PUMICE POZZOLAN: Summary *of* Phase One Research on Hess Pozz

by the Concrete and Materials Research and Evaluation Laboratory, Department of Civil and Environmental Engineering, University of Utah.

Dr. Paul J. Tikalsky, currently dean of the College of Engineering, Architecture and Technology at Oklahoma State University, led a comprehensive study of Hess Pumice Pozz in 2012 while at the University of Utah. He was assisted by Uma Ramasamy.

Both Hess Pozz grades were studied: Hess StandardPozz (DS-325) and Hess UltraPozz (NCS-3). This research was conducted to determine pozzolanic properties and complimentary cementitious capability of the pumice for use in combination of portland and hydraulic cements. According to ASTM C 618, pozzolans are the siliceous and aluminous material in finely divided form and in the presence of moisture, at ordinary temperature chemically react with calcium hydroxide to form compounds possessing cementitious properties. The control mixture was 100% cement.

Part of the Concrete and Materials Research and Evaluation Lab at the University of Utah.

Health and Safety

The University of Utah study corroborated previous test data, which indicates that Hess Pumice Natural Pozzolans are free of Crystalline Silica and other hazardous materials.

Compressive Strength

In the study, a relatively high water/cement ratio of .485/1 was used for the control and three additional mix designs utilizing the pumice pozzolan. (Note: This is a worst-case scenario…the properties and strength only get better as the w/c ratio goes down.) The pumice pozzolan mix designs ranged from 3300 PSI to 4600 PSI in 7 days

HESS POZZ GRADES

Hess StandardPozz DS-325

PARTICLE SIZE SPECIFICATION

Dx	Micron Size
D50	14-16

Hess UltraPozz NCS-3

PARTICLE SIZE SPECIFICATION

Dx	Micron Size
D50	2 - 4

CHEMICAL COMPOSITION

Common Name: Pumice
Chemical Name: Amorphous Aluminum Silicate
Silicon Dioxide - 87.4%
Aluminum Oxide - 10.52%
Ferric Oxide - 0.194%
Ferrous Oxide - 0.174%
Sodium - 0.128%
Potassium - 0.099%
Calcium - 0.090%
Titanium Dioxide - 0.0074%
Sulfate - 0.0043%
Magnesium Oxide - 0.126%
Water - 1.11%

COMPRESSIVE STRENGTH (4X8 CYLINDERS)

Following ASTM C39, compressive strength of 4"x8" cylinders were tested with different grades of pumice. Mixtures containing pumice reached the compressive strength later than control mixture. However, the minimum strength at age 7 days is greater than 3000 psi and at age 28 days is greater than 4500 psi. Concrete with slightly slower strength gain qualities is less likely to be subject to early age cracking and has long term strength capability.

MIXTURE	STRENGTH: 7 DAYS (PSI)	28 DAYS (PSI)
100C	5636	7400
80C20DS325	3343	4860
70C30DS325	3398	5359
80C20Ultra	4648	7083

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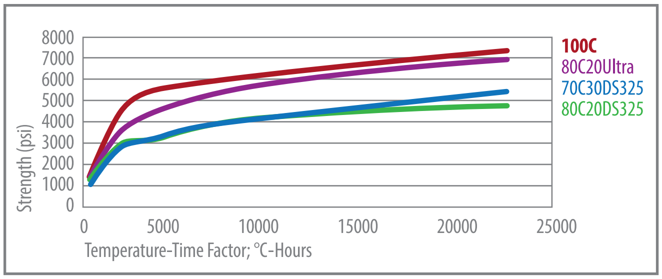
STRENGTH-MATURITY RELATIONSHIP

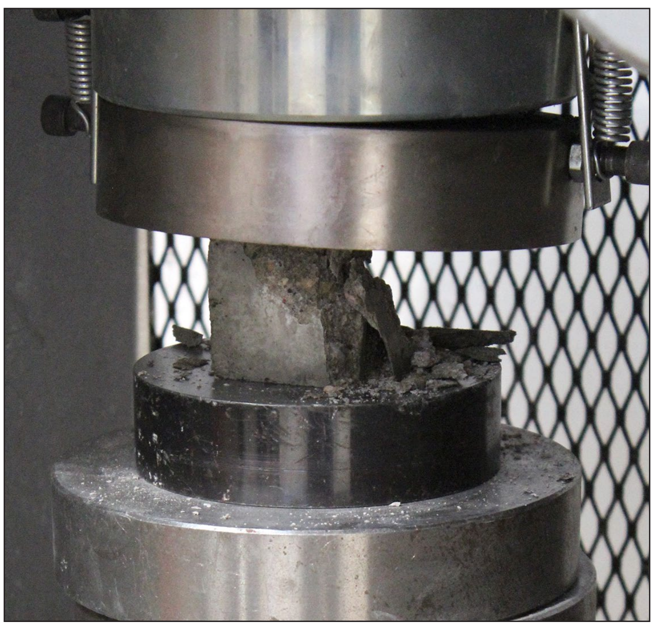
Strength maturity relationship obtained according to ASTM C1074.



ACTIVITY INDEX

Determined in accordance with C595 Annex A1. Activity Index is calculated by dividing the average compressive strength of test mixture cubes with average compressive strength of control mixture cubes.

MIXTURE	ACTIVITY INDEX
100C	
80C20Ultra	131.2
70C30DS325	92.4
80C20DS325	69.8



Compressive strength testing

and from 4800 PSI to 7000 PSI in 28 days. Pozzolan quantity and particle size accounted for the variation in strengths. These factors are consistent and predictable, pour after pour. All of the pozzolanic qualities can be enhanced and compressive strengths can be boosted generously with the addition of an HRWR to lower the water to cement ratio.

Workability & Set Times

Pumice pozzolan based mix designs remain very workable and set times are not significantly longer than the 100% cement control. The various pozzolan mix designs had an extended set time versus the control of anywhere from 44 minutes up to a maximum of 81 minutes. This is directly related to the lowered and extended Heat of Hydration function provided by the pumice pozzolan and higher water-to-cement ratios due to the increased water demand of the pozzolan.

If a quicker set and high early strength are desired, the use of a water reducing agent will offset these properties. Pumice pozzolan based concretes can be 'engineered', with the use of a HRWR, to produce high-performance, high-strength concretes without compromising the amazing chemical resistance properties outlined in the U of U study.

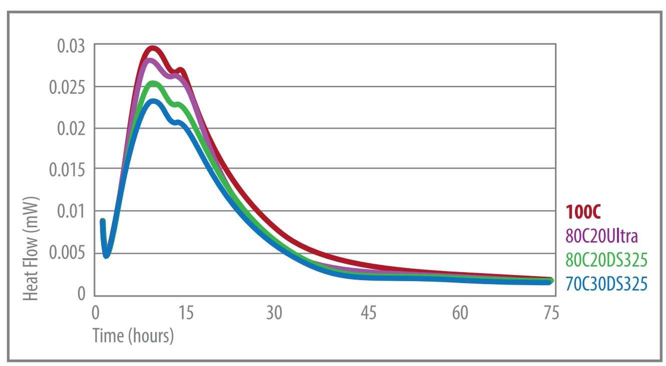
Heat of Hydration

Hess Pumice Natural Pozzolans reduced the heat of hydration anywhere from 10 - 40% during the first 100 hours, depending on the ultimate mix design, thus lowering the threat of thermal cracking and allowing for a cooler, controlled set.

Nevertheless, without reducing the w/c ratio, there is sufficient early strength gain to be useful in almost any concrete application, especially if the UltraPozz is used. After 100 hours the cement-water hydration process wanes while the pumice pozzolan mixes continue to hydrate until one of the two remaining hydration agents, Calcium Hydroxide or Pumice Pozzolan, have been consumed. This slow pozzolanic hydration process can continue for months and even years, bringing the long-terms strength of the pumice based concrete well beyond the Ordinary Portland Cement (OPC) control.

HYDRATION KINETICS: PUMICE BLENDED CEMENTS

100% cement mixture produces more heat as compared to the mixtures containing pumice. As the pozzolanic content increases, the main peak of heat flow decreases.



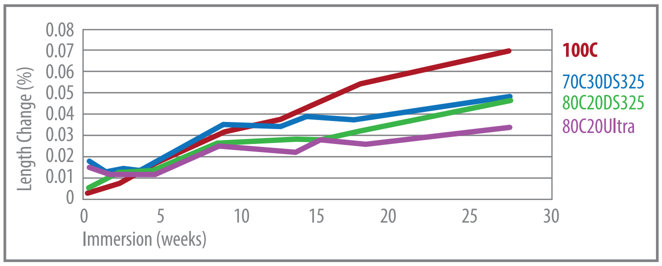
Long-term compressive strength tests were not conducted by the University of Utah, however, previous tests indicate that the eventual compressive strength of the pumice pozzolan mixes will exceed the control by 15-40% depending on mix design.

Sulfate Mitigation

Sulfate resistance testing was conducted in accordance with ASTMC1012, which specifies that a cement or cement blend with 'High Resistance' to sulfate attack must remain below .05% expansion over a 6 month period. All three of the Hess pumice pozzolan based blended cements performed exceptionally well and qualified, per ASTM, as 'High Sulfate Resistance Cements.'

SULFATE MITIGATION

Per ASTM C1012, mortar mixture designs were tested for sulfate resistance through 6 months. Mixtures containing pumice are classified as HS (High sulfate resistant cement) as the length change is less than 0.05% after 26 weeks.



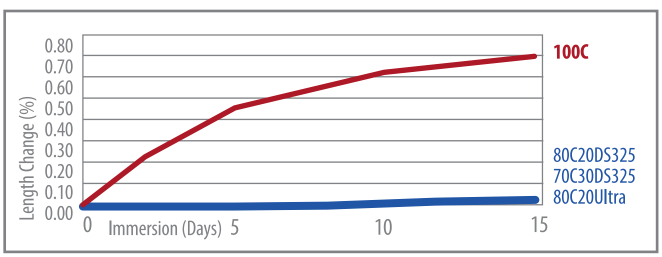
Alkali Silica Reaction (ASR)

The graph below tells the story better than words. Using the same expansive aggregate in each mix design, the control with 100% OPC quickly fell into the 'deleterious' category while the three pumice pozzolan-based cements were clearly resistant to the ravages of ASR.

MITIGATING ALKALI SILICA REACTION

Mortar mix designs tested according to a modified ASTM C1567 procedure using Type 1 cement and 25% replacement of fine aggregate with ground cullet glass. The percent length change for "acceptable expansion" is less than 0.10% at fourteen days with reactive aggregates.

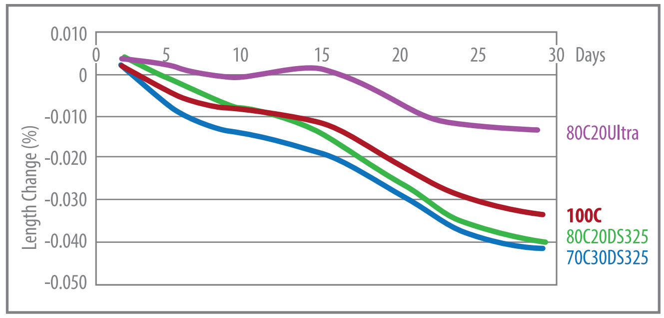
MIXTURE	ASR % LENGTH CHANGE	RATING
100C 25%Glass	0.699	Deleterious Expansion
80C20DS325 25%Glass	0.029	Acceptable Expansion
70C30DS325 25%Glass	0.011	Acceptable Expansion
80C20Ultra 25%Glass	0.017	Acceptable Expansion




Uma measuring length change during ASR testing

SHRINKAGE

Mixture designs were tested for length change in 6"x12"cylinder concrete specimens. The addition of ultrafine pumice reduced the length change (shrinkage) compared to 100% cement.




Rebar cage for bridge support column

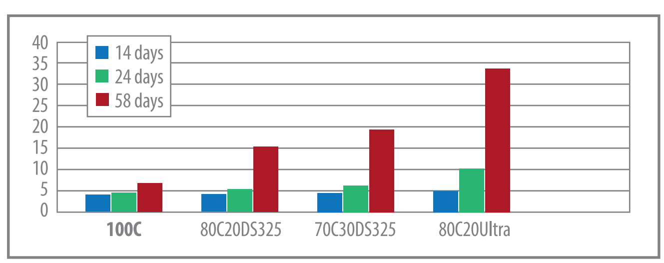
Resistivity

Chloride penetration resistance is a key factor in protecting reinforcing steel embedded in the concrete from corrosion and ultimately protecting the concrete from failure caused by expansion of the iron oxide hydrate (rust). The three pumice pozzolan mix designs increased resistivity anywhere from a minimum of 214% of control to nearly 500% for the Hess UltraPozz.

RESISTIVITY AT DIFFERENT TIME INTERVAL IN kΩ-cm

ASTM C192 procedure was followed to make 6"x12" cylinders and moist cured according to ASTM C511. Resistivity increases over time for the mixture with pozzolans whereas it remains relatively constant for the mixture with 100% portland cement.

MIXTURE	14 DAYS	24 DAYS	58 DAYS
100C	4.1	4.6	6.8
80C20DS325	4.3	5.5	15.7
70C30DS325	4.3	6.3	19.2
80C20Ultra	5.1	10.5	33.8

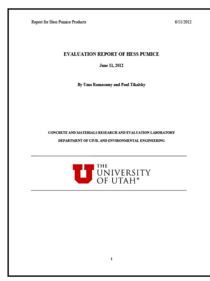


Conclusion

Pumice tested in this research was determined to be pozzolanic and potentially complementary in its reactions in portland cement concrete. The various grades of pumice behave differently in the hydration characteristic even with the same chemical composition, which may be due to varying particle size distribution. Ultrafine pumice showed improved performance over other grades of pumice in hydration, strength and in durability characteristics such as sulfate resistance and alkali silica reaction (ASR). The greater hydration characteristics of ultrafine pumice are also supported by the compressive strength and the penetration resistance results of the same. Although the water demand may be slightly higher for mixtures containing pumice, the use of a water reducing admixture will effectively offset this demand, resulting in comparable set times to 100% cement mixtures.

DS-325 pumice showed improved performance over cement in durability characteristics. If the application requires primarily durability characteristics, i.e. high sulfate resistance and high ASR resistance, then DS-325 pumice can be used as a part of cementitious material. If the requirement is both strength and durability, then ultrafine pumice can be used. The heat produced from mixtures containing pumice is less than that of mixtures with 100% cement which makes it advantageous in mass concrete placements. To maintain higher strength, improve durability characteristics, and reduce the potential for thermal cracking, ultrafine pumice can be used as a portion of the total cementitious material content.

Measuring the diameter of the cylinder using a Pi tape.



A PDF copy of the complete University of Utah report can be downloaded at www.hesspozz.com

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Have specific questions?
Want to do in-house testing in your own lab?
Contact Brian.

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