PVC Polymer Formulation Reinforced with Ground Wheat Straw Filler

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Omtec

- Omtec Inc. manufactures ground Wheat Straw Biofiller (gWSBF) in several grades (average particle lengths)
- gWSBF-25 + polypropylene (PP) is used in the interior storage bins of the Ford Flex (assembled in Canada) – 1000 um nominal particle length

Motivation

- Wheat straw is an agricultural residue (waste); about 300m tons available/year (2010)
- Global market volume of 32.3 m mt (million metric tonnes) in 2011
- North America produces about 900,000 tons of PVC annually; only about 1% is recycled (2012)

PVC

- Widely used for long-life (30y+) construction products: pipes, window frames, etc. About 75% of use.
- Thousands of formulations.

PVC Risks

- Manufacture, Product Life, and Recycling pose health risks due to inherent Chlorine (Cl) content
- Environmental concerns:
  - Leaking of chlorine and toxic chemicals when incinerated or landfill
  - Variety of additives in mixed PVC sourcing can hinder processing

Fillers, Biofillers

- Fillers – different lengths, different uses
  - >1 um lowering its cost per unit volume
  - < 1um impact modifiers

- Biofillers are used in PP and PVC plastic composite materials:
  - PP (polypropylene) [1]:
    - Ropes, lab equipment
    - Global market volume of 45.1 m mt, US$65b (2008) [2]
    - Up to 75% by weight
    - Typ. Particle size 10 – 60 mesh (2,000 - 180 um)
  - PVC (polyvinyl chloride) [1]:
    - Up to 60% by weight, but 20%-40% typ.
    - Typ. particle size: 40-120 mesh (425 - 125um)

Reference:

[1] Juan Bravo - Struktol Company of America, "Engineered Process Additives for the Global Wood-Plastics Composities Market", Nov. 2007 http://www.struktol.com/pdfs/STP0255%20-%20Engineered%20Process%20Additives.pdf

[2] http://en.wikipedia.org/wiki/Polypropylene

[3] http://www.prnewswire.com/news-releases/pvc-market-demand-continues-to-rise-despite-toxic-dangers-in-everyday-products-167706545.html

PVC + Wheat Straw Formulation

- Starting point: Wood –PVC formulation from Hajji et al. (2008) [4]

Purpose	Initial	Final
Matrix	PVC (K57) Lacovyl SO71	PVC Oxyvinyl 185, K=57
Biofiller	Wood flour, pine; 150-200um; 50%-wt	Ground Wheat Straw: WSBF-25(400um – 2000um); WSBF-35 (100um-500um); 0%, 10%, 20%, 30%-wt; and WSBF-35
Stabilizer	Thermolite T890F	Thermolite T890-S
PVC Heat Stabilizer/lubricant		Calcium Stearate
Process Aid	Plastistrength 770 & 530 & 320	Plastistrength 770 & 530 & 320
Acrylic impact modifier	Durastrength 320	
External lubricant		Pure Wax
UV Stabilizer		Tinuvin P

[4] P. Hajji, F. Marchand, R. Pirri, Wood-PVC Composite: formulation optimization, Institute of Materials, Minerals, and Mining, 2008.

Experiment

1. Weigh and mix powders, additives, biofiller.
2. Hot mixing.
3. Pelletizing (extrusion.)
4. Injection molding of test strips.
5. Mechanical Properties measurements (ASTM.)
6. Weathering Properties measurements (ASTM).
7. Weathering Properties (outdoor, on-going.)

Extrusion

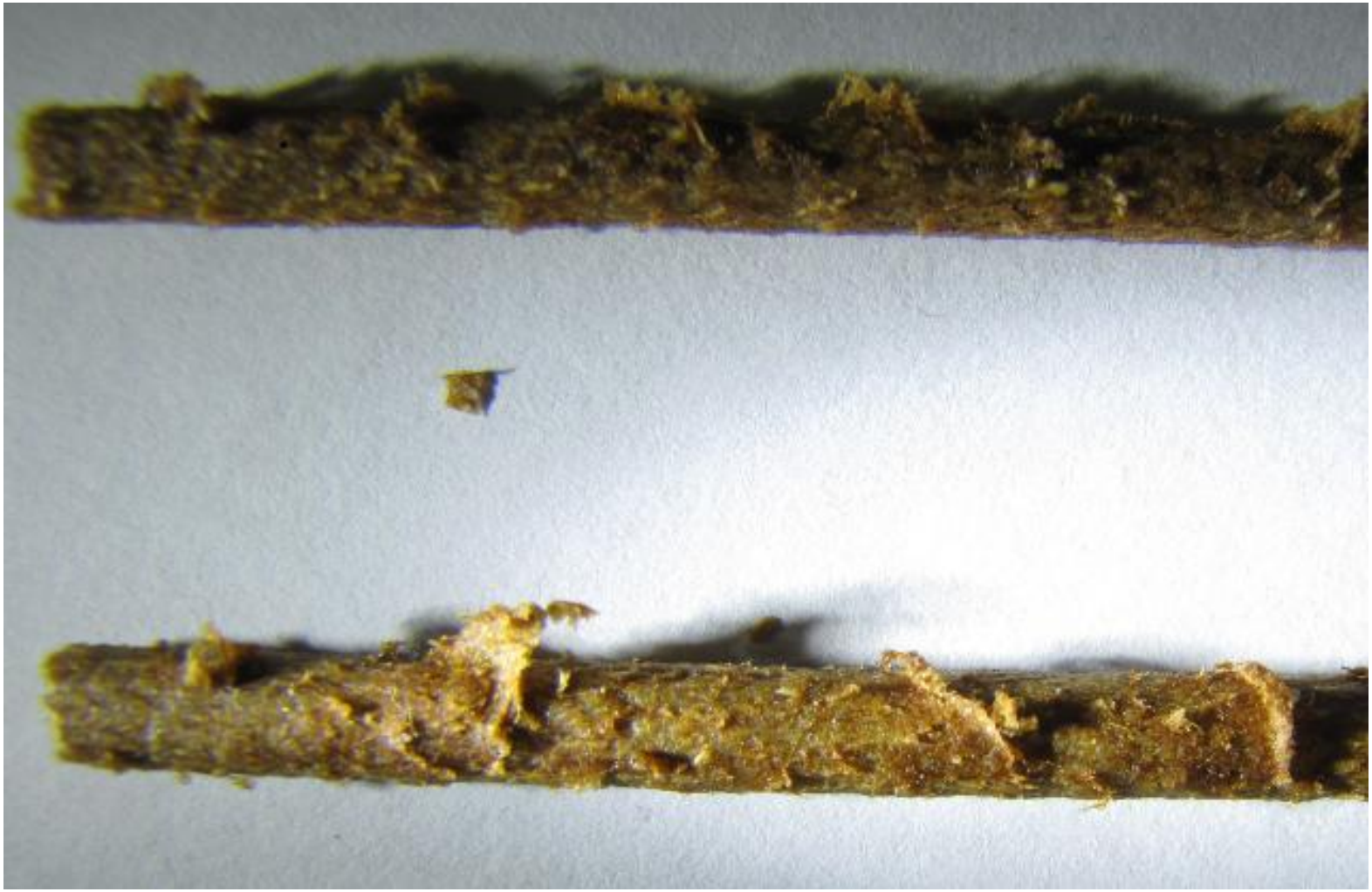


Figure 1. Extrudite 30%-gWSBF-25, ready for cutting into granules (closeup)

Test Strips

Figure 2. Test Strip produced by Injection Molding (PVC formulation only). Approx. 40g.

Test Strips

Figure 3. Test Strip produced by Injection Molding (PVC + gWSBF-25 20%-wt) . Approx. 40g.

Test Strips

Figure 4. Test Strip produced by Injection Molding (PVC + gWSBF-25 30%-wt). Approx. 40g.

Testing – Mechanical Properties

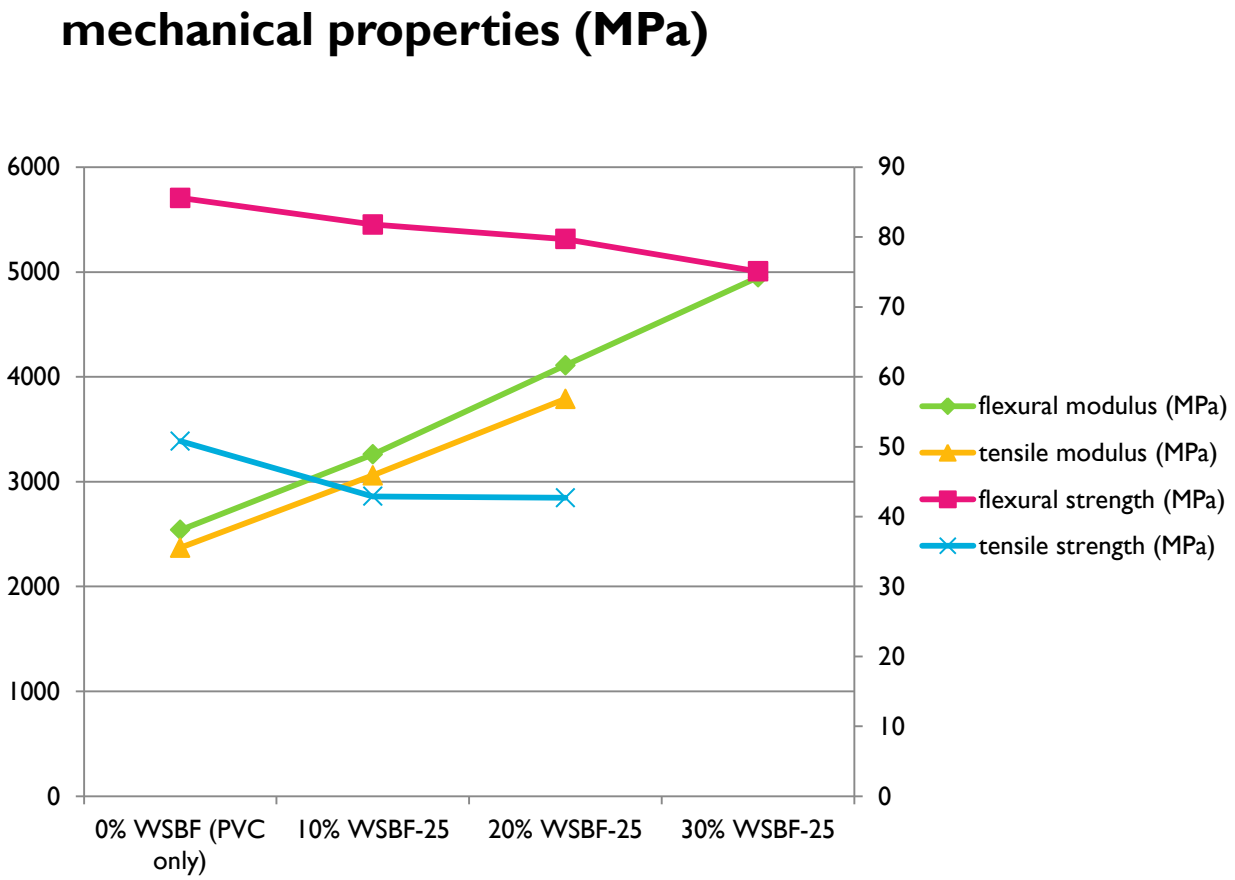
#	Test Standard	Mechanical Property	Expected Value, 100% PVC [5]	0% WSBF (PVC only)	10% WSBF-25	20% WSBF-25	30% WSBF-25	20% WSBF-35	Units
1	ASTM D790-90	flexural modulus	2000-5500	2540	3260	4110	4950	3580	MPa
2	ASTM D790-90	flexural strength	28-97	85.6	81.8	79.7	75.08	75.08	MPa
3	ASTM D790-90	flexural elongation (strain at yield)		5.20	4.10	2.70	2.80	2.43	%
4	ASTM D638-89	tensile modulus	2400-6900	2370	3060	3790	3630	Note 1	MPa
5	ASTM D638-89	tensile strength	50	50.8	42.9	42.7	40.64	Note 1	MPa
6	ASTM D638-89	tensile elongation	0.15	3.70%	2.66%	1.84%	2.22%	Note 1	%
7	ASTM D256-90	impact strength (izod, notched)	4	59	52	33	30	34.9	J/m
8	ASTM D792	density	1.3-1.7	1.29	1.38	1.38	1.38	1.36	g/cm3

PVC-only Samples are within expected values [5].

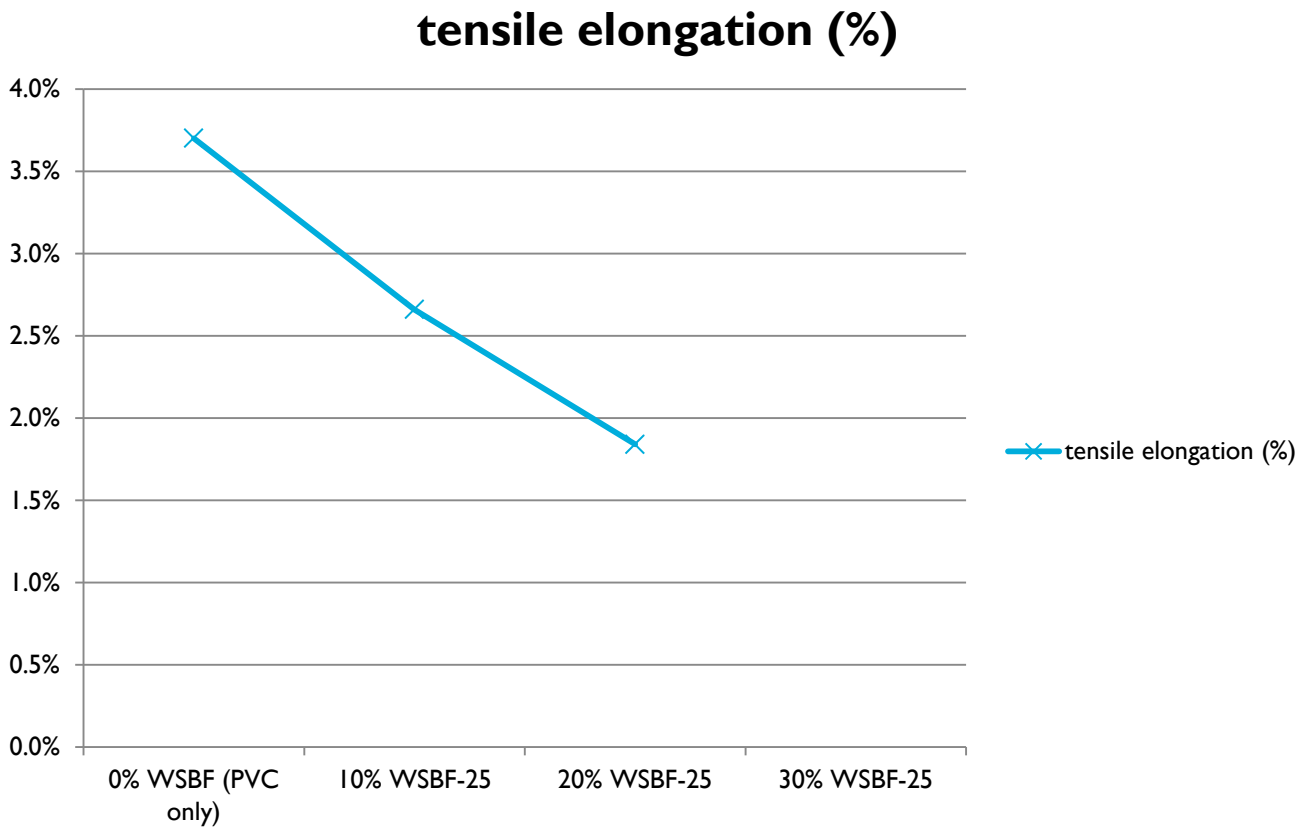
Note 1 – could not make tests due to low flowability of injection molded test strips

[5] TexWire, Wire & Cable Technical Resources, PVC Detailed Properties, http://www.texwire.us/cablewire/pvcproperties.html

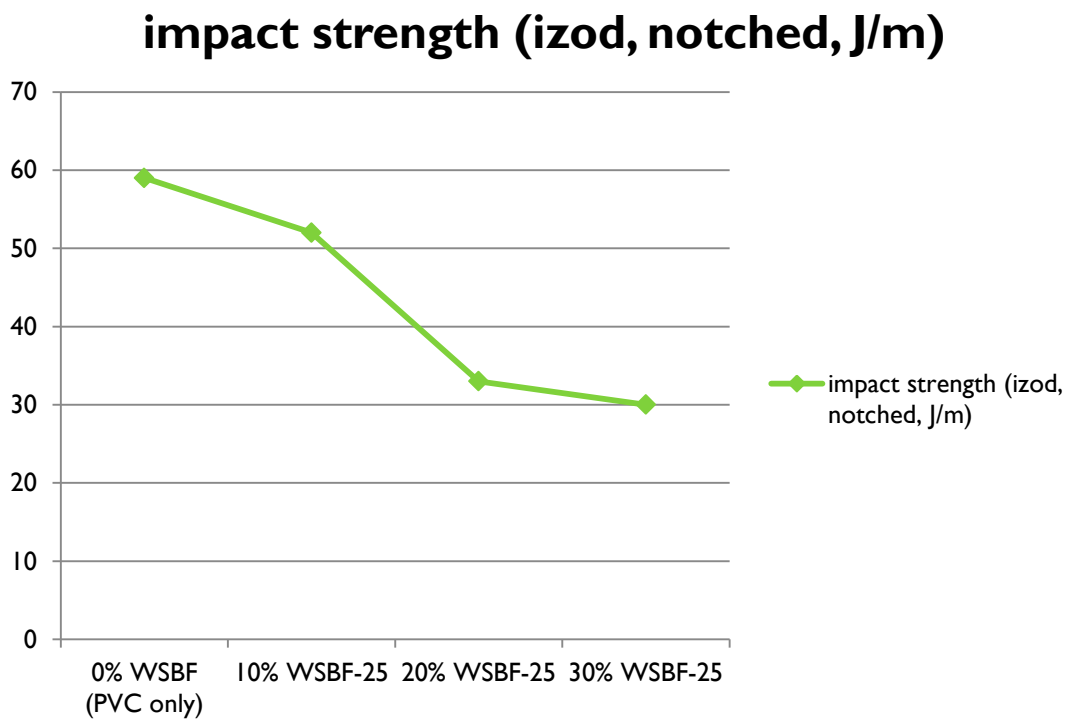
Testing – Mechanical Properties



Testing – Mechanical Properties



Testing – Mechanical Properties



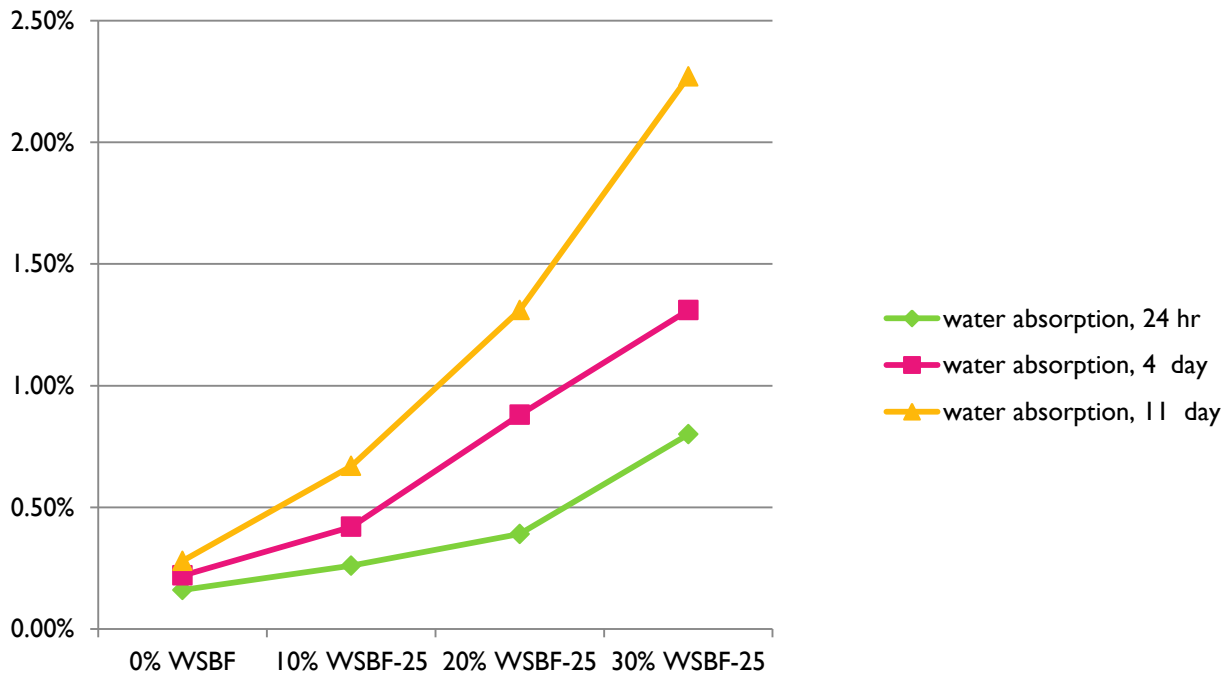
Testing – Weathering Properties

Water Absorption

#	Standard	Test Type	Expected Value, 100% PVC [5]	0% WSBF	10% WSBF-25	20% WSBF-25	30% WSBF-25	20% WSBF-35	Units
1	ASTM D570	water absorption, 24 hr	0.1% - 1.5%	0.16%	0.26%	0.39%	0.80%		%
2	ASTM D570	water absorption, 4 day		0.22%	0.42%	0.88%	1.47%		%
3	ASTM D570	water absorption, 11 day		0.28%	0.67%	1.31%	2.27%		%

Testing – Weathering Test (ongoing)

Water Absorption



Conclusions

As Wheat Straw filler load increases from **0% to 30%:**

- Flexural and Tensile Strengths:
  - Decrease 10%-20%
- Tensile and Flexural Modulus':
  - Increase 55%-95%
- Izod impact (notched):
  - Decreases 50%
- Water Absorption:
  - 5x – 10x increase in water absorption (from 0% to 30% WSBF), but still less than 2.5% after 11 days

Questions?