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# DEEP BENCH MARKS IN CLAY AND PERMAFROST AREAS

BY

3-1466 → M. BOZOZUK, G. H. JOHNSTON AND J. J. HAMILTON

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# DEEP BENCH MARKS IN CLAY AND PERMAFROST AREAS

BY M. BOZOZUK,[1] G. H. JOHNSTON,[1] AND J. J. HAMILTON[1]

## SYNOPSIS

This paper describes the design and use of deep bench marks by the Division of Building Research of the National Research Council of Canada. The bench marks consist of an inner pipe protected by an outer casing from the effects of seasonal ground movements and frost action. In sensitive clays the bench mark is installed by jacking or driving the outer casing with relatively simple equipment. In stiffer clays it is inserted in an augered hole and then turned and pushed to refusal with a drill rig. In permafrost areas, the bench mark is placed in a drilled or steamed hole to a depth at which the lower portion of the inner rod is securely anchored in the perennially frozen ground. Details of bench mark assemblies and installation techniques for soft clays, stiff clays, and frozen ground are described.

In precise level survey work for engineering construction, or for assessing the performance of structures, a reliable bench mark is essential. A pin installed in a rock outcrop, on a concrete foundation resting on stable soil, or on piles driven to bedrock usually constitutes a satisfactory reference datum. Where, however, bedrock is covered by a thick mantle of compressible soil or glacially deposited materials that are perennially frozen, it may be difficult to locate a suitable bench mark. At such times it is common practice to use a spike driven into a tree or fencepost, or to use stone steps, house foundations, survey monuments, fire hydrants, etc. Generally, these have proved unsatisfactory for long-term precise datum references in clay and permafrost regions in Canada, since they are vulnerable to numerous natural disturbances.

Seasonal shrinking and swelling of clay subsoils under grass-covered fields cause vertical ground movements to depths of 15 ft or more. Near large elm trees, Bozozuk and Burn (**1**)[2] have measured vertical movements varying from 3 in. at the ground surface to ½ in. at a depth of 14 ft in Leda clay in Ottawa. In the Santa Clara Valley in California, a decline of artesian pressures in aquifers has caused geodetic bench marks to settle as much as 9 ft from 1912 to 1959 (**2**). These bench marks were not established on bedrock. In areas where seasonal frost action occurs it is not uncommon for concrete steps, pavements and posts to heave several inches during the winter, and in some cases fence posts have been pushed completely out of the ground.

Field studies in permafrost areas have indicated several important factors that must be considered in the establishment of a reliable datum point. Frost-heave

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[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

forces in the active layer are particularly critical in those northern areas where seasonal freezing and thawing occurs to depths of 4 ft or more. Movements caused by frost action are generally cumulative and can result in a total heave of several inches (or even feet) over a number of years. Significant movements are also caused by the expansion and contraction of frozen ground as a result of the annual variation in ground temperature (3). Such movements may occur to depths where the variation in temperature is as little as 2 F. Due to the lack of ground temperature data in most northern areas, a depth of 30 ft is usually assumed.

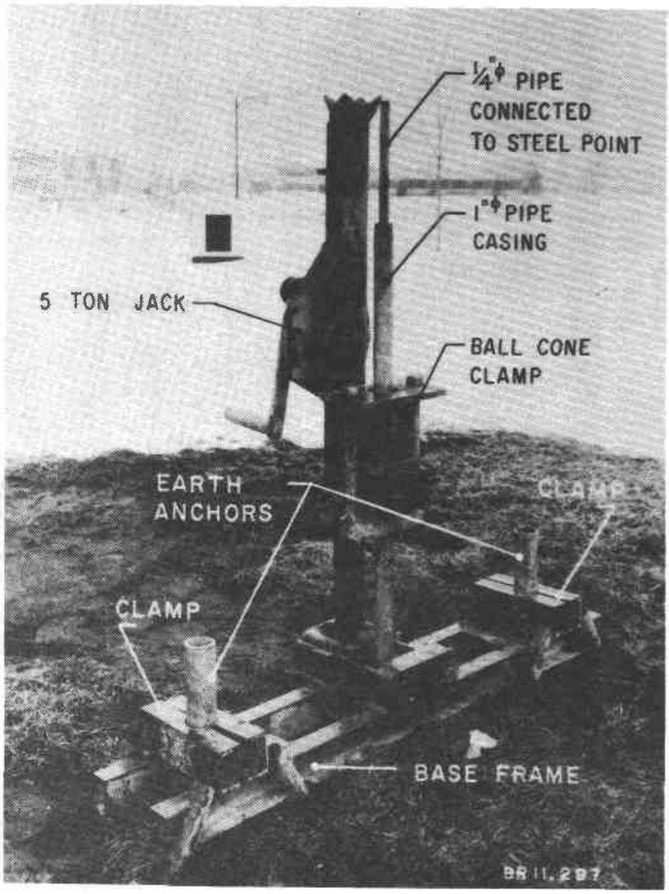


FIG. 1.—Jacking Equipment for Installing Deep Bench Marks in Sensitive Marine Clay.

Surface phenomena and installation methods can also affect the stability of bench marks. Care should be taken when locating bench marks where patterned ground phenomena (ice wedge polygons in particular) and solifluction or slope

TABLE I.—MATERIALS AND EQUIPMENT FOR INSTALLING DEEP BENCH MARKS.

| Sensitive Marine Clays | Lacustrine Clays | Permafrost Areas |
|---|---|---|
| | EQUIPMENT | |
| 1. Jacking equipment consisting of a 5-ton jack, ball cone clamp, base frame, and two earth anchors<br>2. 1½-in. earth auger and extensions<br>3. Auxiliary tools, such as pipe cutters, vice grips, shovels, pipe wrenches, measuring tapes, spirit level, funnel, hammer, etc. | 1. Drill rig with hydraulic head, "A" rod chuck and accessory equipment to auger 4-in. holes to depths of refusal<br>2. Pipe cutters and dies for ¼-in. and 1-in. pipe<br>3. Auxiliary tools, consisting of pipe wrenches, vice grips, funnel, shovel, tape, spirit level, etc. | 1. Standard diamond drill with hydraulic head and "A" rod chuck<br>2. Accessory drilling tools and equipment including AX and NX casing<br>3. Pipe cutters and dies for ¼-in. and 1-in. pipe<br>4. Pipe wrenches, vice grips, tape, shovel, etc. |
| | MATERIALS[a] | |
| 1. 1⅜-in. diam steel foot<br>2. ¼-in. pipe, 3 ft long<br>3. ¼-in. and 1-in. pipes in 10-ft lengths to complete installation<br>4. SAE 80 gear oil<br>5. 4-in. standard iron pipe casing 3 ft long with coupling and brass cap cover<br>6. ¼-in. and 1-in. wrought iron couplings | 1. 1½-in. diam steel foot<br>2. Stainless steel ball datum point<br>3. 1-in. wide spring bushing (coiled strap of 30-gage galvanized iron)<br>4. ¼-in. pipe, 3 ft long<br>5. ¼-in. and 1-in. pipe in 10-ft lengths to complete the installation<br>6. 4-in. standard iron pipe 3 ft long with coupling and brass cap cover<br>7. SAE 80 gear oil, and used crankcase oil<br>8. Backfill, such as sand, gravel, or dry concrete mix<br>9. ¼-in. and 1-in. wrought iron pipe couplings | 1. 1½-in. diam steel foot<br>2. Stainless steel ball datum point<br>3. Spring bushing 1-in. wide (coiled strap of 30-gage galvanized iron)<br>4. ¼-in. pipe, 9 ft long with spot weld roughening<br>5. ¼-in. pipe, 11 ft long<br>6. ¼-in. and 1-in. pipe in 10-ft lengths to complete the installation<br>7. 1-in. pipe, 1½ ft long with cap<br>8. SAE 80 gear oil or wax-oil mixture<br>9. Fine to medium sand for slurry backfill<br>10. ¼-in. and 1-in. wrought iron pipe couplings |

[a] All pipes and couplings are galvanized iron.

movements are evident, or near potential thawing influences such as buildings, roads, and streams. Sometimes drilling techniques will alter soil conditions so that a bench mark will not "re-freeze" after installation. Bench marks, therefore, must be constructed so that they will not be affected by soil movements, frost heave, temperature variations, surface phenomena or other natural disturbances.

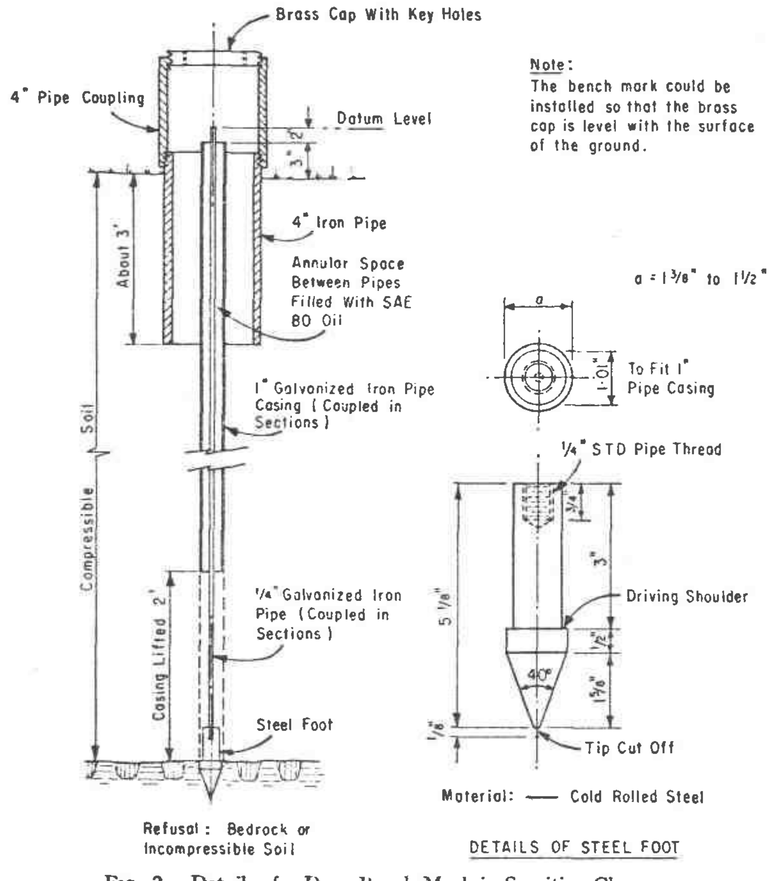


FIG. 2.—Details of a Deep Bench Mark in Sensitive Clay.

## TYPES OF BENCH MARKS

A steel rod driven through soft clayey soil and firmly seated on bedrock or in a stable material can be used as a bench mark. It must, however, be protected or be strong enough to resist the forces of frost heave and the loads imposed on it from volume changes in the surrounding soil. Terzaghi (4) proposed that a steel rod coated with asphalt and wrapped in oil-soaked waste should be lowered into a cased borehole and rammed firmly into the bottom; the casing would then be removed to allow the soil to fill the borehole. Asphalt and oil-soaked waste would protect the steel rod from corrosion and from vertical movements in the surrounding soil. The Swedish Geotechnical Institute's bench mark, described by Kjellman et al (5), is based on this principle. Taylor (6) described a bench mark established in Cambridge in 1927. It consisted of a 6-in. steel pipe filled with concrete and seated in bedrock 120 ft below the surface of the ground. No protection was provided against movement in the surrounding soil. A simple, easily installed bench mark was described by Peckover (7). It consists of a steel foot driven to refusal or into a stable layer of soil and connected to the surface with an iron pipe protected by a permanent oil-filled casing. A more elaborate bench mark, sunk 250 ft through clay to chalk during the construction of the "Shell Centre" on London's South Bank, is described in *Engineering Construction* (8). A 6-in diameter inner pipe supporting the bench mark was protected from corrosion and

FIG. 3.—Installing a Deep Bench Mark in Lacustrine Clay with a Truck-mounted Drill Rig Equipped with Hydraulic Feed.

isolated from the surrounding soil by a large telescopic casing filled with a special grease.

Some methods devised to establish reliable datum points in permafrost areas have been described by Johnston (9). This review indicates that datum points founded on or near the ground surface have moved considerably over relatively short periods of time so that they were unsatisfactory for purposes of vertical control. Construction of these bench marks varied from piles of wood or stone placed on the ground surface (10) to concrete piers or pipe placed to depths of 6 to 8 ft in permafrost (11,12). Pipes enclosed in oil-filled casing and embedded well into perennially frozen ground appear to be reliable after several years of observation (13), although no long-term records of their performance have been reported. Bench marks have been installed in both steamed and drilled holes, but drilling is generally favored since it creates the least disturbance to the frozen material and cuts the "freeze-back" period to a minimum.

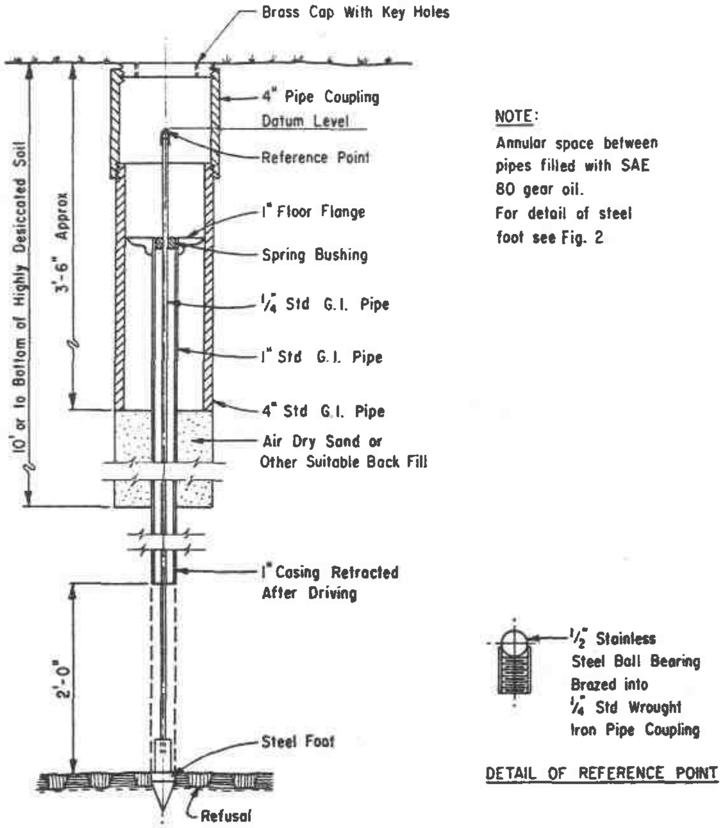


FIG. 4.—Details of Deep Bench Mark for Lacustrine Clay Areas.

This paper describes the design and installation techniques for bench marks used by the Division in performance studies of engineering foundations. Basically, they consist of a steel foot seated on bedrock or in some other stable material and connected to the surface with an iron pipe protected by an oil-filled casing.

## BENCH MARKS IN SENSITIVE CLAYS

Bench marks have been installed to depths of 95 ft in the sensitive clays near Ottawa by two men in one day with relatively simple equipment. The subsoil is a marine clay common in the Ottawa-St. Lawrence River valleys that varies in thickness from a few feet to about 200 ft. Generally, they are slightly overconsolidated, with a natural water content usually greater than the liquid limit. Due to their sensitivity, remolding reduces them to a fluid consistency with a shear strength about 1 per cent of their undisturbed value.

Following the procedure given in Appendix I, the bench mark can be driven into the soil manually with a 30-lb drive weight (7), or jacked into the ground with equipment similar to that developed by the Norwegian Geotechnical Inst. (Fig. 1). The materials and jacking equipment for the bench mark are listed in Table I, and a sketch of a completed installation is shown in Fig. 2.

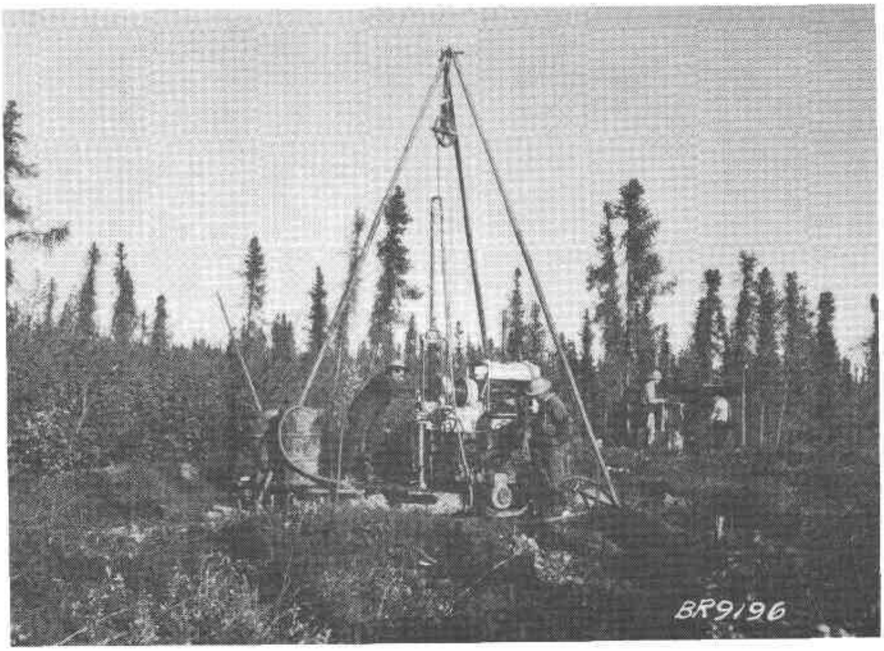


FIG. 5.—Drilling and Sampling for a Bench Mark Installation in a Permafrost Area Using a Diamond Drill with Hydraulic Feed.

## BENCH MARKS IN LACUSTRINE CLAYS

Deep bench marks have been installed in highly plastic clays on the Canadian prairies with a drill rig (Fig. 3). The clays originate from glacial lakes Agassiz and Regina and range in thickness from a few feet to 90 ft. They are medium to stiff in consistency, with sensitivity ranging between 1 and 2. Liquid limits may range as high as 110 per cent, and plasticity indexes as high as 80 per cent. The clays or silty clays are usually underlain by glacial till deposits of varying thicknesses and characteristics.

The procedure described in Appendix II is required for installing a bench mark using a hydraulic powered drill rig capable of augering with continuous flight augers with a slow-speed rotation and thrust. The materials and equipment for this installation are listed in Table I and the details of the completed bench mark are shown in Fig. 4.

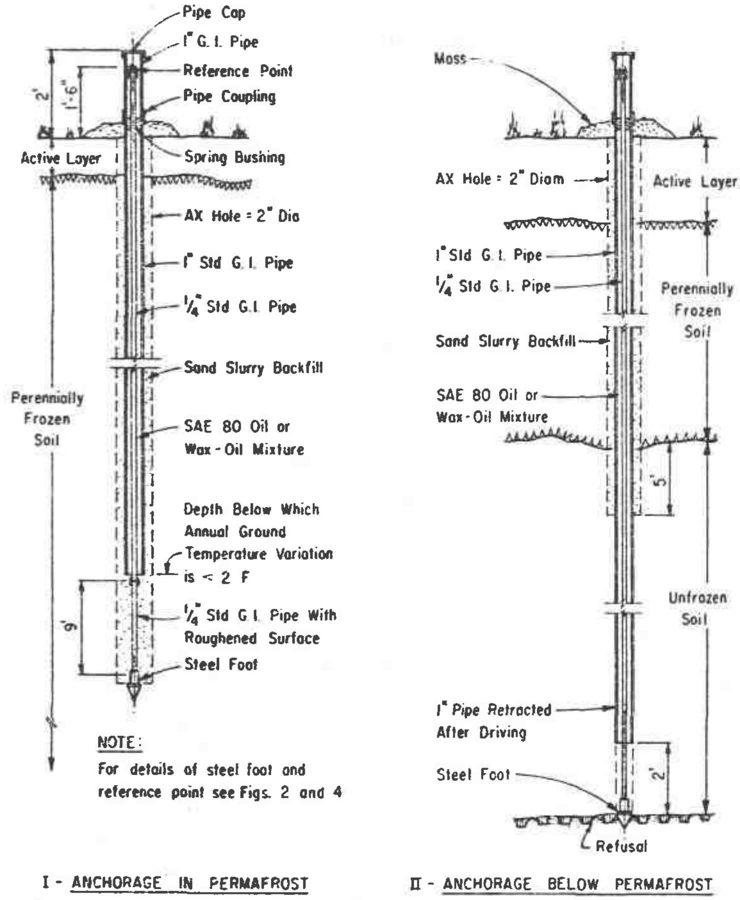


FIG. 6.—Details of Deep Bench Marks in Permafrost Areas.

## BENCH MARKS IN PERMAFROST AREAS

In the continuous permafrost zone of northern Canada where permafrost occurs to depths greater than 100 ft and ground temperatures are well below 32 F, bench mark stability is dependent on adequate anchorage of the datum pipe in the perennially frozen ground at a depth where the mean annual ground temperature is nearly constant. In the discontinuous zone near the southern boundary of the permafrost region, permafrost occurs in scattered patches, is less than 100 ft thick, and ground temperatures are near 32 F. Because it is relatively unstable under these conditions, it is preferable to found the bench mark in stable material beneath the bottom of the perennially frozen ground.

Deep bench marks have been installed in both the continuous and discontinuous zones of permafrost. Soil and permafrost conditions have varied from gravels and stony glacial tills containing extensive ice segregation and frozen to several hundred feet (mean annual ground temperature about 26 F) to fine-grained varved soils containing appreciable quantities of ice and frozen to a depth of about 25 ft (mean annual ground temperature about 31.5 F).

Permafrost and soil conditions should be determined before installing a bench mark because they govern the installation procedure. Information relating to soil type, depth of permafrost (discontinuous zone), ice segregation, etc. can be obtained by sampling during the drilling operation (Fig. 5), or may be inferred from previous investigations carried out in adjacent areas.

When the bench mark is to be anchored in permafrost, the procedure given in Appendix III, Section (*a*), is followed. As some movement of the datum pipe may take place during the freeze-back period (perhaps 1 to 4 months), a bench mark should not be used as a datum until it has been established that no movement has occurred or that movements have ceased. If a bench mark is to be placed on or in a solid stratum below the perennially frozen layer in the discontinuous permafrost zone, the procedure given in Appendix III, Section (*b*) is used. The details of these bench marks are given in Fig. 6.

## LOCATION, PROTECTION, AND MAINTENANCE

It is most important to select a location where the bench mark will be inconspicuous to the public, readily accessible, and suitably protected from traffic and construction equipment. In permafrost areas it should be located in a high, reasonably well drained, undisturbed location well separated from potential thawing influences such as roads, buildings or streams.

To protect the bench mark, a 4-in. casing capped with a brass cover containing identification marks should be used. The cap should also be provided with holes or slots so that a special key or wrench is required to open it, thus lessening the possibility of damage by vandalism. The holes would also provide ventilation to minimize condensation inside the casing. If necessary, additional protection could be provided by placing a cement slab around the installation.

In highly corrosive lacustrine soils, additional protection against corrosion may be achieved by sliding a semi-rigid plastic pipe ($1\frac{5}{8}$ in. ID) over the 1-in. pipe casing to a depth of 10 ft, or to the bottom of the 4-in. auger hole, before the final filling of the 1-in. pipe with oil. The piezometric head at the bottom of the plastic pipe and the lower specific gravity of the oil, relative to the soil pore water, will force the oil to a high level in the plastic pipe and reduce corrosion.

In permafrost areas precautions should be taken to prevent undue disturbance of the insulating moss cover and ponding of water at the site. The assembly normally protrudes above the ground surface so that it is readily accessible and easily identified. It should be well marked and protected with additional moss and a timber crib placed on the ground surface.

These bench marks should require little maintenance, although it may be necessary to add oil periodically to those placed in clay areas or through permafrost since some leakage may occur. If excessive frost heaving should cause the 1-in. casing to cover the datum pipe, the casing may be cut off or the inner pipe extended by adding short lengths of $\frac{1}{4}$-in. pipe. For the latter case, a careful level survey will be required to establish a new elevation.

## EFFECTS OF GROUND TEMPERATURE

The datum rod of the bench mark assembly is subject to expansion and contraction caused by temperature variations in the surrounding soil. The variation of temperature in the rod, however, should be less than that in the neighboring soil because of the protection it receives from the oil and the casings. Based on ground temperature measurements made at Ottawa, Ontario, and Knob Lake in Labrador under natural surface cover and a snow cleared roadway respectively (Crawford and Legget (14)), the maximum change in length of an iron rod was calculated to be 0.001 ft and 0.002 ft.

To reduce or eliminate effects of temperature variations, additional insulating cover could be provided for the bench mark installations. Other methods include installing them beneath buildings where ground temperatures are nearly constant, or by substituting a more stable metal or alloy for the top 10 ft of datum rod. Field experience has shown, however, that the deep bench marks installed to date are suitable for surveys read to 0.001 ft.

## DISCUSSION

Measurement of the movement of engineering structures founded on compressible or otherwise unstable soils is important for both practical and theoretical reasons. Settlement may be taking place even before construction begins if the site has been preloaded with fill or if new drainage conditions are lowering the ground water table. Seasonal volume changes of clay soils as influenced by climate and vegetation cannot be fully assessed without reliable bench marks. Practical implications of such movements include discrepancies of survey elevations obtained at different seasons of the year, errors introduced into calculations of earthwork or other construction volumes, and additional expense incurred in more frequent control surveys from distant bench marks. It is important, therefore, to have a reliable bench mark close at hand to (1) determine whether such movements are occurring, (2) use as a control datum during construction, and (3) check the performance of the struc ture once it has been built.

The deep bench marks used by the Division of Building Research in sensitive clays, lacustrine clays, and permafrost regions are simple and economical to install. Basically, they consist of a datum pipe resting in stable material and protected by an oil-filled casing. Experience has indicated that they are suitable for surveys that are read to 0.001 ft.

Consultants, engineers, owners, and contractors should consider the installation of a deep bench mark as an essential part of the exploratory soil sampling program for engineering structures. A reliable bench mark may be installed on the site easily and inexpensively to provide a datum for surveying during the construction period and for checking the performance of the completed structure, especially where the distance to an established bench mark is so great as to reduce the accuracy of the surveys to the site.

*Acknowledgments:*

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## APPENDIX I

## INSTALLATION OF A DEEP BENCH MARK IN SENSITIVE CLAY

1. At the desired location, bore a hole large enough for a 4-in. pipe casing to a depth of 3 to 4 ft. Center the base frame over the hole and clamp it firmly to the ground by means of two earth anchors. The turning of the spiral earth anchors into the ground can be eased if two pilot holes are augered in advance. At the center of the large hole, auger a $1\frac{1}{2}$-in. pilot hole vertically through the fissured crust to a depth of 15 ft or more. Check the auger frequently with the carpenter's level to ensure that the hole is vertical.

2. Assemble the steel foot, the 3-ft, and 10-ft lengths of $\frac{1}{4}$-in. galvanized iron pipe. String a 10-ft length of 1-in. galvanized iron pipe casing over the $\frac{1}{4}$-in. pipe so that it is seated firmly on the shoulder of the steel foot. To prevent relative movements between component parts, clamp the inner pipe firmly with vise grips at the top of the casing. The 3-ft length of $\frac{1}{4}$-in. pipe projecting above the casing permits easier coupling of successive pipes and casings. It also ensures that the first $\frac{1}{4}$-in. pipe coupling above the steel foot will be located inside the 1-in. pipe casing after the installation is completed.

3. Lower the unit into the hole, and jack it into the ground to refusal as quickly as possible with the jacking device, adding successive lengths of pipe as required. (Usually a 50-ft bench mark can be jacked into the ground within 2 hr.) This operation should be completed in one working period since any delays will permit the casing to "seize" in the soil, at which time it becomes very difficult to move even with much heavier jacking equipment.

4. To ensure that the steel foot is firmly seated, check the refusal of the bench mark to penetration by percussion driving. This may be done by threading an additional length of 1-in. pipe, adding a jar plate, then driving with a hammer or drive weight. Take care not to overdrive the pipe casing. When satisfactory seating of the steel foot has been achieved, the elevation of the top of the $\frac{1}{4}$-in. datum pipe should be established precisely with an engineer's level.

5. Jack the casing up 2 ft to separate it from the steel foot. Check the elevation of the datum pipe to ensure that it has not been lifted with the casing.

6. Cut off the casing about 3 in. above ground, or as required, and the inner pipe 2 in. above the casing. The top of this pipe serves as the reference datum.

7. Fill the 1-in. pipe with heavy oil. Install the 4-in. pipe casing, together with the coupling and brass cap, as shown in Fig. 2, allowing 5- to 6-in. clearance between the datum pipe and the brass cap.

NOTE.—If desired, this installation can be improved with the addition of a stainless steel ball datum point, a "spring" bushing to center the inner pipe within the 1-in. casing and with the addition of a floor flange to provide lateral stability for the 1-in. casing within the 4-in. diam pipe, as described in Appendix II.

## APPENDIX II

## INSTALLATION OF A DEEP BENCH MARK IN LACUSTRINE CLAY

1. Position and level the drill rig over the point selected and remove the sod. Bore a 4-in. hole to the bottom of the highly desiccated soil strata (10 ft or more), using continuous flight augers. In these cohesive, self-supporting clays, a casing is not required to keep the hole open. It may be necessary to auger or wash bore a small-diameter pilot hole before setting the bench mark pipe in very stiff clays or clay shales.

2. Pour 2 to 3 gal of automotive crank case oil into the augered hole. In clayey soils near saturation there will be very little loss of oil into the soil, and a 4-in. hole will be filled to a depth of about 4 ft.

3. Assemble the materials, following step 2 of Appendix I. Center the pipes through the "A" chuck of the drill rig and lower them into the hole. It is most important at this stage that the pipe is vertical and that it is well centered in the chuck of the drill rig.

4. Push and rotate the pipes into the ground to refusal, adding successive lengths as required. By using a slow speed of rotation and a steady push with the drill feed, penetration resistance is reduced and the chances of obtaining a straight and vertical installation are greatly increased. This operation should be continuous and completed within a working period. Although the oil lubrication and the oversized hole made by the $1\frac{1}{2}$-in. diam steel foot tend to reduce skin friction, the casing may "set up" quite firmly in the soil if it is allowed to stand for a period of time.

5. Usually penetration refusal is easily detected by the reaction of the drill rig and by rotation of the pipe casing relative to the inside pipe. After loosening the drill chuck, refusal of the bench mark to penetration by percussion driving can be checked, as outlined in step 4 of Appendix I.

6. With the drill rig retract the 1-in. casing 2 ft and check the elevation of the inner pipe to ensure that it has not been lifted with the casing.

7. Cut off and thread the 1-in. pipe 6 in. below the desired final elevation of the bench mark datum point, and the $\frac{1}{4}$-in. pipe about 5 in. above the 1-in. casing. If the datum elevation is at or below existing grade, a shallow pit must be dug around the pipe to allow the use of the pipe cutter and threader.

8. Fill the 1-in. pipe with gear oil. This time-consuming operation can be speeded considerably if two or three $\frac{1}{8}$-in. holes have been drilled in a staggered pattern in the first 3-ft section of $\frac{1}{4}$-in. iron pipe to allow trapped air to escape from the bottom of the casing. Install the spring bushing (coiled strap of 30-gage sheet galvanized iron) at the top of the 1-in. casing, thus centering the inner pipe. Finally, screw on the special steel ball datum point.

9. Fill the 4-in. auger hole with air-dry sand or gravel (maximum particle size $1\frac{1}{2}$ in.) or with dry concrete mix to within 3 ft of the ground surface. Push the 4-in. pipe into the hole, making sure that it is well centered and that a clearance of at least 6 in. is provided between the datum point and the brass cap. Screw the floor flange onto the 1-in. pipe by means of a small rod inserted in one of the bolt holes. Finally, backfill the hole around the 4-in. casing with suitable fill or cast a concrete marker pad around it.

## APPENDIX III

## INSTALLATION OF DEEP BENCH MARKS IN PERMAFROST AREAS

(*a*) *Bench Marks Anchored in Permafrost:*

1. Carefully position the drill rig so that disturbance of the moss cover will be kept to a minimum. Place a suitable length of NX casing through the active layer into the perennially frozen ground to prevent thawed material and surface water from entering the hole. Drill a hole to a depth of 39 ft with AX size drill equipment, using an AX core barrel if samples are desired; otherwise use an AX non-coring bit. If caving occurs, AX drill casing should be placed to the bottom of the hole. When the hole is completed, bail out all the water.

2. Connect the steel foot to the 9-ft length of $\frac{1}{4}$-in. pipe having a roughened surface and lower it into the hole to a depth of 8 ft. String a 10-ft length of 1-in. pipe over the 11-ft length of $\frac{1}{4}$-in. pipe. With the vice grips clamped securely to the top of the inner pipe to prevent it from sliding out of the 1-in. casing, raise the two pipes vertically above the hole and connect the $\frac{1}{4}$-in. pipes together. Retaining a hold on the outside pipe, lower the assembly into the hole, adding successive 10-ft lengths of $\frac{1}{4}$-in. and 1-in. pipe until the steel foot rests on the bottom. Secure the 1-in. pipe so that it projects about 6 in. above the ground. The inner pipe should then protrude about 1 ft above this casing.

3. Holding the pipes in this position, carefully backfill the hole with a not-too-wet sand-slurry mixed so that it just pours easily. If drill casing has been used withdraw it carefully so that the relative positions of the bench mark pipes are maintained as the hole caves in around them. To ensure that the lower portion of the datum pipe is adequately surrounded by soil it may be necessary to fill the lower part of the hole with the slurry before removing the drill casing. If such is the case, even greater care is required to maintain the relative positions of the bench mark pipes as the drill casing is removed.

4. Remove the NX casing from the active layer and backfill the hole to the ground surface, carefully replacing the moss cover around the pipes.

5. Fill the annular space between the inner and outer pipes with an SAE 80 gear oil or a special wax-oil mixture. This mixture can be made up of 70 per cent oil (such as Mentor 29) and 30 per cent wax (such as Socony Mobil Cerise AA) by weight, mixed after heating to about 200 F. The mixture is poured into the assembled 10-ft lengths of pipe and allowed to congeal before they are placed in the drill hole.

6. Install the "spring bushing" inside the top of the 1-in. pipe casing and mount the stainless steel ball datum point on the top of the $\frac{1}{4}$-in. pipe.

7. Connect the $1\frac{1}{2}$-ft length of 1-in. pipe and pipe cap to the top of the 1-in. casing protruding above the ground surface.

8. If desired, a suitable length of 4-in. pipe with pipe cap may be driven into the ground over the bench mark assembly to provide additional protection.

(*b*) *Bench Mark Anchored Below Permafrost:*

1. Following the same procedures given above, drill an AX hole to a depth 5 ft below the perennially frozen layer.

2. If the unfrozen soil underlying the permafrost is relatively soft, complete the installation following the procedures given in Appendix II.

3. If the unfrozen soil is stony or very stiff it may be necessary to extend the bore-hole to bedrock or other resistant material. The installation can then be completed following the procedures used for anchoring bench marks in permafrost.

## DISCUSSION

Mr. W. E. Schmid.[1]—Does the $\frac{1}{4}$-in. rod of the benchmark in deep installations have a tendency to buckle?

M. Bozozuk et al (*authors*).—The $\frac{1}{4}$-in. datum rod of the deep bench mark has not shown any tendency to buckle under field use. The $\frac{1}{4}$-in. pipe couplings located at 10-ft intervals and the gear oil in the 1-in. casing provide sufficient lateral support to prevent any appreciable buckling. To ensure that no buckling would occur, a $\frac{3}{8}$-in. pipe could be used for the datum rod.

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