# Using EXCEL to determine SONREB curve coefficients

In order to create a SONREB curve for estimating the compressive strength of a particular concrete it is necessary to carry out both ultrasonic pulse velocity measurements and rebound measurements on samples of the concrete and then to correlate this to the compressive strength determined in the press.

The following example shows an example of practical data collected using Pundit 200 and Silver Schmidt OS8200.

| | **Pundit 200** | **OS8200** |
|---|---|---|
| **Compressive Strength $f_{ck}$** | **Ultrasonic Pulse Velocity (V)** | **Q-value (S)** |
| 29.5 | 4237 | 36 |
| 32.6 | 4608 | 38 |
| 40.3 | 4484 | 45 |
| 41.2 | 4630 | 42 |
| 44.2 | 4587 | 49 |
| 45.3 | 4673 | 56 |
| 48.5 | 4644 | 49 |
| 50.6 | 4695 | 47 |
| 51.5 | 4717 | 50 |
| 52 | 4760 | 56 |
| 55.8 | 4744 | 57 |
| 57 | 4722 | 53 |
| 58.1 | 4728 | 57 |
| 60.9 | 4673 | 66 |
| 62.3 | 4732 | 54 |
| 68.6 | 4854 | 61 |

The SONREB curve is expressed in the format:

Compressive Strength $f_{ck} = a.V^b.S^c$

Where:

a, b and c are constants

V is the ultrasonic pulse velocity in m/s

S is the rebound value.

So the question is how to determine the constants a, b and c from this data.

The LINEST function of EXCEL can be used to do this. Below is an extract from the EXCEL help file:

“The LINEST function calculates the statistics for a line by using the "least squares" method to calculate a straight line that best fits your data, and then returns an array that describes the line. You can also combine LINEST with other functions to calculate the statistics for other types of models that are linear in the unknown parameters, including polynomial, logarithmic, exponential, and power series. Because this function returns an array of values, it must be entered as an array formula. Instructions follow the examples in this article.

The equation for the line is:

y = mx + b

–or–

y = m1x1 + m2x2 + ... + b (if there are multiple ranges of x-values)

where the dependent y-values are a function of the independent x-values. The m-values are coefficients corresponding to each x-value, and b is a constant value. Note that y, x, and m can be vectors. The array that the LINEST function returns is {mn,mn-1,...,m1,b}. LINEST can also return additional regression statistics.”

The array format is:

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | $m_n$ | $m_{n-1}$ | . . . | $m_2$ | $m_1$ | b |
| 2 | $se_n$ | $se_{n-1}$ | . . . | $se_2$ | $se_1$ | $se_b$ |
| 3 | $r^2$ | $se_y$ | | | | |
| 4 | F | $d_f$ | | | | |
| 5 | $ss_{reg}$ | $ss_{resid}$ | | | | |

Where:

| Statistic | Description |
|---|---|
| se1,se2,...,sen | The standard error values for the coefficients m1,m2,...,mn. |
| seb | The standard error value for the constant b (seb = #N/A when ***const*** is FALSE). |
| r2 | The coefficient of determination. Compares estimated and actual y-values, and ranges in value from 0 to 1. If it is 1, there is a perfect correlation in the sample — there is no difference between the estimated y-value and the actual y-value. At the other extreme, if the coefficient of determination is 0, the regression equation is not helpful in predicting a y-value. For information about how r2 is calculated, see "Remarks," later in this topic. |
| sey | The standard error for the y estimate. |
| F | The F statistic, or the F-observed value. Use the F statistic to determine whether the observed relationship between the dependent and independent variables occurs by chance. |
| df | The degrees of freedom. Use the degrees of freedom to help you find F-critical values in a statistical table. Compare the values you find in the table to the F statistic returned by **LINEST** to determine a confidence level for the model. For information about how df is calculated, see "Remarks," later in this topic. Example 4 shows use of F and df. |
| ssreg | The regression sum of squares. |
| ssresid | The residual sum of squares. For information about how ssreg and ssresid are calculated, see "Remarks," later in this topic. |

In the case of SONREB we have a power series curve so we have to work with the natural logarithms of the data in order to use LINEST. To do this we first use the function “LN”.

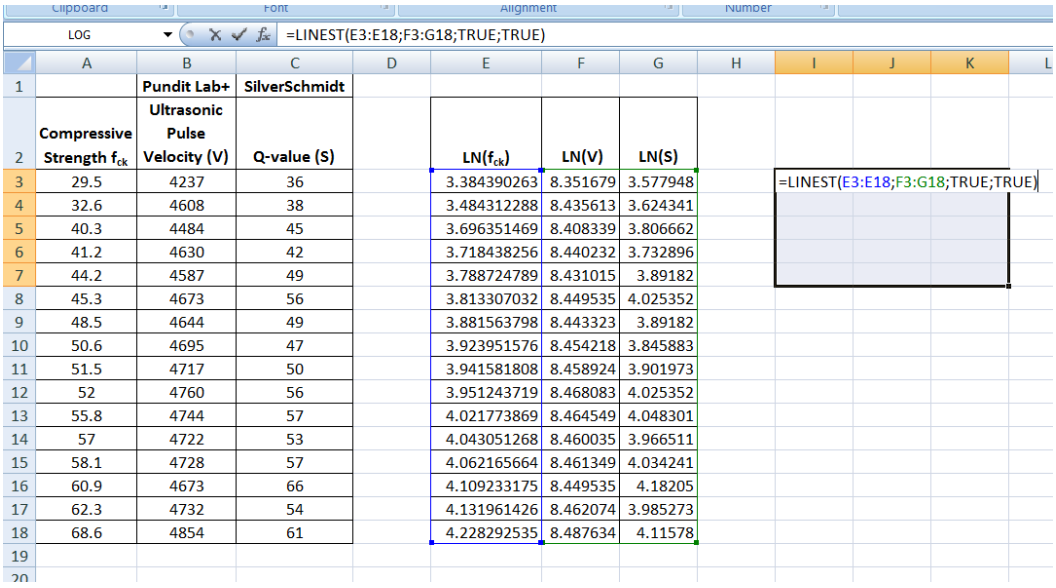
| LN($f_{ck}$) | LN(V) | LN(S) |
|---|---|---|
| 3.384390263 | 8.351679 | 3.577948 |
| 3.484312288 | 8.435613 | 3.624341 |
| 3.696351469 | 8.408339 | 3.806662 |
| 3.718438256 | 8.440232 | 3.732896 |
| 3.788724789 | 8.431015 | 3.89182 |
| 3.813307032 | 8.449535 | 4.025352 |
| 3.881563798 | 8.443323 | 3.89182 |
| 3.923951576 | 8.454218 | 3.845883 |
| 3.941581808 | 8.458924 | 3.901973 |
| 3.951243719 | 8.468083 | 4.025352 |
| 4.021773869 | 8.464549 | 4.048301 |
| 4.043051268 | 8.460035 | 3.966511 |
| 4.062165664 | 8.461349 | 4.034241 |
| 4.109233175 | 8.449535 | 4.18205 |
| 4.131961426 | 8.462074 | 3.985273 |
| 4.228292535 | 8.487634 | 4.11578 |

The corresponding formula will be:

y=m1x1+m2x2+b where:-

The SONREB coefficients we require a, b, c = EXP(b), m2, m1

To enter the array function select an array of 3 columns x 5 rows and enter the LINEST function in the top left hand corner of the array as shown:-




| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | Pundit Lab+ | SilverSchmidt | | | | | | | | | |
| 2 | Compressive Strength $f_{ck}$ | Ultrasonic Pulse Velocity (V) | Q-value (S) | | LN($f_{ck}$) | LN(V) | LN(S) | | | | | |
| 3 | 29.5 | 4237 | 36 | | 3.384390263 | 8.351679 | 3.577948 | | | | | |
| 4 | 32.6 | 4608 | 38 | | 3.484312288 | 8.435613 | 3.624341 | | | | | |
| 5 | 40.3 | 4484 | 45 | | 3.696351469 | 8.408339 | 3.806662 | | | | | |
| 6 | 41.2 | 4630 | 42 | | 3.718438256 | 8.440232 | 3.732896 | | | | | |
| 7 | 44.2 | 4587 | 49 | | 3.788724789 | 8.431015 | 3.89182 | | | | | |
| 8 | 45.3 | 4673 | 56 | | 3.813307032 | 8.449535 | 4.025352 | | | | | |
| 9 | 48.5 | 4644 | 49 | | 3.881563798 | 8.443323 | 3.89182 | | | | | |
| 10 | 50.6 | 4695 | 47 | | 3.923951576 | 8.454218 | 3.845883 | | | | | |
| 11 | 51.5 | 4717 | 50 | | 3.941581808 | 8.458924 | 3.901973 | | | | | |
| 12 | 52 | 4760 | 56 | | 3.951243719 | 8.468083 | 4.025352 | | | | | |
| 13 | 55.8 | 4744 | 57 | | 4.021773869 | 8.464549 | 4.048301 | | | | | |
| 14 | 57 | 4722 | 53 | | 4.043051268 | 8.460035 | 3.966511 | | | | | |
| 15 | 58.1 | 4728 | 57 | | 4.062165664 | 8.461349 | 4.034241 | | | | | |
| 16 | 60.9 | 4673 | 66 | | 4.109233175 | 8.449535 | 4.18205 | | | | | |
| 17 | 62.3 | 4732 | 54 | | 4.131961426 | 8.462074 | 3.985273 | | | | | |
| 18 | 68.6 | 4854 | 61 | | 4.228292535 | 8.487634 | 4.11578 | | | | | |
| 19 | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | |

Press CTRL+SHIFT+ENTER to complete the entry of the array function:

The array will show the following data. They key to the data is shown in the table on the right. The coefficients “b” for the pulse velocity and “c” for the rebound hammer can be read directly. For the constant “a” it is necessary to convert it back to the correct form by using an exponential function.

| c(S) | b(V) | a |
|---|---|---|
| 0.860156 | 2.809633 | -23.2105406 |
| 0.198111 | 1.083358 | 8.586289002 |
| 0.880203 | 0.085978 | #N/A |
| 47.75848 | 13 | #N/A |
| 0.706089 | 0.0961 | #N/A |

| | | |
|---|---|---|
| m2 | m1 | b |
| se2 | se1 | seb |
| r2 | sey | |
| F | df | |
| ssreg | ssresid | |

Coefficient c = 0.860155674
Coefficient b = 2.809633333
Coefficient a = 8.31362E-11 =EXP(-23.2105406)

So the SONREB curve for this set of data would be:

$$f_{ck} = 8.314x10^{-11}.V^{2.8096}.S^{0.8602}$$

with a correlation coefficient of 0.88.