Tensile Testing of Basalt Fibers Using a T150 UTM

Application Note

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Figure 1. Agilent T150 UTM in action.

Introduction

Basalt is a naturally occurring volcanic glass that has a nominal Young's modulus of 89 GPa.[1] In the work described here, an Agilent T150 universal testing machine (UTM) was used to measure the Young's modulus and fracture strength of two types of basalt fiber: one without binder and one with binder.

The Test Subject

Ten specimens of the two types of basalt fiber (without and with binder) were tested under the following conditions:

- Specimen length: 10.43 mm ± 0.55 mm
- Strain rate: 0.00833/sec (extension rate: ~5 mm/min)

$$\text{strain rate} \equiv \frac{\Delta L}{L \cdot t} = \frac{5\text{mm}}{10\text{mm} \cdot 60\text{sec}} = 0.0083\overline{3}/\text{sec}$$

All 20 test specimens are described in Table 1. Two strands were used for each fiber type; four to six specimens were obtained from a single strand.

A T150 UTM with pivot grips was used to test the 20 specimens. This instrument, shown in Figure 1, utilizes patented technology to measure the mechanical properties of many kinds of fibers and wires.[3,4] To test a fiber, a screw-driven stage moves the upper grip away from the lower grip, while an actuator-transducer acts on the lower grip. This actuator-transducer keeps the lower grip in a constant position by controlling the force applied to the grip. The force acting on the fiber is the force required to keep the lower grip in its target position.

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Individual fiber specimens were mounted across cardstock templates. An optical microscope with 40x magnification was used to verify that only one fiber was mounted. After placing the template in the grips, the sides of the template were cut away to expose the specimen to the test.

Specimens were extended to the point of fracture using a strain rate of 0.00833/sec. For a nominal specimen length of 10 mm, this corresponds to an extension rate of 5 mm/min

Results and Conclusions

Figure 2 shows the stress-strain curve for specimen NB1-T1. The Young's modulus is calculated as the slope of this curve between Marker 1 and Marker 2. Marker P is set at the point of fracture. Tables 2 and 3 summarize the results for fibers without binder and with binder, respectively.

The Young's moduli for the two fiber types were similar: 79.8 GPa for the fiber without binder, and 75.1 GPa for the fiber with binder. However, the fiber with binder had significantly higher strength. The stress and strain at fracture were 54% higher for the fiber with binder.

The fact that the scatter in the present results is much smaller reveals that the scatter in the previous results was indeed due to strand-to-strand variation. In the future, batch testing should include evaluation of multiple specimens from a strand and multiple strands from a batch.

Specimen Name	Fiber Type	Strand	Length, mm	Diameter, microns
NB1-T1	Without binder	1	9.88	18.4
NB1-T2	Without binder	1	10.18	18.4
NB1-T3	Without binder	1	9.81	18.4
NB1-T4	Without binder	1	9.88	18.4
NB2-T5	Without binder	2	10.06	18.4
NB2-T6	Without binder	2	10.43	18.4
NB2-T7	Without binder	2	10.37	18.4
NB2-T8	Without binder	2	10.14	18.4
NB2-T9	Without binder	2	10.76	18.4
NB2-T10*	Without binder	2	10.50	18.4
WB1-T1*	With binder	1	10.65	13.0
WB1-T2	With binder	1	11.05	13.0
WB1-T3	With binder	1	10.95	13.0
WB1-T4	With binder	1	10.95	13.0
WB1-T5	With binder	1	10.95	13.0
WB2-T6	With binder	2	10.90	13.0
WB2-T7	With binder	2	10.55	13.0
WB2-T8	With binder	2	10.75	13.0
WB2-T9	With binder	2	10.30	13.0
WB2-T10	With binder	2	10.30	13.0

* Results from this specimen were not included in calculation of average.

Table 1. Summary of tests.

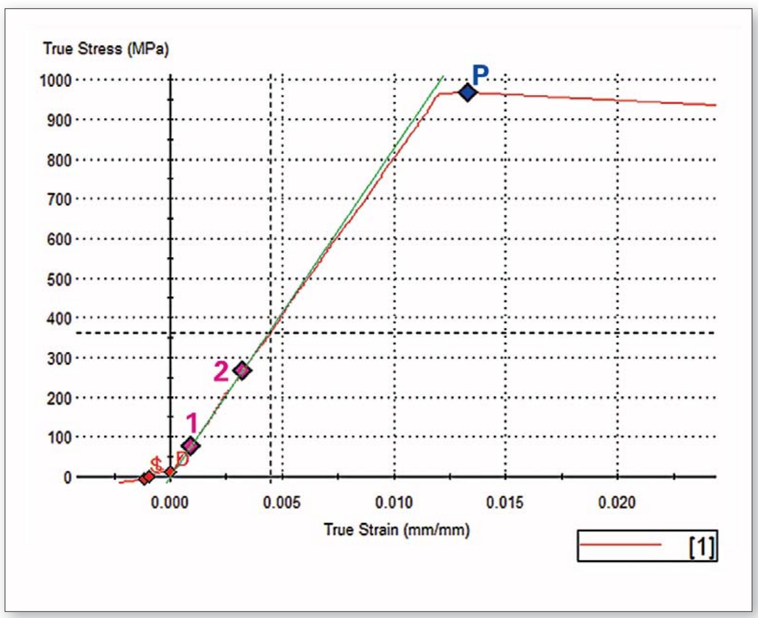

Figure 2. Typical stress-strain curve for basalt fiber without binder.

Test	Specimen Name	Modulus GPa	Max Stress MPa	Max Strain mm/mm	Start Time
	1 NB1-T1	82.160	953.963	0.013	11:45:42 AM
	2 NB1-T2	79.503	1931.210	0.027	11:51:31 AM
	3 NB1-T3	80.023	1930.759	0.028	11:56:16 AM
	4 NB1-T4	75.109	1700.092	0.025	12:01:12 PM
	5 NB2-T5	79.522	1415.046	0.020	12:05:27 PM
	6 NB2-T6	81.809	1819.275	0.026	12:13:08 PM
	7 NB2-T7	79.884	1906.214	0.03	12:19:21 PM
	8 NB2-T8	78.735	1928.830	0.027	12:34:37 PM
	9 NB2-T9	81.074	1521.637	0.025	12:38:46 PM
	10 NB2-T10*	60.010	1877.571	0.033	12:44:32 PM
Mean		**79.758**	**1678.558**	**0.024**	
Std. Dev.		**2.079**	**331.901**	**0.005**	

* Results from this specimen were not included in calculation of average.

Table 2. Summary of results for fibers without binder.

Test	Specimen Name	Modulus GPa	Max Stress MPa	Max Strain mm/mm	Start Time
	1 WB1-T1*	65.191	353.804	0.006	1:22:14 PM
	2 WB1-T2	71.900	2568.599	0.038	1:31:31 PM
	3 WB1-T3	76.152	2833.336	0.040	1:37:10 PM
	4 WB1-T4	72.157	2860.727	0.043	1:41:42 PM
	5 WB1-T5	72.817	2124.288	0.031	1:46:59 PM
	6 WB2-T6	78.437	2233.875	0.031	1:55:44 PM
	7 WB2-T7	75.821	2726.621	0.039	2:02:32 PM
	8 WB2-T8	75.121	2627.882	0.037	2:08:24 PM
	9 WB2-T9	77.875	2950.263	0.042	2:15:43 PM
	10 WB2-T10	75.935	2328.578	0.033	2:23:48 PM
Mean		**75.135**	**2583.797**	**0.037**	
Std. Dev.		**2.379**	**294.652**	**0.005**	

* Results from this specimen were not included in calculation of average.

Table 3. Summary of results for fibers with binder.

Uncertainty in strand diameter is the largest source of uncertainty in these measurements. Stiffness is calculated directly from measurements of force and displacement, but in order to calculate the Young's modulus of the fiber, the fiber diameter must be known. In this work, nominal values for diameter were used to calculate Young's modulus and maximum stress. For the plain basalt fiber (without binder) there is a discrepancy between the measured Young's modulus (80 GPa) and the nominal value for Young's modulus of basalt (89GPa). The source of this discrepancy is very likely an error in the fiber diameter. Therefore, these results might be improved by measuring the fiber diameter directly by scanning-electron microscope.

Technology and Applications

The T150 universal testing machine's nanomechanical actuating transducer head functions as a load cell, delivering high sensitivity over a large range of strain. To enable mechanical properties to be determined continuously as the specimen is strained, the Agilent Continuous Dynamic Analysis (CDA) option allows the direct, accurate measurement of the specimen's stiffness at each point in the experiment. CDA makes it possible to determine storage and loss modulus, as well as to measure complex moduli over a range of frequencies.

Applications of the T150 UTM include yield of compliant fibers and biomaterials, dynamic studies of fibers and biomaterials, and tensile and compression studies of polymers.

References

1. http://www.albarrie.com/techfabrics/continuousfiber.aspx

2. Agilent Technologies' Tensile Testing of Basalt Fibers, Jennifer Hay, January 15, 2009.

3. UTM Demonstration Video, available on request from Agilent Technologies.

4. W.C. Oliver, Statistically Rigid and Dynamically Compliant Material Testing System, U.S. Patent No. 6679124, available online at: http://www.freepatentsonline.com/6679124.html?query=swindeman+and+oliver&stemming=on.

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