Recycled Rubber Material Report for Dena Nanotech Ltd

Dr Cristina Tuinea-Bobe

Methodology

The aim of the following analyses was to determine the following parameters for a recycled rubber material at room temperature:

- tensile strength at break;
- elongation at break;
- impact strength at break;
- flexural strength;
- water absorption in 24 hours.

The tensile strength and elongation at break are parameters that can be obtained from the same test performed on an Instron 5568 device. The test samples were produced with a saw cutter. Due to the skin-like finish on the top and bottom of the samples, the thickness of the samples could not be altered for any of the tests. The thickness of the samples was approximately 13 mm. The dimensions of the test specimen were 50 mm total length, 13 mm gauge width, and 25 mm gauge length (ISO 1798).

The flexural strength test (ISO 679) was performed on an Instron 5564 device. The samples had the following dimensions: 96 mm length and 26 mm width. The dimensions of the samples were calculated for the specific sample thickness so as to keep the proportions according with the test standard. The dimension span used for this test was 80 mm.

The impact strength at break (Izod impact strength testing, ISO 13802) was performed using a Instron Dynatup POE 2000 device. A notched sample was used to determine the impact strength. The dimensions of the samples were 64 x 13 x 13 mm.

To determine the water absorption of the sample in 24 hours, the sample was weighed before the test, immersed in water, and kept for 24 hours in an oven at a constant temperature of 23°C under air tight conditions.

All the samples were cut at the University of Bradford.

Results

Tensile strength and elongation at break tests

The parameters listed below were acquired at a cross head speed of 10 mm/min. The samples were fixed in the clamps of the device as can be seen from the images in Figure 1.


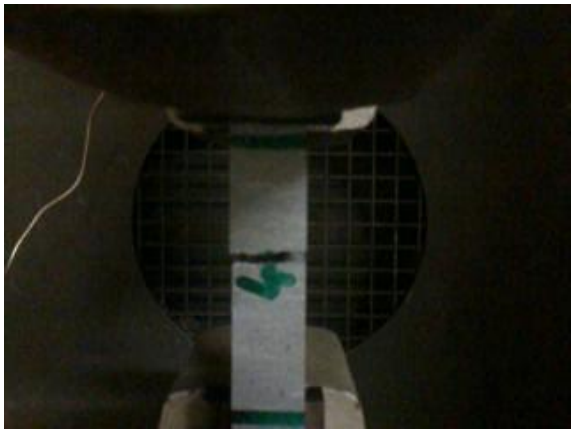

Figure 1: Images of the samples gripped in the tensile testing device.

The results of the tests are presented in the Table 1 and Figure 2. The samples average modulus was 2000±130 MPa, with an average extension (elongation) at brake of 4.4±0.5 mm. The average tensile stress at break (tensile strength at break) was 16.5±1 MPa.

Table 1: Results of the tensile strength and elongation at break tests measurements.

Sample	Area (cm^2)	Modulus (MPa)	Load at break (N)	Extension at Break (mm)	True strain at Break (mm/mm)	Tensile stress at Break (MPa)
1	1.65574	1,973.77	2,759.67	3.91675	0.02578	16.66727
2	1.65078	2,020.17	2,729.14	4.14989	0.02729	16.53239
3	1.63811	1,852.58	2,465.25	3.77534	0.02486	15.04934
4	1.6441	2,159.30	2,939.58	4.35005	0.02859	17.87954
5	1.64084	2,103.14	2,807.96	5.0833	0.03333	17.11292
6	1.63706	1,800.78	2,456.22	4.65	0.03053	15.00384
7	1.6205	2,090.62	2,820.73	4.79993	0.0315	17.40648
Mean	1.64	2000.05	2,711.22	4.39	0.03	16.52
Stdev	0.01	133.38	183.35	0.48	0.003	1.12

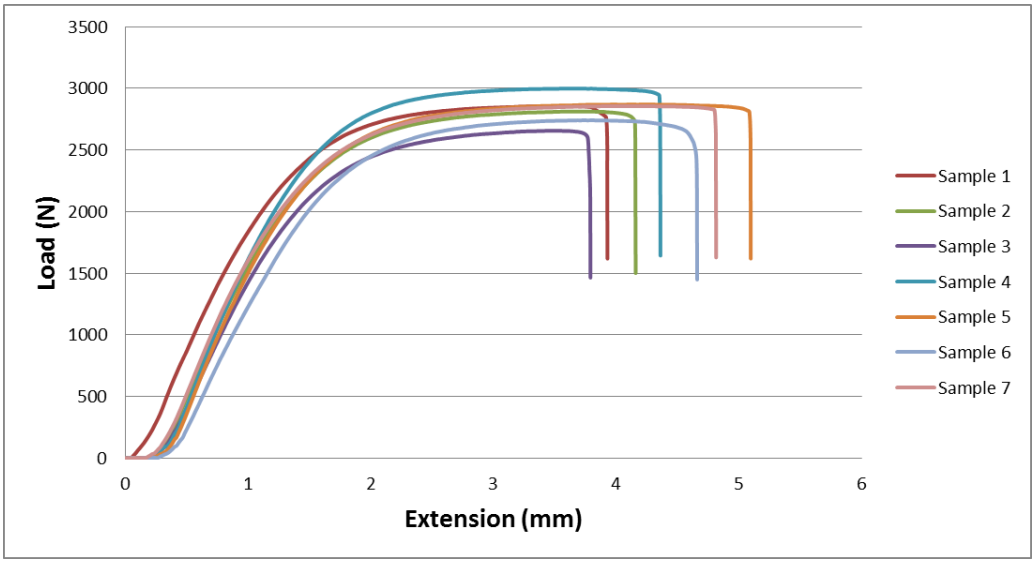

Figure 2: Tensile test graph for samples 1 to 7 showing the extension point at brake as a function of load.

As observed from Figure 3, the sample has a Young's Modulus comparable with typical high strength polymers, and of wood and wood products. This showed that the material has sufficient strength to be used for construction applications.

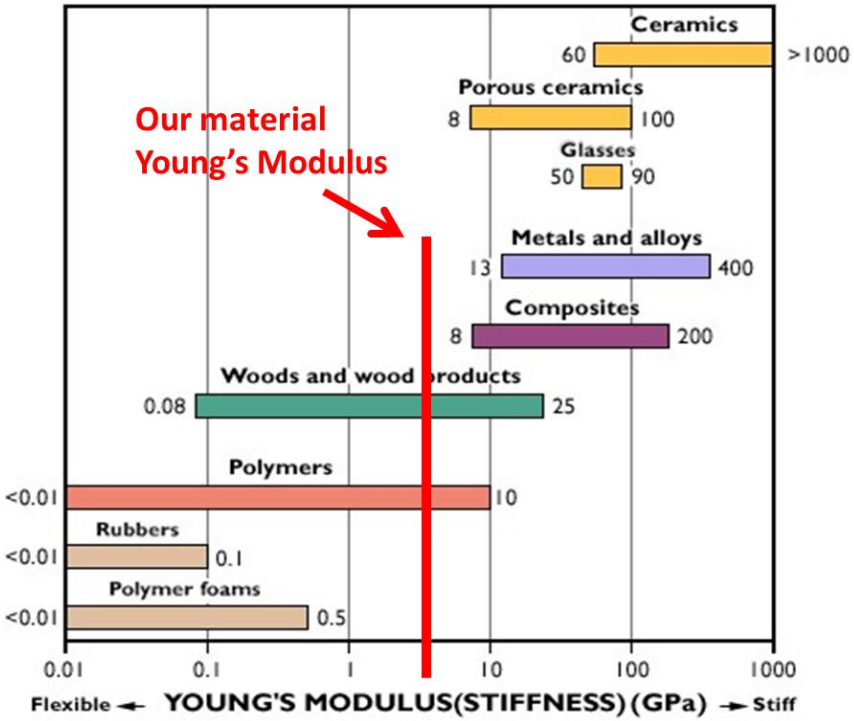

Figure 3: Young's Modulus for different materials.

Flexural strength tests

The samples were mounted in the test device as shown in Figure 4. As can been seen from the right image, the material bends under the force applied, but does not crack or brake. This shows good pliability of the material, which is important if the material is to be used without full support over the entire surface.

Figure 4: Sample mounted for the flexural test in the Instron 5564 device.

The results of the tests are presented in Table 2. The samples average modulus was 1100±26 MPa, and the maximum stress was 27±0.8 MPa. The average flexural strain was 0.03±0.0005 mm/mm at a load of 966 N.

Table 2: Results of the flexural strength test measurements.

Sample	Maximum Load (N)	Maximum Stress (MPa)	Flex Modulus (MPa)	Flexure strain at Maximum Flexure load (mm/mm)
1	905.1	26.3	1,068.49	0.03216
2	948.15	27.56	1,097.56	0.03108
3	949.22	27.59	1,128.16	0.03104
4	965.99	28.07	1,113.38	0.03108
Mean	942.12	27.38	1,101.9	0.03
Stdev	25.991	0.755	25.54	0.0005
Minimum	905.1	26.3	1,068.5	0.031
Maximum	965.99	28.07	1,128.2	0.032

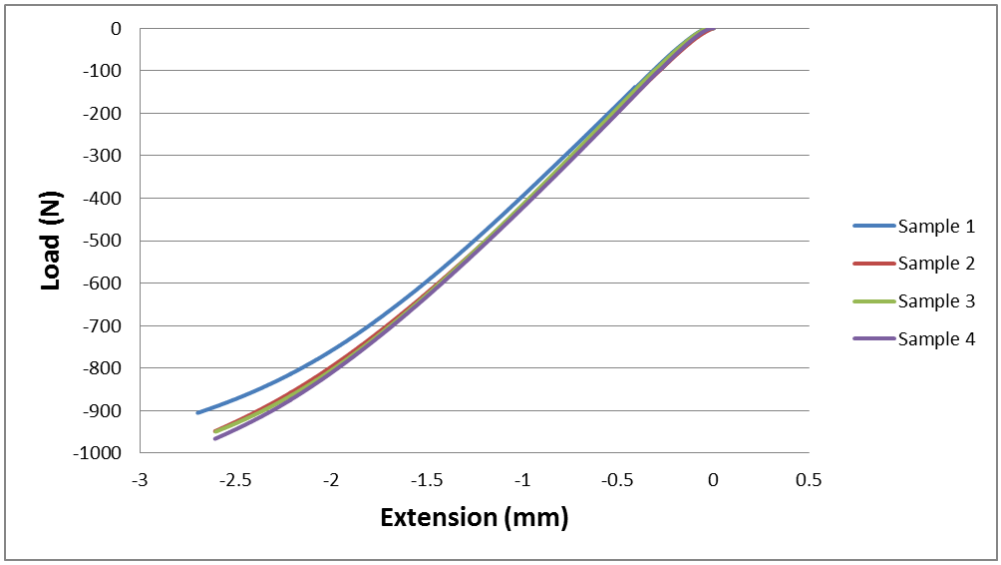

Figure 5: Flexural test graph showing the extension of the sample as a function of load.

As mentioned above, the flexural modulus defines the relationship between a bending stress and the resulting strain. Strain is a measure of the amount that a material will deform when a stress is applied. Elastic strain is reversible and will disappear after the stress is removed, meaning that the material will return to its original state. At high levels of stress, a material will permanently deform and will not return to its original dimensions. This is referred to as plastic strain or yielding. The tests performed here were maintained in a region where the material should not permanently deform since our interest was not to see when the material fails (result obtained in the previous test), but how much it can deform. The material deformation for the performed test is elastic as the material recovers its initial shape after the load is removed. This is an expected result as the base material of the composite is rubber based.

Water absorption tests

The water absorption test was performed in an oven at a constant temperature of 23°C and under air tight conditions. The sample weighed 18.3 g, and was placed in a beaker containing 800 ml water. The water absorption was monitored over 24 hours by measuring the weight. No weight increase was observed for the sample, indicating that the material does not present absorption properties over this time scale.

Conclusions

The tested material has a tensile strength value in the range of that for polymers and wood. This makes the material suitable for construction applications. The flexural test shows that the material has good elasticity under applied loads when the sample was rested on an 80 mm span. The material could be used, for example, for flooring, but the distance between the support spans should be taken in account. This kind of application is also supported by the water absorbance test.