



# **Black Gold is** ***Green***

**Pat Kennedy, PE**

**Capital Maintenance Program Manager  
Denver Public Works, Street Maintenance**

**Arizona Pavements/Materials Conference**

**Arizona State University**

**Nov 16, 2011**

# Recycled Materials

- **Recycling commonplace**

- Aluminum Cans

- News

- Glass

- Asphalt

- Or

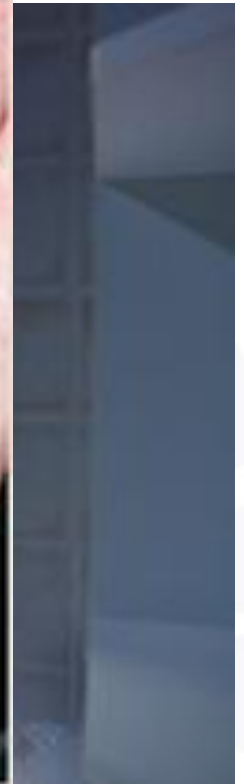
- 20

- Av



IMA

# Asphalt Additives



# Process



+



+



=



+



+



+



=



# High Tech Process

- **High Tech**
  - Oil Content by burn off
  - Crusher
  - Gradation

Component	1/2" Virgin Mix	1/2" 25% RAP Mix	
	Percent	Percent Rock	Percent RAP
Coarse agg	30.00%	22.50%	7.50%
Fine Agg	49.00%	36.75%	12.25%
Sand	20.00%	15.00%	5.00%
Lime	1.00%	1.00%	
Oil	5.60%	3.68%	1.43%

# Low Tech Process

- **Low Tech**
  - Oil content by burn off
  - Screen
  - Hammer mill

Component	1/2" Virgin Mix	1/2" 25% RAP Mix
	Percent	Percent Rock
Coarse agg	30.00%	27.00%
Fine Agg	49.00%	30.00%
Sand	20.00%	17.00%
RAP		25.00%
Lime	1.00%	1.00%
Oil	5.60%	3.68%

# Operation



# Operation



31  
for

Denver gets it done!



# Operation



# Operation



# Operation



Denver gets it done!

# Operation



3  
De

- **Oil will be age hardened**
- **Burn off will be affected by contaminants**
  - **Dirt**
  - **Organics**
  - **Road grime**
- **Anticipate 0.3% from contaminants**
- **Resultant oil will have reduced low temp properties**

- **Gradation**
  - Periodic/Frequent gradation
  - Adjust fines rather than coarse aggregate
- **Oil**
  - Check oil content when doing gradation
  - Watch voids, adjust by +/- 0.1%

# Cost Difference

Component	Unit Cost (lb)	1/2" Virgin Mix			1/2" 25% RAP Mix		
		Percent	Weight (lb)	Cost	Percent	Weight (lb)	Cost
PG64-22	\$ 0.250000	5.60%	112.00	\$ 28.00	3.68%	73.50	\$ 18.38
RAP oil	---	---	---	---	1.43%	28.50	---
Coarse agg	\$ 0.006725	30.00%	566.40	\$ 3.81	27.00%	512.50	\$ 3.45
Fine Agg	\$ 0.003475	49.00%	925.10	\$ 3.21	30.00%	569.40	\$ 1.98
Sand	\$ 0.003325	20.00%	377.60	\$ 1.26	17.00%	322.70	\$ 1.07
Lime	\$ 0.069500	1.00%	18.90	\$ 1.31	1.00%	18.90	\$ 1.31
RAP Agg	---	---	---	---	25.00%	474.50	---
<b>Cost/ton</b>			<b>2000.00</b>	<b>\$ 37.59</b>		<b>2000.00</b>	<b>\$ 26.19</b>

**Savings**

**\$ 11.41**

**30.3%**

Component	Unit Cost (lb)	3/4" Virgin Mix			3/4" 25% RAP Mix		
		Percent	Weight (lb)	Cost	Percent	Weight (lb)	Cost
PG64-22	\$ 0.250000	5.30%	106.00	\$ 26.50	3.75%	75.00	\$ 18.75
RAP oil	---	---	---	---	1.25%	25.00	---
3/4" Rock	\$ 0.006360	22.00%	416.68	\$ 2.65	18.00%	342.00	\$ 2.18
Coarse agg	\$ 0.006725	13.00%	246.22	\$ 1.66	18.00%	342.00	\$ 2.30
Fine Agg	\$ 0.003475	49.00%	928.02	\$ 3.22	19.00%	361.00	\$ 1.25
Sand	\$ 0.003325	15.00%	284.14	\$ 0.94	19.00%	361.00	\$ 1.20
Lime	\$ 0.069500	1.00%	18.94	\$ 1.32	1.00%	19.00	\$ 1.32
RAP Agg	---	---	---	---	25.00%	475.00	---
<b>Cost/ton</b>			<b>2000.00</b>	<b>\$ 36.29</b>		<b>2000.00</b>	<b>\$ 27.00</b>

**Savings**

**\$ 9.29**

**25.6%**

# Results

- **Denver asphalt plant produces 200,000 tons annually**
- **Savings is \$2,000,000**
- **Annual paving program ~ 220 lane miles**
- **Average cost per lane mile, soup to nuts is \$73,000**
- **Savings allows us to pave additional 27 lane miles (12% increase)**



# Hot-In-Place-Recycling

- **25%-30% of our program is HIPR (Cutler)**
- **Top 1" of existing asphalt heated and scarified**
- **Additional 1" 25% RAP mix added and blended into existing**
- **Resulting pavement is 60%+ recycled asphalt**
- **Obtained 10 years life on arterial applications**

## Project type

- **Low volume streets**
- **Low percentage; 10%-15% RAP**
- **Non modified binder**

## Resources

- **NAPA** <http://www.asphaltpavement.org/>
- **MGPEC (Denver Association)** <http://www.mgpec.org/>
- **Producers**

# Questions



**Pat Kennedy, PE**  
**Denver Street Maintenance**

[william.kennedy@denvergov.org](mailto:william.kennedy@denvergov.org)