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Charles M. Ziegler  
State Highway Commissioner

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GRADATION AND CONSOLIDATION  
OF  
FORCUS BACKFILL

Roy Greenman  
Assistant Engineer of Soils

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## GRADATION AND CONSOLIDATION OF POROUS BACKFILL

Roy Greenman  
Assistant Engineer of Soils  
Michigan State Highway Department

In 1945 the Michigan State Highway Department in cooperation with the Michigan State College Experiment Station started an investigation concerning the design and construction of pavement foundations. It was realized that pavement design analysis was greatly hindered because of insufficient factual data regarding the behavior of different types of foundations under varying field conditions.

The investigation was divided into four major divisions including:

1. The evaluation of foundation conditions under existing pavements.
2. Investigation of consolidation methods.
3. Subbase construction and its relation to pavement design.
4. Determination of subgrade bearing value.

This report describes briefly the scope of work done so far on the problem of gradation and consolidation of porous backfill in relation to highway structures as performed under part two of the foundation investigation.

Granular material when used as a porous backfill will shrink unless properly compacted, causing subsequent deformation of the pavement surface adjacent to structures. Shrinkage of the backfill may be due to loss of material by filtration, consolidation of the porous backfill material, or a combination of both factors. It has been definitely established that any type of granular material, when placed loose, will undergo a rearrangement of particles when subjected to traffic vibrations. The rearrangement of the particles will

result in settlement varying in amount depending on the material and the amount of porous backfill in place.

Porous backfill must, first of all, function as a filter. To do this it must be so graded that (1) adjacent soil will not infiltrate into the porous backfill, (2) the fines in the porous backfill will not be displaced by water movement (3) the porous backfill will be permeable. Second, the porous backfill must be of such texture that it can be placed under almost any weather condition. It is also desirable to have a material that requires a minimum amount of work to consolidate it to such density that no detrimental settlement will occur.

In the first phase of the investigation tests were performed for the purpose of determining the range of grading permissible for the backfill to function as a filter. The second part was concerned with the determination of the most suitable density requirement for different backfill materials and how best to obtain this density. A study was also made to determine the effect on consolidation of varying the moisture content.

#### GRADATION STUDIES

For the purpose of studying the value of the backfill as a filter, gradation studies were made on several different materials including dune sand, natural sand, bank run gravel, pea gravel, coarse aggregate, slag and combinations of these materials. The backfill was placed in a model trench constructed with one glass side to facilitate observations. A sand "blanket" was placed on top of the porous backfill and water introduced into the top of the trench. During the test a careful record was kept of the amount of sand passing through the filter and collected at the outlet. A visual inspection of the amount of sand filtering into the porous backfill and

filling up the voids also was made. In either case the sand passing through the backfill will tend to obstruct the flow in the drainage structure.

The gradation studies were adapted from similar work conducted by the U. S. Corps of Engineers at the Waterways Experiment Station located at Vicksburg, Mississippi. The only variation was that the Michigan studies were made to find a backfill material which would be adaptable to all Michigan soils thereby eliminating the necessity for making special studies to determine the necessary gradation of backfill material for each individual soil.

From the gradation studies it was found that the following gradation limits were most desirable for backfill material from the standpoint of permeability and stability:

Grade B Backfill

<u>Passing</u>	<u>Percent</u>
2" screen	100
1" screen	70 - 100
1/2" screen	45 - 100
4 sieve	20 - 70
10 sieve	10 - 50
40 sieve	5 - 30
Loss by washing	0 - 5

In most cases Michigan's bank run gravels will meet these grading requirements.

CONSOLIDATION

The consolidation study has been made for the purpose of determining the most efficient method of consolidating porous backfill and to answer the following questions:

1. What degree of compactive effort is required to prevent detrimental settlement of porous backfill materials?
2. What effect does water have on compaction by vibration?
3. What densities would be required when using various materials for structural backfills?
4. What is the best method of obtaining the proper degree of compaction?
5. What special treatment would be required for different materials?

For the purpose of studying these problems, a model abutment was first constructed with a backfill capacity of approximately sixteen cubic feet. The materials investigated were of the same type as those employed in the gradation studies. Studies were made with the model in the following manner:

1. The material was placed in the model in a loose condition and weighed.
2. Material was placed in the model in 4 inch layers and each layer was vibrated with a bullet-nosed concrete vibrator.
3. The model was completely filled and the entire volume vibrated.
4. The material was vibrated continuously during the filling operation.
5. The same materials were consolidated by hand tamping in 4 inch layers.

Moisture contents and densities were recorded on all tests. Following completion of the backfill in each case, the model was flooded for 20 minutes and after a reasonable length of time sufficient to permit drainage of free water, the moisture content was determined to check the permeability of the backfill.

The results from the consolidation studies showed conclusively that the bullet-nose vibrator was faster and gave greater densities than did hand tamping. Also it was observed that variations in moisture content had little or no effect on the consolidation of the materials. Use of consolidation methods resulted in shrinkage values ranging from 20 to 30 percent for the various materials. Density increases amounted to approximately 14 percent for dune sand and coarse aggregate and as much as 37 percent for bank run gravel and natural sand. The studies indicated quite definitely that vibration was the most efficient method for the consolidation of porous back-fill materials.

The next step in the investigation was to determine what type of vibratory equipment was the most suitable for this work. For this purpose the investigation was moved into the field where a timber bin was constructed of 3 inch planking 16 feet long, 10 feet wide and 6 feet deep. The larger bin or model was constructed in order that heavier and larger types of vibrators could be used. Bank run gravel only was used in these studies. The gravel met Class B gradation requirements.

Several types of vibrating equipment were investigated, including the bullet-nosed vibrator, and the three most effective units will be described briefly. One of the three vibrators, suitable primarily for small areas and in those areas where the vibrator must be handled manually, was called a "Platform Vibrator". The Platform Vibrator was made by mounting a vibrator unit on a section of 3-inch plank. The power was provided by a 110 volt, 3 phase, 60 cycle, A.C. squirrel-cage induction motor operating at 3600 r.p.m. The machine has an impact rating of 1 H.P. See Figure 1. A similar machine mechanically operated which was also found effective, is shown in Figure 2.

Another type found effective, particularly for small areas, was a Jackson Backfill Tapper operated by a 110 volt, 3 phase, 60 cycle A.C. motor with a striking member forged integrally with the rotor shaft. The striking member delivers a blow to a tappet which in turn works on a tamping bar to which a 10-inch conical tamping disc had been attached. See Figure 3.

The most effective compaction by vibratory means was obtained by a Jackson PT-21A Vibrator Motor, mounted crosswise at the center of two 8-foot lengths of 2-3/8 inch tubing. A piece of 2-1/2 inch by 2-1/2 inch by 1/8 inch angle iron was welded to the front tube. When run at approximately 4,000 v.p.m. and pulled down a sloping face of the material at a rate of about 13 feet per minute this machine was very effective on relatively large quantities of material. See Figures 4 and 5. This machine is not adaptable to small projects because it requires power equipment to move the machine up and down the face of the backfill. The vibratory equipment was furnished by the Electric Tamping and Vibrator Company of Ludington, Michigan, who cooperated with the Highway Department in these studies.

At the beginning of the consolidation studies a Goldbeck pressure cell was installed at the bottom, middle and top of the backfill next to the wall to determine what increase in lateral pressure might occur due to different consolidation methods. Although the results were not conclusive, there was an indication that the lateral pressure increased very slightly for the six foot depth of fill employed in these studies.

Vibratory compaction resulted in an increase in density of approximately 8 percent and shrinkage values around 10 percent. These values are considerably lower than those attained in the small model tests and subsequent field studies. It is believed that this was due to the fact that the backfill

material may have received partial consolidation when it was dropped into the bin from the power shovel.

As a result of the above tests, it has been conclusively demonstrated that some type of consolidation is necessary when granular materials are used as backfill for structures. The method of obtaining the desired density economically is still somewhat of a problem. From all observations made it is believed that some type of compaction combining tamping and vibration will be the most effective.

#### FIELD PRACTICE

The foregoing studies were made on model fills of various sizes. For the purpose of studying consolidation methods under actual field conditions the porous backfill for three bridges was required to be consolidated to a certain density. The backfill material used on the three projects consisted of bank run gravel meeting Class B gradation requirements as mentioned in the preceding text. The maximum density of the porous backfill material was determined in the laboratory by vibrometer tests. The density required on the job was specified at not less than 90 percent of the maximum density determined by the vibrometer tests.

The Contractors for these three bridge projects elected to use jack hammers equipped with tamping plates and a D4 caterpillar tractor for consolidating the fill. The backfill material was placed in 6 to 8 inch layers and compacted with the jack hammers in the areas inaccessible to the tractor. Densities were determined by means of the Bainhart density apparatus. The results from the tamper and tractor method of consolidation were satisfactory. No difficulty was encountered in obtaining densities in excess of the 90



percent required and in many cases density values were equal to or in excess of those obtained by the laboratory vibrometer tests. Shrinkage values were around 25 percent and density increases of 13 percent were obtained. It is believed, however, that some vibratory type of equipment can be adapted to this work which will be less expensive than the tamper and tractor method.

Further experiments of this nature are being carried on. A field project consisting of consolidating backfill in a metal crib 200 feet long, 10 feet wide and 20 feet deep will be the next project on which vibratory equipment will be used.

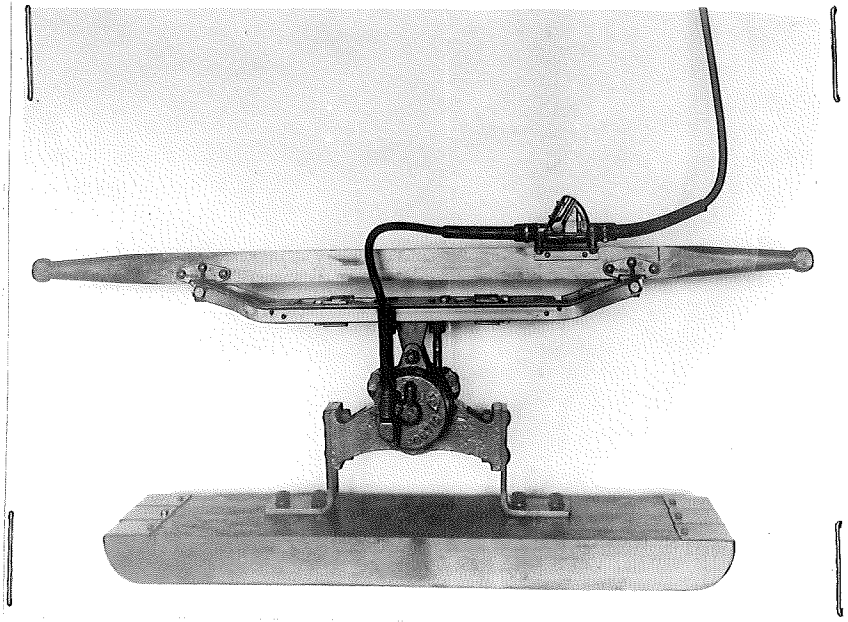


Figure 1. Hand operated platform vibrator

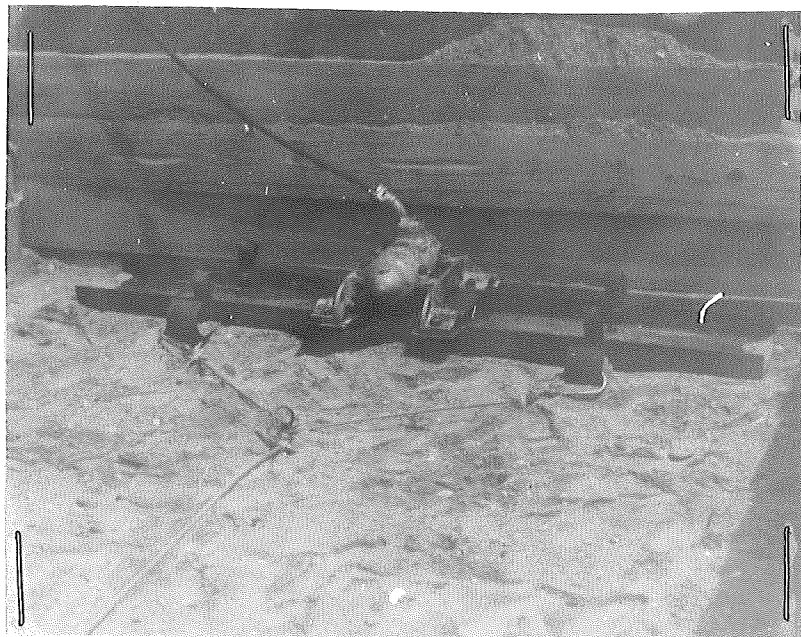


Figure 2. Mechanically operated platform vibrator

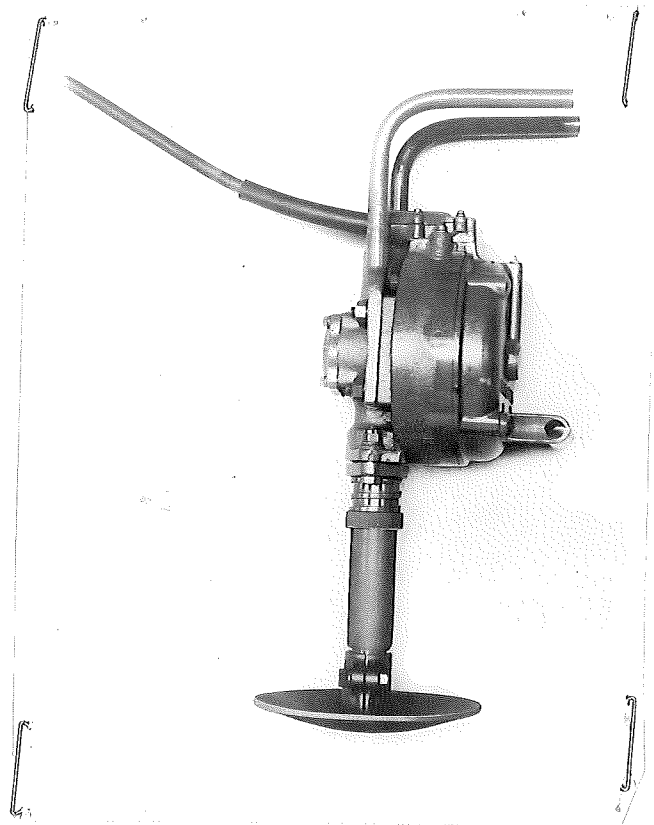


Figure 3. Jackson backfill tamper



Figure 4. Vibratory Tubes actuated by Jackson PT-21A Vibrator Motor.

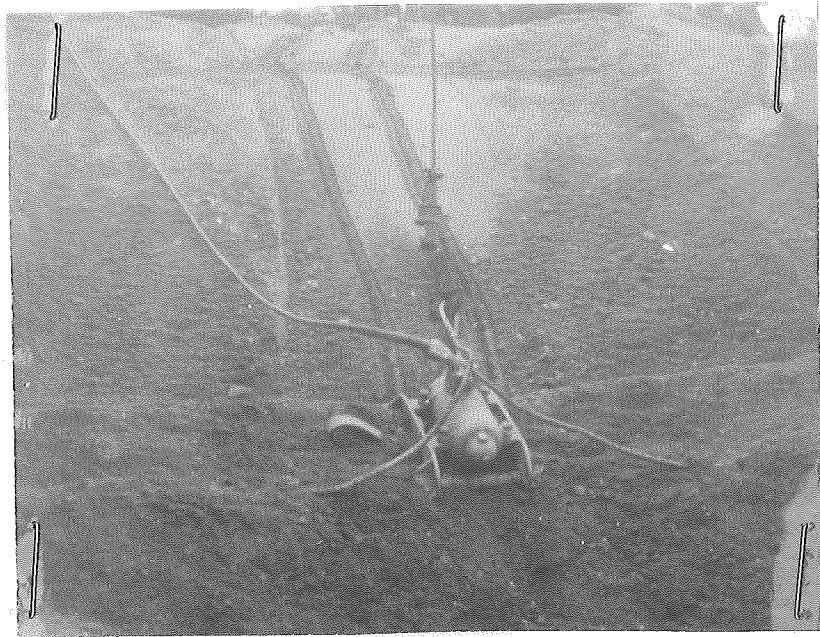


Figure 5. Vibrator Tube in operation.