

# DIN SPEC 19289:2022-08 (E)

## Fibre-reinforced composites - Measurement of Interfacial Shear Strength by means of a Micromechanical Single-Fibre Pull-Out Test; Text in English

---

Inhalt	Seite
Foreword .....	5
Introduction.....	6
1 Scope.....	7
2 Normative references .....	7
3 Terms and definitions.....	7
4 Principle.....	9
5 Abbreviations, symbols and dimensions.....	9
5.1 Symbols.....	9
5.2 Abbreviations .....	10
6 Apparatus.....	11
6.1 Fibre diameter determination .....	11
6.1.1 General.....	11
6.1.2 Vibroscopic fibre linear density and diameter test.....	11
6.1.3 Optical fibre diameter determination .....	12
6.2 Embedding station .....	12
6.3 CRE testing machine .....	13
7 Test specimen.....	13
8 Procedure .....	15
8.1 Overview .....	15
8.2 General.....	16
8.3 Fibre sampling and preparation.....	17
8.3.1 General.....	17
8.3.2 Fibre diameter determination .....	17
8.3.3 Fibre insertion into the embedding device.....	17
8.4 Matrix preparation .....	17
8.4.1 Thermoset matrices .....	17
8.4.2 Thermoplastic matrices .....	17
8.4.3 Concrete matrices .....	17
8.5 Preparation of matrix droplet.....	17
8.5.1 General.....	17
8.5.2 Thermoset matrices .....	18
8.5.3 Thermoplastic matrices .....	18
8.5.4 Concrete matrices .....	18
8.6 Fibre positioning, embedding and final forming .....	18
8.7 Solidification of the test specimen.....	19
8.7.1 General.....	19
8.7.2 Thermoset matrices .....	19
8.7.3 Thermoplastic matrices .....	20
8.7.4 Concrete matrices .....	20
8.8 Test specimen requirements and final validation.....	20
8.9 Post-preparation and conditioning.....	21
8.9.1 General.....	21
8.9.2 Thermoset matrices .....	21

8.9.3	Thermoplastic matrices .....	21
8.9.4	Concrete matrices .....	21
8.10	Pull-out test.....	21
8.10.1	General .....	21
8.10.2	Test specimen insertion and clamping .....	22
8.10.3	Testing conditions.....	23
8.10.4	Testing .....	23
8.10.5	Validation.....	23
9	Evaluation.....	23
9.1	General .....	23
9.2	Measured values and basic evaluation.....	23
9.2.1	Fibre diameter .....	23
9.2.2	Embedded length.....	24
9.2.3	Maximum force and apparent interfacial shear strength .....	24
9.2.4	Interfacial frictional force and stress .....	24
9.3	Further evaluations.....	24
9.3.1	General .....	24
9.3.2	Local interfacial shear strength derived from the debonding force.....	24
9.3.3	Alternative determination of local interfacial shear strength .....	25
9.3.4	Critical energy release rate .....	25
10	Expression of results.....	25
11	Test report.....	25
Annex A (informative)	Images of embedding procedure.....	29
A.1	Exemplary images of a correct embedding procedure .....	29
A.2	Exemplary images of invalid embedding procedures .....	30
Annex B (informative)	Images of force-displacement curves of pull-out tests.....	32
Annex C (informative)	Exemplary embedding and pull-out settings for thermoset matrices .....	36
Annex D (informative)	Exemplary embedding and pull-out settings for thermoplastic matrices.....	40
Annex E (informative)	Exemplary embedding and pull-out settings for concrete matrices.....	44
Annex F (informative)	Specific material parameters.....	47
Annex G (informative)	Typical test results and precision data .....	49
Bibliography	.....	52

## Figures

Figure 1	— Test specimen, crucible dimensions .....	14
Figure 2	— Test specimen, lateral section.....	14
Figure 3	— Test specimen in CRE testing machine, lateral section .....	15
Figure 4	— Typical temperature profile for thermoset matrices .....	16
Figure 5	— Typical temperature profile for thermoplastic matrices .....	16
Figure 6	— Ideal force-displacement curve .....	22
Figure A.1	— GF/Two-component EP with amine hardener.....	29
Figure A.2	— GF/PP .....	29

Figure A.3 — CF/Concrete .....	30
Figure A.4 — Natural fibre (Sisal)/PP .....	30
Figure A.5 — Development of bubbles while curing (GF/PU) .....	30
Figure A.6 — Drop forms no convex shape — too little matrix material (CF/PC).....	31
Figure A.7 — Development of bubbles while melting (CF/PC).....	31
Figure A.8 — Misalignment of the fibre after fast cooling .....	31
Figure A.9 — Incomplete melting — preparing an invalid test specimen due to an incompletely melted matrix.....	31
Figure B.1 — Exemplary pull-out curves of thermoset matrices.....	33
Figure B.2 — Exemplary pull-out curves from thermoplastic matrices, part 1.....	33
Figure B.3 — Exemplary pull-out curves from thermoplastic matrices, part 2.....	34
Figure B.4 — Exemplary pull-out curves from a concrete matrix.....	34
Figure B.5 — Exemplary regular vs. invalid pull-out curves.....	35

## Tables

Table 1 — Test characteristics, symbols, and dimensions .....	9
Table 2 — Materials and abbreviations.....	11
Table C.1 — Exemplary embedding and pull-out settings for thermoset matrices.....	36
Table D.1 — Exemplary embedding and pull-out settings for thermoplastic matrices.....	40
Table E.1 — Exemplary embedding and pull-out settings for concrete matrices .....	44
Table F.1 — Exemplary parameters for matrix materials (used during the development of this document).....	47
Table F.2 — Exemplary parameters for fibre materials (used during development of this document).....	47
Table G.1 — Precision data of round robin test on thermoset matrices.....	49
Table G.2 — Precision data of round robin test on thermoplastic matrices.....	50
Table G.3 — Precision data of round robin test on a concrete matrix.....	51