Portable Digitilt Tiltmeter

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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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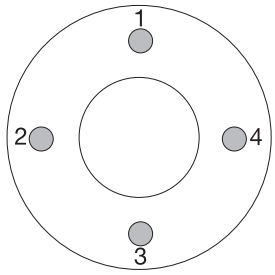
Introduction

The Portable Digitilt Tiltmeter System

The Digitilt Tiltmeter System consists of three components: Tilt plates, tiltmeter, and readout.

Tilt plate

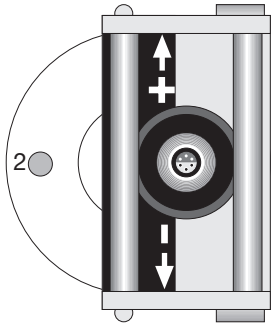
The tilt plate is a bronze disc about 5.5 inches (140mm) in diameter. It is fixed to the structure with grout or screws. The four pegs on the tilt plate are used to orient the tiltmeter.



Horizontally-mounted tilt plates allow tilt readings in two planes that are 90 degrees apart. Vertically-mounted tilt plates allow tilt readings in one plane.

Tiltmeter

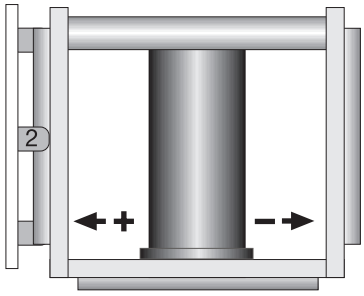
The portable tiltmeter is carried from tilt plate to tilt plate to obtain readings. Alignment bars on the bottom and two sides of the tiltmeter are used to position the tiltmeter on the tilt plate.



Tiltmeter placed onto a horizontal tilt plate.

Two readings are taken for each tilt plane, one reading in the plus (+) direction and one reading in the minus (-) direction.

The base plate of the tiltmeter has + and - marks to assist proper orientation of the tiltmeter.



Tiltmeter placed against a vertical tilt plate.

Readout

The Digitilt readout displays tilt readings in "Digitilt units" rather than degrees of tilt. Digitilt units are integers and are easy to work with. The reading is signed (+ or -) according to the direction of tilt.

Metric Tiltmeters: Readings from metric tiltmeters are displayed as 25000 x the sine of the angle of tilt. For example, a tilt of 30 degrees is displayed as 12500.

English Tiltmeters: Readings from English tiltmeters are displayed as 20000 x the sine of the angle of tilt. For example, a tilt of 30 degrees is shown as 10000.

Note: Older readouts, such as the Digitilt 09 Indicator, display a decimal in the reading. Later readouts omit the decimal. This manual assumes that you will write the number as an integer (no decimal). For example, a reading displayed as 1.2500 should be written as 12500, and a reading of 0.0360 should be written as 360.

Installation of Tilt Plates

Introduction

Location: Tilt plates should be placed on structural members that are representative of the larger structure. When a single location does not adequately represent the structure, additional tilt plates should be placed at other locations.

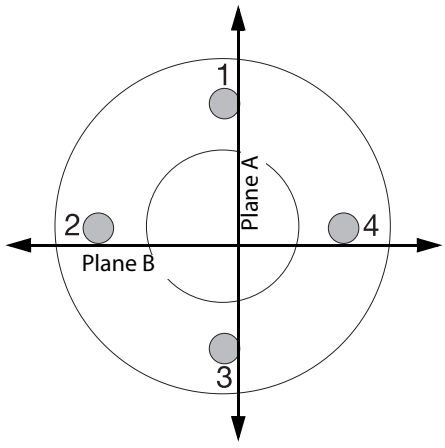
The number of tilt plates needed is determined by the stiffness of the structure and the accuracy desired. Stiffer structures require fewer plates. Higher accuracy requires more plates.

Orientation: Tilt plates are generally placed with one set of pegs oriented to the expected direction of rotation. Tilt plates can also be oriented to a survey grid.

Access: Portable tiltmeters are read manually, so the tilt plate must mounted in a place that is easy to reach.

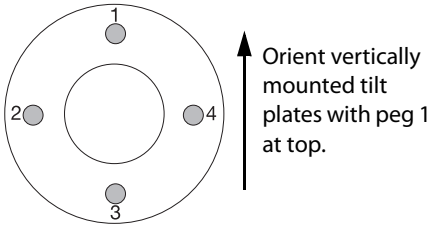
Orientation of Horizontal Tilt Plates

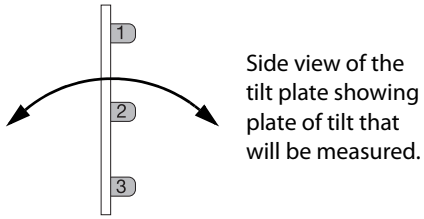
Horizontal plates provide two planes of measurement. Plane A is defined by pegs 1 and 3. Peg 1 is usually oriented toward the direction of tilt. Plane B is defined by pegs 2 and 4. Peg 4 is usually oriented toward the direction of tilt.



Orientation of Vertical Tilt Plates

Vertical tilt plates should be aligned so that a vertical line can be drawn through pegs 1 and 3.





Mounting Tilt Plates

Tilt plates can be fixed to the structure with anchors and screws or with grout. When the tilt plate will see temperature changes or weather, a combination of both anchors and grout works best.

Anchors and Screws

1. Prepare a clean, flat surface.
2. Place the tiltmeter onto the structure in its intended orientation. Mark locations for anchors.
3. Drill holes large enough and deep enough to accommodate anchors. Groutable anchors are recommended.
4. Screw tilt plate onto anchors. Use 1/4-inch diameter, flat head screws or an equivalent.
5. Fill holes with grout, then press tilt plate into place. Check that plate is horizontal or vertical. Check that no grout adheres to the pegs.

Grout Only

1. Prepare a clean surface.
2. Place a pad of grout thick enough so that the tilt plate can be pressed into it and levelled.
3. Orient the plate correctly and press it into the grout. Allow grout to enter the screw holes and overlap the edges of the plate. Check that no grout adheres to the pegs.

Taking Readings

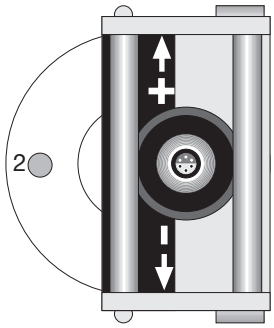
Set Up

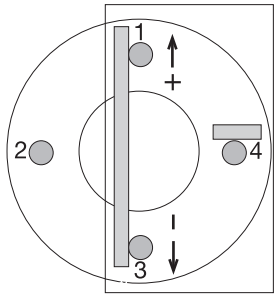
Allow the tiltmeter to adjust to ambient temperature. If possible, store the tiltmeter at the same temperature as the reading environment. Connect the tiltmeter to the readout and power up. Check your log book or data sheet to find the proper orientation for the tiltmeter. A sample data sheet is provided at the end of this chapter.

Reading Horizontal Tilt Plates

1. Take the A readings first. In the drawings below, pegs 1 and 3 define the A plane. Place the "+" end of the tiltmeter on peg 1, wait for a stable reading, and then record it on your data sheet. Then rotate the tiltmeter 180 degrees and place the "-" end of the tiltmeter on peg 1, wait for a stable reading, and record it.
2. Repeat these steps three times to ensure that you have good, repeatable readings. In theory, A+ and A- readings would be identical except for a different sign (+/-). In practice, you will see a difference of up to 50 units between the two readings due to the bias of the sensor and small irregularities of the tilt plate.

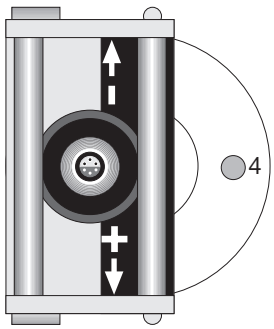
Take the A+ reading with the + end of the tiltmeter on peg 1.

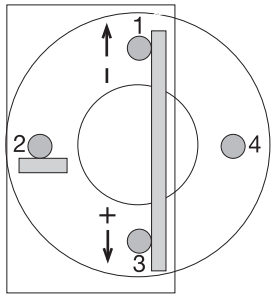




The alignment bars on the bottom of the tiltmeter touch three pegs.

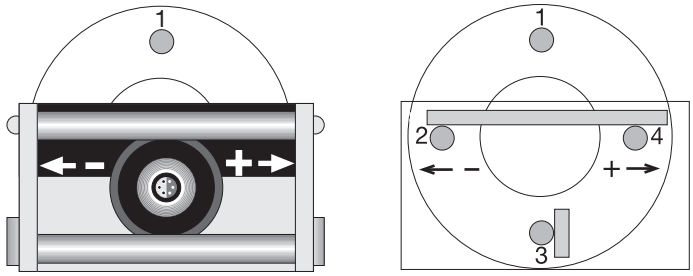
Rotate the tiltmeter 180 degrees, and take the A- reading with the - end of the tiltmeter on peg 1.





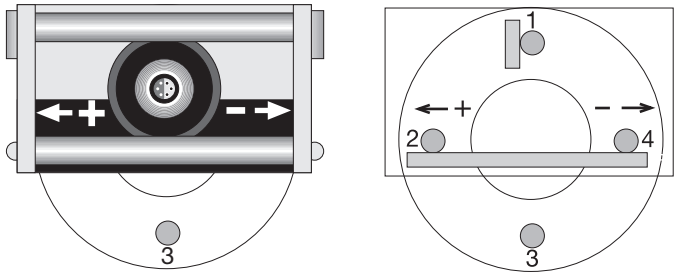
3. Take the B-plane readings next. The B plane is defined by pegs 2 and 4. Place the "+" end of the tiltmeter on peg 4, wait for the reading to stabilize, then note the reading. Then rotate the tiltmeter 180 degrees and place the "-" end of the tiltmeter on peg 4. Again, wait for the reading to stabilize and then note it.

Take the B+ reading with the + end of the tiltmeter on peg 4.



The alignment bars on the bottom of the tiltmeter touch three pegs.

Rotate the tiltmeter 180 degrees and take the B- reading with the - end of the tiltmeter on peg 4.



Reading Vertical Tilt Plates

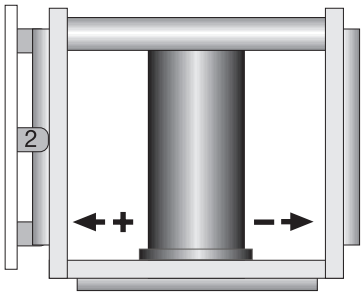
Vertical tilt plates allow readings for one tilt plane, the plane defined by pegs 1 and 3. The tiltmeter is aligned using the alignment bars on the ends of the tiltmeter.

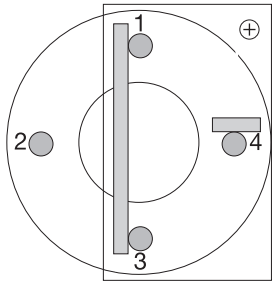
Record the A+ reading first. Place the "+" end of the tiltmeter against pegs 1 and 3. (The plus is marked on the base plate of the tiltmeter). Wait for readings to stabilize, then note the reading.

Record the A- reading next. Place the "-" end the tiltmeter against pegs 1 and 3, wait for readings to stabilize, then note the reading

Repeat these steps three times to ensure that you have a good repeatable reading.

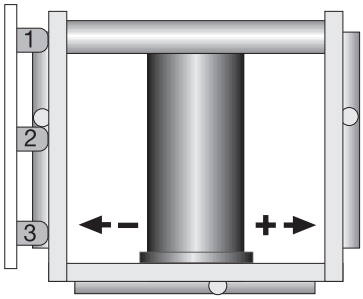
Take the A+ reading with the + end of the tiltmeter placed against pegs 1, 3, and 4.

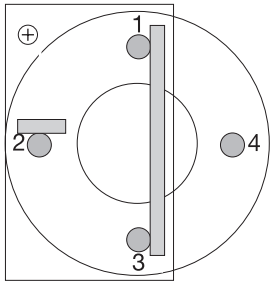




The alignment bars on the side of the tiltmeter touch three pegs.

Rotate the tiltmeter 180 degrees and take the A- reading with the - end of the tiltmeter placed against pegs 1, 3, and 2.





Field Data Sheets

Sample datasheets are provided on the following two pages: a "Basic" data sheet and an "Old Style" data sheet.

Basic Data Sheet

Use the Basic data sheet if you plan to input data into a spreadsheet on your computer. Use one sheet per tilt plate.

Tilt Plate: Enter a tilt plate number or ID.

Location: Tell where the tiltmeter can be found.

Peg for A+ Reading: Enter a peg number from 1 to 4. The A+ reading is usually taken on Peg 1.

Peg for B+ Reading: Enter a peg number from 1 to 4. The B+ reading is usually taken on Peg 4.

Date, Time, and Temperature: Record this data each time you take a set of readings.

A+and A-: Enter the A plane readings. Ignore the decimal point displayed by older readouts. For example, a reading of 1.2500 should be written as 12500, and a reading of 0.0360 should be written as 360.

B+ and B-: Enter the B plane readings. With vertical tiltmeters there are no B plane readings

Old Style Data Sheet

This is the original style data sheet developed when users did not have computer and spreadsheets. It includes some values used for data reduction.

Tilt Plate: Enter a tilt plate number or ID.

Location: Tell where the tiltmeter can be found.

Peg for A+ Reading: Enter a peg number from 1 to 4. The A+ reading is usually taken on Peg 1.

Peg for B+ Reading: Enter a peg number from 1 to 4. The B+ reading is usually taken on Peg 4.

Date, Time, and Temperature: Record this data each time you take a set of readings.

A+and A-: Enter the A plane readings.

Diff: Enter the value of (A+) minus (A-). This the algebraic difference of A+ and A-).

Change: The initial Change is simply the initial Diff value. Subsequent Change values are the current Diff minus the initial Diff.

B Readings, Diff and Change: Enter as with A plane readings.

Tiltmeter Data Sheet

Tilt Plate Number: Peg for A+ Reading:

Location: Peg for B+ Reading:

Date	Time	Temperature	A+	A-	B+	B-

Tiltmeter Data Sheet

Tilt Plate Number: Peg for A+ Reading:

Location: Peg for B+ Reading:

Date	Time	Temp	A+	A-	Diff	Change	B+	B-	Diff	Change

Data Reduction

Overview

We are generally interested in finding the change in the tilt of the structure. To find change in tilt, we subtract the initial tilt from the current tilt and convert the result to degrees or units of displacement.

To find the rate of change, plot change in tilt in degrees or displacement against days.

Displayed Readings

Slope Indicator readouts display "Digitilt units" rather than angles or deviation. Digitilt units are defined below:

$$\text{Displayed Reading} = \sin\theta \times \text{Instrument Constant}$$

$$\text{Reading}_{\text{English}} = \sin\theta \times 20{,}000$$

$$\text{Reading}_{\text{Metric}} = \sin\theta \times 25{,}000$$

Combining the + and - Readings

We obtain two readings for each tilt plane, a "+" reading and a "-" reading. In the data reduction process, combine the two readings to eliminate sensor bias. We call the resulting value "DIFF" (for algebraic difference). A positive DIFF value indicates tilt toward the + end of the tiltmeter.

$$\text{DIFF} = (+\text{Reading}) - (-\text{Reading})$$

Calculating Tilt

To convert the DIFF value to degrees of tilt, we divide it by 2 x the instrument constant and apply the arc sine function. Metric tiltmeter have an instrument constant of 25000. English tiltmeters have an instrument constant of 20000. A positive tilt angle indicates tilt toward the + end of the tiltmeter.

$$\text{Angle of Tilt} = \text{asin}\left(\frac{\text{DIFF}}{2 \times \text{Instrument Constant}}\right)$$

We divide by 2 because the DIFF value comprises 2 readings.

Calculating Change in Tilt

To find the change in tilt (in degrees), subtract the initial DIFF from the current DIFF, divide by 2 x the instrument constant, and apply the arc sin function. A positive change in tilt indicates tilt toward the + end of the tiltmeter:

$$\text{Change in Tilt} = \text{asin}\left(\frac{\text{Change in DIFF}}{2 \times \text{Instrument Constant}}\right)$$

Example

Find the change in tilt in degrees and units of displacement.

Combine + and - Readings

Find the algebraic difference of the + and - readings. Be sure to keep the sign, since this shows the direction of tilt. In the example below, the "+" reading was 533, and the "-" reading was -513:

$$\begin{aligned} \text{DIFF} &= (+\text{Reading}) - (-\text{Reading}) \\ &= (+533) - (-513) \\ &= +1046 \end{aligned}$$

Calculate the Change in DIFF

Subtract the initial DIFF from the current DIFF. In this example, the initial DIFF was +698.

$$\begin{aligned} \text{Change in DIFF} &= \text{Current DIFF} - \text{Initial DIFF} \\ &= (+1046) - (+698) \\ &= +348 \end{aligned}$$

Convert Change in DIFF to Degrees

To convert the Change in DIFF to degrees, divide it by 2 x the instrument constant and apply the arc sine function. The instrument constant is 25000 for metric tiltmeters and 20000 for English tiltmeters. The example below uses the English constant.

$$\begin{aligned} \text{Change in Degrees} &= \text{asin}\left(\frac{\text{Change in DIFF}}{2 \times \text{Instrument Constant}}\right) \\ &= \text{asin}\left(\frac{348}{2 \times 20000}\right) \\ &= \text{asin}(0.0087) \\ &= 0.49847 \end{aligned}$$

Convert Change in DIFF to Displacement

To convert the Change in DIFF to units of displacement, divide the change value by 2 x the instrument constant and multiply by a length. In the example below, we have an English tiltmeter and assume that its tilt reading represents a 4 foot span of the structure. We want our displacement value to be in inches, so we will multiply by 48 inches.

$$\begin{aligned} \text{Displacement} &= \text{Length} \times \frac{\text{Change in DIFF}}{2 \times \text{Instrument Constant}} \\ &= 48 \times \frac{348}{2 \times 20000} \\ &= 48 \times \frac{348}{2 \times 20000} \\ &= 0.4176 \text{ inches} \end{aligned}$$