Effects of Tamping and Pavement Breaking on Round Conduit

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(Manuscript received July 20, 1959)

Underground conduits may be subjected to low-frequency dynamic loads caused primarily by the operation of mechanical tamping and pavement-breaking machines. These external loads will produce circumferential bending moments in the conduit wall. The magnitude of the bending moments has been determined by measurement of the circumferential fibre strains in thin-walled metal tubes subjected to the external dynamic forces transmitted through various soil media. Finally, the bending moments are expressed in terms of the the equivalent crushing strength.

I. INTRODUCTION

An extensive investigation to establish the minimum strength requirements for round conduit, based upon the effect of static loads has been reported by one of the authors.[1] It was shown that the minimum required strength depends on the magnitude of the load applied at the surface of the fill, the properties of the backfill material, the height of the backfill over the conduit, the trench width and the bedding condition.

The increasing use of heavy-duty power-activated equipment for tamping backfill in trenches and for breaking pavement has made it necessary to expand this investigation in order to determine the effect of dynamic forces on underground conduit and pipes. This study is intended to show the conditions under which tamping or pavement-breaking equipment may be used without damaging underground conduit that has the minimum strength required to withstand static loads.

External loads acting upon the conduit produce circumferential bending moments in the conduit wall. The magnitude and distribution of these bending moments caused by the operation of tamping and pavement breaking machinery have been determined in tests conducted recently at the Outside Plant Development Laboratory, Chester, New

Jersey, and in Chicago, Illinois. These tests were made with gravel, sand and sandy clay as backfill and with various heights of cover over the conduit. Different energies were applied for both tamping and pavement breaking under conditions simulating as nearly as possible those encountered in the field.

II. TEST APPARATUS AND PROCEDURE

A test method, which was previously developed for the determination of the circumferential bending moments in thin-walled conduits under static loads,[1] was modified for the recording of dynamic loads.

The test device consisted of a thin-walled steel tube one foot in length having an outside diameter of 4 inches and a wall thickness of 0.062 inch. Four SR-4 strain gages (type A-5) were attached, at intervals of 90 degrees, to the inside periphery of the tube at points equidistant from the tube ends. Fig. 1 shows the steel tube with the attached strain gages. The tube ends were sealed with sponge rubber discs to prevent the entry of dirt and moisture. Each strain gage served as the variable arm of a bridge circuit that was connected to an oscillograph (Minneapolis Honeywell Visicorder). This recorder provided a continuous photographic record of the strain readings.

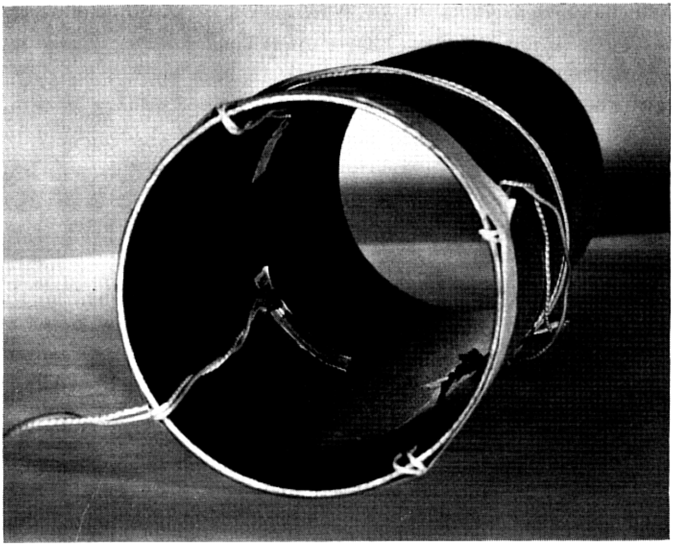

Fig. 1 — Thin-walled tube with SR-4 strain gages.

A Hydrahammer, manufactured by the Ottawa Steel Division of the L. A. Young Spring and Wire Corporation, Ottawa, Kansas, was used to provide the impact loads at the surface above the conduit. The Hydrahammer consists essentially of a weight that is dropped from different heights and is capable of applying energies up to 7500 foot-pounds. Two different weights have been used during this investigation: (a) approximately 1000 pounds using the tamper and (b) approximately 900 pounds using the demolition head.

Fig. 2 shows the three test conditions considered during this investigation.

2.1 *Tamping*

The measuring tube was positioned lengthwise at the bottom of a 24-inch-wide trench between two pieces of plastic conduit, as shown in Fig. 3. It was oriented so that one of the strain gages was at the top of the tube. The backfill material was then placed in the trench to the desired height of cover. Care was taken to insure that no stones were present at the bottom of the trench or in the fill close to the measuring tube. The tests were conducted with 18, 24, 30, 36 and 42 inches of cover, using gravel, sand and sandy clay as backfill materials. The mechanical tamper was positioned so that the tamping head struck the surface of the fill directly over the tube. For consistency in the test it was necessary to restore the fill at the striking point to its original height after each blow.

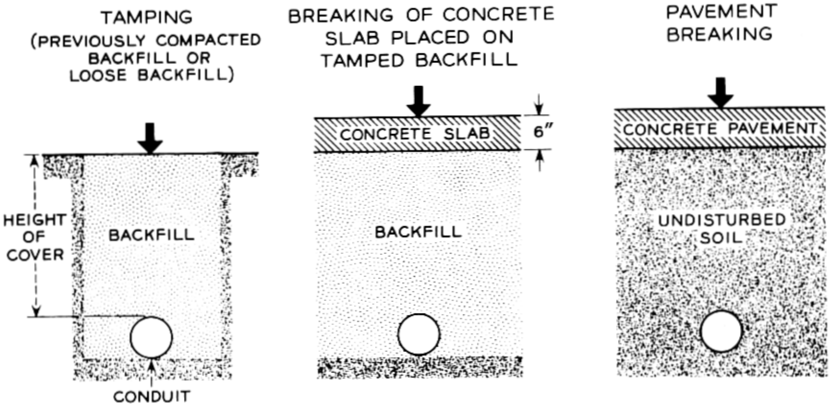

Fig. 2 — Test conditions.

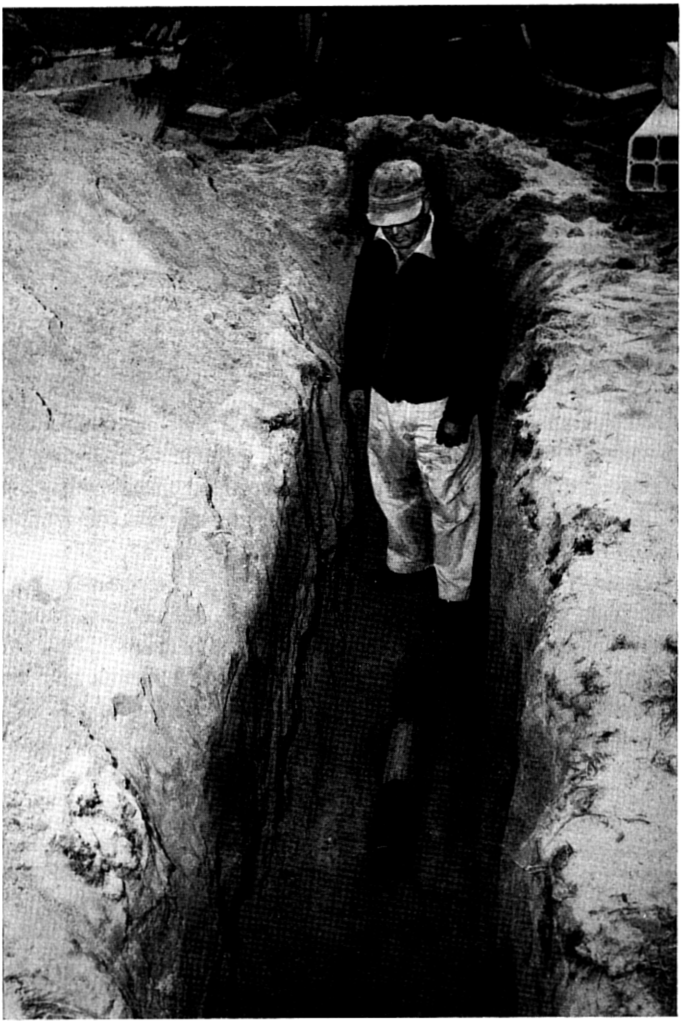

Fig. 3 — Measuring device positioned in trench.

Two procedures were used to apply the impact loads:

i. The energy produced by the Hydrahammer was increased from 1125 to a maximum of 6750 foot-pounds in increments of 1125 foot-pounds. A number of blows were applied at each energy level until the readings did not change significantly.

ii. The maximum energy of 6750 foot-pounds was delivered directly to the loose backfill and repeated until the measurements remained constant.

2.2 *Breaking of Concrete Slab Placed on Tamped Backfill*

To simulate the effect of pavement breaking on round underground conduit, reinforced concrete slabs, three feet square and six inches thick, cast from a 1:2:3 mix and air-cured for 28 days prior to the tests were used. The measuring tube was placed at the bottom of a three-foot-deep pit and covered to a height of 12 or 24 inches with gravel or sandy clay. The fill was lightly compacted and the reinforced concrete slab was positioned so that its center was directly over the measuring tube. Figs. 4 and 5 show the Hydrahammer equipped with the demolition head breaking the concrete slab. An energy of 6750 foot-pounds was used for this part of the investigation.

2.3 *Pavement Breaking*

Actual pavement-breaking tests were conducted at two locations in Chicago, Illinois. Horizontal holes slightly smaller than the outside di-

Fig. 4 — Hydrahammer with demolition head breaking reinforced concrete slab.

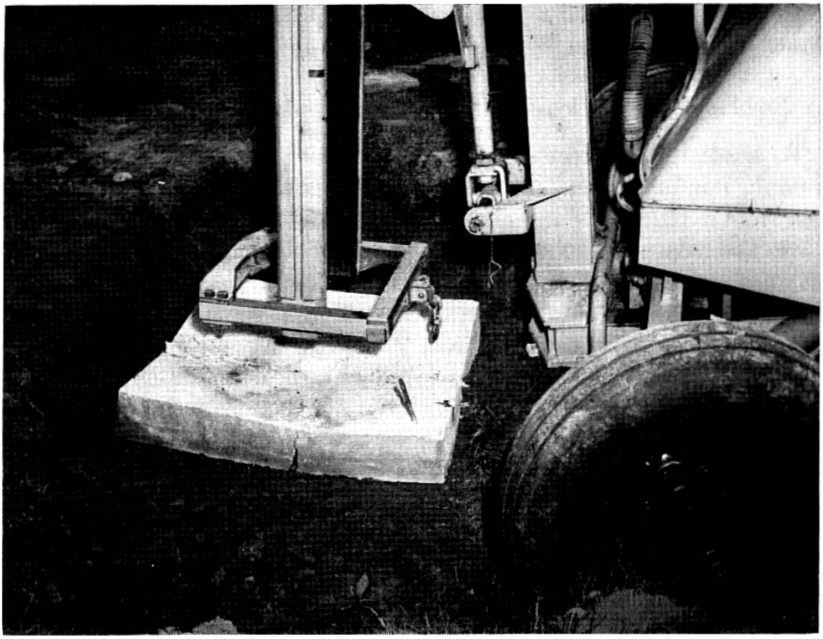

Fig. 5 — Reinforced concrete slab after one blow of 6750 foot-pounds.

ameter of the measuring tube were drilled beneath existing concrete roadways from pits dug beside the road. A hydraulic jack was used to press the measuring tube into the hole for a distance of four feet. A steel tube was inserted in advance of the measuring tube and a piece of four-inch conduit was used to fill the remaining length of the hole. The pit was then backfilled and tamped. Three tests were made, the height of cover consisting of: (a) 3 inches of sandy clay, 21 inches of a mixture of ashes and cinders and 7 inches of concrete; (b) 3 inches of sandy clay, 21 inches of a mixture of ashes and cinders, 5 inches of concrete and 2 inches of asphalt; and (c) 12 inches of crushed stone and 8 inches of concrete. The tamper applied an energy of 6750 foot-pounds directly over the center of the measuring tube. Measurements were taken until the pavement above the conduit was completely broken up.

Table I summarizes the test conditions.

III. TEST RESULTS

The circumferential bending moments in the walls of the test tubes were determined and recorded by means of the test apparatus and procedure described in Section II.[1] A typical example of such a recording is shown in Fig. 6. The duration of the signal caused by the impact is about 0.1 second, and the bending moment at the bottom of the conduit is about double that at the top or at the sides of the conduit. This relation, however, was not observed in all tests; it was more frequent in clay or wet sand than in gravel. The same phenomenon had been observed during an investigation of the effect of static loads on round conduits,[1] when it was concluded that the bedding condition was responsible. The same considerations apply for this investigation. Due to a change in bedding, the moment at the bottom may vary up to 235 per cent, while the moments at the side points change only a maximum of 12 per cent. To compensate for wide variations in the test results attributable to bedding, the maximum bending moment at the bottom of the tube was considered to be double the average of the values measured at the side points.

During mechanical tamping, the maximum bending moment at a given depth increased with the number of blows until it attained a limiting value. This value was generally obtained with the third blow of the tamper. For pavement breaking, the maximum bending moment was obtained immediately after the concrete pavement cracked.

In the remaining sections of this paper, the maximum bending moment

TABLE I — LIST OF TESTS AND TEST CONDITIONS

Test Condition	Type and Height of Cover and Thickness of Pavement	Applied Energy (ft-lbs)
Tamping of previously compacted backfill	24, 30, 36, 42 inches gravel	1125, 2250, 3375, 4500, 5625, 6750
	18, 24, 30, 36 inches sand	1125, 2250, 3375, 4500, 5625, 6200
	18, 24, 30, 36 inches sandy clay	1125, 2250, 3375, 4500, 5625, 6750
Tamping of loose backfill	24, 30, 36, 42 inches gravel	6750
	18, 24, 30, 36 inches sand	6750
	18, 24, 30, 36 inches sandy clay	6750
Breaking of concrete slabs placed on tamped backfill	12 or 24 inches gravel, 6 inches concrete	6750
	18 or 24 inches sandy clay, 6 inches concrete	6750
Pavement breaking	3 inches clay, 21 inches ashes and cinder, 7 inches concrete	6750
	3 inches clay, 21 inches ashes and cinder, 5 inches concrete, 2 inches asphalt	6750
	12 inches crushed stone, 8 inches concrete	6750

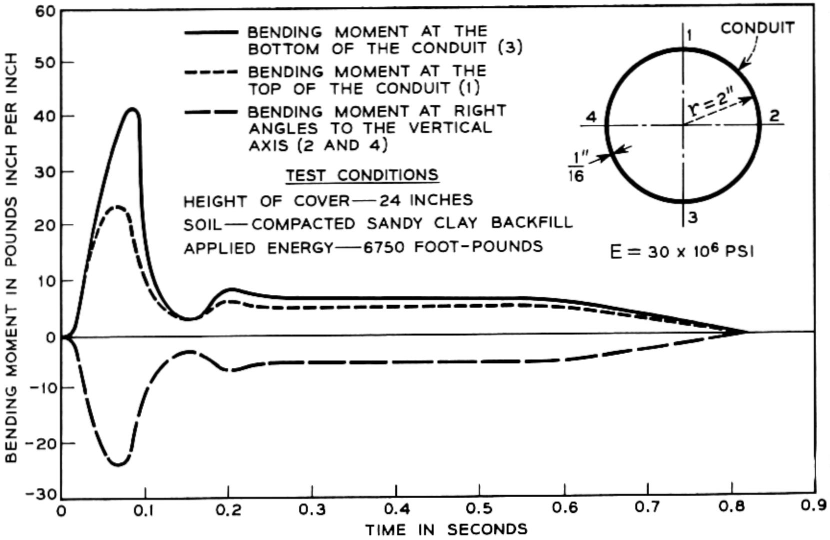

Fig. 6 — Bending moments in round conduit caused by operation of heavy tamping equipment.

will be expressed in terms of the "equivalent two-point load." The equivalent two-point load is the two-point (two-edge bearing) load that, in a compression test on a test tube held between two rigid flat plates, will cause the same maximum bending moment in the tube wall as the maximum bending moment obtained from field measurements such as shown in Fig. 6. The choice of this expression as a measure of the bending moment has been discussed.[1]

3.1 *Tamping*

Figs. 7 and 8 show the equivalent two-point loads for four-inch-diameter round conduit covered with gravel and sandy clay, respectively. In each figure the abscissa represents the energy applied by the tamper and the ordinate the equivalent two-point load, with a logarithmic scale having been used for both coordinates. The data were obtained by tamping the initially loose fill over the conduit, the energy applied by the Hydrahammer being increased from 1125 foot-pounds in steps of 1125 foot-pounds to a maximum of 6750-foot-pounds. A linear relationship between the logarithm of the applied energy and the logarithm of the equivalent two-point load could be observed. For each case, this relationship was derived from the data, using the method of least squares.

The plotted lines were extended beyond 6750 foot-pounds to obtain equivalent two-point load values for energies up to 20,000 foot-pounds.

If a blow were delivered by the tamping equipment upon loose sandy clay or wet sand backfill, the equivalent two-point load values obtained were rather inconsistent: these values were up to three times higher than those obtained when the tamping energy was increased by increments to its maximum. This phenomenon was not observed with gravel or dry sand as backfill.

3.2 *Breaking of Reinforced Concrete Slab Placed on Tamped Backfill*

The equivalent two-point loads obtained when breaking reinforced concrete slabs placed on previously compacted backfill are shown in Table II. The values of Table II should be compared with the results

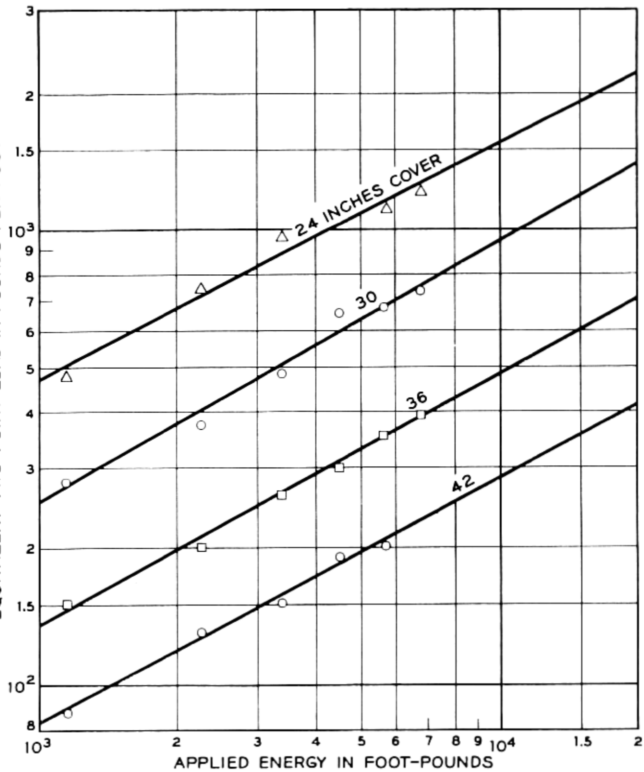

Fig. 7 — Equivalent two-point load vs. applied energy for gravel cover.

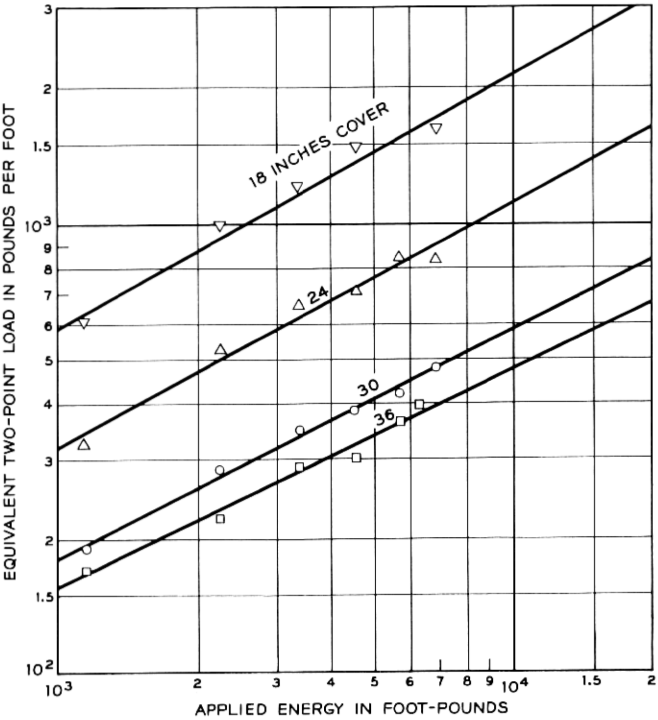

Fig. 8 — Equivalent two-point load vs. applied energy for sandy clay cover.

shown in Figs. 7 and 8, which were obtained by tamping backfill previously compacted at the same energy level. The height of cover is considered to be the distance between the bottom surface of the concrete and the top of the conduit. For the same height of cover and applied energy, the results obtained when breaking the concrete slab are slightly smaller than the values obtained by tamping, since the broken concrete provides some additional protection to the conduit. However, this additional protection is comparatively small and variable, dependent upon the thickness of the concrete, and will be neglected. Energies insufficient to break the slab will produce relatively small forces acting on the conduit.

3.3 *Pavement Breaking*

The equivalent two-point loads obtained by pavement breaking are also shown in Table II. A comparison of the equivalent two-point load values obtained by tamping (Figs. 7 and 8) with those obtained by pave-

TABLE II — EQUIVALENT TWO-POINT LOAD OBTAINED BY BREAKING CONCRETE SLABS AND PAVEMENTS

Test Condition	Type and Height of Cover and Thickness of Pavement	Applied Energy (ft-lbs)	Equivalent Two-Point Load (lbs/ft)
Breaking of concrete slabs placed on tamped backfill	12 inches gravel, 6 inches concrete	6750	2200
	24 inches gravel, 6 inches concrete	6750	720
	18 inches sandy clay, 6 inches concrete	6750	1300
	24 inches sandy clay, 6 inches concrete	6750	560
Pavement breaking	3 inches clay, 21 inches ashes and cinder, 7 inches concrete	6750	600
	3 inches clay, 21 inches ashes and cinder, 5 inches concrete, 2 inches asphalt	6750	600
	12 inches crushed stone, 8 inches concrete	6750	2000

ment breaking shows the same relationship as that obtained for the breaking of the reinforced concrete slab. For the same height of cover and applied energy, the equivalent two-point loads obtained by pavement breaking are slightly smaller than those obtained by tamping.* As in the case of breaking the slabs, this difference will be neglected.

IV. DISCUSSION OF TEST RESULTS

The test results show that tamping well-compacted fill produces about the same loads acting on the conduit walls as are obtained by pavement breaking, provided the heights of cover, the types of cover and the applied energies are the same.

Figs. 7 and 8 show the effects of the applied energy, the height of cover and the type of cover on the equivalent two-point loads. Results obtained with sand cover were not as consistent as were the values for gravel and sandy clay. This may have been due to a change in moisture content: because of weather conditions, the sand used as backfill material varied from dry to rather wet.

The strength requirements for round underground structures, previously determined on the basis of static loading conditions,[1] showed the highest strength to be required when wet clay was used as backfill material. Fig. 9 shows the required equivalent two-point load as a function of the height of cover for static loads, with the different curves represent-

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* The values listed in Table II are maximum values obtained after the pavement failed. Prior to this failure, the measurements were very small.

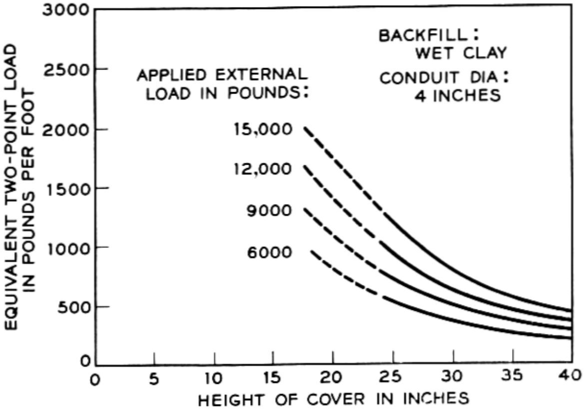

Fig. 9 — Equivalent two-point load caused by static load vs. height of cover.

ing various wheel loads. It is desirable that underground conduit be capable of withstanding a maximum wheel load of 15,000 pounds.

Fig. 10 gives the equivalent two-point load of four-inch-diameter round conduits obtained by tamping well-compacted backfill or by pavement breaking as a function of the height of cover for gravel as the backfill material. Gravel has been chosen because the highest equivalent two-point load values were obtained with this material. Since the type of the

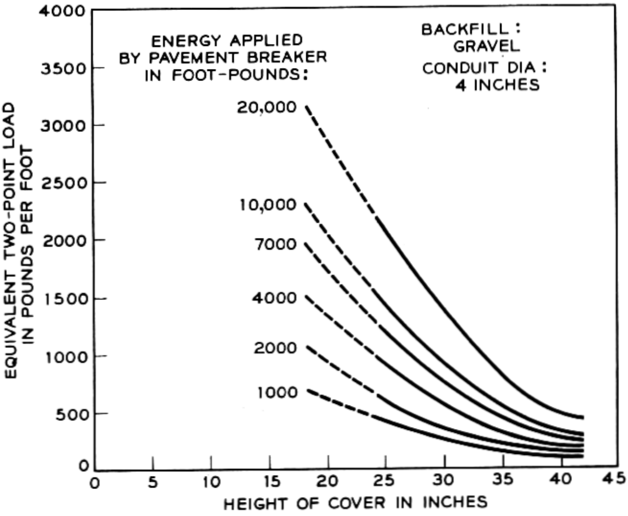

Fig. 10 — Equivalent two-point load caused by pavement breaking vs. height of cover.

subsoil is generally unknown when a pavement breaker is used, the worst conditions should be considered. The different curves in Fig. 10 represent the energies applied by the pavement breaker.

A comparison of Figs. 9 and 10 shows that a conduit having the desired minimum strength requirements based on static considerations should withstand without damage the effects of pavement breaking if equipment of 7500 foot-pounds capacity is employed and the height of cover is at least 24 inches. It appears that the equivalent two-point load due to pavement breaking increases more rapidly with a decrease of the height of cover than does the equivalent two-point load caused by static loads.

Fig. 11 shows the equivalent two-point loads obtained by tamping loose sandy clay backfill. These curves were derived from Fig. 8. To consider the effect of tamping loose fill, the values obtained by tamping compacted sandy clay fill were multiplied by three, in accordance with the experimental data. A comparison of Figs. 9 and 11 shows that tamping loose sandy clay fill with an applied energy of more than 1500 foot-pounds at a height of cover of 24 inches would exceed the assumed minimum crushing strength of the conduit (two-edge bearing load of 1200 pounds per foot) and could cause breakage. The effect of tamping loose backfill is much more severe than that of pavement breaking because the loose backfill in the trench acts like a piston in a cylinder and drives down on the ducts when it is subjected to the blows of the tamper. Furthermore, the tamping head penetrates farther into the loose fill and thus reduces the effective height of cover.

Additional tests were conducted tamping various types of backfill in trenches containing different conduits of known crushing strengths and conduit formations. The results of these tests support the findings of this investigation.

V. SUMMARY AND CONCLUSIONS

Field tests have been conducted to investigate the effect of the use of heavy tamping and pavement breaking equipment on round underground conduits. The results show that conduit may be damaged when heavy-duty equipment with a capacity of 7500 foot-pounds is used as a pavement breaker unless the height of cover over the conduit is at least 24 inches. This is valid for conduits having a crushing strength of 1200 pounds per foot. For stronger conduits the height of cover can be reduced.

The unrestricted use of power-activated machines for tamping loose fill, at a height of cover of 36 inches or less, may cause failure of conduit

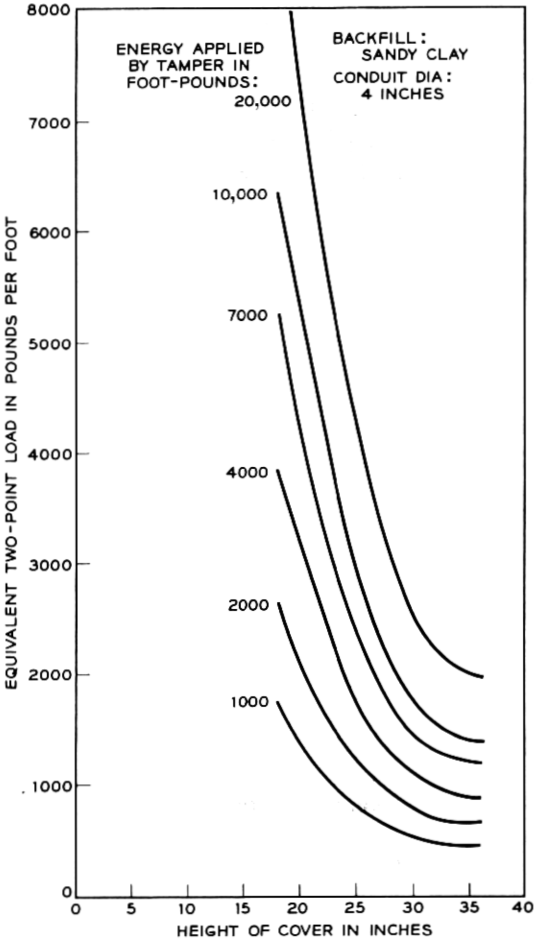

Fig. 11 — Equivalent two-point load caused by tamping on loose fill vs. height of cover.

having a crushing strength of 1200 pounds per foot in two-edge bearing. Compaction of the fill by hand tamping, prior to use of the mechanical tamper, would contribute some improvement. However, this is only of academic interest because, judging from the test results, the height of the hand-tamped cover should be at least 24 inches if a 7500-foot-pound machine is to be used safely at full capacity as a tamper.

REFERENCE

1. Weissmann, G. F., Strength Requirements of Round Conduit, B.S.T.J., **36,** May 1957, p. 737.