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For the measurement of resistance force
to calculate the compressive strength
of young sprayed concrete
to EN ISO 14488-2 (Method A)



1 This user guide

This guide covers the use of the Mecmesin VFG/AFG Shotcrete Penetrometer, as supplied for the measurement of the resistance force of young sprayed concrete. It also covers the procedure for the subsequent calculation of the compressive strength of the concrete according to EN ISO 14488-2 (Method A) and similar industry test methods.

For detailed operation and technical specifications of the gauge instruments, please refer to the documentation for the model you are using.

1.1 VFG Touchscreen force gauge

Vector Instrument Operator Manual (Part No. 431-987),

<https://help.mecmesin.com/docs/vector-instrument-operator-manual>.

Sections covering general use and 'Using your VFG as a Shotcrete Penetrometer' are relevant.

1.2 AFG Advanced force gauge

Advanced Force Gauge Operating Manual (Part No. 431-213), also included.

<https://help.mecmesin.com/docs/advanced-force-gauge-afg-operating-manual-includes-afti-display>

Sections covering the AFG 1000 model are relevant.

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2 The Shotcrete Penetrometer

2.1 Introduction

Mecmesin's Shotcrete Penetrometer models provide accurate readings of the forces required to penetrate sprayed or poured concrete during the initial strength development stage of curing. These resistive force readings are then used to convert to a compressive strength value. Its accuracy and portability make it ideal for on-site testing to BS EN ISO 14488 (Method A).

The VFG version has in-built functionality which automates some of the steps in the process when certain settings are activated.

Any differences in usage between the two versions (VFG or AFG) are highlighted at the relevant point in this document.

2.1.1 AFG Shotcrete Penetrometer

The AFG version requires the user to take individual force measurements (e.g., in Newton units), record them manually into a *Test Protocol Form* and perform calculations to convert the result to a final MPa value.

2.1.2 VFG Shotcrete Penetrometer

The VFG version may be used in three ways:

1. The same manner as the AFG model, outlined above.
2. Using the *Statistics Mode* of the VFG which will perform statistical analysis of the force data, including calculating the mean of the data set of ten values.

3. Using *Penetrometer Mode* which performs the statistical analysis and converts to a final MPa value. This methodology utilises all of the Shotcrete Penetrometer's dedicated functionality.

3 Using the Penetrometer

3.1 EN ISO 14488-2 overview

The test standard series 14488 applies to concrete and related products. Part 2 specifically relates to 'Compressive strength of young sprayed concrete'.

The strength development of young sprayed concrete is assessed in the ranges of 0.2 MPa to 1.2 MPa with Method A of the standard, which requires penetration needle apparatus. The Mecmesin Shotcrete Penetrometer is used to perform these in-situ tests.

This user guide refers to EN ISO 14488-2, however, there are other related standards which apply the same process: EN 14488-2, DIN EN 14488-2, ISO 14488, BS ISO 14488.

The following sections of this user guide refer to those sections of the standard specifically applicable to usage of the penetrometer.

3.2 Principle

The penetrometer is fitted with a penetration needle of specified dimensions and Method A is used to measure the force required to push the needle into the sprayed concrete to a depth of 15 mm $\pm$ 2 mm.

The penetrometer indicates the resisting force, from which an estimated compressive strength can be derived by means of the appropriate example conversion curve. The curve is associated with aggregate size and the conversion graph shown in Appendix A referencing 8 mm and 16 mm aggregates are typical.

3.3 Apparatus

3.3.1 Penetrometer

The Mecmesin Shotcrete Penetrometer is suitable for testing to this standard at the required accuracy of 10 N (please refer to the specifications for the gauge).

3.3.2 Needle

The penetration needle should have a diameter of 3 mm ± 0.1 mm and a tip with a taper angle of $60^\circ \pm 5^\circ$.

The Mecmesin Shotcrete Penetrometer includes 15 needles which fit into the adaptor and are secured by a grub screw, as shown below.



3.4 Test specimen

The testing procedure can be used for measurements at any location without advance preparation.

A sprayed concrete layer of no less than 100 mm thickness is required for testing.

3.5 Strength calculations

The resulting strength calculation from the test data requires the measurement of compressive force at multiple sample points.

The VFG version of the penetrometer handles the statistical calculations automatically, taking into account an appropriate in-built calibration curve (8 mm or 16 mm aggregate), and converting to Mpa units. These data may be exported to Excel via the print functionality when a PC is connected to a serial port.

The AFG version requires manually recording readings and performing calculations by hand.

3.5.1 Test protocol form

A test protocol form is needed to record these data; an example form is provided in Appendix B (for VFG) and Appendix C (for AFG).

The standard indicates the required information to be recorded in order to meet the regulations, and those data will be referenced in this user guide.

3.5.2 Conversion curves (AFG version)

Appendix A of this user guide contains a graph of conversion curves to enable the calculation of the equivalent compressive strength (MPa) of the concrete from a penetrometer force reading (N).

This graph is derived from the example calibration curves provided in EN 14488-2 Annex A (informative) of the test standard.

Two linear curves and their associated formulae are reproduced for two typical aggregate mixes of <8 mm and ≤16 mm respectively. The compressive strength value on the y-axis may be derived from a resistance

force reading on the x-axis either by direct extraction from the curve, or calculation via the appropriate formula, as indicated.

These curves are provided as reference examples based on data published in the standard, however the individual concrete mix will affect the accuracy of the approximation. The user is at liberty to implement their own correlation function if this would be more appropriate.

The VFG version automatically applies this conversion using the curves from Appendix A.

4 Penetrometer test procedure

The testing procedure of EN ISO 14488-2 (Method A) is repeated in batches at several time intervals, for example at 5, 20, 40, 60 and 120 minutes, or up to the time when the calculated compressive strength values still remain below 1.5 MPa.

NOTE: When the calculated compressive strength values increase to above 1.5 MPa, the penetrometer procedure is no longer applicable, as this indicates the concrete has cured beyond the initial strength development phase. Please refer to the full test standard for more information.

4.1 Prepare the penetrometer

The penetrometer is supplied with the gauge (VFG or AFG) ready to use for compressive strength evaluation. Please refer to the appropriate gauge manual to confirm or apply the required settings.

4.1.1 VFG settings

The VFG Shotcrete Penetrometer product is supplied pre-configured from the factory to the required units, sensor and statistics settings to implement the strength calculations directly.

Refer to *Vector Instrument Operator Manual* to modify these settings.

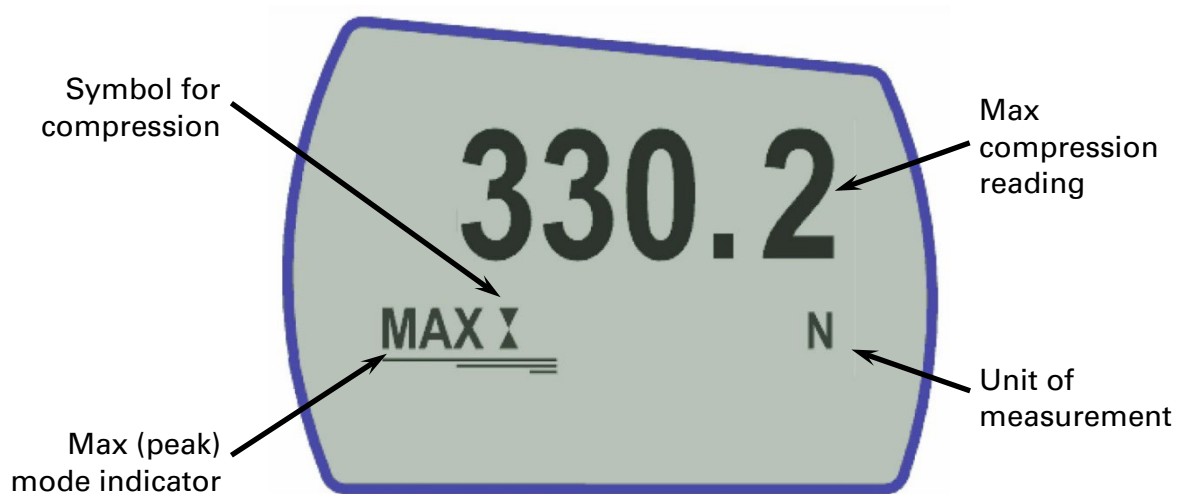


Statistics settings to perform shotcrete strength calculations (with 8 mm aggregate option)

4.1.2 AFG settings

Refer to the *Advanced Force Gauge Operating Manual*, if necessary, to apply the following conditions:

1. The penetrometer is set to record maximum (peak) readings.
2. The unit of measurement is set as appropriate for the conversion formula/curve (Newton).
3. The display is oriented to be conveniently read (inverted).



4.2 Prepare the test protocol form

Obtain a new, blank, test protocol form and record:

1. the time of the completion of spraying
2. the place of spraying.

Test Protocol Form - EN ISO 1488-2 (Method A): Penetrometer	
Completion of Spraying	
Time:	11:10
Place:	Loc A 7

4.3 Test the concrete at ten sample locations

4.3.1 Prepare the sample data row (batch)

To calculate the single representative value for the compressive strength of the shotcrete at each test instance, ten individual samples are taken with the Penetrometer.

The data are entered into a row on the test protocol form against the timestamp, for example at 5, 20, 40, 60, 120 minutes.

Record the start time of the testing, for example at 5 minutes, and enter the time in the cell as indicated below:

Times of Testing			Penetrometer: penetration resist					
Mins	Start	End	1	2	3	4	5	6
5	11:15							
20								
40								

4.3.2 Take the ten readings

For each sample reading perform the following steps:

1. Ensure the penetrometer indicator is set to zero.
2. Select an area representative of the sprayed region.
3. Apply the device perpendicularly to the surface of the sprayed concrete layer and steadily push in the needle to a depth of 15 mm in a single continuous movement. If this is prevented, for instance, because of a large aggregate particle or reinforcement, then discontinue and repeat in an adjacent location.

4. AFG: Read the maximum compressive (resistance) force from the display.
5. AFG: Record the value on the protocol form in the next column entry position on this time occurrence row:

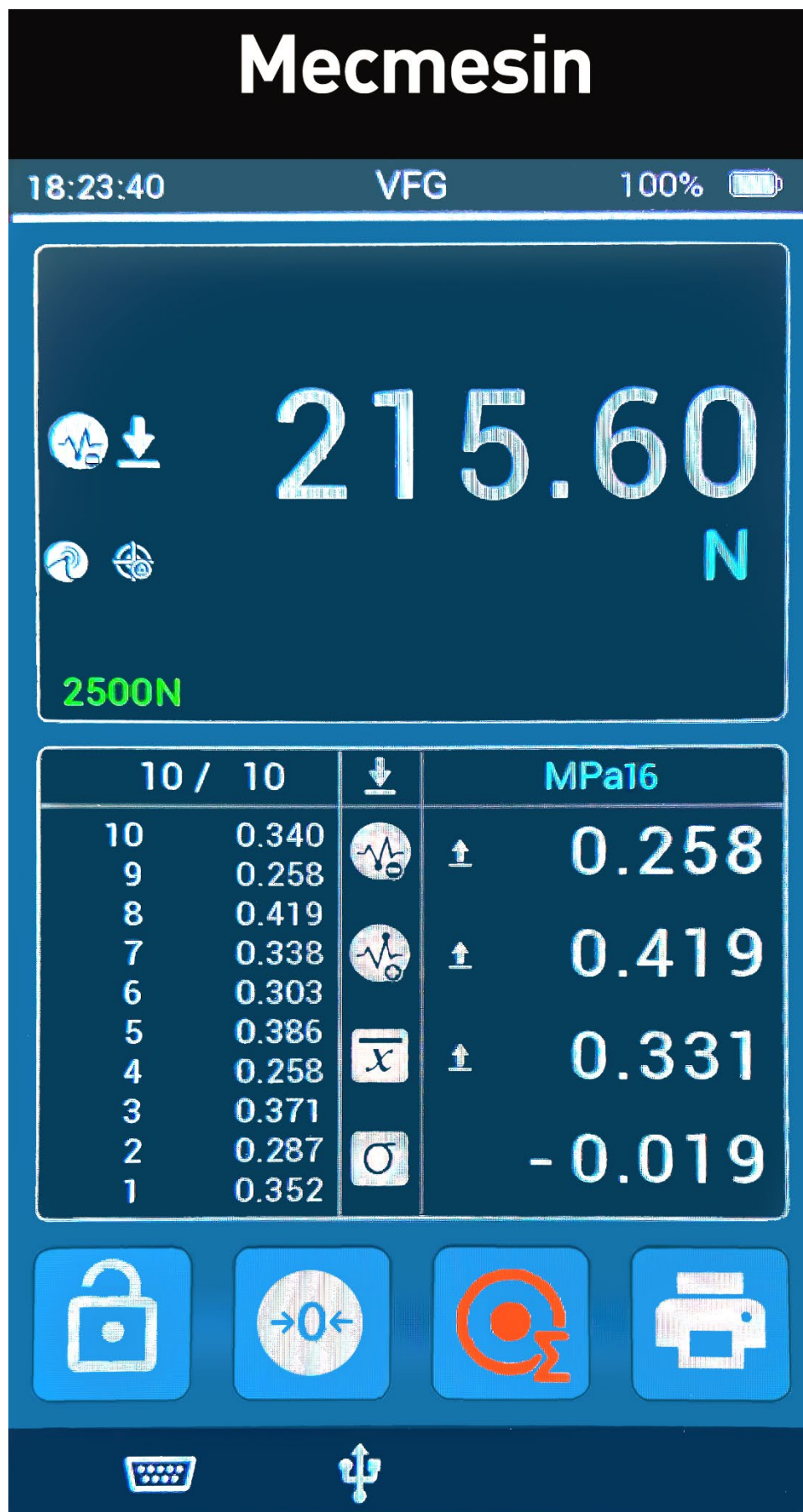
Times of Testing			Penetrometer: penetration resist					
Mins	Start	End	1	2	3	4	5	6
5	11:15		122					
20								
40								

6. Clean the needle, if necessary.
7. Reset the penetrometer to the initial condition, as at point 1, above.
8. Repeat the test ten times as quickly as possible (and within one minute for strengths below 0.5 MPa). AFG: Record each force value in the next cell on the test protocol form.
9. Record the end time for this timestamp:

Times of Testing			Penetrometer: penetration resist					
Mins	Start	End	1	2	3	4	5	6
5	11:15	11:21	122	131	114	109	98	12
20								
40								

4.3.3 Transmit statistical data to Excel (VFG)

Transmission of the data from the VFG Penetrometer to a spreadsheet application may be achieved with the recommended Mecmesin cables and freely available RS232 data-to-keyboard parsing software. Refer to the *Vector Instrument Operator Manual* and the software supplier's documentation for more information.



Statistical data in the secondary display is transmitted by the Print button

The VFG Penetrometer may be set up to transmit the statistical data by the Print button. Each data set will output in the following order:

1. 10 readings
2. Number of readings (10)
3. Minimum value
4. Maximum value
5. Mean value (in set units or compressive strength MPa)
6. Standard Deviation

The test protocol form should be set up to accept these data in this specific order:

Agg:	8 mm									
penetration resistance test readings (MPa)						Mean				
5	6	7	8	9	10	[No.]	[Min.]	[Max.]	MPa	[SD]
0.39	0.3	0.34	0.42	0.26	0.34	10	0.258	0.414	0.331	0.019

NOTE: Here the VFG has been set to Penetrometer Mode in the sensor settings, therefore the Mean is expressed as strength in MPa.

Penetrometer (Penetrometer Mode OFF)										
penetration resistance test readings (N)						Mean				
5	6	7	8	9	10	[No.]	[Min.]	[Max.]	N	[SD]
-183	-216	-178	-183	-222	-151	10	128	222.2	185.3	29.45

NOTE: Here the VFG has NOT been set to Penetrometer Mode in the sensor settings, therefore the Mean is expressed in the chosen force units.

5 Expression of results

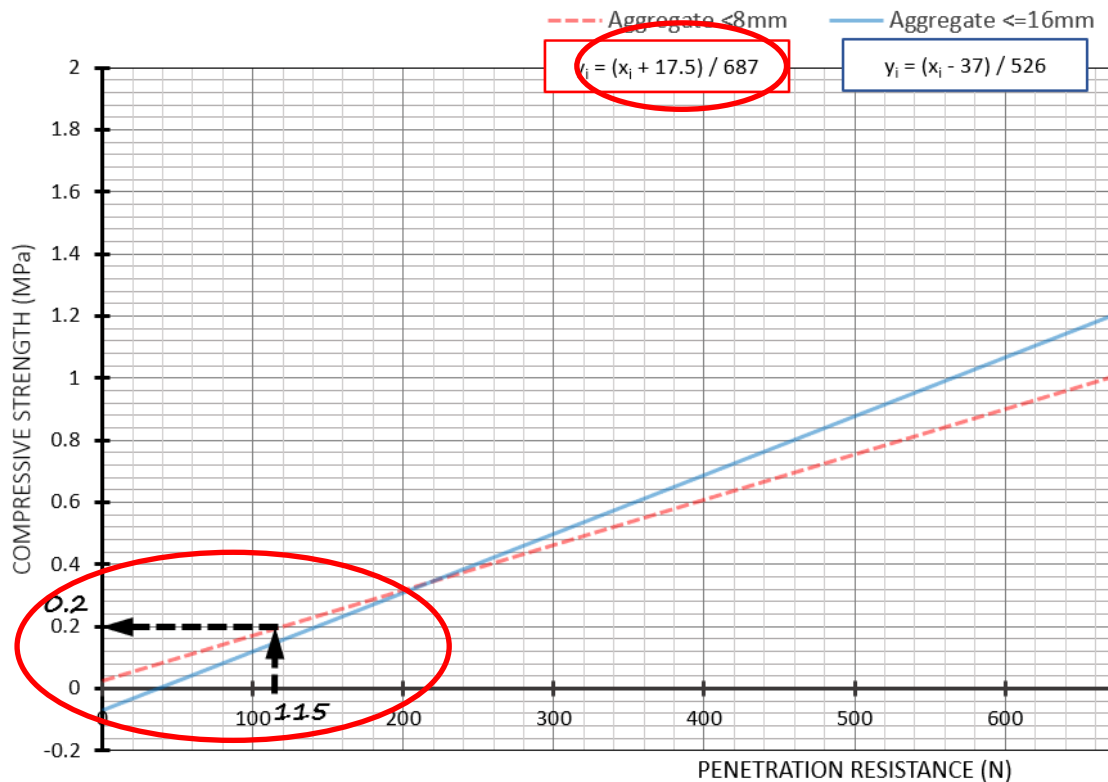
5.1 Calculation of compressive strength (AFG)

The AFG version requires manual calculation of the mean MPa value for each of the performed test process batches:

1. Calculate the mean resistance force from the ten readings on the form, and enter the value in the appropriate cell:

Penetrometer: penetration resistance test readings (N)										Mean
1	2	3	4	5	6	7	8	9	10	
122	131	114	109	98	125	119	120	103	108	115

2. Derive the estimated compressive strength, using the mean resistance force value, from the relevant conversion curve or formula. In the example below, the conversion relating to a mix with aggregate size less than or equal to 8 mm has been used ($115 \text{ N} \equiv 0.2 \text{ MPa}$):



NOTE: Extrapolation beyond the limits on the conversion curve is not permitted (1.5 MPa).

- Record the compressive strength value in the appropriate cell on the test protocol form:

Penetrometer: penetration resistance test readings (N)								Mean	Mpa
3	4	5	6	7	8	9	10	115	0.2
114	109	98	125	119	120	103	108		

5.2 Calculation of compressive strength (VFG)

The compressive strength is calculated automatically, if the recommended settings are applied. Otherwise, manual conversion will be needed as for the AFG version.

5.3 Test report

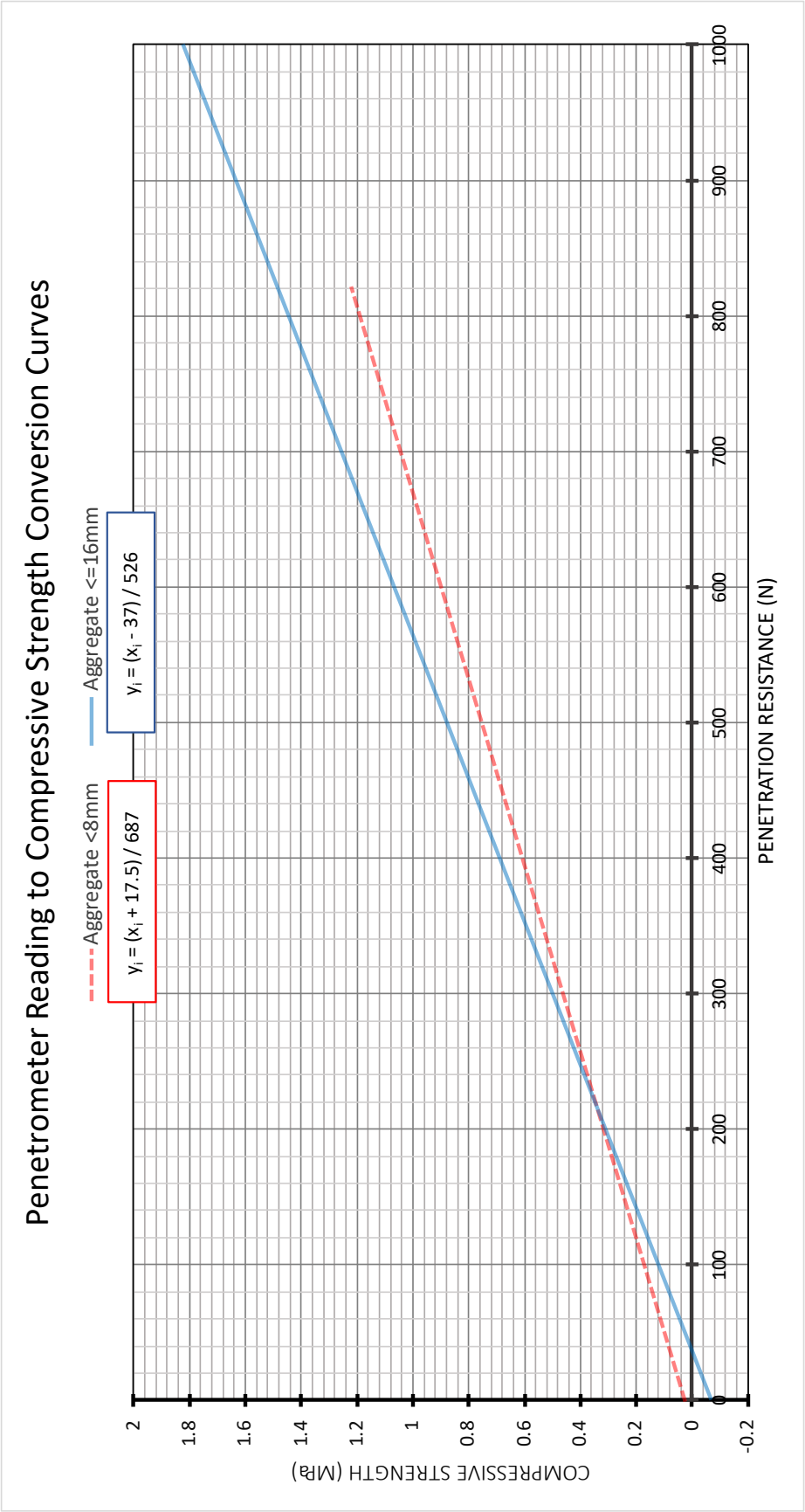
The test report for EN ISO 14488-2 (Method A) shall include:

1. test protocol form
2. description of the location and date of testing
3. type and serial number of the test equipment
4. times of completing spraying, and start and finish of testing, to the nearest minute
5. ten measurements of resistance force, and the mean value to the nearest 10 N.

5.4 Usage of the Method A test report

On completion of the initial strength development phase, the Method A test report will indicate a number of calculated compressive strength values for several time points. These data should be plotted on a graph, with the equivalent data from Method B of the standard, to indicate the evolution of the compressive strength over time. This complete graph can then be used to categorise the concrete product to the specific strength classes according to EN 14487-1 or equivalent standards.

Appendix A: Conversion curves graph



Appendix B: Example blank test protocol form (VFG)

Project:

Date:

Agg:

Completion of Spraying

Time:

Place:

Test Protocol Form - EN ISO 1488-2 (Method A): VFG Penetrometer (Penetrometer Mode)

1

2

3

4

5

6

7

8

9

10

Penetration resistance test readings (MPa)

Times of Testing (Batches)

Mins

Start

End

Mean

MPa

[No.]

[Min.]

[Max.]

[SD]

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Completion of Spraying	Time:		
	Place:		
	Project:		
	Date:		
	Agg size:		

$$\text{Aggregate } \leq 8 \text{ mm: } Y_i = (X_i + 17.5) / 687$$



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