# SULFURCRETE®
# SULFUR CONCRETE TECHNOLOGY

*H.A. (Howard) Okumura*
Process Engineer
Materials and Metallurgy


**COMINCO LTD.**
Trail, British Columbia, Canada V1R 4L8
**Tel: 250/364-4830 Fax: 250/364-4272**
**EMail: Howard_Okumura@trail.cominco.com**

## THE OPPORTUNITY

SULFURCRETE® sulfur concrete is a unique product with properties that make its use advantageous in many circumstances. The use of sulfur concrete is in it's infancy, the opportunity to take advantage of the special properties awaits.

Cominco has been a user since the development of the technology in the 1970's. The economics of sulfur concrete make it a financially attractive solution where the special properties can be utilized.

## INTRODUCTION TO SULFURCRETE

The use of elemental sulfur with aggregates to make a sulfur concrete has been attempted for years. Problems were encountered due to the complex nature of sulfur chemistry. While initially excellent strength properties were obtained, over a short period of time the material would fail. Unmodified sulfur will cool to a plasticized form with good strength characteristics. However, eventually it will convert to a brittle orthorhombic crystal structure with poor strength characteristics.

SULFURCRETE sulfur concrete uses a proprietary sulfur polymer modifier SRX ™ to stabilize the sulfur such that the crystal structure will not change. SULFURCRETE is the trade mark name for a stable sulfur polymer cement concrete (sulfur concrete).

SULFURCRETE is the patented sulfur concrete technology developed by Dr. Alan Vroom in the early 1970s. Cominco Ltd. purchased the rights to the technology in North America, South America and the Pacific Rim.

Cominco is the producer of the SRX sulfur polymer stabilizer additive to SULFURCRETE sulfur concrete, and has technical support available for production and product development.

## CHARACTERISTICS OF SULFURCRETE

### i Corrosion Resistance

The most common application of sulfur concrete has been in corrosive industrial facilities. It is very resistant to attack by many aggressive environments such as acids and salts. See the "Chemical Resistance Chart" at the back of this document for a list of common environments and their suitability.

Sulfur concrete is particularly advantageous in corrosive environments where the use of equipment, tools or ambient conditions may damage the outer surface. It has the advantage of providing corrosion resistance in a structure that is not reliant on the integrity of a coating or membrane.

### ii Strength Properties

Sulfur concrete can be designed to a wide range of strength characteristics. Typically, it has greater strength properties than portland cement concrete. This includes abrasion resistance, compressive, tensile and flexural strength.

### iii Fatigue Resistance

The fatigue resistance characteristic of sulfur concrete is significantly different compared to regular concrete. It will sustain substantially more repeat loadings before failure at higher percentages of the failure load.

### iv Impermeability

Sulfur concrete contains no water in the mixing process, producing no connected pore structure. Thus, it has very low permeability and excellent freeze-thaw durability.

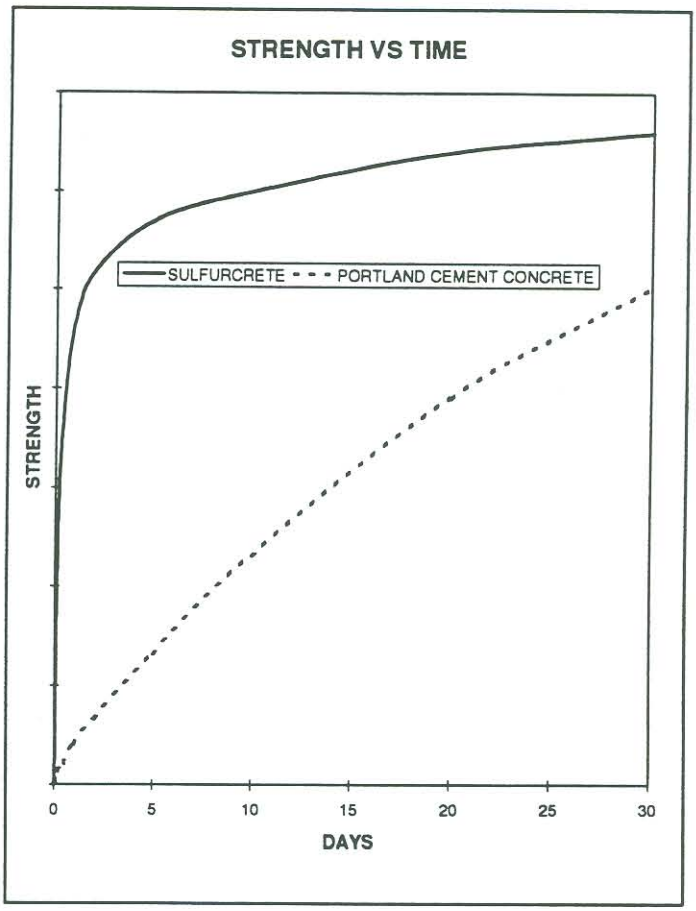
## v Setting

Sulfur concrete sets and obtains strength as a result of the solidification (cooling) of the sulfur. This has several advantages compared to regular concrete:

* Sulfur concrete obtains its strength much faster than portland cement concrete as illustrated. The time required to obtain sufficient strength for use is dependent on the size of the application. It is typically ready for use in hours, but the time can be in minutes.

* The setting of sulfur concrete does not involve an exothermic reaction (heat generating).

* The rate of setting can be controlled by controlling the temperature (removing the heat) of the material.




## vi Environmental

The cement component of sulfur concrete is mostly elemental sulfur, an abundant by-product and inexpensive material. It is environmentally progressive because it reduces the amount of new resource requirements.

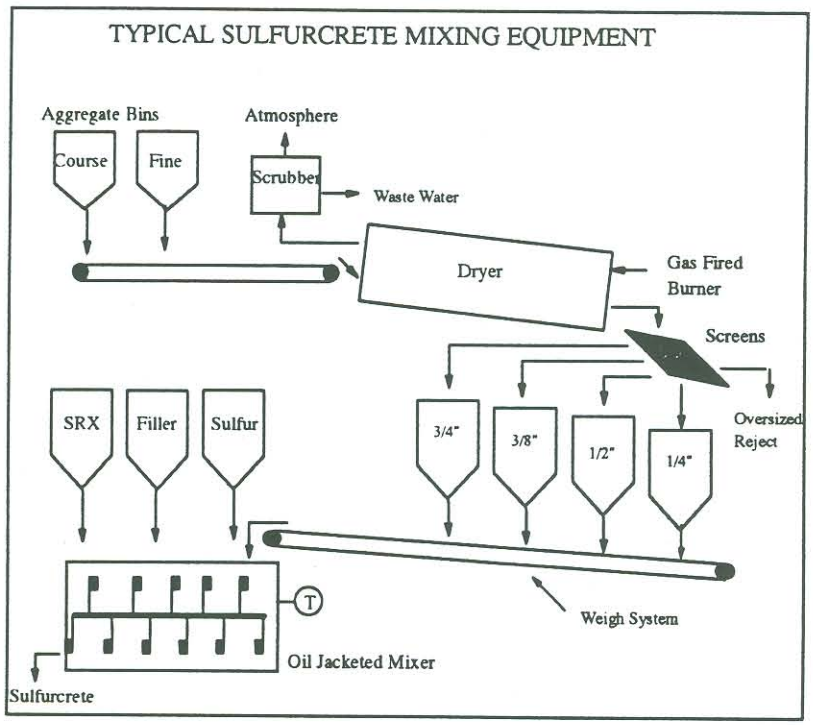
Sulfur concrete is a recyclable material because it hardens as a result of solidification of the sulfur, a reversible process.

## HANDLING AND PLACING

The procedure for handling and mixing sulfur concrete are critical in ensuring the final product quality. A production plant will resemble a small asphalt plant; the process is illustrated. The composition of SULFURCRETE sulfur concrete is typically:

| Component | Weight Percent |
|---|---|
| SRX™ Sulfur Modifier | 1.2 % |
| Sulfur | 11.5 |
| Coarse Aggregate | 42 |
| Fine Aggregate | 40 |
| Mineral Filler | 5.3 |

All materials must be weighed during proportioning to specified tolerances since gradation of the aggregates is crucial. The aggregates and filler must be dried so there is no moisture content. All ingredients need to be controlled in a narrow temperature range during mixing and handling.




The molds for sulfur concrete (precast or pour-in-place) must be dry and preheating them will provided a better finish. Once poured, it will begin to solidify as the material cools. Finishing the surface must be done before the surface begins to solidify. The mix design is manipulated to provide suitable workability for the application. The same slump measurements used with regular concrete apply.

Sulfur concrete obtains its strength as a result of solidification of sulfur. Heat control will dictate the cooling rate, thus solidification time must be accounted for when finishing the application. Molds can be removed as soon as the material has cooled. The time is a function of the mass and shape of the product.

## PHYSICAL PROPERTIES

The specific properties of sulfur concrete are dependent on the mix design. Typical values of properties of sulfur concrete are:

| | |
|---|---|
| Compressive Strength | 40 (5800) to 65 (9500), MPa (psi) |
| Tensile Strength | 4.0 (580) to 6.2 (900), MPa (psi) |
| Flexural Strength | 8.4 (1200) to 11.2 (1600), MPa (psi) |
| Modulus of Rupture | 9.3 (1350) to 12.8 (1850), MPa (psi) |
| Modulus of Elasticity | 4.14 (600), MPa (psi) |
| Linear Coefficient of Expansion | $8.5 \times 10^{-6}$ / °C |
| Linear Shrinkage | 0.01 % |
| Moisture Absorption | < 0.4 % |
| Density | 2.4 S.G., 150 $lb/ft^3$ |

## APPLICATIONS

SULFURCRETE sulfur concrete has been used in both precast and pour-in-place applications since the late 1970's. Some of the applications and advantages are:

### Industrial Floors

Used In- Acid and salt environments such as fertilizer, mineral processing and acid plants.

Chosen For- Its excellent corrosion resistance in a structural material which can withstand industrial activity.

### Process Applications

Used In- Process related industrial applications such as pump bases, sumps, tanks, pits, containment areas, channels, tank pedestals, footings, beams, etc..

Chosen For- The corrosion resistance, strength characteristics and quick setting time.

### Overlays

Used In- Overlays of existing corroding facilities.

Chosen For- An overlay can be ready for use in hours and can greatly reduce the production lost as a result of process downtime.

### Agricultural and Food Processing Plants

Used In- Buildings housing livestock and in food processing areas.

Chosen For- Its corrosion resistance and impermeability make it durable and hygienic in an area where organic material is present. Sulfur concrete is easy to sterilize thus resistant to bacterial growth.

### Pipe Line Weights

Used In- Weights made to hold down gas and oil pipe lines in wet and cold environments, such as swamps.

Chosen For- The ability to pour sulfur concrete in low temperatures allowed these weights to be poured in -40 oC temperatures. Low permeability also make them resistant to freeze thaw cycling.

**CHEMICAL RESISTANCE CHART FOR Sulfur Concrete**

ACETALDEHYDE
ACETIC ACID
ACETIC ACID, GLACIAL
ACETIC ANHYDRIDE
*ACETONE
ACETYL BROMIDE
ACETYL CHLORIDE
*ACETYLENE DICHLORIDE
ACETYL SALICYLIC ACID
ALUMINUM BROMIDE
ALUMINUM CHLORIDE, SULFATE
ALUMINUM PLUORIDE
AMMONIA
AMMONIUM BROMIDE
AMMONIUM CARBONATE
AMMONIUM CHLORIDE, SULFATE
AMMONIUM FLUORIDE
*AMMONIUM HYDROXIDE
AMMONIUM NITRATE, NEUTRAL
AMMONIUM PERSULFATE
AMMONIUM PHOSPHATES
*AMMONIUM SULFIDE
A14MONIUM TUNGSTATE
*AMYL ACETATE, ALCOHOL
*ANILINE
ANILINE HYDROCHLORIDE
ANTIMONY CHLORIDE
ANTIMONY OXYCHLORIDE
ANTIMONY POTASSIUM TARTRATE
*AQUA REGIA
ARSENIC COMPOUNDS, NT OR ACID
BARIUM CHLORIDE
BARIUM HYDROXIDE
*BARIUM SULFIDE
BENZALDEHYDE, NT OR ACID
*BENZENE, BENZOL
BENZENE SULFONIC ACID
BENZOIC'ACID
BENZYL ACETATE
BENZYL ALCOHOL
BENZYL CHLORIDE
BORIC ACID
BROMINE, LIQUID OR GAS
BROMINE WATER, SATURATED
*BUTANOL
*BUTYL ACETATE
*BUTYL CARBITOL
*BUTYRIC ACID
CALCIUM CHLORIDE
CALCIUM HYDROXIDE
*CALCIUM HYPOCHLORITE
CALCIUM SULFATE
*CARBON BISULPIDE (DISULFIDE)
CARBON BISULFITE
CARBON DIOXIDE
CARBON OXYCHLORIDE, PHOSGENE
*CARBON TETRACHLORIDE
*CAUSTIC SODA & POTASH
*CHLOROACETIC ACID
*CHLORAL (TRICHLORACETIC ALDEHYDE)
*CHLORBENZENE
*CHLORINE DIOXIDE, WATER
*CHLORINE, LIQUID OR GAS
*CHLOROFORM
*CHLORONAPTHALENE
CHLOROSULFONIC ACID
*CHROMIC ACID
*CHROMIC CHLORIDE
CHROMIUM POTASSIUM SULFATE
CITRIC ACID
*COPPER ACETATE, CHLORIDES SULFATE
*COPPER NITRATE, NEUTRAL
*CRESOL
*ETHER
*ETHYL ACETATE
ETHYL ALCOHOL
ETHYLAMINE
*ETHYL BROMIDE
*ETHYL CHLORIDE
*ETHYLENE DICHLORIDE
ETHYLENE DISULFONIC ACID
*ETHYLENE OXIDE
ETHYL ETHER
ETHYL SULFATE
ETHYL SULFURIC ACID
FATTY ACIDS
FERRIC CHLORIDE, NITRATE & SULFATE
FERRIC & FERROCYANIDES
FLUOBORIC ACID
*FLUORINE GAS
FLUOSILICIC ACID
FORMALDEHYDE
*FORMIC ACID & COMPOUNDS
GALLIC ACID
*GLYCOL MONOACETATE, DIACETATE, TRIACETATE
*HYDRAZINE SULFATE
*HYDRIODIC ACID
HYDROBROMIC ACID
HYDROCHLORIC ACID, 37.5% CONC.
*HYDROCYANIC ACID
HYDROFLUORIC ACID
HYDROGEN SULFIDE
HYPOCHLOROUS ACID
*IODINE
IODOFORM
LACTIC ACIDS & LACTATES
LEAD CHLORIDE
LEAD NITRATE, NT. OR ACID
MAGNESIUM CHLORIDE, NITRATE & SULFATE
MALEIC ACID & COMPOUNDS
MANGANESE CHLORIDE, OXIDES & SULFATE
MERCURIC CHLORIDE
METHANOL (METHYL ALCOHOL)
*METHYL ACETATE
*METHYL CYCLHEXANOL
*METHYLENE CHLORIDE
METHYL SULFATE
METHYL SULFONIC ACID
MOLYBDENUM ACIDS & OXIDES
NAPTHALENE
NAPTHOLSULFONIC ACID
NICKEL CHLORIDE & SULFATE
NITRIC ACID, 50%
NITROBENZENE
NITROGEN OXIDES
*NITROGLYCERINE
NITROPHENOL
*NITROTOLUENE
*OILS, VEGETABLE, MINERAL & ANIMAL
*OLEIC ACIDS & COMPOUNDS
OXALIC ACIDS & COMPOUNDS
*PARAFFIN WAX
*PERCHLORIC ACID
*PHENOL, 20% SOLUTION
PHENOL SULFOACIDS
PHOSPHORIC ACID
PHOSPHOROUS BROMIDE
PHOSPHOROUS CHLORIDE
PHOSPHOROUS OXYCHLORIDE
PHTHALIC ACID
*PICRIC ACID
POTASSIUM BICHROMATE
POTASSIUM BROMIDE
POTASSUIM CARBONATE
POTASSIUM CHLORATE
POTASSIUM CHLORIDE, NITRATE
POTASSIUM CYANIDE
POTASSIUM FERRIC & CYANIDE
*POTASSIUM HYDROXIDE
POTASSIUM OXALATE
POTASSIUM PERMANGAN
*POTASSIUM PEROXIDE
*POTASSIUM PERSULFAT
SALICYLIC ACID
SILICON TETRACHLORID
SODIUM ACETATE
SODIUM BICARBONATE
SODIUM BICHROMATE
SODIUM BISULFATE, BI
*SODIUM CARBONATE
SODIUM CHLORIDE, NIT
SULFATE
*SODIUM HYDROXIDE 1%
*SODIUM HYPOCHLORITE
*SODIUM PEROXIDE
*SODIUM SULFIDE
SODIUM TARTRATE
STEARIC ACID
SULFURIC ACID, 98%
*SULFURIC ACID, FUMI
SULFUR CHLORIDE
*SULFUR, MOLTEN
SULFUROUS ACID
SULFUR OXIDES
SULFUR OXYCHLORIDE
TARTARIC ACID & COMP
TIN CHLORIDE & SULFA
*TOLUENE (TOLUOL)
TOLUENESULFONIC ACID
*TRICHLORETHYLENE
*TRISODIUM PHOSPHATE
UREA
URIC ACID
WATER
XYLENE
ZINC CHLORIDE, NITRA
SULFATE

*= not recommended. The above information is to be considered a guideline only. The actual effect of these chemicals may depend upon the temperature, concentration and other contaminants. Tests should be conducted under the actual plant conditions to determine the suitability of this product for the intended purpose.