

Testing of Aggregate Properties  
CE 334L

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December 2, 2008

*This report details the testing of four different size ranges of Poraver, a mixture of expanded glass granules, to determine the aggregate properties for use in concrete mix design. Specifically this testing sought to determine the specific gravity; absorption and gradation of the Poraver samples for use in mix design for the USC ASCE Concrete Canoe. This experiment made use of standards from the American Society for Testing and Materials (ASTM Standards C29, C128 and C136). Our experimental data yielded specific gravities around 0.5 and absorption of approximately 6%. The errors in this data are largely believed to stem from deviation from the standard procedure specified in the ASTM Standards due to the availability of testing equipment. This report also includes gradation curves and the Material Safety Data Sheet for Poraver as reference data for use by the USC ASCE Concrete Canoe teams.*

### *Project Expectations and General Information*

The main goal of this project was to analyze and collect information regarding the physical properties of the aggregates used in the American Society of Civil Engineer's Concrete Canoe mix. In the past, the team had issues with the workability of the concrete and had to add more water than expected to the mix for improved consistency. Prior to the addition of the extra water, the mix did not achieve the desired slump and was difficult to mold because it was constantly crumbling. In order to prevent the same situation as previous years, we strove to gather more information about the properties of aggregates before creating our mix.

The aggregate tested comprised of four batches ranging in size from 0.1 mm to 2 mm and is composed of 99% recycled expanded glass materials with no volatile organic compounds (VOCs). This aggregate was chosen for the concrete canoe because it is lighter than water and therefore reduces the weight of the canoe.

### *Referenced Standards*

For this project, we referenced the ASTM Standards for Concretes and Aggregates and more specifically, standards C29, C128, C136. Standard C29 is for unit weight and voids in aggregates, standard C128 is specific gravity and absorption of fine aggregate and finally standard C136 is sieve analysis of fine and coarse aggregates. In testing standards C128, we included the procedure described by C29 (see Purpose and Testing Procedure for ASTM C128).

### *Purpose and Testing Procedure for ASTM C128*

This test method covers the determination of bulk and apparent specific gravity, and the absorption of fine aggregates. It determines, after a period of 24 hours soaked in water, the bulk specific gravity and the apparent specific gravity. A 1 kilogram sample of each sized aggregate must be dried in the oven at a temperature of 110°C plus or minus 5°C until a constant weight is attained (i.e.

the sample is fully dry). We scaled down the sample size to 500 grams, then allowed the sample to cool to a comfortable handling temperature and immerse sample in water, then permitted it to stand for 20 – 28 hours. After said time, we decanted excess water with care to avoid loss of fines, spread the sample on a flat, non-absorbent surface, in our case an unopened garbage bag. The ASTM standard suggests exposing the samples to a gently moving current of warm air, but given that our samples were comprised of such fine particulate matter and that we had a limited amount of time in which to complete the testing procedure, we opted to oven bake the samples at a temperature of 100°C until they were fully dry, approximately 15 minutes. From there we performed a cone test to determine the surface moisture of the samples by looking for slump after 25 drops of the tamper.

The next steps in the procedure involved using a pycnometer or a Le Chatelier flask. We made phone calls all over campus but could not locate either apparatus- so we had to get creative. Instead of a pycnometer or Le Chatelier flask, we used a bulbous flask to complete the test. The procedure called for adding 500.0 grams of the surface-dried sample to the flask and adding water using a buret to volumetrically determine the amount of water added. Once again, we scaled the sample down to 50.0 grams, and added 100 mL of water to the samples- just enough to submerge them. Please note that any changes made to the procedure remained consistent across all four samples. After rolling the flask to remove air bubbles, the total weight of the mixture was recorded for each sample, as was the weight of the flask filled with water to the same level as with the sample and water mixture.

To determine the absorption, we decided to use a 50 gram sample comprised of 47 grams of aggregate and 3 grams of water (approximately 6% of the total sample by weight). We oven dried each sample at a temperature of 110°C and reweighed the samples. The absorption was then calculated as the difference between the surface dry and oven dry mass. Since we were not concerned with the void content of our aggregates, we used this information to determine the unit weight as described in ASTM C29, which we were able to complete using the specific gravity and the volume of the sample as found in ASTM C128.

Using this data, the bulk specific gravity, apparent specific gravity and absorption could be calculated.

#### *ASTM C128 Calculations and Data*

The following data was collected for the surface dry samples:

	0.1-0.3 (g)	0.25-0.5 (g)	0.5-1 (g)	1-2 (g)
Weight of cup	101.7	89	92.5	112.5
Surface Dry Sample	50	50	50	50
Weight of Sample	148.5	135.9	138.1	159.4

The following data was collected during submergence of water and includes the subsequent bulk specific gravity, bulk specific gravity (saturated surface-dry basis) apparent specific gravity and absorption calculations as well.

	0.1-0.3 mm	0.25-0.5 mm	0.5-1 mm	1-2 mm
Weight of Flask (g)	124.7	125	124.9	125.1
Total Mass (g)	274.4	274.5	274.4	278.8
Weight of Sample after heating (g)	149.7	149.5	149.5	153.7
Pycnometer + specimen + water (C)	274.45	274.75	274.65	274.85
Pycnometer + water (B)	303.5	306.3	316.3	308.4
Weight of Oven-Dry (A)	46.8	46.9	45.6	46.9
Bulk specific Gravity	0.592	0.575	0.498	0.561
BSP Saturated SD	0.633	0.613	0.546	0.598
Apparent SG	0.617	0.598	0.523	0.583
Absorption (%)	6.838	6.610	9.649	6.610

The bulk specific gravity is calculated using the following equation:

$$\text{Bulk sp gr} = A / [B + 500 - C]$$

\*\* Please note 50 is substituted for 500 in our calculations

Where:

A= weight of oven dry sample in air, g

B= weight of pycnometer filled with water, g

C= weight of pycnometer with specimen and water to calibration mark, which is calculated by:

$$C = 0.9975 V_a + 500 + W$$

Where:

$V_a$ = volume of water added to pycnometer, mL

W= weight of pycnometer empty, g

The bulk specific gravity (saturated surface-dry basis) is calculated the following way:

$$\text{Bulk sp gr (surface dry)} = 500 / (B + 500 - C)$$

\*\*Please note, 50 is substituted for 500 in our calculations

The Apparent Specific Gravity is calculated using:

$$\text{Apparent SG} = A / (B + A - C)$$

And finally the Absorption percent is calculated using the following equation:

$$\text{Absorption, \%} = [(500 - A) / A] \times 100$$

\*\* Please note, 50 is substituted for 500 in our calculations

## *ASTM C128 Analysis and Results*

Specific gravity is the ratio of the density of a substance (solid or liquid) to the density of water at 4°C and atmospheric pressure. Since our sample was comprised of glass bubbles of varying size, all of which floated when introduced to water, it would make sense that their specific gravities were less than 1. Apparent specific gravity was higher than bulk specific gravity, which can be explained by the fact that we calculated the bulk specific gravity using Poraver straight out of the bag, while we calculated the apparent specific gravity using the oven dried Poraver, which had a slightly smaller mass due to the removal of air content moisture. As explained in the Calculations section, this would cause the apparent to be ever so slightly larger than the bulk. Absorption is a measure of a substance's ability to soak up water, calculated as a percentage of total mass. We believe that our absorption values are too high, which is addressed in the Sources of Error section.

## *Purpose and Testing Procedure for ASTM C136*

This test method covers the determination of the particle size distribution of fine and coarse aggregates by sieving. The point of the sieve analysis is to map grain size distribution to establish the viability of aggregate samples for whatever uses might be required. In general, it is better to have an even distribution of particle size from small to large so that any and all gaps in a mix can be filled.

A sample of each aggregate is dried in an oven at 110°C ± 5°C until it is of constant weight. Sieves are arranged in a tower by decreasing pore size, with the largest pore size at the top of the stack and the smallest pore size at the bottom, all placed on top of a catch-all container. The sample is poured into the top of the stack, a cover is placed on top, and the whole stack is placed into a mechanical shaker that then agitates the stack for five minutes. Once shaking is complete, the stack is removed and each sieve is separated and weighed. The sample distributes itself through the sieves with each particle passing through sieves with pore sizes larger than its diameter and finally catching on the sieve with a pore size slightly smaller than its diameter. Once the weight of Poraver caught on each sieve is determined by subtracting the weight of the empty sieve from that of the sieve after the test, its percentage of the whole sample can be determined, and grain size distribution mapped.

## *ASTM C136 Data and Calculations*

Sieve	Weight of Sample (g)	0.1-0.3 mm	0.25-0.5 mm	0.5-1 mm	1-2 mm
10	521.9	521.9	521.9	521.9	522.5
16	676.9	677.1	576.9	677.1	821.0
35	457.4	457.6	564.5	704.3	546.2
48	334.0	339.3	461.5	353.8	334.3
80	442.3	704.4	468.1	452.6	444.0

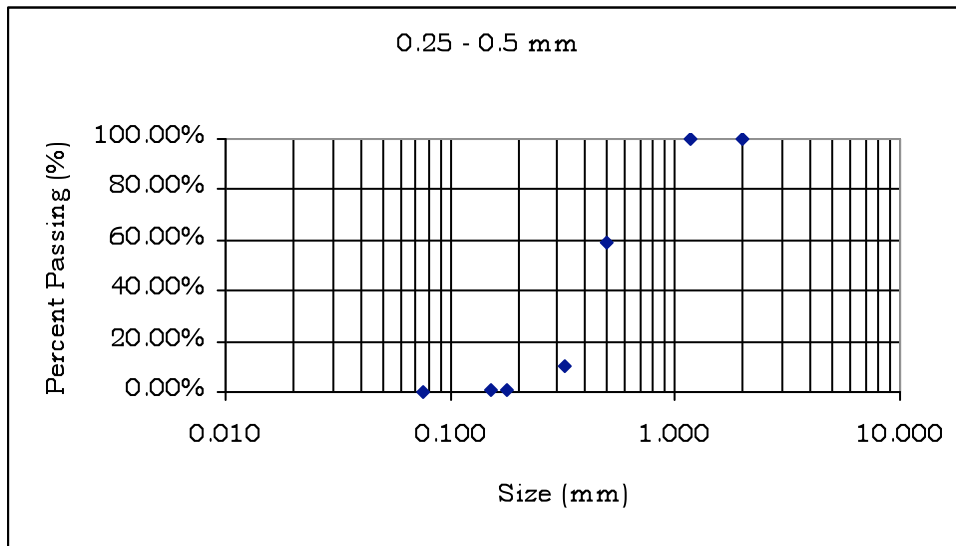
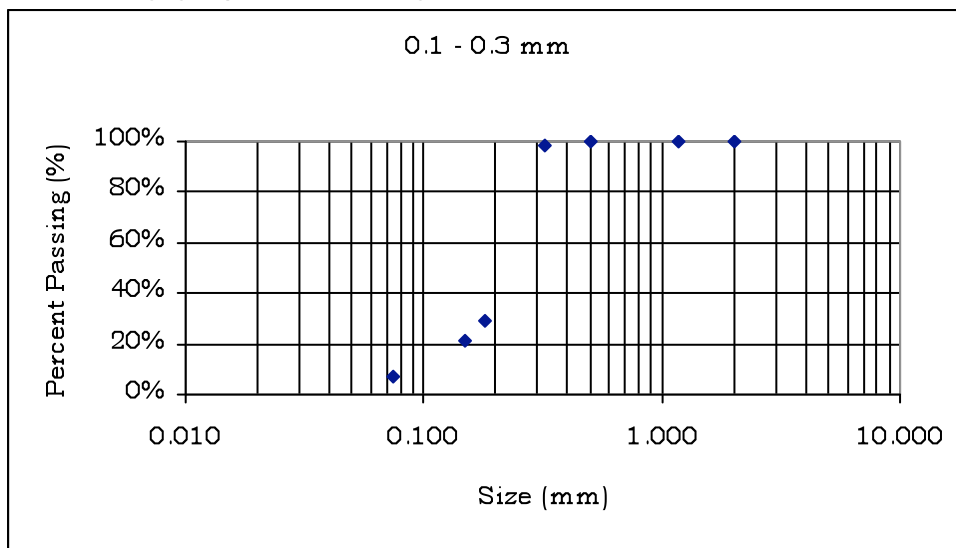
100	426.7	457.9	427.0	427.6	426.8
200	413.2	466.6	413.7	414.5	413.2
Bottom	387.3	413.3	388.1	388.7	387.3

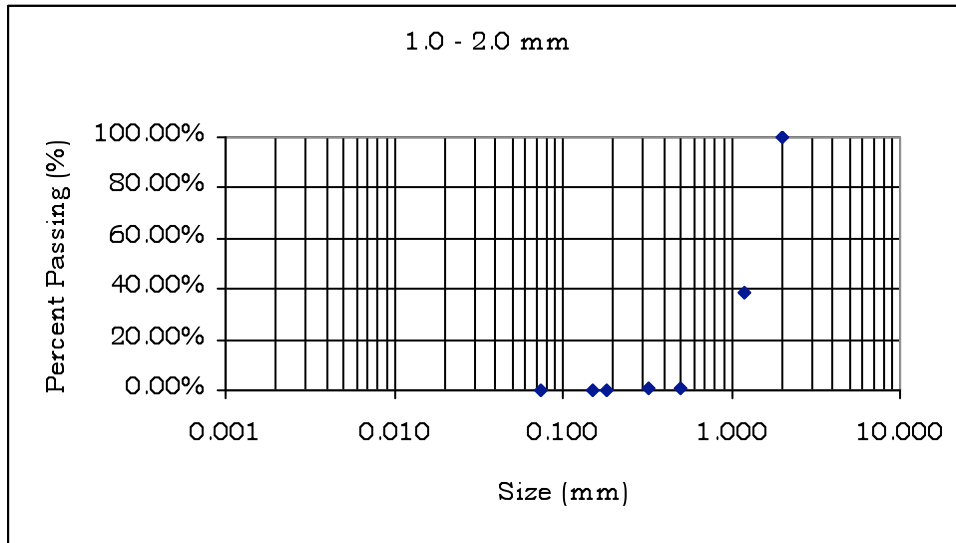
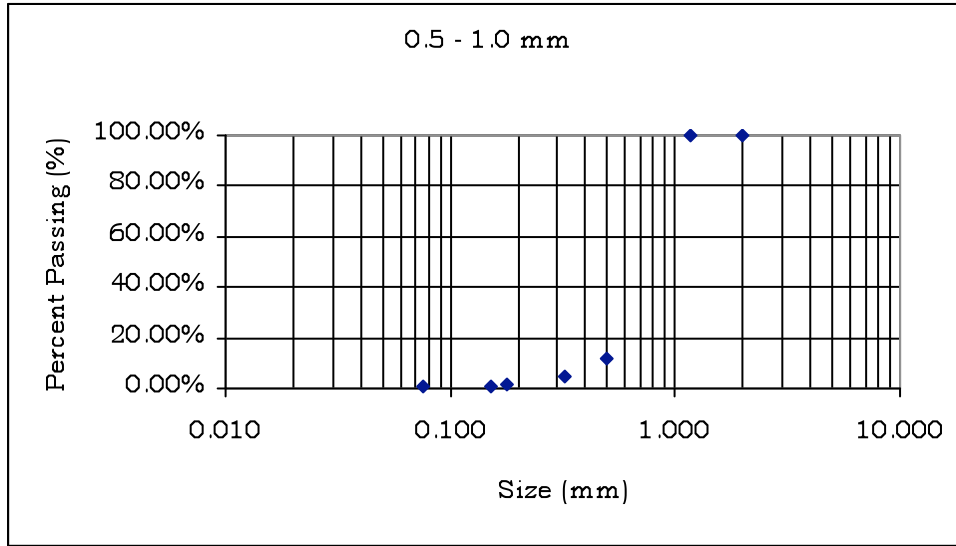
*ASTM C136 Analysis and Results*

Each of our sample sizes were put through the sieving system and the weights remaining on each sieve were measured. From that information, the percent of the sample passing each sieve was calculated using the formula

$$1 - [\Sigma(\text{mass retained on all larger diameter sieves})]/(\text{total mass of sample})$$

The resulting graphs of each grain size distribution are as follows.





*Potential Sources of Error*

The largest potential source of error throughout testing came from deviation from the standard ASTM procedures outlined. We believe that further testing is required to substantiate the experimentally determined absorption. Our methods for drying the samples after the 24-hour saturation period proved ineffective and forced us to air dry the samples for an additional 12 hours. It is likely that the samples reached their surface dry condition prior to the time we returned. In this case, the samples would have continued to dry past the surface dry condition required by the ASTM standards. In an attempt to alleviate this, we increased the moisture content of an oven dry sample for the calculation of the absorption. However, ASTM Standard C128 stipulates that this 6% moisture increase be maintained over the same 24 hour period.

Our saturation period for the 6% increase was only 1 hour, which may not have allowed the sample to fully absorb the water. Moreover, we did not re-perform the surface moisture test (by jiggling the sample) to ensure that the sample was in its surface dry state. Additionally, the volumetric measuring of the sample and water in the flask was not precise to the degree a Le Chatelier flask or Pycnometer would have been. Our flask lacked volumetric gradation entirely. To overcome this, we marked the height that sample and water rose to within the flask and then refilled the flask to that mark. This procedure would be more accurate for larger sample sizes that did not require accuracy to the milliliter.

Appendix 1: Poraver Material Safety Data Sheet



**MATERIAL SAFETY DATA SHEET**

MSDS DATE: 02/12/2007

**SECTION 1: PRODUCT AND COMPANY IDENTIFICATION**

**PRODUCT NAME:** PORAVER® (all grain sizes)  
**SYNONYMS:** Expanded Glass Granules

**MANUFACTURER:** DENNERT PORAVER GMBH  
**ADDRESS:** Gewerbegebiet-Ost 17  
 D-92353 Postbauer-Heng

**TELEPHONE:** +49 / 91 88 / 94 02-0  
**FAX PHONE:** +49 / 95 52 / 71-255

**SUPPLIER:** PORAVER North America Ltd.  
**ADDRESS:** 135 Bayfield Street Suite 101  
 Barrie, Ontario L4M 3B3

**PREPARATION INFORMATION:** Prepared by Research and Development

**TELEPHONE:** (705) 719-9822  
**FAX PHONE:** (705) 719 9886

**CHEMICAL NAME:** Glass  
**CHEMICAL FAMILY:** Glass Oxides  
**CAS NUMBER:** 65997-17-3  
**CHEMICAL FORMULA:** Not Applicable  
**CANADIAN WHMIS CLASSIFICATION:** Not Controlled / Not Regulated

**PRODUCT USE:** Construction Materials

**SECTION 2: COMPOSITION/INFORMATION ON INGREDIENTS**

<u>Ingredient</u>	<u>Chemical Formula</u>	<u>Typical % By Weight</u>	<u>CAS #</u>
Silicon Dioxide	SiO <sub>2</sub>	70 %	60676-86-0
Sodium Oxide	Na <sub>2</sub> O	15 %	1313-59-3
Calcium Oxide	CaO	11 %	1305-78-8
Magnesium Oxide	MgO	2 %	1309-48-4

**SECTION 3: HAZARDS IDENTIFICATION**

**WHMIS HAZARDOUS INGREDIENTS**.....: None

**POTENTIAL HEALTH EFFECTS**

**ROUTES OF ENTRY**.....: None expected. Poraver is an expanded glass bead and the ingredients are in a fused crystalline structure.

**EYES**.....: This product is an eye irritant due to the mechanical abrasion of the crystals.

**SKIN**.....: This product is a skin irritant due to the mechanical abrasion of the crystals.

**INGESTION**.....: Small glass particles present in this product may cause injury to the trachea, stomach and intestines.

**INHALATION**.....: This product is a nuisance dust. OSHA PEL (total particulate, not otherwise regulated) 15 mg/m<sup>3</sup>, (respirable particulate, not otherwise regulated) 5 mg/m<sup>3</sup>. ACGIH TLV (nuisance particulates) 10 mg/m<sup>3</sup> (inhalable), 5 mg/m<sup>3</sup> (respirable).

**ACUTE HEALTH HAZARDS**.....: None known.

**CHRONIC HEALTH HAZARDS**.....: Chronic exposure to respirable dust in excess of appropriate exposure limits may cause lung disease.

**IRRITANCY**.....: This product will irritate the skin through mechanical abrasion of the crystals.

**SENSITIZATION**.....: None Known.

**CARCINOGENICITY**.....: None Known.

**REPRODUCTIVE TOXICITY**.....: None Known.

**TERATOGENICITY**.....: None Known.

**MUTAGENICITY**.....: None Known.

**TOXICOLOGICALLY SYNERGISTIC PRODUCTS**.....: None Known.



# MATERIAL SAFETY DATA SHEET

MSDS DATE: 02/12/2007

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## SECTION 4: FIRST AID MEASURES

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**EYES**.....: flush eye with running water for 15 minutes, consult a doctor.  
**SKIN**.....: Wash skin with soap and water; consult a doctor if irritation develops.  
**INGESTION**.....: Consult a doctor.  
**INHALATION**.....: Remove to fresh air. If breathing difficulty is encountered, seek medical aid.  
**NOTES TO PHYSICIANS OR FIRST AID PROVIDERS**.....: Glass particles present in this product can cause internal injury to the trachea, stomach and intestines.

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## SECTION 5: FIRE-FIGHTING MEASURES

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**FLAMMABLE LIMITS IN AIR, UPPER**.....: Not Applicable.  
**(% BY VOLUME) LOWER**.....: Not Applicable.  
**FLASH POINT**.....: Not Available.  
**AUTOIGNITION TEMPERATURE**.....: Not Available.  
**CONDITIONS OF FLAMMABILITY**.....: Not Flammable.  
**NFPA HAZARD CLASSIFICATION**  
HEALTH: 0 FLAMMABILITY: 0 REACTIVITY: 0 OTHER: 0  
**HMIS HAZARD CLASSIFICATION**  
HEALTH: 0 FLAMMABILITY: 0 REACTIVITY: 0 PROTECTION: 0  
**EXTINGUISHING MEDIA**.....: Use extinguishing media appropriate to the primary cause of the fire.  
**SPECIAL FIRE FIGHTING PROCEDURES**.....: None.  
**UNUSUAL FIRE AND EXPLOSION HAZARDS**.....: None Known.  
**HAZARDOUS DECOMPOSITION PRODUCTS**.....: None Known.  
**SENSITIVITY TO MECHANICAL IMPACT**.....: None **SENSITIVITY TO STATIC DISCHARGE**.....: None

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## SECTION 6: ACCIDENTAL RELEASE MEASURES

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**ACCIDENTAL RELEASE MEASURES**.....: Shovel up or vacuum up material and dispose of waste in accordance with local, state / provincial and federal regulation.

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## SECTION 7: HANDLING AND STORAGE

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**HANDLING AND STORAGE**.....: Respirable dust may be generated during processing, handling and storage. Stored in a cool, dry, ventilated area. Protect against physical damage. Use adequate ventilation and dust collection. Practice good housekeeping. Do not allow dust to collect on walls, floors, sills, ledges, machinery, or equipment.

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## SECTION 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

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**VENTILATION**.....: Provide local and/or general exhaust to control dust generation below exposure limits. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area.  
**RESPIRATORY PROTECTION**.....: Wear a NIOSH approved mask for control of nuisance dust. Respirable dust levels should be monitored regularly.  
**EYE PROTECTION**.....: Wear safety glasses with side shields to protect against eye contact.  
**SKIN PROTECTION**.....: Wear general purpose work gloves to protect skin from irritation.



**MATERIAL SAFETY DATA SHEET**

**MSDS DATE:** 02/12/2007

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**SECTION 9: PHYSICAL AND CHEMICAL PROPERTIES**

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PHYSICAL STATE.....: Solid  
APPEARANCE.....: White beads  
ODOR.....: None  
ODOUR THRESHOLD.....: None  
PHYSICAL STATE.....: Solid  
pH AS SUPPLIED.....: Not Applicable  
pH (Other).....: 10.7 (100 g in 1 l of water)  
COEFFICIENT OF WATER/OIL DISTRIBUTION.....: Not Available  
BOILING POINT.....: Not available  
MELTING POINT.....: approximately 750 °C  
FREEZING POINT.....: approximately 750 °C  
VAPOR PRESSURE (mmHg).....: Not applicable  
VAPOR DENSITY (AIR = 1).....: Not applicable  
SPECIFIC GRAVITY (H2O = 1) @ 25 ° C.....: 0.27 – 0.9  
EVAPORATION RATE... BASIS (=1).....: Not applicable  
SOLUBILITY IN WATER.....: Insoluble  
PERCENT SOLIDS BY WEIGHT.....: 100  
PERCENT VOLATILE BY WT.....: 0  
VOLATILE ORGANIC COMPOUNDS (VOC).....: None  
MOLECULAR WEIGHT.....: Not Applicable  
VISCOSITY.....: Not Applicable

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**SECTION 10: STABILITY AND REACTIVITY**

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STABILITY.....: Stable  
CONDITIONS TO AVOID (STABILITY).....: None known  
INCOMPATIBILITY (MATERIAL TO AVOID).....: None known  
HAZARDOUS DECOMPOSITION OR BY-PRODUCTS.....: None known  
HAZARDOUS POLYMERIZATION.....: Will not occur  
CONDITIONS TO AVOID (POLYMERIZATION).....: None Known

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**SECTION 11: TOXICOLOGICAL INFORMATION**

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TOXICOLOGICAL INFORMATION.....: This product contains trace amounts of heavy metals such as lead, chromium and antimony. Users need to be aware of their presence even though they are lower than any required reporting limit.

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**SECTION 12: ECOLOGICAL INFORMATION**

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ECOLOGICAL INFORMATION.....: This product has been tested Via TCLP1311 and found to have no Leachable compounds present.

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**SECTION 13: DISPOSAL CONSIDERATIONS**

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WASTE DISPOSAL METHOD.....: Dispose of waste in accordance with local, state / provincial and federal regulation



## MATERIAL SAFETY DATA SHEET

MSDS DATE: 02/12/2007

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### SECTION 14: TRANSPORT INFORMATION

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#### U.S. DEPARTMENT OF TRANSPORTATION

PROPER SHIPPING NAME.....: Not regulated  
HAZARD CLASS.....: Not applicable  
ID NUMBER.....: Not applicable  
PACKING GROUP.....: Not applicable  
LABEL STATEMENT.....: Not applicable

#### WATER TRANSPORTATION

PROPER SHIPPING NAME.....: Not regulated  
HAZARD CLASS.....: Not applicable  
ID NUMBER.....: Not applicable  
PACKING GROUP.....: Not applicable  
LABEL STATEMENTS.....: Not applicable

#### AIR TRANSPORTATION

PROPER SHIPPING NAME.....: Not regulated  
HAZARD CLASS.....: Not applicable  
ID NUMBER.....: Not applicable  
PACKING GROUP.....: Not applicable  
LABEL STATEMENTS.....: Not applicable

#### CANADIAN TDG

PROPER SHIPPING NAME.....: Not regulated  
HAZARD CLASS.....: Not applicable  
ID NUMBER.....: Not applicable  
PACKING GROUP.....: Not applicable  
SPECIAL SHIPPING INFORMATION.....: None

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### SECTION 15: REGULATORY INFORMATION

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CANADIAN WHMIS CLASSIFICATION: Not Controlled / Not Regulated

#### U.S. FEDERAL REGULATIONS

TSCA (TOXIC SUBSTANCE CONTROL ACT): All ingredients listed on the TSCA inventory  
CERCLA (COMPREHENSIVE RESPONSE COMPENSATION, AND LIABILITY ACT): RQ 1 lb as chromium is equivalent to 2,000 lb of Poraver.

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### SECTION 16: OTHER INFORMATION

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**DISCLAIMER:** The information in this Material Safety Data Sheet (MSDS) is believed to be correct as of the date issued. Poraver North America Ltd. makes no warranties, expressed or implied, statutory or otherwise, including, but not limited to, any implied warranty or condition of merchantability or fitness for a particular purpose or course of performance or usage of trade. The user is responsible for determining whether the Poraver product is fit for a particular purpose and suitable for the user's method of use or application. Given the variety of factors that can affect the use and application of the Poraver product, some of which are uniquely within the user's knowledge and control, it is essential that the user evaluate the Poraver product to determine whether it is fit for a particular purpose and suitable for the user's method of use or application.