Sustainability in Rubber and Plastics

Nicki Hershberger: ARDL

ORG September 2023

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Akron Rubber Development Laboratory (ARDL)

- Independent Testing Laboratory
- Founded in 1962
- ~100 Employees
- Mechanical Testing Labs
- Chemical Testing Labs
- Consulting - Industry-based Expertise
- Technical Training

Accreditations

- A2LA (ISO 17025)
- ISO 14385
- ISO 9001
- ASTM
- ACS
- SAE
- SPE
- APA
- ABFE
- DSA
- OEM'S
- IAPMO
- NRC
- NACE

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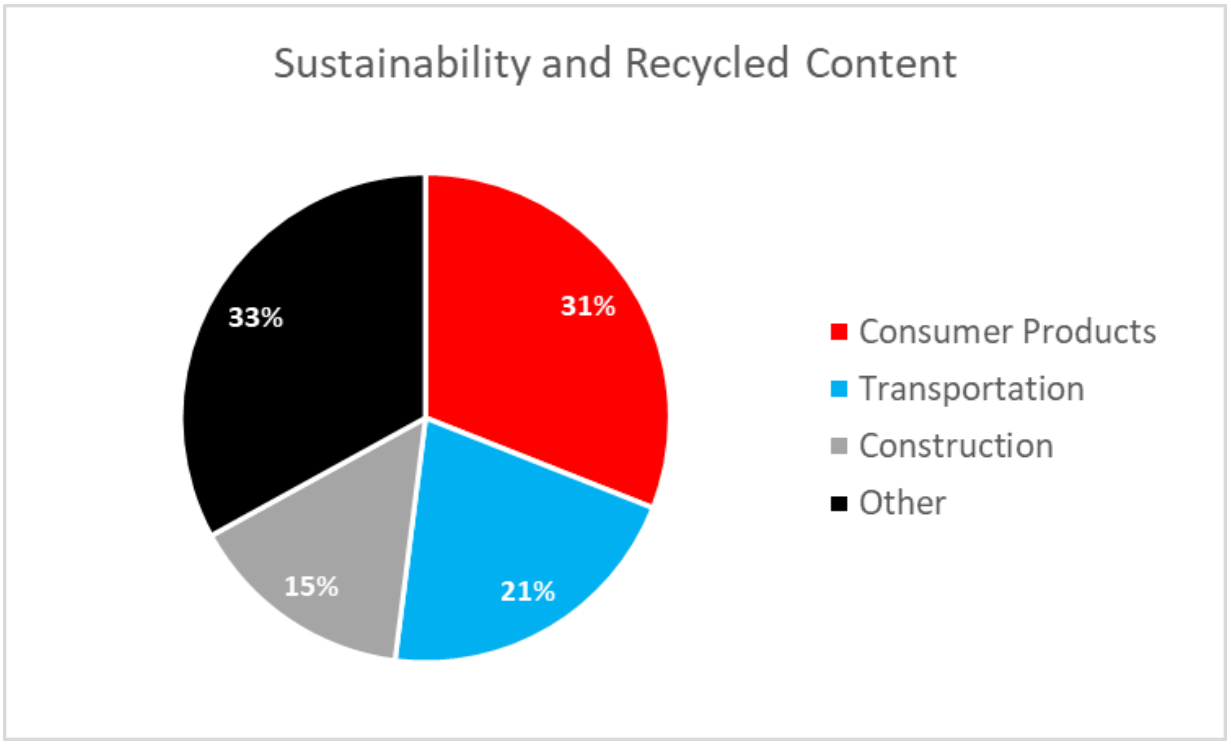
Presentation Outline

- Market segments driving sustainability
- Raw material issues that opened the doors for sustainable products.
- Sustainable raw materials and current published data
  - Soybean Oil
  - Devulcanized Tires
  - Pyrolyzed Black
  - Carbonized Soybean Hull
  - Coal Dust
  - Recycled Silica

Sustainability and Recycled Content in Elastomers



Consumer products see the largest push for sustainable / recycled use.

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Frank Esposito: Rubber and Plastics News
https://www.rubbernews.com/sustainability/hardwork-balancing-growth-sustainability

Openings for Sustainable Products

- 1). Restrictions on aromatic oil in EU.
- 2). Carbon black being labeled a carcinogen.
- 3). Tire restrictions in landfills
- 4). Hazardous waste from precipitated silica

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Elastomer Recycle / Sustainable Areas

- **Soybean oil from soybean hulls**
- Corn oil
- **Devulcanized rubber**
- Recycled rubber
- **Pyrolyzed carbon black**
- **Pyrolyzed soybean hull**
- **Pyrolyzed rice hull**
- Clean non-carcinogenic carbon extracted from methane
- Ground egg and nut shells
- Lignin
- **Recycled silica**
- Natural rubber
- Recycled plastics
- Recycled asphalt
- Hemp fiber
- Oil and resins from pine trees

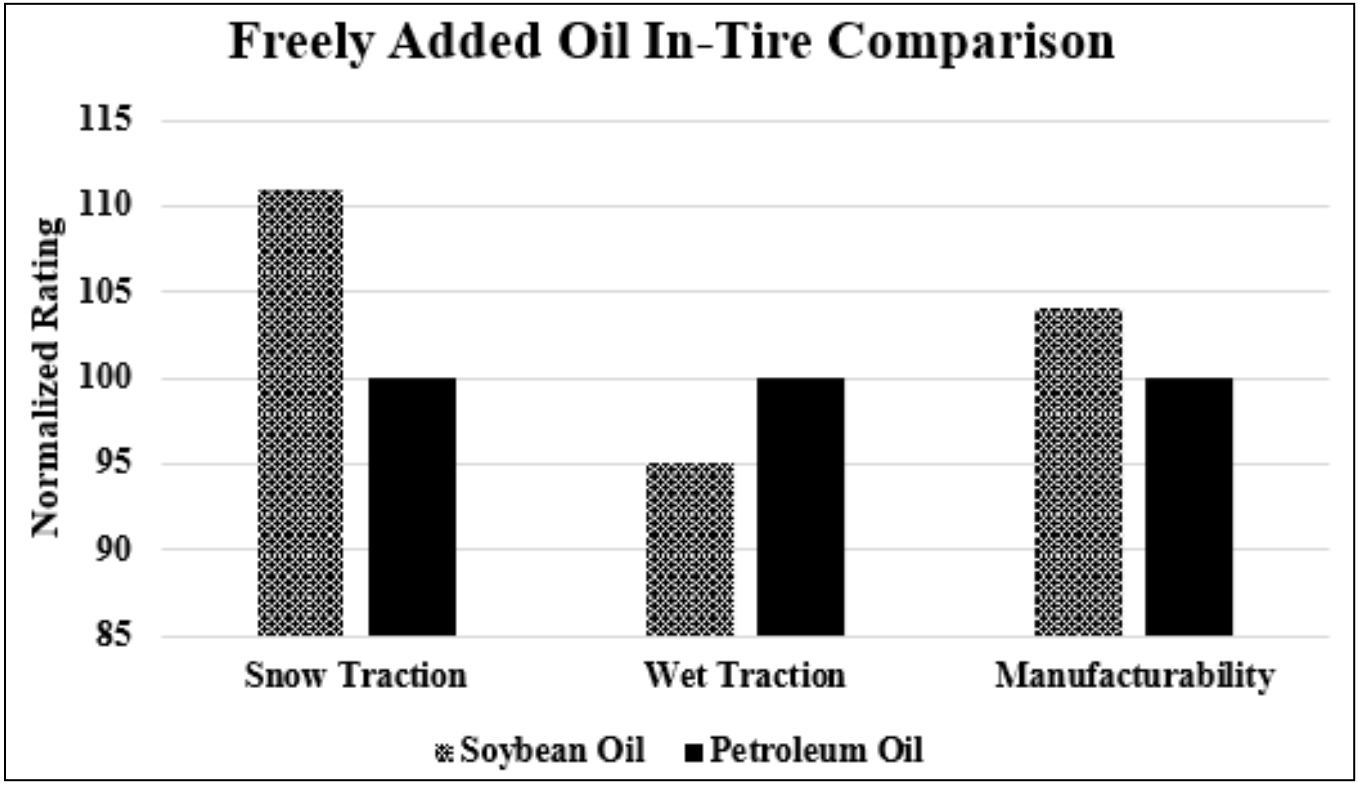
Soybean Oil in Tire Treads

Soybean oil can be used as a replacement for Aromatic or even TDAE oil in tire treads

- Soybean oil Advantages
  - Abundant
  - Renewable
  - Has thermal stability like other standard rubber process oils
  - Is chemically compatible
  - Is physically compatible
  - Has no PAH's (not a carcinogen)
- Soybean Oil Compounding Adjustments
  - Lower levels can be used in SSBR because its more compatible
  - Soybean oil may change Tg so changes in polymer percentages may be needed

Soybean Oil in Tire Treads

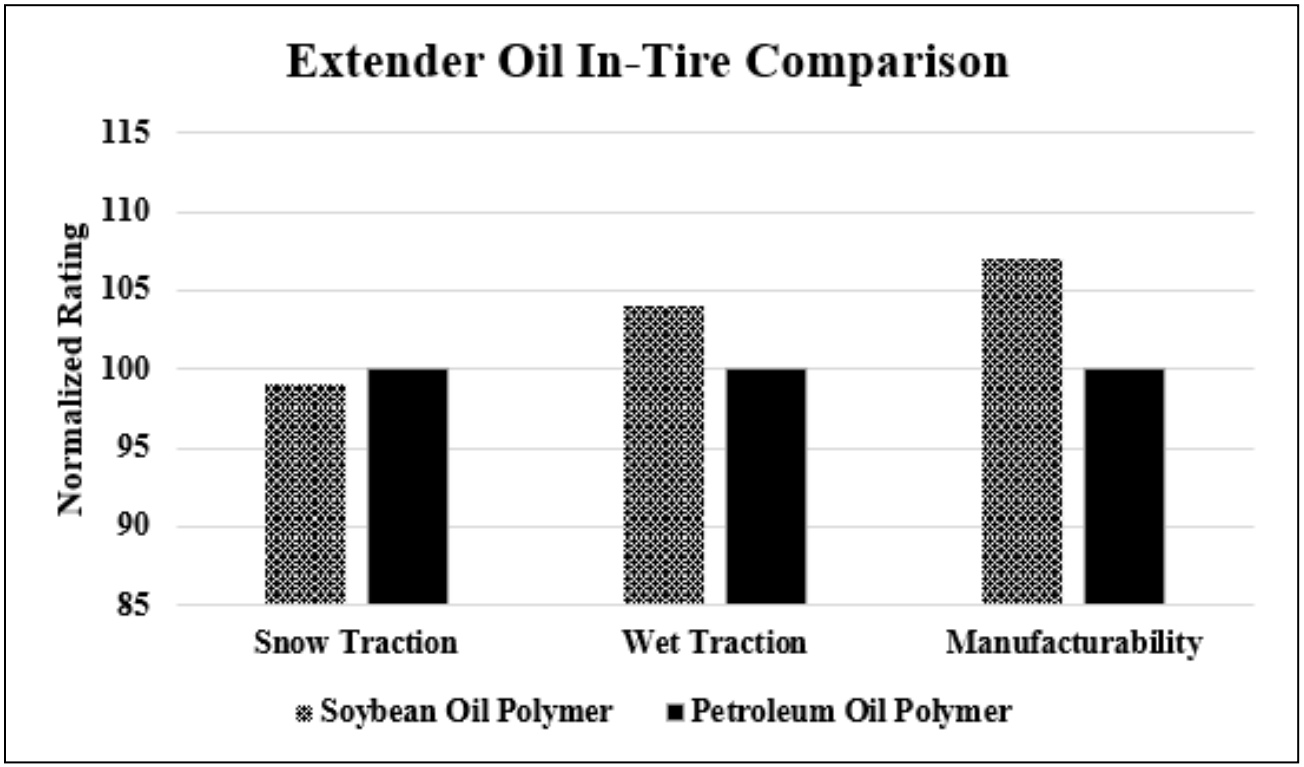
- Loose soybean oil used



The use of loose soybean oil improves snow traction but has some disadvantage in wet traction.

Soybean Oil in Tire Treads

- Soybean oil extended polymer



The use of soybean oil as an extender in SSBR has little impact on snow traction and improves wet traction.

Devulcanized Tire Use in Rubber

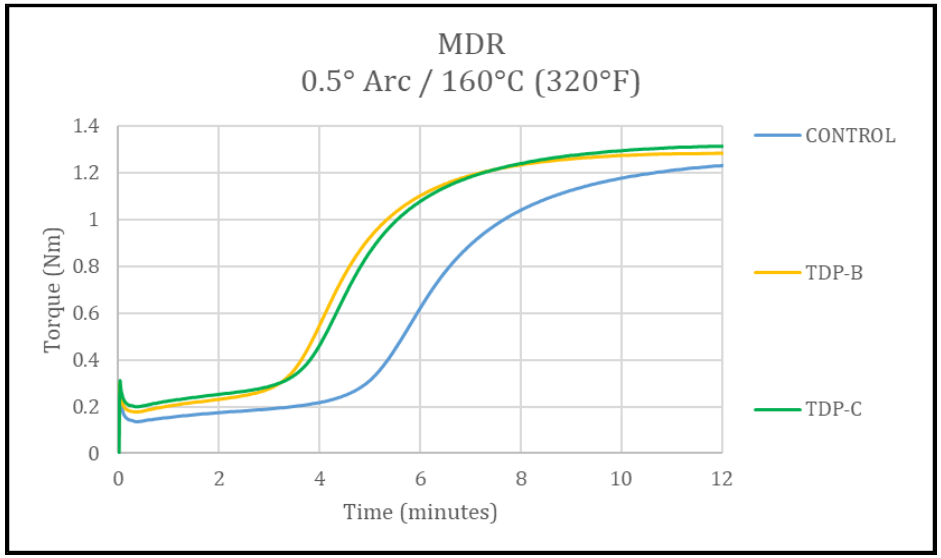
Devulcanized tires can be used as a partial replacement for NR, SBR, SSBR, and Carbon black.

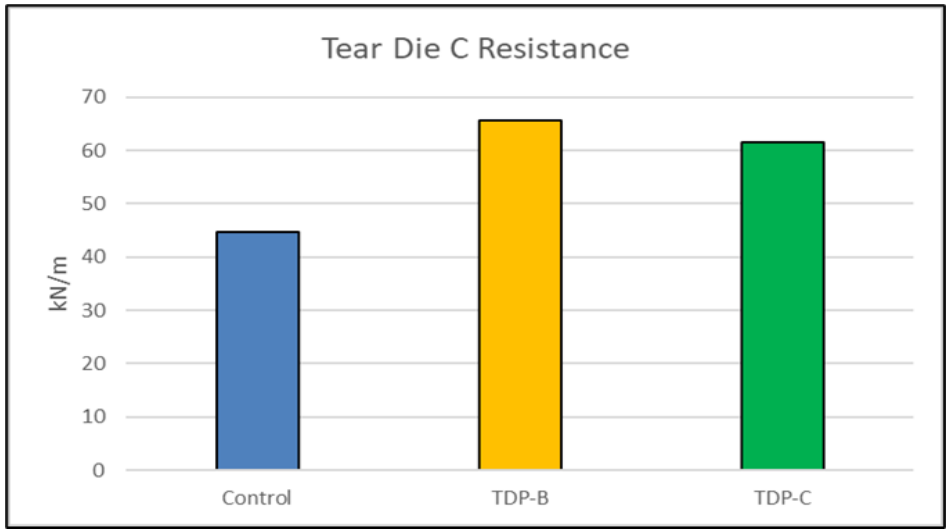
- Devulcanized Tire Advantages
  - Abundant
  - Recycled content
  - Cheaper than virgin polymers
  - Provides excellent tear resistance and toughness
  - Reduces heavy metal leaching in landfills
  - Reduces material going to landfills
- Devulcanized Tire Compounding Adjustments
  - Works best in NR, SBR, and SSBR formulations because its more compatible
  - Decreases cure rate so zinc oxide and accelerators may need adjustment
  - Most devulcanized tire material is 50% so virgin polymer and (possibly)filler will need to be reduced.
  - Sulfur levels may need to be increased
  - Devulcanized material is sensitive to mix temperature (drop temperatures 280˚F Max)

Devulcanized Tire Used in Off Road Tire Application

	PHR Control	PHR TDP-B	PHR TDP-C
Polymer System	100.00	80.00	80.00
TDP-B Reclaim		40.00	
TDP-C Reclaim			40.00
Filler System	60.00	60.00	60.00
Process Oil	24.00	24.00	24.00
Activation System	6.50	6.50	6.50
Antioxidant Sytem	4.25	4.25	4.25
Cure System	3.35	3.35	3.35
	198.10	218.10	218.10

TDP-B: Truck tire devulc.
TDP-C: Passenger tire devulc.





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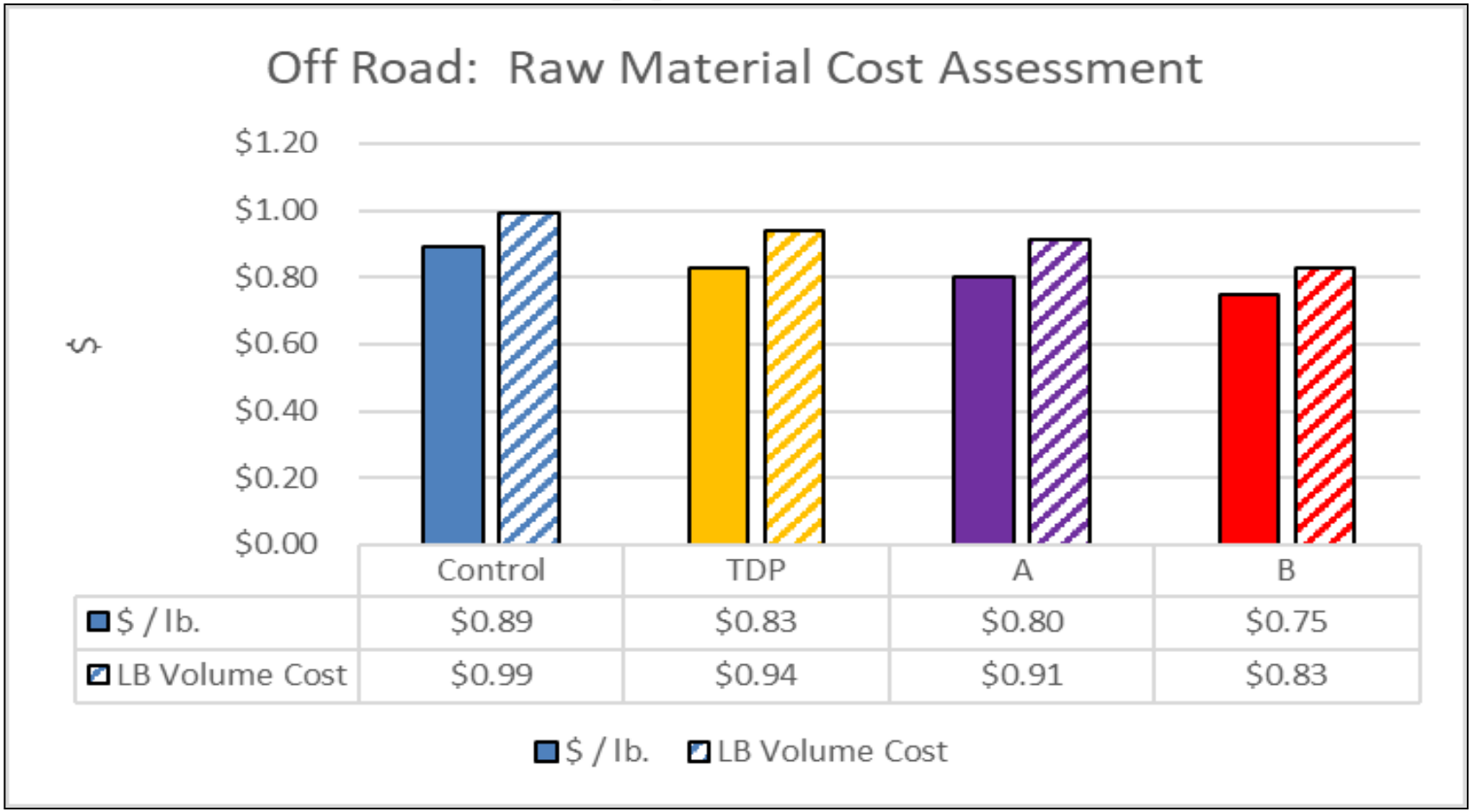
The Use of Tire or Scrap Derived Polymer in Tire and Non-tire Applications. Kathy Perevosnik North Shore Rubber and Lora McCambridge, Polymerics Inc.

Devulcanized Tire Use in Off Road Tire Application



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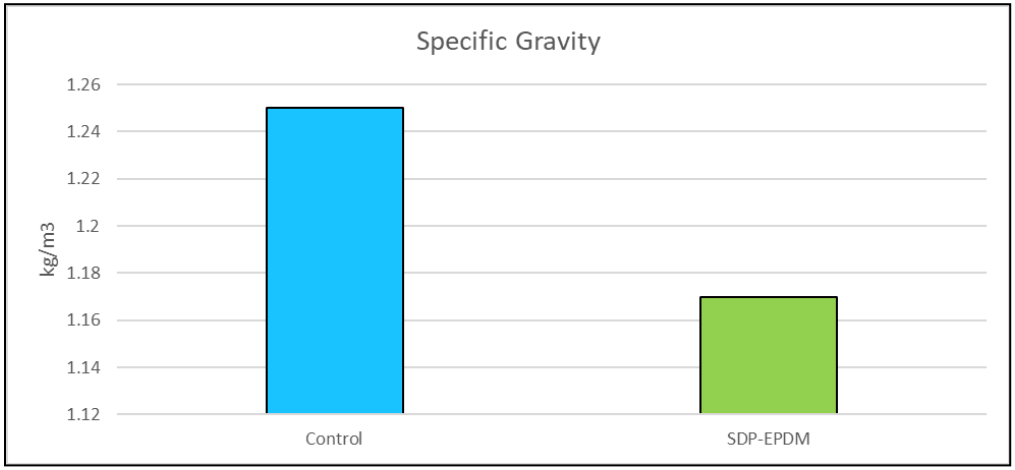
Devulcanized EPDM Use in Roofing

	PHR	PHR
	R Control	**100% SDP**
EPDM polymer system	100.00	
SDP-EPDM		200.00
Filler system	170.00	
Process oil system	60.00	
Activation system	6.50	6.50
Cure system	6.50	6.50
	343.00	213.00

	Control	**SDP-EPDM**
Tensile, MPa	11.8	12.1
50% Modulus, MPa	2.2	2.6
100% Modulus, MPa	3.4	5.7
Elongation, %	508	183
Hardness, Shore A points	71	72



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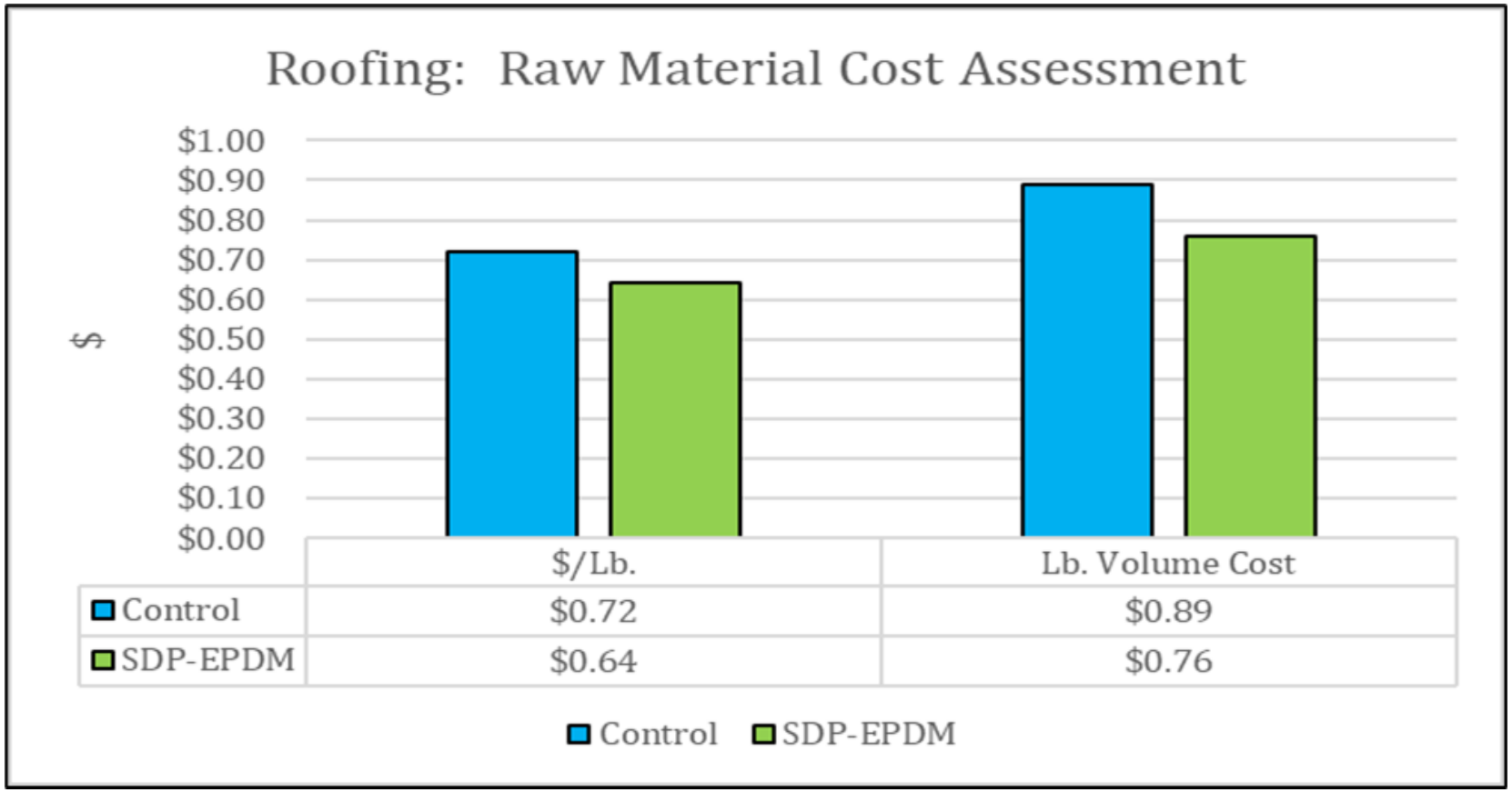

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Pyrolyzed Tire use in Rubber

Pyrolyzed tires can be used as a partial replacement carbon black.

- Pyrolyzed Tire Advantages
  - Abundant
  - Recycled content
  - Cheaper than virgin carbon black
  - Requires less water to make and emits significantly less air pollution

- Pyrolyzed Tire Compounding Adjustments
  - Tends to work as a partial replacement for semi-reinforcing blacks (n550, N660, N762, and N774)
  - Decreases cure rate so zinc oxide and accelerators may need adjustment
  - Normal use is up to 30% replacement of carbon black

The Use of Tire or Scrap Derived Polymer in Tire and Non-tire Applications. Kathy Perevosnik North Shore Rubber and Lora McCambridge, Polymerics Inc.

Bolder Industries

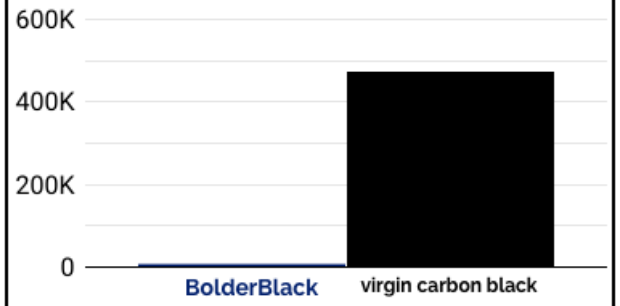
Environmental Impact Report

Bolder Industries Material

Equals 40,000

5,867
Tires diverted from landfills

Water (gallons) used



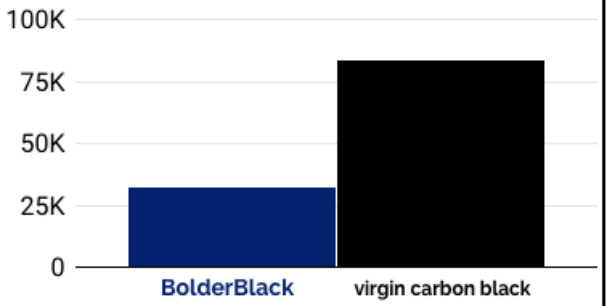
464,394
less gallons of H2O used

equivalent to

4,953,535
12 oz water bottles

98%
Less H2O used

Electricity (kWh) used



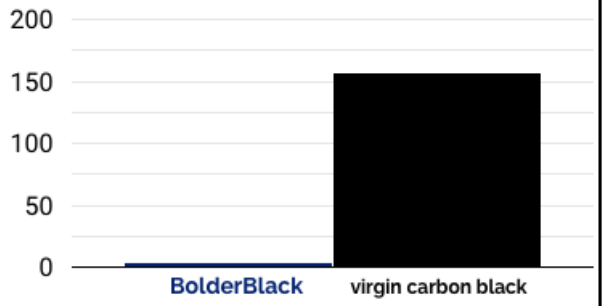
51,327
less kWh power used

equivalent to

5
fewer U.S. homes of electricity

61%
Less electricity used

CO2 (tons) produced



154
less tons CO2 emitted

equivalent to

32
fewer cars on the road

97%
Less CO2 emissions

*based on a life-cycle analysis (LCA) performed by Bolder Industries and technically evaluated by ThinkStep.

Pyrolyzed Tire use in Rubber

Carbon Black	N550	N660	N774	BB
Durometer Shore A, points	72	70	64	67
Tensile, MPa	15.2	15.0	13.2	13.9
Elongation, %	316	361	380	459
100% Modulus, MPa	1.2	1.2	1.1	1.3
300% Modulus, MPa	14.7	13.4	11.00	8.6
Tear Die C	72	70	64	67

BB stands for Bolder Black pyrolyzed black

The pyrolyzed black falls between a 600 and 700 series carbon black

Pyrolyzed Tire use in Rubber

Pyrolyzed carbon black in a BIIR inner liner formulation replacing N660

% Bolder Black	0	5	10	15	20	25	30	40	50
Durometer Shore A, points	44	43	42	44	43	42	42	41	41
Tensile, MPa	9.4	9.5	9.7	9.1	9.2	9.1	9.3	9.1	9
Elongation, %	852	878	857	836	823	814	799	781	792
100% Modulus, MPa	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.8
300% Modulus, MPa	2.5	2.6	2.6	2.5	2.6	2.8	2.9	3.0	2.8
Compression Set 22 hrs. @ 70°C, % set	30.7	29.8	30.5	32.2	32.4	31.0	31.2	29.8	30.6

Up to 50% pyrolyzed black can be used with minimal changes if any

Carbonized Soybean Hull used in Rubber

Carbonized soybean hull can be used as a partial replacement carbon black.

- Carbonized Soybean Hull Advantages
  - Abundant
  - Renewable resource
  - Does not impact human food supply
  - Cheaper than virgin carbon black

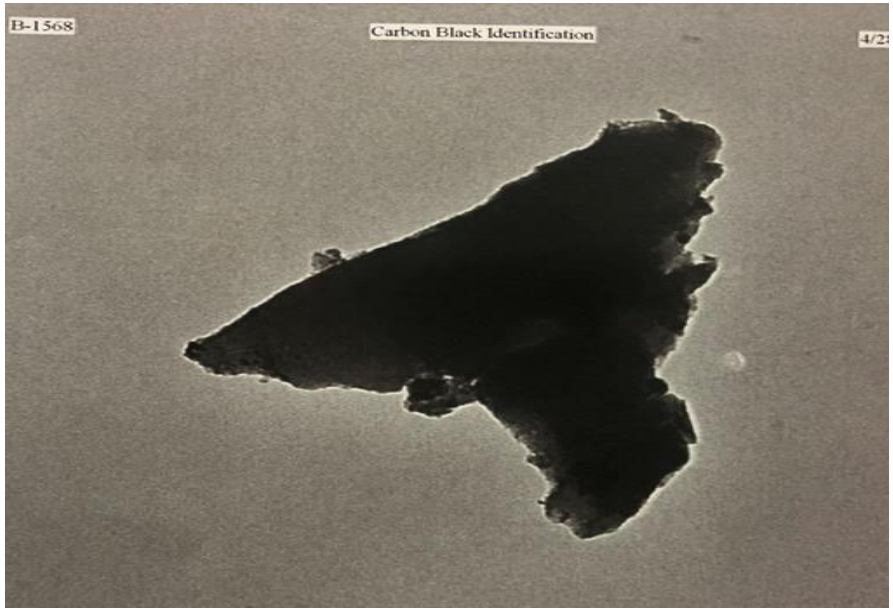
- Carbonized Soybean Hull Compounding Adjustments
  - Tends to work as a partial replacement for semi-reinforcing blacks (n550, N660, N762, and N774)
  - Decreases cure rate so zinc oxide and accelerators may need adjustment
  - Normal use is up to 25% replacement of carbon black

Carbonized Soybean Hull used in Rubber

Carbonized soybean hull is carbon, but it is very different than carbon black.

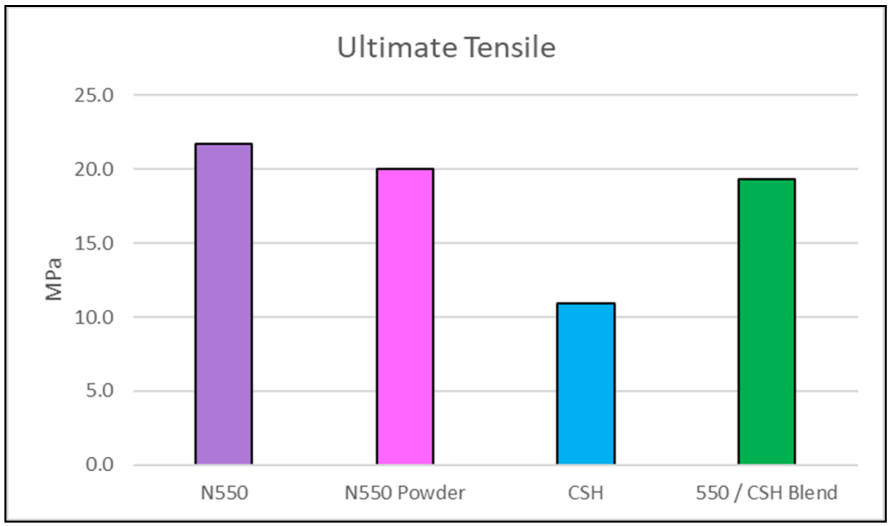
Typical Carbon Black

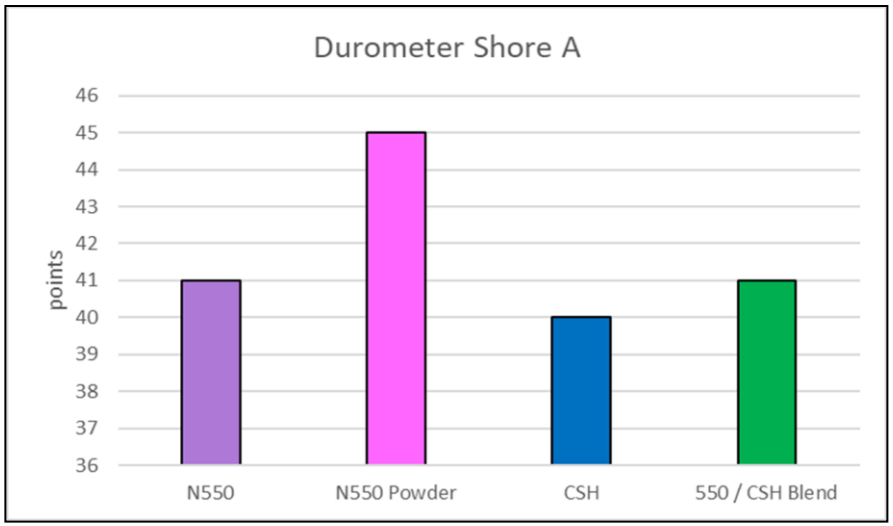
CSH

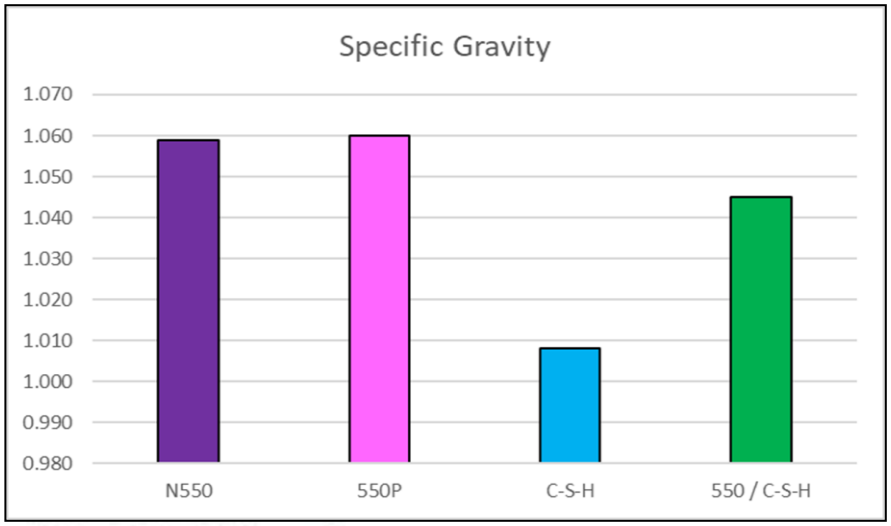


ASTM D 3849 Carbon Black Typing

Carbonized Soybean Hull in NR formulation







- C-S-H as a 25% replacement of N550 provides similar tensile and durometer properties.
- However, it also has lower specific allowing for weight reduction that would be of interest in automotive applications

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Coal Dust Use in Rubber

Coal dust can be used as a partial replacement carbon black.

- Coal Dust Advantages
  - Abundant
  - Produces 2.1 kgs less CO_2 per kg than carbon black
  - Cheaper than virgin carbon black
  - Has a lower specific gravity

- Coal Dust Compounding Adjustments
  - Tends to work as a partial replacement for semi-reinforcing blacks (n550, N660, N762, and N774)
  - Has a platy aspect ratio so can reduce permeability
  - Normal use is up to 15% replacement of carbon black

Coal Dust Use in NBR

	PHR	PHR	PHR
	Control	15 AB	25AB
Nipol 1052	100.00	100.00	100.00
N762	100.00	85.00	75.00
DOS	13.00	13.00	13.00
Zinc Oxide	5.00	5.00	5.00
Stearic Acid	1.00	1.00	1.00
Naugard 445	2.00	2.00	2.00
Austin Black 325		15.00	25.00
Spider Sulfur	1.25	1.25	1.25
TBBS	1.00	1.00	1.00
TMTM	0.50	0.50	0.50
	223.75	223.75	223.75

First Pass Mix		Second Pass Mix	
0:00	Add Nipol, ZnO, Stearic, 1/2 N762	0:00	Sandwich
1:30	Add the rest	200°F	Sweep
260°F	Sweep	220°F	Drop
300°F	Drop		

Coal Dust Use in NBR

ORIGINAL PHYSICAL PROPERTIES, ASTM D412, D2240

Die C dumbbells tested at 20 in/min.

Shore A Durometer, points

	Control	AB 15	AB 25
Tensile, psi	2482	2276	1972
50% Modulus, psi	352	351	345
100% Modulus, psi	815	735	667
200% Modulus, psi	1988	1503	1214
300% Modulus, psi	-	2079	1600
Elongation, %	275	364	412
Durometer Shore A, points	72	73	73

TEAR RESISTANCE, ASTM D624, DIE C

Tested at Gilchrist Facility

Smooth 90° Specimens tested at 20 in./min.

	Control	AB 15	AB 25
Tear Resistance lbf/in	180	192	202

SPECIFIC GRAVITY; ASTM D792

Tested at Gilchrist Facility

Tested In Water

	Control	AB 15	AB 25
Specific Gravity, median	1.27	1.25	1.24

Equates to a 3% Weight Reduction

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Recycled Silica in Rubber

Recycled silica is derived from waste from steel mills

- Recycled Silica Advantages
  - Recycled
  - It comes from abundant low-cost feed stocks
  - Its 99% pure silica
  - Produces no toxic or hazardous waste
  - Has no CO_2 emissions
- Recycled Silica Compounding Adjustments
  - none

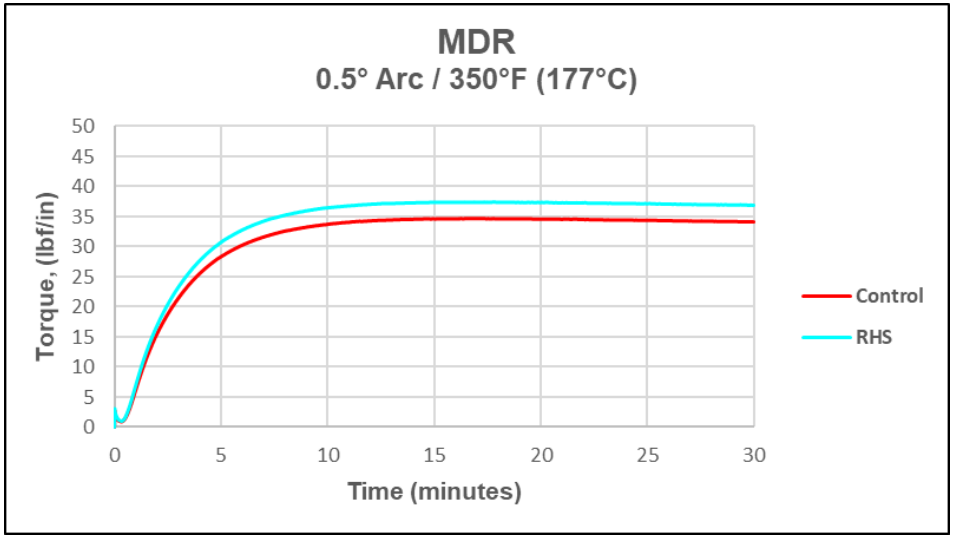
https://yavasilica.com/product

Recycled Silica in HNBR

	PHR	PHR
	Control	RHS
Zetpol 2020EP	100.00	100.00
N330	20.00	20.00
Ultrasil 7000	30.00	
DOS	8.00	8.00
Zinc Oxide	5.00	5.00
Silquest A 174	1.50	1.50
TMQ	1.00	1.00
YAVA 1124 PPI		30.00
DBPH-50	10.00	10.00
Tac 72%	2.00	2.00
	177.50	177.50

ASTM D 5289 Vulcanization Using Rotorless Cure Meter:
Montech Upgraded MDR-2000
30 minutes, 350°F, 0.50 Arc

	Min Torque, ML, lbf-inch	Cure Time, T50, min	Cure Time, T90, min	Scorch Time, TS1, min	Max Torque, MH, lbf-inch
Control	0.92	2.34	6.74	0.58	34.66
RHS	1.01	2.32	6.64	0.56	37.45



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Recycled Silica in HNBR

ORIGINAL PHYSICAL PROPERTIES, ASTM D412, D2240

Die C dumbbells tested at 20 in/min.

Shore A Durometer, points

	Control	RHS
Tensile, MPa	2466	2407
50% Modulus, MPa	512	619
100% Modulus, MPa	1379	1643
Elongation, %	143	127
Durometer, points	81	81

TEAR RESISTANCE, ASTM D624, DIE C

Specimens tested at 20 in./min.

	Control	RHS
Tear Strength, lbf/in	118	119

ROTARY ABRASION ASTM D5963

Control Abrasive, Grade 201

40 rpm, 10 N load

Median of three specimens reported

	Control	RHS
Abrasion, mm^3	117	127
Specific Gravity	1.177	1.177

Thank you for Attending!

Are There Any Questions?

Feel free to email me or visit ARDL.com and click

SPEAK WITH AN EXPERT