occurred to me that it was highly desirable to prepare a written memorandum of the decisions which were made at that time and what it means to those of us concerned with the preparation of the engineering plans and specifications. In that connection, the tentative program which was established is such that everyone involved should have a clear understanding of the amount of work that must be done at any given time in order to meet the schedule which is proposed. In this connection, my interest will be limited to the airport itself, including the grading and paving of the runways, taxiways, etc. The buildings and miscellaneous facilities are not involved in any of the services which I have proposed to render.

The first dead line to be considered is the preparation of estimates of cost to be available by the June 22 meeting of the Council of the City of Toledo. The following items of work are involved and, in connection with each one, the problems to be solved are indicated:

1. COMPLETION OF SOIL SURVEY

Due to the fact that the area was not cleared or completely staked, the soil survey made by Stokstad and Barnes covers only a portion of the area to be graded. Generally speaking, their survey is a strip 150 feet on both sides of runway centerlines. The taxiways are likewise covered by a strip map but are somewhat uncertain as the taxiways were not staked and it was difficult for Stokstad and Barnes to keep themselves located. It would be highly desirable to complete this soil survey within the limits of grading which extend out to the ditch lines shown on the plan.

The balance of the soil survey could be most effectively done when the area has been cleared, but, as pointed out in our discussion, it would be impossible to wait that long and still meet the proposed schedule. Consequently, we tentatively agreed that, as soon as you received your contract from the City for the general supervision of the construction project, you would stake the taxiways and outside limits of the area to be graded and notify us when this would be done so that arrangements could be made to complete the soil survey. In the event that this survey could not be completed in time for the estimates to be presented on June 22, we would have to base the estimate of topsoil stripping and any other elements which depended on the soil survey on the present incomplete strip maps. I have a man working on drawing up the soil survey on a set of the reproducible sheets so that prints could be obtained for use in making the rest of the survey. It would then be my plan to present the results of the soil survey to you on these reproducible prints.

2. COMPLETION OF GRADING PLAN AND ESTIMATE OF BALANCED CUT AND FILL

The second important item involved in the cost estimates is the total yardage involved in the earth moving contract. Certain problems which affect this estimate are the amount of topsoil stripping, the shrinkage factor to be used, a check on the balance between cut and fill, and, finally, the preparation of an area grading plan.

A. Estimate of Topsoil Stripping

It has been recommended that all of the topsoil containing more than negligible amounts of organic matter be stripped from the site and stockpiled as a preliminary grading operation. The topsoil should be handled separately to insure that it is not mixed in the compacted fill beneath the paved areas and to conserve this material for topsoil dressing of the sandy field areas. Any excess of topsoil which may result may be used on other City projects or sold. The amount of topsoil stripping will vary widely in the different soil types involved and it was for this estimate particularly that the complete soil survey is needed. Regardless of whether the topsoil stripping is set up on a square yard basis or a cubic yard basis, it will be a separate pay item and a reasonably accurate estimate of cost will depend upon the area of each soil type and the depth of topsoil to be removed in each case. Measurement of the quantities which must finally be paid for should be decided with the objective of simplifying the method of measurement. If the topsoil survey is sufficiently accurate, it may be desirable to establish the pay quantities directly from that estimate and eliminate the necessity of measuring this later in the field.

B. Shrinkage Factor

The determination of the shrinkage factor to be used in establishing the balance between cut and fill is important as it will affect the major pay quantity and will also establish the final grade. The bulk of the excavation will be from surface soils which are quite loose and these loamy materials will be compacted to a relatively high density under the paved areas and to some indeterminate figure in the balance of the fill. Our present estimate is a shrinkage of 30%, which, while higher than usual in earth moving, may be, if anything, a little bit low for the type of soil and the type of grading operation involved in the Toledo Airport. It would be highly desirable to determine the density in place in a number of representative soil types and then conduct compaction tests in the laboratory to get a measure of this shrinkage factor which would be somewhat better than our present guess. Arrangements will be made, as soon as someone can be released from other work now in progress, to take some undisturbed samples in the field and to get samples for laboratory compaction tests.

C. Checking the Balance of Cut and Fill

I have a man working on our computation of the cut and fill involved in the entire area to be graded. Some of this work was done as a class problem, as it made an excellent exercise for the class in Airport Design and Construction. However, they were unable to complete the problem and check all the details, and that is what this man is doing. I expect to have this estimate available in the near future and will be interested to check it over with your own figures.

D. Area Grading Plan

It is planned to make up an area grading plan which we have discussed on several previous occasions. The bulk of this work has also been done by the class in Airport Construction and is being finished up by the man I have working on this job now as a part of the Engineering Research project. It is planned to use the extra set of reproducible prints which you sent up and were just received last Thursday to draw the grading plan on and transmit it to you for such use as you may be able to make of it. There may be some adjustments, as I note on the latest plans that we received that there have been some changes in grade and some changes in the layout of the paved area, particularly around the terminal building. Perhaps these will not be enough to make any substantial change in the grading estimate, and I hope not, as we will not have time for any extensive revisions.

E. Subgrade Manipulation

Subgrade manipulation is a factor which must be taken into consideration in the specifications and is one which we have not discussed at any length. I plan to recommend that the specifications require that the top 12-inches of the finished subgrade be compacted to the standard density in all areas including particularly the cut areas. This subgrade manipulation should be taken care of automatically in the fill areas, which will have been brought up to grade at standard density, but the cut areas present a different situation. It is possible that these areas will be compacted in the regular grading operations, so that they will be close to standard density. If the grading contract was going to be completed before the paving, we would have an opportunity to check densities in the cut and determine whether or not any additional compaction was necessary. This represents one of the penalties from handling the job under one contract and in a hurry, as we are now forced to do it. We cannot take a chance on the densities in the cut areas being below the requirements for subgrade stability, so we will have to specify that all such areas will be manipulated or compacted to a depth of at least 12 inches. This quantity will then have to be included in the contract as a pay item, and the contractor will have to be paid for it even though he may have to do a minimum amount of extra work in that connection. If we have the time to do it, we should make some natural density tests at considerable depth below the surface in the areas where the heavy cuts will be made. In this way we might determine whether the natural density is fairly close to the requirement that we will be specifying or whether these cut areas will need the compaction which is discussed above. Possible compaction in the cut areas will also affect the shrinkage factor and the balance of cut and fill.

3. PAVEMENT DESIGN

In connection with pavement design, we may already have a sufficiently accurate idea of pavement thicknesses to make up a cost estimate suitable for the June 22 meeting of the Council. On the other hand, this is a matter that I want to take up with Mr. Stokstad and work out an equivalent design in both rigid and flexible pavements that we will be able to support completely in the case of any controversy. For this purpose, we should have a positive determination of subgrade bearing capacity, i.e. the subgrade modulus, for rigid pavement design, and allowable bearing pressure, for flexible pavement design. If time permitted, I had hoped that a few of the standard plate loading tests could be made on the compacted subgrade to serve as the final criterion for pavement design, but this is obviously out of the question under present scheduling. The substitute will be to run some CBR tests in the laboratory, and we will get samples for this purpose and get these tests underway as soon as it is possible to schedule this work in the presently crowded laboratory program.

In connection with pavement design, American Bitumuls is still pressing rather hard for consideration of a stabilized base in the place of the conventional dense graded aggregate of either crushed stone or densely graded gravel. You know my lack of enthusiasm for the soil stabilization of the so-called low-cost type, but I am still wondering if we should give it any consideration in the competitive designs. Before accepting such a base, I would want to run a very comprehensive series of stability tests to demonstrate that the material was completely adequate from the standpoint of load-carrying capacity and sufficiently well stabilized to resist deterioration in service. Such an investigation is another one of the things which must "go by the board" in the stepped-up schedule, and I doubt very much if we will have time to properly evaluate such a base course and include it in the competitive designs.

I believe that the above outline completely covers the items on which you will be relying for us to provide you with design recommendations needed in the preparation of plans and specifications. If there is anything further, you may let me know, and in any event we will have to keep in close touch, so that the several aspects of the work will be properly timed to meet the scheduled dead line. Personally, I am sorry that we have to do the job in such a hurry, but, as stated in our conference, the advantages of getting this work under contract and partially completed this year, before the Ohio Turnpike construction becomes active, are so obvious that they cannot be set aside. My hope is that we will be able to meet this schedule without sacrificing any of the important elements which will affect the quality of the final product.

Yours very truly,

W. S. Housel

WSH/fsm
cc: Mr. O. L. Stokstad

June 16, 1953

MEMORANDUM

TO: W. S. Housel

FROM: O. L. Stokstad

In accordance with your request, I spent Wednesday, 10 June 1953, in Toledo for the purpose of attending a conference relative to topsoil salvage and topsoil use on the new Toledo Express Airport. The meeting was called by Mr. Porter W. McDonnell and Mr. A. Stepleton, consultants on the project. Present at the meeting were Mr. R. Williams, C.A.A. office in Columbus, Mr. Stewart Mendell, C.A.A., Mr. John R. Kessinger, agronomist from the New York C.A.A. office and Mr. Clayton Piper, Toledo Airport Commission.

The meeting was called at Mr. McDonnell's home from where Mr. McDonnell, Mr. Williams, Mr. Kessinger, and the writer drove to the airport site in order to better study the nature of soil and turfing problems. The Plainfield, Newton, and Maumee soils were examined in considerable detail by the use of a tile spade. Small profile samples were collected by Mr. Kessinger for the purpose of making such laboratory tests as will aid him in making turfing recommendations.

Generally, Mr. Kessinger believed that turf could be established on the area more cheaply without the use of topsoil because of high salvaging costs. It was tentatively decided that areas to be turfed should be classified, based on anticipated use intensity. Building areas generally and shoulder areas within 30 feet of runway, taxiway, or apron pavements should be topsoiled before seeding. Other areas where no traffic is anticipated, Mr. Kessinger believes that turf may be most cheaply established by the use of fertilizer, seed and mulch only. If the areas between the runways and taxiways are to serve as turfed landing strips for light planes, it was recommended that topsoil be used as an aid in obtaining a tough dense turf.

Loss and shrinkage factors were discussed, and it was agreed that the factor for topsoil would be about 50%, especially if the material is stockpiled. The shrinkage factor for other grading quantities will likely be from 30 to 35%, because of the loose nature of the soils involved. Loss in grading quantities will result from clearing and grubbing activities and also from the fact that levels were taken when the ground was frozen.

O. L. Stokstad

OLS/fsm

UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE

July 14, 1953

Stepleton, McDonnell & Barber
Associate Engineers & Architect
Colton Building
Toledo, Ohio

Attention: Mr. Porter W. McDonnell

Subject: Soil Survey Information, Toledo Express Airport, Project 2146

Gentlemen:

In accordance with our conference of Friday, July 10, we are transmitting herewith the original copies of the Soil Survey Report or summary by Mr. Stokstad with three sheets on which the present soil survey information has been shown. These sheets have not been completed as the soil survey had not been completed over the entire grading area. In accordance with our recent discussion of this matter, it is contemplated that, when the clearing has been completed, the soil survey will be completed for information and for use during construction. At that time, these three sheets can be completed and made part of the information drawings.

It is suggested that the soil survey information being transmitted herewith be classified as supplementary information and a note made on the drawings or in the specifications that additional soil information is available upon request to your office. The results of laboratory tests which have recently been completed for design information may also be classified as supplementary, but will not in all probability be of any value to bidders on the proposed Airport. It is the writer's plan to compile all of the more recent tests and summarize the design recommendations which have been transmitted to you from time to time in our conferences and include it all in one report. This report will be submitted as soon as possible to get all of the information together in final form.

Yours very truly,

W. S. Housel

WSH/fsm
Encls.

MICHIGAN
STATE HIGHWAY DEPARTMENT

Lansing 13

INTEROFFICE COMMUNICATION

January 27, 1954

Memorandum for the Files

Spent Friday, January 22, 1954, in Porter McDonnell's office in Toledo in conference with Messrs. Porter, Stepleton, Piper, regarding the Toledo Express Airport. Involved was a brief discussion of stage construction for the N - S runway and an extensive discussion of the turfing problem. It has become necessary to cut costs of the project in order to stay within the budget established by the City of Toledo. Apparently, there is only $20,000.00 available for turfing about 400 acres of new grading. It is necessary to use this money in a manner which will protect the investment in grading and also to permit proper use of the field.

It was decided to use intensive treatment for runway and taxiway shoulders and general building areas and to provide minimum treatment for outlying areas. Intensive treatment involves the use of topsoil (salvaged and stock-piled), fertilizer, and seeding with the possibility of some mulching. The minimum treatment will consist of employing city forces in planting a cover crop like rye along with a legume such as dwarf sweet clover. These areas will then be further improved by the use of fertilizer and seed, after the airport is in use. In fact, Mr. Piper, airport manager, has already started his farm crews on a program of planting areas where the grading is completed. The west over-run and glide angle area was seeded to rye last fall.

Tentative arrangements were made for a meeting at the project office on Saturday, January 30, 1954, mainly for the purpose of discussing soil management practices. Mr. Piper is accustomed to the heavy clay soils of the old airport, and he is interested in a discussion of possible changes in methods to better meet the requirements of the fine sand soils of the new site.

Olaf L. Stokstad

OLS:mw

cc: W. S. Housel
H. E. Barnes

UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE

November 30, 1954

Mr. Porter W. McDonnell
Stepleton, McDonnell, Barber & Evans
Associated Engineers & Architects
Suite 201 - Colton Building
Toledo 2, Ohio

Subject: Design of Paving for the Toledo Express Airport
Engineering Research Institute Project 2146.

Dear Mr. McDonnell:

This will confirm our telephone conversation of November 29, 1954, regarding the specific loading conditions for which the paving for the Toledo Express Airport was designed. Being an Express Airport under the C.A.A. classification, the wheel load applications used were as given by the Civil Aeronautics Administration Technical Standard Order N6, dated November 4, 1947, and shown as Table 1 in their pamphlet on "Airport Paving" published in May, 1948.

Accordingly, the pavement for the Toledo Express Airport was designed for a single wheel load of 45,000 pounds, and the equivalent dual wheel load of 60,000 pounds. Thicknesses of both flexible type pavement and concrete pavement were worked out by the several current methods for these wheel loads. These methods included those formulated by the C.A.A., U.S. Army Engineers, and the Portland Cement Association. While the designated loads thus represent the design capacity by definition, it is the writer's opinion that the actual load supporting capacity is not limited by those figures. Under the combination of granular subsoil, good drainage, and excellent follow-through on compaction and pavement construction throughout the construction period, it is the writer's opinion that the actual capacity of the pavement is considerably in excess of the design capacity.

This subject will be discussed in greater detail in our final report on this project, on which we are working at the present time.

Yours very truly,

W. S. Housel

WSH:je

cc: Stepleton,McDonnell,Barber & Evans (3)

ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN

Work Report for June, 1953 Project 2146

To Stepleton, McDonnell and Barber

On Soil Survey at Toledo Express Airport

REPORT ON WORK DURING MONTH

This is the first monthly work report on this project which was authorized by Stepleton, McDonnell and Barber under date of May 4 and approved under date of May 19. This work has grown out of the writer's contacts with the City of Toledo and their engineers in the planning and design of the new Toledo Express Airport. Consultation on this project has been underway for some months. There was some laboratory testing required last fall but it was not extensive and it was carried under the Soil Mechanics Contingency Fund and transferred to the project under date of June 2, 1953. A more comprehensive program of soil investigation started in April with the field soil survey which was conducted by Mr. O. L. Stokstad and Mr. H. E. Barnes. Results of laboratory soil tests which have been previously conducted were included in a report on preliminary design recommendations submitted to the clients under date of November 28, 1952. The soil survey information has been transmitted to the Engineers in the course of various design studies and in preparation of the plans and specifications. No formal report has been made on it as the data were to be incorporated in their plans when it was in final form. As a matter of fact, the soil survey has not been completed over the entire airport area and it is planned to do this when the clearing contract has been completed which will not be for several weeks.

In the meantime, the various phases of airport design and the preparation of plans and specifications has been underway. There were several conferences in Toledo during the month at which time these problems were reviewed with both the engineers and city officials and the results of our studies in the form of definite recommendations have been transmitted to the engineers in these conferences. Since June 18, we have provided some assistance in the preparation of the plans and specifications by sending Mr. H. Cetin to Toledo to work with engineers of Stepleton, McDonnell and Barber and he was still there at the end of the month.

(Signed) W. S. Housel

ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN

Work Report for July, 1953 Project 2146

To Stepleton, McDonnell and Barber

On Soil Survey at Toledo Express Airport

REPORT ON WORK DURING MONTH

During the month of July, the engineers for the Toledo Airport were preparing the plans and specifications for the grading and paving contract which it was hoped could be let before the end of the month. The writer made a number of trips to Toledo for consultation with the designing engineers and to assist in the preparation of plans and specifications. These plans were completed during the month and bids were taken on July 28.

Our work on this project may be nearing completion, but we have yet to prepare a final report bringing together the various soil investigations which were undertaken through the Engineering Research Institute and presenting our design recommendations in complete form as they have been given to the engineers from time to time.

(Signed) W. S. Housel

ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN

Work Report for August, 1953 Project 2146

To Stepleton, McDonnell and Barber

On Soil Survey at Toledo Express Airport

REPORT ON WORK DURING MONTH

The design phase of this project has been completed and contracts have been let by the City of Toledo for the grading and pavement construction. This work was getting under way during August and daily reports from the Toledo Testing Laboratory, which is in charge of inspection, have been received.

On August 21, the writer was in Toledo and made an inspection of the airport project in company with representatives of the consulting engineers and representatives of the city and contractor. The inspection work is well organized and it is anticipated that the work will go ahead smoothly.

Our only responsibility in connection with this work is the general supervision and review of the work that is accomplished from time to time. We still have, however, a final report to be prepared on the work done in connection with the design phase, covering the results of laboratory tests on the subgrade soils and the material to be used for the subbase, all of which have been completed and the results given to the consulting engineers in conferences from time to time.

(Signed) W. S. Housel

ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN

Work Report for September, 1953 Project 2146

To Stepleton, McDonnell and Barber

On Soil Survey at Toledo Express Airport

REPORT ON WORK DURING MONTH

There was no work done on this project during the month, but the writer has been receiving daily reports from the job on the progress of the grading contract and the density control which is being carried on by the Toledo Testing Laboratory.

There is nothing further to report except that the project is still active and we have some work to be done, particularly the preparation of a final report on certain phases of the project. This work is not pressing, and it will therefore be postponed until the opportunity to complete the report has improved.

(Signed) W. S. Housel

A P P E N D I X   C

RESULTS OF SOIL TESTS FOR

PAVEMENT DESIGN AND CONSTRUCTION

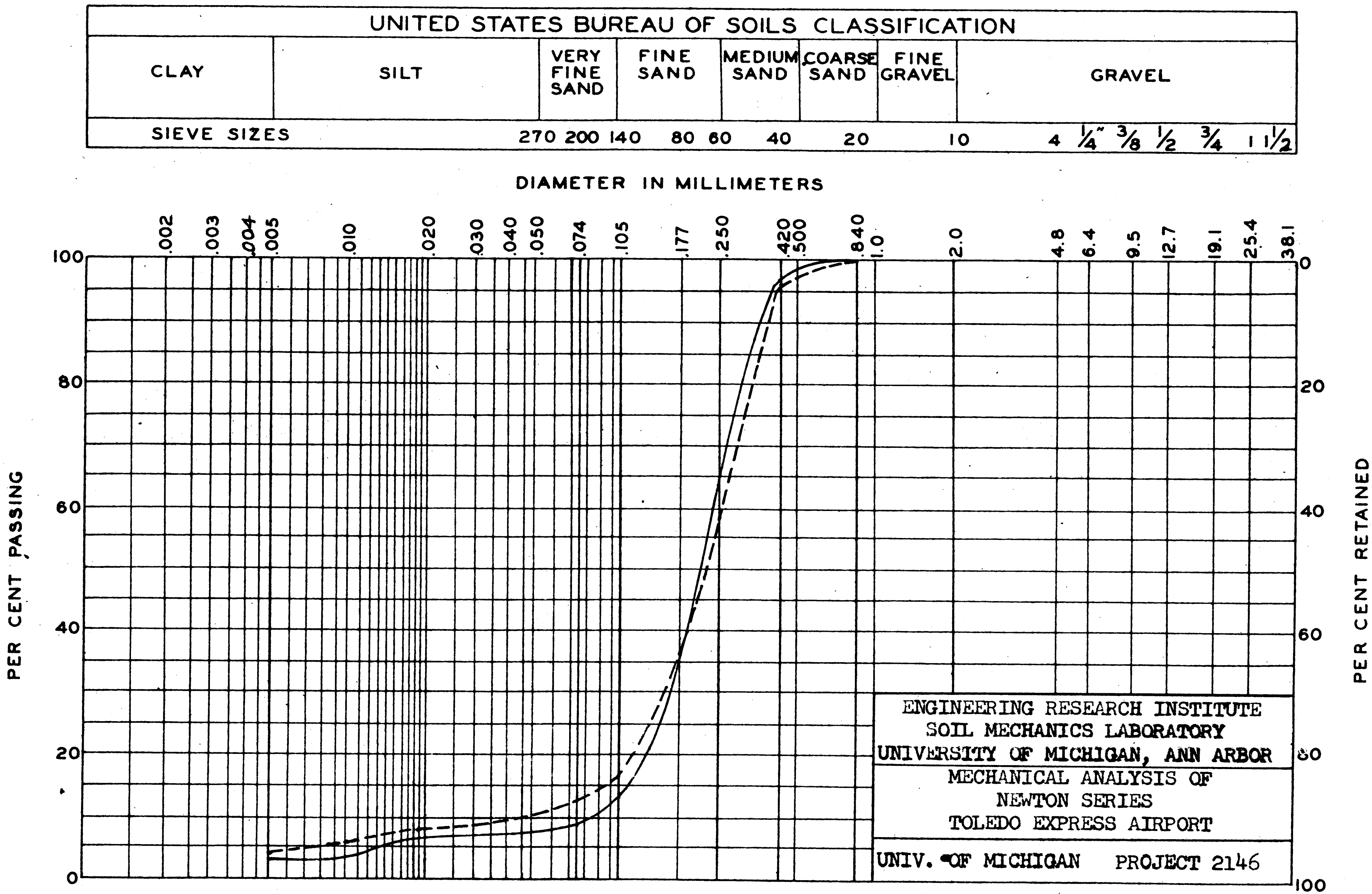
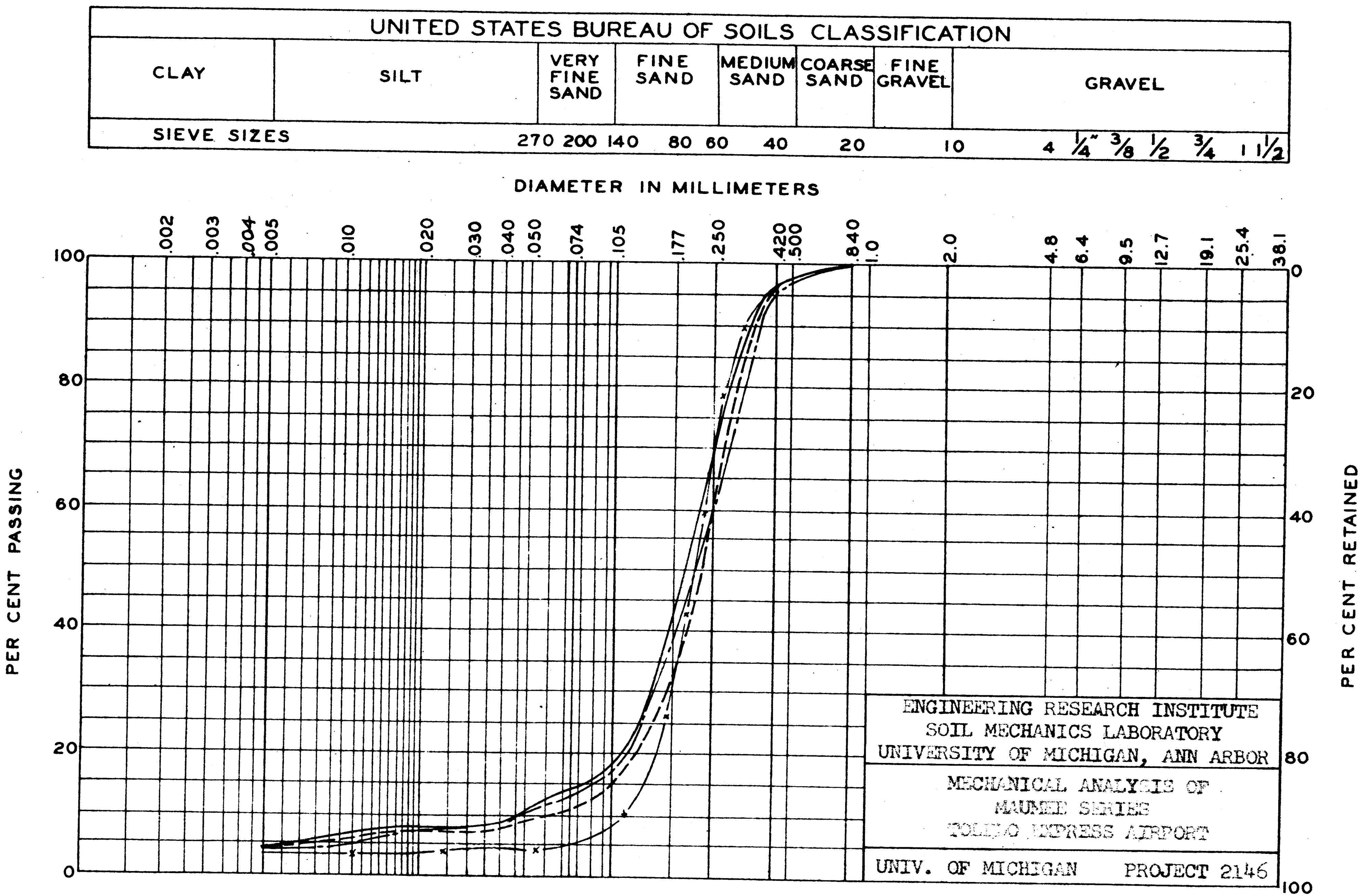

UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
100 80 60 40 20 0
PER CENT RETAINED
0 20 40 60 80 100
ENGINEERING RESEARCH INSTITUTE
SOIL MECHANICS LABORATORY
UNIVERSITY OF MICHIGAN, ANN ARBOR
MECHANICAL ANALYSIS OF
NEWTON SERIES
TOLEDO EXPRESS AIRPORT
UNIV. OF MICHIGAN PROJECT 2146

Figure 1



UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
100 80 60 40 20 0
PER CENT RETAINED
0 20 40 60 80 100
ENGINEERING RESEARCH INSTITUTE
SOIL MECHANICS LABORATORY
UNIVERSITY OF MICHIGAN, ANN ARBOR
MECHANICAL ANALYSIS OF
MAUMEE SERIES
TOLEDO EXPRESS AIRPORT
UNIV. OF MICHIGAN PROJECT 2146

Figure 2

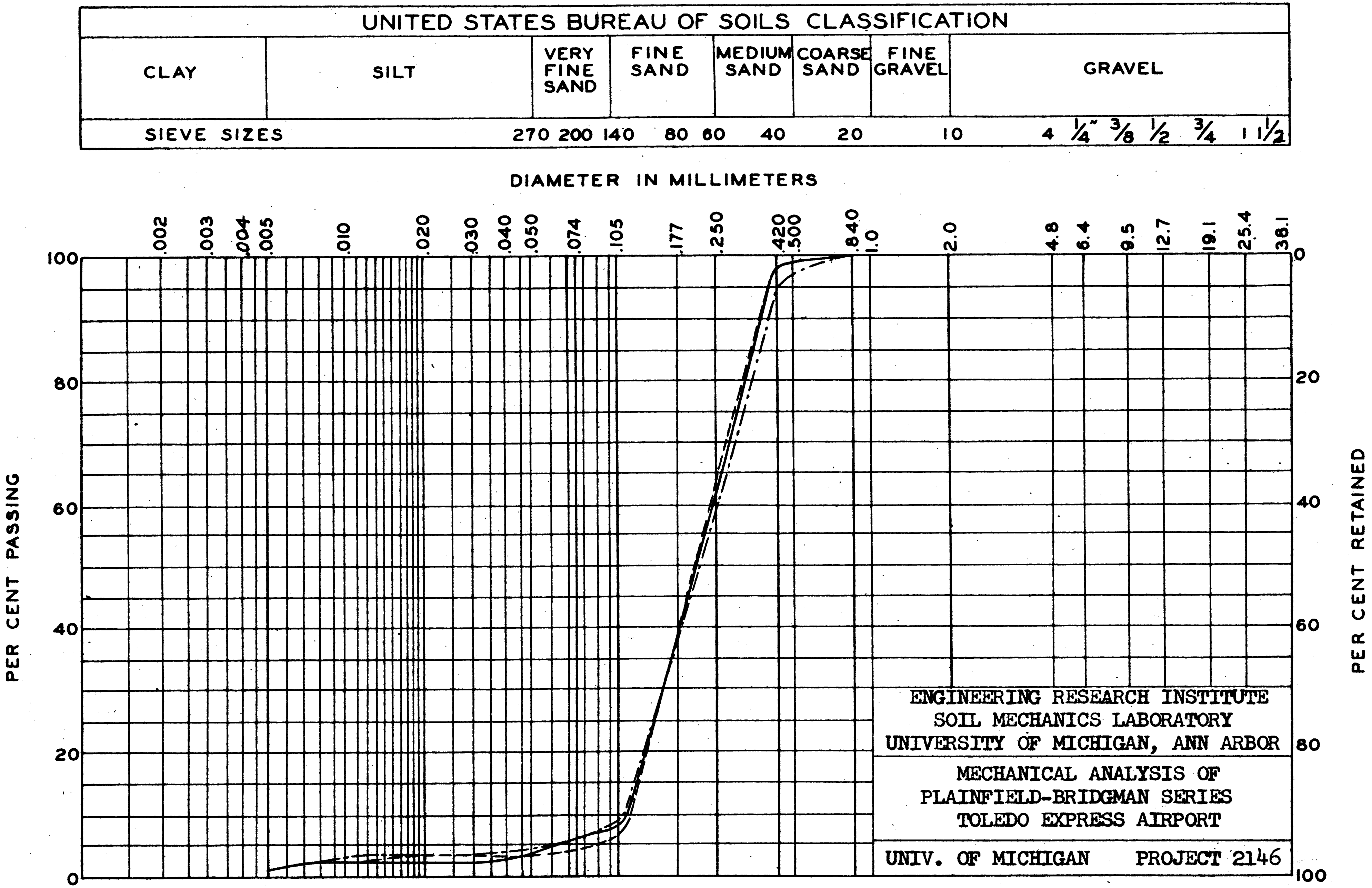

UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
100 80 60 40 20 0
PER CENT RETAINED
0 20 40 60 80 100
ENGINEERING RESEARCH INSTITUTE
SOIL MECHANICS LABORATORY
UNIVERSITY OF MICHIGAN, ANN ARBOR
MECHANICAL ANALYSIS OF
PLAINFIELD-BRIDGMAN SERIES
TOLEDO EXPRESS AIRPORT
UNIV. OF MICHIGAN PROJECT 2146

Figure 3

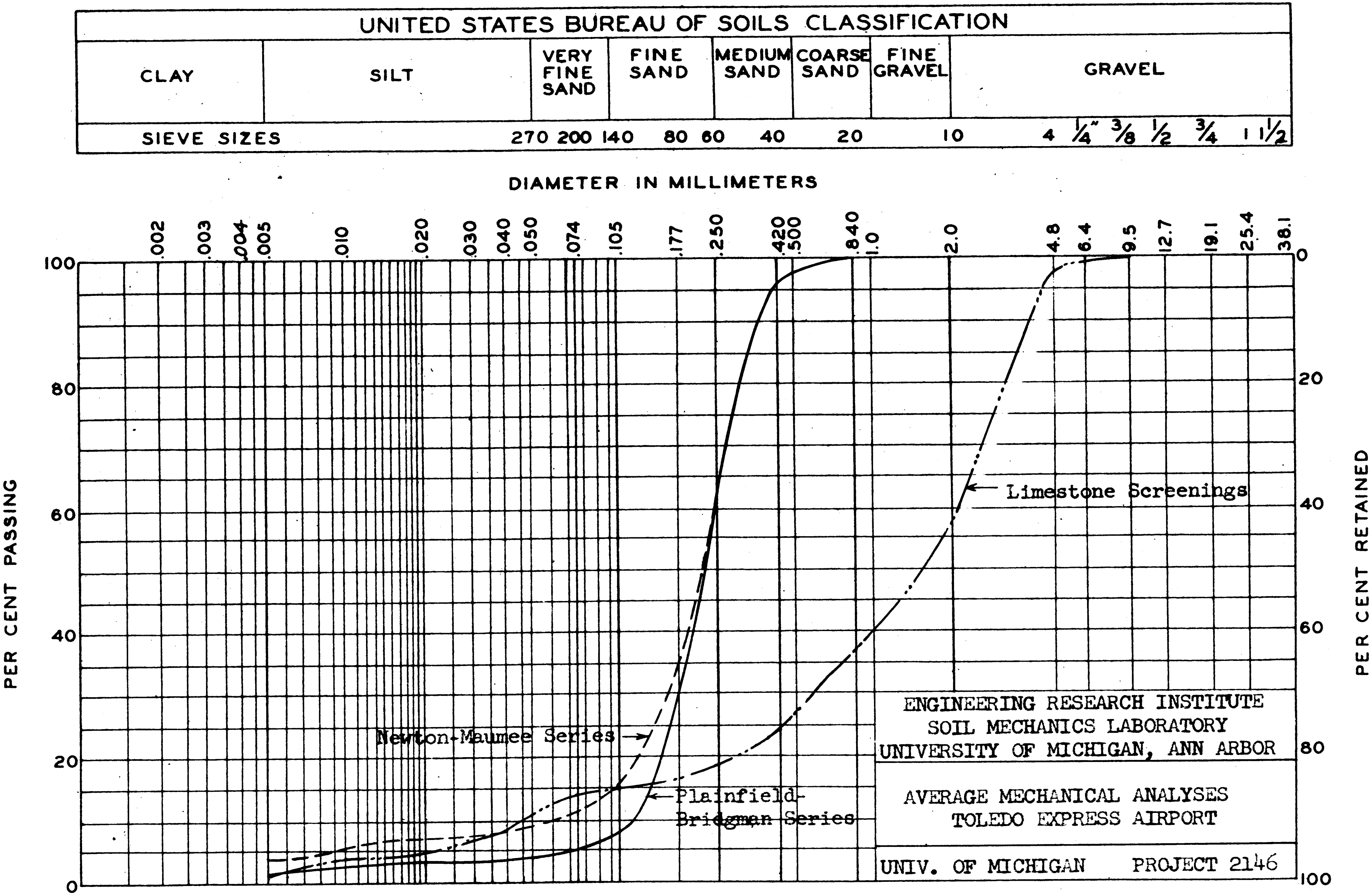

UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
100 80 60 40 20 0
PER CENT RETAINED
0 20 40 60 80 100
Limestone Screenings
Newton-Maumee Series
Plainfield-Bridgman Series
ENGINEERING RESEARCH INSTITUTE
SOIL MECHANICS LABORATORY
UNIVERSITY OF MICHIGAN, ANN ARBOR
AVERAGE MECHANICAL ANALYSES
TOLEDO EXPRESS AIRPORT
UNIV. OF MICHIGAN PROJECT 2146

Figure 4

COMPACTION CHARACTERISTICS

Project 2146 Lab. Sample No. 53H856
Location Toledo Express Airport Field Sample No. 7-1P
Tested by GPL Date 6-53 Plotted by W. R. Date 2-1-55
Description or Remarks: Representative of Newton-Maumee Series

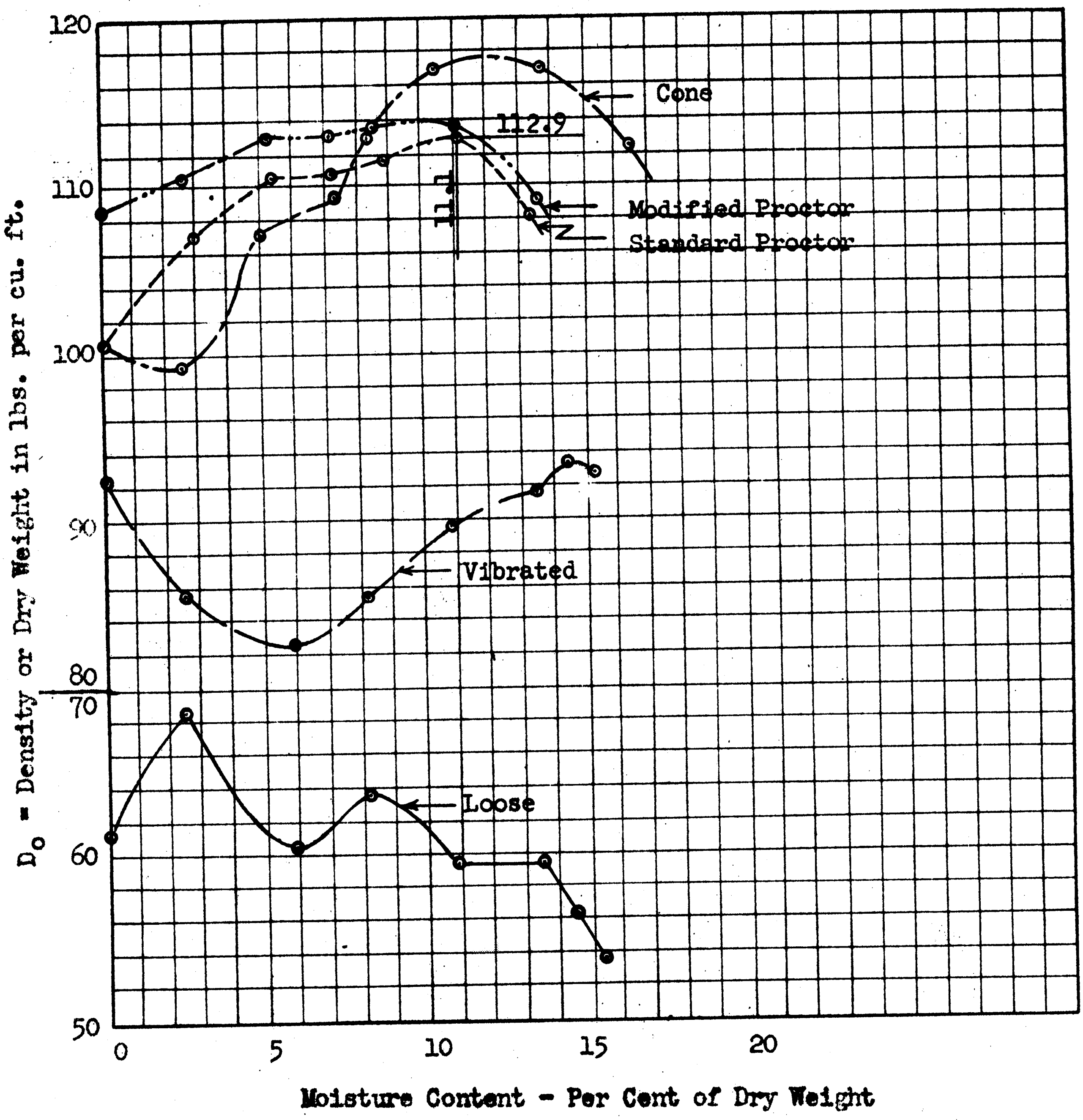


Figure 5

COMPACTION CHARACTERISTICS

Project 2146 Lab. Sample No. 53H837
Location Toledo Express Airport Field Sample No. 1-1P
Tested by GPL Date 6-53 Plotted by G. S. Date 2-1-55
Description or Remarks: Representative of Plainfield-Bridgman Series

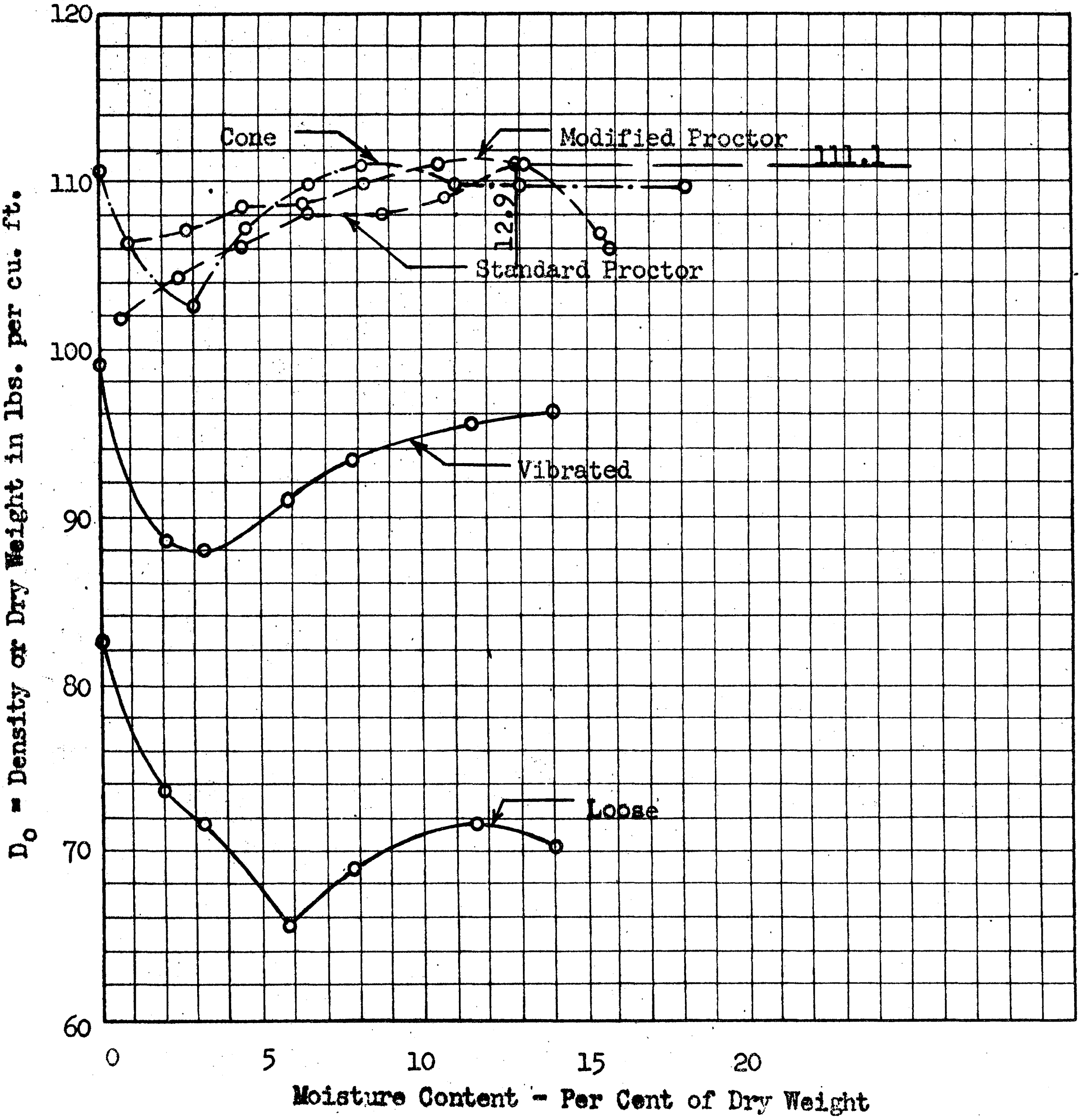


Figure 6

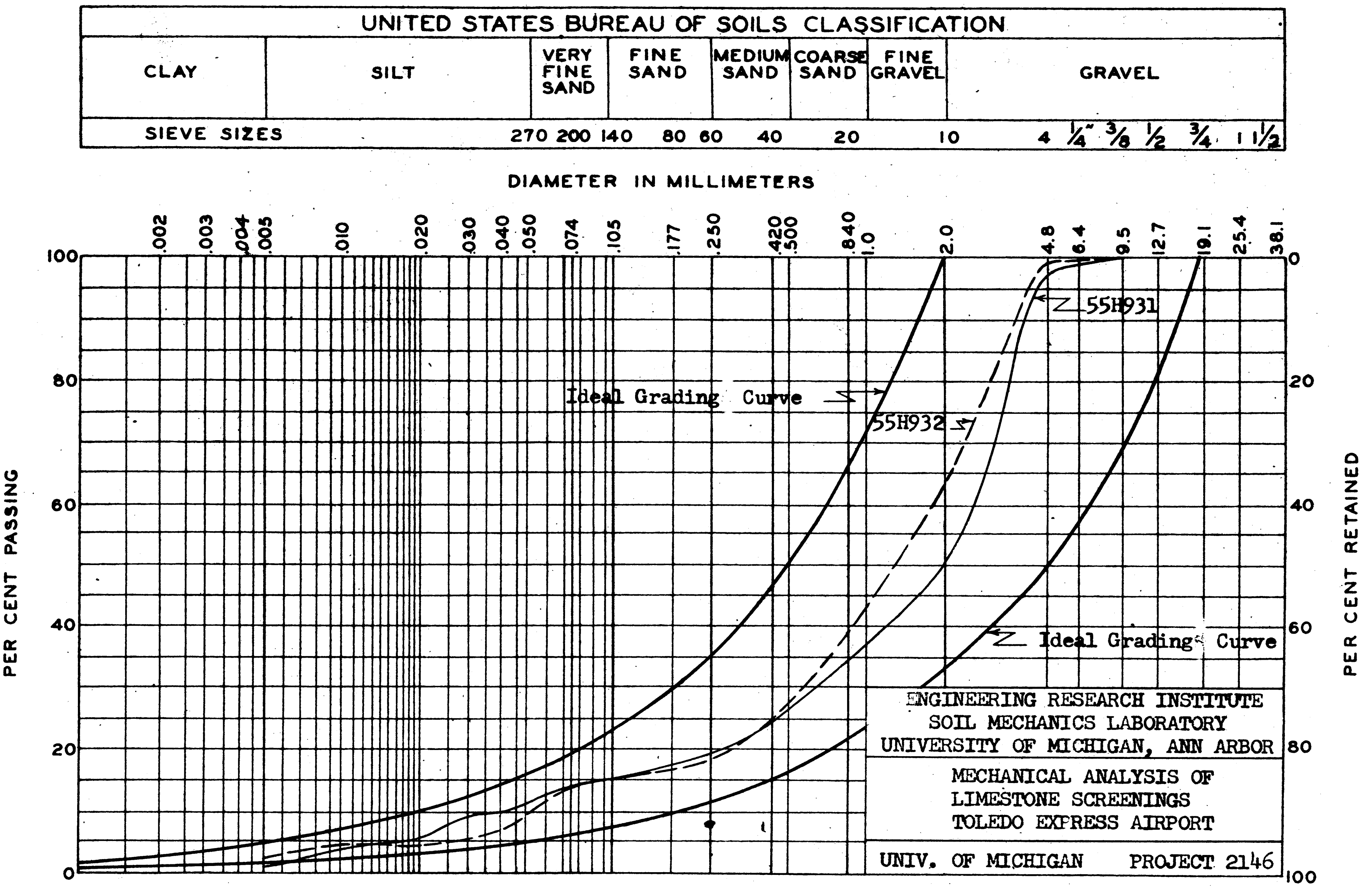

UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
PER CENT RETAINED
0 20 40 60 80 100
Ideal Grading Curve
55H931
55H932
Ideal Grading Curve
ENGINEERING RESEARCH INSTITUTE
SOIL MECHANICS LABORATORY
UNIVERSITY OF MICHIGAN, ANN ARBOR
MECHANICAL ANALYSIS OF
LIMESTONE SCREENINGS
TOLEDO EXPRESS AIRPORT
UNIV. OF MICHIGAN PROJECT 2146

Figure 7

COMPACTION CHARACTERISTICS

Project 2146 Lab. Sample No. 53H931,932

Location Toledo Express Airport Field Sample No. - -

Tested by GPL Date 7-53 Plotted by G. S. Date 2-1-55

Description or Remarks: Representative Limestone Screenings

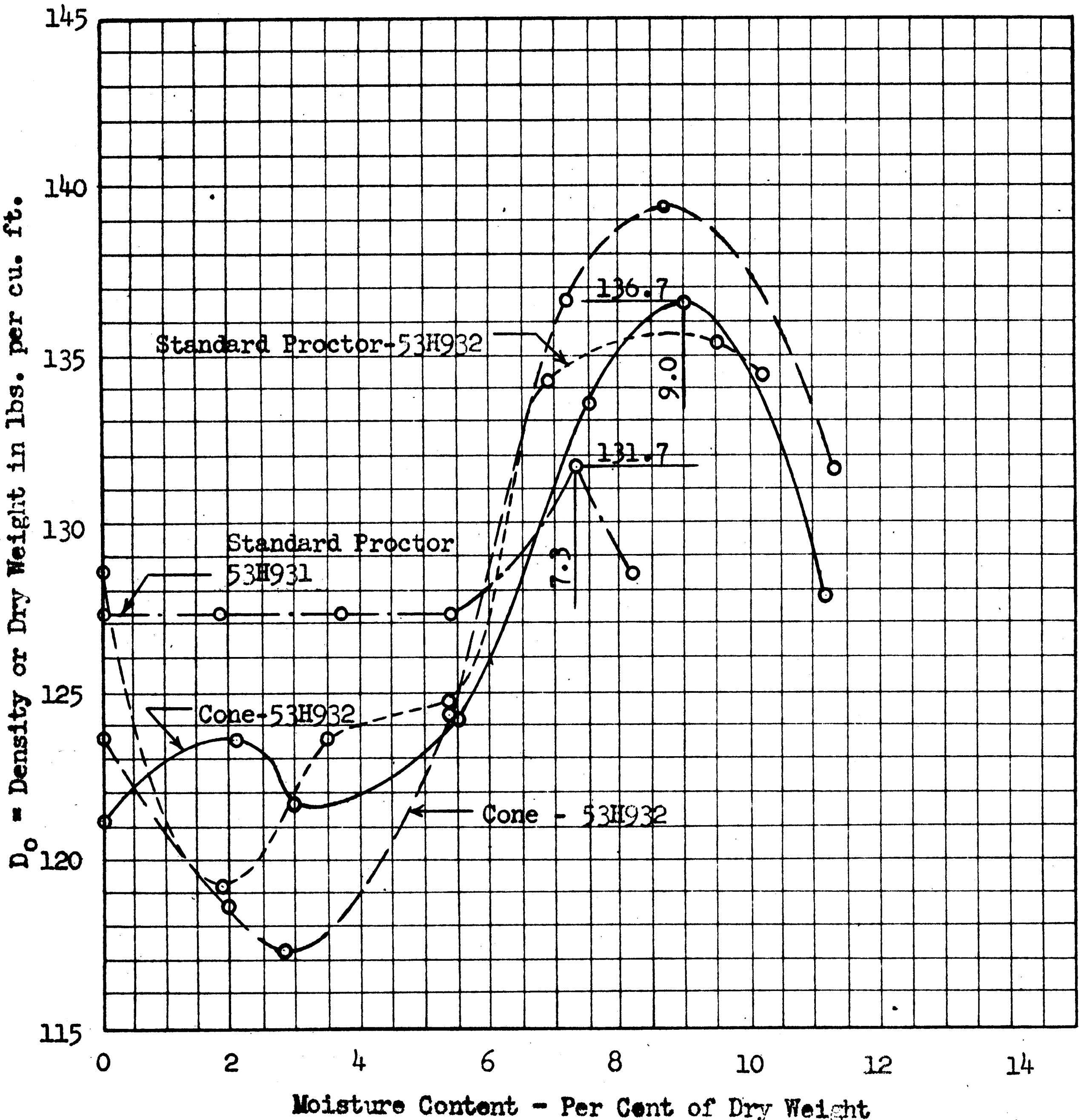
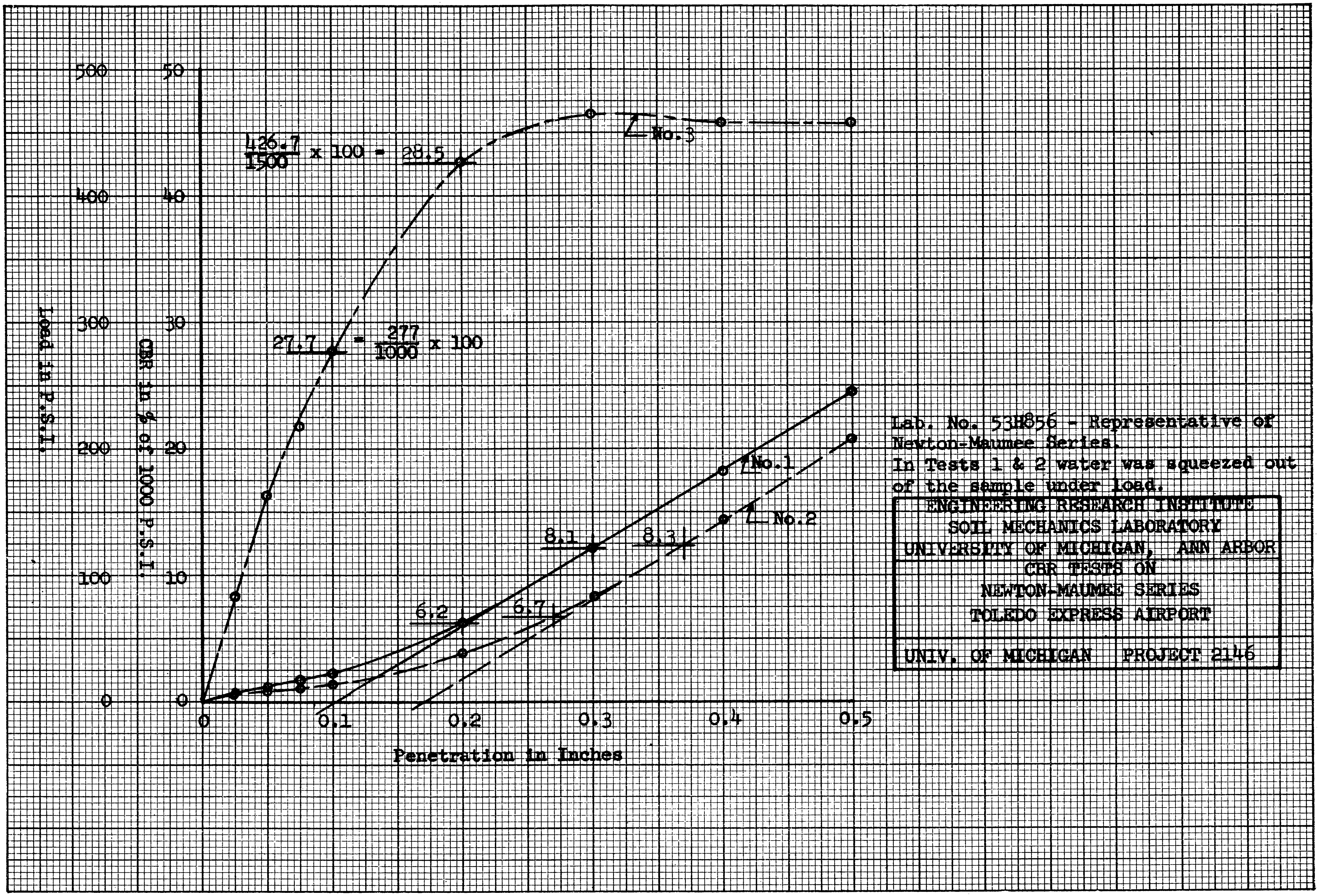


Figure 8



Load in P.S.I.
CBR in % of 1000 P.S.I.
500
400
300
200
100
0
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
0.5
Penetration in Inches
426.7 / 1500 x 100 = 28.5
27.7 = 277 / 1000 x 100
No.3
No.1
No.2
8.1
8.3
6.2
6.7
Lab. No. 53H856 - Representative of Newton-Maumee Series.
In Tests 1 & 2 water was squeezed out of the sample under load.
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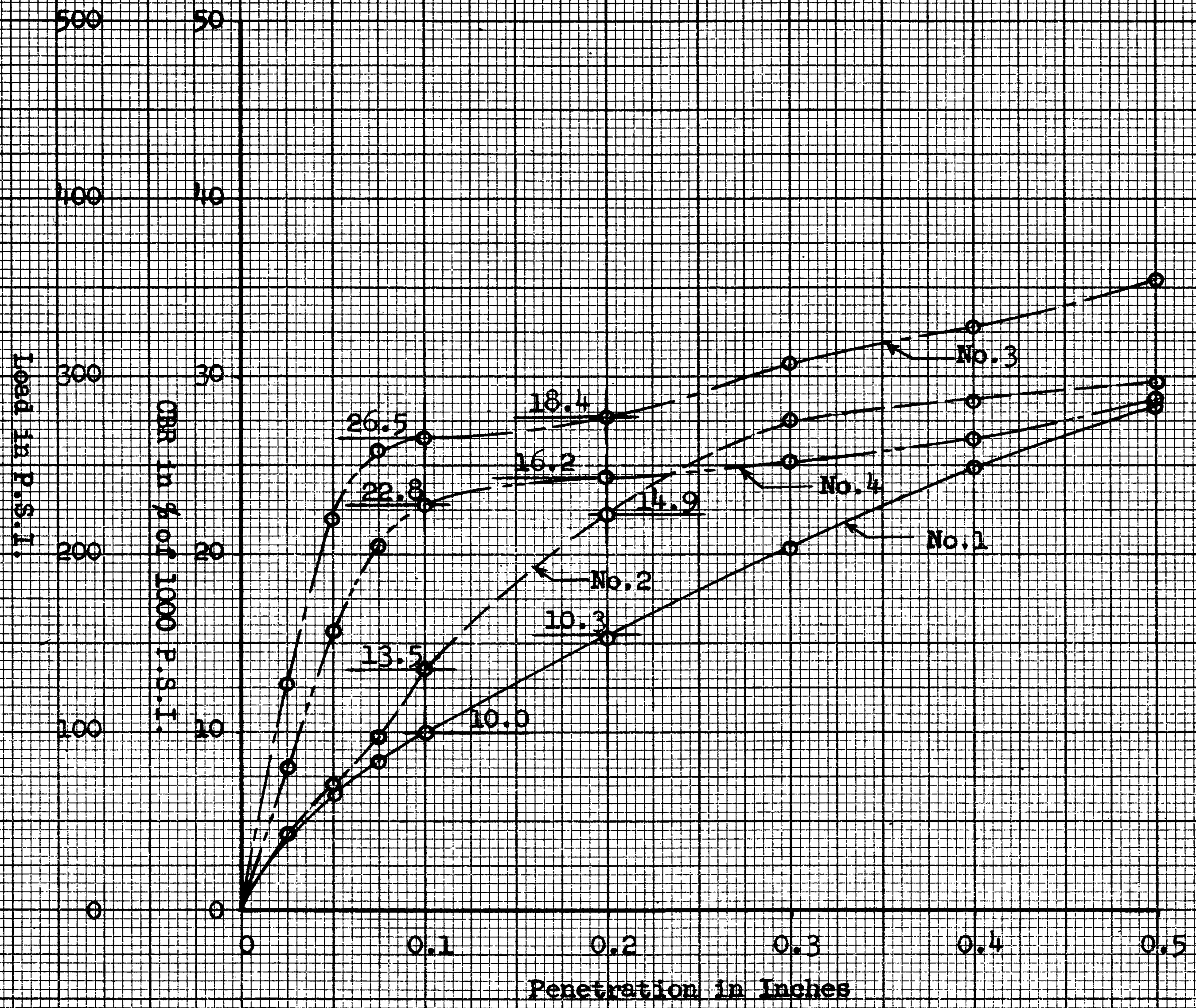
UNIVERSITY OF MICHIGAN, ANN ARBOR
CBR TESTS ON
NEWTON-MAUMEE SERIES
TOLEDO EXPRESS AIRPORT
UNIV. OF MICHIGAN PROJECT 2146

Figure 9



Lab. No. 53H837 - Representative of Plainfield-Bridgman Series.
In Tests 1 & 2 water was squeezed out of the sample under load.

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SOIL MECHANICS LABORATORY
UNIVERSITY OF MICHIGAN, ANN ARBOR
CBR TESTS ON
PLAINFIELD-BRIDGMAN SERIES
TOLEDO EXPRESS AIRPORT

UNIV. OF MICHIGAN PROJECT 2146

Figure 10

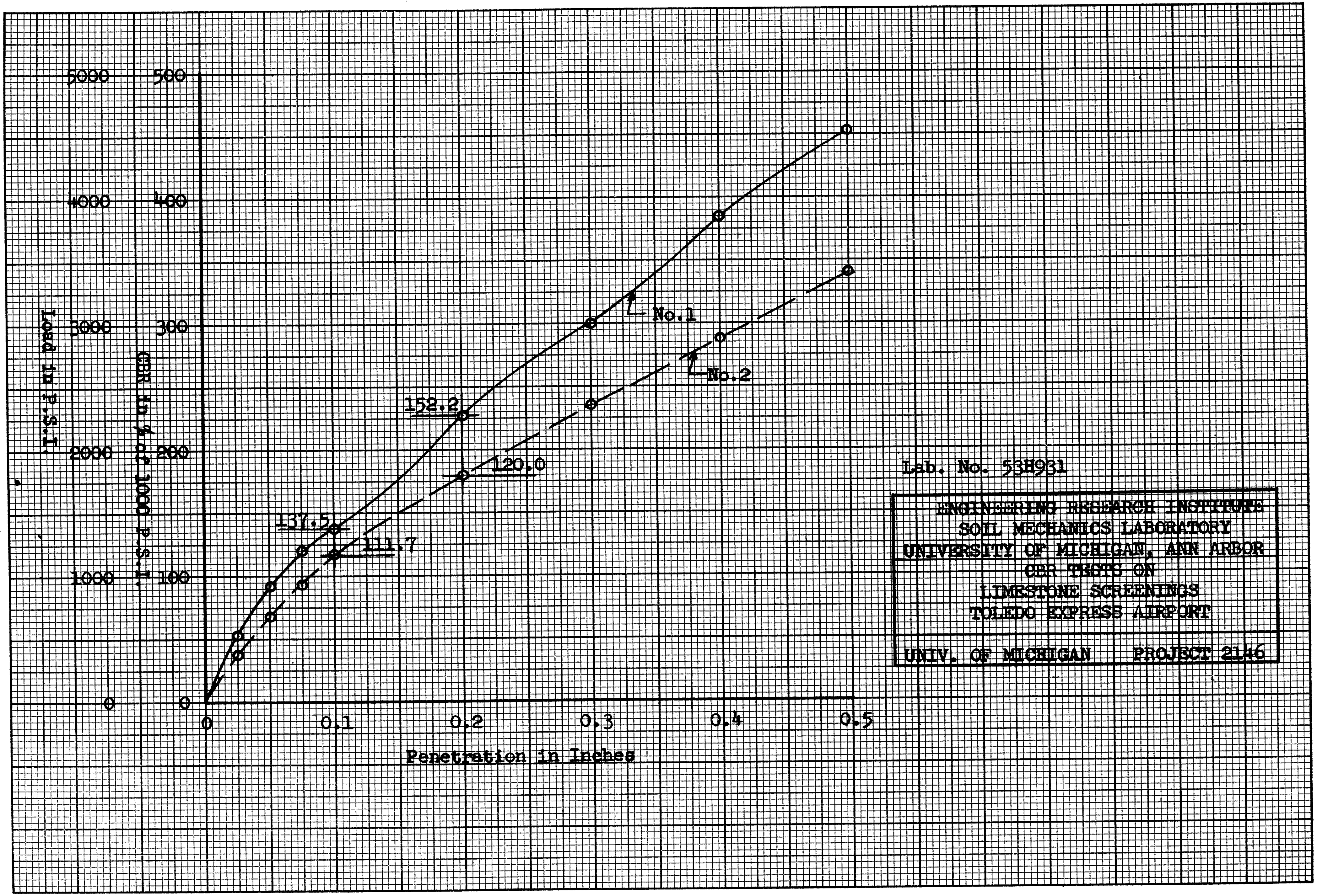

5000
4000
3000
2000
1000
0
500
400
300
200
100
0
Load in P.S.I.
CBR in % of 1000 P.S.I.
0
0.1
0.2
0.3
0.4
0.5
Penetration in Inches
152.2
120.0
137.5
111.7
No.1
No.2
Lab. No. 53H931
ENGINEERING RESEARCH INSTITUTE
SOIL MECHANICS LABORATORY
UNIVERSITY OF MICHIGAN, ANN ARBOR
CBR TESTS ON
LIMESTONE SCREENINGS
TOLEDO EXPRESS AIRPORT
UNIV. OF MICHIGAN PROJECT 2146

Figure 11

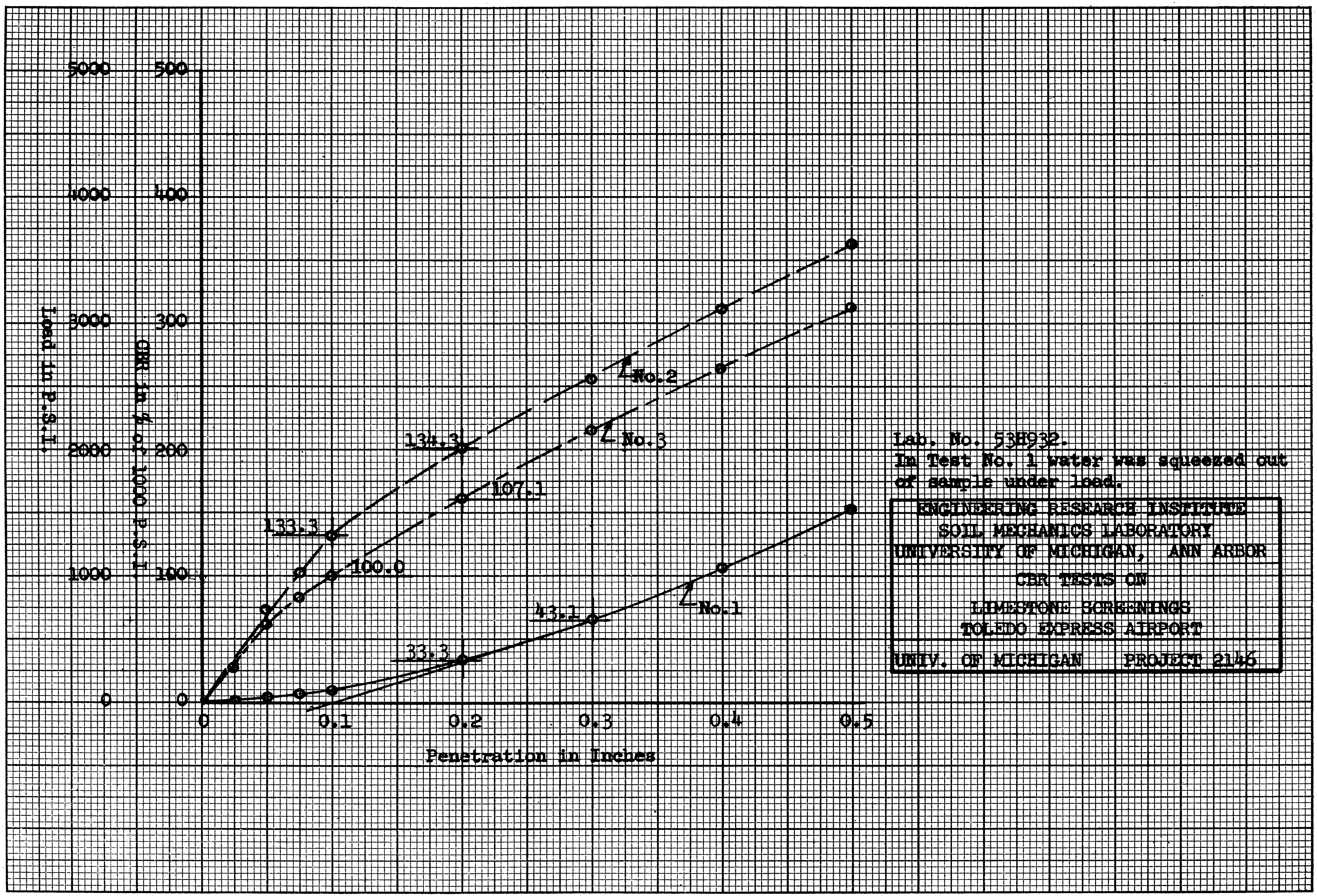
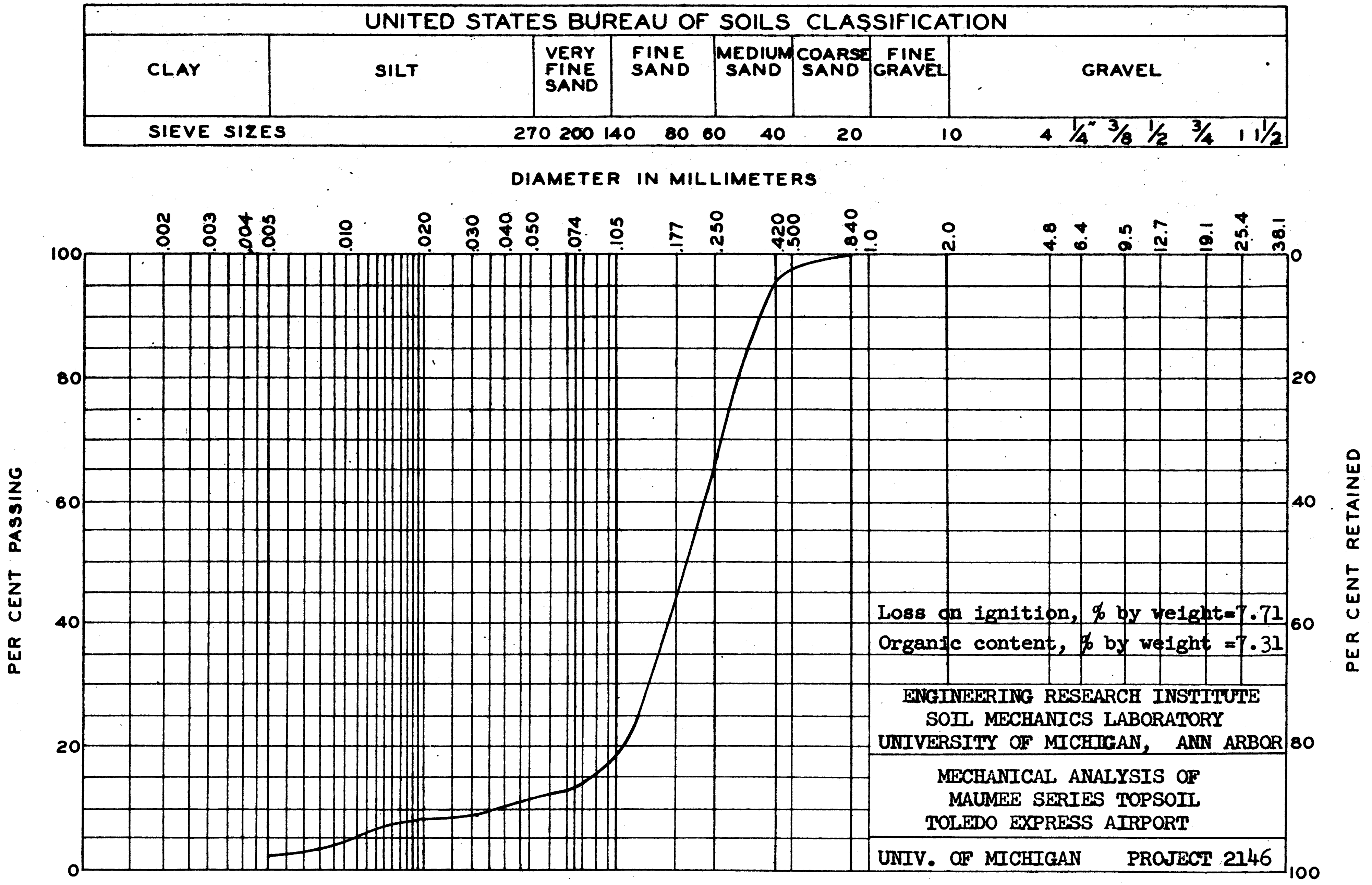

5000
4000
3000
2000
1000
0
Load in P.S.I.
500
400
300
200
100
0
CBR in % of 1000 P.S.I.
0
0.1
0.2
0.3
0.4
0.5
Penetration in Inches
134.3
133.3
107.1
100.0
43.1
33.3
No.1
No.2
No.3
Lab. No. 53H932.
In Test No. 1 water was squeezed out of sample under load.
ENGINEERING RESEARCH INSTITUTE
SOIL MECHANICS LABORATORY
UNIVERSITY OF MICHIGAN, ANN ARBOR
CBR TESTS ON
LIMESTONE SCREENINGS
TOLEDO EXPRESS AIRPORT
UNIV. OF MICHIGAN PROJECT 2146

Figure 12



UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
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FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
PER CENT RETAINED
0 20 40 60 80 100
Loss on ignition, % by weight=7.71
Organic content, % by weight =7.31
ENGINEERING RESEARCH INSTITUTE
SOIL MECHANICS LABORATORY
UNIVERSITY OF MICHIGAN, ANN ARBOR
MECHANICAL ANALYSIS OF
MAUMEE SERIES TOPSOIL
TOLEDO EXPRESS AIRPORT
UNIV. OF MICHIGAN PROJECT 2146

Figure 13

TABLE I

SUMMARY OF CBR TEST RESULTS
NEW TOLEDO AIRPORT

Lab. No. 53 H	Test No.	Surcharge Load Lbs.	Laboratory Control Test		Test Sample		% Compaction	CBR in % Penetration	
			Dry Density p.c.f.	Optimum Moisture % by Dry Wt.	Dry Density p.c.f.	Moisture % by Dry Wt.		0.1"	0.2"
837	1	20	111.1	12.9	109.8	12.8	98.8	10.0*	10.3*
	2	20			110.3	13.0	99.3	13.5*	14.9*
	3	20			110.6	4.9	99.5	26.5	18.4
	4	20			111.4	6.8	100.3	22.8	16.2
856	1	20	112.9	11.1	111.8	11.1	99.0	6.2*	8.1*
	2	20			111.3	11.6	98.6	6.7*	8.3*
	3	20			116.7	6.8	103.4	27.7	28.5
931	1	20	131.7	7.3	136.5	3.9	103.6	137.5	152.2
	2	20			131.5	4.0	99.8	111.7	120.0
932	1	20	136.7	9.0	143.0	7.5	104.6	33.3*	43.1*
	2	20			135.5	5.5	99.1	133.3	134.3
	3	20			135.8	5.6	99.3	100.0	107.1

* Water squeezed out of sample under load.