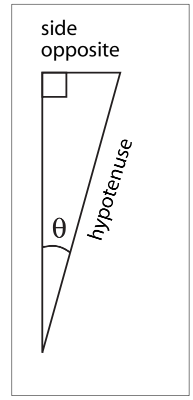
Data Reduction

Inclinometer Measurements

We use inclinometers to monitor lateral movements, but the inclinometer probe measures tilt. How is tilt translated to a lateral movement?

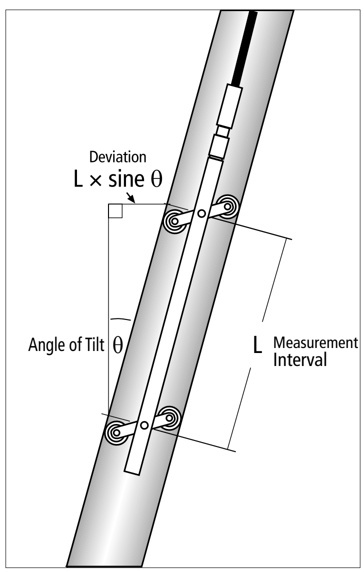
The basic principle involves the sine function, an angle, and the hypotenuse of a right triangle.We are interested in finding the length of the side opposite the angle θ, as shown in the drawing.



$$\sin\theta = \frac{\text{side opposite}}{\text{hypotenuse}} \quad \text{OR} \quad \text{side opposite} = \text{hypotenuse} \times \sin\theta$$

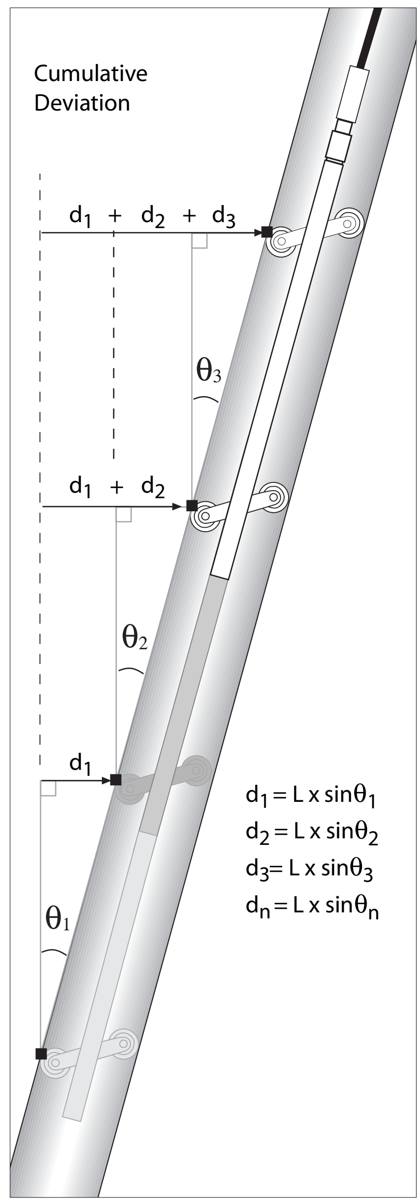
Inclinometer Terminology

The angle θ is the angle of tilt measured by the inclinometer, the hypotenuse is the "measurement interval," and the side opposite is called "deviation," as shown in the drawing below.



The deviation value at each interval is the lateral position of the top of the casing relative to the bottom of the casing at each interval. If we sum the deviations and plot them, we can see the profile of the casing.

Changes in deviation indicate lateral movement of the casing. If we sum and plot changes, we have a high resolution representation of lateral movement of the casing (and the surrounding ground).



Displayed Readings

Slope Indicator's readouts display "reading units" rather than angles or deviation. Reading 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 Readings

The standard two-pass survey provides two readings per axis for each interval. The probe is oriented in the "0" direction for the first reading and in the "180" direction for the second reading. The two-pass survey has several advantages. First, it provides a way to eliminate the sensor bias, which can change from survey to survey. Second, it provides a means of detecting error through checksums and other routines. Third, it tends to smooth the effect of random errors.

During data reduction, the two readings are combined. We find the algebraic difference of the two readings and then divide by 2. The example below shows readings from an English-unit probe tilted one degree.

$$\text{A0 Reading} = 359 \qquad \text{A180 Reading} = -339$$

$$\text{Combined Reading} = \frac{359 - (-339)}{2}$$

$$= 349$$

Bias

In the example above, the tilt of the casing is 1 degree. In theory, the readout should display values of +349 for the first pass and -349 for the second pass. But the actual readings are 359 and -339. This is caused by a bias in the output of the accelometer. The bias may be negative or positive.

In this example, the bias is positive, so it increases the positive reading and decreases the negative reading, even though the measured angle has not changed. However, when the two readings are combined, the bias is eliminated and the correct value emerges, as shown below:

Tilt angle = 1 degree. The sine of 1 degree x 20,000 is 349, so, in theory, the readout should display 349. However, in this case, the sensor has a positive bias of 10, so the displayed readings are:

Displayed A0 reading = 359 **(349 + 10 units of bias)**

Displayed A180 reading = -339 **(-349 + 10 units of bias)**

Combined reading = 349 $\frac{359 - (-339)}{2}$

Checksums

A checksum is the sum of a "0" reading and a "180" reading at the same depth.

A0 reading = 359 **A180 reading = -339**

Checksum = 359 + (-339)

= 20

Calculating Deviation

To calculate lateral deviation, we combine the A0 and A180 readings, divide by the instrument constant, and multiply by the measurement interval. In the example below, we show an English-unit calculation:

$$\textbf{Lateral Deviation} = \textbf{Measurement Interval} \times \sin\theta$$

$$= \textbf{24 inches} \times \frac{359 - (-339)}{2 \times 20,000}$$

$$= 0.4188 \text{ inches}$$

Combine the A0 & 180 readings and divide by 2 since there are two readings.

Divide by instrument constant to obtain sine of angle.

Calculating Displacement

Displacement, the change in lateral deviation, indicates movement of the casing. To calculate displacement, we find the change in the combined readings, divide by the instrument constant, and multiply by the length of the measurement interval.

$$\textbf{Combined Reading}_{\text{initial}} = 698 \qquad \textbf{Combined Reading}_{\text{current}} = 700$$

$$\textbf{Displacement} = \textbf{Measurement Interval} \times \Delta\sin\theta$$

$$= \textbf{24 inches} \times \frac{700 - 698}{2 \times 20,000}$$

$$= \textbf{0.0012 inches}$$

Calculate the change in combined readings (current-initial) and average them