Commercialization of SulfCrete®:

An Alternative Low-Carbon Concrete

Paul Kalb

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SULFCRETE

Background

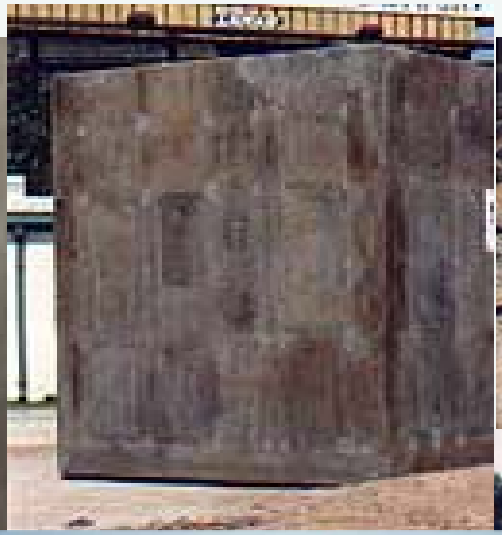
- Sulfur is a by-product material generated from the production of oil and gas and the cleanup of coal-fired power plant emission gases

- Millions of tons/year are produced throughout the world - supply exceeds demand and large volumes of by-product sulfur are in storage (>21 M tons)

By-products to Co-products

- Excess by-product sulfur can be recycled into beneficial concrete co-products (e.g., pipes, aggregate for road construction, paving stones, railroad ties) for improved sustainable development
- Potential for displacement of conventional hydraulic cement in many applications; large potential markets

Sulfur Polymer Concrete Products

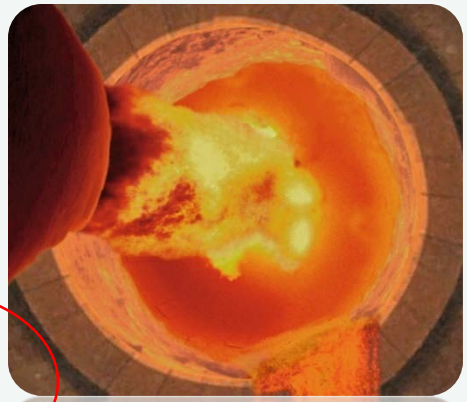





Recycling industrial by-products to produce new commercial co-products

Sulfur: the Green Concrete

- Large amounts of CO_2 are generated in the production of conventional hydraulic cement as limestone is converted to calcium oxide using high temperature fossil fuel kilns:



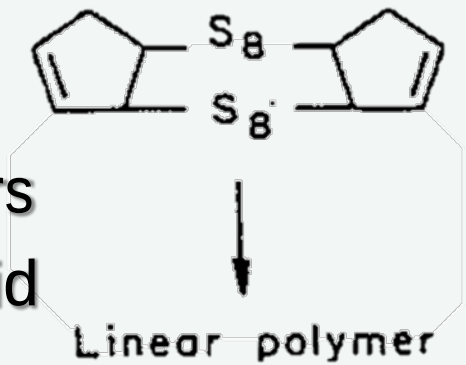
$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$$

- The cement industry accounts for **5 - 7%** of all the anthropogenic production of CO_2 annually

- Displacement of conventional hydraulic cement with sulfur-based thermoplastic binders (SPC) can reduce concrete industry carbon footprint

Sulfur Polymer

- Elemental sulfur is a thermoplastic that undergoes a solid phase change on cooling which results in changes in density and mechanical instabilities



- Sulfur polymer was developed by researchers in U.S., Canada, and Europe to suppress solid phase change and improve performance for use as an alternative construction material

- Currently, production of conventional sulfur polymer is limited by the cost and availability of dicyclopentadiene (DCPD) and oligomer additives used for processing

SulfCrete® Formulation

- Conventional SPC is not cost-competitive and has not gained a significant market share
- BNL and collaborators developed an innovative and *cost-effective* alternative stabilized sulfur binder known as **SulfCrete®**
- (5) U.S. and international patents issued
- Replaces expensive organic additives (DCPD) with inexpensive fossil energy by-products and high surface area fillers (refinery distillates and coal fired fly ash)

SulfCrete® Mechanical Strength (MPa)

SSBAF Mechanical Testing	20° C	50° C	14 day immersion
Average Compressive strength	62.3	59.6	56.7
Standard Deviation	3.8	4.5	1.6
Average Flexural Strength	8.1	8.0	10.1
Std Deviation	1.1	2.0	1.1

Typical conventional SPC:

Compressive strength **27.6**

Flexural strength **5.2**

Sulfur Polymer Cement Handbook, The Sulphur Institute

Typical hydraulic cement concrete:

Compressive strength **20 – 40**

Flexural strength **3 – 5**

http://www.engineeringtoolbox.com/concrete-properties-d_1223.html

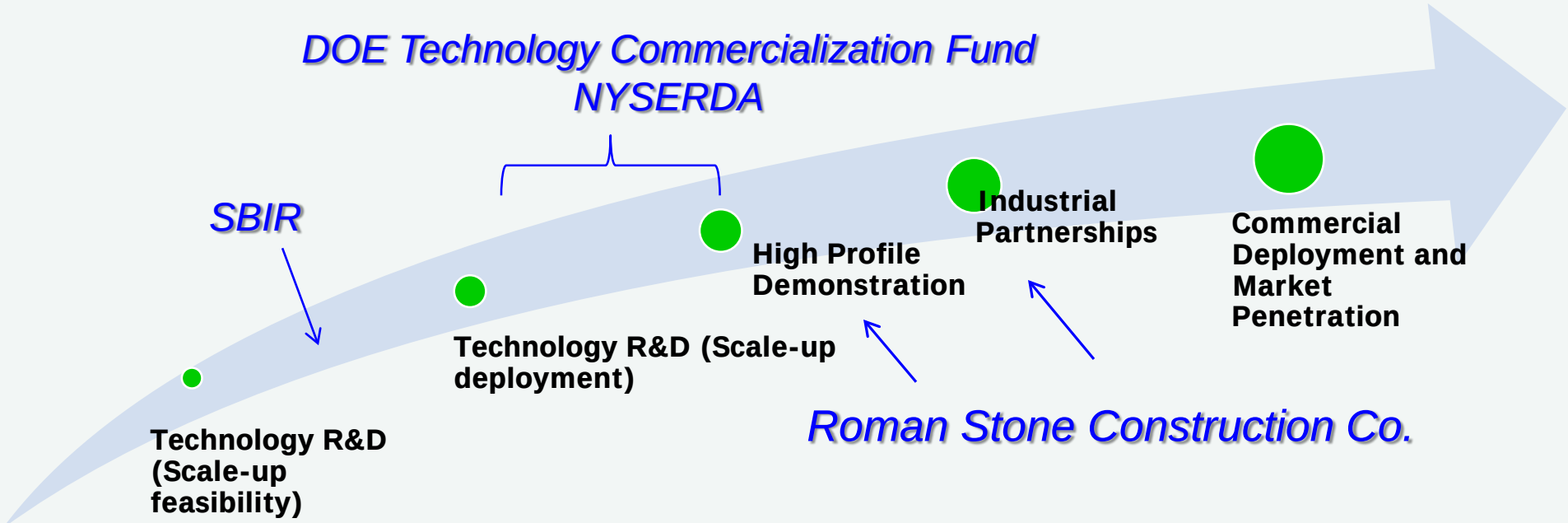
SulfCrete® Technology Status

- Limited lab-scale R&D and scale-up feasibility by BNL resulted in successful formulation with favorable mechanical properties
- Formulation optimization needed to identify lowest cost and best performance
- Engineering scale-up and demonstration
- Concrete product fabrication and testing

SulfCrete® Commercial Status

- Green SulfCrete, Inc. and BNL negotiated an exclusive license agreement
- Green SulfCrete is seeking business opportunities, capitalization and industrial partnerships
- Partnership with Roman Stone Construction, Inc.
- BNL and SulfCrete team won:
  - NSF Phase I grant for scale-up feasibility (complete)
  - DOE TCF grant for scale-up engineering and demonstration (awarded, pending contracts)
  - NYSERDA grant for scale-up product (awarded, pending contracts)

Green SulfCrete Business Plan



DOE Technology Commercialization Fund

Goals:

- Design, develop, and demonstrate a working pilot-scale SulfCrete® production facility
- Fabricate real-world SulfCrete® products and test (under leveraged support from NYSERDA)

DOE Technology Commercialization Fund

Tasks:

1) Engineering scale-up; process equipment selection & preliminary testing
2) Characterization of materials
3) Optimization of formulations and process parameters
4) Short-term performance and QA/QC testing
5) Demonstration of integrated processing
6) Selection of SulfCrete® pre-cast products for production
7) Fabrication/testing of SulfCrete® pre-cast products
8) Determine marketing potential and outreach

Summary and Conclusions

- SPC results in lower greenhouse gas emissions: *greener alternative than OPC*
- Compared with conventional SPC, SulfCrete® uses multiple FE by-products to produce cost-effective co-products for a more sustainable world
- DOE TCF and NYSERDA projects will demonstrate pilot-scale viability needed to establish commercial viability