PAPER INDUSTRY BYPRODUCTS
Generation, Characteristics, and Road-Related Applications

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The Use of Industrial Materials in Highway and Road Construction

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Presentation Coverage

- Introduction to NCASI
- Background on the U.S. pulp and paper industry
- Review of the generation, characteristics, and management of byproduct solids
- Discussion of specific road construction and related applications
NCASI  
National Council for Air and Stream Improvement

- Non-profit technical organization focusing on environmental issues of the forest products industry
- Member companies represent >90% of the pulp and paper and a large fraction of wood products produced in U.S.
- NCASI activities include research and information gathering, technical assistance and mill support, and education and training
- For its members NCASI produces technical reports, newsletters, regulatory alerts, handbooks, meeting proceedings, webinars, and podcasts

...environmental research for the forest products industry since 1943
U.S. Pulp and Paper Industry

- 360 pulp & paper mills operating at present
- National annual capacity, 2009: 94 million tons of paper, paperboard, and market pulp

- Mills are located in 40 states. Top 10 states in 2000:
  GA   AL   LA   SC   VA   WA   OR   WI   MI   ME

- Variety of mill capacities, manufacturing processes, raw materials, fuels, and end products
Byproduct Generation

- Annual generation of byproduct solids and solid wastes by the U.S. pulp and paper industry: 15 million dry tons
- Including two major materials
  - Wastewater treatment plant (WWTP) residuals ("paper mill sludge")
  - Boiler ash
- This presentation will review these two materials with an emphasis on WWTP residuals
**WWTP Residuals**

- **≈ 5.5 million dry tons annually**  
  (≈ 16 million wet tons/year)

- **Types**
  - Primary (including deinking residuals) – Solids from settling of raw wastewater
  - Secondary (waste activated sludge) – Solids from settling of biologically treated wastewater
  - Combined primary and secondary
  - Dredged

- **Mechanical dewatering is the norm, with a solids content typically 30-40%, range 20-60%** *

- **Very small number of mills dry residuals (70-95% solids)**

*Solids content expressed on total-weight basis*
Primary WWTP Residuals

- Primary WWTP residuals consist mainly of
  - Wood fiber and wood fines
  - Mineral or inorganic matter (e.g., kaolin clay, CaCO$_3$, TiO$_2$)
- “Ash” (mineral) content of primary WWTP residuals ranges from $<10\%$ to $>70\%$ (dry wt. basis)
- At typical solids contents, residuals are characterized by high compressibility and low shear strength
Potential Environmental Issues (Chemical Constituents)

- Heavy metals and trace elements: Concentrations tend to be similar to or below those in municipal biosolids
- Dioxins: A historical issue for residuals from bleached-kraft pulp mills, with current concentrations comparable to those in municipal biosolids
- PCBs: Also a historical issue, as their use in carbonless copy paper was banned in 1971, and levels in deinking residuals (certain recycling mills) declined precipitously
- Hazardous waste: Not hazardous based on Toxicity Characteristic Leaching Procedure (TCLP)
**WWTP Residuals – Beneficial Uses**

- Significant outlets are agricultural uses and onsite combustion for energy recovery

- To date, transportation-related uses have mostly been confined to:
  - Research and demonstration projects
  - Established programs involving a limited number of mills
  - R&D and experience outside the U.S.
Potential Roadside Uses

- Promotion of vegetation growth
  - Soil conditioner (organic matter)
  - Fertilizer (plant nutrients)
  - Liming agent (soil pH)
- Erosion control
  - Incorporated into the soil
  - Surface application (mulch)

Documentation of vegetation growth (agricultural settings) is extensive

Documentation of erosion control is limited but growing
Municipal Landfill Closure with Mill WWTP Residuals
Starting in 1977, loose-sand roads in the Chequamegon National Forest, WI, were stabilized with residuals.

Incorporation was done at a rate of about 5% dry-wt. to a depth of about 6 inches.

The mixture formed a stable surface, substantially reducing erosion.

Rutting could occur in low-lying areas with poor drainage and during heavy rain.

Residuals addition was reserved for lower-volume roads in areas deficient of readily available aggregate.

Cost-per-mile was ≤15% than that for using aggregate.
WWTP Residuals in Asphalt

- The Department of Science and Technology in the Philippines evaluated four WWTP residuals as the fiber in stone mastic asphalt (SMA)
- The residuals, first dried and ground, differed in ash (mineral) content and fiber length distribution
- Marshall specimens were prepared with bitumen ranging from 4.5 - 6.5% and residuals from 0.2 - 0.5%
- Stability was improved with residuals addition
- SMA was obtained that met stability, flow and air voids specifications for medium and heavy traffic roads
**WWTP Residuals in Concrete**

- Fibrous WWTP residuals might be used in structural concrete to enhance flexural strength and cracking resistance

- Research at Univ. of Wisconsin-Milwaukee found that small amounts (0.5-1% by wt.) of residuals can improve freeze-thaw, salt-scaling, and abrasion resistances and flexural strength of ready-mix concrete

- The research also showed problems can arise with water demand, fluidity, and setting time, resulting in 10-20% lower compressive strength
**WWTP Residuals in Concrete**

- Most recent work has examined WWTP residuals in concrete containing high-carbon coal fly ash, which is becoming more common as utilities install low-NOx burners.
- The residuals are intended to replace air-entrainment chemicals and impart resistance to freeze-thaw cracking.
- Work to date demonstrates that residuals are capable of providing high resistance to freeze-thaw cracking.
Ash or Slag from WWTP Residuals

- Thermal treatment of WWTP residuals can produce material (“PSA”) high in limestone, lime and/or metakaolin, depending on residuals composition and combustion conditions.
- PSA (“TopCrete”) produced from four deinking mills in Holland is successfully marketed as a cement substitute.
- UK Environmental Agency has a “quality protocol” (favorable beneficial use determination) on PSA use in concrete and other applications.
Ash or Slag from WWTP Residuals

- An engineering company in Georgia is pursuing the commercialization of PSA in the U.S.
- One issue: US mills often burn WWTP residuals along with wood or coal.
- There have been instances of residuals going to U.S. cement plants as raw material.
- In Wisconsin, Thermagen Power produces glass aggregate for use in asphalt and concrete, among other applications, from burning WWTP residuals in a cyclone boiler.
**Boiler Ash**

- ≈ 4 million dry tons annually

- **Types (based on fuel)**
  - Wood including bark
  - Coal
  - Wood and coal
  - Wood, coal, or both with miscellaneous solid fuels

- **Wood ash**
  - Often high in unburned carbon
  - Often high in calcium
  - Usually cementitious or pozzolanic
  - Particles are angular or irregular
Wood Ash – Beneficial Uses

- Significant outlets are agricultural applications and earthen construction

- To date, transportation-related uses have mostly been confined to
  - Research and demonstration projects
  - Established programs involving a limited number of mills
  - R&D and experience outside the U.S.
Wood Ash in Soil Stabilization & Road Construction

Canada

- Laboratory research at Univ. of Guelph demonstrated that a wood fly ash (LOI = 21%, Ca = 250 mg/kg) could improve the strength and stiffness of soil
- The lab work was confirmed in field research by treating a landfill haul road having clayey soil, which resulted in reduced rutting
- Subsequently, the pulp mill involved in the research began to routinely treat forest haul roads with the fly ash
- The treated roads have an increased allowable load during the winter
Wood Ash in Soil Stabilization & Road Construction

Finland

- Fly ashes (wood and wood-peat) and ash-WWTP residuals mixtures have been used in demonstration projects to renovate unpaved and low-volume paved roads
- A mixture of WWTP residuals and fly ash* yields a material with good frost insulation, bearing capacity and workability
- The residuals-ash mixture was also a fill material in the construction of shoulders on a narrow gravel road
- Sampling of groundwater during several years for various inorganic parameters indicated “no risk to the environment.”

* Binder (cement, lime or gypsum) at 1% to 2% may also be added.
Wood Ash in Soil Stabilization & Road Construction

- This work has lead to some routine use of wood ash and residuals-ash mixtures in road construction.
- Similar activity is occurring in Sweden, and Finland is assisting Russia to develop demonstration projects.
Wood Ash in Concrete

- Use of wood (and other biomass) fly ash in concrete is a subject of research, e.g., Brigham Young University, University of Wisconsin-Milwaukee

- Issues with wood ash in concrete include:
  - Technical standards that are material specific (coal ash)
  - Requirement for low-carbon ash (freeze-thaw resistance)

- Southeastern pulp mill has its coal-wood fly ash state-DOT approved (designated Class F) and used in concrete for highways and bridges

- Ash from a wood-fired boiler at the mill is injected into a coal-fired boiler, providing better use of wood for energy and producing a low-carbon combined ash

- Coal-wood bottom ash from the mill employed as aggregate in asphalt mixes and in concrete blocks
Questions and Comments

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