Designation: D6598 – 11

Standard Guide for Installing and Operating Settlement Platforms for Monitoring Vertical Deformations[1]

This standard is issued under the fixed designation D6598; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This guide provides recommended designs and procedures for the fabrication, installation, operation, and reading of settlement platform to determine the magnitude and rate of foundation, fill settlements, or both generally under a fill or embankment load. Two types of settlement platforms are described – those being monitored by elevation surveys from an external bench mark and those that include an internal reference system supported on unyielding soil or rock beneath the compressible layer(s) of interest.

1.2 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This guide does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this guide to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgement. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D5092 Practice for Design and Installation of Groundwater Monitoring Wells

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *settlement platform*—a system consisting of a square base platform with an extendible riser pipe of known length which is used to monitor vertical deformations at the elevation of the base platform by survey measurements made of the top of the riser pipe.

3.2.2 *external and internal reference point system*—with an external system, the amount of settlement is determined by referencing the elevation of the settlement platform to an outside elevation benchmark; with an internal system, the amount of settlement is determined by measuring the relative displacement of two co-axial riser pipes moving relative to each other, the outer riser pipe being attached to the base platform and the inner riser pipe being fixed to an unyielding stratum.

3.2.3 *anchor*—an anchor system that provides an internal fixed reference point below the base of the settlement platform system.

3.2.4 *extendible riser*—a metal shaft or pipe which can be incrementally lengthened using sections of the same material and appropriate couplings as fill is placed and compacted to ensure that the top of the riser remains above the level of the surrounding ground surface. Depending on whether an external or internal reference point is being used, there may be one or two risers.

3.2.5 *isolation casing*—a casing of a larger diameter than the extendible risers is used in some installations to prevent down-drag of soil on the extendible riser that would otherwise

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

be in contact with the soil from placing additional load on the platform and thereby leading to overestimates of deformations.

3.2.6 For definitions of other terms used in this guide see Terminology D653.

4. Summary of Standard Guide

4.1 The standard guide presents recommended designs for settlement platforms along with procedures to install, operate and monitor them. The standard guide focuses on methods that permit (i) the effect of fill placement on underlying strata and (ii) the determination of the relative deformation within a fill. The guide addresses ways in which the instrument is protected from downdrag effects from the fill soils as well as measures to protect the instrument from damage by earth moving equipment. Standard survey procedures are used to determine the magnitude of deformations. Recommended procedures for reporting the details of an installation and the recorded deformations are presented.

5. Significance and Use

5.1 Earthen fills are often constructed as engineered structures, for example, dams, or to support engineered structures, for examples, roads or buildings. The weight of the fill may compress or deform the supporting soil or rock foundation resulting in settlement of the soil throughout the embankment. Temporary embankments or surcharge fills are constructed to increase the strength and/or reduce the compressibility of foundation soils prior to placement of the actual foundation or structure. The designers often monitor the settlement of the earth structure as a function of time to document the magnitude and rate of settlement, to evaluate the potential for future settlement, or to confirm the effectiveness of the surcharge and the schedule for its removal. The monitoring is performed using settlement platforms installed prior to or during the embankment construction. A platform provides an accessible survey point that settles with a selected soil horizon within or below the embankment. Careful design and installation of the settlement platform can isolate the survey point from extraneous sources of movement such as frost-induced heave, compression within the embankment, or volume changes caused by moisture gain or loss.

5.2 Various settlement platform designs have been developed by the agencies and practitioners that use them. This standard guide provides designs and procedures that can be referred to in design guidelines, specifications and reports.

5.3 This standard guide is not meant to restrict the use of other equally appropriate designs and procedures for the fabrication, installation, operation, and reading of settlement platforms to monitor deformations in earthen deposits during and after construction.

NOTE 1—Notwithstanding the statements on precision and bias contained in this guide, the precision of this guide is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing. Users of this guide are cautioned that compliance with Practice D3740 does not itself ensure reliable testing. Reliable testing depends on many factors; Practice D3740 provides a means of evaluating some of these factors.

6. Materials

6.1 A variety of materials are used in combination to provide a cost-effective, modular system. Given that the anticipated operational life of settlement platforms is typically relatively short, concerns about long term durability are generally negligible. Accordingly issues such as component weight, the ease with which the riser pipe can be extended and cost tend to dominate material selection decisions. The entire settlement platform system consists of 4 or 5 distinct components depending on the specific design. Typical alternative configurations are shown in Figs. 1-3. Key distinctions between these different configurations are summarized in Table 1. Additional considerations regarding materials for each of these components are provided below.

TABLE 1 Suitability and Use of Various Platform Configurations

Configuration	Fill Deformations	Foundation Deformations	External Reference	Internal Reference
Fig. 1	No^{A}	Yes	Yes	No
Fig. 2	No^{A}	Yes	No^{B}	Yes
Fig. 3	No^{A}	Yes	No^{B}	Yes

^{A} Fill settlements could be determined with this configuration if base platform placed at higher elevation.
^{B} External reference (control) could be used with these configurations also.

6.2 *Base Platform*—a square base platform typically ranging between 0.3 to 1.0 m on side is placed at the elevation for which the vertical deformation is required. In some cases, a steel platform 5 to 15 mm thick is used. Alternatively, a platform 25 to 50 mm thick fabricated from plywood is sometimes used. This may be particularly desirable in short term applications where degradation of the wood is not a concern. Other materials such as concrete can be used for the base platform. In all cases, the thickness of the base platform should be selected giving consideration to the area of the platform to ensure that its rigidity is sufficient to avoid local bending.

6.3 *Riser Pipe*—a rigid metal shaft or an assembly of a rigid metal shaft and a rigid metal pipe, typically 25 to 50 mm in diameter, is used to reflect the vertical deformation of the platform at the ground surface. As layers of fill are placed, the riser pipes are extended by adding additional sections of pipe. Threaded couplings are typically used. These have the advantage that after the survey program is complete, some, if not all the riser pipe can be recovered before the installation is grouted to seal off any unwanted access for water to the subsurface. Use of PVC or other lightweight pipe materials is not recommended for reasons of survivability.

6.4 *Riser Pipe Isolation Casing*—an external pipe is sometimes used to isolate the riser pipe from the surrounding soil. This is done to prevent the effects of extraneous sources of movement such as frost-induced heave, skin-friction due to compression within the fill itself, or moisture induced volume changes. Given that this casing is only to isolate the riser pipe from these surrounding effects and does not constitute part of the deformation measuring system, PVC or other lightweight pipe materials are typically recommended. As with the riser pipe, the isolation casing can be extended as layers of fill are added. Isolation casing is typically only required if the fill or embankment height is greater than about 6 m or the plate is to be seated on a thin stiff layer overlying softer material where a

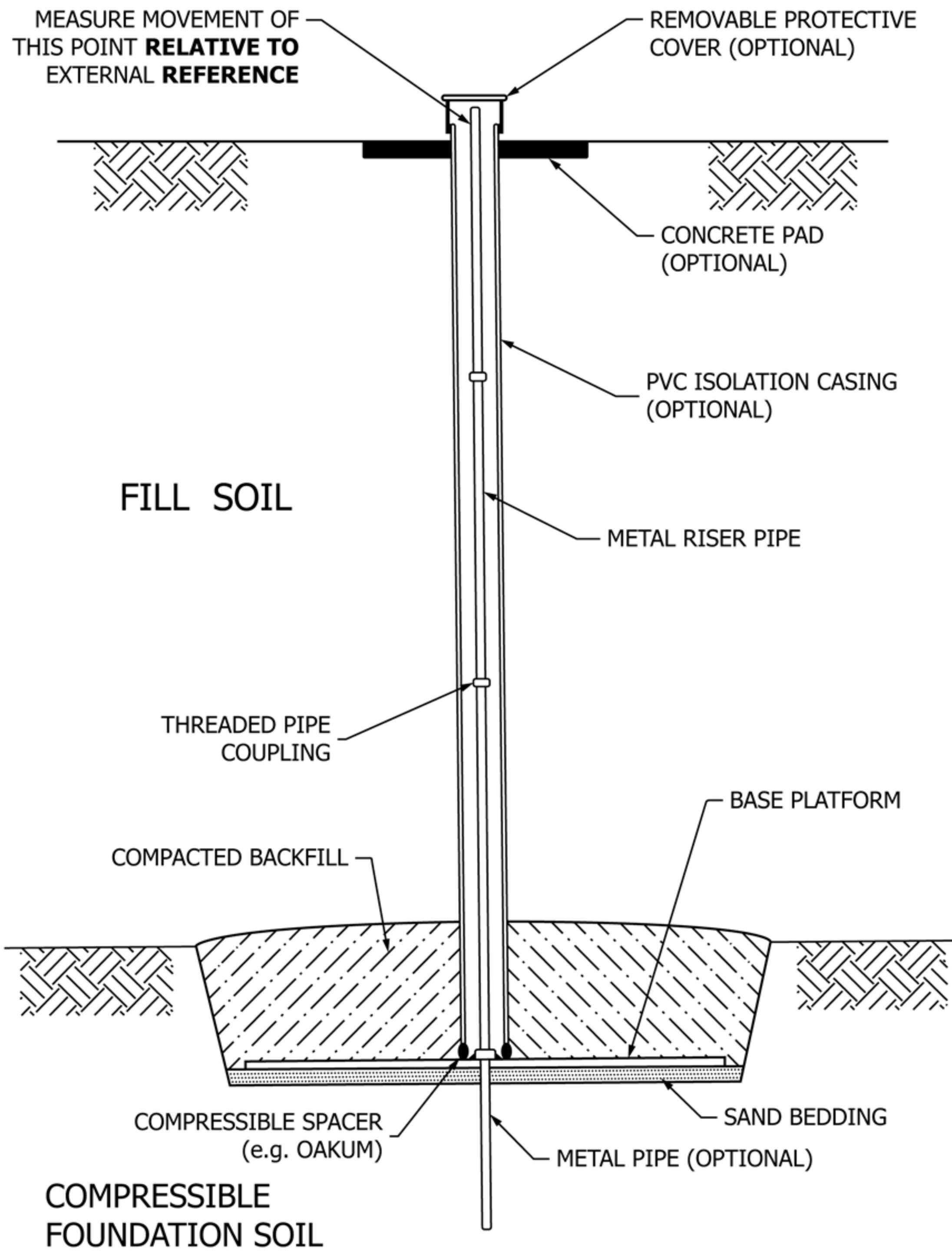

FIG. 1 Typical Installation for Externally Referenced Settlement Platform

punching failure might occur as a result of the down-drag load applied to the riser-pipe.

6.5 *Surface Protection Monument*—for settlement platforms that remain in place following completion of construction, installation of a surface protection monument to protect the riser pipe from tampering is advisable. Design of a protective casing system as described in Practice D5092 is recommended.

6.6 For installations where an internal reference or benchmark supported on unyielding soil or rock beneath the compressible layer(s) of interest is used, rigid metal pipe similar to that described in 6.3 above is recommended. Alternatively, an anchor is used in conjunction with metal pipe to ensure a fixed base reference point. A typical anchor may consist of a number of metal prongs which are driven from an initially retracted

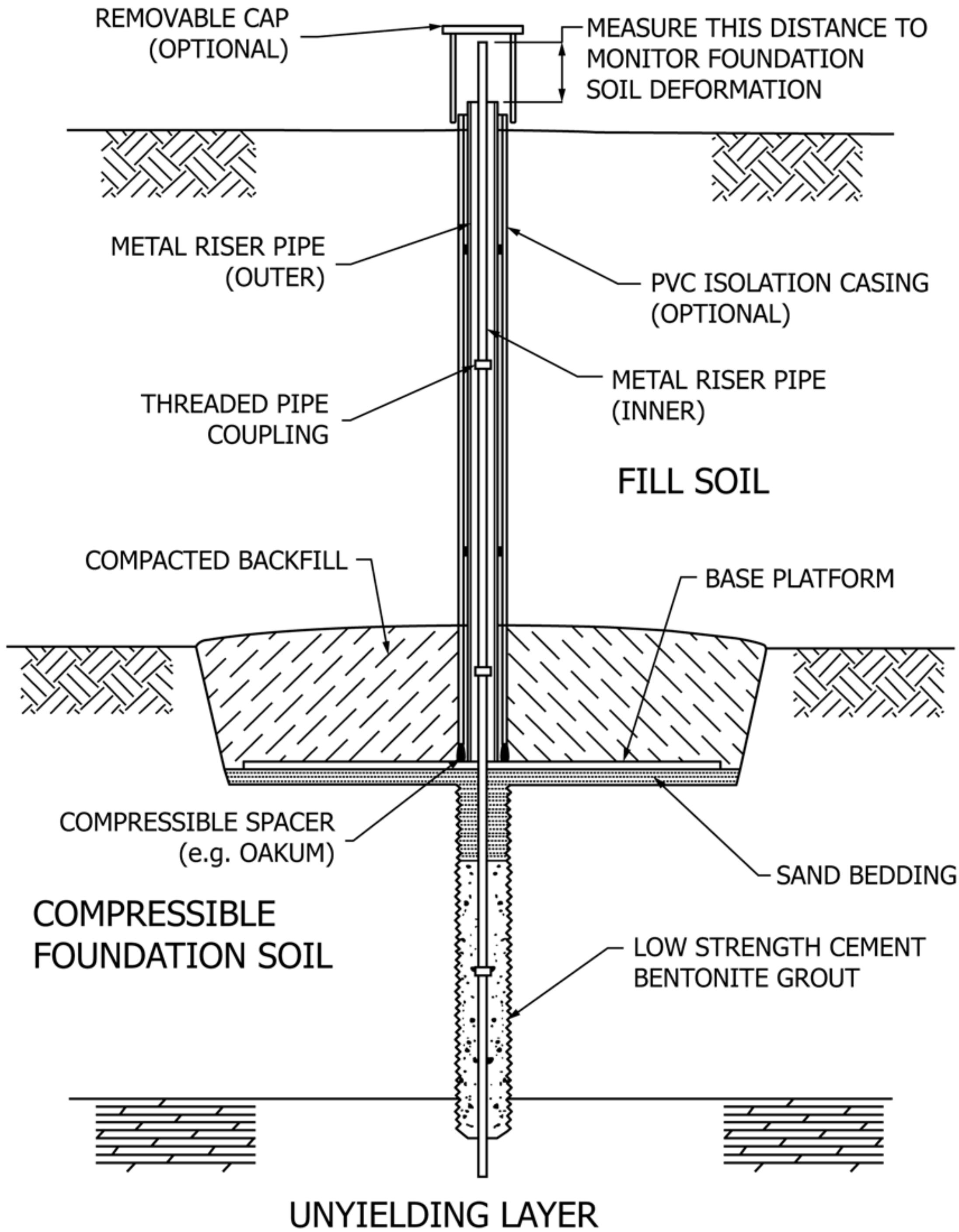

FIG. 2 Typical Installation for Internally Referenced Settlement Platform with Grouted Pipe

position through slots in the conical drive point of an outer metal pipe using an inner metal riser pipe.

7. Procedure

7.1 A variety of instrument designs are possible depending on the specific application for which the settlement platform is to be used and whether an external or internal reference point or bench mark is to be used. This standard test method describes a number of settlement platform systems intended to reflect these alternative configurations as well as a number of other features such as the use of riser pipe isolation casing.

7.2 Assuming that either the fill level is at the elevation that the base platform is to be installed or an excavation has been made to permit the level of interest to be accessed, installation of the base platform is preceded by the placement of a bedding layer. Typically, a free-draining clean sand is used (see Fig. 1 for example). If that an external reference point is used, the first

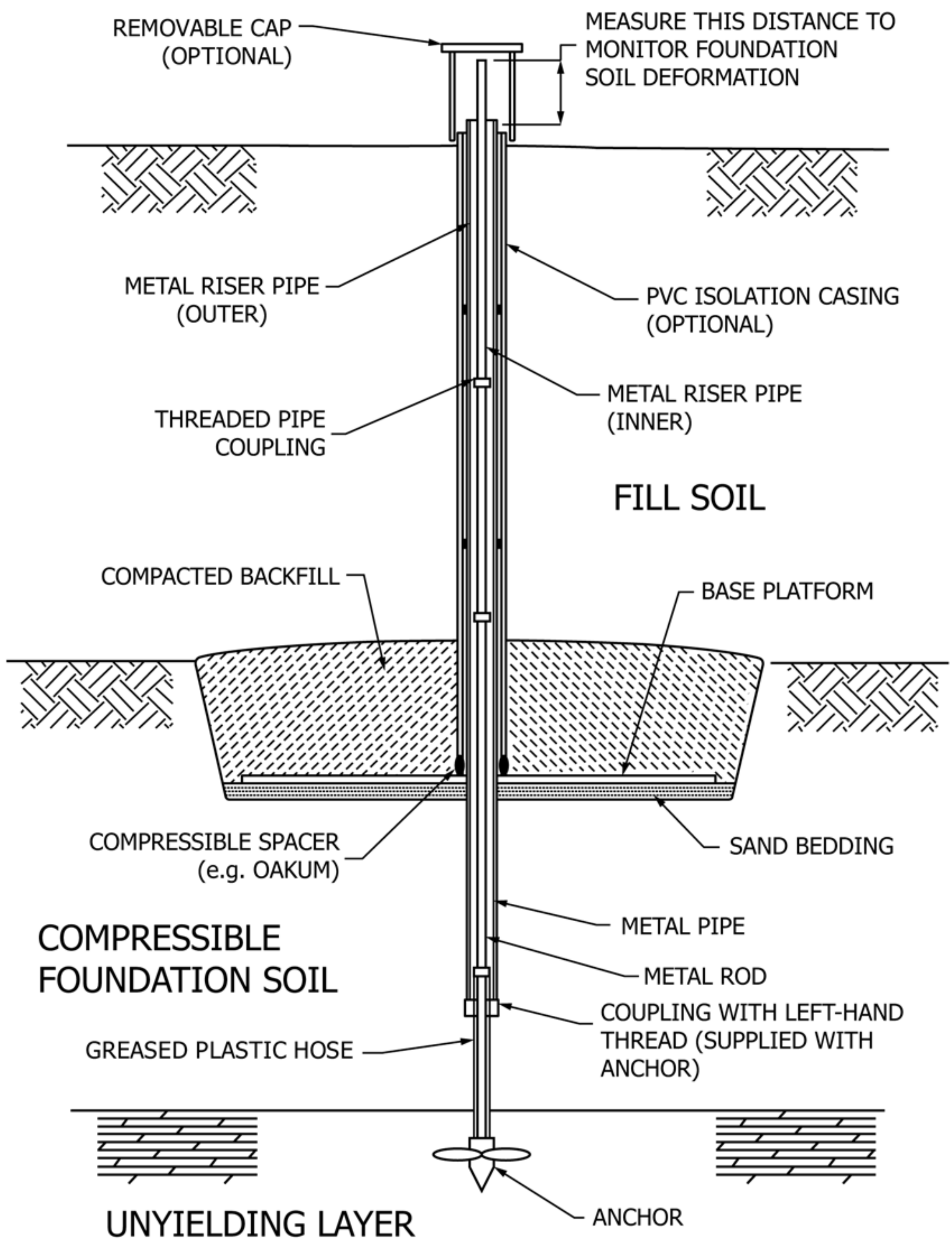

FIG. 3 Typical Installation for Internally Referenced Settlement Platform with Borros Anchor

section of riser pipe is connected to the base platform and the platform is positioned on the bedding sand and leveled manually. If that an internal reference system is used, the lower end of the shaft is first embedded in the unyielding soil stratum (see section 7.3). Backfill is then hand placed and compacted on top of the base platform to provide initial stability. The level of compaction required should be established for the specific project. Ensure that the riser pipe remains vertical during early filling. The zero reading or initial elevation of the top of the base plate is determined and recorded at this stage prior to the placement of any fill layers with earth-moving equipment. Use of a measurement system capable of measuring deformations to an accuracy of 1% of the estimated total deformation is appropriate in most cases. For cases where total deformations are limited to the order of a few centimeters, accuracy is limited by the practicality of making the measurements. As filling progresses, additional sections of riser pipe are added to maintain the top of the riser pipe above the elevation of the fill. Sections of riser pipe between 1 and 2 m long are convenient for assembly as well as monitoring purposes. In cases where concerns exist about the influence of extraneous factors as noted in section 6.4 on the recorded deformations, riser pipe isolation casing are added as appropriate to ensure that the top of the isolation casing remains at least 25 mm below the top of the riser pipe and always above the top of the fill (see Fig. 1 for example).

7.3 If an internal reference point is used, then a system configuration such as shown in Figs. 2 and 3 should be used. A principal difference between these systems and the externally referenced system shown in Fig. 1 is the section of shaft or anchor that extends below the elevation of the base platform into the underlying unyielding layer. While externally referenced systems are used to indicate the relative vertical movement between the top of a riser pipe that is rigidly connected to the base platform and a remote survey point, internally referenced systems permit measurement of the relative vertical movement between the top of an outer riser pipe. The outer riser pipe is rigidly connected to the base platform and an inner riser pipe that is rigidly connected to an anchoring system founded in an underlying unyielding layer and passes through the center of the base platform. The anchor is installed by pre-drilling or hand-augering a hole into the competent stratum. The anchor is then placed in the hole and grouted in place using a cement-bentonite or similar material of sufficiently low strength to avoid supporting the platform. At contact between the grout and the platform avoid contact that influences the measured settlement. The unyielding layer should occur at shallow depths below the base plate to ensure economy of the internally referenced system relative to the cost of referencing surveys to an external point or bench mark. The choice between an externally or internally referenced system is based on comparative costs – the deeper the compressible layer, the more likely an externally referenced system is chosen.

7.4 Readings of the elevation of the top of the riser pipe are taken at time intervals frequent enough to permit critical deformations to be recorded. In addition, readings are taken immediately before and after any action such as the addition of extra sections of riser pipe. These measurements, as well as an independent measurement of the length of the section of pipe being added, permit appropriate corrections to be made to the recorded measurements. When extra sections of riser pipe are being added, ensure that only the coupling at the bottom of the section being added turns. Use two wrenches, one to hold the new section of pipe and the other to hold the coupling or the pipe immediately below it, depending on whether or not the coupling was in place during the last sequence of measurements.

7.5 Appropriate measures shall be implemented to maintain the alignment of the riser and the riser pipe isolation casing in a vertical position during the period that data is be collected. Construction equipment must be operated in a manner to ensure that the settlement platforms are not damaged or displaced laterally. Each assembly shall be clearly marked and flagged with ground stakes or protective barricades, if appropriate.

7.6 Although settlement platforms are generally used for relatively short-term applications, there may be some cases where long-term performance is a consideration. Issues such as their performance over extended periods of time as well as corrosion of the components should be appropriately considered. For cases where factors such as backfill materials and methods, down-drag, isolation casing alternatives or effects of the instrument on load distributions are likely to impact the precision of the recorded measurements, appropriate procedures are identified on a case by case basis.

7.7 The number and spacing of settlement platforms is project dependent and therefore no specific guidelines are presented in this standard.

8. Report

8.1 For settlement platform measurements, report the following information:

8.1.1 Settlement platform identification and initial elevation

8.1.2 Reference point type

8.1.3 Elevation of the reference point

8.1.4 Description of measuring device(s) used

9. Keywords

9.1 monitoring fill placement; field instrumentation; settlement platforms ; vertical settlement

SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this guide since the last issue, D6598–07, that may impact the use of this guide. (Approved November 1, 2011)

(*1*) Added units statement to the Scope.
(*2*) Revised Terminology to include reference to Terminology D653.