STABILIZATION CONTROL ON THE WASHINGTON NATIONAL AIRPORT

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SYNOPSIS

The runways of the Washington National Airport, surfaced with 3½ in. of bituminous concrete on a stabilized gravel base 9 in thick, are located almost entirely in what was originally shoal water and mud flats along the Virginia shore of the Potomac River This low area was filled to an elevation of 12 to 16 ft above the normal water level with material consisting of sand, gravel cobbles, silt and muck pumped by means of hydraulic dredges from borrow pits located in the river on the outskirts of the field By placing the pipelines of the hydraulic dredges longitudinally along the runways, the granular material was collected in the runway areas and the silt and muck floated off to be deposited by ponding in the intermediate areas between and outside of the runways

The gravel in the runways was combined with soil from the adjacent upland areas to produce a dense, well graded, stable base course for the bituminous concrete surfacing The work of stabilization consisted of scarifying the graded gravel runways, removing oversize stone, adding the proper amount of soil, mixing the gravel and soil by means of cultivators, disk harrows, and plows, compacting with rollers, and shaping with motor graders and drags

Control over the base stabilization in accordance with established requirements as to gradations, physical properties and densities was accomplished by coordinating the construction operations with the tests performed on the raw materials and the mixtures This work was directed from a portable field laboratory located on the runways

The landing field of the Washington National Airport occupies over 500 of the 720 acres comprising the airport[1] About 325 acres of the landing area is located in what was originally shoal water and mud flats along the Virginia shore of the Potomac River. This low area was filled to an elevation of 12 to 16 ft. above the normal water level with material pumped from the river by means of hydraulic dredges The remainder of the landing field was brought to grade with dry fill obtained during the grading of the adjacent upland areas.

Borings disclosed that there was a layer of soft mud varying from 5 to 20 ft in thickness over most of the site Underlying the mud was a stratified deposit of sand, gravel, cobbles, and additional silt. In order to secure as stable foundations as possible for the runways under the existing conditions and to reduce the differential and ultimate settlements likely to occur, the runway areas were trenched to a width of 200 ft and a depth of 12 ft. below mean low water or to hard bottom if encountered at less depth.

The excavated trenches were then backfilled with material pumped from borrow pits located in the river on the outskirts of the field.

The material in the borrow pits contained 60 percent of sand and gravel and 40 percent of silt and muck. By placing the pipe lines of the hydraulic dredges longitudinally along the runways, the granular material was collected in the runway areas and the silt and muck floated off to be deposited by ponding in the intermediate areas between and outside of the runways.

The gravel fill was built up to a height of 6 to 8 ft. above the final grade of the runways, the additional material serving as a surcharged load to hasten consolidation of the newly placed fill material and

[1] Stabilization of Gravel Runways on Washington National Airport, by Henry Aaron and J A. Kelley, Jr, *Public Roads,* vol 22, No 8, October 1941.

any compressible material in the foundation below. It served also to furnish gravel for widening the runways and for use in other areas of the airport.

A preliminary investigation disclosed that the material in the runways did not occur as uniform mixtures of sand and gravel, but instead the composition of the fill consisted of stratifications and pockets of sand, gravel and cobbles, and in certain locations layers and pockets of clay and muck were encountered

The behaviour of the existing runway material under the action of construction traffic showed a large variation in stability. Some portions were well compacted while other sections remained loose and became rutted. Sponginess and rutting were observed in the mucky areas. These conditions indicated the need for stabilization in order to provide satisfactory support over the entire area to be paved.

The design called for a stabilized base 9 in. thick after compaction for the runways and taxiways located in the hydraulic fill area and a 12-in base constructed in two 6-in. courses on the dry fill areas of the landing field as well as the relocated Mt. Vernon Memorial Highway over Four Mile Run. Access roads, service roads, parking zones and most of the taxiways were designed to have a 5-in. compacted gravel lower course and an 8-in. stabilized gravel upper course. The width of the stabilized base extended 3 ft. beyond the edges of the asphaltic concrete surface which was 200 ft wide on the North-South and the Northwest-Southeast runways, 150 ft. on the Northeast-Southwest and East-West runways, and 75 ft. on the taxiways Figure 1 shows the layout of these facilities and typical cross sections are shown in Figure 2.

MATERIALS INVESTIGATED

Tests performed on samples taken from the runways (see Table 1) indicated that the material, in general, was a nonplastic mixture of sand and gravel with variable amounts of large rock and cobbles The percentage of large rock varied considerably from place to place. After removing this material, however, the remaining sand and gravel was fairly well graded but was lacking in material passing the No. 200 sieve As a result, it was decided to stabilize the gravel by the addition of a binder soil from the upland area.

Two portions of the upland area, one at Roaches Run and the other at the proposed parking zone south of the Public Roads Administration laboratories (Fig. 1), were designated as the locations most convenient for obtaining binder soil without interference with the grading operations. Accordingly, a soil survey of these areas was made to determine the characters and quantities of soils available for use as binder material for stabilization.

Borings were made to determine the soil profiles and samples representative of the different layers of the profile were tested in the Public Roads Administration soils laboratory. The surveying, sampling and testing were performed in accordance with the standard methods of the American Association of State Highway Officials.

An adequate supply of acceptable soil materials, consisting of yellowish and yellowish red sandy loams and clay loams, was available in the two pits. They were friable in consistency and could be readily pulverized. With respect to the gradations of the samples, the fraction passing the No. 200 sieve ranged from 32 to 83 percent. The liquid limits varied from 19 to 38 and the plasticity indexes from 2 to 17.

STABILIZED MIXTURE REQUIREMENTS

In order to provide for variations in the materials encountered in the runways, four different gradings were permitted in the stabilized mixtures. They were based on the maximum size of the gravel in the mixture after the large rock and cobbles

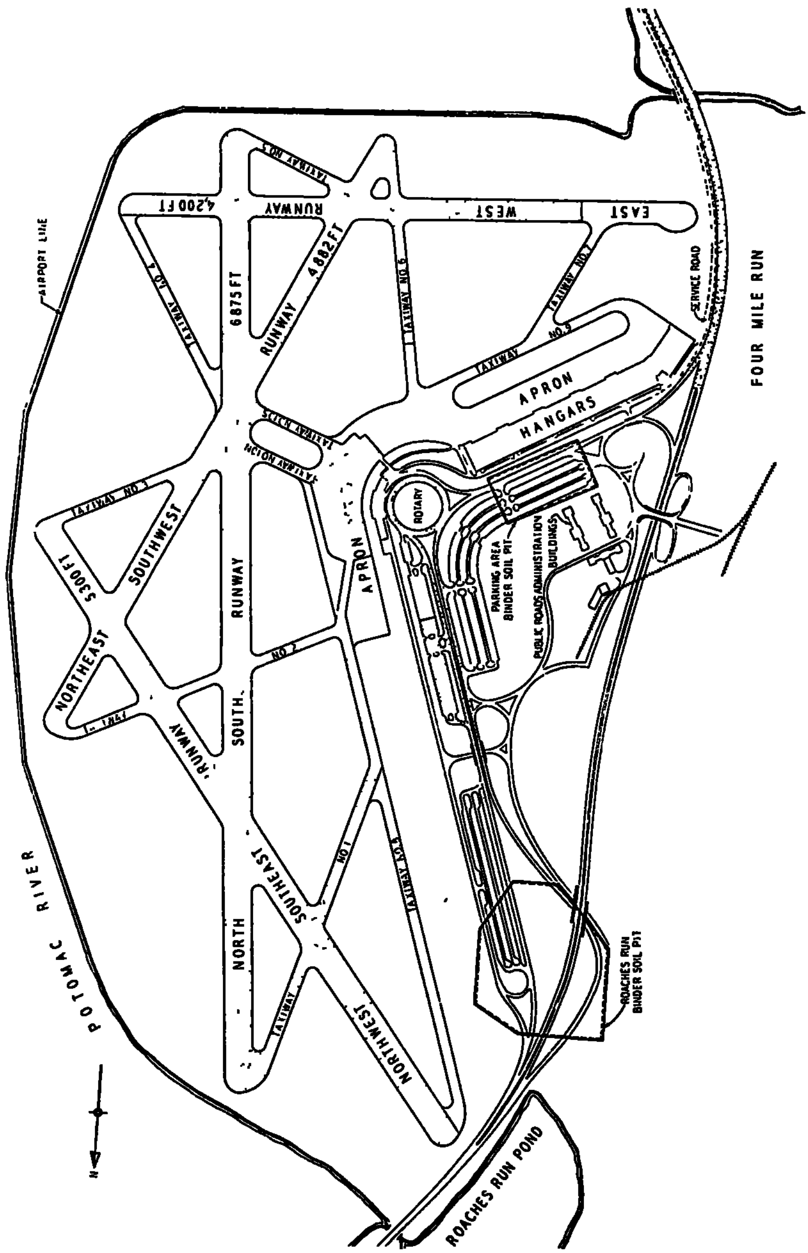


Figure 1. Layout of Runways, Taxiways, Aprons and Roads—Washington National Airport. Shaded Areas Indicate Work Completed During 1940

had been removed. The permissible grading limits are given in Table 2.

It was required that the gravel be combined with binder soil in such proportions that the resulting mixture would fall within the limits of Grading B, C, D or E, whichever best fitted the material available. However, since it was desired to use any suitable material existing in the runways which could be satisfactorily stabilized, some tolerance from the limits given in Table 2 was allowed at the discretion of the engineer.

In addition to the grading requirements, it was further required that the fraction passing the No. 200 sieve should be less

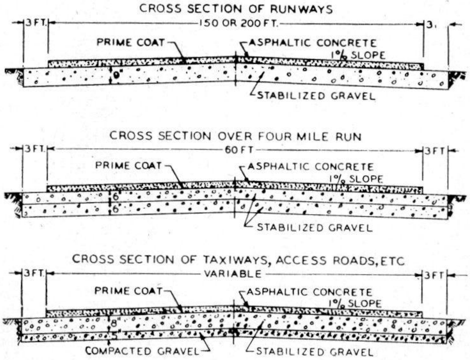


Figure 2. Typical Paving Cross Sections—Washington National Airport

than one-half of the fraction passing the No. 40 sieve, and also that the fraction passing the No. 40 sieve should have a liquid limit not greater than 25 and a plasticity index not greater than 6.

Control over the base stabilization in accordance with these requirements was accomplished by coordinating the construction operations with the tests performed on the raw materials and the mixtures. This work was directed from a portable field laboratory (Fig. 3) located on the runways.

CONSTRUCTION METHODS AND CONTROL

The rough grading was generally performed by bulldozers which pushed the surcharged fill material off to the sides of the area to be stabilized. When gravel was needed in other locations, it was formed into large piles by the bulldozers and loaded into trucks by means of a dragline. Motor patrol graders were used to bring the runway to approximate grade and cross section.

Many areas containing unstable mucky material were encountered during the grading operations. When the muck was

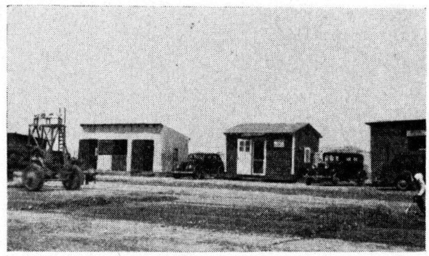


Figure 3. Portable Laboratory and Offices on Runways. Laboratory in Center

Figure 4. Oversized Stone Brought to Surface by Scarifying and Cultivating

in the form of seams or thin layers, it was excavated by means of large tractor-drawn scrapers. Deep pockets were cut out with draglines. All muck deposits were removed to a minimum depth of 3 ft. below subgrade elevation and replaced with gravel.

After the grading was completed, the runway material was scarified with a heavy duty rooter to an approximate depth of 12 in. The scarified gravel was then further loosened with a field cultivator and all oversized stone brought to the surface (Fig. 4) were removed by hand. These operations were continued until the depth to be stabilized was, for all practical purposes, free of all stones larger than about 3 in and other objectionable material such as clay balls.

The use of the rooter and field cultivator in connection with the removal of oversize stone indicated that the construction equipment could be operated more efficiently on long strips 50 ft. wide than on short sections 206 ft. wide As a result, the runways were divided into two inner lanes 50 ft. wide and two outer lanes 53 ft. wide and all work was performed on each lane as a separate unit.

When sections of the runway had been satisfactorily cleared of oversize stone and other undesirable material, samples were taken from the 12 in. of loosened material

TABLE 1

RESULTS OF TESTS PERFORMED ON SAMPLES TYPICAL OF GRAVEL PUMPED INTO RUNWAYS OF WASHINGTON NATIONAL AIRPORT

Sample No	1	2	5	7	9	12	13	16
	Sieve analysis							
Percentage passing								
2-in sieve	86	100	100	92	96	63	75	100
1½-in sieve	86	95	96	89	93	58	70	98
1-in sieve	85	85	95	81	89	53	62	93
¾-in sieve	80	71	92	71	82	46	56	86
⅜-in sieve	65	53	79	51	62	36	45	71
No 4 sieve	53	40	66	37	44	29	36	58
No 10 sieve	42	34	55	25	32	24	29	48
No 40 sieve	25	27	36	14	13	11	18	34
No 200 sieve	3	2	5	7	2	2	5	5
PHYSICAL CONSTANTS OF MATERIAL PASSING NO 40 SIEVE								
Liquid limit	NP[a]	NP	NP	30[b]	NP	NP	NP	NP
Plasticity index				9				

[a] NP denotes nonplastic
[b] Sample No 7 was taken in an area containing a thin layer of muck

TABLE 2

GRADATION REQUIREMENTS FOR STABILIZED MIXTURES

Sieve designation	Percentage by weight passing square mesh sieves			
	Grading B	Grading C	Grading D	Grading E
3-in	100			
2-in	65–100	100		
1½-in		70–100		
1-in	45–75	55–85	100	
¾-in		50–80	70–100	90–100
⅜-in	30–60	40–70	50–80	70–100
No 4	25–50	30–60	35–65	50–90
No 10	20–40	20–50	25–50	35–80
No 40	10–25	10–30	15–30	20–50
No 200	3–10	5–15	5–15	8–25

and their gradations were determined in the laboratory. At the same time, samples of binder soil were obtained from the pit and analyzed The percentage of binder soil to be added to the gravel and the area to be covered by each load of binder soil was calculated from the results of these tests.

As the removal of the stone from a section sufficiently large to permit satisfactory operation of the mixing equipment was nearing completion, a crew of laborers was sent to the binder soil pit where a bulldozer had stripped off the topsoil containing vegetable matter and had pushed up a large pile of approved binder soil. The binder soil was loaded by hand into transportable, bottom dump,

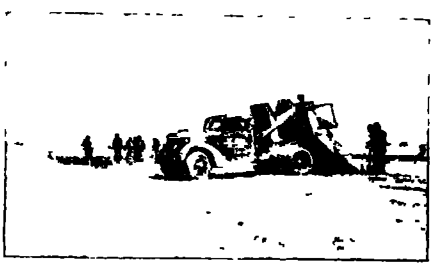


Figure 5. Depositing and Spreading Binder Soil

2-cu. yd. boxes, hauled to the runways, dumped (Fig. 5), and spread by hand over an area previously staked out in accordance with instructions issued by the testing laboratory

The first step in the mixing was to cut in the binder soil by means of the field cultivator. This was followed by one trip with a two-way tandem disk harrow equipped with disks 28 in. in diameter. In order to facilitate the distribution of the binder soil through the full depth to be stabilized, the disked material was turned with a four-bottom gang plow. Mixing with the disk harrow and cultivator was repeated until the binder soil and gravel were thoroughly and uniformly mixed to the specified depth.

Water was applied whenever necessary during the mixing operations The need for water was determined by the requirements for compaction. Tests made on the base course material in locations where satisfactory compaction was obtained showed that 5 to 7 percent of moisture was required to give the desired results. This checked very closely with the optimum moisture content of 10 percent (American Association of State Highway Officials' Method T 99-38) on the material passing the No. 4 sieve which averaged about 60 percent of the total mixture.

While the mixing was in progress, frequent checks were made on the moisture content, the uniformity of the mixture and the depth of the mixed material.

The loose mixture of gravel and soil was bladed to approximate cross section with a motor patrol and then compacted with multi-wheel, pneumatic-tired rollers weighing about 6 tons. This rolling was continued until an unyielding surface was produced under the weight of these rollers. At least two trips were required to secure this condition. Final compaction was obtained by means of a three-wheel, 10-ton roller. The motor patrol and a multiple blade drag were used to keep the surface properly shaped during the rolling.

The surface was maintained in a moist condition by sprinkling while these operations were in progress.

Weak spots which developed in the base or subgrade during the rolling were examined by means of test pits and corrected according to the needs of the particular case. A further check on the subgrade stability was obtained by operating a 12-ton, solid-tired truck over the compacted surface. A failure due to weak subgrade is shown on Figure 6.

After the base had been compacted to a minimum dry density of 130 lb. per cu. ft., the elevation and cross section was checked by an engineering party. Final shaping consisted in cutting the high spots and filling in low areas in accordance with stakes driven to grade elevation at 25-ft. intervals. This work was performed by hand or by motor patrol depending on the size of the area to be corrected. The surface was then finished by rolling with a 5-ton tandem roller. The appearance of the completed base course is shown in Figure 7.

The quality of the stabilized mixture was checked by tests performed on

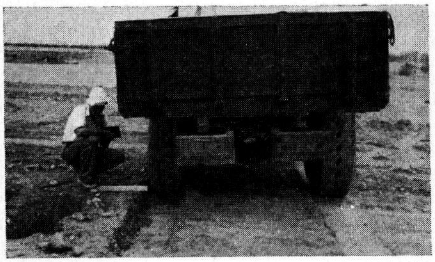


Figure 6. Failure Due to Weak Subgrade

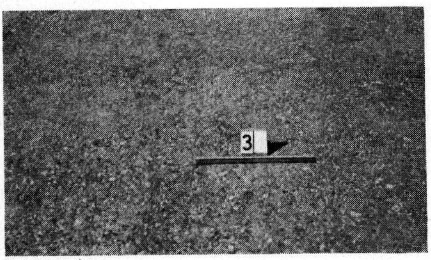


Figure 7. Appearance of Completed Base Course

samples taken at regular intervals after the mixing was completed. When the results of tests indicated an unsatisfactory mixture at a certain location, additional samples were obtained in sufficient number to determine the limits of the area in this condition. All such areas were reconstructed.

The final step in the stabilization procedure was an application of tar prime at a rate of about 0.25 gal. per sq. yd. This application was not permitted until the base course conformed with all the requirements relating to quality of mixture, density and stability.

SAMPLING AND TESTING

Sampling of the gravel consisted in digging a hole 12 in. deep in the graded runway after the oversize stone had been removed and collecting approximately 15 lb. from the sides of the hole. Samples were taken from each 50 or 53-ft. strip at

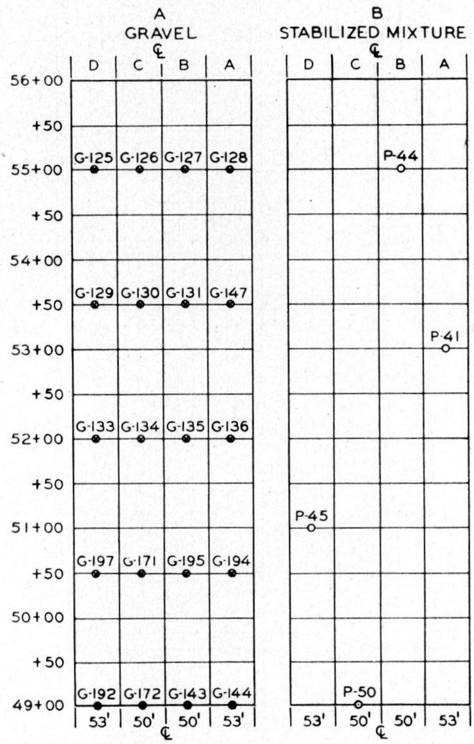


Figure 8. Plan of Sampling Locations—Washington National Airport

intervals of 150 ft. as illustrated on Figure 8-A, placed in dust-tight canvas bags and delivered to the portable field laboratory which was located as close as possible to the section of the runway under construction.

The sample was first dried in shallow pans over a gasoline camp stove, with continuous stirring to prevent burning. After the dried sample had cooled off, it was quartered down to about 4 lb., placed in a pan and ground with a rubber covered pestle to break up the aggregation of particles. Any fine material which had a tendency to adhere to the coarse gravel was removed with a wire brush. All of the material was then shaken through a nest of sieves ranging in size from the maximum to the minimum called for in the gradation requirements for the stabilized mixtures. The fraction retained on each sieve added to that retained on the sieves with larger openings was weighed and the percentage of the total sample retained was calculated

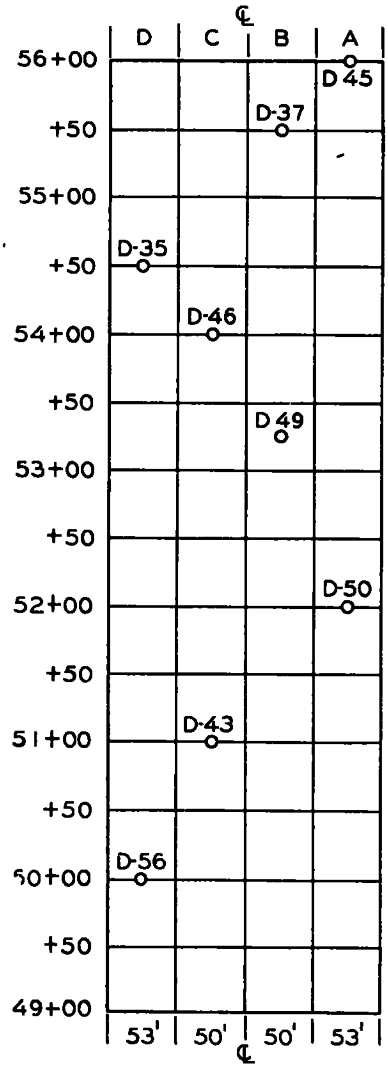


Figure 9. Typical Distribution of Density Tests—Washington National Airport

At the start of the work, samples of binder soil were obtained from the pit. After the hauling was commenced, samples were taken from the soil deposited on the runways These samples were tested for moisture content as well as gradation which was determined in the same manner as for the gravel.

One sample of the stabilized mixture was taken for each 200 lin ft. of runway as shown on Figure 8-B. Some of these samples were tested in the portable field laboratory. The majority, however, were sent to the Public Roads Administration laboratory where their gradations, liquid limits, and plasticity indexes were determined in accordance with the standard methods of the American Association of State Highway Officials.

DENSITY DETERMINATION

The locations where density tests were made depended on the order in which different areas were completed. A typical pattern is shown on Figure 9. The test procedure used on this project may be described as follows:

A soil collecting tray, 15 in. square, having a 4½-in circular opening in the center was set in place on the leveled surface and a hole was dug through the compacted base by loosening the material with a trowel or pointed bar. The loosened material was scooped out with a large spoon, placed in a pail, and weighed on a milk scale of 30-lb capacity. The indicator on the scale was adjusted for the weight of the pail so that the weight of the material removed from the hole was read directly The moisture content of this material was then determined in the laboratory.

The circular opening in the tray served as a template for digging the hole while the tray itself collected the loosened material which tended to scatter during the digging, together with any which might spill from the spoon in transferring the material from the hole to the pail.

After all the loosened material had been removed, the hole was filled with motor oil (S A.E. 40) from a 3-gal. can (Fig. 10) and the can plus the oil remaining in it after filling the hole was weighed. The weight of the can plus the original volume of oil had been previously determined. The difference between the two weights

Figure 10. Density Test. Pouring Oil in Hole

gave the weight of oil in the hole. A hand suction pump was used to remove the oil from the hole.

The volume of the hole was then determined by dividing the weight of the oil in the hole by the known weight of 56 lb. per cu. ft. of oil

The density of the base course in pounds per cubic foot as compacted in the moist condition was calculated by the formula:

of oil in the hole was 5 2 lb, and the weight of moist material removed from the hole was 12 65 lb. The weight of the oil is spotted on the chart at point A This

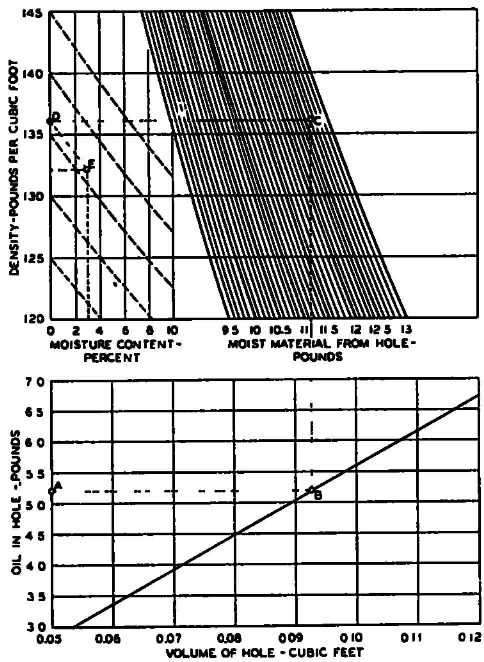


Figure 11. Graphical Calculation of Density from Test Data

corresponds to a volume of 0.0929 cu ft. at point B.

A vertical line from point B intersects the curve corresponding to 12.65 lb. of

$$\text{Wet density} = \frac{\text{Weight of moist material removed from hole}}{\text{Volume of hole}}.$$

After the moisture content of the material removed from the hole was determined, the dry density of the base in pounds per cubic foot was computed by the formula:

moist material at point C. The wet density of 136 2 lb. per cu. ft is indicated at point D on the density scale. With a moisture content of 3 percent the dry density of 132.2 lb. per cu. ft. is found at point E

$$\text{Dry density} = \frac{\text{Wet density} \times 100}{\text{Percentage of moisture} + 100}.$$

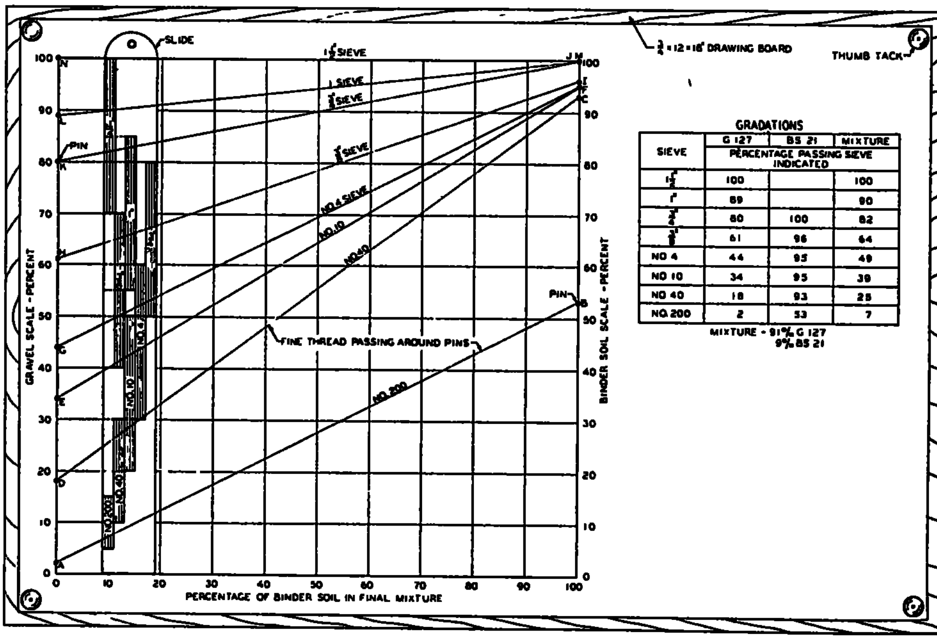
For a rapid calculation of the density in the field, the chart shown on Figure 11 was used. In one of the tests, the weight

This chart was set up to cover the ranges in weights, volumes and densities encountered on this particular project.

PROPORTIONING THE MATERIALS

In practically all cases, the gravel required the addition of binder soil to provide a stable mixture. It was found that best results were obtained from the available materials with a mixture having approximately 7 or 8 percent passing the No. 200 sieve for the B, C, and D gradings and about 10 or 11 percent for the E grading. Tests performed on the mixtures showed that the liquid limit and plasticity index requirements could be satisfied with any acceptable gradation resulting from the combination of the existing gravel with the binder soils used on this project.

This simplified the proportioning to the consideration of grading alone. On the basis of their gradations, the proper proportions of the two materials, gravel and binder soil, were determined by either the trial and error method or the graphical method. The trial and error method consisted in assuming a certain percentage of binder soil to add to the gravel and calculating what the resulting mixture would be. If this assumed percentage did not prove satisfactory other percentages were tried until the calculations indicated a suitable mixture. After a little experience with the available materials, the desired combination could be obtained on the first trial.



SIEVE	G 127	BS 21	MIXTURE
	PERCENTAGE PASSING SIEVE INDICATED		
1½"	100		100
1"	89		90
¾"	80	100	82
⅜"	61	96	64
NO 4	44	95	49
NO 10	34	95	39
NO 40	18	93	25
NO 200	2	53	7

Figure 12. Graphical Method for Proportioning Two Soil Materials to Produce Specified Grading of Stabilized Mixture

The proportioning of the materials by the graphical method was performed on the mechanical device illustrated in Figure 12. This consisted of a 12 by 18-in. drawing board on which was mounted a piece of cross section paper at least 10 in. long by 10 in. wide and having 10 divisions to the inch in each direction, a movable paper scale, several pins represented by the small circles on the figure, and a fine thread looped around the pins. The fine thread is represented on Figure 12 by the lines connecting the pins and having sieve designations.

The movable scale is a strip of cross section paper having the same vertical scale as the fixed sheet. The limits of the specified grading are blocked off on this scale. A different movable scale had to be made for each grading band.

The operation of this device may best be illustrated by a typical example. For convenience in following the procedure, the sieve analyses of gravel sample 127 (G-127) and binder soil sample 21 (BS-21) which are to be combined are shown on Figure 12. The first step is to place pins along the vertical scales of the fixed sheet at points corresponding to the percentages passing the various sieves, on the left for the gravel and on the right for the binder soil. Next, the end of the fine thread is tied to pin A marking the percentage of gravel passing the No. 200 sieve (2 percent) and stretched across to pin B designating the percentage of binder soil passing the same sieve (53 percent). The thread is then extended straight up along the binder soil scale to pin C, across to pin D, up along the gravel scale to pin E, across to pin F, and so on to pins G, H, I, J, K, L, M, and ending at pin N.

The movable scale is placed under the threads along the pins on the left side and then moved to the right until the line (indicated by the left edge of movable scale) is reached where the greatest number of threads are crossing within the limits specified for the corresponding sieve sizes marked on the scale. The intersection of this line with the horizontal scale at the bottom of the sheet indicates the percentage of binder soil to be added to the particular sample of gravel while the gradation of the mixture produced by this combination is read on the vertical scale at the points where this line intersects the lines formed by the different segments of the thread running across the sheet between the pins.

DISTRIBUTION OF BINDER SOIL

The calculation of the binder soil distribution was based on (1) the compacted dry density of the stabilized base assumed for design purposes as 135 lb. per cu. ft., (2) the moisture content of the soil as determined in the laboratory, (3) the percentage of binder soil in the mixture determined as described above, and (4) the weight of soil contained in the 2-cu. yd. transportable box which was found to average 4,870 lb. The variation in weight of any individual load from the average was negligible in amount.

The form used for the calculation is illustrated in Table 3. On the basis of a dry density of 135 lb. per cu. ft, the weight of dry materials in one square yard of compacted stabilized base, 9 in. thick, equals 911 lb The amount of dry binder soil in pounds per square yard to be spread on the runway is equal to 911 multiplied by the percentage of binder soil in the mixture divided by 100. In the case of gravel sample 127 and binder soil sample 21, for example, this amounts to $\frac{911 \times 9}{100}$ or 82 lb. Correcting for a moisture content of 8 percent, this value becomes 82×1.08 or 89 lb. of moist binder soil per square yard. Dividing the weight of a load of binder soil (4,870 lb.) by 89 gives 55 sq. yd. as the area covered by one load of binder soil.

For convenience in spreading by hand the width of spread for each load was fixed at a maximum of 25 ft. for the inside 50-ft. strips of the runways and 26½ ft. for the outside strips 53 ft. wide. The linear distance in feet per load was computed for the corresponding width.

It will be seen from the foregoing calculation that for a given width of spread the linear distance per load depends on the percentage of binder soil in the mixture and the moisture content of the binder soil. Accordingly charts were constructed from which the distribution of

TABLE 3

FORM FOR BINDER SOIL DISTRIBUTION CALCULATION—WASHINGTON NATIONAL AIRPORT

Design data.		Computed by	K
Compacted weight of stabilized mixture (lbs. per cu. ft)	135	Checked by	T
Thickness stabilized (inches)	9		
Compacted weight of stabilized mixture (lbs per sq yd)	911	Date	5–9–40

Binder soil pit	R R	R.R	R R	R R			
Binder soil type	BS-21	BS-21	BS-21	BS-21			
Moisture content (per cent)	8	12	8	8			
Binder soil required (per cent)	4	6	9	9			
Binder soil per load (lb)	4,870	4,870	4,870	4,870			
Dry binder soil required (lb per sq yd)	36	55	82	82			
Moist binder soil required (lb per sq yd)	39	59	89	89			
Distribution (sq yd per load)	125	83	55	55			
Width of spread (ft)	26½	25	25	25			
Lineal distance per load (ft)	42	29	20	20			
Gravel samples represented	125	126	127	131			

R R. denotes Roaches Run

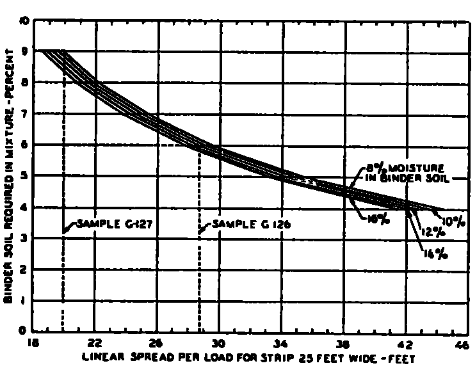


Figure 13. Graphical Determination of Binder Soil Distribution—Washington National Airport

the binder soil was determined graphically The chart used when the width of spread was 25 ft. is shown in Figure 13.

Figure 14 is an example of the sheet furnished to the superintendent of stabilization showing the dimensions of the area for each load of binder soil to be placed on different parts of the runway. In runway or taxiway sections of irregular shape, a binder soil distribution sheet such as shown on Figure 15 was issued to the superintendent Under these conditions, the application of binder soil was made to the nearest one-half load or one cubic yard.

STABILIZED MIXTURES COMPARED WITH ESTABLISHED REQUIREMENTS

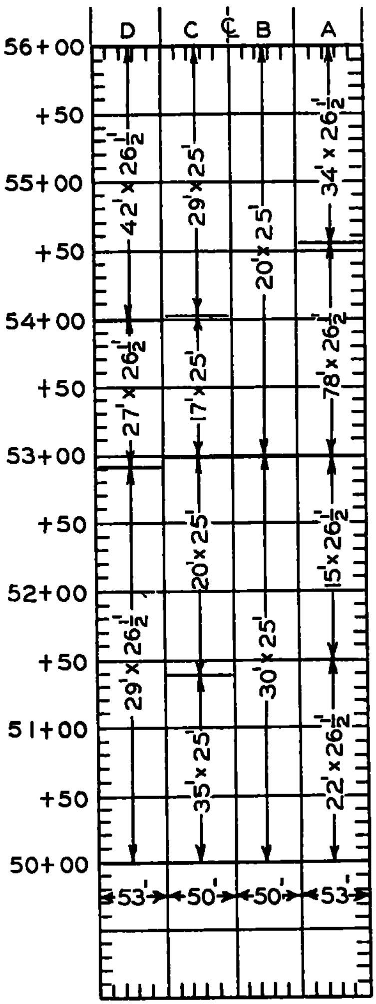
The results of the sieve analyses performed on the samples of stabilized mixtures from the runways are summarized graphically on Figure 16. The samples were grouped into gradation ranges corresponding as closely as possible to the grading requirements given in Table 2.

None of the samples had a gradation typical of the B grading. This grading was included in the requirements on the basis of materials represented by samples 12 and 13 in Table 1. However, practically all of the material remaining after removal of the oversize stone during the construction operations was smaller than 2 in. Only one sample had more than 10 percent retained on the 2-in. sieve and was included with the samples in grading C.

Stabilization Record - Washington National Airport

Location NORTH - SOUTH RUNWAY

Date MAY 9, 1940



To - Superintendent of Stabilization
From - Inspector (P.R.A.)

Subject - Binder soil distribution.

The area indicated on sketch by ... . is in condition to receive binder soil type BS-2J from pit located in upland area ROACHES RUN .... and shall be distributed as follows:

Sta.	to Sta.	Strip	Quantity in lbs. per sq.yd.	Lineal feet per load for width of 25' & 26½'
50+00	56+00	ABCD	VARIABLE	SEE SKETCH

Figure 14. Instructions for Distribution of Binder Soil

The range in gradations designated

D-E was made necessary by the fact that almost all the gravel samples had some material retained on the 1-in. sieve but many of these could not be placed in the C or D grading because of the high percentages passing the smaller-sized sieves. Many of the samples with material coarser than 1 in. had more than 80 percent smaller than the $\frac{3}{4}$-in. sieve. These samples generally had more material passing the No. 10 and No. 40 sieves, even before the addition of binder soil, than was per-

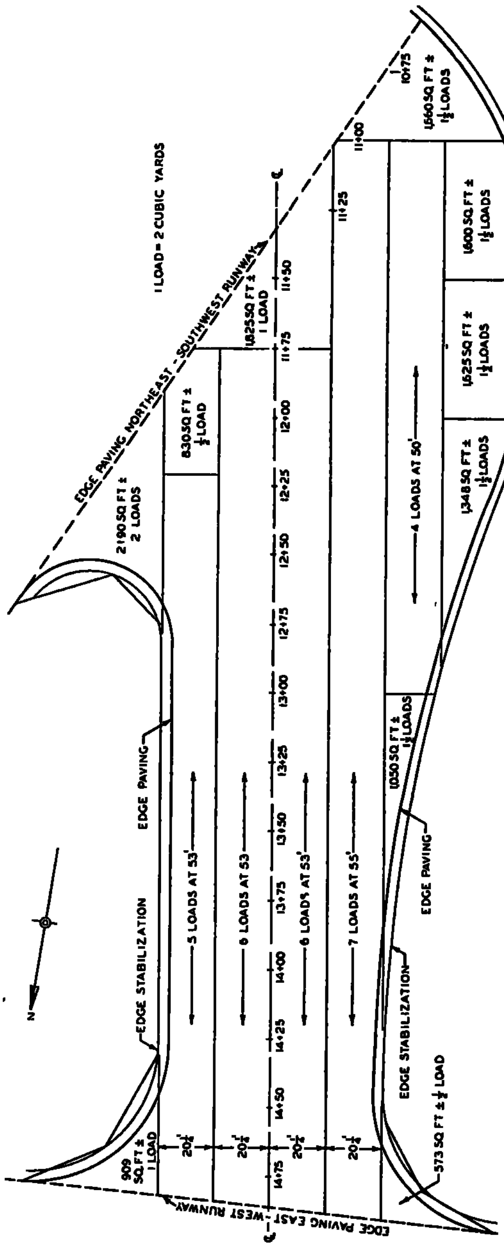


Figure 15. Binder Soil Distribution Sheet for Taxistrip No. 6, Sec. 1—Washington National Airport

mitted in the specifications for the C and D gradings. Since binder soil was required in practically all instances, the gradations of the resulting mixtures could not possibly fall within the limits specified. For this reason, all samples having between 80 and 90 percent passing the ¾-in. sieve were included in the D-E grading while those having more than 90 percent finer than the ¾-in. sieve were placed in the E grading.

The samples having 80 percent or less passing the ¾-in. sieve were placed in the C grading if the amount smaller than the 1-in. sieve did not exceed 85 percent and in the D grading when the percentage finer than the 1-in. sieve was greater than 85 percent.

The ratios of the fractions passing the No. 200 sieve to the fractions passing the No. 40 sieve ranged from 0.14 to 0.50 with an average of 0.27 for all the samples from the runways.

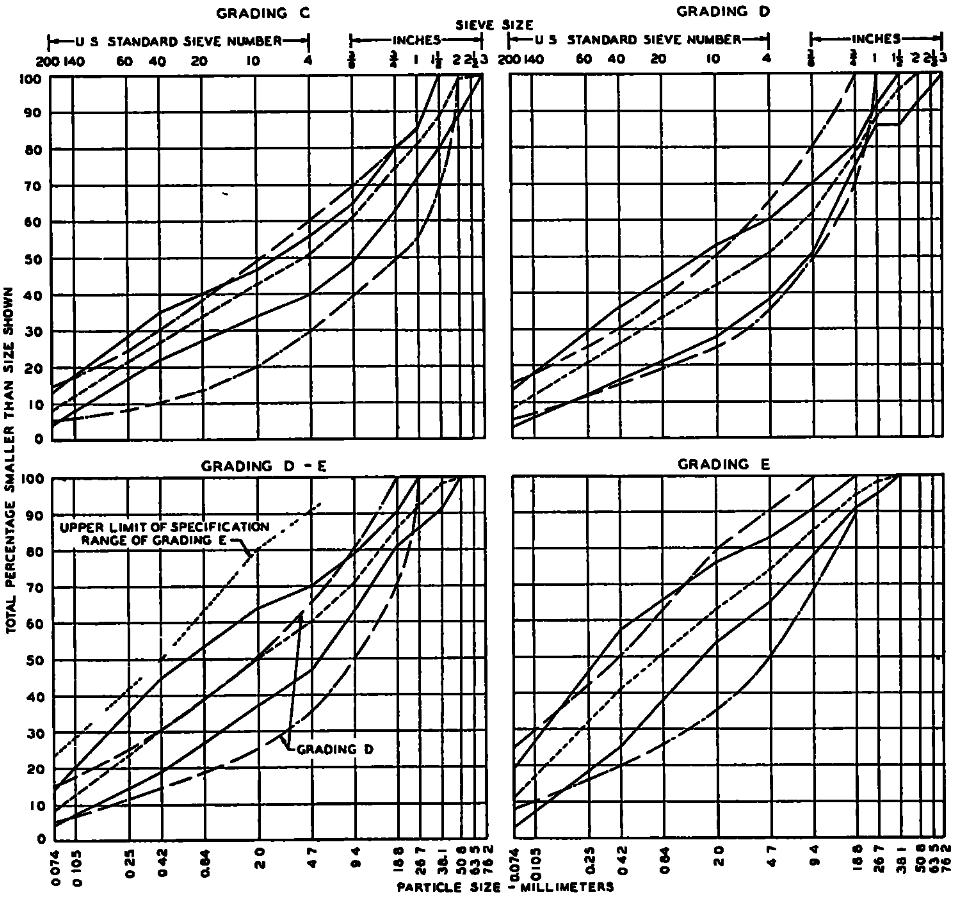


Figure 16. Results of Sieve Analyses of Stabilized Base Course Mixtures Compared with Specifications

With respect to the physical properties of the fractions passing the No 40 sieve, the results of tests may be summarized as follows:

Maximum liquid limit	23
Average liquid limit	18
Maximum plasticity index	6
Average plasticity index	1

A liquid limit of 25 and a plasticity index of 6 were the maximum permitted. In the design of the mix an attempt was made to hold the plasticity index to 3 or less in order to insure a stable base course under adverse moisture conditions Only 4 percent of the samples tested had plasticity indexes higher than 3 while 36 percent had plasticity indexes of zero Another 36 percent were so granular that the plasticity index could not be determined. Of interest in this connection is the fact that the nonplastic mixtures were compacted just as readily as those having a measurable plasticity index.

The base course densities secured on the runways ranged from 126 to 143 lb per cu. ft. with an average dry density of 134 lb. per cu. ft as compared with the density of 135 lb. per cu ft. used in designing the mixture. The low density of 126 lb. per cu ft. was obtained on the north-west end of the Northwest-Southeast runway. This portion of the runway was constructed before arrangements had been made to control the density or to check the stability of the subgrade.

After the minimum density requirement of 130 lb. per cu ft. was established, lower densities were permitted only when the amount of rolling indicated that no increase in density could be secured. Such conditions were encountered in a few isolated cases where the mixtures were sandy rather than gravelly in character. These mixtures had densities ranging from 128 to 130 lb per cu. ft.

CONCLUSION

The foregoing discussion of the results obtained on this project demonstrates the importance of control in the construction of a base course having the desired gradations, physical properties and densities. The first essential in establishing a control procedure is investigation of the materials available for stabilization. Frequent sampling and testing are necessary during construction to furnish information for combining the individual materials in proper proportions and to check the quality of mixtures and density of the base produced as a result of the mixing and rolling operations.

Control to be effective must be exercised in such a manner that the construction operations may be coordinated with tests performed on the materials and the mixtures. This requires that laboratory facilities be provided on the site.