Technical Report Documentation Page

1. REPORT No.

2. GOVERNMENT ACCESSION No.

3. RECIPIENT'S CATALOG No.

4. TITLE AND SUBTITLE

Studies of Construction Problems and Methods of Compacting Different Type Soil to Optimum Density

5. REPORT DATE

1949

6. PERFORMING ORGANIZATION

7. AUTHOR(S)

Root, A.W. and W.S. Maxwell

8. PERFORMING ORGANIZATION REPORT No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

California Division of Highways
3435 Serra Way
Sacramento (16), California

10. WORK UNIT No.

11. CONTRACT OR GRANT No.

13. TYPE OF REPORT & PERIOD COVERED

12. SPONSORING AGENCY NAME AND ADDRESS

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Synopsis

The Materials and Research Department of the California Division of Highways, working in close cooperation with the Construction Department, is often called upon to assist in the investigation and solution of consturction compaction problems.

This paper describes brieftly several recent studies of various phases of compaction attainment and control on construction projects, including: proposed changes in compaction procedures on specific projects; failure to achieve the required compaction on certain projects, and determination of the necessary corrective measures; observation and evaluation of new types of compactors. A brief description and analysis of each of these studies is presented.

The conclusions reached are applicable only to the specific project in question and the data obtained must be correlated with more comprehensive long time studies now in progress before any general conclusions can be drawn.

The expanded post-war construction programs of various agencies have apparently stimulated the design and production of new compacting equipment. Several new units now in use on California highway projects are discussed, and limited data are presented to indicate their efficiency in comparison with conventional equipment.

17. KEYWORDS

18. No. OF PAGES:

25

19. DRI WEBSITE LINK

http://www.dot.ca.gov/hq/research/researchreports/1930-1955/49-05.pdf

20. FILE NAME

49-05.pdf

STUDIES OF CONSTRUCTION PROBLEMS AND METHODS OF COMPACTING DIFFERENT TYPE SOILS TO OPTIMUM DENSITY

By

A. W. Root
Senior Physical Testing Engineer

and

W. S. Maxwell
Assistant Highway Engineer

California Division of Highways
3435 Serra Way
Sacramento (16), California

This is an advance copy of a paper to be presented at the First Pacific Area National Meeting of the American Society for Testing Materials (1916 Race Street, Philadelphia 3, Pennsylvania) to be held in San Francisco, California, October 10 to 14, 1949. This advance copy is issued primarily to stimulate discussion. Discussion is invited and may be transmitted to the Executive Secretary. The paper is subject to modification and is not to be republished as a whole or in part pending its release by the Society through the Executive Secretary.

 49-05

Synopsis

The Materials and Research Department of the California Division of Highways, working in close cooperation with the Construction Department, is often called upon to assist in the investigation and solution of construction compaction problems.

This paper describes briefly several recent studies of various phases of compaction attainment and control on construction projects, including: proposed changes in compaction procedures on specific projects; failure to achieve the required compaction on certain projects, and determination of the necessary corrective measures; observation and evaluation of new types of compactors. A brief description and analysis of each of these studies is presented.

The conclusions reached are applicable only to the specific project in question and the data obtained must be correlated with more comprehensive long time studies now in progress before any general conclusions can be drawn.

The expanded post-war construction programs of various agencies have apparently stimulated the design and production of new compacting equipment. Several new units now in use on California highway projects are discussed, and limited data are presented to indicate their efficiency in comparison with conventional equipment.

STUDIES OF CONSTRUCTION PROBLEMS AND METHODS OF COMPACTING DIFFERENT TYPES OF SOIL TO OPTIMUM DENSITY

By

A. W. Root*
W. S. Maxwell*

Introduction

The necessity for thorough compaction of earth dams, embankments and base courses is widely recognized and the usual construction compacting methods and control testing procedures are generally known.

Many informative and comprehensive articles have been written on the subject of compaction; however, most of these articles have pertained to laboratory investigations or to field studies conducted in conjunction with prearranged test sections involving accurate control of materials, moisture content and compactive effort.

This paper deals with a different, but perhaps equally important, phase of compaction operations; namely, the day-to-day problems which have been encountered on construction projects, and the methods used to solve such problems where neither time nor facilities were available for elaborate, carefully controlled test sections.

Usually these problems fall in one of the following four categories:

(a) A contractor elects to adopt a compaction procedure other than that specified, and desires approval of the proposed change.

(b) The specified compaction is not being obtained, and it is desired to ascertain the reason for the substandard compaction

*Senior Physical Testing Engineer, California Division of Highways
*Assistant Highway Engineer, California Division of Highways

and to determine the proper corrective measures.

(c) The contractor wishes to use compaction equipment other than the approved types designated in the Standard Specifications, and it is desired to determine the effectiveness of the new equipment.

(d) Miscellaneous studies involving special or unusual compaction requirements or controls.

The material for this paper has been derived largely from field reports and illustrates the experience acquired through a number of years, during which time the importance of compacting soils to their optimum density has been stressed persistently. An attempt has been made to select reports of typical studies conducted during the past year by the Materials and Research Department of the California Division of Highways and to present at least one example of each of the above four types of problems.

To assist in the evaluation of data to be presented, the specification compaction requirements and control testing procedure of the California Division of Highways will first be briefly discussed.

California Standard Specifications stipulate that the relative compaction shall be 90% or more, and also designate the minimum amount of compacting equipment and the maximum thickness of layers. The purpose of specifying methods as well as end results is to assure that all soils are compacted to the maximum extent practicable rather than merely meeting the 90% relative compaction requirement; using the specified methods and equipment many granular materials are readily compacted to 95% or 100% relative compaction.

The term "relative compaction" is defined as the ratio of the density of material in place to that of the same material compacted in accordance with a specified test procedure, both densities being based on dry weights. The sand volume apparatus (Figure 1) designed and adopted as standard equipment by the California Division of Highways in 1941 is used in measuring the volume of the test hole in the determination of in-place density. For determination of "optimum moisture" and "maximum density" the California Impact Method apparatus and test procedures developed by the Materials and Research Department in 1929 is used in lieu of the Proctor, AASHO or modified AASHO tests used by many agencies. This test procedure is described in "Compaction of Earth Embankments," T. E. Stanton, Proceedings-Highway Research Board-1938; the test apparatus is illustrated in Figure 2. Densities obtained with the California method are generally higher than those obtained with the AASHO Method T-99-38.

Control testing is carried on continuously by field personnel under supervision of the resident engineer. With the exception of projects within close proximity of the ten District laboratories each construction project has a field laboratory, usually adjacent to the resident engineer's field office. The completeness of this project laboratory and the number of personnel assigned to the testing operations are determined by the size of the project and volume of testing work involved. The attached photograph (Figure 3) illustrates a field laboratory currently in use in District X.

****

Returning to the discussion of compaction problems, the first to be considered is a proposed change of procedure.

The design of a freeway near Sacramento required the placing of 16" of imported borrow over a clay subgrade to serve as the base for Portland Cement Concrete pavement. The imported material, consisting of clean, cohesionless sand from a nearby borrow pit was being spread by bulldozers and blades to the specified 4" thickness loose layers after which it was compacted by wobble-wheel type pneumatic-tired rollers.

The sand as excavated was very wet so that when first spread and rolled it was stable and shaped up well. As the moisture evaporated from the surface, the sand shifted and displaced under the contruction haul traffic until the area became simply a mass of loose sand that hampered the operation of equipment. Obviously, it was useless to continue placing and compacting the material in 4" layers which could not be maintained under the haul traffic without the continued application of water and possible subsequent damage to the clay subgrade.

To remedy this condition it was proposed to place the full 16" thickness in one layer thereby eliminating the haul traffic required by the 4" layer procedure.

To determine the effect of this proposed change of procedure on the relative compaction, a test section 40' wide and 1200' long was set up with sufficient sand spread to provide the full 16" compacted thickness layer. Following a period of rolling with small pneumatic-tired rollers, five compaction tests were performed at various locations in the area. All tests showed relative compaction in excess of the 95% specified for this particular project. Furthermore, the average in-place dry density on the test section was 112 lbs/c.f. compared with an average of 110 lbs./c.f. for the material previously placed in 4" layers.

As a result of this compaction study, a contract change order was approved for placing the imported borrow in one 16" layer, thereby expediting the construction and improving the quality of the work. It should be pointed out, however, that had the imported borrow material been other than clean sand such a change would not have been necessary or desirable.

Next are four examples of projects on which compaction studies were made because the specified relative compaction was not being attained.

1. On a recent project in Santa Barbara County, difficulty was experienced in obtaining the specified 90% relative compaction in embankments, and at several locations it was necessary to remove and recompact portions of embankments which were not properly compacted. As the contractor contended that due to the character of the soil it was impossible to

achieve the specified compaction with conventional equipment, the Materials and Research Department was called on to investigate.

The 5.5 mile project involved the compaction of 16 embankments ranging from 1' to 17' in height, and one embankment with a maximum height of 28'. The embankment material was obtained from a number of cuts, with considerable variation in the character of soil encountered in the different cuts, and within individual cuts. Sands, loams and clays were all present.

At the commencement of the grading work the compacting equipment consisted of several units of 40" diameter drum size sheepsfoot tampers, which units were later replaced by sheepsfoot tampers of 54" and 60" diameter. In addition to these tampers a wobble-wheel pneumatic-tired roller and a three-wheel roller were in use.

The compaction study on this project included an analysis of some 123 compaction tests performed by the resident engineer's inspectors; observation of compacting operations in progress at two locations; a check on the number of yards placed per unit of compacting equipment, and testing of the compaction being obtained under the observed conditions.

Study of the job records revealed that, almost without exception, where areas of low compaction were removed and recompacted the required 90% relative compaction had been attained. Furthermore, these areas of low compaction were scattered throughout the project and not confined to a specific fill location or type of soil. In several instances the original field moisture was above optimum.

During the course of the field study embankments were under construction at two locations. At one of these locations a volume of 230 c.y. per hour of brown sandy clay was being compacted by a sheepsfoot roller and pneumatic-tired wobble-wheel roller. The moisture content was 16% compared with an optimum of 13% and the relative compaction attained was 90%.

At the second location the movement of equipment was restricted by the shape and size of the embankment being constructed. Compacting units consisting of a sheepsfoot roller and a three-wheel roller were obtaining the specified 90% relative compaction on a black sandy loam with a field moisture content of 13% which was also the optimum for this material.

The fact that practically all of the originally low compaction areas were recompacted to meet specification requirements indicated the soil could be satisfactorily compacted with conventional methods and reasonable effort. The low compactions occurred during the time the small light weight sheepsfoot rollers were being used. Also, as already mentioned, the moisture content of the material was in several instances considerably above optimum. The removal and recompaction of these areas with the heavier rollers provided both aeration to reduce the moisture content and increased compactive effort as compared with the original conditions.

It was concluded that specified compaction could be attained with sufficiently heavy rollers, reasonable effort and proper moisture control; therefore, no changes in specifications or methods of payment to the contractor were warranted. The contractor cooperated in careful control of the compaction operations on the remainder of the project and no further difficulties were experienced.

2. In some instances in localities where water is costly and it is believed the natural moisture content of the soil material will permit satisfactory embankment compaction without additional water, a watering item is not included in the contract.

A project of this nature involving construction of embankments up to 75' in height is now under construction in the southern section of the State. The major portion of the material being encountered in roadway excavation is of a granular nature, mostly decomposed granite, with a natural moisture content range of 6 to 15%. The usual 90% relative compaction is required and no special compaction procedure is stipulated other than the maximum loose spread layer thickness shall be 4" instead of the 8" commonly specified for embankment construction.

During the early stages of the grading, difficulty was encountered in attaining the specified compaction, and it was the belief of the contractor that the lack of water was in many instances responsible for the failure to meet specification requirements. Both sheepsfoot and pneumatic-tired rollers were in use.

An analysis of the results of 54 routine control tests showed the relative compaction ranged from a low of 82% to a high of 96% and that there was apparently no correlation between moisture contents and attained degree of compaction. Furthermore, in 85% of the reported tests the natural moisture content of the material was within 3%± of the control test optimum moisture. Tests indicated the material was not extremely critical to water content; therefore, it was concluded that insufficient and non-uniform compactive effort was probably the principal reason for the unsatisfactory compaction.

To verify this conclusion a test section was constructed in conjunction with the routine grading operations in progress on a large embankment. Decomposed granite roadway excavation material with a moisture content of approximately 8% as compared to the optimum moisture content of 11% was placed in 4" loose spread layers and compacted by a single-axle two-wheeled pneumatic-tired compactor with approximately 50,000 pounds total load on the axle and a tire inflation pressure of 90 psi. Tire tracks indicated the compactor covered a total linear width of approximately 3' per pass; therefore, it was considered that 15 passes per layer over the test lane width of 22' would be equivalent to 2 passes over any given spot. Accordingly, each layer was subjected to 15 passes of the compactor. Relative compactions of 92% and 93% resulting from this procedure indicated that even with a moisture content 3% below optimum the specified compaction could be obtained with pneumatic-tired rolling. It is interesting to note that following the above outlined field study no further difficulty has been encountered on this project and satisfactory compaction is being consistently obtained.

3. A laboratory study was requested on another project where the specified relative compaction was not being attained--a recent contract for the construction of a four-lane divided highway in Solano County. On this project the cement treated subgrade consisted of volcanic tuff to which was added and mixed on the roadbed 2.5% to 4.1% by weight, of Portland cement.

The special provisions of the contract stipulated that the cement treated material be compacted to a density of not less than 95% of that determined as the maximum compaction for the material when tested in accordance with Laboratory methods; the laboratory method for compaction of cement treated soil is a 2000 psi. static compression procedure and not the impact method used for compaction control of untreated soils. Fourteen compaction tests performed by field personnel showed that in every instance the relative compaction was less than the required 95%.

To ascertain the degree of compaction attainable on this job with varying amounts of compactive effort, a test section was laid out for compaction with controlled rolling; in other respects the construction of the test section was identical with the routine procedure being used throughout the project. After completion of the processing and spreading operation, three portions of the test section were compacted by 15, 25 and 35 passes respectively, of the 12-ton 3-wheel roller used for compaction of the cement treated subgrade on the project. Following is a tabulation of these test data:

Section	Roller Passes	Test Hole	In Place % Moist.	In Place Density	*% Relative Compaction
"A"	15	1	27	72	84
		2	27	73	85
"B"	25	3	29	72	84
		4	30	72	84
"C"	35	5	36	65	76
		6	34	66	77

*Relative Compaction based on 86 lbs/c.f. density attained in 2000 psi. static test at optimum moisture content of 19%.

The moisture content of the imported borrow material as delivered on the road was above optimum; previous compaction tests indicated, however, that even at optimum moisture this material could not be compacted to the specified density with the equipment in use, and air drying of the material on the grade would have necessitated delaying the construction until weather was warmer and fog was less prevalent.

It was concluded from the results of this study that compaction of this particular type of material to the usual density specified for cement treated soils was not practicable. The purpose of the cement treatment of subgrade under Portland cement concrete pavement is to prevent erosion and pumping; the tuff used on this project has good stability, and by increasing the cement content the desired hardness and resistance to erosion can be obtained at densities obtainable with construction equipment.

It is interesting to note that at the end of this project an adjoining project under a different contract was in progress to extend this four-lane highway. The material being used on this second project was a stream bed sand and gravel entirely different in all characteristics from the volcanic tuff just discussed. With a minimum of equipment and compactive effort, relative compaction well above 95% was readily obtained in contrast to the difficulty encountered on the preceding project; therefore, at the point of junction between the projects conditions changed completely within a distance of only inches.

4. Volcanic tuff has been used in several instances in the past, but would not be classified as a commonly used material in California. Therefore, it is somewhat coincidental that at the same time the compaction difficulty was being encountered on the above discussed project, similar difficulty was reported from another project using tuff for cement treated subgrade. With the exception of minor differences in construction procedure and physical characteristics of the tuff material, conditions were identical on the two projects.

Here again, test sections were compacted by 15, 25 and 35 passes of a 12-ton 3-wheel roller. It is interesting to note the similarity of the percent relative compaction attained on the two projects with the different amounts of compactive effort, as evidenced by the following combined tabulation of test results of both projects.

Roller Passes	% Relative Compaction Project "A"	Project "B"
15	84 85	84 84
25	84 84	84 85
35	76 77	79 81

Also, on both projects the 25 roller passes failed to increase the compaction above that attained by 15 passes and 35 roller passes resulted in a lower density. It should be noted the number of passes in all instances refers to passes distributed over a 12' wide lane and not over a specific spot within the lane.

These instances, in which the specified degree of compaction was not obtained, are definitely the exception and not the rule. Experience has proved that 90% relative compaction, based on the California Impact Method Test, is attainable with reasonable compactive effort and moisture control.

****

The Materials and Research Department, in collaboration with the Construction Department, has investigated several new types of compacting equipment, some of which show considerable promise.

On a project in the City of Los Angeles the Contractor desired to investigate the possibilities of a new type of equipment for compaction of sewer trench backfill.

The tamper proposed for use was a pneumatic device similar to the machine used for breaking pavement, but equipped with a 14" x 24" flat-faced tamping foot in lieu of the concrete breaking tools. It was the opinion of the manufacturer this tamper could satisfactorily compact deep trench backfills in one layer directly from the ground surface level, thereby eliminating the necessity for compacting a number of thin layers.

Trenches 2.5' wide and 12' deep excavated for installation of sewer pipe were to be backfilled with imported sandstone material in the lower 5' followed by native soil, consisting of clayey silt and sand, in the remaining seven feet. The specifications required that all backfill be compacted to not less than 90% relative compaction based on the standard impact method test.

The bottom 2.5' of sandstone was compacted by flooding. The remaining 2.5' of sandstone and the 7' of native soil were pushed into the trench by a blade and left in a loose condition for compaction by the tamper.

Sixty lineal feet of backfill was compacted in a period of 33 minutes by tamping the surface. The design of the tamper limited the depth of tamping foot action to approximately 12" below the original ground surface; therefore, as the backfill was compacted, it was necessary to blade in additional material to return the level of the backfill to within reach of the tamper.

The following tabulation, of results of compaction tests at several depths below ground surface, indicates that satisfactory compaction had been obtained only in the top 2' of the backfill and that the tamper did not produce the specified relative compaction in lower portions of the backfill.

Depth	Material	In Place % Moist.	In Place Dry Lbs/c.f.	Impact Test % Moist.	Impact Test Dry Lbs/c.f.	% Relative Compaction
0'-2'	Native Cly. Silt and sand	12.1	118.6	12.6	121.4	98
2'-4'	"	12.6	106.4	13.0	121.4	88
4'-6'	"	12.0	83.6	12.3	122.0	68
6'-7'	"	11.4	82.0	12.8	120.4	68
7'-8'	Imported Sandstone	8.6	84.8	13.4	117.6	72

No determination was made of the effectiveness of this tamper in compacting areas other than trench backfill. Because the machine in use on this project was so constructed that the tamper foot would reach only about one foot below the surface of the ground on which the truck was supported, the full depth of trench backfill had to be compacted in one lift. Accordingly, no tests were made to determine the thickness of lift which could be satisfactorily compacted by this tamper.

This study indicated that for the depth of trench and type of soil prevailing on this project the tamping machine in question did not obtain the required degree of compaction. Further tests would be necessary to determine its effectiveness under other conditions.

During the past year several compacting rollers new to California have made their appearance on construction projects.

On each of these, limited observations and tests have been performed in an attempt to determine their effectiveness. In all instances data available at this time are too meager to permit conclusions of general validity; therefore, in the following discussion, the various units will be identified by code letter rather than by manufacturer's trade name. All the following described units are of the towed type and not self-propelled.

Unit "A" illustrated in Figure 4 is a pneumatic-tired roller consisting of a front group of 8 wheels and a rear group of 9 wheels with the wheels mounted in pairs on short axles in a suspension that permitted the wheels to follow surface irregularities and still exert their compactive effort. The gross weight of roller and ballast at the time of the test was 15,000 lbs. carried on a total of 91 linear inches of tire width for a weight per linear inch of 165 lbs. Tire size was 6:50 x 16 and inflation pressure 40 psi.

For purposes of comparison this roller was operated alongside a conventional 3-wheel 12-ton roller in the compaction of a crushed rock and sand material being placed in 4" loose spread layers. The pneumatic roller attained 99% relative compaction as compared to 104% for the three-wheeled type.

Unit "B" illustrated in Figure 5, is a four-wheel pneumatic-tired roller with the wheels mounted dual on either end of a single axle. The gross weight of 30,000 lbs. was carried on a total linear tire width of 48" for a weight per linear inch of

625 lbs. Tire size was 12:00 x 20 and inflation pressure 90 psi. A unique feature of this compactor is a mechanism incorporated into the unit which transmits through the wheels vibration of sufficient intensity to vibrate a considerable volume of the embankment being constructed. This roller is currently in use compacting a decomposed granite material on a project in Southern California and is attaining relative compactions of 90% to 96%. A series of tests were performed for purposes of comparison of this unit with Unit "C".

Unit "C" illustrated in Figure 6 is a drum type roller somewhat similar in design to the conventional sheepsfoot roller except that the drum consists of solid end plates of 7/8" thickness steel plate and a cylindrical shell formed by a square mesh gridwork of 1-1/2" diameter steel bars with 3-1/2" square openings between adjacent bars. There are, of course, no tamping studs affixed to the drum as in the case of a sheepsfoot roller.

As used on the test section, the total weight of this roller plus ballast was computed to be approximately 22,000 pounds; since the total effective rolling width of the unit was considered to be 69", the weight per linear inch of width was about 319 lbs. This unit is currently in use on the same project as is Roller "B" and apparently is attaining a slightly higher degree of compaction in routine operations than is roller "B".

In conjunction with routine grading operations on the project, test lanes were constructed with 5" loose spread layers of decomposed granite compacted by 4 passes per layer with the vibrating, pneumatic tired roller "B" and 4 and 8 passes of the square mesh roller "C". The pneumatic-tired unit with 4 passes produced approximately the same degree of compaction as did the steel mesh unit with 8 passes, both of which were satisfactory.

Unit "D" illustrated in Figure 7 was a 100-Ton capacity pneumatic-tired unit similar in construction to an earthmoving scraper with two wheels in front, three in the rear and a body between for loading with ballast. Arrangement of the wheels provided an effective rolling width of 9'. As loaded at the time of observation, the gross weight was approximately 50 tons and the inflation pressure of the 24:00 x 32 tires was 45 psi.

In order to compare this unit with a 60" diameter drum size sheepsfoot roller having an approximate weight of 300 psi on the tamping feet, test sections were constructed with 6" layers of a silty sand material and compacted by 5, 10 and 15 passes respectively with each roller. Relative compaction attained on each section is shown in the following tabulation:

	% Relative Compaction	
Roller Passes	Unit D (Pneumatic)	Sheepsfoot Roller
5	89	87
10	97	92
15	97	90

During the rolling operations the soil behaved like sand with the sheepsfoot failing to "walk-out" even after 15 passes so it was not surprising that the pneumatic roller surpassed the sheepsfoot tamper under these conditions.

The fourth category of miscellaneous studies involving special compaction controls or requirements includes a variety of compaction problems; no one project could be considered typical and the following example was selected to illustrate one of the ramifications of compaction control.

A multimillion dollar State building was being constructed on reinforced concrete footings over a somewhat compressible, rather weak, silty formation. While excavating for footings during the construction of the building, a large abandoned cesspool was discovered in a location where it would be crossed by one of the footing walls. To prevent differential settlement between the backfill area and the adjacent natural ground it was necessary that the backfilled area have the same compressibility as the undisturbed ground, and it was requested that this department assist in the selection and compaction of the backfill material.

Compaction tests were made in the undisturbed ground adjacent to the cesspool, and undisturbed cores were taken for consolidation tests. Samples of similar soil being excavated from adjacent footings were also tested and it was found that this soil would have to be compacted to somewhat greater than the in-place density in order to reproduce the compressibility of the undisturbed natural soil. Unconfined compressive strength and direct shear tests indicated that at the higher density the remolded soil would have about the same shear strength as the undisturbed soil. Based on these soil tests the material for backfilling the cesspool was selected from adjacent footing excavation and compacted with pneumatic tampers to the predetermined density. Frequent compaction tests made to control the density of the backfill showed that the variation in density of the backfilled material was no greater than the variations occurring in the adjacent undisturbed soil.

Although there can be no conclusive proof of the success of the backfill operation until long-time observations have been made of the completed structures, no serious difficulty is anticipated.

*****

Summary and Conclusions:

It was the intent of this paper to portray some of the practical aspects of compaction work, particularly its application to highway construction, rather than to present any new developments in theory or testing procedure. The large number of improved compactors, both new designs and heavier versions of conventional types, which have become available commercially during the postwar period, is evidence that encouraging progress is being made toward the attainment of the high soil densities which theory and laboratory tests have proved desirable. The fact that any one type of compaction equipment is not likely to be equally effective for all types of soil presents another difficulty, especially on California highway construction, where a number of radically different soil types are frequently encountered on one project.

Recognizing the superiority of heavier compacting equipment, California in 1945 increased the minimum weight requirements for tamping rollers to 250 psi. on the tamping feet. The 40" diameter drum sheepsfoot tampers, which have been generally used in the past, are rapidly being replaced by heavier models; contractors and equipment men are evincing increasing interest in pneumatic-tired rollers, both the conventional type and some extremely heavy new units. Several compactors of new and radically different design have recently appeared on the market and advance information from manufacturers representatives indicate that additional new models are on the way.

The increased efficiency of improved compacting equipment should effect more thorough compaction without increase in construction costs, and may ulimately result in revisions of present standards of compaction. Mutual cooperation of engineers, contractors and equipment companies is essential for continued progress along this line; diligence and sound judgment on the part of the resident engineers and inspectors will continue to be important ingredients in the process of accomplishing thorough compaction.

FIELD LABORATORY and TESTING EQUIPMENT

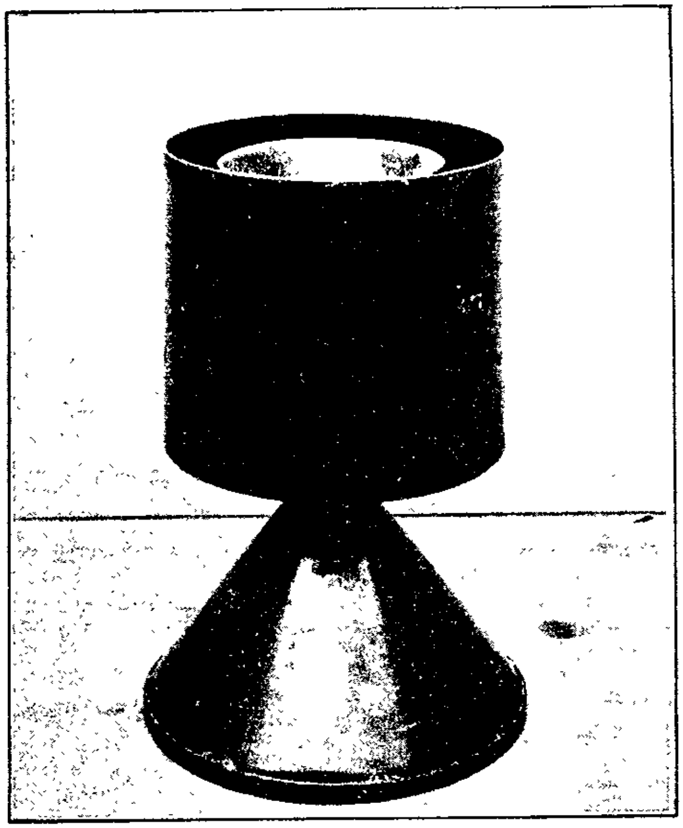

Fig 1 — California
Sand Volume Aparatus.

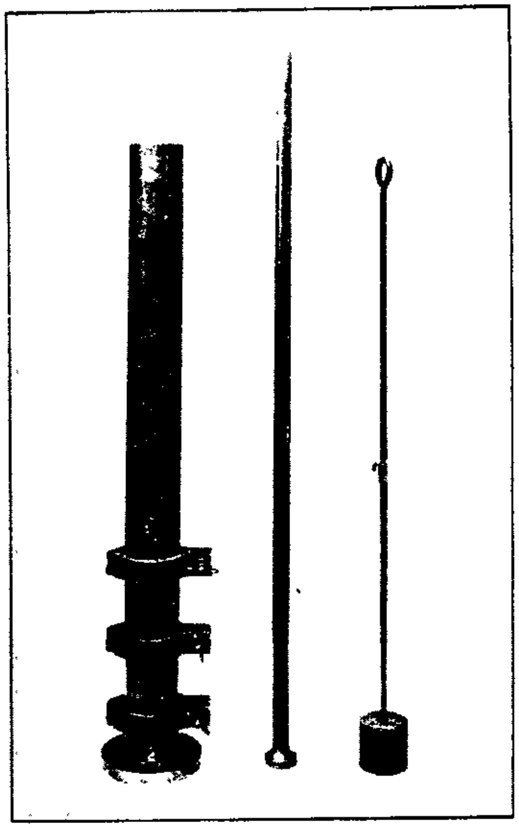

Fig 2 — California Impact
Compaction Test Aparatus.

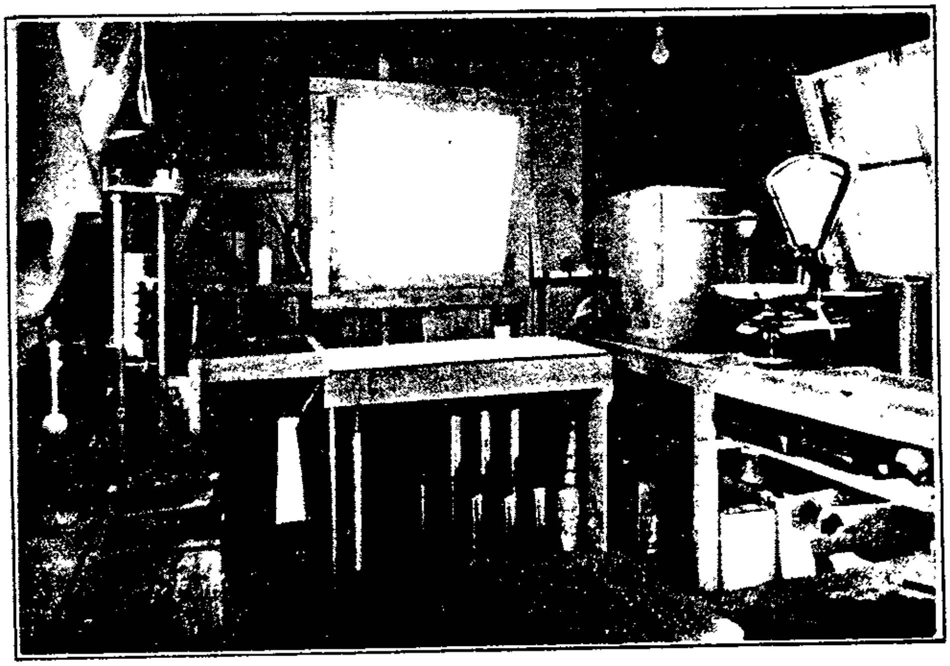

Fig 3 — Field Laboratory District X.

COMPACTING EQUIPMENT

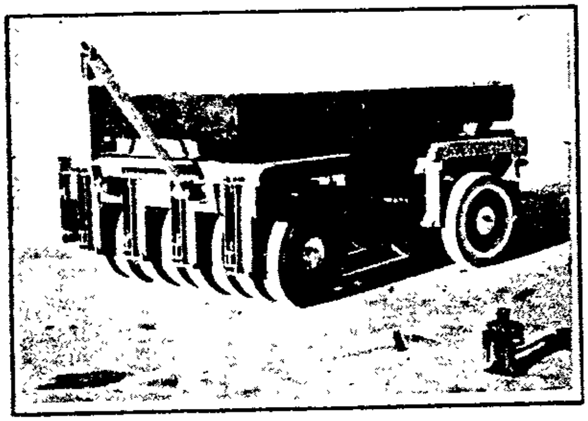

Fig 4-Unit A.

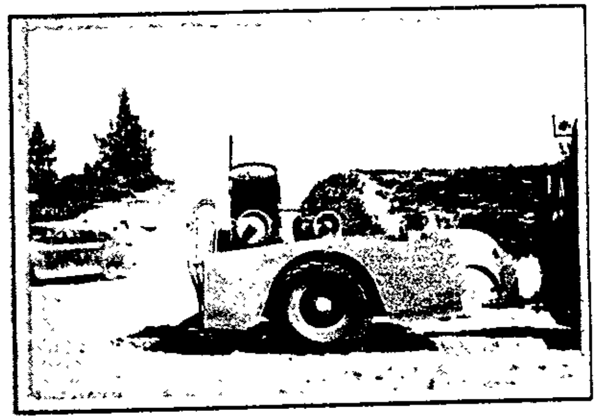

Fig 5-Unit B.

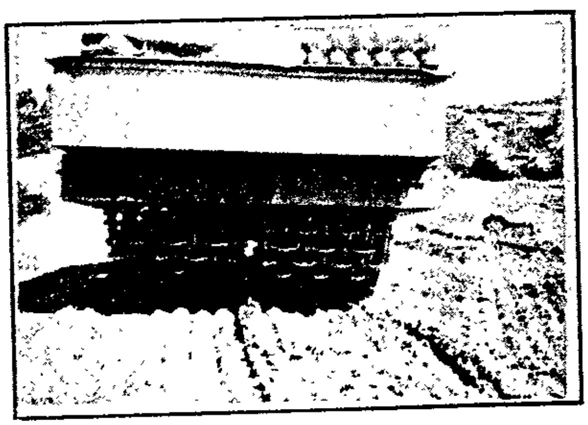

Fig 6-Unit C.

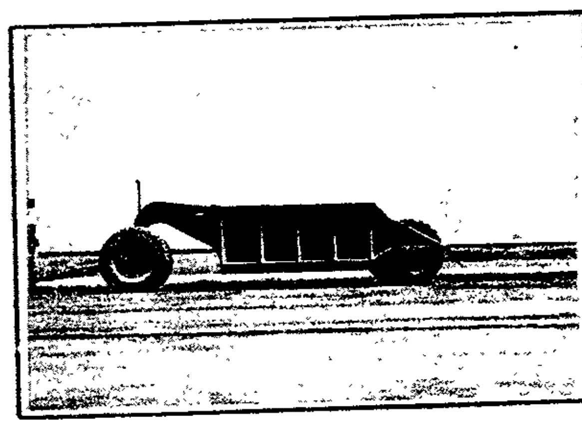

Fig 7-Unit D.