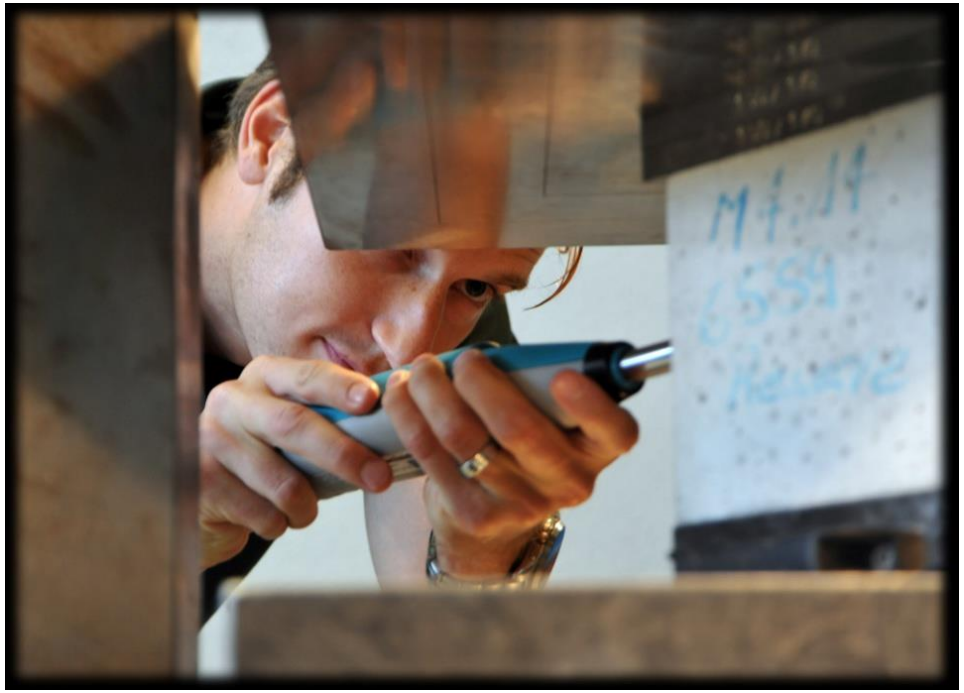


Process to create a custom correlation curve for concrete compressive strength estimation

Why do it?

- NDT methods like the rebound hammer and ultrasonic pulse velocity do not measure compressive strength. In order to estimate the strength, a correlation is required. The accuracy of the estimation depends on how well this correlation curve is determined.
- Every concrete mix has its own correlation curve. There is no such thing as one curve fits all.
- Use of manufacturers correlation curves is not allowed in major standards.
- It is necessary to develop a specific relationship between the NDT test and the compressive strength.
- This procedure calibrates your instrument (hammer or UPV) to the specific concrete you are testing.
- This procedure provides the most reliable and the most accurate results.

Applications

- It is often used on large projects to determine the optimum time for formwork removal.
- It is often used by precast element manufacturers for their most commonly used mixes for both quality control and to determine the optimum time for formwork removal.
- It can be used to estimate the strength at different locations in the structure using the same concrete mix.

The process using correlation to cores

- EN 13791 describes a process for calibrating your hammer to the concrete under test using a correlation to cores, that is also recognized by ASTM.

- In-situ Concrete Compressive Strength Assessment - Cores and NDT | Screening Eagle Technologies - YouTube

Workflow

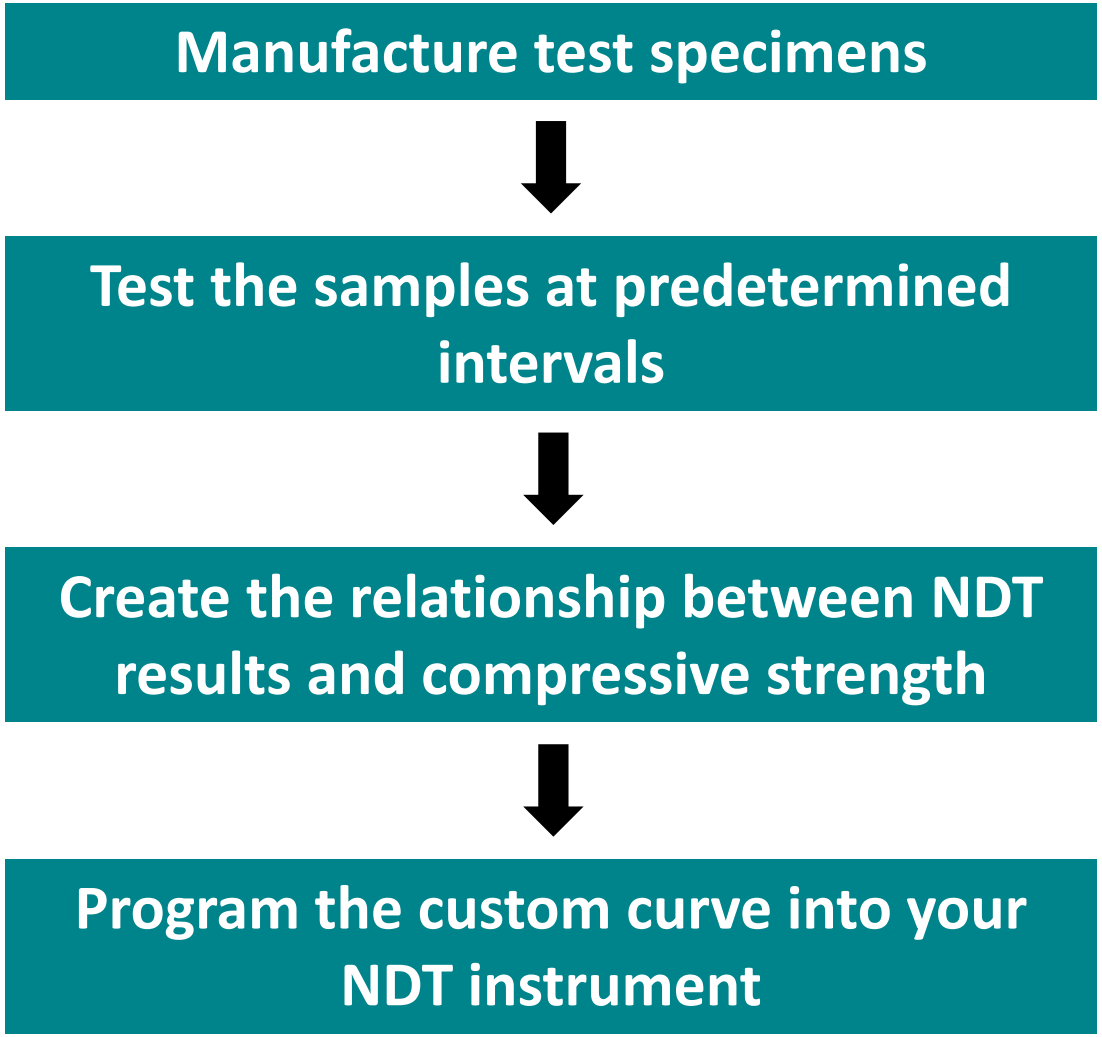
The process using standard test specimens

1. Manufacture a sufficient number of test specimens
2. Test the specimens (NDT test plus crush test) at pre-determined intervals during the curing process
3. Use the data pairs obtained (NDT result plus crush test result) to establish the relationship
4. Program the correlation curve into your NDT instrument

Your NDT instrument is now calibrated to the concrete mix

Workflow

The process



Reference Example - BAM

- In order to illustrate and explain the recommendations made here, reference will be made to methodology used by BAM to create conversion curves for the Proceq Silver Schmidt hammers.

Erstellung von Umwertekurven für Betonprüfhämmer der neuen Generation

Ausfertigung	1. von 5 Ausfertigungen
Auftraggeber	PROCEQ SA Ringstraße 2 8603 Schwerzenbach Switzerland
aufgestellt durch	Dipl. Ing. Sascha Feistkorn
Prüf- / Versuchsmaterial	Silverschmidt 2 N Silverschmidt 2 L Silverschmidt 2 L mit Pilzbolzen Digi Schmidt N Digi Schmidt L
Prüfdatum	12.10.2009 – 23.11.2009
Prüfort	BAM, Unter den Eichen 87, 12205 Berlin
Prüfung gemäß	Stand der Technik

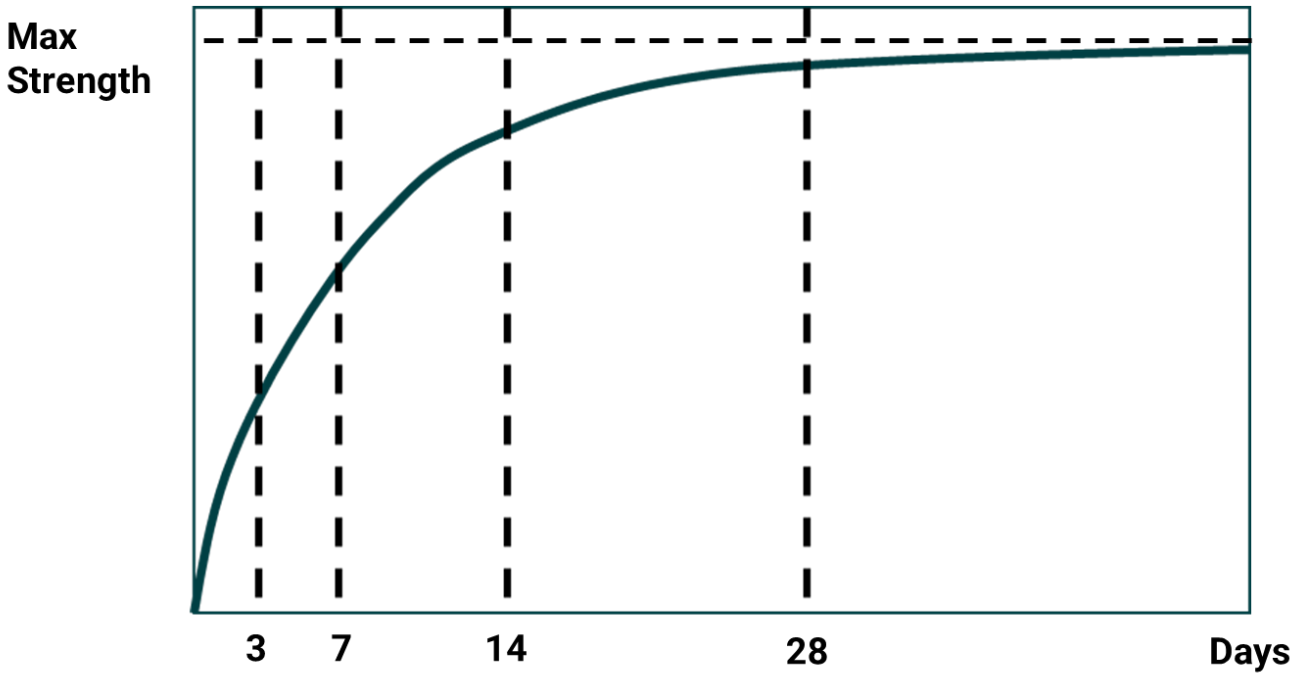
How many test specimens are sufficient?

- Easily said, the more specimens, the better, but this is also expensive and impractical.
- The BAM Silver Schmidt example used 33 samples for each mix and they tested 3 samples at each test interval to ensure having a valid result.
- EN13791 recommends taking a minimum of 10 cores in order to create a correlation between in-situ compressive strength and the NDT test instrument. It is based on having at least 8 valid core results if two of the cores result in an invalid crush test.
- Taking this as a guide, the recommendation is to have at least 8 valid results when working with test specimens.

≥ 8 test specimens recommended

Determination of the test interval

- In order to have a full range of strengths the specimens have to be tested at different intervals from the time of casting.
- Strength develops rapidly in the early stages and slows down as it approaches the maximum strength.



- The rate of strength development must be taken into consideration when planning the tests

Test more often in early stages

Test intervals adjusted to curing characteristics of the mix under test

Test Interval - Reference Example

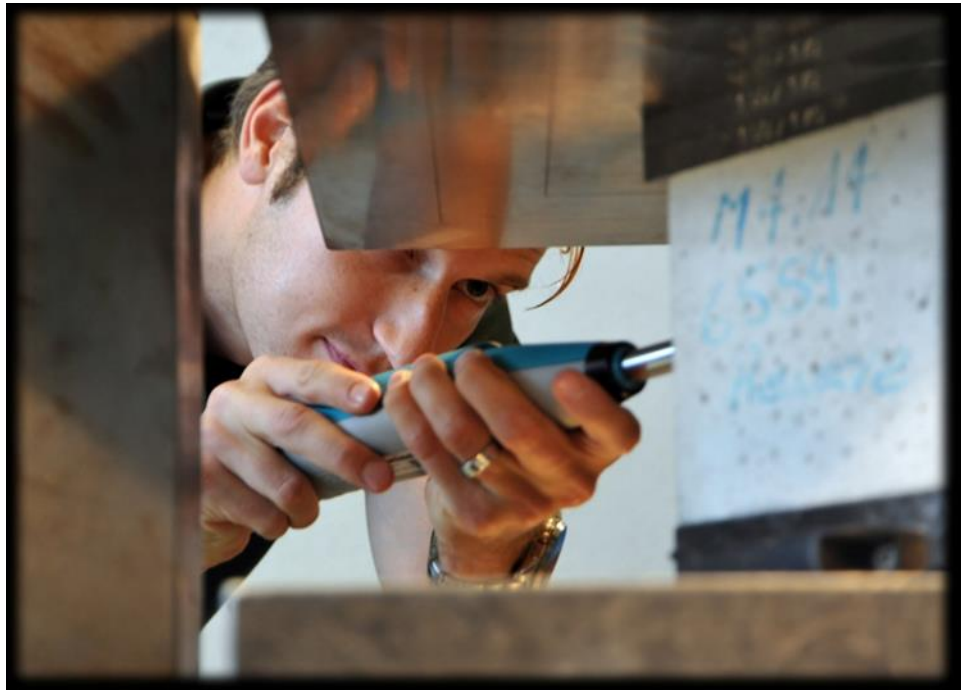
Date of manufacture	Day 0	10:00
Cube Test 1	Day 1	11:00
Cube Test 2	Day 1	14:00
Cube Test 3	Day 1	16:30
Cube Test 4	Day 2	7:45
Cube Test 5	Day 3	7:45
Cube Test 6	Day 4	9:30
Cube Test 7	Day 7	7:40
Cube Test 8	Day 11	7:45
Cube Test 9	Day 16	9:15
Cube Test 10	Day 23	7:30
Cube Test 11	Day 28	10:00

- Concrete strength range from 30 N/mm^2 to 55 N/mm^2
- 11 test dates
- Tests more frequent at early stages

Performing the NDT test

- In order to obtain consistent results, it is recommended to fix the specimen in the press before carrying out the NDT test

- In the reference example a force of 2.5 MPa was used to pre-stress the specimens



- Perform the NDT test according to your regional standard,

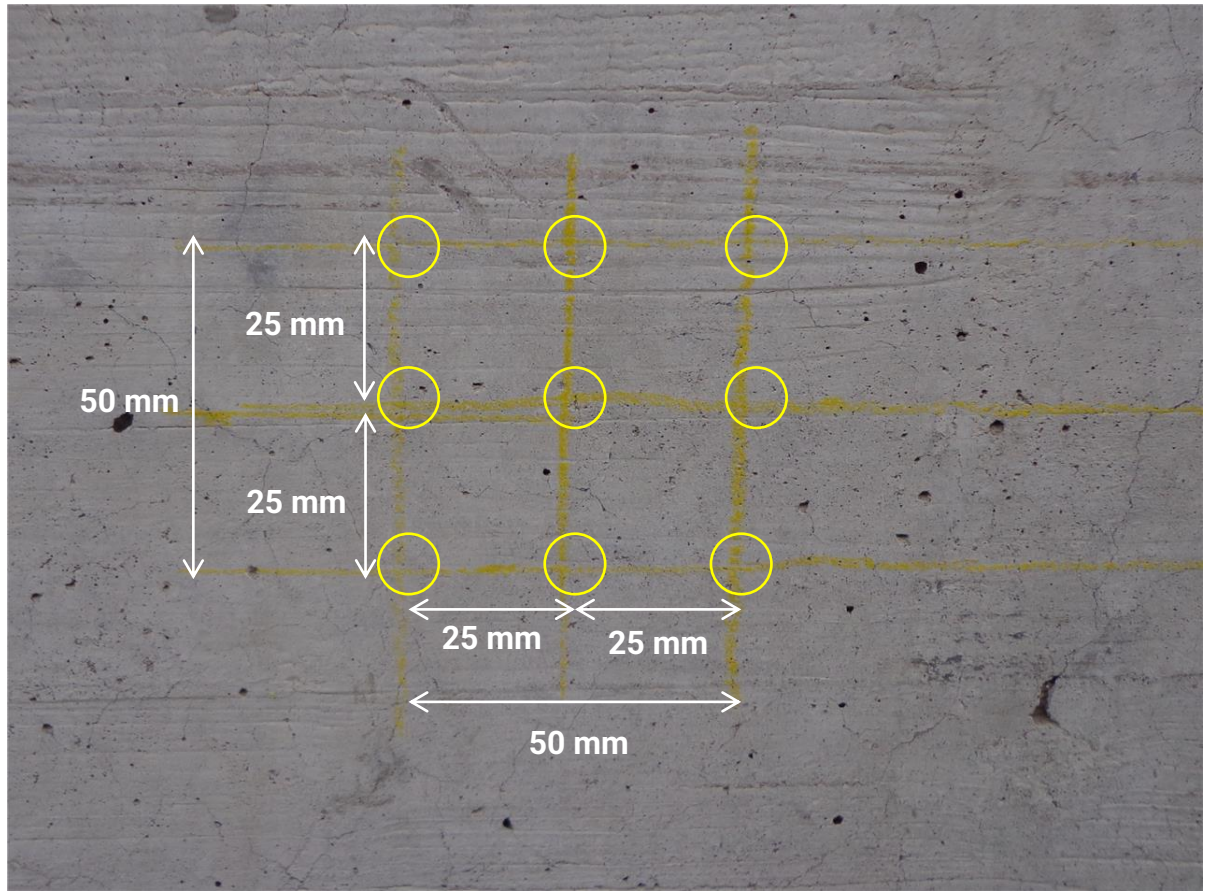
  e.g.
  EN 12504-2 or ASTM C805 for a rebound hammer
  EN 12504-4 or ASTM C597 for UPV

Workflow

Is there enough space on a 150 mm cube for the test?

- EN 12504-2
  Minimum 9 impacts 25 – 50 mm apart.

- Smallest valid grid is 50 x 50 mm for all 9 impacts



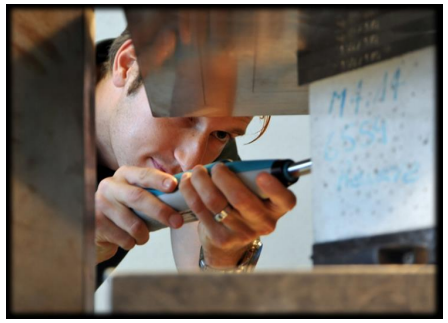
Determine the compressive strength

- On completion of the NDT test(s) perform a crush test to obtain the compressive strength of the specimen

Workflow

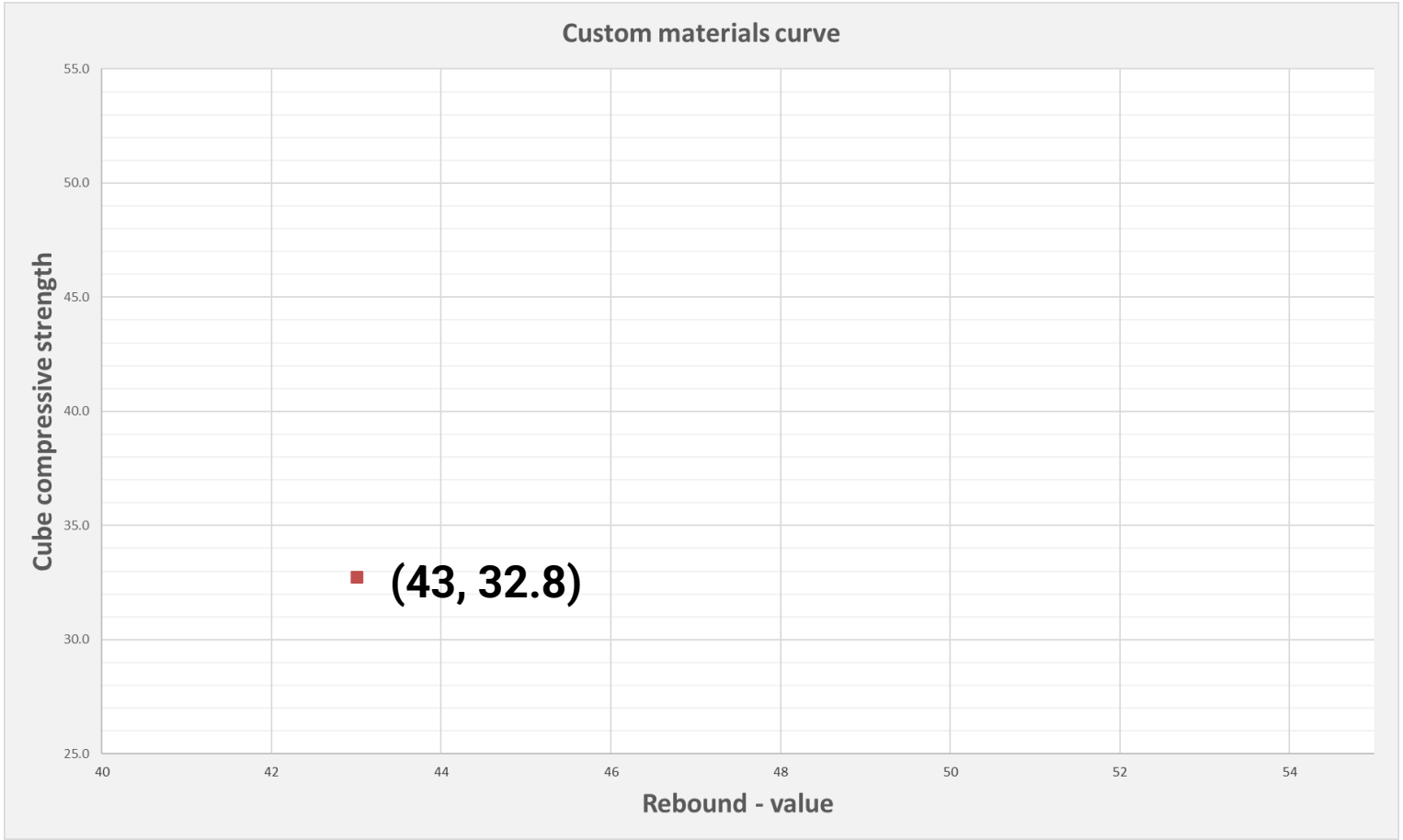
Estabishing the correlation curve

- The rebound value plus the crush test result provides one data pair for the correlation.



32.8

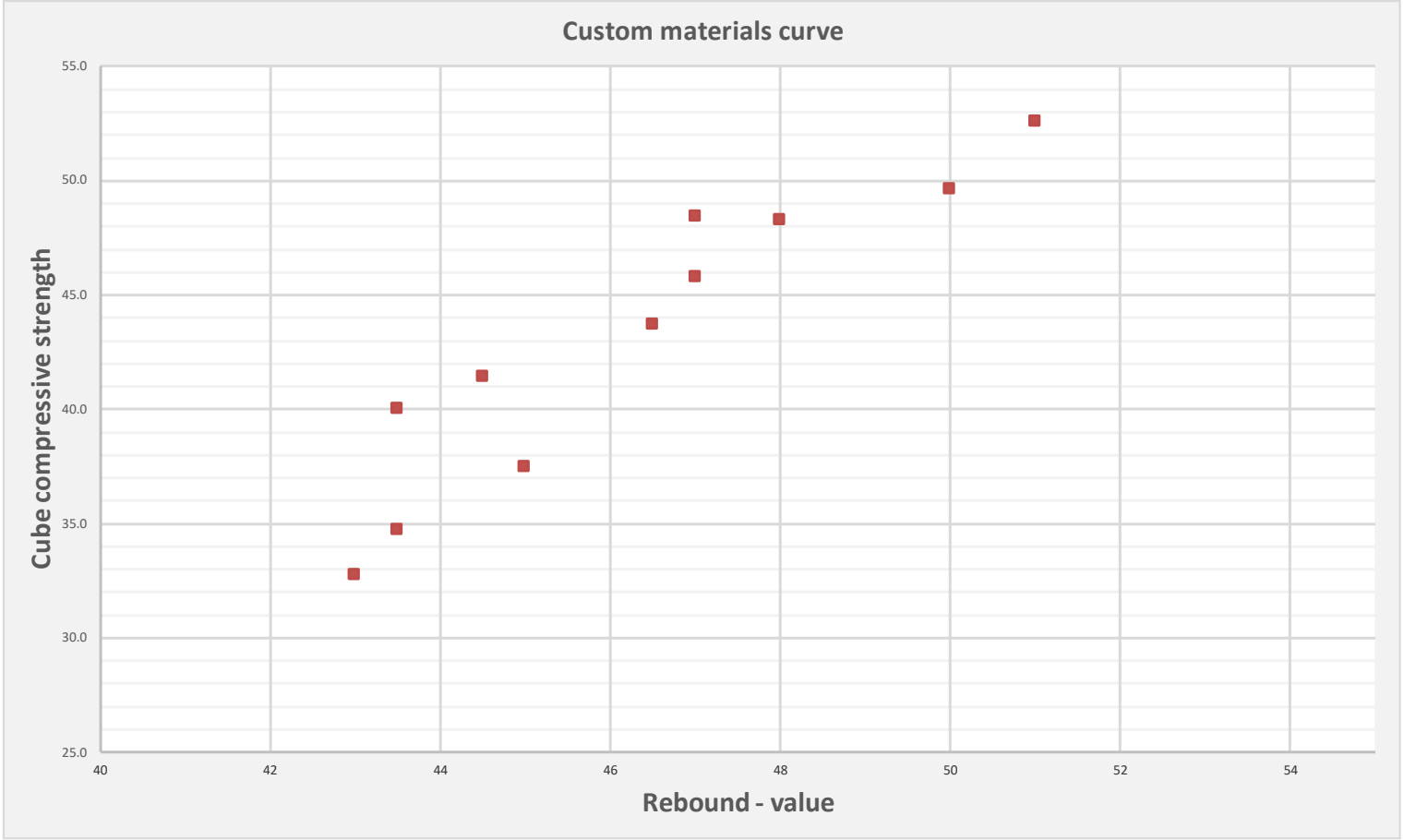
43 MPa



Workflow

Estabishing the correlation curve

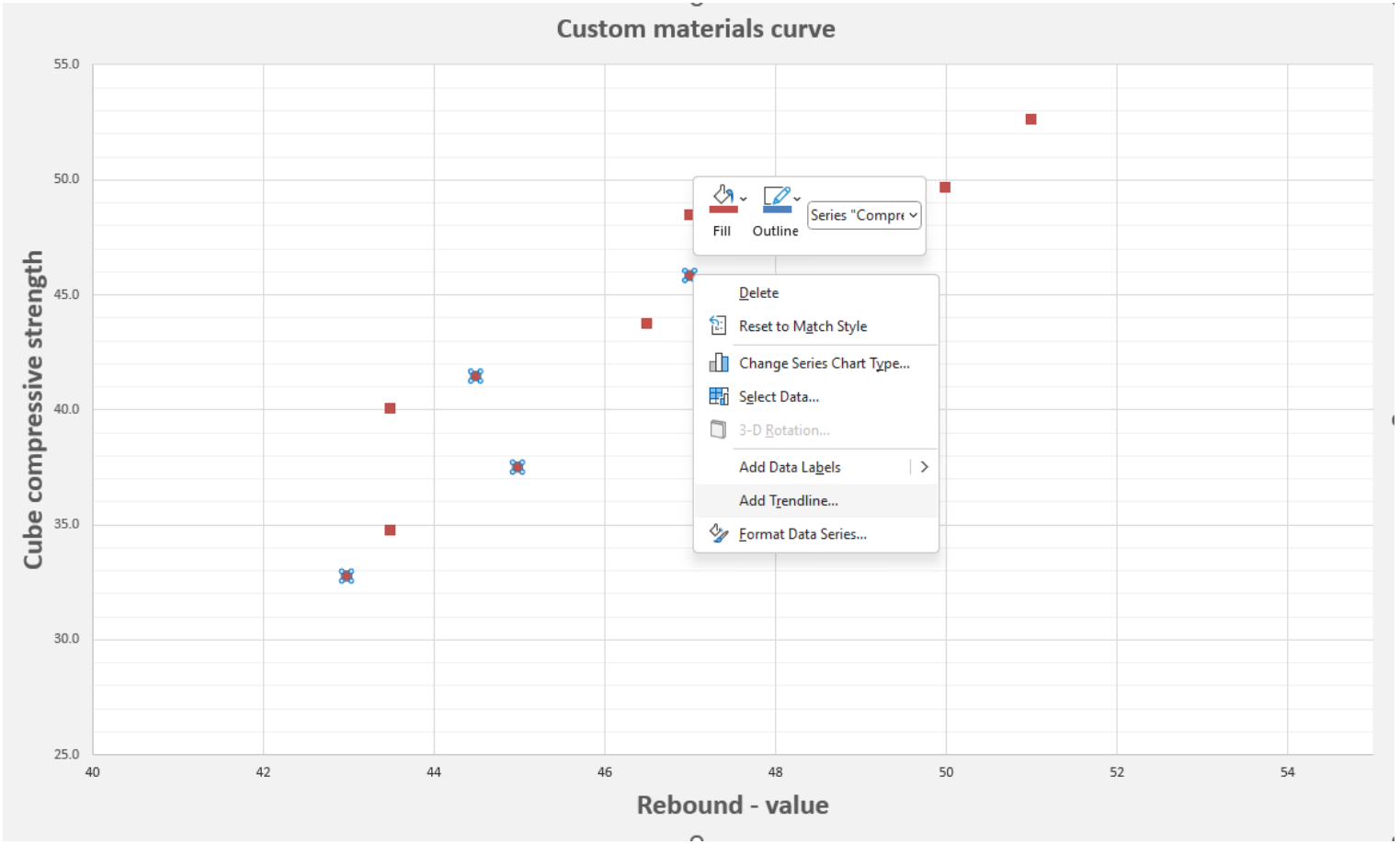
- Once all samples have been tested we have a complete data set
- Each dot here represents one cube (11 in total)



Workflow

Estabishing the correlation curve

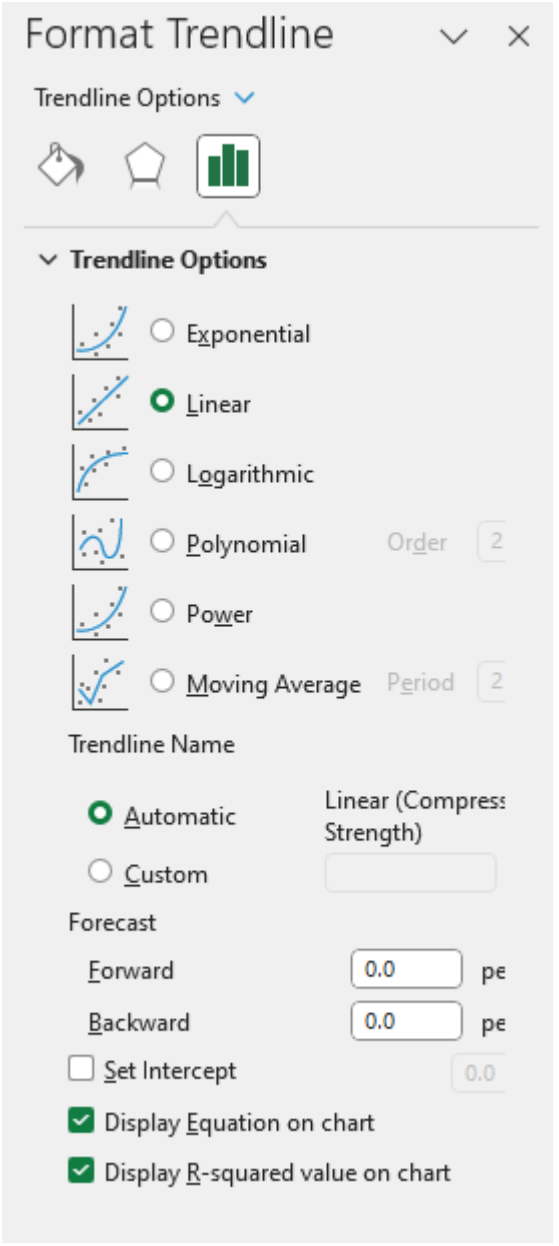
- To obtain the correlation curve right click on one of the data points and “Add Trendline”



Workflow

Trendline function

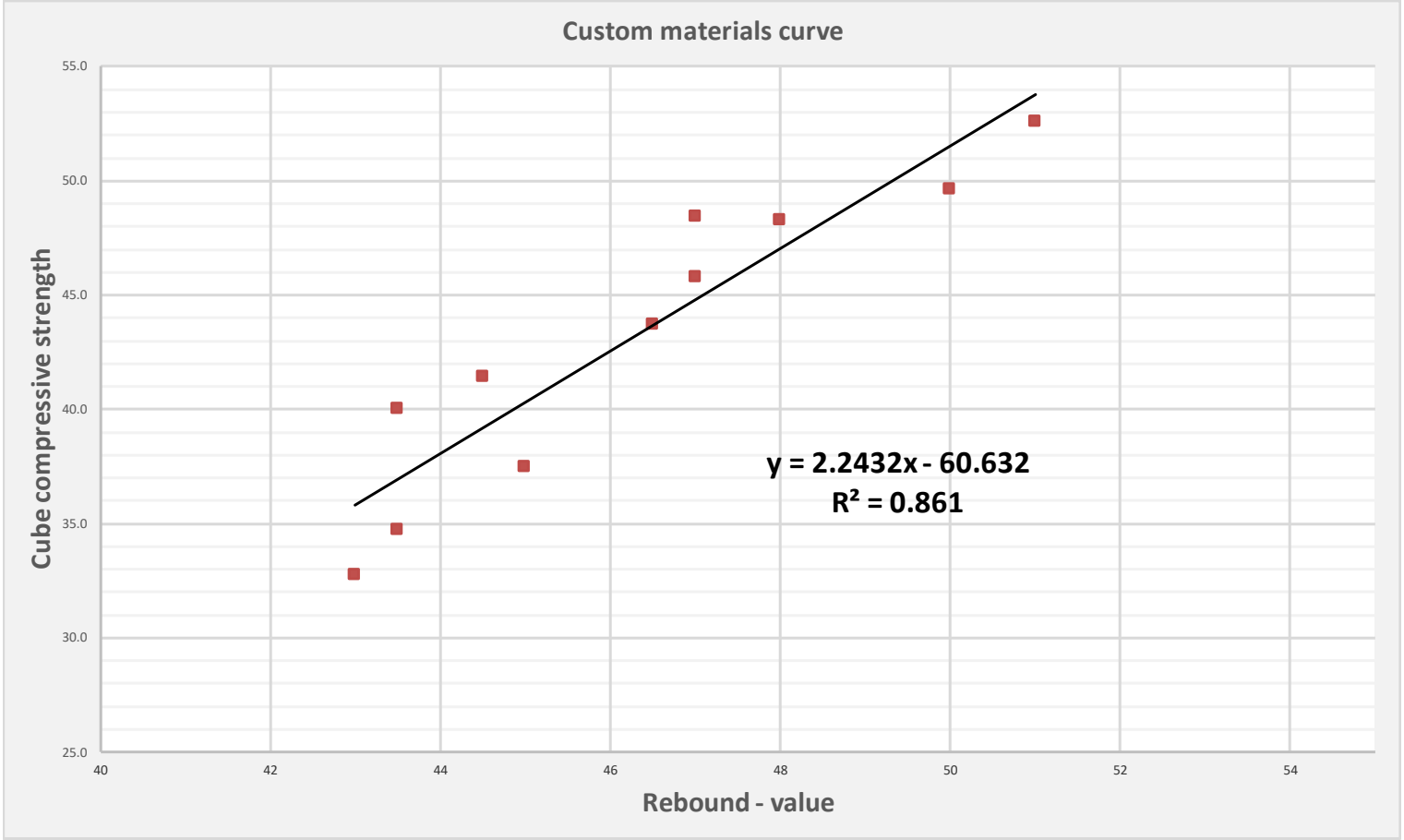
- The trendline function creates a best fit curve for the data set
- Depending on the range of strengths either “Linear” or “Exponential” is recommended.
- Select “Display Equation on chart” to show the correlation curve
- Select “R-squared value on chart” to show how good the correlation is
  (This may also be used to help selecting the best curve type – a higher R-squared value indicates a better fit)



Workflow

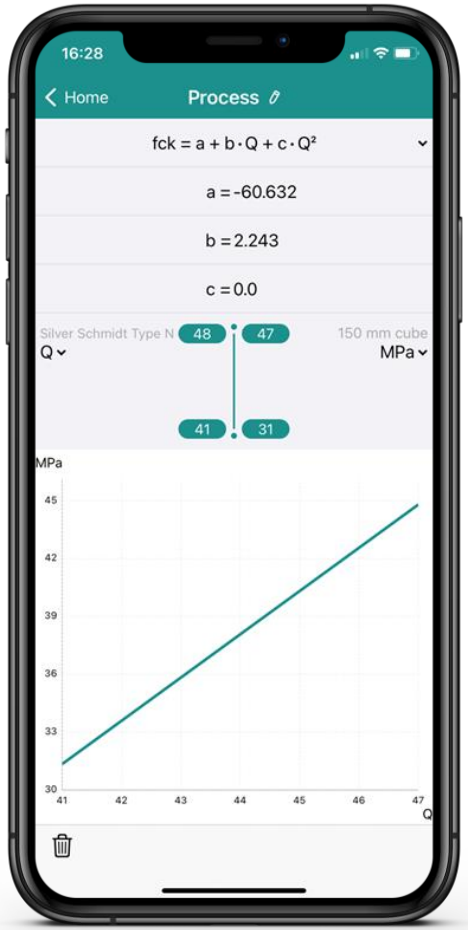
Estabishing the correlation curve

- The correlation curve has now been created.



Workflow

Program the curve for use with a Schmidt hammer



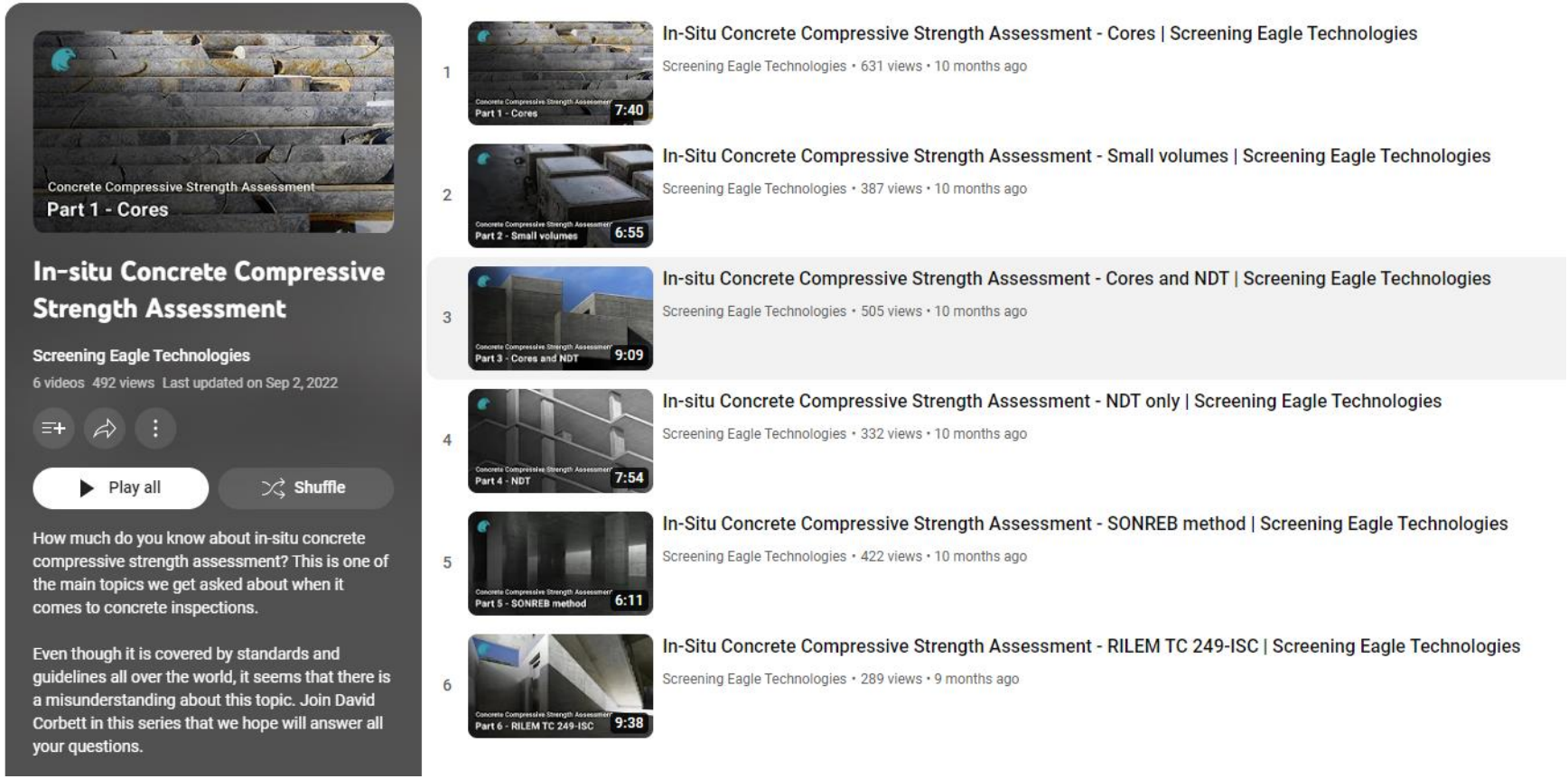
The correlation curve can be entered as a custom materials curve into the Schmidt app

The Schmidt hammer has now been calibrated to this specific concrete mix

Relationship to In-situ strength

- The in-situ strength is generally less than that measure on standard specimens.
- A correction factor is normally applied to accommodate this difference.
- EN typically applies a factor of 0.85

Screening Eagle Technologies YouTube Channel
Further information on compressive strength estimation



[In-situ Concrete Compressive Strength Assessment - YouTube]

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