Measurements of in-plane shear properties of GEV206 at ambient room conditions using V-notched beam test specimen

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[2]

Issue/revision	date	pages	Summary of change
0	Nov. 14, 2003	Na	Na
	Nov. 21, 2003	5	the reference to the VUB 30-off data is corrected

1. Introduction

The in-plane shear properties, shear modulus G_{12} and it's degradation as function of an applied strain, ultimate shear strength (shear strain and shear stress to failure) for GEV206 system are measured at ambient room conditions (OPTIMAT reference conditions). This work is a part of the work package 8, OPTIMAT TG3, and is carried out according to DPA of TG3. The test that are carried out at Risø are presented in this report at this moment. The additional test results will be added as they will be provided by other partners.

The main focus of the report is on the results of in-plane shear properties obtained by using V-notch beam specimen. However, there is a short reference made to the results obtained by using the alternative methods, such as the tensile test with 30-off axes specimens. The detailed analysis of the two alternative methods will be a subject of an other report.

The materials and specimens as well as experimental procedures and measurements are discussed shortly in corresponding section of the report. The results are presented and discussed in section "Results and discussions", and all the additional information (illustrations) are given in Appendix.

2. Specimens and material

The material tested is GEV206, OPTIMAT reference material. The test specimens are manufactured and prepared according to the selected test method, see for details [1]. Specimens are cut to the final dimensions out of plate by a diamond cutting tool and V-notch is cut by using programmable milling tool. The geometry of the specimens is illustrated in Figure 1.

The strain gauge rosettes ± 45, HBM 1,5/120XY21 is mounted on both sides (back to back) of the specimen as it is shown in Figure 1.

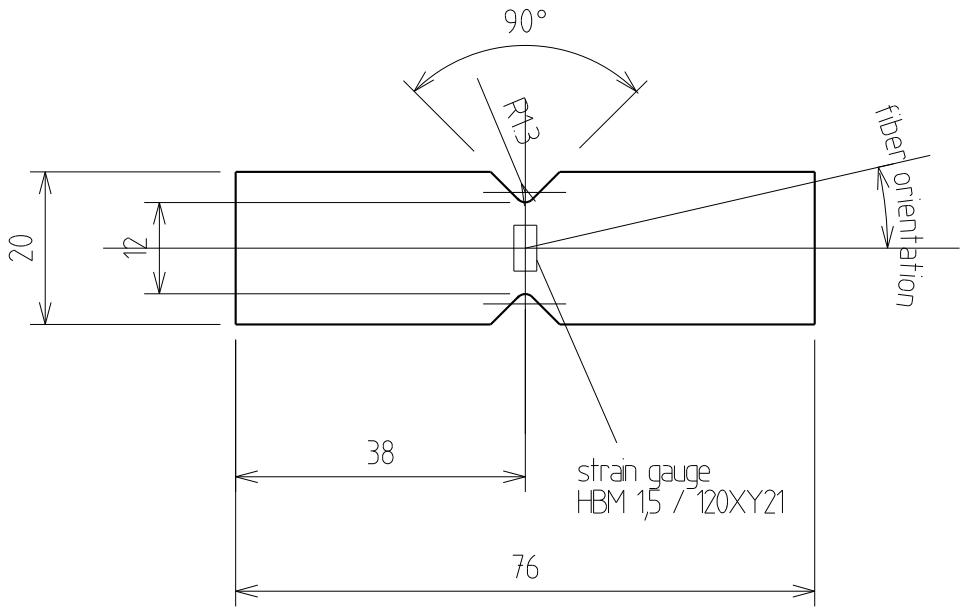

Figure 1: The geometry and set-up of the V-notched specimen.

The list of specimens that are manufactured and prepared for the test are listed in 1. Totally seven (7) specimens are planned to test, where three of them to be tested using standard [1] loading ramp (called, static), and four specimens to be tested using loading - unloading ramp with increasing applied strain level for each loading step. The loading - unloading ramp is used in order to measure the degradation of shear modulus as a function of applied strain.

Table 1: List of specimens, GEV2006-I04-0(90)

Specimen ID	Dimensions		Gauge factor		Fiber orientation degree	Loading	
	W mm	Th mm	G-fact A	G-fact B		Speed mm/min	Ramp
GEV206-I04-00-31	12.15	3.721	1.96	1.96	0	2	static
GEV206-I04-00-32	12.20	3.695	1.96	1.96	0	2	static
GEV206-I04-00-33	12.20	3.743	1.96	1.96	0	2	static
GEV206-I04-00-34	12.15	3.699	1.96	1.96	0	2	load-unload
GEV206-I04-00-46	12.15	3.702	1.96	1.96	0	2	load-unload
GEV206-I04-00-47	12.14	3.719	1.96	1.96	0	2	load-unload
GEV206-I04-00-48	12.15	3.624	1.96	1.96	0	2	load-unload

3. Test procedures and measurements

Tests are carried out according to the ASTM standard D 5379/D 5379M [1] in general. The V-Notched Beam Test Fixture is used, and cross head speed of $2.0(mm/min)$ according to the [1] is used. The load is measured using a standard load cell $\pm 25(kN)$ mounted on standard hydraulic INSTRON test machine. Strain is measured by back to back mounted $\pm 45^o$ strain gauge rosettes, see Figure 1. The data sampling of $5(Hz)$ is used for all the data (load, displacement, strain).

The static loading ramp is straight forward as it is described in standard [1] to measure in-plane shear modulus and shear strength of the material.

The loading - unloading ramp is designed so that there are five (5) steps possible until specimen breaks. The initial shear modulus, G_{12}, is measured in the first step within range of applied shear strain $0.05(\%) \leq \gamma_{12} \leq 0.35(\%)$. The fellowing steps of loading ramp are used to measure the degradation of the shear modulus as a function of applied shear strain.

All the tests are carried out at ambient room conditions.

4. Results

The tests carried out at Risø are presented and discussed at this moment. The more, obtained by other partners of TG3 will be added. There are seven specimens tested totally, where three of them are tested using, so called, static ramp, and four specimens are tested using, so called loading-unloading ramp. The initial shear modulus G_{12} (initial- property of the material without damage) is measured within limits of applied shear strain, $0.05(\%) \leq \gamma_{12} \leq 0.25(\%)$. The measured values and calculated average are given in Table 2. The strain - stress curves of the static and loading-unloading tests are given in 2 and 3 respectively. The strain and stress to failure are measured for all specimens, and values are given in Table 2.

Table 2: Experimental results of the in-plane shear properties of GEV206 using V-notched beam specimen. OPTIMAT reference material at reference environmental conditions.

Specimen ID	Width (mm)	Thickness (mm)	G_{12} (GPa)	σ_{12} (MPa)	γ_{12} $(\%)$
GEV206-I04-00-31	12.15	3.72	8.5	84	7.82
GEV206-I04-00-32	12.20	3.69	8.4	83	8.08
GEV206-I04-00-33	12.20	3.74	8.9	82	7.78
GEV206-I04-00-34	12.15	3.69	8.6	80	7.67
GEV206-I04-00-46	12.15	3.70	4.8	77	7.97
GEV206-I04-00-47	12.14	3.71	7.1(1)	83	7.89
GEV206-I04-00-48	12.15	3.62	5.3	83	7.93
Average	12.16	3.70	7.3	81	7.88
STDEV	0.03	0.04	1.69	2.43	0.13

(1)-$6.8\,[GPa]$ if the strain interval $0.05(\%) \leq \gamma_{12} \leq 0.25(\%)$ is used

The shear modulus is calculated by using least squares method to fit a linear function to the experimental data of the strain - stress curves, see Appendix Figures 4-10.

Studying the strain - stress curves carefully, it was found, that the strain stress curve change the slope significantly around applied strain level $\gamma_{12} = 0.24\,[\%] \div 0.26\,[\%]$.This change of the slope is consistent for all specimens and it affects the measurements of the shear modulus if the change of the slope happens to be within the range of applied strain where the modulus is measured. It is supposed that the change of the slope indicates on the damage formation, and the initial shear modulus should be measured before the damage takes place. For many of the specimens it possible to measure the initial shear modulus within the considered range of applied strain, $0.05(\%) \leq \gamma_{12} \leq 0.25(\%)$. It is because the change of the slope (damage) takes place right after the mentioned limits of applied shear strain. The good illustration of the case where the damage affects the measurements of the shear modulus is the strain-stress curve of the specimen, GEV206-I04-00-47, see Figure 9. The shear modulus $G_{12} = 6.8\,[GPa]$ is measured within the range of $0.05(\%) \leq \gamma_{12} \leq 0.25(\%)$ applied strain, and $G_{12} = 7.1\,[GPa]$ if it is measured before the damage takes place. The shear modulus, obtained by two different methods is consistent and comparable with each other. However, the shear stress and strain to failure are somewhat higher as compared with data given by VUB [2] where the alternative method, 30^0- off axes tensile specimens are used, see Table 3.

Table 3: In - plane shear properties of GEV206 using different test methods.

Test method/Lab	G_{12} $[GPa]$	σ_{12} $[MPa]$	γ_{12} $[\%]$
V-notch, (Risø)	7.3	81	7.88
30-off, (VUB)	7.45	53	2.29

Additional experimental data are needed in order to draw the final conclusions regarding the in-plane shear properties of the GEV206 at ambient room conditions. The detailed analysis of the in-plane shear properties obtained by the alternative methods will bi subject of another report. Also there are more experimental data planned to be available in a nearest future from within the TG3 covering both methods.

The loading-unloading tensile test is curried out in order to measure degradation of the in-plane shear modulus, G_{12} as a function of applied strain. To mention here that the stiffness degradation is considered as a measure of the damage evolution, and the obtained results can be further used in damage dependent lamination theory to describe the inelastic behavior of the material and to do damage based predictions of lifetime. The measured stiffness degradation as a function of applied strain, $G_{12}(i)/G_{12}(0)$ is measured and results are given in graphical way in Figure 11. Also the numerical values are given in Table 4.

Table 4: Experimental results of the in-plane shear properties of GEV206, OPTIMAT reference material at reference environmental conditions. Measurements of the stiffness degradation.

Specimen	γ_{12} $[mm/mm]$	G_{12} $[Pa]$	$\frac{G_{12}(i)}{G_{12}(0)}$
GEV206-I04-00-34	2.309E-03	9.04E+09	1.000E+00
	3.023E-03	8.234E+09	9.113E-01
	9.623E-03	4.489E+09	4.968E-01
	7.005E-02	1.603E+09	1.774E-01
	7.542E-02	2.77E+09	3.060E-01
GEV206-I04-00-46	2.718E-03	4.868E+09	1.000E+00
	6.621E-03	4.808E+09	9.877E-01
	1.759E-02	3.716E+09	7.634E-01
	5.020E-02	2.234E+09	4.589E-01
	7.948E-02	2.413E+09	4.957E-01
GEV206-I04-00-47	2.451E-03	7.01E+09	1.00E+00
	3.371E-03	5.389E+09	7.69E-01
	5.676E-03	3.875E+09	5.53E-01
	4.123E-02	3.894E+09	5.55E-01
	6.583E-02	2.675E+09	3.82E-01
GEV206-I04-00-48	2.622E-03	5.38E+09	1.00E+00
	6.064E-03	5.122E+09	9.52E-01
	1.343E-02	4.147E+09	7.71E-01
	4.058E-02	2.587E+09	4.81E-01

5. Concluding remarks

The in-plane shear properties of GEV206 at ambient room temperature are measured using V-notch beam specimens. The obtained values are compared with data obtained using the alternative (30^0-off tensile test) method. The in-plane shear properties obtained by two different methods are considerably different.

The data obtained at Risø are presented and analyzed at this moment. The additional data, that will be obtained by other partners of TG3 will be included in the nearest future, as there are more test planned to be carried out according to DPA.

A. Appendix

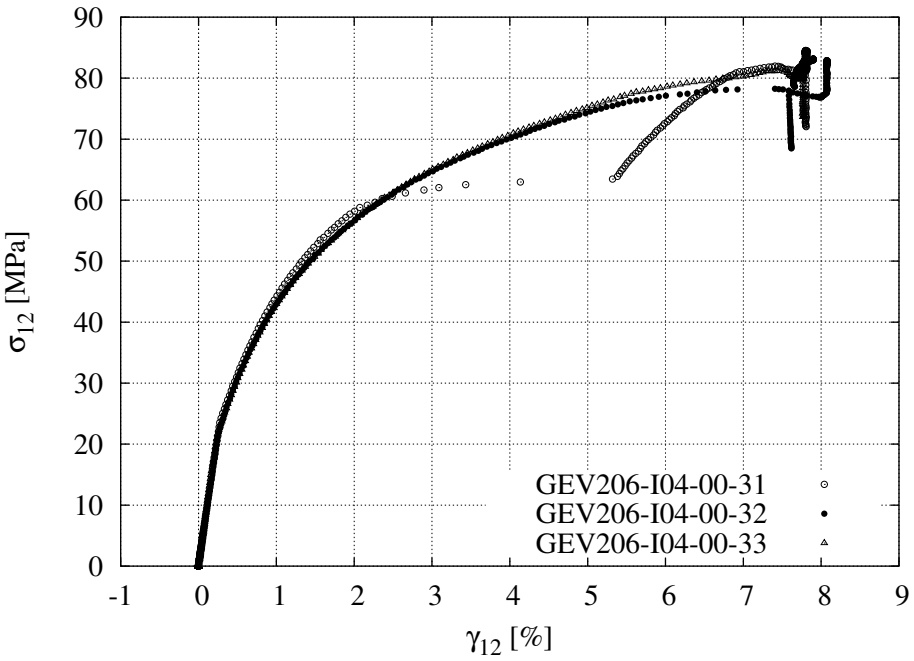

Figure 2: Static shear tests using V-notch specimen. Strain - stress curves.

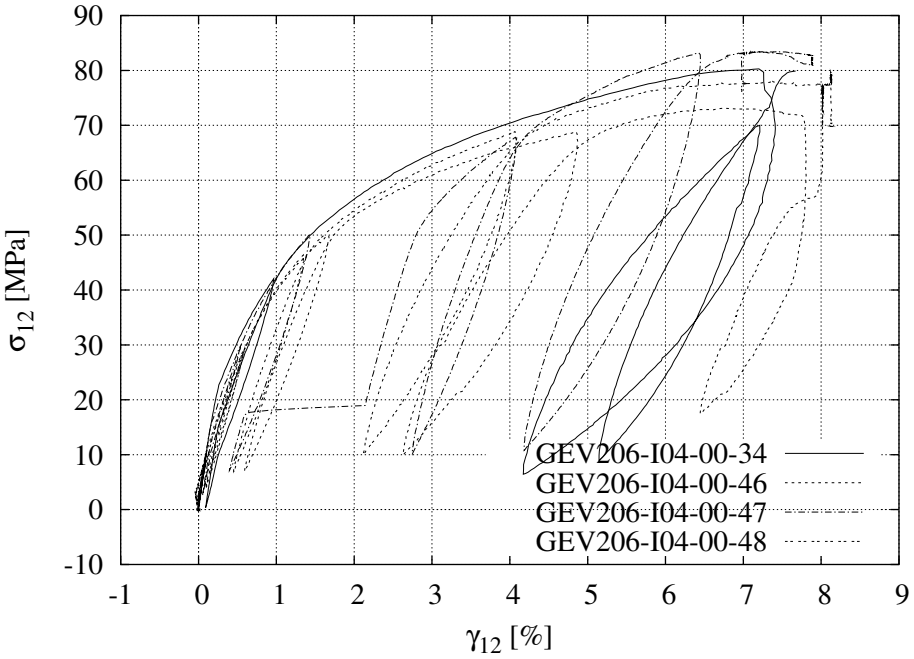

Figure 3: Stain - stress curves of the loading unloading test, GEV206-I04-00.

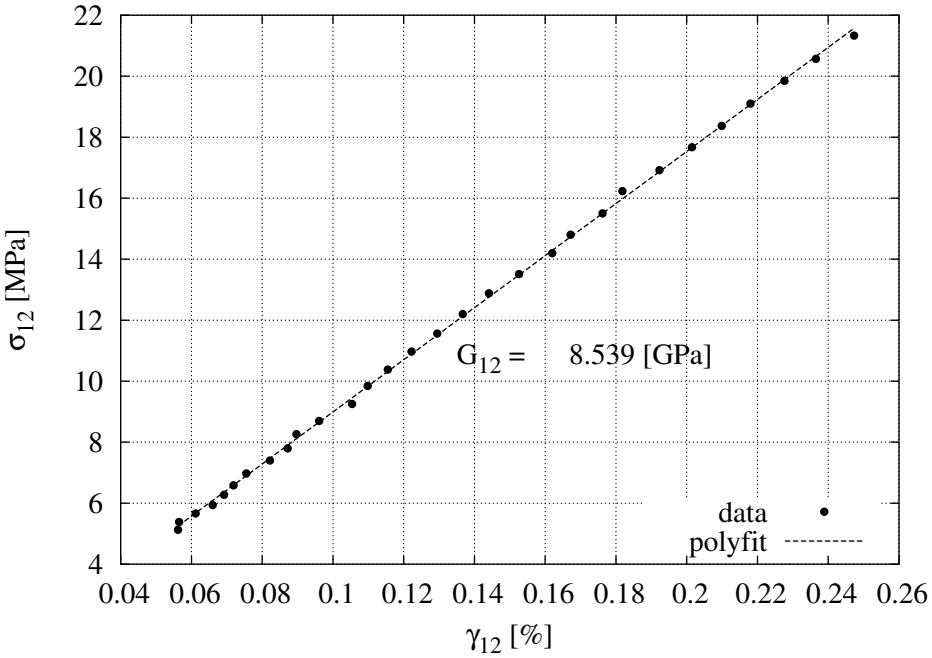

Figure 4: The results of static shear test. Calculated shear modulus for GEV206-I04-00-31.

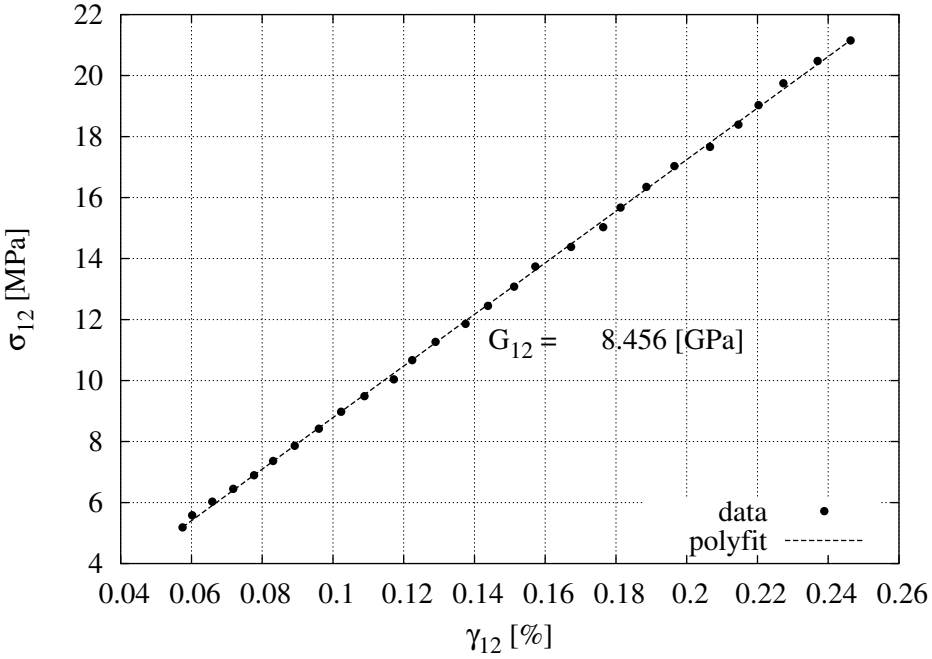

Figure 5: The results of static shear test. Calculated shear modulus for GEV206-I04-00-32.

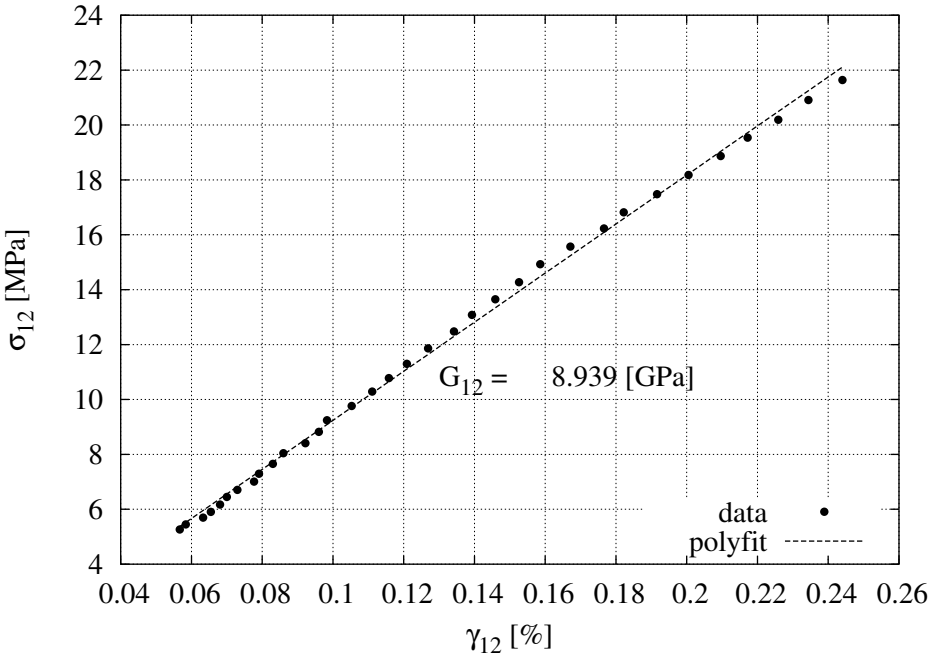

Figure 6: The results of static shear test. Calculated shear modulus for GEV206-I04-00-33.

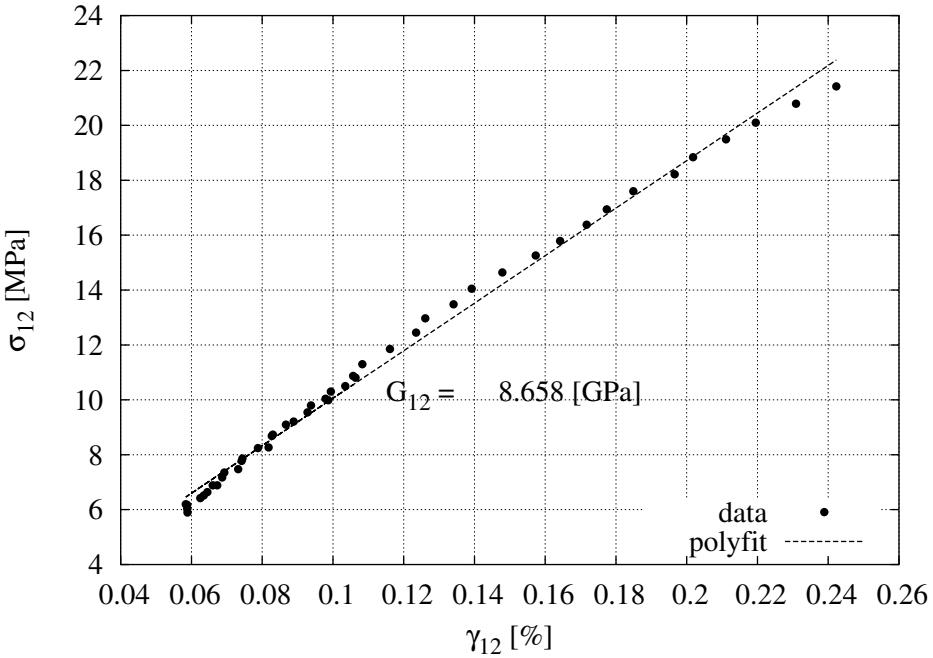

Figure 7: The results of static shear test. Calculated shear modulus for GEV206-I04-00-34.

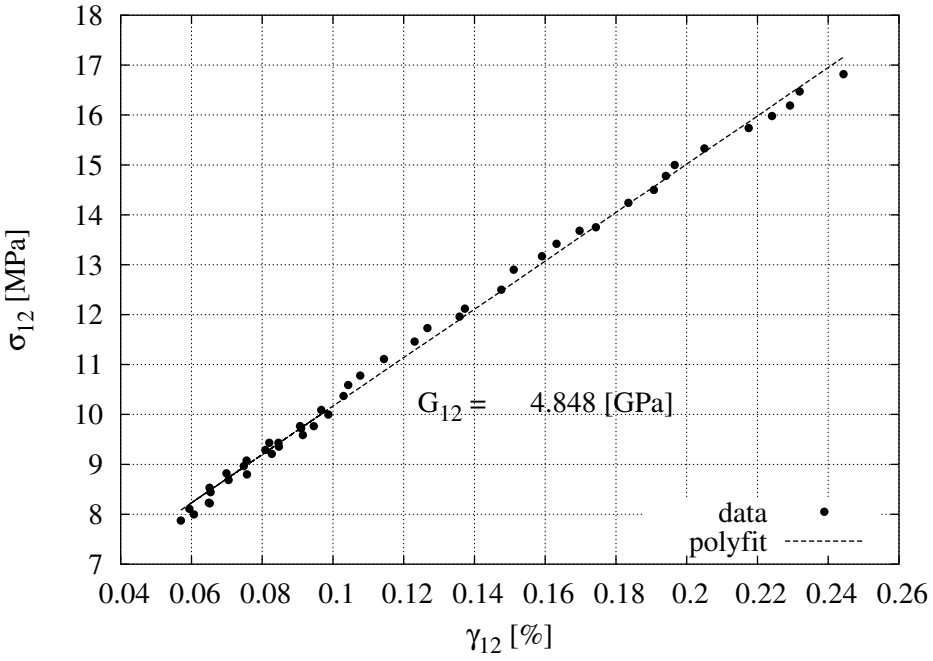

Figure 8: The results of static shear test. Calculated shear modulus for GEV206-I04-00-46.

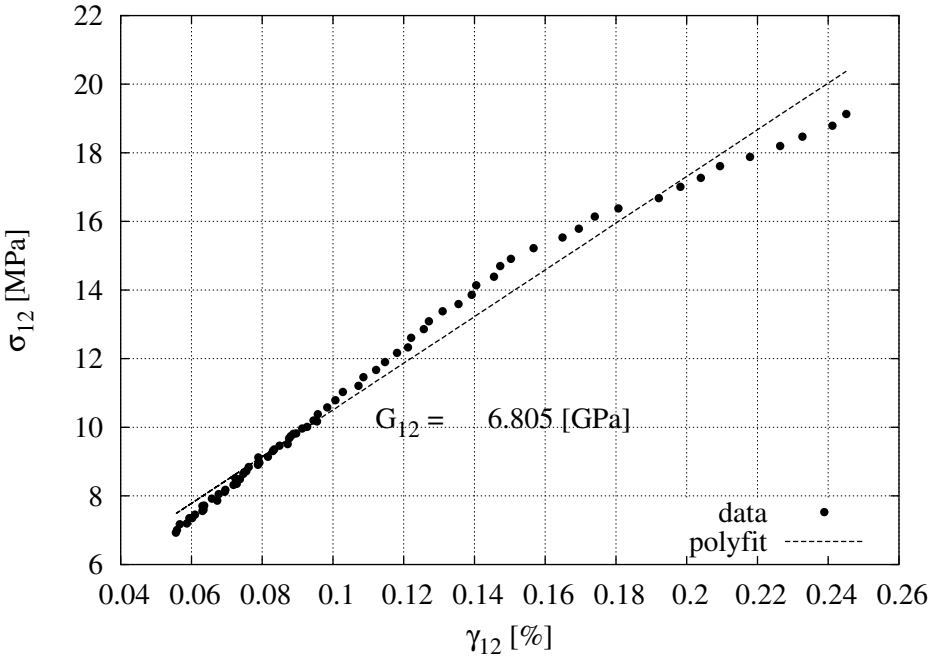

Figure 9: Figure #: The results of static shear test. Calculated shear modulus for GEV206-I04-00-47. The shear modulus that is measured within the strain limit $0.05(\%) \leq \gamma_{12} \leq 0.15(\%)$is $G_{12} = 7.1\,[GPa]$.

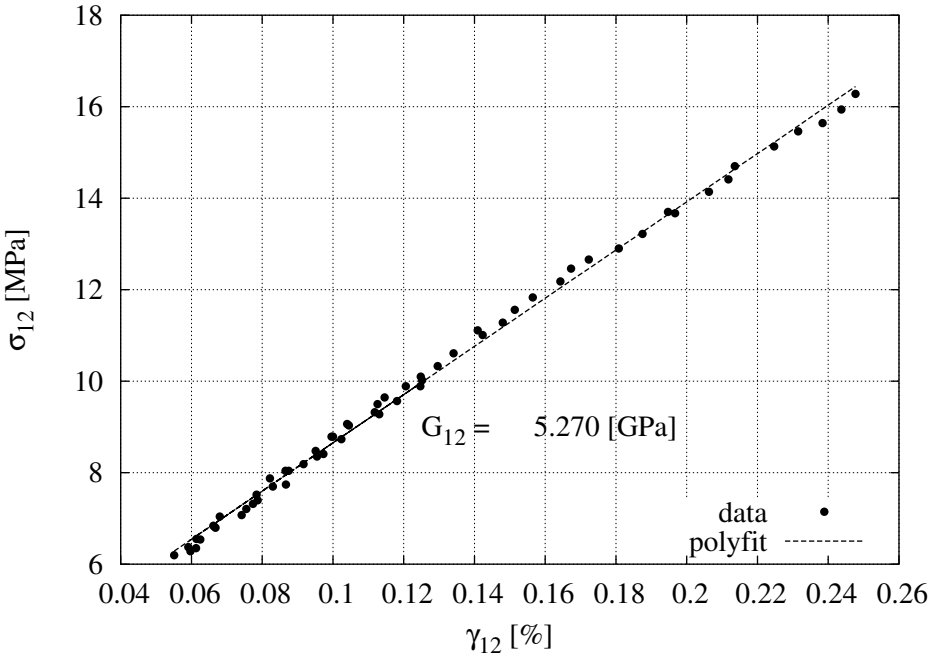

Figure 10: The results of static shear test. Calculated shear modulus for GEV206-I04-00-48.

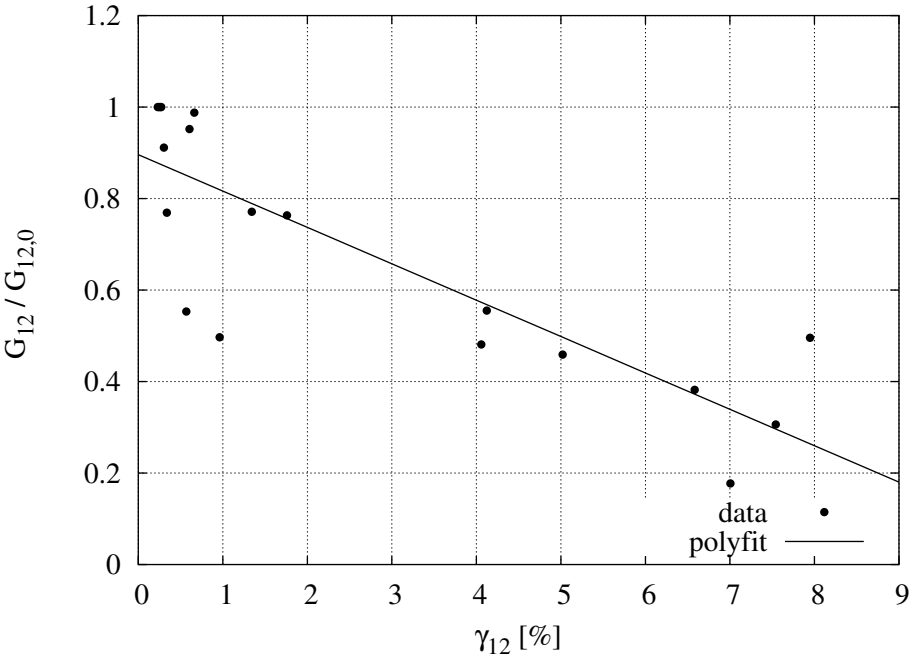

Figure 11: GEV206-I04-00, Normalized shear modulus versus applied shear strain. The linear fit $y = ax + b$. The constants are calculated, $a = -7.95094$, $b = 0.89590$.

References

[1] ASTM D 5379/D 5379M-98, Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method.

[2] OB_TG3_R011-rev.0, Static testing TG3: static tension tests on UD-material with fibers at 0^0, 90^0 and 30^0. Loading-unloading-reloading tests. Arwen Smith, Danny Van Hemelrijck, VUB.