HIGHWAY RESEARCH BOARD

BULLETIN No. 5

REPORT OF COMMITTEE ON COMPACTION OF SUBGRADES AND EMBANKMENTS

PRESENTED AT THE
TWENTY-SIXTH ANNUAL MEETING
1946

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HIGHWAY RESEARCH BOARD
DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH
NATIONAL RESEARCH COUNCIL

WASHINGTON 25, D. C. - JUNE 1947

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REPORT OF COMMITTEE

ON COMPACTION OF SUBGRADES AND EMBANKMENTS

The Committee on Compaction of Subgrades and Embankments was formed in 1941 for the purpose of studying the principles of compaction, its use, cost, and to obtain all information available that is pertinent to the subject. A questionnaire was prepared and sent to all of the 48 states and the District of Columbia in 1942 in order to obtain information on embankment performance and compaction requirements. The information from this questionnaire together with recommendations of the Committee for embankment and subgrade construction and compaction was published in Wartime Road Problems Bulletin No. 11, "Compaction of Subgrades and Embankments" by the Highway Research Board.

The Committee in 1946 prepared another questionnaire and sent it to the 48 states, the District of Columbia, the United States Engineer Department, and the Bureau of Yards and Docks of the United States Navy Department. This questionnaire was designed to obtain information on compaction methods and requirements, compaction equipment used, inspection methods and tests, and cost for both embankments and subgrades. All of the replies and an analysis of some of them are included in this report.

Another interest of the Committee is the influence compaction has on the absorption of moisture in earth type bases and subgrades and the effect of traffic on their density. Some investigation has been done on the subject and more is planned in 1947 and it is hoped that a report - probably a progress report - may be made of the results of the investigation next year.

The compaction of subgrades and embankments for airports will be studied more in the future, especially the use of "supercompaction". Three well known engineers with considerable airport construction experience have consented to serve on the committee and assist in this study.

QUESTIONNAIRE RESULTS

EMBANKMENTS

The following is a discussion of the data obtained from this questionnaire, and comparisons are made, whenever possible,

with the data obtained from a similar questionnaire sent out in 1942. The 1942 questionnaire covered embankment performance as well as compaction. It is to be noted that the 48 states are divided into seven groups, as was done in the 1942 summary, in an attempt to place together those states having similar climatic and soil conditions. With a few exceptions, the states in each group use the same methods of compaction and have approximately the same requirements.

1. Layer Thickness, Equipment, and Required Compaction. The 1942 questionnaire revealed that embankments in all of the states were being constructed in layers and compacted by rollers or distribution of hauling or both. The same methods are still being used by all of the states, according to the 1946 survey (See Table 1), except that six states report using thinner layers. The thickness of compacted layers vary from 3 in. to 24 in. The tabulation below gives the various thicknesses specified and the organizations specifying them:

Thickness of Layers Inches	Number of Organizations
3 - 6	1 state
4 - 24	1 "
5	1 "
6	15 states, District of Columbia, and U. S. E. D.
6 - 8	3 states
6 - 9	1 state
8	13 states
8 - 12	3 "
10	2 "
12	7 " and Navy Dept.
24	1 state

Apparently the most popular thickness is 6 in., with 8 in. running a close second. A summary of the practice in the

TABLE 1. EMBANKMENTS - LAYER THICKNESS, EQUIPMENT AND REQUIRED COMPACTION (1946 SURVEY)

State	Are embankments constructed in layers. What thickness? (Inches)	What method of compaction is used for various soils?	Compaction requirement and measurement.
North-east			
Maine	12 Max.	Smooth or pneumatic rollers	Satisfactory
New Hampshire	8 - 12	Tamping and smooth rollers	Satisfactory
Vermont	12	Tamping rollers	6 trips of roller-minimum
Massachusetts	12	Tamping and smooth rollers	1 roller per 100 cu. yds. per hour
Connecticut	12	Equipment	Satisfactory
Rhode Island	24	Smooth rollers	Satisfactory
New York	6 - 8	Smooth, tamping & pneumatic rollers	90% AASHO-Minimum
Michigan	8 - 12	Tamping and pneumatic rollers	95% AASHO
Wisconsin	8 - 12	Equipment, tamping rollers - special	Special-95% AASHO
Middle-east			
Illinois	6 Max.	Tamping, smooth & pneumatic rollers	6 to 9 trips. Also 90% AASHO
Indiana	6 - 9	Smooth & Tamping rollers & tractors	90%-95% AASHO
Ohio	8	Tamping & smooth rollers	90%-102% AASHO
Pennsylvania	8	Tamping and smooth rollers	Satisfactory
New Jersey	6	Smooth, tamping & pneumatic rollers	4 to 8 passes of rollers
Kentucky	12	Tamping and pneumatic rollers	90%-100% AASHO
Tennessee	6	Tamping rollers	100% AASHO
West Virginia	8	Tamping and smooth rollers	90%-100% AASHO
Virginia	8	All type rollers	95% AASHO
Maryland	8	Tamping & smooth rollers & equip.	90%-100% AASHO
Delaware	6	Tamping rollers	95% AASHO
District of Columbia	6	Smooth & tamping rollers	90%-100% AASHO

TABLE 1 - Continued

State	Are embankments constructed in layers. What thickness? (Inches)	What method of compaction is used for various soils?	Compaction requirement and measurement.
Mountain			
Montana	8	All types of rollers and equipment	90%-100% AASHO
Idaho	8	All types of rollers	90%-100% AASHO
Wyoming	5	Tamping & pneumatic rollers	Satisfactory
Utah	8	Tamping rollers	90%-100% AASHO
Colorado	8	Tamping & smooth rollers	90%-100% AASHO
Nevada	8	Tamping & smooth rollers & equip.	85%-90% AASHO-Mod.
New Mexico	3 - 6	Tamping, smooth, & pneumatic rollers	90%-100% AASHO
Arizona	12	Tamping & pneumatic rollers & equipment	95% AASHO
Pacific			
Washington	4 - 24	Tamping & smooth rollers & equip.	95%-100% AASHO
Oregon	8	Tamping & pneumatic rollers	95% AASHO
California	6 - 8	Tamping & smooth rollers	*90% Cal. Standard Min.
U.S.E.D.	6	Tamping, pneumatic, smooth rollers & crawler type equipment	90% Mod. AASHO
Bureau of Yards and Docks, Navy Department	12	Tamping, smooth, & pneumatic rollers	90%-95% AASHO

*California

Expect to secure the maximum compaction obtainable with a given soil containing a suitable moisture content and the specified amount of rolling.

TABLE 1 - Continued

State	Are embankments constructed in layers. What thickness? (Inches)	What method of compaction is used for various soils?	Compaction requirement and measurement.
South-east			
Mississippi	6	Tamping rollers	Satisfactory
Alabama	8	Tamping, smooth & pneumatic rollers	95% AASHO
North Carolina	6	All types of roller	2 trips per inch loose thickness of layer
South Carolina	6	Equipment, tamping rollers, & jetting	Satisfactory
Georgia	6	Tamping and pneumatic rollers	5 trips of roller minimum
Florida	6	Tamping rollers and tractors	Satisfactory
North-central			
Minnesota	12 Max.	Tamping rollers	6 to 12 trips of roll 95%-100% AASHO
Iowa	6	Tamping rollers	6 to 12 trips of roller
Missouri	6	Tamping rollers	90% AASHO
South Dakota	6	Tamping rollers	Satisfactory
North Dakota	10	Tamping rollers	90% AASHO
Nebraska	6*	Tamping or smooth rollers	90% AASHO
Kansas	6	Tamping & pneumatic rollers	90% AASHO
South-central			
Arkansas	10	Tamping and pneumatic rollers	Satisfactory
Louisiana	8	Tamping rollers and tractors	95% AASHO
Oklahoma	6	Tamping & pneumatic rollers	Satisfactory
Texas	6 - 8	Tamping & pneumatic rollers	90% AASHO

*Nebraska

On secondary roads and with sands, no rolling is required and layers up to 12 in. are permitted. No density requirement specified for this type of work.

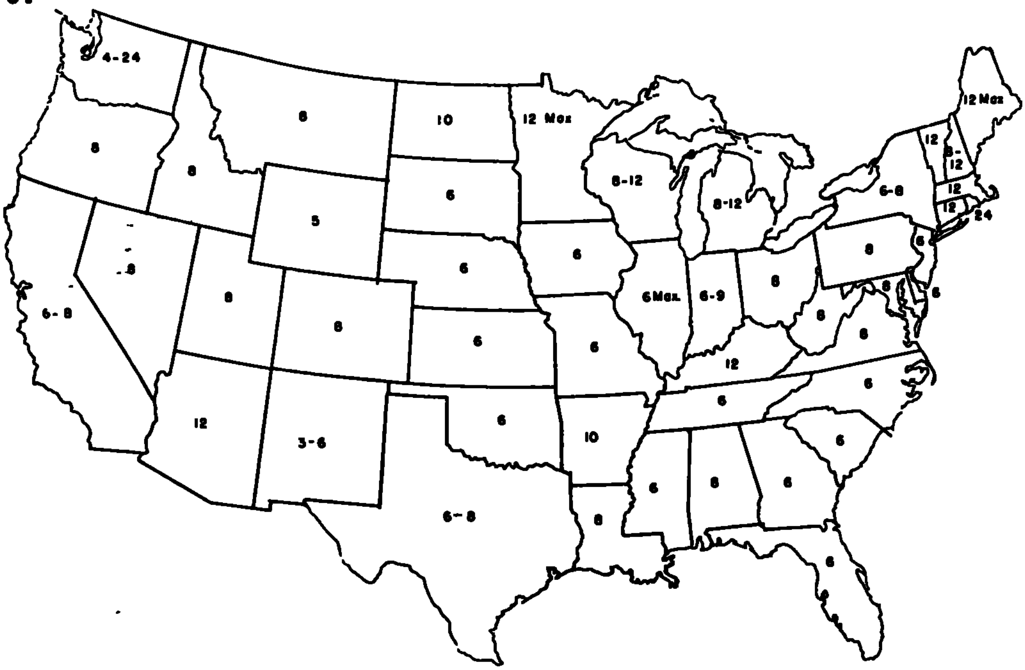

Figure 1
Thickness of Lift - Compaction of Embankments - 1946

various states on the thickness of lift for compaction of embankments is shown in Figure 1.

Compaction requirements vary somewhat, according to the 1946 survey. The most popular requirement seems to be a certain percentage of the compaction obtained by a standard test adopted by the American Association of State Highway Officials under the designation T99-33. The required percentage varies from 90 to 100 percent. Twenty-seven states, the District of Columbia, and the Navy Department specify this requirement. One state specifies this requirement on special work.

Two other compaction tests are used as a measure of compaction; the Modified AASHO and the California Standard. Both tests use higher compactive efforts and secure higher densities at lower moisture contents. One state and the U.S.E.D. use the Modified AASHO as a measure of compaction and specify a requirement of 85 to 90 percent, respectively. The State of California, alone, uses the California Standard test and specifies a minimum requirement of 90 percent of the density produced by it.

Twelve states specify that compaction shall be done to the satisfaction of the engineer. The thickness of layers and rolling are required by their specifications, but the amount of rolling is left up to the engineer in charge of the work.

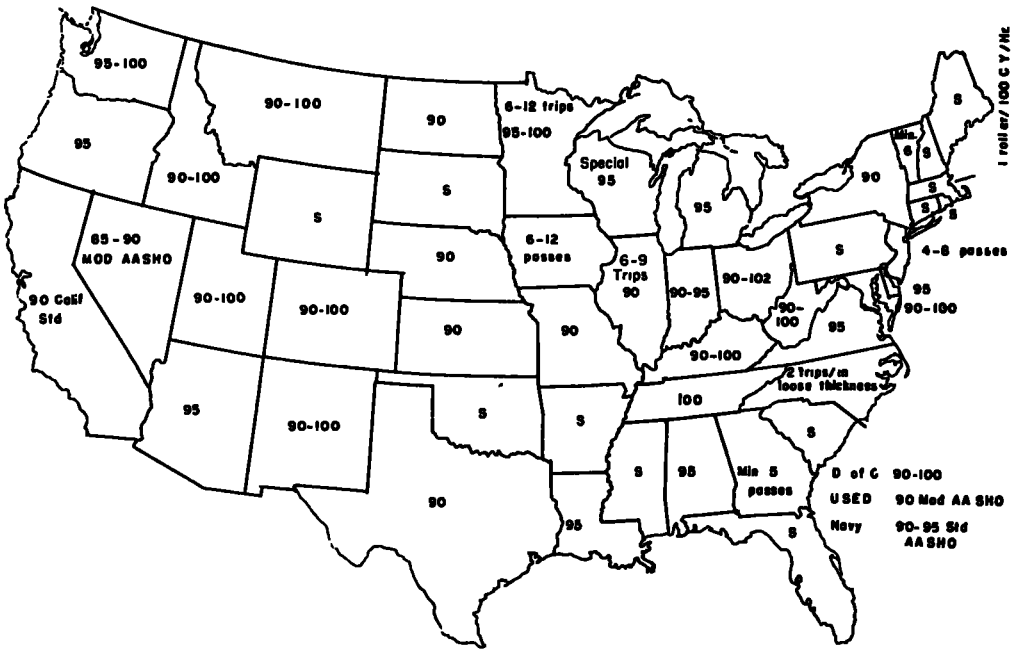

Figure 2

Compaction Requirements - 1946

This is the second most popular requirement as revealed by the 1946 compaction survey.

Five states specify a definite number or a minimum number of trips to be made by the roller over the full width of each layer. One of the five states specifies two trips per inch of loose thickness of layer.

One state requires one roller per 100 cu yd of embankment per hour. The practice of the various states on compaction requirements is summarized graphically in Figure 2.

2. *Moisture Requirement, Cost of Compaction and Water.* Data from Table 2 reveals that compaction at a definite moisture content known as the "optimum" for the soil is specified by 17 states, the District of Columbia, the U.S.E.D., and the Navy Department. Two states use this requirement only on special work..

Compaction is paid for directly by 11 states at a cost of $0.03 to $0.075 per cu yd of embankment. Two states pay for compaction directly on special work at a cost of $0.025 to $0.05 per cu yd of embankment. Other organizations do not pay for compaction directly, as it is included in the unit price for excavation.

Twenty-five states report paying for water used in raising the moisture content of the soil to the "optimum" for

TABLE 2. EMBANKMENTS - MOISTURE REQUIREMENT, COST OF COMPACTION AND WATER (1946 SURVEY)

State	Is specified requirement met?	Is "optimum" moisture for compaction specified?	Is compaction paid for directly? What is the cost?	Is water paid for directly? What is the Cost?
North-east				
Maine	----	No	No	No
New Hampshire	Yes	No	No	No
Vermont	Yes	No	No	No
Massachusetts	Yes	No	No	No
Connecticut	Yes	No	No	No
Rhode Island	Yes	No	No	No
New York	Yes	Yes	No	Special
Michigan	Yes	Yes	No	No
Wisconsin	Yes	----	Special - 5¢ per cu. yd.	No
Middle-east				
Illinois	Yes	Yes	No	Force Acct
Indiana	Yes	Density only	No	No
Ohio	Yes	Yes	No	$3 per M. Gal.
Pennsylvania	Yes	No	No	No
New Jersey	Yes	No	No	No
Kentucky	Yes	Yes	No	$1.50 per M. Gal.
Tennessee	Yes	Yes	No	$3 per M. Gal.
West Virginia	Yes	Density only	No	$5 per M. Gal.
Virginia	Yes	Yes	No	No
Maryland	Yes	No	No	No
Delaware	Yes	Yes	No	No
District of Columbia	Yes	Yes	No	No
South-east				
Mississippi	Yes	Where practicable	No	No
Alabama	Yes	Yes	No	No
North Carolina	Yes	No	No	No
South Carolina	Yes	No	No	No
Georgia	Yes	No	No	No
Florida	Yes	No	No	No

TABLE 2 - Continued

State	Is specified requirement met?	Is "optimum" moisture for compaction specified?	Is compaction paid for directly? What is the cost?	Is water paid for directly? What is the Cost?
North-central				
Minnesota	Generally	No	No	$4 per M. Gal.
Iowa	----	No	No	No
Missouri	Yes	Density only	Yes, Cost 7¢ per cu. yd.	80¢ per M. Gal.
South Dakota	----	No	No	$2.25 per M. Gal.
North Dakota	Yes	Special	No	$2 per M. Gal.
Nebraska	Yes	Special	No	$1 per M. Gal.
Kansas	Yes	Density only	Yes, Cost, 3.9¢ per cu. yd.	24¢ per M. Gal.
South-central				
Arkansas	----	No	Yes, Cost 3¢ per cu. yd.	Yes, M. Gal.
Louisiana	Yes	Yes	No	No
Oklahoma	Yes	Yes	Yes, Roller hours.	$1.90 per M. Gal.
Texas	Yes	Yes	Yes, Cost 3.5¢ per cu. yd.	$1.50 per M. Gal.
Mountain				
Montana	Yes	No	Special. Cost 2.5¢ per cu. yd.	$2 per M. Gal.
Idaho	Yes	Density only	Yes. $4 to $6 per roller-hr.	$1.50 per M. Gal.
Wyoming	Yes	No	Yes. $3.50 per roller-hr.	$2 per M. Gal.
Utah	Yes	Yes	*Yes. 7½¢ per cu. yd.	$1.63 per M. Gal.
Colorado	Yes	----	Yes. $3 per roller-hr.	$1.50 per M. Gal.
Nevada	Yes	Yes	Yes. 4¢ per cu. yd.	3¢ per cu. yd.
New Mexico	Yes	Yes	No	$3 per M. Gal.
Arizona	Yes	Yes	Yes. 5¢ per cu. yd.	$3 per M. Gal.
Pacific				
Washington	Yes	Yes	No	$2.50 per M. Gal.
Oregon	Yes	No	No	$2.75 per M. Gal.
California	Yes	Density only	No	$2 per M. Gal.
U.S.E.D.	Yes	Yes	Optional	in some cases $2 to $3 per M. Gal.
Bureau of Yards and Docks, Navy Department	Yes	Yes	No	No

*Utah

Paid for at unit bid price per roller hour and unit bid price per 1000 gal. of water, which amounts to 7½¢ to 8¢ per cu. yd.

compaction. The cost of this water varies from $0.24 to $5.00 per 1000 gallons, with an average of $2.19. One state pays for water by Force Account. One state pays for water only on special work.

The states which pay for water seem to fall into certain definite groups. All states in the Mountain and Pacific groups pay for water. All except one in the South-central group, and all except one in the North-central group pay for this item. Only five out of 12 in the Middle East group pay for it.

SUBGRADES

1. Requirements and Costs. The compaction survey of 1946 included the compaction of subgrades, separate from embankments. The survey revealed that the requirements for subgrade compaction was the same as for embankments in 30 states (See Table 3). Nine states specify "satisfactory rolling"; four states use a percentage of the compaction produced by the AASHO test; one state used this latter requirement only on special work; California specifies 90 percent of the California Standard as a minimum requirement; one state and the U.S.E.D. specify a certain percentage of the compaction produced by the modified AASHO compaction test; two states and the Navy Department specify extra rolling of the subgrade; and Florida requires a bearing of 30 to 60 lb per sq in.

Twenty-four states make no specific requirement as to the depth the subgrade is to be compacted. Most of them have the same requirements for subgrade as they do for embankments. Several states specify that the subgrade be rolled to the satisfaction of the engineer. Twenty-three states, the U.S.E.D., and the Navy Department specify definite thicknesses for subgrade compaction. One state specifies a definite thickness only on special work, and one state makes a variable requirement. Ten states specify a thickness of 6 in.; four states specify an 8-in. thickness; six states specify a 12-in. thickness; other states and the Navy Department specify thicknesses from 6 in. to 18 in.; and the U.S.E.D. uses a variable thickness requirement, depending upon the soils and type of work.

Only 11 states pay for subgrade compaction; the remaining states and organizations require the cost to be included in the unit price bid for excavation. Payment is made by the square yard by two states, the cost varying from $0.10 to $0.15 per sq yd; by the cubic yard by five states, the cost varying from $0.02 to $0.039 per cu yd, except in one state, which reports a cost of $0.50 per cu yd; by the mile by one state, the cost varying from $400 to $1300 per mile. Two states report paying for subgrade compaction by the day and by the roller-hour, the

cost being $30 to $40 per day and $3.00 per roller-hour.

EMBANKMENT AND SUBGRADES

1. Moisture-Density Procedure, and Personnel and Equipment. The assembled data in Table 4 show that the moisture-density compaction procedure is used by 24 states, the District of Columbia, the U.S.E.D., and the Navy Department. Seven states report using the procedure only on special work, and two states report using it only in the compaction of subgrades. Many states specify only a density requirement.

2. *Miscellaneous Information.* The 1946 survey also includes data on field inspection personnel, field testing equipment, amount of field testing, methods of determining field density and moisture, contemplated changes in specifications, and procedures for drying out wet soils in embankment construction. These data are shown in Tables 5 to 8 inclusive.

It is believed that the 1946 compaction survey shows the trend of the compaction of subgrades and embankments in this country at the present time. More attention is paid to compaction now than in 1941, and it is reasonable to conclude that its importance is being realized by all organizations with the result that in the future, compaction requirements will be more rigid on all work. More attention could be paid to the compaction of subgrades and it is the intention of the committee to stress this fact in the future, by making investigations and reporting the results. Some work along this line is now under way and will be reported next year.

TABLE 3. SUBGRADES - REQUIREMENTS AND COSTS (1946 SURVEY)

State	What is the requirement for subgrade compaction?	What is the depth of this requirement?	What is the cost?
North-east			
Maine	Same as for Emb.	----	----
New Hampshire	Satisfactory rolling	----	----
Vermont	Same as for Emb.	----	----
Massachusetts	Satisfactory rolling	----	----
Connecticut	Satisfactory rolling	----	----
Rhode Island	Same as for Emb.	----	----
New York	95% AASHO	48" in Emb.	----
Michigan	Satisfactory rolling	----	----
Wisconsin	Same as for Emb.	----	----
Middle-east			
Illinois	Special	Variable	Not given
Indiana	Same as for Emb.	6"	No pay item
Ohio	95%-105% AASHO	6"	No pay item
Pennsylvania	Satisfactory rolling	Not specified	No pay item
New Jersey	Same as for Emb.	----	----
Kentucky	Satisfactory rolling	----	No pay item
Tennessee	Satisfactory rolling	----	No pay item
West Virginia	Satisfactory rolling	6"	----
Virginia	Same as for Emb.	8"	No pay item
Maryland	Same as for Emb.	----	No pay item
Delaware	Same as for Emb.	----	No pay item
District of Columbia	Same as for Emb.	----	No pay item
South-east			
Mississippi	Same as for Emb.	----	----
Alabama	100% AASHO	6"	No pay item
North Carolina	Same as for Emb.	----	----
South Carolina	Satisfactory rolling	----	No pay item
Georgia	Same as for Emb.	----	No pay item
Florida	30 to 60 p.s.i. Bearing	12"	10¢ to 15¢ per sq. yd.
North-central			
Minnesota	Extra rolling	12"	No pay item
Iowa	95% AASHO	6"	$400 to $1300 per mile
Missouri	Same as for Emb.	12" & 18"	50¢ per cu. yd.
South Dakota	Same as for Emb.	12"	No pay item
North Dakota	Same as for Emb.	Same as for Emb.	No pay item
Nebraska	Same as for Emb.	6"	No pay item
Kansas	Same as for Emb.	6"	3.9¢ per cu. yd.

TABLE 3 - Continued

State	What is the requirement for subgrade compaction?	What is the depth of this requirement?	What is the cost?
South-central			
Arkansas	Same as for Emb.	8"	No pay item
Louisiana	Same as for Emb.	----	----
Oklahoma	Same as for Emb.	6" to 12"	10¢ per sq. yd.
Texas	Same as for Emb.	6" to 8"	3¢ to 3½¢ per cu. yd.
Mountain			
Montana	Same as for Emb.	8" including cuts	2¢ to 3¢ per cu. yd.
Idaho	Same as for Emb.	8" including cuts	$30 to $45 per day
Wyoming	Same as for Emb.	12" including cuts	No pay item
Utah	*Extra rolling	Not specified	*No pay item
Colorado	Same as for Emb.	12"	$3 per hr. for roller
Nevada	Same as for Emb.	6"	Rolling hr 3¢ per cu. yd.
New Mexico	95% AASHO	6"	No pay item
Arizona	Same as for Emb.	----	----
Pacific			
Washington	Same as for Emb.	12" including cuts	No pay item
Oregon	Same as for Emb.	Not specified	No pay item
California	**90% Cal. Std.	6"	No pay item
U.S.E.D. - Highways	95% Mod. AASHO	6" Minimum	No pay item
U.S.E.D. - Airfields	90%-100% Mod. AASHO	Varies with wheel load & soil types.***	No pay item
Bureau of Yards and Docks, Navy Department	Extra rolling	6" to 18"	No pay item

*Utah - Extra rolling average cost, $3.93 per hr.

**California - 90% California Standard is the minimum requirement. Expect to secure the maximum compaction obtainable with a given soil containing a suitable moisture content and the specification amount of rolling.

***The following is a table of Compaction Requirements for Flexible Pavements. (Airfields)

TABLE A

COMPACTION REQUIREMENTS

Wheel Load	Depth in Inches Below Pavement Surface to Which Indicated % of Mod. AASHO Density Should Extend			
	All Subgrades Except Cohesionless Sands		Cohesionless Sands	
	100%	95%	100%	95%
5,000	-	-	-	12
15,000	-	12	12	24
40,000	12	18	24	36
60,000	18	30	30	48
150,000	30	54	48	78

TABLE 4. EMBANKMENTS AND SUBGRADES - MOISTURE-DENSITY PROCEDURE AND PERSONNEL AND EQUIPMENT (1946 SURVEY)

State	Is Moisture-density procedure used in compaction?	What personnel and equipment are required for inspection when this procedure is used?
North-east		
Maine	No	———
New Hampshire	No	———
Vermont	No	———
Massachusetts	No	———
Connecticut	No	———
Rhode Island	No	———
New York	Yes	2 men, scales, compaction kit, field density apparatus, gasoline stove, etc.
Michigan	Yes	1 man, scales, compaction kit, field density apparatus, oven, etc.
Wisconsin	Special only	———
Middle-east		
Illinois	Yes	1 man with density apparatus, compaction test equipment, scales, oven, etc.
Indiana	Density Control	1 man with density apparatus, scales etc.
Ohio	Yes	1 man with density apparatus, compaction test equipment, penetrometer, scales, oven, etc.
Pennsylvania	No	———
New Jersey	No	———
Kentucky	Special work	2 men with density apparatus, oven, scales, etc.
Tennessee	Yes	1 man with density apparatus, oven, scales, etc.
West Virginia	Yes	1 to 3 men, density apparatus, oven, scales, etc.
Virginia	Yes	1 man with density apparatus, compaction test equipment, oven, scales, etc.
Maryland	Yes	1 man with density apparatus, compaction test equipment, oven, scales, etc.
Delaware	Yes	1 man and helpers with density apparatus, compaction test equipment, oven, scales, etc.
District of Columbia	Yes	1 man with density determination equipment, scales, etc.
South-east		
Mississippi	Yes	Field laboratories
Alabama	Yes	1 man with density apparatus, ovens, scales, etc.
North Carolina	No	———
South Carolina	No	———
Georgia	Special work	1 man and necessary equipment
Florida	No	———
North-central		
Minnesota	Special work	1 man with density determination equipment, compaction test equipment, scales, stove, etc.
Iowa	Subgrades only	1 man, necessary equipment

TABLE 4 - Continued

State	Is Moisture-density procedure used in compaction?	What personnel and equipment are required for inspection when this procedure is used?
Missouri	Yes	1 man with density determination equipment, compaction test equipment, scales, stove, etc.
South Dakota	No	———
North Dakota	Special work	Necessary equipment for compaction test and embankment density determination
Nebraska	Yes	1 man with each outfit equipped with all necessary compaction test and density equipment
Kansas	Special work	All necessary equipment for compaction test and embankment density determination
South-central		
Arkansas	No	———
Louisiana	Yes	1 man and necessary equipment for compaction test and embankment density determination
Oklahoma	Special work	1 man for each outfit equipped with necessary equipment for compaction test and density
Texas	Yes	1 man with equipment necessary for performing compaction and density tests
Mountain		
Montana	Yes	Necessary men and equipment for performing compaction and density tests
Idaho	Density control	1 man with each outfit with necessary equipment for determining dry densities
Wyoming	Yes	1 man with each outfit with compaction and density equipment, penetrometer, stoves, scales, etc.
Utah	Yes	2 men and necessary equipment for compaction test and density determination
Colorado	Yes	2 men and necessary compaction and density test equipment
Nevada	Yes	1 man with small field laboratory for compaction and density tests
New Mexico	Yes. Subgrades only	1 man with compaction and density equipment
Arizona	Yes	1 man with compaction and density equipment
Pacific		
Washington	Yes	1 man with compaction and density equipment
Oregon	Yes	1 man with compaction and density equipment
California	Yes	1 man with compaction and density equipment
U. S. E. D.	Yes	1 man with each outfit with compaction and density equipment
Bureau of Yards and Docks, Navy Department	Yes	2 men with equipment for determining moisture and density tests

TABLE 5. EMBANKMENTS - FIELD TESTS FOR CONTROL (1946 SURVEY)

State	Minimum field tests for embankment compaction control		
	Moisture Tests	Density Tests	Other Tests
North-east			
Maine	———	———	———
New Hampshire	As required	As required	None
Vermont	None	None	———
Massachusetts	None	None	None
Connecticut	None	None	None
Rhode Island	None	None	None
New York	1 every 3 hrs.	1 every 3 hrs.	———
Michigan	4 per day	4 per day	Check tests
Wisconsin	As required	As required	———
Middle-east			
Illinois	Not specified	Not specified	———
Indiana	None	As required	———
Ohio	As required	As required	None
Pennsylvania	None	None	None
New Jersey	None	None	None
Kentucky	As required	As required	———
Tennessee	As required	As required	———
West Virginia	Each lift	Each lift	———
Virginia	4 per day	4 per day	———
Maryland	As required	As required	———
Delaware	As required	As required	None
District of Columbia	As required	As required	———
South-east			
Mississippi	As required	As required	———
Alabama	As required	As required	———
North Carolina	None	None	None
South Carolina	———	———	———
Georgia	As required	As required	None
Florida	Visual	None	None
North-central			
Minnesota	As required	As required	None
Iowa	As required	As required	None
Missouri	As required	As required	As required
South Dakota	None	None	None
North Dakota	4 per day	4 per day	Penetrometer
Nebraska	As required	As required	As required
Kansas	As required	As required	None

TABLE 5 - Continued

State	Minimum field tests for embankment compaction control Moisture Tests	Density Tests	Other Tests
South-central			
Arkansas	None	None	None
Louisiana	1 per 1000 ft.	1 per 1000 ft.	------
Oklahoma	2 per lift per soil	2 per lift per soil	------
Texas	1 for each soil	1 for each soil	Density
Mountain			
Montana	As required	1 per 5000 cu. yd.	None
Idaho	1 per 500 cu. yd.	1 per 500 cu. yd.	None
Wyoming	As required	1 per 2000 cu. yd.	------
Utah	1 per 2000 cu. yd.	1 per 2000 cu. yd.	L.L. & P.I.
Colorado	As required	1 per 2000 cu. yd.	------
Nevada	As required	As required	------
New Mexico	1 per 2000 cu. yd.	1 per 2000 cu. yd.	None
Arizona	As required	As required	None
Pacific			
Washington	As required	As required	------
Oregon	As required	As required	------
California	As required	As required	------
U.S.E.D.	As required	As required	------
Bureau of Yards and Docks, Navy Department	As required	As required	L.L. & P.I.

TABLE 6. EMBANKMENTS AND SUBGRADES - MOISTURE DETERMINATION METHODS (1946 SURVEY)

State	How are moisture determinations made?
North-east	
Maine	None made
New Hampshire	Oven drying
Vermont	———
Massachusetts	None required
Connecticut	None required
Rhode Island	———
New York	Drying in pan over stove
Michigan	Drying in oven in laboratory. Over stove in field.
Wisconsin	Drying in oven
Middle-east	
Illinois	Alcohol method and drying over stove
Indiana	Drying over stove
Ohio	By penetrometer reading on sample compacted in mold and wet weight
Pennsylvania	Not made
New Jersey	Drying over stove
Kentucky	Drying over stove
Tennessee	Drying over stove
West Virginia	Drying over stove
Virginia	Drying over stove
Maryland	Not determined
Delaware	Drying over stove
District of Columbia	Drying over stove
South-east	
Mississippi	Oven drying and drying over stove
Alabama	Drying over stove
North Carolina	Not determined
South Carolina	Drying over stove or in oven
Georgia	Drying over stove
Florida	Not made. Visual inspection used
North-central	
Minnesota	Sample placed in air-tight can and dried in lab. oven
Iowa	Drying over stove
Missouri	Drying over stove
South Dakota	Not determined
North Dakota	Drying in oven
Nebraska	Drying in oven or over stove. Also by penetrometer reading
Kansas	Drying over stove

TABLE 6 - Continued

State	How are moisture determinations made?
South-central	
Arkansas	Not determined. Visual inspection used.
Louisiana	Drying in oven
Oklahoma	Drying in oven
Texas	Drying in oven
Mountain	
Montana	Drying in oven
Idaho	Drying over stove
Wyoming	Drying over stove
Utah	Drying in oven
Colorado	Drying over stove
Nevada	Drying over stove
New Mexico	Drying in oven. Also, alcohol method.
Arizona	Drying over hot-plate or in oven
Pacific	
Washington	Sample placed in air-tight can. Dried in lab. oven.
Oregon	Drying over stove or in oven
California	Drying in oven
U.S.E.D.	Drying over hot-plate or in oven
Bureau of Yards and Docks, Navy Department	Drying in oven

TABLE 7. EMBANKMENTS AND SUBGRADES - DENSITY DETERMINATION METHODS (1946 SURVEY)

State	How are field density determinations made?
North-east	
Maine	None made
New Hampshire	On undisturbed samples - paraffin coated
Vermont	None made
Massachusetts	None required
Connecticut	None made
Rhode Island	None made
New York	Balloon apparatus
Michigan	On undisturbed samples and balloon apparatus
Wisconsin	Sand method
Middle-east	
Illinois	Sand method
Indiana	Sand method
Ohio	Sand method
Pennsylvania	Not made
New Jersey	Not made
Kentucky	Sand method
Tennessee	Balloon method
West Virginia	Sand method
Virginia	Sand method
Maryland	Sand method
Delaware	Sand method
District of Columbia	Sand method
South-east	
Mississippi	Sand method
Alabama	Sand method
North Carolina	Balloon apparatus
South Carolina	Sand method
Georgia	Sand method
Florida	None made
North-central	
Minnesota	Sand method
Iowa	Heavy oil method
Missouri	Sand method
South Dakota	None made
North Dakota	Heavy oil method. Also penetrometer reading
Nebraska	Undisturbed sample, sand, and heavy oil methods
Kansas	Sand method

TABLE 7 - Continued

State	How are field density determinations made?
South-central	
Arkansas	None made
Louisiana	Sand method
Oklahoma	Sand method
Texas	Balloon apparatus
Mountain	
Montana	Heavy oil method
Idaho	Sand method
Wyoming	Sand method
Utah	Sand method
Colorado	Sand method
Nevada	------
New Mexico	Sand method
Arizona	Sand method
Pacific	
Washington	Sand method
Oregon	Heavy oil and sand methods
California	Sand method
U.S.E.D.	Heavy oil, balloon, sand, and undisturbed samples
Bureau of Yards and Docks, Navy Department	Sand method

TABLE 8. EMBANKMENTS AND SUBGRADES - CONTEMPLATED SPECIFICATION CHANGES AND DRYING OUT WET SOILS IN EMBANKMENT CONSTRUCTION (1946 SURVEY)

State	Are changes in specification requirements contemplated?	How are wet soils dried out in embankment construction
North-east		
Maine	No statement	No statement
New Hampshire	Possible	Aeration
Vermont	Yes	Aeration
Massachusetts	No	No procedure specified
Connecticut	Yes, by special provision	No experience
Rhode Island	Yes	———
New York	No	Aeration
Michigan	No	Aeration
Wisconsin	Yes	Aeration
Middle-east		
Illinois	No	Aeration
Indiana	No	Aeration
Ohio	No	Aeration
Pennsylvania	No	Aeration
New Jersey	Yes	Aeration
Kentucky	No	Aeration
Tennessee	No	Aeration
West Virginia	No	No statement
Virginia	No	No definite method
Maryland	Yes	Aeration
Delaware	Yes. Mod. AASHO	Aeration
District of Columbia	No	Aeration
South-east		
Mississippi	Yes, to specify density	No statement
Alabama	Yes. Variable density requirement	Aeration
North Carolina	No	Aeration
South Carolina	No	No statement
Georgia	Yes, to specify density	Aeration
Florida	Possible	Aeration
North-central		
Minnesota	No	Aeration
Iowa	No	Aeration
Missouri	No	Aeration
South Dakota	No	Aeration
North Dakota	No	Aeration
Nebraska	Yes	Aeration
Kansas	No	Mix with dry soil or aeration

TABLE 8 - Continued

State	Are changes in specification requirements contemplated?	How are wet soils dried out in embankment construction
South-central		
Arkansas	Yes, moisture density control	Aeration
Louisiana	No	Aeration
Oklahoma	No	Aeration
Texas	Yes. Increased density requirements	Aeration
Mountain		
Montana	No	Aeration
Idaho	No	Aeration
Wyoming	Yes, heavier rollers	Aeration
Utah	Possible by special provisions	Aeration
Colorado	No	Aeration
Nevada	No	Aeration
New Mexico	No	Aeration
Arizona	No	No problem
Pacific		
Washington	Yes. More rigid compaction control.	Aeration
Oregon	Yes. Bid price for compaction	Aeration
California	No	Aeration
U.S.E.D.	Yes. Variable density requirements.	Aeration
Bureau of Yards and Docks, Navy Department	No	Aeration