VW Settlement Cell

52612099

This equipment should be installed, maintained, and operated by technically qualified personnel. Any errors or omissions in data, or the interpretation of data, are not the responsibility of Slope Indicator Company. The information herein is subject to change without notification.

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Introduction

Introduction

The VW settlement cell is designed to measure settlements in construction areas which are inaccessible to standard optical survey techniques. It is especially useful in measuring large changes in settlement under earth dams, landfills, and soft soils.

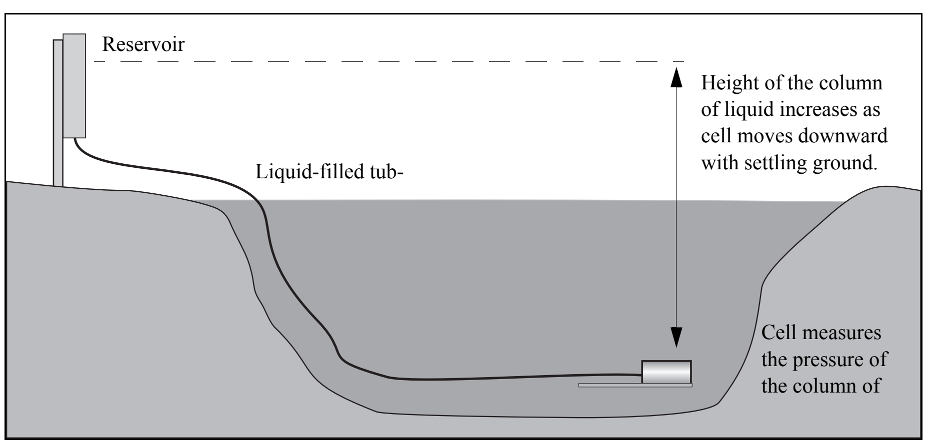
Theory of Operation

A settlement cell is a device used to monitor settlements in embankments, fills, and foundation soil. It provides a single point measurement of settlement or heave.

The settlement cell consists of three components: a liquid filled tube, a pressure transducer, and a reservoir of liquid. One end of the tubing is connected to the pressure transducer, which is embedded in the soil. The other end of the tubing is connected to the reservoir, which is located at a higher elevation on stable ground, away from construction activity.

The transducer measures the pressure created by the column of liquid in the tubing. The height of the column is equal to the difference in elevation between the transducer and the reservoir. As the transducer settles with the surrounding soil, the height of the column increases and the transducer measures a higher pressure.

Settlement is calculated by converting changes in pressure to millimeters or inches of liquid head.



Components

Components of the settlement cell system are:

VW Settlement Cell

The settlement cell is supplied with tubing and signal cable attached. An optional settlement plate may be included.

Tubing

Twin 3/16-inch diameter tubes bundled inside a polyethylene jacket. Tubing is pre-filled with de-aired liquid and is terminated with two quick-connect fittings that connect to the reservoir. Above-ground runs of tubing should be kept as short as possible.

Signal Cable

Signal cable is bundled with the liquid-filled tubing.

Reservoir

The simple vented reservoir accommodates one settlement cell and is suitable for manual or automated readings. Its liquid level must be maintained regularly.

The motorized, constant-level reservoir and connection manifold accommodates eight or more cells and is suitable for long-term unattended monitoring.

Barometer

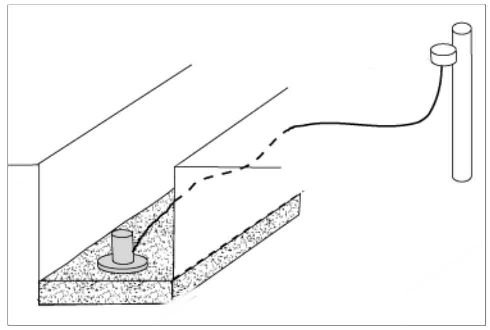
A on-site barometer is used to record atmospheric pressure at the same time that a settlement cell reading is taken. Variations in atmospheric pressure can change settlement cell readings ± six inches (150 mm) or more when no actual settlement or heave has occurred.

The barometer reading must be obtained on site at the same elevation as the reservoir. The barometer should provide station pressure, i.e. the actual pressure of the atmosphere, with no adjustment for elevation above sea level.

Reports from weather stations are not adequate for two reasons: they are no on site, and they usually report a normalized pressure, which is useful for tracking movements of weather fronts, but not suitable for correcting settlement readings.

Installation of the Settlement Cell

Installing the Settlement Cell



1. Stake out locations for the settlement cell, the reservoir, and the connecting trench.
2. Excavate the trench to the depth and width specified by the designer. The trench should be deep enough so that the cell will be protected from roller compactors.
3. Remove sharp stones and rocks and place a 100 mm layer of wet, fine sand on the bottom of the trench.
4. Attach the optional settlement plate to the bottom of the cell. Place the settlement cell and note its serial number.
5. (0ptional) Survey the exact elevation of the cell.
6. Cover the cell with at least 100 mm of hand-compacted sand.

Install Tubing and Cable

1. Route cables and tubing along the trench. Some installers make loops in the cable and tubing where it exits the sensor and at any location where the trench changes direction or elevation.
2. Place a layer of sand over the cable and tubing. Hand compact the sand. Then backfill the remainder of the trench with hand-compacted select fill. Keep in mind that subsequent layers of fill will be compacted by heavy rollers, so the fill that you are placing now must protect the sensor, cable, and tubing.

Install the Reservoir

1. Mount the reservoir on a wall or post that is outside the area affected by settlement. The best location would be one that keeps the reservoir out of direct sunlight and also minimizes the length of tubing that is above ground. The idea is to minimize temperature changes in the liquid. Note that you should probably test the system before mounting the reservoir permanently. See test instructions below.
2. Fill reservoir with deaired liquid. Allow liquid to bleed from quick-connect plugs. In the future, you will be replenishing the liquid in the reservoir when it evaporates. We recommend that you replace the evaporated liquid with just water, since water is the component that accounts for most of the evaporation. The water does not have to be deaired.
3. Fill quick-connect sockets (on tubing from cell) with deaired liquid, then press onto the quick-connect plugs. Note that liquid is under pressure in the tubing and excess liquid may splash out when you make the connection.

Terminate Signal Cable

Connect signal cable to data logger or terminal box.

Test the System

This test checks the response of the cell to changes in the elevation of the reservoir. Since the test occurs over a short period of time, you do not need to correct for barometric pressure.

1. Take a reading of the settlement cell.
2. Move the reservoir upwards 0.5 meters from its initial position. Take another reading.
3. Move the reservoir downwards 0.5 meters from its initial position. Take a third reading.
4. Convert the readings to head of water. The second and third readings should show a 0.5 m change in head. Note that the calculated head is approximate, not absolute.
5. After testing, mount the reservoir at its permanent elevation

Obtain Initial Readings

Record pressure and temperature from the VW settlement cell. Also record barometric pressure.

Taking Readings

Introduction

These instructions tell how to read the VW piezometer with Slope Indicator's portable readouts. Instructions for reading VW sensors with a Campbell Scientific CR10 can be found at www.slopeindicator.com. Go to Support - Tech Notes and click on the link titled "CR10-VW Sensors."

Overview

1. Before you take readings, you must maintain the level of the liquid in the reservoir. To do this, you remove the cover and the plug from the overflow tube. Add water and allow it to run out the overflow tube. Then take a reading. When you are done, replace the cover and plug. Obtain a temperature reading at the same time. Note that the temperature reading is the temperature at the cell, which is buried.
2. Obtain barometer reading. The barometer reading must be obtained on site at the same elevation as the reservoir. The barometer should provide station pressure, i.e. the actual pressure of the atmosphere, with no adjustment for elevation above sea level. Reports from weather stations are not adequate for two reasons: they are no on site, and they usually report a normalized pressure, which is useful for tracking movements of weather fronts, but not suitable for correcting settlement readings.

Reading with the VW Data Recorder

1. Connect signal cable to the data recorder:

Binding Posts	Wire Colors	
VW	Orange	Red
VW	White & Orange	Black
TEMP	Blue	White
TEMP	White & Blue	Green
SHIELD	Shield	Shield

2. Choose Hz + RTD or Hz + Thermistor.
3. Select the 1400-3500 Hz range.
4. The recorder displays a pressure reading in Hz and a temperature reading in degrees C.
5. Also, record barometric pressure with barometer.

Reading with the VWP Indicator

1. Connect signal cable to the jumper (52611950) from the VWP indicator, as shown in the table below.

Clips	Wire Colors		Function
Red	Orange	Red	VW
Red	White & Orange	Black	VW
Black	Blue	White	TEMP
Black	White & Blue	Green	TEMP

2. Read the settlement cell: Select the 1.4-3.5 kHz range with the Sweep key. Select Hz with the Data key.
3. Read the temperature sensor: Select °C with the Data key. Note that the VWP Indicator reads RTDs only and cannot read thermistors.

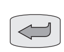
Reading with the DataMate MP

The DataMate MP allows you to choose engineering units for your readings. However, for ease of data reduction, we recommend that you record readings in Hz. See the DataMate MP user manual for directions on programming.

Manual Mode

1. Connect signal cable to the DataMate's bare wire adaptor (BWA), as shown below:

Terminals on BWA or Terminal Box	Wire Colors		Function
5	Blue	White	RTD
6	White & Orange	Black	VW
7	White & Blue	Green	RTD
8	Orange	Red	VW
10	Shield	Shield	Shield

2. Switch on. Press  (Manual Mode).
3. Scroll through the list to find "Vibrating Wire Hz."
4. Press  to excite the sensor and display a pressure reading in Hz and a temperature reading in degrees C. Note that this setting provides readings only for RTDs, not thermistors
5. Obtain barometer reading separately.

Data Reduction

Overview

For each settlement measurement, you have collected three readings: a frequency reading, a temperature reading, and a barometer reading.

1. Convert the frequency reading to pressure in psi or bar, using the factors supplied on the sensor calibration record. Note that each cell has unique factors. This is the cell pressure.
2. Calculate and apply a barometric correction.
3. Convert the corrected cell pressure to meters or feet of liquid head.
4. Calculate settlement or heave by subtracting the initial head from the current head.

Step 1 Convert frequency reading to psi or bar

Convert the Hz reading to psi or bar using the "manual" ABC factors found on the sensor calibration record:

Cell Pressure = $AF^2 + BF + C$, where F is the sensor reading in Hz.

Step 2 Calculate and apply barometric correction.

1. Subtract the barometer reading from 1 atm (1013.25 mb or 29.92 inches of mercury). This is the barometric correction value in mb or in Hg.

   Barometric Correction = 1 atm - barometer reading.

2. Convert the barometric correction value to psi or bar.

Starting Unit	Multiplier	Resulting Unit
millibar	0.001	bar
	0.014.503	psi
Inch Hg	0.03386e	bar
	0.49115	psi

3. Add the barometric correction to the cell pressure. This is the corrected cell pressure.

   Corrected Cell Pressure = Cell Pressure + Barometric Correction.

Step 3 Convert corrected cell pressure to head of water

Convert the corrected cell pressure to head of water using one of the conversion factors below.

Head of Water = Corrected Cell Pressure x Conversion Factor

Starting Unit	Multiplier	Resulting Unit
psi	27.73	inch
	2.31	feet
	704.3	mm
	0.7043	m
bar	10215	mm
	10.215	m

Step 4 Calculate Settlement

The change in head of water represents settlement or heave. If the change is positive, settlement has occurred. If the change is negative, heave has occurred:

$$\text{Change in Water Head} = \text{Water Head}_{current} - \text{Water Head}_{initial}$$

Optional Adjustments

Correcting for density of liquid

The deaired liquid supplied with the settlement cell is a 50/50 mixture of water and ethylene glycol, which is about 7% heavier than water. This is normally not an issue, since settlement involves changes rather than absolute values.

The table below shows how the density of the water/ethylene glycol mix varies with temperature. To calculate the actual head of liquid, divide the head of water value by the appropriate value in the table below. This is normally 1.07.

Before you decide to use these values, consider that the temperature of the column of liquid is unlikely to be uniform. Buried tubing in moderate climates tends to stay between 10 and 15 degrees C. However, the temperature of the liquid in tubing that is not buried, including the liquid in the reservoir, can vary significantly during the day.

Head of 50/50 Ethylene Glycol/Water = Water Head / Density Factor

Temperature,ºC	Density Factor
-10	1.0800
-5	1.0775
0	1.0750
5	1.0725
10	1.0700
15	1.0672
20	1.0645
25	1.0617
30	1.0590
35	1.0560
40	1.0530

Using the Temperature Reading

The temperature reading obtained from the RTD or thermistor is the temperature at the sensor. Since the temperature coefficient of the sensor is quite small, and the temperature around the buried sensor is fairly stable, it is generally not useful to correct the sensor output for temperature changes.

If utmost accuracy is required, it is more useful to apply the temperature reading of the sensor in calculations of water density, which is addressed above.

Appendix A
Constant-Level Reservoir

Introduction

This appendix tells how to install the motorized, constant-level reservoir.

Components

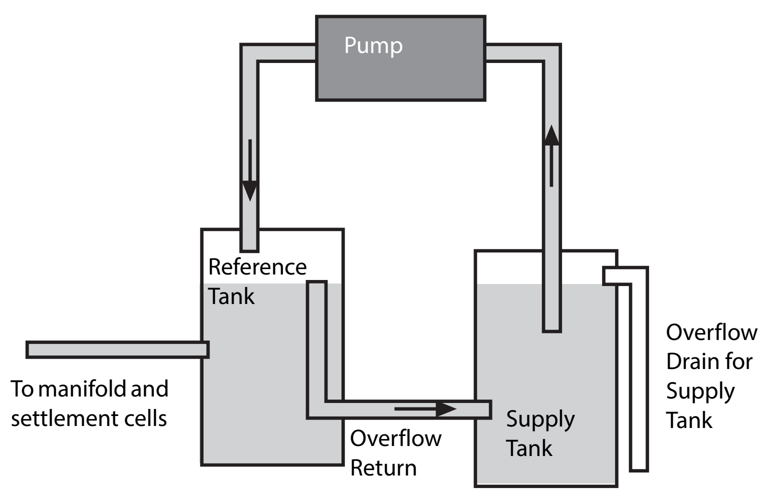
- Reservoir with two tanks and an overflow pump. This is enclosed in a box.
- Connection manifold (one or more). The connection manifold is enclosed in a separate box.
- Tubing to connect manifolds to the reservoir.
- De-aired liquid to fill reservoir and manifolds.

Requirements

- AC power for the overflow pump.

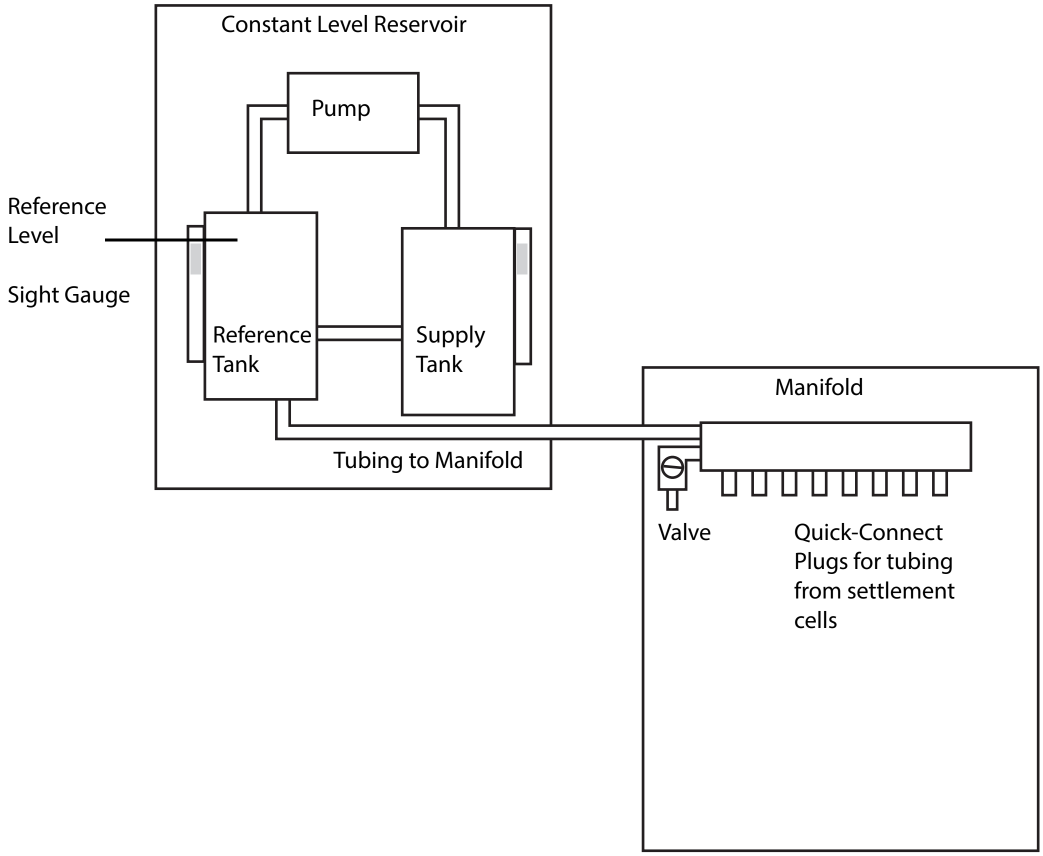
Operation

The constant-level reservoir has a reference tank with an overflow tube and a supply tank with a pump. Liquid is pumped slowly from the supply tank to the reference tank. The level in the reference tank remains constant because excess water flows out the overflow tube and back into the supply tank. Liquid must be added to the supply tank from time to time to replace liquid that has evaporated. Level sensors in the tanks signal the data logger when the liquid level is too low.



Setup

The schematic below shows the basic components and layout of the constant-level reservoir.



1. Mount reservoir and the manifold on a wall. Manifold must be mounted at lower elevation than the reservoir. Devise means of protecting reservoir and manifold from direct sunlight.

2. Connect tubing from reference tank to manifold. Open valve of manifold so that air can escape.

3. Fill system with liquid, starting at the reference tank and supply tank. For now, check that overflow tube on supply tank is capped. When both tanks are full, liquid flows through tubing to manifold and eventually exits from valve at end of manifold when system is full.

4. Bleed liquid through each quick connect plug to ensure that air is eliminated from system.

5. If there is a second manifold, connect it to the first manifold, then fill with liquid and eliminate air from system.

6. Connect settlement cells to manifolds. Tubing from settle-

ment cell is terminated in quick-connect sockets. Fill each quick connect socket with deaired liquid before you connect it to the manifold. Connect to any available plugs on the manifold.

7. Connect reservoir level switches to CR10 system. Connect settlement cell signal cables to CR10 system. Electrical connections are provided in a different document.

8. Start pump. The pump moves liquid from the reservoir tank into the overflow tank. It works very slowly (3 ml per minute) to maintain a constant level of liquid in the overflow tank. Any excess liquid drains out of the overflow tank and is returned to the reservoir tank. Because the pump works so slowly, it may take some time for the overflow action to begin. It is difficult to see the overflow, so to verify that the pump is working, you may have to touch to top of the overflow tube to feel the water.

9. Check level of liquid in supply tank. Uncap overflow tube to allow excess liquid to drain away. Overflow tube should remain uncapped.

Electrical Connections

All electrical connections are documented in a wiring diagram supplied with the data logger.

Appendix B
Acceptance Tests

Introduction

The main purpose of an acceptance test is to provide reasonable assurance that a sensor is functioning properly. Unless you have access to sophisticated test facilities and calibration equipment, acceptance tests should not be expected to achieve the accuracy and precision of the calibration data provided on the sensor calibration record. Thus when you evaluate the results of an acceptance test, look for obvious non-conformance rather than an exact match between your data and the data on the calibration record.

Quick Zero Check

1. Ideally, this test would be conducted in a draft-free room where the settlement cell and reservoir can be kept at a constant temperature. At a minimum, the settlement cell and reservoir should be placed in a location that is out of direct sunlight and allowed to reach thermal equilibrium with the surface it is resting on and the surrounding air. This takes approximately one hour. Do not handle any of the components during this time or during the test.

2. The reservoir should be mounted upright and have de-aired liquid added to verify that it is at its top level. Ideally, the diaphragm of the settlement cell should be at the same elevation (within ±1 inch) as the top of the fluid level in the reservoir.

3. Connect the signal cable to the readout and obtain a frequency reading. Check that you have obtained a repeatable reading.

4. Apply calibration factors to convert the frequency to a pressure reading in psi.

5. If your local elevation is above sea level, the pressure reading that you obtain will most likely be negative because the sensor calibration is referenced to one standard atmosphere (sea level). To calculate an approximate correction for elevation, allow 0.5 psi for every 1,000 feet of elevation above sea level (0.1 kPa per 10 m). Add the correction to your reading. For example, if the elevation is 5,000 feet, add a correction of 2.5 psi to the pressure reading.

6. The settlement cell is working satisfactorily if the difference

between the corrected pressure and zero is within 2 percent of the full scale of the piezometer (2 psi for a 100 psi piezometer).

7. To make a more precise check, you would correct for the true altitude, the barometric pressure, and the temperature.

Pressure Check

This test is conducted in a place where you can secure the settlement cell at a fixed location and have the ability to place the reservoir at 2 or 3 different elevations (for example, 10 and 50 ft). In order to perform an accurate check, you should maximize the elevation difference between the settlement cell and the reservoir. You will need the sensor calibration sheet.

1. Place the reservoir at the first reading elevation (minimum of 10 ft above the settlement cell).
2. Measure the elevation difference between the reservoir and the settlement cell to within ±1 inch. Measure from the location of the upper surface of the settlement plate to the upper level of the liquid in the reservoir.
3. Add de-aired liquid to be sure the reservoir is at its top level.
4. Secure the reservoir and wait for at least one hour for the system to adjust to the ambient temperature. Be sure that the settlement cell, tubing and reservoir are not exposed to direct sunlight. Connect the settlement cell signal cable to the readout device. Check that you can obtain repeatable readings. Record the frequency reading and the temperature reading at the shallow elevation.
5. Raise the reservoir to the next elevation. The settlement cell should not be moved and should be located at exactly the same position and have the same reference used for the previous reading. Allow the system (settlement cell, tubing and reservoir) to adjust to the ambient temperature at that elevation (at least one hour). Check that you have repeatable readings, then record the frequency reading, and the temperature reading.
6. Repeat until all readings have been obtained.
7. Convert the hertz readings to units of pressure by applying the calibration factors specific to the settlement cell.
8. Subtract the shallow elevation from the highest elevation. We do this to avoid having to correcting for altitude.
9. Convert both pressure values to feet or meters of liquid head

(using the conversion factors on page 8 of this manual) and compare to the distance between the two chosen elevations

10. There are many variables that can degrade the accuracy of this test, including positioning errors, the specific gravity of the de-aired liquid, the temperature of the reservoir at each elevation, etc. You can attempt to correct for these, but the real purpose of the test is to verify that the settlement cell is reacting to an elevation change and is giving you roughly the reading that you would expect.

11. This is an acceptance test and you should not use this procedure to calibrate the Settlement Cell. The factory calibration is done under controlled conditions and is far more precise.