SETTLEMENT GAGES AND SETTLEMENT RODS

GEOTECHNICAL CONTROL PROCEDURE
GCP-15
Revision #5

AUGUST 2015
GEOTECHNICAL CONTROL PROCEDURE:
SETTLEMENT GAGES AND SETTLEMENT RODS

GCP-15
Revision #5

STATE OF NEW YORK
DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL ENGINEERING BUREAU

AUGUST 2015
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I. INTRODUCTION

This manual establishes uniform statewide procedures for fabrication, installation, documentation, maintenance and disposal of settlement gages and settlement rods.

Installation of this instrumentation is for determining the total amount and time rate of foundation settlement.

Continuing analyses of instrumentation readings during construction may indicate that a design waiting period can be reduced without detrimental effects on the final riding surface of the pavement. Moreover, actual and predicted behavior can be compared, thus improving future design methods on similar foundation materials.

II. SETTLEMENT RODS

1. **Introduction**
   A settlement rod is usually installed at subgrade elevation and indicates foundation settlement after the embankment is constructed to subgrade elevation.

2. **Fabrication and Installation**
   Settlement rods shall be installed as shown in Figure 1 at the locations shown on the plans immediately after embankment or surcharge construction is completed. The elevation of the top of the steel rod at the time of the installation shall be determined and recorded. The exposed length of pipe shall be made conspicuous, to reduce the chance of damage.

3. **Documentation and Data Collection**
   Readings for each installation are to be recorded weekly for one month commencing with the date of installation. Readings thereafter are recorded monthly until termination of the construction waiting period or otherwise for a period of time specified in the contract or by the Engineer. All readings are to be recorded, on Form GE 436 (see Figure 2), in triplicate, with one copy immediately forwarded to the Geotechnical Engineering Bureau, one to the Regional Geotechnical Engineer, and one to the project files.
Notes:

1. The pipe shall be installed to a depth of approximately 4 ft. (1.2 m) and cleaned for its full length prior to the placement of the steel rod.
2. The pipe shall be capped except during reading operations.

Figure 1 Fabrication and Installation Details for Settlement Rods
**Figure 2**

**PROJECT IDENTIFICATION**

**SETTLEMENT REPORT ROD GAGE**

- **ROD GAGE NO.**
- **STATION & OFFSET**
- **OGS ELEVATION**
- **FINAL ELEVATION**
- **FILL HEIGHT (meters)**
- **DATE INSTALLED**
- **INSTALLED BY**
- **INSPECTED BY**
- **READINGS BY**

**INITIAL ELEVATIONS**

<table>
<thead>
<tr>
<th>DATE</th>
<th>ROD ELEVATION (meters)</th>
<th>TOTAL SETTLEMENT (DIFF. FROM INITIAL) (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

**ROD ELEVATIONS**

<table>
<thead>
<tr>
<th>DATE</th>
<th>ROD ELEVATION (meters)</th>
<th>TOTAL SETTLEMENT (DIFF. FROM INITIAL) (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

One copy shall be submitted weekly to:

Director, Geotechnical Engineering Bureau  
Department of Transportation  
State Campus – Building 7  
Albany, NY 12232–0863

E.I.C.  
Telephone No.

GE 436 (3/95)
III. PIPE SETTLEMENT GAGES

A. Surface Gage

1. **Introduction**
   A pipe surface settlement gage indicates total foundation settlement behavior during and after embankment construction.

2. **Fabrication**
   The gages shall be constructed in accordance with the details shown in Figure 3.

3. **Installation**
   The gages shall be installed on level ground in accordance with the details shown in Figure 4.

   At the time of installation, an initial reference mark shall be scribed on the pipe and the mark’s elevation determined and recorded. The pipe shall be scribed to an accuracy of ¼ in. (6.3 mm) at maximum intervals of 3 ft. (1 m) measured from the initial mark. Immediately after each pipe is scribed, the graduations shall be numbered to reflect the distance in feet (meters) from the initial scribe, in a durable paint of a color contrasting with that of the rod. Any additional extensions shall be scribed as stated above.

   An adjustable hose clamp shall be placed around the pipe at the scribe mark. This clamp provides a place to rest the survey rod when determining the elevation of the scribe mark. The clamp is simply loosened and moved upward as the fill is progressed.

4. **Documentation and Data Collection**
   Readings for each installation are to be recorded weekly commencing with the start of construction and continued through the construction waiting period or for a period of time specified in the contract or by the Engineer. All readings are to be recorded, on Form GE 437, (see Figure 5), in triplicate, with one copy immediately forwarded to the Geotechnical Engineering Bureau, one to the Regional Geotechnical Engineer, and one to the project files.
Note: 1. The use of either a steel base or a wood base settlement gage shall be the Contractor’s option.

Figure 3  Pipe Surface Settlement Gage
Note: 1. Letters on schematic drawing correspond to columns on Form GE 437 (Figure 5).

Figure 4
<table>
<thead>
<tr>
<th>EMBANKMENT AREA</th>
<th>PIPE GAGE INFORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATE</td>
<td>SURFACE ELEVATION (meters)</td>
</tr>
<tr>
<td>* OGS</td>
<td></td>
</tr>
</tbody>
</table>

One copy shall be submitted weekly to:

Director, Geotechnical Engineering Bureau  
Department of Transportation  
State Campus – Building 7  
Albany, NY 12232-0863

E.I.C. ____________________________  
Telephone No. ___________________  

GE 437 (3/65)

Figure 5
B. Subsurface Gage

1. Introduction
   A pipe subsurface settlement gage measures the magnitude of settlement occurring within a portion of a foundation below the initial tip elevation of the gage. It consists of a subsurface anchor post (see Figure 6) and a protective cover.

2. Fabrication
   The protective cover shall be constructed in accordance with the details and notes shown in Figure 6.

   The subsurface anchor posts are not fabricated on the site, but purchased from a commercial supplier.

3. Installation
   These gages shall be installed at locations designated on the plans by driving or pressing the anchor post, using the outside casing (NPS 1), from the surface of the embankment foundation to the elevation specified in the plans (see Figure 7). The anchors post shall then be expanded by tapping, with a small sledge hammer, the inside pipe (NPS ¼) while the outside casing is held in a fixed position. A 3 ft. (1 m) piece of pipe is now added to the inside pipe, with the inside pipe held in a fixed position, the outside casing shall be detached at the left-hand threaded connection and retracted about 3 ft. (1 m) (see Figure 6).

   Extensions of the casing and pipe shall be added as the embankment is progressed, so that the top of the inside pipe is at no time less than 1 ft. (0.3 m) above the outside casing, or the casing at any time no less than 1 ft. (0.3 m) above the embankment surface. At the time of installation, an initial reference mark shall be scribed on the portion of the inside pipe extending above the outside casing, and the mark’s elevation determined and recorded. Each additional rod extension shall be scribed to an accuracy of ¼ in. (6.3 mm) at maximum intervals of 3 ft. (1 m) measured for the initial mark. Immediately after each pipe is scribed, the graduation shall be numbered to reflect the distance in feet (meters) from the initial scribe, in a durable paint of a color contrasting with that of the pipe. The exposed lengths of pipe and casing shall have a protective cover that is painted a conspicuous color to reduce the likelihood of damage.

   An adjustable hose clamp shall be placed around the pipe at the scribe mark. This clamp provides a place to rest the survey rod when determining the elevation of the scribe mark. The clamp is simply loosened and moved upward as the fill is progressed.
Note: 1. All wood shall be ¾ in. (19 mm) exterior plywood coated with wood preservative.

Figure 6  Pipe Subsurface Settlement Gage
4. **Documentation and Data Collection**

Readings for each installation are to be recorded weekly commencing with the date of installation and continued through the construction waiting period or for a period of time specified in the contract or by the Engineer. All readings are to be recorded, on Form GE 437, (see Figure 5), in triplicate, with one copy immediately forwarded to the Geotechnical Engineering Bureau, one to the Regional Geotechnical Engineer, and one to the project files.

---

**Note:**

1. Letters on the schematic drawing correspond to columns on Form GE 437 (Figure 5).

**Figure 7**
IV. MANOMETER SETTLEMENT GAGES

A. Surface Gage (Closed System)

1. Introduction
A manometer surface settlement gage indicates the magnitude of settlement occurring in the embankment foundation during and after embankment construction. A typical installation consists of a base and readout box, which are interconnected by two fluid lines and an air line. The manometer gage works on the principle that a fluid seeks its own level. The fluid line reflects any change in elevation between the base and readout box. The air line maintains the same atmospheric pressure at the base that exists at the readout box. The distance between the readout box and base should not exceed 230 ft. (70 m).

2. Material
The fluid used shall be a 50-50 mixture of ethylene glycol and water. The fluid shall be mixed 24 hours in advance of use, to allow any entrapped air to escape.

The tubing shall be continuous (i.e. no splices) ½ in. (12.7 mm) O.D. polyethylene and natural (milky) in color. The elbow and tee unions used (see Figure 14) shall be polypropylene, with an “O” ring seal, grab ring and spacer.

Compatible tubing and fittings manufactured by the Paraflex Division of the Parker Hannifin Corporation or an approved equal shall be used. Components and part numbers are listed below for reference purpose only.

<table>
<thead>
<tr>
<th>Component Name</th>
<th>Paraflex Part Number</th>
<th>Quantity per Manometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ in. (12.7 mm) Polyethylene Tubing</td>
<td>E-86-0500</td>
<td>As needed</td>
</tr>
<tr>
<td>Polypropylene Elbow Union</td>
<td>P8EU8</td>
<td>2</td>
</tr>
<tr>
<td>Polypropylene Tee Union</td>
<td>P8TU8</td>
<td>3</td>
</tr>
</tbody>
</table>

These components are manufactured by:
Parker Hannifin corporation
Paraflex Division
1300 N. Freedom Street
Ravenna, Ohio 44266

A list of local suppliers of tubing and fittings is available upon request from the Geotechnical Engineering Bureau.

The sand shall conform to the gradation requirements contained in §703-07 of the Standard Specifications.
3. **Fabrication**
Prior to fabrication and installation of the base and readout box, it is necessary to check for any elevation differences between locations. An appreciable difference in elevation is a governing factor in the height dimension of both the readout box and base, which is shown in Figure 8. The top of the base and readout box shall be at the same elevation.

The base, readout box, and fluid and air lines shall be constructed in accordance with the details and notes shown in Figures 9 through 14.

4. **Installation**
A trench is excavated between the proposed locations of the base and readout box. The allowable dimensions of the trench are 1 ft. (0.3 m) minimum in depth by 1 ft. (0.3 m) minimum to 2 ft. (0.6 m) maximum in width. The trench is then backfilled with a minimum of 6 in. (150 mm) of clean compacted sand with provides a cushion of the tubing. The trench bottom is to be level or have a slight downward sag with the longitudinal midpoint of the trench being the low point. This assures free movement of the fluid.

The tubing is then placed in the trench as shown in Figure 10. The tubing shall be uncoiled from the roll in such a manner that it will lay flat in the trench. It is recommended that the tubing be kept at room temperature to aid in handling. The tubing shall not be allowed to cross itself or other tubing in the trench. The middle line of tubing shall be the primary fluid line.

As the tubing is laid in the trench a shovel of sand shall be placed on the tubing a 3 ft. (1 m) intervals. This helps maintain the tubing in a parallel configuration.

The readout box and base are now placed at their respective locations. Fluid and air lines shall be temporarily secured with tape to the readout box and base and be cut at approximately 2 ft. (0.6 m) above the top of the readout box and base.

The fluid lines shall then be filled using a gravity flow system with an elevated reservoir of sufficient capacity to fill the tubing, approximately 2 ½ gal. per 165 ft. (10 L per 50 m) of tubing (see Figure 11). The reservoir is connected to the tubing at the base and fluid is allowed to run out at the readout box until it is assured that there are not entrapped air bubbles in the line. This requires inspecting the exposed tubing by walking along the trench during the filling operation.

Once the flow is stopped and the reservoir is removed, the fluid and air lines shall be cut at the base to finished length and fastened and secured as shown in Figure 13. The air line connector shall be 1 ft. (0.3 m) higher than the primary fluid line connector and the secondary fluid line connector shall be 3/8” (10 mm) lower than the primary fluid line connector as shown in Figure 14.
Figure 8    Typical Elevation Differences
Note: 1. All lumber shall be securely fastened and then coated with a wood preservative. Paints and stains are not acceptable preservatives.
2. Both the base and readout box shall be painted with a red fluorescent paint.
3. See Figures 10 through 14 for details of lines and reading scale.
4. 1 x 4 lumber bracing of the post at the base after the protective cover is in place is required.

Figure 9
Figure 10

Parallel Configuration

Fluid Lines

Air Line

Note: Tubes Should Not Cross

Figure 11  Gravity Flow System for Filling the Tube
Note: 1. A 6 ft. (1.8 m) length of wooden folding rule (predrilled for tacking) with ¼ in. (6.3 mm) graduations shall be tacked on the center of the readout box as shown.
2. The 1 ft. (0.3 m) graduation on the scale should be set at the same level as that of the fluid in the primary fluid line.

Figure 12     Readout Box
The system shall then be checked for leakage as follows:

1. Plug both fluid lines at the readout box with rubber stoppers.
2. Apply a constant air pressure of 20 psi (150 kPa) ± to the air line.
3. Spray the connections at the base with a liquid soap and observe for leakage (the presence of air bubbles will indicate leakage). The fluid levels at the base should also be at the same level. If they are not, there is a leak in the fluid lines.

After the system is proven to be free of leaks the tubing at the readout box shall be cut to final length and tacked in place as shown in Figure 12.

The window is then cut into the secondary fluid line as low as possible in the readout box (approximately 4 ft. (1.2 m) below the connector line at the base).

The next step is to add fluid slowly to the top of the primary fluid line at the readout box until fluid is observed flowing from the secondary or lower fluid line. The system should be observed at the base during this operation for movement of fluid from the primary fluid line to the secondary fluid line such that no fluid shall rise above the connector line.

The window is then cut into the primary fluid line at the readout box 6 to 8 in. (150 to 200 mm) above the fluid level in the primary line established for the previous step (i.e. 6 to 8 in. (150 to 200 mm) above the connector line at the base). This elevation should be checked with a survey level prior to cutting the window into the primary fluid line.

After the system has been checked and the base protective cover is in place, the trench shall be backfilled by hand with uncompacted sand until at least 8 in. (200 mm) of sand cover the tubing. The remainder of the uncompacted sand backfilling can be done by machine. The uncompacted sand trench will act like a flexible pipe and allow for movement of the tubing during settlement of the base. The construction of the embankment within a 3 ft. (1 m) radius of the base shall be compacted using a hand vibratory compactor until the embankment is constructed to 2 ft. (0.6 m) above the top of the base.

The final step in the installation is recording the elevations of the bottom of the base and the top of the readout box and of the initial fluid levels in the base and readout box.
Figure 13  Base
Figure 14

Detail A
5. **Readings**

   It is recommended that the manometer readings be taken in the morning hours at about the same time of day. This helps to limit temperature effects on the fluid.

   Prior to every reading a small amount of fluid (about 1 in. (25 mm)) should be added slowly to the primary or upper fluid line by means of a squeeze bottle. This is required due to the evaporation of the fluid. Wait approximately 5 minutes and repeat operation at 5 minute intervals until fluid is seen flowing from the secondary or lower fluid line. Once this occurs cease adding fluid and wait for the flow to stop. When the flow stops, record the fluid level of the primary line.

6. **Documentation and Data Collection**

   Form GE 435 (Figure 15) is used for data collection of all manometer settlement gages and is self explanatory.

   Settlement gage readings and top of readout box elevations for each installation are recorded weekly during embankment construction and monthly thereafter until termination of the construction waiting period or otherwise for a period of time specified in the contract or by the Engineer.
### PROJECT IDENTIFICATION

### SETTLEMENT REPORT MANOMETER GAGE

- MANOMETER GAGE NO.
- STATION & OFFSET
- PLATFORM BASE ELEV.
- DATE INSTALLED
- INSTALLED BY
- INSPECTED BY
- READINGS BY
- INITIALS

### EMBANKMENT AREA

<table>
<thead>
<tr>
<th>DATE</th>
<th>SURFACE ELEVATION (meters)</th>
<th>FILL HEIGHT (DIFFERENCE IN ELEV. FROM INITIAL) (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>* QGS</td>
<td></td>
<td></td>
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</table>

### READOUT TERMINAL

<table>
<thead>
<tr>
<th>SURVEY</th>
<th>FLUID LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>REFERENCE MARK ELEVATION (meters)</td>
<td>INITIAL MINUS READING (meters) (E)</td>
</tr>
<tr>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

One copy shall be submitted weekly to:

Director, Geotechnical Engineering Bureau
Department of Transportation
State Campus – Building 7
Albany, NY 12222–0883

E.I.C. ____________________________

Telephone No. ___________________
B. Subsurface Gage (Closed System)

1. Introduction
   A manometer subsurface settlement gage measures the magnitude of settlement occurring within a portion of a foundation below the initial top elevation of the gage.

   A manometer subsurface gage consists of a surface manometer readout box and a subsurface anchor point base. The details of the manometer readout box and subsurface anchor post were previously covered in this manual.

2. Fabrication
   The readout box and protective cover shall be construed as shown in Figure 16. The only difference in fabrication between the manometer subsurface gage and the manometer surface gage is that the former utilizes a subsurface anchor post as the base.

3. Installation
   The gage shall be installed as shown in Figure 16. The installation procedures are generally the same as previously described for the surface manometer and subsurface settlement gages.

4. Documentation and Data Collection
   Form GE 435 (Figure 15) is used for data collection of all manometer subsurface settlement gages.

   Settlement gage readings and readout box elevations (top of box) for each installation are recorded weekly during embankment construction and continued through the construction waiting period or for a period of time specified in the contract or by the Engineer.
Figure 16  Manometer Subsurface Settlement Gage
V. DOCUMENTATION

A. Forms and Distribution

Settlement data are to be recorded on the following forms, available from the Regional Geotechnical Engineer:

1. Settlement Gages
   a. Pipe
      i. Surface GE 437
      ii. Subsurface GE 437
   b. Manometer
      i. Surface GE 435
      ii. Subsurface GE 435

2. Settlement Rods GE 436

These are completed in triplicate for each reading interval, with one copy immediately forwarded to the Geotechnical Engineering Bureau, one to the Regional Geotechnical Engineer, and one to the project files.

B. Responsibility and Format for Data Collection

The Project Engineer is responsible for obtaining all settlement gage and rod readings, with elevations read and recorded to a precision of ¼ in. (6.3 mm).

C. Frequency of Data Collection

The Geotechnical Engineering Bureau may alter the reading schedule for settlement platforms and/or settlement rods when encountering unusual foundation conditions. When this occurs, the Geotechnical Engineering Bureau will forward the altered reading schedule to the Regional Geotechnical Engineer with a copy for the Project Engineer.

VI. MAINTENANCE

When an installation is disturbed or damaged to the extent that integrity of the data is lost or compromised, the Project Engineer is to notify the Regional Geotechnical Engineer, who with the Geotechnical Engineering Bureau, will determine whether to re-establish or abandon it. If an installation is damaged after fulfilling its intended function, the State may waive the corrective maintenance and order the damaged installation abandoned in accordance with Part VII of this manual. Final payment as stipulated in the item specifications will be made when such an action is ordered.
A. Settlement Gages

1. Pipes
   Bent or broken sections of pipe gages shall be replaced or repaired as necessary to provide a satisfactory plumb installation. Following corrective work on pipe gages, the scribe marks will be accurately re-established by one of the following methods:
   
a. from an undisturbed scribe mark,
   b. by sounding to the gage base, or
   c. by establishing another scribe mark in accordance with Part III of this manual.

   The Project Engineer enters in the regular settlement gage report the date damage occurred, the date it was corrected, and if necessary the newly established initial readings. The Contractor may elect to replace any damaged installation in accordance with Part III of this manual, except that in the case of a pipe settlement gage the level surface for the new base shall be a minimum of 4 ft. (1.2 m) below the existing embankment surface. When a replacement settlement gage is installed, the damaged gage shall be abandoned in accordance with Part VII of this manual.

2. Manometers
   Manometer bases damaged or disturbed before the embankment surface is 5 ft. (1.5 m) above the top of the protective cover shall be re-established in compliance with the requirements of Part IV of this manual. After the embankment surface has exceeded 5 ft. (1.5 m), the Contractor has no further responsibility for the manometer base. The Contractor shall, however, maintain the readout box so that the requirements of Part IV of this manual are complied with throughout the construction waiting period.

VII. DISPOSAL

All settlement gages and rods shall be abandoned after termination of the construction waiting period, unless the Geotechnical Engineering Bureau requests in writing that installations be retained for future readings. Procedures for abandonment are as follows:

A. Settlement Gages

1. Pipes
   Within the subgrade area, the pipe of an abandoned installation shall be removed to a minimum of 2 ft. (0.6 m) below subgrade surface or existing embankment surface, whichever is lower, then capped and the void backfilled and compacted in conformance with the general specification for excavation and embankment.

   Outside the subgrade area, the pipe of an abandoned installation shall be removed at least 2 ft. (0.6 m) below the final embankment surface or existing embankment.
surface, whichever is lower, then capped and the void backfilled in conformance with the requirement of the general specifications for excavation and embankment.

2. Manometers

   The abandoned manometer base shall be left in place and the readout box shall be removed as ordered by the Engineer.

B. Settlement Rods

   Each settlement rod shall be removed and the void backfilled and compacted in conformance with the general specifications for excavation and embankment.